Using a Marketplace to Form Multidisciplinary Systems Engineering Capstone Project Teams

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Using a Marketplace to Form Multidisciplinary Systems Engineering Capstone Project Teams

Abstract

Our previous research has shown that multidisciplinary capstone projects can enhance development of Systems Engineering (SE) competencies. However, undergraduate engineering capstone projects typically focus on only one engineering discipline. In order to assist faculty and students in forming multidisciplinary teams, a marketplace for multidisciplinary SE capstone projects has been created by a Systems Engineering Research Center (SERC) project conducted at Stevens Institute of Technology. The marketplace enables potential project sponsors to advertise opportunities to a broad audience of potential student teams representing a variety of engineering disciplines. It also allows students the opportunity to form their own teams based on common interests and complementary skills.

In our pilot year the capstone marketplace offered a variety of challenging projects to several engineering schools. In one case, students from three different disciplines at two universities created a capstone project that engaged two different project sponsors with similar interests and needs. This effort, referred to as the Dual-Use Ferry project, investigated the design of safe ferry transports that could also serve to deploy emergency relief supplies in the event of a natural catastrophe.

Multidisciplinary student engineering teams face a number of challenges that do not arise within single disciplinary teams. Similarly, teams formed from multiple universities need to work more diligently to stay connected than do teams that can meet face-to-face easily. It was determined that SE concepts and techniques helped the students on the Dual-Use Ferry project overcome some of the disciplinary and distance barriers that might otherwise have prevented them from working together effectively. It was also found that these types of teams require more discipline and attention to scheduling and communication issues as well as awareness of interdependencies between the different tasks than single disciplinary single university capstone projects.

Introduction

A marketplace for capstone SE projects was created in the summer of 2012 at Stevens Institute to bring together potential project sponsors, students from various engineering schools, and faculty who supervise those students. Sponsors propose projects on the marketplace website that are viewed by the students and faculty. Students and faculty apply for projects through the website. Those applications are then reviewed by the marketplace supervisors and the project sponsors. Student teams may consist of students from different schools, or all from the same school.

At the start of the fall 2012 semester, a University of Alabama in Huntsville (UAH) Mechanical and Aerospace Engineering (MAE) capstone design class instructor became aware of the ABC Center design project marketplace. The UAH instructor was anxious to partake in a multidisciplinary effort as previous attempts to initiate such design projects at UAH proved difficult to sustain. As a result, the opportunity to participate in a capstone design project via a
marketplace specifically dedicated to multidisciplinary design projects was welcomed. A UAH MAE student design team selected the Humanitarian Aid and Disaster Recovery (HADR) kit project as their year-long senior design project. The UAH student team members were interested in the prospect of working with Stevens Institute Engineering Management (EM) and Naval Engineering design students in order to acclimate themselves to a real-world engineering design scenario whereby multiple disciplines and entities are required to provide a design solution.

The present paper will describe the need, initiation, and development of the capstone design project marketplace, the various projects made available through the marketplace, a detailed description of a recent Dual-Use Ferry multidisciplinary project, and the resulting impact and lessons learned.

**Background**

Our previous work had demonstrated that students who worked on multidisciplinary capstone projects had increased interest and learning in basic SE concepts. However, forming multidisciplinary capstone projects is difficult at many engineering schools. Students from different academic departments often need some supervision by faculty from their "home" departments. This may result in 3 or 4 faculty members working with a single multidisciplinary project team. If the teams are small, say 4 or 5 students, the resulting faculty overhead is too large.

One strategy to overcome this is to combine sub-teams of students, where each sub-team is supervised by a single faculty member. This results in a larger overall team, which has its own advantages and disadvantages. A larger team can accomplish more, producing more interesting and effective products. Coordinating a larger team is more difficult; increasing the probability that some students will lose touch or become frustrated. In some cases it can be effective to use graduate student teaching assistants to help coordinate the larger teams.

Another difficulty in forming multidisciplinary teams is identifying students who are interested and able to assume the roles needed on projects. Often, faculty members are unfamiliar with the capabilities of students in other disciplines, and students tend to work only with other students in their home departments after the first two years of college. By placing project opportunities in a central location such as the marketplace, the students were empowered to identify those projects that best fit their interests and abilities.

Finally, a central marketplace also makes it easier for students from different schools to find one another and work together on projects. Partnering between schools provides several benefits:

- students at schools that could not otherwise conduct multidisciplinary projects are able to participate on those types of projects
- students are exposed to a wider diversity of teammates
- a greater variety of student skills and abilities is available when forming teams
However, such partnerships also introduce new challenges:

- students at different schools may have different academic calendars, causing delays at startup or forcing early completion for some students
- students may be geographically too distant to meet face-to-face, and must learn how to communicate effectively via teleconferencing
- students at different schools may have different weekly schedules or be in different time-zones, making it more difficult to find times when they can work together.

This project was a pilot effort to determine:

- whether students from different disciplines at different universities could form an effective capstone engineering team
- whether the faculty overhead in managing a distributed team was significantly greater than managing "local" teams
- which strategies would be most effective in ensuring the success of distributed teams and in reducing faculty overhead.

There were two other projects initiated through the capstone marketplace, but neither of those involved collaboration between multiple universities.

**Dual-Use Ferry Project**

The Dual-Use Ferry project will be discussed, in detail, as an example of the type of multidisciplinary project that can initiate and evolve from the marketplace. This multidisciplinary, multi-university project was a result of merging two separate projects that were available on the marketplace – the HADR kit project and a safe, affordable ferry design project. The HADR kit project was originally proposed through a 2010 United States Department of Defense (DoD) sponsored design challenge. The marketplace ferry design project was targeted towards developing nations where ferry accidents are caused by unsafe operation of inappropriate vessels, such as Bangladesh. The ferry would be specifically designed to effectively and efficiently support logistics in a disaster situation while serving as a commercial ferry in normal conditions. The Dual-Use Ferry project arose as it was determined that the HADR kits could be designed such that they could be stowed and deployed from the ferry vessels. This allowed for multiple design teams to work collaboratively to meet the project requirements. Table 1 provides project details for each of the three students teams involved in the Dual-Use Ferry multidisciplinary design project.
Table 1. Dual-Use Ferry sub-projects

<table>
<thead>
<tr>
<th>Team</th>
<th>No. of Team Members</th>
<th>Major</th>
<th>Project Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stevens Institute</td>
<td>2</td>
<td>Naval Engineering</td>
<td>• Dual-Use Ferry design</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Develop and validate an overall Concept of Operations (using Bangladesh as a case study)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Engineering Management</td>
<td>• Overarching project management</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td></td>
<td>• Primary customer liaison</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Coordinate efforts of the 3 teams</td>
</tr>
<tr>
<td>UAH</td>
<td>6</td>
<td>Mechanical and Aerospace Engineering</td>
<td>• HADR kit design with a focus on solar powered water purification</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Fabricate and test a functional full-scale model</td>
</tr>
</tbody>
</table>

Note that the project tasks specified in Table 1 are the overall project requirements for each team and do not constitute the entirety of the project tasks required of each team. A more detailed description of the efforts completed by each of the three student teams is described in the subsequent sections.

Ferry Design Sub-Project

The dual-use ferry was initially a separate student project based on a need for a safe, affordable ferry to be used in developing nations where numerous ferry accidents result in deaths numbering in the thousands annually. These accidents are in large part due to the reuse of vessels that are ill-suited for passenger transport and the operational area. The ferry project was part of a pilot program that Interferry and the International Maritime Organization have initiated to address domestic ferry safety worldwide.

This pilot project involved two Naval Engineering students from Stevens Institute working on their senior design project. The students were provided with excellent technical support from two project mentors, Dr. Roberta Weisbrod and Mr. Jon Kaskin. Additionally they received useful information from a Bangladeshi ferry operator who provided information that helped define a route and requirements for number of passengers and other cargo requirements.

The student project encompassed defining design needs, hull form comparison, vessel arrangements, stability analysis, structural considerations, resistance estimations, propeller design, machinery selection and auxiliary system recommendations. All of this analysis needed to include a strong emphasis on manufacturing cost and complexity so that the vessels could be manufactured in Bangladesh.
The dual use of delivering humanitarian aid and disaster recovery (HADR) kits for this safe-affordable ferry was added to the ferry requirements, as it was a good opportunity to improve the experience for both students groups and it was a natural extension for a ferry that was to operate in Bangladesh, a developing nation subject to frequent natural disasters. The added tasks included coordination with the Stevens Institute EM and UAH HADR groups to ensure that the ferry was designed to be able to carry a sufficient number of HADR kits, and that the means existed for reasonably loading and unloading these kits in the affected regions and in specific ports. A rendering of the RO-Pax HADR kit capable ferry is shown in Figure 1 below.

Figure 1: Student Designed RO-PAX Ferry

The team was primarily advised by an adjunct Naval Engineering faculty member with additional support from adjunct and full time department faculty. The two mentors representing expertise from Interferry and US Navy Military Sealift Command provided invaluable information and assistance to the students. In addition to the final group presentation there were 3 progress presentations/meetings throughout the project with either in person or conference call participation from both mentors. These frequent interactions as well as additional communications via e-mail or phone helped steer the project in a direction that lead to a better end product and overall project outcome for all involved.

**ConOps Development and Project Management Sub-Project**

The Stevens Institute EM team consisted of four students that through the EM curriculum had been introduced to fundamentals of relevant disciplines such as project management, operations research, logistics, modeling and simulation, and SE. In addition, one of the team members was a US Marines veteran that had been involved in HADR operations.

At the start of the project, the primary challenge for the EM team was to gain an understanding of the objectives of the two original projects (HADR kit and ferry design) and merge them into a
A sub-project that would provide value to the sponsors and the two other teams. The core of the EM design project would be to develop a Concept of Operations (ConOps) for a Dual-Use Ferry in a flood induced disaster situation. This would provide a framework to develop logistics models to facilitate requirements development for the two other sub-projects and to provide some validation of the overall concept. The team chose Bangladesh as a case study to develop the ConOps. Given that Bangladesh is an area that is frequently struck by flood disasters, it not only provided a realistic case, but also the availability of data and experiences from previous disasters. Based on the available data, the EM formulated a network model of supply and demand nodes with an associated cost model to analyze the logistical parameters of the problem. Results of the logistical details, based upon cities in Bangladesh, are provided in Figure 2.

Figure 2. Sample output from the network model for logistical analysis
As a learning experience, this was an excellent project for the Stevens Institute EM students. They were placed in a situation where they had to balance the interests of their key stakeholders, namely the Navy sponsor and the two other student teams, as well as the academic requirements and schedule of their own two semester capstone course. The team matured throughout the two semesters, and provided good insights and lessons learned during the final presentation to the sponsor together with the two other teams.

**HADR Kit Design Sub-Project**

The HADR kit was initially desired by the DoD in order to support the immediate needs of first responders in a humanitarian or disaster crisis by providing the basic human requirement of potable drinking water generated from a self-contained kit powered by renewable energy. An MAE team from UAH decided to pursue this project as their capstone design project at the start of the fall 2012 semester. The immediate customer for this project was a US Navy representative. Communication with the customer was maintained by the Stevens Institute EM team. The customer provided initial project requirements, information and guidance throughout the design project, and a final product assessment at the end of the spring 2013 semester.

Commencement of the multidisciplinary HADR kit design effort began by determining the manner and frequency of communication between the 3 student design teams. Since the Stevens Institute EM team maintained oversight of the ferry design team and HADR kit design team, the UAH team only needed to communicate directly with the EM team. The students agreed that weekly updates via email and/or Skype® sessions would be convenient for the EM student team and the HADR design student team. Additionally, the UAH HADR design team assigned one team member to assume the role of team liaison with the Stevens Institute EM design team and then convey the meeting details to the rest of the UAH team.

Early during the fall 2012 semester the responsibilities and tasks of each student team were also delineated. It was determined that the Stevens Institute EM students would be the primary liaison to the US Navy project customer so as not to inundate the customer with redundant questions from multiple students. The Stevens Institute student team would then relay customer requirements, answers to questions, and any other information to the UAH team members. It was also determined that the UAH MAE design team would focus upon the engineering design and development of the HADR kit as well as the fabrication of a functional full-scale model to present to the US Navy customer at the Product Readiness Review (PRR) at the end of the academic year.

Numerous other tasks and responsibilities were assigned to each of the two teams associated with the HADR kit design and project management as defined by the course instructors and student team members. A breakdown of the project tasks and the responsible entity is provided via a flowchart in Figure 3. The flowchart was created by the two student teams and was regarded as a critical SE tool that enabled each team to clearly understand all tasks required for project completion as well as how the workload would be distributed. The flowchart was essential in defining the scope of the project with respect to each student team. It replaced the initial confusion about team responsibilities with clearly established boundaries that illuminated the path forward. A Work Breakdown Structure (or project schedule) was also created in order to
define timelines for completion of the tasks specified in Figure 3. The schedule was critical in order to mesh schedules of the various teams and ensure that the project would be completed.

As the Stevens Institute EM student team was the primary customer liaison, the project requirements were identified and documented by the Stevens Institute team and then shared with the UAH team. The UAH team reviewed the requirements which were then refined and updated based upon initial research and feasibility studies. Some of the top-level project requirements were defined as follows:

- all HADR kit component power shall be generated from renewable resources
- the produced water shall meet the quality standards of the US government and the Environmental Protection Agency (EPA)
- the water filtration system shall produce a minimum of 1000 gallons of potable water per day
- the system shall generate a minimum constant power of one kilowatt of energy per day
- all components inside the HADR kit shall be secured to avoid damage during transportation
- the components of the HADR kit shall be pre-installed in a manner consistent with minimizing set-up time before the kit is operational
- all components of the HADR kit will be thoroughly tested for a variety of environments so as to expand the global utility of the system
- proper warning and instruction labels consistent with the Occupational Safety and Health Administration (OSHA) standards shall be utilized to avoid risk of operator injury

Figure 3. HADR kit team coordination with vessel design team

UAH MAE Team

Stevens Institute EM
• additional training material extending past written instructions shall be generated for personnel training
• maintenance guidelines, procedures, and documentation shall be included in each kit so as to promote proper system care and extended product life

As previously stated, the UAH MAE team focused upon a HADR kit design solution and fabrication of a functional full-scale model. During the fall 2012 semester, the UAH team focused upon the conceptual, preliminary, and detailed design of the HADR kit and mock-up. Refinement of the kit design and fabrication of the model occurred during the spring 2013 semester with a PRR taking place in May 2013.

During the conceptual design phase, another ConOps was created by the UAH team that solely focused upon the operation of the HADR kit. The HADR kit ConOps provides an easily understood visual explanation of the full scale HADR kit purpose and its operations—as shown in Figure 4. In the event of a natural disaster (e.g., flood, tsunami, hurricane, earthquake), basic human requirements such as access to potable water flow are disrupted. Local water sources become contaminated with bacteria and viruses originating from common refuse and human waste. As conveyed through the ConOps graphic, the HADR kit is designed to be a self-contained, single operator, rapidly deployable unit that filters and purifies water. The ConOps is another SE tool that proved to be very useful to the student teams as a visual explanation of the HADR kit operations.

Figure 4. HADR kit ConOps

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Classroom Diagram Example: Natural Disaster Contaminates Water → Potable Water (99.999% Pure) → Excess Water Storage
HADR Kit Deployed → Battery Backup / Night Ops → Contains Voltage Control Unit
Supplies → Solar Daytime Operation / Battery Charging → 3 GPM Pump
The UAH designed HADR kit is composed of a Joint Modular Interface Container (JMIC), deep cycle marine batteries, solar panels, a charge controller, and a pumping/filtration system. The JMIC container is 51.75” length x 43.75” width x 43” height. When empty, the container weighs 329 lbs and has a maximum cargo capacity of 3,000 lbs. A Computer Aided Design (CAD) rendering of the design is provided in Figure 5. The front and top of the JMIC are removable. The operator removes and unrolls the solar panels. The pump is hard mounted inside the JMIC between the filters. The batteries, which remain inside the JMIC, are wired to the charge controller and then the solar panels. The batteries are then connected to the electrical panel, which contains a 10 amp barrel fuse. During daytime operation, the solar panels simultaneously charge the batteries and supply the pump. During night time operations, the batteries operate the pump while the charge controller prevents electricity from bleeding back into the solar panels. The kit inlet and outlet bulkhead fittings use a 3/4” standard hose coupling for extending the reach of the kit without having to move it. The aforementioned design details and a detailed description of the design process used by the UAH team was documented in a final report provided to the US Navy customer.

Figure 5. SolidWorks® CAD model of the UAH HADR kit design solution (packing material is not shown)

The final UAH functional model was built to scale and was intended to provide a means to test the water filtration system. An image of the model taken during verification testing of the water filtration system is provided in Figure 6.
A final design review, the Product Readiness Review (PRR), was conducted in Washington, DC on May 31, 2013. The student teams, faculty advisors, as well as US Navy customer representatives were in attendance. Each of the 3 student teams presented their final product details and results via PowerPoint® presentations. Finally, the HADR kit functional model was demonstrated. The US Navy customers were very pleased with the efforts and results put forth by the student teams. The students had many positive reactions with respect to the PRR and some are highlighted as follows:

- being able to finally meet and engage with the other student teams
- the chance to present to the US Navy customer and receive immediate feedback
- the opportunity to travel offsite to present the final design review
- being able to discuss and demonstrate the HADR kit in person

Additional comments provided by the UAH MAE student design team members are as follows:

- “Overall, this design project is a critical learning experience. It provides a real world account and experience that is quintessential to future engineering employment activities.”
- “Even though scheduling, planning, and building has presented many obstacles, it has also provided valuable lessons and experience in the engineering applications of designing and manufacturing.”
- “Requirements will not always be presented in a specific manner, and long distance communication will be inevitable. Roadblocks, stagnant workloads, and bottlenecks will occur, but it is how the team maintains its ability to adapt and overcome that is essential. This group worked tirelessly to develop the initial requirements with Stevens Institute, as well as researching, manufacturing, assembling, and fine tuning every component to result in a successful design.”

Figure 6. Functional, full-scale model of the UAH HADR kit undergoing water filtration sub-system testing.
Facilitating Multidisciplinary Projects

As previously stated, one of the primary challenges in initiating and continuing multidisciplinary design efforts is the extra faculty workload that is perceived to be required. However, from the perspective of the UAH capstone design instructor, and with respect to the administration of the Stevens Institute marketplace, this perception proved to be false. Typically, within a UAH capstone design class, there are 4 to 6 senior design teams; each with different projects and customers. The selection of a marketplace project proved to require no additional faculty workload—compared to other capstone design projects—with respect to project administrative tasks or team advisement and assessment.

Each of the three student teams that worked on the ferry vessel and HADR kit design projects were advised and evaluated by their course instructor in a manner consistent with any other student team at the respective universities. Each team had to meet their class requirements and evaluation standards. Individual student and team assessment methods were not deviated from, with respect to the methods employed by the class instructors. With regard to the multidisciplinary design aspect, each instructor determined how they would evaluate their own students. For example, the UAH capstone design class instructor determined that no additional assessment tool would be implemented in order to gage how well the HADR kit MAE design team interacted with the Stevens Institute SE design team. Instead, the multidisciplinary aspects of the projects were embedded within the project requirements. Each student team at UAH has initial projects requirements that derive from the customer with input, many times, from the instructor. In the case of the HADR kit design project, the UAH instructor provided some additional project requirements that included working with the Stevens Institute student teams to develop a HADR kit design solution, sharing SE design tools and methodologies, and requiring weekly contact, at a minimum.

Multidisciplinary Design Challenges

Each of the three student teams associated with the Dual-Use Ferry design project encountered various challenges. However, the issues mimicked real-world, engineering workforce scenarios. As such, the challenges provided the students with an accelerated understanding of what future employment situations may entail, as well as how to resolve them.

The Stevens Institute Naval Engineering team encountered some challenges with the multi-team approach. The communication and coordination between the student groups was insufficient, frequently breaking down with the ferry and HADR groups progressing on parallel paths without adequate knowledge of the progress of the partner group. These challenges certainly can be overcome with stronger faculty involvement and a better approach to coordination at both the faculty and student levels. Examples of potential improvements which are currently be implemented on a similar project include mandatory group meeting across disciplines and the establishment of clear roles and expectations for communication leads for the separate disciplines and teams. Based on a first semester analysis these changes are having a positive impact.
Additionally as the safe affordable ferry and the HADR kit projects were conceived and initially developed as separate projects there was insufficient planning for a coordinated joint project. Again lessons learned from this effort have been implemented into an ongoing multi-disciplinary project that seeks to correct these deficiencies. Some of the changes include: clear project requirements relative to the multi-disciplinary nature of the project, joint meetings with the students and faculty advisors representing the departments whose students are collaborating, and the implementation of basic systems engineering and engineering management processes in the planning and execution of the project.

The Stevens Intitute EM student team encountered the following challenges:

- The difficulty of aligning their own understanding of what the project was about with the other parties involved
- The challenge of scoping a complex problem into specific scenarios, requirements and subsystems at the right level of abstraction
- Scheduling and coordination of deliverables and real-time communication with the other teams
- The pressure from the other teams to get information from them so they could complete their own deliverables on time
- The difficulty of discipline jargon in communications both with the other teams and the sponsor

While the EM team reported that the management experience was very valuable, the design experience left some things to be desired. Too much time was spent on getting a grasp of the project, finding their “place” in the overall project, and understanding what the other teams needed from the EM team. This, together with the strike of Hurricane Sandy towards the middle of the fall 2013 semester, significantly impacted the motivation and progress of the team during the first semester. As a result the development of a ConOps, requirements and models occurred much later than desired.

From the perspective of the UAH MAE HADR kit design team, many of the issues specified by the Stevens Institute EM team were echoed by the UAH team. However, the most critical challenge to overcome for the UAH team was the time-lag with respect to receipt of the project requirements. As a result, the UAH team was approximately 2 months behind schedule compared to other UAH MAE capstone design teams and was out of sync with the timeline and schedule of other UAH teams. Other issues reported by the UAH team are as follows:

- The weekly status updates at times became difficult to maintain due to conflicting schedules
- UAH access to the customer was non-existent as the Stevens Institute SE team was the liaison
- Terminology differences associated with engineering design and SE methodologies and processes taught at the two universities
- Over 1000 miles separated UAH and Stevens Institute and did not allow for face-to-face meetings
Current Efforts

As a result of the successful inaugural implementation of a marketplace project, a subsequent UAH MAE capstone design team has begun efforts on another marketplace project. During the 2013-2014 academic year, the UAH team selected the marketplace design project that entails the mechanical design and development of a sailboat disablement system for the US Special Operations Forces (USSOF). Initially, a Stevens Institute mechanical engineering team was going to partner with the UAH team in the development of a singular system. However, at the start of the fall 2013 semester, the USSOF customer decided that each team should develop their own sailboat disablement system. The customer preferred this option as it would provide additional design solutions.

It should be noted that the current UAH capstone team consists of 10 student team members. The UAH HADR kit team consisted of 6 student team members. Typically, within the UAH capstone design class, enrollment ranges between 25-30 students. Team sizes of 4-6 students, traditionally, are preferred. However, each of the 10 UAH sailboat disablement project team members indicated a very strong preference for the USSOF project. The students had garnered information from the previous HADR kit team as to the unique opportunity to engage in a relevant and interesting senior design project made possible through the marketplace. As a result, the UAH capstone instructor allowed for a larger team size in order to accommodate all 10 students and their desire to participate in the project.

There are currently six capstone engineering projects initiated by the marketplace this year, including the sailboat disablement project. Although most of the projects are being conducted by individual universities, the SERC marketplace project has begun implementing some of the lessons learned from the Dual-Use Ferry project on all marketplace projects:

- We collect feedback from sponsors, faculty and students at the end of the first term to make sure that projects are on track to satisfy their clients. This also helps to keep separate teams from losing touch with one another.
- We provide a skeleton systems engineering process with suggested deliverables and milestones throughout the year.
- We encourage sponsors to participate in frequent reviews of student work.

We believe that most of the extra faculty overhead needed to participate in a distributed team effort can be minimized by agreement on a common lifecycle process across the sub-teams.

Related research

This is not the first attempt to conduct capstone engineering projects across multiple schools. Early work in this area\textsuperscript{4,5} concentrated on bringing together students from different schools who shared the same engineering discipline. A recent workshop on globally distributed teams reported on several such efforts in software engineering\textsuperscript{6,7,8,9}. Since software projects usually do not include physical artifacts to be created and shared between teams they are easier to conduct across multiple sites. Recently there has been an interest in moving traditional engineering tasks toward cloud-based tools, which also enables collaboration across multiple sites\textsuperscript{10}. 
Conclusion

The SERC capstone design project marketplace has allowed for student teams across the US to partake in sponsored projects that address a specific and relevant need. The opportunity for students to work on a multidisciplinary and multi-entity senior design project has proven to be enticing for the design students as they are aware that the experience will provide them with critical engineering design, SE, and communication skills. The Dual-Use Ferry design project enabled three student teams to generate a design solution for an important need of the US Navy. The project allowed the student teams to holistically understand the design problem and provide a resolution. While the challenges and issues associated with this effort were the result of initial confusion as to the problem definition and scope, it was the challenges and issues that provided the students the most concrete understanding of what can be expected as professional engineers and, as a result, was a tremendous learning experience. Specifically, the ability to define a problem, integrate various entities, communicate to all participants such that they can understand the task at hand, scheduling, maintaining proper oversight, and clear verbal and written communications were some of the top lessons learned by the Dual-Use Ferry student teams. At the end of the design effort, a design solution was provided to the customer. The customer was very pleased with the resulting effort and stated that future marketplace design efforts would be welcomed and supported.

Acknowledgments

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