Genesis of a Team Teaching Paradigm – Development of A Space Option in Aerospace Engineering

Drs. Rachel Shinn and Ronald Madler
Embry Riddle Aeronautical University, Prescott, AZ

Abstract

This paper describes the team teaching dynamics that the two authors experienced while developing a spacecraft design option within the Aerospace Engineering Department at Embry-Riddle Aeronautical University in Prescott, Arizona. The authors found it necessary and desirable to work as a team in developing the space courses since there was no release time allocated to this new program and course development. We discovered that we were able to create a much better program by utilizing our collective strengths. This has also allowed us to know precisely what the students are learning in the space option. We are currently recruiting faculty in other departments to work with us since spacecraft design is truly an interdisciplinary activity. Our hope is to change the traditional teaching paradigm of faculty working in isolation to a team paradigm in which faculty work collaboratively to create a more efficient learning process. It is our opinion that if we just pay lip service to the idea of interdisciplinary teams without trying to incorporate these concepts into our own operations, our student and industry stakeholders will recognize that we are not practicing what we preach. In describing this process, we will also describe the development courses and curricula that support this new space option.

I. Introduction

As educators, we talk a lot about the importance of teams and how important it is to work across disciplines. However, we do not often practice cross-disciplinary work, nor do we often work effectively in teams. Yet, this is what we expect of out students. It is easy to get caught up in our own area of expertise, and thus much more difficult to reach out to other disciplines to attempt to work together. The area of space and spacecraft, however, presents a clear opportunity for teaming and cross-disciplinary work. We have begun to work in this way at Embry Riddle Aeronautical University, Prescott in our development of a space option within aerospace engineering.

The authors have backgrounds in spacecraft attitude dynamics, spacecraft systems engineering, and orbital mechanics. We are the team teachers of the new courses. However, educating students in space technology involves many more disciplines than our own. Electrical engineering, for example, is a key area in space technology. So, as we have been developing this program, we have needed and received input as well as team teaching from members of other departments on campus.

II. Spacecraft Design Courses

The spacecraft preliminary and detail design courses that we developed gave us the first opportunity to work with the student teams as well as team-teach. The preliminary design course consists of having the students do a paper design of a spacecraft or spacecraft system. The students choose a project and are held to the requirements thereafter. Our role has been to shepherd them through the design process and to help them learn about subsystems they may not be sufficiently familiar with. The authors met for a minimum of four hours per week to discuss where we were heading and to prepare documents that the students would need to accomplish their intermittent tasks during the design process. We each graded the students' projects and presentations and then compared notes at the end. We negotiated the final grade on each graded event, based on our individual inputs.

This process enabled us to develop these design courses while maintaining a full teaching load. Without sharing the load, it would have been very difficult to develop and teach these new courses in the midst of teaching a full load (12 units). In addition, our different backgrounds allowed us to give input to the students from different points of view. We each could target our areas of strength when helping the students, giving the students more comprehensive help. The most important aspect of this team teaching experience was the ability to refine ideas by the constant exchange of ideas between us. Designing the course was, for us, similar to the design process of the students. And in that regard, communication was key to making a product that was better than either of us could have done on our own. In addition to meeting on a regular basis to work on course curriculum, we also attended the design lab together, so that the students could benefit from our different backgrounds.

Given our backgrounds within traditional aerospace engineering, there are spacecraft subsystems that require a strong electrical engineering background, which are not our strong points. In two of these areas, communications and power, we had two members of our engineering faculty serve as guest lecturers and as resources for our students. Another factor that enabled our students to succeed in their designs of communications and power subsystems was the addition of an electrical engineering student to our class. The team with the electrical engineering student was very effective, and illustrated that mingling the two disciplines (AE and EE) when doing spacecraft design is extremely helpful. We plan to incorporate more EE students into our design courses in the future and are currently recruiting for next year.

We have also developed a Spacecraft Detail Design course in which the students are required to design, build and test a project related to spacecraft. The actual design project will change from year to year, but retains the above characteristics. This year, we required the students to build a single class project which contained multiple subsystems and technologies related to those used in space. The project was to build an assembly, which was required to withstand a pre-determined load, have a solar panel which was electrically able to light an LED with sunlight, have a control system which had the solar panel track and find a light source, while in motion (simulating acquisition and tracking of the sun) and which had a propulsion system that would move the assembly down a track. It was required to be self-powered and for all the subsystems work together. This required the entire class to work as a single team with multiple sub-teams and for all the subsystems to be integrated. Their improved teaming over the previous preliminary design course was evident and very good to see.

III. Challenges

Some of the challenges we faced were: communicating with one voice to the students in a team teaching environment; utilizing our time efficiently; the students' reluctance to handle the ambiguity that is inherent in the design process; the students' lack of understanding of spacecraft subsystems before the class; the open nature of the design process made it difficult to plan the course in detail without constraining the design process unnecessarily.

While we communicated often and effectively with each other and each of us knew what the other was doing, getting this to appear so to the students proved to be challenging. Documentation of exactly what is expected keeping a detailed schedule of changes is the key to clarifying this concern. This semester, we have kept all documentation on a common directory available to the students with an updated schedule and updated documentation on expectations for deliverables. This seems to help, but will need to be refined as the course matures.

Efficient use of instructor time was also a challenge. However, as the course continues to improve, we expect the efficiency to also improve. Last semester, we spent a minimum of 4 hours per week outside of class consulting on issues about the class. That time was spent developing documentation, planning and revising the schedule – all things that needed to be done with both of our input. As the course matures, more course material will be established and we will have a better idea of what a reasonable schedule is. This should make for more efficient use of our time. Constraining the design process to make course planning easier, yet leaving enough flexibility that allows group creativity during the design process is a balance that we will continue to work.

We have added a prerequisite course, resulting in more design time within the design courses, and hope that this will alleviate the students' sense of being overwhelmed. The fact that the students had not had a course in spacecraft subsystems, meant that they had to spend a lot more time up front becoming familiar with their own subsystems and they often were not familiar with what other team members were talking about during group meetings. This is being addressed for next year's group by requiring a course in spacecraft subsystems that will emphasize the electrical engineering subsystems with which they are least familiar.

The prerequisite course in Space Systems Engineering is being taught this spring to prepare next year's students for the design sequence. It was intended as an overview of all spacecraft subsystems, but has evolved into a course that briefly reviews orbital and spacecraft attitude considerations and focuses on the areas that students are not exposed to in any other course. Our students in the space option are already required to take courses in which they receive some depth in orbital mechanics and spacecraft attitude dynamics and control. The subsystems in which the space systems course focuses are power, thermal, communications and data handling. Having a course focus on these other areas is essential. We have effectively used faculty members from

Electrical Engineering to cover power, communications and data handling. This has allowed the students to obtain a good understanding of the essential issues for design in these areas. Our expertise provides the focus on spacecraft, the background as to how these technologies are applied in space and the space related issues affecting these subsystems.

This team teaching approach has involved three other instructors in addition to us. The results are very good so far. Without our space focus, the information would not be relevant to the students and without the expertise of our guest lecturers, we would not be able to provide adequate depth to give the students the tools to effectively do their spacecraft design.

From the students' perspective, some of the major challenges were: the difficulty of working in teams; the students' limited background in space systems; the difficulty in defining workable tasks given a large open-ended design project.

Team members who did not pull their weight frustrated the other students, and the team leaders found it challenging to pull their teams together. We observed that communication among team members was not a given, even with active instructor intervention. This taught us that we must explore more methods to enable students to better communicate within their team. We also observed that the team with the best communication came up with the best, integrated design effort. Since we do not have the opportunity to observe the students' team dynamics prior to the senior design courses, we have found it difficult to assign teams in the most effective way. Because we have also developed a space systems lab class in which teamwork is a part, we have the opportunity to find out what sort of team dynamics we are in for in the design course and this may help us to create more effective teams.

Observing the same group of students (the seniors) in the spacecraft detail design course, we have seen that although the previous course (spacecraft preliminary design) was tumultuous in terms of teaming, the students did learn from the experience and their maturity is evident in their teaming in this course. Since one of the objectives is to give students the experience working in teams, a certain degree of tumult may need to be expected. However, we hope that the teaming experiences that the students gain in the Spacecraft Systems Lab (junior level course) will enable them to work more effectively in their senior design courses.

The space systems lab was primarily developed to give students some hands-on experience that would help them in the detail design course, as well as give them some physical understanding of how space dynamics work. It has turned out to give us an opportunity to start the teaming which is essential in the design courses. The lab course gives students experience with vibrations testing, strain gauges, center of gravity and mass properties measurement, momentum exchange for attitude control, electrical power and communications. It also contains a final project, which uses experience gained from the other labs.

For the concern of the difficulty of defining workable tasks within the students' design project, we hope that more familiarity with spacecraft subsystems and the ability to perform back of the envelope calculations, will allow them to understand and lay down the required tasks for a system trade study. One of the goals of the space systems course is to give students the tools to do these essential calculations.

While this was a lot of work to develop these courses as a team, it is a task that would have been overwhelming to an individual. Additionally, the students received a more balanced perspective by this effort than could have been achieved by one person. Also, from the curriculum development point of view, we converged on a curriculum which covers all the spacecraft systems, emphasizes the multi-disciplinary nature of spacecraft design, demonstrates the necessity for teams, and results in an integrated curriculum product. Each faculty also is familiar with the entire space option sequence. This differs from most curricula where each faculty teaches their specialty without knowing exactly what is being taught in the supporting and follow-on courses. As a result of this integrated, cohesive program approach, the support courses directly and efficiently bear on the design sequence.

IV. Further Course Development

Having taught the design sequence once through, we discovered the need for better preparation for our students in the area of space systems. This has lead to the development of a space systems course and a space systems lab. Both of these courses are being offered for the first time this spring (2001) and are being team-taught between the two of us as well as guest appearances from some of our EE and CS faculty. The teaming required here is less intense than that required for the design courses given that there is a clear book and sequence laid out for us to follow. Teaming is still an important factor in the design of this course, however. Our choice of topics relates directly to the design courses and our emphasis comes directly from our experience with the design courses.

To fill out our space curriculum, the space courses we currently offer or have available are: Space Systems Engineering, Space Systems Lab, Spacecraft Attitude Dynamics and Control, Spacecraft Preliminary Design, Spacecraft Detail Design, Space Mechanics, Space Propulsion, Space Environment, Advanced Astrodynamics and Structural Dynamics. All of these are new courses except for Structural Dynamics and Space Mechanics. The first seven of these are required courses for the space option and the rest are electives. Other courses we are thinking about including are: a course on spacecraft thermal control (mostly heat transfer), space power and space communications.

V. Conclusions

We have created a curriculum for space that gives the students some breadth in the issues related to spacecraft design. We have had to do this as a team to have any hope of conveying to our students the multidisciplinary nature of spacecraft design. We truly intend for this sequence to involve a balance of electrical and aerospace engineers and to illustrate how important multi-disciplinary teams are to spacecraft design.

DR. RACHEL E. SHINN

Dr. Rachel Shinn is currently an assistant professor of Aerospace Engineering at Embry-Riddle Aeronautical University in Prescott, AZ. She received her PhD in Applied Mathematics at the California Institute of Technology in Pasadena, California. Before beginning her teaching career, she spent five years in the space industry, at Hughes Aircraft Co., working as a spacecraft systems engineer, with a specialty in spacecraft attitude dynamics.

DR. RONALD A. MADLER
Dr. Ronald Madler is an associate professor of Aerospace Engineering at Embry-Riddle Aeronautical University in Prescott, AZ. He received his PhD in Aerospace Engineering Sciences at the University of Colorado, Boulder.