2006-1483: AN UNDERGRADUATE CAPSTONE DESIGN EXPERIENCE UTILIZING STUDENT ENGINEER - STUDENT MANAGER TEAMS

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An Undergraduate Capstone Design Experience
Utilizing
Student Engineer – Student Manager Teams

Abstract

The capstone design experience is widely accepted as an essential element of contemporary engineering education. With the encouragement of the ABET and in recognition of their innate value, many undergraduate institutions have more recently established interdisciplinary capstone design experiences. Design experiences involving students of differing engineering disciplines offer the possibility of more complex, meaningful projects and introduce traditional engineering students to the terminology and technology of related disciplines. At the same time, the value of undergraduates trained in the Systems Engineering and Systems Engineering Management disciplines has been realized both by industry and the Department of Defense. While capstone design experiences which involve interaction among students schooled in different engineering and engineering technology disciplines are becoming more common, those which also include students trained in Systems Engineering and Systems Engineering Management are less common. A design experience in which student engineers and student managers must cooperate to plan, design, fabricate, test and report on their designs can be extremely enlightening for all involved and very closely mimics "real world" design experiences. We describe here our first year's experience with combined student engineer-manager capstone design teams. We compare the experiences and impressions of both engineering and management students who worked on these interdisciplinary teams with students who had no management trained students involved in their design experiences. The impressions and experiences of faculty project mentors are included as well. Finally, we note some of the challenges encountered by faculty in the organization and management of this design experience. The evidence will show that while this arrangement has its difficulties, the quality of the design experience has been enhanced in significant ways.

Overview

The capstone design experience is widely accepted as an essential element of contemporary engineering education. With the encouragement of the ABET and in recognition of their innate value, many undergraduate institutions have more recently established interdisciplinary capstone design experiences. Design experiences involving students of differing engineering disciplines offer the possibility of more complex, meaningful projects and introduce traditional engineering students to the terminology and technology of related disciplines. The experiences also permit students to build teamwork skills in preparation for professional practice.

At the same time, the value of undergraduates trained in the Systems Engineering and Systems Engineering Management disciplines has been realized both by industry and in particular by the Department of Defense[i]. While capstone design experiences which involve interaction among students schooled in different engineering and engineering technology disciplines are becoming more common, those which also include students trained in Systems Engineering and Systems Engineering Management are unique. A design experience in which student engineers and student managers must cooperate to plan, design, fabricate, test and report on their designs can be extremely enlightening for all involved and even more closely mimics "real world" design experiences.

We describe here our first year's experience with combined student engineer-manager capstone design teams. We describe the detailed motivation for the creation of our Systems Engineering and Systems Engineering Management majors, describe the process by which we formed and assessed student performance, and compare the experiences and impressions of both engineering and management students who worked on these interdisciplinary teams with teams lacking management trained students. The impressions and experiences of faculty project mentors are included as well. Finally, we note some of the challenges encountered by faculty in the organization and management of this design experience. The evidence will show that while this arrangement has its difficulties, the quality of the design experience has been enhanced in significant ways.

Motivation for Systems Engineering

The senior leadership if the US Air Force has recognized the importance of systems engineering to meet the challenges of its ever evolving technology. Former Secretary of the Air Force, Dr. James Roch, began the creation of a broadly based program of systems-engineering education and certification across the service. At the suggestion of former Chief of Staff of the Air Force, Gen John Jumper, that effort included the creation of the System Engineering Major at the US Air Force Academy. The Secretary's goal was not only to create a core of officers who possess a systems-level perspective for research, developmental engineering and acquisition of new systems, but to develop that same perspective among graduates who serve as Air Force pilots, operations officers and battle managers.

Through the combined efforts of departments from the Engineering, Basic Sciences and Social Science Divisions, the Academy's Systems Engineering major was established in 2003 with its first graduates to be commissioned in June 2006. In recognition of the importance of a discipline with a more managerial focus, the Systems Engineering Management major was also created. These two academic programs share a core of courses focusing upon systems management processes, probabilistic modeling, and human factors. The Systems Engineering major incorporates an additional 27 semester hours of majors option courses drawn from the Aeronautical, Astronautical, Electrical, Computer Science, Behavior Science, and Mechanical Engineering majors. These courses differentiate among the nine Systems Engineering Options possible within the major. The Systems Engineering Management major includes an additional 30 semester hours of courses drawn from the traditional management major as well as Design of Experiments and a technical Systems Focus Option. A more complete description of the content of both majors is found in Appendix A. Both majors share a two-semester Capstone Design experience in which students from these majors are integrated with capstone design teams of traditional engineering majors. The goal of each of these teams is to engage in a challenging project where the skills developed in their corresponding majors can be applied and developed. It is this capstone experience which is the focus of this paper.

The Questions

From a purely pedagogical perspective, the integration of students schooled in management into teams of engineers is highly appealing. Teams just like this are common in industry. Such an experience permits our traditional engineering students not only to refine their technical and interpersonal skills, but to understand the terminology, processes, and challenges of management as well. As one might well imagine, such a sweeping change in capstone design raised many questions and issues. How would Systems Engineers (SE) and Systems Engineering Management (SEM) majors be assigned to teams in the traditional engineering majors? What expectations would faculty mentors have for these managers? How could they be assessed appropriately? Would the management students be accepted and integrated effectively? Would the managers have a positive impact on the design experience? In retrospect, the challenges involved in creating, mentoring, and assessing these engineer-manager capstone teams were not nearly as insurmountable as they might seem. Although our first year's experience is only half-complete as this paper is written, we are growing more confident that this change will prove highly positive for our institution and its graduates.

Creating Engineer-Manager Student Teams

The process of creating the Systems Engineering Major required the involvement of all of our institution's engineering departments. Each saw the opportunity to enroll students in their respective disciplines through the SE major's options. While cadets completing the SE options were not as thoroughly schooled in the rigors of the respective disciplines, they became well known by both department faculty and cadets enrolled in the corresponding academic major. It was therefore, quite natural for the System Engineering majors to be enrolled into the capstone design courses of their respective SE options.[ii] Engineering departments generally arranged their capstone teams so that one to three SEs were assigned to a project team.

The Systems Engineering Managers however, proved a greater challenge to match to capstone projects. The degree of familiarity each cadet had with engineering disciplines as well as their corresponding faculty and cadets was much lower than that of the SE majors. A cadre of faculty members drawn from our Departments of Behavioral Science and Leadership as well as the Department of Management took responsibility to execute this process. Fundamentally, the number of SEM majors which each engineering department felt they could accommodate within their established team structures, any departmental preferences in an SEMs academic preparation, and the preferences of individual students were combined using an optimization algorithm. Some engineering departments also completed personal interviews to select students most suitable for their design teams. Level of student interest was widely accepted as a key factor in the selection process. Our engineering departments generally assigned one or two SEMs to each capstone team.

Faculty Expectations

It is difficult to quantify the initial expectations which capstone faculty mentors had for the SE and SEM majors joining their teams. However, after some informal interviews, it is safe to say that faculty generally considered the SEs to be more or less equivalent to their traditional engineering major counterparts. While a lower level of technical expertise was expected, engineering faculty expected a greater knowledge of and willingness to engage in the managerial aspects of the project process.

All of the engineering departments either expected or where hopeful that their team's SEMs would assume the role of Project Manager. More detail in planning, closer monitoring of project progress, and an improved quality in reporting were expected by faculty. In cases were very large teams were assembled, SEMs were expected to represent sub-teams, ensuring their specifications were clarified and integrated.

Assessing Engineer-Manager Student Teams

All of USAFAs engineering capstone students are assessed primarily through a series of formal review presentations. These reviews generally mimic the DoD system acquisition process and include, a Systems Requirements Review, a Preliminary and Critical Design Review, Status Reviews and a Final / Acceptance Review. Each successive review is intended to show design, construction and project management status, project work and monitor costs and risks. It is generally from these reviews which the contributions of each individual student can be assessed. The authors can only speak with confidence to the exact details of student assessment in capstone teams in the Department of Electrical and Computer Engineering. However, the general grading process describe here is similar among all of our capstone courses.

Each project review is attended by a faculty team consisting of the project mentor, the capstone course director or assistant course director, and a senior reviewer. While the mentor's role is commonly understood, the involvement of other faculty members is less clear. The course director or his assistant is present primarily to ensure that the assessment process is uniformly administered across the course. Ideally, the senior reviewer is highly experienced in the execution of capstone projects. He serves as a "sanity check", better assuring that the expectations of the mentor are not too high and that students are performing appropriately. Each faculty team member contributes a grade to the team's performance at each review. Each also assigns an individual performance grade to each student. Students are graded based upon their expected role on the project team. An SEM who does not step up to his role as program manager will not score well even if the project is being run magnificently by an engineering major. In our grading scheme, mentors contribute half the team and individual grade while the course faculty contributes 30%, and the Senior Reviewer 20%.

In addition to the faculty grade, we have long felt the perspectives of our students to be an important aspect of the assessment process. At each review, our cadets are asked to grade the respective performance of each team member. A point cap is established to limit grade inflation. One-fourth of the individual grade for each review is assigned by the team members.

An important element of each review was the development of a set of common management products. While the specific products chosen by different engineering departments varied, Electrical and Computer Engineering asked for five. They were a Mircosoft Project based Schedule, a Requirements Traceability Matrix, Trade-off Analysis, Risk Analysis, and Technical Documentation. Although the responsibility to develop these products was generally not assigned by faculty, the cadet teams soon made them responsibility of the team's Systems Engineer or Systems Engineering Manager. This assignment was generally welcomed by all team members. As we will demonstrate below, traditional engineering students lacked familiarity with the products while SE and SEM students were less familiar with the technology of the projects.

Most design teams used MS Project to develop and present their schedule. They were asked to identify the major milestones in the two semesters, major efforts in the design and fabrication process, individual(s) primarily responsible for each effort, start and stop dates, and time required. The level of detail in the schedule required of each team was tailored based on the number of cadets on the team and whether or not the team included a system engineer or system engineering manager.

Each project team was also tasked to develop a requirements traceability matrix. In theory, an engineer should be able to justify any element in the final product by tracking to successively higher requirements until arriving at one of the system level requirements in the problem statement. In practice, few if any capstone design projects will achieve that level of traceability; nor should they, probably. But the exercise is beneficial to emphasize to the budding engineers and engineering managers that such a matrix is a powerful tool in keeping a design within bounds; and that it provides a solid foundation for development of a requirements verification plan. Again, the level of detail expected in the requirements traceability matrix was tailored to the team composition.

Trade-off analyses were presented in matrix form. Decision criteria were developed by the teams, appropriate relative weightings of the criteria were determined, and fitness scores for each alternative were estimated. Many teams arrived at the realization that for a capstone design project, availability of parts played an almost overwhelming role in the design approach decision.

Risk analysis and management seemed to be a difficult concept for some of the design teams. They were tasked to identify the top two or three risk items and present their evaluation of those items using a two-dimensional grid. With probability on one axis and consequence on the other, the teams were able to roughly identify how high a risk was posed by a particular item. The difficult part of this exercise was getting the teams to realize that not every aspect of a design project will always be 100% successful. Students, like inexperienced engineers, assume that every design challenge can be solved in a matter of hours if they work hard enough, and that everything will be available when they need it.

Each team was tasked to develop a test plan and write a technical report for the project. The test plan was to identify the specific verification methods and procedural steps to certify that their final product satisfied the requirements of the problem statement. The technical report was to document the design and to provide operational instructions as necessary. First drafts of both documents were required late in the first semester, and refined drafts were submitted during the second semester with the final products delivered at the end of the second semester.

This common set of five management products enabled the course faculty to consistently evaluate the varied project teams and gave the students a realistic introduction to the type of reporting required for engineering projects. Initially, many of our students doubted the value of the management products and favored starting the design work without developing a thorough plan. Throughout the first semester, most students realized the value of the structured approach and how it could save them valuable time later in their projects. We hope our students will carry this lesson forward throughout their engineering careers.

Acceptance of SE and SEM Majors

The students executing the capstone design projects are intimately involved with their projects on a daily basis. As such, they are in the best positions to judge the value and success of integrating students specializing in systems engineering into traditional engineering design projects. To quantify and track the students' impressions of the value of integrating systems engineering majors into the course, the faculty administered a course critique survey at the midterm point and at the end of the 2005 fall semester. We were able to survey only cadets assigned to capstone projects sponsored by the Department of Electrical and Computer Engineering. This section summarizes the structure, content, and results from the survey.

The faculty administered an anonymous survey to the 30 students enrolled in the EE / CompE capstone design course during regularly scheduled class periods to give them adequate time to thoughtfully respond to the questions. Although a few students quickly completed the survey with minimal effort, the majority spent 15 to 20 minutes evaluating the questions and providing detailed written comments. The response rate was not perfect, because of absences and blank surveys, but 100% of the systems engineering majors (four out of four) responded and at least 24 of the remaining 26 electrical and computer engineering majors (92.3%) responded to the surveys.

For both the midterm and final versions, the surveys each had three parts. The first part, Part A, was a set of nine questions only for the students majoring in systems engineering to respond with both numerical ratings and written comments. The second part, Part B, was a set of 10 questions with the same format as Part A, but only for the students majoring in either electrical or computer engineering. Both Parts A and B remained the same for the midterm and final surveys. The final section, Part C, contained questions for all of the students related to the content of the course and their overall impressions of the material or course administration. The questions in Part C were different between the midterm and final surveys and did not specifically address the role of systems engineering students in the course, so the results for this part of the surveys are not included in this paper.

For the numerical scores, the students were asked to use the scale shown in Table 1 to evaluate each question. Although written comments are extremely helpful and often offer solid suggestions for improving the course, the six-point scaled forced the students to quantify their impressions so that the faculty could more easily track them over time. In addition, the six-point scale mirrored the scale used throughout the institution for academic course critiques, so the students were familiar with it and could easily apply it to this survey.

Table1. Evaluation scale for numerical survey responses.

Score	Response
1	Very Poor or Strongly Disagree
2	Poor or Somewhat Disagree
3	Fair or Slightly Disagree
4	Good or Slightly Agree
5	Very Good or Somewhat Agree
6	Excellent or Strongly Agree

Tables 2 and 3 summarize the numerical results from the midterm and final surveys. Table 2 contains the responses from the systems engineering students and Table 3 contains the responses from the electrical and computer engineering students. The table columns display the question number, the number of responses, average score, and standard deviation for questions from both the midterm and the final surveys, the change in the average score between the midterm and the final surveys, and the complete text of the question. The results merit some detailed comments.

Table 2. Survey results for questions asked of systems engineering majors.

	Midterm			**Final**				
Q	**n**	**Avg**	**Std Dev**	**n**	**Avg**	**Std Dev**	**Change in Avg**	**Question**
A1	4	5.00	0.82	5	3.20	1.30	**-1.80**	The lessons related to project implementation (shared hardware resources and machine room orientation) will be very helpful to successfully completing of my design project.
A2	4	5.00	1.41	5	4.60	1.34	**-0.40**	I would have preferred to begin work on my design project without the instructional lessons presented in this course thus far.
A3	4	4.50	1.73	5	4.20	1.79	**-0.30**	My project team is working together well and each person is making meaningful contributions appropriate to their major.
A4	4	4.75	1.26	5	5.00	1.22	**0.25**	My systems engineering course work has prepared me well to contribute to my project team.
A5	4	3.75	1.50	5	4.40	2.07	**0.65**	My engineering course work has prepared me well to make contributions to my project.
A6	4	5.00	0.00	5	4.20	0.84	**-0.80**	I am much more certain about my role on my design team now than I was at the beginning of the semester.
A7	4	2.50	1.29	5	2.60	2.07	**0.10**	The traditional engineering majors on my design team do not understand the impact which my expertise can have upon the success of our project.
A8	4	4.00	2.16	5	3.80	1.92	**-0.20**	I have effectively become the leader of my design team.
A9	4	4.50	1.29	5	5.00	1.22	**0.50**	Thus far, I am pleased with my decision to join a Design Team sponsored by the Department of Electrical Engineering.

Table 3. Survey results for questions asked of electrical and computer engineering majors.

Q	Midterm n	Midterm Avg	Midterm Std Dev	Final n	Final Avg	Final Std Dev	Change in Avg	Question
B1	24	3.92	0.78	25	3.84	1.28	**-0.08**	The course lessons related to project planning (e.g. systems engineering methods, software development practices) will be very helpful to successfully completing my design project.
B2	24	3.92	1.64	24	4.00	1.91	**0.08**	I would have preferred to begin work on my design project without the instructional lessons presented in this course thus far.
B3	24	4.67	1.40	25	4.28	1.57	**-0.39**	My project team is working together well and each person is making meaningful contributions appropriate to their major.
B4	24	4.33	1.46	25	4.48	1.26	**0.15**	My electrical or computer engineering major's course work has prepared me well to contribute to my project team.
B5	24	3.08	1.84	25	2.96	1.79	**-0.12**	If the curriculum would have allowed, I would have taken courses in Systems Engineering.
B6	24	3.75	1.59	25	4.56	1.00	**0.81**	I am much more certain about my role on my design team now than I was at the beginning of the semester.
B7	15	1.87	0.92	14	2.50	1.45	**0.63**	The SE or SEM major on my design team does not know enough about technology to contribute meaningfully to our project.
B8	15	3.07	2.05	14	2.71	1.98	**-0.35**	An EE or CmpE major has become the leader of my design team.
B9	15	5.33	1.40	14	5.43	0.65	**0.10**	Thus far, I am pleased to have an SE/SEM on my design team.
B10	9	2.33	1.22	9	1.78	1.09	**-0.56**	(Respond if your team has no SE or SEM assigned) From what I have observed thus far I am very happy that only traditional engineers are assigned to my design team.

First, in Table 2, note that there are four response for each question at the midterm and five responses for each question for the final survey. There are only four students with systems engineering majors enrolled in the course, so for the final survey, the systems engineering questions contain the responses from one of the electrical or computer engineering majors. Since the survey was anonymous, there is no way to identify the survey that should be removed, so the results are presented as they were collected.

In Table 3, note that the number of responses is not the same for each question. Questions B1 through B6 should have the full number of responses, so variations are because of blanks in the surveys. Questions B7 through B9 were directed to those students on design teams that did have systems engineering students on the team. Question B10 was directed to students on design teams that did not have systems engineering students on the teams. These last four questions help isolate the impressions of the two different types of teams enrolled in the course.

From the questions directed toward the systems engineering students in Table 3, the responses to four of the questions highlight the success of the integrated capstone design course from their perspective. First, Question A3 addressed how well the project team was working together and how well each person was contributing to the project based on academic major. The midterm and final survey averages for this question were 4.50 and 4.20, respectively. Although there is a slight negative trend in the data, the overall results are positive and the students generally agree that their peers are working well together and doing the work that they should be doing to make the project successful. The negative trend in the averages for this question could be result of the project teams becoming more involved with their projects and there being higher demands on their performance at the end of the semester. In future offerings of this course, this survey question should be split into two distinct parts to clearly identify how well the project team works together and how well each student is contributing based on academic major.

Secondly, Question A4 scored 4.75 and 5.00 on the midterm and final surveys, respectively, and indicates the systems engineering students feel their prior course work has well prepared them to function with and contribute to an interdisciplinary team. Feeling that they are well prepared is one indicator that the course has the proper scope for systems engineers and gives them an opportunity to both apply their previous course work and to educate their peers about the systems engineering process.

Question A7 is the third key question and it is worded with a negative, so low scores indicate a positive outcome. Question A7 averaged 2.50 and 2.60 on the midterm and final surveys. These results show that the systems engineering students believe the other students on their projects understand how they make valuable contributions and fit into the overall design process. Being accepted as a team player and a valued contributor is important for the systems engineering students to view the overall course in a positive light and to relay their impressions to future systems engineering students who are allowed to indicate their preferences for selecting design projects.

Finally for the systems engineering students, Question A9 evaluated their satisfaction with their decisions to work on a design project in the Department of Electrical and Computer Engineering. This question averaged scores of 4.50 and 5.00 on the midterm and final surveys, which indicates that they are not only pleased with their decisions, but their satisfaction has increased throughout the semester. Student satisfaction with the course shows that the process of integrating systems engineering majors with electrical and computer engineering majors is meeting with initial success, at least from the perspective of the systems engineering students.

Turning to the results from the surveys for the students majoring in electrical and computer engineering, there are also four questions that merit discussion. Questions B3 and B4 are complements to Questions A3 and A4 discussed above, but targeted for the electrical and computer engineering majors. Question B3 averaged 4.67 and 4.28 for the midterm and final surveys, respectively, which closely mirror the averages for Question A3, including the slight negative trend over time. Therefore, the electrical and computer engineering students also have a positive impression of how well their teams are working together and how well each student is contributing to the project based on academic major. Question B4 averaged 4.33 and 4.48 for the midterm and final surveys, which indicates the electrical and computer engineering majors believed they were well prepared for the capstone design project based on previous course work. The numerical results were slightly higher for the systems engineering majors on the same question, but the positive ratings again show that the course has the proper scope for the enrolled students.

The third key question for the electrical and computer engineering majors was Question B9 and was asked of only the students on project teams with a systems engineering student. The question average 5.33 and 5.43 for the midterm and final surveys, respectively, which stand out as the highest averages across all of survey questions. The consistently high scores show that the electrical and computer engineering majors are very pleased to have systems engineering support on their design projects. We cannot determine the underlying reasons for these high scores, but the positive impressions are noteworthy and indicate the electrical and computer engineers appreciate their counterparts from the systems engineering discipline. In addition, these results directly complement those from Question A7 asked to the systems engineers and discussed above.

The final question of note for the electrical and computer engineering majors was Question B10 and was asked of only the students *without* a systems engineering major on their project teams. This question asked them to rate their satisfaction with only having electrical and computer engineering majors on their design teams and received average scores of 2.33 and 1.78 on the midterm and final surveys. The low and decreasing nature of the averages shows that the students without systems engineering support, wish that they had it and that the more they are involved with the project, the more value they place on the systems engineering role. The response to this question shows that all of the electrical and computer engineering students recognize the value of the contributions made by the systems engineering students, even if a systems engineering student is not assigned to their team. Clearly the students communicate informally about their projects and this one topic has certainly made the rounds as the students form their impressions of the course.

Overall, the results to the numerical surveys show that students majoring in systems engineering can be successfully integrated into capstone design projects involving students majoring in electrical and computer engineering. The students accept others with different academic majors, realize the valuable contributions they can make to the success of an interdisciplinary project, feel like they made a good decision to work on such a project, and, for some, are apparently jealous when they do not have direct access to systems engineering support.

Team Performance Comparisons

In order to obtain some indication of performance by student-manager teams, grade data for the first semester of this academic year's capstone projects sponsored by our department were analyzed. Only grade data specifically related to the projects was considered in the comparison. These data did include four project reviews and the draft technical report. Four of the eight projects had active SEs or SEMs involved throughout the semester. The overall average score for these four teams was 86.2%. The average score for the four teams which did not have active SE or SEM involvement was 80.77%. This nearly 5.5% difference represents one-half letter grade on our grading scale and is large enough to be significant. Clearly, the strengths of the individual team members had an impact upon this difference. It is also true that the SEs and SEMs provided extra manpower which gave them an advantage based purely upon numbers. However, the difference in performance as averaged over the observations of a dozen different faculty members is hard to deny.

Challenges and Impressions

Upon reflection, the greatest challenge in the creation of student engineer-management teams was to overcome the inertia of current practice. Clearly accommodations needed to be made by many of our engineering division departments to accept SE and SEM students into their design teams. There were issues of course credit to be settled and details of scheduling to be worked through. The initial process for assigning cadets to teams took cooperation and thoughtful planning. In truth, it was the commitment of department chairs to complete this enterprise, and the effort of a few key faculty members to orchestrate the details which made this transition possible. With the proper attitudes, there is no fundamental reason why a similar arrangement cannot find a place at other undergraduate institutions.

Summary

We have described the process by which the US Air Force Academy has created student engineer-student manager teams for its undergraduate capstone design experience. While originally meant to support the vision of the senior leadership of our service as well as that of the Accreditation Board for Engineering and Technology, this experience is proving highly beneficial both to our Systems Engineering and System Engineering Management majors, and to our traditional engineering majors as well. Survey data show that at least the students in the Electrical and Computer Engineering Capstone Projects value the contributions of their System Engineerings and System Engineering Managers to their teams. Grade data shows that the teams possessing SEs or SEMs are generally assessed as performing better than teams without SEs or SEMs.

We are confident that our graduates will join the ranks of engineering professionals much better prepared to understand and meet the challenges of the future. We recommend consideration of our experience to undergraduate institutions possessing or considering the institution of Systems Engineering majors as an example of what might be accomplished in the capstone experience for the benefit of their engineering graduates.

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Appendix A
Major's Course Requirements for the USAFA
Systems Engineering and Systems Engineering Management Majors

Systems Engineering Major

21 Semester hours of major's courses:

1. Sys Engr 290 Introduction to Systems Engineering I
2. Sys Engr 301 Introduction to Systems Engineering II
3. Ops Rsch 321 Probabilistic Models
   or Ops Rsch 411 Topics in Mathematical Programming
4. Comp Sci 211 Intro to Programming for Scientists and Engineers
5. Beh Sci 373 Introduction to Human Factors
6. Systems Engineering Capstone Design I
7. Systems Engineering Capstone Design II
8. Sys Engr 405 Systems Engineering Seminar I
9. Sys Engr 406 Systems Engineering Seminar II

27 Semester hours of courses determined by the cadet's choice of systems engineering option: Aeronautical Systems, Communications Systems, Computer Systems, Control Systems, Electronic Systems Design, Human Systems, Information Systems, Mechanical Systems and Space Systems.

Systems Engineering Management Major

18 Semester hours of systems engineering major's courses:

1. Sys Engr 290 Introduction to Systems Engineering I
2. Sys Engr 301 Introduction to Systems Engineering II
3. Ops Rsch 321 Probabilistic Models
   or Ops Rsch 411 Topics in Mathematical Programming
4. Beh Sci 373 Introduction to Human Factors
5. Systems Engineering Mgt Capstone Design I
6. Systems Engineering Mgt Capstone Design II
7. Sys Engr 405 Systems Engineering Seminar I
8. Sys Engr 406 Systems Engineering Seminar II

30 Semester hours systems engineering management major's courses:

1. Math 243 (or Math 253) Calculus III (or Advanced Placed Calculus III)
2. Math 359 Design of Experiments
3. Systems Focus Option (select one)
   i. Mech Engr 312 Thermal Fluids Systems Engineering I
   ii. Aero Engr 241 Aero-Thermodynamics
   iii. Math 245 Differential Equations
   iv. Engr 311 Electrical Power Systems

v. Comp Sci 211 Introduction to Programming for Scientists and Engineers
vi. Comp Sci 210 Introduction to Programming
vii. Geog 310 Geospatial Information Analysis
viii. Comp Sci 310 Information Technology
ix. Mgt 391 Management Information Systems
x. Math 344 Matrices and Differential Equations

4. Mgt 303 Management Perspectives
5. Mgt 345 Human Managerial Systems I
6. Mgt 342 Managerial Accounting
7. Mgt 477 Production and Operation Management
8. Mgt 437 Managerial Finance
9. Systems Engineering Mgt Option I
10. Systems Engineering Mgt Option II

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[i] See for example the Department of Defense Systems Engineering Planning Preparation Guide, pg 1 found at: http://www.acq.osd.mil/ds/se/publications/pig/sep_prepguide_v1_2.pdf

[ii] Some individualized assignment of SEs outside their official option is permitted especially when those options share a significant number of courses.