VU-GWHF Partnership for Humanitarian Engineering

Garrett M. Clayton[1], Allen Tan[2], Jordan Ermilio[3], and Aaron Wemhoff[1]

1 – Associate Professor, Department of Mechanical Engineering, Villanova University
2 – Director, Phnom Penh Design Lab, Golden West Humanitarian Foundation
3 – Director, Villanova Engineering Service Learning, Villanova University

Over the past three years, Villanova University (VU) and the Golden West Humanitarian Foundation (GWHF) have partnered to engage students in international engineering design projects focused on unexploded ordnance (UXO) remediation. To date, senior design projects stemming from this partnership have involved over 25 undergraduate and graduate engineering students, with more than 10 students traveling to the GWHF's facilities in Cambodia for design review and prototype testing. In this paper, the VU-GWHF partnership will be presented from the project partners' perspectives. Project details, including scope, selection, planning and implementation, will be discussed.

1. Introduction

In this paper, we discuss an ongoing international partnership between the Mechatronic Systems Lab (MSL) and Villanova Engineering Service Learning (VESL) at Villanova University (VU) and the Golden West Humanitarian Foundation's (GWHF's) Phnom Penh Design Lab (based in Cambodia). GWHF is recognized by the international humanitarian explosive ordnance disposal (EOD) community as one of the premier non-governmental organizations (NGOs) for the research, development, and implementation of solutions to address this sector's most difficult technical challenges. Based on GWHF's expertise, this partnership has focused on providing engineering support for their initiatives through senior design projects.

Funding for this collaboration is provided from GWHF through a State Department Education Grant. Thus, the primary goals of this relationship are to:

1) *Develop globally-engaged engineering researchers*. The engineering landscape has become international, thus requiring globally-engaged, globally-minded engineers[1]. Through the experience of working on an international, interdisciplinary project, students come away with the skills necessary to make a significant impact in the international engineering community.

2) *Introduce future engineers to humanitarian engineering issues*. ASME identifies engineering solutions for the developing world as one of the key issues facing engineering in the next 20 years[1]. By working in a developing country on humanitarian

engineering issues – specifically issues associated with explosive remnants of war (ERW) remediation – students are able understand and meet the unique constraints that exist when engineering in this context (e.g., cost constraints and availability and/or quality of materials).

As mentioned, the goals of this collaboration are educational in nature. As an added benefit, engineering design and development projects are also carried out through the senior design sequence in the Department of Mechanical Engineering at VU. Students are given a faculty advisor and have frequent interactions with representatives from GWHF. As part of this experience, students are given the opportunity to travel to Cambodia to interact to give a design review at the midpoint of the project. Over the past 3 years, two multi-year projects have been initiated: the development of a low-cost EOD robot (3 years) and an ordnance burning filtration hood (2 years).

The remainder of this paper is organized as follows. First, background regarding the general problem of ERW as well as an overview of GWHF and VESL are presented. Next, details of the partnership, followed by perspectives from both VU and GWHF are presented. Finally conclusions and future work are discussed.

2. Background

2.1. Explosive Remnants of War in Cambodia

Starting in 1965 and continuing for 3 decades, Cambodia was embroiled in armed conflict. US bombings during the Vietnam War made Cambodia perhaps the most bombed country in history[2]. Many bombs did not explode, leaving unexploded, but still active bombs throughout the country – US bombing sites are shown in red/orange in Fig. 1 along the Cambodia-Vietnam border. Following this period, the Khmer Rouge came to power resulting in the Cambodian genocide[3]. The Khmer Rouge were eventually pushed to the Cambodia-Thailand border, where significant numbers of landmines were deployed by both Cambodia and Thailand to prevent the Khmer Rouge from entering their respective countries[3] – active landmine sites are shown in purple in Fig. 1 along the Cambodia-Thailand border.

ERW contamination – more than 4500 km^2 contaminated[3] – has significantly affected Cambodia in a number of ways. As of June 2012, more than 64,121 people have been killed, injured or disabled in accidents[3-5]. Economic growth is stifled because expansion of farms and other livelihood activities is impeded[3]. Thus, there is a critical need to solve this problem. Note that although this proposal focuses on Cambodia, this problem exists in other developing countries as well. It is estimated that 100 million landmines are spread throughout 84 countries and that 20,000 people are injured or killed by landmines worldwide[6]. This problem is compounded by

the fact that many of these ERW are in developing countries that cannot afford the costs of removal[6,7].

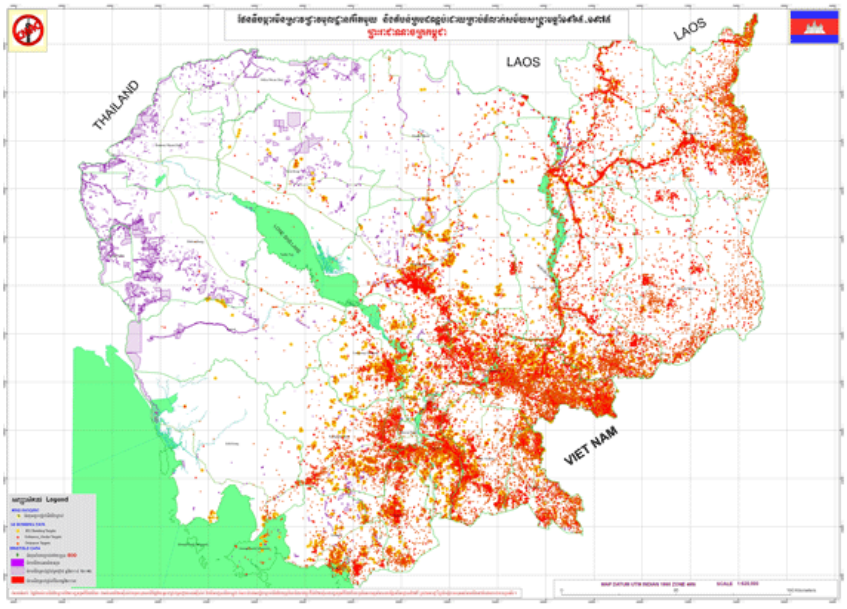

Figure 1: Landmine and UXO Contamination in Cambodia adapted from Ref. 3. Legend: Red/Orange – US bombing locations, Purple – Other ERW.

2.2. Villanova Engineering Service Learning (VESL)

The College of Engineering at Villanova University has a long history of providing technical services to support humanitarian initiatives. For over twenty years, engineering faculty and students have been participating in engineering outreach activities, which are commonly referred to as Engineering Service Learning. In 1991, a small group of engineering students and faculty traveled to work with the Cheypo-Bayano Mission in Panama. Students who graduated were excited to return to Panama to see their projects through to completion, which included a large water supply distribution system and a bridge for a small remote community in the region. At that time, the concept of service learning did not exist, but these types of activities have been strongly encouraged due to the Augustinian Heritage at Villanova University. In fact, the idea of ministry has been a strategic part of the university's mission since 1979, and there are presently an estimated 800 students and advisors who travel annually to over 40 locations globally (including the US) to volunteer on service projects. These projects include engineering and non-engineering activities, but the success of the engineering service learning program has been significantly influenced by the culture of service that exists at Villanova University and the Augustinian values which are routed in service to society.

2.3. Golden West Humanitarian Foundation (GWHF)

GWHF is recognized by the international humanitarian ERW remediation community as one of the premier non-governmental organizations for the research, development, and implementation of solutions to address this sector's most difficult technical challenges. To highlight their expertise, examples of the GWHF research team's research and development successes are:

1) *The Cambodian Explosive Harvesting Program:* In this program, explosives from unexploded bombs are recycled into humanitarian charges to be used in demining. This program has provided over 300,000 explosive demining charges to partners in Cambodia – which accounts for 100% of the explosive charges used by humanitarian demining operations in Cambodia.

2) *Mobile Bomb Cutting System:* One way to dispose of or recycle unexploded bombs is to physically cut them. This system, developed by GWHF, provides a means for the local cutting of bombs and other ordnance that are too dangerous to transport, but are safe enough to handle locally by professionals. This represents a large percentage of ordnance found in small makeshift storage sites in post-conflict nations as well as dropped aircraft bombs. This has been successfully deployed to Vietnam, Cambodia, the Solomon Islands and the Marshall Islands, facilitating the disposal of ordnance that was previously unmanageable.

3) *Detection Technologies:* GWHF researchers continue to push the boundaries with systems that have increased the efficacy of Battle Area Clearance (BAC) operations, garnering great interest from numerous organizations and governments worldwide and sparking changes in the detection industry. This includes work that lead to a more comprehensive understanding of the detection depths possible and required for safe human habitation.

GWHF's interdisciplinary staff of experts is considered one of the best in the fields of EOD, ERW detection technologies and engineering research and development. Specifically relevant to the present proposal is GWHF's engineering staff, which carries substantial experience in the research and development of numerous demining related technologies, such as the DTW Tempest[8]. Also related is GWHF's EOD staff, which possess over 100 years of cumulative EOD experience and are considered some of the foremost in the field.

3. Partnership

Approximately 3 years ago, authors Clayton and Ermilio were on a flight from Taipei, Taiwan to Phnom Penh, Cambodia with a group of 3 students on an engineering service learning trip to work at a remote elementary school and to explore potential engineering projects in the region. On that flight, we met one of GWHF's senior EOD technicians, who invited us to tour their research and development facility. During this trip, the team visited GWHF's facilities, and the VU-GWHF collaboration was born.

3.1. Project Organization

One of the fundamental approaches that VESL employs when engaging in international humanitarian initiatives is working with in-country partners who have the capacity to implement projects. As a result, this project has been organized and planned with the full participation of GWHF team in all aspects of the project. The scope of the project has been defined by Villanova Faculty and the GWHF team while taking into consideration the feasibility of completing any projects over a two semester sequence that could continue for multiple years. As a result, the project selection process has been simplified in that projects are identified first by the in-country partner based on their program objectives and resources, and then the faculty team discusses different projects based on available expertise and resources. Student teams then select a project from within a set of possible projects and elect to work on a humanitarian engineering project as a part of their senior design coursework. Where possible, the faculty team recruits from within the college to ensure that student teams have the necessary skills, and that there is a sincere interest in learning and working on a VESL project.

Within the senior design course, a process that includes common elements of the project cycle is used; however the academic nature of the project, presents some unique challenges. These challenges include: academic reporting requirements that are not always consistent with the project partner's needs, ensuring the necessary skills within the student team, gauging the student's availability to work on a project, and ensuring continuity from year to year. With respect to academic reporting, every effort was made to ensure that the needs of the in-country partner were prioritized and integrated into the course requirements. In addition to this, faculty advisors ensured that the student teams maintained a clear client relationship with the project partner, and student teams were instructed to address the project partners as the primary audience when completing academic reporting requirements.

A second year iteration does not usually follow the typical senior design process. This is primarily because of the complex nature of coordinating a multi-year project and ensuring continuity. The below example demonstrates how this sequence has been used during the Explosive Ordnance Disposal Robot project, and it is being anticipated that future projects will follow a similar process.

Year 1 (Summer)
- Project Identification
- Feasibility
- Partner Coordination and Planning

Year 1 (Fall Semester)
- Project Proposal
- Research Existing Technology
- Analysis of Existing Technology
- Conceptual Design

Year 1 (Winter Break)
- Design Review and Project Partner Coordination

Year 1 (Spring Semester)
- Preliminary Designs and Prototyping
- Conceptual Approval of Preliminary Designs
- Construction and Testing
- Reporting

Deliverable: Proof of concept working prototype of low-cost EOD Robot with some functionality and limited performance capabilities.

Year 2 (Summer)
- Partner Coordination

Year 2 (Fall Semester)
- Analysis of Preliminary Designs
- Design Revisions
- Construction of Design Revisions
- Analysis of Design Revisions

Year 2 (Winter Break)
- Field Testing and Design Review

Year 2 (Spring Semester)
- Design Revisions
- Construction and Field Testing
- Reporting

Deliverable: Final Design of a working prototype for the EOD Robot with full functionality and limited performance capabilities.

Year 3 and Onward: The current academic year has followed a similar iteration of the Year 2 Design Process with the objective of perfecting sub-systems needed for increasing performance capabilities. In addition to this, Year 3 includes project partner coordination particular to in-country manufacturing of the EOD Robot that will be needed for full-scale production.

The importance of working with project partners that have the capacity to implement cannot be overstated. The project implementation phase often entails three unique parts: proof of concept-prototyping, final design and construction, and full-scale production. In particular, the partnership between GWHF and VU has leveraged the expertise and skills of both members, so that students can innovate and design, faculty can research and teach, and field personnel can implement high impact initiatives. Ultimately, the success of this partnership has been a result of GWHF's appreciation of the learning opportunity that this work brings to undergraduate engineering students, and their ability to implement projects in complex environments. At the

same time, the success of this partnership has been a result of VU's appreciation of the project partner's needs, and their ability to leverage humanitarian design projects with undergraduate engineering curriculum. Throughout this process, students have been able to gain valuable experience in an international setting, collaborate with experts in the humanitarian technology field, and develop applied skills in engineering design and analysis. A particularly unique aspect of this project is the opportunity that students have had, to engage with partners with expertise in international humanitarian initiatives.

3.2. Example Projects

3.2.1. Low Cost Explosive Ordnance Disposal (EOD) Robot: EOD robots are a critical tool for many EOD operations, however EOD robots currently on the market are too expensive for use in the developing world. Students at Villanova have been working on this problem for the past two years. Using low-cost electronics, materials, and standard machining techniques, a low cost EOD platform has been developed (see Fig. 2). It should be noted that cost was also reduced by identifying the critical functionality of the EOD robot and designing the platform with this in mind.

Figure 2: VU students perform a field test of their EOD robot at the GWHF research facility in Kampong Chhnang, Cambodia.

3.2.2. Ordnance Burning Filtration Hood: The ability to safely burn explosives is a hugely valuable tool in ordnance stockpile destruction operations. At present, environmentally safe methods are only available at large-scale industrial demilitarization plants. This leaves no clean solution for the majority of small-scale stockpile destruction missions in post-conflict developing nations. Students at Villanova developed a portable filtration hood that theoretically meets the design specifications. The second iteration of this project will include the construction and testing of a prototype.

4. Participant Perspectives

Overall, this 3+ year partnership has been very positive for both involved parties (i.e., VU and GWHF). Below are perspectives on the partnership from each of the organizations.

4.1 VU Perspectives

The partnership between GWHF and VU has been extremely rewarding for both the students and faculty involved in the projects – both because of the projects themselves, which could stand on their own without their international and humanitarian components, and because of the international and humanitarian components. Some of the key points behind the success of these projects are:

1) GWHF came into these projects understanding that these are learning experiences for the undergraduate students involved. It was made very clear that the developed devices are not the only goal and that, in some cases, developed devices are not viable. GWHF's support for and understanding of this has been critical in the successful administration of this partnership. We have been lucky to produce potentially viable devices, but the reduced pressure put on the students by the sponsors enabled faculty advisors to allow students to make mistakes and learn from them.

2) Both partners have made significant efforts to have on-site visits. GWHF has travelled to VU for end-of-year design reviews in 2 of the 3 years of the projects and were able to do a project kick-off meeting at VU this past fall. VU faculty and students have travelled to Phnom Penh in each of the 3 years for mid-project reviews and prototype demonstration and testing. Without these in-person visits, the projects would not have been successful.

3) Projects are very carefully chosen to be exciting to VU students, important to GWHF, and within the capabilities of VU faculty and students.

4.1.1. Perspectives from the Low-Cost EOD Robot advising team: The EOD robot project is currently in its third year, with plans for one more project-year that will focus on commercializing the robot for sale in developing countries. This project attracts students from a broad range of interests, from students involved in the VU's mechatronics minor program, to students with varied backgrounds who are part of VU ROTC, to students who are interested in humanitarian endeavors (note that these groups are not exclusive.) Due to the exciting nature of the project, we can be very selective about the students that are chosen and have thus, had really excellent, high-achieving students involved in this project.

This project has been extremely popular with students. We believe that this popularity stems from the hands-on, humanitarian nature of the work. At the end of the project, they truly feel that they have been part of something that is making the world safer.

4.1.2. Perspectives from the Ordnance Burning Filtration Hood advising team: The filter hood project has been ongoing for the past two years. In each of these years, a team of four students was involved. Interestingly, nearly all (6 of 8) of the students working on the project are from the Naval ROTC program at VU. Based on this, it appears that this project is drawing from students that have a potential interest in exploring a career in the broad area of energetic materials (as it may apply to careers in the Navy).

The fume hood project does not have the overall popularity of the EOD robot project. Three possible reasons exist for the relative lack of interest, which may motivate project choices in the future. First, the students do not have a background in energetic materials (as stated above), and they therefore have stayed away from an area where they have no background. Second, the students who have chosen the fume hood project are not as interested in service learning trips, which is evident by the fact that only 3 of the 8 students involved in the project have traveled to Cambodia for field work, whereas 8 or the 14 students on the EOD robot teams have made trips (the sample size is small, but there appears to be a trend). Finally, the initial phase of the fume hood project required two years to complete the initial design-build-test cycle, which means that the students in Year 1 did not have the satisfaction of constructing and testing their design. The fume hood team in Year 1 had no prior knowledge of energetic materials, so they spent the majority of the year learning about the subject area prior to developing a paper design of how to remediate the combustion products through a fume hood. The Year 2 team built on the knowledge base developed from the Year 1 team in implementing a modified version of the Year 1 design. The current Year 2 team is developing a full-size system prototype for purposes of cooling and filtering the product stream, thereby removing toxic fly ash from the product stream. The Year 2 group seems to be more enthusiastic regarding the project as the construction phase is more enjoyable for students than the background information collection and paper design development. We anticipate that the Year 2 team will complete and test the prototype by the end of the semester, thus providing a means for GWHF testing over the summer and allowing for a design revision for next year.

4.1.3. Student Outcomes: It is our observation that the desired outcomes are being achieved. Based on the positive reaction from GWHF, Students involved in this project are, indeed, developing and applying the skills necessary to work in the international engineering community. In addition, based on student reports, it is clear that the students are truly understanding the impact that engineers can have on the developing world, i.e., they are developing an appreciation for the need for and implementation of engineering solutions for humanitarian causes.

Some qualitative feedback from students suggests that, these types of international experiences have an impact on their understanding of engineering in a global context. Post project evaluations and surveys from student participants provide an interesting perspective about the value of international partnerships. With respect to the GWHF – VU partnerships, some anecdotal information is provided below as it relates to the field activities associate with this project.

- How did this experience impact your understanding of engineering?
    - "It completely changed my outlook on engineering. It broadened my view of what engineers can do and how they can actually change people's lives."

- How did this experience change your perspective of the world?
    - "It made me realize how resourceful, determined and proud people are."

After the project has ended, the involved students go on to great things. As noted previously, a number of the students involved in the project have been Naval ROTC students – 8 of 22 students. Of these ROTC students, 4 have pursued (and 2 have been selected for) the Navy's EOD career path. Of the non-ROTC students, 2 entered the military, and at least 7 have gone on to pursue graduate degrees (many from the EOD project, in the area of robotics).

4.1.4. International Travel: Of the 22 students that have been involved in this project, a total of 11 students have traveled to Cambodia for testing and design reviews. During these trips, students are able to interface both socially and professionally with the project partner – effectively creating a multidisciplinary team of engineers and EOD specialists. The students that are able to take these trips gain the full advantages of having an international project – they get to see the humanitarian issues we are addressing first had, engage with the culture, and deploy their prototype in the field.

4.2. GWHF Perspectives

In addition to facilitating academically, professionally and personally rewarding interactions between team members, students and faculty from the Villanova University Department of Engineering have brought significant value to Golden West product development programs in terms of technical assistance. The "in house" resources of Golden West, characteristic of many small to medium sized NGOs, is limited, particularly in the technical specialties. When structured correctly, having access to the diversity of experts present at university (found in both students and faculty) an NGO can effectively expand their product development capabilities without committing substantial financial resources. These relationships can result in the development of products which make substantive contributions to humanitarian outcomes.

The majority of products which Golden West has historically considered candidates for development are not commercially viable without financially subsidized development. Development costs are too significant to recover from sales due to the low prices and/or volumes that humanitarian markets can sustain. While this could be viewed as a disincentive, we assert that these products are precisely the opportunities where humanitarian engineering stands to make the largest impact. This concept is similar to the benefit developing nations receive from generic pharmaceuticals: product utility without amortizing development costs. In many cases, despite the market's inability to support development, the demand for the finished product is sufficiently large (due to need) that sales will cover production costs. Capitalizing on the economies of these processes avoids the pitfalls associated with aid dependence if the production of the final product can be supported by commercial sales through local markets. In other words, the overall humanitarian viability of a product should not be unduly weighted by the financial cost of development.

Equally as important as financial models, understanding the strengths and weaknesses of undergraduate students is critical to effectively leveraging their contributions to create programmatic value. Undergraduate strengths, as they relate to humanitarian product development, can include a lack of professional bias, literacy in the most current technologies, willingness to challenge the status quo and a passion for making a meaningful contribution. Limitations include depth of technical knowledge, ability to organize workflows and familiarity with professional standards for communication.

From our experience, undergraduate contributions have been most valuable during the early stages of product development when every solution is "on the table". This stage leverages all of the aforementioned student attributes and provides the student with an opportunity to deconstruct and analyze a real world problem. This stage requires minimal management from the NGO team. Once a solution has been identified and work begins to convert a prototype into a viable production model, the skillset required will likely be outside of what an undergraduate team can support.

The NGO and faculty team should make an effort to consider the resources that will be available for product commercialization in the event of a successful outcome. This assessment should have some degree of influence the project selected. Recognizing that an undergraduate student team is unlikely to have the skills and/or time to take a prototype to production, both the NGO and the faculty partner must assess internal and external capabilities to facilitate this transition. Failure to perform this assessment during project selection can result in successful projects that lack modality to market. While this scenario results in a successful learning outcome for students, this allocation of resources, in the humanitarian context, may be considered parasitic by the partner

NGO and/or other stakeholders, ultimately jeopardizing the long-term viability of the relationship.

A fundamental factor influencing the effectiveness of the NGO-University engineering partnership is the structure of the working relationship. The Golden West – Villanova relationship was initiated through outreach from the university. Many NGOs operating in the context of a developing nation are inundated by propositions from both individuals and institutions for collaboration. Unfortunately, many small to medium sized NGOs dedicate the majority of their human resources to program execution, limiting their capacity to deal with these requests. By initiating contact in the field, the university demonstrates commitment. It is our assertion that these interactions offer the highest probability of initial success.

Once trust has been established between the individual program "sponsors" from the respective institutions, this relationship should be reinforced through regular visits to the partnering organization's operational location. While visits by students to developing nation field sites are more obviously beneficial, visits from the partner NGO's key staff to the university are also necessary. These visits extend the relationship past the individual faculty contact to other elements within the university, which ultimately strengthens the position of the faculty collaborator within their institution and opens channels of communication that may lead to additional opportunities of symbiotic value creation. NGO staff also benefit from the perspective gained through understanding a partner organization's capabilities and culture firsthand.

5. Conclusions and Future Directions

In this paper, a partnership for humanitarian engineering between GWHF and VU was presented, including perspectives from both organizations. Future directions include potential commercialization of the developed devices as well as expanding the relationship to include graduate research projects.

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