End of AY 2017 Report for SIP - Group 3

Project Title

Space Innovation Policy for Disaster Risk Management

Team

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Objective: Explain what social/global issues that this project tried to address and why the issue is important.

The overall objective of the project "Space Innovation Policy for Disaster Risk Management" is to study space development, in the Asia-Pacific region mostly, from a Science, Technology and Innovation Policy perspective, for applications focussing primarily on disaster management and environment monitoring.

Our main target is two-fold: (1) a macro-level study on innovation policy in the space sector in general, quite theoretical, that we call "Innovation Panorama" and (2) a micro-level evaluation of a specific interesting case, the Philippines National Space Development Program, for which we produced several outputs.

Overall, the objective of this project is thus to improve the natural disaster mitigation in Asia, with a special focus to the relatively more disaster prone and economically weaker Southeast Asia. The background is that Southeast Asia is one of the most natural disaster-prone regions of the world, and lacks the sociopolitical, economic and technological systems to mitigate them. A 2015 UNESCAP report estimated that 6 billion people from the Asia-Pacific region were affected by natural disasters from 1970-2014, or 88% of people affected globally during that period. Natural disaster mitigation requires significant infrastructure investments and hence financial resources, but space systems can fill this gap by providing leapfrog "instant infrastructure", with lucrative cost savings via international cooperation. The space sector has seen a marked increase in innovation in the past few years, and it is now possible to capitalize on rapidly expanding possibilities for technology development and novel systems deployment.

Method: Explain through what kind of approaches you tried to achieve the objective.
*About the list and details of the interview, add the appendix.

This project will use plural social science research method to portrait possible effective policy changes to government in satellite innovation and procurement processes.

Work on innovation policy will be subdivided in two main blocks: (1) Investigation on the space innovation landscape, focusing on actors and institutions involved, and (2) Data analytics, focusing on defining appropriate methods to analyze these characteristics. Combining these two aspects we will be able to produce a tentative analysis of the innovation panorama regarding space technology, useful for applications ranging from policy recommendations to business analytics.

The case study on the Filipino space program was based on the unique opportunity to witness the inception of a national space program. The main source of information was a research trip to the Philippines, in which we could visit the Department of Science and Technology (DOST), the National Space Development Program (NSDP), the PHL-Microsat group, the University of Philippines Diliman.

Outcome: Explain what kind of results you obtained from this project and discuss how it addressed your focal social/global issues.

- A poster presented at the UN-SPIDER conference in Beijing (Sep. 2016): *Space Innovation Policy for Disaster Management Capabilities*
- Two presentations at the GPPN in Sciences Po, Paris (Feb. 2017): *Shelter 2.0* (also presented as a social startup idea at Hult Prize Dubai, Mar. 2017) and *LESAT (Location-based Emergency Shelter Awareness and Training)*
- Two presentations at the 68th International Astronautical Congress: *Space Innovation Policy for Disaster Management Capabilities: A Case Study on the Nascent Filipino Space Program* and *LESAT*
- Upgraded the paper "Space Innovation Policy for Disaster Management Capabilities: A Case Study on the Nascent Filipino Space Program" into a journal paper "An Early History of the Philippines Space Development Program," submitted on February 27, 2018 to *Acta Astronautica* (Elsevier)
- Two members (Goutham and Marc) created a startup company *Optimacy*

Budget: List the budget this project implemented. *About the details, add the appendix.

Purposes	**Expense**
UN Conference in Beijing, September 2016	155,000 JPY
IAC 2017, September 2017	297,060 JPY
Research books	23,000 JPY
Fieldwork in Manila, January 2018	285,000 JPY
Total	760,060 JPY

68th International Astronautical Congress (IAC), Adelaide, Australia, 25-29 September 2017.

28th IAA SYMPOSIUM ON SPACE AND SOCIETY (E5)
Space Assets and Disaster Management (4)

IAC-17-E5.4.8

SPACE INNOVATION POLICY FOR DISASTER MANAGEMENT CAPABILITIES: A CASE STUDY ON THE NASCENT FILIPINO SPACE PROGRAM

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Abstract

In its 2015 Asia-Pacific Disaster Report, the United Nations Economic and Social Commission for Asia-Pacific (UNESCAP) noted that between 2005 and 2014, 1,625 disasters had been reported, killing half-a-million people, affecting the life of approximately 1.4 billion and generating economic damages worth US $523 billion. In particular, the Filipino archipelago concentrates several risk factors for hydro-meteorological disasters. Although most of these deadly disasters can be addressed using a wide range of space technologies (space remote sensing, satellite communication and positioning systems), the access to such technologies is highly unequal. For this reason,the Philippines initiated in 2015 the National Space Development Program (NSDP), aiming at the establishment of a national space agency and an indigenous satellite industry within the next two decades. Starting from a presentation of the origins and motivations of the Filipino space program, this paper explains in detail the current progress of its development as well as addresses more generally the space policy goals of the Philippines. Finally, this paper introduces initial considerations, from an innovation studies perspective, on the Filipino space development program, as a very interesting case study for a larger reflection on space development in the Asia-Pacific region.

Keywords: Philippines Space Development Program, Innovation Policy, Disaster Management, NSDP

Introduction

As the most disaster-prone region in the world, Asia-Pacific suffers from close to 40% of the globe's 'natural' catastrophes [9]. Since 1970, more than 5000 major disasters have hit this region causing more than 2 billion fatalities and affecting the lives of around 6 billion [30]. The Philippines, in particular, being a low-lying coastal country, is continuously at high risk. As promoted in the *Sendai Framework for Disaster Risk Reduction 2015-2030*, the use of Earth Observation (EO) should be increasingly used for the evaluation of hazard exposure, vulnerability and risk and is therefore an indispensable source of information to support decision-making related to disasters [31].The Philippines do not have a national space agency and hence must rely on cooperation from international space agencies of developed countries like NASA and JAXA. The Philippine institutional arrangements and disaster management systems tend to rely on a reactive approach, in contrast to a more effective proactive approach, in which disasters are avoided, by appropriate land-use planning, construction and other pre-event measures which avoid the creation of disaster-prone conditions [7]. To evolve to a more proactive role, it is important that a national framework for comprehensive disaster risk management be prepared and implemented which incorporates the essential steps of integrated risk management, including risk identifi-

cation, risk reduction, and risk sharing with financing. Establishing a dedicated space program and a National Space Agency can go a long way in serving these needs. Following this reasoning, Filipino House Representative Angelo B. Palmones proposed in December 2012 the establishment of a Philippine Space Agency (PSA) in a bill which however failed to pass.

1 The first steps of space development in the Philippines

The original vision of the 2012 bill was to establish a self-reliant and coherent space program supposed to play a pivotal role for the national economic and social development for the Philippines [7]. With the belief that space science should not be the monopoly of developed countries, the scientific vision of the PSA was inspired from the *Twelve-year Plan for Chinese Aerospace* and the Space Research and Remote Sensing Organization (SPARSSO) of Bangladesh, which works closely with JAXA, NASA and ESA. One the other hand, the proposed business model took inspiration from the Chinese Great Wall Industry Cooperation (CGWIC), created for the design, manufacturing and launching of satellites. The focus was on general space science exploration and improving telecommunication standards to upgrade and replace Agila-2, the only Filipino-owned satellite which was designed and built by CNES and decommissioned in 2013. However, it failed to resonate with the major needs of the Filipino people or gain much public or political support since these goals were by no means a high priority of a developing country like the Philippines, frequently stricken with poverty and catastrophic natural disasters. Coincidentally, Palmones also faced subsequent electoral trouble which further impeded the chances of the bill to succeed.

Super-Typhoon Haiyan (also known as Yolanda), which made landfall in the Philippines in November 2013 — killing 6300 victims, affecting over 16 million people and causing economic damages greater than US $800 million in the Philippines alone [29], proved to be a turning point for the Philippines space program. The Filipino authorities were prepared for record-breaking wind-speeds, but totally unprepared to deal with storm surge despite early warnings. Hence the citizens in the affected regions were not evacuated leading to catastrophic consequences and Haiyan became the costliest and deadliest typhoon to have ever hit the Philippines in the last century. After Haiyan, an opinion poll among Filipino citizens suggested that they considered Disaster Preparedness to be their greatest concern, surpassing poverty [10]. Subsequently, Dr. Rogel Sese, a well-known Filipino astrophysicist[1], carried out a survey of the needs of national stakeholders of a potential Filipino space program, and came up with a proposed structure for development of space science in the Philippines [25]. This led to a change in political will in the Filipino Government and eventually to the foundation of the NSDP in September 2015 followed by the PHL-Microsat Program in early 2016 through the initiative of the Philippine Council for Industry, Energy and Emerging Technology Research and Development (PCIEERD) of DOST. They will serve as interim development programs to prepare for the creation of the PSA by studying its feasibility and usefulness.

2 The two aspects of space development in the Philippines

As preliminary stages for the development of the PSA, the DOST has been separately supporting two programs with different goals: the National SPACE (*Space Promotion, Awareness, and Capabilities Enhancement*) Development Program (NSDP) focusing on the political side, and the PHL-Microsat program working on the technical side.

2.1 Political Side: The National SPACE Development Program

In 2014, two years after the failure to establish the PSA with House Bill 6725 [7], Dr. Rogel M. Sese started investigating the concept of space development by heading a project with the DOST on the crafting of a *Philippine Space Development and Utilization Policy* (NSDUP). From a survey of all potential stakeholders of a Filipino space development program, six Key Development Areas (KDAs) were identified, leading to the official establishment of the NSDP in September 2015 by the DOST [34].

The NSDP is responsible for a large number of tasks, indispensable to initiate a domestic space agency as well as indigenous satellite development capabilities [13]:

- Prepare several documents such as a **National Space Research and Development Agenda** to define a timeline for the implementation of the *National Space Development and Utilization Policy*, a **Satellite Development Roadmap** to define the

[1] Currently Focal Person for the Philippine Space Science Education Program (PSSEP) of the Department of Science and Technology's Science Education Institute (DOST-SEI) and Program Leader of the NSDP.

specific satellite technologies needed by the Philippines in the next 15 years, a **Space Industry Development Roadmap**, a **National Satellite Data Sharing and Management Protocol** to simplify procedures for satellite data handling and sharing and a **Philippine Satellite Data Catalog** to compile all available data in the Philippines.

- Study opportunities of collaboration with international organisations for all space-related activities.
- Promote the participation in regional and international forums for space technology development and utilisation.
- Define the institutional arrangements under which the PHL-Microsat project and the Philippine Earth Data Resource and Observation (PEDRO) will be integrated into the PSA in the future.
- Define the various roles of domestic stakeholders in their relations to the PSA.

As a mainly policy-focused entity, it is clear that the main goal of NSDP is to define the characteristics and lay the groundwork for the creation of the PSA by analysing the various needs of the stakeholders and addressing their respective concerns. While the outputs of the NSDP are confidential — due to strict regulations of the DOST — the spirit of these documents, and in particular the *National Space Development and Utilization Policy*, can be found in the variety of bills proposed in the House and Senate (see 4.2).

2.2 Technical side: PHL-Microsat

PHL-Microsat followed a similar timeline as the NSDP, with a concept definition in 2013-2014 and implementation from 2015. While also initiated and financially supported by the DOST, it has no direct relationship with NSDP, as it pursues different goals [35]. NSDP is however closely following the progress of PHL-Microsat, as it is an indispensable milestone towards the establishment of the PSA [34].

With Philippine universities and other research centres currently lacking necessary know-how required to build a satellite, as pointed out by Dr. Sese, PHL-Microsat entered into a partnership with Tohoku University (for the bus development) and Hokkaido University (for payload and thermal design) in Japan [17]. It allowed PHL-Microsat to produce Diwata-1, the first satellite built and developed by Filipino engineers. Diwata-1 was launched on March 23, 2016 from the International Space Station using JAXA's Kibo module. It is currently on a circular Low Earth Orbit of 51° of inclination and an altitude of 400 km [16].

Concerning more technical characteristics, Diwata-1 is a 50-kg micro-satellite with three main instruments [17]:

- A high precision telescope with a spatial resolution of 3 meters at 400 km altitude for disaster damage evaluation.
- A multi-spectral imager with liquid crystal tunable filter, having a spatial resolution of 80 meters, for ocean monitoring.
- A wide field camera with a seven-kilometre spatial resolution for meteorological forecasting.

Diwata-2 is scheduled to follow in 2018, with improved instrumentation and capabilities [18].

While it is unclear whether PHL-Microsat will be integrated into the PSA or support some commercial spin-offs, the goal of training local engineers and scientists has clearly been fulfilled. As an example of the impact achieved, for the first time the University of the Philippines Diliman is teaching a space-related course "Introduction to Space Technology" [35].

3 Domestic support

Nationwide acceptance is essential for the adoption of such a costly initiative as space development. In particular for developing countries stricken with poverty like the Philippines, establishing a program costing hundreds of millions of US$ requires substantial domestic support from all levels of society.

3.1 Public opinion

The most important target for the promotion of the Philippines' space program is the Filipino people. An efficient governmental promotion strategy as well as the success of Diwata-1 greatly contributed to establish the current strong public support towards space technology development in the Philippines [34].

3.1.1 Efficient governmental promotion strategy

While the 2012 PSA bill failed to pass in the House possibly due to an overwhelming focus on space science and telecommunication, the government of the Philippines and in particular the DOST adopted a new approach for the promotion of space development, based on the real concerns of the Filipino people. This new communication strategy relies on three axes: disaster

management, agriculture and the environment. These elements resonated in the minds of Filipinos, and became a game changer compared to 2012.

The second aspect of the governmental strategy for the promotion of space technology consists in outreach events organized by the DOST. In particular, the annual National Science and Technology Week, organized last time in July 2017, has had a great positive impact over the Filipino youth, by showcasing the first successes of the Philippines' space development program such as Diwata-1.

3.1.2 The great effect of DIWATA-1

The most recent milestone of the Philippines' space program is the launch of Diwata-1, the first satellite ever developed and built by Filipino citizens, and thus first Filipino micro-satellite.

From the beginning, the role of Diwata-1 was to accelerate the process of establishment of the PSA, as declared last year by Dr. Joel Joseph S. Marciano, project leader of PHL-Microsat in the *Manila Bulletin* [32]. Therefore, the success of Diwata-1 strongly resonated in Filipino society thanks to large media coverage, associated with strong comments from the state. In fact, following the deployment of the satellite from the ISS's Kibo module, the House of Representative of the Republic of the Philippines issued a resolution to express the "jubilation" felt by the Filipino people as well as the positive impact of Diwata-1 in "heightening the call for a larger government support for science and technology" [8]. The DOST also unsurprisingly welcomed the launch of Diwata-1 with utmost consideration, as initiator of the project.

However, while Diwata-1's launch was widely celebrated in the Philippines, the lack of any comment from President H.E. Rodrigo Duterte should be noted.

3.2 Political support

From the political side, the establishment of a Filipino Space Agency has also been associated with a tremendous support in both chambers of the Congress. In fact, no less than six bills aiming at the creation of the PSA are currently being examined in the House and the Senate.

3.2.1 In the House of Representatives

Four bills were submitted in the House of Representatives under the name of "Philippine Space Act of 2016" or "PhilSA". The first house bill was proposed by Rep. Erico Aristotle C. Aumentado and Rep. Seth Frederick P. Jalosjos on September 15, 2016 [3], followed by Rep. John Marvin "Yul Servo" C. Nieto and Rep. Edward Vera Perez Maceda on November 7, 2016 [4], Rep. Joey Sarte Salceda [5], and Rep. Maximo B. Rodriguez, Jr. on December 6, 2016 [6].

An interesting point is that all bills are exactly the same. It has however been welcomed warmly by the NSDP, as it displays a clear interest of the House for the PhilSA and helped to accelerate the adoption process [34].

It was recently decided to merge all four bills into a single one, which is currently being drafted [36].

3.2.2 In the Senate

The senate has seen two proposed bills, under the name "Philippine Space Act", the first one by Senator Paolo Benigno "Bam" A. Aquino IV on October 18, 2016 [20] and the second one by Senator Loren Legarda on December 1, 2016 [21]. Their text is exactly similar as the House bills.

Concerning the status of the bills, they have already been discussed in the first Technical Working Group Meeting in the Senate [36], and are still in the process of becoming laws.

4 Space Policy of the Philippines

Having seen the high level of domestic support for the Philippine space development program, and therefore the likeliness of the *Space Act* being adopted by the Congress, it is interesting to further investigate Filipino space policy.

4.1 Proposed bills in House and Senate

The most interesting available sources to learn elements of space development in the Philippines are the various bills proposed in the House of Representatives and the Senate. While documents produced by the NSDP are confidential, it has been brought to the authors' attention that the bills contains most of the spirit of these documents, and in particular of the *Philippine Space Development and Utilization Policy* of 2014 [36].

As explained in 3.2, all bills have the same text. Divided into 24 sections, the bill defines all elements related to space development in the Philippines. While the scope and goals of the Philippine national space policy will be presented in 4.2 and the roles and structure of the PSA in 4.5, this section will focus on the other elements included in [3].

In particular, section 19 proposes the creation of a *Philippine Space Development Fund* of 10 billion pe-

sos (approx. US $196.4 million[2]) granted by the Filipino government from its share in the gross income of the *Philippine Amusement and Gaming Corporation* and the *Bases Conversion and Development Authority*. From this budget, 2 billion pesos (approx. US $39.3 million) will be transferred to the PSA every year for five years. This fund will also be authorized to receive grants, donations and contract loans with financial institutions.

4.2 *The Philippine Space Development and Utilization Policy*

The most important document summarizing the space policy of the Philippines is the *Philippine Space Development and Utilization Policy*. According to [3], the Filipino space policy will focus on six "Key Development Areas":

1. "National Security and Development" to ensure the development of space applications increasing the security of the Filipino people.

2. "Hazard Management and Climate Studies": as explained previously, disaster management is one of the biggest priorities of the Philippines as well as the main reason to initiate a space development program after the deadly Haiyan typhoon.

3. "Space Research and Development" to pump up scientific growth in what [3] calls "vital areas of space science, technology and allied fields".

4. "Space Industry Capacity Building", to develop local capabilities of satellite development, on the model of what was done in Japan with PHL-Microsat.

5. "Space Education and Awareness", to develop training programs for space engineers and scientists. In particular, in November 2016 during the 23rd Asia-Pacific Region Space Agency Forum (APRSAF), the Secretary of DOST, Prof. Fortunato T. dela Peña announced the goal to "produce at least 800 trained aerospace scientists and engineers within the next 10 years" [14].

6. "International Cooperation", very important for the Philippines, which aims at becoming an important contributor to space development and space science in ASEAN and around the world.

[2]From average Peso to US Dollar exchange rate in August 2017: 1 peso = US $0.019637. Hereafter, all conversions will be done using the same rate.

	Type of satellite				
	GEO Telecom	LEO Telecom	Optical-Infrared	SAR	Microwave
Communications	■	■			
Agriculture			■	■	
Forestry			■	■	
Environment			■	■	
Urban Planning			■	■	
Climate Studies			■		■
Coastal Monitoring and Ocean Studies			■	■	■
Disaster Risk Reduction and Management	■	■	■	■	■
National Security	■	■	■	■	■
Flood Monitoring				■	■

Figure 1: Priority application for the Philippines, by satellite type [23]

4.3 Satellite applications and technology development roadmap

When drafting the main principles of the Filipino space development program, the NSDP analyzed in depth the comparative advantages of various satellite technologies to solve challenges facing the Philippines. The findings of this research were partially presented in July 2017 during a workshop in Jakarta [23], and can be found on figure 1.

Based on this, the NSDP established a key document for understanding technology policy: a satellite technology development roadmap (see figure 2), presented at the same workshop.

We can see a correlation between the data of the two figures with a priority given to the development of optical-infrared and SAR satellites, technologies having the widest applications, including the three axes adopted for the promotion of the Philippines' satellite development program: agriculture, environment and disaster risk management.

4.4 Short-term institutional changes

Over the next few years, the institutional framework of the Philippine space development could undergo several changes: the planned termination of the PHL-Microsat project and the possible transformation of the NSDP into a stable office.

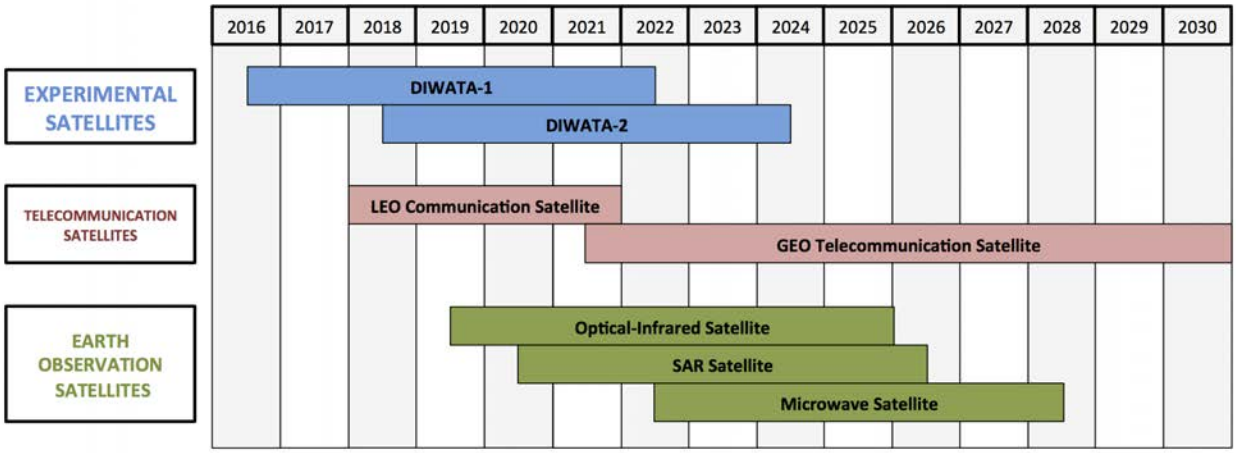

Figure 2: Technological roadmap for Filipino space development [23]

4.4.1 A National Space Development Office?

Apart from the support to Congress bills, one of the other paths currently followed by the NSDP is the promotion of an executive order for the creation of a National Space Development Office, in order to replace the current NSDP, which would therefore cease to exist. By replacing a "project" by a real "office" within the DOST, the executive order would create a more permanent and stable structure in charge of space development until the establishment of the PSA.

This "NSDO executive order" has already been drafted and submitted to the presidential office and is expected to be signed and to enter into force in the future [34].

4.4.2 After the completion of PHL-Microsat

As explained in 2.2, PHL-Microsat is a project aiming at the development, building and deployment of the two first Filipino micro-satellites, Diwata-1 and 2. Therefore, after its completion in 2018, symbolized by the launch of Diwata-2, the project will be terminated, irrespective of the status of the PSA bill [34]. While the satellites are the official property of the DOST and will be operated by Filipino actors (DOST as well as universities and research centers, before the establishment of the PSA), another important aspect is the expected future of PHL-Microsat project's researchers.

An important aspect regarding PHL-Microsat staff is that they all have very different profiles and affiliations. Some of them are students while others are researchers and teaching staff of Filipino universities. Although they are expected to continue to contribute to the Philippines' space development program in universities and later as PSA staff, they are not tied by any contractual clause [34, 35].

4.5 Status and roles of the PSA

The final important point to be raised concerning the Filipino space policy is the detailed explanation of the various expected roles of the PSA. In particular, the bills currently under evaluation in the Congress would order the PSA to "address space-related issues", "advance space science and technology research", "coordinate all national space activities", and "provide a framework for harmonious cooperation" [3].

More precisely, the PSA will be in charge of the implementation of all aspects of *The Philippine Space Development and Utilization Policy*, as described in 4.2. Section 8 of [3] explain in details the tasks and responsibilities of the PSA. An annual report of the activities of the PSA will have to be submitted every year to the Office of the President and to the Congress.

Concerning its status, [3] defines the PSA as a central government agency (section 6), attached to the Office of the President (section 9) and headed by a director general having the rank of *Cabinet Secretary* (section 10). The PSA is also expected to incorporate currently existing organizations in charge of space science, namely the *Philippines Aerospace Development Corporation* of the Department of Transportation and Communication, the *Manila Planetarium* and the *Philippines Space Education Institute* of the DOST (section 13).

Finally, the PSA will be granted an initial sum of 1 billion pesos (approx. US $19.6 million) from the Office of the President, the DOST and the Department of National

Defense. After this, the PSA budget will be included in the yearly *General Appropriations Act* (section 20). A grant of 2 billion pesos (approx. US $39.3 million) per year will also be provided during five years from the *Philippine Space Development Fund* (section 19).

5 Considerations from Innovation Policy

The considerable investment required to establish and sustain a space program historically discouraged developing countries [1], and so they relied on foreign assets and services (either purchased or offered) to provide useful data for governmental and commercial purposes. On the other hand, cost reduction phenomena associated to the *NewSpace* innovation trend seem to offer good chances for the development of domestic space capabilities with acceptable investments [26].

House and Senate bills proposing the creation of the PSA have shown awareness of the costs generated by the lack of a domestic space agency and industry [3–6, 20, 21], while not specifying the way to obtain a positive impact on the economy and society. In this section, we present a possible first step towards the definition of a suitable innovation policy for the Philippine space sector, to create a value-generating domestic industry without running into unsustainable costs for the government.

5.1 The relative benefits of 'Technology-push' and 'Demand-pull' strategies

The technology-push/demand-pull distinction classifies a certain policy depending on the funding approach chosen to pursue innovation in a given field. As ample discussion is given in the literature [2, 11], we will limit our definition to very fundamental concepts: a technology push policy pays for the development, a demand pull policy pays for the product. This can be alternatively described with the supply side policies/demand side designs dichotomy proposed by W. Edward Steinmueller [27]. It becomes very clear how the early stages of space development in most countries pursuing ambitious space programs (US, Russia, Europe, China, etc.) have been supported by policies of the first kind, as the great technological achievements needed would have been too risky and not commercially applicable for the industry. In recent years, however, demand-pull is gaining momentum, as it proved to be effective and cost-saving in a variety of fields. The commercial space contracts awarded by NASA in recent years are a clear example of such trends [28].

In this paper, we chose to use Dr. Sese's classification of "Areas for Future Philippines Space R&D" [22] and to try to identify which policy better suits each one of them:

1. "Space sub-system production": producing subsystems simplifies development by reducing the need for integration, a major obstacle for new entrants. Furthermore, due to limited export restriction, expertise in the field can be easily acquired with international cooperation, as the Diwata-1 case clearly shows. The gap to be filled by the domestic industry to become competitive being relatively limited, a demand pull approach might be appropriate for such components.

2. "Satellite assembly, integration and test facilities": with hardware complexity exponentially increasing with the number of components, it is hard to imagine the private sector taking the huge risk of investing in this field. A technology-push approach would be probably beneficial in early stages, possibly leveraging partnerships between industry and academia. Once fundamental capabilities have been domestically developed, a shift towards demand-pull would be desirable.

3. "Space applications and services": as they consist in software, usually cheaper than hardware, services using space infrastructure (domestic or foreign) while adding value by various means, such as big data and machine learning, can be supported from the beginning by demand-pull policies.

4. "Launch vehicle services and facilities": developing launch capability is probably the most challenging of the goals identified here. With export restrictions and strict intellectual property protection by foreign industry, international cooperation in early stages could be a difficult option. Due to the very large cost and risk, as well as uncertain and distant return associated with setting up a launch program, technology-push may be beneficial, mainly driven by the DOST and the Department of National Defense, as it will be further discussed in 5.3.

5.2 Universities' spin-offs

Supporting university spin-offs is a powerful method to extract value from university research [33]. The benefit of retaining a portion of the company ownership, the main economic benefit for private universities, is complemented, for public ones, by the broader goal of supporting national growth. US and Japanese governments, among many others, created policies facilitating university spin-offs and guaranteeing both direct

and indirect returns [24]. Various studies have tried to classify these phenomena, but only basic characteristics have been defined so far by the theory [15, 19, 24].

A university spin-off is, on a smaller scale, a transition between technology-push and demand-pull schemes. Government-supported university research necessarily adopts the first approach (as it would be impossible to take "entrepreneurial risk") to create breakthrough innovations. Once this has been achieved, supporting the creation of university spin-offs becomes demand pull, as the government signals its or others' willingness to pay for the output of this research.

The Philippine policy for university IP management is considered at a comparable level to those of other ASEAN countries, while still lagging behind the best practices [12]. While it's clearly hard for a Philippine university to offer breakthroughs comparable to those of other research powerhouses, the relative isolation of the space technology sector makes even smaller steps valuable. Under the DOST support, an improved scheme for university spin-offs supporting the technology goals of the PSA, and competitiveness growth for the country more generally, should be created following the policy transition discussed here. This would be especially beneficial for the development of local small satellite production capabilities, as it would address the previously discussed difficulties.

5.3 The development of LEO launchers for small satellites

In a presentation at the 23rd APRSAF in Manila, Philippines, the Secretary of DOST, Prof. Fortunato T. dela Peña, announced a series of long-term goals for the Philippine space development including the development of "indigenous rocket and missile launch capability" [14]. The association of rockets and missiles shows the focus of the Filipino government on LEO small satellites launchers. Contrary to inaccessible expensive large launchers for GEO satellites or interplanetary probes, LEO launchers are quite affordable and can be developed in parallel with missiles, being roughly similar equipment. Synergies can therefore be found between the DOST and the Department of National Defense on this specific goal.

Historically, rocket development has closely followed missile development (e.g. the German V2). Therefore, a close collaboration between military and civil actors on such goal would promise a quick and efficient development phase. Nevertheless, the development of launchers, even for LEO small satellites, is a complex problem, which would probably benefit from discussions with international partners.

5.4 The need for international cooperation

A key element for the Filipino space development is international cooperation. In particular for countries having limited financial means like the Philippines, it could be critical for the realisation of ambitious projects to find synergies with other established foreign space agencies. For the Philippines, this can be done in two ways:

1. At the ASEAN level, several countries are either willing to develop space technologies or are currently operating their own satellites. However, the greatest challenges facing the region (disasters, food insecurity, etc.) require much more than what can already been done with ASEAN countries' indigenous capabilities. A concerted effort of all space countries in the region could, first of all, help provide a stronger answer to these challenges and contribute to the quick and efficient development of space technologies in growing economies like the Philippines. There is no doubt that the experience gathered by Malaysia, Thailand or Indonesia during the initial stages of their space development programs can be of great relevance for the Filipino government.

2. The second possibility of cooperation is with rich and highly-developed space-faring countries such as the US or Japan, traditionally close to the Philippines. PHL-Microsat is a useful first step to initiate such partnerships through universities' academic cooperation. Nevertheless, much more can and should be done. The main advantages for the Filipino government in following this path is to accelerate the establishment of its space program by benefiting from technology transfers from foreign space agencies, research institutes and private companies, and by improving its pool of space engineers and scientists trained in foreign institutions.

As briefly evoked in 1, an interesting example of an institution established through a high level of international cooperation is the space agency of Bangladesh, the Space Research and Remote Sensing Organization (SPARSSO).

Conclusion and future works

Initiated in 2015 — after a failed attempt in 2012 and a comprehensive study carried out in 2014, the NSDP aims at laying the groundwork for the establishment of the PSA. Thanks to a reasonable while ambitious

Philippine Space Development and Utilization Policy as well as various roadmaps drafted by NSDP officers, important bills for the creation of the PSA were filed and are currently being discussed in both chambers of the Congress. These bills enclose most of the philosophy of the NSDUP, summarized in six *Key Development Areas* such as "hazard management and climate studies", "space research and development" or "space industry and capacity building".

Concerning the institutions themselves, while PHL-Microsat will be terminated after the completion of its goals — the launch of Diwata-2, NSDP is likely to be upgraded into an actual "office" within the DOST, before being integrated to the PSA after its establishment, expected from 2018.

From the point of view of innovation policy, several naive recommendations can be given but seem to have been already understood and integrated into the Filipino strategy:

1. While some degree of technology-push could be useful to initiate an embryo of space industry in the Philippines, a demand-pull approach should be favoured as it would ease the financial burden of the Filipino government. It is reasonable considering the country's R&D goals (development of bus and payload subsystems), and its interest in analytics.
2. The development of indigenous satellite development capabilities might also be facilitated by policies favourable to university spin-offs.
3. Launching capabilities should be limited to the more modest goal of LEO orbits by finding synergies between civil applications of the DOST and missile development by the Department of National Defense.
4. An accent should be put on international cooperation, not only with highly advanced countries like the U.S. and Japan but also with developing Asian neighbours to initiate a positive dynamic of parallel development in the Asia-Pacific region.

Finally, this case study on Filipino space development aims at opening a wider discussion on space development and space innovation policy in Asia-Pacific, about both past programs (e.g. Thailand or Malaysia) and future initiatives.

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Space-based Disaster Risk Management by Location-based Emergency Shelter Awareness and Training (LESAT)

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Abstract

Natural disasters have the potential to reverse years of hard-gained economic developments. In the wake of a disaster, preparedness is of critical importance to ensure that the victims can reach the nearest emergency evacuation shelter safely, quickly and efficiently. However, due to widespread communication blackouts and panic following a disaster there is often delay in deciding when, where and how to evacuate which could prove to be fatal. Location-based Emergency Shelter Awareness and Training 'LESAT' is a smartphone application that uses space-based location data like GPS and overlays it with Earth Observation satellite data to provide personalized training to individuals to make them better aware of the potential risks of disaster(s) in their current habitat, the location of the nearest emergency evacuation shelter(s) and the ideal evacuation routes to reach them. A model implementation of this application in the Philippines has been analyzed. The different stakeholders involved have been identified and potential incentives for each of them to participate in this project have been recognized.

Keywords: Augmented Reality, Disaster Risk Management, Earth Observation, GPS, Philippines.

1. Introduction

According to the report by United Nations Office for Disaster Risk Reduction (UNISDR), "just in the last 10 years, natural hazards have amounted to $1.4 trillion in losses due to total damage, affected 1.7 billion people and resulted in the deaths of 0.7 million"[1]. Defined by great damage, loss, and destruction in human lives, natural disasters are sudden and calamitous events, which create large humanitarian and development challenges. There is no country that is immune to these disasters, although vulnerability varies region to region. Asia-Pacific in particular fares worse owing to a multitude of factors such as its geographical location, relative economic poverty and high density of population among others. As the most disaster-prone region in the world, they suffer close to 40% of the globe's 'natural' catastrophes [2]. "Since 1970, more than 5000 major disasters have hit this region causing more than two billion fatalities and affecting the lives of more than six billion" [3]. Globally, we continue to see increasing trends in rapid climate change, warming temperatures, and financial costs. Indeed, climate change manifests itself through the hydrological cycle. With greater intensity, rainfall variability and glacial melt contributing to floods, storms, and sea level rise. Small island developing states as well as low lying coastal communities such as the Philippines are especially at high risk. As decades of economic development is often lost within a matter of minutes when a natural calamity strikes, reducing disaster risk and increasing resilience to natural hazards are mandatory requirements for sustainable development.

1.1. The Role of Space-based Data in Disaster Risk Reduction

Disaster Risk Reduction (DRR) is a cross-cutting issue in the 2030 Sustainable Development Goals (SDGs) with direct relation to at least 25 targets in 10 out of the 17 SDGs related to poverty, ending hunger, ensuring healthy lives, education, building resilient cities and climate change [4]. Preparedness is a crucial and perhaps the most important component of the DRR cycle, which also includes elements of prevention, response and rehabilitation in its full cycle. Although disasters are inescapable, their worst effects can be partially or completely prevented by the act of preparation. Early warnings as well swift and decisive strategies can offer timely responses that saves millions of lives. For example, it has been known for decades that it is much more effective to evacuate people before a flood than it is to rescue people during or after one. Providing relief to victims only after the disaster limits valuable opportunities to better absorb, recover, and build resilience from disaster shocks and stresses. It is essential to believe and work towards a culture of prevention and

risk reduction rather than just reaction and relief. In this context, Community-Based Disaster Preparedness (CBDP) approaches are increasingly important elements of vulnerability reduction and disaster management strategies. They are associated with a policy trend that values the knowledge and capacities of local people and builds on local resources, including '*social capital*'. Most often, CBDP are used to increase the resilience to a natural hazard by raising *awareness* of people to the disaster risks. This is because community members who perceive their lives and livelihoods to be especially vulnerable are more likely to cooperate in relevant preparedness initiatives [5]. Also, increasingly institutions and political frameworks are recognizing the benefits of using space-based data for DRR purposes. A prominent example is the Sendai Framework for DRR 2015–2030, which explicitly promotes the use of Earth Observation (EO) to gather data that is needed to elaborate information on hazard exposure, vulnerability and risk and hence as an indispensable source of information to support decision-making related to disasters. EO has been widely applied to disaster risk management (including disaster preparation, response, recovery and mitigation). Data collection and processing methods have advanced substantially. Freeing data archives ranging back over more than 30 years (for example Landsat/NASA) and EO programs like Copernicus provide a plethora of various types of satellite data and products. Such advances need to find their way in applications related to DRR, including in the indicators to monitor advances in these areas. EO from ground and space platforms and related applications represent a unique platform to observe and assess how risks have evolved in recent years, as well as to track the reduction in the level of exposure of communities to natural hazards over the years.

2. Emergency Shelter Awareness

Emergency evacuation shelters allow for a place of temporary safety, resources, and protection most profoundly against disasters involving immediate evacuation such as floods, storm surges, earthquakes, and fires. They play an absolutely vital role catering to the well- being of the displaced affected populations and act as the first promoter of rehabilitation. Once inside, people feel less panic and anxiety in the wake of chaos. Since shelters are usually equipped with stocks of food, water, and telecommunication, they play a key role in preventing loss of life. However, the evacuation itself, which may pre-empt an event or occur in the wake of an incident must be carefully planned beforehand so that it ensures the safest and the most efficient evacuation time of all residents. Otherwise, a disorganized evacuation can result in confusion, injury and property damage. One of the most common effects of a large disaster is the immediate massive blackouts caused in the existing communication channels due to telephonic congestion, power outage, road blockages, land inundation, infrastructure damage etc., resulting in extreme difficulties in effective evacuation. With special reference to disasters such as earthquakes, tsunami, storm surges, and floods where quick evacuation is of prime necessity, a matter of minutes to reach a safe shelter can mean the difference between life and death.

Research observations have shown that even if the choices for emergency evacuation centers exist, evacuation rates vary and not everyone leaves. The factors that affect such evacuation decision making process of the populace usually include perception and beliefs of the local community, finding the credibility of the warnings issued, reinterpreting the situation depending on past experiences, ignoring the warnings, level of education and average age of the population, desire to protect their property from the hazard etc. Such circumstances beg the question: What does it take to persuade people that warnings are issued only for their own safety and security? Studies in [7] state that, *people do not evacuate for several reasons including, but not limited to, past experience, traffic, immobility, lack of transportation, limited social capital and the desire to shelter-in-place.* (Mileti, Drabek and Hass, 1975).

It has been found that usually, the initial reaction to warnings of a disaster threat is skepticism, rather than panic [8]. If it seems that the warning is credible, the common reaction is an attempt to corroborate its validity, typically by listening to broadcasting media such as radio and television or by speaking to friends, families, or neighbors. If there is contradictory information or ambiguity concerning the threat, recipients of the warnings will tend to downplay the threat. Moreover, the members of susceptible populaces will exploit any "ambiguity" in a warning message that further allows them to reinterpret the situation in a nonthreatening way [8, 10]. Such attitude of people finally leads to a situation where there is a proportion of people who do not heed the warnings issued and are hesitant to evacuate which in turn causes pandemonium in spite of the availability of the evacuation centers. For example: *In Australia when interviewing residents that had evacuated during the Maitland 2007 flood, only 52% said they would evacuate in any future flood* (Gissing, Molino et al. 2008) [9]. One other example from Hurricane Andrew, South Dade County, Florida, 1992 shows: *while it is estimated that seven million residents evacuated, three million refused to leave* [10]. Another important factor is the educational level of the population which plays a major role on evacuation decision-making compared to income or occupational status (e.g., Moore, et al, 1963: 80-83) [6]. Similarly, age is sometimes also considered as a significant issue. Practically it is sometimes difficult for the aged people to rush towards the evacuation centres because of their poor physical condition even if they are

aware of the same. *Several studies indicate that those over 60 are less likely to leave than younger people* (Moore, et al, 1963; Smith, 1979) [6]. Hence, to combat all such tendencies of people, a greater focus on risk communication is required as a part of disaster preparedness in order to maximize evacuation rates and save millions of lives.

Our research shows that there are two major problems people face with respect to emergency evacuation and which may prove fatal:

Q1. When to Evacuate?

The timing which people choose to leave following a warning to evacuate is extremely variable. Murakami, Takimoto et al. [11] studied the case of 2011 tsunami in Japan, and found that 37% commenced evacuation during or directly following the earthquake, 31% evacuated sometime afterwards, 14% did so when the danger became obvious, while 18% did not evacuate at all. Petrolia and Bhattacharjee [12] assessed the intentions of people to evacuate in respect of hurricanes in the US. They found that 34% of those sampled, indicated they would evacuate, 28% would wait before deciding, 30% would not evacuate and 8% didn't know what they would do. A recent Nature article [13] reported that during the cyclone Nargis which had a casualty of 138000 in Myanmar, "all interviewed eyewitnesses ignored warnings owing to lack of cyclone awareness (...) the inundation penetrated 50 km inhibiting last minute evacuations". In another study [14], it was found that "Only 25% of people decided to go to safety shelter after an earthquake" (after 921 Chi-Chi Earthquake, Taiwan). Yet another study [15], confirms the fact "the occupant of the house, leaves only if he/she believes that his/her home would be affected". These and other similar trends reflect the inability of the public to understand and follow evacuation procedures.

Q2. Where to Evacuate?

Even if the community member decides to evacuate (bypass Q1), the ability to find the location of a safe emergency shelter within a typically short window of time is crucial. This window is smaller in economically challenged developing countries, making the awareness of the location of shelter and the time and route to reach it, an important requirement in a successful evacuation. Lack of such knowledge, can result in much larger number of casualties. For example, in our interview with Mr. Ven Paolo Venezuela, a Filipino DRM practitioner, it was found that in Typhoon Haiyan "perhaps half the 6000 deaths are unaccounted for – probably drowned from storm surge, and likely because they did not know the location of safe shelter and believed they were already in one". Although it is not a frequent incidence, but sometimes because of lack of knowledge of the surroundings evacuees involuntarily flee in the direction of greater hazard. Hence, it is of great importance to be familiar with the closest safe assembly area or nearby emergency evacuation center for safe escape.

2.1 Current DRR Practices

Disaster risk reduction is gradually being recognized as a major influence in achieving sustainable development, although it still remains a challenge to systematically integrate DRR into development planning and activities. [16]. At present different levels of preparedness initiatives exist in most countries. The wealth of developed nations permits them to allocate adequate funds for disaster mitigation and preparedness measures. For example, these countries encourage researchers to identify danger prone areas and recommend appropriate measures for safety and shelter by providing them adequate amount of money. The developed nations also create intricate training systems to prepare disaster response teams. Such training systems are kept accessible to everyone from first responders to community volunteers for responding to a crisis more efficiently and quickly. Furthermore, these countries exploit the best technologies and high-level education to develop warning systems for the common people [17]. Japan, the United Kingdom, the United States, Sweden, Australia, New Zealand etc. are the examples of developed nations that have advanced emergency management programs focusing on resilience. If we consider the instance of Japan, it is arguably the world leader in readiness. Every year since 1960, many Japanese schools, public and private organizations conduct region wide emergency evacuation drills on specific disaster awareness days. Such initiatives which are characterized by their large reach and high impact, help the country to top the list when it comes to disaster preparedness.

In comparison to developed nations, developing countries suffer more from natural disasters because of their weak warning procedures and impecunious living conditions. These countries usually lack sufficient funding, appropriate knowledge about disasters and enough equipment to diminish their vulnerability. However, in developing nations also, local disaster drills exist, which are often conducted by small organizations (such as a school or a university). Such drills are typically performed on a smaller scale and these are more flexible and frequent with a smaller reach, which require less investment. Nonetheless, currently there is a niche in the provision of direct and 'customized individual training' to each member in a community – one which is flexible, can have a large target audience and needs significantly less investment. The socio-technical system design we have developed here is one which would target this niche – in the context of training and empowering the

community to tackle the aforementioned difficulties during the necessity of an emergency evacuation

3. Location-based Emergency Shelter Awareness and Training (LESAT)

3.1 Rise of GPS enabled smartphone usage

The idea behind LESAT's design is to tap into 'pre-existing socio-technological behavior' prevalent in this 21st century – widespread popularity and usage of "smartphones". According to the Ericsson Mobility Report, 2016, the smartphone penetration in Philippines is around 40% with predictions of up to 70% by 2020. Our proposal combines this rapidly developing trend along with the necessity to provide customized information about emergency evacuation shelters to individuals utilizing the location awareness capability (GPS) present in a smartphone. Also in the absence of GPS in the phone, the approximate location could be identified by using triangulation between three or more radio towers.

3.2 Earth Observation satellite data

The usage of space technology and data in the DRR efforts has been on the increase. Earth observation provides advanced products and related tools that can be used to support risk analysis and risk reduction. Many countries face the difficulty of lacking environmental data. Ground-based monitoring systems like climate stations involve high costs, maintenance and data sharing policies. Therefore, they are often not available. Due to large-scale reprocessing activities, the archives of satellite imagery are constantly growing. We can access time series covering almost 50 years. This facilitates the assessment of underlying risk factors and impacts of global change over time. Satellite information is increasingly available for free. For example, data from LANDSAT, Sentinel, NOAA, ESA's EO Catalogue, INPE Image Catalogue, ISRO's Bhuvan- Indian Geo Platform, JAXA's Global Alos 3D World, Vitovision etc., are all available for free.

Table 1 shows the different satellite data types for different disasters and their corresponding data providers. The data providers are mostly branches of international space organizations like NASA, JAXA and ESA, which shows the importance of International Cooperation for Disaster Risk Preparedness and Response.

Since at the onset of disasters, communication lines may be affected, it is advisable to not have complete reliance on real-time updates for disaster response furthermore strengthening our earlier found niche that localized preparedness is very important for preventing loss in the aftermath of a disaster.

Table 1. Earth Observation data types and providers for DRR

DISASTER	DATA TYPE(S)	DATA PROVIDER(S)
Drought	Interferometric SAR Imagery	NESDIS NOAA, NDMC NASA
Earthquake	Ground-based Data, Interferometric SAR Imagery and GPS	USGS, JMA, Live Earthquake Map EMSC, Global Earthquake Monitor, Sentinel 1A, READI NASA-UCSD
Flash Flood	Visible and Infrared Imagery	NSSL NOAA
Flood	Radar Imagery	GPM NASA/ JAXA, GFMS NASA
Forest Fire	Visible and Infrared Imagery, LIDAR and SAR Imagery	Global Fire Map NOAA
Landslide	Ground-based Data, Interferometric SAR Imagery and GPS	USGS, DRIP-SLIP NASA, NASA Catalog of Global Landslide, GFMS NASA
Lightning	Visible and Infrared Imagery	NSSL NOAA
Snowstorm and Hail	Visible and Infrared Imagery	NSSL NOAA
Tornado	Visible and Infrared Imagery	NSSL NOAA
Typhoon, Cyclone and Hurricane	Visible and Infrared Imagery, GPS	TSR UC-London, NHC NOAA, JMA, CYGNSS NASA, CIMSS
Tsunami	Ground-based Data, Radar Imagery, and GPS	JMA, DART NOAA, PTWC NOAA, READI NASA-UCSD, POSITIM, Tsunami Alarm System
Volcanic Eruption	Interferometric SAR Imagery, Visible and Infrared Imagery	USGS, JMA, NOAA-CIMSS, ASTER & MODIS NASA, EUMETSAT

In this regard, historical database containing information regarding the effects of past disasters in a certain region can be of priceless importance. For example, users can have a guideline regarding the best way to access a shelter if they have an idea which streets are least likely to be flooded. This can be easily predicted looking at historical statistics of flood inundation levels in different streets of any given city from the open-access historical database in the websites of the data providers

in Table 1. LESAT will take into account this historical data and overlay with GPS data to develop customized disaster specific shelter information to the user. Thus, it can provide users the best possible route to access a nearby shelter from their location in the onset of a disaster since the shortest path shown by google maps to access a shelter may not be the best choice under such circumstances. Not only is this information useful during the onset of a disaster, but city authorities can also use this historical information to improve the resilience of city planning and rebuilding post the disaster.

In case communication lines are not affected during the occurrence of a disaster and users have internet access, LESAT will provide real-time disaster updates like actual flood inundation levels in the city, city traffic, congestion, estimates of the number of people at nearby shelters and warning signals in case evacuation is needed. Although Government, social media and news channels are expected to provide real-time information, it is always preferable to also have it automatically delivered via the Disaster Mode in LESAT. This makes Disaster Response more robust due to increased level of redundancy.

3.3 LESAT – The Concept

LESAT is a location-based technology (application/firmware) that provides customized information to its users and, since it requires the development of only an 'app', is of significantly lower investment and potentially massively scalable. LESAT works in 3 modes. 2 modes are used for training – before the disaster, and the final mode is used to provide customized info to the user in the aftermath of one.

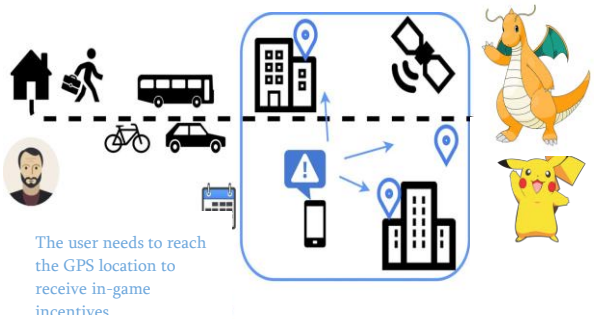
3.3.1 Training Mode 1: Passive - Sit 'n' See

In this mode, LESAT works along the following principle: On a designated day, nearby emergency evacuation shelters are shown to the user based on his/her current location (at home, at work or even during commute - this is important because in complex metropolis like Manila or Tokyo, people often travel long distances every day in their daily lives). LESAT would be active only on this day. The user can proceed with his/her usual daily activities. As he/she passes through pre-marked proximity 'zones' near the evacuation shelters (detected by the phone's GPS), a pop-up would be displayed in his/her phone notifications (with a photo and address of the shelter). In general, public buildings such as local schools, churches or city offices are generally designated as emergency evacuation shelters to be used in the advent of a major natural disaster. The user may choose not to interact with the LESAT pop-up. In case, he/she chooses to interact additional 'customized' information is displayed. The information would include the 'localized' severity of major disaster effects in that region– for example, water levels in case of a major flood, wind speeds in case of a typhoon etc. The data for the same would be obtained from national disaster management agencies of the country and also from pre-existing open databases of earth observation satellite data (Table 1). However, the government(s) in general always tend to follow a 'precautionary measure' with respect to disaster information dissemination. This means that the potential localized severity of a disaster may often be over-estimated resulting in the loss of faith of the public over the advisory, a phenomenon which can be termed as "cry- wolf". In order to mitigate this, actual occurrences of disasters in the area, in the past would also be displayed. Due to the passive nature of this mode, the cognitive bandwidth used by the individual is almost invisible, making this techno-policy solution a form of 'nudge'. With multiple such drills conducted in a year, we tap into the behavioral skill - 'memory' of the participant due to sheer repetition and exposure, resulting in his/her ability to locate the nearest shelter without any external support. This is especially advantageous in a situation where a communication congestion or blackout occurs. After a predetermined number of times of undertaking this training drill, the user may choose to opt out of the system after successfully answering a questionnaire which tests his/her knowledge of the location of the evacuation center(s). This also serves the purpose of a way to measure indirectly, the efficacy of this 'nudge' approach.

Fig. 1. LESAT Training Mode 1: 'Sit' n 'See'

3.3.2 Training mode 2: 'Play' n 'Go'

LESAT in this mode takes advantage of the prevalence and popularity of 'augmented reality' and applications based on it such as massively popular games – Pokémon Go, Ingress, Mario Run etc. It also taps into the 'human behavioural reward system'. It works in the following way: on the same designated day, emergency evacuation shelters are made as GPS markers which the user/player needs to physically reach in order to receive in-game incentives. This mode is more persuasive and it makes sure that the user knows not only the location of the emergency shelter, but also the means of reaching it – route and time, resulting in an additional layer of information. This info is understood not only cognitively but also "through his feet". LESAT in this mode can also be extended to train the user under different disaster scenarios. As an additional layer of challenge and also to make the user interaction more personal, real-life situations are simulated by adding a layer of uncertainty to the simulation. In the event of a disaster such as tsunami it is possible that some shelters are not accessible at all, some are not easily accessible by the elderly population and some are accessible only within a specific time window after the disaster. All these scenarios could be simulated under this mode of LESAT using in-game incentives or rewards. For example, some routes where potential blockages may arise post-disaster might be 'closed' in-game or given lower incentives, forcing people to take alternate routes. However, since one of the requirements for massive scaling of this app is being 'low-fat' in nature – meaning not requiring large volume of data for working, scenario simulations could be provided as add-on downloads. In order to implement this training mode, partnerships are required with developers of apps/games that utilize location knowledge and augmented reality. For example, Pokémon Go's Niantic is one prime candidate. However, this specific requirement of an external partnership is from a bane – the participating companies get crucial media exposure due to participation in such CSR activities resulting in a win-win situation.



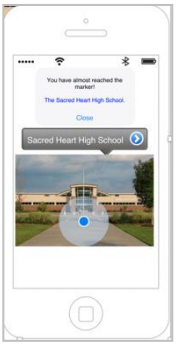


Fig. 2. LESAT Training Mode 2: 'Play' n 'Go'

3.3.3 Mode 3: Disaster Mode: Custom Info

LESAT also serves the user just before/after a major disaster strikes. If communication connectivity is possible, it displays customized information - direction & time - for reaching the shelter, in a simple, easy to understand format. This information is directly 'pushed' by the telecom service provider, in accordance with a mobile alert regulation, for reliable reception. Even if no or limited connectivity is possible, the mode will display the (time-stamped) latest known danger level, and saved names, addresses and contact info of nearest shelters to home and workplace, or other user-relevant locations. Crucially, any shelter displayed will be appropriate for the disaster at hand, e.g. "5-m storm surge", thanks to stored data on shelters, cross-checked with the latest disaster information. Finally, the danger meter will be calibrated to local historical events, paying special attention to not exaggerate the threat, or "cry wolf". If internet data connectivity is also available, based on the GPS location of the user, the government authorities are also notified when a user reaches a specific shelter location. This very valuable information can be used by the DRRM personnel to better understand not only the requirements at each shelter (for example, a shelter with more elderly need more medical care etc.), but also aid them in understanding the worst affected areas (for example, in case no one reaches any shelter(s) in a particular area, it is possible that they are not able to and hence need external help). However, to alleviate privacy concerns, either just the count of total people is provided or users (after an agreement) can provide their identities too. It is also interesting to know that once prior cached data of maps can be downloaded, the usage of GPS does not require the presence of internet connectivity. Therefore, even in the absence of internet communication, it is still possible by the by the user to know the direction to the nearest emergency evacuation centre.

Fig. 3. LESAT Disaster Mode 3: Custom Information

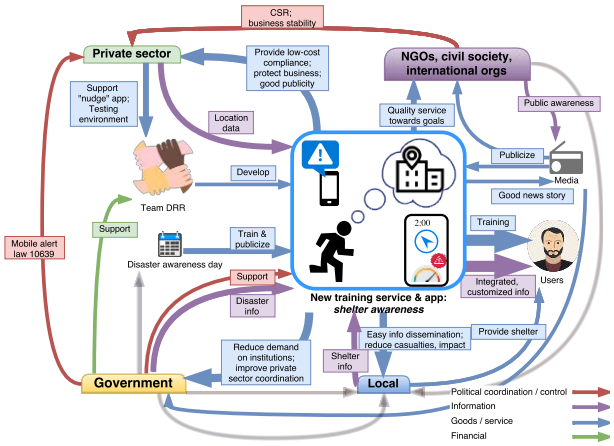


Fig. 4. Stakeholder map and interactions

4. Model Implementation in Philippines

A stakeholder map and value network for the LESAT system is shown below in Fig. 4. Firstly, it is important to note that the LESAT service is not just an app, but an integrated sociotechnical system coordinating several players and interactions. These players are shown here. In the centre is the LESAT training service and app, immediately to the left is *Team DRR*, for now our team, which is responsible for its development and execution. The other main players are grouped into the private sector, top left; government (assumed to be national level), bottom left; "local" (meaning especially local authorities and government), bottom right; and NGOs, civil society and international organisation ("3rd sector"), top right. Users are obviously key, to the right.

The main flows and flow type between groups are indicated. The principal ones are: information flowing from the private sector, government and "local" to LESAT, and then to the user; goods/service flowing back from LESAT to the private sector, government, local and also to users and civil society, and from the private sector to team DRR, and "disaster awareness day" to LESAT and "local" to the user; "political coordination/control" flowing from the government and civil society to the private sector. The minor flows include services going from Team DRR to LESAT, the media to civil society and government, and LESAT to the media; also, the only financial flow is from government the Team DRR development team.

The main idea is that LESAT requires data, services, and support or cooperation from many diverse actors; it should appropriately incentivize each of these actors to cooperate, by providing a service in return. Users are the main beneficiaries, but the self-interest of other stakeholder must be considered, in gauging their likelihood to aid. The government sector is the main client, as LESAT will reduce demand on its institutions, and so it provides financial support to the development team, Team DRR. It will also provide disaster information data to the LESAT system - this might be done via existing websites and information provision. Importantly, the government also provides some support, particularly moral and legal support for the system - official sanction. Government exerts relevant political control on the private sector with, in the Filipino case, Mobile Alert Law 10639. This law requires telecom companies to provide timely warnings to all its users, free of charge, in the case of a natural disaster. A further motivation for government support and funding is to help in improving coordination between the government and private sector, in accordance with this law.

Moving to the private sector, the main specific flows are receiving from LESAT the service of low-cost compliance with the mobile alert law, as well as protection of their business (clients, infrastructure, supply chains, employees...) and good publicity. It provides technical support to the Team DRR, including a testing environment, and importantly provides the critical location data to LESAT. Familiarity with this data, and ability to "push" data and apps directly to users is the rationale for the support role.

The local sector must provide shelter information, including number, location, and some characteristics of local shelters (e.g. suitability to type of disaster, access points, distance above sea level, capacity, contact information...). It is incentivized to do so by receiving the service of information dissemination that LESAT provides. LESAT should also reduce damage and casualty rates on local communities, hopefully incentivizing cooperation. It shouldn't be forgotten that it is the local sector that ultimately provides shelter to users in any scenario.

Civil society obtains a quality service in accordance with its aims, that is in disaster risk reduction. By being given the explicit opportunity to partner or associate with LESAT, it should be possible to obtain its aid in (a) public awareness of LESAT, (b) influencing Corporate

Social Responsibility (CSR) initiatives, to increase the likelihood of private sector engagement. In this way, the private sector can be approached on three fronts: (1) via government influence because of support for the project, (2) by self-interest, in complying with regulation cheaply and protecting their business, (3) via improving their public image. The third point can be broached from either the sponsorship/branding of the service, or via CSR budgets and activities, and perhaps via a mixture of both.

The media is an important player because of the important function of public awareness of LESAT. It can be incentivized by the providing of a "good news story" both by LESAT directly, and civil society, and in return can provide some publicity and awareness to the users. It must be pointed out that there are some network effects present here: the incentives of all players to aid LESAT is proportional to its user base and reach; this user base in turn is likely also proportional to the functionality and usefulness of LESAT, based on the resources and cooperation provided by these players. Because of this "snowballing" effect, the initial phase and gain of momentum (or user base) is critical and bears careful consideration. As such, we believe that another system, "Disaster awareness day", is worth considering. Coordinated by government, this is a multi-stakeholder event and platform for providing disaster-related information and training. A partnership with the government can aim to a high-profile rollout of LESAT at Disaster awareness day, in combination with other pre-existing measures. Such a strategy can reduce the risk of a "low-level trap" of user base in the early phase.

Finally, in this manner the user is provided with both training and *customized* and *integrated* data by LESAT. It is worth pointing out that most of the data required is pre-existing; the value generation of LESAT is by integrating it, packaging it, presenting the relevant parts and training the user with it. This is perhaps in accordance with current business wisdom: though *data* is typically not very valuable, timely and relevant *information* is extremely so. This transformation is where the main value addition resides.

It is worth looking at more detail of the different sectors, which are not unitary but composed of several interacting actors (Fig. 5.a). The government sector's disaster reduction efforts have, in the Filipino case once again, been recently conveniently centralized through the efforts of the National Disaster Risk Reduction and Management Council, or NDRRMC. This was in response to the fiasco of Typhoon Haiyan, which traumatized Filipino society in 2013 and demanded institutional reform. The NDRRMC serves to coordinate the efforts of several ministries and other agencies. The membership is extensive and includes representation from the Department of the Interior, the Department of Natural Resources and Environment, the Statistics Authority, and the Department of Science and

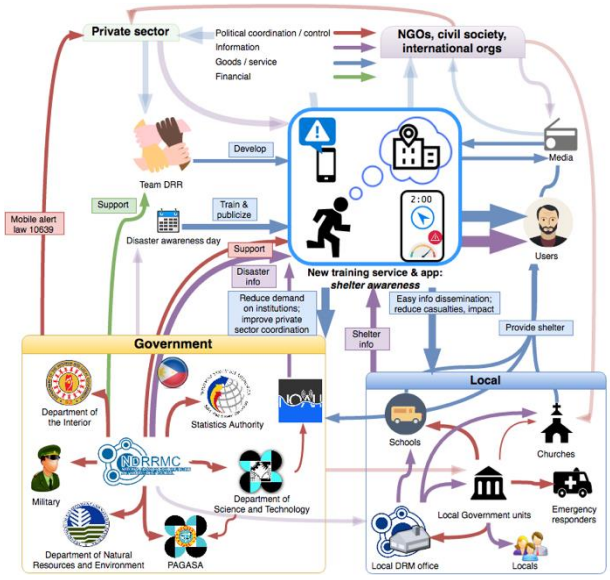


Fig. 5.a Detailed information on actors in the government and local sector

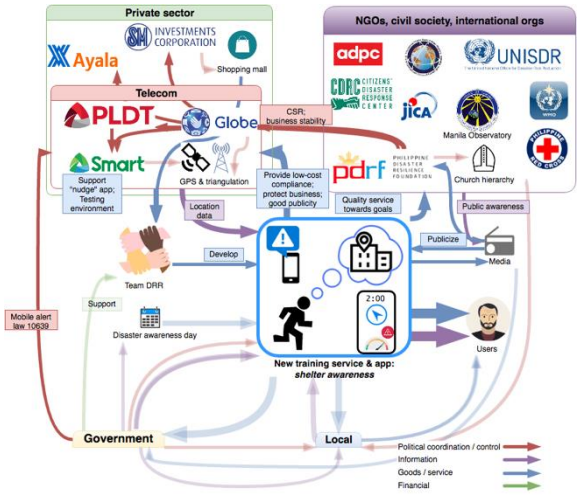


Fig. 5.b Detailed information on actors in the private sector and the civil society

Technology - with its agencies, the weather agency (PAGASA) and the notable project NOAH (on mapping and information dissemination, recently defunct). The overall leadership is assumed by the military. Vis-à-vis LESAT, the "one-stop-shop" of NDRRMC simplifies any negotiation, and potentially allows support from various government departments. It also testifies to the government priority that is disaster risk reduction. Project NOAH's heritage also simplifies the timely acquisition of up-to-date verified disaster data. Finally, the NDRRMC has direct links to local offices and government units, potentially facilitating simultaneous agreement and coordination.

Next looking at the organisation of local authorities, we note the most relevant actors as the government units and aforementioned local DRRM office, first responders, and schools and churches - the most typical shelters in the Philippines' (and many other countries') dual-use shelter system. This organisation likely facilitates DRRM office links to schools and first responders. However, it is likely that local authorities' control over churches is less strong, as such these should be dealt with differently than via government channels.

Looking at the Fig. 5.b, firstly within the private sector, we break down the relevant players into the telecom sector and the rest. Telecom companies, dominated by Globe and PLDT in the Filipino case, own and provide the GPS and triangulation data required for the functioning of LESAT. They also have the expertise needed to use such data, and push any notifications. Another relevant private sector player is SM Investments Corporation, the owner of a major shopping mall chain. Due to SMIC's commitment to disaster risk reduction, it has been suggested that these might be good testing grounds for the LESAT system. All companies listed here have their CEOs on the Board of the Philippine Disaster Resilience Foundation, a funded, voluntary and recent private-sector-led effort intending to demonstrate its intention to reduce disaster risk for society.

The civil society key player is the Philippine Disaster Resilience Foundation (PDRF), representing the private sector's DRR agenda. It will be the main point of contact for LESAT, and allow the coordination and streamlining of many important industry players' DRRM and CSR agenda. Due to its board being composed of the CEOs of said companies, it should be very influential. It is also important to point out that the Catholic Church hierarchy is also on the PDRF board, forming a good point of influence for the previously-mentioned parish Church shelters at the local level. Though the Church is a key player in Filipino society, it should also be noted that due to its unique history, Filipino civil society is uncommonly strong and well-developed. This strength should be utilized, through such organizations as the Citizens Disaster Response Center (CDRC) and the Manila Observatory and *many* grassroots NGOs which may help information dissemination and publicity about LESAT. Finally, international organizations may be key for significant LESAT functionality - notably the World Meteorological Organization (providing cooperation on weather information and warnings) and the UN Charter for sharing space data, foreign aid organizations such as JICA, and others already working on the disaster risk reduction problem and with rich experience, such as the Asian Disaster Preparedness Center (ADPC) and Filipino Red Cross.

However, the above stakeholders are definitely not an exhaustive list - we've only tried to list and organize the most important actors and interactions. For example, other international donors may be important such as the World Bank (provider of large loans for disaster response), foreign militaries and aid (notably US military aid and ASEAN cooperation), universities may have a helpful role in the development of the app, the medical and insurance sectors are interested parties, as are the IT sector, charities, banking, lawyer groups and trade unions.

5. Conclusion

LESAT is an innovative socio-technological solution designed to provide training for individuals to help them realize the necessity to evacuate and help them locate and access emergency evacuation shelters in the occurrence of a natural disaster. The training is customized to each individual, and provided through the use of location-based (e.g. GPS) smartphone application /firmware. In addition to the GPS data pre-existing space-based data such as risk maps for different disasters are also overlaid upon the location data to provide customized information about the relevant emergency evacuation shelter and evacuation route for each scenario. LESAT works in multiple modes with different levels of cognitive bandwidth required by the users in each mode. The passive mode is a form of ‘nudge’ and makes the user aware of the presence of an emergency shelter nearby and also its location. The active mode requires the user to physically reach the specified shelter under different scenarios. In return, the user is provided in-game benefits from different applications with which LESAT is tied to. In the disaster mode, customized info is repeated during disasters. A model implementation in Philippines is analysed through a detailed analysis of stakeholder map. Policies to implement are designed in a way such that that all major players have incentives to participate and gain from the implementation. LESAT is a low-investment and highly scalable solution for improving the preparedness of the community to the adverse socio-economic impacts of natural disasters.

Acknowledgements

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