Managing Senior Design Projects to Maximize Success: The TAT Team

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Introduction

The typical engineering technology curriculum culminates in a capstone senior design course or sequence. The goal of this course/sequence is to have students demonstrate their mastery of the concepts they have learned throughout their degree program. While many different approaches to senior design courses exist, most programs require the students to work in teams to design and implement a “product” that requires skills related to their major.

In the past, the Electronics and Telecommunications Engineering Technology (EET/TET) Programs at Texas A&M used a typical model for senior design where the entire class met once a week in a standard lecture format so that each team could present a short synopsis of their progress. The teams were then left to their own devices to work on their projects until the next lecture. This methodology produced unreliable results with a few excellent teams completing their projects while most groups achieved varying degrees of success (or failure). Although there is something to be said for allowing students to pass or fail on their own merits, it is also true that for most students the capstone senior design course is their first attempt at a true open-ended design problem where they pose the question and develop the answer. Without access to continual technical and project management review, valuable learning opportunities are lost.

The EET/TET Programs have adopted a new approach to managing the capstone design sequence. The sequence is now divided into two courses. The first course has three primary objectives. The students

- learn the fundamentals of project management including topics such as proposal writing, risk management, scheduling, financial management, etc…
- find a real-world sponsored project and develop a preliminary design that is ready for implementation.
- identify a technical assistance team that will be available as a resource to them as they implement their design. It is this team that will guide the students to a successful outcome in their second semester.
Upon completion of the first course, the Technical Assistance Team, or TAT team takes over the management of the students through the second semester of the sequence. The TAT team is composed of three individuals: the instructor of the senior design course, a faculty advisor who has expertise germane to the project, and a “sponsor” who focuses on deliverables and the quality of the final product. Using weekly, thirty-minute TAT meetings the students report progress through a presentation of deliverables, discussion of issues and concerns, and creation of action items. The results of this new process have been excellent. The quality and success of senior design projects has increased dramatically. The results of most of the projects are now a source of pride for the students and often lead to funded projects within the programs. In this paper, details of the new process will be given and example results will be discussed.

Original Senior Design Project Course

Prior to implementing the new senior project course suite into the Electronics and Telecommunications Engineering Technology educational experience, a single senior design course was used as the capstone experience for all students. The expectation of this course was that, in a 15-week timeframe, individual students could come together, form teams, identify a project, develop and implement a hardware/software-based solution, and participate in a valuable and positive learning experience that produced a viable product prototype. In addition, the structure of the course required a single faculty to member to possess the technical knowledge, interest, and expertise necessary to accommodate large numbers of student teams working on very diverse design projects. Needless to say, this single course rarely met the goals and expectations of the EET/TET faculty.

Members of the EET/TET Industrial Advisory Board also began to stress the need and importance of project management tools and techniques for EET/TET graduates. These members communicated the growing need for these skill sets in entry-level employees, but wanted the educational experience to be grounded in a “real-world” team project. In so doing, the student would learn by doing rather than just developing a vocabulary and general knowledge of the underlying concepts through a lecture-only based course. With the help of many private sector individuals, the EET/TET faculty embarked on redefining a new senior project course sequence that could incorporate many of the industries’ recommendations while also reducing the negative aspects of the current single capstone course. Through the continued development, review, and improvement process, the new senior design project course sequence is fulfilling all stakeholders’ expectations. The faculty is seeing a better investment in the education of the programs’ young men and women, the students are obtaining a higher level of satisfaction in being able to deliver something of value, and the private sector is playing a more active role in the mentoring of the students. In addition, industry is embracing the new graduate from the EET/TET that now augments the solid technical education with a real-world appreciation of many of the tools, techniques, and processes used by practicing project managers. Instead of a frustrating experience that produced little value, the new course sequence is allowing many teams to plan, design, develop, and demonstrate viable product prototypes. By implementing the Technical Assistance Team (TAT) approach to the development, each team now receives the review, guidance, and appropriate assistance to provide a high probability of success. The Benefit/Cost ratio of this undertaking continues to be high. The private sector and other external
organizations are responding very favorably to the new sequence which often leads to funded projects for the students.

**Current Course Structure**

*Project Management (First Semester)*

Replacing the single, capstone senior design course is now a two-course, senior design course experience. The two courses must be taken in sequence and must be taken in the last two semesters leading to graduation. This requirement allows the students to bring the maximum amount of educational and practical experience to the sequence as possible and also encourages the private sector to be more actively involved in the entire process. The first course (ENTC 419) is Technical Project Management and the second course (ENTC 420) is Senior Design. Unlike most undergraduate courses, these two courses are tightly coupled. The first course is used to “plan” the project and the second course is used to “implement” the project.

In the planning stages, students use the ENTC 419 course to research, evaluate and select the following:

- **Team Members** – (2 to 4 is generally the team composition).
- **Team Identification** – the student team must create a “presence” that appears to conduct business as if it were a company. This includes a company name, logo, web presence, etc.
- **Project** – a well-defined project that includes a problem statement, a conceptual design, and a detailed list of deliverables.
- **Project Advisor** – individual who will participate as the “senior engineer” within a company that provides guidance and technical assistance to the team.
- **Project Sponsor** – individual who participates as the “customer” for the project and may represent an external organization that is providing resources and funding to the student team.

The student team will develop the project definition through a series of written and oral documentation efforts including a Quad Chart to communicate potential project ideas followed by a white paper that presents a conceptual design. The teams will then make a formal presentation of their project white paper to interested industry representatives, faculty, and other students. Following project acceptance by satisfactory completion of the white paper presentation, the student teams prepare a formal written technical proposal that includes:

**Section I – Introduction**

A. General –
B. Background
C. Technical Challenge
D. Benefits
E. Proposal Structure

**Section II – Project Scope**

**Section III – Statement of Work**

A. Functional Design
B. Work to be Performed
C. Precedence Diagram
D. Task Schedule
E. Milestones
F. Deliverables
G. Sponsor Requirements

Section IV – Risk Assessment

Section V - Team Organization and Qualifications
   A. Hierarchy Chart
   B. Member Qualifications

Section VI – Project Costs

Appendices

The project proposal is the bridge from ENTC 419 to ENTC 420. This document is a major, graded assignment for ENTC 419 and is then used as the foundation of all work performed in ENTC420. This document, together with the technical merit assessment, establishes the benchmark by which the team project grade will be assessed.

In parallel with the planning process of their own project, ENTC 419 students acquire basic knowledge of project management tools and techniques using the Project Management Body of Knowledge 2000 (PMBoK 2000). These include the Work Breakdown Structure, Responsibility Assignment Matrix, Network Logic Diagram, Gantt Chart, and Risk Management Cards. All of these tools are used in the planning and communications of the project’s scope, time and costs. In addition, the teams will set up their projects to utilize Earned Value as the primary method to control and report the status of their projects during execution in the following semester to their Technical Assistance Team.

The overall goal of the ENTC 419, Technical Project Management course is to provide students with an understanding and appreciation of working effectively in a team environment to accomplish an open-ended design project. By effectively planning and communicating the project scope, a realistic assessment of project time and costs can be made. Successful completion of this course provides the student with the tools and knowledge necessary to plan, conduct, manage, and document a valuable and beneficial senior design project.

Senior Design  (Second Semester)

ENTC 420, Senior Project is the second course in the two-course sequence. Teams of students that have successfully completed the ENTC 419 course requirements will move on to this course in the following semester. Many teams have found that significant benefit can be achieved by using the semester break period to move up the power curve for their projects. Team members will do additional research, develop and evaluate alternative designs, assemble needed support resources, meet and interact with their advisor/customer, etc so that their level of preparation is more fully developed when the ENTC 420 semester begins. Some student teams have used the summer break to participate in undergraduate research initiatives or undertake industry internships that help prepare them for the work they will accomplish as part of their projects.
Where ENTC 419 focused on the planning of the project, ENTC 420 now focuses the student team’s attention on the execution and control of their proposed project. Overall, the course has the following requirements:

1. Each team member contribute a minimum of 10 hours per week of productive work on the project. In the formal proposal, the team outlined the project down to the individual tasks and assigned lead responsibility for each of these work packages to a particular team member.

2. Coordinate and conduct a 30-minute project status review meeting each week with the team’s Technical Assistance Team.

3. Provide a formal mid-term presentation (Critical Design Review) on the overall technical status of their project.

4. Conduct a final project presentation.

5. Deliver complete technical documentation including items such as:
   a. Test plan and report
   b. Project report
   c. User manual

6. Demonstrate the level of project success through presentation of all project deliverables.

With team sizes ranging from 2 to 4 members and with the increasing sponsorship by the private sector, the EET/TET faculty has found that a standardized methodology had to be created to assess the overall scope of the project in a quantitative manner so that variations could be taken into account. The Technical Merit assessment has been one of the major products of the program’s continued improvement efforts. This assessment is now used by the students to guide their selection and scope definition for their projects. The assessment provides a “level playing field” that accounts for varying degrees of technical content and design from project to project.

Table 1 contains the Technical Assessment criteria that are used in the ENTC 419/420 senior design course sequence. These criteria are used by the students to perform a self evaluation of their project’s merit at the white paper, formal technical proposal, Critical Design Review and final project documentation milestones. It is then used by the Technical Assistance Team to provide the project grade multiplier that used to “normalize” the project. This approach to assessing final grades for ENTC 420 has been well received by all students. Understanding these criteria early in the planning phase allows the student to generate the scope of their project so that it is consistent with the overall goals of the new course sequence.

One of the major improvements that has been implemented in the new course sequence is the Technical Assistance Team. Gone are the days when one faculty member tried to provide overall leadership and technical guidance to large numbers of projects dealing with a wide range of hardware/software development efforts. The new approach, which transfers the responsibility of establishing a Technical Assistance Team to the students, has resulted in much higher levels of success by the student teams. The Technical Assistance Team, or TAT, is composed of the ENTC 420 course director who provides consistency across all projects, the project advisor who acts as the subject matter expert for the team, the project sponsor who acts as the customer/client, and other interested parties including the EET/TET Program Coordinator. The TAT has a vested interest in the overall success of the student team. They collectively form a periodic review that
insures the team remains focused while also providing needed support for all aspects of the project. Although the weekly status reports are intended to be a technical review of the previous week’s accomplishments and to provide input on the upcoming week’s activities, the meeting can also be used to brainstorm and evaluate solutions to problems or issues that have arisen. Technical review of software algorithms, hardware designs, circuit board layouts, test plans, etc are also valuable to the teams. Finally, each week the teams are required to provide a quantitative assessment of their overall project status using Earned Value schedule and cost performance indices (SPI and CPI).

### Table 1 - Technical Merit Factors

<table>
<thead>
<tr>
<th>Technical Merit Factor</th>
<th>Weight (maximum)</th>
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</thead>
<tbody>
<tr>
<td>1. Contains a clearly described and completely understood technical challenge</td>
<td>0.1</td>
</tr>
<tr>
<td>2. Contains a requirement for system integration</td>
<td>0.2</td>
</tr>
<tr>
<td>3. Contains a requirement for system testing</td>
<td>0.2</td>
</tr>
<tr>
<td>4. Contains a requirement for analysis</td>
<td>0.2</td>
</tr>
<tr>
<td>5. Contains hardware design, development and test</td>
<td>0.3</td>
</tr>
<tr>
<td>6. Contains software design, development and test</td>
<td>0.3</td>
</tr>
<tr>
<td>7. Contains a hardware fabrication requirement, typically a prototype</td>
<td>0.2</td>
</tr>
<tr>
<td>8. Contains a requirement for documentation other than the project report</td>
<td>0.2</td>
</tr>
<tr>
<td>9. Contains a requirement for intellectual property protection</td>
<td>0.1</td>
</tr>
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During the seventh week of the semester, all teams must participate in a consolidated Critical Design Review process. Throughout most of the course, the teams work independent of one another and have little knowledge of the overall status of the other projects. At the CDR, all teams are present and thus are able to assess their accomplishments in terms of what other teams have accomplished. In addition, the CDR offers all team members another opportunity to prepare and deliver a formal verbal presentation which will receive critical review and feedback from a large number of individuals. Many students have communicated back to the EET/TET faculty that these “opportunities” to communication have served them well as they have advanced in their professional careers.

One relatively new aspect of the course sequence is the “Request for Extension”. In the twelfth week of the semester, each team must decide whether they will need to request a time extension for their project. If so, they must formally request and justify this extension and state that a penalty of one letter grade “may” be imposed on the project (at the discretion of the TAT members) in granting the additional time. Appreciating the need to remain on schedule and the negative ramifications that falling behind on project milestones and deliverables can have is a new experience for most students.

A final project review is the last step in the new course sequence. Again, this is a formal presentation/demonstration that each team must satisfactorily complete. In addition to conducting a thorough design review, all deliverables are presented and demonstrated to the TAT members. Following this final step, a project grade is awarded that is normalized using the
Technical Merit criteria and communicated to the team along with a high-level critique of their performance. Each team member submits a confidential peer evaluation that is used in conjunction with the course director’s and TAT members’ assessments of each team member’s contribution to the overall success of the project consistent with the responsibilities each member was assigned. This then forms the final grade for each team member.

A Success Story: Location Dependent Information Sensor

While it is continually evolving, this new senior project sequence has been used for several semesters now. As the process is refined, there has been a marked improvement in the quality and success rate of students design projects. The following details the process for one particular group of students with emphasis on how the new process helped them have a successful experience. During the course of the first semester project management course, potential sponsors were invited into the classroom to present potential design projects. While this is not the only means for students to select a design project, it does help them get ideas and make connections with potential sponsors. As part of these presentations, Dr. Morgan acting as the director of the Mobile Integrated Solutions Laboratory discussed a project known as LDIS, or Location Dependent Information System.

The concept for LDIS was originally conceived as a solution for creating self-guided tours. The principle is fairly simple and is depicted in Figure 1. Someone interested in touring the Texas A&M campus could check out an iPAQ equipped with a radio frequency interrogator. As they tour the campus, they could point the interrogator at sites to get information about them. Each building and landmark on the campus would be equipped with an RF tag that could respond to interrogation with a unique URL. The iPAQ would then use wireless network capability to look up the URL and access information about the designated site including pictures, narration, and maps. Thus, the project required two pieces of hardware: an RF interrogator for the iPAQ and a set of microcontroller-based RF tags. The project also included software development in terms of: a program to run on the iPAQ that could use the interrogator to search for tags and then spawn a web browser to access the returned URL; code to run on the microcontroller-based tags; and an example set of webpages with graphics and narration designed for presentation on an iPAQ. It should be noted that under the original senior project methodology, this project would have been too ambitious for even the best teams.

Once a team chose to work on the LDIS project they picked an advisor. It was up to them to choose an advisor with a technical background suitable for their project. Then through several meetings with their chosen advisor and sponsor over the period of a month, they demonstrated an understanding of the requirements for the project. Using the previous senior project format, this work would occur unsupervised over a period of a few days. In retrospect, it was obvious that most groups did not possess a true understanding of the problem they were solving until late into their project. Once the students understood the problem to be solved, they met with their advisor to present a well-defined problem statement, then a functional design, and finally a list of deliverables.
These deliverables not only included the final results of their work, but intermediate deliverables to be delivered on a week-by-week basis to give their advisor and sponsor confidence that they were making progress. In this particular case, these intermediate deliverables included a presentation of their RF communications protocol, software flow charts for their iPAQ and microcontroller code, and schematics/layouts for their hardware. Finally, the group took this work and wrote a final proposal for submission at the end of the first semester.

With a preliminary design and a schedule of deliverables completed, the group began the second semester implementation phase of their project. At this point, their chosen advisor, sponsor and the instructor of the senior design course came together to form the technical assistance team (TAT) that would advise the students through the remainder of their project. In the first week, a final technical merit review was performed to ensure that the project met the requirements for a senior design project. Through this review, the level of senior design projects has become much more consistent that previously.

The students began their implementation immediately and met with the TAT weekly. It was through interactions with the TAT that their intermediate deliverables were critiqued and improved upon. Examples of TAT guidance included:

- A critique of their RF communications protocol. Originally, the students were going to have the RF tags broadcasting continuously using a very simplistic protocol with a substantial amount of overhead. After a discussion with the TAT about power efficiency and timing, the students came up with a greatly improved protocol that addressed the need for efficiency on the part of the RF tags.

- A review of the RF tag hardware. Again, the students had given little thought to the finite battery life of the RF tags. With suggestions from the TAT, they revised their hardware, taking advantage of the low power modes of their microcontrollers and RF transceivers. They obtained a x30 improvement on battery life.
- A review of their choice of antennas and board layout. The students did not have a good understanding of antennas or of high frequency board layout issues. At the request of the TAT, they did research in these areas and made a presentation in one of their weekly meetings. The result was that the information they found helped them greatly in laying out their final board designs.

These are just a few examples of the types of interactions that the students had in their weekly meetings. In addition to the scheduled meetings, the group often sought out their advisor and/or sponsor to ask questions, especially when they reached a technical impasse. While the students worked hard to meet their deliverable deadlines, it became obvious at the mid-term review that they were behind. This gave them an opportunity to assess their progress and make adjustments. As a result, they requested and received a two week extension in which to finish their work.

The final results of their work were impressive. The students demonstrated a fully functional system with a professionally packaged interrogator unit attached to the iPAQ. They also developed a software package in Visual Basic that ran on the iPAQ and allowed the user to search for and interrogate RF tags. The software would then spawn Internet Explorer to display the received URL. In addition, they developed a generic RF tag design and constructed two for demonstration purposes. Finally, they implemented professional web pages for two landmarks on the campus and placed their RF tags at these sites. For the final demonstration, they toured the TAT around campus allowing them to use the system.

Under the previous senior project methodology, most student groups would have wasted substantial amounts of time “spinning their wheels” and the final project often would have been breadboards with very primitive, semi-functional circuits. It is through their prep work and TAT interactions that they were able, by the end of the semester, to demonstrate a fully functional, professionally packaged prototype.

**Discussion and Conclusions**

The new two-semester senior project sequence has been used for seven semesters now. Through a process of review and continuous improvement, the new sequence is now consistently producing quality and successful senior projects. Several factors can be attributed to this success. These include:

- **Early identification of project and technical advisor:** The students now identify their groups, project, sponsor, and technical advisor early in the first semester of the course sequence. This gives them ample time to understand the problem and develop conceptual solutions. Also, requiring them to find an advisor gives them early opportunities to consult with a technical expert.

- **Requirement for presentation of problem statement and requirements, functional design, and deliverables:** One of the major problems with the original capstone design course was that students did not take the time to truly define the problem they were trying to solve or to understand exactly what the final outcome of their work would be. Through three informal presentations to their technical advisor in the first semester, they
are forced to develop a formal problem statement that includes requirements, a complete functional diagram of their proposed solution, and a list of deliverables that they will present over the course of the second semester. By committing themselves to an incremental list of deliverables, they are creating a self-regulating mechanism for keeping themselves on track.

- **Formal proposal with complete preliminary design, timeline, and risk assessment:** The formal proposal due at the end of the first semester helps cement the faculty’s expectations of their project. It also gives the students the opportunity to think through their approach and the risks associated with their project such as availability of parts, etc.

- **Technical merit assessment:** A rigorous and documented assessment of the technical merit of a student team’s project allows them (and the faculty) to objectively assess the worthiness of their project. It has also made the level of effort more consistent between teams which had been a problem in the past.

- **Team oversight by Technical Assistance Team:** Probably the single most important addition affecting the quality and results of student projects has been the TAT. While it is important that the students manage their own projects, having access and oversight by an assistance team made up of “experts” allows the students to overcome roadblocks in their progress more rapidly. Also, having to report weekly to the TAT forces students to try and stay on schedule.

- **Management through deliverables:** This tool allows the TAT to gage the student team progress more quantitatively and objectively. Previously, a group could simply say they were doing well and this was accepted at face value. Now, there are tangible results required for each team to demonstrate that they are on track.

It is through these additions that the majority of student teams are able to complete the capstone design sequence successfully. As a by-product, the faculty now has more confidence in determining those projects that fail to meet minimum criteria, thus resulting in teams having to repeat the second semester. While this is not desirable, students now understand that there is a minimum level of effort and success required to complete the course. Another benefit of this new process is that the level of quality and success of projects has encouraged more external funded participation. One point that should not be overlooked is that faculty feel that this new process is important enough to the student’s education, that they are willing to participate on multiple TATs without the normal offload that comes with additional load. Finally, the students finish their academic careers with a successful piece of quality work. They leave the university with a sense of confidence and pride that they take with them wherever they go.

**References**


Biographies

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