2006-2260: AN INNOVATIVE MODEL FOR THE ADMINISTRATION OF UNDERGRADUATE CAPSTONE PROJECTS

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An Innovative Model for the Administration of Undergraduate Capstone Projects

Abstract

We discuss the program-level model used in the administration of undergraduate Capstone (senior design) projects in the Department of Systems and Information Engineering at University of Virginia's School of Engineering and Applied Science in this paper. A unique model at the time of its inception in 1988, its adoption by other institutions and its longevity are measures of its effectiveness and robustness. We provide an overview of the tasks performed by the various personnel involved in the administration of the undergraduate Capstone projects in chronological order, starting with activities performed during the summer recess, after a brief introduction to our Department's Capstone Program. The goal of providing this "cookbook" review of the model is to provide sufficient information to allow other departments to adopt similar practices.

Keywords: Capstone Project, Senior Design Project, Undergraduate Engineering Education

Introduction

The literature concerning undergraduate Capstone (senior design) projects is overwhelmingly oriented to providing information on individual projects. Articles whose main purpose is the discussion of Capstone project administration and management are, for the greatest part, focused on the administration and management of individual projects; see [1, 2, 3, 4] for example. Articles such as [5, 6] which address program-level administration of Capstone are scarce. To address this paucity of information, we share details of the program-level administrative model used to manage the undergraduate Capstone Program in the Department of Systems and Information Engineering at University of Virginia's School of Engineering and Applied Science (SEAS), a model that supports a vibrant program popular with students, faculty, and clients alike, in this paper.

We adopted our current program-level administrative model in 1988 after a thorough assessment of resources, requirements, and pedagogic goals and objectives. Unique at the time, its effectiveness and robustness in supporting a concomitantly unique pedagogic model of self-managed student teams working on projects dealing with non-trivial issues of external clients is demonstrated in the longevity of both models and their adoption by departments of system engineering at schools such as the United States Military Academy at West Point (USMA) and George Mason University (GMU). The effectiveness and robustness of the administrative model are additionally seen in the ability of the program to expand support seamlessly to the development, progress, and conclusion of an increasing number of projects over nearly two decades.

Following good systems engineering practice, the model has undergone refinement and refurbishing over the years in response to participant needs or emerging technologies. One notable refinement is the adoption of a web-based delivery method for the assignment of students to projects. Using administrative tools with which students are familiar not only provides

reinforcement of classroom learning, but facilitates the successful completion of that administrative activity. Additionally, a permanent record of projects and their artifacts is easily accessible by students working on related or follow-on projects, clients, and faculty. The artifacts may also serve as evidence of outcome assessments, supporting the development of a portfolio for an ABET accreditation review.[7]

We structure our discussion as a review of model personnel, activities, and delivery methods with the goal of providing a "cookbook" that provides the "recipes" for implementation of this model by others. A similar "cookbook" for implementing the pedagogic model is given in [8]. We begin by identifying the model's personnel and briefly discussing their roles. We then provide a review of program and project activities in chronological order, starting with those occurring during the summer recess. We use the academic model of two main semesters, fall and spring, in this review. We identify the personnel responsible for performing each activity. We end with concluding remarks on the presented information.

Administrative Personnel

The personnel involved in our program-level administrative model are drawn from the Department's faculty and administrative staff. The Capstone Program Director, a faculty member, has the main administrative responsibility for the program. The Director co-ordinates the development and staffing of team projects and serves as a resource to project faculty advisors, client advisors, support staff, and students throughout the year. Mike Smith is the current Director, succeeding Pres White.

A key project development activity is client recruitment. All clients are external to the Department, a unique feature of our Capstone program at its inception. Potential clients for Capstone projects are generated through company inquiries, faculty contacts, student and alumni suggestions, and contacts within SEAS. Clients are drawn from the public and private sectors, and must agree to implement the results of a successful project.

Clients must also agree to be full partners in their sponsored projects, providing access to relevant employees for interviews and direction; agreeing to the use of their facilities as appropriate; and agreeing to fund the project at a level that will cover project expenses such as travel, telephone, supplies, specialized hardware and software, conference fees, and, in some instances, support for a graduate assistant. Funding mechanisms include grants, contracts, or gifts to the Department or participating research laboratory.

Clients meet with project teams regularly throughout the year at the client site, at the University, and/or by teleconference. Clients are not asked to participate in any academic related issues, such as grading. However, regular assessments of team progress are solicited, and a final client's assessment of project impact and success is factored into grades.

Faculty advise projects, recruit clients, and serve on the program and organizing committees for the Systems and Information Engineering Design Symposium (SIEDS). SIEDS, organized as an IEEE-sponsored conference (through the Systems, Man, and Cybernetics Society) in 2003 as a successor to the Department's local conference event, is the culminating event in the pedagogic

model. It is a student-focused international forum for the presentation of applied research, development, and design projects in systems and information engineering. The Department's Capstone teams are joined by student teams from universities around the globe, presenting reports on their design experiences. The conference follows the traditional model, with presentations are scheduled into various tracks. The diverse areas of research and study represented by the tracks are testament to the many fields in which systems engineers can have an impact. The tracks at SIEDS 2005 include Risk Analysis (sponsored by Northrop Grumman), Data and Information Systems (sponsored by Appian), Human Factors and Human Computer Interface (sponsored by Lockheed Martin), Logistics and Transportation Systems (sponsored by the National Institute of Aerospace), and Health Systems (sponsored by Accenture). Judges from the sponsoring companies and agencies rank the presentations, and the students who give the first place presentation in each track receive awards at the concluding banquet.

Information on this year's conference is currently available.[9] Over sixty abstracts have been accepted for SIEDS 2006. Capstone teams from UVa will be joined by students from universities such as the University of Maryland, the Georgia Institute of Technology, USMA, GMU, the University of Southern California, Texas A&M, Universidad de los Andes, and Universidade Federal do Rio de Janeiro.

Administrative staff members support the web-based administrative tools, faculty and student activities, SIEDS preparation and implementation for and contract and accounting requirements.

Administrative Activities

June – August

Developing and staffing Capstone projects are the first tasks for each Capstone "cycle." Projects typically reflect the research and professional interests of the faculty advisor and are carefully selected for their appropriateness for the Capstone experience based on the appropriateness of the topic, potential student interest, faculty interests, and funding availability. Once the projects are set through a joint effort of faculty and the Director, faculty elicit and develop materials used by students in the project assignment process, such as project abstracts, beginning-of-course memos (syllabi), company brochures, technical reports, and web site URLs. An example project abstract is given in Figure 1 in the Appendix. These materials are posted to the program administrative site and linked to the relevant project on the assignment page by mid-August. The Director facilitates the posting and linking tasks, ensuring that sufficient documentation exists for each project. The Director reports assignment site status to the faculty and class listservs.

Student assignment to projects follows. Our Department's fourth-year (senior) students review the project information when they return in mid-August, and rank the projects from their first choice down to their last choice, using the web-based form pictured in Figure 2 in the Appendix. When all students have completed the ranking process, the Director inputs the data to a custom project assignment algorithm. The algorithm's objective to minimize the total assignment score subject to team size constraints. The assignment problem is formulated as a minimum cost flow model with an auction algorithm variant. Ties are resolved arbitrarily. The final assignments are based on a Pareto optimal solution – there is no modified arrangement such that a student can

improve his or her assignment without adversely affecting the assignment of another student. Historically, over 75% of the students are assigned to their first or second choice of projects.

Beginning of Fall Semester

The Director announces the project team assignments, and facilitates any necessary changes in team membership. Once project team assignments have been formalized, the Director then assists in the creation of the SIEDS program and organizing committees. Faculty advisors hold orientation sessions for their project teams.

Fall Semester

Faculty advisors meet with their teams as needed; typically, teams will meet on a weekly basis with their advisor. Faculty advisors also serve as technical advisors for students' baccalaureate theses. Thesis topics for our Department's students come from their Capstone project. Drafts of thesis proposals are due throughout September and October, with the final version due in November. The SIEDS Program and Organizing Committees work on relevant tasks. A call for abstracts is broadcast in November.

End of Fall Semester

Faculty advisors obtain client assessment of project progress for use in determining grades and enable on-line course evaluations. The Director and faculty advisors review the evaluations.

Spring Semester

Spring semester administrative tasks performed before spring break are essentially continuations of fall semester administrative tasks. The main student deliverables with which the advisors assist are the baccalaureate thesis (final version due in April), the SIEDS abstract (due in February), the paper for the SIEDS proceedings (due in April), an optional SIEDS poster (due in April), and the final versions of client deliverables. After spring break, the focus is on the final versions of the thesis, SIEDS, and client deliverables. Faculty involved in the administration of SIEDS have a similar task pattern: preparatory tasks before spring break and implementation tasks after. Venue plans for the next SIEDS are also initialized in April, given the demands placed on facilities by local events such as Foxfields, a hugely popular steeplechasing event, and various parties and events celebrating the upcoming graduation exercises. At the end of the spring semester, the Director will conduct a "lessons learned" session reviewing and analyzing the just concluded Capstone project and SIEDS; faculty may begin to line up clients and projects for the next academic year; and the grading and evaluation tasks described for the end of the fall semester are performed.

Conclusions

Experience has shown us that the administrative model described in this paper is essential to the continued success of our Department's Capstone Program. The pedagogic component of the program, consciously designed to mirror the professional environment in which many of our

students will work upon graduation, requires structured, formal management to facilitate and co-ordinate its operation efficiently and effectively, especially considering the Program's size – 17 – 25 projects per year, an enrollment of 75 - 100 undergraduate students, and participation by faculty and graduate students – and scope. Taking advantage of available technology to support administrative processes such as assignment and communication is also a factor in supporting the smooth and seamless operation of the Program. Finally, our administrative model provides opportunities for faculty and students to gain experience in the three key areas of practice in teaching, research, and professional service.

Acknowledgments

We would like to thank the reviewers for their comments and suggestions; Capstone clients for sharing our vision and commitment to engineering education; and the faculty, staff, and students of the Department of Systems and Information Engineering at the University of Virginia's School of Engineering and Applied Science throughout the years for their dedication and efforts. A special thanks goes out to Steve Patek for an interesting and thought-provoking discussion regarding the project assignment algorithm.

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7. www.sys.virginia.edu/capstone

8. Donohue, S.K., Scherer, W.T., and White, K.P. Jr., "Practical Undergraduate Engineering Education in Information Systems and Operations Management: The Capstone Experience at the University of Virginia," to appear in the *International Journal of Information and Operations Management Education*.

9. www.sys.virginia.edu/sieds06

Appendix

Project number: 2006-4
Project title: Support for Development of a Reference Manual on the Benefits of Regional Transportation Operations Collaboration
Client: Science Applications International Corporation (SAIC) - in support of a project for the Federal Highway Administration
Faculty advisors: Professors Jenny Farver, William Scherer, and Michael Smith
Description:

The purpose of project is to assist SAIC in its support to the FHWA Office of Operations to further investigate and develop the work done in the existing white paper entitled "The Tangible Benefits of Regional Transportation Operations Collaboration and Coordination" by conducting the necessary research to analyze, quantify, and document the benefits of regional transportation operations collaboration that have been identified. The fundamental concept of this project is the exploration of performance measurement of the direct benefits of a complex system involving people, processes, institutions, technology, in this case regional transportation collaboration.

The FHWA Office of Operations recently drafted a white paper entitled "The Tangible Benefits of Regional Transportation Operations Collaboration and Coordination." The white paper attempted to characterize and illustrate the tangible benefits that can be derived for each of the agencies and jurisdictions that participate in the regional transportation operations collaboration activity. Five case studies were highlighted in the paper and show a range of collaboration activity from an effort between four county road maintenance agencies to a multi-state wireless network that integrates transportation and criminal justice information for a multitude of agencies. Based upon interviews with some key champions of each collaboration case, the white paper was able to identify some important common benefits such as cost savings, savings in procurement, expanded service area coverage, new funding opportunities, and formalized regional operations structures. Because of the limitations of time, resources, and research capabilities, the white paper was limited in the number of sites that were studied and was unable to investigate and further quantify any of the benefits identified.

Students who select this project will assist SAIC in executing the following tasks from the FHWA RFTP entitled "Support for Development of a Reference Manual on the Benefits of Regional Transportation Operations Collaboration":

* Study Existing Collaborative Activities. Based upon the SAIC work plan and the research methodology, study collaborative activities on 10 locations across the United States. The locations for these collaborative activities include a mix of about 6 that are urban/metropolitan-based and 4 that are rural-based. The number of urban vs. rural sites can vary depending upon the number of available examples. The study locations also represent a geographical mix of east, mid-west, and west. Travel to some of the sites may be required in order to obtain the necessary information, provided that the information cannot be obtained via e-mail or telephone.

* Research the ITS Deployment Benefits Database. Study the ITS Deployment benefits database for information that is relevant to this project. This database may provide information to supplement the investigations conducted in the above task and/or it may provide good crosscutting information on benefits and costs of ITS projects developed through collaborative processes.

* Prepare Reference Guide. Based upon the research conducted in previous tasks, students will assist SAIC in preparing a reference manual that documents the results. The reference manual will include 3 to5-page case studies for all the sites investigated. The reference manual will also include cross-cutting information and lessons learned related to some or all of the key measures investigated, including cost savings, savings in procurement, improved efficiencies, better allocation of resources, expanded service area coverage, new funding opportunities, and formalized regional operations structures. Finally, the reference guide will present a simple methodology for State, local, and regional agencies to use to investigate and identify the benefits of operations collaboration.

The product of this capstone project will be a report describing the metrics used to assess the benefits of regional collaboration and the observed and potential benefits found in the regions studied.

References:
1. "Support for Development of a Reference Manual on the Benefits of Regional Transportation Operations Collaboration" request for task order proposal (available from Professor Scherer)
2. Regional Transportation Operations Collaboration and Coordination (available at http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE//13686.html and http://www.ops.fhwa.dot.gov/aboutus/one_pagers/rtocc.htm)
3. Regional Transportation Operations Glossary (available from Professor Scherer)
4. Regional Concept for Transportation Operations white paper (available at http://ops.fhwa.dot.gov/publications/rcto_white_paper/index.htm)
5. FHWA Program for Creating A Foundation For 21st Century Operations (available at http://www.ops.fhwa.dot.gov/program_areas/progmactiv.htm#iv)
6. Organizing for Regional Transportation Operations (available at http://www.ite.org/library/reg_trans_ops.asp)
7. "Tangible Benefits of Regional Collaboration in Transportation Operations" prepared by D. Wong for FHWA (available from Professor Scherer)

Figure 1. Example Capstone Project Summary
(http://www.sys.virginia.edu/capstone/2006/04.htm)

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Please enter your name here, last name first, and e-mail id.

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In the column labeled "**Rank**", indicate your project preferences. Give a **unique** number to each project, with a rank of 1 indicating your most preferred project assignment and a rank of 18 indicating your least-preferred assignment. **You must rank every project.** While there are no guarantees, last year every student was assigned to one of their first seven preferences.

For a detailed project description, click on project #.

NO.	RANK	PROJECT TITLE	CLIENT	FACULTY ADVISOR
2006-1		US-Brazil Cognitive Engineering Exchange	FIPSE/CAPES	Stephanie Guerlain
2006-2		Enterprise Level Ground System Process Modeling	The Aerospace Corporation	William Scherer
2006-3		Scenario Development and Data Collection Tools for Human-in-the-loop Experimentation in support of Crew-centered System Design Approaches	NASA Langley Research Center	Ellen Bass
2006-4		Support for Development of a Reference Manual on the Benefits of Regional Transportation Operations Collaboration	Science Applications International Corporation (SAIC) – in support FHWA	Jenny Farver, William Scherer, and Michael Smith
2006-5		Virginia Criminal Incident Data Exchange and Analysis System	Virginia Department of Criminal Justice Services	Donald Brown
2006-6		Spatial Analysis System for Uniform Crime Report Data	National Institute of Justice	Donald Brown
2006-7		Ivy Groundwater Assessment and Mapping	Albemarle County Department of Community Development	Garrick Louis
2006-8		Designing a Search Mechanism for Debt Collection	Douglas Fuller, Chief Research Officer, Credigy	Alfredo Garcia
2006-9		Information Management in Sensor Systems	*TBA*	Stephen Patek
2006-10		Collaborative Planning for Securing Critical Infrastructures against Catastrophic Events	Virginia Department of Transportation/Virginia Department of Emergency Management/Virginia Transportation Research Council	Yacov Haimes and Joost Santos
2006-11		Modeling Online Advertising User Behavior	Advertising.com	William Scherer
2006-12		Prioritizing State Highway and Transit Construction Plans	Virginia Department of Transportation and Virginia Transportation Research Council	James Lambert
2006-13		Macro-Economic Cyber Security Models	Department of Homeland Security (DHS)	Barry Horowitz
2006-14		Financial Services Gaming Simulation	Susquehanna International Group	K. Preston White, Jr.
2006-15		Dynamic Multi-agent Coordination (RoboCops)	NASA Langley Research Center	Peter Beling
2006-16		Medical Research Data Storage and Analysis System	UVA Obstetrics & Gynecology Department	Michael DeVore and Lisa Pastore

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Figure 2. Capstone Project Preference Form for AY2005-6 (http://www.sys.virginia.edu/capstone/prefs.asp)