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Using the SAE Aero-Design Competition to Expose Students to Multidisciplinary Design Teams

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Abstract
Students at Saint Louis University have an opportunity to participate in the SAE (Society of Automotive Engineering) Aero-Design student competition. The competition challenges students to design, fabricate and fly an aircraft carrying a desired weight in a pre-determined flight pattern. Participation in the project draws students with diverse backgrounds from across the university. A typical design team includes students majoring in Aerospace Engineering, Mechanical Engineering, Aircraft Maintenance Engineering, Aircraft Maintenance Management, Aviation Science, as well as students from the College of Arts and Science majoring in non-technical/non-engineering fields.

Aside from the obvious challenges of design, analysis, fabrication and flight, the team is exposed to another real-world challenge to engineering design, working in a multidiscipline design team. Students participating on the team may have dramatically differing educational and practical backgrounds. The methods and manners in which each individual approaches a team challenge, whether engineering, application or organizationally based must yield a cohesive group that is focused on the overall success of the team and a positive team experience. Regardless of the abilities of the individuals, in order to succeed, the team must find common ground and establish working relationships with team members of different backgrounds and personality types. The synthesis of multi-discipline talents and efforts is a tool that is used extensively in the manufacturing and industrial world and serves as a precursor to what the student is likely to expect upon graduation.

This paper will examine and identify the aspects of collegial efforts exhibited by students participating in a multidisciplinary team competition and the overall benefit to alumni in their professional life who have previously participated in structured multidisciplinary team efforts at Parks College of Saint Louis University.

Introduction

In recent years many papers have been written and presented at ASEE conferences on team building and assessment of team skills demonstrated by students. [1,2,3] Few have focused on the dynamics internal to the team and discussed the benefits the students gain from teaming with peers from different backgrounds and programs of study. This may be true because as another writer noted "Few opportunities exist in most undergraduate engineering curricula for students of different disciplines, even within engineering, to work together [4]." When in fact, that is exactly the scenario that our graduates will encounter when they begin their career. Multidiscipline design and research teams are used extensively in industry to reduce the time required to complete a complex process or a task. Inexperienced teams must deal with self-imposed barriers based on the individual's preconceived expectations of other team members (and often their own) value to the team based on their education or position. As another writer pointed out "It is no longer adequate to teach concepts and to discuss and analyze their application. Instead, students must be able to experience the practical application of the theories through reliance on fundamental life skills (e.g., communication, teamwork, technical knowledge, and problem solving) [5]."

A recent study illustrated the importance of strong internal dynamics and in recognizing the value of team members from other disciplines. Forty-nine engineers were given a list of forty team member behaviors, and asked to mark those that hinder or hurt team performance[6].

The top two problem behaviors identified are:

1. Some members believe that their technical status insulates their opinions from evaluation by other team members. (87% of participants)
2. When multiple disciplines are involved, the methods from one discipline tend to dominate the team's thinking. (85% of participants)

These behaviors can stifle communication and stagnate the progress of a group. Communication is often cited as a major contributor to team success. The team must be able to communicate openly and have constructive and objective dialog to maintain a positive experience for all members and to ensure a healthy and productive team atmosphere.

One of the challenges in academia, especially in project based competitions such as the SAE Aero competition, is the students are similarly minded. They are generally engineering or engineering technology students and have had a similar academic background. Essentially, they are drawing their creative information from the same database. The writers suggest that to increase the project-based competition experience for all students the teams should involve students from dramatically different academic backgrounds. Students studying engineering, engineering technology, student pilots, technicians and arts and science students should be encouraged to work together and experience some of the challenges of working with individuals with dramatically different perspectives and realize that a member's contributions to the team are not limited to their course of study.

At Parks College, we have such diversified teams. It has been our experience that some of our best design concepts have come from non-engineers. Some of our most creative manufacturing solutions came from engineers who have little manufacturing background. The result is a team experience that provides our students with first hand experience that all members can contribute to the success of the team and they are not limited to their course of study. These truly multidisciplinary teams are more representative of what our students will find in industry, and help open their minds to the idea that all input could be valuable, and should be considered with the same design iteration evaluation process, regardless of its source.

This paper looks specifically at the SAE 2001 design competition team, and will show how multidiscipline participation can benefit the team, and provide a more valuable experience for everyone.

The Competition

The Aero Design competition is held annually during the spring semester. A single competition was replaced in recent years by geographically delineated competitions. The Parks College SAE team competes in Aero Design East. Historically the location of the actual flight competition has been located throughout North America but over the past six years has taken place in the state of Florida.

The Aero Design competition requires the student teams to conceive, design, manufacture, test and fly a radio controlled aircraft optimized to carry weight [7]. "An additional challenge is to accurately predict the amount of weight the aircraft is capable of carrying [7]."

The competition is divided into categories, the "regular" and "open" class. The distinguishing differences between the two classes are most notably the size and freedom from constraint in the open class. The Parks College SAE team currently competes in the regular class.

The competition is separated into two parts, the Design Competition and the Flight Competition. The design aspect includes the theoretical mechanism used to design the aircraft including mathematical proofs and testing. Engineering analysis is used to validate design and a formal report is prepared detailing the methods and tools used in the engineering analysis. A formal presentation is given to a panel consisting of experts from academia and industry. The design aspects of the competition are measured in four areas[7]. Each area is assigned a point value to be determined by the judges. The maximum values for each category includes:

Report	30 points maximum
Plans	30 points maximum
Payload Prediction	10 points Maximum
Oral Presentation	30 points maximum

The flight competition takes place only after a team has completed the required design competition. All teams participating in the Aero Design competition must have completed a qualifying flight prior to the competition. A qualifying flight is defined as competition level flight carrying a minimum of eight pounds of payload. Teams are able and encouraged to pre-qualify with a faculty advisor statement indicating the successful flight.

The goal of the flight competition is for each aircraft to carry as much weight as possible. The flight competition takes place in designated "rounds" in which each team has an allotted period of time to fly their aircraft.

In the event of a successful flight the team will be awarded one point for each ¼ pound lifted as payload. Additional points may be earned on the basis of the teams previously predicted payload accuracy. "The payload estimate score is calculated with the following formula with weights in pounds[7]:

$$\left[20 - (predictedpayload - actualpayload)^2\right]$$

Negative values are calculated at zero.

The aircraft must take-off and land with all of the same parts to be considered a qualifying flight. All parts must remain attached to the aircraft for a valid landing. The only exception is the propeller, which may break in the attempt.

It is expected the aircraft will remain in its original design and be unaltered throughout the competition. An accident may require repair to the aircraft and its structures. Repairs are allowable as long as the fundamental design of the aircraft has not changed. Internal structure, additional coverings and coatings are not considered to alter the aircraft. Alterations to the aircraft may result in penalty points being assessed by the judges.

The Parks College 2001 SAE Aero-Design Team

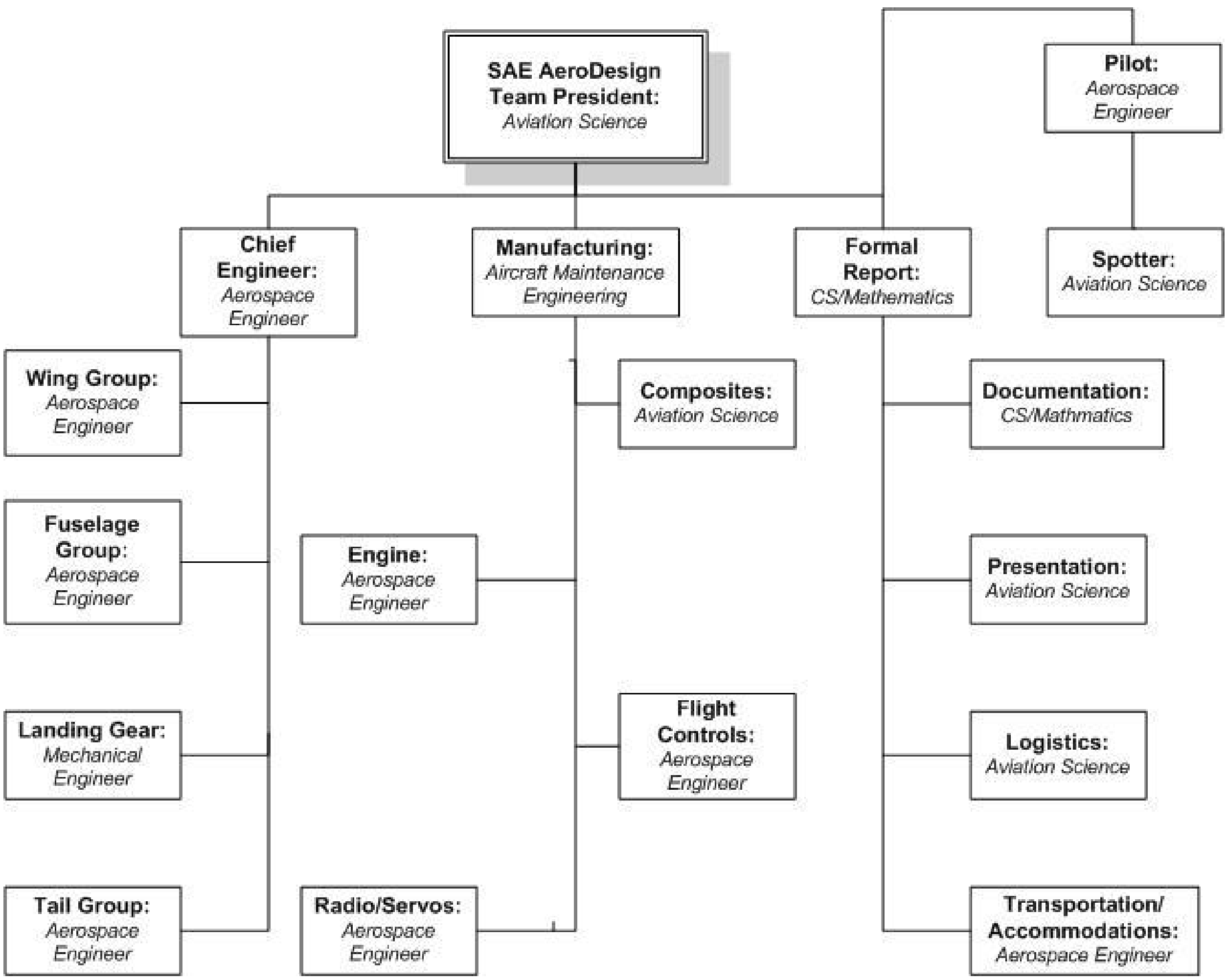
The Parks College chapter of SAE has participated in the Aero Design competition over the past decade. The team has had varying degrees of formal success at the competition while enjoying a great deal of success in the less formal, pragmatic world of working in groups.

The competition team has evolved dramatically over the past 10 years both in student participation and complexity of the aircraft design. Initially spearheaded by a small group of Aerospace Engineering students in 1990, the team has grown to a group of over 15 students with fields of study in management, engineering and aviation science for the 2001 competition team. As the group slowly grew in size and began to receive financial assistance from the university the competition aircraft grew in complexity. Early iterations of fiberglass/epoxy construction were replaced with spar stiffened carbon/epoxy and honeycomb structures. The more recent designs resulted in increased fabrication time and much greater analysis and design time.

Some of the changes incorporated in the 2001 competition aircraft were:

- ❖ Increased wing area
- ❖ Redesigned landing gear
- ❖ Spar stiffened gull wing
- ❖ Stiffened horizontal tail
- ❖ Redesigned engine cowling
- ❖ Redesigned payload bay

The design and fabrication complexity necessitated organizing the effort into teams with responsibilities in design, manufacturing, formal report and flight. The organizational chart is shown below. The program of study of the leader of each group is italicized.



Parks College Aero-Design Organizational Chart

The strength of the team is the diversity of its members. The Aerospace Engineering (AE) students have a strong engineering foundation and provide guidance in design and analysis. The manufacturing process intimidates many engineering students. They rely heavily on their analytic ability and are reluctant to make decisions without data. The Aircraft Maintenance Engineering (AME) students have a foundation in engineering and have also completed courses leading to their FAA Airframe and Powerplant Mechanics license. The AME students understand aircraft structures manufacturing, systems and aircraft repair and have been required to demonstrate skills in aircraft fabrication and repair in the classroom and in airframe laboratories. In general, they are most comfortable with manufacturing and repair. The Aviation Science (AS) students are pilots working on their FAA ratings for commercial, instrument, and flight instruction and are additionally educated in aircraft systems and management. The AS students have a firm understanding of aircraft systems, controls, and flight characteristics. They provide a great deal of general aircraft information and frequently make suggestions to design and configuration based on their flight experience or knowledge of production aircraft. The math and computer science students had an education outside of aerospace, but a strong interest in the competition and in aviation in general.

Team decisions are made by a consensus of the entire team. It's during these discussions that the real challenges of working on a multidiscipline team are exposed. Students are forced to justify and often defend their views. The assertion that "that’s how we did it in class" doesn’t hold very well under scrutiny. This forces critical thinking because decisions are evaluated from a variety of perspectives. Textbook designs or solutions are never incorporated without debate because there are no preconceived notions of how things should be done. The breadth of knowledge that students from different programs of study bring to the team cannot be emulated by combining upper and lower class students from the same program. Nor can combining students who have previously participated in the competition with students who have not.

The Parks College 2001 SAE Aero-Design Competition Team

The students are given deadlines, which must be met in order to continue. Students are required to adhere to a strict budget, and all expenditures must be formally requested and approved by the faculty advisor. Every attempt is made to make the competition design/build/fly process similar to what our graduates will experience in industry.

Benefits to Students

Participation in the competition provides students an opportunity to expand their college experience beyond the instruction in their discipline of study. The experience of design and design of manufacturing is of obvious benefit to the engineering and engineering technology student. In exercising their technical skills the student is introduced to the challenges of practical engineering along with the constraints of producing a concept. The non-engineering student is provided with an introduction to the system like nature of the development and manufacturing of a complex product. The subtleties associated with the development of a product and its transition from concept to working model are often ill-defined, yet, the very budgeting or marketing process as simplistic examples, are based upon the success of the system. Also of great importance, the students gain a new appreciation for the value multi-discipline teamwork. Whether the student is studying engineering, engineering technology, or is in a non-technical program, this change in perspective will benefit the student as they begin their career.

A cross disciplinary approach to education is based on the needs of a changing global marketplace equally important to engineering and science as it is to business. It is no longer adequate to utilize an employee in a particular specialization without regard the related disciplines. The interaction required to address the myriad of issues related to a sophisticated product requires the judicious use of expertise and the ability to commingle talents, perspectives and philosophies in the overall effort of bringing a product to market. It is in the best interest of the student to seize the opportunity to participate in this type of experience.

Rational for a cross-disciplinary component to an undergraduate education includes[5,8]:

- Disciplinary boundaries in organizations are becoming fuzzier
- Career paths often cross disciplinary boundaries
- Cross-disciplinary learning increases students' problem-solving abilities
- Students improve their career flexibility and potential for success
- Students become more productive employees
- Students' lives are likely to be more interesting and fulfilling
- Students' develop a respect for the capabilities of members from other disciplines.
- Students' are exposed to the diversity of people with different backgrounds
- Students gain a more comprehensive understanding of the systems nature of engineering

Engineering colleges are being pressured by industry not only to provide their graduates with intellectual development and superb technical capabilities, but also to educate their students to work as part of teams, communicate well, and understand the economic, social, environmental and international context of their professional activity[8]. The SAE AeroDesign competition is a mechanism by which the foundation of multidisciplinary teamwork and cooperation may be introduced in a practical simulated “real-world” environment.

Enthusiasm from the Parks College AeroDesign team alumni include mentoring opportunities as well as financial support. Alumni have assumed an advisory role and maintain contact with the team upon graduation.

Conclusions

The engineer has evolved from a specialist who focused on all things technical to a key member of a team. While undergraduate education has historically focused on the tools required to be a competent engineer it has only been in recent years that a greater emphasis has been placed on the individuals’ role as part of a team.

Capstone and design courses have been an integral part of many engineering and technology programs for years and in many cases allow the student the opportunity to work within a group.

A weakness in the historical model of capstone/design courses is the make-up of the class. In most cases the course is populated by engineering or engineering technology students enrolled in the same or similar programs. The fundamental weakness of the historical model lies in the lack of group participation from quasi or non-related disciplines.

Projects or course work similar to that provided by the SAE AeroDesign competition allow the student the opportunity to interact and work with students with vastly differing backgrounds and education. This introduction into engineering diversity and team participation is a much sought-after characteristic valued by employers and customers alike. Experience on multidiscipline teams can reduce the individual's biases toward other disciplines, and will ultimately make the student a better team member[10].

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