



SYSTEMS
ENGINEERING
RESEARCH CENTER

Systems Engineering Capstone Marketplace

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Principal Investigator:

William Shepherd, Stevens Institute of Technology

Co-Principal Investigator:

Michael DeLorme, Stevens Institute of Technology

Research Teams:

Auburn University, Michigan Technical University, Missouri Science and Technology,
North Carolina State A&T University, Oklahoma State University,
San Jose State University, Stevens Institute of Technology, University of Texas, Texas
A&M University, Virginia Polytechnic University, U.S. Naval Academy

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EXECUTIVE SUMMARY

This is the Final Technical Report for Research Task 197 (RT-197 – Capstone Marketplace) covering the period 09 Feb 2018 to 30 June 2019. Research funds for this task have been provided from the Capstone Sponsor, OSD’s Director of System Engineering Transformation as well as U.S. Special Operations Command, U.S. Air Force Research Lab, and OSD’s Rapid Response Technology Office. During 17 months of activity, SERC’s Capstone Marketplace generated over 40 research topics from operational military units, and posted them to a web-based Marketplace. The Marketplace attracted proposals from numerous universities nationwide, and 31 Capstone projects were selected for student teams and faculty advisors from 11 universities. 28 Projects were initiated during academic year 2018-2019 as new starts; 3 projects were continuations from the previous year’s Capstone work. In two instances, at Virginia Tech, and Texas A&M University, student teams performed Capstone activities for their government sponsors even though SERC contracts were not completed before the end of the school year. Several limitations in SERC’s contract requirements contributed to this situation and changes are being addressed to fix this for the next academic year.

The goal of this project was to investigate means to expand SERC Capstone Marketplace activities established in 2013, refined in 2014, and further developed in the 2016-2017 academic year. Previous SERC research in RT-19/19a, RT-43, RT 105, RT-131, and RT 150 showed that multidisciplinary Capstone programs enhance development of systems engineering competencies in undergraduate student engineers.

Under authorities granted to SERC in January 2019, SERC can now engage with any accredited university in the U.S. Four non-SERC universities, including San Jose State, U.S. Naval Academy, Oklahoma State, and the University of Texas-Austin have participated in recent SERC Capstones. One Capstone project included a Virginia Tech team collaborating with a University of Maryland biomedical research project, and was the Capstone Marketplace’s first multi-school effort.

Numerous SERC Capstone presentations have been made to universities, military units, and government organizations, the SERC Advisory Board, SERC Research Symposiums, Interagency Working Groups (System Engineering), NDIA’s System Engineering Symposium, and two NDIA annual meetings--Special Operations and Armament technologies. Additional briefings have been provided to senior Army, Navy, and Special Operations staffs and support organizations. SERC is working to attract broader government participation in its 2019-2020 Capstone work.

ORGANIZATION, PROCESS, AND ADMINISTRATION OF THE CAPSTONE MARKETPLACE

PARTICIPATING SPONSORS AND PROJECTS

The Deputy Assistant Secretary of Defense (System Engineering) is the principal sponsor for the SERC Capstone Marketplace. United States Special Operations Command (USSOCOM), the Office of the Secretary of Defense (OSD) Rapid Response Technology Office, and U.S. Air Force Research Laboratory provided additional sponsorship for Capstone work. Project topics for the Marketplace were solicited by Capstone Managers from Army, Navy, Air Force, and Marine Corps Special Operations units and staffs. One Air Force Research Lab project for mass rescue at sea also had interest from the U.S. Coast Guard.

ORGANIZATION OF THE CAPSTONE MARKETPLACE

Research Task 197, the Capstone Marketplace, has built on structure established through SERC's tasking on successive research contracts starting in 2013. The Principal Investigator (PI) and Co-PI assisted in the solicitation and preparation of the Research Topics, set up the website, and handled direct communications with government customers and universities on Capstone processes and academic issues. For several teams, Capstone Managers occasionally assisted the student teams as technical "Subject Matter Experts", especially when communications with government customers were sparse. SERC's staff offices provided project management, accounting, reporting, and accounting support for the Capstones. Stevens Institute's Office of Sponsored Programs provided the necessary contract, finance, and legal support to set up and administer the numerous Capstone subcontracts with participating universities.

INITIATION OF PROJECTS

Marketplace personnel assisted military and government "customers" in editing their inputs and creating suitable Research Topic descriptions. The Capstone editing process was necessary to balance customer requirements with research objectives that had appropriate academic value to the students. The scope of Research Topics was tailored to accommodate the limited time, resources, and experience typical in undergraduate student environments.

In Summer 2018, 41 Capstone Research Topics were posted on the Marketplace website, www.capstonemarketplace.org. The website is an online portal that attracts faculty and their multi-disciplinary student engineering teams, identifying desired solutions for challenging engineering projects. The SERC Capstone Marketplace provides students and academics "real" problems owned by "real" customers.

Soliciting and Award Contracts

Email announcements of Capstone opportunities were sent to schools in the SERC consortium, and to deans and heads of engineering departments at over 100 U.S. universities. Instructions for proposal submissions were posted on the web. Universities provided their Expressions Of Interest (EOI) to the Marketplace, and Requests For Proposal were sent out in response to each EOI. Short

proposals, written by faculty advisors before the start of the semester were received and reviewed by the Capstone Marketplace team and government sponsors. Stevens sent emails to schools offering Fixed Price contracts with incremental deliverables and milestone payments. These contracts are typical in the business world that students will likely encounter in outside work. SERC contracts provided funds only for student materials, travel, limited non-capital special equipment, and outside services. University direct labor was generally not an allowable Capstone expense. The contract agreements were collaborative; universities were expected to provide faculty advisors, facilities, equipment, shop and other support, material, etc. as their no-cost contribution to the Capstone effort. A \$5,000 budget limit was established as a standard for a two-semester project. SERC contracts also required that universities minimize or eliminate facility and administrative overhead charges on Capstone awards, as a main thrust of the Capstone experience is to enhance student educational experience in their senior design courses.

The flowdown of government terms and conditions from Stevens' prime contract to university subcontractors became a significant issue in contract negotiations. Many Federal Acquisition Requirements designed for large acquisition programs did not add value to the small amount of Capstone work being performed. One awardee, Virginia Tech, chose not to accept the Capstone contracts, but performed the Capstone work with their government customers anyway. SERC is making changes to its contract requirements to avoid this situation in the next year.

Management of Capstone Activities

The Capstone Marketplace personnel established contact with universities, faculty advisors, and student teams executing Capstone projects. Communications were continued with each government customer to ensure that kickoff meetings, project plans, scheduling, the design review process, and other key elements of "system" approaches to the Capstones were employed. Marketplace managers posted updates on the Capstone Marketplace website to communicate important details regarding Capstone activity throughout the year. All relevant Capstone documents, reviews, reports, and technical data were archived in a file structure on Stevens Institute's server. Folders with all Capstone deliverables and final reports are being shared with each government sponsor.

Participating Schools and Projects

Auburn University, Oklahoma State, and Stevens Institute continued four Capstone projects through 2018-2019. These were projects started in the 2017-2018 academic year. In Fall 2018, 10 Universities were given contracts for work on 26 new Capstone projects. The U.S. Naval Academy performed 2 Capstone efforts for a Naval Special Warfare (NSW) customer, and were funded directly from OSD for their student work. Capstone managers assisted NSW representatives and USNA in the organization of their Capstone efforts. One Capstone efforts proposed in Table 1 below was cancelled as a result of difficulties establishing acceptable communications and meeting schedules between students, faculty, and government SME's. One additional Capstone effort for NSW was cancelled, as the proposed task did not provide enough academic content for university educational requirements.

Table 1 shows status of Capstone projects done during RT 197. All contracted project deliverables, including project plans, design reviews, and other team status reports are archived at SERC.

Table 1. SERC Sponsored Projects 2017-2018 and 2018-2019

University	Project	DOD Customer/SME	Funding Sponsor	Remarks	Assessment	Number of Students
Auburn 2017	Lightweight Pole	NSW	SOCOM	Continuation project from 2017-2018	Not Evaluated Directly by SERC**	7*
Auburn 2017	Lightweight Ladder	NSW	SOCOM	Continuation project from 2017-2018	Not Evaluated Directly by SERC**	7*
Oklahoma State University	Software Defined Radio Experiment on a DJI Arial Drone	NSWDG	SOCOM	Continuation project from 2017-2018	Not Evaluated Directly by SERC**	2
Stevens Institute 2017	Amphibious Side by Side Vehicle	NSW	SOCOM	Continuation project from 2017-2018	Acceptable	7
Capstone Projects Initiated in Fall 2018						
Michigan Technological University	2018 AFRL 03 Personnel Recovery Hydration	AFRL	AFRL		Acceptable	5
Michigan Technological University	2018 AFRL 04 Personnel Signature Reduction	AFRL	AFRL		Acceptable	5
Michigan Technological University	2018 AFSOC 01 Improved Display of Aircraft Datalink Information	AFSOC	SOCOM	Cancelled as a result of late coordination with Govt SMEs		
Michigan Technological University	2018 AFSOC 03 HOTAS Radio Control	AFSOC	SOCOM		Acceptable Lost SME before Milestone 3	5

Michigan Technological University	2018 ARFL 05 Personnel Recovery - Power	AFRL	AFRL		Acceptable	5
Michigan Technological University	2018 ARMY 01 Novel Back-packable Power Sources	USASOC	SOCOM		Acceptable	4
Michigan Technological University	2018 MARSOC HRM 1 Improved Life-Support for Casualties at Point of Injury	MARSOC	SOCOM		Exceptional	4
Michigan Technological University	2018 NSW 01 Boat HUD	NSWDG	SOCOM		Acceptable	4
Michigan Technological University	2018 NSW 05 Amphibious Side by Side Vehicle	NSWDG	SOCOM		Acceptable	6
Michigan Technological University	2018 NSW 12 Vision Undersea	NSW	SOCOM		Exceptional	8
Michigan Technological University	2018 NSW 14 Mobile Command Center	NSWDG	SOCOM	Cancelled 10/05 due to insufficient academic content		
Michigan Technological University	2018 USCG 01 Mass Rescue Device	USCG	AFRL		Acceptable	4
Missouri University S and T	2018 MARSOC TE 2 Speech Translation	MARSOC	SOCOM		Acceptable	3
Missouri University S and T	2018 MARSOC TE 3 Portable Translator	MARSOC	SOCOM		Acceptable	4
North Carolina A & T State University	2018 SOF 16 Self Intubating Airway Device	SOF	RRTO		Acceptable	3
North Carolina A & T State University	2018 SOF 18 Traumatic Brain Injury Self-Assessment	SOF	RRTO		Acceptable	4
Oklahoma State University	2018 SOF 12 Automated Small Sensor Emplacement	SOF	RRTO		Acceptable	4

Oklahoma State University	2018 NSW 02 Improved Network SUAS	NSWDG	RRTO		Acceptable	3
Oklahoma State University	2018 NSW 11 Flare Sensor	NSWG 2	SOCOM		Exceptional	7
San Jose State University	2018 NSW-25 SUAS Spoofing	NSWDG	RRTO		Acceptable	4
Stevens Institute of Technology	2018 SOF 18 Traumatic Brain Injury Self-Assessment	SOF	RRTO		Exceptional	5
Stevens Institute of Technology	2018 SOF 19 Instrumented Combat Boot	SOF	RRTO		Acceptable	5
Texas A&M University	2018 SOF 14 Augmented/Mixed/Virtual Reality Training	SOF	RRTO		Acceptable	5*
University of Texas at Austin	2018 SOF 16 Self Intubating Airway Device	SOF	RRTO		Exceptional	5
University of Texas at Austin	2018 SOF 20 Tactical Ultrasound	SOF	RRTO	Project added as last Topic for Fall 2018	Acceptable	5
Virginia Tech	2018 SOF 11 Artificial Intelligence – Data Fusion and Machine Learning	SOF	RRTO	SERC Contract not executed for all VT projects	Acceptable	3
Virginia Tech	2018 SOF 17 Machine Learning for Catheter Emplacement	SOF	RRTO	Teamed with UMd for X Ray data sources	Acceptable	3
Virginia Tech	2018 SOF 13 Quantum Precision Nav and Timing	SOF	SOCOM	Project descoped by RRTO to address Quantum data only	Acceptable after change of scope	3*
USNA	2018 NSW 03 UAV Night Time Sensor	NSWDG	RRTO	Funded by MIPR to USNA	Not Evaluated directly by SERC**	4***

USNA	2018 NSW-23 Unconventional Device Actuation	NSWDG	RRTO	Funded by MIPR to USNA	Not Evaluated directly by SERC**	4***
NOTES: * indicates estimate of Capstone student team size ** indicates Capstone evaluations done by government clients. *** Projects at service academies that were funded directly by government funds transfers and evaluated by government customers						

Statement of Work Accomplishments

The Capstone Marketplace and SERC staff have completed their tasking for all the major elements of RT 197 Statement of Work. Table 2 below lists SERC’s activities, comments, and results.

**Table 2 Status of Tasks from
RT 197 Contract “Statement of Work”**

Develop communication assets for universities and Capstone teams	The SERC Capstone Marketplace website has been in active use for the entire contract period. SERC has used the site to provide guidance for Proposals, Project Plans, and basic system engineering processes. Improved templates for Capstone project status and reviews have been developed for student use.
Operate and maintain the Capstone Marketplace website	SERC is using the website as the primary means to post research topics and to communicate important Marketplace details. New Research Topics have been in work and will appear on the site in Summer 2019.
Generate good problem sets and strong SME Participation	41 Research topics were posted from SOF units, Rapid Response Technology Office, AFRL, and U.S. Coast Guard on the Marketplace website. Topics were assigned to universities and worked by student teams, with SME support from government customers.
Widen CM awareness to all SOF	A Capstone Marketplace Summit was conducted in Feb 2019, to discuss progress, changes, and future research. Marketplace personnel have conducted extensive visits, briefings, emails, phone contacts, and web notices to all levels of Special Operations organizations, to increase awareness on Capstone opportunities.
Capstone Marketplace reorganization	Capstone roles, responsibilities, processes, and activities have been documented. Capstone process documents have been created and are posted on the website.

Develop an annual rhythm for sustained Capstone operations	A projected Schedule of Activities for 2019 Capstone participants has been outlined and presented at the Capstone Marketplace Summit in Feb 2019. A copy of the annual Capstone schedule is included as Appendix A.
Plan for engagement with professional societies	Presentations have been made to the 2019 Conference on System Engineering Research in Washington D.C. Additional presentations have been made to the Interagency Working Group, and NDIA Symposia in October 2018, and May and June 2019
Expand CM funding sources	Additional Capstone funding for new 2019 projects has been solicited from OSD and USSOCOM. Other funds from NAVAIR are being sought for the upcoming academic year.

Research Results

Since February 2018, the SERC Capstone Marketplace has managed activities on 4 legacy Capstone projects from the previous academic year, and in Sept 2018, started an additional 28 new research topics. Two of these new topics were assigned to the U.S. Naval Academy and funded directly by the government. Unfortunately, 3 of the Capstone projects at Virginia Tech did not get formal contract agreements completed with SERC. However, these three projects were pursued independently, with universities communicating with government customers; all were concluded with satisfactory results. As a result of these contract difficulties, SERC is simplifying Capstone Marketplace contracts in the future to make the processing of contracts more straightforward.

For the 31 Capstone projects, student levels of effort were very good, several of the Capstone project results were assessed as exceptional. Approximately 150 students got “real world” experience developing solutions to important problems through the Capstone Marketplace.

Outreach Activities

Over the contract period, presentations and briefings on the Capstone Marketplace were made at Virginia Tech, MIT, UNLV, Missouri S&T, Michigan Tech, University of South Florida, U.S. Naval and Air Force Academies, USSOCOM, Air Force Special Operations Command, 7th Special Forces group, U.S. Army Special Operations Command, the U.S. Navy’s Special Warfare Command, NAVAIR, and the Institute for Human Machine Cognition in Pensacola Fla. Capstone work has been presented at SERC’s Sponsored Research Review, two NDIA technical symposiums, and at the System Engineering Interagency Working Group in Washington. SERC also conducted its first Capstone Summit in February for university participants, leadership, and government sponsors.

Lessons Learned, Recommendations, Proposed Changes

CONTRACT REQUIREMENTS

Some faculty advisors overseeing Capstone teams were unaware of the reporting, deliverables, or formats which were specified in the Capstone contracts. Capstone teams were required to show projected spend plans in their Project Plan documents at initial kickoff reviews with customers. Most Capstone teams did not initially provide adequate data. For the future, more information will be provided on the Capstone Marketplace website to ensure awareness of SERC's desires in showing projected schedules and costs as well as technical performance.

CAPSTONE COORDINATORS

As Capstone Marketplace expands, and universities become engaged in multiple Capstone projects, the Marketplace will seek to identify a "Capstone Coordinator"--a single Point of Contact at each school for academic and administrative details for Capstone teams.

REDUCED CONTRACT PAPERWORK

ITAR, Intellectual Property (IP), and other contract certification processes will be streamlined to reduce administrative burdens on university business offices. The Capstone Marketplace will continue to have each university establish their internal policies for ownership of IP with their students and faculty, acknowledging the government's right to use IP without royalty.

TIMING OF RESEARCH OPPORTUNITIES AND SCHEDULES

Ideally, the bulk of new research topics should be generated and posted for universities by the end of the Spring Semester, when some schools form teams and assign projects for the next year. Capstone's schedules for creating new topics must be advanced to better align with academic calendars.

Schedules

Appendix A, "Capstone Marketplace Schedule of Events" lists the key Capstone milestones for both the academic and the government fiscal years. The major highlights of Capstone activity are:

- 1. RESEARCH TOPIC DEVELOPMENT (MAY- JULY).** Government sponsors submit their topic worksheets and communicate with the Marketplace to refine their ideas for new topics. Capstone Managers work with the government sponsors to edit the Research Topic documents as needed. The Capstone Marketplace accepts university inputs on Research Topics, and connects with potential sponsors willing to mentor the respective student teams on the submitted ideas.
- 2. RESOURCING (APRIL-JULY).** SERC personnel identify government resources available to fund student teams.
- 3. RESEARCH TOPIC ANNOUNCEMENTS (June-Aug).** Starting in June, Capstone Marketplace personnel post descriptions of Research Topics on the web.

Universities are notified that new topics are available for awards.

4. PROPOSAL SUBMISSION AND SELECTION (JUNE-SEPT). Once the Research Topics are posted on the website, interested faculty advisors submit a short proposal outlining how they will manage their student teams on each topic. These proposals are evaluated by the Capstone Marketplace and selected by government sponsors.

5. CAPSTONE CONTRACT AWARDS. (SEPTEMBER) Universities are notified of their selection for a Capstone award. Stevens' and respective university business offices start negotiating formal contract agreements.

6. EXECUTION OF PROJECTS (SEPT-JUNE). Capstone teams and their government customers start work on the Research Topic. A first milestone is a Project Plan document which is written by the student team. The plan mirrors a "business plan" that outlines the mutual expectations of the team and their customer. The plan is presented to and approved by the customer at an initial kickoff meeting in the Fall.

7. CAPSTONE SUMMIT (APRIL-MAY). An end-of-year meeting is scheduled to review Capstone work, administrative processes, provide feedback from both universities and government customers, to help make the SERC Capstone environment more productive for all participants.

Establishing the Market Place as a Two-Way Portal

Universities are encouraged to submit their ideas for Research Topics to the Marketplace. SERC has already received topic nominations from Virginia Tech, USF, and Stevens. The Capstone Marketplace managers have shared each university input separately with potential government customers to determine their interest in sponsorship. Ways are being sought to make the website a true "marketplace" which can reduce or eliminate the need for SERC personnel to act as intermediaries in brokering and preserving the confidentiality of these ideas and proposals.

Graduate Involvement

One Capstone team included graduate students on their project. At a recent Capstone Summit the inclusion of graduate students in Capstones was discussed. SERC feels there can be substantial benefit to graduate student involvement on Capstones. The student team environment is an excellent forum for grad students to mentor undergraduates; grad students can bring advanced skills to the team's research; and inclusion of grad students who are pursuing business majors can significantly enhance the team's project management skills. SERC will request approvals to bring grad students into Capstone projects, and will propose that universities adopt the following guidance:

1. Graduate students are selected for their advanced skills and mentoring abilities
2. The bulk of Capstone work must be done by undergraduate students
3. No grad student direct labor costs will be charged to SERC's contract

Industry and Transitions

SOCOM and other government participants desire to see selected student Capstone projects transition to formal, fully funded research work. SERC is investigating ways to attract industry participation in Capstones during the academic year, which may stimulate the transition process. In addition, discussions have been held with government sponsors to develop processes to identify and fund transition work beyond the Capstone effort, at universities or in industry. Methods including Partnership Intermediary Agreements and Other Transaction Authorities are being discussed as ways to attract and engage with transition performers in a rapid and efficient manner.

Conclusions

SERC believes that the Capstone Marketplace is making significant impacts on students' learning experiences as they take on important problems for their government customers. Real customers who assist Capstone students' team in understanding how the product will be used, and who help guide its development provide a unique richness to the educational effort. Student responses to Capstone activities have been uniformly positive.

DOD and military R&D organizations are now regarding the Marketplace and its undergraduate research as a means to increase R&D bandwidth—to address ideas that they may not have the resources or time to pursue. Student Research Topics have been pursued to identify “other” ways to find technical solutions—at low cost. SERC's DOD customers have repeatedly commented that student teams are able to provide independent approaches and fresh looks at technical problems which would be difficult to reproduce in the laboratory environment or defense industry sectors.



Capstone Timelines

