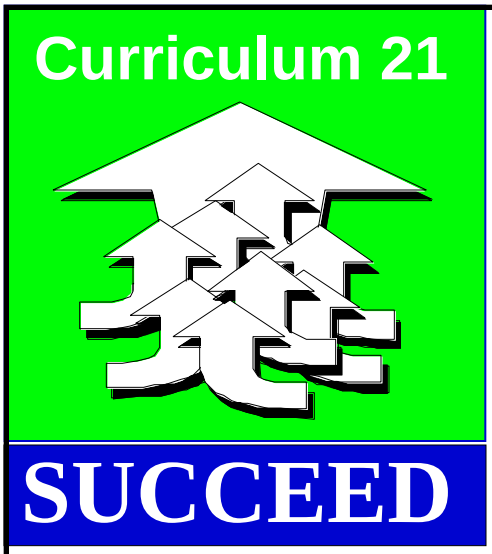

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Freshman-Senior Design Teams: Experience at Virginia Tech

SUCCEED Project:
Vertically Integrated Design

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Virginia Tech

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Freshman-Senior Design Teams: Experience at Virginia Tech

by

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Abstract

In our SUCCEED Project we are including freshman in senior design courses in Aerospace and Ocean (AOE), and Mechanical Engineering (ME). In the past these courses were the so-called "capstone" design courses for seniors. In the spring semester of 1993 freshmen were included on the design teams. We did this to increase freshmen enthusiasm for engineering, hopefully improving retention rates. We also wanted freshmen to understand the need for the engineering science courses required in the sophomore and junior years. Finally, we wanted to prepare students for the senior-level design course, which students in Aerospace Engineering were finding difficult because the orientation was so different from the engineering science courses. The results of this experience have been completely positive. Both the freshmen and senior members of the design teams want to see this approach continued. The freshman replaced their usual engineering fundamentals course project with their part of the senior course. Finally, the quality of the course did not suffer. Aerospace Engineering design teams with freshmen members placed first and third in the AIAA/General Dynamics Undergraduate Team Aircraft Design competition for 1992-93. There are many important aspects of design that do not require engineering science courses, and the freshmen were able to make an immediate contribution in packaging of aircraft components, layout of the aircraft payload, design of the crew station and instrument panel. In these tasks they had to dig out information and learn how to locate data sources, including library research and phone calls to industry. As part of a design team they got insight into the dynamics of teams under pressure and the importance of schedules, deadlines, and effective communication. Several freshmen wanted to continue to participate as sophomores.

A complete assessment will not be available until the first group of freshman, who started the program in the Spring of 1993, graduate. However, initial retention rates and grades are good. Qualitatively, the impact of this program on all those associated with it has been so significant that we already consider it a resounding success. Word of mouth was so strong that members of senior design teams without freshman complained to the AOE Department Head. On the basis of the strong support for this type program, the AOE Department is offering a new course for sophomores in the Fall of 1994. This course will be called Introduction to AOE Design, and will continue the emphasis started in SUCCEED using students who were in the freshman-senior design project as "seeds."

The paper includes details on the selection of the freshman and statistics on their retention rate and grades. The next challenge will be to continue the design emphasis in the second semester sophomore and full junior years.

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Introduction

Use Freshmen in "Senior" Design Teams

- Give Freshmen a better idea of curriculum goals, why those nasty engineering science courses are needed
- Increase enthusiasm
- Improve retention

There is an increasing interest in having engineering students gain a better understanding of the concept of *engineering* during their education. This means that students need to see a balance between the current strong dose of engineering science provided in the engineering curriculum and the creativity and excitement of engineering practice. Of course almost all engineering practice is what the schools call "design."

Since *engineering* and *design* are essentially same thing in the real world, it is not surprising that the importance of design in engineering education has been emphasized repeatedly recently. The situation has been the subject of studies and papers by government,[1] industry,[2,3] and practicing engineers.[4,5] NASA is addressing the problem through their support of the USRA Advanced Design Program.[6] The importance of design to United States competitiveness in the global economy is finally being recognized. Some educators have also discussed the problem.[7,8] The ASEE Magazine, *Engineering Education,* devoted an entire issue to the subject of design in education.[9]

With the emphasis on engineering increasing, there is an interest in including design education at all education levels. The problem then is providing a meaningful experience at the freshman level. We sought to find a way to resolve the problem. Since a freshman in engineering should participate in a realistic design experience, this SUCCEED project investigated providing freshmen with a more realistic design experience through a "vertical" integration of design, where the freshman introductory engineering course is combined with the senior capstone design course.

By involving freshman in a meaningful engineering design experience through our senior-freshman integrated design program, we expect to increase their interest in engineering, provide motivation for the engineering science courses, and improve retention rates. A second goal is to prepare our students for the senior design course. Currently, many students are not prepared for the open-ended project approach, where they are required to establish design criteria and make engineering decisions. The senior design courses provide the best opportunity to have freshmen participate in this type of design, and in the Spring of 1993 selected freshmen joined the senior design teams in Aerospace and Mechanical Engineering at Virginia Tech. This also added a new dimension to those design courses.

This paper describes our approach and our experiences in the first year of the program. Aerospace specific considerations have been described by Marchman and Mason,[10] and the results of the second year of the program will be presented at the 1994 ASEE meeting.[11] We conclude with a discussion of the affect this program is having on the Aerospace and Ocean Engineering curriculum at Virginia Tech.

Approach

- Fall 92: Students identified: volunteers and selection by Engineering Fundamentals Dept. together with a "control group"
- Spring 1993: 20 in ME, 9 in AE
- Fall 93: Select a new group
- Spring 1994: new freshmen working with seniors
- *etc.*
- Monitor student progress continually, including the key evaluation at end of the senior year

In the Fall of 1992 Bob Pusey selected control groups with similar backgrounds. This was done by asking freshman engineering students who expected to elect Mechanical or Aerospace Engineering as their majors to volunteer for the project. Over one hundred students volunteered. The final selection from this group was made based on

the final Fall 1992 grades, and the desire to group students taking part in the project in selected freshmen classes to keep the control group coordinated. A “C” or better in the Fall 1992 freshman engineering class was used as the criterion.

One group worked with seniors, one group did not. Twenty students were selected for participation in the Mechanical Engineering Design Program, and nine for the Aerospace Aircraft Design Program. The Aerospace Design Program is a two semester program, and freshman participating in Aerospace Design attended the final Fall Semester design presentations by the senior design groups on Dec. 1-3, 1992. Starting with the Spring 1993 semester, the freshman working with the seniors replaced their normal engineering fundamentals class project in the freshman *Introduction to Engineering* Course with a project from their work with the senior design teams.

Mechanical Engineering

In **ME,** during the first few weeks of the Spring 1993 semester, the twenty freshmen from the selected group were then asked to pick one of the senior **ME** projects. These students talked to the **ME** professors who were advisors to the projects and to the seniors. Then they picked an ME project and team. The list of projects and the number of freshmen on each project was:

SAE Formula Race Car:	5
SAE Mini Baja Car:	2
Solaray (solar powered electric vehicle):	5
Maintenance Safety:	2
Bioconversion:	2
Third World Solar Energy Conversion:	1
Babcock & Wilcox robot design:	1
Surround Sound Speaker Design:	1
Army Ant cargo mover:	1

The freshmen participated in brainstorming and other idea generating exercises as well as providing drafting help in the later stages of the projects. They participated in oral progress reports during the semester and took part in the final design presentations.

In Aerospace Design, two (in one case three) freshmen were placed on each of the four design teams. The two aircraft design projects in 1992-1993 were the AIAA/General Dynamics Undergraduate Team Aircraft Design Competition, a global range transport, and the NASA/USRA Advanced Design Program project, a vehicle based system to replenish the ozone layer. Three teams worked on the first project, while one team worked on the second. Most of the freshmen joined the AIAA and were officially part of the AIAA design competition. The grade on their work counted as the grade for their project in the freshman course. In most cases their engineering fundamentals instructors attended the final design presentations, which included freshman discussing their part of the project. At the end of the semester we surveyed all the program participants as part of the peer review system used to evaluate individual team member performance.

The project is now in full operation, with the second cycle using this approach having begun in the Fall of 1993. The Engineering Fundamentals (EF) Program identified the students to take part in the project. Freshmen work with seniors in both the Mechanical Engineering (ME), and Aerospace and Ocean Engineering (AOE) Departments throughout the Spring semester.

Specific Examples of Freshman Work

In this section we provide specific examples of what was done during the Spring Semester of 1993. These are representative examples, with similar work being done by all the students, and continuing in Spring 1994.

In Mechanical Engineering:

Amy Porter worked with two seniors designing a luggage carrier for Jeep vehicles. She did preliminary drawings of the back of the Jeep and the components of the carrier. She also did the final drawings of the carrier that were used in the final report, and participated in the final oral presentation.

Kelley Wilson worked with three seniors designing platforms to be used by maintenance personnel at Yokohama Tire in Roanoke, VA, to repair components on a tire building machine. Kelley did the drawings of the platforms and contributed to the final drawings for the report and the final presentation.

Four students worked with a team of seniors on the SAE Formula Car: **Paul Bigby** helped draw the new water pump to be made on a numerically controlled milling machine. He was also involved with using CUTTING EDGE a program that takes 3-D wire frame images and creates the NC code. He also assisted in many other shop activities that pertain to the completion of the new car. **Doug Cartney** worked with the new car design group and used a finite element package. **Robert Hatchett** did shop work on a test rig used to verify the finite element model of the suspension system. **Dave Simmon** did drawings for the barrel type throttle as well as some shop work.

Brett Done worked with a team of four seniors on the Army Ant project. He did the final drawings for the report and participated in the oral presentation.

Karen Meaders was assigned as a full member of a design team on the solar energy project. She did drawings for the final report and participated in the oral progress reports and the final presentation.

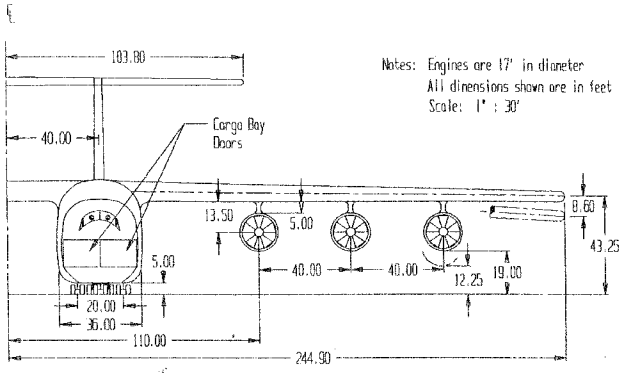
In Aerospace Engineering:

• AIAA Global Range Transport Problem • NASA/USRA Ozone Replenishment System

The AOE students participated either in the design of a global range transport or a vehicle-based system to replenish the ozone layer. On several global range transport teams the freshmen were heavily involved in the layout of the cargo bay to hold the required mix of payload in the minimum space. This required determination of the dimensions of the payload, the layout in the cargo bay using their CAD program, and the determination of the weight and center of gravity for a variety of loading conditions.

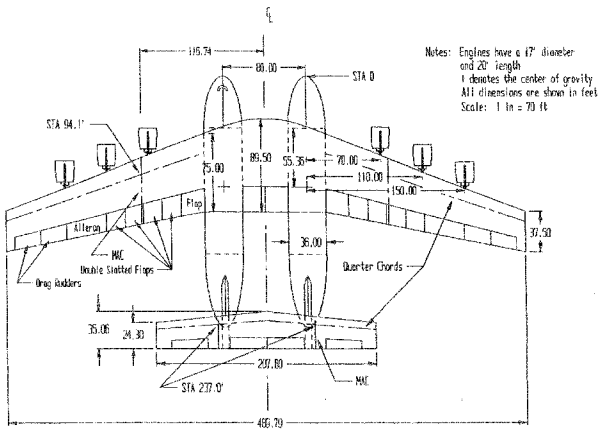
One student worked on landing gear design, and several others worked on the crew station design. In the "ozone" group, one freshman designed the attachment system to connect a large propane tank to the airframe. He said that compared to his assignments in statics class, this is much more realistic to him and has helped him understand the value of that class much more than the normal course assignments.

Examples of the work these students did using CADKey are shown in the following figures. Note that they in fact have a later and much better version of this program than the seniors. Figure 1 is by **Richard Wand**, from work led by Steve Walder (the senior team leader).[12] Wand used these drawings to help obtain a cooperative engineering job.

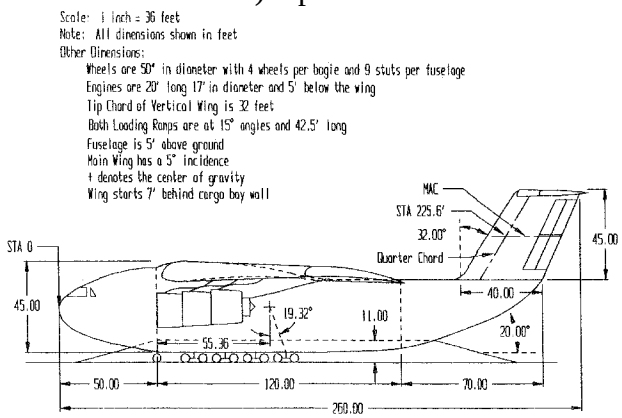


a) front view

Figure 1. Configuration layout by a freshman for the AIAA design competition[12]



b) top view



c) side view

Figure 1. Configuration layout by a freshman for the AIAA design competition (concluded)[12]

Work was also done with cargo layout, including weight, volume and center of gravity estimation. Figure 2 shows a cargo layout done by **Jimmy Fung** to meet the requirements of the AIAA design competition. This was from a team led by Scott Dyer,[13] which, incidentally, won the national undergraduate team aircraft design competition.

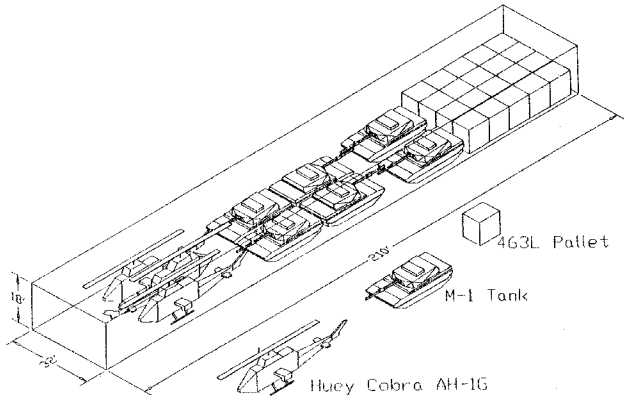
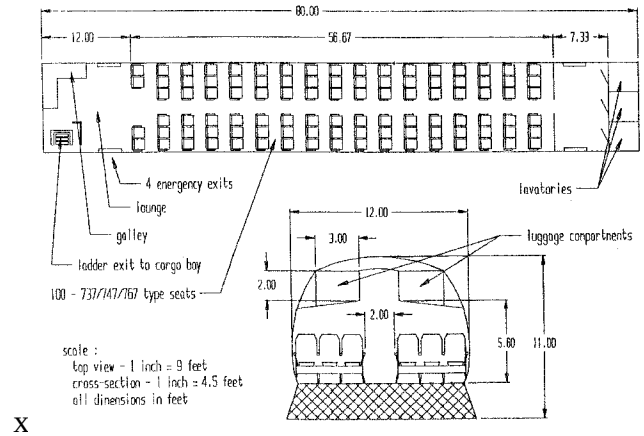


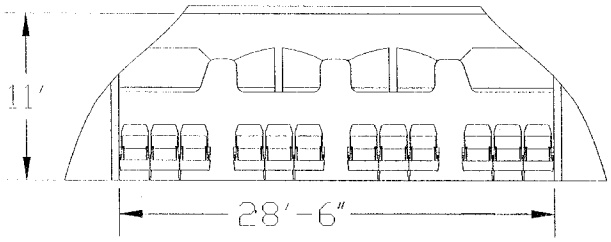
Figure 2. Cargo layout for the 1993 AIAA Team Aircraft Design Competition.[13]

Figure 3 shows some of the cabin layout designs, also required for the AIAA design competition. Figure 3a was done by **Kandler Smith**, working in a senior team led by Jason Pepin[14] which won third place in the design competition. Figure 3b was done by **Sun Lee**, working in Scott Dyer's group.[13]



x

a) cabin layout design by freshman Kandler Smith[14]



b) cabin layout design by freshman Sun Lee[13]

Figure 3. Crew station layouts.

These are only a few examples from the final design reports. The freshman made significant contributions in a variety of areas. Most, but not all, of the contributions emphasized the use of their CAD software.

Outcomes

Significant Findings and Conclusions

The numbers:

- All remained in engineering, 26 of 29 moved to major
- ME: 7 of the 20 picked other engineering majors
- AE: 3 of 9 picked other majors (1 to OE)

The anecdotes:

- All liked it
- Seniors in teams without freshmen complained
- Freshmen used this experience to get co-op jobs
- Freshmen wanted to continue as sophomores

After the Spring Semester, there was 100% retention in engineering. Of the 29 students, all but three were able to transfer immediately into their major field. These three are all expected to be able transfer to their major by the end of the Fall 1993 semester. At Virginia Tech, transfer to major requires both a satisfactory quality credit average and the completion of the complete set of freshman courses. The three that did not transfer were all academically eligible, and only needed to take additional courses to transfer.

All the students remained in engineering. Three of the nine in Aerospace Engineering declared majors in other fields (one chose Ocean Engineering, a sister major in the AOE Department). Of the twenty ME students, seven selected other majors.

In the Mechanical Engineering Department: In general the faculty support the vertical integration concept. While they recognize that the freshmen do not have the skills needed to do design, the freshmen can and do present ideas, have the skills to make drawings, and get to see what ME seniors are able to do after four years of education. The advisor of the Formula Project sees this program as an opportunity to recruit members of the car teams. The seniors welcome the help with the drawings because it frees them to

concentrate on analysis and design. The freshmen get to work on real projects. On the car projects they also get to build hardware. They are impressed with the senior's skills.

Most faculty have suggestions about improving the experience. The freshmen should be given the list of projects in the fall so that they can pick one and be ready to start at the beginning of the spring semester. The faculty have to be prepared to integrate the freshmen into groups more quickly and determine how much structure should be given to the freshmen. The seniors need to be prepared for a mentoring role. Only one student didn't attend many meetings and only occasionally worked with the team.

In the Aerospace and Ocean Engineering Department: The experience has been good. The freshmen are enthusiastic, and in initial discussions with them they were very positive about continuing the program. The AOE experience is that they are able to make significant contributions to the design work. It has been fascinating to watch them ask the seniors questions about the technical reasoning and requirements in areas where they haven't had the necessary course work. They have worked on a variety of assignments, including layout of cargo and passenger compartments, landing gear design, and crew station design. They have the latest version of the standard VPI engineering student CAD program (the complete professional package of CADKEY), and thus have better tools to use than the seniors. This improves the whole team's drawing capability.

This SUCCEED project is already making an impact on the AOE departmental plans. In completely unsolicited comments, upper class students, including seniors not participating in the project, have been very positive about this project. In their monthly "communications" meeting with the AOE Associate Department Head, they suggested that the scope be expanded to include Sophomore and Junior students. As a result, the department is now planning to integrate this approach into our curriculum more broadly than originally conceived. The impact on upper class students may be as great as the freshmen. Currently, the students are initially overwhelmed by the design course. They are not ready for the broad scope of our design course. They need to learn material not

covered in courses, and then make engineering decisions. Vertically Integrated Design addresses these problems. At the end of the first year of the experiment all of the proposed merits have proved real and none of the possible problems evolved.

As a result of the enthusiastic student reception, a one credit course for the Fall Semester of the Sophomore year will be implemented in the Aerospace and Ocean Engineering Department. With a tentative title of "Design in AOE," this will be a one credit course exposing students to the design and manufacturing process as a precursor to the formal engineering science courses, and will include attendance at the final Fall design presentations.

The students in AOE were able to enjoy previously unavailable rewards. AOE Design teams took first and third place in the national AIAA/General Dynamics Team Aircraft Design Competition. Two freshmen were on one team and three (*30% of the entire team!*) were on the third place team. The monetary award was $100 for each member of the first place team and $25 for each member of the third place team, plus national recognition in press releases from the AIAA and press releases to hometown newspapers by the school public relations department, and a certificate of achievement from the AIAA.

One Key Leverage: **The NASA/USRA Advanced Design Program Summer Conference**
• Normally attended by seniors, little feedback to school • Two freshmen attended last year: opens an important new feedback loop

One synergistic effect has been identified with our SUCCEED project. We linked it with Virginia Tech's participation in the NASA/USRA Advanced Design Program. Although all the design teams get the benefit of the USRA program, one team works on a USRA-specific design project. This project is broad in scope, emphasizing environmental and ethical aspects of engineering. Currently, this project focuses on the design of a system to replenish the loss of ozone in the ozone hole over the South Pole. In addition, using SUCCEED travel funds, we were able to take several freshmen to the

NASA/USRA Advanced Design Program Summer Conference. In 1993 the conference was held in Houston, TX, from June 14-18. The senior design students in AOE working on the NASA/USRA project also attended. This activity was added because the ADP Summer Conference is attended by several hundred students from various universities. With only seniors attending, interest and enthusiasm generated at this conference does not feed back into our design program because most of the attendees have already graduated. By including freshman in this activity we expect to obtain a much larger benefit from this meeting in terms of both experience and enthusiasm.

Because of our experience, we will continue our "Vertically Integrated Design" approach and expect it to become a standard approach to engineering education at Virginia Tech. As we will describe below, the benefits will be described to other departments as well as other universities at a workshop to be held in the Summer of 1994.

Lessons Learned

The experience has been good. The freshmen are enthusiastic, and in discussions with them they were very positive about continuing the program. They are able to do a lot of the design work, and they ask the seniors good questions about the technical reasoning and requirements in areas where they haven't had the necessary course work.

During the research we are identifying requirements to coordinate between EF and the ME and AOE departments. As currently conducted, the freshman participation in the design work counts as the term project in their EF class. We need to make sure all instructors are fully aware of the nature of the senior design work. All participating EF instructors are now being invited to attend the "senior" design presentations where the freshmen are now also taking part.

In answer to questions about whether freshmen are a problem on a senior design team, we have evidence that there cannot be a serious problem. In aerospace engineering, teams with freshmen won 1st and 3rd place in the AIAA/GD Team Aircraft Design Competition for 1992-93.

Future Activities/Impacts

Spring 1994
- AE: Aircraft and Spacecraft Design (10 fresh.)
- ME: Slightly Reduced Numbers/Fewer different projects

Summer 1994
- A workshop on our experiences on August 15-16, 1994 at Virginia Tech

Fall 1994
- SUCCEED Results lead to new AOE Sophomore course
  - Intro to Design (really intro to AOE)

- Continue the freshman/senior design experiment at Virginia Tech, with intentions to involving other departments, not participating now, starting in the fall of 1995, and include monitoring student progress and retention, as well as attitude toward engineering.

In the Spring of 1994 this project became part of a mega project on early design. The effort will now be focused slightly differently to achieve the SUCCEED program goals. Our current efforts include the following:

• *We are exporting the experiment to one other SUCCEED institution.* The University of Florida Aerospace Capstone Design course will begin participating in this project. The Aerospace Design course will expand to include students at all levels of education, from freshmen who expressed an interest in the aerospace program to seniors enrolled in the capstone course. Course modules including design methodology and principles and methods of multidisciplinary design will be developed for the freshmen, sophomores and juniors enrolled in a class entitled “Introductory Design Course.” Two credits will be earned by the participants in this class. Following the lecture series, the lower level students will join the senior project (at the University of Florida the seniors participate in the SAE Heavy-Lifter Airplane design competition). The students enrolled in the Introductory Design Course will help manufacture models, perform wind tunnel tests and work on prototype fabrication.

• *We are working with the University of Florida to find ways to extend the vertically integrated design experience into the sophomore year* to build on the enthusiasm

generated by the freshman program. Compared to that at the University of Florida, this program would have students work on a different project each year with each class of student bringing their own unique perspective and capabilities to the project. Accomplishing this requires a group approach to teaching design where any given group includes students from all participating class levels. Aerospace engineering and ocean engineering students will be used in this experiment.

• *We are holding a workshop on Vertically Integrated Design and the Early Design Experiments Mega-Project at Virginia Tech on August 15-16, 1994.* We are inviting representatives of all SUCCEED schools, other academic institutions, and representatives from government and industry. The workshop will include presentations from other NSF Coalition institutions and we will hold discussions of the relative merits and applicability of the various approaches. Finally, we will address the issue of student design teams: when they work and when they don't.

• *We are developing statistics on the effect of the program on the participating students.* We will conduct follow-up interviews and compare the academic record of these students with the nominal student group that didn't participate. We will emphasize the significance of this program in relation to the introduction of collaborative learning techniques into the engineering curriculum, and compare results between the University of Florida and Virginia Tech.

Conclusions

We are completely satisfied with the results obtained in this project. To summarize:

- Using Freshmen in "Senior" Projects Works
- Expanding to other programs in progress
- U. of Fl. to use all classes together
- A workshop at VPI Aug. 15-16 to discuss early design experience
- Appears to be a synergistic idea

Acknowledgments

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