Systems Engineering Capstone Marketplace

Mark Ardis
5th Annual SERC Sponsor Research Review
February 25, 2014
Georgetown University
Hotel and Conference Center
Washington, DC

http://www.capstone2013.sercuarc.org/
Acknowledgments

• Michael DeLorme, Stevens Institute of Technology, Co-PI

• Collaborating Faculty:

<table>
<thead>
<tr>
<th>Faculty</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>Christina Carmen</td>
<td>UAH</td>
</tr>
<tr>
<td>Charles Gooding</td>
<td>Smith</td>
</tr>
<tr>
<td>Eirik Hole</td>
<td>Stevens</td>
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<tr>
<td>Vikki Hazelwood</td>
<td>Stevens</td>
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<tr>
<td>Nathan Scott</td>
<td>Johns Hopkins</td>
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<tr>
<td>Mick West</td>
<td>Georgia Tech</td>
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Building Education & Workforce Capacity in Systems Engineering

Research Question
What is needed to establish a marketplace for undergraduate capstone projects with an emphasis on multidisciplinary projects involving development of systems engineering competencies?

Approach
Develop templates and guidelines to support best practices in systems engineering capstone projects, especially those involving multiple engineering disciplines at multiple universities, plan for transition of pilot marketplace to another organization.
### First Year Partners

#### Civilian Universities
1. Auburn University  
2. Missouri University S & T  
3. Penn State  
4. Southern Methodist University  
5. Stevens Institute of Technology  
6. University of Maryland  
7. University of Virginia  
8. Wayne State

#### Service Academies
1. Air Force Institute of Technology  
2. Naval Postgraduate School  
3. Air Force Academy  
4. Military Academy – West Point  
5. Coast Guard Academy  
6. Naval Academy
## DoD Problems Addressed

<table>
<thead>
<tr>
<th>Problem Area 1: Low-cost, low-power computers</th>
<th>Problem Area 4: Immersive training technologies</th>
<th>Problem Area 2: Expeditionary assistance kit</th>
<th>Problem Area 3: Expeditionary housing systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>57.10%</td>
<td>28.60%</td>
<td>14.30%</td>
<td>21.40%</td>
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</table>
Disciplinary Character of Student Body

- Students from multiple disciplines
- Students from the same discipline
- Students from multiple disciplines, plus a mandatory SE major on each

- 72%
- 14%
- 14%
All Institutions by Major or Program

- Systems Engineering: 65
- Mechanical Engineering: 60
- Electrical Engineering: 27
- Computer Science: 15
- Industrial Engineering: 17
- Civil Engineering: 3
- Software Engineering: 15
- Engineering Management: 8
- Biomedical Engineering: 1
- Aeronautical Engineering: 1
- Other: 52

Total institutions: 264
## DoD/Industry Mentors

<table>
<thead>
<tr>
<th>University/Academy</th>
<th>Mentors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auburn</td>
<td>Advisory board (5 SE professionals from govt. and industry)</td>
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<tr>
<td></td>
<td>Industry Mentor (automotive arena)</td>
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<tr>
<td></td>
<td>PhD TAs (support team)</td>
</tr>
<tr>
<td>Missouri S&amp;T</td>
<td>Boeing Company engineers: Dale Waldo, Louis Pape, Nancy Pendleton,</td>
</tr>
<tr>
<td></td>
<td>Robert Simmons and Robert Scheurer</td>
</tr>
<tr>
<td></td>
<td>Office of Naval Research: Pete Muller</td>
</tr>
<tr>
<td>Penn State</td>
<td>DoD Mentors: Col. Nancy Grandy, and Mr. Phil Stockdale</td>
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<tr>
<td>Southern Methodist</td>
<td>U.S. Marine Corps</td>
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<tr>
<td></td>
<td>Office of Naval Research: Pete Muller</td>
</tr>
<tr>
<td>Stevens Institute</td>
<td>Naval Surface Warfare Center: Eric Shields</td>
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<td>Red Gate Group, Ltd: Joseph Barniak</td>
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<tr>
<td>U of Maryland</td>
<td>Lockheed Martin: Sandy Friedenthal</td>
</tr>
<tr>
<td></td>
<td>DoD Mentors: Dr. David Robie, Kim Watkins</td>
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<tr>
<td>U of Virginia</td>
<td>DoD Mentor: Bill Campbell</td>
</tr>
<tr>
<td></td>
<td>Northrop Grumman engineers</td>
</tr>
<tr>
<td>Wayne State</td>
<td>Army Shelter Expert, Claudia Quigley</td>
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<td>Army TARDEC: Dr. Pete Schil</td>
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<tr>
<td>Military Academy</td>
<td>SRI/Sarnoff: Dr. Rakesh Kumar</td>
</tr>
<tr>
<td></td>
<td>DoD Mentors: LTC Joe Nolan, LTC Chris Vaughn [Joint Advanced Training</td>
</tr>
<tr>
<td></td>
<td>Technologies Lab]</td>
</tr>
<tr>
<td>Air Force Academy</td>
<td>DoD Mentors: a reserve AF Colonel, a retired USMC officer</td>
</tr>
</tbody>
</table>
Industry and DoD Mentors were Critical

“These individuals were vital to the success of the systems engineering capstone because they brought a level of legitimacy, relevancy, and real-world context to the problem that was a catalyst for student learning and mastery of course outcomes.” [Faculty]

“[Our mentor’s] industry experience allowed him to foresee debilitating problems; his managerial skills enabled him criticize in a gentle, useful manner; and his credentials as former vice president of manufacturing for a large motor company lent credence to his comments.” [Faculty]
SE Approach was Eye-Opening

“This is a different approach [compared] to engineering design approaches I was familiar with, where the focus was more on developing the best product with the most features. I believe that the systems engineering approach is a better one because the perfect useless gadget is still useless.” [Student]

“I was not aware of the amount of types of documentation that a systems engineering project required. The different competencies like requirements management and verification and validation showed how important organizational aspects are to a successful project.” [Student]
“Without a doubt, the greatest accomplishment of RT 19 is the demonstration that truly cross-disciplinary capstone design projects can be developed by groups of seniors at the undergraduate level.” [Faculty]

“[Our project] shows very well how teams of people from different backgrounds should communicate and work together. In the real job world almost all teams consist of people from different academic backgrounds so it is very useful.” [Student]
Promising Practices (1/2)

1. Fall semester tools/techniques/approaches SE theory course, followed by spring semester design project course

2. Cross-disciplinary student teams

3. Regular, direct involvement of mentors with student project teams

4. Established relationships with nearby DoD commands and facilities

5. Creative use of mentors from defense prime contractors
6. Structured design reviews with DoD and industry mentors serving as reviewers

7. Use of SE Ph.D. candidates as project advisors

8. Creative imposition of technical, budget, and schedule constraints by faculty to model "real world"

9. For civilian institutions that have on-campus ROTC units, established relationships with ROTC units for requirements analysis, use case testing, and solution viability
Second Year Emphasized Partnerships

- 16 schools participated on 10 projects
- Different partnering models were used:
  - sub-teams
  - service organization
  - faculty training
Third Year Created a Marketplace
Marketplace for Innovative Projects

- **Stakeholders** propose challenging projects
  - Require systems thinking across multiple disciplines

- **Students** volunteer to participate
  - Select their own projects
  - Teams are self-organizing

- **Faculty** provide guidance and academic assessment
  - Advise stakeholders on expectations
  - Advise students on plans and methods
  - Assign grades to students
• Browse the registry for a project

• Select a project and volunteer to participate

• Get approval from stakeholders and faculty mentor to receive credit for the project as part of their academic program

• At the beginning of each term meet with stakeholders, other students and faculty mentors to review objectives and plans

• Work with stakeholders and peers at different schools to complete project objectives

• At the end of each term provide peer feedback to other students, stakeholders and academic project mentors
• Prepare project description

• Allocate resources for project expenses (material and transportation)

• Allocate staff to advise and mentor students

• Review credentials of student applications

• At the beginning of each term meet with students and faculty mentors to review objectives and plans

• Work with students during project

• At the end of each academic term provide feedback to academic project mentors
• Review proposed projects from students

• Approve/deny student participation on projects

• At the beginning of each term meet with stakeholders, students and other faculty mentors to review objectives and plans

• During the term may advise and monitor students

• At the end of the term review results, peer feedback and feedback from stakeholders

• Assign grades to local students
Dimensions of the Marketplace

- Projects might span **multiple years**
- Projects might require **multiple teams that collaborate**
- Projects might include **multiple teams that compete**
- A team might be composed of students from **same school**
- Stakeholders might hire **faculty as consultants** to projects
- **Students might propose projects** that are adopted by appropriate stakeholders
3 Capstone Projects in Pilot (First Year)

• Humanitarian assistance and disaster recovery kit and Dual use ferry
  — Stevens Institute of Technology (Engineering Management and Naval Architecture)
  — University of Alabama in Huntsville (Mechanical Engineering)

• Satellite radiometer
  — Southern Methodist University (Elec. Engineering and Computer Engineering)
  — University of Hawaii at Manoa (Info. Systems)

• Immersive training system
  — Missouri University of Science and Technology (Systems Engineering.)
  — University of Hawaii at Manoa (Info. Systems)
Dual-Use Ferry Project

- Navy sponsored a project to design a safe ferry that could also deploy a Humanitarian Assistance/Disaster Relief (HADR) kit in developing countries

- Stevens Institute of Technology
  - 2 Naval Engineering students: ferry design
  - 4 Engineering Management students: CONOPS, management and communication

- University of Alabama in Huntsville
  - 6 Mechanical and Aerospace Engineering students: HADR kit design and prototype

- CONOPS useful in coordinating sub-teams
Second Year of Marketplace

- United States Special Operations Command (SOCOM) proposed 22 projects
- DoD Corrosion Policy and Oversight proposed 2 projects

- Matched 6 projects with 5 universities:
  - Georgia Institute of Technology: Situational Awareness
  - Johns Hopkins University: Corrosion Detection
  - Smith College: Tactical Assault Light Operator Suit (TALOS)
  - Stevens Institute of Technology: Medical Monitoring
  - Stevens Institute of Technology: Sailboat Disablement 1
  - University of Alabama in Huntsville: Sailboat Disablement 2
http://www.capstone2013.sercuarc.org/

About the Capstone Marketplace

Our mission is to match multidisciplinary student teams with challenging engineering projects. Project sponsors provide domain expertise and advice, while faculty supervisors help guide the teams and grade their work. The capstone marketplace makes it easier for sponsors to reach out to potential students, and it helps students find projects best matched to their interests and needs.

Previous research has demonstrated that students who worked on multidisciplinary capstone projects had increased interest and learning in basic systems engineering concepts. They also developed a better appreciation of the differences in methods and tools of different engineering disciplines.
The following projects are part of the Capstone Marketplace. Each proposed project is intended to address needs identified by industry partners. Students work in small groups to identify, design, and develop solutions for these issues.

**Advanced Body Armor and Helmets**
Design lighter-weight body armor with similar ballistic protection.

**Austere or Unimproved Landing Zone Assessment**
Assess a potential landing site under nighttime conditions.

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Learn More → Learn More →
Project

Sailboat Disablement

Sponsor
Special Operations Forces (SOF)

Status
Active: University of Alabama in Huntsville and Stevens Institute of Technology

Summary
Provide capability to safely disable sailboats
Description

Current Capability

• No capability currently exists to mechanically stop sailboats while underway

Issues

• Stopping sailboats permits SOF to defeat various types of maritime adversaries and will enhance SOF maritime capabilities.
• Specific research outcomes that benefit SOCOM should include:
  ◦ A report
  ◦ Possible model simulations demonstrating efficacy of concept

Capability Needs

• SOCOM requires myriad techniques and hardware with which to carry out maritime disablement operations.
• SOF desires the capability to stop sailboats. More sophisticated possibilities, such as direct energy, SCADA attack or computer network operations are being considered separately, where appropriate.

Student Application  Faculty Application
Faculty Application Form

Project Name:

Sailboat Disablement

1. Information about you

Name:*  

Email Address:*  

Phone Number:  

School or Organization:  

Department
2. Please list the names of the students you will supervise:

Student Names:

3. Information about the project(s) you want to join

In one or two sentences, what do you think the students can produce or achieve on the project(s):
Corrosion Project

- DoD Corrosion Policy and Oversight needs a tool to inspect properties of material coatings, especially in areas that are difficult to access.

- Team of Mechanical Engineering students from Johns Hopkins University are developing a prototype tool.
Sailboat Disablement Project

- Conventional means to stop ships are ineffective against sailboats due to their unusual keel designs
2 Teams Interested in Project

• Stevens Institute of Technology
  — 3 Mechanical Engineering students
  — 2 Naval Research Engineering students

• University of Alabama in Huntsville (UAH)
  — 10 Aerospace Engineering students

• Initially the 2 teams agreed to collaborate

• SOCOM sponsor requested that teams work independently
Stevens Institute Team Initial Designs
• Identify successful practices
• Collect resources to support practices
• Prepare templates and guidelines for participants
• Assess results of Second year of marketplace
• Prepare for Third year of marketplace
• Plan for transition of marketplace
Templates and Guidelines

• Expectations and activities for participants
  — Sponsors: Financial support, schedule
  — Mentors: Meetings and reviews, availability
  — Faculty: Meetings and reviews, feedback
  — Students: Meetings and reviews, deliverables, self-leadership

• Lifecycle models for projects
  — Include good SE practices
  — Agile: time-boxed, flexible

• Agreements
  — Intellectual property
  — Nondisclosure

• Expect to have continued participation by SOCOM

• Looking for additional sponsors
  — Most projects cost $10K or less
  — Great opportunity to meet and influence talented engineering seniors
  — Need 2 or 3 paragraph problem statement

• Looking for academic participants
  — Expect to have projects on website by early April

• If you are interested or have suggestions please contact:

  mark.ardis@stevens.edu

  http://www.capstone2013.sercuarc.org/
Transition to Independence

• Looking for champions to take over the marketplace
  ― Might be someone from a professional society, like INCOSE
  ― Might be someone from academia
  ― Might be someone from the entrepreneurial community

• If you are interested or have suggestions please contact:

  mark.ardis@stevens.edu

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