# Team Air Mail

## Preliminary Design Review

*2014-2015 Space Grant Midwest High-Power Rocket Competition*

UAH Space Hardware Club Huntsville, AL


Top: Will Hill, Davis Hunter, Beth Dutour, Bradley Henderson, Jordan Teats, Evan Tingley, Bryan Turpin
Bottom: Andrew Miller, Mark Reuter, Warren Buzzard, Stephanie Krueger, Geoff Suiter
Not pictured: Chris Thackston, Thushananth Rajendra

## I. Table of Contents

## II. Executive Summary + Budget

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### Budget

| Item | Amount | Total |
| --- | --- | --- |
| Registration | 400.00 | |
| Hardware | 1,623.00 | |
| Testing | 928.00 | |
| Travel | 9,760.00 | **$12,711.00** |

## III. Nomenclature

- RF – Radio frequency
- CP – Center of aerodynamic Pressure
- CG – Center of Gravity
- ABS - Acrylonitrile butadiene styrene
- CNC – Computer numerically controlled
- IMU – Inertial measurement unit
- MCU – Microcontroller unit
- PCB – Printed circuit board

## IV. Rocket Design

### A. Materials Selection

When selecting the materials that will make up the rocket, the main factors that were taken into consideration were density and strength. Nearly all of the rockets made by the UAH Space Hardware Club are fabricated from carbon fiber or fiber glass, so the team has substantial experience with both materials. Fiberglass tends to be heavier while also providing less structure, so carbon fiber was chosen for fabrication of the rocket body tubes and fins. However, carbon fiber is not RF transparent. This problem was solved by placing the tracker, the only part of the rocket that needs to be communicated with, in the nose cone, which will be made out of 3D printed ABS. This was an easy material to select mainly because it is extremely easy to shape it to the exact form needed using campus resources. Additionally, our team has a great deal of experience flying 3D printed parts on rockets, including tests specifically on nosecones using high-thrust motors.

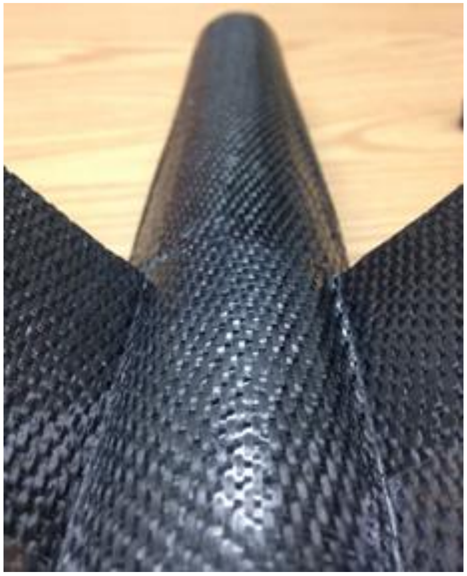


**Figure 1. Booster Prototype** . *This is an early prototype of the booster stage composed of carbon fiber*

### B. Diameter Constraints

The primary limitation the rocket design is the diameter of each stage. Determining the diameter of the booster was very straightforward. The goal is to make it as small as possible in order to apply the most thrust to the dart. This means the booster will be minimum diameter, so the inner diameter of the booster will match the outer diameter of the motor casing, 54mm.

**Figure 2. Dart and Booster** . *These are the first version of the dart and booster with the ABS transition and nose cone pieces.*

Since the dart does not house a motor, the diameter is dictated by the amount of space needed for electronics, the largest piece being two 9V batteries that power altimeters/ejection systems. The considered diameters included 1”, 1.25”, and 1.5” inner diameter tubes. The 1” model had the best performance; however, the electronics were not able to fit in such a small space. The 1.5” diameter had the worst performance, but it is big enough to fit a tracker already developed by the club. Finally, the team decided on the 1.25” body tube with a tracker fabricated in house to fit inside it. During testing, a fairing nose cone with a diameter that would fit the larger tracker the club already owns was used; however, this will be remedied in the final configuration.

### C. Fins

In order to keep the rocket’s flight as stable as possible without any spin, a 4-fin design was chosen for both the booster and the dart. Additionally, the fins will be as thin as possible in order to reduce frontal area and decrease drag. So, by using only three layers of carbon fiber, it is possible to make the fins only 0.050” thick while maintaining appropriate rigidity. Furthermore, rocket simulation software was used to optimize shape for the fins. After finding the theoretical best shape for the fins, it was adjusted for ease of manufacturing.

### D. Electronics Integration

The electronics system in the dart will be integrated via a sled which will be inserted on the flight line. The team will then use one or more remove before flight pins to activate the payload just before flight. The sled for the electronics will be made out of CNC machined aluminum to serve as the holder of the plate that the electronics are mounted on. It will also serve as a bulkhead to protect the payload from the ejection charges. The plate suspended between the two aluminum bulkheads will be composed of fiberglass. It will also be securely attached to the body tube via bolts to keep it from falling out and to provide structure to avoid crumpling during flight.

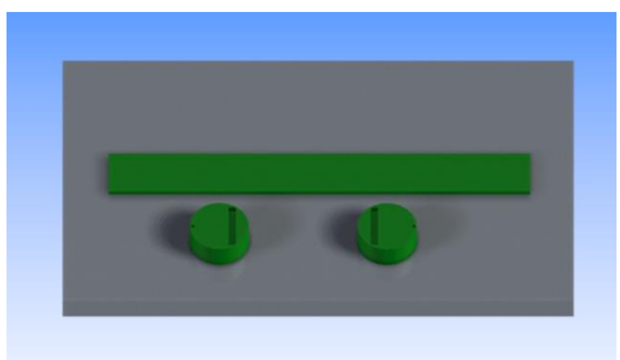


**Figure 3. Electronics Sled Pieces** . *The first version of the electronics sled was printed and looked like this. The final pieces will be shaped similarly but will be different materials*

**E. Descent Control**

Descent control for both the Booster and Dart will be accomplished using traditional parachutes sized appropriately for each, in order to provide a descent rate less than 25ft/sec. The parachutes will be attached to their respective airframes using Kevlar cord, having a length of 2-3 times the length of the airframe which it is attached to and will be tied to eye-bolts secured to the airframes. They will be attached to the Kevlar cord using swivels to prevent the parachutes' shroud lines from becoming tangled due to the airframe spinning during descent.

**Figure 4. Post-Testing Parachute** . *Ground testing of descent control ejection taught us that the parachute needs Nomex protection from the ejection charges*

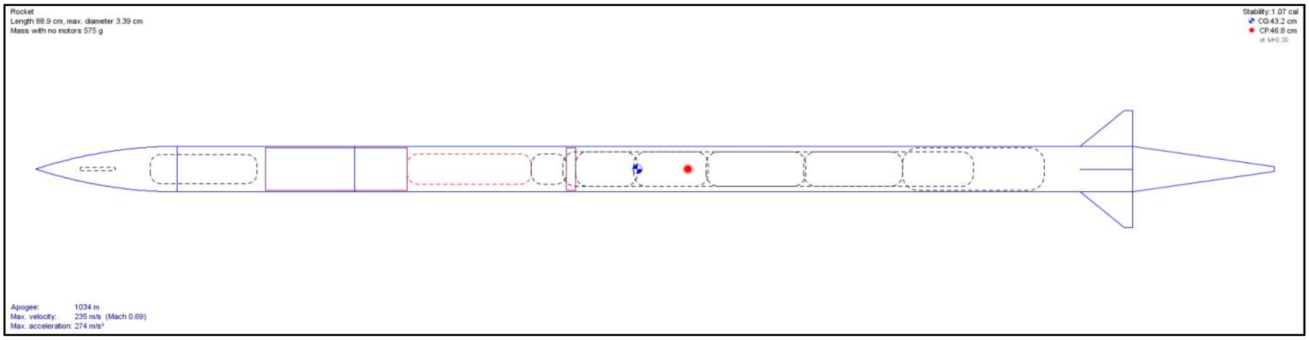
Deployment of the parachutes for both the booster and dart will be controlled by redundant PerfectFlite Stratologger altimeters in each. The Stratologger altimeters were chosen based on the high rate of success the Space Hardware Club has experienced using them and their ease of use when compared to other altimeter options. The primary altimeter on each will be set to fire a deployment charge at apogee. The backup altimeters will be set to fire a second set of deployment charges a few seconds after apogee in case either of the primary altimeters fails.

The type of deployment charge has been designed to provide the maximum amount of pressure to deploy the parachute safely and to prevent damage to the airframe. The deployment charge will consist of sealed black powder ignited by an electric match. The dart will use a maximum of 0.15g of black powder and will endure a pressure force of 37 psi. This will eject the nose cone and recovery system and will allow for a safe recovery. The booster will have a deployment charge of 0.35g of black powder and will endure a force of 32 psi. This is enough force to shear three 2-56 nylon screws and deploy the recovery system. These values were calculated based on the current models and will be adjusted as necessary based on extensive ground testing of the deployment systems.

The use of pyrotechnics is an obvious source of concern regarding damage to the recovery system. The Kevlar chord and airframe are nonflammable but caution must be taken with the parachutes in order to prevent damage and compromise the integrity of the material. In order to mitigate possible damage incurred by the deployment charges, the parachutes will be packed into flame resistant Nomex cloth. This has proved successful in previous, unrelated launches and will be further tested with our design to ensure proper performance of the parachute and recovery systems.

# V. Diagrams

## A. CP/CG of dart after burnout

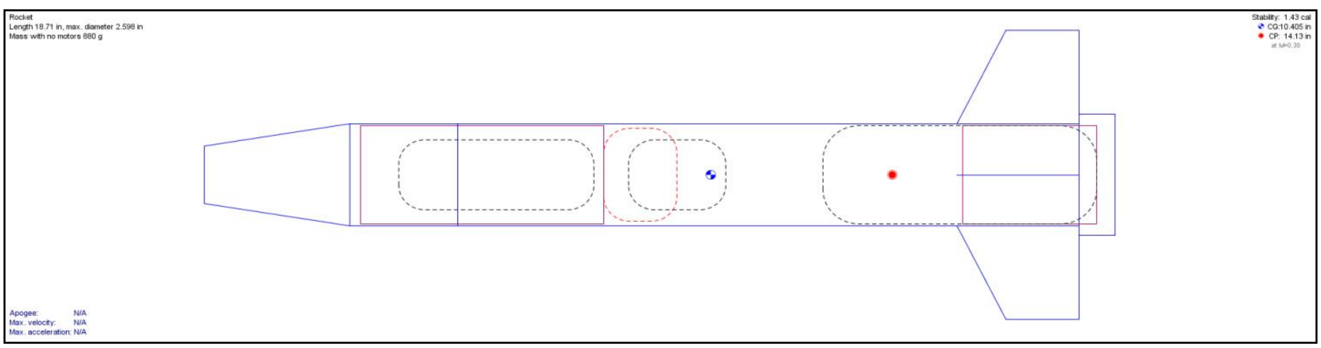



CG: 17 in (from Nose tip)

CP: 18.429 in

Stability: 1.07 cal

## B. CP/CG of booster after burnout

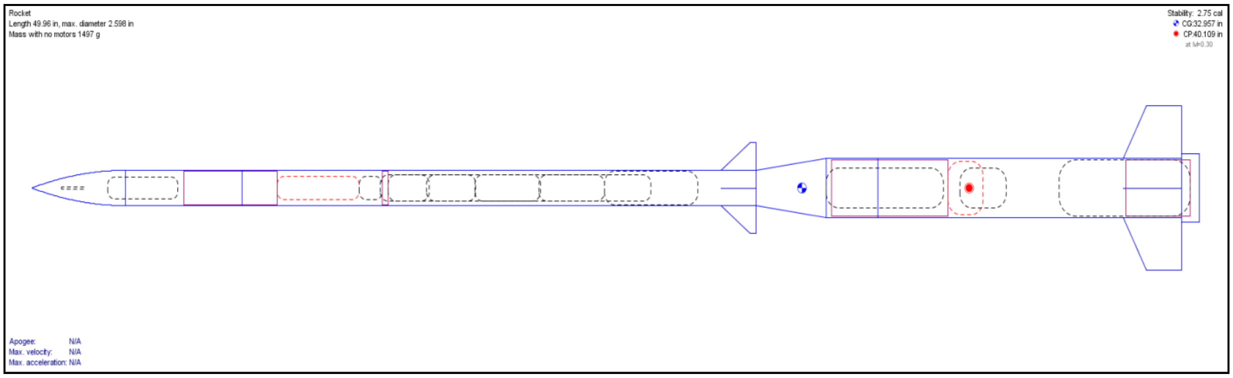



CG: 10.405 in

CP: 14.13 in

Stability: 1.43 cal

### C. CP/CG of combined rocket after burnout

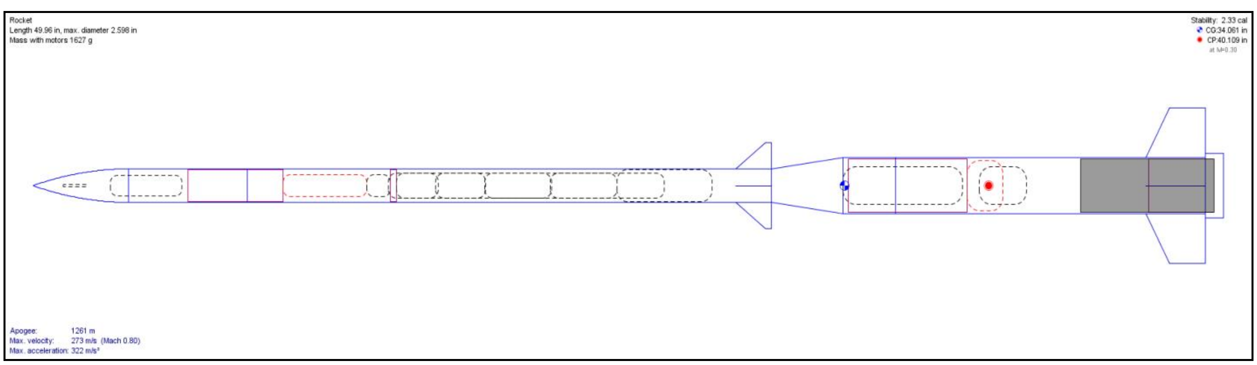



CG: 32.957 in

CP: 40.109 in

Stability: 2.75 cal

### D. CP/CG of combined rocket before burnout




CG: 34.061 in

CP: 40.109 in

Stability 2.33 cal

## VI. Anticipated Performance

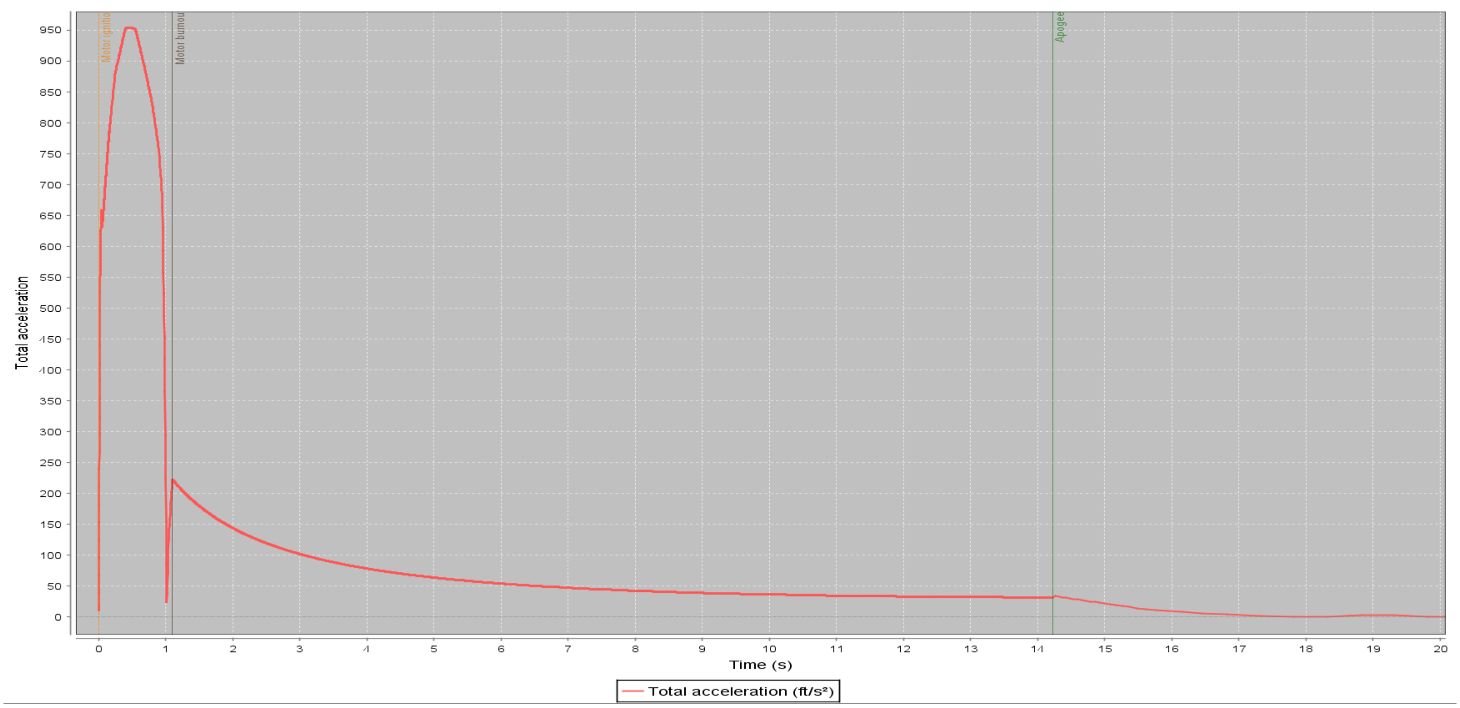
### A. Apogee of Dart and Booster

Upon launch the Dart and Booster will travel together as one rocket system, until motor burnout occurs at which point the Dart will separate from the booster due to the booster having a higher drag force acting upon it. Current simulations show the Booster will reach a maximum altitude (apogee) of about 3,000 feet while the dart is expected to have an apogee of about 6,500 feet. The Booster and Dart will have a separation of 3,500 feet based on current simulations.

### B. Peak Acceleration

The Booster/Dart system will be propelled using the “Vmax” competition designated rocket motor. This will produce a high acceleration that will be applied to both the Booster and the Dart. The peak acceleration is expected to be around $950\frac{ft}{s^2}$, or an acceleration of nearly 30 times that of Earth’s gravitational acceleration. Due to this high magnitude of acceleration, all subsystems of the Booster and Dart must be designed to endure this high acceleration.

### C. Plot of Acceleration vs. Time




## VII. Electronics/Payload

## A. Hardware

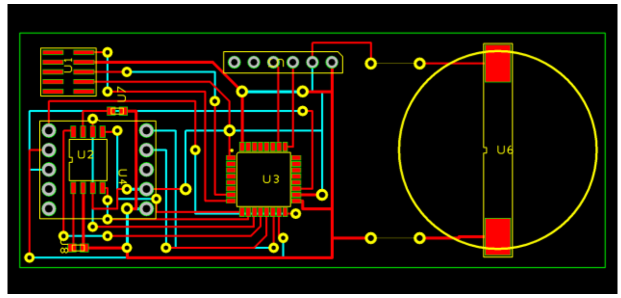


**Figure 5. IMU PCB Layout**. *This is the design for the IMU board. To get an idea of scale, the circular piece is 0.9" in diameter*

In order to collect rotation data of the rocket during flight a printed circuit board with an IMU was designed. The InvenSense MPU-9250 was chosen as the IMU due to the breakout board's ability to measure all 9 axes. The sensor contains a gyroscope, accelerometer, and magnetometer. The team will be using the gyroscopic data to compare rotation to the camera feed. To save the data from the gyroscope an Atmel ATxmega 32E5 MCU will be used. The MCU will save the data to an onboard data flash module, AT45DB321E. To program the MCU there are two sets of header pins. The board will also be connected to a set of batteries using header pins. The board will be located in the payload bay of the dart.

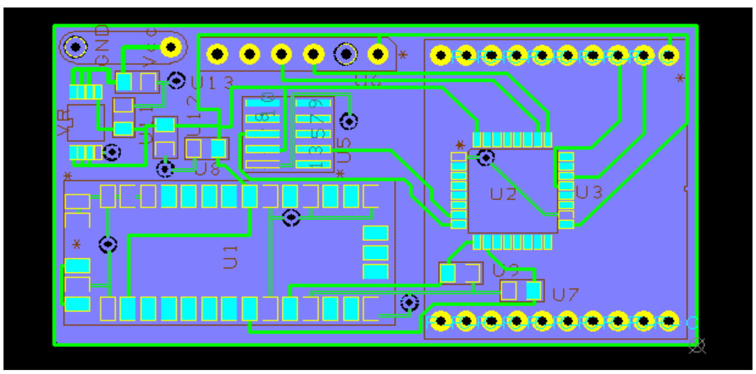


**Figure 6. Tracker PCB Layout**. *This board is about 2"x1", small enough to fit in the nose cone without creating any inconsistency between it and the body tube.*

A second printed circuit board was designed for tracking and retrieval. The tracker board will be placed in the nose cone of the dart as the body of the dart is carbon fiber which is non-RF transparent. A second tracker board will be placed in the booster as well. The tracker board contains an Antenova M10382 which records the board's GPS location. An Atmel ATxmega 32E5 MCU will again be used to take the data from the Antenova module and send the data to an XBee Pro 900 HP radio for broadcasting. The XBee radio will be broadcasting the data to another XBee acting as a receiver on the ground.

## B. Software

The goal of the software is to record rotation of the dart about 3 axes throughout flight and compare the results to an onboard camera to ensure accuracy. This will be achieved by saving the data from the IMU to flash memory to be processed with MATLAB post flight. All 9 axes will be recorded for redundancy, using the IMU's gyroscope, accelerometer, and magnetometer. The filing system will allow the data to be saved to the memory without fear of overwriting or losing the data if the system is restarted or loses power.