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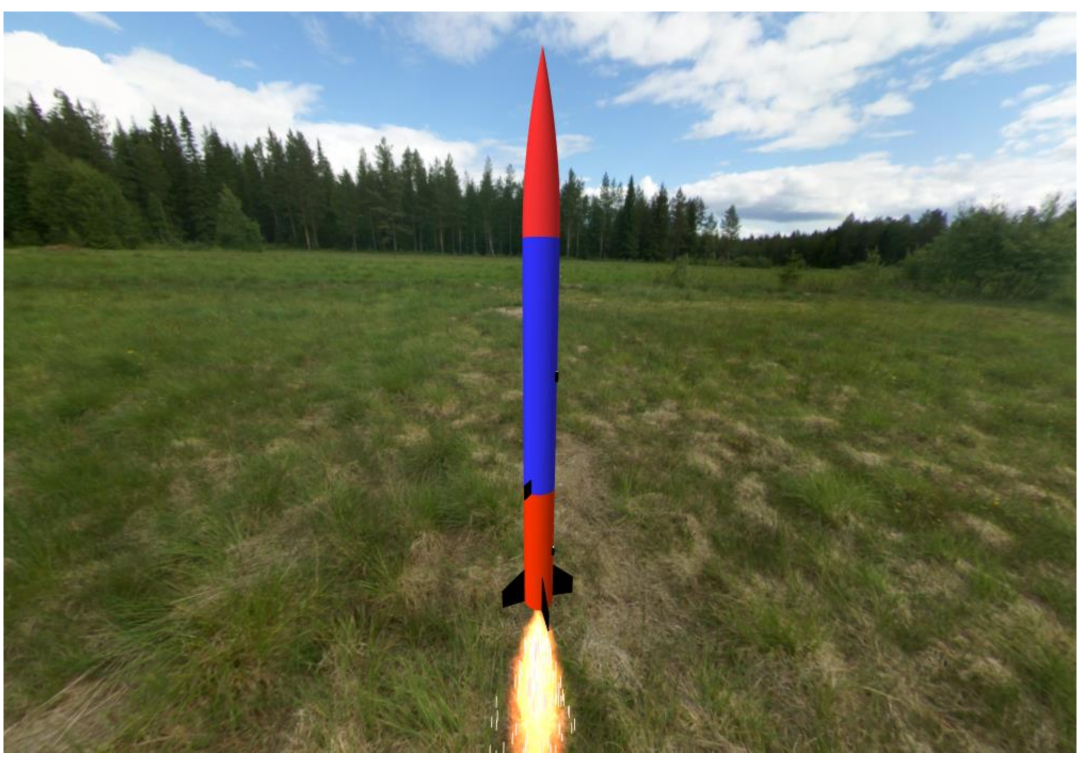
Preliminary Design Report

Whoosh Generator 7

Midwest Regional Launch Competition

Milwaukee School of Engineering

03/09/2018



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Project Statement

The 2017-18 Midwest High Power Rocketry Competition's objective is to design a high-power rocket on an I or J impulse motor to achieve a minimum apogee of 3000ft and be recovered safely. The rocket must be flown twice on the same motor with two different operations. On the first flight, the rocket must stabilize its roll relative to the ground, observed by an onboard camera. On the second flight, the rocket must perform a series of roll operations during certain time increments. Additionally, a multicolored LED must be installed to indicated which operation the rocket is performing, as viewed by the down-facing camera. There were three bonus challenges as well. These bonus challenges are: reprogramming the rocket's operating procedure from a distance, transmitting real-time sensor data to launch pad, and finally, receiving and responding to text-based commands mid-flight.

Executive Summary

A stable rocket was designed to meet all the challenges set down in the 2017-18 Midwest High Power Rocketry Competition. The 4" body tube, ogive nose cone, fiberglass trapezoidal fins, 24" drogue parachute, 60" main parachute, and J760 motor were all selected to ensure a safe flight. The avionics bay was designed using a user-friendly, removable sled mechanism housing a suite of Adafruit sensors, Arduino Mega microcontroller, Raven 3 altimeter, Active GPS antenna, XBee Pro, Whistle 3 GPS Pet Tracker, RGB LED, Mobius 808 #16 camera, and 9V batteries within a cardboard coupler tube. A control system and testing procedure is also in development, which will use the numerical output of the avionics bay to achieve specified roll orientations. This control system uses a set of rotating, external fins, which are mounted to a servo motor. The three bonus challenges were also addressed using the suite of sensors and on-board programming.

Design of Rocket Airframe

OpenRocket Model

The rocket's airframe was initially designed and modelled using OpenRocket software with an accompanying SolidWorks model for additional detail. The OpenRocket model, which will be discussed further in its section after the Design of the Electric Bay section, was used to address the rockets performance and stability. The SolidWorks model was used to accurately design the Avionics Bay and Control System. The OpenRocket model can be seen in Figure 1. The generated OpenRocket model has an estimated apogee of 4540 ft (1383 m) with a stability of 1.69. The CP and CG were located at 41 in (1.04 m) and 48 in (1.22 m), respectively. Figure 2 shows the altitude, velocity, and acceleration as a function of time. Table 1 accompanies Figure 2 with all relevant values.

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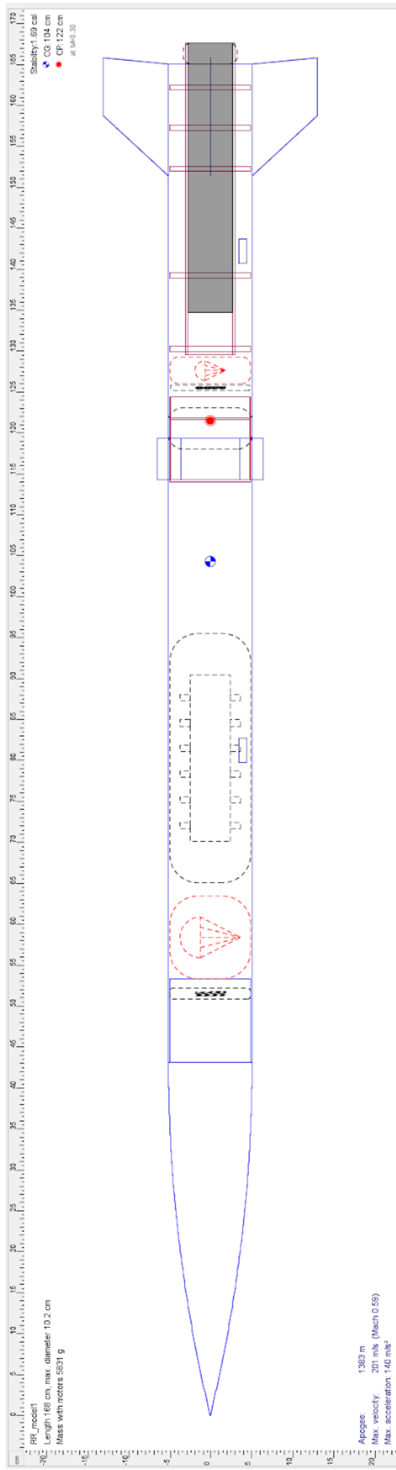

Figure 1: OpenRocket model of Whoosh Generator 7

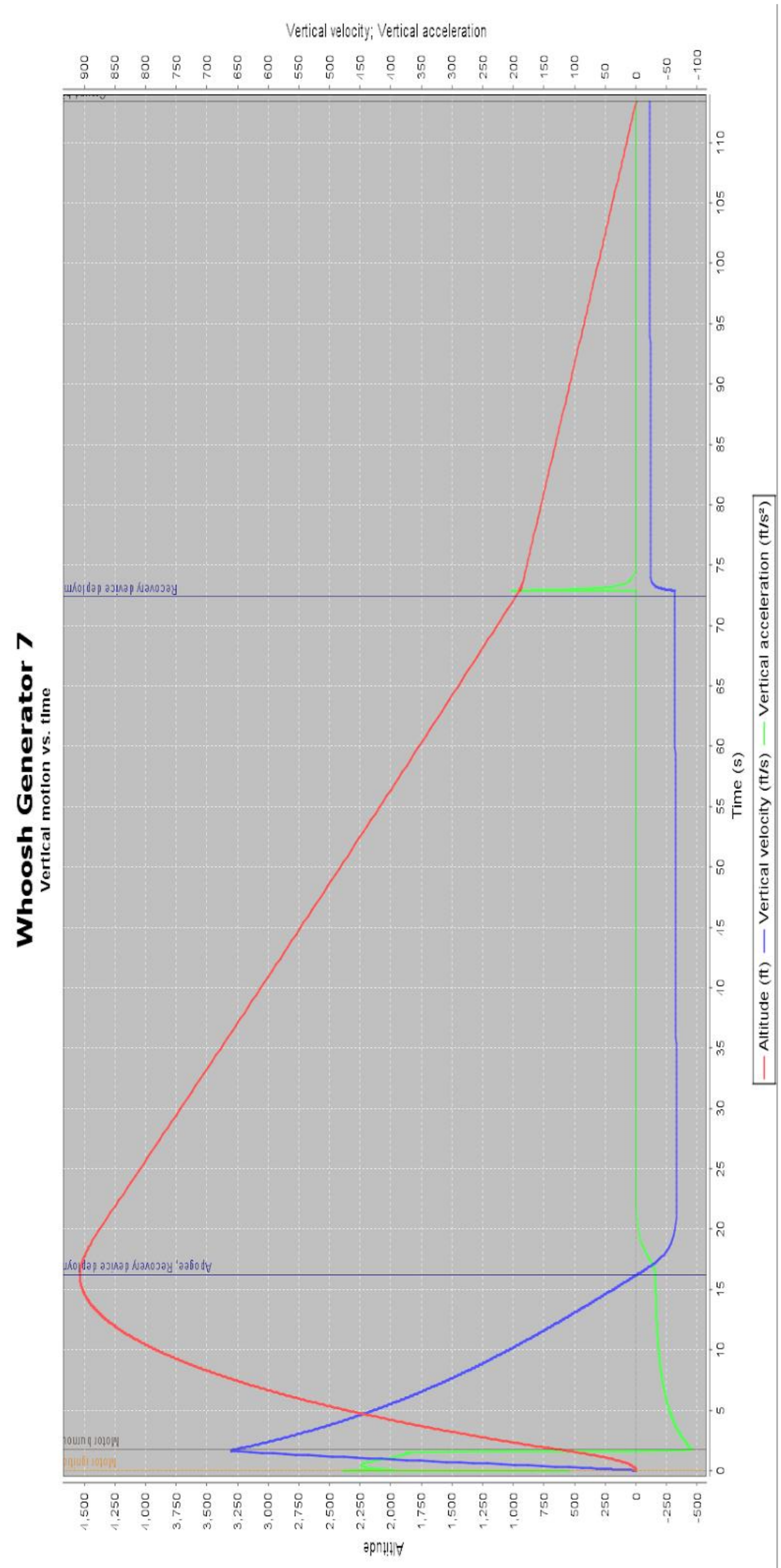

Figure 2: Altitude, velocity, and acceleration of Whoosh 7 rocket

Table 1: Flight Characteristics for Whoosh 7 rocket

Apogee	4540 ft (1383 m)
Maximum Velocity	63.3 ft/s (19.3 m/s)
Maximum Acceleration	476 ft/s^2 (145 m/s^2) (14.8 g)
Time to Apogee	16.2 s
Ground Impact Velocity	23.1 ft/s (7.05 m/s)

It is worth noting that the ground impact velocity was found to be near the maximum value. This will be considered during the control system design process. As these changes occur the model will be updated. There are also considerations being made to waterproof both the AV Bay and control system, changes that will increase the safety and reusability of the rocket. This additional mass may require a larger parachute to be used in order to lower the descent velocity, which could be done with the main parachute or the drogue parachute becoming larger.

Nosecone Design

The ogive nosecone is made from PVC and is 17 inches long and 4 inches in diameter with a 0.219-inch wall thickness. Its shoulder is 4 inches long and 3.871 inches wide with a 0.50-inch thickness.

Main and Drogue Parachutes

A 60” Angel LOC parachute was selected for the main parachute, which was placed between the nose and the AV Bay, to achieve the required landing velocity of less than 24 ft/s. This was a dual deployment system. A 24” Fruity Chutes drogue chute was selected to slow down descent of the rocket before the main parachute’s deployment. The smaller drogue chute would limit the drifting distance from the launch pad as well as the flight time.

Body tube Selection

A 4” Quantum tubing was selected to be the rocket’s airframe. This 0.062" thick tubing allowed centering rings and bulkheads to be epoxied inside it as well as protecting the rocket’s interior on rough landings. This sturdy, machinable body tube served as a strong foundation to build upon.

Bulkheads and Centering Rings

All securing bulkheads and centering rings were manufactured out of plywood from Apogee Rocketry.

Avionics Bay Position

The AV Bay will be discussed in the Avionics section of the Electronic and Payload section of this report. The location of the AV Bay’s position in the rocket can be seen in the Figure 1. The mechanical design of the AV Bay was designed such that it would operate quickly, efficiently, and give the user of the rocket an ease of use. This resulted in a modular design that can be easily operated on the launch pad.

Camera Setup

The camera setup for the rocket comprises of a through-wall camera shroud, manufactured by LiquidFyre. The outer shroud of this camera is made of carbon fiber, and the carrier is machined from a phenolic material. The camera setup consists of a Mobius 808 #16 camera with a wide angle “D” lens. The camera is permanently mounted in the carrier and the camera lens is positioned between the carrier and shroud as shown in the above figure. The camera lens is detached from the main camera body and reconnected using an extension cable. This allows the camera to be mounted in a position that achieves the best angle for viewing the rocket's flight while keeping the camera shroud profile as minimalistic as possible. CAD models of the camera shroud system can be seen in Figures 3. The placement of the camera on the airframe will be finalized when the completed control system is placed on the airframe. This is planned to optimize visual inspection of the control system and LED during flight.

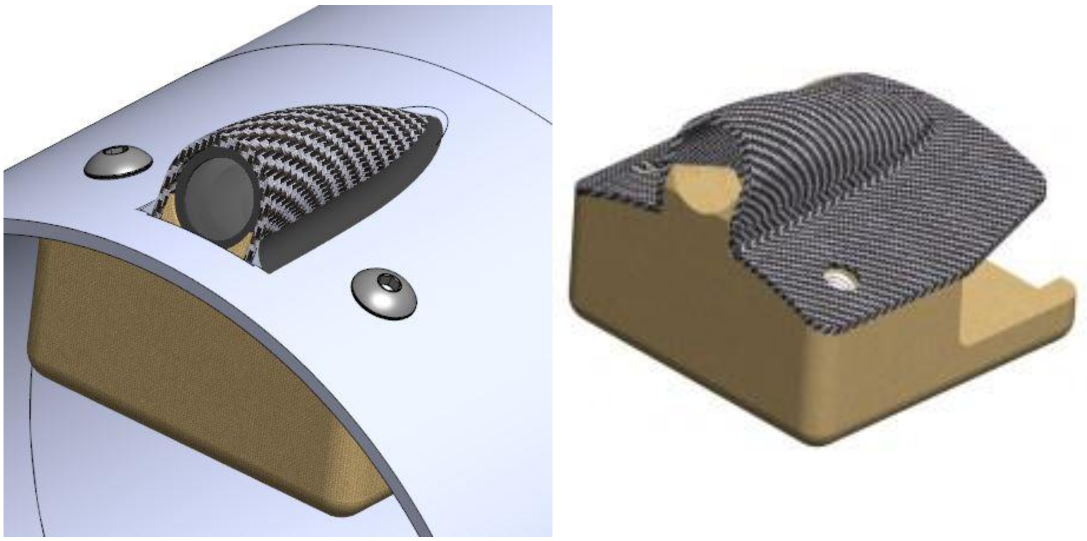

Figure 3: LiquidFyre camera shroud system, shown attached to the airframe and as a separate part

Control System – Physical Design

Physically, the whole fin control system was custom engineered to fit precisely inside of its own control bay. After many design iterations, the result is a control system that is rigid and precise, while remaining simplistic and minimalistic in nature. This was accomplished using a compact mechanical gearing system. At the top of the bay, a servo is mounted which spins a vertically oriented shaft with a small bevel gear on the end. That bevel gear is met by two other bevel gears, oriented perpendicular to the servo gear, and each attached to two horizontally oriented shafts. These shafts are held in place by four aluminum pillow blocks mounted to a bulkhead. Attached to the opposite end of the horizontal shafts is our aerodynamic control surfaces for the roll and stability control of the rocket. An important aspect of this design is that when the servo turns the vertical bevel gear one direction, the two horizontal bevel gears turn in opposite directions. This allows for the orientation of both control fins to be changed in an identical fashion, where they will maintain equal and opposite angles of attack with respect to the airflow around the rocket during the flight. By orienting the fins at equal and opposite angles of attack, a moment will be induced, causing the rocket to roll. Therefore, the rocket's roll stability and orientation maneuvers will be controlled by manipulating the induced moment, which will be created using the mechanical fin control system. Overall this design should allow for precise aerodynamic control and will improve the stability of the airframe during flight and orientation maneuvers. A CAD model of the control bay with the control surfaces can be seen in Figure 4.

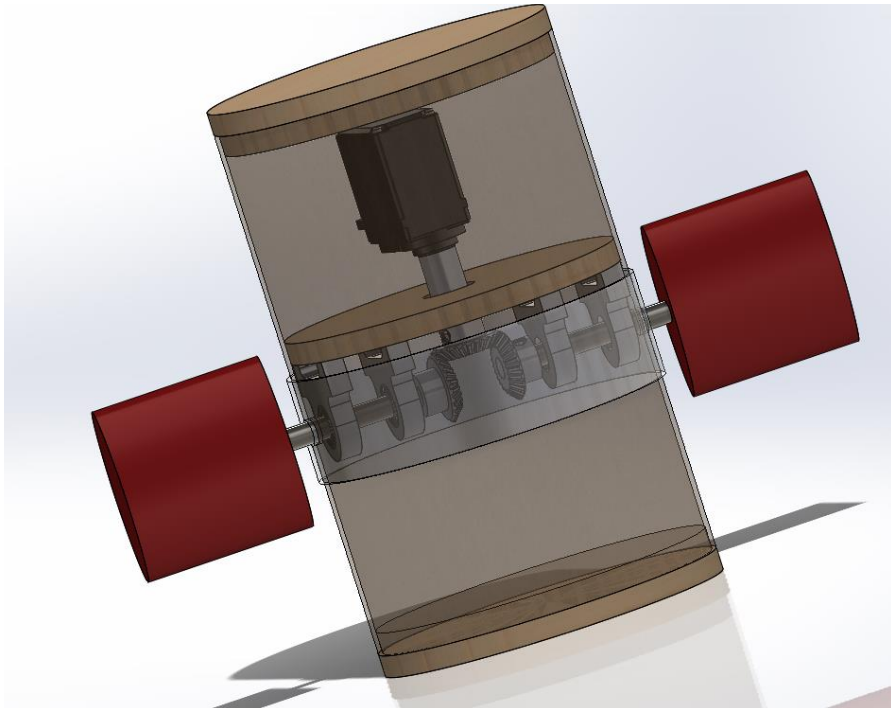

Figure 4: Control bay for the Whoosh 7 rocket

Control System – Future Work

The competition objectives require the rocket to maintain either a stable launch or achieve specific roll orientations. The first launch will focus on maintaining a stable launch three seconds after motor burnout. All following launches will focus on obtaining specific roll orientations. The roll orientations are defined by the cardinal direction (North, East, South, and West) that the rocket's onboard camera is facing.

The rocket will utilize a PID controller to achieve these roll objectives. The PID controller will be implemented within the Arduino Mega in the AV Bay. The PID controller will utilize what is known as a difference equation to change the roll orientation as error values are read from the avionics bay. The difference equation, along with PID tuning values, can be written as:

$$\boldsymbol{u(t) = K_p e(t) + K_i \int_0^t e(t')dt' + K_d \frac{de(t)}{dt}}$$

Where K_p, K_i, and K_d are non-negative, and denote the coefficients for the proportional, integral, and derivative terms respectively. The proportional term allows for the voltage applied to the control servo motor to be proportional an error value. The integral term takes the error history into account, allowing the steady-state error to be controlled. The derivative term controls the servo according to the error's rate of change.

Two separate controllers will be utilized to achieve the two necessary launch roll characteristics. Using the magnetometer and gyroscope, the AV Bay will provide an output in degrees from a specified cardinal direction. For the first launch, the directional reading three seconds after motor burnout will be the set zero value for the control system. Any deviation from this set zero value will be an error value for the PID controller. The error value will be adjusted using the K_p, K_i, and K_d terms within the difference equation, which will output a signal to the servo motor, allowing the control surface to be reoriented to combat any deviation from the zero point. The second controller will function similarly to the first. However, the rocket will be programmed to set itself to specific numerical directional values, based on what the magnetometer is calibrated to. For example, if after motor burnout and the two second wait time, the rocket is facing South, and needs to rotate counter-clockwise to face East, then the PID controller will read its zero point as 90°. This would mean the PID controller will register a 90° error, and the control surfaces will adjust accordingly. These set zero points will be held for the required time outlined in the flight requirements. A block diagram for PID control can be seen in Figure 5.

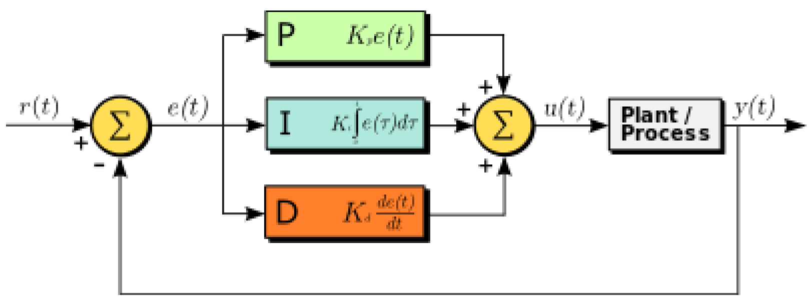

Figure 5: PID control block diagram. The Plant/Process is the rocket itself, r(t) is the specified roll orientation, e(t) is the error from the specified orientation, u(t) is the voltage delivered to the servo, and y(t) is the current roll orientation

Motor Selection and Mounting

The motor selected for both rocket launches was a J760 for its relatively quick burn rate at 1.67 seconds and its overall impulse of 1267 Ns, which is high enough to achieve an apogee of approximately 4540 ft (1383 m), which occurs at a time of 16.2 seconds. A motor mount tube, being a piece of cardboard tubing, was mounted into the lower body tube with three interior couplers using JB weld. The motor was then attached into the motor mount with an Aero Pack 54mm motor retainer. This motor was chosen to give the most controllability time for the maintaining a stable flight and performing roll orientations.

Fin Design

Trapezoidal fins were chosen to stabilize the rocket's flight. The shape of the fins was drawn from experience and the modelling predictions given by the OpenRocket software. An estimated stability, based on the ratio between the location of the center of pressure (CP) and the center of gravity (CG) was found to be 1.69. The fins were cut from 1/8'' thick fiberglass. The geometry of the fins can be seen in Figure 6.

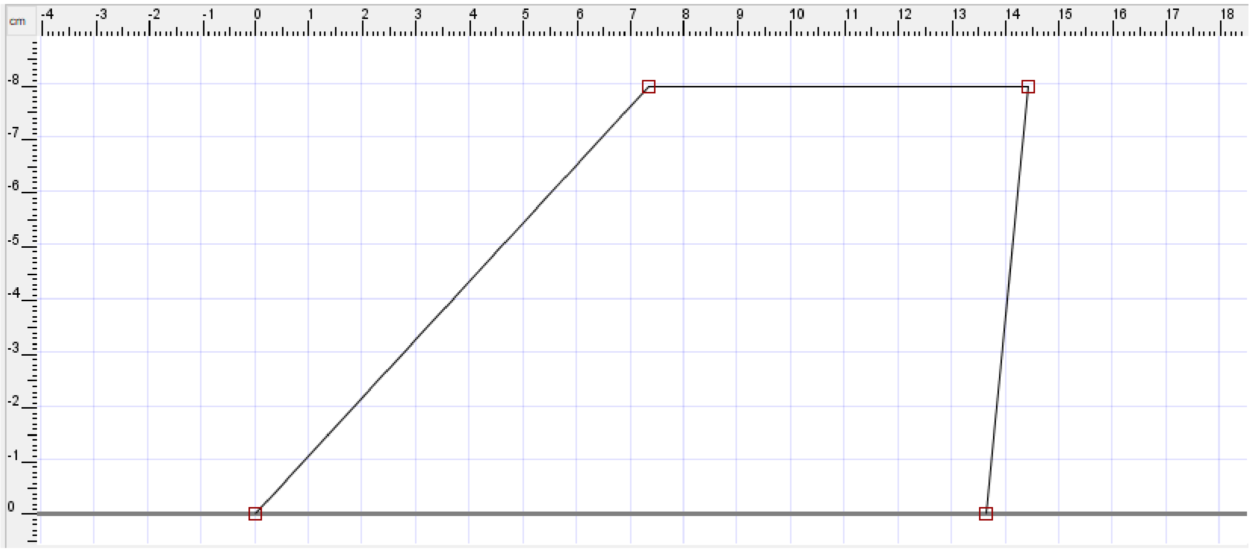

Figure 6: Whoosh Generator 7 fin design. Dimensions are given in cm

Design of Electronics and Payload

The overall electronics bay (AV Bay) design, while simplistic in nature, tackled many complex design objectives to accomplish the many tasks the AV Bay needs to perform. The objective was to design the AV Bay with an emphasis on neatness and ease of use. The main construction of the AV Bay consists of 3.9" phenolic coupler tube capped on both ends with birch plywood bulkheads. Inside, the AV Bay contains a linear steel rail attached to the interior radius of the phenolic tube, upon which rides a ball bearing slide with the electronics sled mounted on top of it. The rail design inside our AV Bay allows for easy and fast removal and installation of the sled, while still providing a secure mounting apparatus for when the rocket takes flight. When the design of the rail was completed, the sled that rides atop the rail was then designed to provide the maximum amount of space and organization potential. For the sled design, two dual sleds traverse the length of the body tube in parallel to one another. This allowed for the largest surface area to mount components while leaving a gap in between the two sleds to run and organize wires. This gap also allowed for the most efficient use of space by allowing the key switches to slide between the two sleds. Overall this design will allow the AV Bay to achieve unparalleled ease of use and organizational qualities unseen in any other rockets. A CAD model of the AV Bay can be seen in Figure 7.

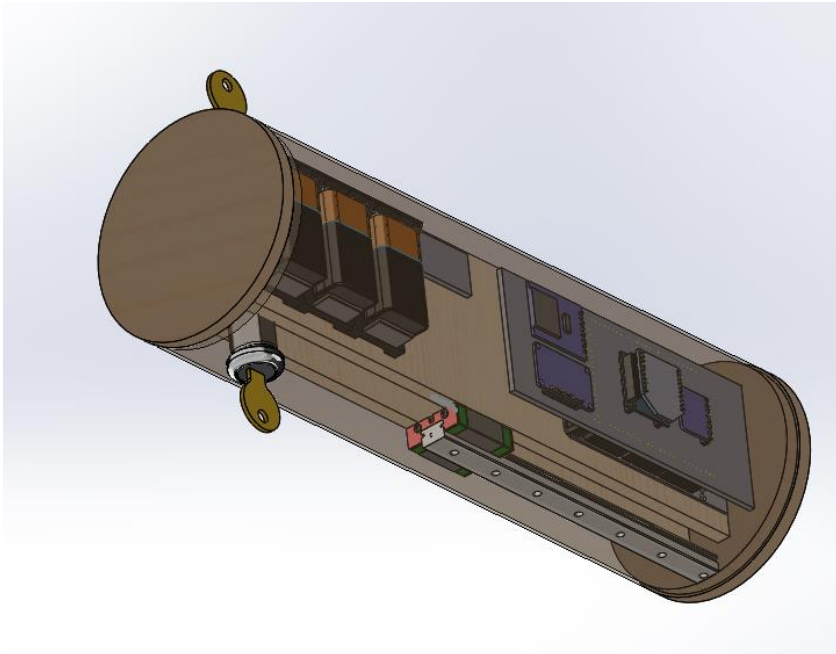

Figure 7: CAD model of Whoosh Generator 7 AV Bay design

Altimeter

The commercial deployment system chosen is the Raven 3 altimeter. Dual deployment will be used for recovery, with the drogue chute deploying at apogee and the main chute deploying at a lower altitude before it reaches the ground. Two screw terminal blocks will be secured to the upper and lower bulkheads that will allow for ease of charge install at launch. The connections from the Raven to the charges will be routed through the Mega shield and the serial connectors. Additional room in the electronics bay was made to securely mount the second altimeter provided at the competition launch.

The altimeter will be connected to the black powder charges that when ignited will cause a sharp rise in pressure which breaks the shear pins in the upper and lower bays, releasing the parachutes. The amount of black powder charges will be determined after the correct masses and lengths for the control system are finalized. The motor ejection, which will likely take place at 17 s will also be accounted for in the lower bay (releasing the drogue parachute). The black powder charges will be attached to the rocket with the key switches off (for clear safety concerns).

Non-Commercial Data Acquisition System

The base of the non-commercial data and control system was the Arduino Mega. This microprocessor was chosen due to its speed and number of serial connections (rx and tx pins). The rest of the electronics used in the non-commercial system are mounted to the top of the mega through a custom-made Mega shield using header pins. The shield will be removable from the Mega, but secure enough so that it will not come loose during flight. The following sensors will be mounted to the custom shield:

- Adafruit LSM9DS0 (Accelerometer, Magnetometer, and Gyroscope)
- Adafruit Micro SD breakout board (datalogging)
- Adafruit Ultimate GPS breakout board (GPS position of rocket)

- Active GPS antenna
- Adafruit BMP280 (Pressure and Temperature)
- XBee Pro Module - Series 1 - 60mW
- 2 Serial Connectors

Each component was specifically chosen for the type of measurement and its usefulness in controlling the both the rocket and PID controller. The primary sensor being the LSM9D0 which has a gyroscope which measures the rotation of the rocket in degrees per second. An accelerometer was selected to detect liftoff of the rocket as well as other flight events. The micro SD breakout board is being used to store the data collected during flight onto a micro SD card. The GPS breakout board, along with active antenna, will record the rocket's position to send down to the ground station as a backup to the commercial GPS system. The BMP280 sensor will be recording the pressure and temperature to help aid the control system in determining flight events.

To avoid a large amount of wires in the electronics bay, a PCB (printed circuit board) will be fabricated. Due to the Arduino Mega being the base of the electronics system, all additional connections (Raven, power, servo control) will be routed through this shield. To constantly maintain a secure connection during and after flight, two serial connectors and cable will connect to the shield to the rest of the components on the rocket. The serial cable is secured by two screws on the connector and can be removed to easily slide out the electronics sled. The upper serial cable connects the key switches, main chute deployment, and LED control to the Mega shield. The lower serial cable provides control of the servo in addition to the drogue chute charge.

The electronic components are mounted to a plywood sled that slides into the shell of the electronics bay through a rail system. The rail allows for easy removal but will secure the sled in during flight. The components on the electronics sled were carefully placed to maximize area as well as maximize functionality. The components are also securely mounted to the sled by screws and other hardware.

Control State Indication

An RGB LED mounted on the exterior of the rocket will be used to indicate the state of the control system per competition guidelines. An RGB LED was chosen due to the overall fewer number of LED's needed to accomplish the task of indicating what state the control program is currently in (turn clockwise, turn counterclockwise, or hold position). Due to many possible color combinations that can be used to indicate the state of the control system, there will be clear distinction between the various colors used as well as a color code to interpret the color output matching it to a state. A table will be generated to indicate which operation the RGB LED is displaying for the launch day.

GPS Tracking

To locate the rocket after launch, it has been decided that the Whistle 3 GPS Pet Tracker will be used. This GPS tracker was chosen over other devices mainly because it is much cheaper than other GPS trackers on the market. The Whistle GPS tracker costs $79.99, with a $6.95 monthly subscription, while other similar devices can cost $200 or more. It functions using cellular networks, so the GPS tracker has the ability to transmit its location wherever cell phone service is available. It also connects to and shows its location on a mobile app for smartphones. This reduces the need for additional equipment for our rocket launches. The Whistle GPS tracker is compliant with the International Protection Marking IPX7, which means that the device is shock resistant and can be submerged in one meter of water for 30 minutes. The battery for the Whistle GPS tracker can power the device for up to seven days. The Whistle GPS tracker will be mounted internally, in the electronics bay of the rocket.

PCB

To reduce the number of wires needed and improve the overall look of the electronics bay, a printed circuit board will be fabricated. The board was designed using Fritzing. The various electronic components were placed and the traces (wires) were routed. Header pins will be soldered onto the pads on the board allowing for the components to be secure but removable. The PCB connects to the Mega through header pins and acts like a shield. All the major electrical connections are made on the shield and are represented in the figure below including the two serial connectors and the connecting the Raven 3. Ribbon cable will be used to connect the serial connectors to the shield in a clean manner. A layout of the PCB can be seen in Figure 8.

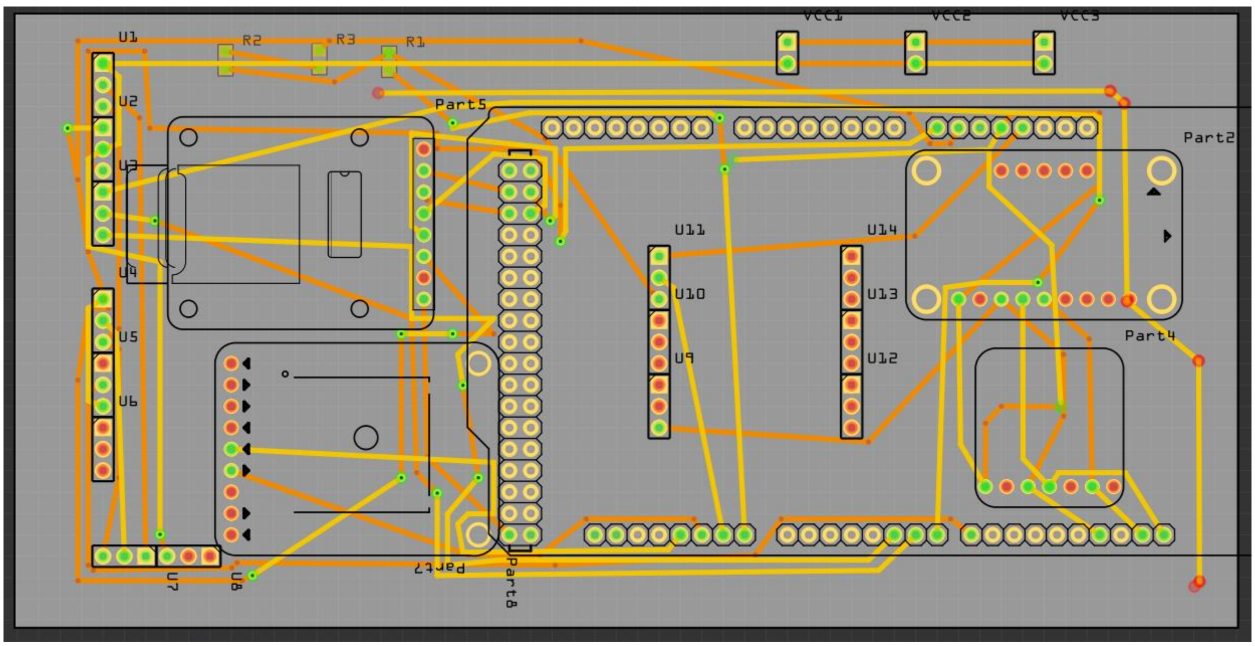

Figure 8: Layout of custom PCB for Whoosh Generator 7 rocket

Key Switches

Two separate key switches on the exterior of the electronics bay will be used to arm the electronic components. One key switch will arm the control system including the mega, servos, and LED's while another separate key switch will arm the Raven 3 and any connected charges. This was done so that the control/telemetry system can be verified prior to launch without arming the connected charges.

Power Supply

Three 9-volt batteries wired in parallel will be used to power the mega, servos, and raven. Current draw for each of the components were calculated to ensure that there would be no problems. The servos operate on 6-volt and so a voltage divider will be used to step down the voltage.

Bonus Challenge

The bonus challenge parameters will be met by including an Xbee network into the design of the rocket. A telemetry system of two 60mW 2.4 GHz Xbee S1 modules will be used to continually keep a signal between the ground station (laptop) and the rocket. Onboard the rocket is one Xbee that has a wire whip antenna to increase the range of the network. The ground station Xbee is connected to a 10dBi antenna through an RP-SMA connector that will guarantee a strong connection through the entire flight and recovery. This system is non-directional, but the strength of the network will increase as the distance and interference due to terrain decreases (line of sight). The Xbee network complies with federal regulations limiting the strength of wireless networks and was taken into consideration when choosing the appropriate hardware. The Xbee network interfaces with the ground station through a serial connection and a custom user interface programed with python. This user interface will allow the reprogramming of the positions of the rocket during the second flight as well as constant telemetry before, during, and after the flight of the rocket. The Xbee network though already secure through the use of the network ID and direct MAC address connection designation, is additionally secured through a password with every transmission. The rocket will continuously be looking for actions during the flight and will do whatever is commanded by the ground station.

Regulations

There are regulations that limit the total transmission for each transmitting unit (node) to 36 Effective Isotropic Radiated Power (EIRP) for each radio. The EIRP is the sum of the radio power and antenna gain. The maximum transmitter power is also limited to 1 watt. The transceiver chosen uses 60mW of power, which correlates to 18 dbm. For the antenna, a small wire antenna with a gain of 3 dbi is going to be added to the sending transceiver on the rocket, boosting the transmitting distance while not limiting the transmit pattern. On the ground, a larger 10 dbi antenna is going to be used to receive the data from the transceiver which will have the largest EIRP combination. Together, the largest node has an EIRP of 28 which is less than 36, meeting all regulations.

Bonus Challenge A: Reprogram

Prior to the rocket being launched, the graphical user interface (GUI) program will allow the ground station to reprogram the rocket with new headings, direction to turn, and delays overwriting the already programed headings, directions, and delays stored on the mega. When new commands are sent to the rocket, the Mega echoes the new commands back to the computer so any possible errors can be detected prior to launch. The user interface will do this automatically, but the data will also be displayed in its raw form in a raw terminal window in the user interface.

Bonus Challenge B: Telemetry

From prior to launch until the rocket reaches the ground, the rocket will continuously transmit chosen sensor data to the ground station. The following data is planned to be transmitted to the ground station through a CSV (Comma Separated Value) using the Xbee telemetry network.

- Altitude
- Rocket Roll Rate
- Control Surface Position
- GPS Position (Latitude and Longitude)

- Acceleration (x,y, and z)
- Magnetometer (x,y, and z)

In addition to just the transmission of the data to the ground station, chosen data such as the altitude, rocket roll rate, and GPS Position will be displayed real time in the user interface on the ground station computer. This data will be automatically saved and logged in the event of a data log failure on the rocket which is not expected but could possibly happen. The resulting data file that is generated will be supplied to the judges from both the rocket and the computer. The transmission rate will be at least 10 Hz and may be greater depending on the number of processes the Mega performs every loop.

Bonus Challenge C

This bonus challenge will be implemented along with bonus challenge B and the command with response will be added onto the end of the CSV string being transmitted. A separate area in the user interface will be added to allow for the input of commands to be sent to the rocket with a send button and a response area to see if the answer given is correct to be verified immediately.

Future Work

Much work remains to be done on the rocket's construction. Most of the machining and assembly remains to be done. The fins will be cut from the fiberglass and the camera holes will be drilled into the airframe. The motor mount will be attached to the airframe as well. Final assembly of the AV Bay will also be conducted. The team aims to have these major components assembled by the Safety Inspection in Kenosha, WI in March.

All construction and manufacturing will be conducted in the MSOE Machine Shop or in the Senior Design Lab in the basement of the Science Building. These areas offer safe and reliable tools and storage spaces. When painting comes, there is an area designated for outdoor painting. The AV Bay has been constructed mechanically but without the most up-to-date PCB design the final AV Bay couldn't be constructed yet. The PD was altered to include sensors for the bonus challenges (from the additional information). The design of the control system affects the lengths of body tube being cut, and therefore the placement of bulk heads and centering rings, which may change with the testing of the control system hence they have not been constructed.

The PCB also needs to be manufactured as well, along with further work into making sure that the avionics bay outputs the correct roll orientation characteristics. These roll characteristics will be used to refine the control system, allowing for its development.

A test flight of the control system will be conducted using a rocket platform from a previous year. This will give a better idea of how the avionics bay and control system are communicating. The team also aims to test the control system in the wind tunnel at MSOE, which would allow for the PID values to be tuned for optimum performance. When the team feels that the tuning values have been refined correctly, a practice launch will be conducted using the whole Whoosh Generator 7 system, to test all systems in a scenario like the Midwest Launch Competition. Further data will also be gathered through a scale model that is being built that will be run on E motors, called Mini Whoosh. Through these empirical methods, a robust control system will be designed and implemented.

Launch Preparation and Execution Procedures

Pre-Flight Procedure

1. Take inventory and make sure all components are present (not damaged)
2. Pack parachutes with fire retardant fabric (verify shock cord knots)
3. Get black powder charges and motor from launch officers
4. Attach black powder charges to the screw terminals with the deployment system key switch in the off position
5. Insert fresh batteries into the electronics sled
6. Make sure all SD cards have no previous data on them
7. Connect the appropriate connectors to the AV Bay sled
8. Arm just the electronics system to verify system is fully operational (for flight #1 mode or flight #2 mode)
9. De-Arm the electronics system though the key switch
10. Slide the electronics sled into the AV Bay shell and secure in place
11. Install shear pins and fasten screws
12. Insert motor into motor mount and install motor end cap
13. Bring rocket up for final safety check
14. Place on launch rod
15. Arm both electronics and deployment systems through keyswitch
16. Verify telemetry system is active and reporting data
17. Insert igniter into the bottom of the rocket
18. Leave the immediate area to the proper designated location
19. Reprogram the rocket per flight judge request to new headings, turn directions, and time delays (Bonus Challenge)
20. Verify correct information was received by the rocket
21. Launch
22. Send any commands to the rocket to perform during flight
23. Track rocket location during flight

Post-Flight Procedure

1. Record final GPS position
2. Recover rocket (after checking the safety of the landing area ie. status of black powder charges) after confirmed by RSO and dearm the rocket via keyswitches
3. Ensure data logging has stopped
4. Bring rocket back to preparation area and show competition judge
5. Extract all data (camera footage, Mega data, telemetry data, competition altimeter) and turn into competition judges
6. Extract Raven 3 data
7. Remove black powder charges and expired motor
8. Prep for another launch is applicable

Design Budget

A detailed budget for the rocket assembly can be seen in Table 2. The registration fee for participating in the Midwest Launch Competition has generously been paid for by WSGC.

Expenditure Plan-Midwest Rocket Team (WSGC)							
Item	**Vendor**	**Requestor**	**Estimated Subtotal**	**Treasurer Approval**	**Date Ordered**	**Expected Delivery**	**Actual Total**
Order 1			**34.77**	Benjamin Jensen	2/12/2018	2/19/2018	**35.19**
Serial to Terminal Female Adapter	Amazon	Alex van Dyck	13.74				
Terminal Electric Barrier Strip Block	Amazon	Alex van Dyck	6.56				
9-Pin Serial Port Cable	Amazon	Alex van Dyck	7.49				
Ribbon Cable	Amazon	Alex van Dyck	6.98				
Order 2			**2.99**		2/12/2018	2/19/2018	**9.04**
Power Distribution Bus	Amazon	Alex van Dyck	2.99				
Order 3			**146.66**	Benjamin Jensen	1/27/2018	2/4/2018	**164.28**
ON/OFF Key Switches x 2	Amazon	Alex van Dyck	21.90				
GPS Tracker	Amazon	Alex van Dyck	79.95				
Dremel Plunge Bit x 2	Amazon	Alex van Dyck	6.88				
Epoxy x 5	Amazon	Alex van Dyck	17.95				
9V Battery (8-pack)	Amazon	Alex van Dyck	19.98				
Order 4			**35.93**	Benjamin Jensen	1/27/2018	2/4/2018	**35.93**
9V Battery Clips	Amazon	Alex van Dyck	6.95				
Linear Guide Slide	Amazon	Alex van Dyck	28.98				
Order 5			**121.25**	Benjamin Jensen	1/30/2018	2/6/2018	**131.06**
Camera	Liquid Fyre Rocketry	Alex van Dyck	91.25				
Camera Shroud	Liquid Fyre Rocketry	Alex van Dyck	30.00				
Order 6			**108.84**	Benjamin Jensen	1/30/2018	2/6/2018	**133.79**
Body Tube 48-in. x 2	Public Missile	Alex van Dyck	65.90				
Coupler Tube 36-in	Public Missile	Alex van Dyck	20.99				
Nosecone 3.9-in	Public Missile	Alex van Dyck	21.95				
Order 7			**31.66**	Benjamin Jensen	1/30/2018	2/6/2018	**35.79**
Aluminum Fasteners	Apogee Rockets	Alex van Dyck	31.66				
Order 8			**208.06**	Benjamin Jensen	1/30/2018	2/6/2018	**216.06**
Pillow Blocks x 4	Servo City	Alex van Dyck	23.96				
Bevel Gears x 3	Servo City	Alex van Dyck	23.97				
Spline Servo-Shaft Connector	Servo City	Alex van Dyck	4.99				
1/4" Stainless Steel Shaft	Servo City	Alex van Dyck	7.18				
180 Servo Gearbox	Servo City	Alex van Dyck	134.98				
Shaft Coupler	Servo City	Alex van Dyck	4.99				
Shaft Mount Pinion Gear	Servo City	Alex van Dyck	7.99				
Order 9			**41.16**	Benjamin Jensen	2/10/2018	2/17/2018	**41.16**
Model Rocket Launch Kit	Hobby Lobby	Ben Jensen	41.16				
Order Total to Date			**731.32**				**766.71**

APPENDIX A-5

MENTOR REPORT FORM

Mentors are to use this form to report their interaction with their teams. Mentors must submit this form to the Technical Advisor by the date and time specified for each report. We anticipate that mentors need to spend at least a few hours with each team for each report – and possibly more than a few for less experienced teams. We thank you in advance for your time!

Mentor Name: Frank Nobile TRA/NAR #: TRA 4077

Team Name: Woosh Generator 7 School Name: MSOE

Current phase of the competition: ☒ Preliminary Design ☐ Flight Readiness

For the current phase of the competition indicate: SAFETY CHECK AT THE EAA

In person:
Number of Interactions: 2 Number of Interaction Hours: 2

Remote (Phone, Skype, e-mail, …):
Number of Interactions: _____ Number of Interaction Hours: _______

List of Topics Discussed: AERO DYNAMIC DESIGN AND STRUCTURE

General Comments about Team Interactions & Mentoring Discussions: Willing to work with mentor

General Comments about Difficulties/Obstacles with Team Interactions & Mentoring: NA