THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE
Department of Electrical and Computer Engineering

CPE 495 Fall 2015

GAMBLS: Interim Report

Due date: 12/07/2015

Project Summary

This project's goal is to develop a rocket payload for USLI rocket. Data from sensors including accelerometers, gyroscopes, magnetometers, and atmospheric pressure sensors will be recorded at approximately 1 kHz rate on-board. This data will be transmitted from the rocket to a ground station during flight and will also be stored on board. All data will be available post-recovery for download. The sensors will include a pitot-static system incorporated into the rocket nose cone to measure velocity. This payload will begin collecting data at launch and continue gathering data until reaching apogee at 5280 feet. A ground-based system capable of in-flight processing of transmitted data and post-flight processing of high-fidelity information will also be developed.

Team Description

Jason G Renner - Project Manager

Patrick R Williamson - Software development

Michael A Bizanis - Hardware Development

Tin T Tran - Test Master

All of the members of our team have similar experience with electronics. We have all taken the embedded systems class for programming microcontrollers and have taken circuits classes. However, none of the team members have built rocketry items or created their own circuit board before, so we will be spending considerable time learning. The main areas we lack experience in are circuit board design, surface mount soldering, and Atmel Studio programming. We have gained experience in surface mount soldering by creating the power boards with the help of John Jetton. We have also become more familiar with Atmel Studio as we study the code from last year's senior design team. During the next semester, each member of the team will have to continue learning more about Atmel Studio, and learn how to design boards using Eagle.

If one our members is unable to finish the project, we will still be able to finish the project because we all have generally the same amount of knowledge regarding this project. However, such a situation would greatly increase the workload for the remaining three people.

Introduction

The USLI project is a competition sponsored by NASA to see which team of university students can create the best rocket which meets a range of requirements. Our requirements as the CPE team are to design a payload which meets the requirements of our customer, Jason Winningham. The College of Engineering at UAH is sponsoring the USLI team which we are a part of. These requirements were obtained through talks with the team leader for the UAH USLI team.

Marketing Requirements

This payload has the following requirements:

- Shall operate under the under the rigors of flight
- Shall operate effectively for multiple launches
- Shall be able to idle on the launch pad for up to forty-five minutes and still be able to operate during flight
- Shall store data on the rocket and transmit data to a ground station
- Shall take data from an accelerometer, gyrometer, magnetometer, and atmospheric pressure sensor and have the capability to add more sensors

Engineering Requirements

The payload must contain the following instruments:

- 3-axis accelerometer (3 channels)
- 3-axis gyrometer (3 channels)
- 3-axis magnometer (3 channels)
- One pressure sensor for ambient pressure (up to 15 psi)
- Develop a way to synchronize data between multiple copies of this payload in order to compare events between payloads.
- Five additional channels of data which may be used for sensors chosen by the USLI team
- Minimum 500 Hz sampling rate
- Sensors and five additional channels must have a 12-bit minimum resolution
- Capable of making 5 voltage measurements (0 - 5 V) at up to four feet from the payload.
- Noise tolerant digital or differential analog signaling required for the five additional channels and any other signals traveling more than five inches
- System shall provide a minimum of 1W power to sensors and associated support components (e.g. ADCs, bus transceivers) for remote sensors
- Capable of operating under a 50g acceleration loading

- Capable of operating under vibration experienced during a rocket flight.
- Have a means of confirming operational state when the rocket is on the launch pad
- Have a means of powering on and off via an external switch when the payload is in the assembled rocket
- Must be capable of being integrated with the rest of the rocket, powered up, and operational within 45 minutes
- Must be ready for re-flight (new batteries installed, data transferred to ground station, and empty memory) within 45 minutes
- Capable of operating for up to one hour in the powered up (standby) state on the rocket pad
- Capable of fitting inside of a 3.5-inch cylinder with a 4 inch height
- Weigh under 1 kg
- contain an independent power source (i.e. not require power from other systems in the rocket)

Background:

In general, the package on the market is large, heavy, and expensive. The market packages are always have unnecessary features or lack of features for our needs.

For example, R-DAS (http://www.aedelectronics.nl/rdas/) has inadequate data rates and sensors, but it is lacked of RF transmitter. BigRedBee (http://www.bigredbee.com/) has GPS with RF transmitter but lacking of other sensors.

Our customer has specialized the requirements for the package, and we cannot find find any built solution package for them. So we decided to build our own circuit board to meet all requirements from our customer.

Trade-off Analysis of Design Alternatives (patrick will do this)

We initially planned to use an Arduino board to utilize the sensors, but the board did not have the amount of storage space required to hold the sampled data. We next looked at the Raspberry Pi board, which had the option for a micro SD card, which solved the storage space problem, but the operating system that was on the board was not fast enough to support the sampling frequency we are aiming for. We eventually settled on redesigning the boards used by previous teams that worked on the same rocket payload project in the past. Since the previous team had different requirements for the payload, we will be redesigning it to fit our needs. With the redesigned board, we will be able to include components that we will need to realize our goal, with adequate storage space, as well as a high enough processor speed to handle the sampling rate.

Response to Feedback

After project proposal, we had a lot of feedbacks from our professor, students, and guest. All feedbacks are very helpful for our team to realize how hard this project is, and how much work need to be done for this project. we took advice that we contacted previous UAH teams to take advantage of “lessons learned” from them.

All feedbacks for our alternatives designs which is we was going to use Raspberry Pi 2 and breakout board sensors to collect data. all those feedbacks helped us come up with proposed approach solution for the project which is create our own circuit board, develop working software and hard from previous team, and coordinate with MAE team to evaluate payload during the test launches.

We came up with this solution because the Raspberry Pi has a realtime operating system which will slow down the process of taking data which will not meet our requirement sample rate. In addition, all breakout board sensor are design for prototyping, not finish, and the Micro SD card are know failure points-data has been lost on multiple flights due to the inherent unsuitability of SD to a dynamic physical environment.

Global/Societal Impact of Project

The environmental impact of the GAMBLS payload itself will be negligible. The payload weighs less than two pounds, generates no noise, and runs on very little power. The rocket itself will have more impact as it creates considerable noise but does not create waste. The lifecycle of the GAMBLS payload could last up to 2-4 years before it makes sense to develop a new payload with more up to date sensors. Given the amount of circuitry in the payload it makes sense to recycle it in a manner similar to recycling cellular phones.

Security is not an issue with the GAMBLS payload because it does not transmit through a network. It simply transmits data that any receiver could read. However, this data could not be repurposed for malicious use at this time. The payload has very limited capabilities.

It is possible for the GAMBLS payload to experience inter-operability issues if the design of the rocket changes so that the payload will no longer fit. Additionally, if someone wishes to add or remove sensors from the 5 additional inputs we have left open, that person will have to write new code to determine how that data is interpreted. Finally, adding more than 5 new sensors will require the entire design of the circuit board to be changed at which point it would make more sense to design a whole new payload.

Personal privacy was not considered in designing the GAMBLS payload. The goal of the payload is transmit and store high-fidelity data for whoever wants to receive it. Anyone who receives the data must also figure out how to interpret it. Considering that this payload will only be used for non-military flight data transmissions, it is safe for this data to be public knowledge.

The main safety issue for our product is the LiPo battery. Abrasions of the battery's surface could cause it to spark during flight, creating a fire. To protect the battery, we have encased it between the power board and the sensor board with a layer of foam around it. There are few safety issues in the development of our product because it is low voltage. The biggest danger may be getting burned by a soldering iron.

Our product is not marketed and exists purely for the use of UAH. It conforms to FCC regulations and does not violate any patent laws.

This design is focused more towards hardware than software. The reason we have to build the payload from the ground up is because other microcontroller systems available for data collection to not sample fast enough. We thought about using a Raspberry Pi or Beaglebone, but their hardware simply isn't powerful enough. Therefore, we are focusing on creating hardware first, and then writing software to match the hardware.

Test Plan

Requirement Number	Verification Requirement	Success Criteria	Verification Method
P1	Pitot Probe Measurement	Sample atmospheric pressure at 500 Hz up to 15 psi	Test Launch
P2	Acceleration Measurement	Sample rocket acceleration at 500 Hz up to 50g	Ground Test
P3	Rotation Measurement	Sample rocket rotation at 500Hz up to 2000 dps	Ground Test
P4	Magnetism Measurement	Sample magnetism around rocket at 500 Hz up to 12 gauss	Ground Test
P5	Data Stored to Flash Memory	Flight data can be recovered through USB download	Ground Test
P6	Data Transmitted to Ground	Flight data is transmitted to ground after apogee	Test Launch

Unit Tests

Verify Embedded System correctly changes states

Retrieve Non-volatile data from Embedded System

Test wireless communication via subscale rocket launch or alternative scenario

Integration Tests

Test the wireless state controls from Ground Station

Verify packet retrieval at ground station and process data

Acceptance Tests

Dedicated MAE Team decides acceptance testing.

CPE 495 Go/No Go Milestone(s)

Our milestone was to take data from the pitot board using an arduino. We have had partial success. We have connected the pitot probe to an arduino and are receiving data, but do not know how to interpret it. At this point we have been able to get the Tracker working and getting data through RF transmitter to Hyperterminal or QT Ground station. In addition, we finished soldering 3 RF/Power Board and we are still working with designing the sensors board and modifying the Pitote probe board with another ADC or use different sensors.

With our knowledge at this state of the project, we believe that we can delivery this project on time for the final launch on April.

On the Spring semester, we will try to finish the sensors board design and soldering it in a month of January. We will working on embedded code and testing device on February.

CPE 496 Course Team-Specific Deliverables

At the end of CPE 396, the team will able to deliverable two finished GAMBLS packages with working embedded software and provide a specific schematics, and software for ground station.

The GAMBLS package will be included:

- 2 x RF/POWER Boards
- 2 x SENSOR Boards
- 2 x PITOT PROBE Boards
- Finished embedded code for the system.
- Ground station Receiver

CPE 496 Project Work Breakdown Structure and Base Line Project Schedule

January 6-15
- Design Sensor Board, Order Parts
- Critical Design Review

January 20-29
- Parts Arrive?
- Begin ARM embedded Code

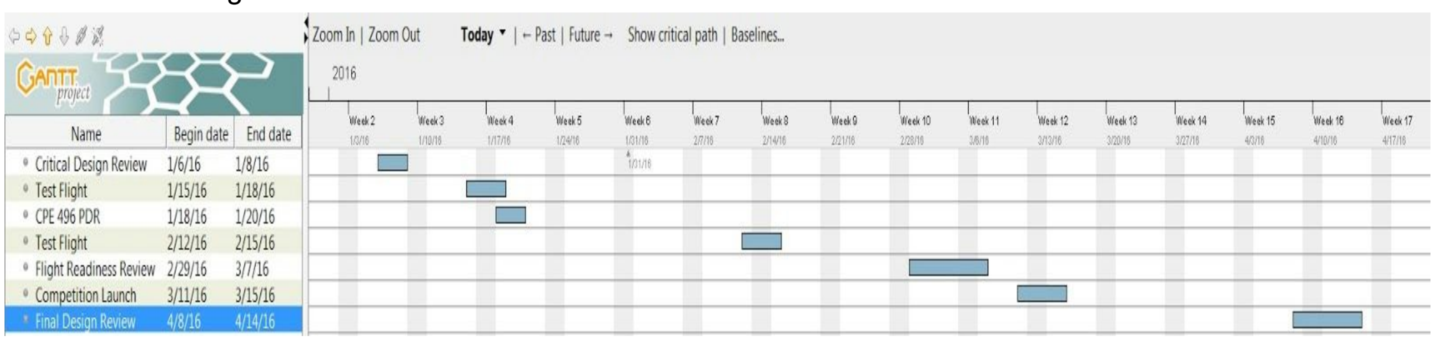
January 30-February 11
- Finish Software

February 12-14
- Payload Test Flight

February 15-March 10
- Correct Software Problems
- Acceptance Tests

March 11-14
- Flight Readiness Review

March 15-April 14
- Final Design Review



CPE Professional and Ethical Statements of Responsibility

The GAMBLS payload team hereby reaffirms their commitment to the good of this project, and pledges to adhere to UAH's ethical responsibilities throughout the CPE 496 project.

CPE 496 Project Cost Evaluation

Type	Item	Cost ea.	Qty required	Total Cost
Microcontroller	Atmel ATSAM-4S	6.17	2	12.34

Accelerometer, 3-axis, ± 100G	STMicroelectronics H3LIS331DL	10.96	2	21.92
Accelerometer, 3-axis, ± 12G	STMicroelectronics LIS331HH	5.37	2	10.74
Barometric Pressure / Altimeter	Measurement Specialties MS5607-02BA03	5.42	2	10.84
Flash Memory IC	Spansion S25FL256S	3.44	4	13.76
Gyroscope, 3-axis	Bosch BMG160	6.25	2	12.50
Magnetometer, 3-axis	STMicroelectronics LIS3MDL	1.79	2	3.58
ADC, 4-channel	Maxim Integrated MAX11060	6.48	2	12.96
GPS Module	GlobalTop Technology FGPMMOPA6H	29.95	1	29.95
Radio Module	Xbee Pro S3B 900HP	39.00	2	78.00
LIPO Battery, 2000 mAh, 3.7V	MIKROE-1120	13.51	2	27.02
LIPO Recharging IC	Microchip MCP73831T-2ATI/OT	0.76	2	1.52
Battery Fuel Gauge	Maxim DS2782E+	7.46	2	14.92
3.3V Regulator	Micrel MIC5219-3.3YM5 TR	1.54	2	3.08

60 PSI Pressure Sensor	Honeywell NBPDLNN015	12.32	1	12.32
100 PSI Pressure Sensor	TruStability NSCDANN100	29.91	1	29.91
Passive components (R, C, L, etc.)	Various	30.00	1	30.00
Wires, Cables, Connectors	Various	25.00	1	25.00
Solder Paste	Zephyrtronics SPE-0012	24.75	1	24.75

PCBs, 2-layer, 1 oz copper	Various, 2"x3"	30.00	6	180.00
Antenna, 900 MHz omnidirectional	Abracon APAMS-104	6.00	1	6.00
Antenna, 900 MHz, directional	Data Alliance AYA-9012	21.99	1	21.99
Shielded Cable	http://www.mcmaster.com/#shielded-communication-wire/=tzr1zz	0.42	15	6.30
Structual Components	Hardware			300.00
Ground Component	FTDI Serial to USB	25.00	1	25

TOTAL	
TOTAL	951.72
TAX	85.65
SHIPPING	47.59
Grand Total	1084.96

Conclusions

The CPE 495 project we have chosen is very demanding because of the accelerated schedule and depth of knowledge we must learn. Our most difficult problem has been learning where to start. None of the team members knew anything about circuit board design, surface mount soldering, or rocketry in general. Fortunately, the CRW team along with Jason WInningham have explained many of the aviation aspects. Additionally, John Jetton and Dr. Wells have provided valuable advice regarding circuit board soldering and design along with guidance for the direction of the project.

During 496, we will need to study circuit board design more, as we still must redesign the sensor board, and then write software to control the ARM MCU on the board. I believe the hardest problem next semester will be time. The Flight Readiness Review is due March 14th, at which point the payload must be fully operational. In order to beat the clock, we must get the sensor board designed, and have parts ordered as soon as possible in order to give ourselves the maximum possible amount of time to develop software.

Appendix A: Copy of Progress Reports

Progress Report 1

1) Describe the current state of the project highlighting the progress that has been made since the last reporting period.

- We have been working with MAE team to get all requirements for our part of the rocket. And right now we are working on rewrite the requirements from technical terms to customer terms.
- We are trying to understand the requirements and figure out how to solve the problem.
- We are trying to get the idea of what equipment we need to use to do the job.

2) Identify the major issues or problems that have been encountered.

We have some problems with understanding some of the requirements, but we are contacting them to specify:

- Develop a way to synchronize data between payloads in order to compare events between payloads, i.e., some sort of absolute time stamp

We don't understand what they mean with time stamp. They want the time when we collect the data or the time flight since launch etc. We are still working on this.

- Five additional channels of data which may be used for sensors chosen by the USLI team

After talking to the MAE team, we have decided to simply measure voltages at those 5 channels and work with them more once they MAE team knows which sensors to install on those channels.

- Noise tolerant digital or differential analog signaling required for all signals traveling more than five inches

After talking to the MAE team, we realize they mean is, “not just a wire connection between components” meaning, they want us to use some type of voltage differential or some other method of reducing noise for signals traveling more than five inches, because a simple wire will have too much noise after more than five inches.

We have some trouble with collapse schedule with MAE team, so meeting with MAE team to work on the project is a little bit hard, but we are doing pretty good right now via email.

3) Outline the overall plans for the next reporting period.

- We will decide what brand sensors we will use to collect the data.
- Decide the role of each person in the team
- Trying to have 2 meetings a week for the team.
- Will finish project proposal before proposal day.

Progress Report 2

1) Describe the current state of the project highlighting the progress that has been made since the last reporting period.

Since the last reporting period, we have created a schedule from now until December of which aspects of the project we will work on each week. We have also met with the MAE team to discuss which hardware and software did or did not work last year and what we need to do for the two launches we have during this semester.

2) Identify the major issues or problems that have been encountered.

We were able to find some of the sensor parts online but have had problems finding sensors that can operate under a 50g acceleration load. Using the hardware from last year as a starting point, we should be able to find hardware that works under a 50g acceleration load.

3) Outline the overall plans for the next reporting period.

Before next Saturday (Oct 24), we will finish the Project Management Exercise. On Monday we will try to set up a meeting with Jason Winningham to discuss finding parts.

Progress Report 3

1) Describe the current state of the project highlighting the progress that has been made since the last reporting period.

- We are trying to finish the slides for project proposal presentation, and we are also working on Requirements Specification & Project Management Exercise.
- We had a look at the hardware which was used from last year, and finally we got idea what sensors we are going to look for.
- We attended one class period with MAE team and other payload team.
- List all the part of hardware that we will need

2) Identify the major issues or problems that have been encountered.

- We have some issue with the requirements for sensors, especially accelerometer has to meet +- 50g.
- Gyrometer has to be 5hz
- We have to finish PDR paper for MAE team which are due on 30th
- We don't know hardware that we buy will be worked with 50g acceleration
- Also the safety of the battery in 50g environment will be ok

- We don't know that we need to use 1 or 3 pressure sensors.
- We are trying to make a cool name for our team.

3) Outline the overall plans for the next reporting period.

- Turn in Requirements Specification & Project Management Exercise and presentation slides on 27th
- Practice on the presentation
- Finish PDR paper on time to turn in for MAE team.
- Give the list of parts to MAE to order.

Progress Report 4

1) Describe the current state of the project highlighting the progress that has been made since the last reporting period.

- Successful delivered the presentation
- Turned in Requirements Specification & Project Management Exercise
- Got a final decision for the project, we will design our own circuit board
- Figured out the name for the group: GAMBLS stands for Gyro meter, Accelerometer, manometer, barometer launch system.
- Finished the PDR paper and turned in to MAE team.

2) Identify the major issues or problems that have been encountered.

- We don't know how to build circuit boards, so learning how to build it will slow the timeline for our project.

3) Outline the overall plans for the next reporting period.

- Contact with Dr. Well or Jason to get information about soldering class at ADTRAN to attend.
- Research and learn how to create our circuit board
- Maybe come up with the list of sensors, and all other stuff that we need to use to build entire circuit board

Progress Report 5

1) Describe the current state of the project highlighting the progress that has been made since the last reporting period.

- Finished PDR presentation slides and ready to present on November, 17.
- Got a better understanding about the previous project and each component used
- We decided which sensors, microprocessor, and microcontroller that we are going to use

2) Identify the major issues or problems that have been encountered.

- We are still having trouble with creating our circuit board.
- The data sheets for sensors are very long and take time to understand.

3) Outline the overall plans for the next reporting period.

- We will learn how to solder on Sunday November, 8
- We will Try to finish the embedded code for the pitot probe first to do Milestone

Progress Report 6

1) Describe the current state of the project highlighting the progress that has been made since the last reporting period.

- Finished soldering 3 Power and RF boards
- Dr. Wells Agreed on making the Pitot probe pressure sensors work to do Milestone demonstration.
- Met with the CRW team on Thursday to do analysis on Pitot board
- We practiced on programming AVR microcontroller

2) Identify the major issues or problems that have been encountered.

- Redesigning the sensor board
- Cannot get the data from the tracker through RF

3) Outline the overall plans for the next reporting period.

- Get the Pitot board to correctly take samples from the Pitot probe
- Make the radio transmitter communicate with the ground station

Progress Report 7

1) Describe the current state of the project highlighting the progress that has been made since the last reporting period.

- We able to get information from GPS through RF communication
- Made progress on board design
- Tested existing GUI with RF communication

2) Identify the major issues or problems that have been encountered.

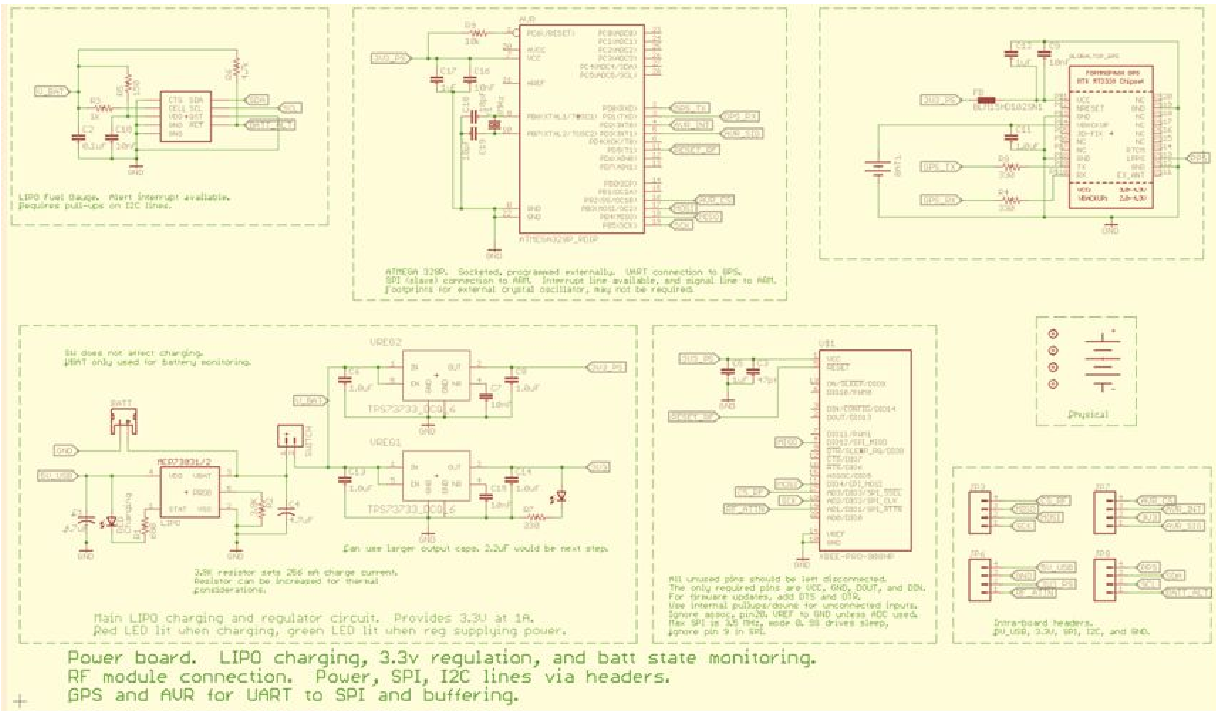
- After talking to members of the MAE team, we may have to use a higher resolution ADC for the pitot board. However, our milestone is still to take data from the current pitot probe design.
- Still learning how to design sensor boards in Eagle.

3) Outline the overall plans for the next reporting period.

- Code for Pitot probe sensor to get data with arduino to do Milestone
- Finish Interim Report
- Going to subscale launch and testing the tracker.

Appendix B: Source Code/Schematic Diagrams (as needed)

Power Supply/RF Circuit Board
Schematic



Pitot-Static Circuit Board

Schematic