Integrating Engineering Practice into Undergraduate Curricula Using Project Simulation: Outcomes Related to Retention and Persistence

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Abstract - This paper presents a summary of the project simulations that the faculty in the Department of Electrical and Computer Engineering at Indiana Tech developed for the department’s students. The simulations are based on the design and fabrication of a self-contained telemetry and television downlink package for a rocket launch. The paper discusses the original motivation for the project, and provides project background and scope for each academic year. It outlines student learning outcomes including: exposure to systems integration, environmental constraints, design tradeoffs, and simulation. Additionally, the paper presents the benefits to persistence and retention of engaging departmental constituencies in the project, which resulted in both significant interaction between students at all levels, and interaction with recent program graduates, local industry, and both practicing engineers and retired engineers. Finally, it presents project plans and progress for the current 2004-2005 rocket project simulation: a collaborative effort with Embry-Riddle Aeronautical University to loft a launch vehicle to an altitude of greater than 62 miles, the boundary of space.

Index Terms - project simulation, capstone design, undergraduate design, multidisciplinary design, industrial collaboration.

INTRODUCTION

In the fall of 2002 the department held focus meetings with both the faculty and the IEEE student branch, and in response to student input the department sponsored a special project for the students in the 2003 spring semester to provide them with leadership and mentoring opportunities, as well as to evaluate departmental program outcomes. This was an interdisciplinary, multilevel, extra-curricular activity for the electrical engineering (EE) and computer engineering (CpE) student groups. The students that participated in the simulation were self-selected, as participation was not required. Fifty percent of the EE senior class chose to participate in the project. Seventy five percent of the junior class, and one freshman also participated. Using this simulation assessment tool the department evaluated several program and ABET outcomes. The project selected for the simulation involved development of a rocket borne instrumentation package. It necessitated liaison between the Indiana Tech student team and the Northeast Florida Association of Rocketry (NEFAR) to determine design constraints and launch schedules. The project simulation produced an NTSC fast scan television and telemetry downlink for a 1-2 mile altitude launch. The students exceeded expectations in meeting the design goals, demonstrated leadership and teamwork skills, and developed troubleshooting and project management skills. The 10 May, 2003 launch made headline news as released on the Reuters news wire and reported on Yahoo!® News [1].

In the 2003 fall semester, Indiana Tech substantially expanded the project simulation by committing to provide an onboard NTSC television subsystem and telemetry downlink for the launch of the Florida Institute of Technology (Florida Tech) SERRA rocket, a one-stage rocket with an un-powered dart upper stage. The anticipated launch altitude for this system was 18-20 miles, and the launch forces were substantially higher than the previous year’s project simulation. Furthermore, recovery from the ocean was a design requirement. Therefore, the payload provided to Florida Tech had design requirements for survival at a depth of 100 feet.

Because a flight into outer space (an apogee above 62 miles) on a subsequent Embry-Riddle Aeronautical University (ERAU) rocket was the ultimate goal, the team established design requirements for the package intended to satisfy a flight profile with a 75-mile apogee at 20 miles downrange. The resultant volume, weight, and environmental constraints were a significant challenge for the students, faculty, and industrial advisors on the project simulation. The project simulation subsystems design activities were apportioned to several design teams, some supervised by faculty, others by industry advisors. Two of the major subsystems were designed, fabricated, and tested by EE seniors as their capstone design projects. Elements of other subsystems were completed as class projects in a laboratory based design course and in a special topics course.

In the 2004 fall semester, the integration activity on the original SERRA payload continued, with a successful test...
launch of this package completed on January 8, 2005 in Palm Bay, FL. As previously mentioned, in addition to the SERRA design project, the department committed to provide a telemetry package for the ICARUS project. This rocket is a two-stage, spin-stabilized rocket with an anticipated minimum launch altitude of 62 miles. The spin stabilization made a live television feed impractical, although the possible use of a small still camera is currently under consideration. This change greatly reduced the power and cooling requirements for ICARUS. The ERAU student team plans to provide a buoyant, watertight section for the Indiana Tech payload, which greatly simplified the mechanical packaging requirements. As a result, the ERAU project design has been much easier to achieve.

The 2003-2004 SERRA project simulation management structure at Indiana Tech consisted of faculty advisors functioning as engineering managers for each subsystem design team. Regular project reviews were conducted, usually every week, during which teams would present progress reports. Faculty kept a log of action items that were reviewed at each meeting. Regular contact with the SERRA design team was maintained to keep abreast of changing requirements and schedule updates. The 2004-2005 ICARUS project simulation at Indiana Tech has a student based project management team in place in which both faculty and retired engineers serve as consultants, with a (senior) engineering student, who participated in the previous year’s project, serving as technical lead. An Indiana Tech MBA student is assisting with project management.

Students reported on project progress for both the 2002-2003 and the 2003-2004 project simulations at the 2003 and 2004 ASEE Section Conferences, respectively [2-3].

SYSTEM REQUIREMENTS AND DESIGN

The 2002-2003 project simulation requirements were not particularly difficult to achieve. Launch was at the NEFAR launch site at Bunnell, FL using a K motor. This allowed for line-of-sight recovery on land. The launch forces were limited to approximately 8-g’s, depending on vehicle weight. Subsystems were fabricated using off-the-shelf components, and the mechanical package was fabricated using parts available for amateur rocketry. The launch schedule and requirements were under the control of the Indiana Tech design team. However, the NEFAR site hosted launches once a month, requiring the students to do time management in order to present a finished project to meet the NEFAR launch schedule. The project family tree is shown in Figure 1. Note that elements of the simulation were completed as part of a special project in a CpE laboratory based design class. Other design elements were completed as part of the IEEE student branch activity. The entire 2002-2003 project simulation was performed under the direction of the department chair.

Figure 1: Subsystems for the 2002-2003 rocket project simulation.
The 2003-2004 project simulation requirements were far more challenging. The expected launch acceleration was 15-20 g’s, sustained for 10-15 seconds with mission duration of up to 1 hour. Given the slant range requirement (approximately 78 miles), and the employment of an NTSC fast-scan television downlink, the downlink RF power (and thus primary power) system requirements were significantly increased relative to those of the 2002-2003 project. The downlink transmitter produced an output power of approximately 20 watts peak. Since the video downlink used conventional DSB-AM modulation, the power amplifier (PA) was a linear design and was relatively inefficient. This in turn provided a design challenge for the PA’s heat sinking within the constraints of the instrument package. The requirement for recovery from the ocean at depths approaching 100 feet was met by designing a pressure vessel with aluminum bulkheads (which served as heat sinks), and with a clear, polycarbonate tube for a body. The tube required a stiffening ring near the center of the assembly. The design and fabrication of this package was completed with the assistance of Undersea Sensor Systems, Inc., a sonobouy manufacturer located in Columbia City, IN. The design and fabrication of the airborne RF exciter, PA, subcarrier generator, transmit antenna, and of the ground station receive antenna, preamplifier, receiver, recorder subsystem, and power supply was provided by three retired Raytheon engineers and one of the Indiana Tech Electrical Engineering students. The remaining system components (power subsystem, sensor package, video subsystem, telemetry data processing subsystem, system software, and the mechanical structure of the entire package) were designed and fabricated by Indiana Tech students.

Mechanical integration of the digital and RF segments of the instrument package was a challenge for the team due to the relatively high RF power radiated in close proximity to the system’s TV camera and digital electronics. As a result, the students received a real-world lesson involving hardware integration and shielding techniques. The students also experienced the realities of a real-world delivery deadline in order to support the SERRA launch schedule. The 2003-2004 project family tree is shown in Figure 2.

Note that the student designs were completed as senior projects, course projects, and special projects offered within the department. Other elements of the student design were completed as part of the IEEE student branch activity. Faculty and industry advisors served as lead engineers on design teams and directed student activity during the design process. The responsibility for project management activities was carried primarily by the faculty and industry advisors.

Some 2004-2005 project simulation requirements are quite different from those of the previous year. The ERAU
will be a two-stage, spin-stabilized rocket with a spin rate of up to 20 Hz. It is intended to attain an altitude of at least 62 miles, and has a significant instrument package weight restriction relative to the SERRA launch vehicle. With the exception of the spin rate, launch dynamics are expected to be comparable to the SERRA launch loads. Recovery is from the water, but the ERAU team has agreed to provide a watertight, buoyant payload section, which removes the pressure vessel requirement. The student team decided that the high spin rate made inclusion of a fast scan (NTSC) television system impractical. The subsequent elimination of this subsystem reduced downlink bandwidth requirements, and thus reduced power and cooling requirements. The RF subsystem design is once again under the direction of retired Raytheon engineers. The student design elements are offered as course projects within a laboratory based design course and as part of the IEEE student branch activities. The project management responsibilities for this year’s project are carried by the students, with the faculty and industrial advisors serving as consultants. A preliminary system family tree is shown in Figure 3.

**OUTCOMES**

I. Student Participation and Mentoring

In the 2002-2003 project simulation, most of the participants were juniors and seniors, as shown in Figure 4. Two of the graduating seniors from that year participated in the 2003-2004 project as advisors. In the 2003-2004 project simulation, three fourths of the participants were juniors and seniors, but the participation of freshmen and sophomores improved substantially. For the current project year (2004-2005), half of the undergraduates participating are freshmen and sophomores, and once again, two graduates from the previous project year are participating as advisors.

In previous project years, the project’s faculty advisors observed program graduates teaching undergraduates how to

![Figure 3: Subsystems for the 2004-2005 rocket project simulation.](image-url)
use the printed-circuit board (PCB) layout software, as well as how to setup and use the test equipment and other tools in the design laboratory. This project year, for the first time, the faculty advisors observed juniors and seniors teaching the freshmen and sophomores how to: use the PCB tools to design and produce PCBs, solder and desolder using the ESD workstation, build connectors, setup and use the tools to fabricate parts for the mechanical package, and perhaps most significantly, develop a technical leadership role. Thus, it is believed that the increase in sophomore participation and the mentoring activity of the seniors represents a positive development that will lead to a self-sustaining mentoring environment as the project simulation continues into subsequent years.

II. Program Simulation Outcomes


The 2003-2004 project simulation was not complete at the end of the spring 2004 semester. Unfortunately, the SERRA booster team suffered a setback when a vendor that was to provide booster parts failed to deliver them on schedule. This ultimately pushed the schedule out far enough to cause the SERRA team to fail to produce a flyable airframe. The Indiana Tech payload for the SERRA project was assembled for a test flight with an N motor at the NEFAR launch site at Palm Bay, FL. The test flight took place on 8 January, 2005, and received extensive coverage in the Ft. Wayne press [4-7]. As planned, the test launch provided both real-time telemetry and a live video feed with video overlay. The sensor data that was stored in onboard memory is currently under analysis, with plans to use the inertial measurement unit (IMU) and pressure sensor data to perform a trajectory reconstruction. The assembled Indiana Tech payload from this launch is shown in Figure 5. A photograph of the Palm Bay launch is provided in Figure 6.

Figure 4: Participation in the project simulation by student year.

III. Participation and Mentoring by Retired and Practicing Engineers

The 2002-2003 project simulation involved only Indiana Tech faculty. The 2003-2004 project simulation brought in three retired Raytheon engineers to help with the design and fabrication of the airborne RF section, antenna, and certain ground station components. Additionally, these engineers served as mentors for the students during the systems integration and test phases of the project. Program graduates, who worked on the previous year’s design project, provided advisement and mentoring to the students. Practicing engineers from a sonobuoy manufacturer (Undersea Sensors Systems, Inc, in Columbia City, IN) assisted with the design and fabrication of the pressure vessel, and provided prototype circuit boards from student generated artwork files. They also...
provided some consulting for the power board design. A local aerospace company (ITT Aerospace in Ft. Wayne, IN) assisted with the fabrication of the IMU mounting assembly for the 3-axis spin and acceleration sensors. However, the most significant interaction took place between the students, the program graduates, and the retired Raytheon engineers. These engineers regularly attended rocket project meetings, and worked closely with the students in the design and fabrication of their subsystem.

CONCLUSION

It has been noted recently that the conventional “eat your spinach” approach to engineering education loses many undergraduate engineering students to other majors before they ever reach an engineering design class [8]. At Indiana Tech, we have developed a project simulation to involve students at all levels so that freshmen and sophomores get involved early in the fun part of engineering. The project simulation offers an environment where the freshmen and sophomores can get to know the juniors and seniors, and where everyone can meet and interact with recent graduates and practicing engineers. We expect the project simulation to have a positive impact on retention and persistence. Our students at all levels are enthusiastic participants in the project. We also plan to expand the project simulation to include non-engineers, and this year we have an MBA student assisting with the project management task.

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REFERENCES


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