High Altitude Design Project and Its Potential Impact on Interdisciplinary Undergraduate Education, Final Report

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0.1 Project Summary

The College of Engineering and Computer Science (CECS) is fostering improvement in undergraduate engineering curriculum via an adaptive, innovative, and interdisciplinary senior capstone design project program developed to meet the critical changes in technology, society, and the future of engineering. Based on the literature survey [1–6], the engineering education profession must adapt by:

1. Cultivating innovative characteristics such as cognitive and analytical skills, ingenuity, and creativity to prepare future engineers to be global citizens and leaders in business and public service

2. Addressing the context within which engineering education must train students to anticipate and address professional, geopolitical, economical, and societal needs

3. Understanding how the evolution of technological advances will impact the world and the engineering profession in the future.

These actions are the principles upon which the High Altitude Balloon program is based. This exciting program requires collaboration between students from diverse engineering fields, including mechanical, materials, electrical, and computer science, to research, design, construct, launch, and track a High Altitude Balloon (HAB) system. The HAB senior design program stimulates learning about complex engineering systems and enables students to accomplish these important engineering skills:

- wireless communication
- design a balloon filling mechanism
- solar radiation studies
- flight path prediction and aerodynamics
- control system design
- wind data studies
- data analysis for computing
- shape memory composites
- payload material design
- develop a balloon tracking system
- heat transfer analysis
0.2 Project Description

Expenditures from the Teaching Enhancement Grant can be broken into 3 categories:

1. Senior Design - Deployment of a Shape Memory Composite Truss (Section 0.2.1)

2. Senior Design - Development of a New Command Module (Section 0.2.2)

3. Infrastructure - Parts and components to improve the lab infrastructure for future efforts. (Section 0.2.3)

0.2.1 Deployment of a Shape Memory Composite Truss

A launch of the completed truss was performed on July 27, 2008. Details of the educational experience is conveyed in the attached paper by the student team members [8]. That paper one second place in the American Society of Engineering Educators North Central Section Conference as a student paper.

Upon locating the payload post-launch, it was found that the parachute had broken free from the payload. This means the payload likely returned to the ground at terminal velocity from 87,000 ft. The payload survived and the beacon was still active which allowed us to locate the payload approximately 15 minutes after entering the surrounding area (of course this was easy since fortuitously it landed in the middle of the only harvested field around). The experiment during this launch was the deployable truss. Due to the belief that the over-inflated balloon caused the premature rupture during the last launch, and the fact that we put more helium in this balloon, the truss deployment initiation altitude was changed from 70,000 ft to 35,000 ft. Unfortunately, the truss did not deploy and we were unable to get pictures, above approximately 5,000 ft, of the “non-deployment”. This was not a total loss however as there were some valuable lessons learned as documented on the website.

Successes include communication of the flight and experiment status during flight (as opposed to having to view logs after recovery), providing real time information for the first time. Further, hardening of the electronics and communication systems proved successful in that all systems continued to function even though the parachute failed, dropping the payload to the ground at terminal velocity.

Students responsible for experiment learned or applied:

- Ground testing
- Heat transfer
- Power management
- Structural analysis
- Mechanism design
0.2.2 Development of a New Command Module

A new command module was designed and implemented by Electrical Engineering senior design team. Specifically, this command module includes GPS receivers, controller, and communication components. The controller reads the serial GPS string, then parses the string to obtain: (1) time, (2) satellite lock status, (3) altitude, (4) position, (5) ground speed and (6) heading. The controller next formats all the data into a readable string, sends it to the Kenwood TH-D7A transceiver to be transmitted to the chase vehicle and ground station.

The telemetry data is obtained through the use of a specially designed communications controller. The communications controller is responsible for obtaining the altitude, speed, position, and heading data from a GPS unit, storing it, and relaying it to a radio transceiver. Once the data is sent to the radio, it digitally transmits the information via the 2 meter (144.000 – 148.000 MHz) amateur radio band.

Two communications controllers have been designed. The first generation controller is based on the Parallax Basic Stamp. This controller provides limited data logging and sensing capabilities. It is currently being used on the HiBal missions. The second generation controller is based on the WildFireMod micro-controller from Intec Automation. This is a Linux based system with expanded data logging and sensing capabilities.

The BASIC Stamp Communications Controller was developed under the efforts of the 2005 Senior Design Team. This first generation communications controller gathered the GPS telemetry data at a rate of 1 Hz. Logging the telemetry data was limited to once every minute due to the limited on board memory of the BASIC Stamp. The telemetry data was sent out via a Kenwood TH-D7A hand-held radio at a rate of once per minute. The BASIC Stamp Communications Controller has only 2 external sensors – the GPS sensors, and a temperature sensor. This is due to limited handling capabilities of the BASIC Stamp.

Upon testing the previously existing controller, erratic behavior was observed. The time taken to acquire the GPS data was inconsistent. Times up to 4 minutes were observed. When the GPS data was gathered, it was often garbled, and erroneous. While troubleshooting the unit, an uncharacteristic signal was observed on an oscilloscope. The shape of the RS-232 communications
signal was not a normal, sharp square wave. Instead, the leading and falling edges of the signal looked much like a typical RC signal. This behavior caused errors on the serial communications side of the BASIC Stamp.

Another problem cropped up during the May 2008 launch. It is believed that during the descent, possibly when the balloon burst and the parachute deployed, the battery for the BASIC Stamp became detached. This loss of power prevented any more telemetry transmissions. Luckily a back up system was in place, and the payload was recovered.

Due to observations made by the HiBal team and a desire for more data, a more capable communications controller was in demand. This led to the development of the Linux-based Communications Controller. This controller is based on the WildFireMod board manufactured by Intec Automation and features expanded memory, serial ports, ADCs, and a faster processor. These features are beneficial for the following reasons:

- Expanded memory allows for more data points to be taken, resulting in more accurate telemetry data. A better “picture” of the balloon’s flight can be formed from the increased data.

- Additional serial ports provide convenient connections for any RS-232 device. Currently, one serial port is being used for GPS data acquisition.

- Analog-to-Digital Converters allow for easy interfacing to analog sensors, such as accelerometers, pressure sensors, temperature sensors, and humidity sensors.

- A faster processor allows for increased computing capabilities and more complex processes can be performed.

The Linux-based Communications Controller is based on Intec Automation’s WildFireMod microcontroller. This microcontroller runs µC (shorthand for micro-controller) Linux. By using a Linux-based system, handling multiple processes at once becomes much easier. Also, a Linux-based system makes file handling a much simpler task. Specifications of the Intec Automation WildFireMod board are:

- 64MHz Freescale ColdFire MCF5282 Microcontroller
- 512K fast on-chip FLASH EPROM
- 64K fast on-chip SRAM
- 4 MB flash memory for program storage
- 16 MB fast SDRAM for program execution
- Up to 1GB removable SD memory card (for non-volatile storage)
- (8) 10 bit ADC ports, with 140 kHz sampling rate
• 16 I/O pins
• 3 Serial ports
• LCD/Keypad Interface

The Generation II Communications Controller has been fully tested on the ground to verify proper function. This new communication controller will ensure that it is a reliable upgrade to the existing BASIC Stamp Communications Controller.

0.2.3 Infrastructure

Third and most important group of expenditures was on the establishment of the WSU amateur radio station. The station will be capable of transmitting and receiving in the amateur 144 MHz and 444 MHZ at 1500 kW power (1/3 of a typical strong AM radio station). The station will provide a permanent resource for the HAB team for communication with distant teams during launch and recovery, although this will only be within a 25 mile radius of the university. The greatest benefit will be the ability to control the balloon remotely (commanding execution of experiments and recovery systems) as well as receiving data from the balloons. Currently our installed systems are only able to receive very limited data during flight, such as temperature or altitude/location data. With the tower for receiving, we will be able to receive streaming video from the balloon over hundreds of mile radius while in flight.

This video will allow us to assess the condition of the experiments during flight and make command/control decisions. Further, we will be able to switch between cameras (using cameras purchased before this grant) during flight to investigate the most interesting parts of the flight. It is hoped that we will have sufficient success to not only provide live streaming video over the web during flights, but that we will be able to encourage local TV stations to broadcast video, live or otherwise, from WSU flight experiments and thus increase WSU visibility in the region.

Funding for this was leveraged to obtain funding from Ohio Space Grant and professor Wu to complete the project. In working with multiple sources we now have the infrastructure to not only support an amateur radio club that augments the High Altitude Balloon Team (although significant overlap in membership exists), but also can be used for EE students for purely radio based senior design projects and thesis work.

Because of additional funding from NASIC, installation of the tower on the Josh Center is being delayed to make sure that the design, including conduit installation, cable installation, roof penetration, and antenna placement, is selected to provide the greatest potential for growth possible within available funds. Equipment purchased with this grant is being tested and assembled by this year’s HAB team EE senior design students with assistance from the ME students.
Other purchases made in infrastructure were described in the original budget (parachutes, helium, balloons) to ensure that the project wouldn’t run out of supplies leaving the other infrastructure unusable as well as ground tracking systems (GPS navigation systems linked to the digital position reporting network) that allow multiple vehicles to obtain real-time position information and navigation instructions. The systems also enhance team communication during the recovery process. Timely payload recovery subsequent to landing is important to assure that additional damage (whether through weather, vandalism, theft, or simply sinking in water) does not occur.

0.3 Major Outcomes of this Support

Numerous positive outcomes resulted from this support, without which most would not have been possible, and some would have been unlikely:

- Co-sponsorship for WSU Amateur Radio Club station: $3000 was cost shared from on PI’s (John Wu) account, and an additional $6000 of sponsorship is being provided by the Ohio Space Grant Consortium. Additional funding (yet to be determined) from NASIC for a parallel educational activity.
- Award of an NSF CCLI for $147,586.
- Inclusion as a proposed sub-contractor for near space experiments by ILC Dover in a proposal to DARPA for the Rapid Eye program. We will be a sub-contractor to ILC in the next round.
  - ILC Dover has a history of design work in space (for example, supplies space suits to NASA).
  - Rapid Eye is a DARPA program to provide high altitude, long endurance surveillance platforms anywhere in the globe within 2 hours (http://www.darpa.mil/ucar/programs/rapideye.htm).
  - Our rate of recovery to date exceeds commercially available options at a fraction of the cost.
  - Attraction of funds from NASIC to install a satellite tracking system on the roof of the Russ Center for use by EE students.
0.4 Summary

The Teaching Enhancement Grant has directly caused the WSU HAB program to take a step to the next level. Support has enabled significant additional collaborations and opportunities beyond our wildest expectations (Section 0.3). The team of faculty are now trying to leverage these opportunities to move the program beyond a nationally recognized High Altitude Balloon program to a nationally recognized educational center of excellence through and NSF phase II and further collaborations at the national level. The WSU HAB Team is grateful for the faith placed in us via this funding that enabled the rapid growth of this program.
Bibliography


