Design and Optimization of Carbon Fiber Composite Structures and Precision Apogee Control in Sounding Rockets

Team 190 Project Technical Report to the 2025 IREC

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For the 2025 International Rocket Engineering Competition (IREC) hosted by the Experimental Sounding Rocketry Association (ESRA), Rocketry at Virginia Tech has designed and developed a sounding rocket for the 10,000 foot apogee, Commercial off the shelf (COTS) propulsion category of the competition. Each year the team works to design a rocket to carry an 8.8 lb payload to exactly 10,000 ft. The configuration of this rocket includes a 3U form-factor, 8.8 lbs, Cubesat payload designed to provide Global Positioning System (GPS) location and general sensor data telemetry; a Student Research and Designed (SRAD) recovery electronics bay; and a precision apogee control system named the Active Drag System (ADS). The airframe of the rocket is partially composed of SRAD carbon fiber composites including the body tubes, fins, and motor tube; all of these components are manufactured in-house. The rocket, named Roadkill, performed two successful test launches over the course of the academic year.

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Nomenclature

ABS	Acrylonitrile Butadiene Styrene
ADS	Active Drag System
AEDL	Aerospace Engineering Design Lab
AGL	Above Ground Level
APRS	Automatic Packet Reporting System
BEC	Battery Eliminator Circuit
CAD	Computer Aided Design
Cd	Coefficient of Drag
CFD	Computational Fluid Dynamics
Cg	Center of Gravity
CNC	Computer numerical control
CONOPS	Concept of Operations
COTS	Commercial off the shelf
Cp	Center of Pressure
ESRA	Experimental Sounding Rocketry Association
FEM	Finite Element Model
FOR	Flyer of Record
FS	Factor of Safety
GPS	Global Positioning System
HPR	High Powered Rocketry
I2C	Inter-Integrated Circuit
IMU	Internal Measurement Unit
IREC	International Rocket Engineering Competition
LCO	Launch Coordination officer
Li-Ion	lithium-ion
MS	Margin of Safety
PCB	Printed Circuit Board
PID	Proportional Integral derivative
PVC	Polyvinyl Chloride
PWM	pulse width modulation
RSO	Range Safety Officer
SISO	Single Input Single Output
SRAD	Student Research and Designed
TPU	Thermoplastic Polyurethane
TRA	Tripoli Rocketry Association
TWR	thrust to weight ratio
UART	Universal Asynchronous Receiver/Transmitter
UBEC	Universal Battery Eliminator Circuit

I. Introduction

A. Mission Statement

ROCKETRY at Virginia Tech is a student-led design team at Virginia Polytechnic Institute and State University in Blacksburg, Virginia. The team aims to promote interest in high-powered rocketry and provide hands-on engineering experience among students at Virginia Tech and members of the surrounding community. As a design team, a safe environment is provided for rocket enthusiasts of all backgrounds to operate high-power rockets and practice engineering design principles. Each year the team works toward competing in the IREC (formerly known as the Spaceport America Cup), hosted by ESRA, as well as providing its members with resources and guidance to obtain high-powered rocketry certification(s). This year, to compete in the $10,000\ ft$ apogee with COTS propulsion category, Rocketry at Virginia Tech has challenged itself to reevaluate past projects and innovate upon them for this year's rocket. The projects include an air brake system with an SRAD flight computer, a telemetry sensor suite, and external GPS and telemetry antennas embedded in carbon fiber to experiment with the feasibility of an entirely carbon rocket. Throughout this report, there is more information about the team's projects, how they appeal to IREC requirements, and how they aid in the team's goals.

B. Team Structure

Rocketry at Virginia Tech is made up of 28 undergraduate students and 2 graduate students in all years and 8 different engineering majors. The organizational structure of the team consists of 3 technical leads, a treasurer, and 2 L1 certification managers. The responsibilities of each sub-team vary greatly but are highly collaborative to ensure that the subsystems of the project are not isolated in their development. The technical leads work with each other and the treasurer to ensure that all IREC guidelines are adhered to, that the integration of the rocket can be accomplished as smoothly and efficiently as possible, and that the team and associated advisors and mentors stay informed. The team's L1 Certification Managers work to help the general team members get their L1 High Powered Rocketry (HPR) Certifications by hosting information and building sessions. Figure 1 presents the breakdown of team leadership, in addition to recognizing the faculty advisors who have mentored, and supported Rocketry at Virginia Tech in pursuit of our mission.

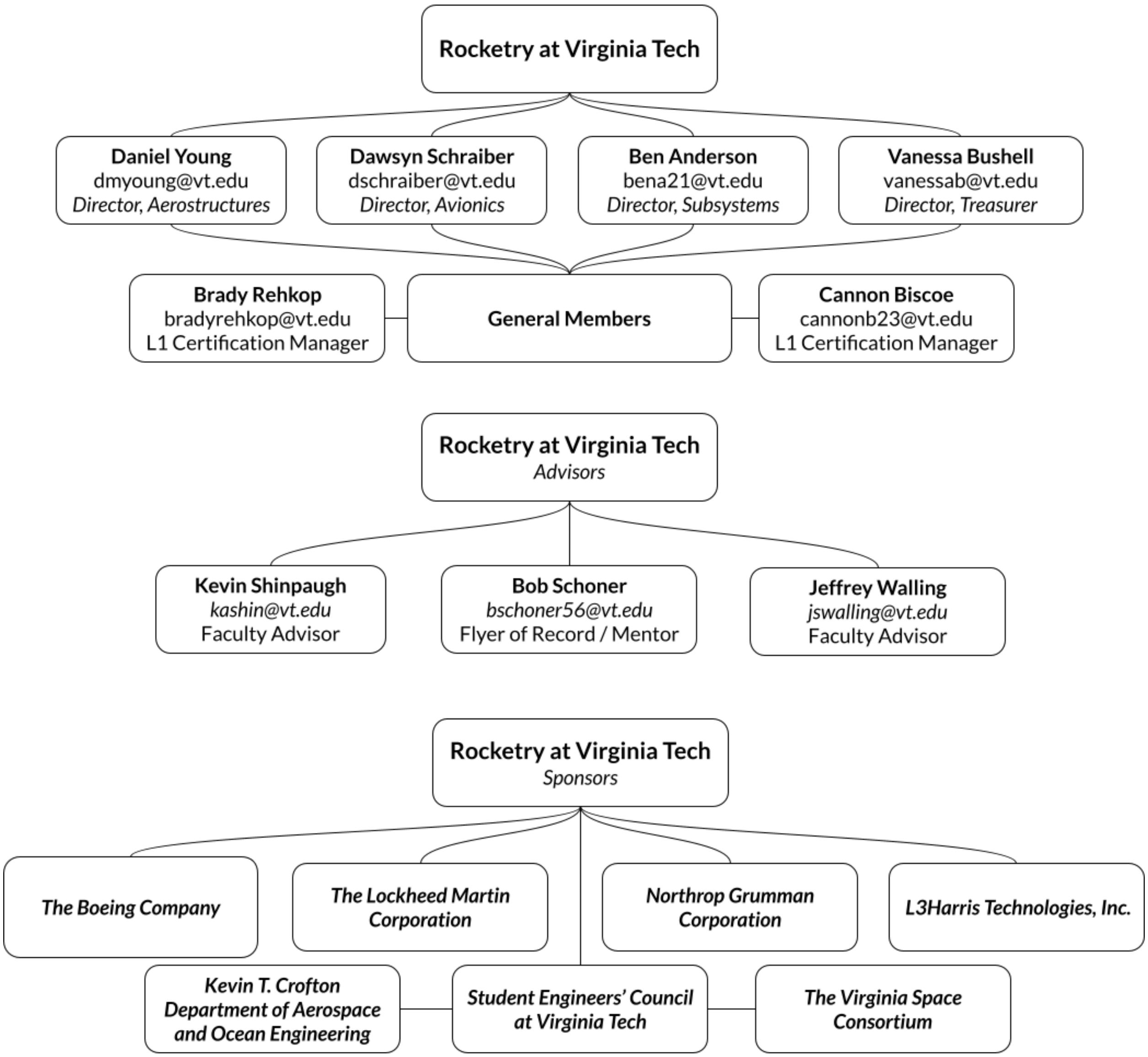

Fig. 1 Rocketry at Virginia Tech 2024-2025 Team Structure.

C. Mentors and Stakeholders

The team's mentor and Flyer of Record (Flyer of Record (FOR)) is Bob Schoner, a level 3 certified Tripoli Rocketry Association (TRA) member, former prefect for the TRA prefecture #143 in Christiansburg, VA and former head of the local New River Valley Rocketry association. Bob Schoner attends the team's test launches when able and provides Range Safety Officer (RSO) support to the team at certification launches in Kentland Farms, near Blacksburg, VA.

Rocketry at Virginia Tech's primary faculty advisor, Dr. Kevin Shinpaugh, is a collegiate professor of the Kevin T. Crofton Department of Aerospace and Ocean Engineering who works with a variety of university design teams including NASA SLVT, NASA Robotic Mining Competition, RASC-AL RoboOps, RockSat-X, Gobble Rockets, and other design teams. He is a level 2 certified TRA member. Dr. Shinpaugh provides additional support at team certification launches as the Launch Coordination officer (LCO) as well as hosts team Undergraduate Research meetings for bi-weekly updates and consistent feedback on how to improve.

Rocketry at Virginia Tech's secondary faculty advisor, Dr. Jeffrey Walling, is a collegiate professor of the Bradley Department of Electrical and Computer Engineering. He provides support in the form of weekly Undergraduate Research meetings with a focus on the electrical and computer subsystems on the rocket.

The team received financial support from a variety of sponsors. Financial support was provided by corporate sponsors, such as L3Harris Technologies, Lockheed Martin, and The Boeing Company. Other support was provided by the Student Engineers' Council at Virginia Tech, the Virginia Space Grant Consortium, and finally the Kevin T. Crofton Department of Aerospace and Ocean Engineering. Rocketry at Virginia Tech was able to manufacture the team's 2025 launch vehicle through the use of the Aerospace Engineering Design Lab (AEDL) and its equipment, a lab space owned and operated by the Kevin T. Crofton Department of Aerospace and Ocean Engineering. Lastly, the team received mentoring regarding current and past projects from its extensive alumni network now employed at various companies including L3Harris, Lockheed Martin, SpaceX, Norththrop Grumman, Aerojet Rocketdyne, TORC Robotics, and others.

II. Mission Concept of Operations Overview

An overview of the launch vehicle concept of operations is shown in Figure 2. Once the pre-flight checklist is completed, and the RSO allows the team to continue to the pads, the team will continue with the rocket arming sequence. After all personnel are ensured to be a safe distance from the vehicle, ignition will occur. The motor will provide thrust until burnout at approximately 720 m Above Ground Level (AGL). This begins the coast phase of the ascent. Once the coast phase begins, onboard telemetry systems will verify motor burn has ended. They accomplish this using a timer that begins at the start of acceleration and comparing to expectations and by detecting the start of negative acceleration. From this time onward, during the coast phase, the ADS will deploy and retract as necessary to get the rocket as close to $10,000\ ft$ as possible until apogee. The ADS will retract again at the start of descent just as the first apogee charge should be ignited by the primary recovery electronics. Should it be determined by the ADS that the rocket will not reach $10,000\ ft$, then the system will not deploy.

At apogee, the vehicle will begin the recovery sequence. At approximately $T_{apogee}\ s$, the onboard recovery system will eject the drogue parachute. The rocket will descend at approximately 26.5 m/s. At 244 m the rocket will undergo its second recovery event, ejecting the nose cone to allow for the main parachute to exit and deploy from the upper body tube. At this point the rocket will descend at 5.5 m/s and land at around 170 seconds after launch. During the duration of the flight, the payload, recovery system, and ADS will each transmit GPS coordinates to a ground station. Both recovery events will be armed with additional backup black powder charges for redundancy, further detailed in the Recovery Subsystem section.

Once the vehicle has touched down, onboard GPS will continue to broadcast landing zone coordinates back to a ground station. The launch operations team will proceed to recover the vehicle once it is safe to do so. Following this, on board data including in-flight footage will be off-boarded from the vehicle and the team will debrief on the flight.

A flowchart of the mission's Concept of Operations (CONOPS) can be seen below in Figure 2 with a more illustrative approach to describing the order of events during the launch vehicle's flight. Further information about each phase of flight can be found in the vehicle subsystems' respective sections.

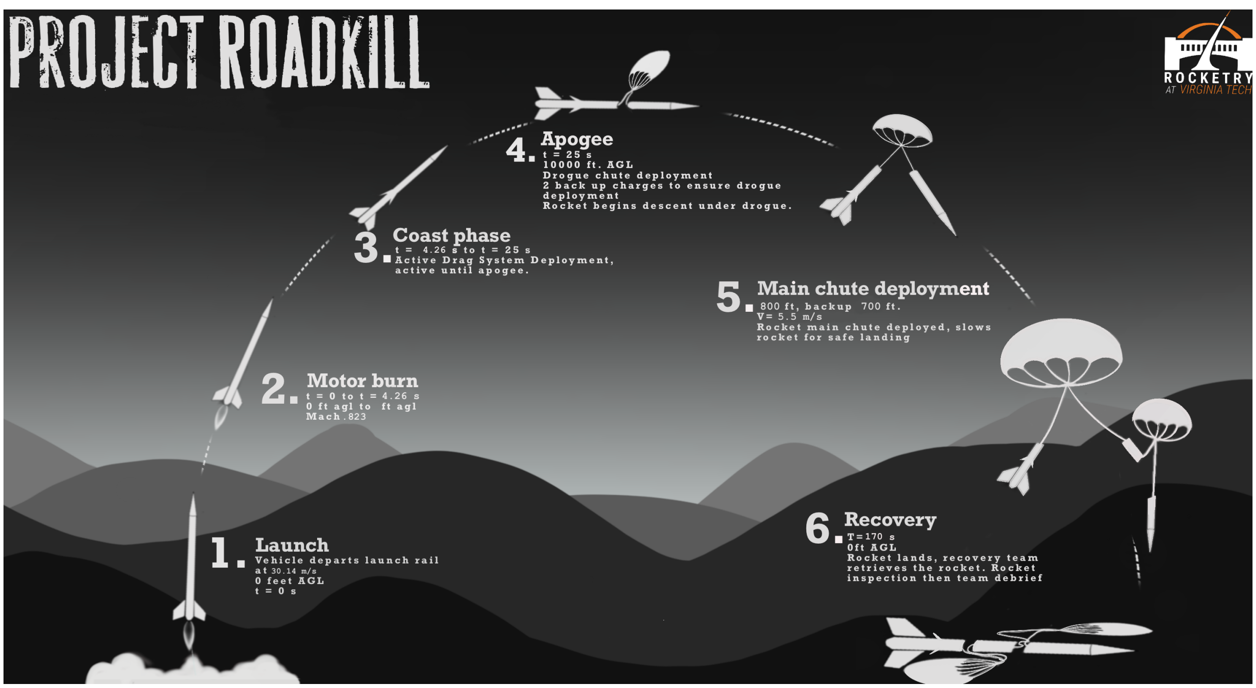

Fig. 2 Concept of operations graphic

III. System Architecture

A. Overview

Rocketry at Virginia Tech's 2025 launch vehicle, named 'Roadkill,' is a typical dual-deploy, dual-separation L3 rocket configuration with additional interdisciplinary projects to better accommodate the rules and requirements for IREC. These projects include the ADS with an SRAD flight computer for air brake deployment and rocket state estimation; an autonomous on-board camera control circuit for efficient capture and post-flight analysis; externally mounted antennas on an SRAD carbon fiber thrust structure for the purpose of RF pass-through to use for redundant GPS and telemetry; and an 8.8 lb, 3U Cubesat payload telemetry and sensor suite. Roadkill will be flying on an Aerotech M2500T, chosen both for the thrust to weight ratio (TWR) and resultant apogee $(10,840\ ft)$ closest to the target $(10,000\ ft)$ it provides. More details on these subsystems and the decisions surrounding their designs are found in the following sections.

B. Vehicle Trajectory and Flight Characteristics

Table 1 Mass Breakdown of the 2024-2025 Launch Vehicle

Subteam	System	Mass (g)
Structures	Nosecone	1,332
Structures	Internal Structure	5,279
Structures	Aeroshell	4,360
Structures	Fins	360
Avionics	Active Drag System	1,361
Avionics	Electronics Bay	1,315
Recovery	Chutes + Hardware	2,169
Payload	3U CubeSat	4,464
Propulsion	Casing Hardware	3,353
Propulsion	Propellant	4,711
Liftoff		29,945
Burnout		25,234

Table 2 Predicted flight data of the 2024-2025 launch vehicle.

Characteristic	Value	Unit
Liftoff TWR	8.38	N/A
Off-Rail Velocity	98.9	ft/s
Liftoff Stability	2.31	N/A
Burnout Stability	4.64	N/A
Burnout Mach	0.823	N/A
Maximum Velocity	941	ft/s
Maximum Acceleration	9.17	g
Uncorrected Apogee	10,840 ft	ft
Corrected Apogee	10,000	ft

Table 3 Simulation atmospheric data for Saragosa, Texas based on historical data in the month of June.

Characteristic	Value	Unit
Atmospheric Pressure	1.01	atm
Temperature	36.67	$^\circ C$
Elevation Angles	5	$^\circ$

C. Propulsion Narrative

Rocketry at Virginia Tech's 2025 launch vehicle is a COTS solid motor-powered launch vehicle measuring 130 in in length with a body diameter of 6.17 in. The vehicle structure is designed to carry propulsion, avionics, recovery, payload, and telemetry subsystems to an apogee of $10,000$ ft AGL. The vehicle's airframe is designed to allow for some limited replacement of vehicle sections both for modularity and flexibility of design in case of damage. This has allowed for multiple thrust structure sections to have been developed and tested over the 2025 design period. In its current configuration, Rocketry at Virginia Tech's 2025 launch vehicle is designed to fly on an AeroTech M2500[2] constrained by the motor casing in the thrust structure. The thrust structure includes the motor tube, fins, centering rings, tailcone, and a bulkhead, with all but the motor tube being made of SRAD carbon fiber. The motor tube is made of COTS fiberglass tubing. The thrust structure provides motor retention and transfers thrust loads into the airframe during flight. The vehicle's aerostructure is made of an SRAD carbon fiber body tube and tailcone, a COTS fiberglass body tube, COTS fiberglass couplers, and a COTS 5.5 : 1 Von Karman nose cone. The team uses a mixture of COTS fiberglass plates and SRAD carbon fiber plates for the centering rings and/or bulkheads used throughout the vehicle. The vehicle is estimated to have a mass of 66.0 lbs at liftoff; this decreases to 55.61 lbs by burnout and chute deployment due to loss of propellant mass. The system-level breakdown of masses is given in Table 4 based upon real measurements of as-built systems. Two tools were used to evaluate trajectories and flight characteristics: OpenRocket and RASAero II. Since the vehicle will travel into the transonic region by max-q, RASAero is used to supplement results from OpenRocket due to its lesser accuracy in the supersonic regime. All models were run at local atmospheric pressures of 1.01 bar and temperatures of 36.69°C according to historical weather data for Saragosa, Texas in June. Simulated launch elevation angles are 84 ± 1° in accordance with IREC Requirement 10.1. At liftoff, the vehicle has a TWR of 8.38 based on the M2500's average thrust of 2500.0 N and a liftoff mass of 66.0 lbs. Assuming a 4.88 m (17.0 ft) launch rail is provided by ESRA at Spaceport America, the vehicle will have an off-the-rail velocity of 98.9 ft/s . Stability margin is computed in dimensionless calibers using equation 1:

$$Stability\ Margin = \frac{C_g - C_p}{D_{airframe}} \tag{1}$$

where Center of Pressure (Cp) and Center of Gravity (Cg) are the distances from the tip of the vehicle to its center of pressure and center of mass, respectively, and $D_{airframe}$ is the vehicle's body diameter. Based on this, the vehicle has a stability margin of 2.31 calibers when leaving the launch rail, rising to 4.64 as the center of mass shifts forward during flight. This stability range, in addition to the estimated off-the-rail velocity, satisfies the stability requirements (10.2, 10.3, and 10.4) outlined by IREC.

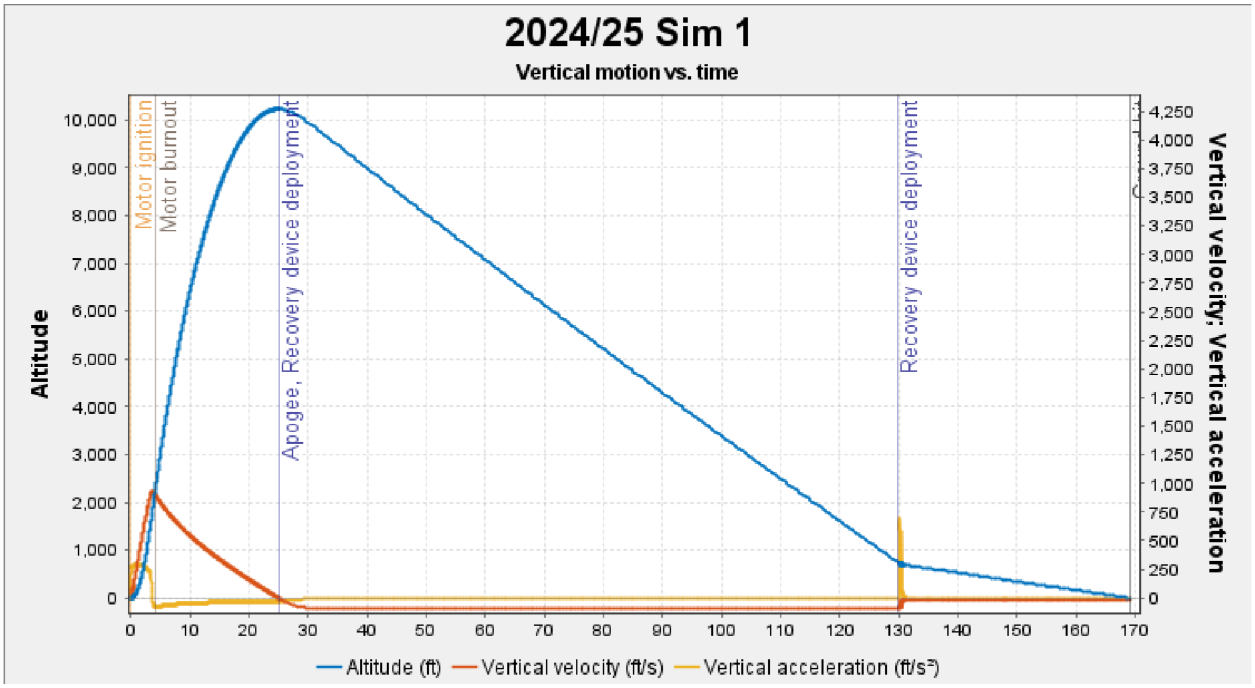

Fig. 3 Model of rocket in Open Rocket

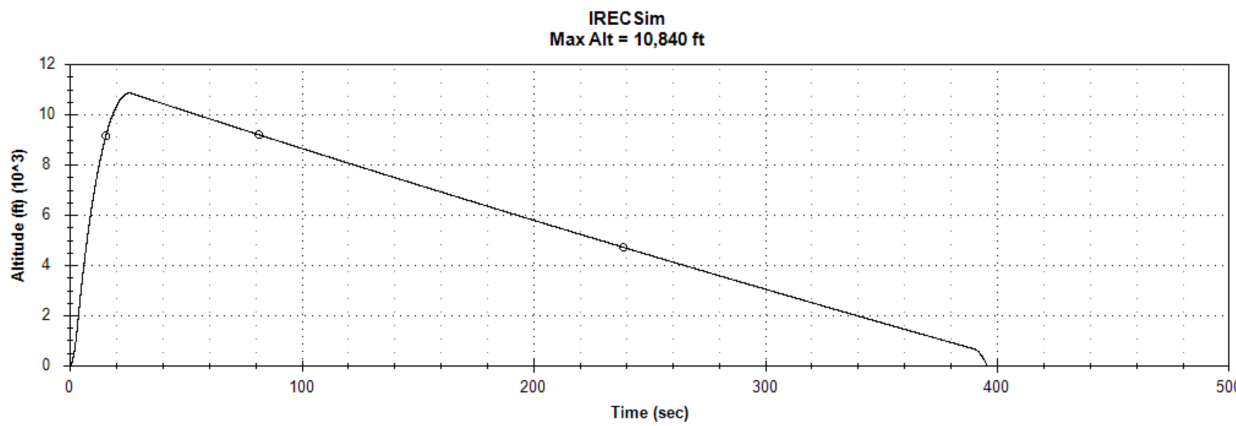

Fig. 4 Model of rocket in RASAero

Based on the average of the three models' uncorrected (without ADS deployment) apogee predictions, the vehicle is expected to achieve an apogee of $10,822\ ft$ AGL in $0\ mph$ winds and $10,526\ ft$ AGL in the extreme case of $20\ mph$ winds. The tendency of the vehicle to overshoot the target apogee is intended to ensure the vehicle is capable of breaking $10,000\ ft$ with the remaining altitude to be scrubbed off by ADS deployment. All models estimate a maximum velocity of $941\ ft/s$ or Mach 0.823.

D. Aero-structure Subsystem

The Aerostructures subteam is responsible for designing, manufacturing, and testing the launch vehicle. The subteam develops a launch vehicle that fits within the parameters of the competition, and manufactures necessary parts for the vehicle to work. The subteam continues to improve the launch vehicle through testing and analyzing of all load-bearing components and manufactured materials using finite element analysis and laboratory testing. The subteam strives to manufacture precise components for increased ease of integration so the full launch vehicle can be assembled in a timely manner using only basic hand tools. In addition, the subteam works with other subteams to integrate avionics, payload, and recovery into a unified launch system.

1. Vehicle architecture

The body of the launch vehicle is designed to accommodate all subsystems necessary for flight, including the payload, COTS solid rocket motor, avionics, and recovery. The vehicle is designed to meet all of the integration requirements for each subsystem. The rocket's overall length is 330.2 cm (130 in), with an outer diameter of 15.7 cm (6.17 in) and the ability to use any 98mm Aerotech motor casing, although it is currently fitted for the Aerotech 98/10240. A general layout of the launch vehicle can be seen in Figure 5. The dry mass of the vehicle is 21.9 kg. The mass will be broken down further in Table 4.

Table 4 Rocket Mass Breakdown

Part	Mass (g)
Nose Cone	1,332
Payload Section	5,288
Upper Body Tube	1,566
Recovery Bay	2,316
Lower Body Tube	972
Active Drag System	1361
Thrust Structure	4,360
Motor	8,064
Total	29,945

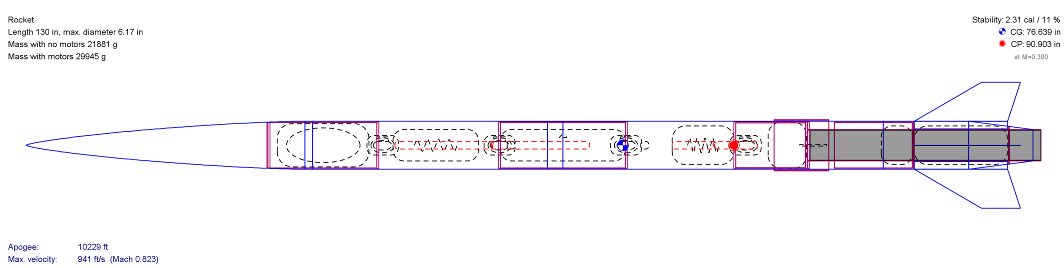

Fig. 5 OpenRocket flight simulation

The fin can and/or thrust structure are both built to house the Aerotech 98/10240 motor casing, as well as mount the four composite fins that will have a detailed description in the 'Fins' subsection. The motor is placed inside of a COTS wound fiberglass motor tube. Three centering rings are then attached to the motor tube to ensure alignment within the thrust structure. The motor tube is secured to the boattail and motor casing by a centering ring and bulkhead epoxied at the base, with another centering ring placed at the top of the fins.

In front of the motor casing is the ADS bay. The bay is 16.5 cm in length and secures the ADS in a way that it is not load bearing. The ADS is located in the aft-most location possible, which is done to minimize the destabilizing effect of deploying control surfaces into the airstream forward of the vehicle's initial center of pressure.

In front of the ADS bay is the drogue chute bay, housing the drogue chute which aids in the recovery of the rocket. The drogue chute is deployed at apogee through a break in the body tube caused by ejection charges.

In front of the drogue chute bay is the recovery bay where all the recovery altimeters, tracking electronics, and onboard camera are located. The 'Recovery' subsection will describe the exact components located inside the recovery bay in more detail. The recovery bay serves as a coupler between two body tubes, and is capped off on each end with fiberglass bulkheads. This orientation of components helps prevent the escape of pressure created by the ejection charges and ensures the separation of the body-tubes.

Above the recovery bay is the main parachute bay. The main parachute is stored in this location until the nose cone is ejected, which causes the main parachute to deploy. This event is controlled by the altimeter(s) and occurs at 800 ft. The nose cone is a COTS component, consists of wound fiberglass strand, and is Von Karman shaped. It has a 2 cm switch band around it, as well as a shoulder that extends outside the nose cone, allowing for it to be coupled with the body-tubes. The shoulder is extended 20.3 cm into the body tube, and satisfies the requirement that all couplers extend by at least one body tube diameter. The coupler that creates this shoulder also extends 12.7 cm into the nose cone and is where the payload is housed. A third recovery bulkhead is located at the base of the nose cone coupler and consists of an attachment point for the shock cord.

The final assembly of the launch vehicle with an exploded view of all subassemblies can be seen in Figure 6. The subassemblies are shown from left to right: ADS, recovery bay, and payload.

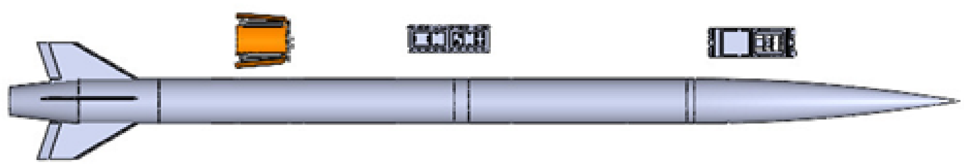

Fig. 6 Full Stack

2. Airframe

The team manufactures epoxy reinforced SRAD carbon fiber tubes and uses COTS fiberglass tubes for the airframe structure. The body-tubes house the vehicle's internal structure and various subsystems. Carbon fiber is used to construct the vehicle's body-tubes because it has a high yield strength to weight ratio; moreover, the team is using carbon fiber that was donated to the team from a previous school year.

The carbon fiber reinforced body-tubes are manufactured through a wet layup process using a 6-inch diameter aluminum mandrel tube. The mandrel is coated in petroleum gel to act as a release agent, and then layered with wax paper that is a barrier between the tube and carbon fiber. The layup utilizes 3 full layers of carbon fiber that will be wrapped around the mandrel, and then doused in West System epoxy resin to harden and hold the layers together in place. The layup will then rotate over a heater to dry before it is post-processed. After it is dried, the tube will be effectively sanded to remove all rough patches/edges from the surface, and then coated in an additional layer of epoxy. The additional layer of epoxy will help solidify the aerodynamics of the tube(s), and allow for a smooth integration into the rocket, as well as minimize possible edge/gap issues. After this layer has dried, the body-tube is removed by a mandrel press system that will push the tube off and keep its structural integrity. Shear pins will be used to conjoin the body-tubes at the two primary separation points, and rivets will be used at the nose-cone and base of the body-tube connection points.

Before designing and analyzing components of the launch vehicle, a safety factor must be determined to ensure that it can withstand the expected flight loads. The design safety factors used for analyzing yield and flutter stability failure are listed in Table 5.

The primary load considered when designing the thrust structure is peak thrust. Based on how the thrust structure was designed, the thrust load is transferred up the motor tube through the epoxy fillets holding the centering rings. To verify that the load path and structural design considerations were accounted for, tensile tests for the carbon fiber epoxy material were completed by the aerostructures subteam using the MTS 4202 Instron machine. 3 dogbone samples of the

Table 5 Design Safety Factors

Driving Failure	Mode	Design Safety Factor
Strength	Yield	1.50
Stability	Flutter	1.50

carbon fiber epoxy material, following the ASTM D3039, can be represented in Figure 7.

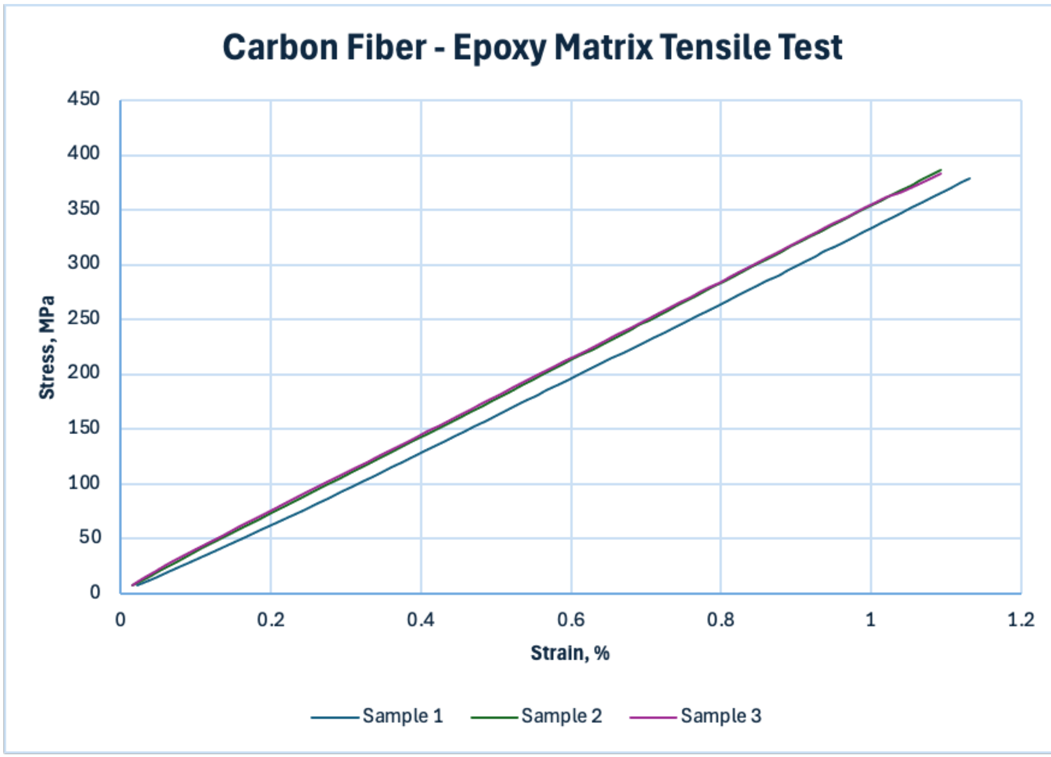

Fig. 7 Tensile testing results from April 2025.

The linear data for samples 1, 2, and 3, displayed in Figure 7, express a consistent trend of material behavior. The linear functions of all 3 samples demonstrate both the consistency of our specimens, as well as sufficient mechanical behaviors. The samples displayed a brittle failure and ultimate stress of approximately 382.5 MPa as well as a Young's Modulus of about 342.9 MPa as can be seen in Figure 8.

Fig. 8 Carbon fiber epoxy specimens: 1, 2, and 3 after tensile testing.

The tensile tests allow the design stress to be determined as equation 2 represents the factor of safety for brittle materials. Given this factor of safety equation, it is possible to determine the design stress, or allowable stress, for the motor tube. Once the variables are plugged in as can be represented in Table 6.

$$FS = \frac{Ultimate\ Stress}{Design\ Stress} \tag{2}$$

Table 6 Variables for FS Equation

FS	Ultimate Stress	Design Stress
1.50	382.5 MPa	255 MPa

The motor tube was also meant to be made of a carbon fiber epoxy matrix. Although this did not end up being the case, analyzing its material properties will still help the team in future years when planning thrust structure design. To understand the behaviors of the motor tube better, a compression test was performed using the MTS 4202 Instron machine. The data collected from the Carbon Fiber Compression tested a body tube of diameter 104.4 mm and height 205.4 mm, that displays a yield stress of 43.4 MPa and an ultimate stress of 43.7 MPa.

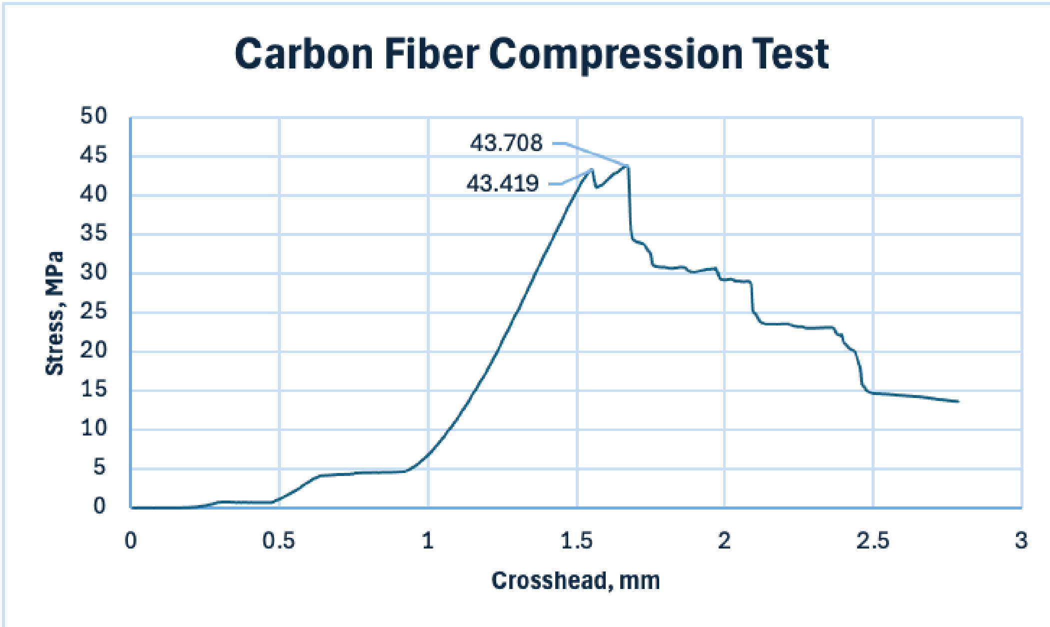

Fig. 9 Compression testing results from April 2025.

Table 7 Variables for FS Equation

FS	Ultimate Stress	Design Stress
1.50	43.7 MPa	29.1 MPa

When evaluating the graph, plugging in the Factor of Safety (FS), and ultimate stress into equation 2, the design stress can be represented again in Table 7 above. The design stress 29.1 MPa, reflects the allowable stress that the motor tube may undergo given a factor of safety of 1.5. Evaluating the factor of safeties for each of the component materials, provides sufficient insight into the allowable stresses that each part can undergo given the variables of peak thrust.

3. Fins

The fins of the rocket consist of a Nomex honeycomb core sandwiched between two sheets of carbon fiber reinforced with epoxy resin. The fin manufacturing process begins by securing a sheet of mylar onto a granite slab with tape. The mylar ensures that the epoxy does not stick to the granite so it can be reused. A small amount of epoxy is spread across the mylar and then a layer of carbon fiber is laid over top. More epoxy is used to coat the other side of the carbon fiber layer. The Nomex layer is then placed on the carbon fiber, and a second granite slab is added on top of everything. Additional weight is applied to ensure the fins are kept flat during the curing process. Once the epoxy dries, the weight and top slab are removed. The slab is placed flat on the workbench and prepped again by laying a mylar sheet on top. Another small layer of epoxy is spread onto the mylar and a sheet of carbon fiber is laid on top. The carbon fiber is saturated with more epoxy, and the dry half of the layup with the Nomex is flipped on top of the wet carbon fiber. At this point the fin layup consists of a Nomex layer in-between two single sheets of carbon fiber, which are all sandwiched between two layers of mylar and two granite slabs. Additional weight is again placed on top of the granite slab to keep the fins flat while they cure. After the completed layup is dried, an angle grinder, fitted with a cutoff wheel, is used to trim and clean up the edges of the layup so it fits within the water-jet machine.

Using a Computer numerical control (CNC) water-jet, two fins are cut from each layup. After the general shape of the fin is cut out, they are fitted with leading and trailing edge pieces. These pieces are 3-D printed in Acrylonitrile Butadiene Styrene (ABS) and sanded smooth to ensure a seamless transition between the fins and the edge of the 3-D print. Super glue is used to initially secure the leading and trailing edge pieces to the ends of the fin, directly onto the Nomex. After the leading and trailing pieces are added, an additional layer of carbon fiber is wrapped and vacuum sealed around the entire structure. The entire surface of the fin is roughed up using sandpaper to help adhesion to the next carbon fiber layer.

The geometry of the fins with both the leading and trailing edge pieces attached is shown in Figure 10.

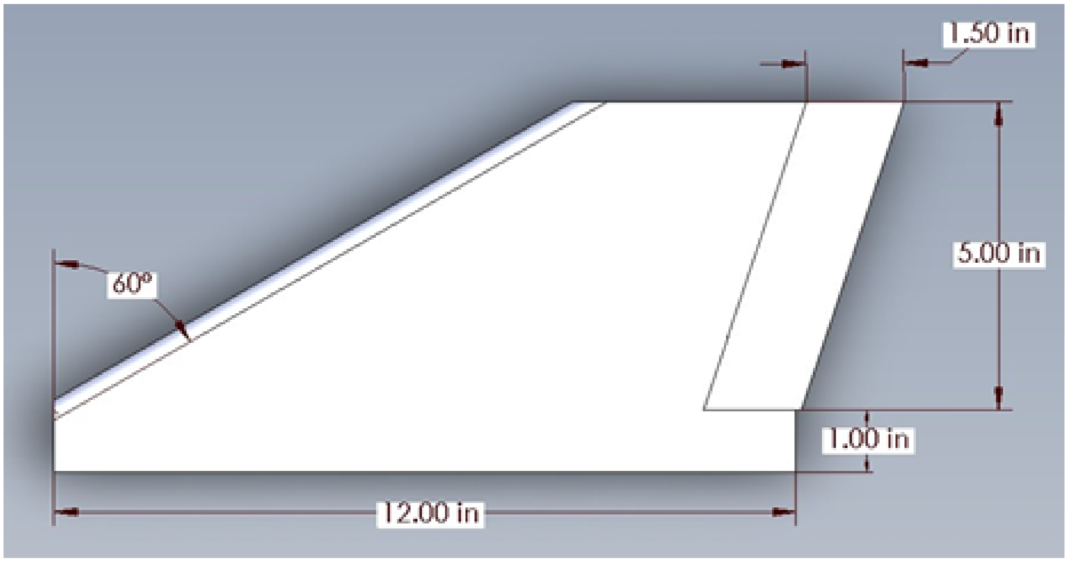

Fig. 10 Fin Geometry

To start the process for the second wrap, a sheet of carbon fiber is cut so that it is large enough to wrap around the whole fin piece. In addition to the carbon fiber, a sheet of mylar and absorbent material is cut to the same size. The absorbent material is laid down first, then the mylar, and then the new carbon fiber layer with the fin. Next, a layer of epoxy is applied to both sides of the fin and the carbon fiber is wrapped around the leading edge. The carbon fiber layer is smoothed out until there are no bumps and then the mylar and absorbent material are wrapped around the leading edge as well. The mylar is a non-adhesive, porous material used in order to ensure that nothing is able to stick to the layup during the vacuum sealing process. The absorbent fabric is used to absorb any epoxy leftover. Finally, the whole fin system is placed into a vacuum sealing bag, and the vacuum sealer, set on auto, is used to vacuum seal the bag. This process allows for the leading and trailing edge to be secured to the fin, creating one seamless piece that has no bubbles or creases.

When the epoxy fully dries inside the vacuum bag, the fin is removed and trimmed of any excess carbon fiber. Each fin will be sanded down and coated in a thin layer of epoxy on the surface. This process may be repeated again if any of the fins have visible roughness patches on the surface.

Fin flutter is a critical failure mode that must be considered for launch vehicle fins. The high dynamic loads caused by the aerodynamic forces during flight can cause the fins to deform or potentially shear off of the airframe. The fins are designed with Nomex sandwiched between two-ply carbon fiber layers to limit bending and reduce weight. Testing data collected in April 2025, shown in Figure 11, was used to estimate the effective elastic modulus of the fin material. It can be seen that the two tested samples yielded very similar stress-strain curves.

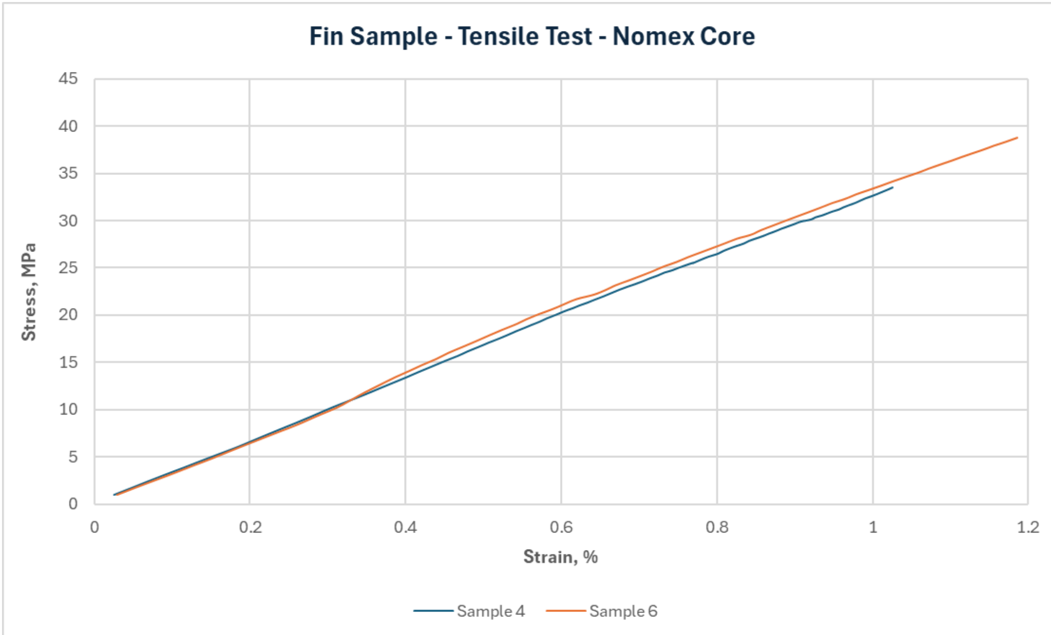

Fig. 11 Stress-strain curve results from April 2025 testing.

Using the lowest slope result for the most conservative estimate, the E_{eff} of the fin construction was determined to be 3.36 GPa. Equation 3 was then implemented to calculate the G_{eff} assuming a Poisson's ratio of 0.3.

$$G_{eff} = \frac{E_{eff}}{2(1+\nu)} \tag{3}$$

Equation 4 calculates the flutter velocity of the fins based on the known geometry and material properties of the fins as well as the estimated atmospheric properties during flight (Apogee Components). The projected peak velocity altitude, 2200 ft, was used to find atmospheric properties, as well as expected temperatures at the launch site during the time of competition.

$$V_f = a\sqrt{\frac{G_{eff}}{\frac{1.337AR^2P(\lambda+1)}{2(AR+2)(\frac{t}{c})^3}}} \tag{4}$$

With the known geometry and $Geff$ of the fins as well as the estimated flight conditions, the V_f was determined to be M1.31. With a maximum expected Mach number of M0.82, this gives us a Margin of Safety (MS) for flutter stability of +0.07. This margin was calculated using a design FS of 1.5 per Spaceport requirement 8.2.2. These results are summarized in Table 8.

Table 8 Design Safety Factors

Mode	V_{max}	V_f	Factor of Safety	MS
Flutter Stability	M0.82	M1.37	1.31	0.07

Along with the factor of safety and margin, it must be noted that the fin construction consists of an additional layer of carbon fiber on the leading and trailing edges of the fins which increases the elastic modulus and strength of the fins, which could not be incorporated into the material testing procedure.

E. Recovery Subsystem

1. Recovery Bay

This year's recovery bay is a modified version of previous years' designs. The design is modular, with 2 identical components that stack one upon the other to form the full bay. These two components are held together by four threaded rods. Each component contains an inset face with equally spaced mounting holes to secure the electronics mounts. The four vertical edges of each component contain wiring channels with alternating curved brackets to help secure wires in place. The inside of each component contains a slot for the batteries, and one face of the bay contains a slot for a sliding door that can be removed, for easier access to these slots. The sliding door has a handle on top to ensure convenient removal and replacement. The CAD model of the recovery bay structure is shown in Figure 12.

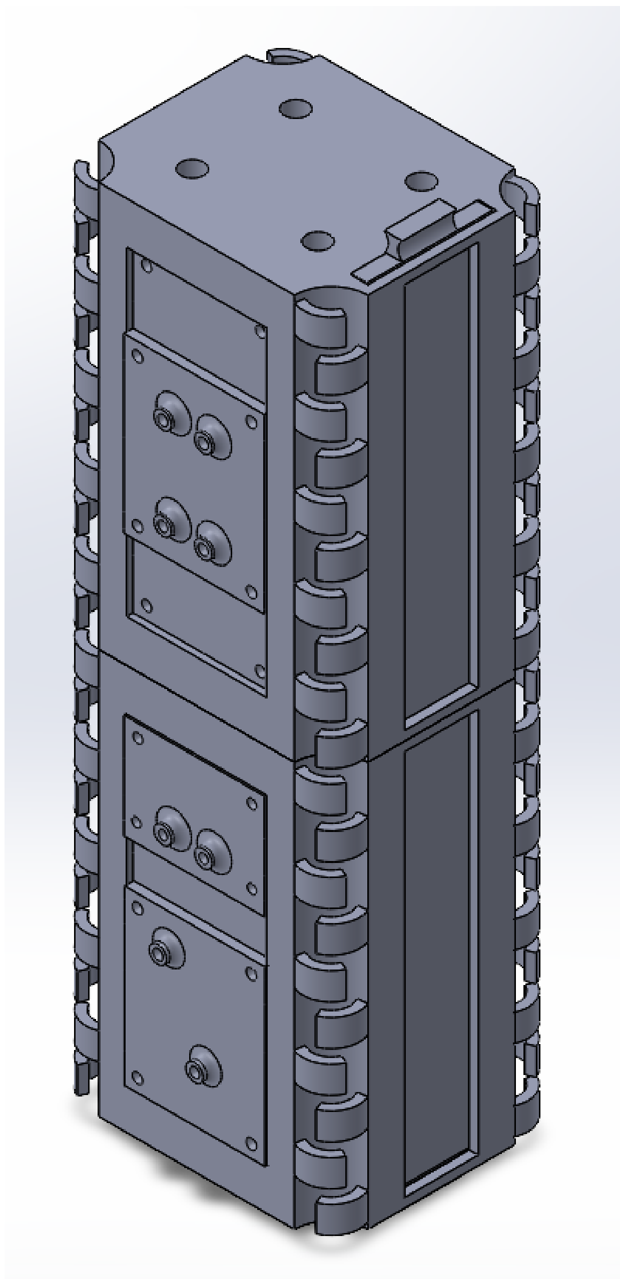

Fig. 12 Recovery Bay CAD Model.

The electronics components contained in the recovery bay are detailed in the 'Recovery Electronics' section. The mounts for these electronics were simplified from previous years' designs. Most of the mounts consist simply of a 0.118 *in* thick flat rectangular plate with elevated cylinders and mounting holes for the heat-set inserts required to secure the electronic components to the mount. These mounts also contain four additional holes to secure them to the bay itself. Despite the fact that the electronics vary in size and shape, the mounts are designed with the ability to fit nearly anywhere on the recovery bay due to the standardized spacing of the outer screw holes. In previous years, the electronics mounts contained "walls" around the components, leading to a snug fit but often interfering with ease of access and blocking wires. Because of these issues, the walls on the mounts were removed.

This year, in addition to the telemetry system installed in the Recovery Bay, a surface-mounted camera was incorporated into the setup. A 3-D printed shroud was designed to securely hold the camera, with the goal of minimizing drag on the rocket. The camera is mounted facing downward within the shroud on the switch band of the recovery bay, and its wires with a terminated JST connector are routed through the recovery bay coupler and sealed with epoxy. The shroud is angled about 4 degrees outward to optimize the camera's field of view during flight. This camera also serves as a redundant system to verify the ADS' deployment during flight. The CAD model of the camera shroud is shown in Figure 13.

All 3-D printed components utilize ABS to prevent against subsystems' structure melting due to high temperatures at the launch field.

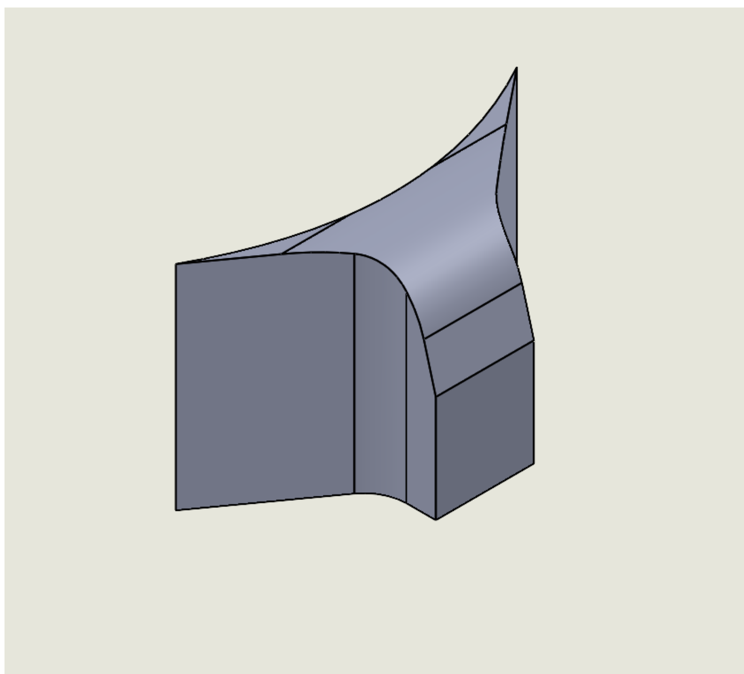

Fig. 13 Camera shroud that is mounted on the switch band of the recovery bay coupler

2. Recovery Electronics

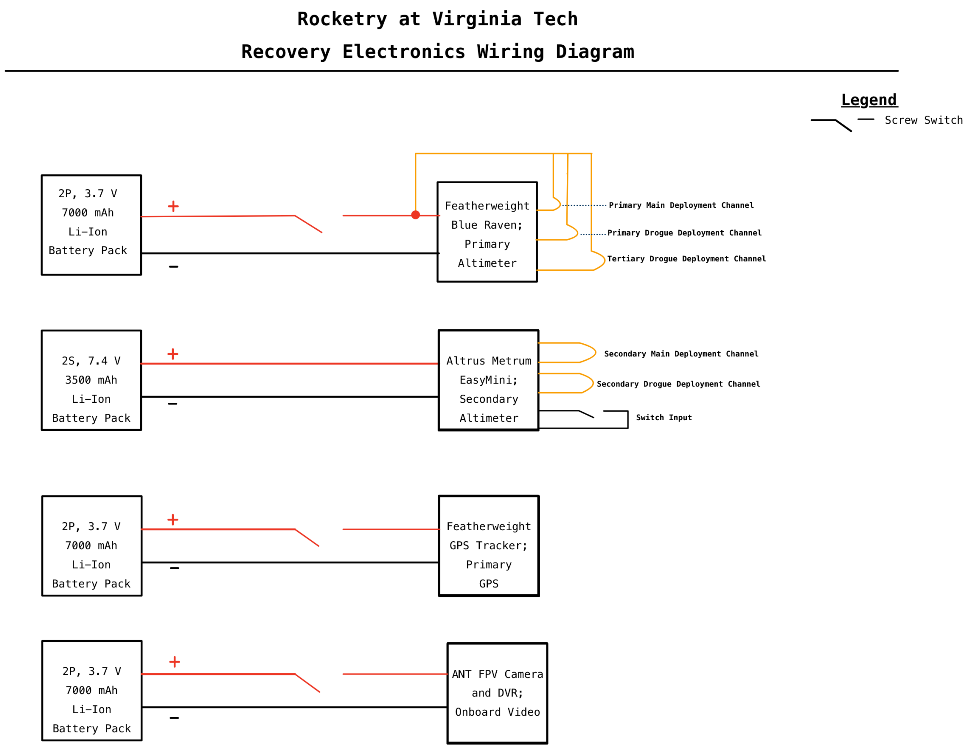

Fig. 14 Recovery Electronics Wiring Diagram

The active recovery electronics consist of two barometric altimeters, a COTS GPS, and a RunCam camera control circuit. The altimeters used are a Featherweight Blue Raven (primary) and an Altus Metrum EasyMini (secondary). The GPS used is a Featherweight GPS tracker, which operates in the unregistered $900 - 915$ MHz frequency band with the ability to change channels on the field to avoid interference between teams. Redundant GPS tracking is provided by the payload and the ADS and are detailed further in their respective sections.

The recovery altimeters are powered by combinations of 3.7 V 3500 mAh 18650 lithium-ion (Li-Ion) battery cells. The combinations used are 2S (2 cells in series for a voltage of 7.4 V and capacity of 3500 mAh, used on the EasyMini) and 2P (2 cells in parallel for a voltage of 3.7 V and capacity of 7000 mAh, used on the Blue Raven, Featherweight GPS tracker, and RunCam DVR, camera, and control circuit). These battery packs have a higher capacity than common alkaline 9 volt batteries and previously used lithium-polymer batteries while retaining ideal operating voltages for the selected electronics. The high capacity of these batteries are selected to extend useful life in the field in the event of delays during launch operations. To prevent any failure, the altimeter power systems are completely isolated from each other and any other subsystems. The altimeter power connectors are connected to the boards with robust XT-60 connectors to prevent accidental disconnection during flight as well as wire strain or breakage at connection points. To improve longevity, MissileWorks screw switches are used as arming switches which not only prevents unnecessary battery drain, but also allows all systems to be safely activated on the launch pad. The switches are mounted flush to the external switch band for easy access at the pad. The altimeters are then wired to multiple charge wells on both the top and bottom bulkhead. To prevent the wires from becoming loose under vibration, routing through the installed wire channels and additional hot glue is utilized in appropriate intervals. This also reduces the stress the wires may experience during flight loads.

3. Parachutes and Recovery Hardware

The main parachute used for our design is a SkyAngle Cert-3 XL. The drogue used is a Recon Recovery 30 in Parachute. This provides our rocket a descent rate of 82 ft/s under drogue and 17 ft/s under main. Apart from providing the ideal descent rates, these parachutes were selected based on the strong over-the-crest shroud line construction (see image), weight, and packing size, which was factored into the structural design of the rocket. The main parachute fits into its bay without excessive friction or bunching, which will ensure an ideal deployment and recovery of the rocket. Baby powder is utilized when packing the parachutes to prevent sticking and allows for a smoother parachute deployment. 18 in square kevlar blankets are wrapped around the parachutes and "dog barf" (Fireproof Cellulose Insulation) is used as an additional precautionary measure to protect the parachutes from hot ejection gasses.

To connect the parachutes to the bulkheads, $3/8$ in tubular kevlar shock cord is used. The drogue parachute has a shock cord length of 60 ft while the main parachute has a shock cord length of 30 ft. This is done to prevent collisions between the body tubes after recovery events and to prevent the bulkheads from experiencing excess stress during ejection. Metal quick-links and barrel swivels are then used to secure the shock cord to the bulkheads. On the bulkheads, forged U-bolts are used as permanent mounting points. This is done to prevent the quicklink from slipping out during ejection. The use of quicklinks, barrel swivels, and U-bolts helps minimize damage to the shock-cord and allows for easier integration of the recovery system.

Fig. 15 Skyangle Cert 3 used for recovery.[1]

4. Ejection System and Tests

Charge wells made of Polyvinyl Chloride (PVC) pipe are mounted on both the drogue and main bulkheads. The drogue bulkhead has 3 charge wells while the main bulkhead has 2. The drogue bulkhead charge wells hold the primary, first redundant, and second redundant black powder charges. The main bulkhead charge wells hold the primary and redundant black powder charges. Table 9 below shows the charge well, deployment condition, and black powder concentration. To ignite the black powder, e-matches are used which are connected using dedicated pyro channels. The e-matches are placed on top of the black powder and packed tightly with "dog barf" to ensure downward propagation of the flame front, increasing the reliability of complete burning of the black powder. Multiple tests were also performed by the team to obtain the corresponding values, theoretical estimates (simulations), ground tests, and practice flights.

Table 9 Black Powder Ejection Charges

Charge Well	Ejection Condition	Black Powder [g]
1 (Drogue Bulkhead)	Primary Altimeter (Apogee, Barometric and IMU)	4.5
2 (Drogue Bulkhead)	Redundant Altimeter (Apogee + 1s, Barometric)	5.5
3 (Drogue Bulkhead)	Primary Altimeter (Apogee + 200 ft/s downward, Barometric)	6.5
1 (Main Bulkhead)	Primary Altimeter (800 ft)	5
2 (Main Bulkhead)	Redundant Altimeter (700 ft)	6

F. Payload Subsystem

1. Overview

As with the other subsystems found in the rocket, the payload subsystem was a collaborative project between the Subsystems and Avionics subteam(s). The Subsystems team handled the design and manufacturing of a structure to securely contain the electronics stack provided by the Avionics subteam. For the sake of structural integrity, intended weight, and specific height constraints, it was decided to follow a two-piece, 3U-CubeSAT design made of 3-D printed ABS reinforced with steel rods. The payload contains an active GPS antenna; a GPS module; an accelerometer; 3 Internal Measurement Unit (IMU)s; a long-range, low-power wireless communication device (LoRa); a Raspberry Pi Pico; a barometer; a Battery Eliminator Circuit (BEC); a Li-Ion battery pack; and an additional radio module.

2. Structure

The top half of the payload contains houses the electronics, aside from the battery and additional radio module, distributed across three mounting plates. The electronic plates are made of 3-D printed ABS, take on the shape of a T with a thickened base, are secured on one end with shelve-like pieces referred to as "chopsticks," and on the other end with heat-set inserts and screws. The "chopsticks" are attached to the primary frame using heat-set inserts and screws as well. For the second and lower portion of the payload, is three walled box of the same width and length as the top section, except with a slight indent in one wall for placement of the radio antenna, space for the battery pack, and a gap for a removable door on the fourth wall, shown in Figure 16. Functionality of the electronics within the top portion of the payload are initiated through the use of a screw switch, accessible from the outside of the rocket. Other notable features on the payload are: the GPS cover on the top-most part of the structure intended to secure the GPS and keep it from being damaged; filleted edges to aid in assembly and disassembly of the payload; adjustable position options for electronic plates, shelves.

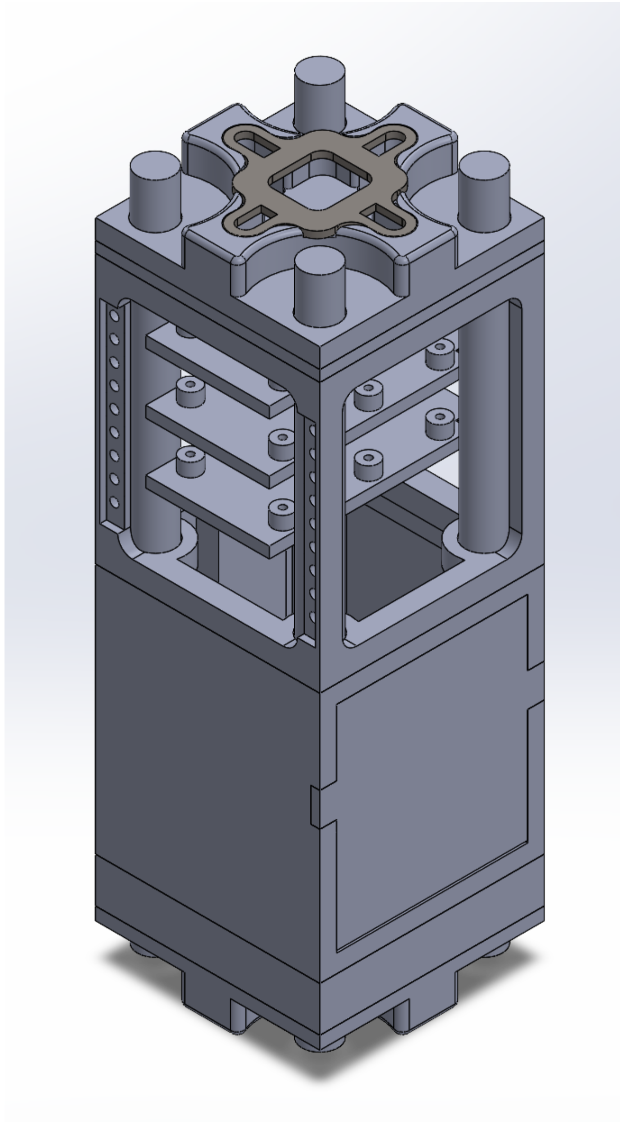

Fig. 16 CAD model of Payload Structure

3. Electronics

As previously mentioned, the top half of the payload houses the majority of the electronics. The first plate below the bulkhead contains a U-Blox NEO M9N GPS module; ADXL375 high-range ±200G accelerometer; and an ISM330DHCX ±4G IMU all connected to one Inter-Integrated Circuit (I2C) bus. The top of the second plate contains a Heltec WiFi LoRa 32 (V3) that is connected over Universal Asynchronous Receiver/Transmitter (UART) to an additionally mounted Raspberry Pi Pico. On the underside of the second plate, there is the BMP390 barometric pressure sensor. The third and final plate holds an ISM330DHCX ±4G IMU, an LSM6DSO32 ±32G IMU, and a 5V, 8A Universal Battery Eliminator Circuit (UBEC). Note that the sensors and GPS module present on the first plate are on a different I2C bus than the sensors on the second and third plate. A Li-Ion battery pack is located in the bottom section of the payload to power it all through the UBEC. The battery pack is in a 3S3P configuration (3 cells in series for a voltage of 11.1 V and capacity of 3500 mAh with 3 rows of cells in parallel for a total capacity of $10,500$ mAh). Next to the battery is the RFD900X radio connected over UART to the Raspberry Pi Pico.

The reasoning behind the layout of the electronics system is mainly for convenience, as it allows the removal and replacement of sensors at any time in a mostly simple way. Qwiic (I2C) connectors are used so that it is simple to unplug a cable and plug in a new sensor board. The other two upper plates also have components mounted with vibration-damping gaskets and 3-D printed Thermoplastic Polyurethane (TPU) to allow for the isolation of the rocket's intrinsic vibrations and the subtraction of the noise pattern from collected data. This is to help analyze sensor data for further development of the ADS' flight computer and improve its apogee predictions. Sensor data is streamed to a ground station from both the Heltec LoRa board and the RFD900. The Heltec LoRa board is on the same channel/frequency as the LoRa board found in the ADS electronics stack to form a mesh network. The LoRa boards broadcast in the Automatic Packet Reporting System (APRS) Compressed Position Report format, while the RFD900 broadcasts in a custom format.

G. Active Drag System

1. Overview

To achieve the team's overall goal of reaching exactly $10,000\ ft$, an airbrake system was designed and integrated into the rocket. The Active Drag System (ADS) is utilized during the coast phase of the launch, deploying vertical flaps after motor burnout and retracting at apogee. When extended, the flaps increase the total drag force on the rocket to decrease the vertical velocity and accomplish the altitude precision goal.

Although the current iteration of the ADS is based upon last year's design, the redesign aimed to enhance the system's effectiveness, modularity, and integration. It is expected that the current design has the capability to reduce the rocket's apogee by $1,000\ ft$.

To prevent premature deployment during the boost phase, a mechanical lock was implemented within the ADS interior. An electronically controlled lock on the servo motor works alongside the mechanical lock.

2. Design

Each ADS flap measures $7\ in$ in length with an arc length of $3.75\ in$ and incorporates an internal stainless steel slot to guide pin movement. The slots have a channel approximately $1\ in$ long with a small hole at the top just large enough for the pin to fit in. The slot hole is located high enough to prevent the pins from falling out during flight. The fins are attached to the top of the ADS columns using bolts and internally mounted lock nuts. The slot and bolts create a mechanical lock preventing the flaps from detaching from the rocket. A rack and pinion drive system, housed between the lower disks of the ADS, actuates the flaps. The racks and rods were fabricated using aluminum metal 3-D printing to ensure sufficient strength to withstand flight loads. A servo motor drives the gear system to control flap actuation. Additionally, the top disk supports all ADS electronics and pressure-seals the ADS PCB board with a port hole above the flaps to maintain accurate barometric sensor readings during operation. A CAD model of the ADS is shown in Figure 17 below.

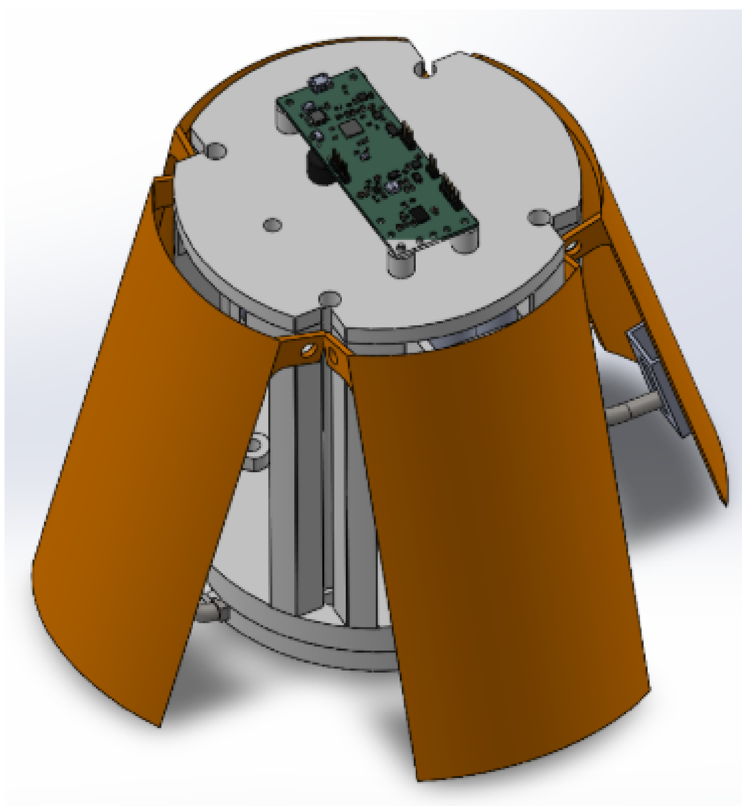

Fig. 17 Active Drag System with flaps deployed.

3. Manufacturing

The four slots for each flap were cut with a CNC water jet and bent on a steel edge. The flaps were constructed by layering five pieces of carbon fiber into a custom, 3-D printed mold with a thin layer of epoxy applied between each layer. Both the top and bottom of the molds were coated in petroleum jelly to prevent the carbon fiber from sticking to the mold. The metal slot was placed between the second and third layer, and the remaining layers of carbon fiber were cut to fit the extruding slot. Once all layers were applied, the top layer of the mold was sat on top and the structure was clamped for 24 hours. Once removed from the mold, the flap was trimmed to the dimensions of the design. Holes were drilled into each side for attaching to the system and the entire flap is sanded. The racks and threaded rods were custom ordered. The rest of the parts, other than electronics, were 3D printed using a ABS filament and either bolted or screwed together.

4. Computational Fluid Dynamics

To determine the influence of the ADS on the aerodynamic characteristics of the launch vehicle, several Computational Fluid Dynamics (CFD) models were created using Ansys Fluent. The algorithm of the ADS utilizes the Coefficient of Drag (Cd) of the launch vehicle to determine the necessary ADS deployment. Thus, CFD simulations were run for five different ADS deployment models over many different air speeds to find the rocket's total Cd at these various conditions. The five models are of the rocket's outer surface with the ADS flaps deployed at 0°, 5°, 10°, 15°, and 20°. CFD simulation was run on these models at air speeds ranging from 50 m/s to 300 m/s in increments of 50 m/s.

A large domain surrounding the rocket was simulated to ensure boundary layer effects did not skew the results. Mesh refinement was used in locations around the rocket where greater stagnation pressure and turbulence were expected. Areas of less interest used a larger mesh size to reduce overall element count and simulation time.

CFD simulations were conducted in Ansys Fluent using an omega-SST model and assuming air as an ideal gas. The inlet of the domain was simulated to have a uniform air velocity, and the exit a uniform atmospheric pressure. Simulations were run until all convergence criteria were met, or until the residuals plateaued at a small enough value that was still above the convergence limit, leading to ± 1 N of possible error in results. The simulations were run to obtain the total drag force on the rocket. Cd values were obtained via the drag equation using the total drag produced by the rocket, fixed fins, and ADS flaps, and the projected area of the rocket and fixed fins, but not including the ADS. This was done in order to simplify comparisons between the ADS deployment states. The calculated frontal area of the rocket and fins was approximately 226.34 cm^2.

Due to the complexity of the geometry and the high computational time of these simulations, many simulations have not been completed yet. Work on the CFD simulations will continue to be done prior to the competition to ensure the rocket has a usable ADS.

5. Finite Element Analysis

A finite element model of the ADS was created in order to validate the mechanical design of the system under the estimated flight conditions. The model for the analysis was simplified to ensure efficient processing and computational time. This simplified CAD included a single flap with the push rod fixed in all degrees of freedom at the center. The setup allows for accurate representation of the ADS deflection and stress amplitudes caused by the drag forces on the overall system.

The model took into account the various materials of the system which would account for each of their material properties, most importantly tensile yield strength. The baseplate and guardrails are both made of ABS plastic, while the flap itself is a carbon fiber epoxy wet layup. All of the hardware in the system was run in ANSYS under material properties of structural steel or 316 stainless steel (mounting hardware).

A drag force of $115 N/fin$ per the CFD results was used in the Finite Element Model (FEM) as well as a fixed support at the baseplate. Other constraints were accounted for through manual contacts and beam connections. Eight beam connections were created to simulate the ADS being bolted down to a baseplate during flight. The beam connections each had a stress radius of 1.7 mm and were loaded with a bolt pretension of 835 N. A revolute joint was created between the flap/pin and column connection to replicate the movement allowed to the flaps in flight.

Mesh sizing was incorporated at locations of concern where levels of modeling accuracy were desired. These locations were mounting holes, the pin location on the flaps, pin location on the columns, and the faces of the columns and flap that are connected. The mesh refinement at the mounting holes is important to reduce risk of ANSYS concentrating all loads to those locations and skewing results. The meshed ADS is shown in Figure 18.

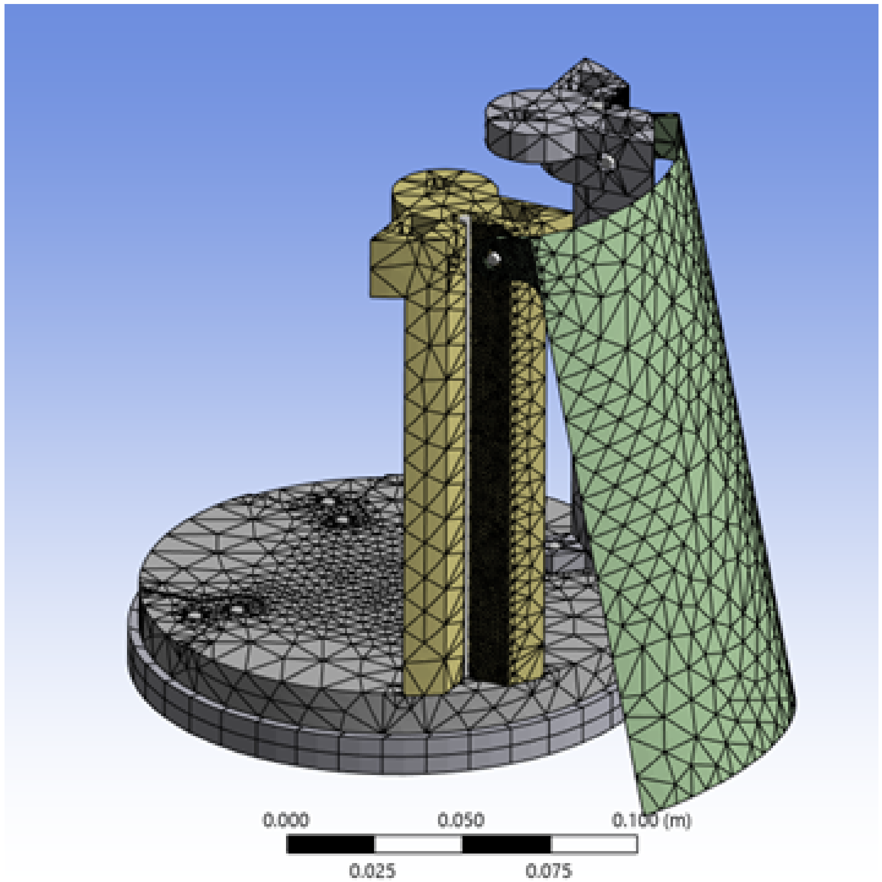

Fig. 18 Mesh of ADS

The next area of concern was the deformation that may be experienced around the flap and pin joint. In the figure below, the ANSYS simulation returned a max value at this location of 0.00121 m which is under the max allowed value of 0.002 m. This deformation could be decreased to a smaller value by utilizing an increase in material thickness, proper hole sizing, and pin selection. The team did not see a need to change the design due to the fact that the ADS flap did not see fracture or yielding at this location during the simulation.

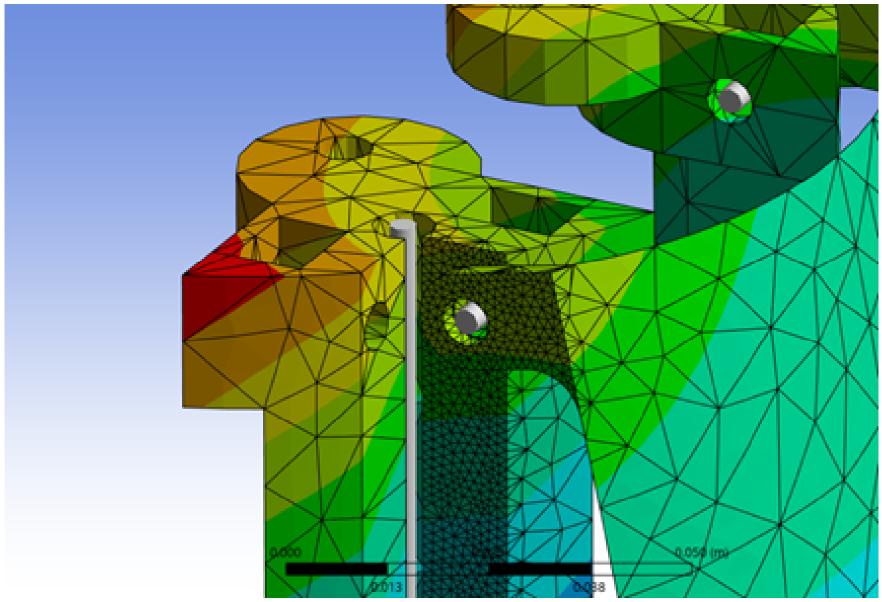

Fig. 19 Deformation on Flap/Column Connection

Figure 19 displays the equivalent or von-Mises stress results on the overall ADS. The lighter colors demonstrate a higher stress than that of the whole body. This allows the team to visualize the stresses and understand how the various stress components impact the entire structure as a whole. Not only does this allow the team to understand the max stresses, but it builds a greater understanding for how the materials act in relation to one another. It is seen that the highest stress experienced by the ADS is at the flap and pin connection and is measured at 172 MPa. This maximum stress does not exceed the yield stress of the carbon fiber matrix the flap is manufactured from which shows it can endure the flight loads without failure or yielding.

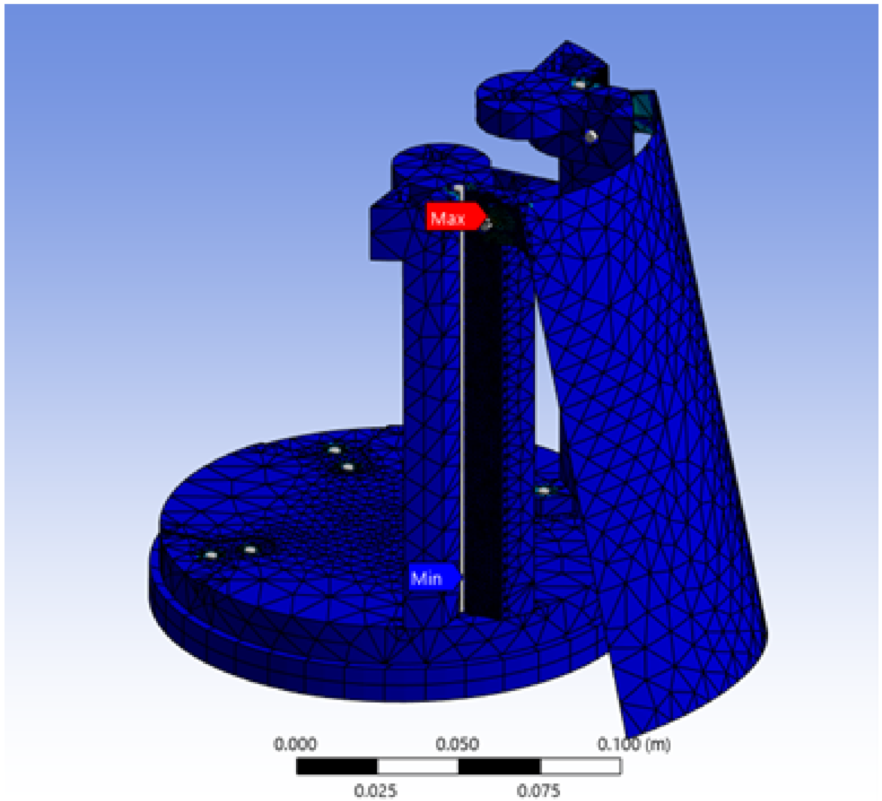

Fig. 20 Maximum Stress at Flap and Pin Joint

Finally, the system produced a factor of safety greater than 1 in all cases, with the highest FS being 15 and the lowest being 1.5 around the mounting holes. This shows the design can withstand the maximum load seen during flap deployment and overall flight.

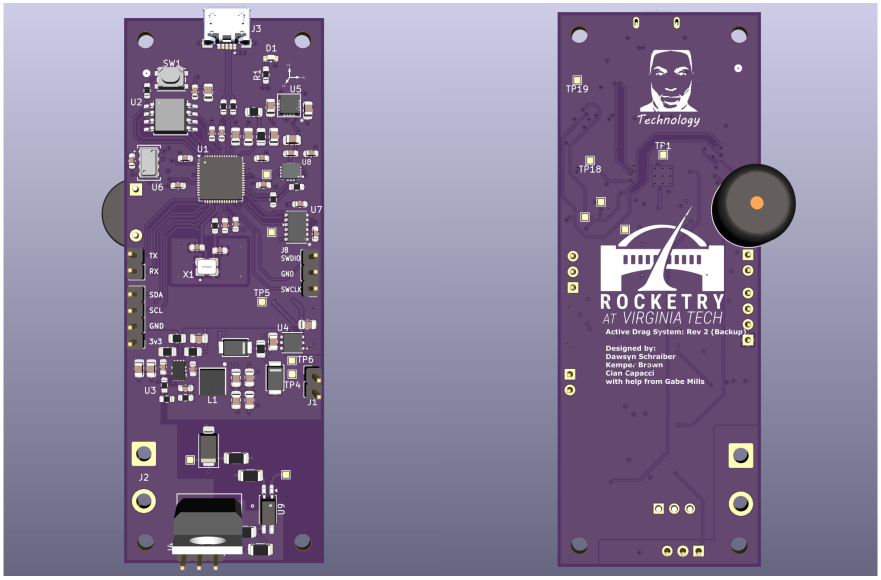

Fig. 21 KiCad 3-D Rendered View of SRAD PCB

A custom 4-layer PCB was developed with the purpose of acting as the primary ADS flight computer. The flight computer features several sensors commonly found in commercial recovery altimeters as well as a servo enable circuit designed in the previous year to aid in power management.

The primary microcontroller found on the flight computer is a Raspberry Pi RP2040, a dual-core ARM Cortex M0+ with 29 GPIO pins and built-in USB support for ease of flashing and debugging; it is paired with 16 Megabytes of external Quad SPI flash memory for code and flight data storage. The team had previously used the RP2040's development board counterpart in tandem with a sensor suite, so a familiarity surrounding its development ecosystem had already been established.

As previously mentioned, commercial recovery altimeters – especially the Altus Metrum TeleMega[3] given its open-source nature – were rather inspirational in the process of sensor selection. The TE Connectivity MS5607 Barometric Pressure Sensor, the Analog Devices ADXL375 3-axis digital MEMS accelerometer, and the Memsic MMC5983MA 3-axis magnetometer are all found on the flight computer, just as with the TeleMega. A TDK-Invensense IIM-42653 6-axis IMU is also present.

The MS5607 barometric pressure sensor operates at 500 Hz, where 24-bit pressure is sampled (in millibars) and compensated with temperature (in $^{\circ}C$). This pressure value is subsequently converted to an altitude (in meters) via a lookup table generated by a script based on the International Standard Atmosphere[2]. The ADXL375 accelerometer operates at 500 Hz where 16-bit acceleration data is sampled (in Gs) in all 3-axes. This accelerometer serves to observe high-frequency events that the IMU may not be able to catch due to its lower sensitivity. The MMC5983MA magnetometer operates at 200 Hz where 16-bit magnetic data is sampled (in Gs) in all 3-axes. The magnetometer serves as the primary method for obtaining initial orientation data and a reference for axis assignment prior to launch. The IIM-42653 IMU operates at 500 Hz, where 16-bit acceleration and gyroscopic rate data is sampled (in Gs and degrees per second, respectively) in all 6-axes. This serves (with the MS5607) as a primary in-flight measurement device for use in state estimation and event detection. All of the aforementioned sensors are interfaced as slave devices on an I2C bus by the master RP2040 due to its simplicity in trace routing on a PCB and adequate transfer speeds. Similarly, all sensor peripherals operate on the same regulated 3.3 V input voltage as the RP2040.

The team selected the Sincecam 50 kg, 8.4 V, Low Profile Servo as the actuation mechanism for the ADS flap deployment. The servo features a 50 kg/cm torque and a 270-degree rotation angle, which makes it ideal for use in applications that require high torque and precise motion control. The servo has a pulse width modulation (PWM) input signal which will flow from the RP2040 to the servo through a diode present to provide reverse current protection. The servo is dynamically powered by the 7.4 V battery only during the flight. This is achieved through an N-channel power transistor that acts as an electrical switch for the servo's power supply, driven via an optocoupler that is controlled by a

GPIO pin on the RP2040. The flight computer will only enable the servo upon launch detection in order to lock the servo to full retraction until the coast phase of flight.

To supplement telemetry efforts found throughout the rocket, a Heltec WiFi LoRa 32 (V3) and a U-Blox NEO-M9N GPS breakout module are found on the underside of the flight computer's mounting plate. These radio modules are connected to the antennas found external to the carbon fiber thrust structure and embedded in epoxy with cables run through the structure to allow for RF passthrough. The LoRa module is connected to both the GPS module via I2C and the flight computer via UART. The flight computer provides the regulated 5 V required for the LoRa and GPS modules.

The flight computer receives power from a custom Lithium-Ion battery pack in a 2S4P configuration (2 cells in series for a voltage of 7.4 V and capacity of 3500 mAh with 4 pairs of cells in parallel for a total capacity of $14,000$ mAh). The flight computer and associated ADS electronics will only be enabled when the externally accessible MissileWorks screw switch is enabled at the pad prior to flight.

7. Algorithm

With the increase in the number of sensors from previous designs and increased desire for a more robust system architecture, it was decided to utilize FreeRTOS for the primary tasks' handling (e.g. sensor sampling and data logging) and interrupts for event handling (state changes). FreeRTOS allows designating sensor sampling and event responses to one core and data logging and serial debugging to the second core. This task designation ensures no overlap between the 'hard real-time' tasks and the 'soft real-time' tasks.

Upon power enable, the RP2040 initializes its I2C bus and subsequently all the sensors to configure their appropriate ranges, output data rates, and any sensor offsets where needed. The barometric sensor takes an initial reading to establish a base ground altitude. The barometric sensor's driver is then configured to trigger an interrupt event when it crosses 30 m above the base ground altitude. Similarly, the IMU is set to trigger its interrupt pin high when an acceleration above 2.5 Gs occurs. These are the events that are utilized to declare the beginning of a launch event. As they are interrupt-based, the microcontroller is free to allocate its resources to reading data and reacting rather than polling for the launch event to occur. In turn, a state machine is used to determine the different stages of the launch and the ADS' functionality at each of those stages. The states consist of being on the pad at idle, boost (i.e. motor burn), coast, apogee, recovery, and end.

The initial launch events determine the point at which the state machine transitions from the idle state to the boost state. A hardware timer is then initialized and started for 110% of the simulated motor burn time (4.6 s for the M2500T). The end of this timer, in combination with falling below the 0.9 g acceleration threshold, marks the transition from the boost state to the coast state. The coast state transitions to the apogee state at the point where the velocity is determined to cross from positive to negative. The recovery state is marked in the immediate iteration following as the first recovery event occurs at and/or after apogee. When the rocket is detected to have fallen within 10% of the established base ground altitude and/or has maintained a constant altitude for several seconds, the state machine determines the end of flight, stops logging data, and disables the servo. A state machine update and response occurs at a frequency of 100 Hz via the FreeRTOS scheduler. Data logging occurs throughout the entirety of flight and even captures the first 5 seconds prior to flight thanks to a circular buffer initially stored in RAM that is dumped to the external flash upon launch detect. This state machine's functionality has been verified with camera footage and logged data at previous test launches.

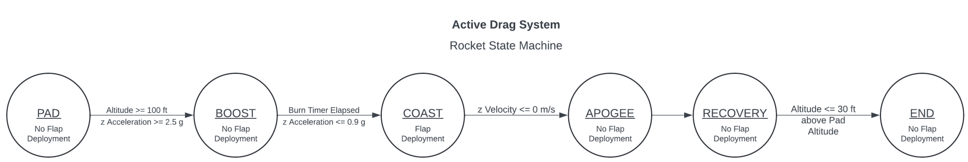

Fig. 22 ADS State Diagram

The ADS' behavior in each of these states, except for the coast state, is to log data and retract the ADS flaps via the correct PWM configuration. To preserve battery power, the servo is disabled using the servo-enable circuit during the idle and end states. The coast state is largely when the ADS is active. A two state Kalman Filter based upon kinematics uses altitude converted from the pressure read from the barometer sensor as the measurement and the z-axis component of the acceleration from the IMU as the control to obtain the climb rate.

The current step drag coefficient is computed from the filtered altitude, the z-axis component of acceleration, and the fused climb rate. These measurements along with the current state are serialized and logged to the external flash chip for later inspection and analysis. The difference of the estimated optimal drag coefficient (e.g. to achieve $10,000\ ft$ apogee) and the current computed drag coefficient is given as the input for a Single Input Single Output (SISO) Proportional Integral derivative (PID) controller. A PID controller is used to adapt an interpolated curve correlating the simulated drag coefficient and percentage deployment of the ADS. This percentage deployment is then translated to a proper pulse width to provide the servo's PWM input. In the coast state, if there is ever an error in reading sensor data or an attitude greater than $30°$ the flaps will be retracted accordingly.

IV. Conclusion

For the 2025 International Rocket Engineering Competition in the 10k COTS category, Rocketry at Virginia Tech has designed and manufactured a launch vehicle that features a precision altitude control active drag system and a near fully SRAD carbon fiber composite airframe. In the process of designing one of the team's most innovative projects to date, Rocketry at Virginia Tech aimed to improve on past iterations of subsystems as well as lay the groundwork for future team members to expand on these same subsystems, and have a highly successful year at competition.

Throughout this year the team has improved on past projects, and has seen huge success in new manufacturing methods. The team's design and build process has become more reliable, and has allowed the team to produce lightweight rocket structures for this year's rocket. The team has also seen massive success in subsystems like the SRAD which has proven itself to be better than even in this year's redesign. With the teams continuing success the team brightly awaits competition with fresh hope for success.

Rocketry at Virginia Tech faced many new challenges this year as it underwent a full leadership restructuring. Reducing the team from 8 subteams to 3 allowed for better communication between subteams on system and integration requirements and facilitated the passing of knowledge from one year to the next. With the help of the team's university mentors and generous alumni network, the team was able to construct one of its most innovative projects to date and looks forward to pushing the envelope in the future.

Going forward, the team seeks to continue improving our manufacturing, design, and analysis to do more than just build a high-powered rocket, but also to expose our members to industry standard engineering practices by giving them the opportunity to apply what they've learned in the classroom to one of Virginia Tech's most complex student researched and designed engineering projects.

Appendix A: System Requirements

S.5. PROPULSION SYSTEMS

S.5.1.1 A Commercial Off The Shelf (COTS) motor is defined as a motor which has been certified by the Canadian Association of Rocketry, Tripoli, or NAR, and appears on the then current combined Certified Rocket Motors List.

S.6. RECOVERY SYSTEMS AND AVIONICS

S.6.2. Batteries Contained in the Rocket

S.6.20.1. Lithium-Polymer (LiPo) batteries are not permitted due to fire hazard unless installed in the powered device by the manufacturer or recommended and supplied by the manufacturer.

S.6.20.3. NiMH (Nickel-Metal hydride) batteries are allowed in metal casing and any form factor.

S.6.20.5. Other Li-Ion batteries are permitted if packaged in a cylindrical metallic casing.

S.7. ACTIVE FLIGHT CONTROL SYSTEMS

S.7.1. Restricted Control Functionality

S.7.1.1. All launch vehicle active flight control systems shall be implemented strictly for pitch and/or roll stability augmentation, or for aerodynamic braking.

S.7.1.2. Under no circumstances will a launch vehicle entered in the SA Cup be actively guided towards a designated spatial target.

S.7.1.3. ESRA reserves the right to make additional requests for information and draft unique requirements depending on the team's specific design.

S.7.1.4. A neutral state is defined as one which does not apply any moments to the launch vehicle (e.g., aerodynamic surfaces trimmed or retracted, gas jets off, etc.).

S.7.2. Unnecessary for Stable Flight

S.7.2.1. Launch vehicles implementing active flight controls shall be naturally stable without those controls being implemented (e.g., the launch vehicle may be flown with the control actuator system (CAS) – including any control surfaces – either removed or rendered inert and mechanically neutral, without becoming unstable during ascent).

S.7.3. Designed to Fail Safe

S.7.3.1. Control actuator systems (CAS) shall default to a neutral state whenever either an abort signal is received for any reason, primary system power is lost, or the launch vehicle's attitude exceeds 30° from its launch elevation.

S.7.4. Boost Phase Dormancy

S.7.4.1. Control actuator systems (CAS) shall remain in a neutral state until one of the following conditions is met:

S.7.4.1.1. The launch vehicle's boost phase has ended (i.e., all propulsive stages have ceased producing thrust).

S.8. JOINTS IMPLEMENTING COUPLING TUBES

S.8.5.1. Airframe-to-coupler sliding joints intended to separate during a recovery event

S.8.5.1.1. Joints shall be designed such that the coupling tube extends no less than 1 body tube diameter (1 caliber) into the airframe section from which the coupler will separate during flight.

S.8.5.3. Joints not intended to separate during flight

S.8.5.3.1. Joints shall be designed such that the coupling tube extends into the mating component to the lesser of 1 body tube diameter (1 caliber) or the maximum depth possible by the design of the mating component.

S.8.5.3.2. Joints shall be affixed by mechanical fasteners and/or permanent adhesive.

S.8.5.4. Regardless of implementation (e.g., RADAX or other join types) airframe joints shall prevent bending.

S.10. LAUNCH AND ASCENT TRAJECTORY REQUIREMENTS

S.10.1. Launch Azimuth and Elevation

S.10.1.1. Launch vehicles shall nominally launch at an elevation angle of 84°±1° and a launch azimuth defined by competition officials at the IREC.

S.10.1.2. Range Safety Officers reserve the right to require certain vehicles' launch elevation be lower if possible flight safety issues are identified during pre-launch activities.

S.10.1.3. Competition officials may allow staged flights to launch at 87°+1

S.10.2. Launch Stability

S.10.2.1. A rail departure velocity of at least 30 m/s (100 ft/s) is required

S.10.2.2. Teams unable to meet 10.2.1 may use detailed analysis to prove stability is achieved at a lower rail departure velocity, preferably via flight testing. Alternatively, multiple computer simulations may be used, but must evaluate stability under a variety of launch conditions.

S.10.2.3. Departing the launch rail is defined as the instant at which the launch vehicle first becomes free to move about the pitch, yaw, or roll axis.

S.10.3. Ascent Stability

S.10.3.1 Launch vehicles shall maintain a dynamic stability margin of at least 1.5 body calibers, regardless of Cg movement and/or shifting center of pressure Cp location, from launch through the first recovery system deployment event.

S.10.4. Over-Stability

S.10.4.1 Launch vehicles shall not be "over-stable" during their ascent, defined as having a static stability margin >4 calibers or a dynamic stability margin during flight >6 calibers.

S.11. ESRA PROVIDED LAUNCH SUPPORT EQUIPMENT

S.11.1. ESRA-Provided Launch Rails

S.11.1.1 All teams competing in the solids (COTS or SRAD) categories shall use SA Cup supplied launch control systems.

S.11.1.2 ESRA shall provide launch rails measuring at least 5.2 m (17 ft) long, 1.5" x 1.5" (aka 1515) aluminum guide rails of the 80/20® type.

Appendix B: System Weights, Measures, and Performance Data

Table 10 Basic Rocket Information

Stages	1
Length	130"
Airframe Diameter	6.17"
Number of fins	4
Fin Semi-span	5"
Tip Chord	5"
Root Chord	12"
Fin Thickness	0.25"
Vehicle Structure Weight	48.24 lb
Propellant Weight	10.39 lb
Motor Case Empty Weight	5.4 lb
Payload Weight	9.84 lb
Liftoff Weight	66.02 lb
Center of Pressure (from nose)	90.903"
Center of Gravity (from nose)	76.639"

Table 11 COTS Aerotech M2500T Characteristics

Characteristic	Quantity
Manufacturer	Aerotech
Designation	M2500T
Diameter	98mm
Length	29.57"
Total Weight	15.79 lb
Prop Weight	10.39 lb
Avg Thrust	2,500 N
Initial Thrust	2,709 N
Max. Thrust	3,711 N
Total Impulse	9,671 Ns
Burn Time	3.9 s
ISP	209 s
Motor Case	98/10240
Propellant	Blue Thunder

Table 12 COTS Altimeters and Specifications

Altimeter	Manufacturer	Model	Charges Controlled (See Parachute Table for sizing)	Scoring
Primary	Featherweight	Blue Raven	Drogue Primary, Drogue Failsafe, Main Primary	Scoring Primary
Backup	Altus Metrum	EasyMini	Drogue Backup, Main Backup	Scoring Backup

Table 13 COTS Parachutes and Specifications

Parachute Data	Type	Black Powder Charges (Primary, Backup)	Deployment Altitude (Primary, Backup)	Descent Rate
Drogue	Recon 30"	4.5g/5.5g/6.5g	Apogee / Apogee+1s / Apogee+200 ft/s	82 ft/s
Main	SkyAngle Cert-3 XL	5g/6g	800ft / 700ft	17 ft/s

Table 14 Shock Cord and Linkages

Shock Cord + POA Data	Type	Test Strength	Length	Supplier	Knots Used	POA Hardware
Drogue	3/8" tubular Kevlar	3,600 lb	60’	Wildman	Bowline	1/4" quick link + barrel swivel
Main	3/8" tubular Kevlar	3,600 lb	30’	Wildman	Bowline	1/4" quick link + barrel swivel

Appendix C: Project Test Reports

C.I Recovery System Testing - Ejection Testing

Multiple ground tests were conducted to experimentally acquire minimum charge sizing for flight testing. Tests were conducted in "sagging" and "hogging" positions to simulate flight stress on the airframe coupler and separation points. Actual or simulated masses of all sub-components including parachutes, shock cords, and parachute protection were installed in the rocket for ejection testing to accurately represent flight characteristics.

C.II Recovery System Testing - Ejection Testing Results

Testing determined minimum values of 3.5 grams for drogue separation and 4 grams for main separation. Shear pin configuration of 4 x 4-40 pins in the drogue parachute section and 6 x 4-40 pins in the main parachute section was also validated.

Charge selection for flight testing was completed using the ground test values as minimums. The primary charges were increased by 1 gram over the test value (4.5 grams for drogue primary and 5 grams for main primary) with the redundant charges being further increased. Charge sizing escalates in order of redundancy. Table 15 below includes final charge sizing information for all deployment events.

Table 15 Final Charge Sizing

Event	Primary	Secondary	Tertiary
Drogue	4.5g	5.5g	6.5g
Main	5g	6g	N/A

C.III Electronics Power Draw Testing

All electronic systems are powered by combinations of 18650 Li-Ion battery packs and as such should be evaluated to determine the expected power duration. Table 16 details each onboard electronic system and its associated power consumption and battery information. Additionally listed is the expected duration (calculated using equation 5) of the battery given a constant draw of the maximum observed current draw as a worst case scenario.

$$Battery\ Duration\ (hrs) = \frac{Battery\ Capacity\ (mAh)}{Load\ Current\ (mA)} \tag{5}$$

As can be seen, all critical electronics (e.g. altimeters, payload, and tracking electronics) are able to survive for more than 24 hrs to accommodate any unforeseen long periods between launches at competition.

Table 16 Electronics' Power Consumption

Electronic System	Voltage (V)	Maximum Current (mA)	Battery Capacity (mAh)	Expected Duration (hr)
Payload	12.6	120	10,500	87.5
Featherweight GPS Tracker	4.2	108	7,000	64.8
Featherweight Blue Raven	4.2	200	7,000	35
RunCam Control Circuit	4.2	490	7,000	14.3
Altus Metrum EasyMini	8.4	10	3,500	350
ADS without Servo Operation	8.4	145	14,000	96.5
ADS with Servo Operation	8.4	921	14,000	15.2

C.IV Flight Testing

Flight testing was used to further validate the vehicle design and onboard systems. Narratives of each test flight are included below and Table 17 shows a brief list of their purpose and results.

Table 17 Test Flights

FLIGHT	DATE	MOTOR	SYSTEMS TESTED	RESULT
1	3/22/25	L2200	Vehicle structure, recovery system	Success
2	4/27/25	M1939	Full Spaceport configuration, mass reduction, full ADS and payload	Success

C.V Flight Testing - Test Launch 1

The first test launch featured the full 2025 vehicle with varying degrees of subsystem functionality. All subsystems' electronics and hardware were present; however, software for the payload and the ADS was not fully complete. Unfortunately, the data logging for the ADS had a strange corruption bug and the payload was unable to retain a GPS fix, but the ADS state machine was functional and the payload was able to transmit other sensor data up to a kilometer away. Similarly, the external carbon fiber antennas were able to transmit telemetry. The recovery system was, on the other hand, fully functional and the rocket's recovery was nominal. The rocket reached $5,343\ ft$.

C.VI Flight Testing - Test Launch 2

The second test launch saw a full IREC 2025 configuration rocket with all systems present as they will be for competition. All systems were functional, recovery was nominal, the payload was able to transmit up to $1.5\ km$ away, and the ADS with the onboard footage was verified to have deployed after motor burnout and prior to apogee with supporting data logs. The flight had some weathercocking because of the wind and the slow burn of the M1939, but overall the flight was a success. The rocket was simulated on the M1939 to reach a $11,600\ ft$ apogee, and the flight actually reached $10,358\ ft$.

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Appendix D: Hazard Analysis

Hazard	**Possible Causes**	**Risk of Mishap and Rationale**	**Mitigation Approach**	**Risk of Injury after Mitigation**
Black powder	Mishandling of rocket before flight/poor arming procedures Poor ground test procedures	Medium; Black powder charges pose a significant risk to personnel if mishandled. Poorly planned ejection tests also have the potential to damage flight vehicle.	Proper distancing from BP tests Arm deployment electronics for flight on pad, not before Utilize proper switches for electronics (screw switches or similar device)	Low
Li-ion battery burn/fire	Shorting battery terminals Dropping/Cutting/Crushing batteries	Medium; Lithium-Ion batteries are used frequently, so they pose a significant risk to team personnel if mishandled	Instruct team members of correct handling of Li-ion batteries	Low
Falling rockets	Recovery system failure Public rocket launches	High; Ballistic descent could have a catastrophic effect on the flight vehicle and poses an extreme risk to personnel and property.	Follow SRR guidelines to make recovery system as robust as possible Instruct team members on proper launch day etiquette (point to descending rockets, give verbal warnings, etc.)	Low
Unstable flight; could cause unpredictable trajectory, endangering personnel	Improperly sized fins Loss of fins Rail button failure	Medium; Occurs if improper analysis and testing are done beforehand or if improperly integrated	Test fin assembly to point of yielding and/or failure Simulate fin flutter and size fins to avoid resonance Calculate maximum loading on rail buttons to ensure safety factor	Low
Motor failing to be restrained inside the vehicle; could cause unrestrained motor to fly towards people	Thrust plate failing/ yielding Bolts responsible for restraining thrust plate fail in shear Bearing stress on aluminum channels deforms holes	High; Loading from thrust is hard to determine analytically in each component of the rocket, leading to some uncertainty in the factor of safety	FEA simulation to verify safety factor >2 Compression testing the internal structure/ airframe assembly to yield/failure	Medium

Appendix E: Risk Assessment

Risk	Possible Causes	Risk of Mishap and Rationale	Mitigation Approach	Risk of Injury After Mitigation
GPS System malfunction	Loss of satellite connection	Medium; Consequences could include failure to locate rocket after landing which would mean a total loss of flight vehicle	Integrated and non-integrated test of GPS hardware to find and document limitations in range	Low
	Loss of power		Use shake table and pressure testing to ensure batteries and wiring are secure	
	Interrupted RF signal to ground station			
Altimeter malfunction	Loss of power	Medium; Consequences could include failure to deploy parachute which could cause ballistic descent, which can be catastrophic to the flight vehicle as well as dangerous to personnel	Follow all manufacturer guidelines on powering and static port sizing/placement	Low
	Poor static port hole placement/sizing		Use shake table and pressure testing to ensure batteries and wiring are secure	
Parachute/recovery harness tangling	Poor folding	Medium Risk; Parachute tangling could be dangerous to flight vehicle as higher descent rates mean higher probability of damage to the rocket upon landing. Higher descent rates also pose a risk to personnel.	Instruct all members on proper parachute folding	Low
	Ejection charge malfunction		Use ejection charge tests to ensure parachute is completely deployed from airframe	
Unstable flight; could cause unpredictable trajectory, endangering the launch vehicle	Improperly sized fins	Medium; Occurs if improper analysis and testing are done beforehand or if improperly integrated.	Test fin assembly to point of yielding and/or failure	Low
	Loss of fin(s)		Simulate fin flutter and size fins to avoid resonance	
	Rail button failure		Calculate maximum loading on rail buttons to ensure safety factor	
Motor failing to be restrained inside airframe	Thrust plate failure/yielding under normal load	High; Loading from thrust is hard to determine analytically in each component of the rocket, leading to some uncertainty in the factor of safety.	FEA Simulation to verify safety factor >2	Medium
	Bolts responsible for restraining thrust plate fail in shear		Compression testing the internal structure/airframe assembly to yield/failure	
Yielding of internal structure	Actual max stress greater than expected max stress	Medium; Occurs if improper analysis and testing are done beforehand or if improperly integrated.	Bulkheads prevent aluminum from buckling to the point of structural failure	Low
Premature drag separation	Pressure differential between chute bay and free stream	Low	Calculating the max pressure differential and required shear pins to prevent separation	Low
Errors in Active Drag System (ADS) structural analysis	Imperfect drag force load conditions used in simulations	Medium; Unsymmetric failure of ADS may result in instability during flight.	Determine there is a safety factor of at least 2 (TBR)	Low
	Internal Forces (i.e. friction, etc.) are ignored		Physical testing performed by Avionics subteam	

	Material properties do not align with the actual materials used in the system (especially non-isotropic materials)		Design ADS such that unsymmetric failure is unlikely	
Incorrect Stability Calculations	Component layout experiences significant changes	Medium; Pressure distributions on a rocket vary depending on angle of attack and trajectory. Simulations may not be able to account for these flight activities. Also, CG is likely to move as development progresses. This may result in unstable flight.	Results compared with Open Rocket and other softwares	Low
ADS structural failure	Inaccurate results determined from FEA simulations	Low; ADS will not deploy until after burnout (high altitude), so launch vehicle should be at a safe distance from personnel. Also, launch vehicle should be stable without ADS. A failure could result in unstable flight and difficulties with recovery.	Avionics will perform testing on the system	Low
	Flight Loads not properly implemented into simulations		Safety factor determined to be greater than 2	
Instability of the LV during ascent	ADS deployment failure	Medium; Personnel will be at a safe distance from the launch pad. Also, the likelihood of the LV heading towards people is relatively low	Personnel will be far from launch pad	Low
	Inaccurate stability caliper calculations		CFD will be performed to verify stability at all stages of ascent	
	Damage to fins or other external components		Stability caliper will be verified using multiple methods	
Li-ion batteries are damaged or shorted	Batteries are not properly handled	Medium; Damaged or shorted lithium batteries could combust and directly harm personnel or destroy other parts of the vehicle structure which could become harmful debris, posing a danger to personnel.	Training all team members in battery handling	Low
	Batteries are not properly mounted		Ensuring mounted power supplies and connections are secure	
	Batteries are not properly stored		Ensuring proper power regulation	
RF telemetry link is broken	Power failure with electronics	Medium; A failure to establish and hold an RF link would result in failure of the SRAD telemetry and GPS system and would result in losing all data is is not logged onboard the electronics and recovered. A GPS failure would also force complete reliance on the COTS GPS for recovery.	Perform telemetry range tests	Low
	RF equipment gets damaged		Test the efficacy of RF transparent sections of the rocket after the launch vehicle is fully assembled	
	The rocket structure blocks RF signals			
ADS structure or deployment fails during flight	ADS is not properly integrated	High; A collapsing ADS structure could produce damaging debris during flight. Additionally, uneven deployment of fins would produce uneven drag and could rapidly change the trajectory of the rocket.	Iteratively running integrated, simulated, and flight tests	Low
	ADS structure is weak		Ensuring proper algorithm safe guards	
	ADS is poorly manufactured		Rack and pinion design severely limits uneven deployability	

Appendix F: Assembly, Preflight, Launch, and Recovery Checklists

Team 190 Rocketry at Virginia Tech

Launch Vehicle *Roadkill*

International Rocket Engineering Competition

Flyer of Record: Bob Schoner

Launch Location: Midland, TX

Pre-Launch Day Operations

Action	Executor Initials	Witness Initials
Assemble the motor according to the provided Aerotech motor assembly instructions		
Insert motor into aft booster section		
Secure motor with forward retention bolt		
Add top rail guide		
Measure out black powder into two gram vials Bundle based on the following charge sizes and label: DROGUE PRIMARY: 4.5 G DROGUE BACKUP: 5.5 G DROGUE FAILSAFE: 6.5 G MAIN PRIMARY: 5 G MAIN BACKUP: 6 G		
Charge camera batteries		
Charge payload battery		
Charge four recovery batteries		
Charge ADS battery		

Active Drag System Assembly

Action	Executor Initials	Witness Initials
Check ADS battery voltage with the multimeter and ensure it reads 8.4V nominal.		
Connect female JST to male JST from LoRa (white) board to GPS (red) board		
Connect battery terminal to RP2040 Micro (Purple) board		
Connect screw switch JST to female JST on battery line		
Slide ADS assembly along threaded rods until flush against nuts. Make sure to align the hole for the antenna wires.		
Thread the antenna wires through the bulkhead and the ADS assembly to connect to the associated GPS (red) or LoRA (white) board(s)		
Plug in antennas		
Enable screw switch and ensure that all boards light up to indicate power-on capability		
Disable screw switch		
Thread two nuts and washers (minimum) along threaded rods to be secured to top of ADS assembly		
Slide airframe onto fin cam coupler and secure with 6 rivets		
Coat the ADS bulkhead with a liberal amount of silicone.		
Insert bulkhead onto ADS threaded rods. Make sure the bulkhead is flush on the coupler.		
Put a rubber washer, metal washer, and nut (in that order) on each of the threaded rods. Tighten down all nuts as much as possible.		
Pull ADS pins slightly out of the airframe. Attach each ADS flap with 2 bolts (ensure the pin is in the flap’s slot). Check ADS pin resistance		
Ensure that the ADS flaps can actuate by hand. If flaps struggle to move, slightly loosen the ADS flap bolts. Push flaps all the way in.		

Payload Assembly

Action	Executor Initials	Witness Initials
Check payload battery voltage with the multimeter and ensure it reads 12.6 V nominal.		
Connect battery terminal to UBEC module.		
Connect all female XT30 connectors to male XT30 connectors.		
Connect RPico to GPS and sensors via QWIC connector.		
Coat the payload bulkheads with a liberal amount of silicone.		
Connect screw switch JST to JST on battery line		
Enable screw switch and ensure that all boards light up to indicate power-on capability.		
Disable screw switch.		
Slide the payload into the coupler and put other bulkhead onto the threaded rods. Make sure bulkheads are flush on the coupler.		
Put a rubber washer, metal washer, and nut with thread lock (in that order) on each of the threaded rods. Tighten down all nuts as much as possible.		
Attach nosecone to payload coupler and secure with 6 rivets.		

Recovery Bay Assembly

Action	Executor Initials	Witness Initials
Check battery voltages with the multimeter and ensure they read nominally: - Blue Raven Battery: 4.2V - EasyMini Battery: 8.4V - GPS Battery: 4.2V - Camera Battery: 4.2V		
Connect labeled battery terminals to labeled female connectors		
Connect labeled deployment charge connectors from altimeters to main parachute bulkhead PM & BM = Primary Main & Backup Main		
Thread Main parachute bulkhead onto Recovery Bay and secure with nuts and washers		
Slide recovery bay into coupler and simultaneously connecting all labeled screw switch connectors and camera connector		
Dawsyn - connect Blue Raven to phone		
Enable one screw switch at a time to ensure each appropriate electronic is enabled (lights enabled); Disable screw switch after each enable		
Coat the main parachute bulkhead and drogue parachute bulkhead with a liberal amount of silicone.		
Enclose the recovery bay with the bulkheads. Make sure the bulkheads are flush on the coupler.		
Put a rubber washer, metal washer, and nut with thread lock (in that order) on each of the threaded rods. Tighten down all nuts as much as possible.		

Day Of Launch Operations

Action	Executor Initials	Witness Initials
Turn on both altimeters, GPS, and camera to check for beeps/lights. Ensure applications connect properly (one by one)		
Check voltage at screw terminals to ensure that all deployment channel connections are made FS, PD, PM ~4.2V BD, BM ~8.4V		
Disable all screw switches, remove screws, and place screws in safe place where they will not be lost		
Ejection Charges: Strip and cut end of e-matches Screw into screw terminals Ensure wire is being clamped, not plastic part of match Measure out black powder amount for each charge DROGUE PRIMARY: 4.5 G DROGUE BACKUP: 5.5 G DROGUE FAILSAFE: 6.5 G MAIN PRIMARY: 5 G MAIN BACKUP: 6 G Bend e-match and place on top of black powder Pack with dog barf and tape it closed Repeat 4x, i.e. for each charge well		
Thread main shock cord through upper airframe and attach yellow (longer side) quick link to join main R-Bay bulkhead and long end of shock cord (knot furthest from parachute knot)		
Insert main side of R-Bay into upper airframe and secure with 6 rivets		
Untape chutes		
Lay out parachute and ensure shock cord has no knots		
Fold main parachute and add baby powder liberally throughout process (Have someone hold parachute together tightly)		
Attach purple (shorter side) quick link to nosecone bulkhead with the short side of shock cord (knot closest to parachute knot)		
Cover parachute with chute protector		
Insert R-bay into main airframe and secure with rivets		
Add cup of dog barf into main airframe		
Place main parachute into main airframe (chute protector facing in)		
Thread shock cord into main airframe and add more baby powder to folded parachute / along edges of nose cone coupler		

Insert nose cone coupler into upper main airframe and secure with 6 (not 8) shear pins		
Attach chute protector to the drogue chute		
Lay out drogue parachute, add baby powder to it, and ensure lines are detangled		
Fold drogue parachute whilst adding baby powder liberally throughout the process		
Cover drogue chute with chute protector		
Have someone hold the drogue tightly		
Attach blue quick link to join ADS bulkhead and long end of shock cord (furthest from parachute knot)		
Attach pink quick link joining R-bay drogue bulkhead and short end of drogue shock cord (closest to parachute knot)		
Thread shock cord into thrust structure		
Place drogue with parachute protector into thrust structure (chute protector facing out)		
Add one cup of dog barf into thrust structure		
Insert R-bay & top half of rocket into thrust structure and secure with 4 shear pins		
Pack the following to bring to pad: - Chris' Rocket Supplies screwdriver - Screws - Shear pins - Wood block - Ignitor - Wire strippers		

Launch Pad Preparations

Action	Executor Initials	Witness Initials
Check vehicle weight with OpenRocket values. If fail, see emergency item 4		
Mark vehicle CG and CP with Vinyl stickers		
Record final off the rail velocities.		
Assemble igniter and tape to the outside of the rocket.		
Engage hand radios between launch crew and by-stander crew if needed.		

On The Rail Operations

Action	Executor Initials	Witness Initials
Take off fin covers		
Put rocket on rail		
Turn on payload while horizontal		
Raise up rocket to lock in place		
Measure rod angle and make note		
Enable GPS by turning on labeled screw switch		
Enable Featherweight tracker and connect via Bluetooth		
Enable ADS		
Enable EasyMini altimeter by turning on labeled screw switch		
Listen for beeps to verify battery voltage and continuity on both deployment channels		
Enable Blue Raven by turning on labeled screw switch		
Connect to Blue Raven via Bluetooth to verify battery voltage and continuity on both deployment channels		
Verify GPS lock from Featherweight tracker		
Insert motor ignitor until it cannot be inserted any further		
Spark test launch box leads		
Clamp pad leads on to igniter leads; ensure that igniter leads wrap around the pad leads and do not / will not touch each other		
Take weather conditions and note prior to launch (e.g. wind speed / gust speed, air pressure, humidity, cloud cover)		
Launch rocket and recover		

Emergency Procedures

1. Failed tug test
    a. Identify loose wires and connections
    b. Locate where they are supposed to be attached
    c. Solder wires where needed
    d. Secure wires in place. Cover in electrical tape.
    e. Tug test again.
    f. If continued failure, scrub launch
2. Failed voltage checks
    a. Identify failed battery
    b. Charge the battery for 15 minutes
    c. Check charge again
    d. If charge increased continue charging until at required voltage
    e. If charge has not changed then repeat 2x
    f. If continued failure to charge, scrub launch
3. Failed securing system
    a. Identify a possible fix
    b. Attempt general fix
    c. If fix fails repeat with new fix
    d. If repeated failure to secure a system, scrub launch
4. Update OpenRocket
    a. Identify if numbers on open rocket are unacceptably different from measured
    b. Identify if flight essential systems meet ESRA requirements
    c. If not, scrub launch
    d. If they do, continue checklist
5. Pad not disarmed
    a. Disarm pad
    b. Continue checklist
6. Altimeter won't arm
    a. Disarm pad
    b. Try 2 times to arm again
    c. If continual failure lower rocket horizontal on pad
    d. Remove rocket from launch rail
    e. Briefly take rocket apart on ground at pad. If the problem is easy and quick fix, then attempt fix there
    f. If the problem is complex or there is uncertainty bring rocket back to tables.
    g. Inform RSO of situation and repair altimeter and bay as need.
    h. Restart checklist at electronics bay Checks, and continue onwards
    i. If repeated failure, scrub launch.

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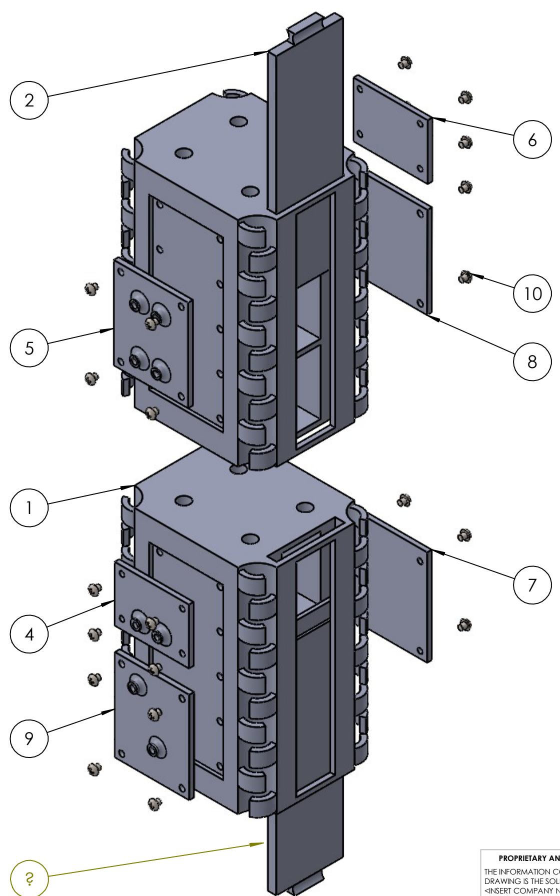
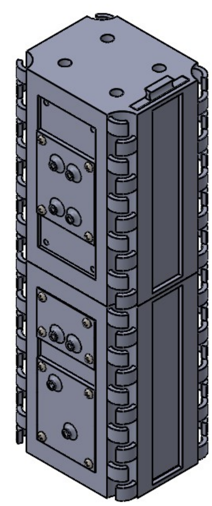
Appendix G: Engineering Drawings

G.I Recovery Bay Technical Drawings

ITEM NO.	PART NAME	DESCRIPTION	QTY.
1	RBay Housing	3D Print - ABS Fllament	2
2	RBay Sliding Door Female	3D Print - ABS Fllament	1
3	RBay Sliding Door Male	3D Print - ABS Fllament	1
4	Altimeter Mount	3D Print - ABS Fllament	1
5	Easy Mini Mount	3D Print - ABS Fllament	1
6	RunCam Mount	3D Print - ABS Fllament	1
7	Raspberry Pi Mount	3D Print - ABS Fllament	1
8	GPS Mount	3D Print - ABS Fllament	1
9	Blue Raven Mount	3D Print - ABS Fllament	1
10	CR-RHMS 0.125-44x0.125x0.125-N	Stainless Steel	24





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UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

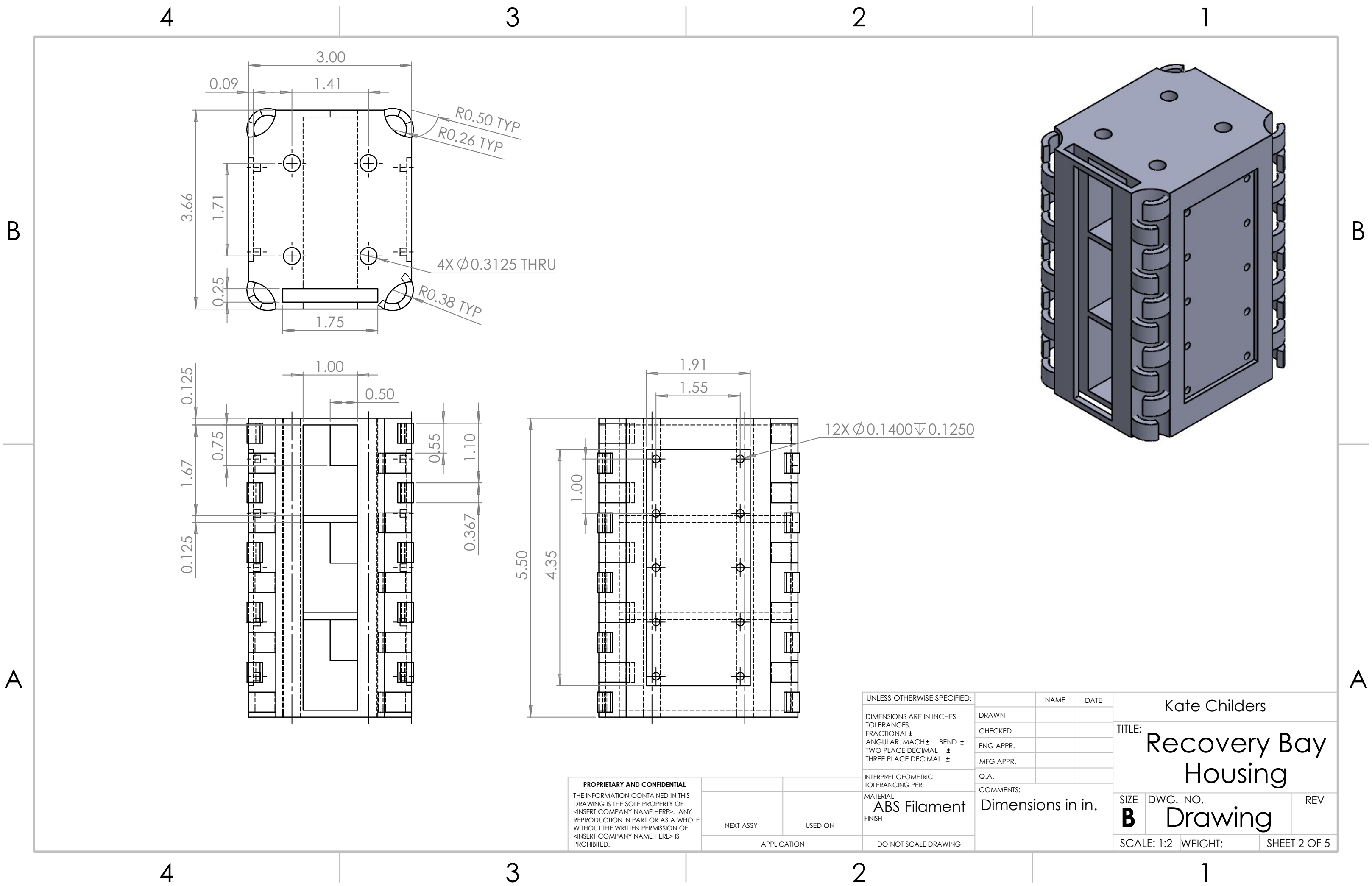
COMMENTS:

Kate Childers

TITLE: Recovery Bay 2024-2025

SIZE B | DWG. NO. Drawing | REV

SCALE: 1:5 | WEIGHT: | SHEET 1 OF 5


3.00
0.09
1.41
R0.50 TYP
R0.26 TYP
3.66
1.71
4X ∅0.3125 THRU
0.25
R0.38 TYP
1.75
1.00
0.50
0.125
0.75
1.67
0.125
0.55
1.10
0.367
1.91
1.55
12X ∅0.1400 ↧ 0.1250
1.00
5.50
4.35
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ABS Filament
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Dimensions in in.
Kate Childers
TITLE:
Recovery Bay Housing
SIZE
B
DWG. NO.
Drawing
REV
SCALE: 1:2
WEIGHT:
SHEET 2 OF 5
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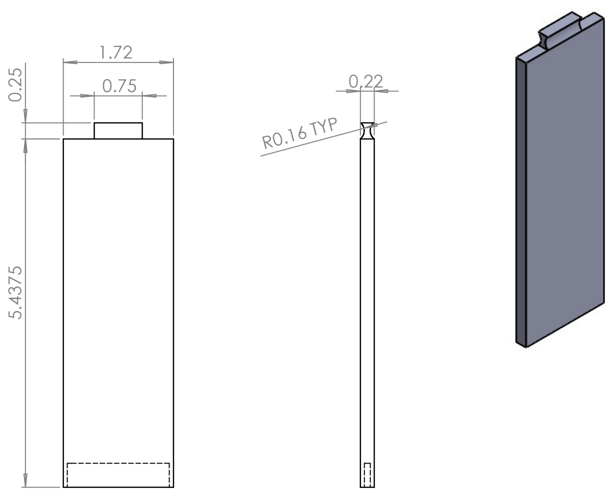
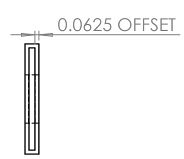
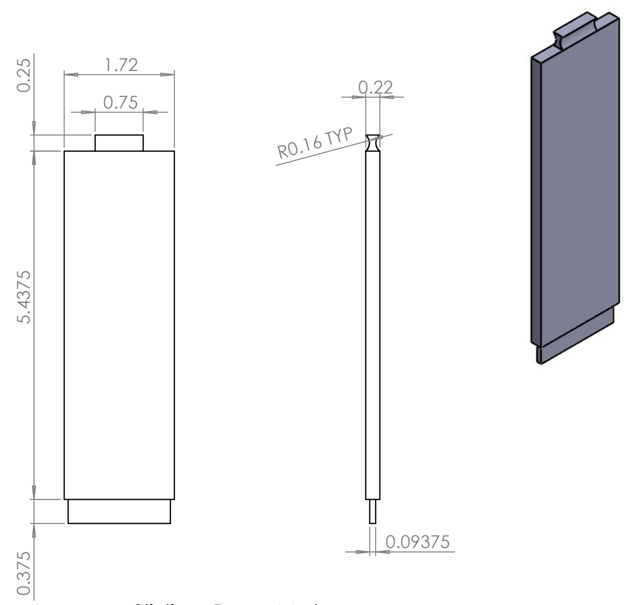
USED ON
APPLICATION





Sliding Door Female
Scale: 1:1.5



Sliding Door Male
Scale: 1:1.5

UNLESS OTHERWISE SPECIFIED:	NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN CHECKED ENG APPR. MFG APPR. Q.A.	
INTERPRET GEOMETRIC TOLERANCING PER:	COMMENTS: Dimensions in in.	
MATERIAL ABS Filament		
FINISH		
DO NOT SCALE DRAWING		

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APPLICATION

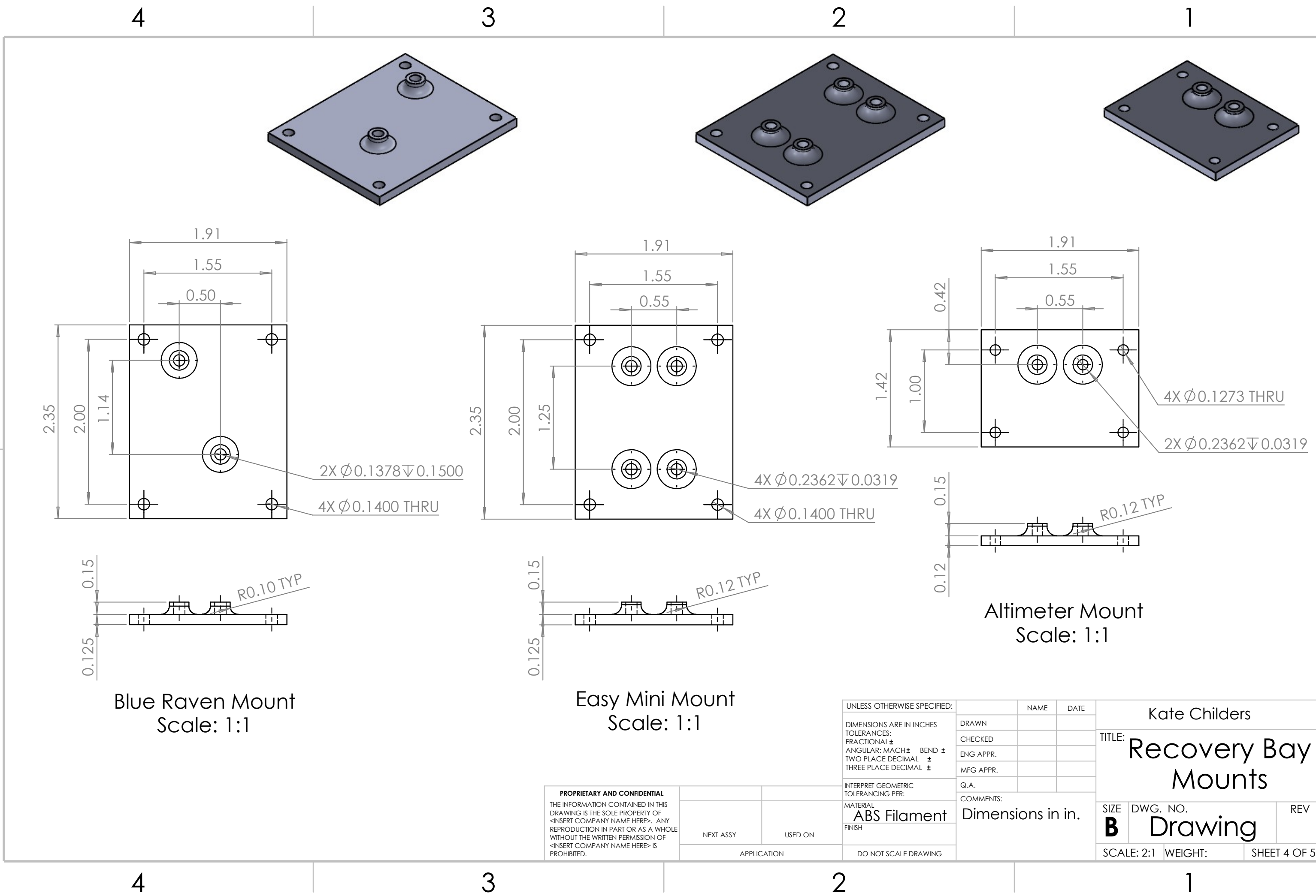
Kate Childers

TITLE:
Recovery Bay
Sliding Door

SIZE B | DWG. NO. Drawing | REV

SCALE: 1:2 | WEIGHT: | SHEET 3 OF 5

SOLIDWORKS Educational Product. For Instructional Use Only.


1.91
1.55
0.50
2.35
2.00
1.14
2X Ø0.1378 ↧ 0.1500
4X Ø0.1400 THRU
0.15
0.125
R0.10 TYP
Blue Raven Mount
Scale: 1:1
1.91
1.55
0.55
2.35
2.00
1.25
4X Ø0.2362 ↧ 0.0319
4X Ø0.1400 THRU
0.15
0.125
R0.12 TYP
Easy Mini Mount
Scale: 1:1
1.91
1.55
0.55
0.42
1.42
1.00
4X Ø0.1273 THRU
2X Ø0.2362 ↧ 0.0319
0.15
0.12
R0.12 TYP
Altimeter Mount
Scale: 1:1
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ABS Filament
FINISH
COMMENTS:
Dimensions in in.
Kate Childers
TITLE:
Recovery Bay Mounts
SIZE
B
DWG. NO.
Drawing
REV
SCALE: 2:1
WEIGHT:
SHEET 4 OF 5
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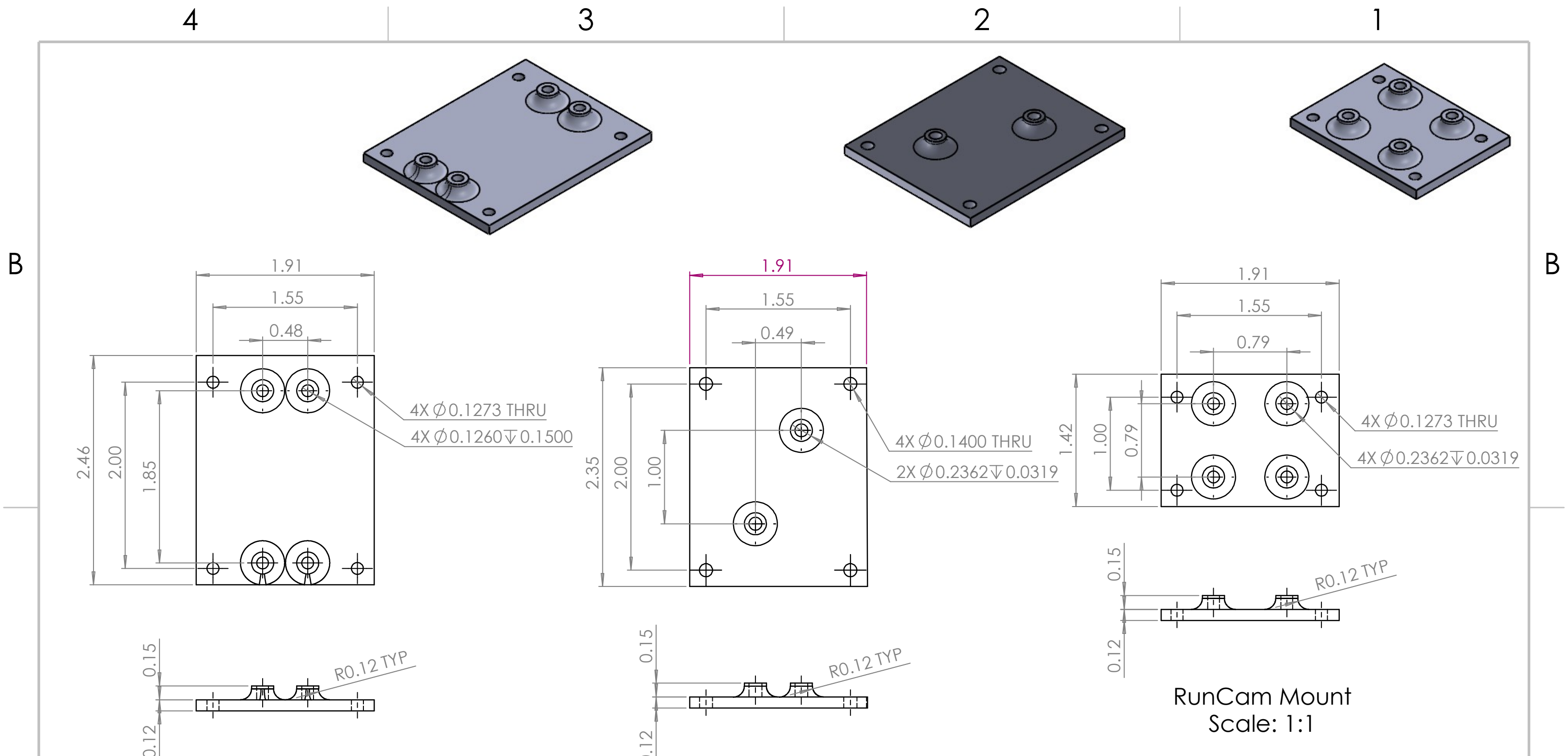
APPLICATION
DO NOT SCALE DRAWING



Raspberry Pi Mount
Scale: 1:1

GPS Mount
Scale: 1:1

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	Kate Childers
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE: Recovery Bay Mounts
	CHECKED			
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL ABS Filament	COMMENTS: Dimensions in in.			SIZE B DWG. NO. Drawing REV
FINISH				
DO NOT SCALE DRAWING				SCALE: 2:1 WEIGHT: SHEET 5 OF 5

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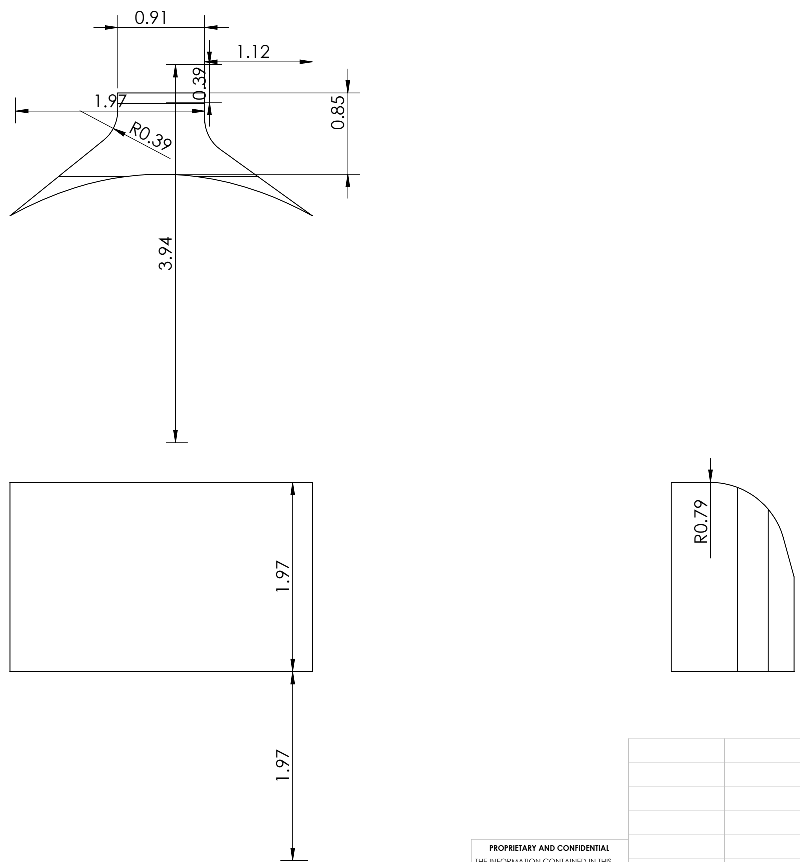
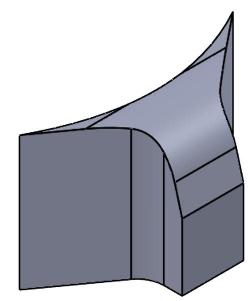
	APPLICATION	

4 3 2 1





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DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

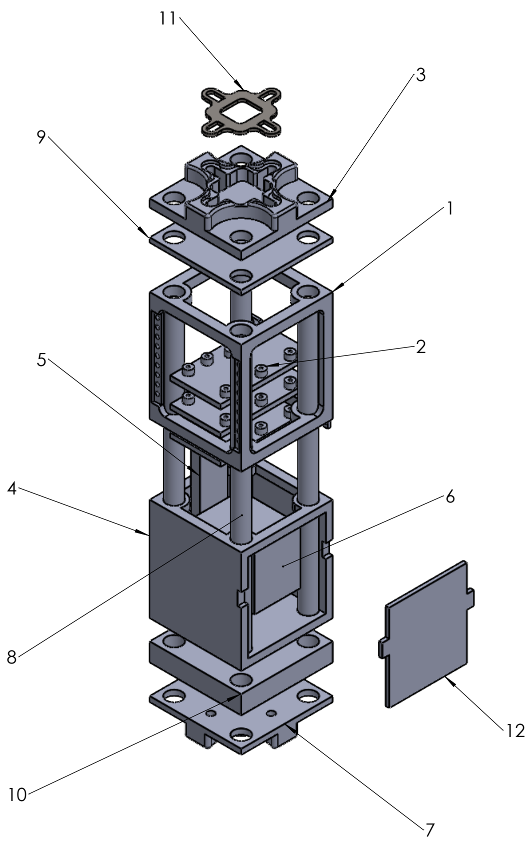
Camera Shroud

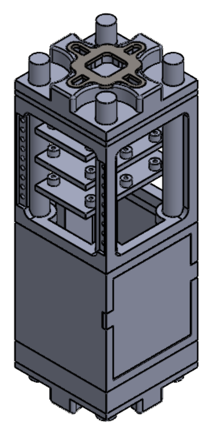
SIZE **B** DWG. NO. REV

SCALE: 1:1 WEIGHT: SHEET 1 OF 1

G.II Payload Technical Drawings

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Electronics Cube	ABS	1
2	Electronics Plate	ABS	3
3	Top Endcap	ABS	1
4	Battery Cube	ABS	1
5	RFD		1
6	Battery	Lithium Ion	1
7	Bottom Endcap	ABS	1
8	Threaded Rod	Steel	4
9	Weight 1	Aluminum	1
10	Weight 2	Steel	1
11	GPS Cover	ABS	1
12	Battery Door	ABS	1





UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL:

TITLE:

DWG NO.

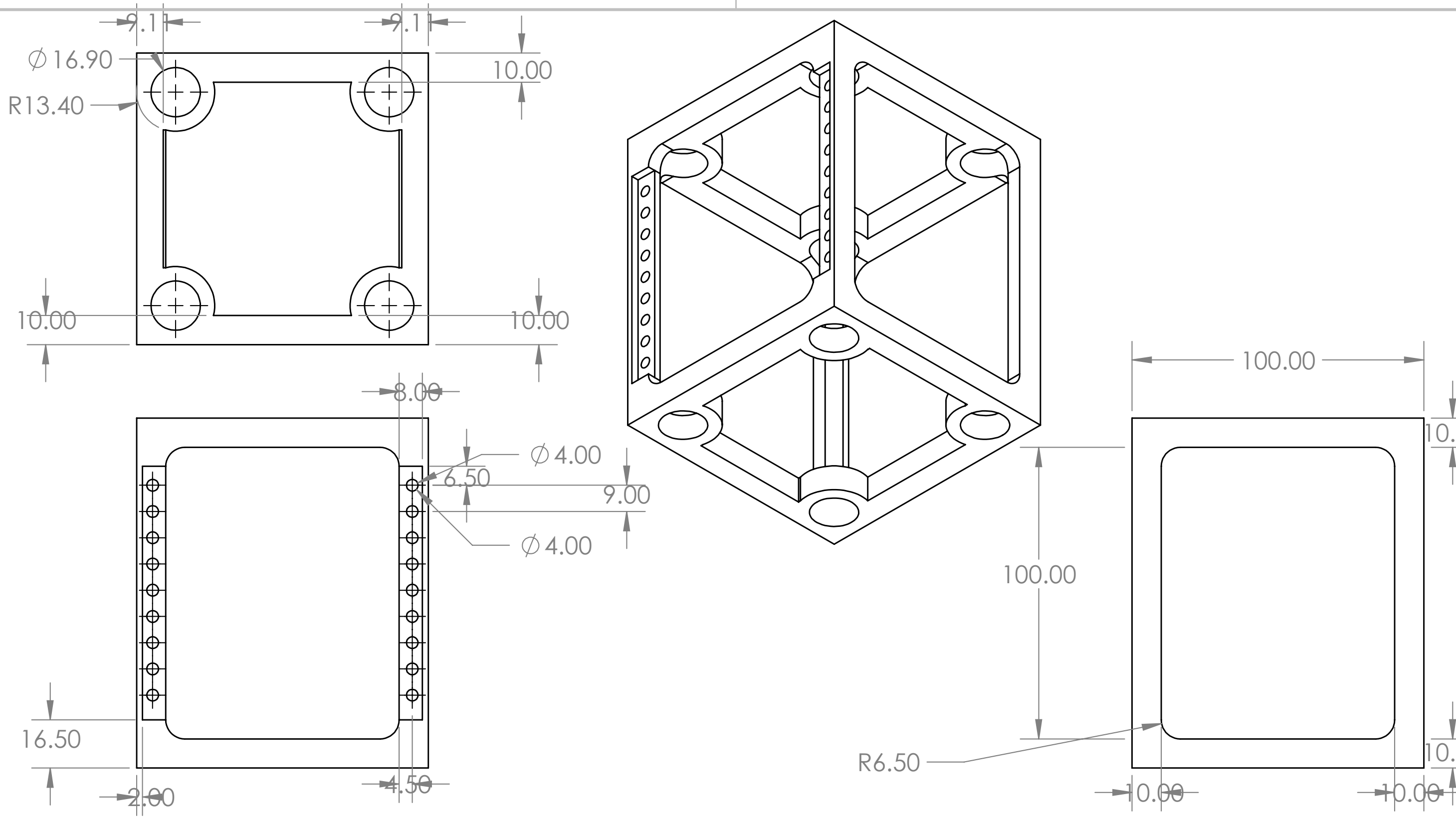
Final Payload Assembly

A3

WEIGHT:

SCALE:1:5

SHEET 1 OF 1



A

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			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

TITLE:

SIZE	DWG. NO.	REV
A	Electronics Cube	2025
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

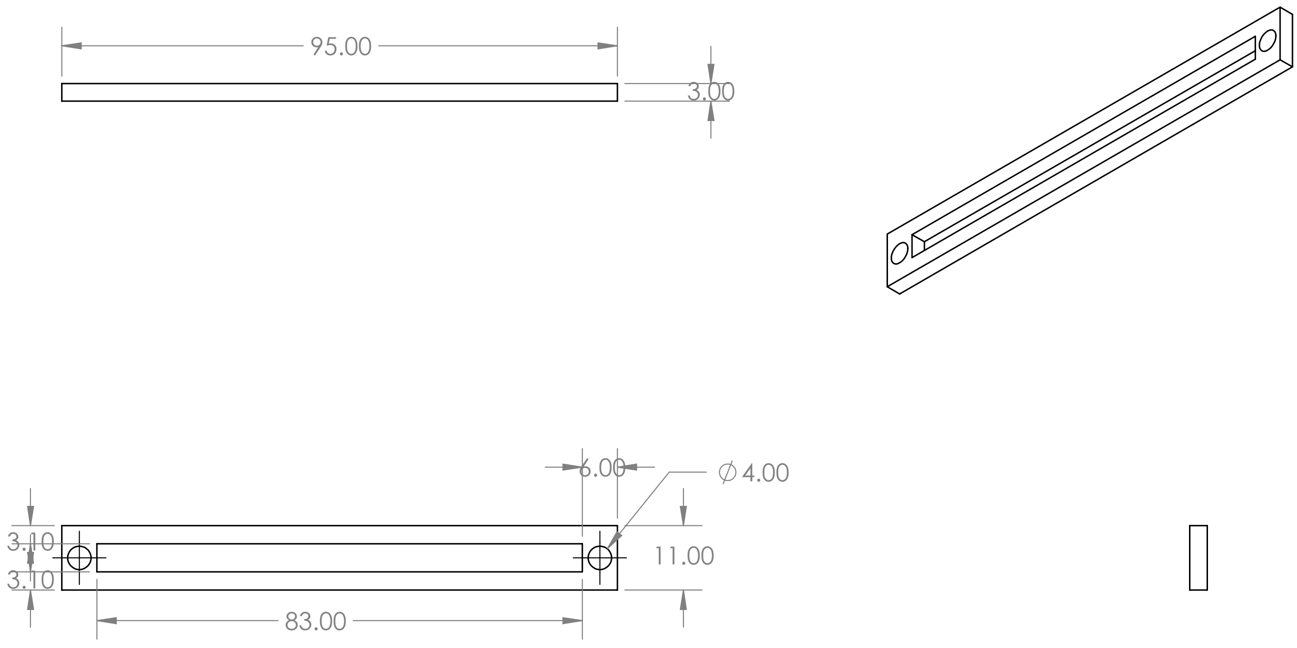
A

2

1

2 1

B B



A A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
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			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE A — DWG. NO. Chopsticks — REV 2025
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:1 — WEIGHT: — SHEET 1 OF 1

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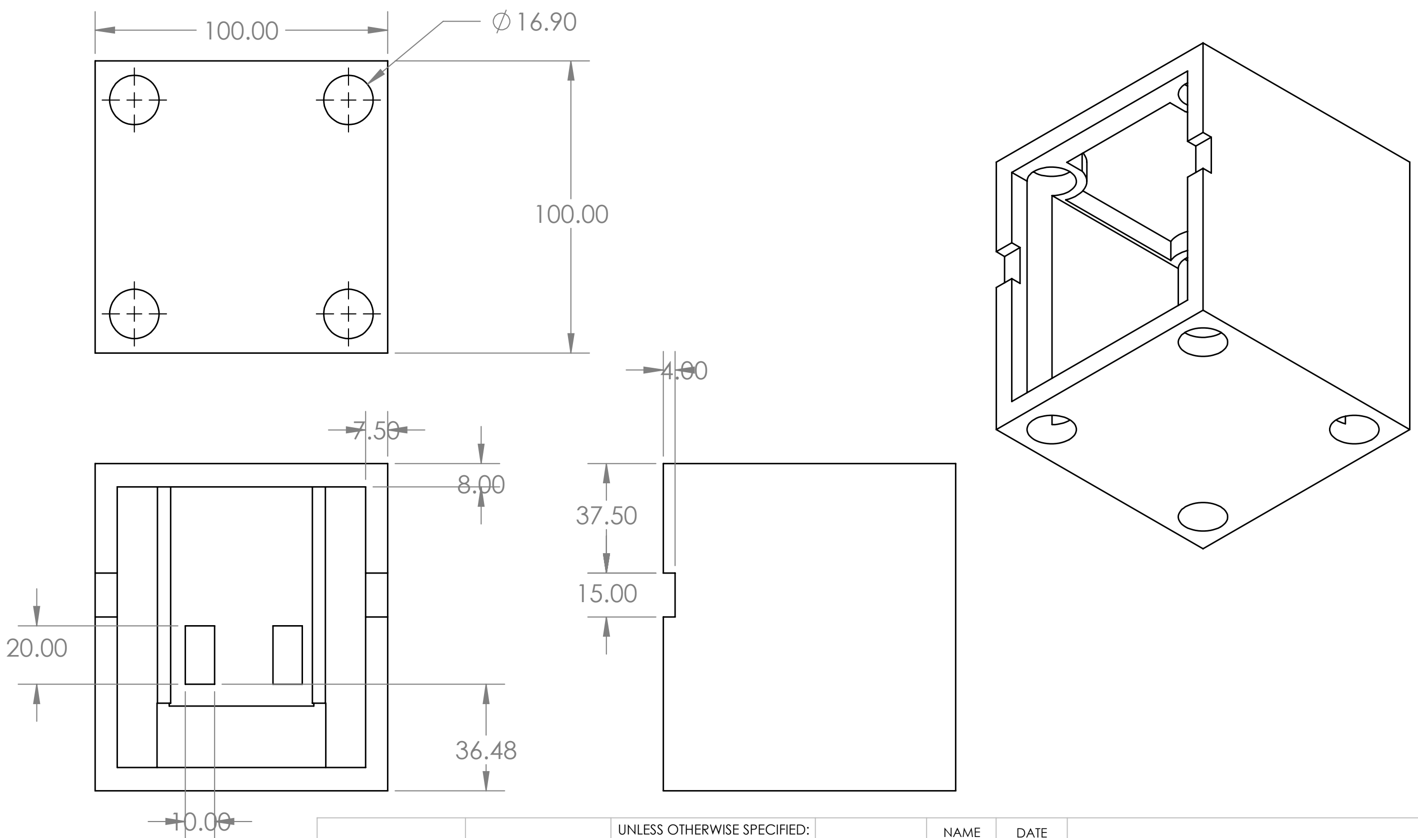
2 1



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			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE A DWG. NO. Battery Cube REV 2025
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:1 WEIGHT: SHEET 1 OF 1

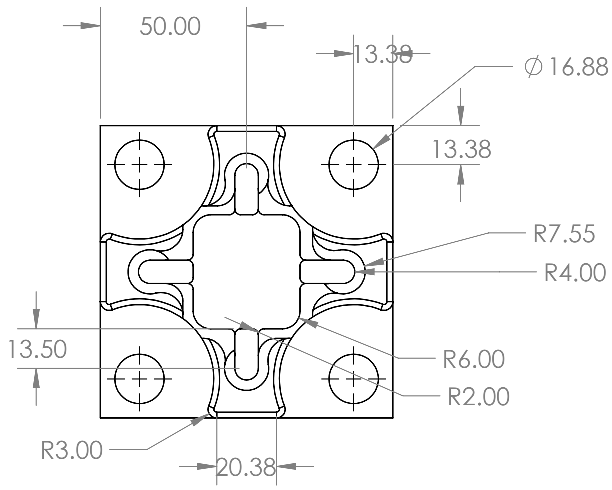
2 1

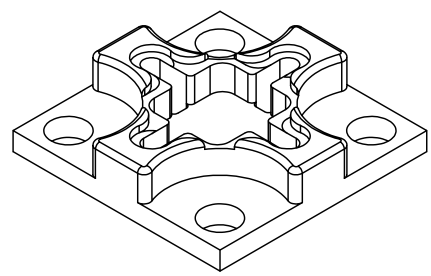
B B

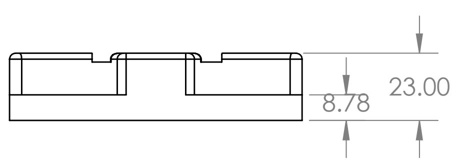
A A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE:
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE DWG. NO. REV
NEXT ASSY	USED ON	FINISH				A Battery Door 2025
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:2 WEIGHT: SHEET 1 OF 1

2 1







UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
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FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

NEXT ASSY | USED ON

APPLICATION

DO NOT SCALE DRAWING

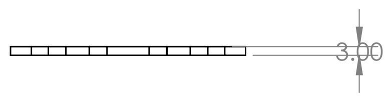
	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

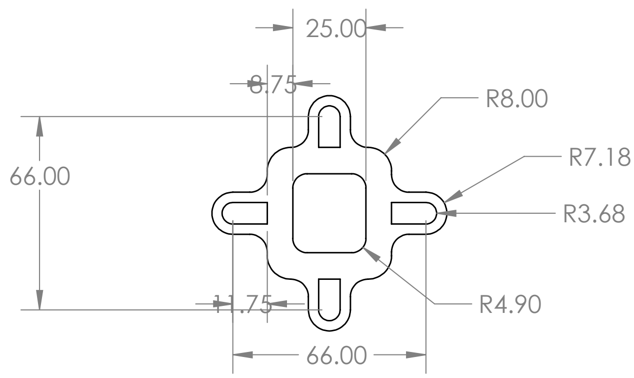
COMMENTS:

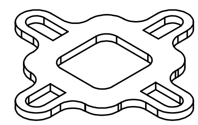
TITLE:

SIZE A | DWG. NO. Top Endcap | REV 2025

SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1







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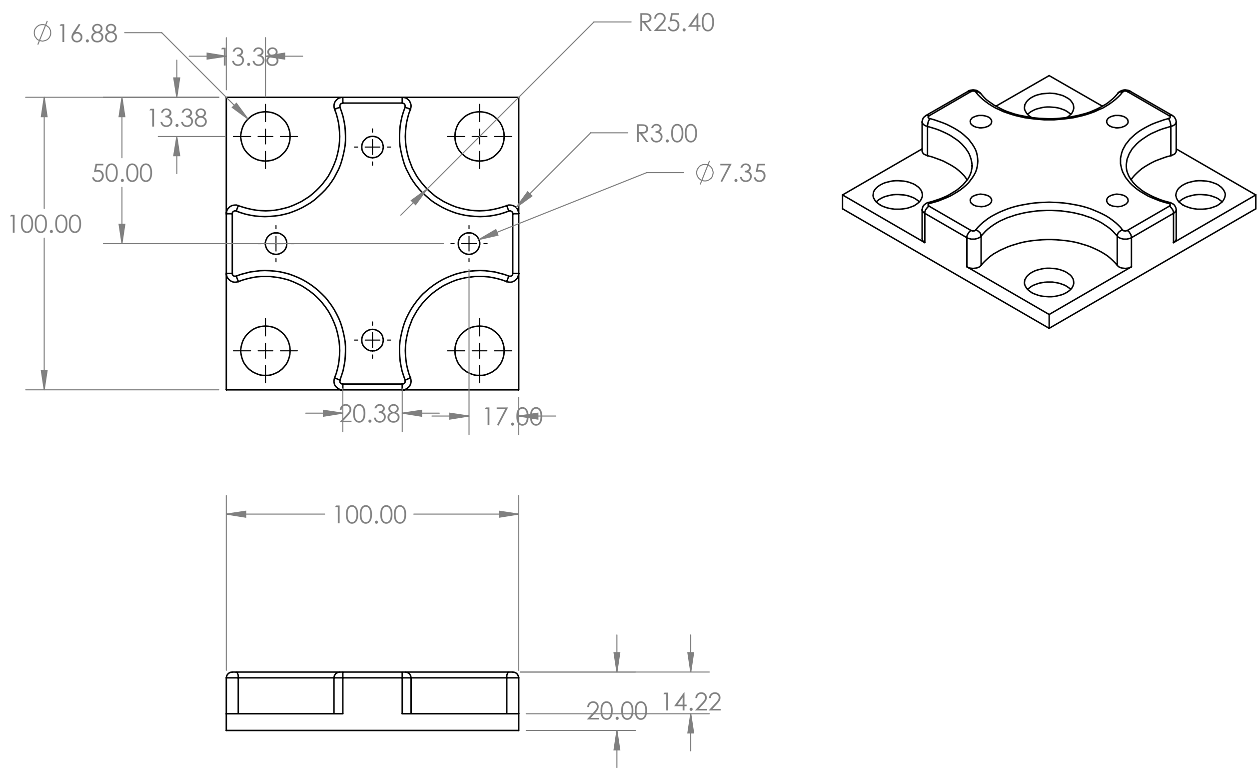
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

TITLE:

SIZE	DWG. NO.	REV
A	GPS Cover	2025
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1



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APPLICATION		

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TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

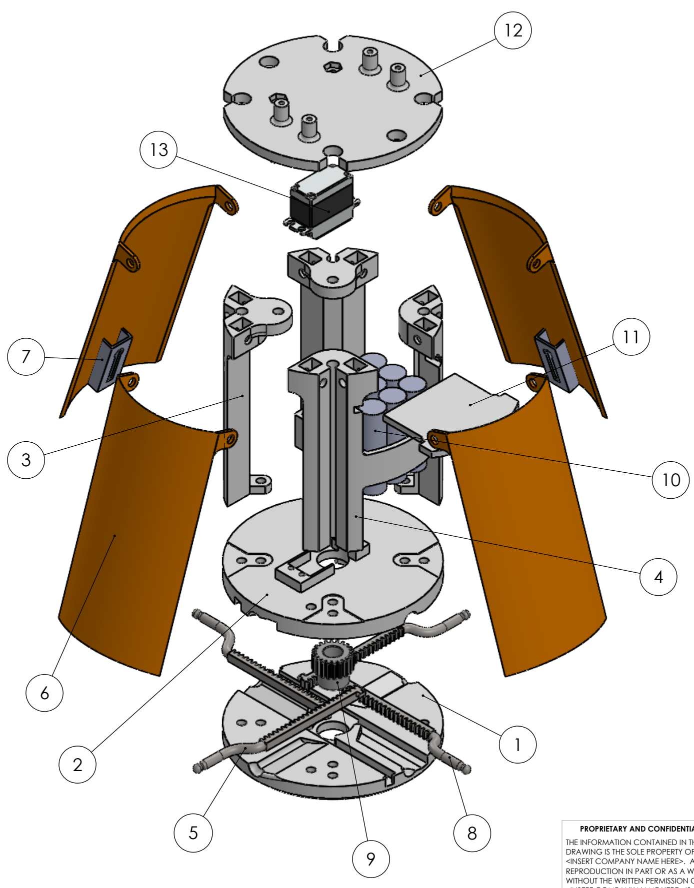
TITLE:

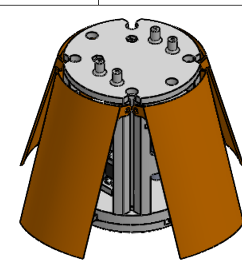
SIZE	DWG. NO.	REV
A	Bottom Endcap	2025

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

G.III Active Drag System Technical Drawings

ITEM NO.	PART NAME	DESCRIPTION	QUANTITY
1	LOWER PLATE	ABS	1
2	UPPER PLATE	ABS	1
3	COLUMNS	ABS	2
4	BATTERY COLUMNS	ABS	1
5	RACK & PIN	Stainless Steel	2
6	FLAP	Carbon Fiber and Epoxy	4
7	PIN GUIDE	Stainless Steel	4
8	RACK & PIN (INVERTED)	Stainless Steel	2
9	DOUBLE GEAR	20 degree pressure angle, gear pitch 20, pitch height 0.45 in	1
10	BATTERY PLACEHOLDER	Placeholder for batterpack to show integration	1
11	BATTERY CAP	ABS	1
12	ELECTRONICS MOUNT	ABS	1
13	SERVO MOTOR	Sincecam 8.4V servo motor	1





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APPLICATION

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DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

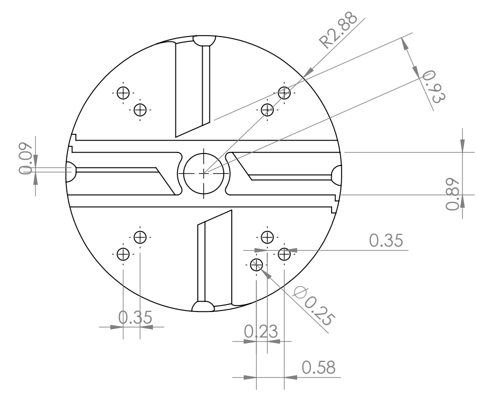
COMMENTS:

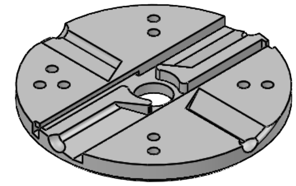
TITLE:

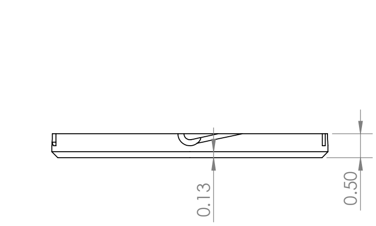
Full ADS Assembly

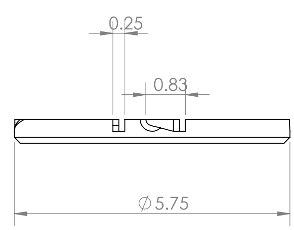
SIZE **B** DWG. NO. REV

SCALE: 1:10 WEIGHT: SHEET 1 OF 1









				NAME	DATE	
		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
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			CHECKED			Lower Sandwich 2025
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE B DWG. NO. REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:2 WEIGHT: SHEET 1 OF 1

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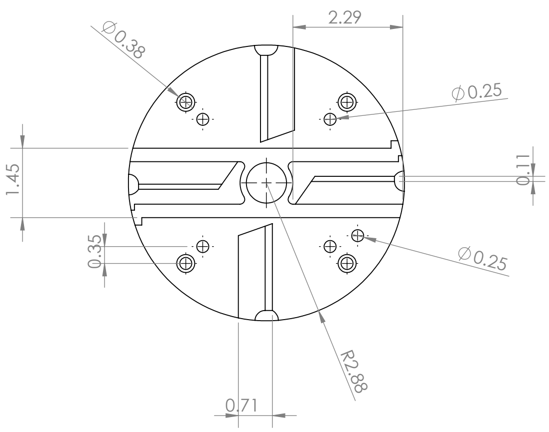

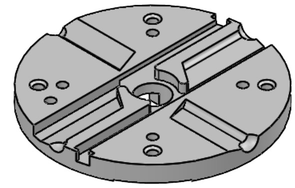

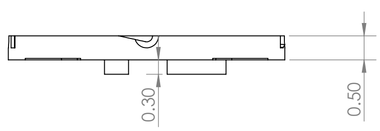

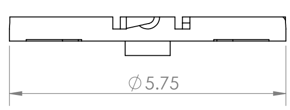

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
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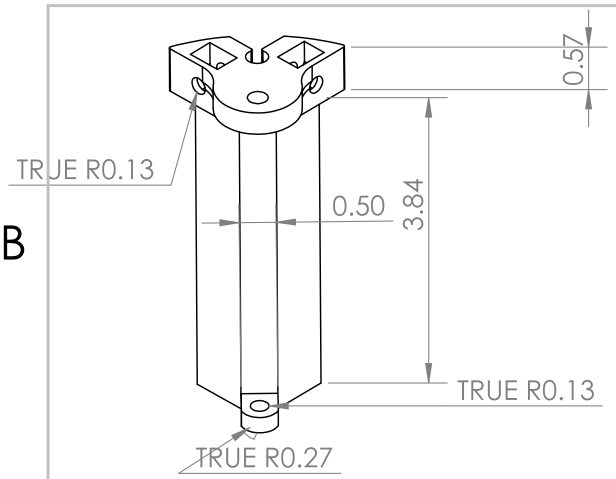
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

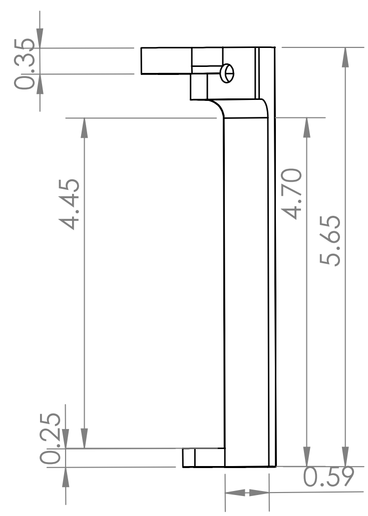
TITLE:

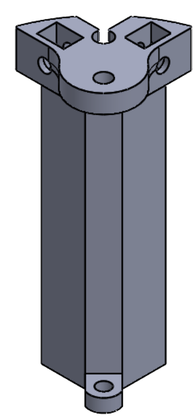
Sandwich Upper 2025

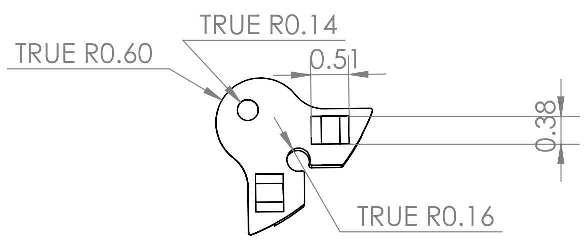
SIZE	DWG. NO.	REV
B		

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

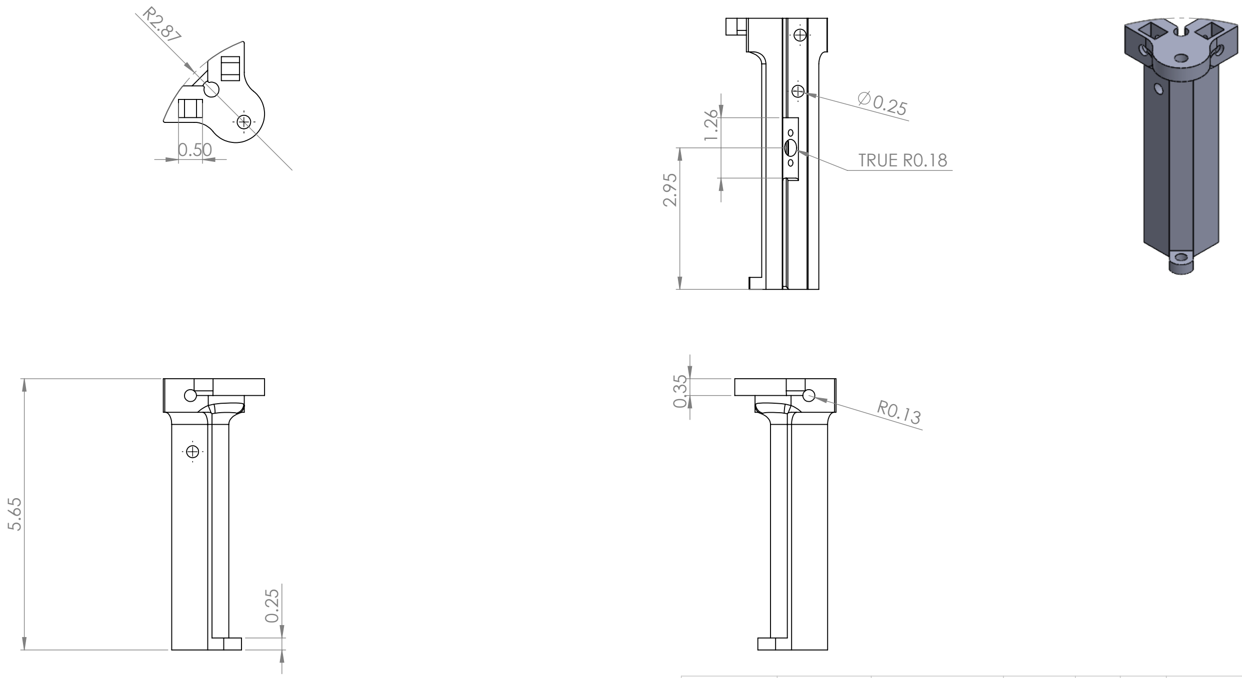








				NAME	DATE	
		UNLESS OTHERWISE SPECIFIED:	DRAWN			TITLE:
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	CHECKED			ADS Column 1 2025
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE A DWG. NO. REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:2 WEIGHT: SHEET 1 OF 1



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NEXT ASSY	USED ON	
APPLICATION		DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

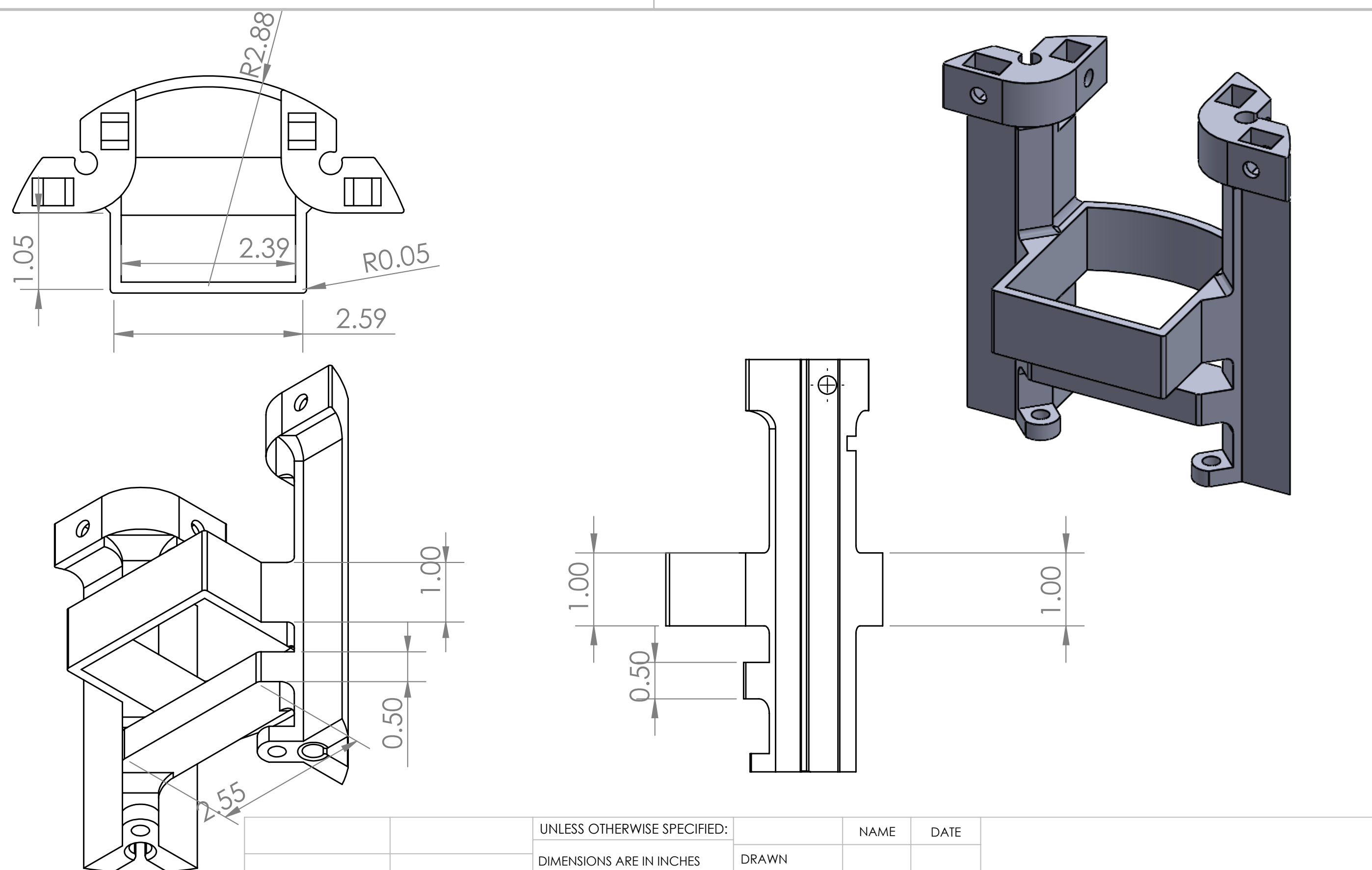
COMMENTS:

TITLE:

Column with Screw Switch Mount

SIZE **B** DWG. NO. REV

SCALE: 1:2 WEIGHT: SHEET 1 OF 1



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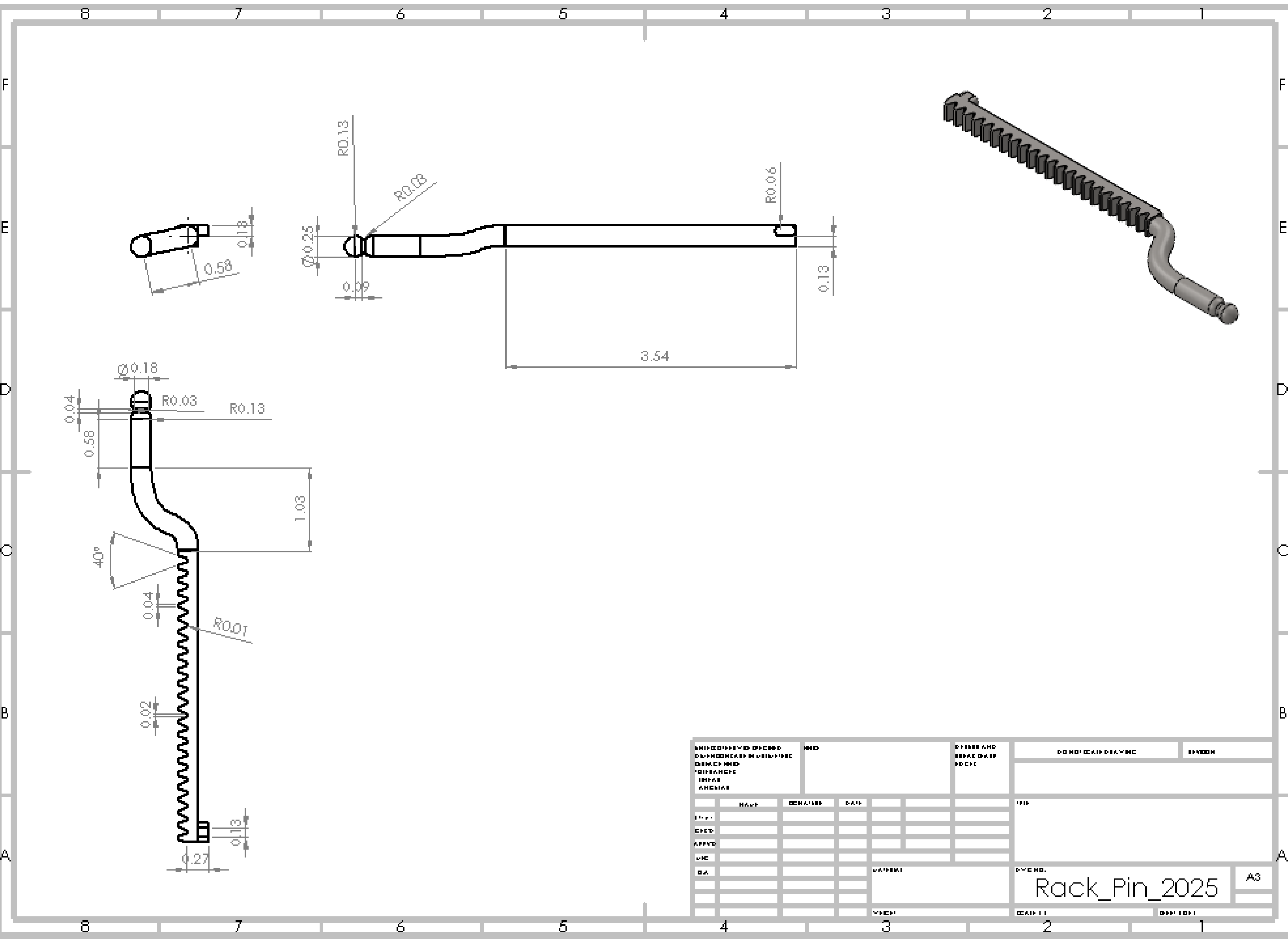
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

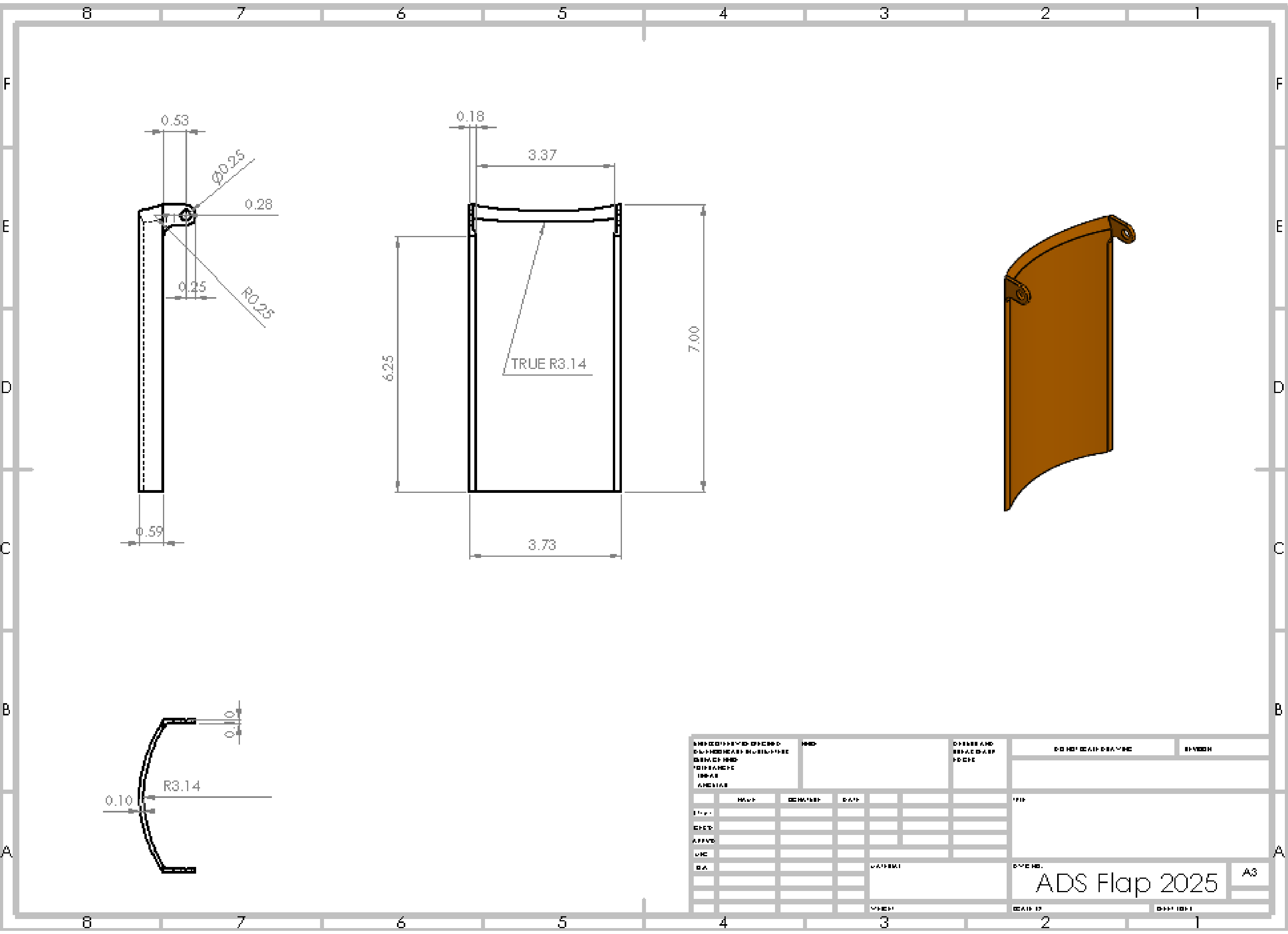
TITLE:

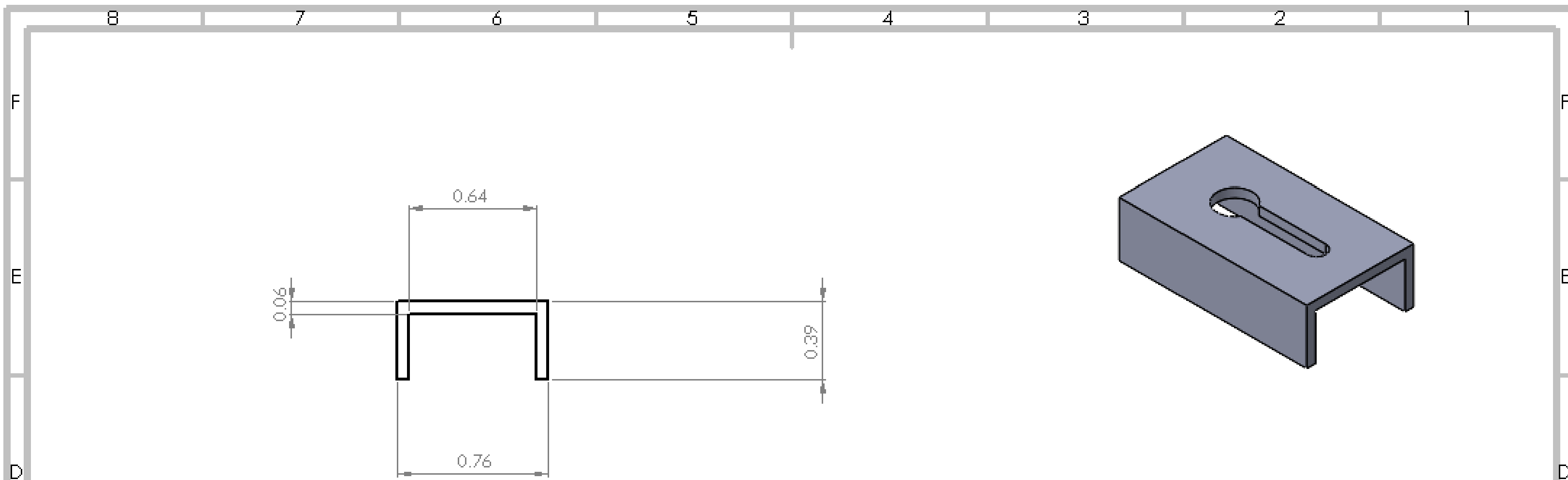
ADS Battery Column 2025

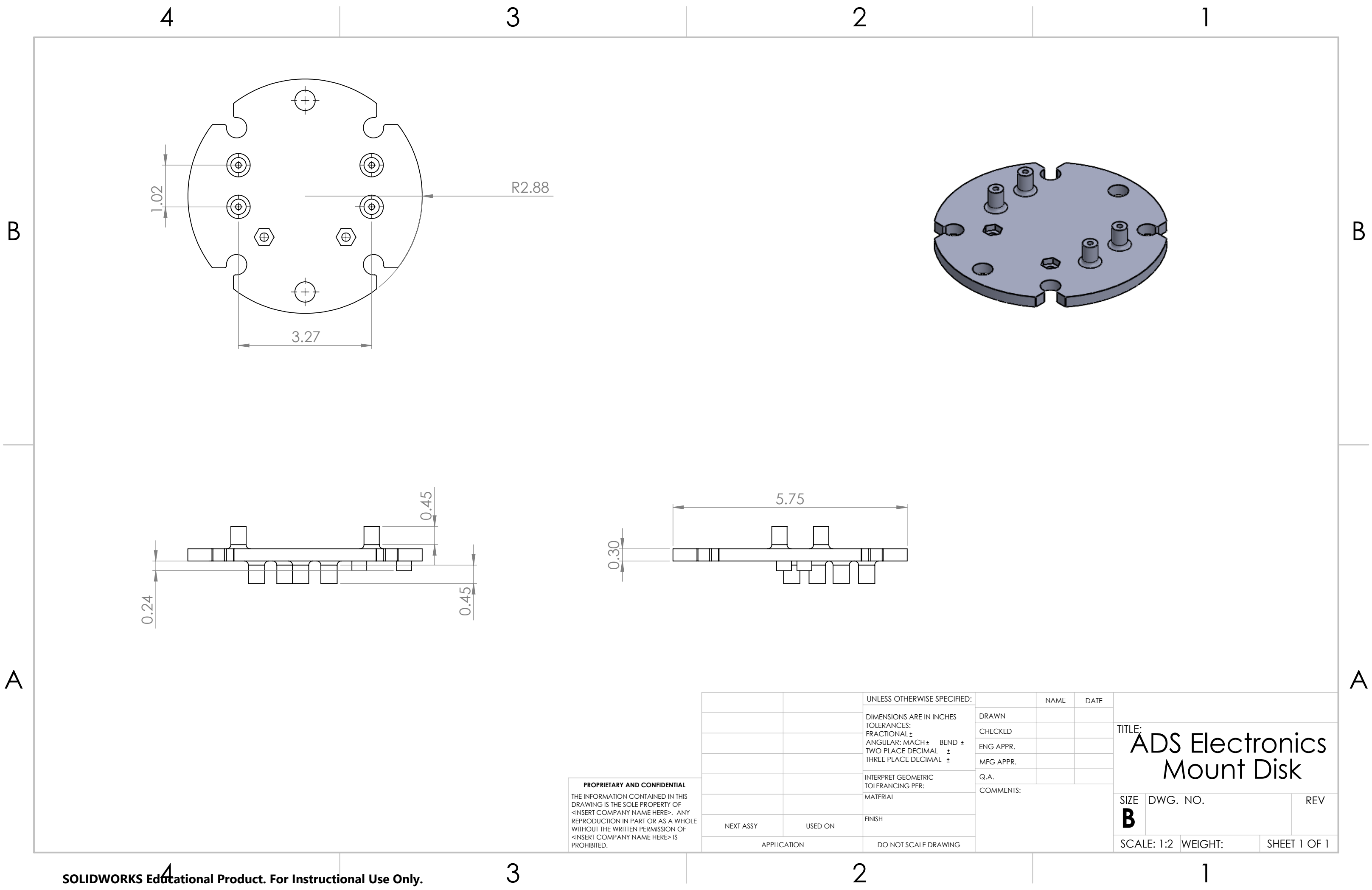
SIZE	DWG. NO.	REV
A		

SCALE: 1:2 WEIGHT: SHEET 1 OF 1


R0.13
R0.03
R0.06
Ø0.25
0.09
0.13
3.54
0.18
0.58
Ø0.18
R0.03
R0.13
0.04
0.58
1.03
40°
0.04
R0.01
0.02
0.13
0.27
Rack_Pin_2025
A3


0.53
Ø0.25
0.28
0.25
R0.25
0.59
0.18
3.37
TRUE R3.14
6.25
7.00
3.73
0.10
R3.14
0.10
ADS Flap 2025
A3


0.64
0.06
0.39
0.76
R0.07
1.33
0.47
0.44
R0.13
0.13
ADS Slot 2025
A3



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

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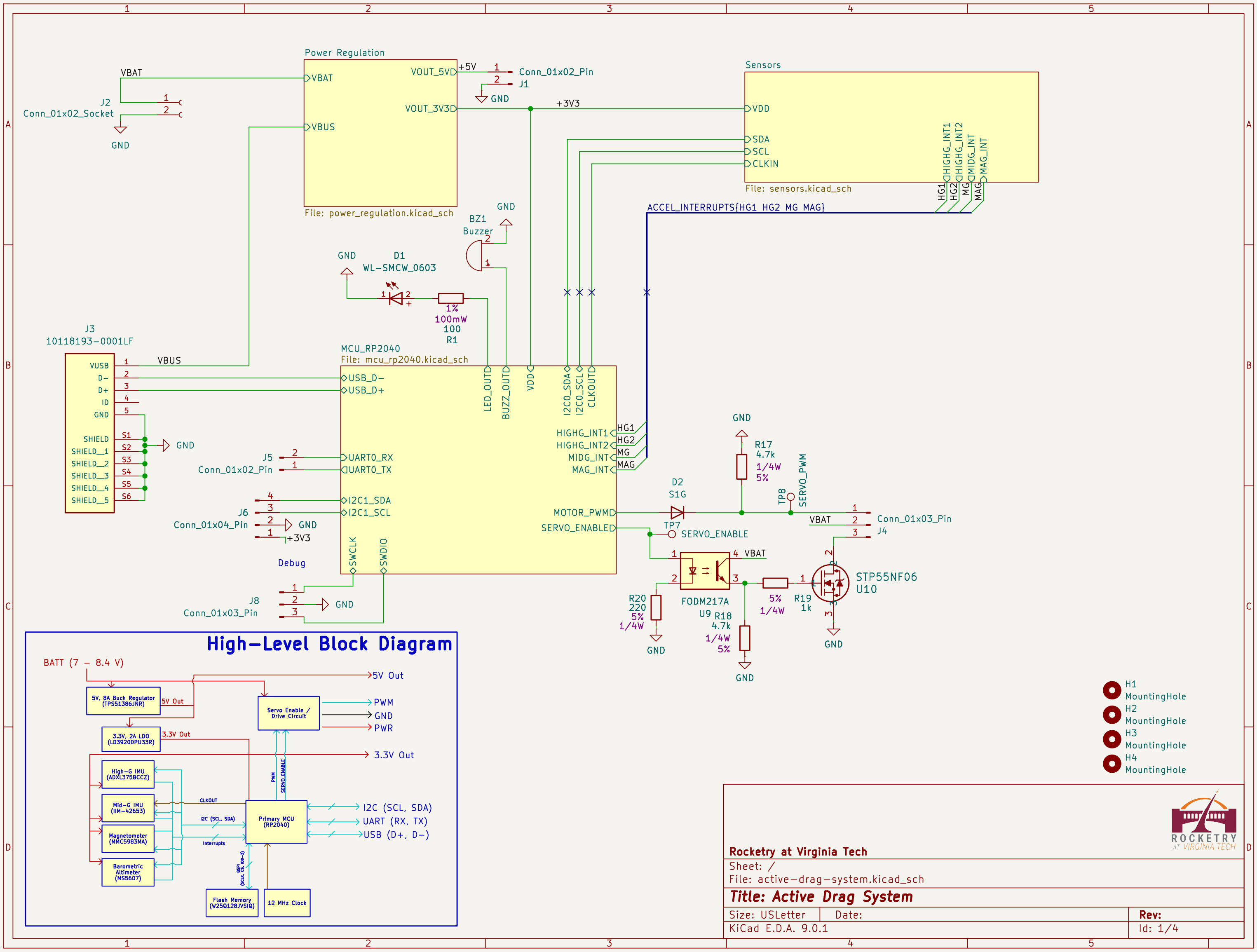
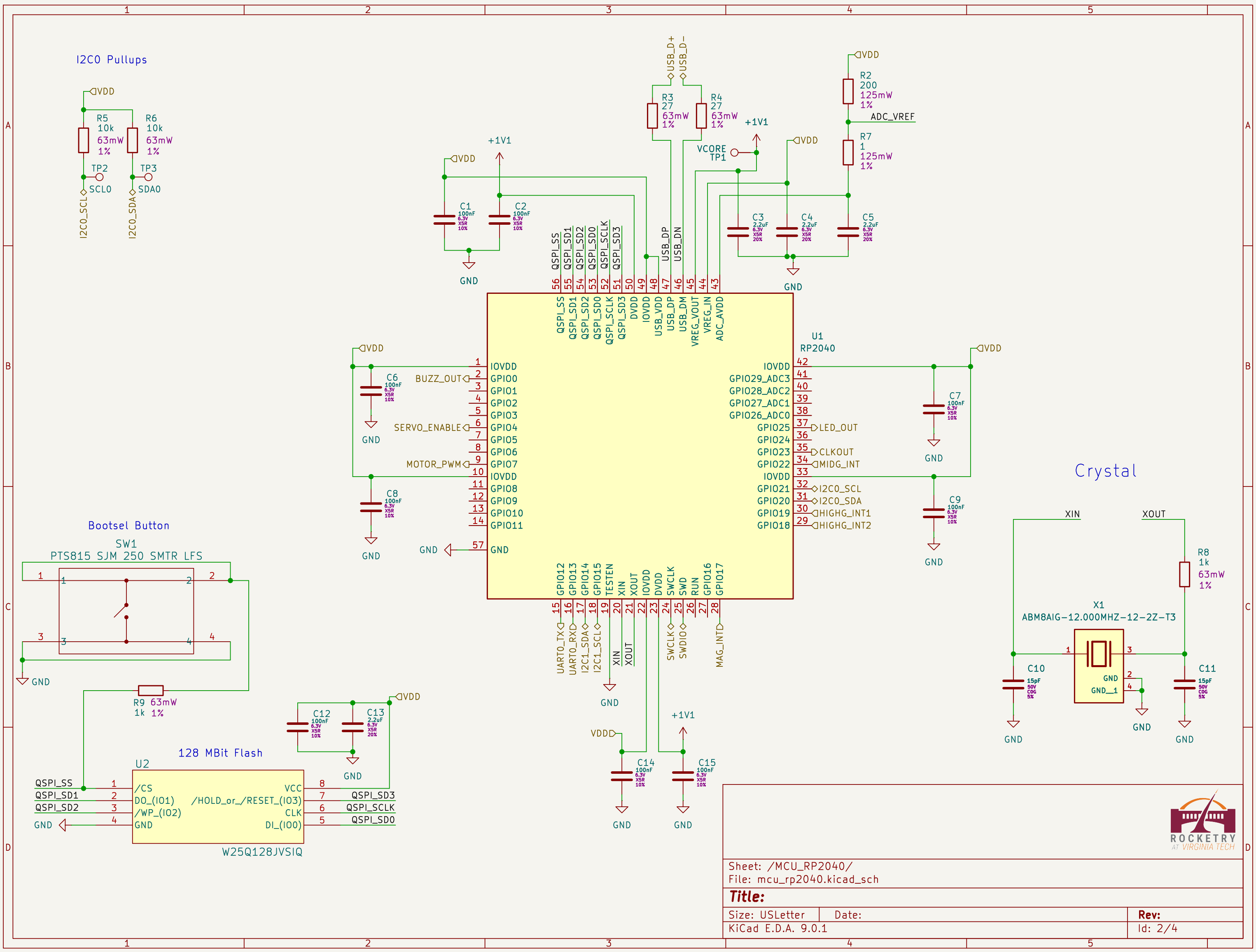
TITLE:
ADS Electronics Mount Disk

SIZE	DWG. NO.	REV
B		

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

G.IV Active Drag System SRAD Flight Computer Schematic


Power Regulation
VBAT
VBUS
VOUT_5V
VOUT_3V3
+5V
Conn_01x02_Pin
J1
GND
+3V3
File: power_regulation.kicad_sch
J2
Conn_01x02_Socket
Sensors
VDD
SDA
SCL
CLKIN
HIGHG_INT1
HIGHG_INT2
MIDG_INT
MAG_INT
File: sensors.kicad_sch
ACCEL_INTERRUPTS{HG1 HG2 MG MAG}
BZ1
Buzzer
D1
WL-SMCW_0603
1%
100mW
100
R1
J3
10118193-0001LF
VUSB
D-
D+
ID
GND
SHIELD
SHIELD_1
SHIELD_2
SHIELD_3
SHIELD_4
SHIELD_5
MCU_RP2040
File: mcu_rp2040.kicad_sch
USB_D-
USB_D+
LED_OUT
BUZZ_OUT
I2C0_SDA
I2C0_SCL
CLKOUT
HIGHG_INT1
HIGHG_INT2
MIDG_INT
MAG_INT
UART0_RX
UART0_TX
I2C1_SDA
I2C1_SCL
MOTOR_PWM
SERVO_ENABLED
SWCLK
SWDIO
J5
Conn_01x02_Pin
J6
Conn_01x04_Pin
Debug
J8
Conn_01x03_Pin
R17
4.7k
1/4W
5%
TP8
SERVO_PWM
D2
S1G
TP7
SERVO_ENABLE
Conn_01x03_Pin
J4
FODM217A
U9
R20
220
5%
1/4W
R18
4.7k
1/4W
5%
R19
1k
STP55NF06
U10
High-Level Block Diagram
BATT (7 - 8.4 V)
5V, 8A Buck Regulator (TPS51386JNR)
5V Out
3.3V, 2A LDO (LD39200PU33R)
3.3V Out
Servo Enable / Drive Circuit
PWM
GND
PWR
High-G IMU (ADXL375BCCZ)
Mid-G IMU (IIM-42653)
Magnetometer (MMC5983MA)
Barometric Altimeter (MS5607)
CLKOUT
I2C (SCL, SDA)
Interrupts
Primary MCU (RP2040)
I2C (SCL, SDA)
UART (RX, TX)
USB (D+, D-)
Flash Memory (W25Q128JVSIQ)
12 MHz Clock
H1
MountingHole
H2
MountingHole
H3
MountingHole
H4
MountingHole
ROCKETRY AT VIRGINIA TECH
Rocketry at Virginia Tech
Sheet: /
File: active-drag-system.kicad_sch
Title: Active Drag System
Size: USLetter
Date:
Rev:
KiCad E.D.A. 9.0.1
Id: 1/4


I2C0 Pullups
VDD
R5
10k
63mW
1%
R6
10k
63mW
1%
TP2
SCL0
TP3
SDA0
I2C0_SCL
I2C0_SDA
Bootsel Button
SW1
PTS815 SJM 250 SMTR LFS
GND
R9 63mW
1k 1%
128 MBit Flash
U2
QSPI_SS
QSPI_SD1
QSPI_SD2
GND
/CS
DO_(IO1)
/WP_(IO2)
/HOLD_or_/RESET_(IO3)
CLK
DI_(IO0)
VCC
QSPI_SD3
QSPI_SCLK
QSPI_SD0
W25Q128JVSIQ
C12
100nF
C13
2.2uF
+1V1
C1
100nF
C2
100nF
USB_D+
USB_D-
R3
27
63mW
1%
R4
27
63mW
1%
VCORE
TP1
R2
200
125mW
1%
ADC_VREF
R7
1
125mW
1%
C3
2.2uF
C4
2.2uF
C5
2.2uF
U1
RP2040
IOVDD
GPIO0
GPIO1
GPIO2
GPIO3
GPIO4
GPIO5
GPIO6
GPIO7
GPIO8
GPIO9
GPIO10
GPIO11
BUZZ_OUT
SERVO_ENABLE
MOTOR_PWM
C6
100nF
C8
100nF
GPIO29_ADC3
GPIO28_ADC2
GPIO27_ADC1
GPIO26_ADC0
GPIO25
GPIO24
GPIO23
GPIO22
GPIO21
GPIO20
GPIO19
GPIO18
LED_OUT
CLKOUT
MIDG_INT
I2C0_SCL
I2C0_SDA
HIGHG_INT1
HIGHG_INT2
C7
100nF
C9
100nF
QSPI_SS
QSPI_SD1
QSPI_SD2
QSPI_SD0
QSPI_SCLK
QSPI_SD3
DVDD
USB_VDD
USB_DP
USB_DM
VREG_VOUT
VREG_IN
ADC_AVDD
GPIO12
GPIO13
GPIO14
GPIO15
TESTEN
XIN
XOUT
SWCLK
SWD
RUN
GPIO16
GPIO17
UART0_TX
UART0_RX
I2C1_SDA
I2C1_SCL
SWDIO
MAG_INT
C14
100nF
C15
100nF
Crystal
XIN
XOUT
R8
1k
63mW
1%
X1
ABM8AIG-12.000MHZ-12-2Z-T3
C10
15pF
C11
15pF
GND
GND__1
ROCKETRY
AT VIRGINIA TECH
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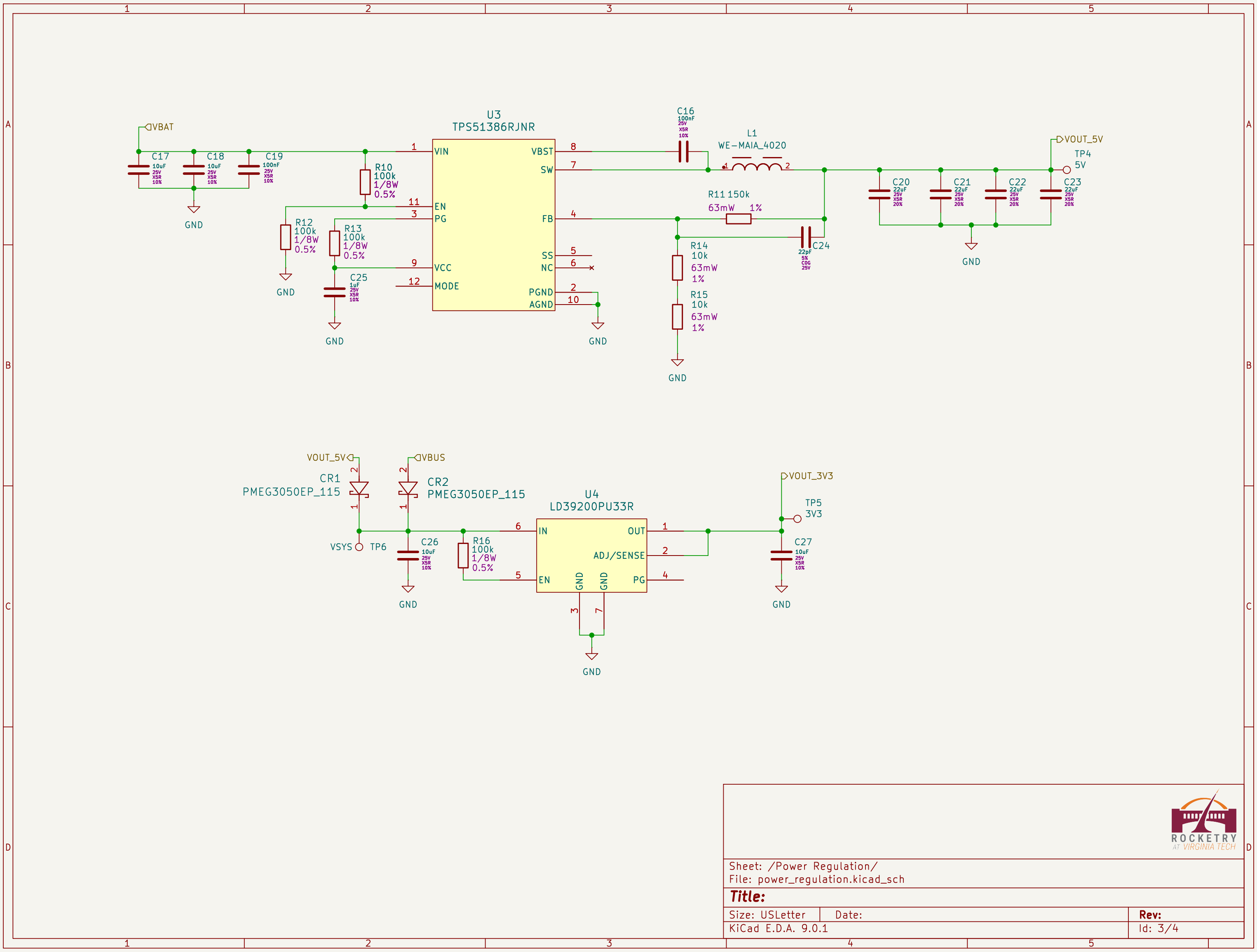
Title:
Size: USLetter
Date:
Rev:
KiCad E.D.A. 9.0.1
Id: 2/4

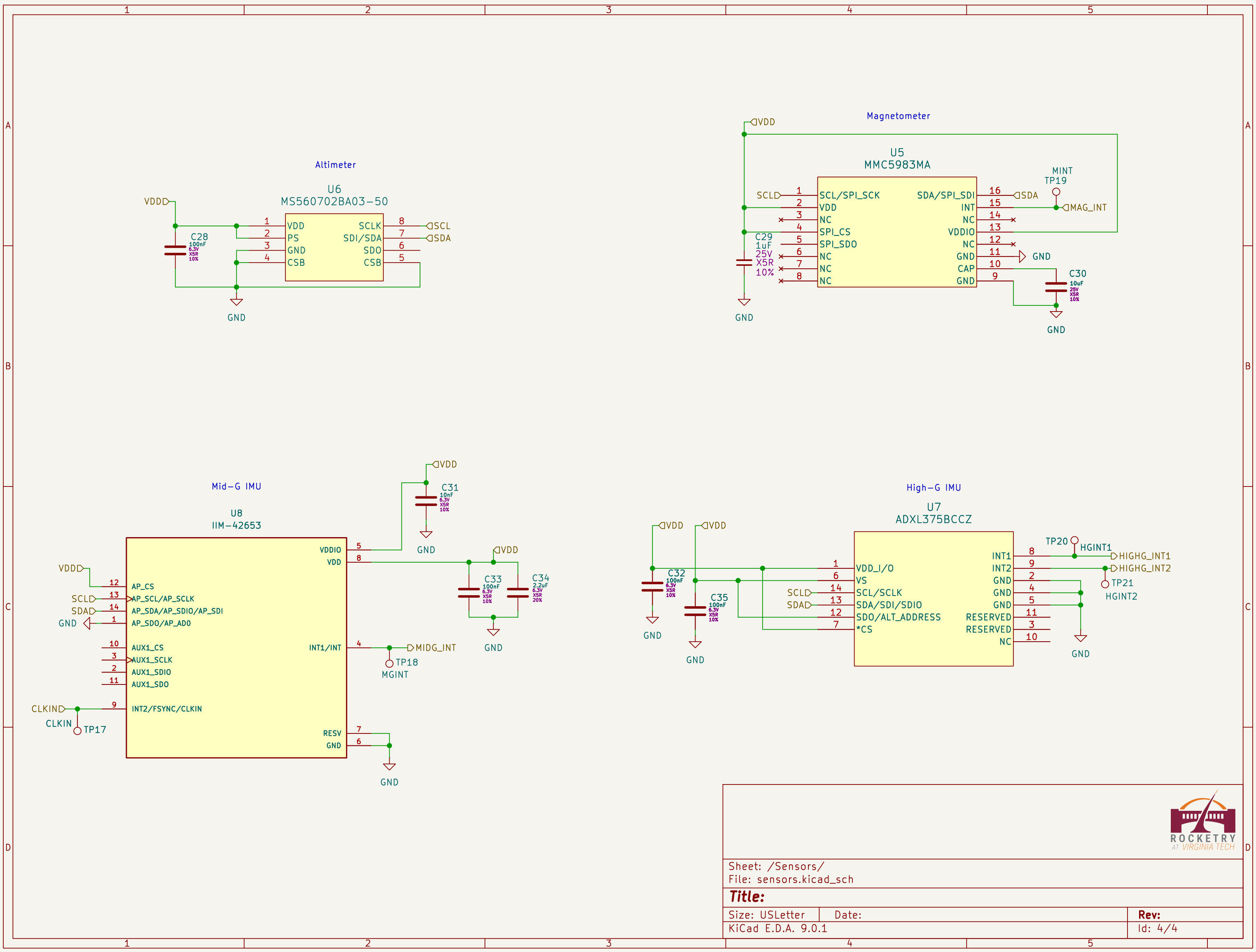


Sheet: /Power Regulation/
File: power_regulation.kicad_sch

Title:

Size: USLetter | Date: | **Rev:**

KiCad E.D.A. 9.0.1 | Id: 3/4



Altimeter
U6
MS560702BA03-50
VDDD
C28
100nF
6.3V
X5R
10%
VDD
PS
GND
CSB
SCLK
SDI/SDA
SDO
CSB
SCL
SDA
GND
Magnetometer
VDD
U5
MMC5983MA
SCLD
SCL/SPI_SCK
VDD
NC
SPI_CS
SPI_SDO
NC
NC
NC
SDA/SPI_SDI
INT
NC
VDDIO
NC
GND
CAP
GND
MINT
TP19
SDA
MAG_INT
C29
1uF
25V
X5R
10%
C30
10uF
25V
X5R
10%
GND
Mid-G IMU
U8
IIM-42653
VDDD
SCLD
SDAD
GND
AP_CS
AP_SCL/AP_SCLK
AP_SDA/AP_SDIO/AP_SDI
AP_SDO/AP_AD0
AUX1_CS
AUX1_SCLK
AUX1_SDIO
AUX1_SDO
INT2/FSYNC/CLKIN
CLKIND
CLKIN
TP17
VDDIO
VDD
INT1/INT
RESV
GND
MIDG_INT
TP18
MGINT
VDD
C31
10nF
6.3V
X5R
10%
C33
100nF
6.3V
X5R
10%
C34
2.2uF
6.3V
X5R
20%
High-G IMU
U7
ADXL375BCCZ
VDD
C32
100nF
6.3V
X5R
10%
C35
100nF
6.3V
X5R
10%
VDD_I/O
VS
SCL/SCLK
SDA/SDI/SDIO
SDO/ALT_ADDRESS
*CS
INT1
INT2
GND
GND
GND
RESERVED
RESERVED
NC
TP20
HGINT1
HIGHG_INT1
HIGHG_INT2
TP21
HGINT2
ROCKETRY
AT VIRGINIA TECH
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Title:
Size: USLetter
Date:
Rev:
KiCad E.D.A. 9.0.1
Id: 4/4

References

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[2] *A Quick Derivation relating altitude to air pressure*. Dec. 22, 2004. URL: https://archive.psas.pdx.edu/RocketScience/PressureAltitude_Derived.pdf (visited on 05/01/2025).

[3] *Altus Metrum Telemega*. Mar. 25, 2025. URL: https://altusmetrum.org/TeleMega/ (visited on 05/01/2025).