



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:

Michigan Technical University, North Carolina State A&T University, Oklahoma State University, University of Southern Alabama, Stevens Institute of Technology, University of Texas, Texas A&M University, Virginia Polytechnic University, U.S. Naval Academy, University of Nevada Las Vegas

Sponsors:

DASD(SE), OSD Rapid Response Technology Office, USSOCOM

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EXECUTIVE SUMMARY

This is the final Technical Report for Research Task 1007 (WRT-1007 – Capstone Marketplace) covering the period 01 May to 29 June 2020, and summary observations and Capstone project results for the full 2019-2020 Academic Year. Research funds for the Marketplace have been provided from OSD’s Director of System Engineering as well as U.S. Special Operations Command and OSD’s Rapid Response Technology Office. During 12 months of activity, SERC’s Capstone Marketplace has matched 18 research needs from military units to student engineering teams pursuing senior design projects. 11 universities received awards to support 24 student Capstone teams. In March 2020, nationwide quarantine restrictions affected all university students and faculty; this had major impacts on Capstone activities, as students were unable to travel or use school laboratories, shops, libraries, and other facilities. In all cases, student teams devised virtual workarounds which achieved satisfactory project objectives for their tasks.

The goal of this project was to investigate means to expand the SERC Capstone Marketplace established in 2013, refined in 2014, and further developed in the 2016-2018 academic years. Previous SERC research in RT-19/19a, RT-43, RT 105, RT-131, RT 150, and RT 197 showed that multidisciplinary Capstone programs enhance development of systems engineering competencies as well as analytic and design skills among undergraduate student engineers.

Under authorities granted to SERC in January 2019, SERC now engages with any accredited university in the U.S. for Capstone work. North Carolina A&T University, University of South Alabama, U.S. Naval Academy, Oklahoma State, and the University of Texas-Austin, all non-SERC universities--have recently participated in SERC Capstones.

SERC Capstone Marketplace presentations have been made to universities, military units, and government organizations, DOD’s Innovation Symposium, the SERC Advisory Board, and the 2019 SERC Research Symposium. Additional briefings have been provided to senior Army, Navy, and Special Operations staffs and support organizations.

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), and the Office of the Secretary of Defense (OSD) Rapid Response Technology Office provided additional resources 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.

ORGANIZATION OF THE CAPSTONE MARKETPLACE

Research Task 1007, the Capstone Marketplace, built on SERC's successive research contracts starting in 2013. The Principal Investigator (PI) and Co-PI assisted in the solicitation and preparation of Research Topics, organized the website, and handled communications with government customers and universities to inform on Capstone processes and academic requirements. Capstone Managers provided academic advice and helped 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 Capstone Marketplace. Stevens Institute's Office of Sponsored Programs provided the necessary contract, finance, and legal support to initiate and administer the numerous subcontracts with participating universities.

INITIATION OF PROJECTS

Marketplace personnel collected inputs from military and government customers and helped to craft these documents as appropriate Research Topic descriptions. This editing process balanced customer requirements and expectations with research objectives and academic content for students. Each Research Topic description was tailored to accommodate the limited time, resources, and experience typical in undergraduate student environments.

In late Summer 2019, 18 Capstone Research Topics were posted to an online website, www.capstonemarketplace.org. The website portal attracted faculty and student engineers interested in pursuing challenging engineering projects. The SERC Capstone Marketplace provides students with real problems and interaction with real customers, where many traditional senior design topics at universities are artificially generated by faculty.

Soliciting and Award Contracts

As new topics were posted in 2019, email announcements of Capstone opportunities were sent to the SERC university consortium, and to deans and heads of engineering departments at over 100 U.S. universities. Universities provided Expressions Of Interest (EOI) forms online in the Marketplace, and Requests For Proposals were sent out in response to each EOI. Faculty advisors, in coordination with their respective business offices, submitted proposals. In most cases, these proposals were written by faculty before the Fall Semester started and student teams were formed. Proposals were then received and reviewed by the Capstone Marketplace team and government sponsors. Stevens Institute offered Fixed Price contracts to the selected universities. A \$5,000 budget limit was established for a typical two-semester project, and SERC contracts required that universities minimize or eliminate facility and administrative overhead charges on Capstone awards. A thrust of the Capstone initiative was to introduce student

teams to standard business tools and practices; Capstone contracts specified incremental design reviews and other system engineering products keyed to milestone payments. SERC contracts provided funds for student materials, travel, non-capital equipment, and outside services. University direct labor was generally not an allowable Capstone expense. SERC contract agreements were collaborative; universities were expected to minimize indirect overheads, and provide faculty advisors, facilities, equipment, shop, material, and other support as their contributions to Capstone efforts.

Management of Capstone Activities

During the academic year, Capstone Marketplace personnel maintained contact with universities, faculty advisors, and student Capstone teams. Managers provided advice to government customers to ensure that kickoff meetings, project plans, scheduling, design reviews, and final project results were completed. 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 are now archived on Stevens Institute’s server. Folders with all Capstone deliverables and final project presentations and reports are being shared with each government sponsor.

Participating Schools and Projects

University of Texas at Austin, Texas A&M, U.S. Naval Academy, and Stevens Institute continued five Capstone projects that were started in the previous academic year. In Fall 2019, new awards were made to universities for Capstone work. In addition to SERC’s subcontracts, the U.S. Naval Academy performed 4 Capstone efforts for a Naval Special Warfare (NSW) customer that were funded by military purchase request (MIPR) from OSD to USNA. Capstone Marketplace managers were designated technical representatives for the USNA Capstones. One project at Virginia Tech was pursued without request for SERC funding, and two projects at other schools were cancelled as a result of scheduling difficulties. For 2019-2020, 24 Capstone student teams worked on 18 Research Topics at 11 Universities. Approximately 120 students were involved.

Table 1 shows status of Capstone projects for WRT 1007. All contracted project deliverables, including project plans, design reviews, and other team status reports are archived with the SERC at Stevens Institute.

Table 1 Summary of 2019-2020 Capstone Projects:

Govt Client	Research Topic Number	Short Title	Universities	Status and Remarks
AFRL	2019 AFRL 01	Cooling aid for Maintainers in Protective Gear	MTU, UT Austin	Interests in cooling for military with PPE as well as maintainers

AFRL	2019 AFRL 02	Quick On/Off Pulse-Ox Monitor	NC A&T	Interest in SOF community for HALO ops
AFRL/USCG	2019 AFRL 03	Mass Rescue Devices	MTU	Continuation from FY 19
NSWDG	2019 NSW 04	Maritime Disablement	USNA Penn-St	Penn State deferred for 2019 year. Possible Fall 2020 start
NSWG2	2019 NSW 21	Military Freefall Flight Data Recorder	USNA	Continuation from FY 19 project
NSWG2	2019 NSW 22	Combat Swimmer Data Recorder	UNLV, Stevens	Fabrication of recorder completed at UNLV. Testing at Stevens restricted by current quarantine efforts
NSWG2	2019 NSW 23	Combat Shooter Data Recorder	UT Austin U of S Ala	UT and USA pursued complimentary development work. Quarantine precluded full integration and test activities. Teams completed virtual modeling and analysis
NSWG2	2019 NSW 24	Ground Force Commander Simulator	MTU	Significant govt interest in follow-on work
NSWG3 N8	2019 NSW 31	Physical and Cognitive System Enhancements	VT	USN customer interested in continued FY 21 research
NSWG4 N8	2019 NSW 41	FLIR Camera Verification of GPS Navigation Integrity	USNA, U of S Ala	Analysis and modeling promising. USN interested in a follow-on effort
NSWG10 N8	2019 NSW 101	Deice/Anti-icing for Unmanned Aerial Systems	OSU	Project complete. Impressive results
SOCOM ST	2019 SOCOM 01	Future Vehicle Stopping	MTU	Complete
USD (R&E)	2019 USD(R&E)-01	Quantum Computing - Algorithm Development for Military Optimization Problems	VT	Virginia Tech withdrew SERC funding request but completed project independently
USD (R&E)	2019 USD(R&E)-02	Augmented/Mixed/Virtual Reality Training	USNA; TAMU	
USD (R&E)	2019 USD(R&E)-03	Blockchain-based Tracking of Machine Learning Algorithms	USF	USF completed with workarounds for quarantine issues
USD (R&E)	2019 USD(R&E) 16	Self-Intubating Airway Device	UT Austin	Continuation from 2019. Interest in transition
USD (R&E)	2019 USD (R&E) 18	TBI Self-Assessment	Stevens	Continuation
USD (R&E)	2019 USD(R&E) 19	Instrumented Combat Boot	Stevens	Continuation

Statement of Work and Accomplishments

The Capstone Marketplace and SERC staff have completed the WRT 1007 Statement of Work. Table 2 below lists SERC’s activities, comments, and results.

Table 2 Status of Tasks from WRT 1007 Contract “Statement of Work”

Develop communication assets for universities and Capstone teams	The SERC Capstone Marketplace website has been in active use for the contract period. SERC has published guidance for Proposals, Project Plans, and system engineering processes on the site. Templates for Capstone project organization, statusing, and reviews have been developed and are also provided on the website. Use of email and on-line web collaborative tools has been increased.
Operate and maintain the Capstone Marketplace website	SERC’s Capstone Marketplace website announces upcoming events, changes, and communicates other important Marketplace details to universities.
Generate good problem sets and strong SME Participation	18 Research topics have been posted from SOF units, SOCOM staff, Rapid and OSD’s Response Technology Office on the Marketplace website. Topics have been assigned to universities and worked by student teams, with SME support from government customers.
Widen CM awareness to all SOF	Capstone Marketplace briefings to potential participants have been conducted throughout the academic year. Marketplace personnel have conducted extensive visits, briefings, emails, phone contacts, and web notices to military staffs and other DOD organizations.
Capstone Marketplace reorganization	Capstone roles, responsibilities, processes, and activities have been revised as of 2019. New Capstone process documents are posted on the website.
Develop an annual rhythm for sustained Capstone operations	A Schedule of Activities for 2019-2020 Capstone participants has been implemented for the Capstone Marketplace. A copy of the annual Capstone schedule is included as Appendix A. This Schedule will be used for the 2020-2021 academic year, no substantial changes are foreseen
Plan for engagement with professional societies	Presentations to industry conferences, including the Special Operations Industry Conference (SOFIC) in Tampa Fla. had been previously planned but were cancelled as a result of 2020 quarantines and travel restrictions.
Expand CM funding sources	Additional Capstone funds for new 2020-2021 projects are being solicited from USSOCOM and other DOD sources.

Research Results

Since Sept. 2019, 24 student teams have completed Capstone projects working on 18 Research Topics that were offered on the Capstone Marketplace website. Several of these 2019 topics were continuations of research done in the previous academic year. Four topics selected by the U.S. Naval Academy were resourced directly by government funds transfers. In these instances, Capstone Marketplace managers provided technical oversight for the USNA teams. Virginia Tech chose to pursue a Marketplace Research Topic independently, without executing a contract agreement with SERC. Despite significant difficulties presented by quarantines, university closures, and travel restrictions, all 2019-2020 projects were concluded with satisfactory results.

Students performed well in the 24 teams; all results were acceptable to the government customers. A few of the Capstone project results provided exceptional insights to their government participants. Approximately 120 students experienced “real world” development work, building solutions to important problems. Each team was requested to edit their final presentations to provide a short “executive summary” of their project in video format. These videos have been reviewed and archived at Stevens Institute. The video summaries are available to government participants and sponsors and can provide an excellent overview of 2019-2020 Capstone work.

As of June 16, 2020, all Capstone teams have satisfied their project deliverables.

Participant surveys were developed and sent to sponsor and faculty participants. These surveys were developed to better assess participant experience, expectations vs. outcomes, and suggestions for improvement.

Results of the academic participant surveys were positive and are summarized below.

Academic/Faculty Survey Results					
<i>Did the student team develop or introduce any novel concepts or solutions?</i>				Yes	No
				6	0
<i>In your opinion, how successful has the student team been in meeting project objectives?</i>	Exceeded all objectives	Exceeded some objectives	Met all objectives	Failed to meet some objectives	Failed to meet any objectives
	0	6	0	0	0
<i>In your opinion, how successful has the student team been in meeting academic objectives?</i>	Exceeded all objectives	Exceeded some objectives	Met all objectives	Failed to meet some objectives	Failed to meet any objectives
	1	5	0	0	0
<i>Please provide a ranking of the educational value of Capstone Marketplace participation for your students.</i>		Excellent	Positive	Typical for a sponsored project	Negative 
		5	1	0	0

<i>Would you participate in another Capstone Marketplace project?</i>	Yes	No
	6	0
<i>Would you recommend participating in a Capstone Marketplace project to future students?</i>	Yes	No
	6	0
<i>Would you recommend participating in a Capstone Marketplace project to your colleagues?</i>	Yes	No
	6	0

Response rates for inputs from government Sponsor/Subject Matter Experts input were affected by e-mail security restrictions on DoD servers. Several participants did still provide feedback. No negative feedback was returned. Selected comments are included below:

- “My feedback is the most positive in all categories. This was a great experience that exceeded expectations. We were very satisfied with our final deliverable. The Capstone Marketplace provided a perfect venue for field testing ideas and creating a proof of concept that illustrates the need for a requirement in our community. It was a great learning experience as well for everyone involved. I would recommend that this project (Ground Force Commander Simulator) be continued by a new team in the next academic year.”
- “Good for U of T, you and the students. Good for the DoD. Good for health care. Good for people.”

For any future Capstone work, end of year surveys will be improved to get more substantial feedback from students, faculty, and government participants.

Outreach Activities

Over the contract period, briefings on the Capstone Marketplace have been made at Virginia Tech, MIT, UNLV, University of South Florida, U.S. Naval Academy, USSOCOM, U.S. Army Special Operations Command, staffs of the U.S. Navy’s Special Warfare Command, the Institute for Human Machine Cognition, and DOD’s Engineer Week in Washington DC. SERC was invited to present its Capstone work at the Special Operations Industry Conference, where the most promising Capstone projects could be evaluated for any potential program transitions. This presentation had to be cancelled in March 2020 as a result of travel restrictions

Lessons Learned, Recommendations, Proposed Changes

CONTRACT REQUIREMENTS

In previous Capstone years, some faculty advisors were unfamiliar with the reporting, deliverables, and formats specified in their Capstone contracts. For 2019-2020, Capstone faculty were required to be aware of SERC's contract documents with their universities. This emphasis will be increased for future Capstone work. A special section on the Capstone Marketplace will be set aside to provide tailored information for university business offices and faculty advisors regarding contract procedures.

CAPSTONE COORDINATORS

The Capstone Marketplace has been able to identify several "Capstone Coordinators"—single Points of Contact on campus for Capstone's administrative details. Emphasis on Capstone coordinators at each university with multiple Capstone teams will be increased in future Capstone work.

REDUCED CONTRACT PAPERWORK

ITAR, Intellectual Property (IP), and other contract certification processes have been streamlined to reduce administrative burdens on university business offices. The Capstone Marketplace will continue to use each university's internal IP policies with their students and faculty, while maintaining the government's rights for IP use.

TIMING OF RESEARCH OPPORTUNITIES AND SCHEDULES

Ideally, the majority of new research topics for Fall 2020 should be generated and posted for universities by the end of the Spring Semester. This Spring has seen unusual difficulties in generating new Capstone topics. As a result of university closures, many student senior design activities may also have delayed starts in the Fall. Capstone Managers are in contact with representatives from OSD, USSOCOM, and the service components to identify appropriate Research Topics for the Fall.

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 also accepts university inputs on new Research Topics, and connects with potential sponsors willing to mentor respective student teams.
- 2. RESOURCING (APRIL-JULY).** SERC personnel identify government resources available to fund student teams.

3. RESEARCH TOPIC ANNOUNCEMENTS (June-Early Sept). 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 planned to review Capstone work, discuss administrative processes, and to provide feedback from both universities and government customers, to help make the SERC Capstone environment more productive.

Establishing the Market Place as a Two-Way Portal

Universities have been encouraged to submit ideas for Research Topics to the Marketplace. This year, SERC received topic nominations from Virginia Tech, USF, and Stevens. The Capstone Marketplace managers have shared each university input with potential government customers to attract interest and sponsorship. The website is becoming a "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

Capstone teams have recently included several graduate students on project teams. SERC sees substantial benefit in graduate student involvement on Capstones. The student team environment is an excellent forum for grad students to mentor undergraduates; grad students can also bring advanced skills to the team's research; and inclusion of grad students who are pursuing business majors can add their management tools and skills. SERC has established informal guidance to include grad students on Capstone projects:

1. Graduate students should be 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

SERC's government sponsors want to see selected student Capstone projects transition to formal research work and product development. SERC is investigating ways to attract industry participation in Capstones, which may stimulate a transition process. In addition, discussions have been held to develop processes that can identify transitions and funding mechanisms for work beyond the Capstones. Methods including Partnership Intermediary Agreements and Other Transaction Authorities are possible ways to engage in transitions in a rapid and efficient manner.

Conclusions

SERC believes that the Capstone Marketplace is having significant impact on students' learning experiences as they take on important problems for their government customers. Real customers for Capstone teams provide a richness to educational efforts which may be lacking in traditional design projects. Student & Faculty responses to Capstone activities have been uniformly positive. For 2019-2020, Capstone Marketplace has created automated evaluations which are included in the Capstone archives and can be characterized by the following quotes from participants:

- "The capstone marketplace project has been a great experience for our senior students. Especially the exposure to a real-life engineering problem with a real sponsor and well-defined project expectations will likely help them in their early professional career."
- "Great program and experience for our students."
- "... great experience with access to military advisors. Much improved from previous years."

DOD and military R&D organizations can use Marketplace undergraduate research to increase their R&D bandwidth—to address ideas that are outside normal R&D resources. Student Research Topics often 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 replicate in the government laboratory environment or defense industry sectors. This sponsor comment provides an excellent reinforcement of this positive outcome:

- "The Capstone Marketplace provided a perfect venue for field testing ideas and creating a proof of concept that illustrates the need for a requirement in our community. It was a great learning experience as well for everyone involved."



Capstone Timelines

