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PROJECT MANAGEMENT IN AN INTERDISCIPLINARY SENIOR DESIGN TEAM

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ABSTRACT

Innovation in the changing undergraduate engineering curriculum mandates efficient management of interdisciplinary capstone senior design projects. This effort requires collaboration and management by students and faculty from multiple disciplines, and provides students an opportunity to learn from other engineering systems. In addition, this approach will i) emphasize problem solving and creative thinking; ii) provide first-hand experience in generating a management plan; iii) expose students to multiple engineering and management disciplines, and to work in diverse, multi-cultural teams; and iv) prepare students with a keen understanding of the interdisciplinary environment necessary for success.

The senior design project (SDP) presented is based on the interdisciplinary collaboration of electrical, computer, and mechanical engineering students and faculty to design an integrated high altitude balloon system that would reach an altitude of 100,000 feet and return safely to earth. This paper presents the modes by which all the above issues in SDP are addressed, results obtained and improvements planned for the next interdisciplinary projects.

1. INTRODUCTION

The College of Engineering and Computer Science at (CECS) Wright State University (WSU) has sought to improve the engineering curricula through an adaptive and innovative approach that incorporates an interdisciplinary senior capstone design project involving computer, electrical, industrial, materials, and mechanical engineering students through an integrated technology High Altitude Balloon (HAB) system. The HAB system is a systematic integrated project that involves investigating a complex process or system with multiple elements of engineering education and research elements such as wireless communication; alternative energy devices including fuel cell and solar radiation studies; control system design; data analysis for computing; payload material design; flight path prediction and aerodynamics; wind data studies, shape memory composites, heat transfer analysis; and developing a balloon tracking system. Through working on this project, students delve into a complex engineering system that (1) exposes them to applied and cutting-edge design projects; (2) encourages them to participate in an integrated, inter-disciplinary curriculum that facilitates engagement by working across engineering disciplines; (3) involves them in methods of applied technology and skills necessary to transition from academic to professional environments. Major challenges in this project were formulation of design requirements; effective management of budget and resources; meeting stringent timelines; effective technical communication among inter-disciplinary team members for meeting the overall design goals; leadership skills; marketing strategies; and development of interpersonal skills to work as a team.

2. HAB SYSTEM

High altitude airborne platforms such as airplanes and unmanned aerial vehicles have presented huge advantages in the US military's arsenal over the past several decades through environmental monitoring, precision navigation, communication, missile warning, and intelligence surveillance and reconnaissance (ISR) platforms. They have been used to provide a low cost, persistent sensor coverage option for tactical operations, and have great ground resolution.

Conventional aircraft have a practical upper altitude limit (60000-80000 ft above the sea level), where engine efficiency greatly diminishes due to lower oxygen levels, causing internal-combustion, turbine engine failure. Also, there exists a region of the earth's atmosphere (about 60000 ft above the sea level) that remains underutilized for Science Technology Engineering and Mathematics (STEM) research. High-altitude maneuvering lighter-than-air platforms such as HAB uses the principle of buoyancy to take advantage of this region and became potential platforms for ISR, precision navigation, environmental monitoring, communication relays, missile warning, and weapon delivery. These vehicles can provide persistent coverage over large areas of the earth's surface with a substantially lower cost than an earth-orbiting satellite, while providing longer loiter times and larger ground footprints than conventional aircraft.

HAB systems have a fairly standard configuration involving a latex balloon, parachute, reducing ring, and command module. Figure 1 below is a schematic of a typical HAB stack. The command module is a capsule that contains the tracking and communications equipment necessary for tracking and recovering the balloon system. It also contains cameras for recording images during flight and a microprocessor for operating the various systems onboard. Studies indicate that it is important to focus on systematic, integrated technology research and design approaches such as a HAB system as an educational tool for undergraduate STEM curriculum [1]. By developing students' instruction around a laboratory setting, and using a systematic design and research approach throughout a project, students can fully conceptualize and understand an engineering system. This approach fosters student engagement and creativity by enabling them to learn science and engineering in a tangible context as opposed to simply a theoretical or computational modeling approach. This systematic research and design approach is in line with an engineering education movement that emphasizes integrated engineering curricula that challenges undergraduate students to form connections between current technological topics and their applicability to societal needs, as well as to envision future challenges in the engineering profession.

The HAB system allows a student to: (a) attain a higher level of competence in STEM; (b) understand the complex industry standards and methodologies for a design; (c) make judgments regarding technical and ethical matters pertaining to a design; and (d) communicate and work efficiently in a diverse research teams from different engineering backgrounds. The main objective of HAB experiences using STEM principles is to inspire the students in research, design, and project management methodologies, e.g., problem identification, literature survey, critical thinking, problem formulation and solving (analysis, simulation, validation, data analysis, implementation, and empirical evaluation), communication skills, documentation, management of resources and budgets, keeping up with the deadlines, independence, collaboration, and participation in a diversity setting. Involvement in a student-focused integrated holistic program will help students to re-conceptualize their view of engineering in a context which addresses societal needs that are driven and influenced by the global market place for engineering services of the future [2].

3. HAB PROJECT MANAGEMENT

The HAB program in CECS of WSU comprises of 4 to 6 undergraduates, one graduate student and 4 faculty mentors. These mentors have various research backgrounds spanning from computer, electrical, engineering education, industrial, materials, and mechanical engineering to accommodate the students' academic needs. Table 1 shows the year round timeline of the WSU HAB project team.

There were multiple tasks that needed to be completed to make the project a success. The first was designing a command module that would withstand extreme environmental conditions and transmit GPS coordinates to aid the team in recovering the payload once it had been launched. Other tasks include designing a balloon filling mechanism, choosing how to connect the payload components together, choosing balloons, gas, and parachutes to use, constructing a gas tank transport crate, creating pre-launch and launch procedures, and decide the initial experiments to be performed.

The first step in the project was to assemble a team and brainstorm on the approaches and experiments to be performed. Some of the experiments proposed for the project were solar cell studies of voltage and current at high altitudes, guiding the payload to land in a desired location, achieving high bandwidth communication with the ground, obtaining temperature, pressure, and humidity measurements during flight, and taking pictures from the payload. A timeline was then set for the completion of tasks, and duties were assigned to team members.

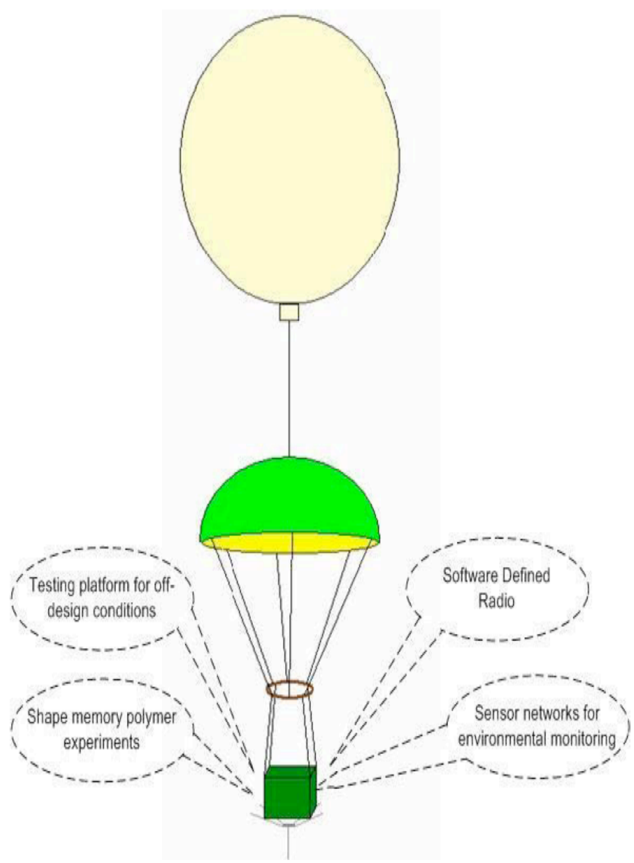
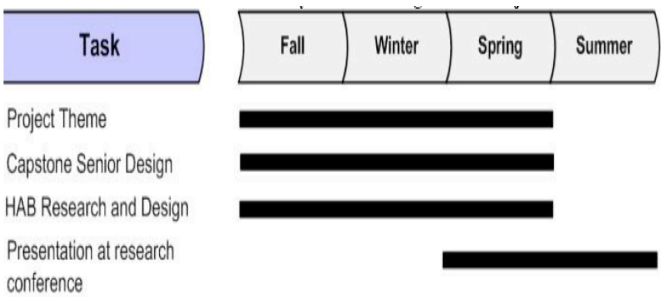


Figure 1: High Altitude Balloon System

Table 1: Year-round cycle of the HAB project



Once the group came to a consensus concerning the desired outcomes of the project, research began to determine the optimal process to follow. Presently, there are many simpler projects being done by an Explorer Post affiliated with NASA Glenn Research Center. Exploration of these projects gives students an essence of what they could pursue towards their project. Each group designs and performs experiments and builds off of other groups' successes and failures. This communication and sharing of information rather than being in strict competition allows future projects to evolve and to be more successful.

There were a number of design constraints in constructing and launching a payload. The first regulations that needed to be considered were outlined by the Federal Aviation Administration (FAA) Title 49 US Code 14 CFR part 101. The operating environment limited the way the payload could be built. The box needed to be lightweight, yet strong enough to take the impact of hitting the ground with the velocity dictated by the parachute. The walls of the payload also needed to be a thermal insulator in order to keep the inside of the box at an acceptable temperature for the electronics. This meant that a process had to be used to make the insulating material stronger and heat transfer involving conduction, convection, and radiation on all sides of the box needed to be considered.

4. MENTORING

The support structure for the participating students includes faculty and graduate student mentors whose role is complicated, multidimensional as their primary responsibilities involve the overall administration of the HAB program, supervision and management of activities for the project. Due to the wide scope of their responsibilities, they need to be individuals with a unique set of skills and abilities that include broad knowledge of STEM fields and appreciation and valuing of diversity, so as to serve as "champions of change" [3]. These mentors have developed skills in interdisciplinary research and education, and also served as spokespersons for the program, emphasizing its focus on competence and its contribution to the advancement of engineering education.

These mentors are aware that that one key strategy in recruiting and retaining students in STEM disciplines is peer mentoring. To accommodate this method, students are required to participate in workshops/seminars during the senior design course and learn about STEM issues while at the same time developing a good rapport with the professors and individuals from the industry. This helped towards a) enhanced communications skills in the students; b) increased knowledge of contemporary issues; c) increased ability to function in a multidisciplinary team; d) understanding professional and ethical responsibilities; f) networking to secure jobs and find mentors for their further career. This method provided a benefit to the participating faculty by enhancing their rapport with the industry to seek more projects.

5. PROJECT TIMELINE

At the beginning of the academic year, faculty mentors delivered a presentation on a few design projects that might be of interest to participating students. Students were given one week to choose from the existing project or formulate a new project to embark upon. During this time, faculty and graduate students worked closely with the seniors to help them identify a project that suits their interests and primarily, requirements of the industry. With the project identified, it is assumed that students have taken necessary courses to match the technical aspects of the design project. Throughout the duration of the program, students met the faculty mentors and graduate student once every week to discuss the progress and plan the week ahead. By the end of fall quarter, the participating students were required to have had attempted a HAB launch and give a preliminary presentation on their respective standing in the project, including future launches. During the winter and spring quarters, students worked on a specific topic of research. At the end of the spring quarter, the students gave their final presentation to fulfill their senior design project requirements.

6. CULTIVATING ETHICS AND PROFESSIONAL STANDARDS

Through the HAB educational model, students learned the importance of making engineering decisions that are consistent with engineering design safety and maintaining the welfare of the public. In the HAB project, some problems that students encounter address ethical issues such as adherence to FAA regulations, management and selection of safe radio frequency range for communication, etc. Students were involved in a technical writing course to help them with their writing and publication of their HAB project. In this technical writing course, students discussed ethical issues such plagiarism, referencing and learning how to differentiate between their contribution and prior knowledge. The HAB students were also encouraged to take EGR 482: Engineering Fundamentals to prepare for the Engineer-In-Training (EIT) state exam (the first step towards becoming a licensed professional registered engineer). In this course, students learn the code of ethics for engineers as described by the National Society of Professional Engineers.

7. LEADERSHIP, SERVICE LEARNING, AND CIVIC ENGAGEMENT ACTIVITIES

The service learning and civic engagement component in a project must involve a relationship to the theory and practice of the academic discipline and student reflection through community outreach or service [4]. The service learning and civic engagement and civic engagement activities address the context within which engineering education must help students in addressing professional, geopolitical, economical; and societal needs in the future [5]. Some of the needs are diversity initiatives and role models in the STEM fields from the Wright STEPP, pre-engineering program where majority of students come from underrepresented groups and disadvantaged backgrounds.

Relation to the theory and practice of STEM principles involved the participating students teaching HAB principles to the Wright STEPP pre-engineering program. One of the mini projects developed to aid in this process is the weather balloon system. Similar to HAB system, the weather balloon system is an integrated technology project that encompasses multiple STEM principles. The hands-on activity for the Wright STEPP students on this project involved soldering components onto a printed circuit board; calibrating and testing the system for optimal functionality; launching the system and analyzing data received during flight to study the temperature profiles in the atmosphere.

8. TECHNICAL AND PROFESSIONAL DEVELOPMENT

In the HAB project, students participated in weekly lectures, seminars, and workshop aimed at enlightening them in issues and activities related to the engineering profession. One of the most difficult endeavors in the engineering curriculum is encouraging students to develop creative, independent thought and a deep level of understanding [6]. One major goal in this HAB program is to prepare students for the engineering profession. Through the HAB experience, students focus on learning about independent research and design methods such as conducting literature review to research a HAB topic, writing a technical manuscript for group presentations and publication in an archival and conference proceedings. The HAB participants were required to attend at least one professional meeting and present their research work to gain confidence in public speaking and have a better understanding of the professional environment.

9. CONCLUSION

As a part of senior design class, all students wre required to participate in background research, design, integration, testing, and documenting the progress of the project. While working on HAB project, students got the opportunity to work with students from other disciplines. One essential aspect students learned is effective communication of technical concepts and ideas to students from a different department. The most valuable experience students gained from the interdisciplinary project is development of teaming skills required to work in the real-time projects, where individual engineer rarely works alone on a project. Through working on this real-time project, students not only enhanced their technical skills, but also their interpersonal skills to work as a team, and were able to improve their intellectual self-confidence.

Some of the potential projects the future HAB teams will work on are a) relaying real-time still and video images to ground as a surveillance mechanism; b) stabilization mechanism to counter the forces acting on the command module during flight, thus creating a platform for science experiments; c) a self contained fuel cell system that could power the whole HAB system allowing for longer duration flights.

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