Systems Engineering Capstone Marketplace
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The goal of this project was to investigate what is needed to establish a marketplace for undergraduate capstone projects with an emphasis on multidisciplinary projects involving development of systems engineering competencies. We hope to increase the number of systems engineering capstone projects conducted at universities each year by facilitating the processes of proposing, matching and engaging student teams with potential sponsors. A previous pilot project had demonstrated that a marketplace system was feasible for accomplishing these goals.

The project consisted of three phases:
1. Initiating and supporting a second year of capstone projects
2. Marketing the Capstone Marketplace to attract additional sponsors and participating schools
3. Development of support materials for sponsors and schools that use the marketplace

Activities of these phases overlapped, but initiation and support of the second year and marketing for the third year were mostly separate.
**INITIATING AND SUPPORTING SECOND YEAR OF MARKETPLACE**

This section of the report summarizes progress made during the first phase of the project.

**PARTICIPATING SPONSORS AND PROJECTS**

Project ideas and potential sponsors for student projects were sought through a combination of search strategies: sponsors and mentors of previous capstone projects, candidate leads suggested by SERC researchers, national laboratory contacts suggested by members of the OASD(R&E) STEM Development Office, and personal networking.

24 separate projects were proposed by 2 sponsors:

<table>
<thead>
<tr>
<th>Sponsor</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOCOM</td>
<td>Advanced Body Armor and Helmets</td>
</tr>
<tr>
<td>SOCOM</td>
<td>Austere or Unimproved Landing Zone Assessment</td>
</tr>
<tr>
<td>SOCOM</td>
<td>Beacon or Targeting Device</td>
</tr>
<tr>
<td>SOCOM</td>
<td>Biometrics-as-a-Service</td>
</tr>
<tr>
<td>SOCOM</td>
<td>Communications/Control</td>
</tr>
<tr>
<td>SOCOM</td>
<td>*Enhanced Mobility / Agility</td>
</tr>
<tr>
<td>SOCOM</td>
<td>Fire/Heat Suppression</td>
</tr>
<tr>
<td>SOCOM</td>
<td>Forensics Science-as-a-Service</td>
</tr>
<tr>
<td>SOCOM</td>
<td>High Altitude Human Performance</td>
</tr>
<tr>
<td>SOCOM</td>
<td>Infrared Beacons</td>
</tr>
<tr>
<td>SOCOM</td>
<td>Latent Print Discoverability</td>
</tr>
<tr>
<td>SOCOM</td>
<td>*Medical Monitoring</td>
</tr>
<tr>
<td>SOCOM</td>
<td>Personnel Rescue</td>
</tr>
<tr>
<td>SOCOM</td>
<td>Power Generation and Management</td>
</tr>
<tr>
<td>SOCOM</td>
<td>Remote Vital Sign Detector</td>
</tr>
<tr>
<td>SOCOM</td>
<td>*Situational Awareness</td>
</tr>
<tr>
<td>SOCOM</td>
<td>Thermal Management</td>
</tr>
<tr>
<td>SOCOM</td>
<td>Underwater Body Locator</td>
</tr>
<tr>
<td>SOCOM</td>
<td>Unmanned Structure Assessment</td>
</tr>
<tr>
<td>SOCOM</td>
<td>Unmanned Vertical Lift Mule for Humanitarian Relief</td>
</tr>
<tr>
<td>SOCOM</td>
<td>Wireless Communication on Small Boats</td>
</tr>
<tr>
<td>SOCOM</td>
<td>*Sailboat Disablement</td>
</tr>
<tr>
<td>DoD Corrosion Policy and Oversight</td>
<td>Corrosion Inspection and Mitigation</td>
</tr>
<tr>
<td>DoD Corrosion Policy and Oversight</td>
<td>*High Rate Inspection Tool for Coatings</td>
</tr>
</tbody>
</table>

The projects annotated with leading asterisks were matched to student teams. In one case, the Sailboat Disablement project, two student teams worked independently on the same project for the same sponsor.
PARTICIPATING SCHOOLS

We invited participation by engineering schools throughout the United States and Canada in this second year of the marketplace.

5 schools joined the project:

<table>
<thead>
<tr>
<th>School</th>
<th>Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Georgia Tech University</td>
<td>1 team of 4 mechanical engineering students followed by a new team of electrical engineering, mechanical engineering and computer science students</td>
</tr>
<tr>
<td>Johns Hopkins University</td>
<td>4 undergraduate students in mechanical engineering</td>
</tr>
<tr>
<td>Smith College</td>
<td>3 undergraduate students in engineering science</td>
</tr>
<tr>
<td>Stevens Institute of Technology</td>
<td>4 undergraduates in biomedical engineering on the Medical Monitoring project 3 undergraduate mechanical engineering students and 2 undergraduate naval engineering students on the Sailboat Disablement project</td>
</tr>
<tr>
<td>University of Alabama in Huntsville (UAH)</td>
<td>10 undergraduates in mechanical and aerospace engineering</td>
</tr>
</tbody>
</table>

Some potential candidate schools and departments reported that it was already too late to consider participation by the time they were contacted. The 2014-2015 academic year projects were announced much earlier in order to avoid this problem.

In addition to the student teams that were matched with projects there were 4 proposed student teams that were not matched from Johns Hopkins University, Stevens Institute and University of Southern California. All of these teams had volunteered to work on projects for SOCOM, but SOCOM was unwilling to support more than the 5 teams that were ultimately funded. Partly this was a misunderstanding about the expected commitment when posting project proposals. It was also a result of a strategic direction imposed by higher-level management at SOCOM after the proposals had been posted.

None of the teams this year included more than one school. The two Sailboat Disablement teams had initially offered to work together, but the project sponsor wanted them to work independently.

EXPERIENCE WITH WEBSITE REGISTRY SYSTEM

A new website was created for this second year of the marketplace based on the lessons learned from the pilot year. The website is populated with project proposals through a simple online editing system used by the project administrators. A standard template is used that includes a small graphic image provided by the sponsor, and a short description of the sponsor’s needs.
Students and faculty can browse through the project proposals on the website and volunteer by means of a short online form. The system saves these requests and sends an email to the project administrator for each one. The administrator then updates the status field of the project and requests more information as needed from the volunteers by email. Although this system appears to add additional burden to the project administrator, in fact very little activity takes place at this time. If the marketplace were to become much larger then more automation would be needed to facilitate the process. The current website software could easily be updated to include those features.

The website also contains a Home page with overview information about the marketplace and how to participate, a Frequently Asked Questions page, and a Resources section where example templates and other guidance can be posted. The plan is to accumulate example artifacts from previous projects as well as important lessons learned by experienced faculty and sponsors to post in the Resources section. Currently it includes a list of suggested activities and deliverables and a set of guidelines for new projects.

**STUDENT TEAM RESULTS**

Each of the student teams was successful. In some cases teams were held up by delays or changes in direction that caused them to rescale their projects. Each of the projects used good systems engineering practices, though some used more than others. For example, the team from Johns Hopkins used some systems thinking and conducted several reviews of their prototypes, but they did not follow as disciplined a process as the teams from Stevens and UAH. This is to be expected in the early days of the marketplace. We may be able to influence and recommend more systems engineering, but we cannot enforce very many specific requirements on these student projects.

We conducted a mid-year survey of faculty, students and sponsors to make sure that all projects were on track. This identified a few misunderstandings about roles and funding, but all projects were making good progress at that point.

**MARKETING FOR THE THIRD YEAR OF THE MARKETPLACE**

This section of the report summarizes progress made during the second phase of the project.

**SOLICITING PROJECT PROPOSALS FROM SPONSORS**

For the third year of the marketplace we hoped to obtain many project proposals in the first quarter of 2014. We started talking to potential sponsors in late 2013 with that goal in mind. In our discussions with SOCOM they expressed interest in continuing to sponsor projects, and promised to send us some proposals by late March 2014. They did send 6 initial proposals by early April and followed up later with 6 additional proposals in May. They promised not to withdraw proposals as they did in 2013-2014, but would fund all projects that had suitable student teams. The DoD Office of Corrosion Policy and Oversight was unable to support projects in 2014-2015, though they were delighted with the results of the project that they had funded in 2013-2014.

We reached out to potential corporate sponsors through INCOSE and NDIA. Presentations were given to INCOSE and NDIA leaderships that were received positively, and follow-up teleconferences were held to discuss ways to reach out to their membership. A mass emailing was sent to members of INCOSE, and follow up emails were also sent. We gave a presentation at the 2014 INCOSE International Symposium to their Corporate Advisory Board. This presentation featured one of the student teams from this past year and was very well received by both the
government and industry participants. Several leads for participation by industry as well as the UK Ministry of Defense are being pursued.

So far we have not received any proposals for projects from industrial sponsors, but we have had teleconferences with a few organizations that are interested in participating in the marketplace. Perhaps they will be ready to submit proposals for the 2015-2016 year.

SOLICITING AND ENCOURAGING ACADEMIC PARTICIPATION

We gave a presentation on the marketplace at the annual conference of the American Society for Engineering Education (ASEE). Since this conference attracts faculty from all engineering disciplines, it is a good venue to meet potential faculty participants in the marketplace. We also targeted some advertising for a specific academic conference, the Capstone Design Conference. This conference is held about every 2 years, usually in the mid-western part of the country. Many of the participants at the conference are faculty supervisors of capstone projects, and many are open to new ways of conducting projects. We provided a flyer for each participant's registration pack and paid for a small advertisement in their proceedings.

In addition we embarked on a nationwide campaign to reach engineering capstone faculty through an email sent by Dinesh Verma to all the deans of engineering schools in the US. At least one school contacted us immediately after receiving this email, and we hope that this will lead to more academic participants. We also sent email to a personal list of engineering faculty involved in capstone projects at US schools.

At Stevens we gave presentations to faculty supervisors of capstone projects and kept them aware of the status of new project proposals as they arrived. There is support for participation at Stevens, but proposals need to be available very early for their process. Most project teams are formed in the spring term, often in April. We were a little late this year so missed some opportunities.

Several leads for academic participation developed at the ASEE conference and INCOSE Symposium are being pursued.

DEVELOPMENT OF SUPPORT MATERIALS

This section of the report summarizes progress made during the third phase of the project.

We investigated potential templates for intellectual property agreements between sponsors and teams. This is particularly important for corporate sponsors, who are more likely to want ownership of intellectual property, or at least insist on non-disclosure agreements with student teams. Unfortunately, there are too many risks in providing a template or collection of templates for sponsors and teams to use. Most marketplace participants have little or no experience with these types of agreements, and there are many subtleties that should be considered. It would be better for participants to obtain their own legal counsel in preparing and engaging in these types of agreements.

We did prepare some guidelines for new marketplace participants that should raise most of the important issues to consider at the start of a project. These guidelines are attached in an appendix, and they are available on the marketplace website.
We hope to collect examples of good project artifacts from completed projects in the future. These will be available on the marketplace website for review by potential participants.

LESSONS LEARNED AND RECOMMENDATIONS

This section provides recommendations for future efforts in this area.

TEAM FORMATION

We continue to see participation by teams of students from single schools in most cases. Although the marketplace concept allows for participation by individual students at different schools it is much easier to engage sub-teams of students, where each sub-team is co-located and supervised by a common faculty member.

In order to create multidisciplinary teams it may be better to work with individual engineering departments at first. They can then invite participation by students from other disciplines at their schools. This may not be the optimal strategy in the long term, but it can be effective in getting schools to participate initially.

FUNDING

We had some delays this past year in providing funding to student projects. It is important that we avoid these problems in the future to make sure that schools continue to participate. Currently we are looking at alternative mechanisms to provide reimbursement for expenses by student teams that would avoid some of the overhead we have now.

PROJECT ENGAGEMENT AND COOPERATION

We continued to recognize the importance of project planning and initiation. The students should meet their sponsor at a kickoff meeting of all team members if possible. A face-to-face meeting would be ideal, or a video virtual meeting could be held. During the meeting the stakeholders (or faculty) can present the problem and some expected results. Students can volunteer for roles, and faculty can help set expectations for sub-team responsibilities. After the meeting each sub-team should share their summary of their understanding of the results of the meeting, including their expected roles and responsibilities, with other sub-teams.

During the project each sub-team should meet at least weekly, and each sub-team should communicate with other sub-teams at least weekly. Each sub-team may elect to assign a communication role to a liaison member of their sub-team to simplify communication between sub-teams and mentors. Gantt charts and timelines for sub-team tasks are useful artifacts for sub-teams to share during the project.

A mid-term review and a final review should be held with the whole team each academic semester. These are good opportunities to involve the stakeholders and mentors. Students should be reminded that they need to meet their deadlines, even though their products may not always be perfect.
ROLE OF CLIENT AND MENTORS

Interaction with clients, mentors and other stakeholders is an important part of the capstone experience. Regular meetings should be scheduled, perhaps monthly, to ensure that students have some minimal level of interaction. Stakeholders should be invited to all reviews. We created a list of suggested activities and reviews that highlight opportunities for mentors to engage with student teams.

Additional reviewers and mentors can sometimes be found by contacting local chapters of professional societies. Members of those chapters may be interested in the student projects and can help by mentoring or reviewing student work. Local chapters of ASME earn credit toward additional funding from their national organization by participating in these types of activities.

ROLE OF FACULTY

Faculty should meet regularly with their teams, especially at the beginning and end of each term. A weekly schedule is best. During these meetings students can report status, report current challenges and share proposed solutions to problems.
CONCLUSION

The second year of the marketplace successfully engaged new sponsors and universities in productive systems engineering capstone experiences. The new website is effective in presenting project proposals to potential participants, and it provides a useful repository for advice and guidance to new sponsors and student teams. Some of these materials have been created from experience in good systems engineering practices, while others are the result of lessons learned from marketplace participants.

Solicitation of participants for the 2014-2015 academic year is ongoing. Currently we have 12 project proposals from SOCOM and 2 from another DoD group on the website. We have received applications from 11 student teams. SOCOM has selected 10 teams to participate on 10 unique projects supporting 8 of the current proposed projects. Outreach is ongoing to try to match the 2 remaining non-SOCOM projects with a school that may have a single semester or off-semester calendar for capstone design.

Presentations we made this year are generating several new leads for both sponsor and academic participants, and we are actively pursuing those leads. Working with INCOSE and NDIA leadership has been helpful in identifying potential industrial sponsors of marketplace projects. We have also engaged the Assistant Secretary of the Army (Acquisition, Logistics and Technology) and are pursuing potential project proposals from their organization.

In the coming year we plan to develop additional resources for faculty, students, and sponsors to post on the marketplace website. We will also investigate adding tools to enable students to develop self-formed teams, both cross-disciplinary and cross-institutional.

Marketing and outreach will continue during the coming year, and we will use faculty and sponsor feedback to develop strategies for broader acceptance of the Marketplace. We will continue to work with INCOSE and NDIA leadership to identify potential industrial sponsors of projects. We will also investigate potential participation by the UK Ministry of Defense.

Long-term plans include finding a potential sponsor and steward for the marketplace, such as INCOSE, and continuing to grow the marketplace to be a national resource for systems engineering capstone experiences.
Capstone Marketplace Project Guidelines

Introduction

These guidelines are meant to assist prospective project sponsors and student teams in the creation, organization and execution of their projects. They are not meant to be prescriptive, but represent best practices in conducting student capstone engineering projects. We hope that they will better prepare participants to get the most satisfaction and value from their projects. All of these guidelines should be reviewed by the sponsor and the student team at the Project Kick-off meeting.

Communication and Points of Contact

Capstone Marketplace projects are undertaken by student teams at various universities in order to satisfy the needs of corporate and government sponsors. Each project should have a Faculty Supervisor who will provide guidance to the student team. Each project sponsor should identify a point of contact in their organization who will provide assistance to the team and act as the Client for the project.

It is good practice for each student team to designate one member of their team as the primary liaison with the client. This will reduce communication overhead and help prevent misunderstandings between the client and the student team. Although most student teams will be assumed to be self-directed, the client should feel free to contact the faculty supervisor for advice or assistance at any time. In addition, it is common practice for the faculty supervisor to ask the client for feedback about the team's performance at various times during the project.

Disclosure of Project Information

Some sponsors may want to review and approve any disclosure of project information, while others may choose to be more lenient. Similarly, some universities may choose not to engage in projects where prior approval for publication is required, while others may not have any such limitations. Prospective sponsors and clients should be aware that schools will assume that no prior review or approval is needed unless otherwise specified.

Intellectual Property

Some sponsors may want to own all or part of the intellectual property created by the project, while others may not. Similarly, some universities may choose not to allow students to sign away the intellectual property developed under the project, while others may have no such restrictions. Sponsors and clients should be aware that schools will assume that students or the schools will own all of the intellectual property that they create unless otherwise specified.

Publicizing Results
Most student teams want to publicize their results, at a minimum through presentation at their school’s “Capstone Experience Exposition” or similar function. Some academic programs may want to further publicize those events or other student accomplishments in local media. Each faculty supervisor should ensure the student team is sensitive to the client’s desires and concerns about publicity and disclosure of results and intellectual property. Thus, the faculty supervisor should ensure that the student team establishes policies and procedures for publications at the beginning of the project and that the client agrees with these. Sponsors and clients should be aware that schools will assume that they can publicize the accomplishments of their students unless otherwise specified.

Some sponsors may want student teams to abide by government regulations in the use of classified or otherwise restricted material, while others sponsors may have no such restrictions. Similarly, some universities may choose not to engage in projects where such restrictions are needed, while others may not have any such limitations. Even when projects are not classified, the project end product may be used in sensitive scenarios. Previous knowledge of the capability of the end product by hostile actors may negate the intended effect or put friendly forces in peril. Consequently, careful coordination should be effected prior to publicizing the project.

**Project Planning and Governance**

It is best practice for capstone engineering teams to prepare a project plan at the start of their project for review with their client. Many misunderstandings can be avoided by clearly stating expectations of both clients and student teams. We recommend that student teams consider the following items when preparing their initial project plan:

1. Concepts and background of the project: What does the client need?
2. Team composition and structure: What are the roles and responsibilities of team members?
3. Project constraints: What resources are available for materials and supplies, and how will expenses be reported and reimbursed?
4. Project Schedule with expected milestones and deliverables: Please see the guidelines for "Activities, Deliverables and Reviews of Systems Engineering Capstone Projects" for suggestions.
5. Communication: How will the team interact with the client and other project stakeholders (e.g., regular status reports, project deliverables) and in which medium (e.g., email, phone, video conference)?
6. Deliverables and Milestones: What will be accomplished, and when will it be done?
7. Risk Analysis: What are the principle risks, and how can they by mitigated?
8. Intellectual Property: Who will own this, and how will it be publicized or kept secret?

There may be other items to consider, depending on the project. For example, students may need to abide by school or government restrictions and regulations in conducting their work. Those restrictions and regulations should be noted and clarified in the initial project plan.