Aquila: WPI High Power Rocketry Club

Team 81 Project Technical Report for the 2022 IREC

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This report, written by the Worcester Polytechnic Institute (WPI) High Power Rocketry Club (HPRC), details the technical specifications of 2022 Spaceport America Cup project Aquila. Project Aquila consists of a 10,000 ft COTS Propulsion sounding rocket and a folding quadcopter payload. The rocket has five major systems which were designed by the team this year. One system, couplings and motor retention, was responsible for designing and fabricating an aluminum coupling mechanism to replace standard coupling tubes. The other systems consisted of a composite fin-can, custom airbrakes, a new CO2 ejection system, and a custom electronics package. The payload team set out to build a vehicle to complete a search and rescue mission. The payload consists of a retention mechanism and a quadcopter. When the payload lands a distance away from the rocket, the retention mechanism will orientate and deploy a folding quadcopter. This quadcopter will then autonomously or manually locate the lower airframe section. This is to simulate a search and rescue mission profile. The 135-person team has designed, built, and tested these systems throughout the academic year and hope to demonstrate their capabilities at competition in New Mexico. While it may be the first year that WPI HPRC is competing at the Spaceport America Cup, we hope to demonstrate our capability to be a competition winning team.

I. Nomenclature

a	=	speed of sound
AR	=	fin aspect ratio
c	=	fin root chord
G	=	shear modulus
ID	=	inner diameter
i	=	time index during navigation
j	=	waypoint index
M	=	bending moment
OD	=	outer diameter
P	=	atmospheric pressure
t	=	fin thickness
V_f	=	fin flutter velocity
λ	=	fin taper ratio

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II. Introduction

THE Worcester Polytechnic Institute (WPI) High Power Rocketry Club (HPRC) is a 135 member strong club on campus. The team was founded in 2018 as a group of students entered NASA's University Student Launch Initiative (USLI). Prior to 2018, students at WPI had competed in the Battle of The Rockets (BOR). This year, the team has chosen to compete in the Spaceport America Cup as an effort to further push our engineering skills. We hope to prove ourselves as a formidable competitor at this year's launches.

The team is comprised of mostly undergraduate team members. The team is structured with three executive board members, Team Captain, Rocket Division Lead, and Payload Division Lead. The Team Captain is responsible for all team activities and oversees the team's ten-person officer board. The officer board consists of the: Treasurer, Safety Officer, Logistics Officer, Engagement Officer, Public Relations Officer, Documentation Officer, Sponsorship Officer, and the executive board. Each division lead oversees the various subteam leads that manage an individual system. Each subteam lead oversees general team members who complete the design, construction, and testing of each system. The following sections will detail the team's technical systems.

III. System Architecture Overview

The Aquila project consists of the launch vehicle, Altair, and payload, Tarazed. Altair stands at 134 inches tall with a 6.17-inch diameter airframe and is expected to reach an apogee of 10,000 feet. The rocket weighs 38.7 pounds unloaded and without payload and 68.1 pounds at liftoff. The vehicle uses a COTS CTI M1800 solid rocket motor for propulsion.

Figure 1. Launch vehicle livery.

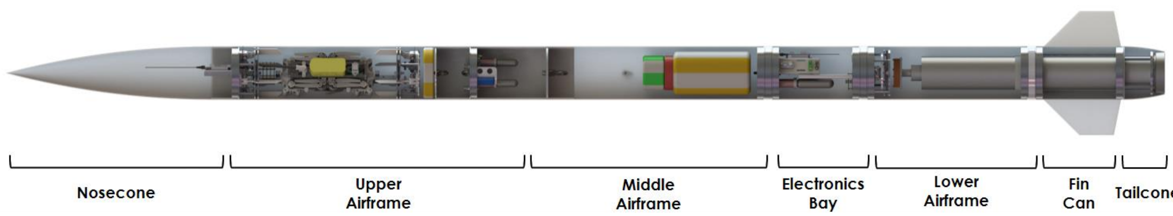


Figure 2. Diagram of launch vehicle sections.

The vehicle is split into multiple sections; the nosecone and upper airframe contain the payload. The middle airframe contains the drogue and main parachutes, and recovery hardware. The electronics bay contains the recovery electronics, GPS tracker, and telemetry antenna. The lower airframe contains the airbrake system, avionics stack, and vibration datalogger. Finally, the tailcone holds the motor retention system. The vehicle makes use of several innovative systems, including a single end deployment recovery system, actively controlled airbrakes, and a novel new airframe attachment method.

The payload consists of a recovery bay, a piston, and a retention system. The sides of the payload retention system contain the stabilization system, with the inside containing the quadcopter, a gripper mechanism, an arm deployment mechanism, parachute release mechanism, plus batteries and electronics.

A. Propulsion

1. Motor Selection

Before the start of the competition year, the team purchased a CTI 98mm 4G motor casing for use on this year's launch vehicle. This casing was selected for a variety of reasons; the team has had significant experience using Cesaroni motors, so this manufacturer was preferred over others. Based on first order estimates of the vehicle size, the 98mm 4G reloads available could deliver the launch vehicle to the target apogee with even the lower impulse reloads, while the higher impulse reloads offered the ability to fly heavier rockets in the future.

With the casing selected, flight simulations determined that the CTI M1800 would be capable of launching the vehicle just above 10,000 feet, allowing the airbrakes to reduce the apogee to the target.

2. Flight Simulations

The flight environment was estimated from historical data from Spaceport America. The nominal flight was simulated with a ground temperature of 95 F, with an atmospheric pressure of 12.8 psi. The elevation of the launch site was determined to be 4595 ft MSL. The vehicle will fly off a 17ft launch rail, but given that the vehicle can rotate once the forward rail button disengages, the rail length was set to 161 in. The launch was simulated with a launch angle of 7 degrees.

OpenRocket was used to conduct the flight simulations. For the nominal case, the vehicle is expected to reach an apogee of 10,353 ft without the use of the airbrakes. In the worst-case simulation, with 20 mph wind and a 10-degree launch angle, the vehicle is expected to reach 10,219 ft. Given that the airbrakes are expected to be capable of reducing the apogee by over 500 ft, the target apogee is within the range of the vehicle.

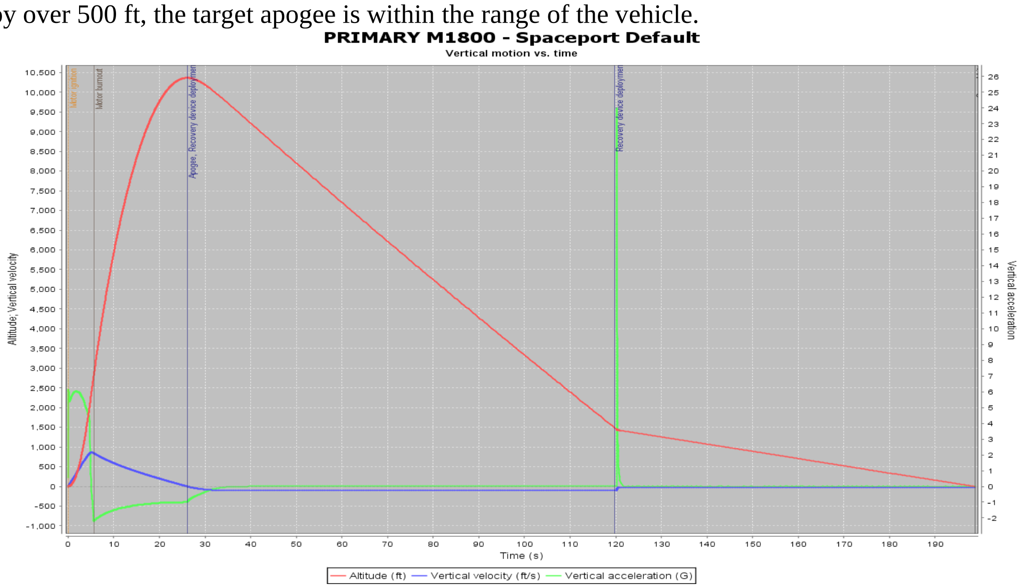


Figure 3. Nominal flight simulation results.

3. Vibration Datalogging

To better understand the vibration environment experienced by the launch vehicle during its flight, the team has integrated a vibration datalogger system onto the forward closure of the motor casing. For data collection, the team is using an enDAQ S5-E100D40 Shock & Vibration sensor. The sensor uses piezoelectric accelerometers to record vibrations at a sampling rate of up to 20,000 Hz. Additionally, the sensor includes a gyroscope and magnetometer, as well as pressure and temperature sensors which can be used to supplement the data. With a battery life of 17 hours of continuous recording at the highest data rate, the sensor is more than capable of operating throughout a launch day.

The sensor is attached to the forward closure of the motor using a machined aluminium plate. The team decided to install the sensor directly onto the motor casing as during burn most of the vibrations on the vehicle will be produced by the motor. When the motor is not burning, the motor casing is rigidly attached to the vehicle, so any buffeting vibrations will be captured.

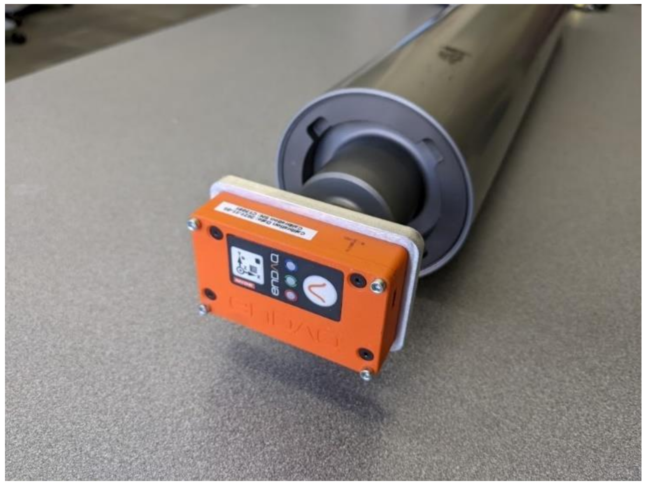


Figure 4. Vibration datalogger installed on motor casing.

B. **Aerostructures**

The aerostructures was responsible for the selection of the nosecone and airframe tubes, as well as the design and construction of custom fiberglass fin can and tailcone.

1. Nosecone and Airframe Tubes

The choice to purchase a COTS nosecone and airframe tube was selected to reduce the amount of composite manufacturing the team needed to do, allowing a focus on development of the fin can and tailcone. Each airframe section is made of G12 fiberglass body tubes, with an inner diameter of 6 in and outer diameter of 6.17 in. The body tubes for the airframe sections were purchased from Composite Warehouse.

The upper airframe is 36 1/8 in, the middle airframe is 26 19/32 in, the electronics bay is 10 in, the lower airframe is 18 29/32 in, and the fin can is 10 in. The launch vehicle also includes a filament wound fiberglass nosecone with a metal tip. The nosecone, which had previously been purchased from Madcow Rocketry, is a tangent ogive with a length of 24 in. The upper and middle airframe are attached with a 12 in section of fiberglass coupler tube, also purchased from Composite Warehouse. Each of the remaining launch vehicle sections are attached to each other using the couplings, as described in Section C.

2. Fin Can

The fin can was manufactured as a tip-to-tip layup using 6oz S-glass fiberglass fabric. Since this was the team's first experience using this technique, multiple prototype fin cans were manufactured to gain experience.

Figure 5. Prototype fin can.

Through the development of these prototypes, the team learnt important lessons regarding fin alignment, filleting methods, and surface preparation procedures to ensure the fin can would be capable of withstanding flight loads.

For the final product, four trapezoidal fin cores were routed from 1/8 in G10/FR4 fiberglass plate and epoxied along their root chord onto the fin can. To ensure alignment, a fin alignment jig was manufactured to align each of the fins vertically along the body tube. The root chords were attached using Loctite EA9460 due to its excellent composite bonding characteristics. With the fins attached, 0.8 in radius fillets were built up at the root chord using G5000 RocketPoxy, chosen for its long work time and flight heritage.

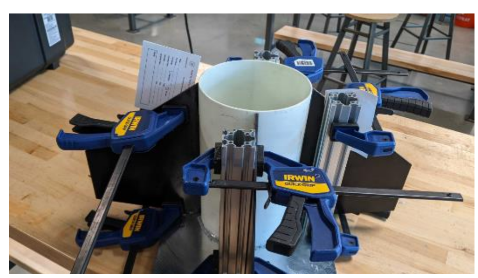


Figure 6. Fin alignment jig.

With the fillets completed and cured on all fins, 3 layers of plain weave 6oz fiberglass were laid between the tips of each fin pair. The layers were oriented at 90/45/90 to give the fin stiffness both in torsion and bending, and the size of each layer was staggered to avoid delamination at the fin edge and give a slight taper to the fin surface.

Before each layup was conducted, the team sanded the fins and airframe until the surfaces passed a water break test, where water spreads into a thin film rather than beading up. This test indicates that the surface energy of the fiberglass is sufficient to achieve a chemical bond with the epoxy resin, rather than simply a mechanical bond.

The fiberglass was wet with PRO-SET LAM-125/LAM-226 laminating epoxy, selected for its high strength and temperature resistance, as well as its relatively low cost compared to similarly performing epoxy resins such as Aeropoxy PR2032/PH3660. The layups were allowed to cure without the use of a vacuum bag, as the prototype fin cans demonstrated that with proper surface prep the extra adhesion force is unnecessary. Once all the layups were completed, the excess fiberglass was cut off and the fin can was sanded and painted, as seen in Figure 7.

Figure 7. Final fin can and tailcone.

An Ansys Composite PrepPost (ACP) static structural simulation was used to verify the fin can design. The tip-to-tip layup with three layers was verified to withstand the expected impact force on landing, which resulted in a maximum deformation of 0.00013 in and a maximum stress of 320.25 psi.

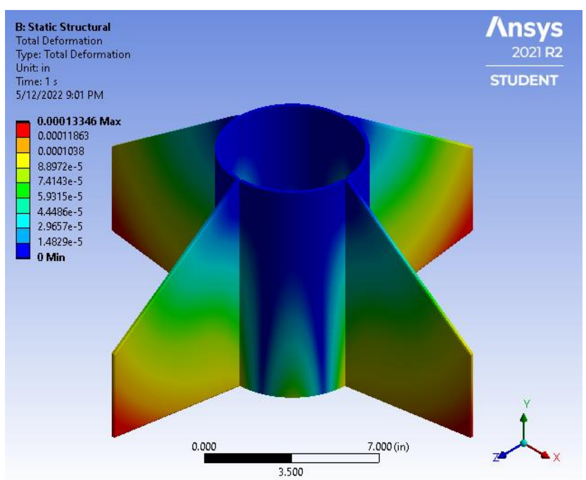


Figure 8. ANSYS simulation of total deformation for fin can.

The fin flutter velocity was calculated with Equation 1, which considers the fin geometry, fin material, and atmospheric properties at the rocket's maximum velocity [1]. The fin has a root chord of 10 in, tip chord of 4 in, semi-span of 6.5 in, and thickness of 0.15 in. The maximum velocity of the rocket will occur at 2800 ft AGL. Although the fins are made of G10 fiberglass, they will also be attached to the rocket body under three layers of fiberglass layups and will have a different shear modulus than just G10 plates. The shear modulus of G10 fiberglass with a fiberglass layup can be approximated conservatively to 1,766,600 psi [2]. These parameters result in a fin flutter velocity of 1652 ft/s, providing a factor of safety over the recommended 1.2 in the newsletter.

$$V_f = a\sqrt{\frac{\frac{G}{1.337AR^3P(\lambda+1)}}{2(AR+2)(\frac{t}{c})^3}} \quad (1)$$

3. Tailcone

The tailcone is a tangent ogive, with a length of 4 ¾ in, forward diameter of 6.17 in, and aft diameter of 5.3 in. These dimensions were selected based on an optimization of the tailcone within OpenRocket for the highest possible altitude. The tailcone reduces the base drag of the rocket, a phenomenon where airflow separates at the sharp end of an airframe, and becomes turbulent, creating a low-pressure zone behind the rocket. The optimization of the tailcone requires balancing this reduction in base drag, with the higher mass and skin friction drag associated with a longer tailcone.

The tailcone was custom-made using 6oz fiberglass sleeve laid up over a 3D-printed mold. As with the fin can, this manufacturing technique had never been attempted by the team before, so multiple prototype tailcones were manufactured and tested before the final tailcone was constructed.

Figure 9. Prototype tailcone manufacturing.

A mold for the tailcone was printed out of PLA, and six fiberglass sleeves were wet with PRO-SET LAM-125/LAM-226 laminating epoxy and laid over the mold. Once the epoxy was cured, the mold was heated until it released, and the excess fiberglass was cut off both ends and sanded down to be flat. Additionally, a bulkhead was made from 1/8 in G10 fiberglass and was attached inside the forward end of the tailcone using RocketPoxy as shown in Figure 10. The bulkhead is mounted to the thrust coupling, which attaches it to the fin can section.

Figure 10. Fiberglass tailcone with epoxied bulkhead.

An ACP static structural simulation was used to verify the tailcone design and whether the six fiberglass layers would be able to withstand landing forces. A load was applied to a single node to simulate the tailcone landing on a sharp edge. The maximum deformation was 0.005 in, and the maximum stress was 8614.1 psi at the node, as shown in Figure 11.

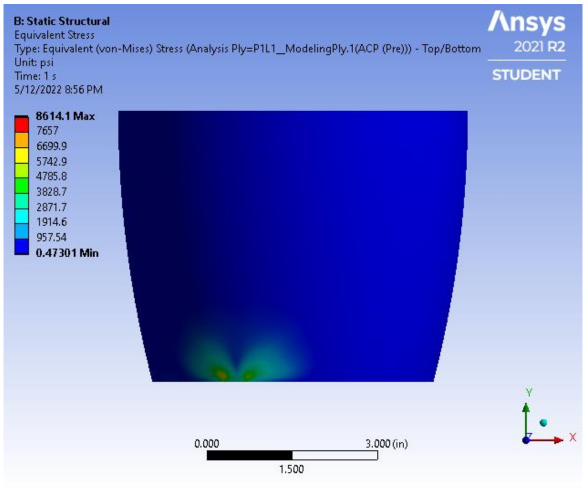


Figure 11. Ansys simulation of von-Mises stress for tailcone.

C. Couplings and Motor Retention

Traditionally, high power rockets utilize coupler tubes to provide a stiff joint between airframe sections. While couplers are flight proven, easy to manufacture, and the default choice for most in the hobby, they do offer some disadvantages. They can be frustrating to assemble, particularly when internal components are mounted inside, as three degrees of alignment are necessary to bolt through the airframe, coupler, and into the component. The stiffness of a coupler joint is also highly dependent on the diameter tolerance and length of the tube, with longer tubes required for stiffer joints. To overcome some of these issues, the team developed a machined airframe joint known internally as a coupling.

1. Couplings

The couplings operate similarly to the captive nut found on the end of a garden hose, with a freely rotating nut attached to one airframe screwing into a fixed threaded coupling on the opposite airframe, as shown in Figure 12. The couplings offer several advantages over coupler tubes; they are lighter and take up less volume in the airframe. They include standardized mounting flanges, which allow for internal components such as the airbrakes and electronics bay to be easily installed and removed. Finally, because tightening the couplings provides a preload to the airframe joint, the joint can be made much stiffer than coupler tubes and removes the need for bolts loaded in shear to hold the coupler in place.

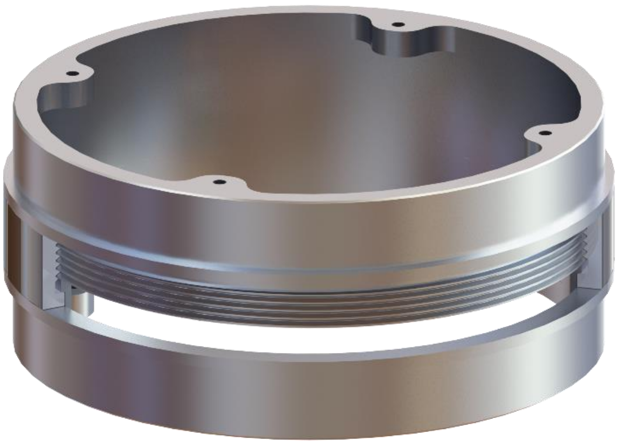


Figure 12. Coupling assembly rendering.

Throughout the launch vehicle, there are 3 coupling joints located between the middle airframe and electronics bay, electronics bay and lower airframe, and lastly lower airframe and fin can. Each joint consists of 4 SRAD CNC machined parts made of aluminium. The fiberglass body tubes are attached to the top and bottom couplings via 3M DP8407NS methyl-methacrylate structural adhesive. This adhesive was chosen for its high shear and peel strength and superior heat resistance and ability to bond dissimilar materials compared to a two-part structural epoxy such as the Loctite EA9460 used on the fin can.

Such a design allows for guaranteed rotational alignment with the use of an alignment boss on the coupling, which only allows the airframes to be assembled in one orientation. In addition, any rolling moments the vehicle may experience throughout flight are transferred to the alignment boss rather than the threaded connection which could potentially disassemble the joint.

At 10 mph winds (nominal launch) and 20 mph winds (absolute worst case launch condition), Aquila will experience 3 and 3.25G's of lateral acceleration respectively. This results in a maximum bending moment of 2667 in-lb for a nominal launch and 2890 in-lb for a worst-case launch, located 66 inches below the top of the nosecone. By using a discrete bending moment solver, developed by the team, a bending moment diagram was created along the rocket body.

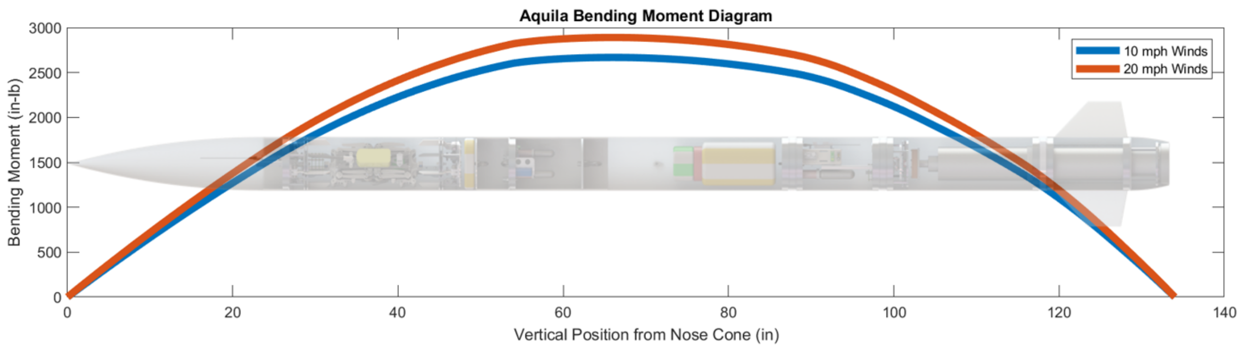


Figure 13. Bending moment diagram with 10 and 20 mph winds.

We are assuming a constant bending moment value throughout the entire length of the launch vehicle equal to the maximum bending moment. Since this novel design is in its first iteration and OpenRocket, has limited accuracy, an engineering safety factor higher than normal was chosen. To counteract the bending moments and prevent the airframe joints from separating an axial preload is applied by the threaded connection. By applying a compressive preload stress equal to the maximum tensile bending stress, any tensile stresses (and thus separation) within the joint will be eliminated. This allows for a rigid and stiff joint that doesn't deflect under bending loads. Mathematical derivations result in this relationship between preload, bending moment (M), coupling outer diameter (OD), and coupling inner diameter (ID).

$$Preload = 8M * \frac{OD(OD^2 - ID^2)}{OD^4 - ID^4} \quad (2)$$

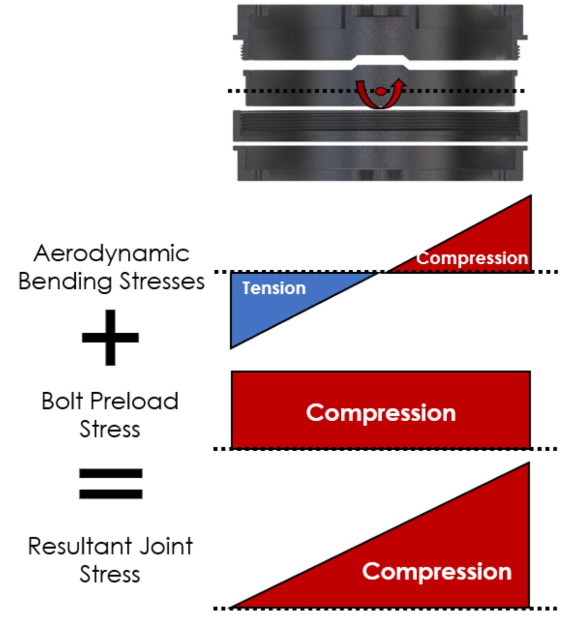


Figure 14. Resultant stress in coupling joint.

The launch vehicle's ability to remain straight and resist bending throughout flights allows us to disregard aeroelastic effects, satisfying the assumptions of our flight simulations.

The couplings can be assembled to a torque specification to provide the proper preload using a torque wrench, breaker bar, and 2 custom collet wrench attachments. This airframe joint design actively prevents joint separation due to lateral loads as opposed to the standard coupler tube which offers little joint rigidity. Standardized mounting flanges allows for simple integration with internal subsystems such as the electronics bay and airbrakes module. This allows for our modular subsystems to be swapped out or moved around different parts of the rocket. Lastly, the couplings are more mass and volume efficient compared to coupler tubes, weighing 70% of its predecessor and takes up 80% less length in the rocket.

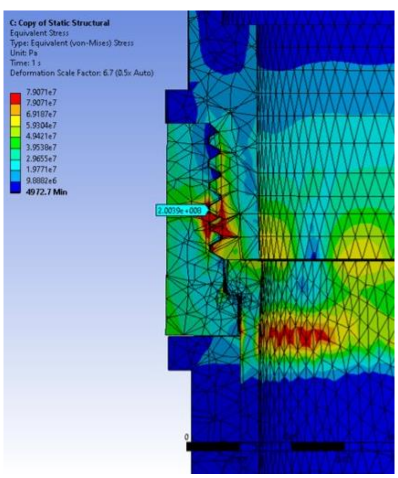


Figure 15. Ansys simulation of coupling under bending load.

Using Ansys Mechanical solid structural, the coupling design was verified to withstand 5.34 the expected load with its failure mode being bending of the inner retaining ring flange. Since the design is in its first iteration and was already significantly lighter than the coupler tube design, a higher than desired safety factor of 5.34 was accepted. Further verification was completed by running a 3-point flexural test to expected operational loads. At the time of the test, Aquila was expected to experience 3700 in-lb of bending moment, higher than the moment for the final vehicle. The test revealed that the retaining ring had plastically deformed, and the entire joint had deflected 0.1mm when unloaded because the coupling was only torqued to only 30% of the required spec. The torquing mechanism used at the time was unable to provide the desired torque because the strap wrench used for torquing was friction based and often slipped on the coupling's smooth surface. Faced with this deformation, the material for the retaining ring was swapped to a stronger 7075 aluminium alloy. With this change, and considering the coupling was not properly torqued we are confident in the ability of the couplings to withstand flight loads.

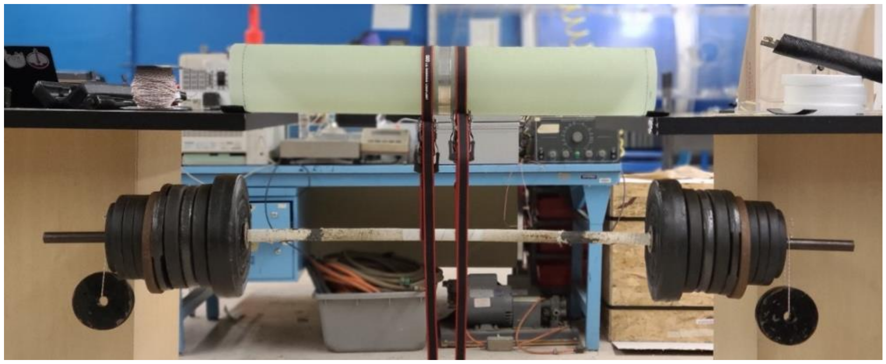


Figure 16. Coupling 3-point flexural test.

The team identified and overcame numerous challenges during the development of the couplings. Machining large parts like these required significant time and the development of multiple fixturing techniques to successfully achieve all the operations. Tolerancing and creating large diameter custom threads also proved to be challenging, with initial prototypes seizing due to poor surface finish, though this problem was solved with improved surface finish and the use of anti-seize grease. After the couplings were first assembled, the team discovered that the launch vehicle was not straight, due to slightly angled cuts on the airframes. To solve this issue, the airframes and couplings were strapped to a known straight spine before epoxying to ensure the concentricity of all airframes.

Figure 17. Airframe sections on alignment spine.

2. Motor Retention System

The motor retention system withstands thrust exerted by motor burn and retains its position throughout flight. It consists of a thrust coupling, hex standoffs, and a COTS Aero Pack motor retainer. The thrust coupling is similar in form to the airframe couplings, but without any threading. During motor burn the hex standoffs transfer the load to the flanges on the thrust coupling while being loaded in compression. These standoffs are capable of withstanding 22.4 times the peak thrust of the motor before buckling. The thrust coupling is made of aluminum 6061-T6 which has a tensile yield strength of 38,000 psi at 200 °F. The maximum stress experienced by the thrust coupling is 12,000 psi at peak thrust, resulting in a safety factor of 3.2.

Figure 18. Rendering of motor retention system.

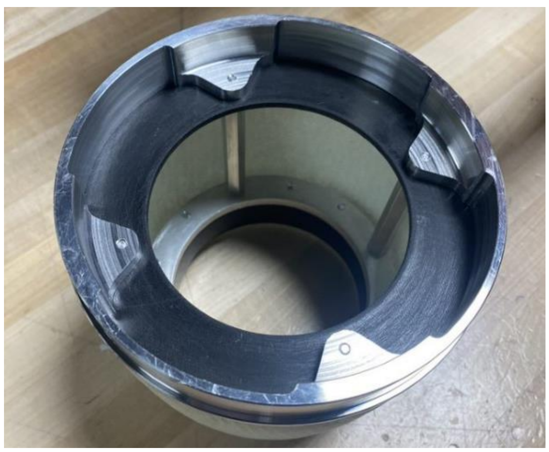


Figure 19. Completed motor retention assembly inside tailcone.

D. Airbrakes

In 2020, the team began the research and development of a design for an airbrake mechanism that allows the rocket to accurately achieve a 10,000 ft apogee by controlling the rocket's drag. For this year's competition, the team iterated upon previous work by prototyping, refining, simulating, and testing the design.

Figure 20. Airbrake assembly.

4. Mechanical Design

The airbrakes are located at the top of the lower airframe and attach via the standardized coupling mounting pattern. The structure is made from machined, and waterjet cut aluminium plates, to simplify manufacturing. The upper plate holds the servo and provides the attachment point to the couplings. The central plate is rotated by the servo. Curved bearing raceways push the fins outward, sliding along linear rails attached to the lower plate.

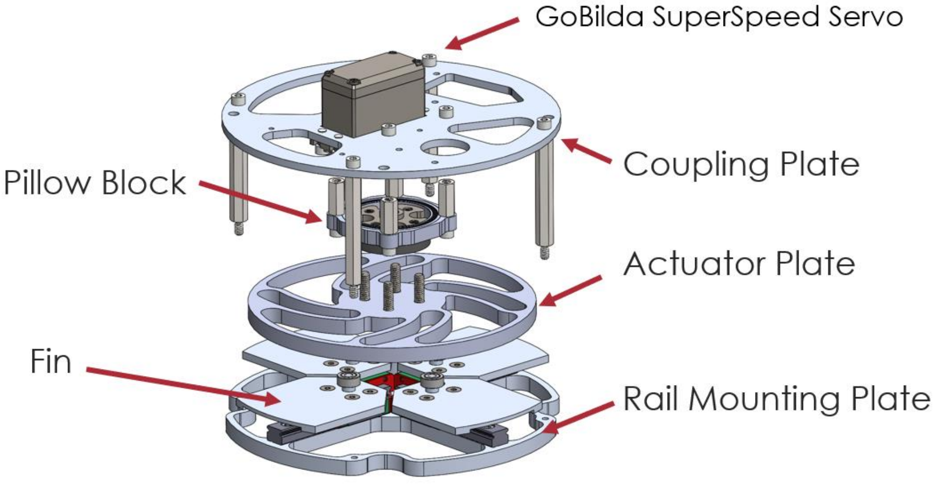


Figure 21. Exploded view of airbrakes.

The use of these curved slots allows for a significant degree of control over the opening characteristics of the airbrakes. By decreasing the angle of the slots, the torque required by the motor is reduced. Alternatively, the angle can be increased to result in a faster opening time. The angle of the slot can also be varied along its length to provide more torque when the airbrakes are fully extended, and a higher actuation speed when the airbrakes are closed. Due to difficulties in the mathematical modeling of the system, an equiangular slot geometry was chosen for simplicity, but a new actuator plate can be easily swapped out if desired.

The airbrakes are driven by a single GoBilda SuperSpeed Servo. The use of a single servo makes it impossible for the airbrakes to deploy asymmetrically, which could produce moments on the vehicle and cause it to go unstable. The servo hub is supported with a pillow block to prevent flight loads from causing the servo to bind. With a no-load speed of 0.035 sec/60° (290 rpm) and stall torque of 5.4 kg-cm (75 oz-in) when operating at 7.4 V, this servo met the team's requirements for the necessary speed and torque for actuation.

The airbrake fins were machined from an aluminium plate. They include press fit bearings which fit freely into the actuator plate slots. The fins are mounted onto 7mm linear rails. These rails provide smooth movement with no binding and are more than capable of withstanding the bending moment produced by the drag on the fins during flight.

5. Simulation

To verify that the airbrakes would be capable of effectively controlling the apogee of the vehicle, we began by simulating a nominal flight using OpenRocket. From this trajectory, we selected a series of points that were representative of the full range of dynamic pressures the launch vehicle will experience during flight. At each of these points, we used Solidworks Flow Simulation to conduct a Computational Fluid Dynamics (CFD) analysis to determine the drag on the vehicle at multiple airbrake extensions. Using results from the simulations, we used MATLAB to determine the relationship between dynamic pressure, airbrake extension, and drag on the vehicle. The SolidWorks Flow Simulation data yielded the following final drag equation with 95% confidence bounds, with x as dynamic pressure and y as extension.

$$D = -0.1503 + 3.646x + 0.07924y - 10.17x^2 + 2.217xy + 6.642x^3 + 2.31x^2y \quad (3)$$

Ultimately, the team determined that at maximum velocity and full extension, the airbrakes will have the capability to produce an additional drag force of about 23 pounds to the launch vehicle. The drag produced at various airbrake extensions and dynamic pressures is shown on the surface fit plot in Figure 22.

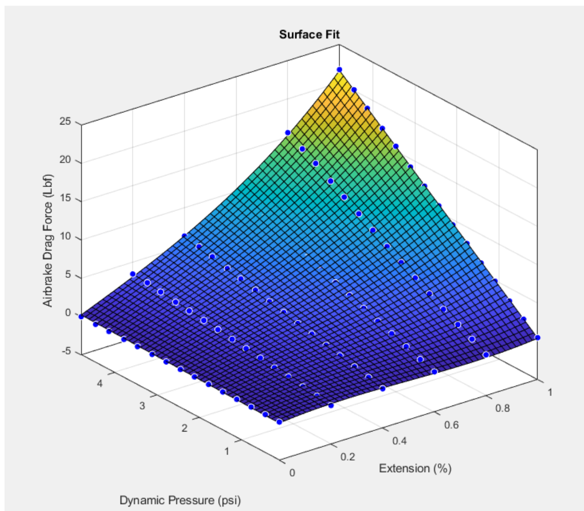


Figure 22. Surface fit of airbrake extension vs dynamic pressure vs drag force.

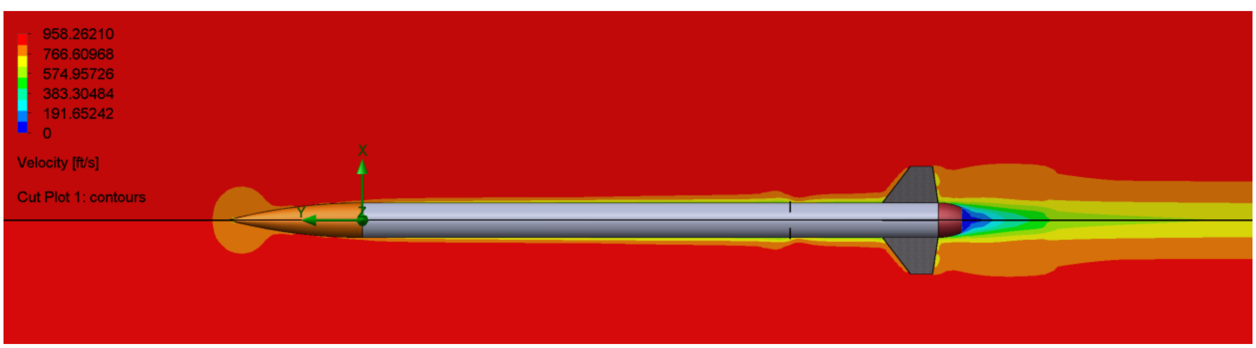


Figure 23. Air velocity contour plot of 100% airbrake extension.

6. Testing

The MATLAB simulations conducted by the team showed that each fin of the airbrakes needed to withstand a maximum of about 5.6lbs of force per fin at full extension immediately after motor burnout. The team needed to determine if the servo motor could actuate the airbrakes with the maximum amount of force applied to them. The test consisted of four equal weights suspended from each airbrake using fishing wire. To prevent the wires from hitting anything below the airbrakes, the entire airbrakes mechanism was suspended on a beam of wood that was secured into a vice. Water jugs were used for weights so an exact weight of 6.72lbs per airbrake could be achieved, giving us a

20% safety margin. With the weights suspended the entire mechanism was actuated to and from full extension in 0.3 second intervals. The servo motor was successfully able to actuate the airbrakes at maximum force without stalling, verifying our design.

Figure 24. Airbrake actuation test.

7. Controls

The goal of the airbrakes controls system is to actuate the airbrakes to change the drag coefficient over the rocket to reach the target apogee of 10,000 ft. Our control system compares the drag coefficient that airbrakes produce in real-time to the drag coefficient that airbrakes need to produce to reach an apogee of 10,000 ft. A PID was chosen as a controller to take in the error between two drag coefficients and output a value of extension of the airbrakes. This way, the control system aims to converge the values of real and target drag coefficients. The control systems subteam wrote a MATLAB flight simulation to test different conditions and obtain optimal PID coefficients before the flight. CFD information was used as a source of force data to simulate the flight. The simulation also considers the system dynamics of the goBILDA Super Speed servo. For this, a transfer function of a motor is obtained through the System Identification MATLAB toolbox. Consideration of the system dynamics of an actuator improves the accuracy of a flight simulation, and therefore ensures the optimal tuning of PID coefficients.

E. **Electronics**

The avionics system is in the lower airframe, mounted on top of the airbrakes. The purpose of the avionics system is to gather sensor data, transmit data to the ground station, and actuate the airbrakes. The avionics system is composed of four custom made circuit boards arranged in a vertical stack. This same system will also be used in the payload self-righting mechanism.

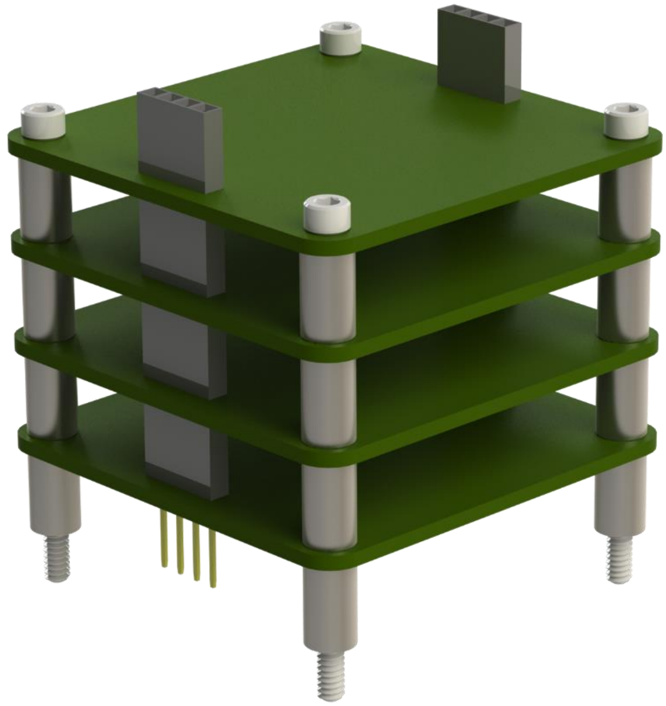


Figure 25. A render of the avionics system structure.

These boards were designed by the electronics team using Altium Designer and manufactured by JLC PCB. Every board has four copper layers, these being a front and back signal layer, as well as a power and ground plane. The four boards in the system are the Power Board, the Telemetry Board, the Sensor Board, and the Controller Board. The Power board is responsible for regulating the battery power and distributing power to the other three boards. All boards are connected to 5V and 3.3V rails from the power board. The power board also delivers power to the airbrake servo. The Telemetry Board is designed to store and transmit data from the rocket. The board has a flash memory chip for recording data locally, and a 915MHz LoRa module for transmission to the ground station. The Sensor Board contains all the sensors for measuring the rocket's motion. The three sensors on the board are a barometric pressure sensor, a 6 axis IMU, and a GPS module. The Controller board is tasked with the computation of the rocket's apogee and running the control system given the sensor data. For this we are using the MicroMod modular Teensy 4.0 processor, which connects to the controller board via an M.2 connector.

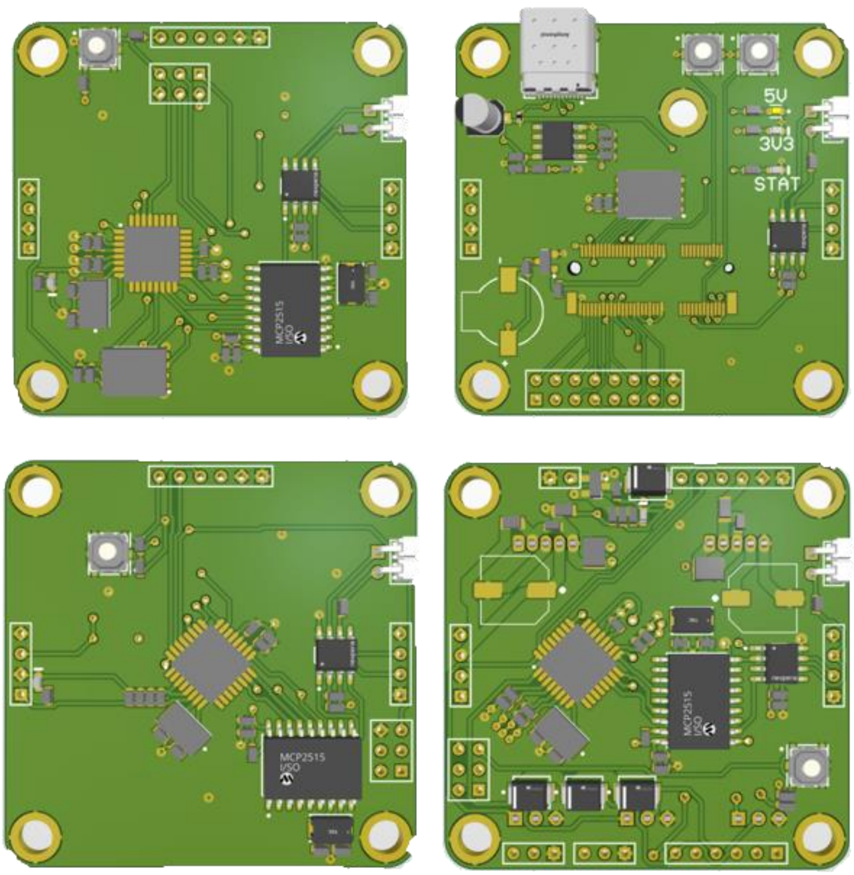


Figure 26. The four avionics boards in altium (Top left- Telemetry Board, Top right – Controller Board, Bottom left – Sensor Board, Bottom right- Power Board).

The four boards in the system communicate over a Controller Area Network (CAN). Each board contains a CAN transceiver and controller chip, as well as an ATMega328 processor except for the controller board. The CAN system provides reliable communication over any number of connected nodes, allowing the system to be expanded upon with additional boards.

The boards were assembled by electronics team members using SMD reflow soldering techniques with hot air guns and a reflow oven. Key functionality of the boards such as programming the ATMega chips and CAN communication has been tested, and further testing is underway.

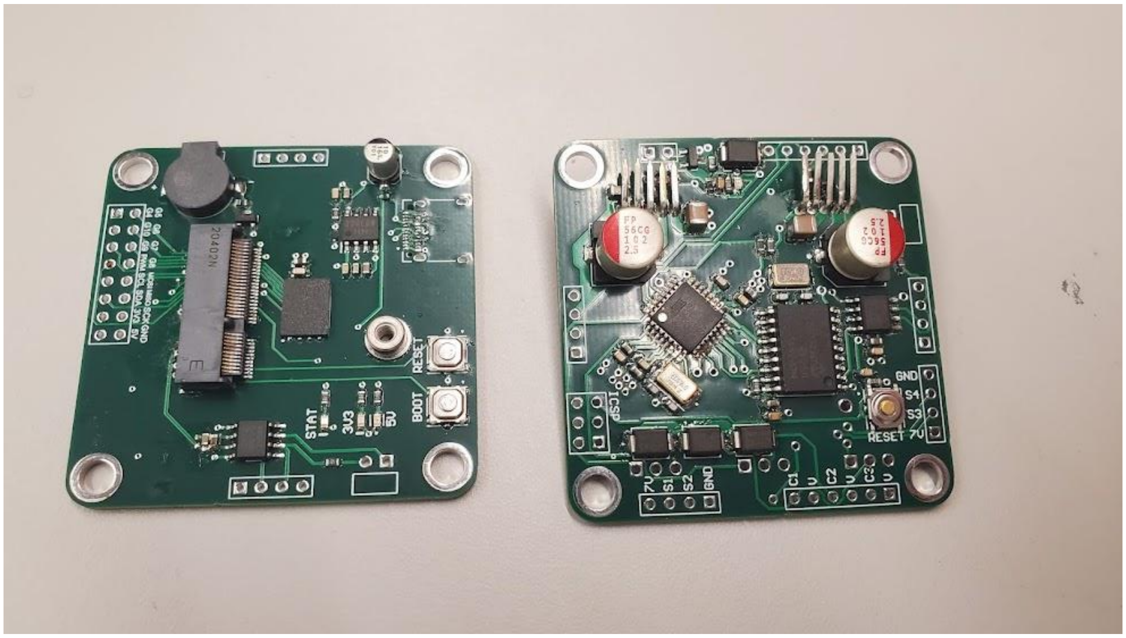


Figure 27. A photo of the assembled controller and power boards.

F. **Ground Station**

The ground station is primarily responsible for being able to quantify, visualize, store, and parse telemetry data live as it comes from Aquila. Along with the primary responsibilities, the ground station team is also responsible for dealing with anything and everything RF whether it be on the rocket or on the ground. The ground station will allow the team to be able to track the rocket as it progresses through its flight and as each vital state is reached. To achieve this, the ground station team has developed a fully custom front end application and backend server to feed data to multiple ground station computers.

8. Data Flow

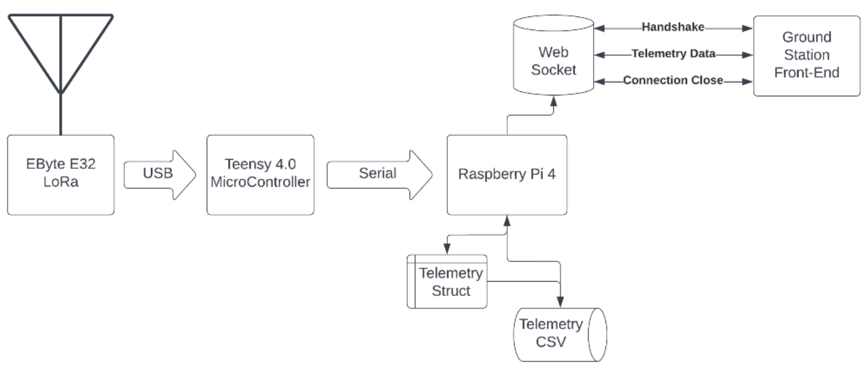


Figure 28. Ground station data process.

Seen above in Figure 28, the flow chart details the process the ground station goes through as soon as it receives data from the rocket. As soon as a packet is received by the EByte E32 LoRa, it is sent via the USB protocol to the Teensy 4.0 Microcontroller which sends a serial stream of data to the Raspberry PI which is running the back-end server. The back-end server then stores the data it parses into a telemetry struct, saves that struct to a CSV file, and pushes the data as a JSON (JavaScript Object Notation) over the WebSocket for the front-end to parse.

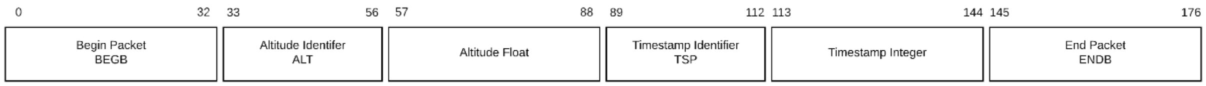


Figure 29. Serial data stream.

Figure 29 shows an example of a serial packet sent by the Teensy 4.0 microcontroller to the backend server of the ground station. At the beginning and end of each packet, a 32-bit ascii sequence of "BEGB" and "ENDB" respectively are sent to guarantee a full packet is sent. In the packet itself, a three-character ascii identifier is sent before each packet of data such as "ALT" for altitude. These specific identifier sequences provide a helpful human interpretation of a serial stream and helps greatly when debugging on a large scale. All floats follow the IEE754 standard, and all integer values are signed following the twos complement standard.

9. *Front-End*

The front-end application has been developed using the power of JavaScript, Node.JS, Electron and React. With JavaScript and the tools/libraries previously mentioned, a fully functional and custom ground station has been developed to meet all the following goals set out for it! JavaScript and the Electron API were used specifically for the ease of development, as well as the multi-platform functionality they provide. The ground station application can be built and deployed for Windows (x64, x86), Mac, and Linux (x86, x64, ARM64).

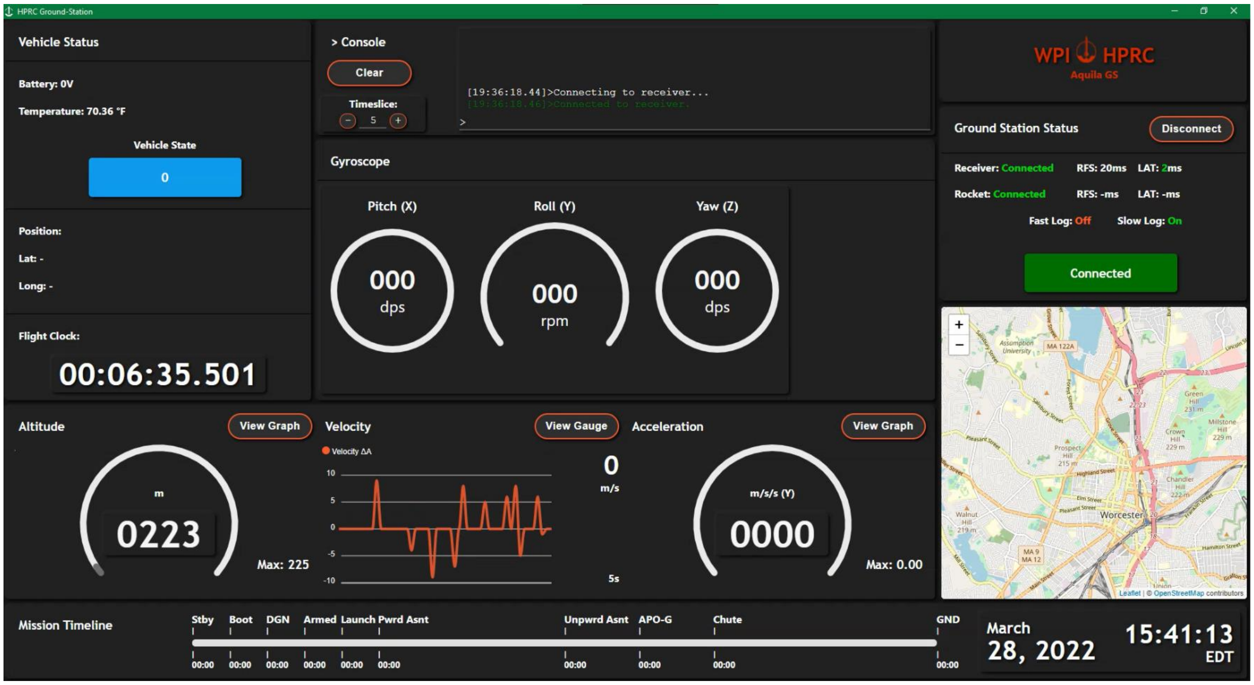


Figure 30. Ground station front-end application.

Seen above in Figure 30, the Ground Station front-end application can scale to multiple display sizes to be as flexible as possible. The application can display the most vital information to us such as battery, temperature, rocket uptime, altitude, calculated velocity, acceleration in the <x, y, z> coordinate frame of reference, and a timeline as the rocket progresses through each stage of flight. All the data on the dials or graphs, can be swapped between graph and dial with the press of a button depending on what the user would like to see. All data can be zeroed with the "zero" command in the console to display data in the reference frame of the rocket instead of earths frame. The ground station also comes bundled with an offline map with detailed Map Data included for New Mexico and Massachusetts.

10. Back-End

The ground station backend was developed with expansion and flexible use in mind in Java. Java was chosen for the backend due to its flexibility with machine architecture and software. Java can be used on most machines and is easily compilable to a single file which can be easily run. The backend takes advantage of object-oriented programming enabling the software to be used in any scenario, with any rocket, with any system, etc. The backend can be easily configured and re-deployed for any task requiring serial data to be parsed and used in a flexible and easy to read format. The backend server will be hosted on a Raspberry PI 4 computer which will host its own network for ground station users to connect to. Once connected, the user will initiate the WebSocket connection on the front end and telemetry data will begin to flow over the WebSocket connection. The backend server uses threaded programming to complete the tasks smoothly and continuously without any hiccups. Through thorough testing and optimization, the transmitter on the rocket can transmit at a rate of 10Hz or every 100ms and the ground station logs a datapoint at an average of every 101ms.

11. Antenna Design

The ground station team was also responsible for designing receiver and transmitter antennas to be used on the rocket and on the rocket. The ground station team eventually chose a Quadrifilar helicoidal antenna for the receiver and a blade dipole antenna for the transmitter.

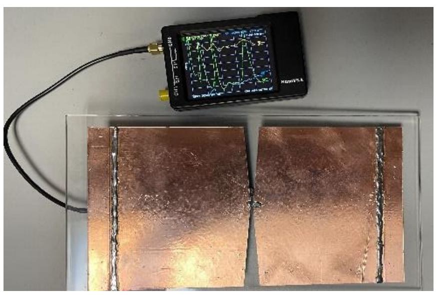


Figure 31. TX antenna.

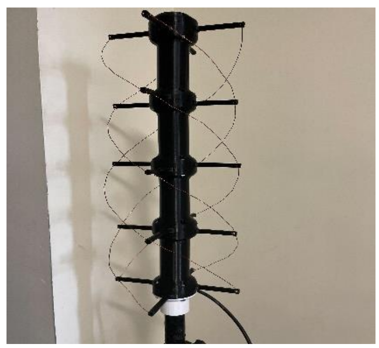


Figure 32. RX antenna.

The ground station team has used MATLAB for all antenna simulation and design. MATLAB has proven to be such a useful tool for dealing with antennas allowing us to analyze the theoretical standing wave ratio (SWR) as well as the theoretical gain. Figure 31 shows a picture of our vector network analyzer (VNA) connected to the transmitter antenna tuned for 915MHz. The Tx antenna was specifically chosen due to its omnidirectional nature at any and every angle to it. At all orientations, except for right at the top, this blade dipole has a gain of approximately -6dBi. Figure 32 is a picture of our prototype receiver antenna. The MATLAB Analysis of this antenna's resonance is shown in Figure 33. It was important that the receiver antenna be resonant and wide-banded across the frequency span of 900MHz-930MHz to be able to move the radios center frequency around the 33cm band to avoid interference.

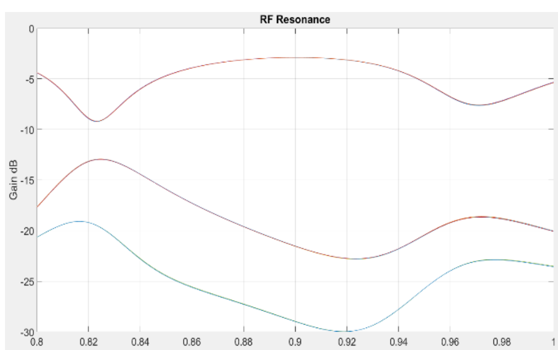


Figure 33. RX antenna analysis.

G. Recovery

The recovery system is responsible for returning the launch vehicle to the ground safely after launch. Aquila utilizes a single ended dual deployment recovery system to reduce the space taken up in the airframe and the number of separation points on the vehicle. The airframes are separated using a COTS CO_2 ejection system.

12. Parachutes and Lines

The only previous experience the team had developing a single ended ejection system was utilizing a Jolly Logic Chute Release. This system proved to be unreliable, and is disallowed at IREC, so a different solution was investigated. The team settled on a system using two redundant Tender Descenders to hold and then release the main parachute from a deployment bag.

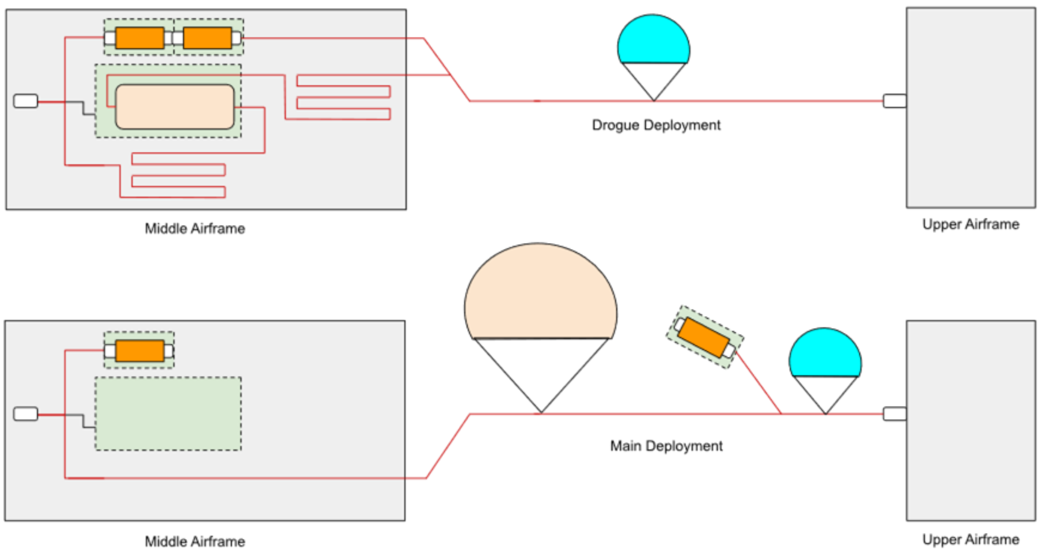


Figure 34. Recovery system deployment stages.

At apogee, the airframe separates and releases the drogue parachute. The load from the drogue parachute is routed through the tender descenders, bypassing the main parachute, which remains inside its deployment bag. The drogue parachute is a 42-inch heavy duty hemispherical parachute manufactured by Spherachutes LLC and stabilizes the descent of the vehicle.

At 1500 feet, the Tender Descenders fire and allow the drogue to pull the main parachute out of its bag, and it inflates. The Tender Descenders are connected in series, such that even if one fails to separate, the main will still be able to release. The main parachute is a 120-inch toroidal parachute manufactured by The Rocketman. The main parachute slows the vehicle to a safe speed for landing and utilizes a reefing ring to reduce the opening shock load. This opening shock was estimated using a 1-DOF numerical simulation based on the opening time calculations provided in T.W. Knacke's *Parachute Recovery Systems Design Manual* [5]. The maximum expected loading was calculated to be approximately 500 lb, well within the capabilities of the shock cord, quick links, and bulkheads.

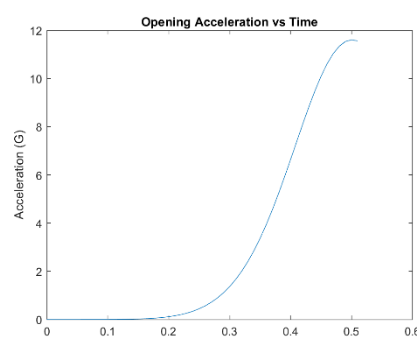


Figure 35. Acceleration during main parachute deployment.

Figure 36 and Figure 37 show the shock cord line diagram, and lengths used. The shock cord is sized such that with the lines taught, each connection point allows the parachute or body section to rotate through 180 degrees without impacting another component. This method results in a total shock cord length of 594 inches, comfortably above the recommended length of 3x the rocket body length.

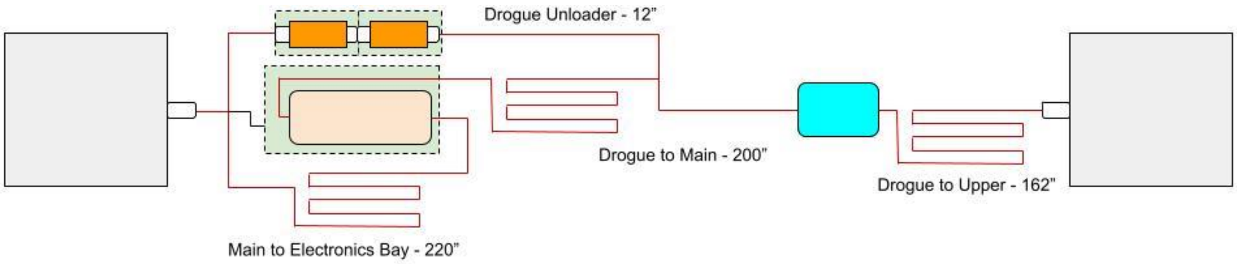


Figure 36. Recovery system line diagram.

Figure 37. Final recovery system lines.

13. Ejection System

The launch vehicle uses two COTS altimeters for altitude recording and controlling recovery events. The primary altimeter is an Altus Metrum EasyMini, and the Backup altimeter is a Featherweight Raven 4. Dissimilar altimeters were chosen so that a design fault in one altimeter would not affect the operation of the other. In addition to being manufactured by different companies, the Raven includes a unique method of apogee detection, using an onboard accelerometer in addition to the more traditional barometer. As such, the redundancy of the system is improved.

Both altimeters are connected to independent power and arming circuits so that a fault in one will not impact the other. Missile Works Screw Switches are used to arm the system, as they are easy to actuate, and the action of tightening the screw protects the switch from opening during flight. Both altimeters are connected to 2S LiPo batteries, which can deliver plenty of current to fire the MJG Firewire Initiators used to ignite the Eagle CO_2 ejection systems and Tender Descenders.

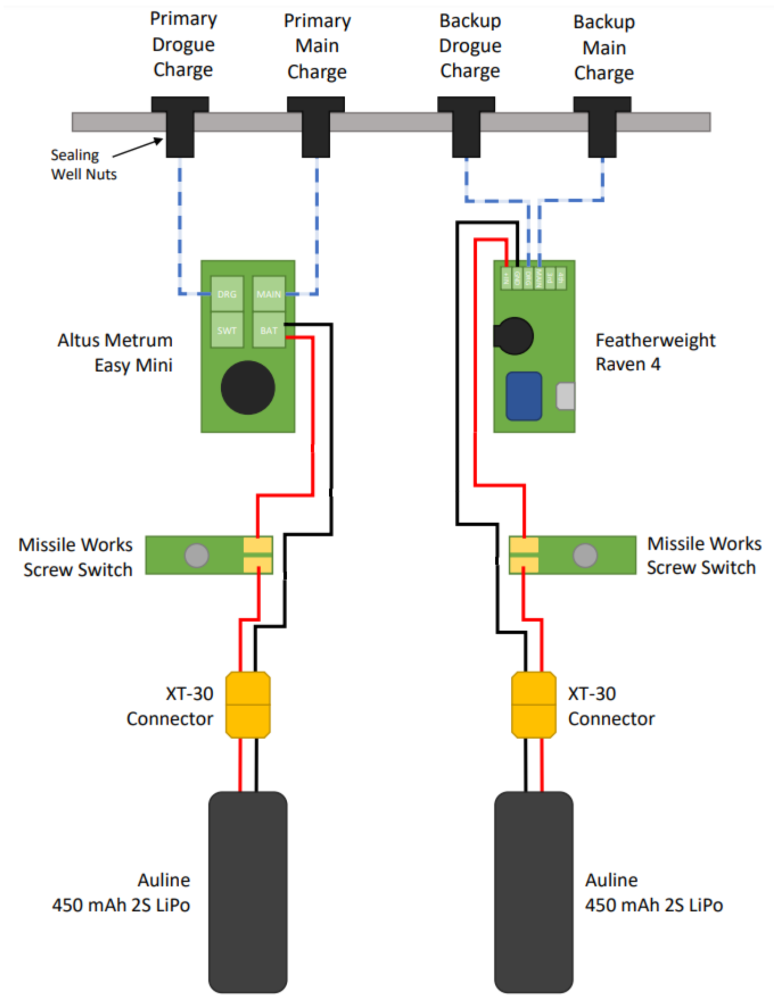


Figure 38. Altimeter wiring diagram.

The Eagle CO_2 ejection system was chosen over just black powder as a separation method for cleanliness and to reduce the exposure of recovery hardware to high temperature gases that degrades them with time. The Eagle CO_2 system can accommodate any CO_2 canister with a ¼ or 3/8-inch thread, so is used on both the payload and rocket ejection systems. Additionally, the system has proved reliable, never failing to fire in any tests. The Rocket uses a 23g cartridge for its primary charge, and a 35g cartridge for its backup, sizes validated through ejection testing.

14. Electronics Bay

In order to house the electronics needed to perform the recovery tasks, an electronics bay was designed. The bay consists of two main parts: the bulkhead and the sled. It also houses a directional antenna for the avionics system to transmit live data back to the ground station. The bulkhead, depicted in Figure 39 attaches to a couplings system and creates a seal to protect the electronics from the ejection gases.

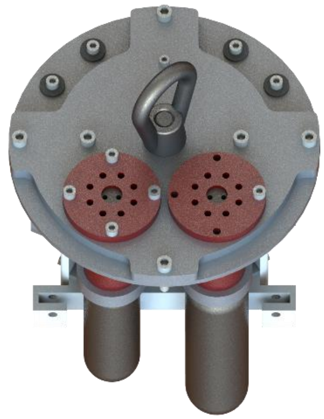


Figure 39. Electronics bay bulkhead.

The plate contains the attachment points for the CO_2 system, eye nut, and sled, as well as sealed through holes for wires. The bulkhead is CNC milled out of 6061-T6 aluminum for strength as all parachute lines attach to the eye nut on the bulkhead. In order to optimize the topology of the plate and reduce weight, SOLIDWORKS Simulation was used to determine where pocketing could occur.

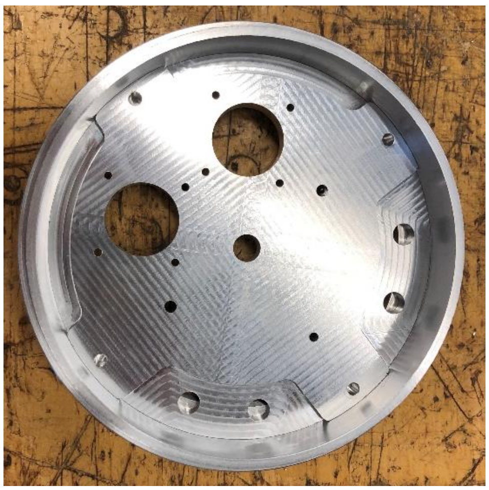


Figure 40. Machined electronics bay bulkhead in coupling.

The sled was designed in a semi-hexagonal shape in order to maximize space and have several flat surfaces to mount the recovery electronics to. The Big Red Bee GPS and antenna are mounted on the front center section of the plate. On each side of it is a recovery electronics system, almost identical aside from a different primary and backup altimeters, the Raven 4 and EasyMini 2.0 respectively. Both electronics systems have a screw arming switch and connect to their two cell LiPo battery via XT30 connectors. Each battery is housed on the back slide of the sled by sliding it in through a slot within the bottom support where an endcap screw can be removed and replaced for easy access.

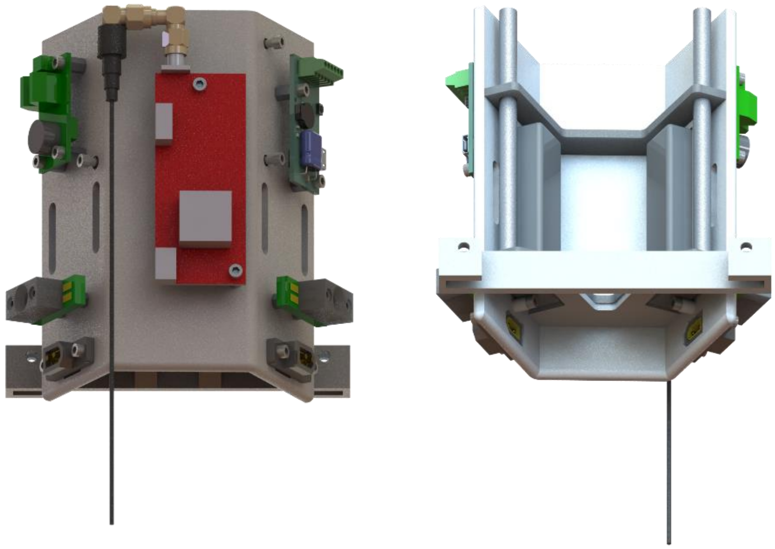


Figure 41. Electronics bay front and back renders.

The sled is 3D printed out of polycarbonate as it is not a structural piece but needs to withstand a range of extreme temperatures. The two supports that slot into the back of the sled are made of CNC routed G10 fiberglass. The sled and supports are epoxied together, and heat set inserts are added to secure all the electronic components. To connect the sled to the bulkhead, two four-inch standoffs go through the top and bottom support and bolts on either side secure them at each end.

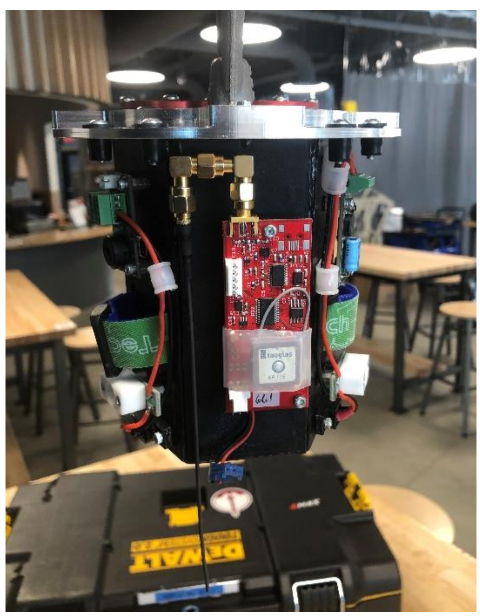


Figure 42. Assembled electronics bay.

H. Payload

The 11-pound Tarazed payload is a functional and deployed folding-arm quadcopter designed to complete the mission of autonomously locating the launch vehicle after landing. The quadcopter is stowed in a retention system in the upper airframe of the launch vehicle during ascent, attached to the nosecone for deployment.

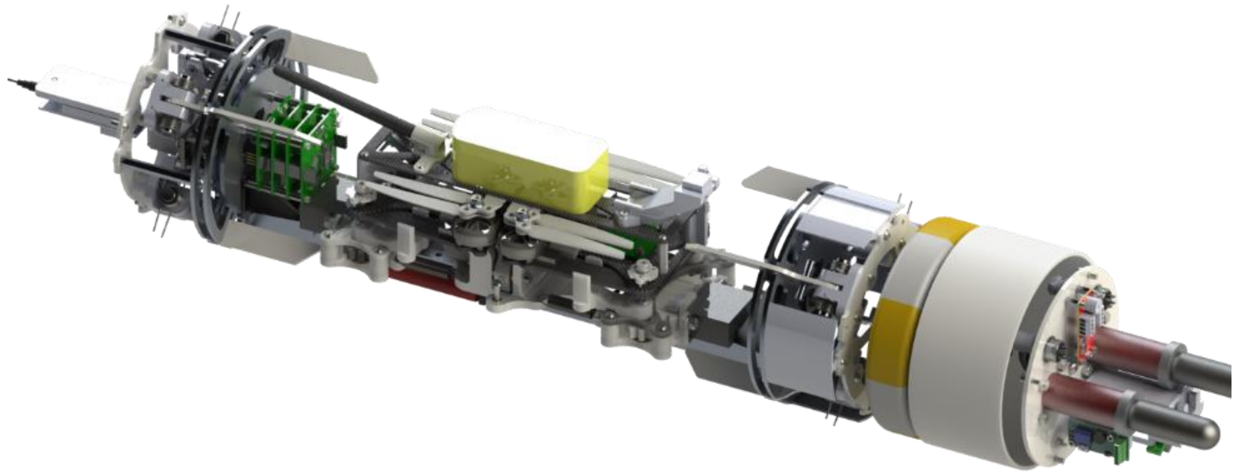


Figure 43. Payload in the stowed configuration.

15. Payload Retention and Deployment

The structure of the payload retention system consists of a spine of 6061-T6 aluminum T bar extrusion with #8 clearance holes drilled every inch for retention system mounting. Aluminum bulkheads are attached to both ends of the spine using pairs of aluminum brackets. To verify that this system could withstand landing forces we utilized SolidWorks Simulation to ensure a factor of safety of at least 2. To increase overall rigidity, two 3D printed polycarbonate brackets were also added to either end of the spine to limit bending even further. This skeleton was chosen for the payload to have a significant amount of open room and adaptability to place our different sub-systems. This design allowed us to design and construct each module separately and then mount them independently to the spine.

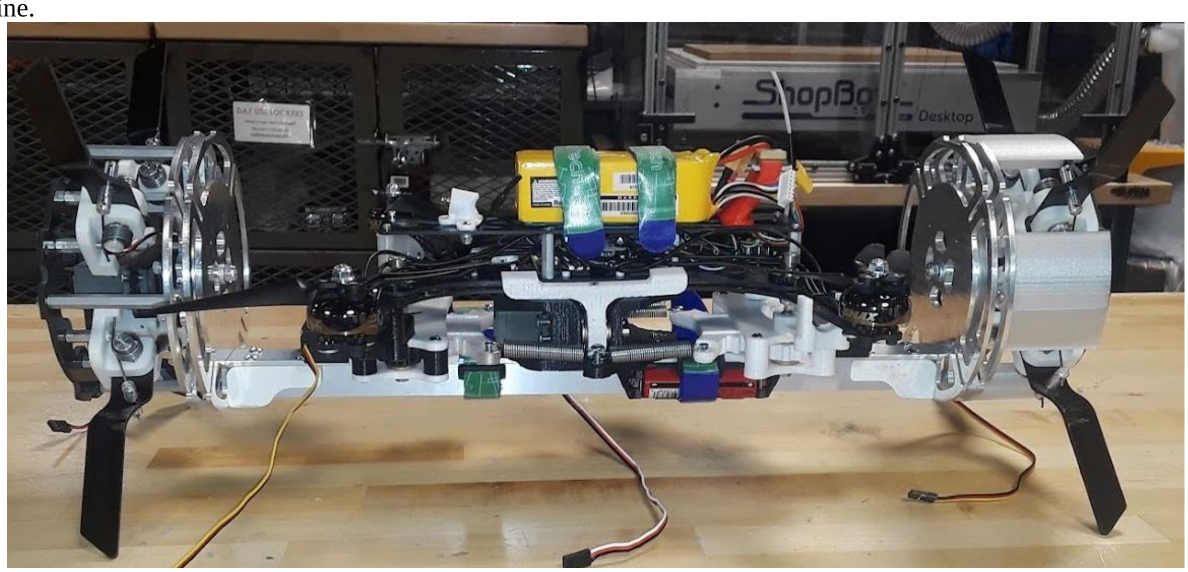


Figure 44. Payload in deployed configuration.

The payload ejects from the rocket at 1,400 ft, after the main parachute has deployed. The payload ejection system consists of a recovery bay similar to the main rocket recovery bay, where the altimeters (a PerfectFlite StratoLogger CF and a Featherweight Raven 4), the Eagle CO_2 system, and an eye nut are mounted to a $1/8^{th}$ in fiberglass bulkhead plate. A 35g CO_2 cartridge is used as the primary deployment charge and a 45g CO_2 cartridge is used as a backup to ensure successful deployment. Above the payload recovery bay is a piston consisting of a cut fiberglass coupler tube epoxied to a fiberglass bulkhead plate. The piston helps form a seal, providing a more constant ejection force on the payload while also protecting the payload electronics from ejection gases. To prevent the piston from separating from the rocket, shock cord is mounted from an eye bolt on the piston to the eye bolt on the payload recovery bay.

A 9 ft Rocketman Ultra-Light Parabolic Parachute is used to slow the payload down to its descent rate of 15ft/s. It is packed between the piston and the payload retention system. The shock cord runs through a slot across the top of the payload retention system to just under the nosecone, where it is attached to a parachute release mechanism. To reduce the risk of the payload dragging or an improper deployment, a quick link attached to the parachute's shock cord is attached to a removable pin. This system consists of a milled 6061-T6 aluminum U bracket and turned pin along with 3D printed polycarbonate servo mount and servo horn adapter. This ¼ inch diameter pin will be manipulated by an HS-5087MH servo. To translate rational motion to linear motion a slider-crank mechanism was created using a combination of 3D printed polycarbonate and machined aluminum links. Upon detection of landing, the payload will actuate the servo and detach the parachute. There are currently implementation issues with this mechanism and other designs such as COTS rotary latches are being researched.

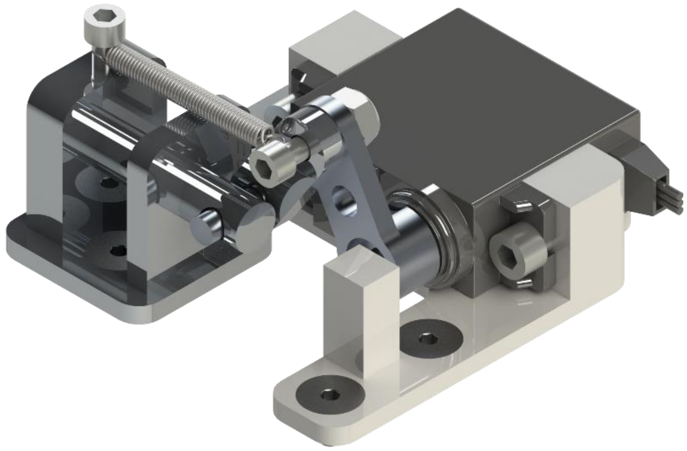


Figure 45. Payload parachute release mechanism.

A payload stabilization system is implemented with two main objectives: lock the payload retention bay during ascent and provide a stable base for the quadcopter. Once ejected from the rocket, four legs on either end of the payload retention bay spring from a locking position into one perpendicular to the rest of the payload. These eight legs are made from 1/8th in CNC routed G10 fiberglass measuring 5 inches in length. The legs are mounted to 3D printed polycarbonate bases with 6061-T6 aluminum shafts and dowel pins to accommodate the torsion springs used to actuate the mechanism. One base is modified to house a rocker switch to power on the payload electronics once deployed from the airframe.

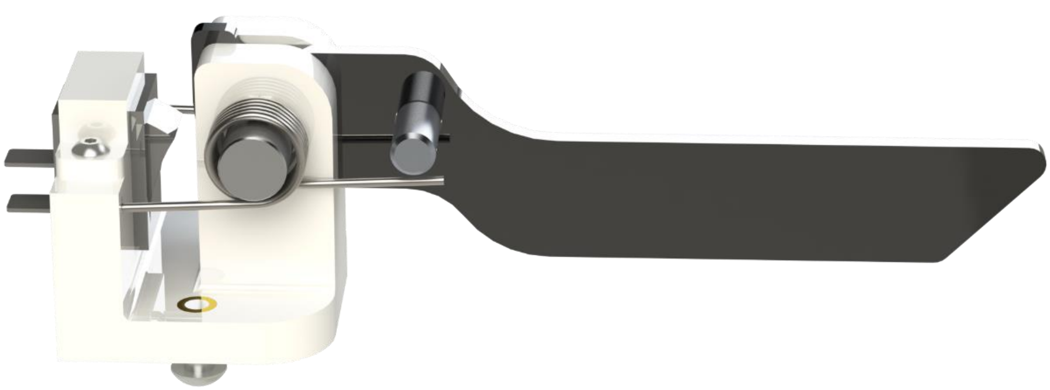


Figure 46. Payload stabilization leg assembly.

Once landed safely on the ground, the stabilization system is capable of rotating the quadcopter to a level position for takeoff. The self-righting mechanism of the stabilization system consists of two sets of CNC milled 6061-T6 aluminum bulkheads on either side of the payload retention system, connected with a custom D-shaft. Thrust bearings between the plates are used to reduce friction and provide consistent rotational motion for the mechanism. One side is powered by a goBILDA Super Speed servo coupled to the D-shaft, driving the rotational motion with feedback from a microcontroller.

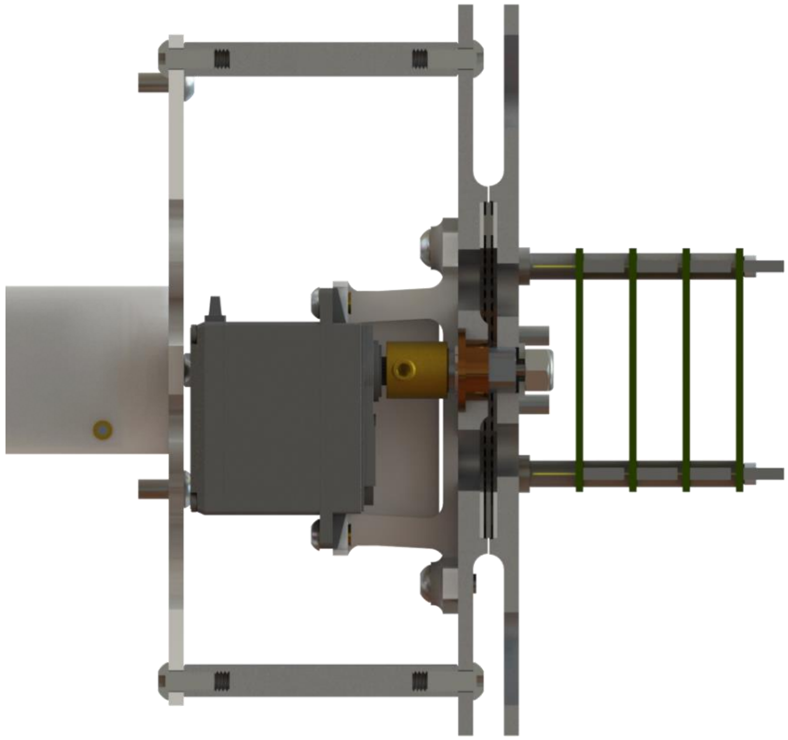


Figure 47. Payload stabilization rotation assembly.

An arm deployment mechanism holds the quadcopter's arms in place during ascent and descent and unfolds them once visual confirmation of a safe landing is made. The mechanism works with two identical modules, each unfolding two arms of the quadcopter. Each module consists of two steel 8mm REX (rounded hex) shafts, a HS-311 servo, and four linear extension springs. This is in addition to 3D printed polycarbonate parts including a two-sided rack and pinion, two lever arms, and an upper and lower retaining plate. During ascent, the servo is in the locked position with an aluminum servo horn retaining the rack. When the microcontroller signals, the servo rotates, releasing the rack and allowing the springs to pull it towards the center of the payload. This causes the pinion gears to turn the shafts and lever arms, pulling out the quadcopter arms until the rack hits hard stop on the upper plate and the arms are locked in place by pins on the quadcopter. All bolts are screwed into the plastic using brass heat-set threaded inserts.

Figure 48. - Top view of payload arm deployment mechanism with gears and rack shown in yellow.

The final component of the quadcopter arm deployment is the quadcopter gripper. This system's purpose is to hold the body of the quadcopter steady throughout ascent. The system utilizes a goBILDA Torque servo, and an assortment of polycarbonate 3D printed parts, including an idler gear, drive gear, and two geared gripper arms. The ratio between the idler gear and the drive gear is a ratio of 18:23. All but the driven gear are mounted with shoulder screws, sleeve bearings, and washers for precision rotation and limited friction. The driven gear is connected directly to servo via a screw and heat set bronze gear servo horn. The quadcopter is further held in place by the bolt heads protruding from the bottom of the quadcopter into the gripper base. These two features make it such that the quadcopter is retained in all axes of motion. Once the arms of the quadcopter unfold and the quadcopter boots up, the gripper releases the quadcopter to complete the mission.

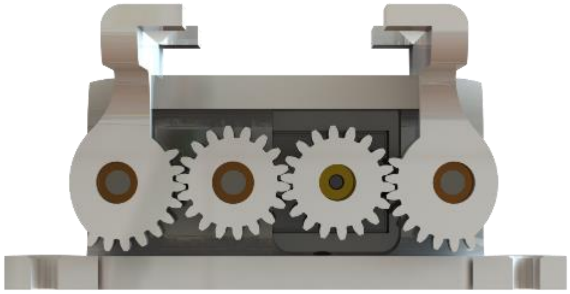


Figure 49. Section view of quadcopter gripper.

16. *Quadcopter*

The quadcopter consists of a frame made from two main sections of carbon fiber plates. The firsts section is the bottom plate sandwich, with two identical 2mm carbon fiber main plates on the outside and the 3mm carbon fiber quadcopter arms laser cut wood spacer mid plate on the inside. The other section is the 2mm carbon fiber top plate and is attached to the bottom plate sandwich with seven 4-40 threaded aluminum standoffs. The quadcopter's main flight electronics are housed in the space between these two sections, with the battery being attached to the top plate using VELCRO pads and straps.

Figure 50. Quadcopter in the Unfolded Configuration.

The size of the quadcopter was determined using eCalc, an online unmanned aerial vehicle (UAV) flight simulation tool. This tool allowed us to simulate flight time with different quadcopter sizes and specifications, helping us choose our vehicle size and powertrain. Using this tool, the best option allowing the quadcopter to fold up inside of the rocket used 6.7 in folding propellers and a 6s 1800 mAh LiPo battery.

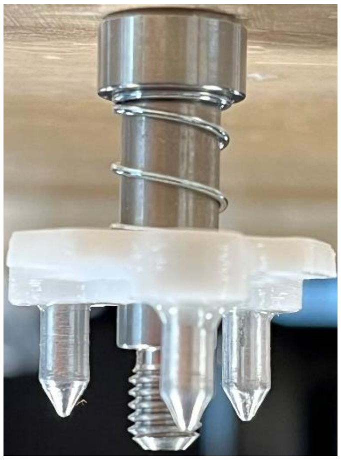


Figure 51. Quadcopter arm locking mechanism.

The quadcopter arms fold inward to fit inside the launch vehicle's airframe. A shoulder bolt was used as a vertical pivot at the base of the arm, allowing for smooth and reliable arm deployment. To lock the arms in place once deployed, three machined aluminum pins are pushed by a spring into matching holes in the quadcopter arms and main body plates. The pins are epoxied into a 3D printed polycarbonate pin carrier that retains the pins and distributes the force of the spring onto the pins, creating the desired locking motion.

Other prominent features of the quadcopter include electronics mounts, with 30.5 mm and 20 mm square hole patterns to mount common COTS UAV electronics found with such hole pattern. A 3D printed camera mount is on the front of the quad and slides over the standoffs, allowing for a RunCam Hybrid 2 to be angled for various viewing angles. 3D printed antenna mounts are affixed on the front and back of the quadcopter for the GPS, LoRa receiver antenna, and FrSky receiver antennas. The LoRa receiver antenna is a directional antenna that receives the rockets telemetry transmission. Because it is directional, it is used for finding the relative direction to the rocket and provides a basis for our navigation algorithm.

IV. Mission Concept of Operations Overview

The vehicles flight is split into 8 phases described here.

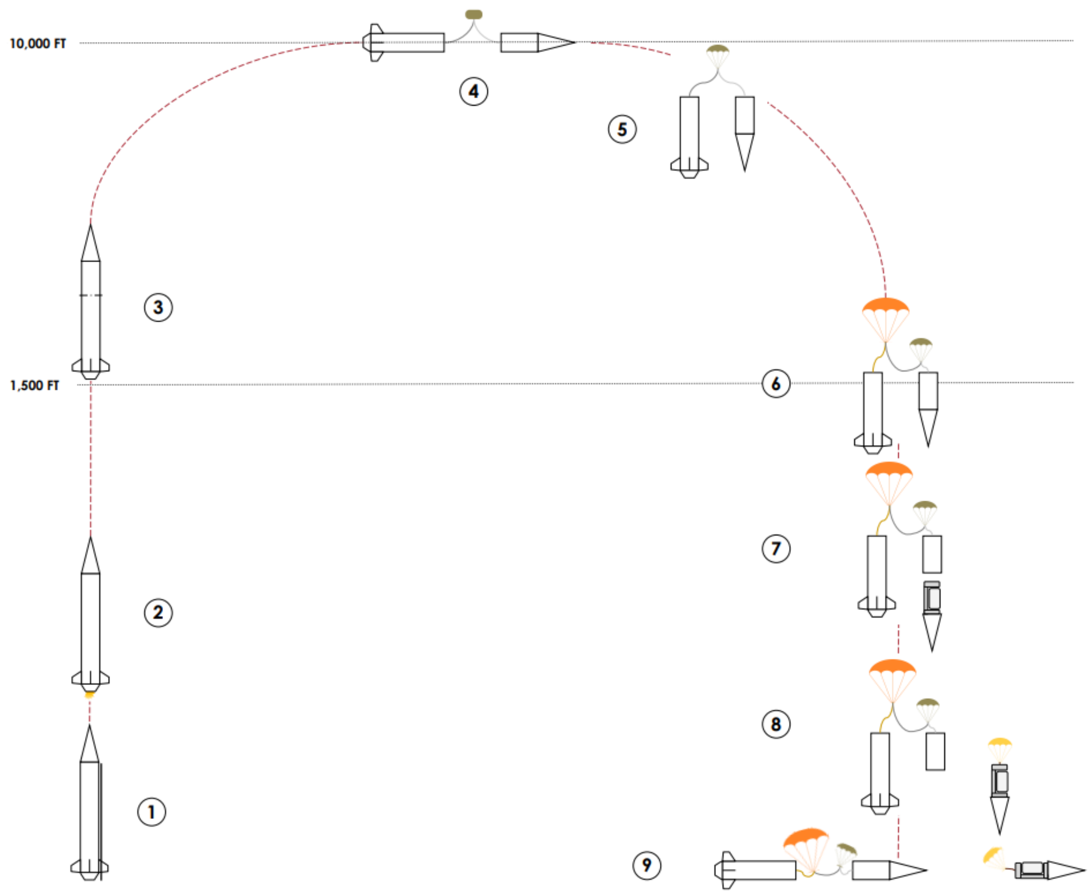


Figure 52. Flight profile diagram.

Phase 1: In phase 1 the vehicle is on the launch rail before motor ignition. In this phase the avionics system has been activated, the rocket and payload altimeters have been armed, and the ignitor has been installed into the motor and connected. The vehicle is ready for launch.

Phase 2: In phase 2 the motor has been ignited and the vehicle is flying under thrust. This phase will last approximately 5.5 seconds, until the motor burns out. During this time, the altimeters and avionics system will detect launch and begin recording data. The airbrakes will not be activated during this phase.

Phase 3: In phase 3 the motor has burnt out and the vehicle is coasting to apogee. During this phase, the altimeters will continue to record flight data. The avionics system will be analyzing sensor data to estimate the state of the vehicle and use this data to control the airbrakes.

Phase 4: In phase 4 the vehicle has reached apogee and the altimeters have detected apogee. The primary rocket altimeter will fire to separate the vehicle and release the drogue, with the backup altimeter firing 1 second after apogee is detected. The airbrakes will fully retract at this stage to avoid tangling the lines.

Phase 5: In phase 5 the vehicle is descending under drogue parachute. The altimeters are continuing to record data to prepare for main parachute deployment.

Phase 6: At 1500 ft the vehicle reaches phase 6, where the main parachute is deployed. The primary and backup altimeters fire both Tender Descenders with no delay to allow the drogue to pull the main parachute from its deployment bag.

Phase 7: At phase 7 and 1400 feet, the payload altimeters fire to release the payload. The payload and nosecone drop away completely from the rocket.

Phase 8: In phase 8, the rocket and payload are descending separately under their own parachutes.

Phase 9: In phase 9, both the rocket and payload have landed. All altimeters cease data recording and begin reporting apogee using beep codes. When the recovery teams arrive, they will activate the payload system, which will carry out its autonomous mission. Once complete, the team will recover the rocket.

V. Conclusions and Lessons Learned

For knowledge transfer from more experienced members to new team members, the team takes various approaches to continue the education of its members. The first resource team members can use is the team's prior technical documents and technical resources found in the team's shared file system. This file system contains years of competition documents, technical reports, and information that can be used. The team has also created a team wiki where team members have written short posts about the work they have done and the lessons they learned in the process. In the summer, the team regularly runs a serious of team workshops based upon team interests. Last summer, the team ran workshops on CAD, CNC, and FEA software. The workshops are multi-day sessions which provide the basic information required to use a desired skill. The team also runs more basic workshops during the beginning of the school year intended to help bring new students up to speed on the team's resources. As an organizational structure, subteam leads, who are usually second year students and older, act as experienced members to teach newer members.

Many of the lessons the team learned this year were a result of a large growth in team size. At our first interest meeting of the year, we had over 250 students attend. Over the consecutive meetings we slowly lost more team members as most clubs at our school do but we still had too many team members for the work at hand. Subteam leads often had to lead teams of 20 students which is too large for adequate education and available tasks. While we must remain inclusive as a club on campus to receive institutional funding, we are looking for ways to better manage large engineering groups and still provide a quality education to any student who wants to participate. We are hoping to include some early design projects such as Level 1 rockets and small machining operations to new students so they can work on skills which can be applied to the rocket and payload at a later date. We have also been struggling to find a good classification for our electronics groups in the team structure. The issue is that electronic systems are a key part of mechanical components and yet they also have standalone components such as the PCB boards and ground station equipment. We are currently investigating better ways to manage our electronics groups in conjunction with our mechanical design.

Appendix

A. System Weights, Measurements, and Performance Data

Rocket Information:

Number of Stages	1
Vehicle Length [inches]	134
Airframe Diameter [inches]	6.17
Number of Fins	4
Fin Semi-span [inches]	6.5
Vehicle Weight [lbs]	38.7
Empty Motor Case/Structure Weight [lbs]	7.8
Propellant Weight [lbs]	10.59
Payload Weight [lbs]	11
Liftoff Weight [lbs]	68.09
Center of Pressure [inches]	102
Center of Gravity [inches]	84.3

Propulsion Information:

Propulsion Type	Solid
COTS, SRAD, or Combination	COTS
Propulsion Manufacturer	Cesaroni
COTS Motor – Manufacturer's Designation	Cesaroni 9870M1800-P
Motor Letter Classification	M
Average Thrust [N]	1797.1
Initial Thrust [N]	1951.1
Maximum Thrust [N]	2240.6
Propellant Weight [g]	4802
Total Impulse of all Motors [Ns]	9869.7
Motor Burn Time [s]	5.5

Predicted Flight Data:

Launch Rail	ESRA Provided Rail
Rail Length [ft]	17
Liftoff Thrust-Weight Ratio [X:1]	6.53
Launch Rail Departure Velocity [ft/s]	71
Minimum Static Margin During Boost [cal]	2.82
Maximum Acceleration [G]	6.27
Maximum Velocity [ft/s]	886
Target Apogee [ft AGL]	10,000
Predicted Apogee [ft AGL]	10,353

Payload Information:

Deployed or Attached	Deployed
Deployment Altitude [ft]	1400
Main Decent Rate [ft/s]	15
GPS	Big Red Bee 70cm 100mw GPS/APRS Transmitter
Altimeter	Featherweight Raven 4 Primary PerfectFlite StratoLogger CF Backup
Recovery System	35g CO_2 Cartridge Primary 45g CO_2 Backup

Recovery Information:

COTS Altimeter	Altus Metrum EasyMini
Redundant Altimeter	Featherweight Raven 4
Drogue Primary & Backup Deployment Charges [g]	23g CO_2 Cartridge Primary 35g CO_2 Cartridge Backup
Main Primary & Backup Deployment Charges [g]	0.3g black powder primary 0.5g black powder backup
Drogue Deployment Altitude [ft]	10,000
Drogue Decent Rate [ft/s]	92
Main Deployment Altitude [ft]	1,500
Main Decent Rate [ft/s]	12.5

B. Project Test Reports

Full-Scale Ground Test

Conducted by: Cameron Best, Thierry de Crespigny, Henry Lambert, Troy Otter, Terence Tan, Aunika Yasui

Date: 4/30/2022

Objective: To test the amount of CO_2 needed to separate the middle and upper airframes for the first recovery event.

Test Variable: Success or failure of rocket separation.

Methodology: The Eagle CO_2 is manually triggered causing the rocket to separate between the middle and upper airframes.

Success Criteria: The rocket separates between the middle and upper airframes and drogue is pulled out with no damage.

Procedure:

1. Load CO_2 system with black powder
2. Assemble the recovery bay into the avionics bay airframe
3. Connect a LiPo battery to the black powder e-match and detonate from a far distance
4. If the rocket does not separate, increase the amount of CO_2 and repeat

Data:
23g cartridge: Successful

Success Criteria Met: Yes

Impact: The minimum size CO_2 cartridge needed to separate the rocket was chosen

Full-Scale Flight Test

Conducted by: Henry Lambert, Aunika Yasui, Kevin Shultz, Cameron Best, Terence Tan, Kelli Huang, Haggay Vardi, Peter Dentch, Daniel Pearson, Abby Hyde, Brad Miller, Max Schrader, Cameron McAfee, Max Friedman, Evan Mandel

Date: 4/2/2022

Objective: To test the single end dual deployment parachute system.

Test Variable: Success or failure of drogue and main parachute deployment.

Methodology: The new parachute ejection system is put onto last year's rocket and triggered at apogee and 1,000 ft with a StratoLogger and Raven 4 altimeter.

Success Criteria: Both the drogue and main parachute are deployed at the correct altitudes.

Procedure

1. Load 5g primary black powder charge and 6g backup black powder charge
2. Load 0.3g of black powder in primary tender descender and 0.8g of black powder into backup tender descender
3. Assemble the recovery bay into the airframe
4. Load the parachutes and their lines
5. Assemble the rocket and mount onto the launch rod
6. Arm the avionics and recovery systems
7. Launch the rocket and observe for parachute deployment
8. Retrieve the rocket

Data:
Drogue deployment at 5715 ft and main deployment at 1000 ft.

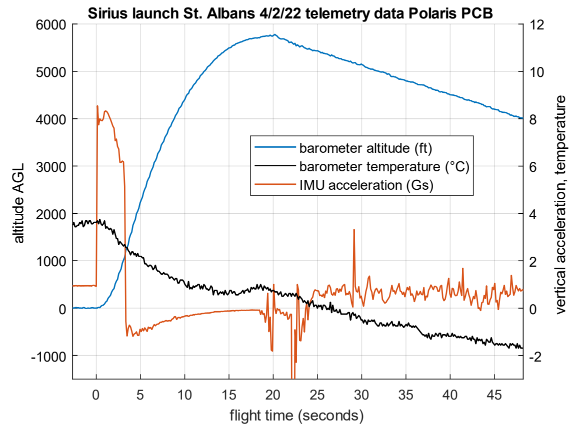


Figure 53. - Flight Test Results

Success Criteria Met: Yes

Impact: The new single end dual deployment system worked, allowing us to move forward with the design.

Payload Ejection Test

Conducted by: Cameron Best, Thierry de Crespigny, Henry Lambert, Troy Otter, Terence Tan

Date: 4/30/2022

Objective: To test the amount of CO_2 necessary to eject the payload from the upper airframe.

Test Variable: Success or failure of payload ejection

Methodology: Eagle CO_2 system is manually triggered, causing the payload to eject without damaging any components.

Success Criteria: The payload ejects without damage to any of the components.

Procedure:

1. Load CO_2 system with black powder
2. Assemble upper airframe and payload horizontally
3. Manually detonate CO_2 system using a LiPo battery. Ensure nobody is too close to the rocket to ensure safety.
4. If payload does not eject, increase the amount of CO_2 and try again

Data:
16g cartridge: Unsuccessful
23g cartridge: Unsuccessful
35g cartridge: Successful

Success Criteria Met: Yes

Impact:
The necessary mass of the CO_2 system was chosen, allowing us to move forward with more accurate mass estimates.

C. Hazard Analysis

Hazard Probability Definitions	
Rating	**Description**
A	The condition is probable if it is not mitigated.
B	The condition may occur if it is not mitigated.
C	The condition is unlikely to happen if it is not mitigated.
D	The condition is highly unlikely to happen if it is not mitigated.

Hazard Severity Definitions	
Rating	**Description**
I	The condition may cause death or permanent disability to personnel or loss of the system.
II	The condition may cause major injuries or significant damage to the system.
III	The condition may cause injury or minor damage to the system.
IV	The condition may cause minor injury or negligible damage to the system.

Hazard Analysis	Severity			
Probability	**I - Irrecoverable**	**II - Significant**	**III - Minor**	**IV – Negligible**
A – Probable	AI	AII	AIII	AIV
B – May Occur	BI	BII	BIII	BIV
C - Unlikely	CI	CII	CIII	CIV
D – Highly Unlikely	DI	DII	DIII	DIV

Personnel Hazard Analysis

Section	Hazard	Cause	Effect	Probability/Severity	Mitigation & Controls	Verification
Construction	Hand Tool Injury	Improper training or human error during the use of tools	Injuries include, but are not limited to cuts, scrapes, even amputation or crushing.	CIII	HPRC members will receive proper training and will have access to instructions on how to operate each tool. Members will also wear proper PPE specific to each tool. If an injury does occur, a member will be given proper medical attention.	Safety officer, leads and/or the lab safety monitor is present during the use of potentially dangerous tools to ensure proper usage and PPE.
	Fire	Human error, short circuit amongst any other event that could cause a fire to start.	Burns, inhalation of toxic fumes, and in extreme cases, death.	DII	Fire control tools such as water and fire extinguishers will be present at the construction site. Additionally, members will wear protective equipment and will separate flammable	Safety officer and/or leads will be present to ensure proper handling of flammable objects and will verify the existence and availability of a fire extinguishing tool nearby.

					objects from potential fire hazards.	
	Electric Shock	Member coming in contact with an exposed wire.	Burns, and in extreme cases, death from electrocution.	DII	Members will inspect all wires before working with them and not deal with live wires often, if at all.	HPRC members will perform an analysis of wires.
Chemical	Exposure to epoxy	Improper PPE worn during construction.	Eye and skin irritation; prolonged and reputative skin contact can cause chemical burns.	BIV	During work with epoxy, members will wear proper PPE including safety goggles, gloves, and clothes that protect the skin from encountering the material.	MSDS sheet for epoxy will be consulted and members will be wearing proper PPE.
	Exposure to carbon fiber/ fiberglass dust and debris	Sanding, using a Dremel tool, machining carbon fiber/ fiberglass.	Eye, skin and respiratory tract irritation.	CII	During work with carbon fiber/ fiberglass members will wear proper PPE including safety goggles, gloves, long pants and long sleeve shirt, as well as a mask to protect their lungs.	MSDS sheet for each material will be consulted to make sure members are wearing proper PPE.

	Exposure to black powder	Loading charges for stage separations or any other contact with black powder.	Serious eye irritation, an allergic skin reaction; can cause damage to organs through prolonged and repetitive exposure.	CIII	Only people who are trained in working with black powder will be allowed to handle it. They will wear proper PPE. Clothing that has black powder on it will be washed in special conditions.	Safety officer will ensure that unauthorized members do not work with black powder. MSDS sheet for black powder will be consulted to make sure members are wearing proper PPE
	Exposure to LiPo	LiPo battery leakage.	Chemical burns if contacts skin or eyes.	DIII	The battery will not be dismantled and will be checked for leaking before use.	WPI HPRC members will provide analysis of the battery.
	Exposure to APCP	Motor damage.	Eye irritation, skin irritation.	DIII	Only a few select HPRC members handle the motor and will wear proper PPE while doing so.	MSDS sheet for APCP will be consulted to make sure members are wearing proper PPE.
Launch	Injuries due to recovery system failure	Parachute or altimeter failure	The rocket/ parts of the rocket go in freefall and injure personnel and spectators in the area	DI	HPRC members will pack the parachutes correctly, ensure the altimeter will be calibrated	HPRC Recovery subteam lead, along with others will oversee this process.

			causing bruising and possible death		correctly, and that the amount of black powder in separation chares are weighed on an electronic scale for accuracy.	
	Injuries due to the motor ejection from launch vehicle	Motor installed and secured improperly.	Motor and other parts of the rocket go in freefall and injure personnel and spectators in the area causing burns and possible death.	DI	The motor will be installed by a certified mentor	Safety officer will ensure that the motor is installed by a certified mentor. Prior to the launch, the rocket will be inspected following a checklist.
	Injuries from premature ignition of separation charges	Improper installation of igniters, stray voltage.	Severe burns.	DI	The battery will be switched off during installation of the igniters, black powder in separation charges will be weighted on an electronic scale.	Safety officer will ensure that all safety procedures are followed during the installation of the charges.
	Injuries due to a premature motor ignition	Improper storage of the motor, damage of the motor or	Severe burns.	DI	Motor and igniters will be bought from official	Safety officer will ensure that installation of the motor

		early ignition.			suppliers, properly installed by a certified mentor and ignited by the RSO.	and ignition are done by certified personnel.
	Injuries due to unpredictable flight path	Wind, faulty parachute, or instability in thrust.	If the rocket goes in unexpected areas, it could injure personnel or spectators.	DI	The rocket will not be launched during strong winds, the rocket design will be tested through simulations to make sure that it is stable during flight.	Weather conditions will be assessed, the rocket will be launched only if the RSO considers the weather safe. Multiple simulations will be run to ensure that the rocket is stable.

D. Risk Assessment

Risk Probability Definitions	
Rating	**Description**
A	The failure is probable if it is not mitigated.
B	The failure may occur if it is not mitigated.
C	The failure is unlikely to happen if it is not mitigated.
D	The failure is highly unlikely to happen if it is not mitigated.

E.

Risk Severity Definitions	
Rating	**Description**
I	Complete loss of the item or system.
II	Significant damage to the item or system. Item requires major repairs or replacement before it can be used again.

III	Damage to the item or system which requires minor repairs or replacement before it can be used again.
IV	Damage is negligible.

F.

Risk Analysis	Severity			
Probability	I - Irrecoverable	II - Significant	III - Minor	IV – Negligible
A – Probable	AI	AII	AIII	AIV
B – May Occur	BI	BII	BIII	BIV
C - Unlikely	CI	CII	CIII	CIV
D – Highly Unlikely	DI	DII	DIII	DIV

G.

Risk Analysis: Launch Vehicle					
Hazard	Cause	Effect	Probability/ Severity	Mitigation & Controls	Verification
Vehicle does not separate at apogee	Insufficient ejection charge, altimeter failure	The rocket would descend at a dangerous terminal velocity. If the main parachute deploys at this speed, the airframe will most likely be severely damaged and the payload cannot safely deploy.	CI	Calculate appropriate ejection charge sizing, and ensure the correct quantity of CO2 is used	Testing of the recovery system. Ground Ejection Test.
Drogue parachute does not inflate	The parachute may not be packed properly, or it might be too tight of a fit in the airframe.	The rocket would descend more rapidly than anticipated velocity. If the main parachute deploys at this speed, the airframe and vehicle will most likely sustain minor damage	CII	The drogue parachute will be properly sized and have a redundant system to deploy it.	Testing of the recovery system using last year's rocket.
Parachute detaches from launch vehicle	Improper installation of the recovery system	This would result in the probable destruction of the rocket and its components upon ground	DII	Proper installation of the recovery system and select correct sizes of hardware to	Testing of recovery system including a ground ejection test and a full-scale test using

		impact as well as failure to complete the payload mission criteria. It could also injure personnel on the ground due to debris upon impact or impact near a person.		handle ejection forces.	last year's rocket.
Main parachute does not deploy	The parachute may not be packed properly, or it might be too tight of a fit in the airframe.	If the drogue parachute deploys, the rocket would still fall at a high speed, leading to damage. The significance of the damage being less than if the drogue did not open. Payload could still deploy.	CII	The main parachute will be properly sized and also have multiple systems to deploy it.	Testing of the recovery system including a full-scale test using last year's rocket.
Melted or damaged parachute	The parachute bay is not properly sealed, or the parachutes are not packed correctly.	This could prevent the parachutes from slowing the rocket's descent rate, resulting in the possible loss of the rocket and payload.	DII	Proper protection and packing of the parachutes.	Testing of recovery system including a full-scale launch using last year's rocket.
Shock cord tangles	Parachutes are not packed properly	Could decrease the parachutes' effectiveness, resulting in the loss of the rocket and payload upon ground impact.	CII	Properly pack the parachutes	Testing of recovery system including an ejection test, and a full-scale launch using last year's rocket.
Electronics bay is not secured properly	Electronic bay does not fit tightly into the airframe	Potential electronics and recovery failure	DII	Manufacture the electronics bay to fit accurately within the airframe. Design	Physical testing of the couplings to ensure tight fit of the airframes with minimal

				couplings to allow a simple, reliable installation of the electronics bay.	movement of any attachable part.
Motor ejected from launch vehicle	The motor is secured improperly.	The motor could possibly go into freefall during flight. If it is still ignited, it may harm personnel in the vicinity or destroy the launch vehicle. It could also create free falling debris that could cause harm.	DI	The motor will be installed by a certified mentor. The motor retention system will also be inspected prior to launching the rocket. Conduct a thorough Finite Element Analysis of the motor retention system. Combine commercial retainers with the manufactured parts to increase the safety factor.	No physical testing prior to launch. A thorough analysis and integration of commercial parts raises our factor of safety and ensures a reliable performance.
Fins break off during ascent	Large aerodynamic forces or poor fin design	Rocket cannot be relaunched, damage to airframe or internal components	DII	Mount fins properly onto the airframe	Material testing of the fins.
Rail buttons fail during launch	Unexpected forces, damage to attachment components	Rocket does not achieve sufficient stability, possible danger to personnel at large distance	DII	Calculate expected loads on rail buttons & attachment hardware, conduct qualitative “hang” test	Conduct a qualitative “hang” test
Launch rail/tower fails	Poorly maintained equipment, improper setup	Rocket does not safely exit rod, damage to vehicle, danger to personnel at a large distance	DI	Launch tower will be setup and maintained by a responsible person at the launch club, and inspected by the	ERSA equipment, so no prior testing will take place

				safety officer prior to launch	
Airframe separates during ascent	Improper connection of airframe sections; large aerodynamic forces cause the airframe to separate	Rocket cannot be relaunched, damage to airframe or internal components	DI	Couplings are tightened in the airframe using torque wrenches. A thorough analysis ensures its capability to withstand expected loads.	Complete analysis of coupling and material strength testing. Conduct a physical static load test to simulate expected in-flight loads.
Altimeter failure	Loss of power, low battery, disconnected wires, destruction by black powder charge, or burnt by charge detonation	Incorrect altitude readings and altitude deployment; can result in potential loss of rocket and payload not deploying from rocket.	DI	There will be a backup altimeter with a second power source in case the main altimeter fails. There will also be a set of backup CO2 charges connected to the backup altimeter. Both altimeters will also be tested before launch.	Altimeter testing included full-scale test of last year's rocket.
Altimeter switch failure	Switch comes loose or disarms during launch or component failure	Incorrect altitude readings and altitude deployment; can result in potential loss of rocket and payload not deploying from rocket	DI	Test switches before launch	Altimeter testing included in full-scale testing of last year's rocket
Recovery electronics bay failure	Loss of power, disconnected wires, destruction by black powder or CO2 charge, or burnt by charge detonation	Altimeter or recovery system failure	DII	Test the electronic bay and altimeter before launch	Full-scale test of electronics on last-year's rocket.
Descent too fast	Parachute is too small	Potential damage or loss	DII	Properly size parachute; test	Testing of recovery system

		of rocket and payload depending on speed of descent		recovery system before launch	in a full-scale launch of last year's rocket.
Motor Misfire	Damaged motor or damage to ignitor prior to launch.	Significant to unrepairable damage to the rocket and possibility of harm to personnel	DI	The motor is only handled by a certified team mentor. If there is a misfire, the team will wait at least 60 seconds before approaching the launch vehicle and will follow the instructions of the RSO.	There will be no prior verifications or testing.
Premature motor ignition	Damaged motor or accidental early ignition.	Possibility to harm personnel in vicinity during ignition.	DII	The motor will be replaced. It will be properly installed by a certified mentor and inspected by the RSO.	There will be no prior verifications or testing.
Motor fails to ignite	Ground support equipment failure, faulty or damaged motor	Launch vehicle cannot launch. Could possibly result in disqualification of team	DIII	The ground support equipment will be maintained by responsible persons from the launch site club. The motor will be stored according to specified guidelines.	Ignitors testing in launch site.
Premature ejection charge detonation	Inadvertent arming, recovery electronics failure	Minor damage to vehicle and harm to personnel in vicinity	DII	Arming switches will be locking, and detailed instructions will be kept and followed pertaining to the arming process.	Full scale testing
Shock cord is severed	Faulty shock cord, weak cord from repeated testing, destruction by	The parachutes would detach from the rocket, leading to the	DI	The shock cord will be properly sized to handle ejection loads. It	Testing of recovery system including a full-scale test using

	black powder charge, or burnt by charge detonation	loss of the rocket. Payload could potentially still deploy.		will also be inspected before the parachutes are packed. A Nomex blanket will protect the shock cord from fire damage and the black powder charges will be measured carefully.	last year's rocket.
Fins do not keep the rocket stable	Damaged fins, improper fin sizing	Predicted apogee is not reached, vehicle sustains minor damage.	CII	Use OpenRocket simulations to make sure the fin design will keep the rocket stable	Will not test before launch. Fins shape and sizing will be verified by both Rocket and Aerostructure team leads.
Fins break off during landing	High impact during landing; point stresses on fins	Rocket cannot be relaunched	CII	Avoid fin designs with weak points and test fins with forces of final descent velocity	Material testing of the fins.
Descent too slow	Parachute is too large	Landing outside of landing range.	CIII	Properly size parachute; test recovery system before launch.	Testing of the recovery system including a full-scale test using last year's rocket.
Pressure not equalized inside airframe	Vent holes are too small	Altimeters do not register accurate altitude	DII	The vent holes will be drilled according to recommendation s determined by external testing	Inspection and verification by Rocket and Aerostructure team leads.
Airbrakes fail to deploy or deploy incorrectly	Electrical or software failure, mechanical parts become stuck	Vehicle over or undershoots expected apogee	BIV	The airbrake system will be tested prior to launch using simulated flight data, and hardware in the loop testing. Mechanical actuation will be	Airbrakes performance will not be verified prior to the competition, and will be tested for the first time during launch

				attempted with expected loads	
Airbrakes deploy asymmetrically	Driving plate or fin pins fail in one section but not others	Vehicle experiences unexpected loads and flight forces, causing an unpredictable trajectory or damage to other components	DII	Conduct analysis of part mechanical strength. Airbrake system is designed to force all fins to deploy evenly when there is no damage to parts	Airbrakes performance will not be verified prior to the competition, and will be tested for the first time during launch
Rocket Catches on Fire	High temperatures, short circuits, physical damage	Significant damage to vehicle, danger to personnel in vicinity due to energetics or harmful gases	DII	Temperature monitored during launches, components tested independently, electronics protected from damage.	No way to verify, but will be monitored and safety precautions will be taken as necessary
Avionics systems fail	Damaged components, faulty power system	Vehicle overshoots expected apogee, flight data is not recorded. GPS positions are not transmitted, causing possible loss of vehicle	CIII	Test avionics systems before launch, verify functionality	Avionics systems testing and full-scale testing using last year's rocket
Payload comes loose in payload bay	Damaged components, improperly designed retention system	Minor damage to vehicle, alteration of flight path	CIII	Perform analysis of payload retention system under expected flight loads, and test strength prior to launch	Independent payload testing

H.

Risk Analysis: Payload					
Hazard	**Cause**	**Effect**	**Probability /Severity**	**Mitigation & Controls**	**Verification**

Payload retention failure	Incorrect programming of the altimeters, or severe damage to the upper airframe and retention pins	Payload deploys prior to apogee	DI	Inspection of upper airframe and retention pins prior to flight. Verification of the altimeter programming by team leads	WPI HPRC will create a payload inspection checklist
Retention system becomes insecure	Damage to retention pins	Payload rattles within upper airframe and causes damage to itself	DII	Inspection of upper airframe and retention pins prior to flight	WPI HPRC will create a payload inspection checklist
Payload Ejection failure	Incomplete separation of upper airframe	Potential launch vehicle tumbling that could affect proper decent	DI	Inspection of CO_2 charges and wiring and reduce friction between payload and upper airframe	Payload ejection test using expected CO_2 charges.
Payload becomes damaged during ejection process	Excessive forces on shock cord during deployment	Payload is damaged	DII	Inspection of shock cord and computed simulations.	Recovery system full-scale test using last year's rocket
Battery catches fire	Overheating of the internals of the payload during launch or outside temperature, faulty battery, incorrect wiring leading to an ignition, ignition within rocket that impacts the security of the payload	The rocket catches on fire and burns during launch, the rocket becomes ballistic and could hurt the environment or people in the crowd, the drone is destroyed and unable to complete its mission	DI	WPI HPRC will design the quadcopter and retention system to be well ventilated to prevent overheating. The payload recovery bay and GPS will be the only batteries turned on during launch to minimalize overheating possibilities	The quadcopter will be run at acceptable levels to not overexert the battery's

I. Assembly, Pre-Flight, Launch and Recovery Checklists

Lower Airframe Assembly Checklist

#	Instructions
1	Inspect the tailcone, fin can, and lower airframe for damage.
2	Connect the tailcone to the lower airframe via the coupling. Torque the coupling.
3	Ensure the 3S LiPo battery for the avionics system is fully charged using a LiPo tester. The voltage should be around 12.6V. A battery measuring less than 12.3V should be charged before use.
4	Install the battery to the battery mount. Secure with the Velcro strap.
5	Connect the battery to the avionics stack. Power on the stack to confirm operation.
6	Power off the avionics stack.
7	Install the airbrakes into the lower airframe via the coupling. Ensure the fins can freely extend.

Vehicle Assembly Checklist

#	Instructions
1	The Lower Airframe, Payload, and Recovery Systems Assembly Checklists should have been completed before beginning this checklist.
2	Connect the recovery quick link to the upper airframe coupler bulkhead
3	Connect the upper airframe and payload to the middle airframe via the coupler tube. Install 2 #2 shear pins.
4	Activate the vibration datalogger
5	Install the assembled motor and secure the motor retention system.

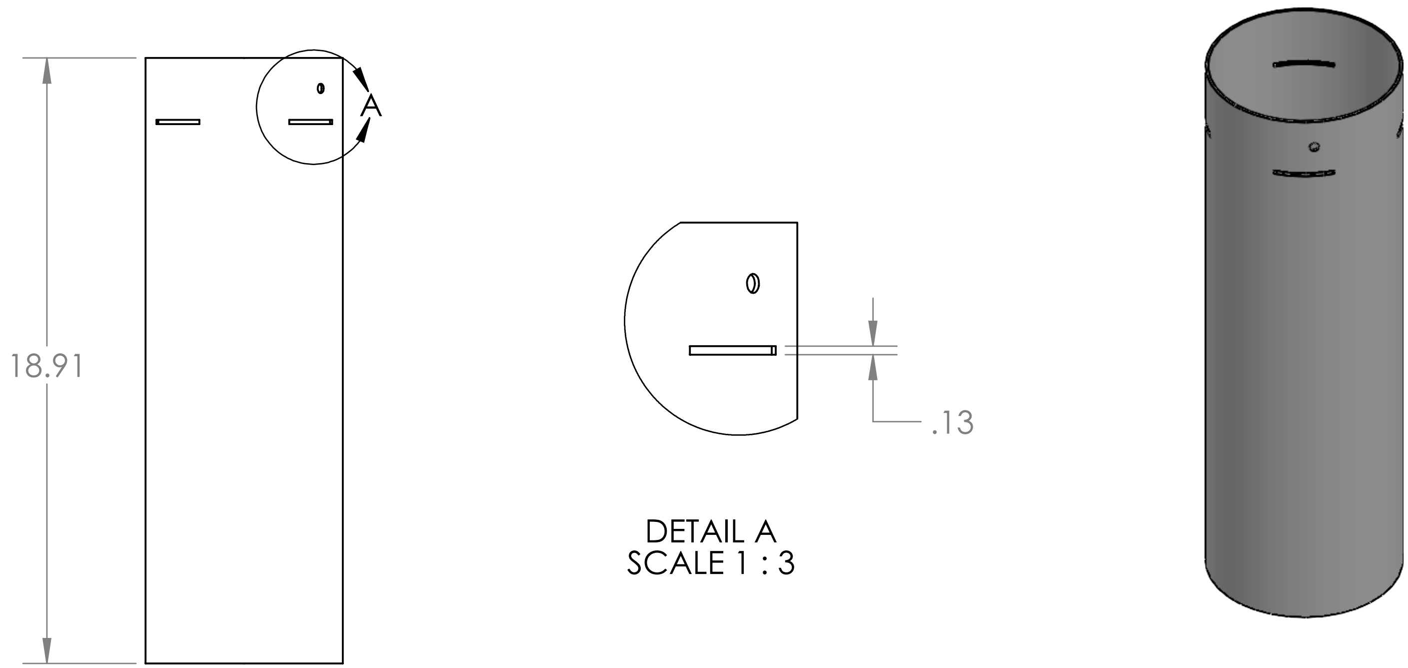
Preflight Checklist

#	Instructions
1	The launch vehicle should be installed on the rail and vertical before beginning this checklist.
2	All vent holes and airframes should be inspected for damage
3	The avionics system should be activated via the screw switch on the lower airframe.
4	The pad team should confirm with the ground station team that telemetry is being received from the GPS tracker and avionics board.
5	The payload altimeters should be armed sequentially, confirming and noting down the beep sequence for each altimeter.
6	The rocket altimeters should be armed sequentially, confirming and noting down the beep sequence for each altimeter.
7	Verify the continuity of the motor ignitor, and that the launch system is inactive.
8	Install the ignitor into the motor.
9	Connect the ignitor to the launch system and confirm continuity.
10	Exit the pad area.

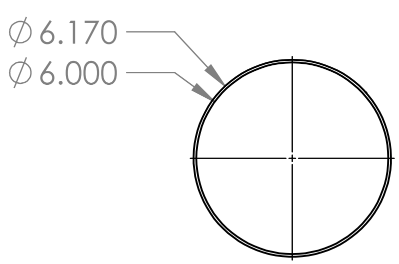
Launch Checklist	
#	**Instructions**
1	Confirm the preflight checklist was completed and review beep sequence data from the altimeters.
2	Notify RSO of launch readiness
3	Launch when approved
	If the vehicle fails to launch
1	Inform RSO of failure to launch
2	If ignitor is still continuous, attempt launch again.
3	If unsuccessful, return to pad when approved to do so.
4	Replace ignitor. Confirm if ignitor fired or not.
5	Re-verify preflight checklist.
6	Restart launch checklist

Recovery Checklist	
#	**Instructions**
1	This checklist should be completed when the rocket and payload are located.
2	Report the location and status of the recovery team to the MCC.
3	Before disturbing the landing site, take photos of the site, launch vehicle, and payload.
4	Record the beep codes of the altimeters.
5	Safe the altimeters.
6	Verify that all energetics are spent.
7	Inspect the airframe for damage.
8	Inspect the recovery system for damage or tangling.
9	Once approval is given to activate the payload, complete the payload mission.
10	Return the vehicle to the team setup area.
11	Disassemble the electronics bay and lower airframe couplings
12	Disconnect all batteries
13	Download flight data from the altimeters and avionics.
14	Inspect internal components for damage
15	Remove and clean the motor casing, CO2 ejection systems, and Tender Descenders
16	Remove and clean the motor casing, CO2 ejection systems, and Tender Descenders

J. Engineering Drawings



DETAIL A
SCALE 1 : 3



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	NJ	5/10/2022
	CHECKED	TMO	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL G12 Fiberglass			

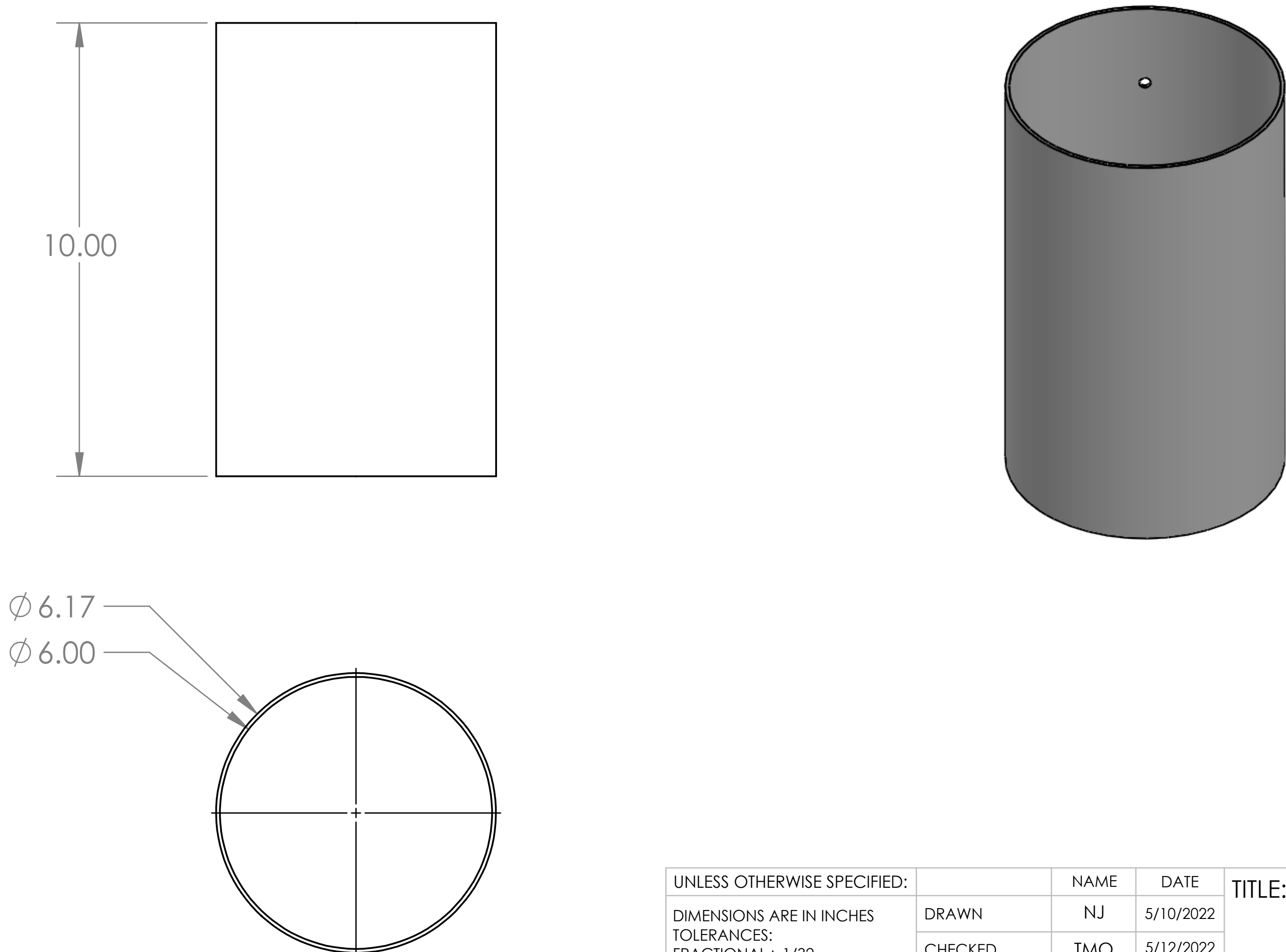
HPRC WPI AIAA

TITLE:

LOWER BODY TUBE

SIZE	DWG. NO.	REV
A	U22-1-1-001	

SCALE: 1:6 | WEIGHT: | SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/32
ANGULAR: MACH ± 1 BEND ± 1
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005

INTERPRET GEOMETRIC
TOLERANCING PER: ASME Y14.5

MATERIAL
G12 Fiberglass

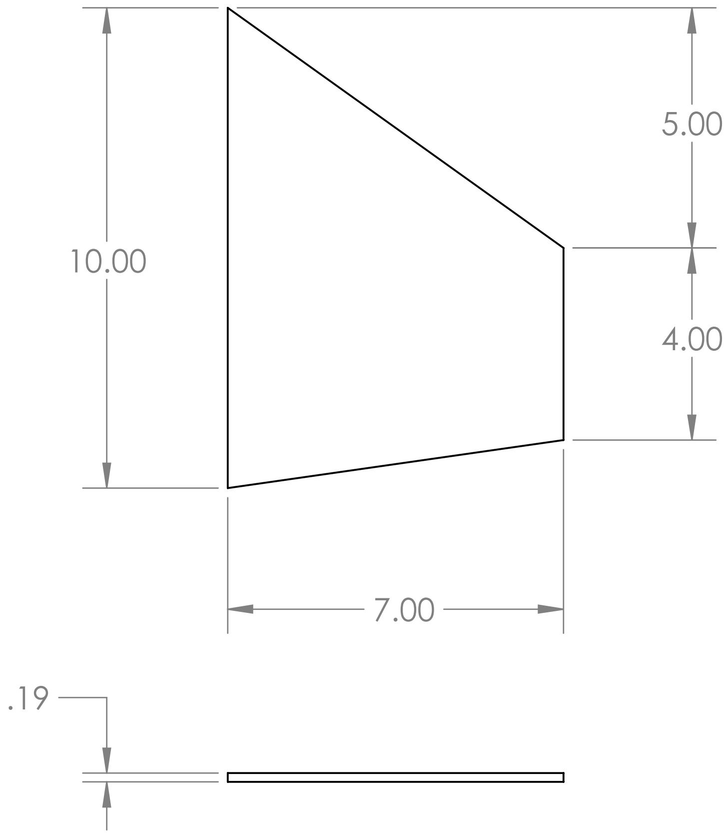
	NAME	DATE
DRAWN	NJ	5/10/2022
CHECKED	TMO	5/12/2022

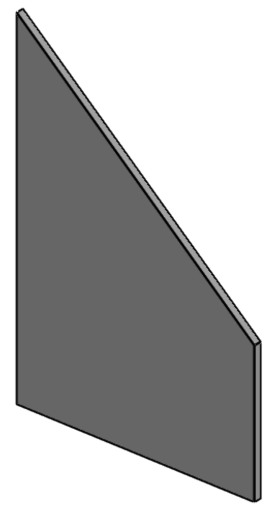
HPRC WPI AIAA

TITLE: FIN CAN

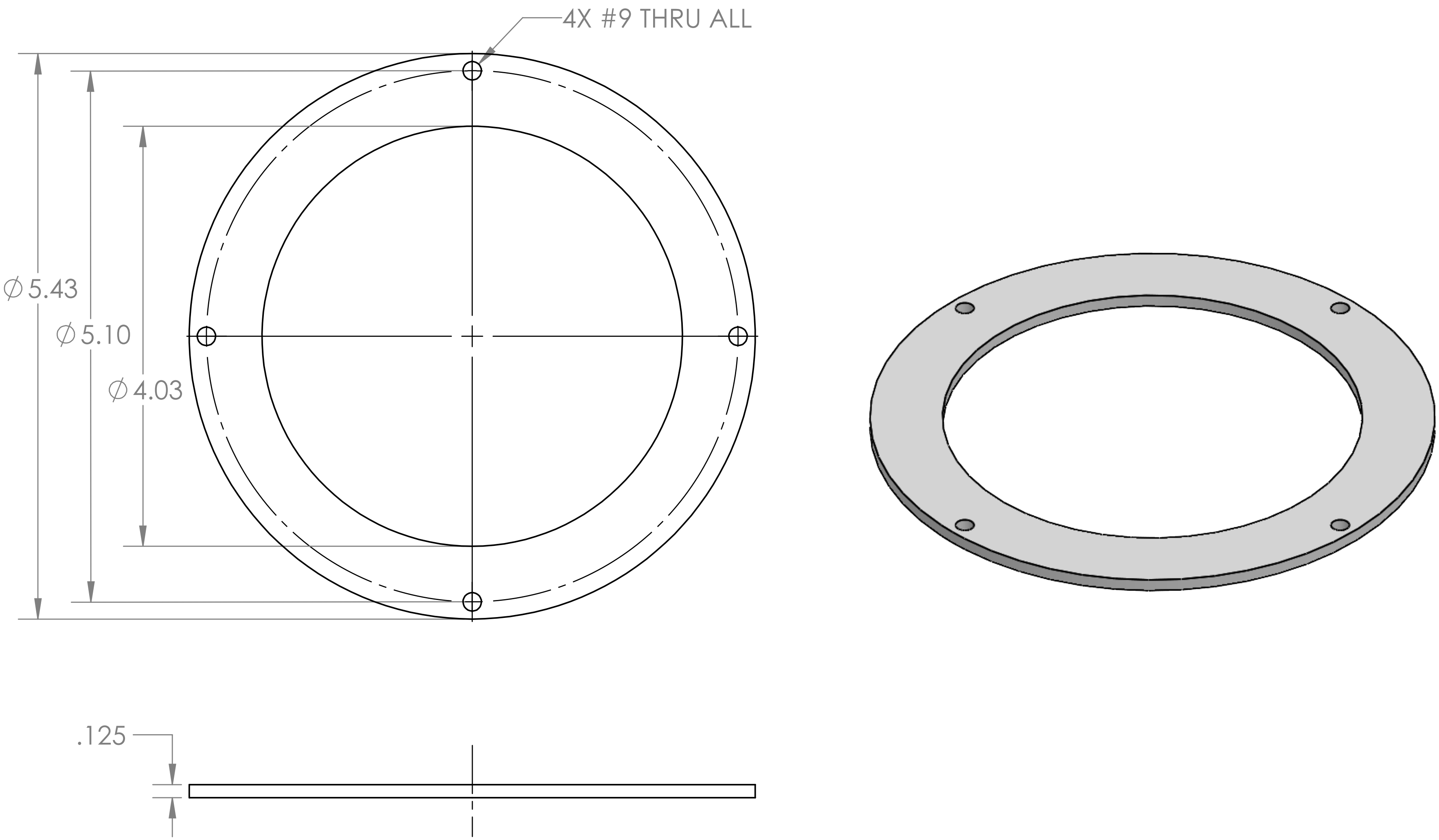
SIZE	DWG. NO.	REV
A	U22-1-1-002	

SCALE: 1:4 WEIGHT: SHEET 1 OF 1





UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	NJ	5/10/2022	FIN
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A DWG. NO. U22-1-1-003 REV
MATERIAL G10 Fiberglass				SCALE: 1:4 WEIGHT: SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/32
ANGULAR: MACH ± 1 BEND ± 1
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5

MATERIAL
G10 FIBERGLASS

	NAME	DATE
DRAWN	TT	5/10/2022
CHECKED	TMO	5/12/2022

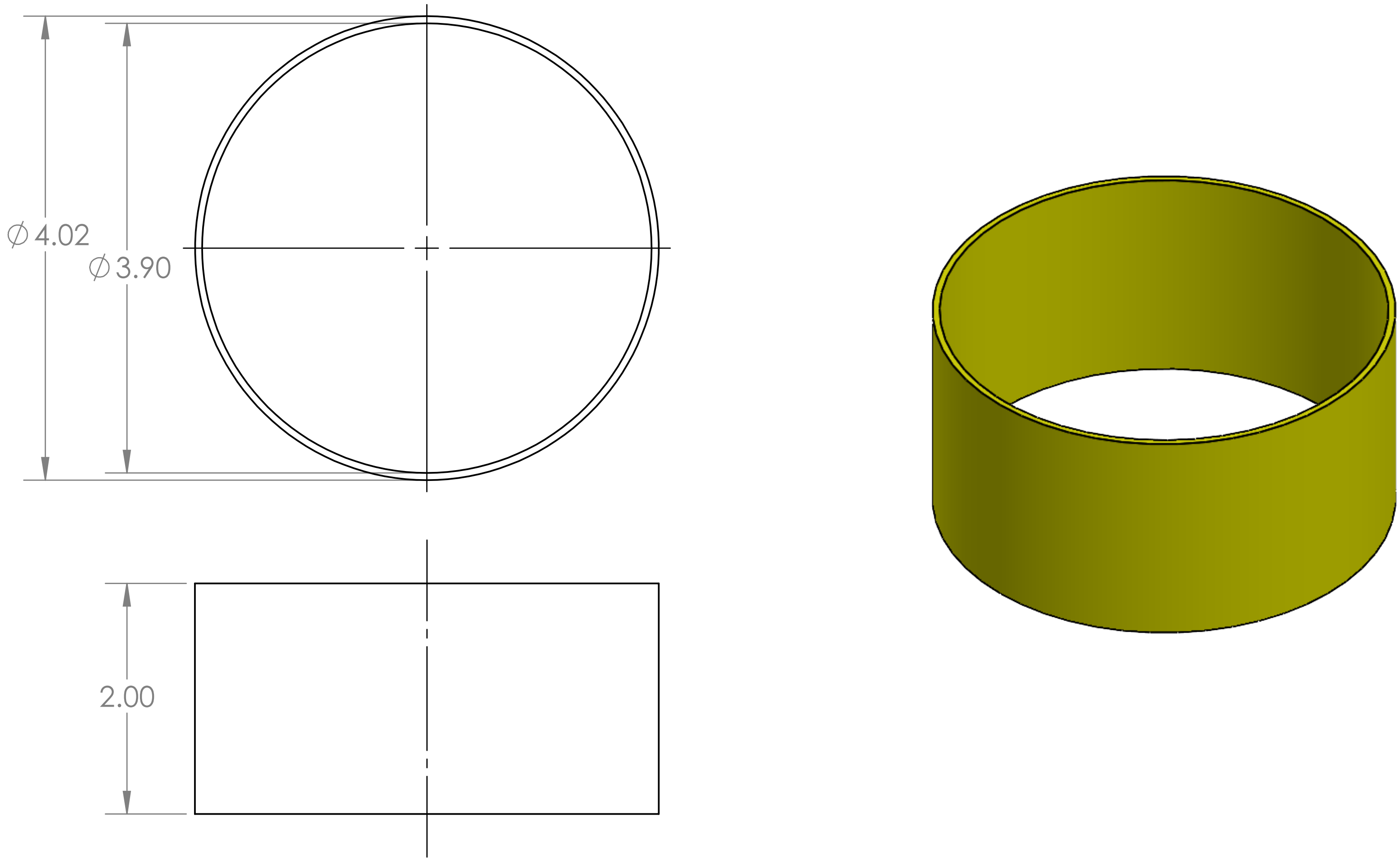
HPRC WPI AIAA

TITLE:

CENTERING RING

SIZE A | DWG. NO. U22-1-1-004 | REV

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



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/32
ANGULAR: MACH ± 1 BEND ± 1
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005

INTERPRET GEOMETRIC
TOLERANCING PER: ASME Y14.5

MATERIAL
G10 FIBERGLASS

	NAME	DATE
DRAWN	TT	5/10/2022
CHECKED	TMO	5/12/2022

HPRC WPI AIAA

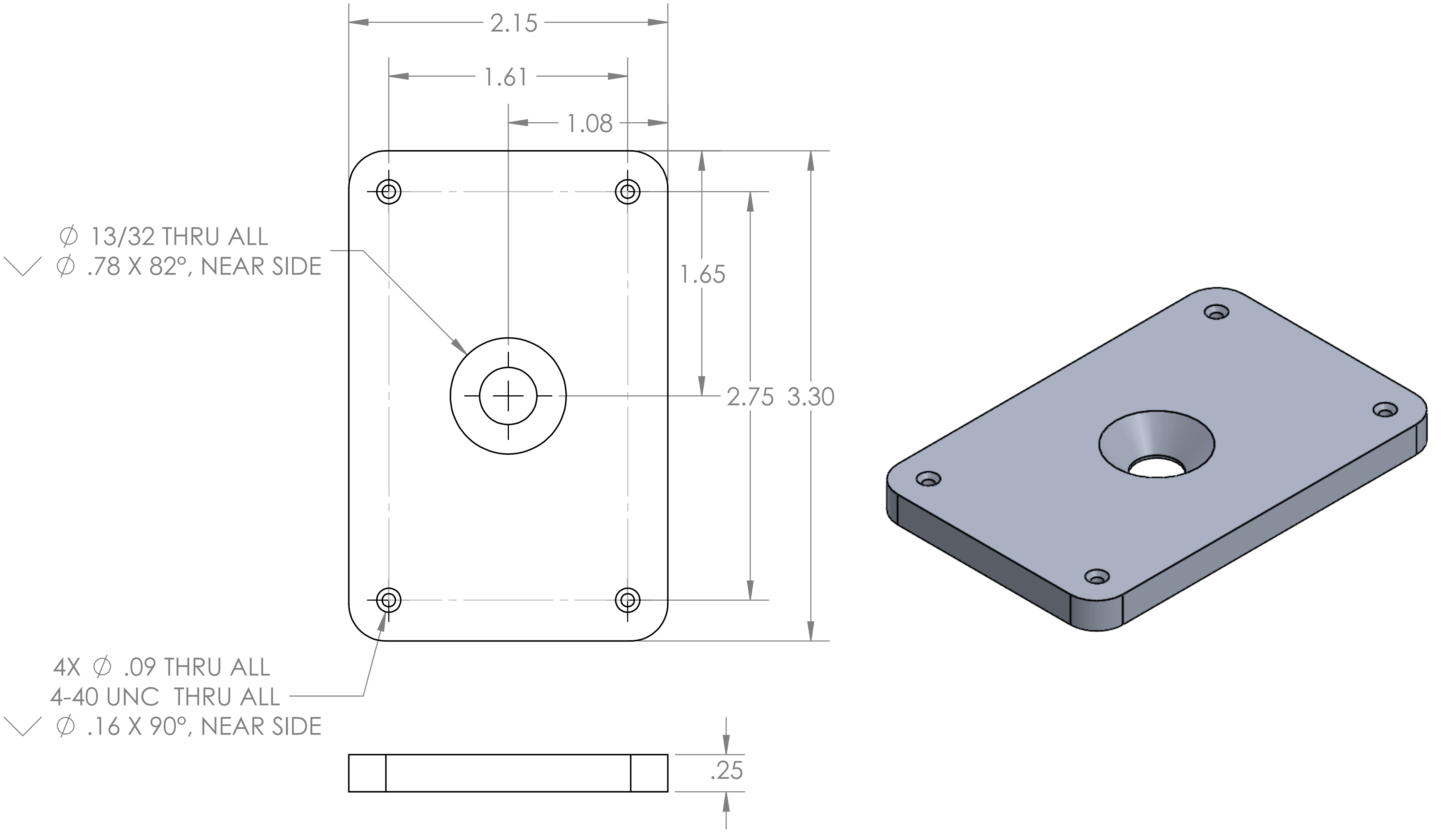
TITLE:
MOTOR TUBE

SIZE **A** DWG. NO. U22-1-1-005 REV

SCALE: 2:3 WEIGHT: SHEET 1 OF 1

2 1

B B



A A

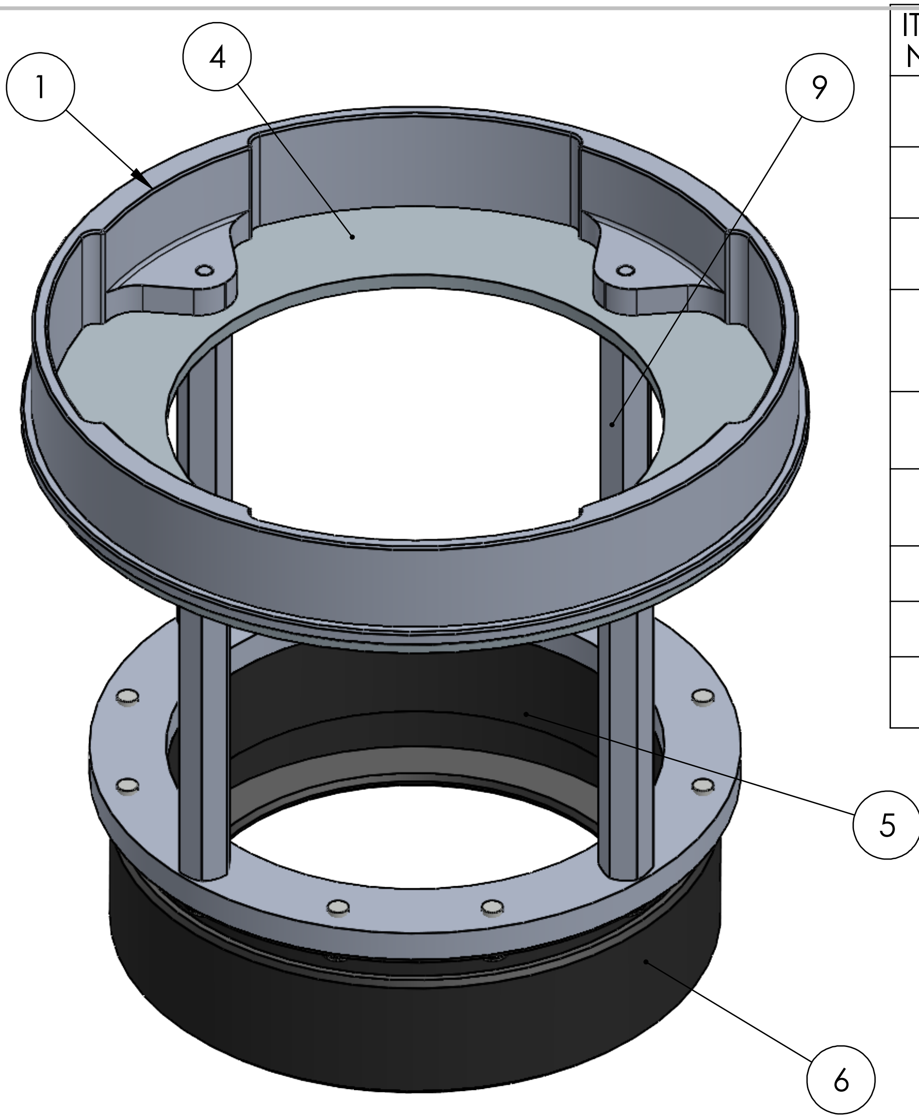
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	TT	5/10/2022
	CHECKED	TMO	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA		
MATERIAL ALUMINUM 6061			

TITLE:
DATALOGGER MOUNT

SIZE	DWG. NO.	REV
A	U22-1-1-006	

SCALE: 1:1 WEIGHT: SHEET 1 OF 1

2 1



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	U22-1-1-101 (THRUST COUPLING)		1
2	U22-1-1-102 (RETAINER PLATE)		1
3	U22-1-1-103 (TAILCONE)	Hidden	1
4	U22-1-1-104 (TAILCONE BULKHEAD)		1
5	98mm Retainer Flange		1
6	98mm Retainer Cap		1
7	#8-32x0.500		4
8	#8-32x0.375		8
9	93505A032	Male-Female Threaded Hex Standoff	4

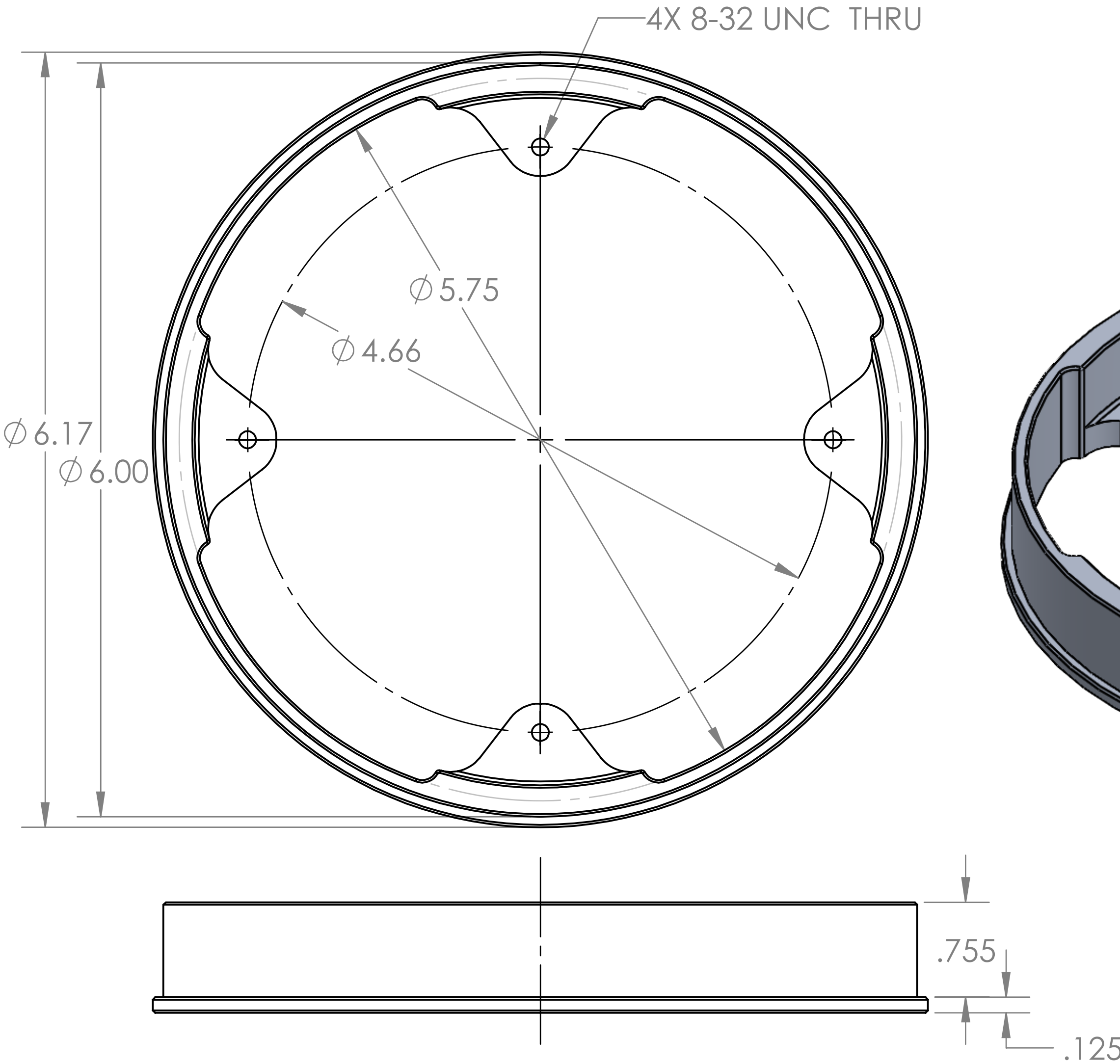
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	TT	5/10/2022
	CHECKED	TMO	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL XXXXXXX			

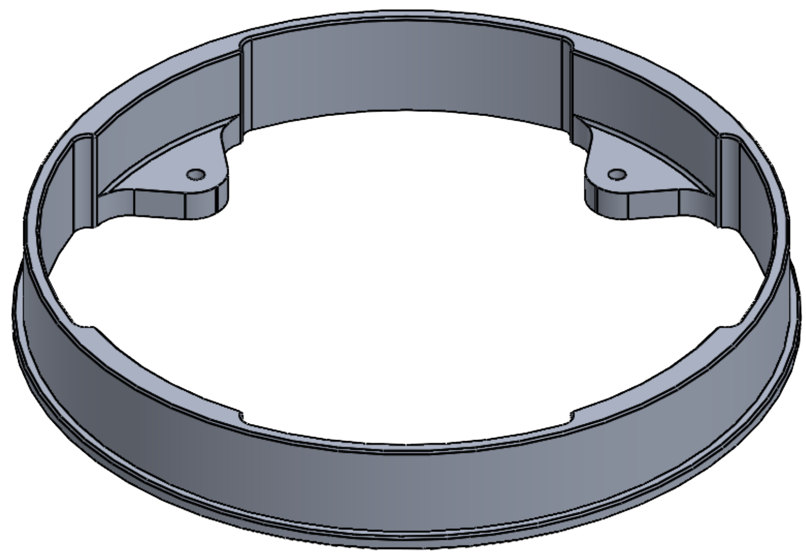
HPRC WPI AIAA

TITLE:

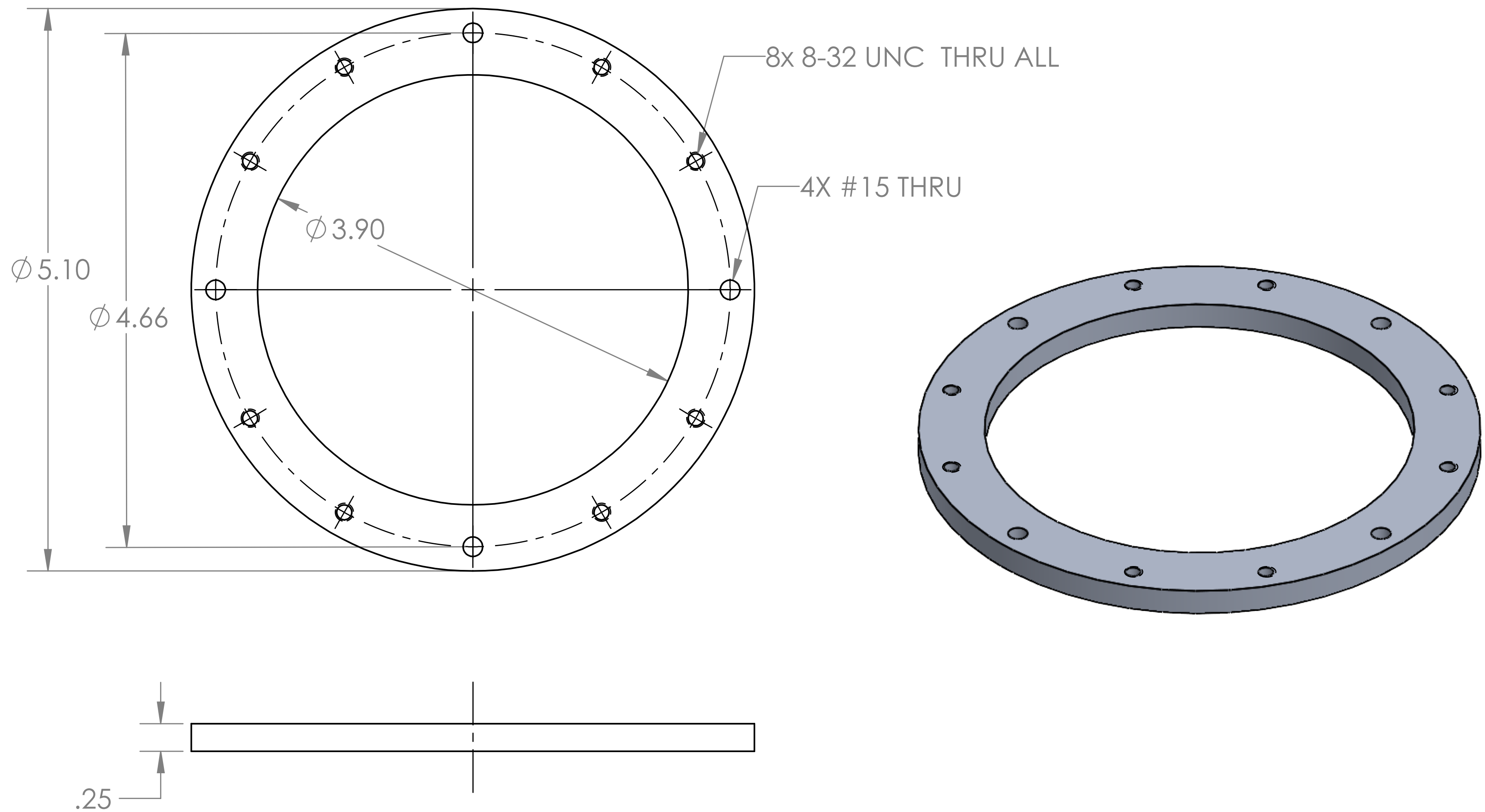
MOTOR RETENTION ASSEMBLY

SIZE	DWG. NO.	REV
A	U22-1-1-100	
SCALE: 1:4	WEIGHT:	SHEET 1 OF 1





UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	TT	5/10/2022	THRUST COUPLING
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A · DWG. NO. U22-1-1-101 · REV
MATERIAL ALUMINUM 6061				SCALE: 2:3 · WEIGHT: · SHEET 1 OF 1



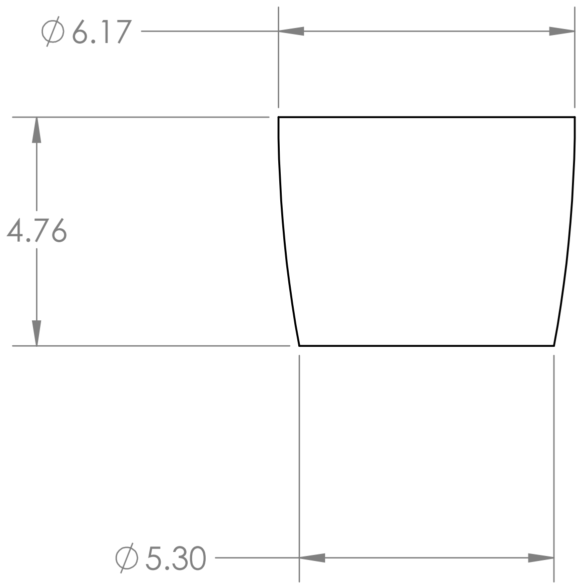
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	TT	5/10/2022
	CHECKED	TMO	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL ALUMINUM 6061			

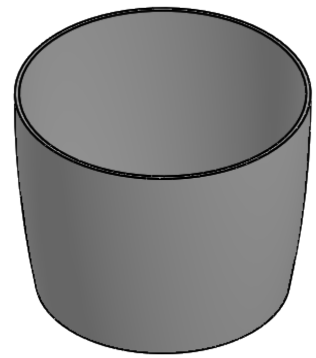
TITLE:

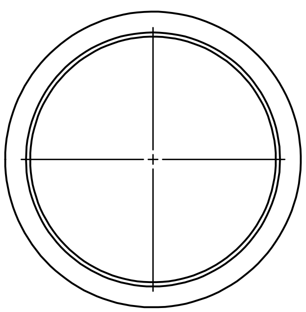
RETAINER PLATE

SIZE	DWG. NO.	REV
A	U22-1-1-102	

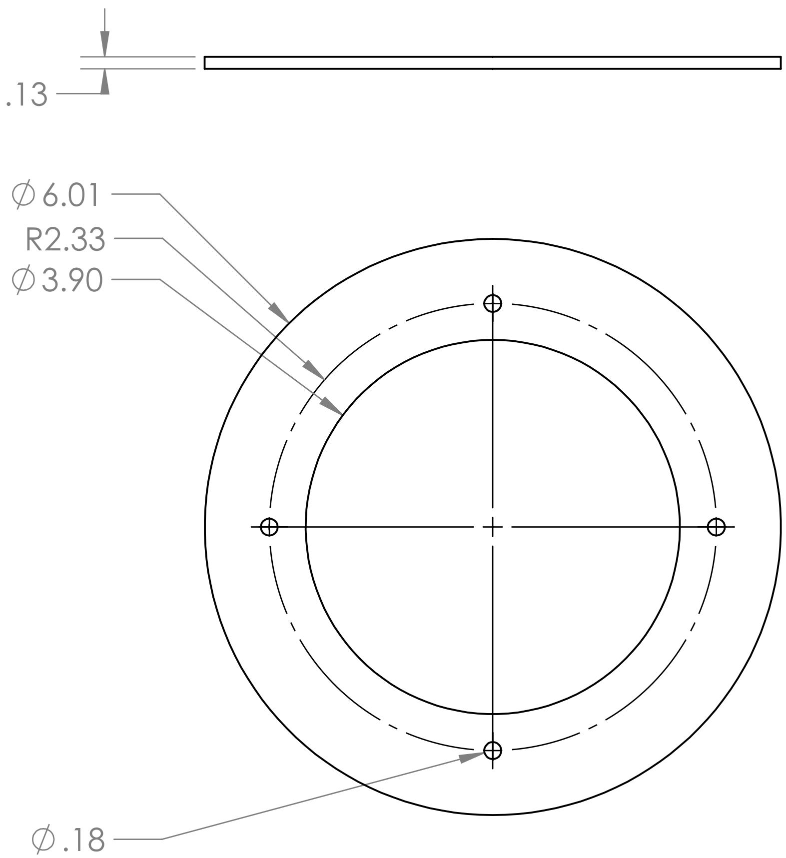
SCALE: 2:3 WEIGHT: SHEET 1 OF 1

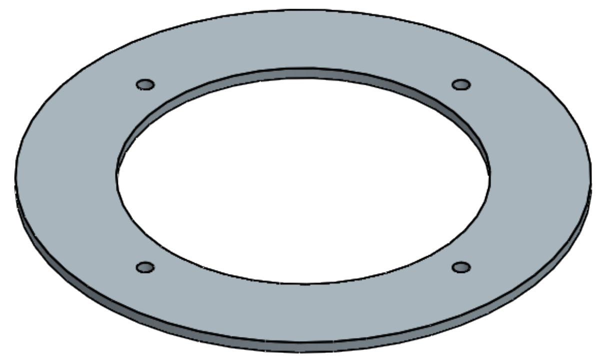




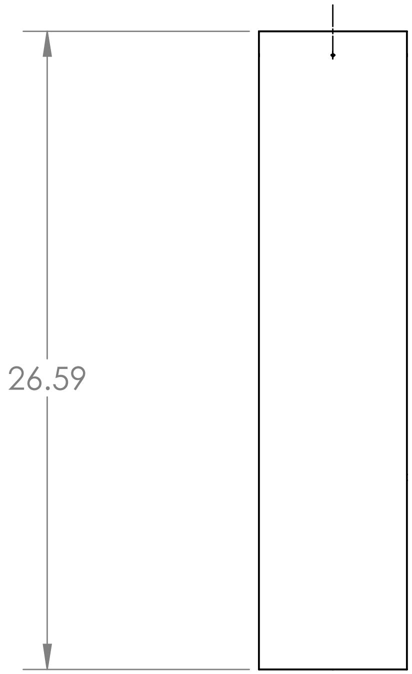


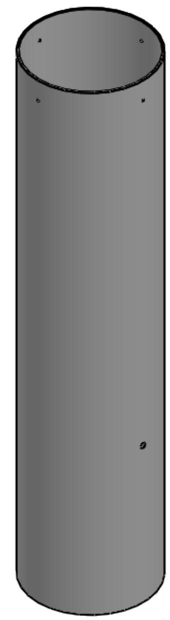
UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE: TAILCONE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	NJ	5/10/2022	
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A DWG. NO. U22-1-1-103 REV
MATERIAL S-Glass				SCALE: 1:4 WEIGHT: SHEET 1 OF 1

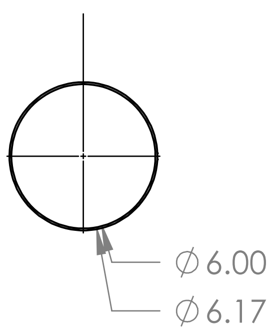




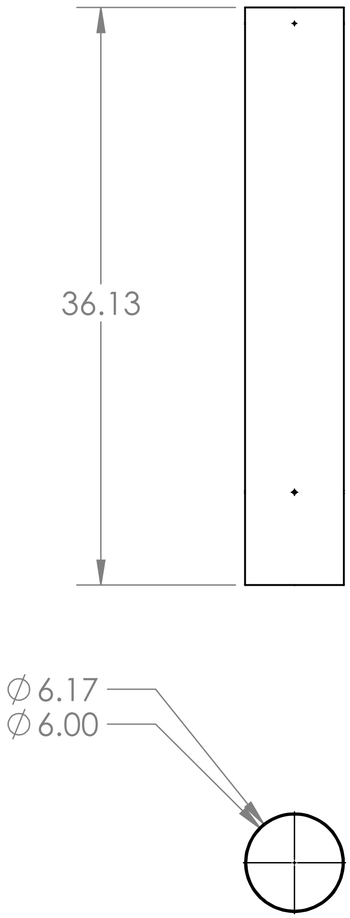
UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE: TAILCONE BULKHEAD
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	NJ	5/10/2022	
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A · DWG. NO. U22-1-1-104 · REV
MATERIAL G10 Fiberglass				SCALE: 1:2 · WEIGHT: · SHEET 1 OF 1



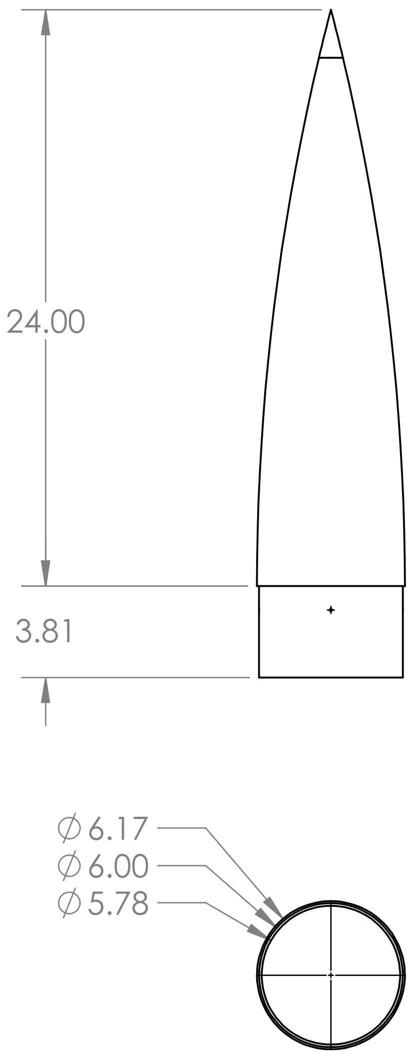




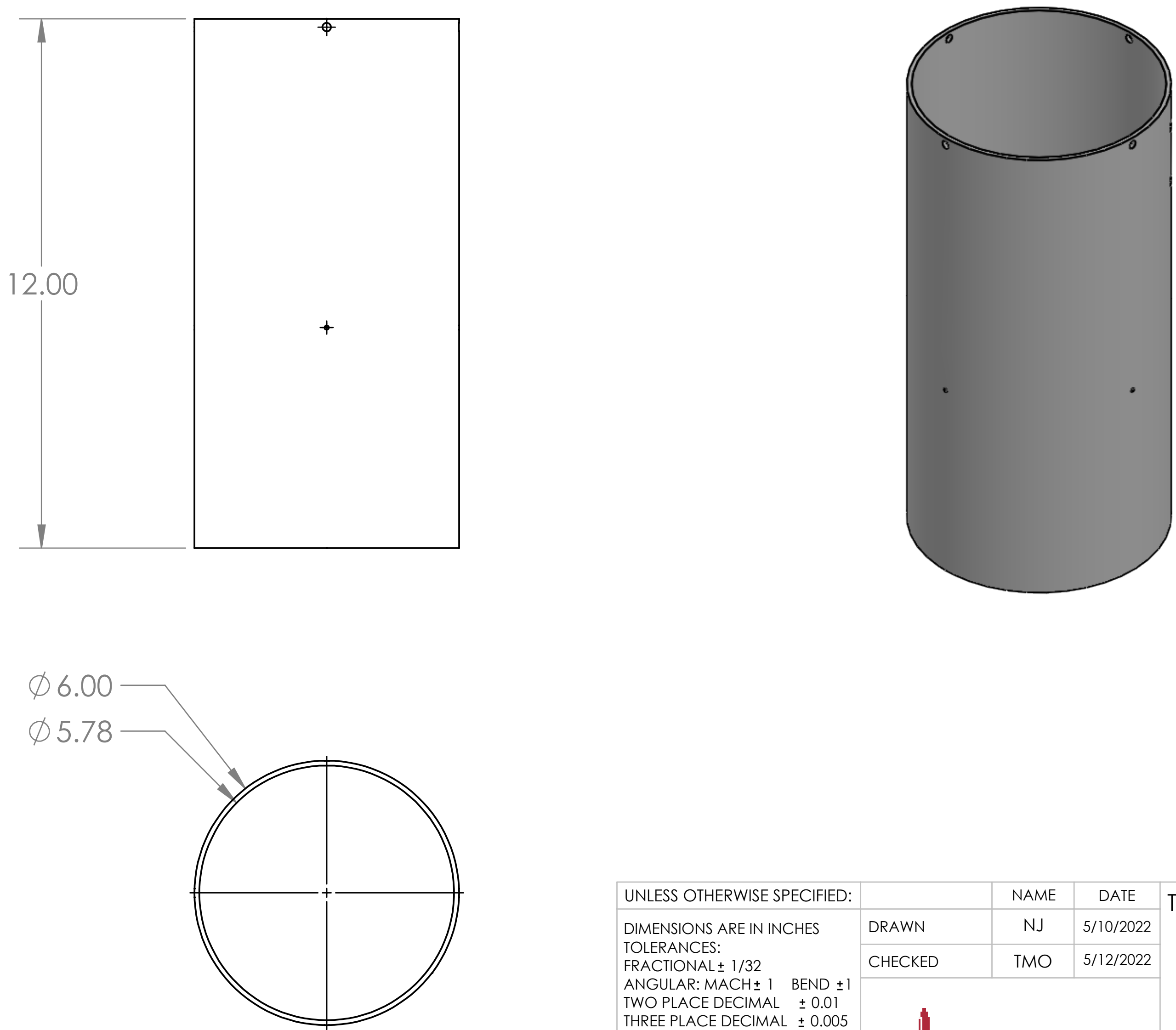
UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE: MIDDLE BODY TUBE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	NJ	5/10/2022	
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A · DWG. NO. U22-1-2-001 · REV
MATERIAL G12 Fiberglass				SCALE: 1:8 · WEIGHT: · SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	**INITIALS**	5/10/2022	UPPER BODY TUBE
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A DWG. NO. U22-1-3-001 REV
MATERIAL G12 Fiberglass				SCALE: 1:12 WEIGHT: SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE: NOSECONE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	NJ	5/10/2022	
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5				SIZE A — DWG. NO. U22-1-3-002 — REV
MATERIAL G12 Fiberglass				SCALE: 1:8 — WEIGHT: — SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/32
ANGULAR: MACH ± 1 BEND ± 1
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5

MATERIAL
G12 Fiberglass

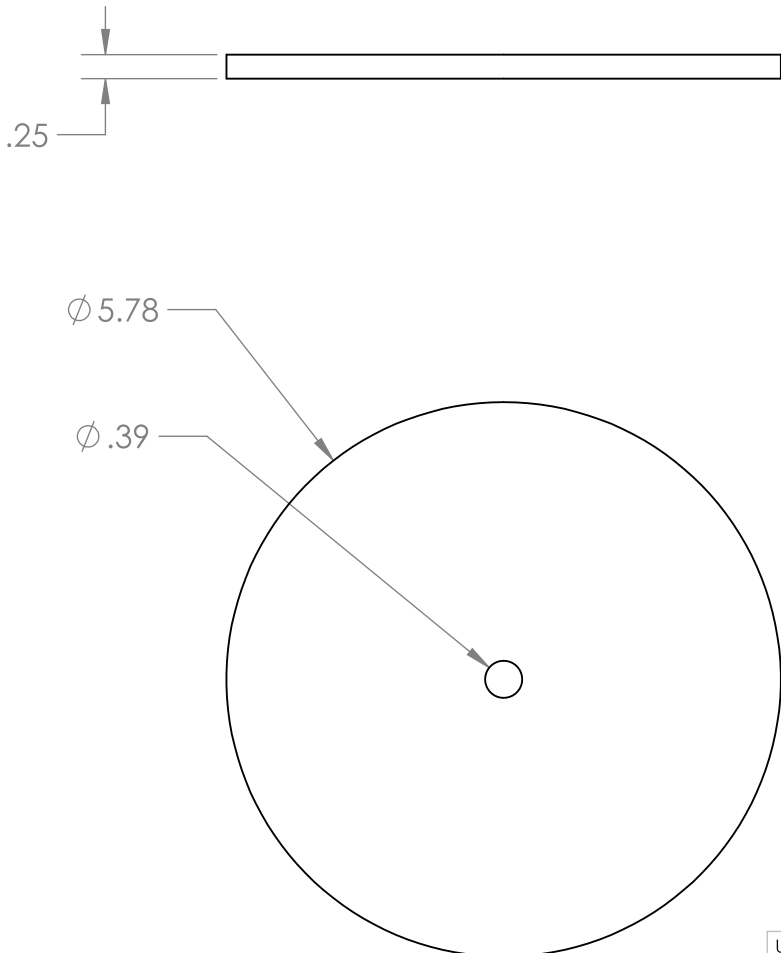
	NAME	DATE
DRAWN	NJ	5/10/2022
CHECKED	TMO	5/12/2022

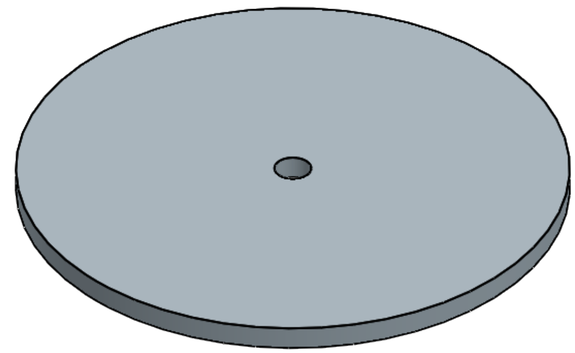
HPRC WPI AIAA

TITLE:
UPPER AIRFRAME COUPLER

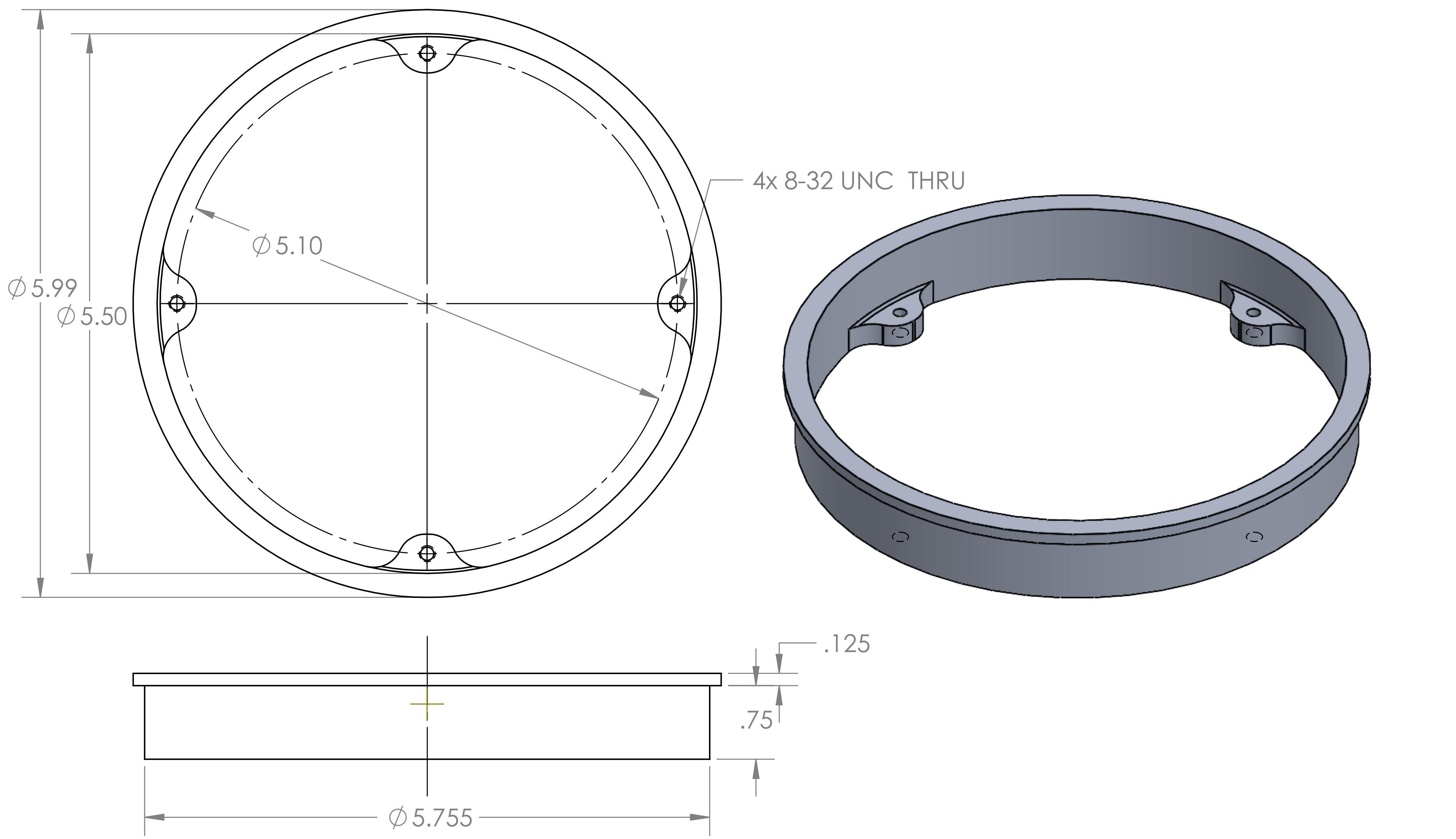
SIZE A | DWG. NO. U22-1-3-003 | REV

SCALE: 1:4 | WEIGHT: | SHEET 1 OF 1

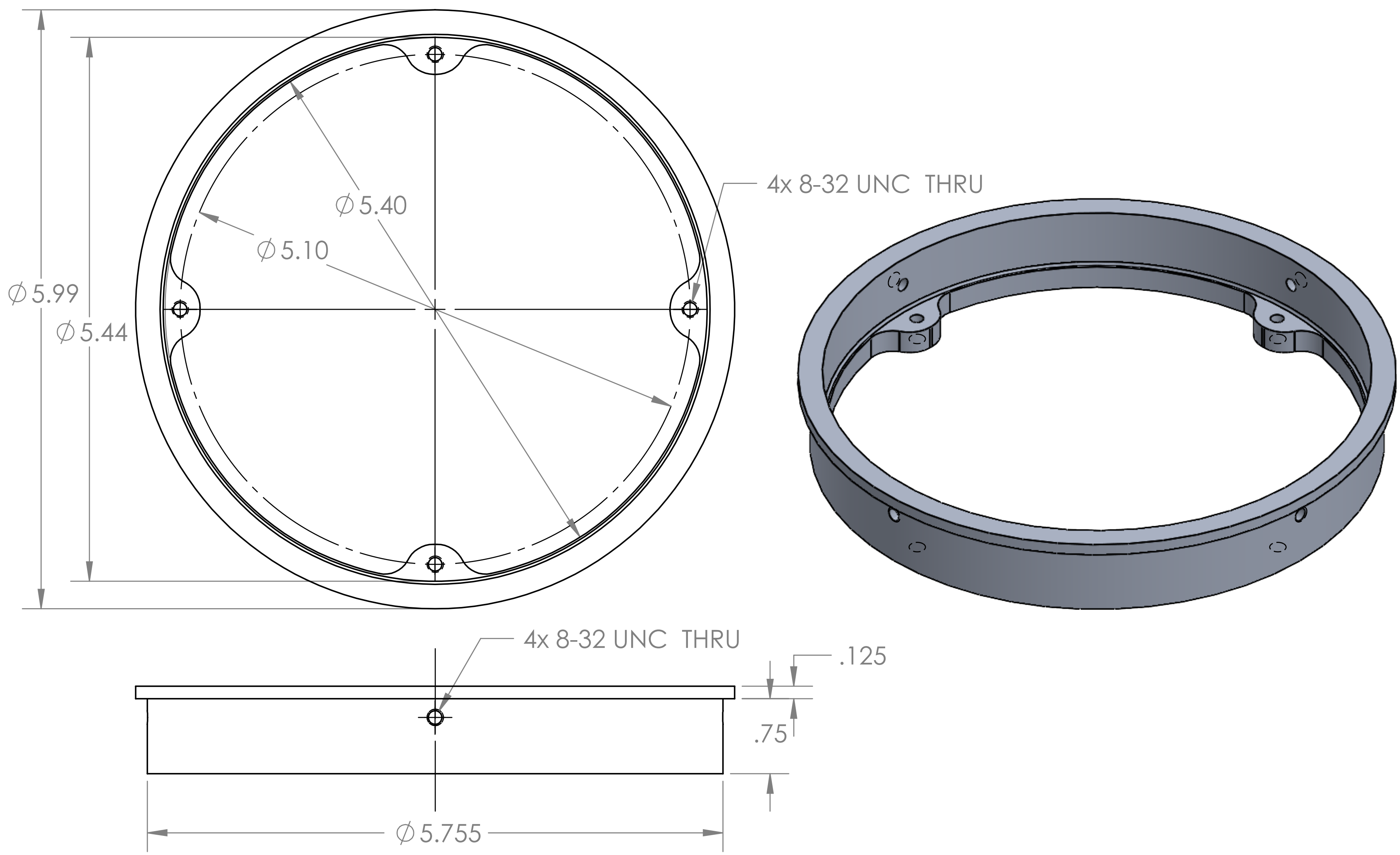




UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	NJ	5/10/2022	COUPLER BULKPLATE
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE **A** DWG. NO. U22-1-3-004 REV
MATERIAL G10 Fiberglass				SCALE: 1:2 WEIGHT: SHEET 1 OF 1

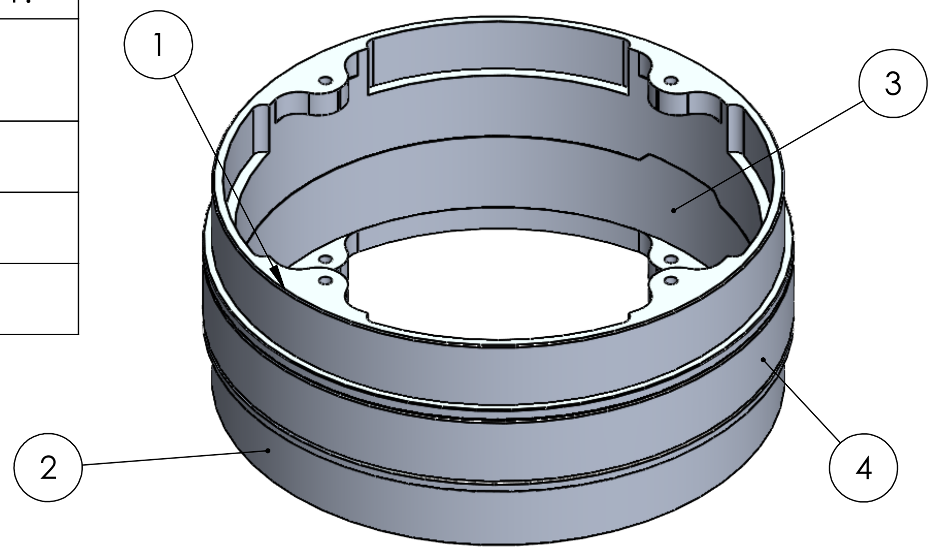


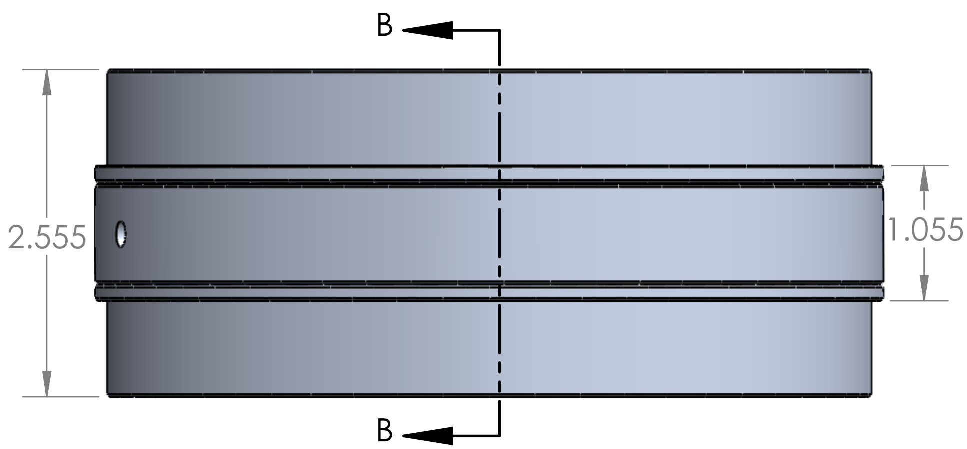
UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	TT	5/10/2022	PAYLOAD COUPLING STANDARD CONFIGURATION
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A · DWG. NO. U22-1-3-005 · REV
MATERIAL ALUMINUM 6061				SCALE: 2:3 · WEIGHT: · SHEET 1 OF 2

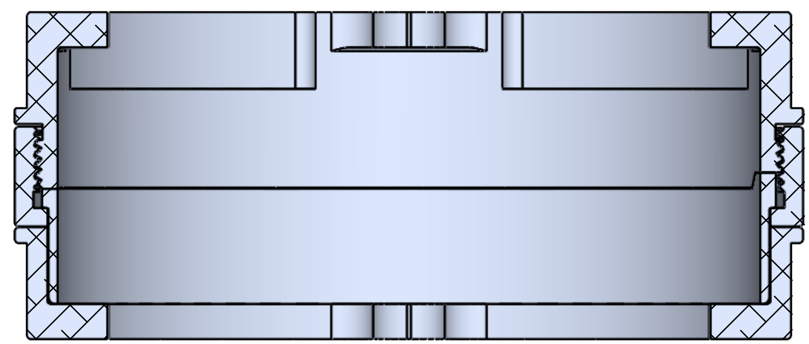


UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	TT	5/10/2022	PAYLOAD COUPLING RECOVERY CONFIGURATION
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A — DWG. NO. U22-1-3-005 — REV
MATERIAL ALUMINUM 6061				SCALE: 2:3 — WEIGHT: — SHEET 2 OF 2

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	U22-1-4-001 (THREADED COUPLING)		1
2	U22-1-4-002 (BARE COUPLING)		1
3	U22-1-4-003 (RETAINING RING)		1
4	U22-1-4-004 (ROTATING NUT)		1







SECTION B-B
SCALE 2 : 3

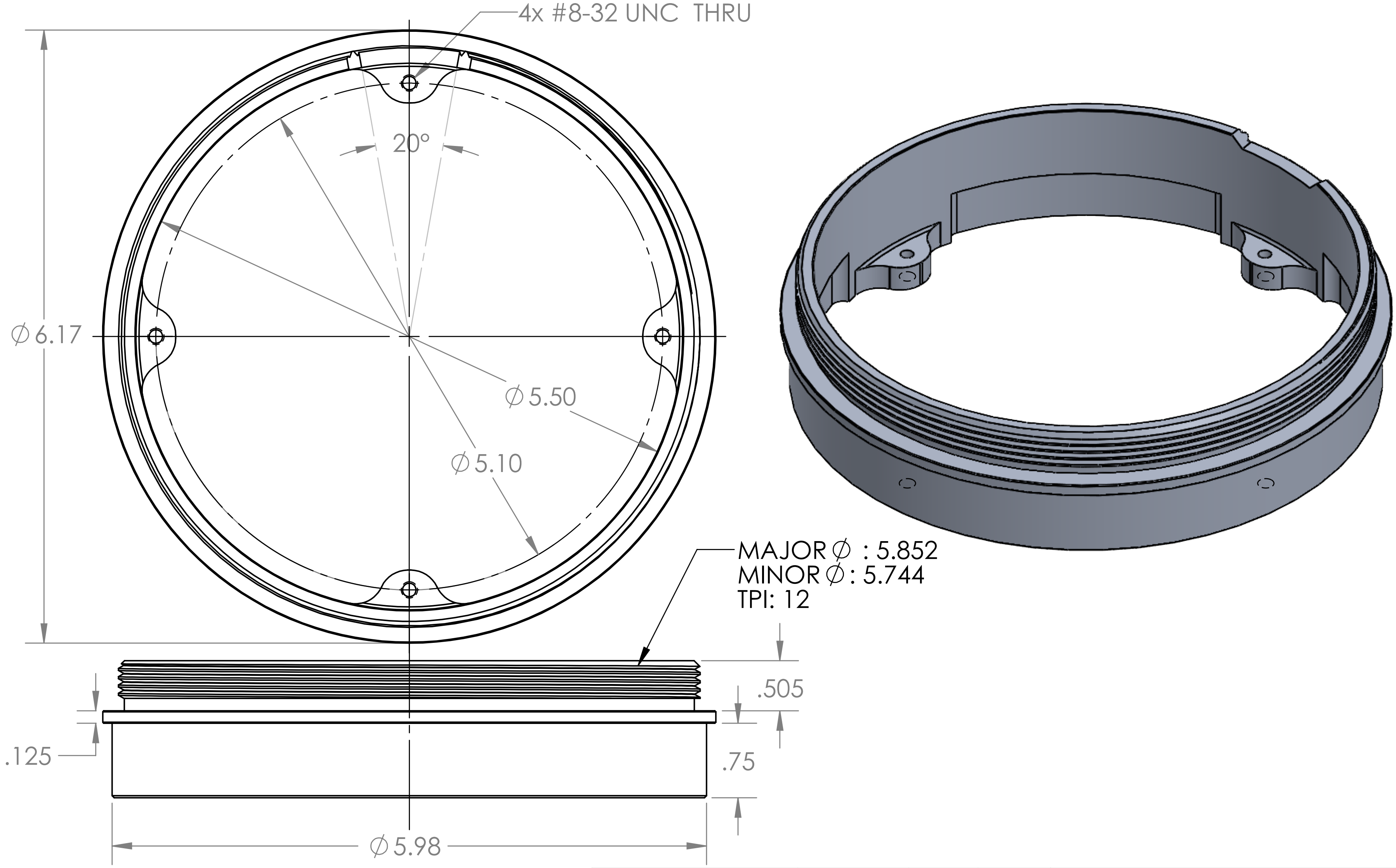
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	TT	5/10/2022
	CHECKED	TMO	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL **INSERT MATERIAL**			

TITLE:

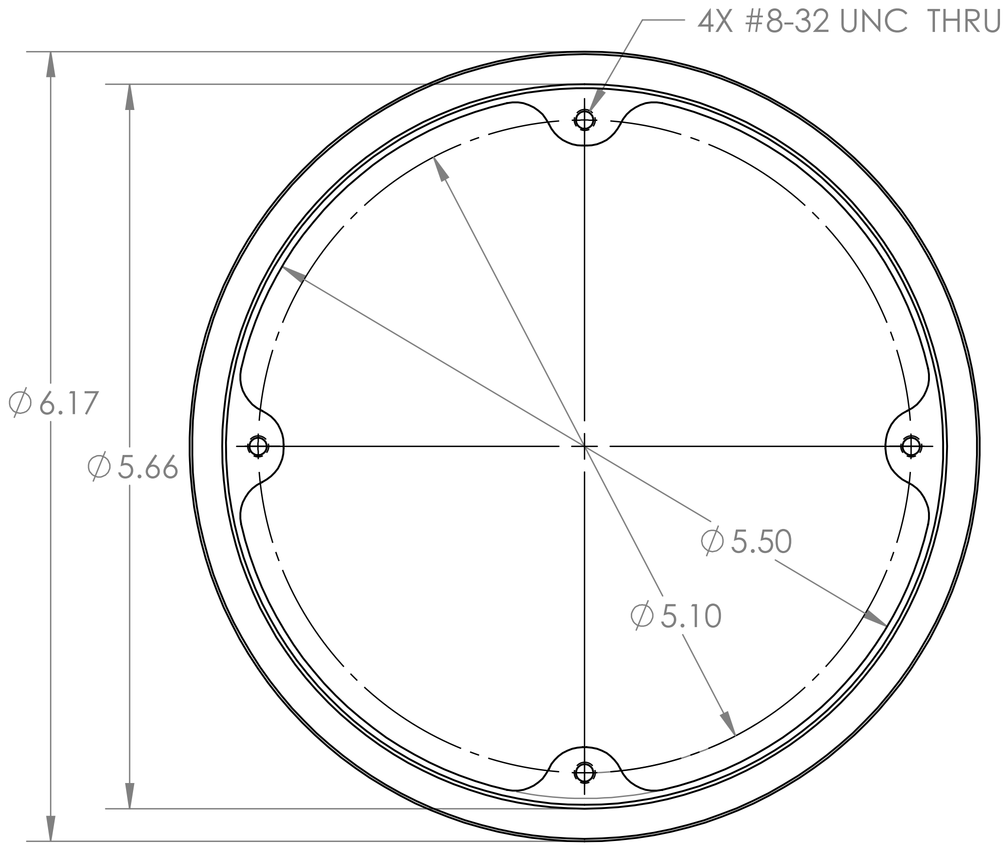
COUPLING ASSEMBLY

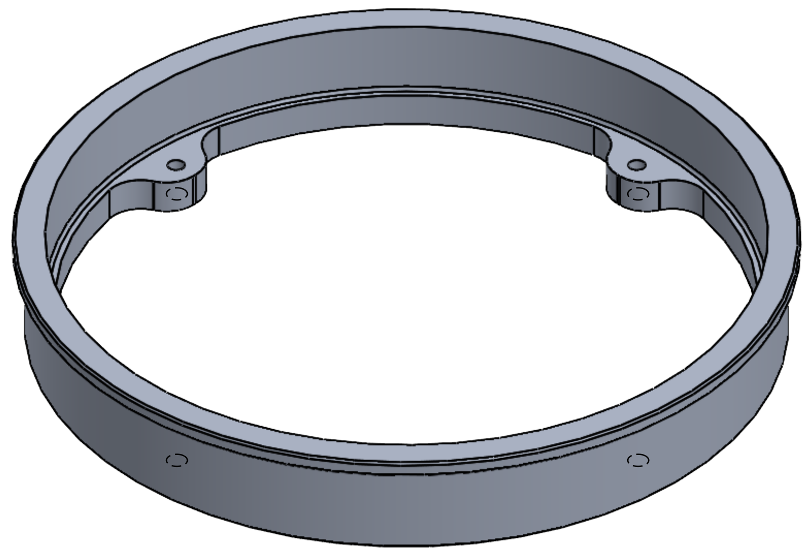
SIZE	DWG. NO.	REV
A	U22-1-4-000	

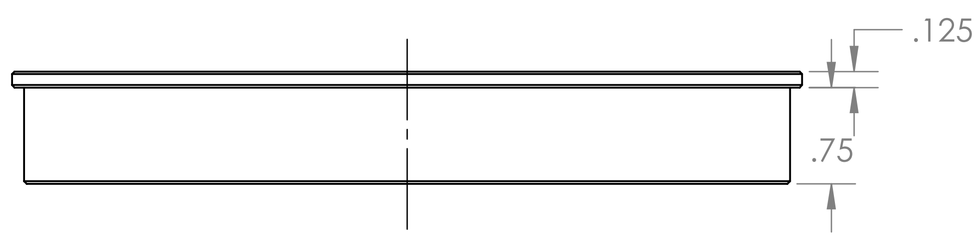
SCALE: 2:3 WEIGHT: SHEET 1 OF 1



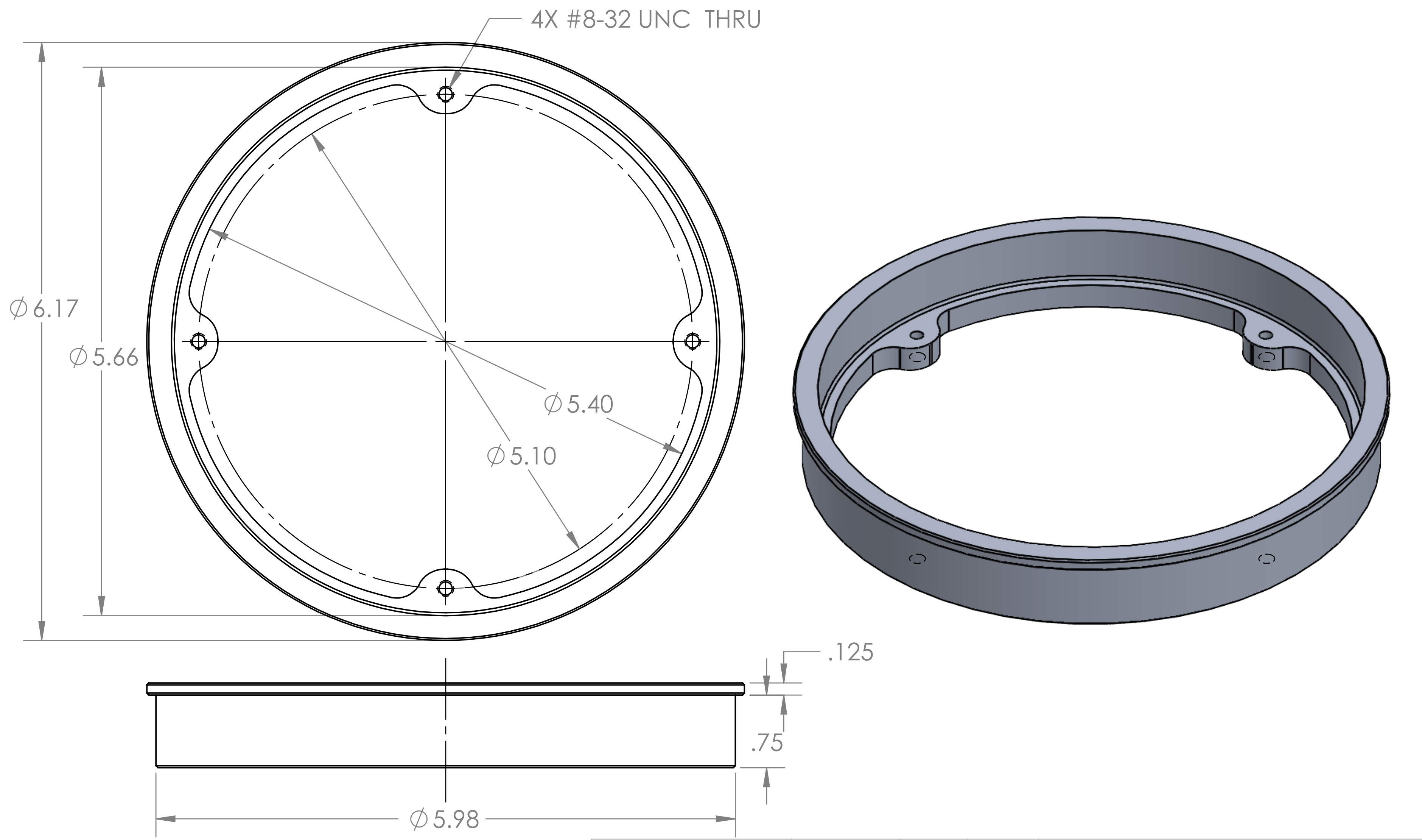
UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	TT	5/10/2022	THREADED COUPLING
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A — DWG. NO. U22-1-4-001 — REV
MATERIAL ALUMINUM 6061				SCALE: 2:3 — WEIGHT: — SHEET 1 OF 1



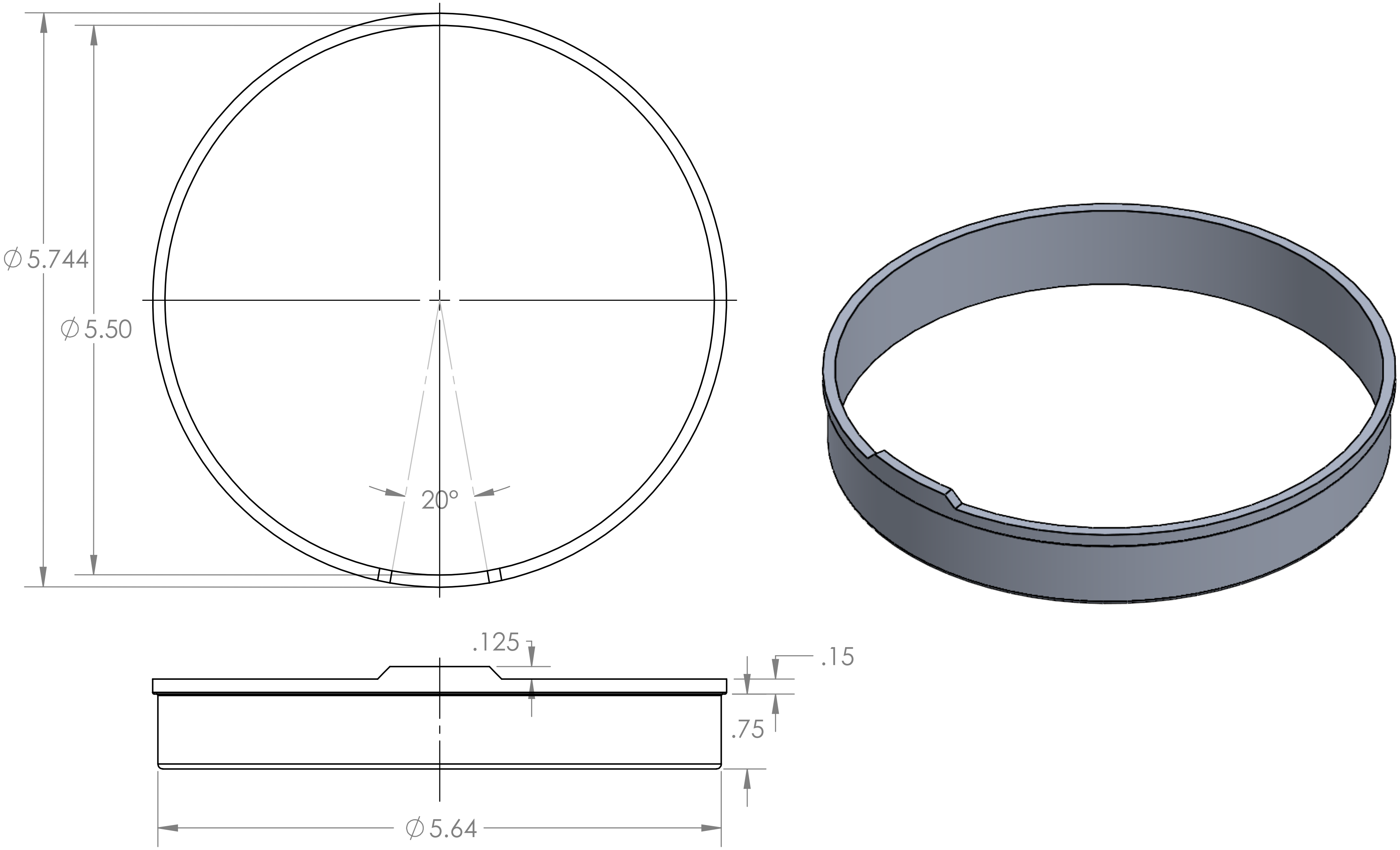




UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	TT	5/10/2022	BARE COUPLING STANDARD CONFIGURATION
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A — DWG. NO. U22-1-4-002 — REV
MATERIAL ALUMINUM 6061				SCALE: 2:3 — WEIGHT: — SHEET 1 OF 2



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE: BARE COUPLING RECOVERY CONFIGURATION
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	TT	5/10/2022	
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A DWG. NO. U22-1-4-002 REV
MATERIAL ALUMINUM 6061				SCALE: 2:3 WEIGHT: SHEET 2 OF 2



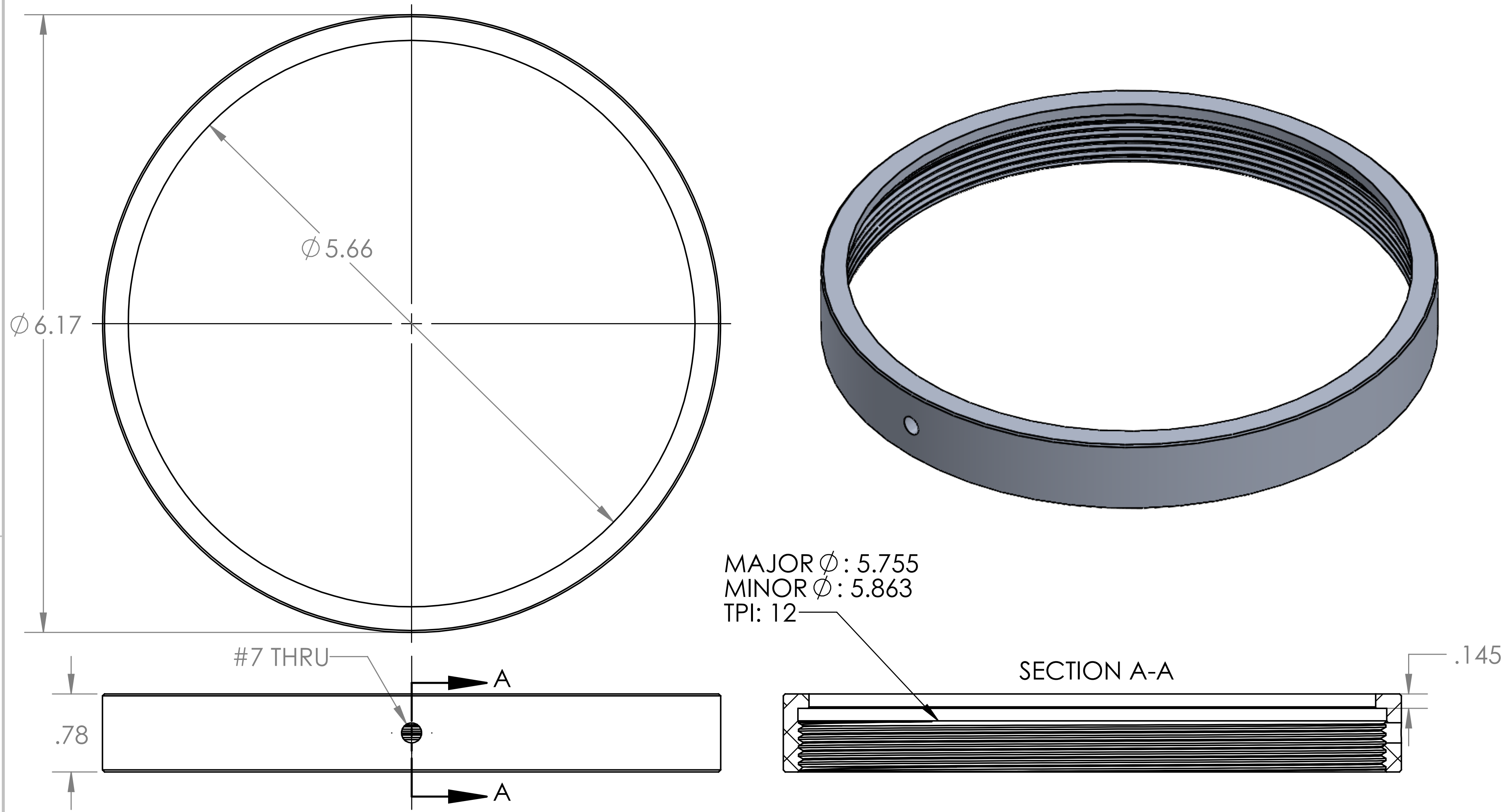
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	TT	5/10/2022
	CHECKED	TMO	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL ALUMINUM 7075			

HPRC WPI AIAA

TITLE:

RETAINING RING

SIZE	DWG. NO.	REV
A	U22-1-4-003	
SCALE: 2:3	WEIGHT:	SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/32
ANGULAR: MACH ± 1 BEND ± 1
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005

INTERPRET GEOMETRIC
TOLERANCING PER: ASME Y14.5

MATERIAL
ALUMINUM 6061

	NAME	DATE
DRAWN	TT	5/10/2022
CHECKED	TMO	5/12/2022

HPRC WPI AIAA

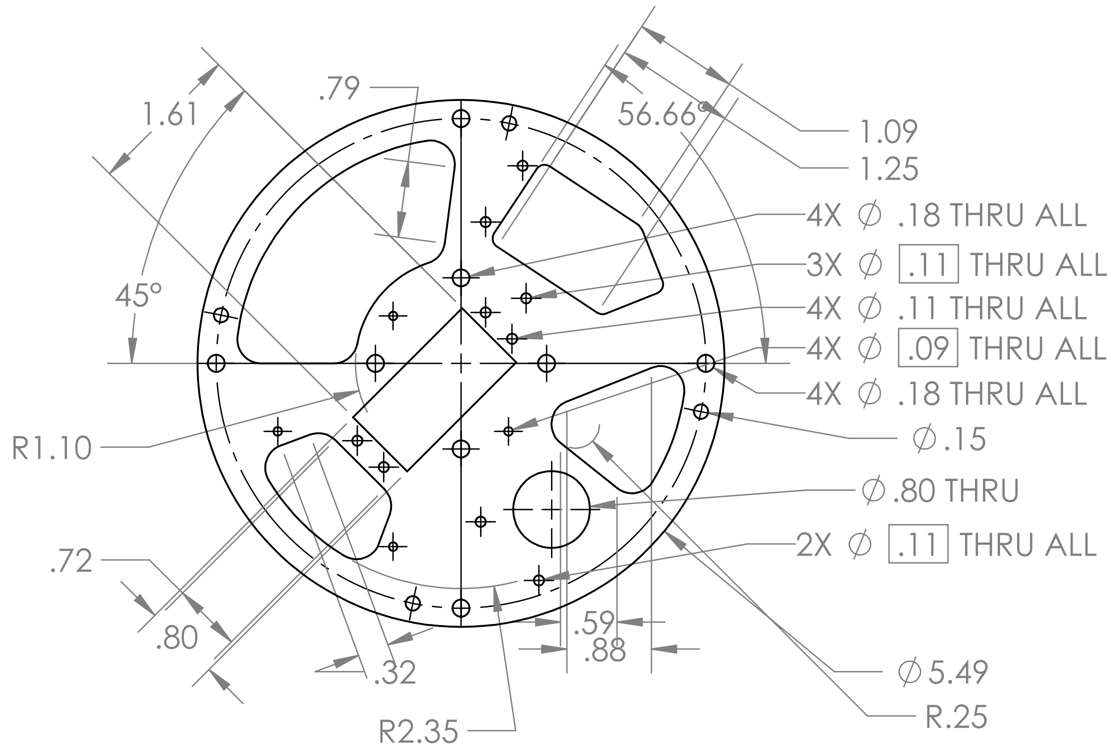
TITLE:
ROTATING NUT

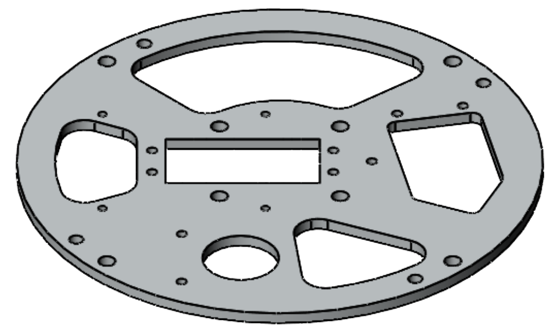
SIZE	DWG. NO.	REV
A	U22-1-4-004	

SCALE: 2:3 WEIGHT: SHEET 1 OF 1

2 1

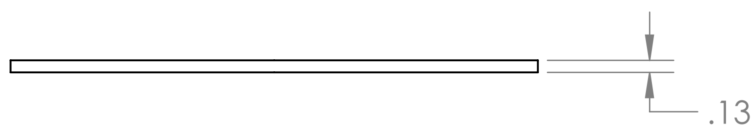
B





B

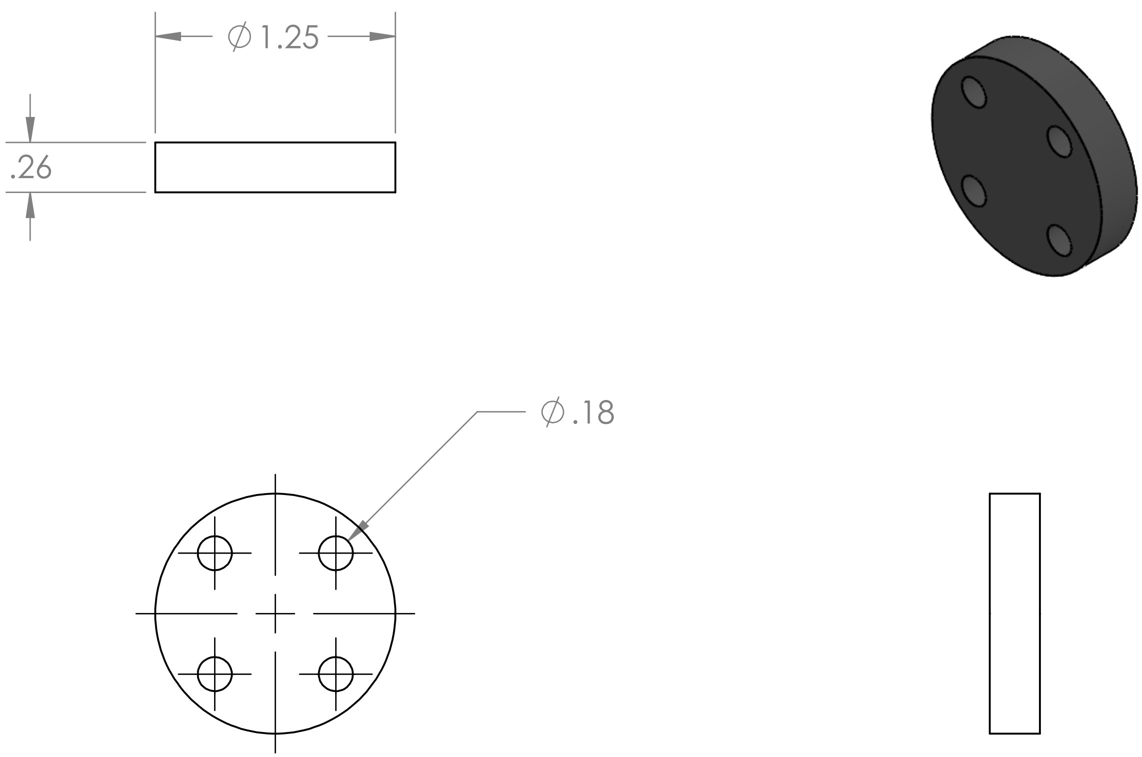
A



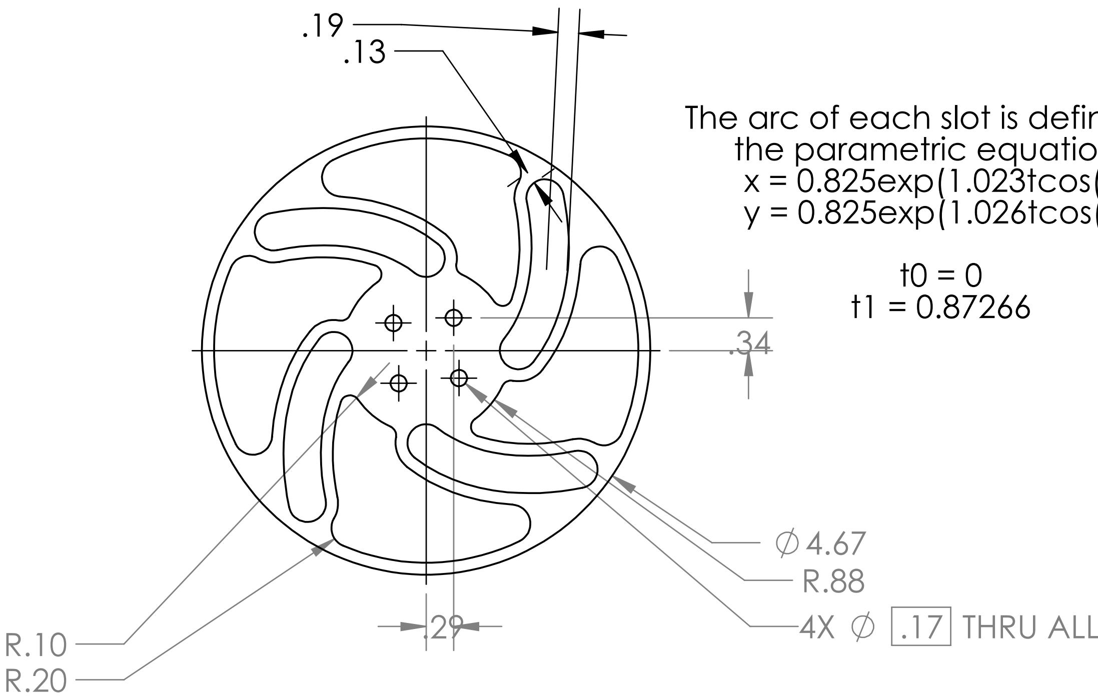
A

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE: COUPLING MOUNTING PLATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	TE	5/10/2022	
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A · DWG. NO. U22-1-5-001 · REV
MATERIAL ALUMINIUM 6061				SCALE: 1:2 · WEIGHT: · SHEET 1 OF 1

2 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE: HUB SEPERATOR
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	JS	5/11/2022	
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A · DWG. NO. U22-1-5-002 · REV
MATERIAL POLYCARBONATE				SCALE: 1:1 · WEIGHT: · SHEET 1 OF 1



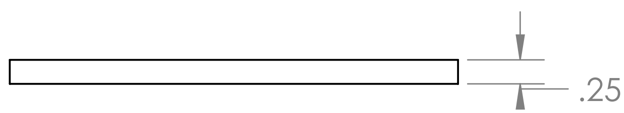
The arc of each slot is defined by the parametric equations:

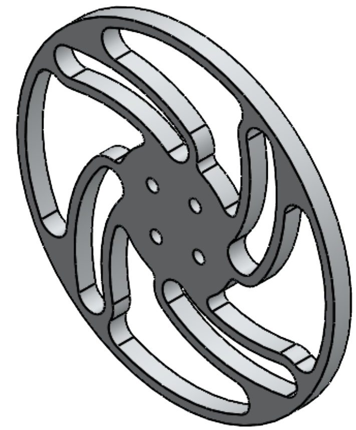
x = 0.825exp(1.023tcos(t))

y = 0.825exp(1.026tcos(t))

t0 = 0

t1 = 0.87266





UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	TE	5/10/2022
	CHECKED	TMO	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL ALUMINIUM 6061			

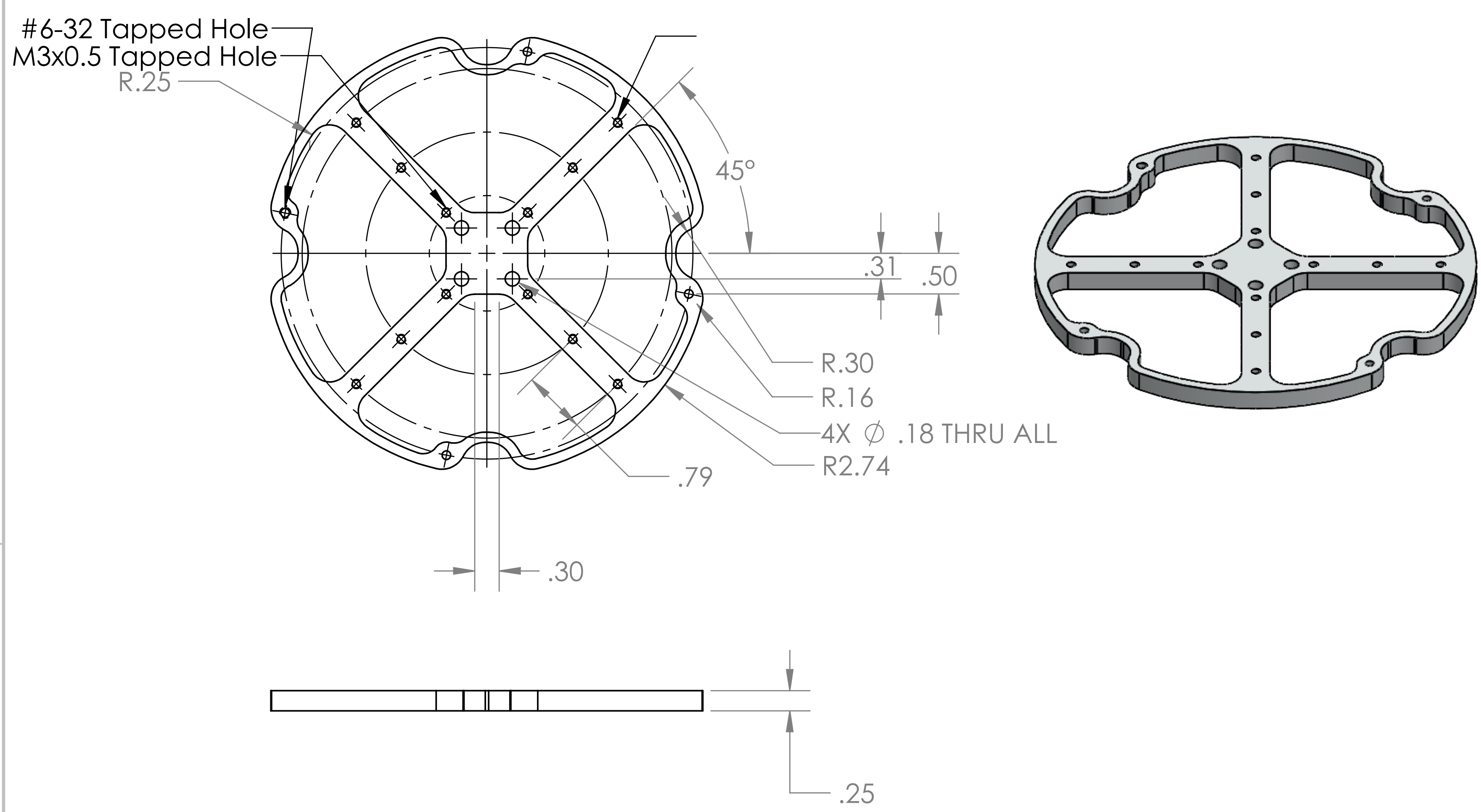
HPRC WPI AIAA

TITLE:

ACTUATOR PLATE

SIZE	DWG. NO.	REV
A	U22-1-5-003	

SCALE: 2:1	WEIGHT:	SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/32
ANGULAR: MACH ± 1 BEND ± 1
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005

INTERPRET GEOMETRIC
TOLERANCING PER: ASME Y14.5

MATERIAL
ALUMINIUM 6061

	NAME	DATE
DRAWN	TE	5/10/2022
CHECKED	TMO	5/12/2022

HPRC WPI AIAA

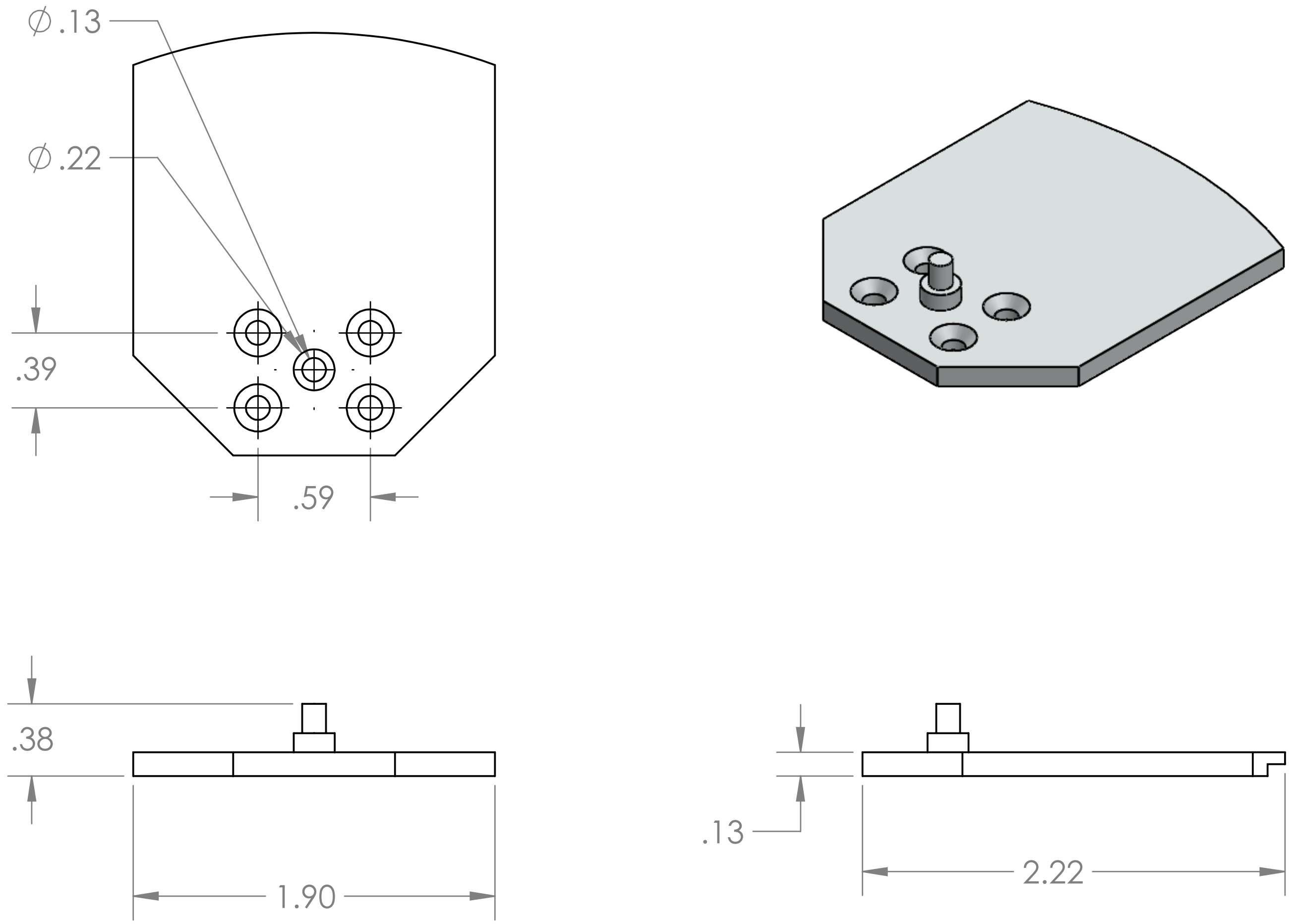
TITLE:
RAIL MOUNTING PLATE

SIZE A | DWG. NO. U22-1-5-004 | REV

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

2 1

B B



A A

UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	JIS	5/11/2022
	CHECKED	TMO	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL AL6061-T6			

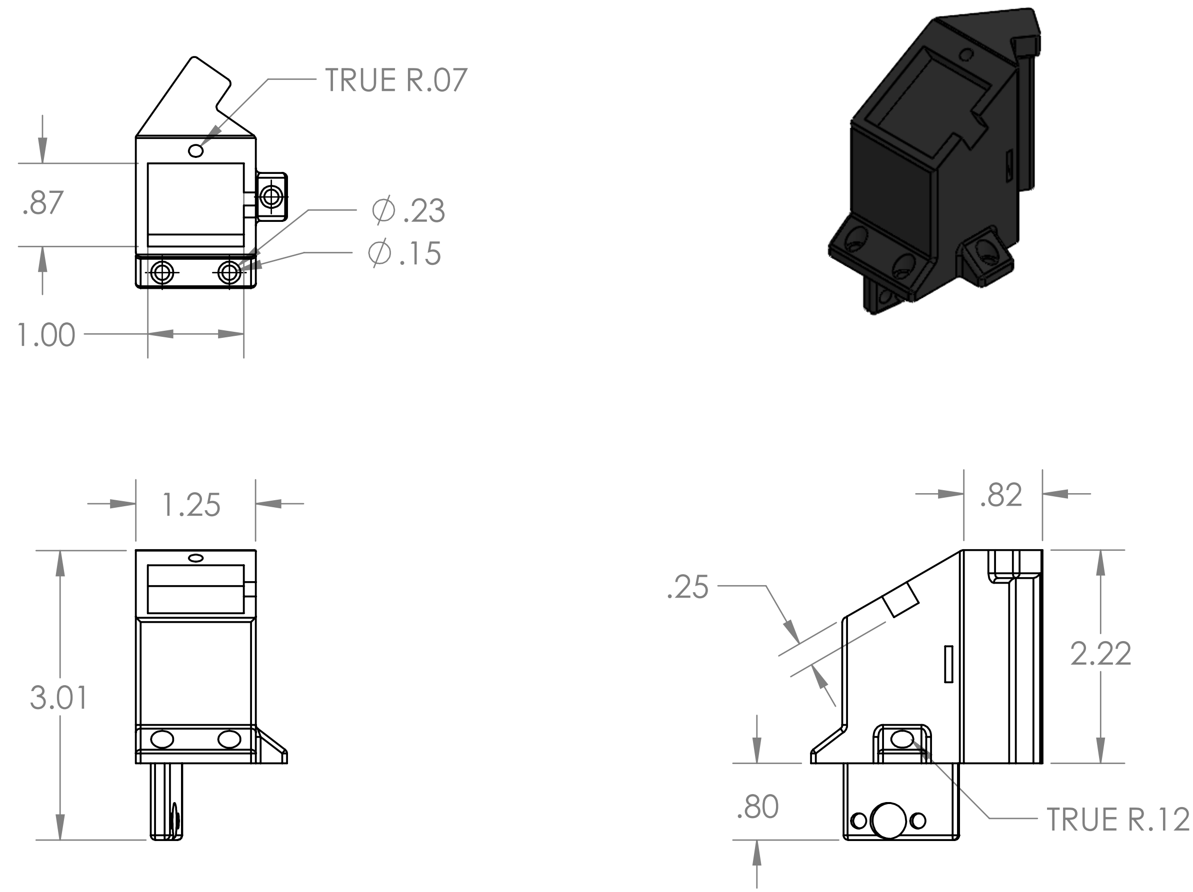
HPRC
WPI AIAA

TITLE:

AIRBRAKE FIN

SIZE	DWG. NO.	REV
A	U22-1-5-005	
SCALE: 1:1	WEIGHT:	SHEET 1 OF 1

2 1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/32
ANGULAR: MACH ± 1 BEND ± 1
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5

MATERIAL
POLYCARBONATE

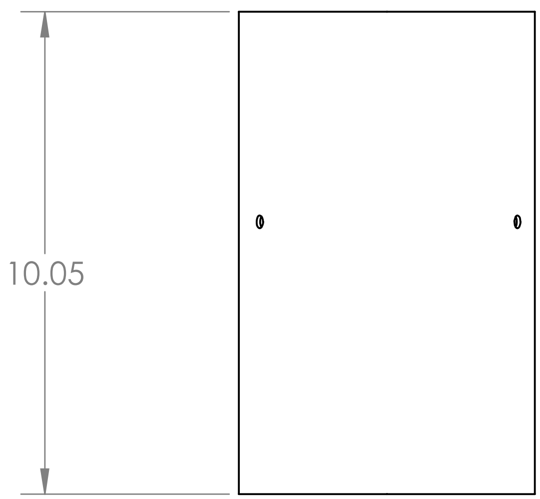
	NAME	DATE
DRAWN	js	5/10/2022
CHECKED	TMO	5/12/2022

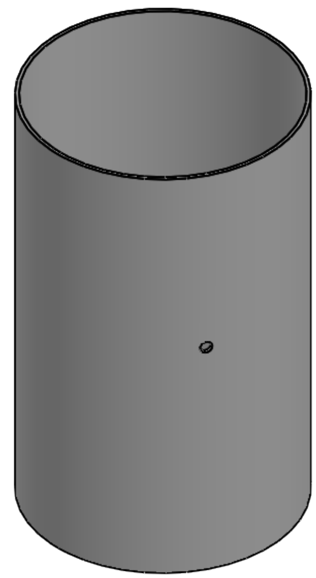
HPRC WPI AIAA

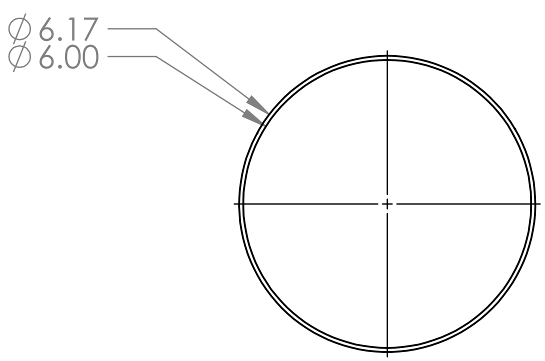
TITLE:
BATTERY GPS MOUNT

SIZE	DWG. NO.	REV
A	U22-1-5-006	

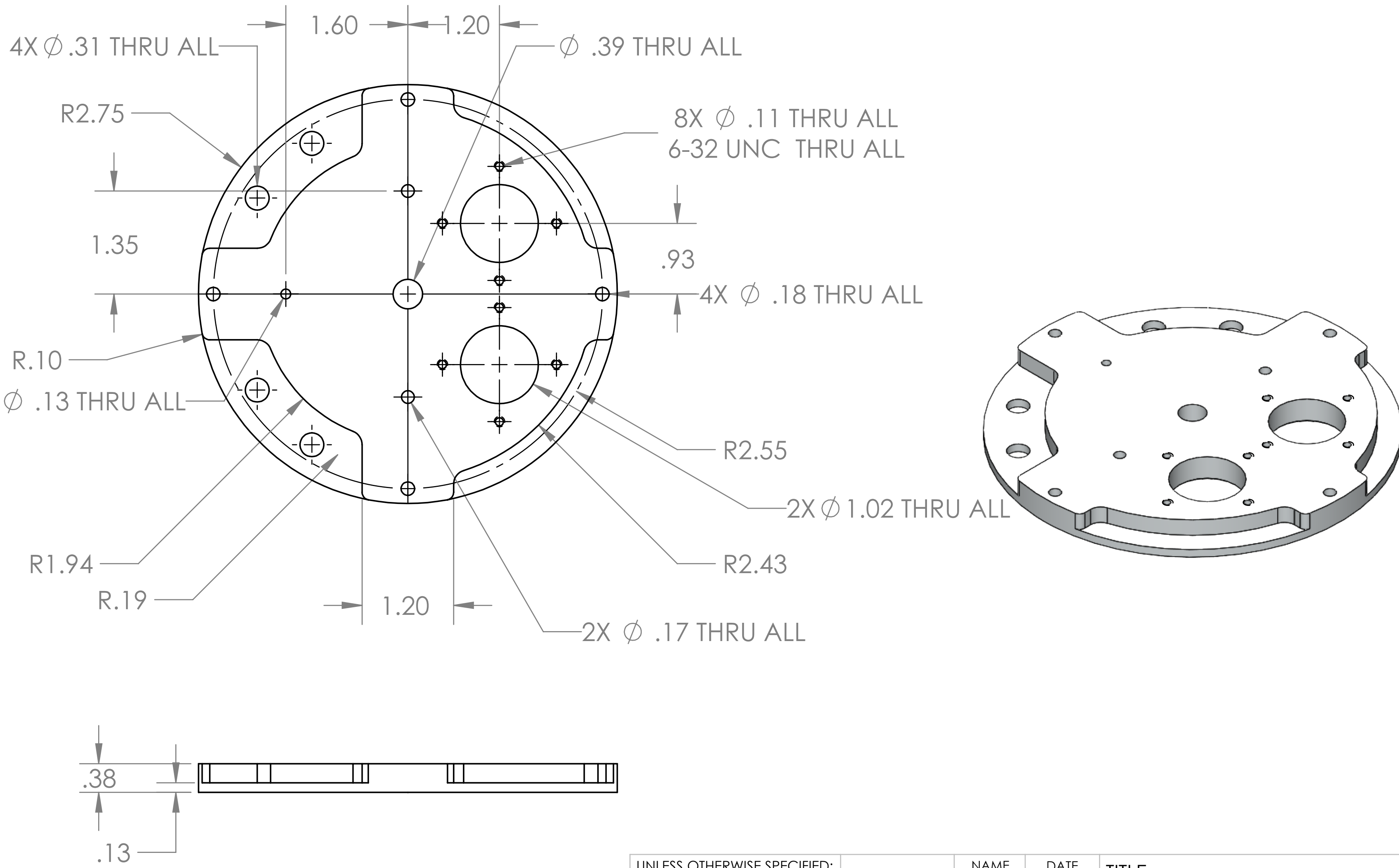
SCALE: 1:2 WEIGHT: SHEET 1 OF 1







UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	NJ	5/10/2022	ELECTRONICS BAY BODY TUBE
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A DWG. NO. U22-1-6-001 REV
MATERIAL G12 Fiberglass				SCALE: 1:4 WEIGHT: SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	JHL	5/11/2022
	CHECKED	TMO	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL Aluminum 6061-T6(SS)			

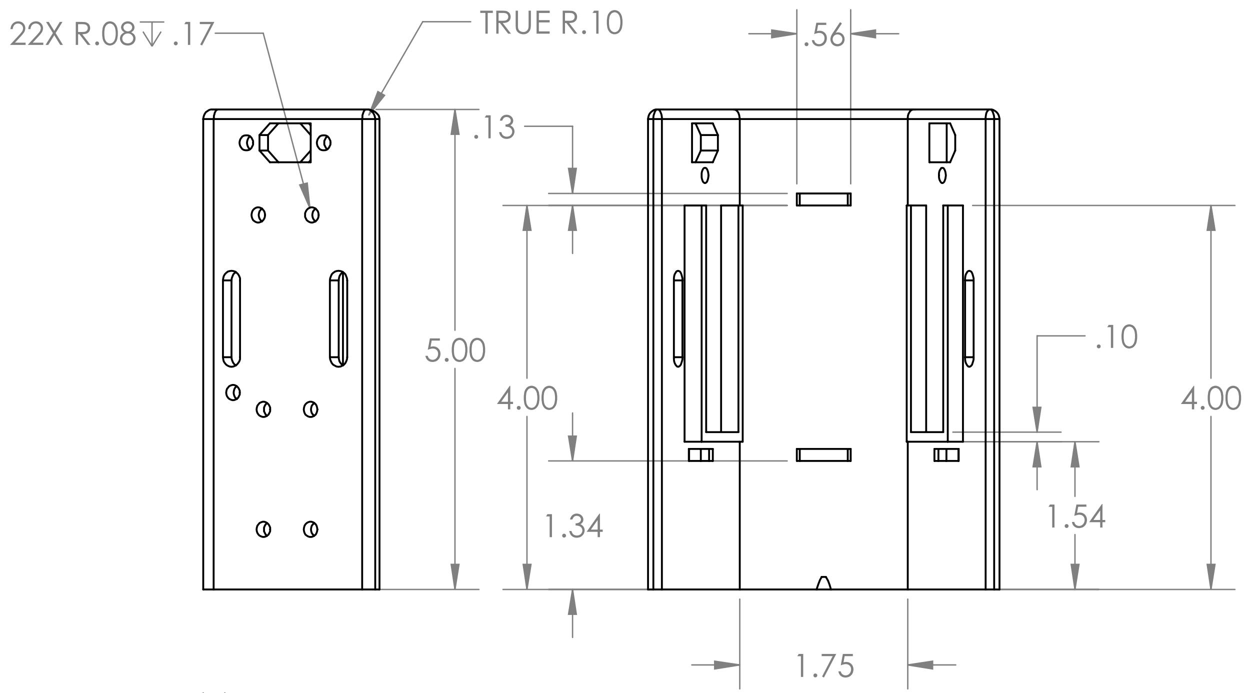
HPRC WPI AIAA

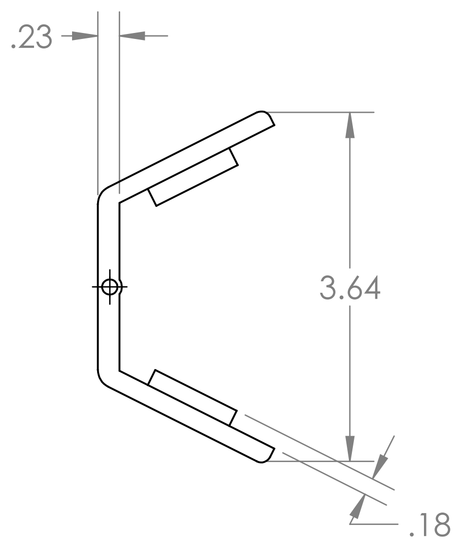
TITLE:

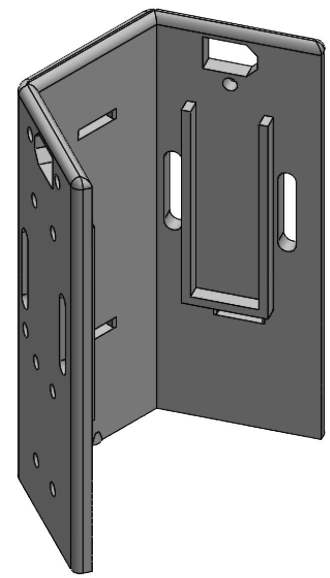
Electronics Bay Coupling Plate

SIZE	DWG. NO.	REV
A	U22-1-6-101	

SCALE: 1:2 WEIGHT: 0.65 lbs SHEET 1 OF 1







UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/32
ANGULAR: MACH ± 1 BEND ± 1
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5

MATERIAL
Polycarbonate

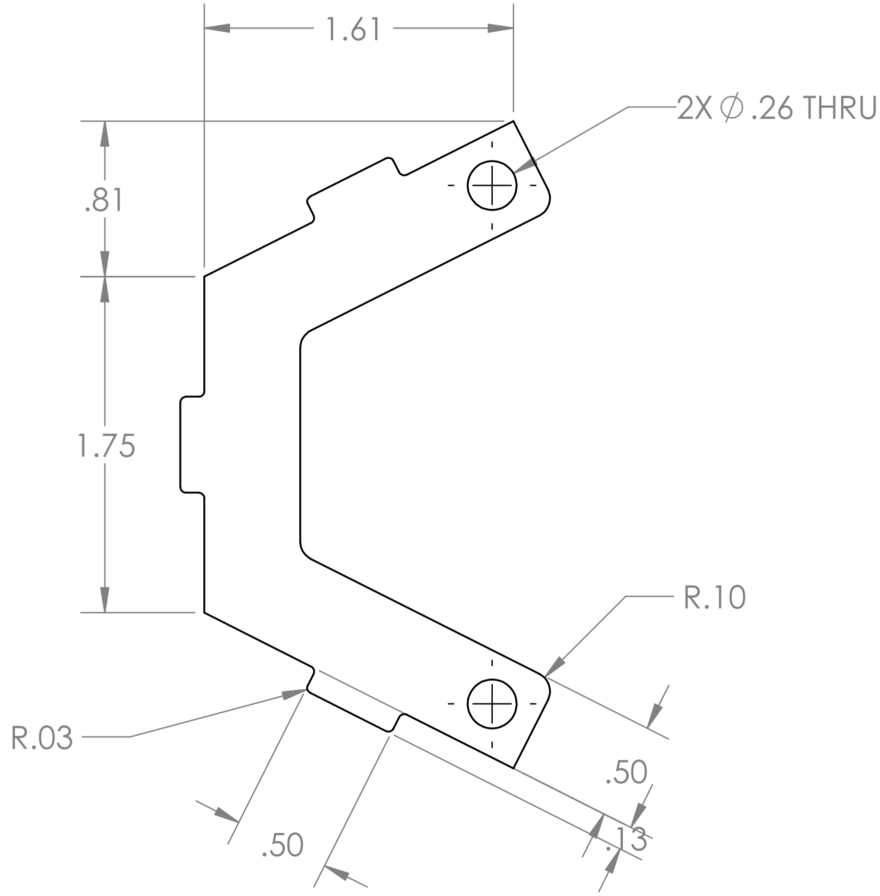
	NAME	DATE
DRAWN	JHL	5/12/2022
CHECKED	TMO	5/12/2022

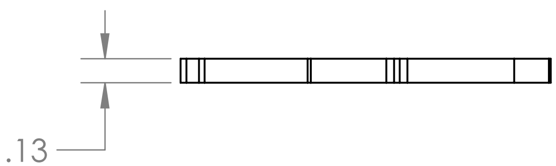
HPRC WPI AIAA

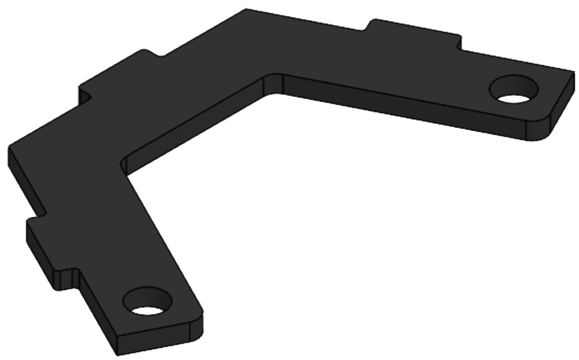
TITLE:
ELECTRONICS SLED

SIZE A | DWG. NO. U22-1-6-201 | REV

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



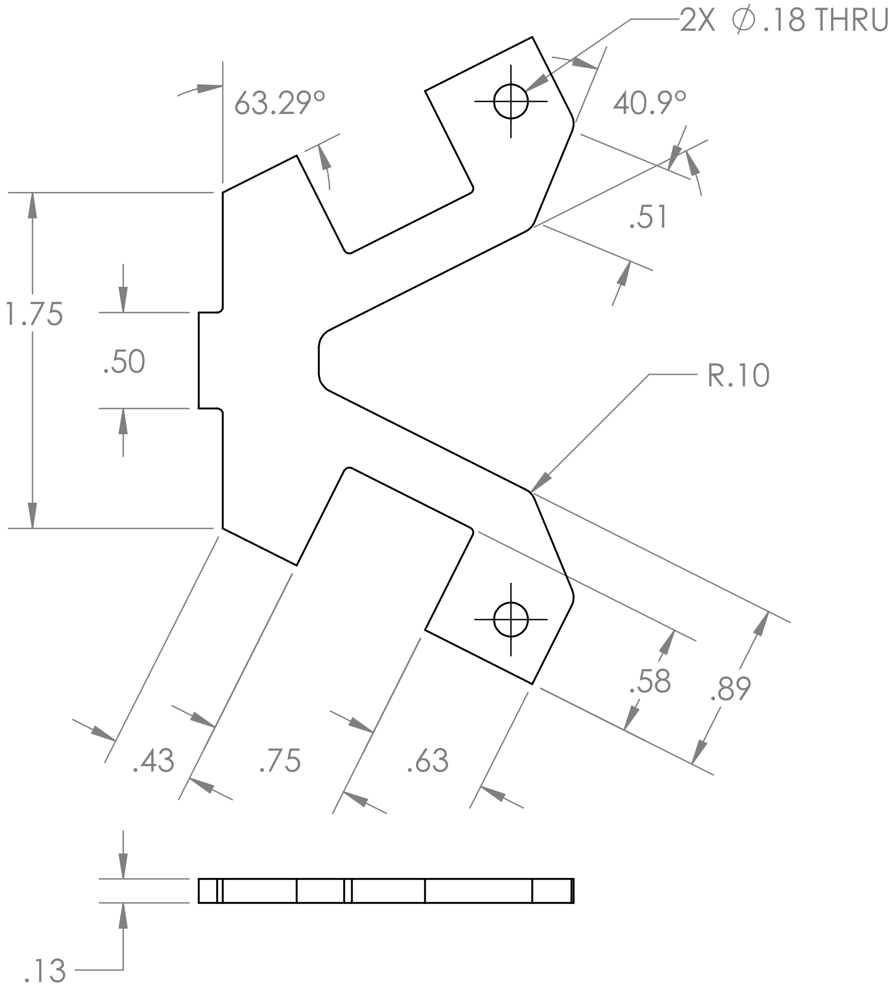


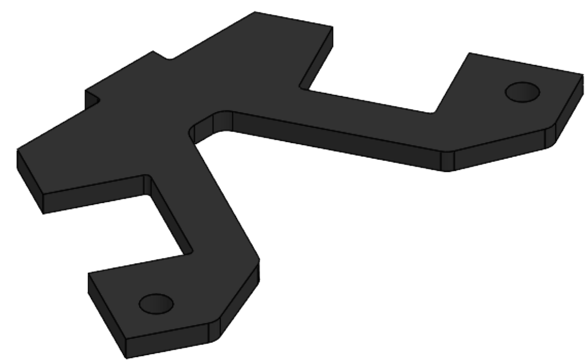


UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	JHL	5/11/2022	TOP SLED SUPPORT
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A DWG. NO. U22-1-6-202 REV
MATERIAL G10 Fiberglass				SCALE: 1:1 WEIGHT: 0.02 lbs SHEET 1 OF 1

2 1

B B

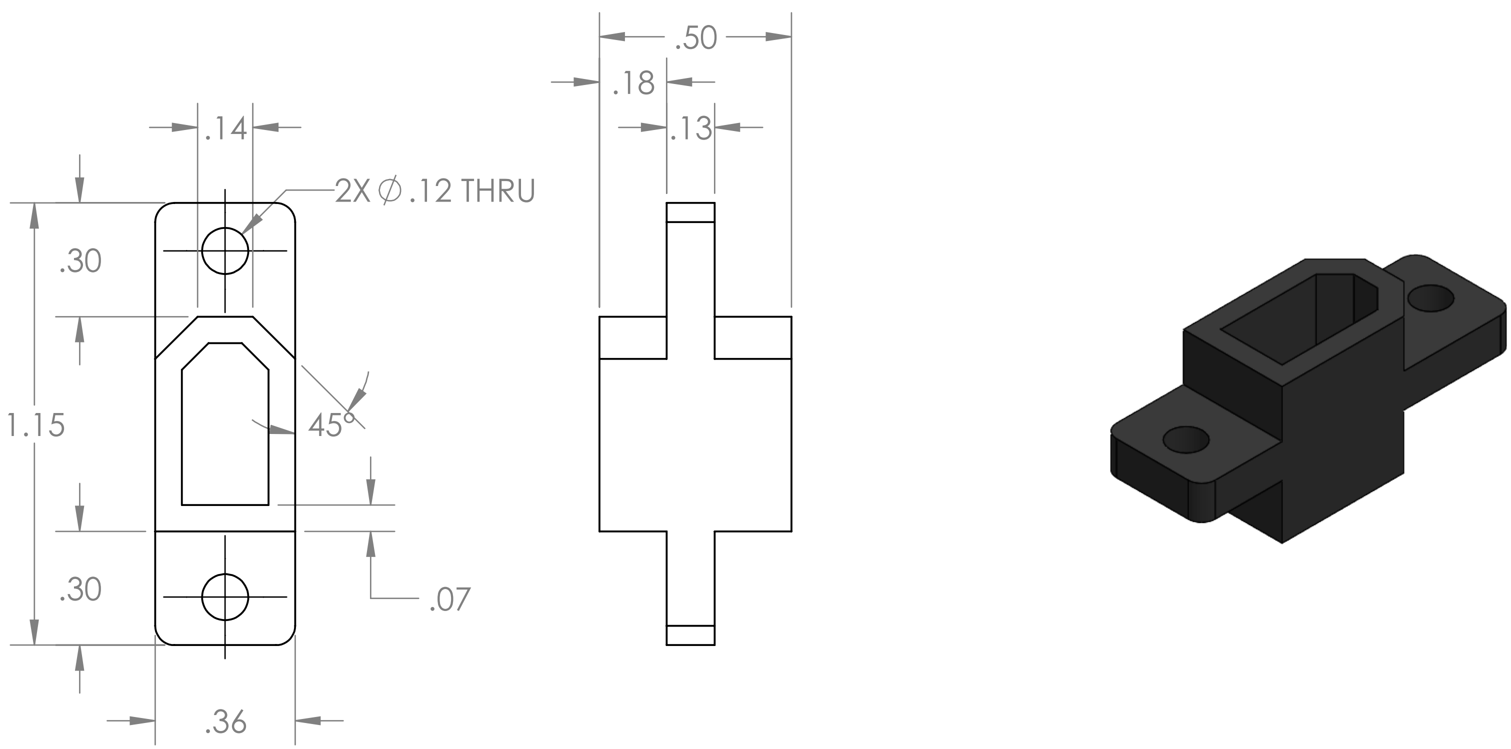




A A

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE: BOTTOM SLED SUPPORT
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	JHL	5/11/2022	
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A · DWG. NO. U22-1-6-203 · REV
MATERIAL G10 Fiberglass				SCALE: 1:1 · WEIGHT: 0.02 lbs · SHEET 1 OF 1

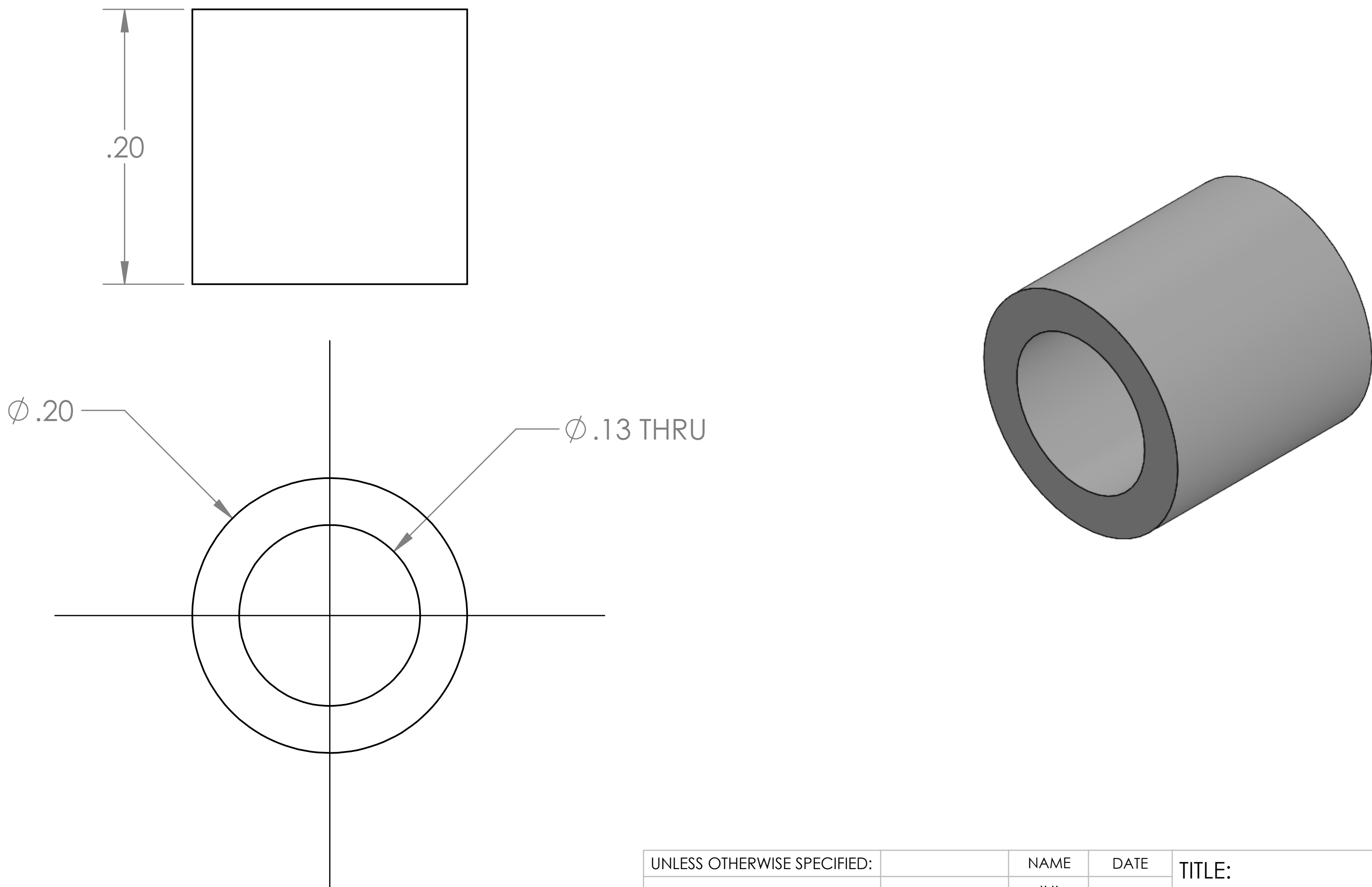
2 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE: XT30 MOUNT	
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	JHL	5/11/2022		
	CHECKED	TMO	5/12/2022		
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A	DWG. NO. U22-1-6-205
MATERIAL Polycarbonate				REV	
				SCALE: 2:1 WEIGHT:	SHEET 1 OF 1

2 1

B B



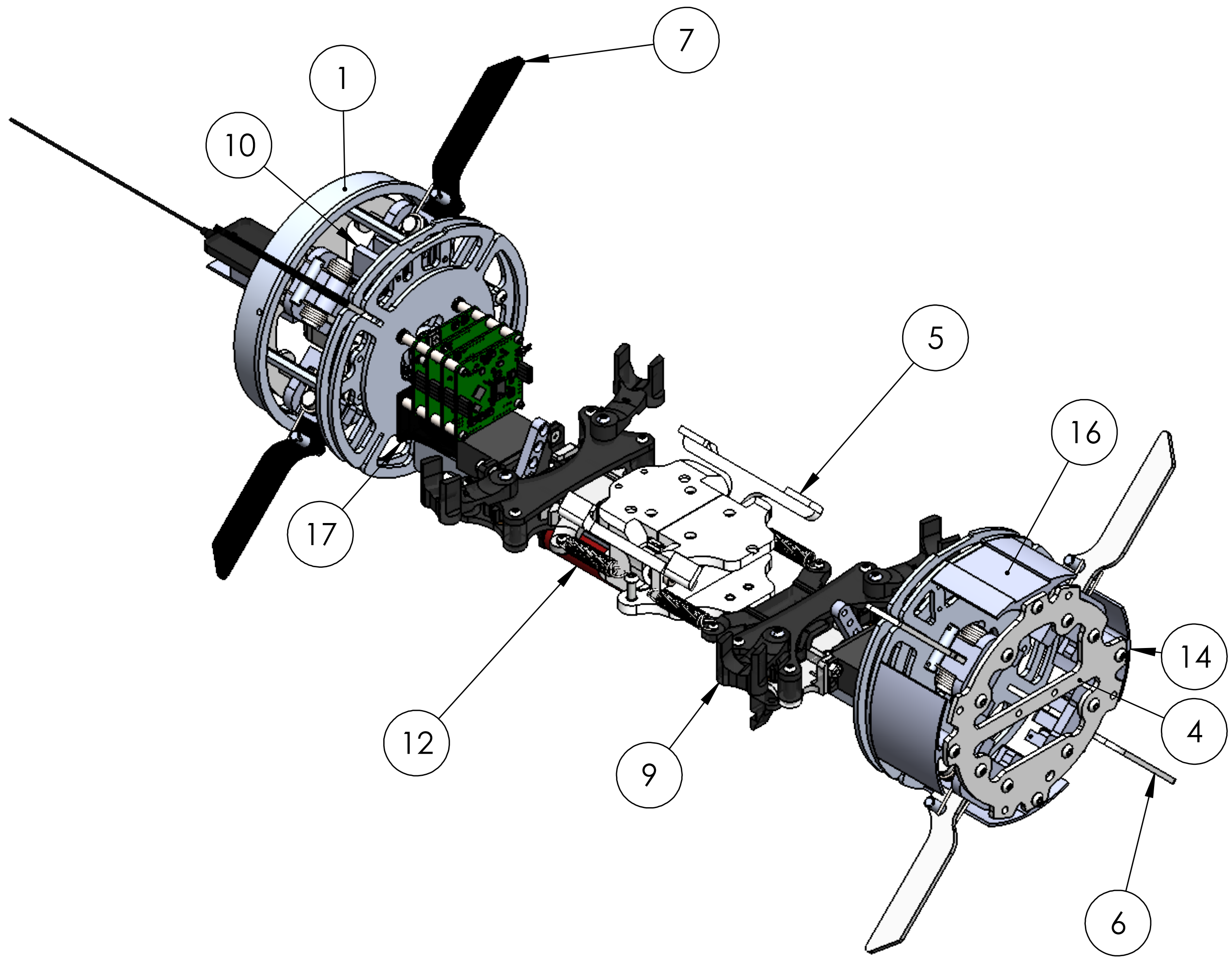
A A

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	JHL	5/11/2022	BATTERY COVER
	CHECKED	TMO	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A DWG. NO. U22-1-6-206 REV
MATERIAL Polycarbonate				SCALE: 8:1 WEIGHT: SHEET 1 OF 1

2 1

2 1

ITEM NO.	PART NUMBER	QTY.
1	U22-2-1-100 (NOSECONE STABILIZATION ASSEMBLY)	1
2	U22-2-1-001 (PAYLOAD SPINE)	1
3	U22-2-1-002 (PAYLOAD SPINE BRACKET)	4
4	U22-2-1-200 (COUPLER STABILIZATION ASSEMBLY)	1
5	U22-2-1-400 (QUAD GRIPPER ASSEMBLY)	1
6	U22-2-1-300 (STABILIZATION ASSEMBLY)	4
7	U22-2-1-300 (STABILIZATION ASSEMBLY)	3
8	U22-2-1-300 (STABILIZATION ASSEMBLY)	1
9	U22-2-1-500 (ARM DEPLOYMENT ASSEMBLY)	2
10	U22-2-2-300 (PARACHUTE RELEASE ASSEMBLY)	1
11	U22-2-1-003 (BATTERY MOUNT)	6
12	18650 Battery	3
13	7712K111_Battery Holder(1)	3
14	Stabilization Sleve 2	3
15	U22-2-1-004 (BACK 90 DEGREE BRACKET)	1
16	U22-2-1-309 (STABLIZATION SLEEVE CUTOUT)	1
17	U22-2-1-005 (FRONT 90 DEGREE BRACKET)	1
18	#4-40x0.250	4
19	#8-32x0.500	8



B B

A A

UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL			

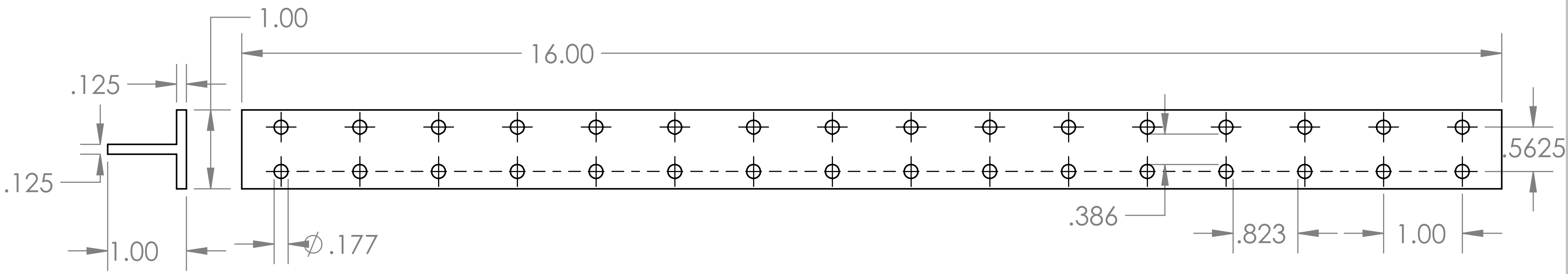
HPRC WPI AIAA

TITLE: Retention Assembly

SIZE A | DWG. NO. U22-2-1-000 | REV

SCALE: 1:4 | WEIGHT: | SHEET 1 OF 1

2 1



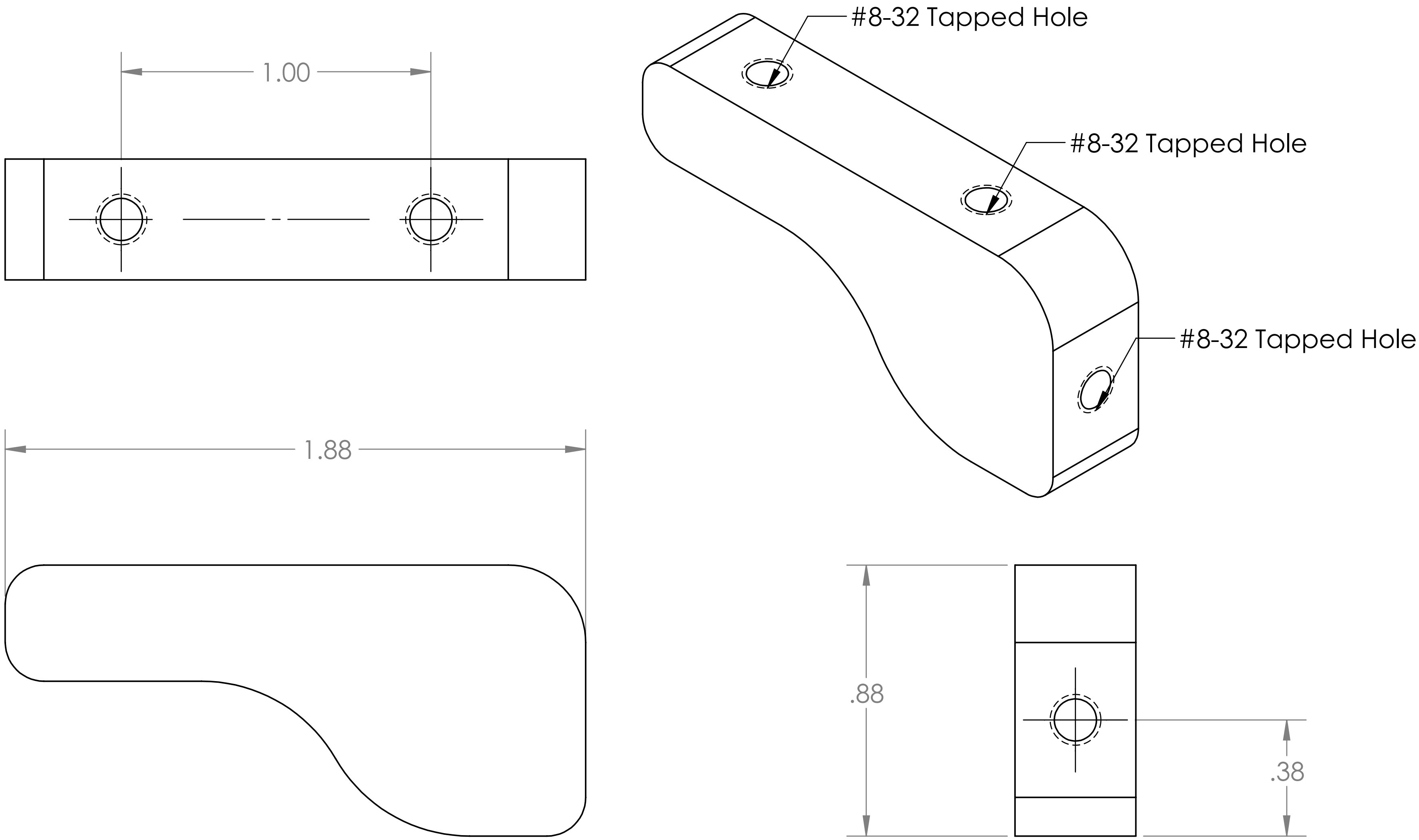
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL 6061 Aluminum			

HPRC
WPI AIAA

TITLE:
Payload Spine

SIZE	DWG. NO.	REV
A	U22-2-1-001	

SCALE: 1:6 WEIGHT: SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL **INSERT MATERIAL**			

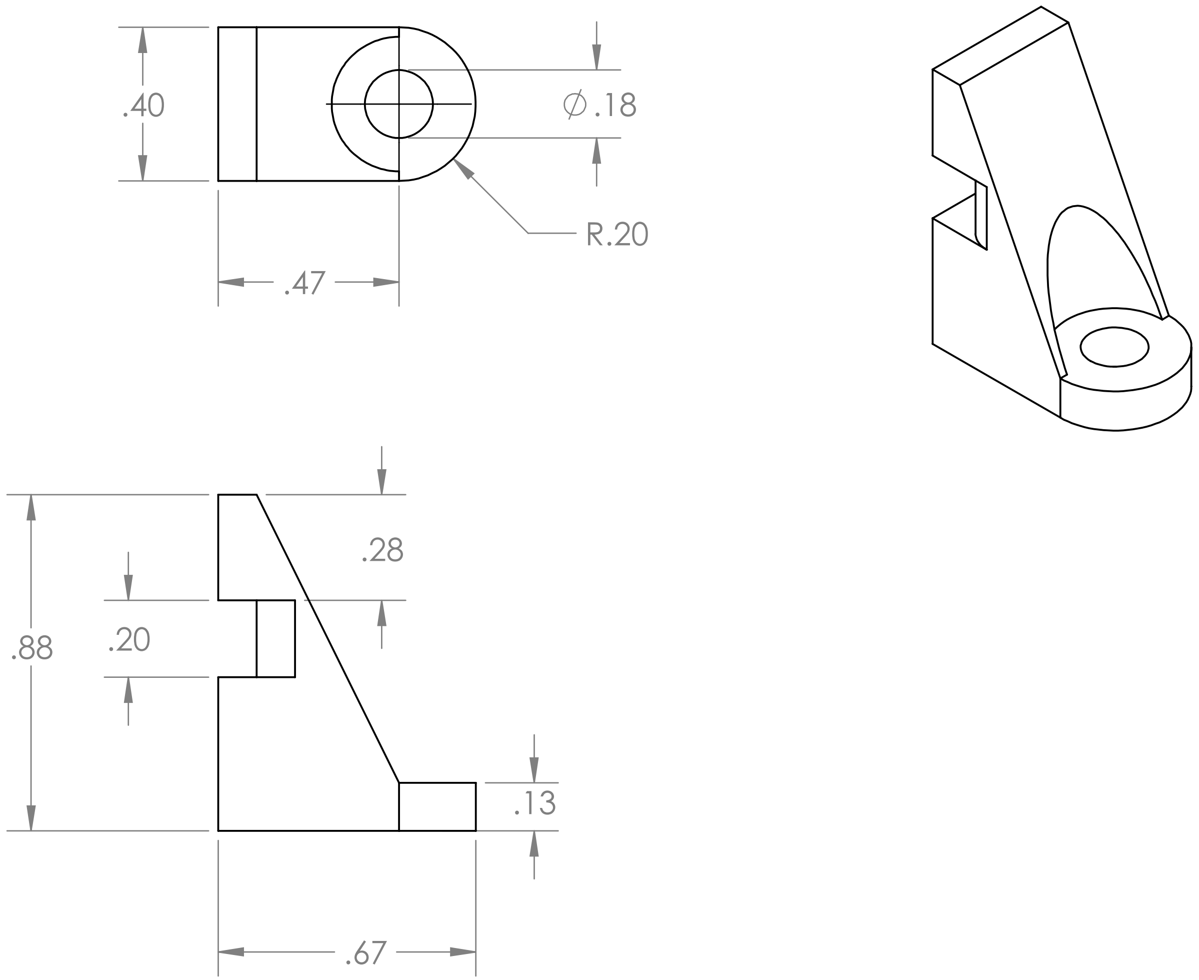
HPRC WPI AIAA

TITLE:

Payload Spine Bracket

SIZE	DWG. NO.	REV
A	U22-2-1-002	

SCALE: 2:1 WEIGHT: SHEET 1 OF 1



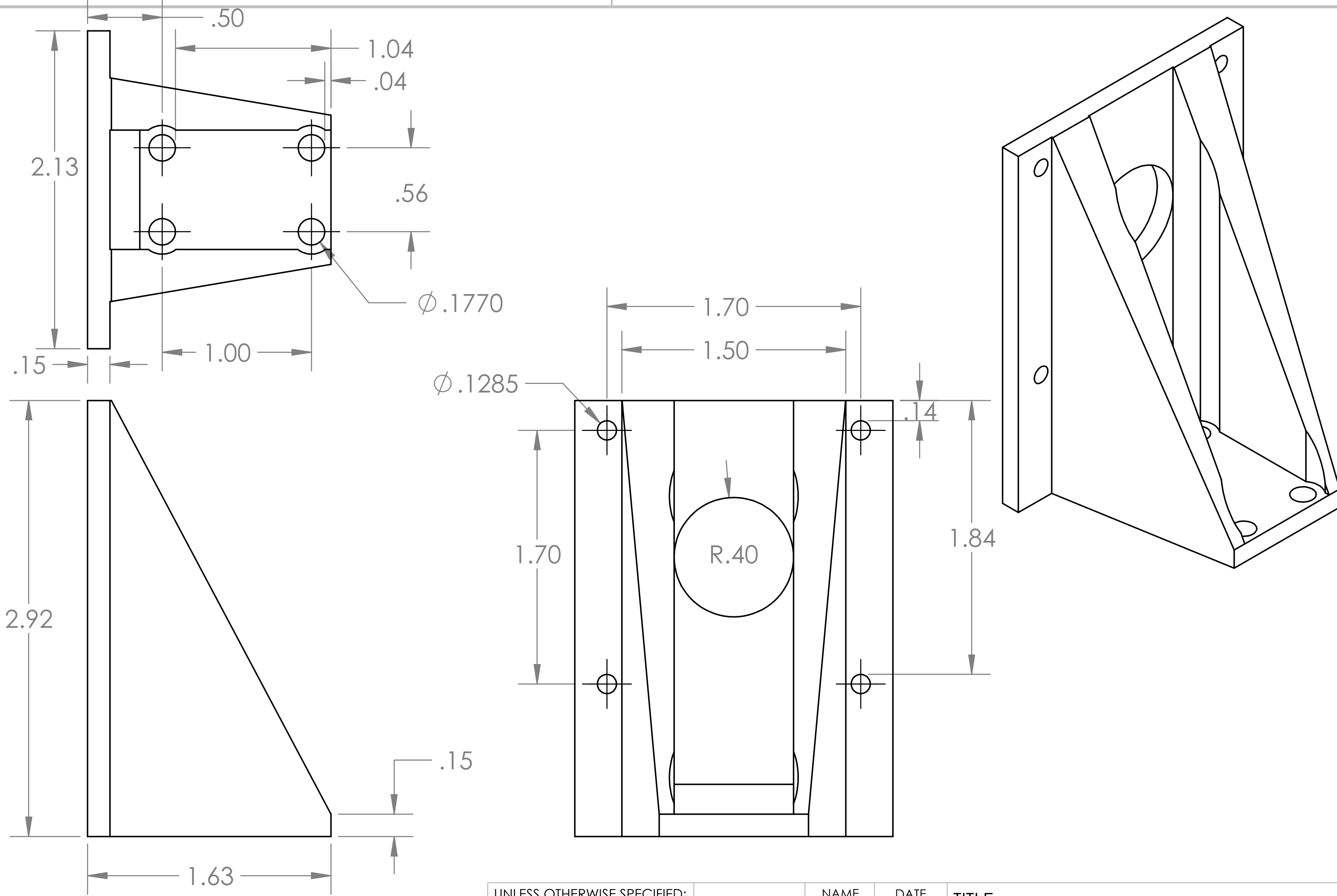
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA		
MATERIAL Polycarbonate			

TITLE:

Battery Mount

SIZE	DWG. NO.	REV
A	U22-2-1-003	

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



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/32
ANGULAR: MACH ± 1 BEND ± 1
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5

MATERIAL
Polycarbonate

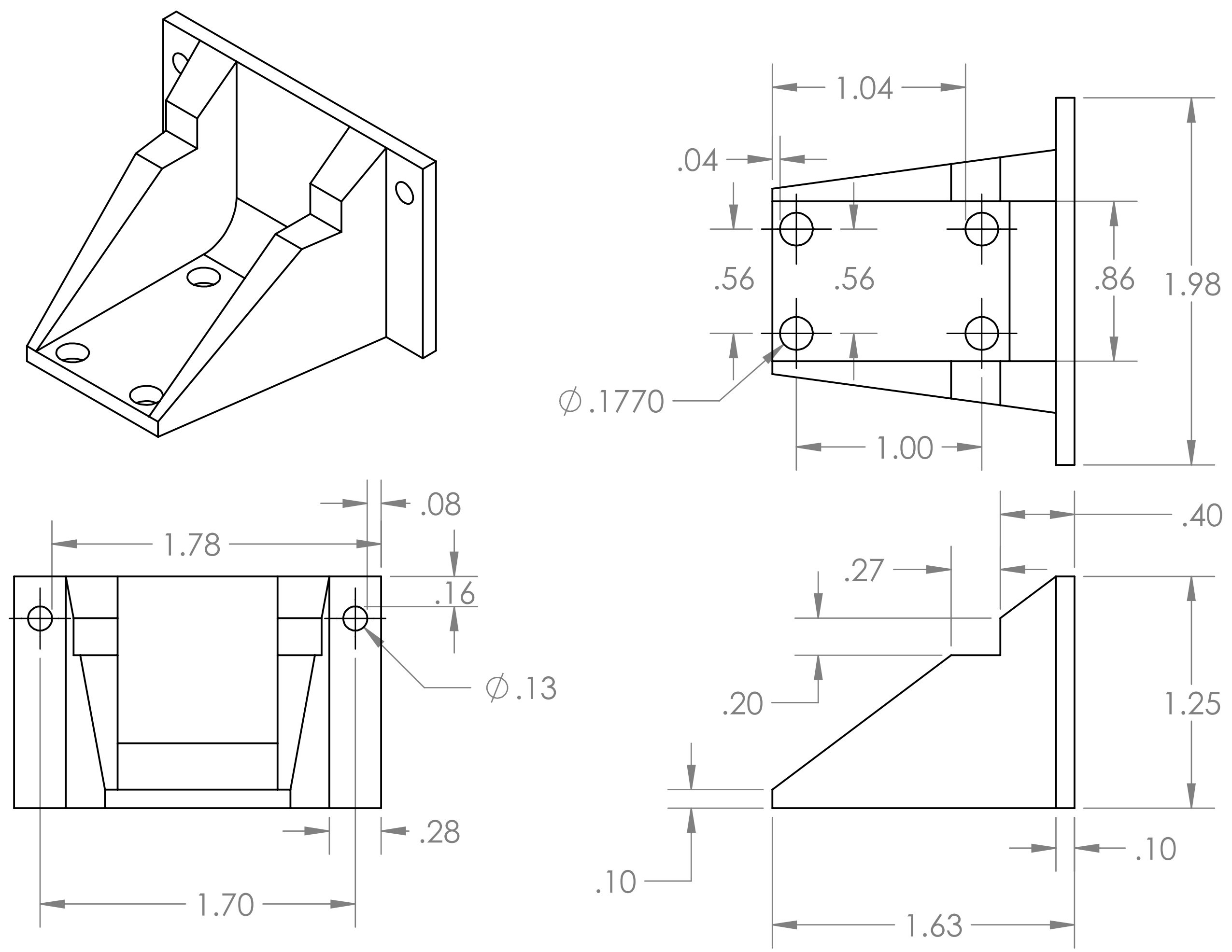
	NAME	DATE
DRAWN	CB	5/10/2022
CHECKED	JR	5/12/2022

HPRC WPI AIAA

TITLE:
Back 90 Degree Bracket

SIZE A | DWG. NO. U22-2-1-004 | REV

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



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/32
ANGULAR: MACH ± 1 BEND ± 1
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5

MATERIAL
Polycarbonate

	NAME	DATE
DRAWN	CB	5/10/2022
CHECKED	JR	5/12/2022

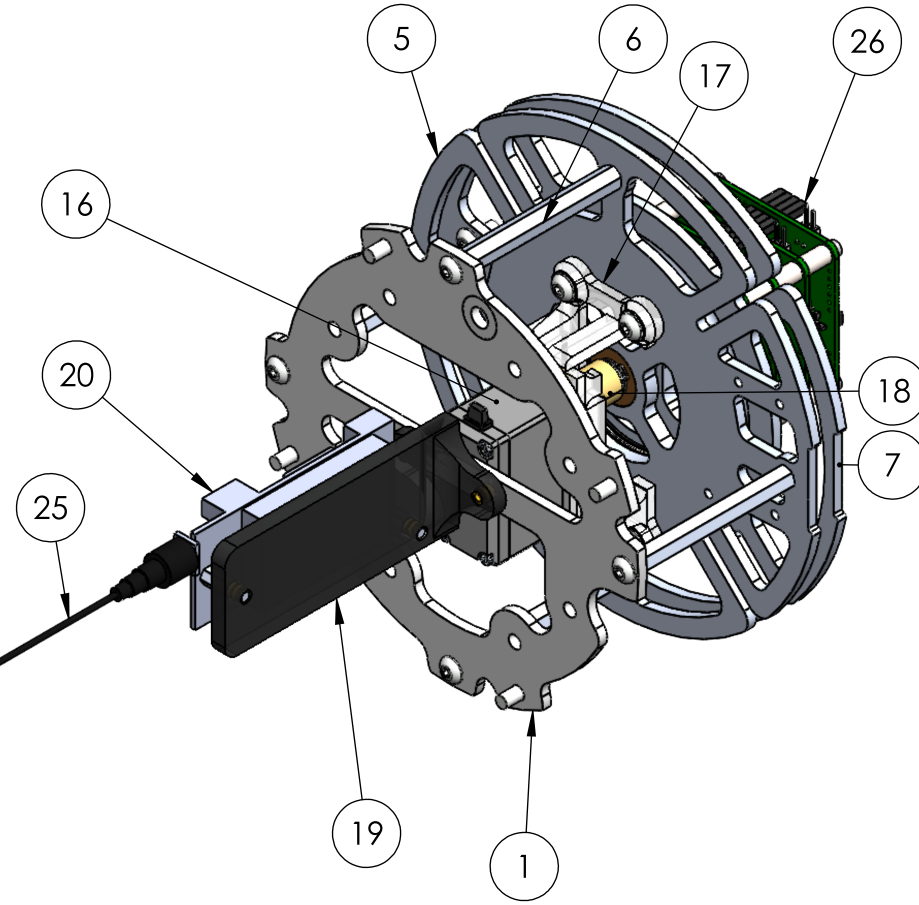
HPRC WPI AIAA

TITLE:
Front 90 Degree Bracket

SIZE	DWG. NO.	REV
A	U22-2-1-005	

SCALE: 1:1 WEIGHT: SHEET 1 OF 1

ITEM NO.	PART NUMBER	QTY.
1	U22-2-1-101 (NOSECONE FORE BULKHEAD)	1
2	#8-32x0.375	18
3	#4-40x0.250	2
4	#6-32x0.250	4
5	U22-2-1-102 (NOSECONE AFT FIXED BULKHEAD)	1
6	91780A043	4
7	U22-2-1-103 (NOSECONE AFT ROTATING BULKHEAD)	1
8	5909K56	2
9	5909K43	1
10	U22-2-1-104 (NOSECONE ROTATION SHAFT)	1
11	6338K414	1
12	98410A117	1
13	#8-32	1
14	#8	1
15	#4	6
16	2000-0025-0004 (GoBILDA Super Speed)	1
17	U22-2-1-105 (NOSECONE SERVO MOUNT)	1
18	4010-0025-0250 assembly	1
19	U22-2-1-106 (NOSECONE PCB BRACKET)	1
20	BigRedBeeGPS	1
21	#4-40x0.375	2
22	#4-40x0.375	2
23	#4-40x0.170	4
24	#6-32x0.150	4
25	BigRedBeeGPSAntenna	1
26	U22-1-5-100 (AVIONICS ASSEMBLY)	1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/32
ANGULAR: MACH ± 1 BEND ± 1
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5

MATERIAL

	NAME	DATE
DRAWN	CB	5/10/2022
CHECKED	JR	5/12/2022

HPRC WPI AIAA

TITLE:

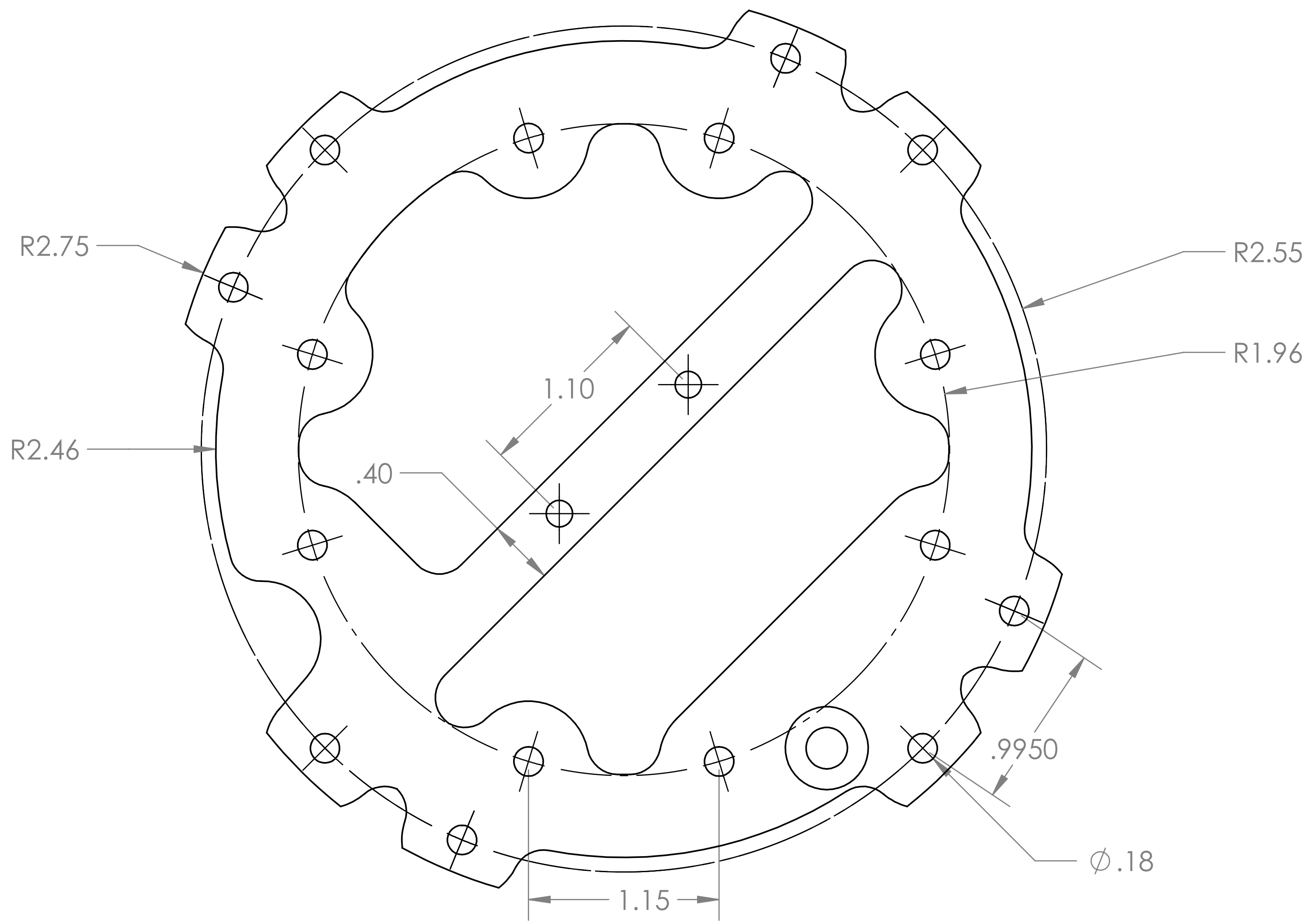
Nosecone Stabilization Assembly

SIZE A | DWG. NO. U22-2-1-100 | REV

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

2 1

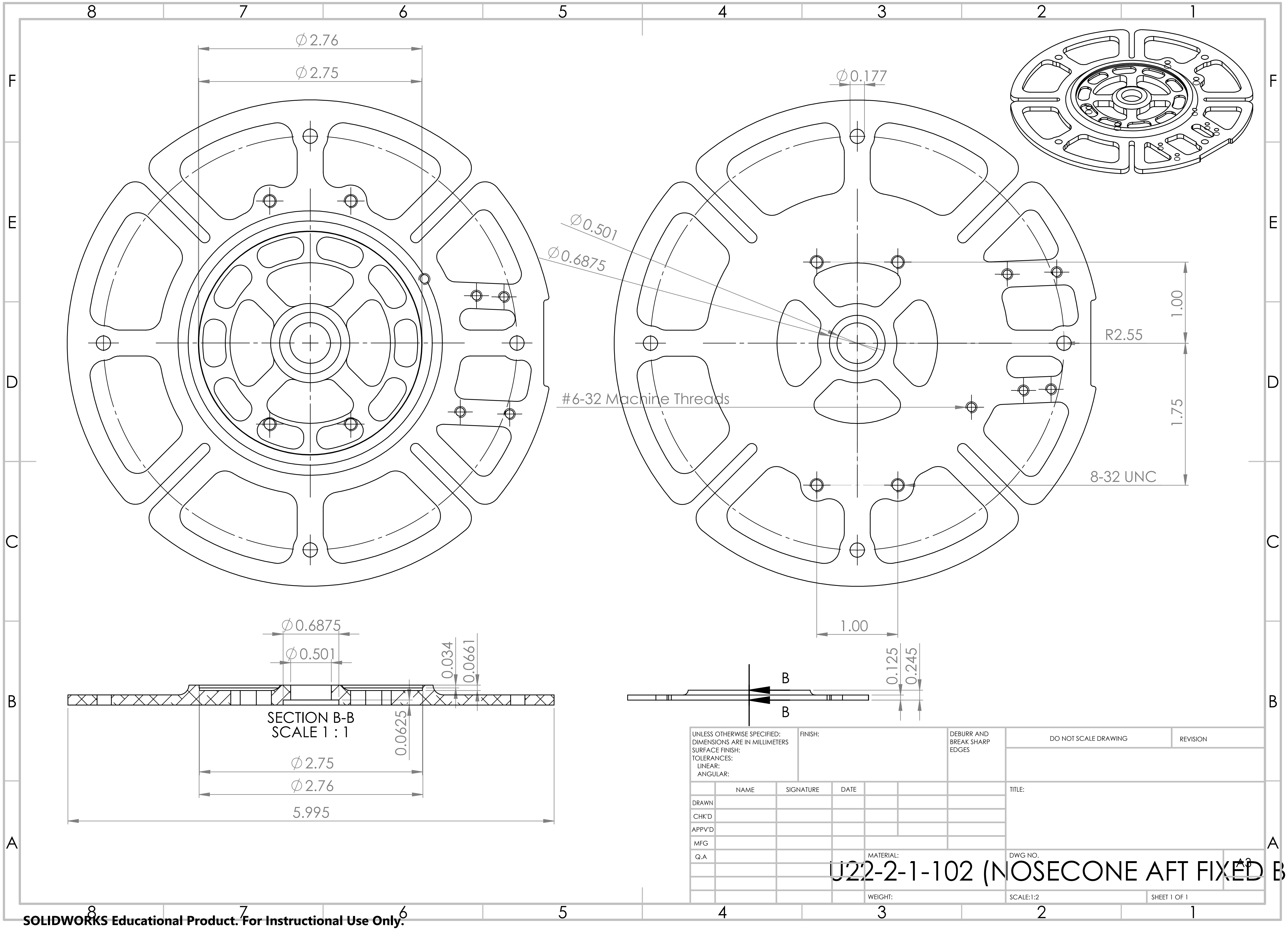
B B



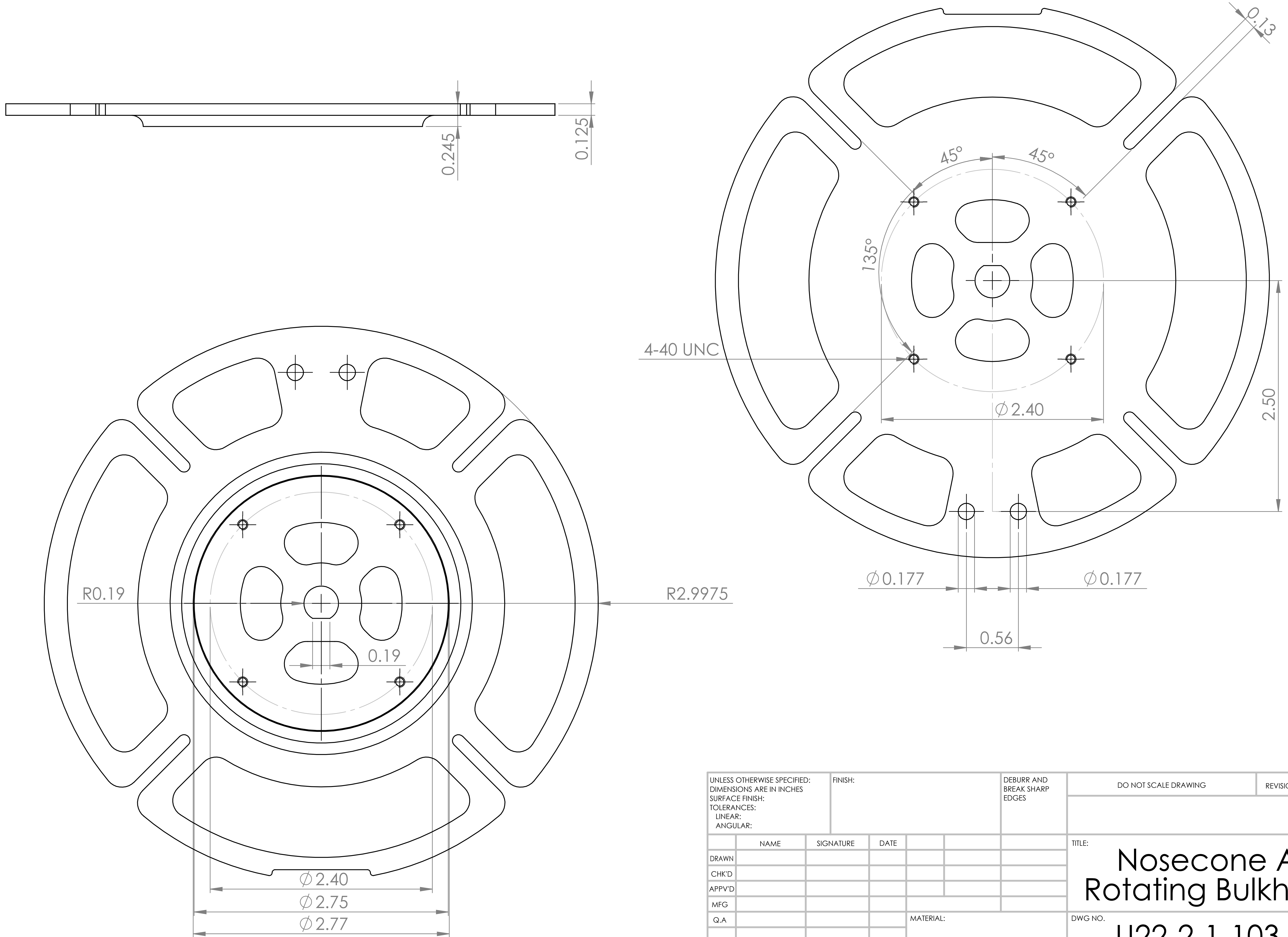
A A

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022	Nosecone Fore Bulkhead
	CHECKED	JR	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A — DWG. NO. U22-2-1-101 — REV
MATERIAL G10 Fiberglass				SCALE: 1:1 — WEIGHT: — SHEET 1 OF 1

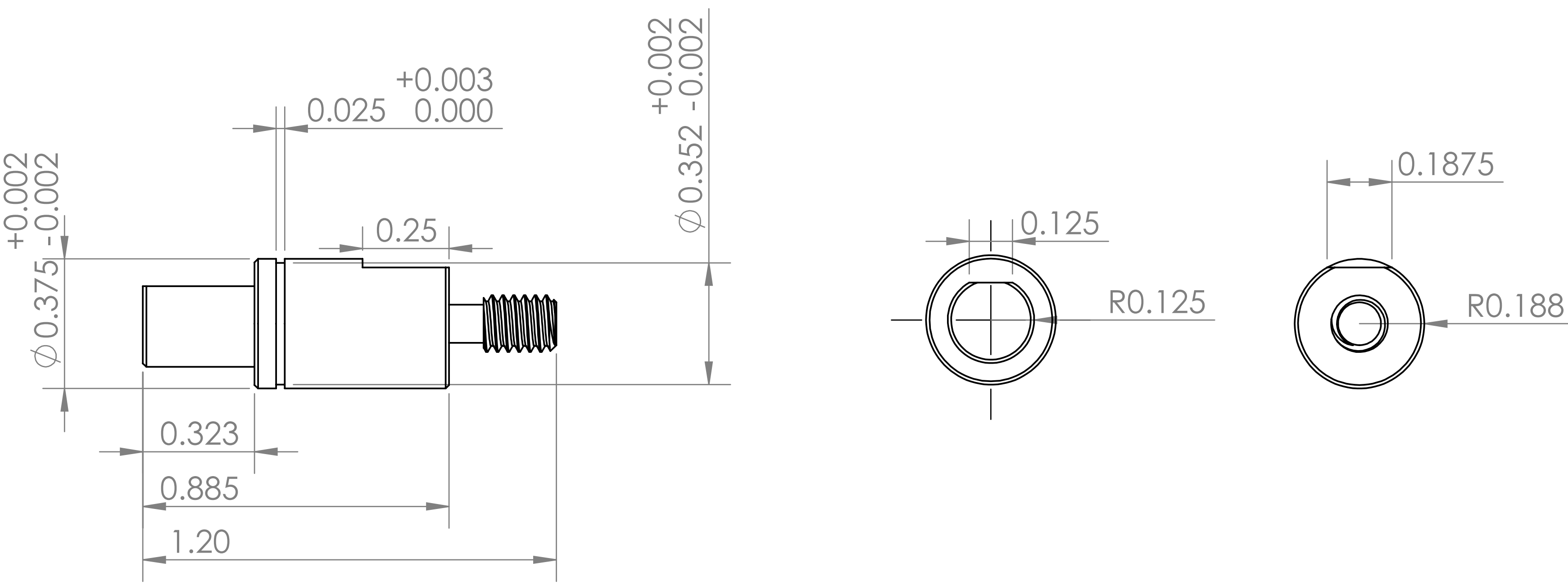
2 1



Ø2.76
Ø2.75
Ø0.177
Ø0.501
Ø0.6875
1.00
R2.55
1.75
#6-32 Machine Threads
8-32 UNC
1.00
Ø0.6875
Ø0.501
0.034
0.0061
0.0625
SECTION B-B
SCALE 1 : 1
Ø2.75
Ø2.76
5.995
B
B
0.125
0.245
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
TITLE:
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
DWG NO.
A3
U22-2-1-102 (NOSECONE AFT FIXED BU
WEIGHT:
SCALE:1:2
SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:		DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE	TITLE: Nosecone Aft Rotating Bulkhead	
DRAWN					
CHK'D					
APPV'D					
MFG					
Q.A			MATERIAL:	DWG NO. U22-2-1-103	A3
			WEIGHT:	SCALE:2:1	SHEET 1 OF 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.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

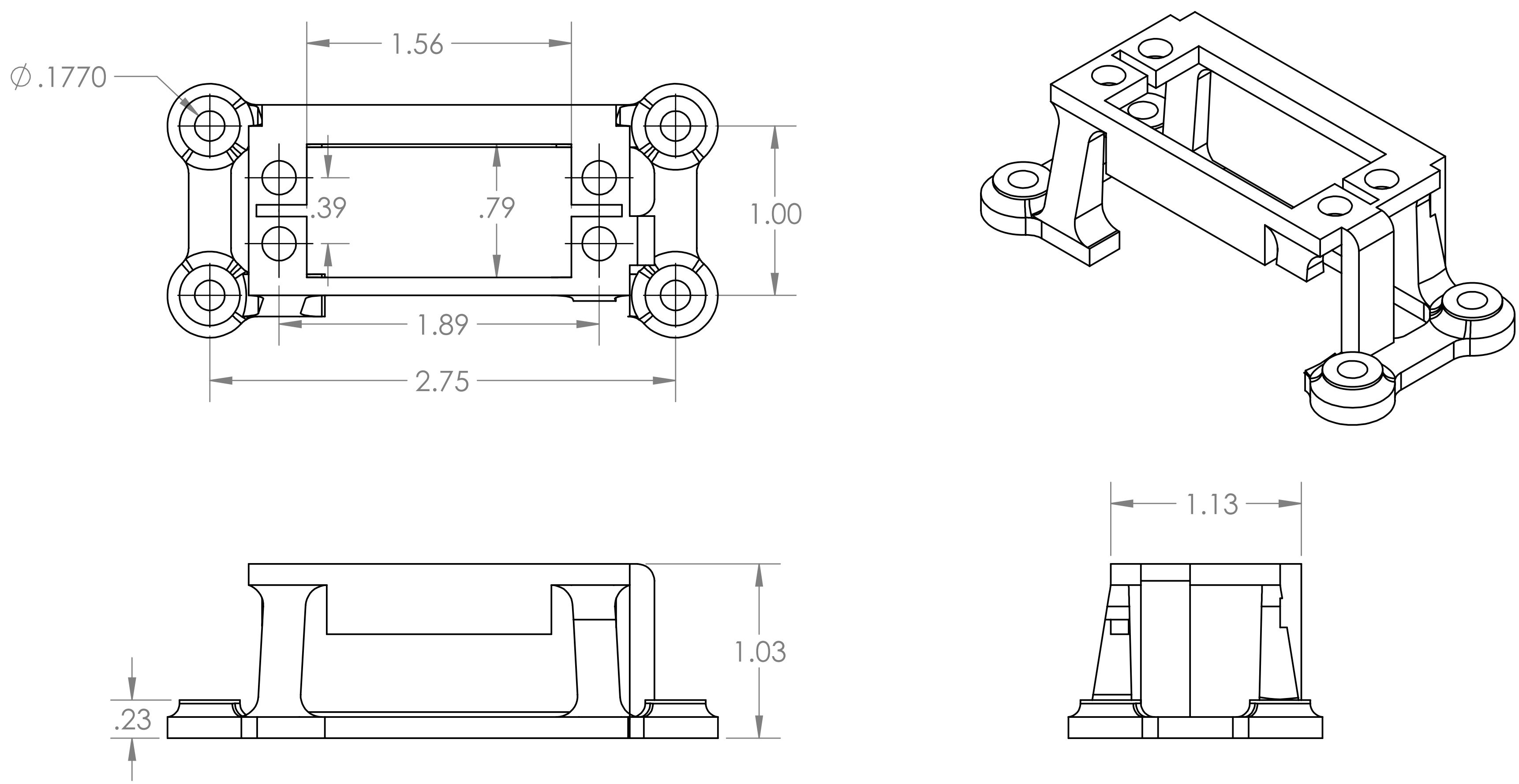
PROPRIETARY AND CONFIDENTIAL

TITLE:

Nosecone Rotation Shaft

SIZE **A** | DWG. NO. U22-2-1-104 | REV

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

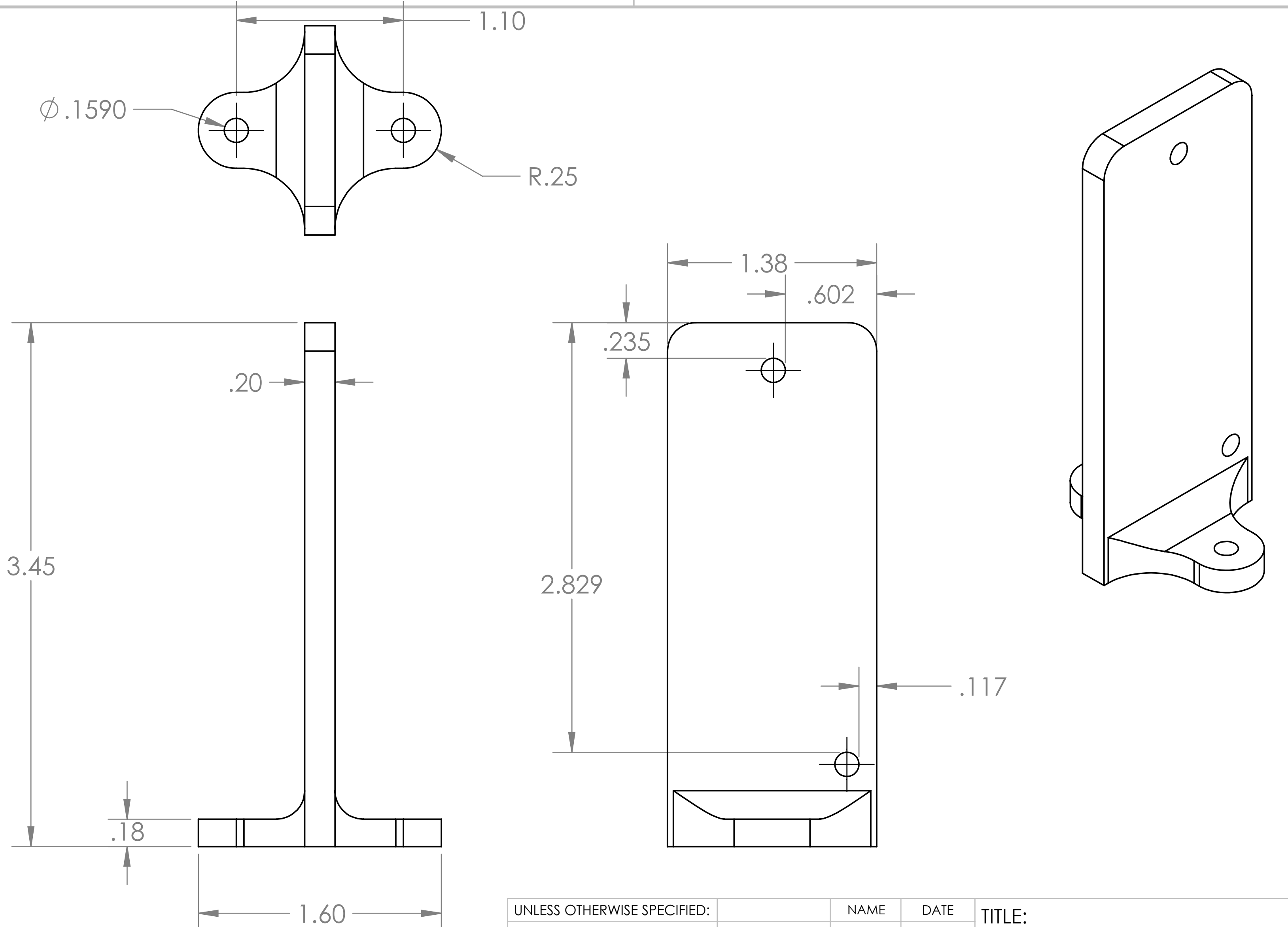


UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA		
MATERIAL Polycarbonate			

TITLE:

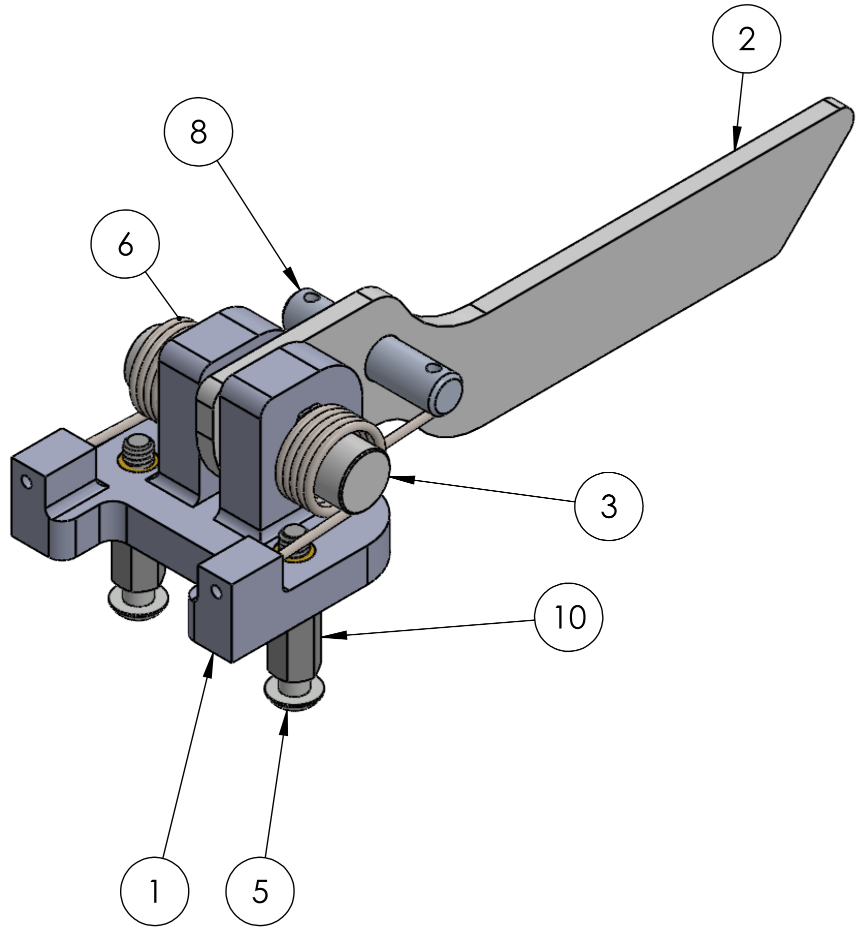
Nosecone Servo Mount

SIZE	DWG. NO.	REV
A	U22-2-1-105	
SCALE: 1:1	WEIGHT:	SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022	Nonecone PCB Bracket
	CHECKED	JR	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A / DWG. NO. U22-2-1-106 / REV
MATERIAL Polycarbonate				SCALE: 1:1 / WEIGHT: / SHEET 1 OF 1

ITEM NO.	PART NUMBER	QTY.
1	U22-2-1-302 (STABILIZATION BASE)	1
2	U22-2-1-301 (STABILIZATION ARM)	1
3	U22-2-1-303 (STABILIZATION ROTATIONAL SHAFT)	1
4	98410A117	2
5	#8-32x0.375	3
6	9271K677	1
7	9271K612	1
8	90145A542	1
9	#8-32x0.250	2
10	93505A452	2



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL			

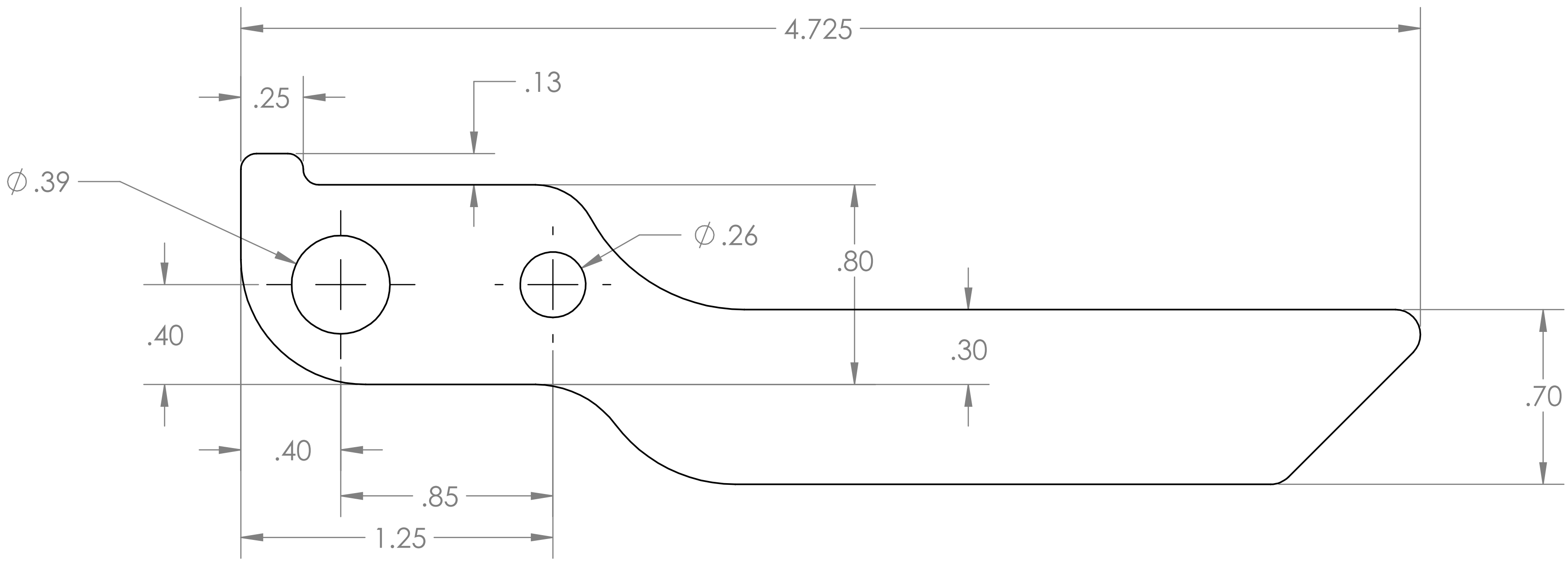
HPRC WPI AIAA

TITLE:

Stabilization Assembly

SIZE	DWG. NO.	REV
A	U22-2-1-300	

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



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA		
MATERIAL G10 Fiberglass			

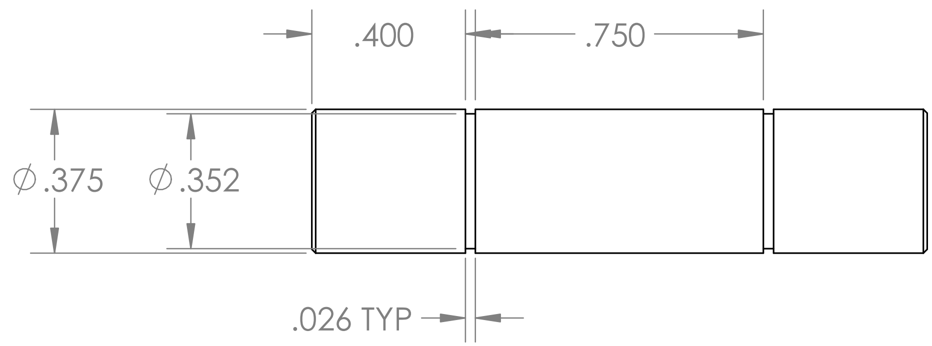
TITLE:
Stabilization Arm

SIZE	DWG. NO.	REV
A	U22-2-1-301	

SCALE: 1.5:1	WEIGHT:	SHEET 1 OF 1

2 1

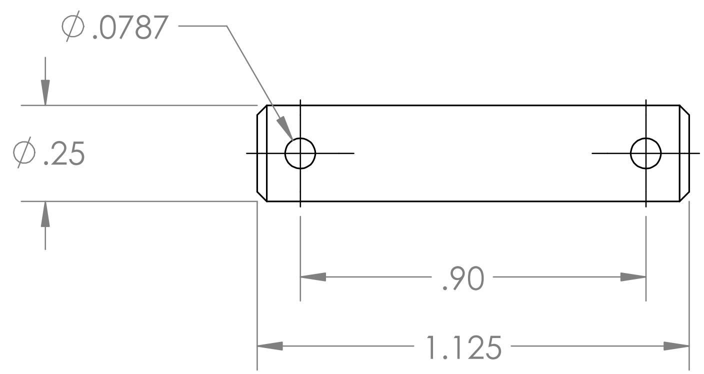
B B



A A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			
			CHECKED			TITLE: STABILIZATION ROTATIONAL SHAFT
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL 6061-T6	COMMENTS:			SIZE A · DWG. NO. U22-2-1-303 · REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 2:1 · WEIGHT: · SHEET 1 OF 1

2 1



NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6

FINISH

DO NOT SCALE DRAWING

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

COMMENTS:

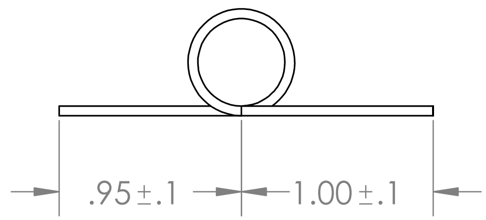
TITLE:
STABILIZATION DOWEL PIN

SIZE **A** DWG. NO. U22-2-1-304 REV

SCALE: 2:1 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		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL Music-Wire Steel	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

TITLE:

RIGHT-HANDED TORSION SPRING

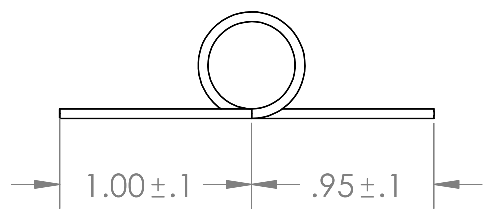
SIZE	DWG. NO.	REV
A	U22-2-1-305	

SCALE: 1:1 WEIGHT: SHEET 1 OF 1

2 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		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL Music-Wire Steel	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

PROPRIETARY AND CONFIDENTIAL

TITLE:

LEFT-HANDED TORSION SPRING

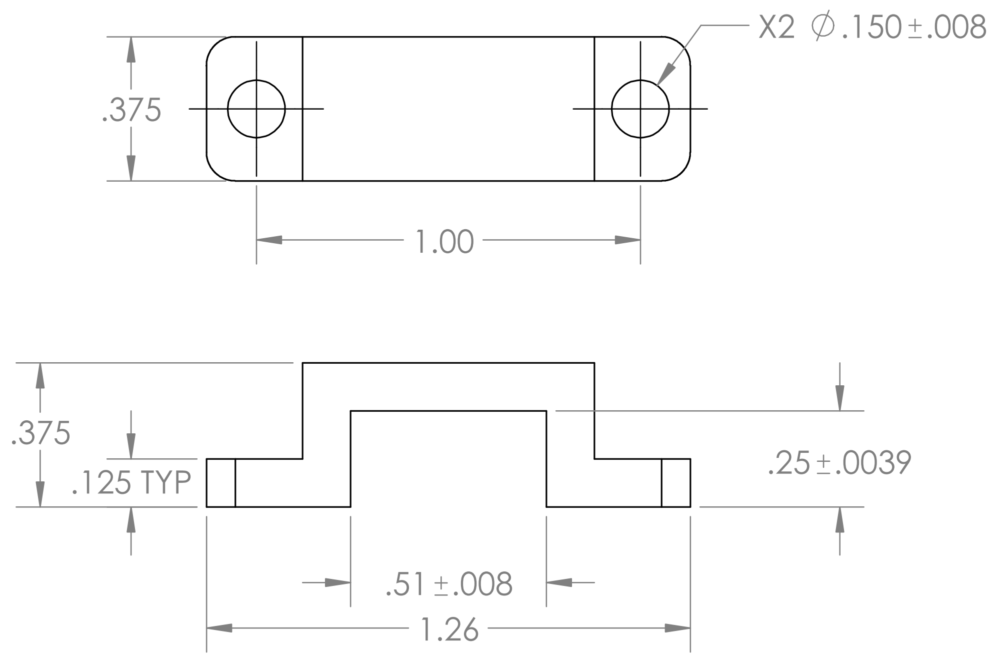
SIZE	DWG. NO.	REV
A	U22-2-1-306	

SCALE: 1:1	WEIGHT:	SHEET 1 OF 1

2 1

2 1

B B



A A

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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
Polycarbonate

FINISH

DO NOT SCALE DRAWING

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

COMMENTS:

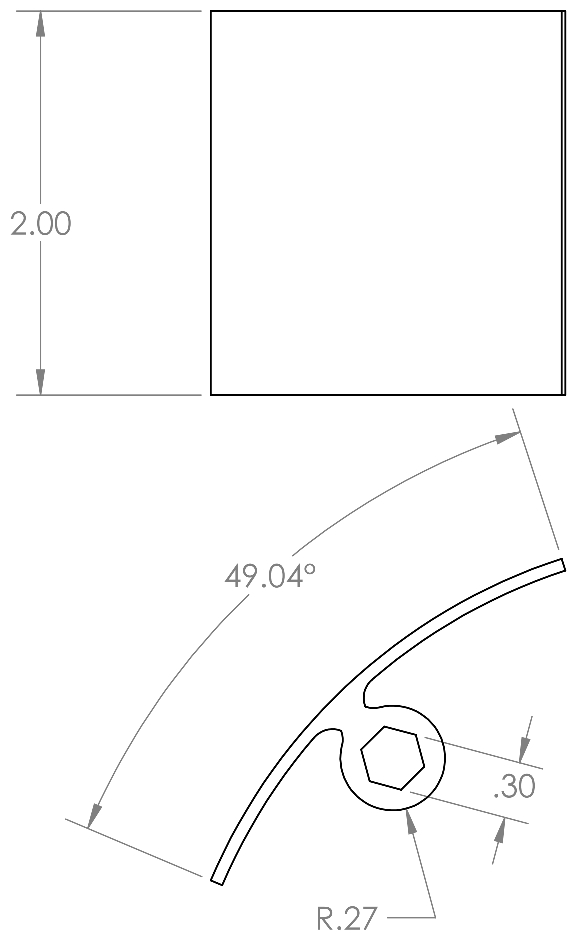
TITLE:

SWITCH SLEEVE

SIZE	DWG. NO.	REV
A	U22-2-1-307	

SCALE: 2:1 WEIGHT: SHEET 1 OF 1

2 1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/32
ANGULAR: MACH ± 1 BEND ± 1
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5

MATERIAL
Polycarbonate

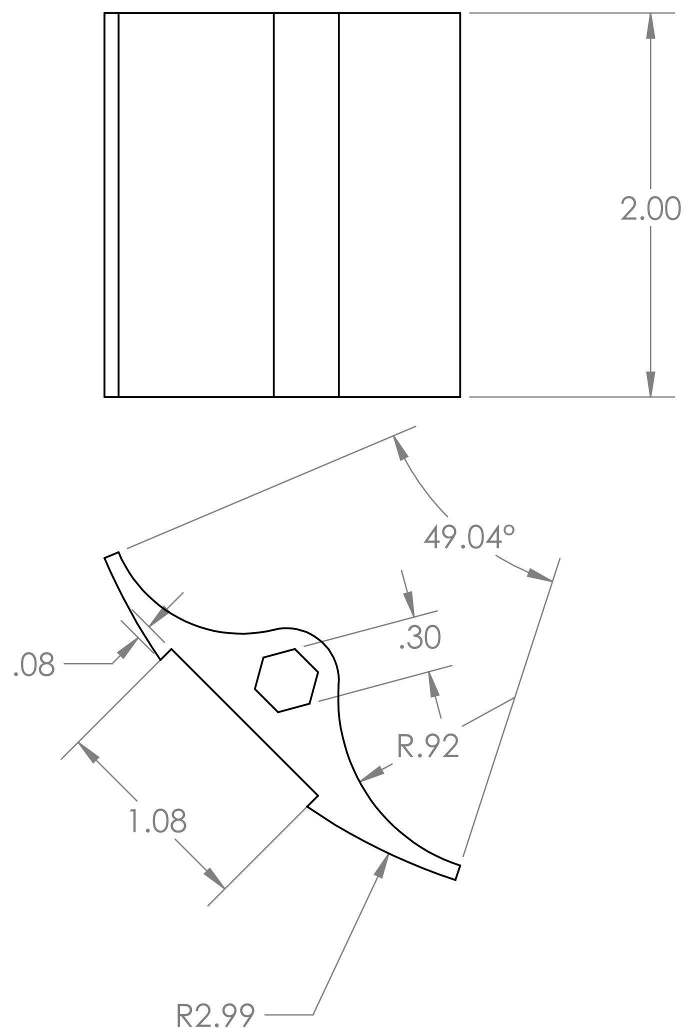
	NAME	DATE
DRAWN	CB	5/10/2022
CHECKED	JR	5/12/2022

HPRC WPI AIAA

TITLE:
Stabilization Sleeve

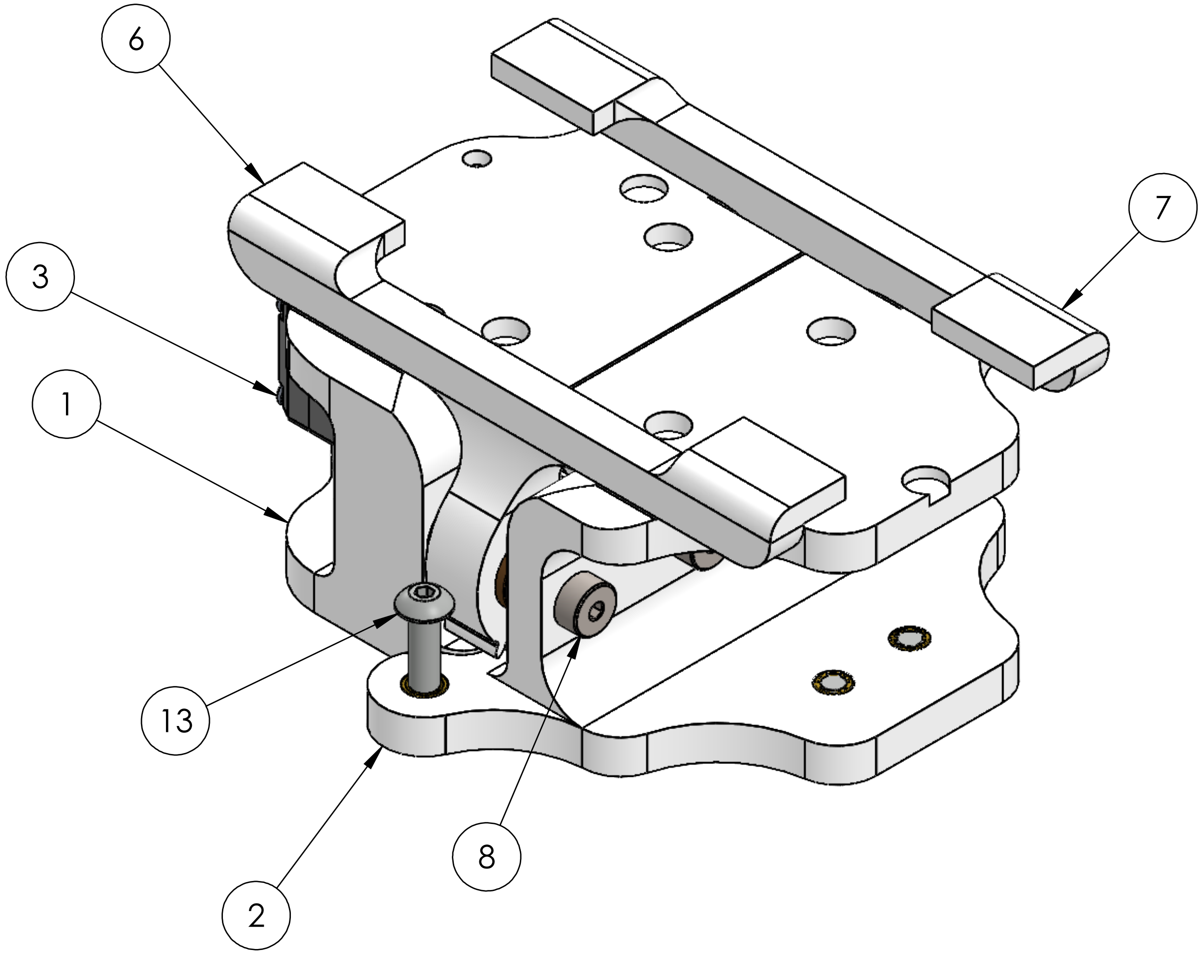
SIZE	DWG. NO.	REV
A	U22-2-1-308	

SCALE: 1:1 WEIGHT: SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022	Stabilization Sleeve Cutout
	CHECKED	JR	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A · DWG. NO. U22-2-1-309 · REV
MATERIAL Polycarbonate				SCALE: 1:1 · WEIGHT: · SHEET 1 OF 1

ITEM NO.	PART NUMBER	QTY.
1	U22-2-1-401 (GRIPPER SERVO MOUNT)	1
2	U22-2-1-402 (GRIPPER SPRING MOUNT)	1
3	2000-0025-0004 (GoBILDA Super Speed)	1
4	U22-2-1-405 (GRIPPER SERVO GEAR)	1
5	U22-2-1-406 (GRIPPER IDLER GEAR)	1
6	U22-2-1-404 (GRIPPER IDLER ARM)	1
7	U22-2-1-403 (GRIPPER SERVO ARM)	1
8	94035A167	3
9	#8-32x0.250	17
10	#8-32x0.375	4
11	#8-32x0.375	8
12	#8-32x0.750	1
13	#8-32x0.500	1
14	#8	6
15	6338K563	6
16	2305-0025-0012.step	1

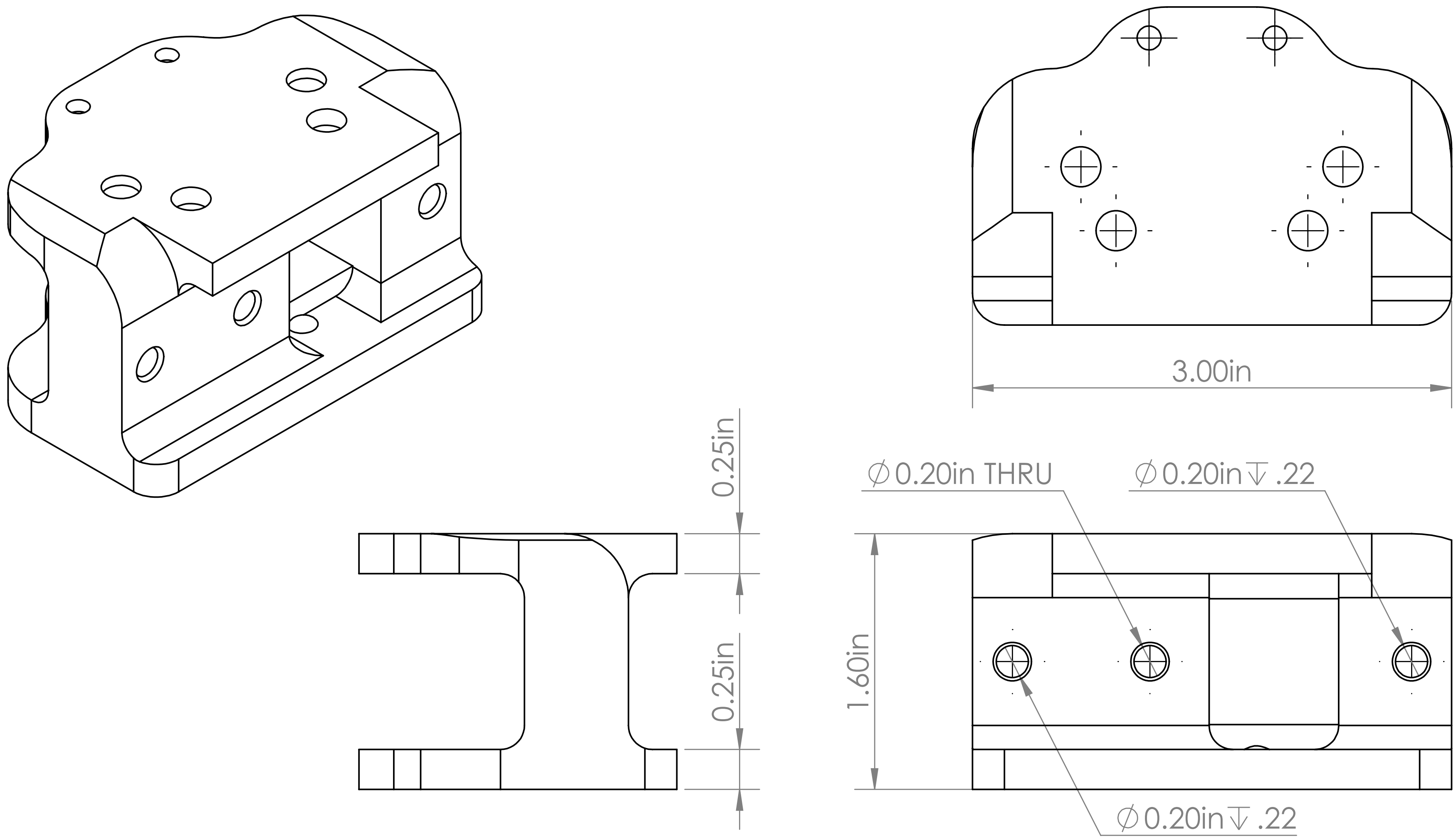


UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL			

HPRC WPI AIAA

TITLE: Quad Gripper Assembly

SIZE	DWG. NO.	REV
A	U22-2-1-400	
SCALE: 1:1	WEIGHT:	SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
Polycarbonate

FINISH

DO NOT SCALE DRAWING

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

COMMENTS:

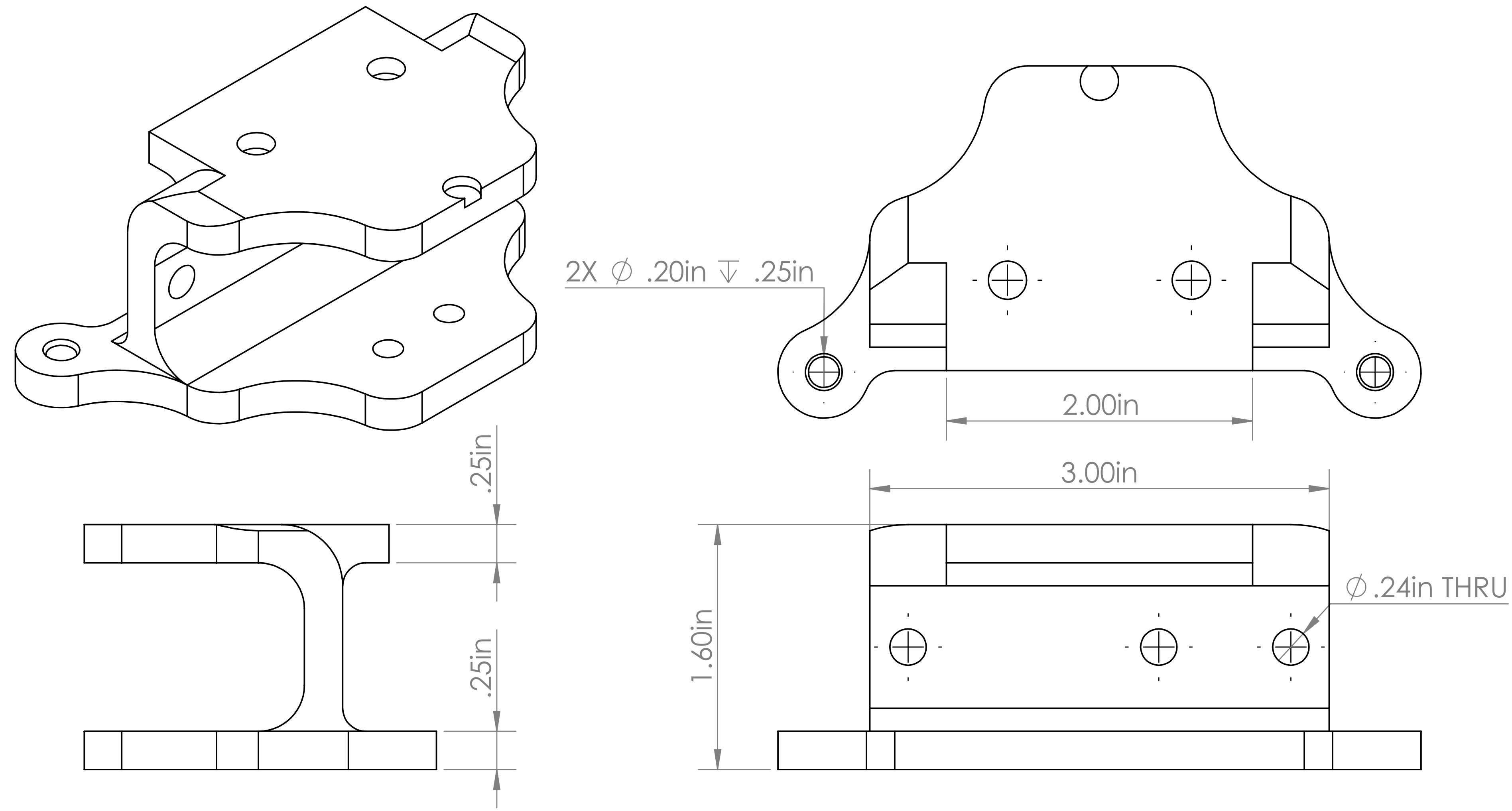
NEXT ASSY	USED ON
APPLICATION	

TITLE:

Gripper Servo Mount

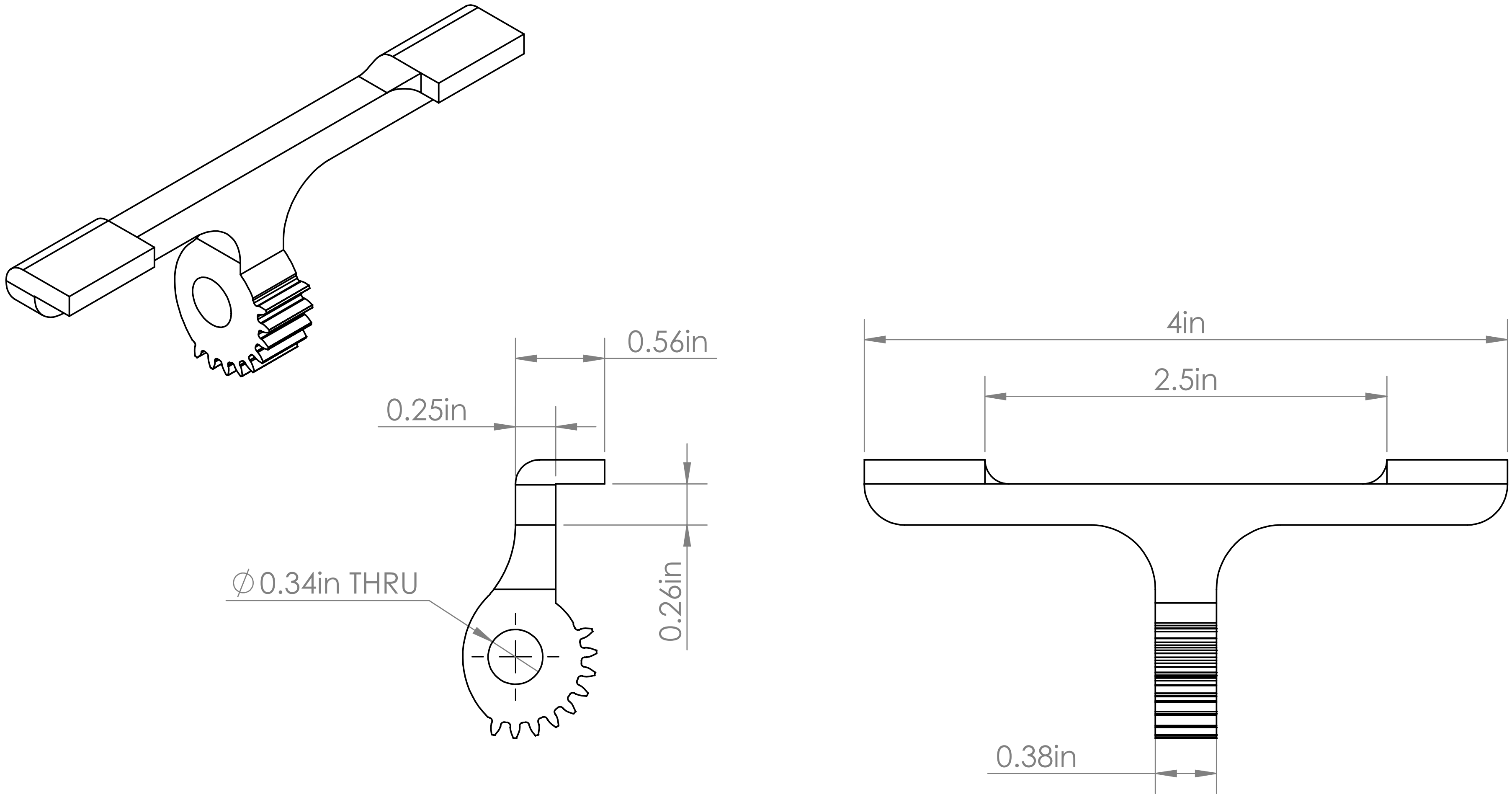
SIZE A | DWG. NO. U22-2-1-401 | REV

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

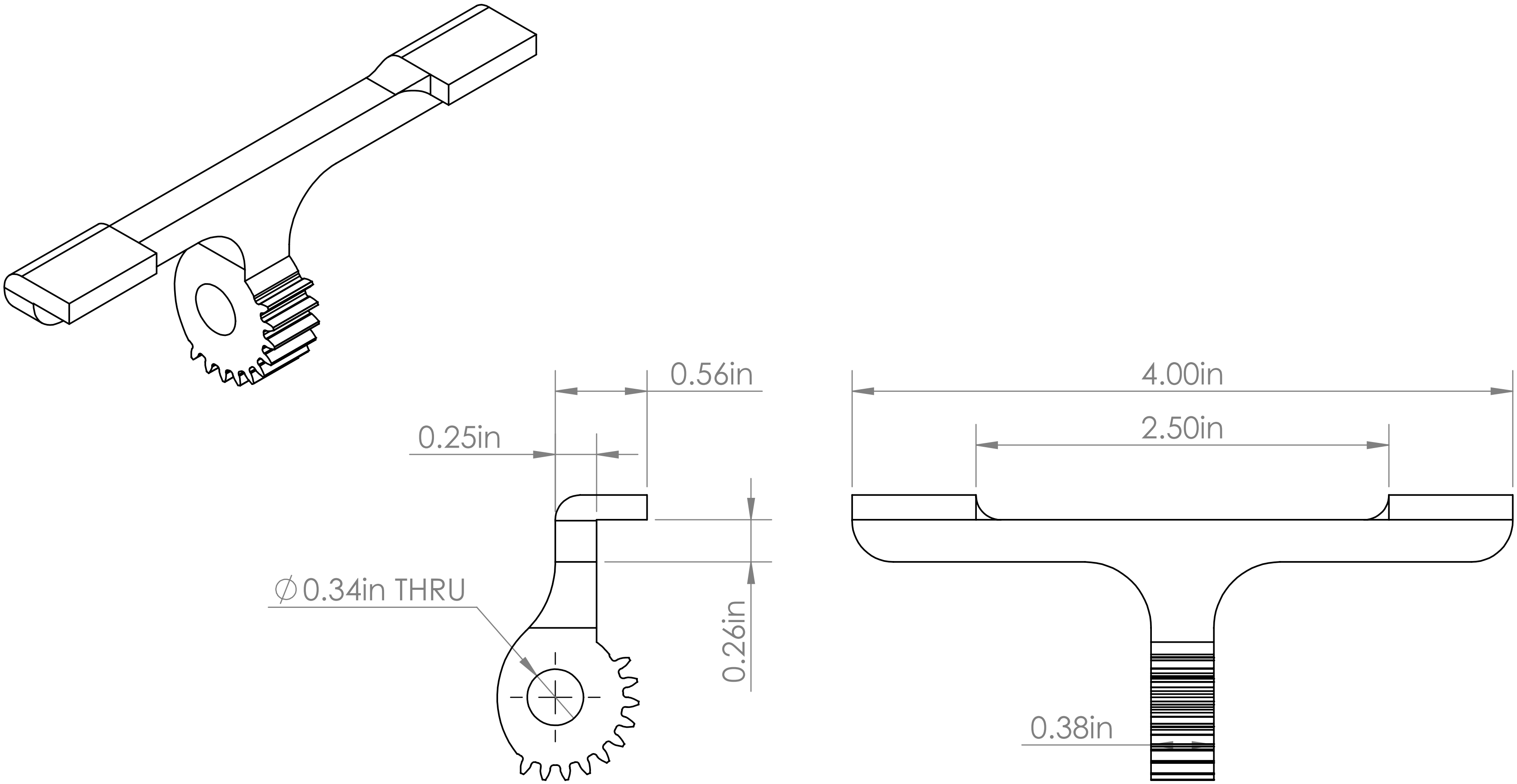


		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE:
			CHECKED			Gripper Spring Mount
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL Polycarbonate	COMMENTS:			SIZE A
NEXT ASSY	USED ON	FINISH				DWG. NO. U22-2-1-402
APPLICATION		DO NOT SCALE DRAWING				REV
						SCALE: 1:1
						WEIGHT:
						SHEET 1 OF 1

PROPRIETARY AND CONFIDENTIAL

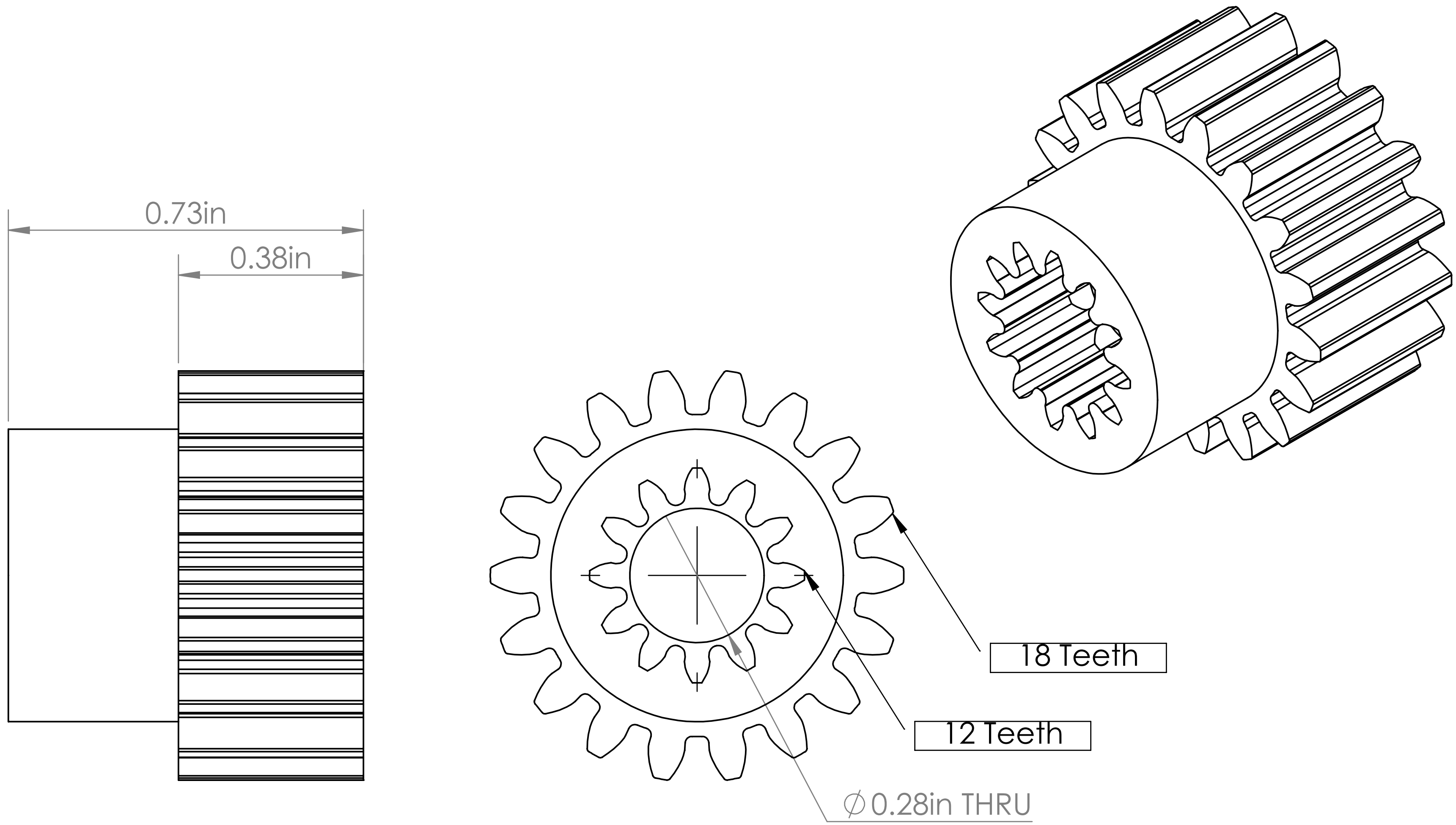


		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE:
			CHECKED			Gripper Servo Arm
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL Polycarbonate	COMMENTS:			SIZE A — DWG. NO. U22-2-1-403 — REV
NEXT ASSY	USED ON	FINISH NONE				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:1 — SHEET 1 OF 1



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE:
			CHECKED			Gripper Idler Arm
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL Polycarbonate	COMMENTS:			SIZE A / DWG. NO. U22-2-1-404 / REV
NEXT ASSY	USED ON	FINISH NONE				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:1 / WEIGHT: 0.02315SHEET 1 OF 1

PROPRIETARY AND CONFIDENTIAL



		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 Polycarbonate	COMMENTS:		
NEXT ASSY	USED ON	FINISH NONE			
APPLICATION		DO NOT SCALE DRAWING			

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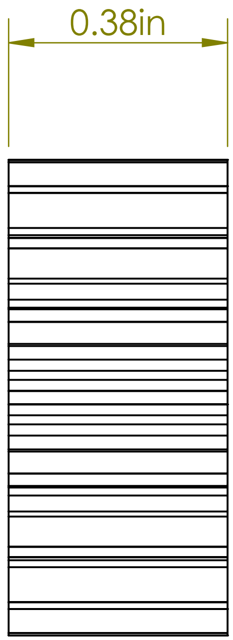
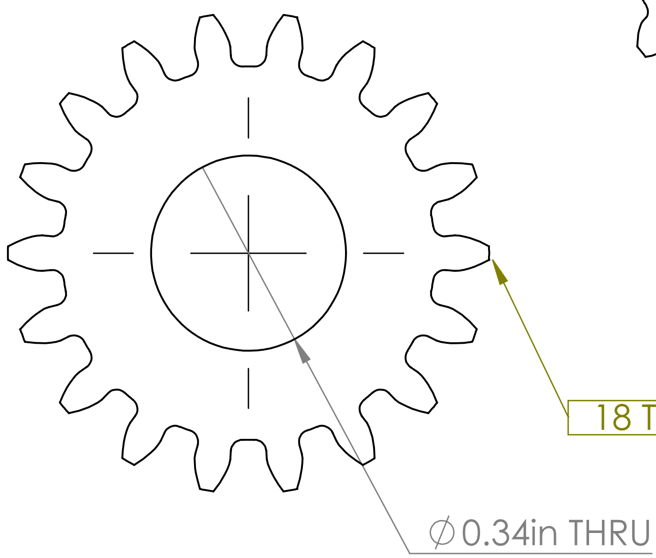
TITLE:

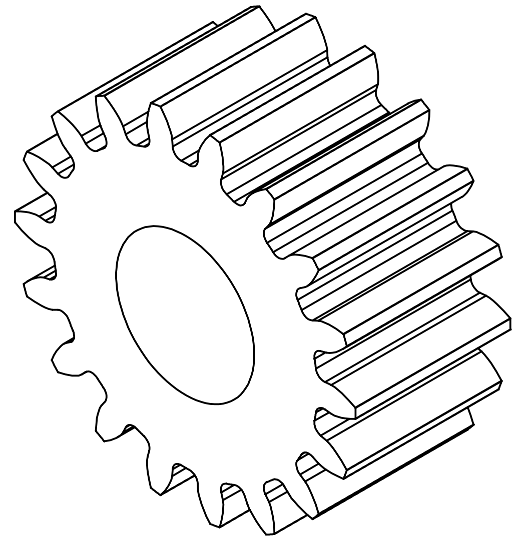
Gripper Servo Gear

SIZE **A** | DWG. NO. U22-2-1-405 | REV

SCALE: 3:1 | WEIGHT: 0.01049328 | SHEET 1 OF 1

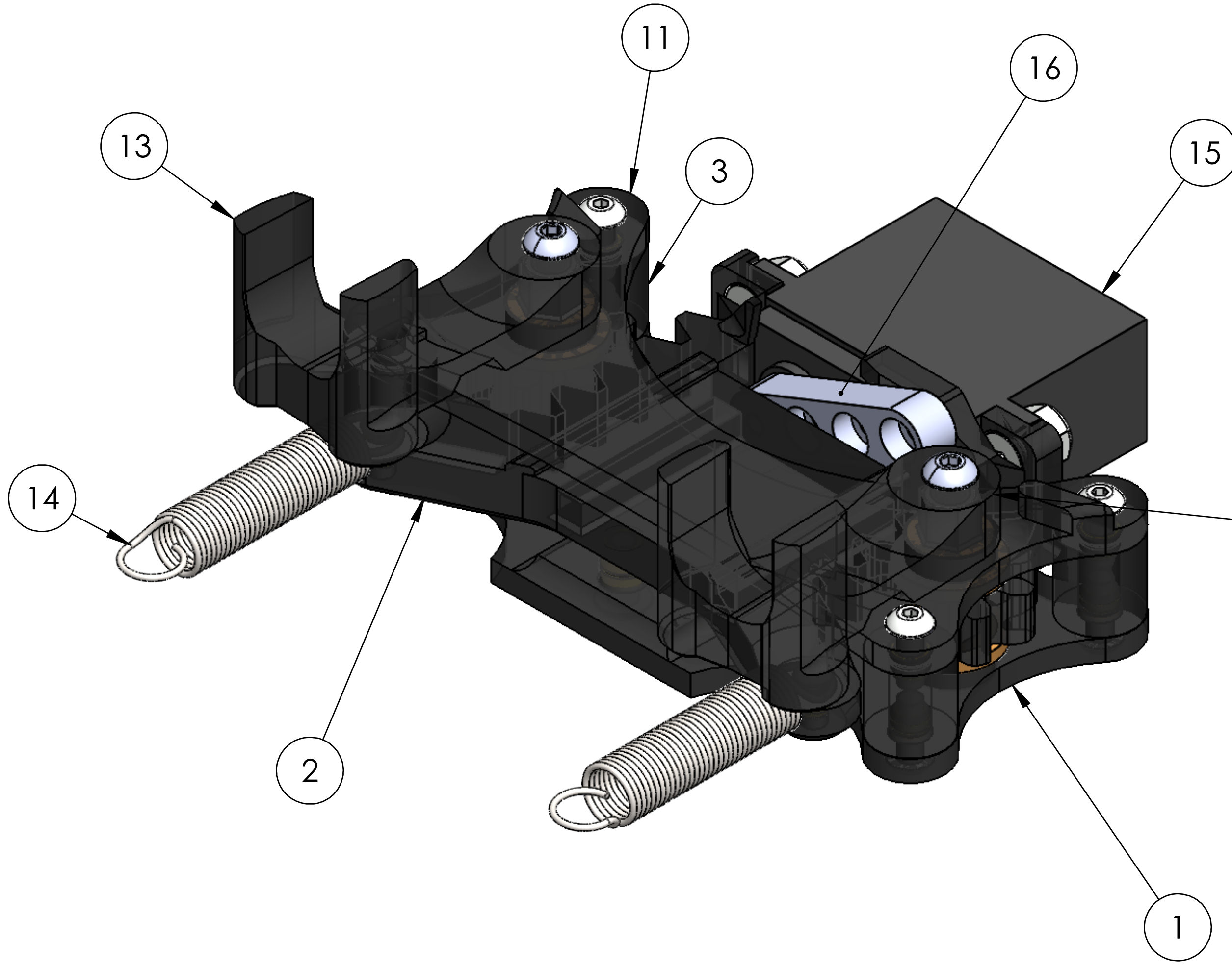






		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			
			CHECKED			TITLE:
			ENG APPR.			Gripper Idler Gear
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL Polycarbonate	COMMENTS:			SIZE A DWG. NO. U22-2-1-406 REV
NEXT ASSY	USED ON	FINISH NONE				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 3:1 WEIGHT: 0.005524 SHEET 1 OF 1

ITEM NO.	PART NUMBER	QTY.
1	U22-2-1-501 (BOTTOM PLATE)	1
2	U22-2-1-503 (WIDE RACK)	1
3	U22-2-1-512 (STANDOFF)	4
4	#4-40x0.170	2
5	#6-32x0.150	8
6	#8-32x0.250	4
7	#6-32x0.375	8
8	#4-40x0.250	2
9	#8-32x0.375	4
10	U22-2-1-502 (D_PROFILE PINION)	2
11	U22-2-1-505 (TOP PLATE)	1
12	U22-2-1-509 (LEVER ARM (MIRRORED))	1
13	U22-2-1-508 (LEVER ARM)	1
14	9654K357	2
15	HS-311 Servo Model	1
16	ServoHorn	1
17	6659K115	4
18	2106-4008-0320 assembly.STEP	2
19	2802-0004-0010.step	2
20	#6-32x0.375	2
21	#6-32	2



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL			

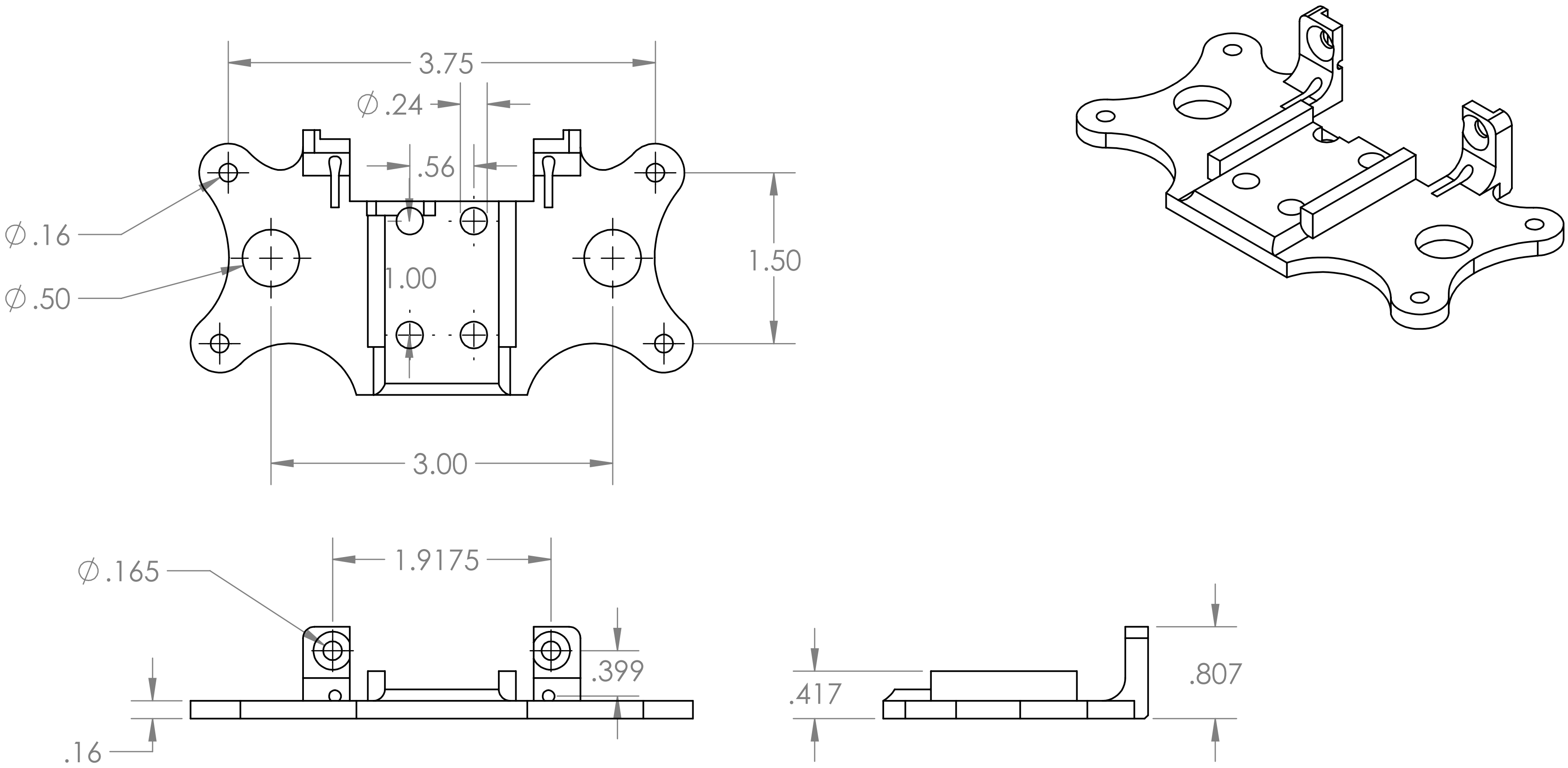
HPRC WPI AIAA

TITLE:

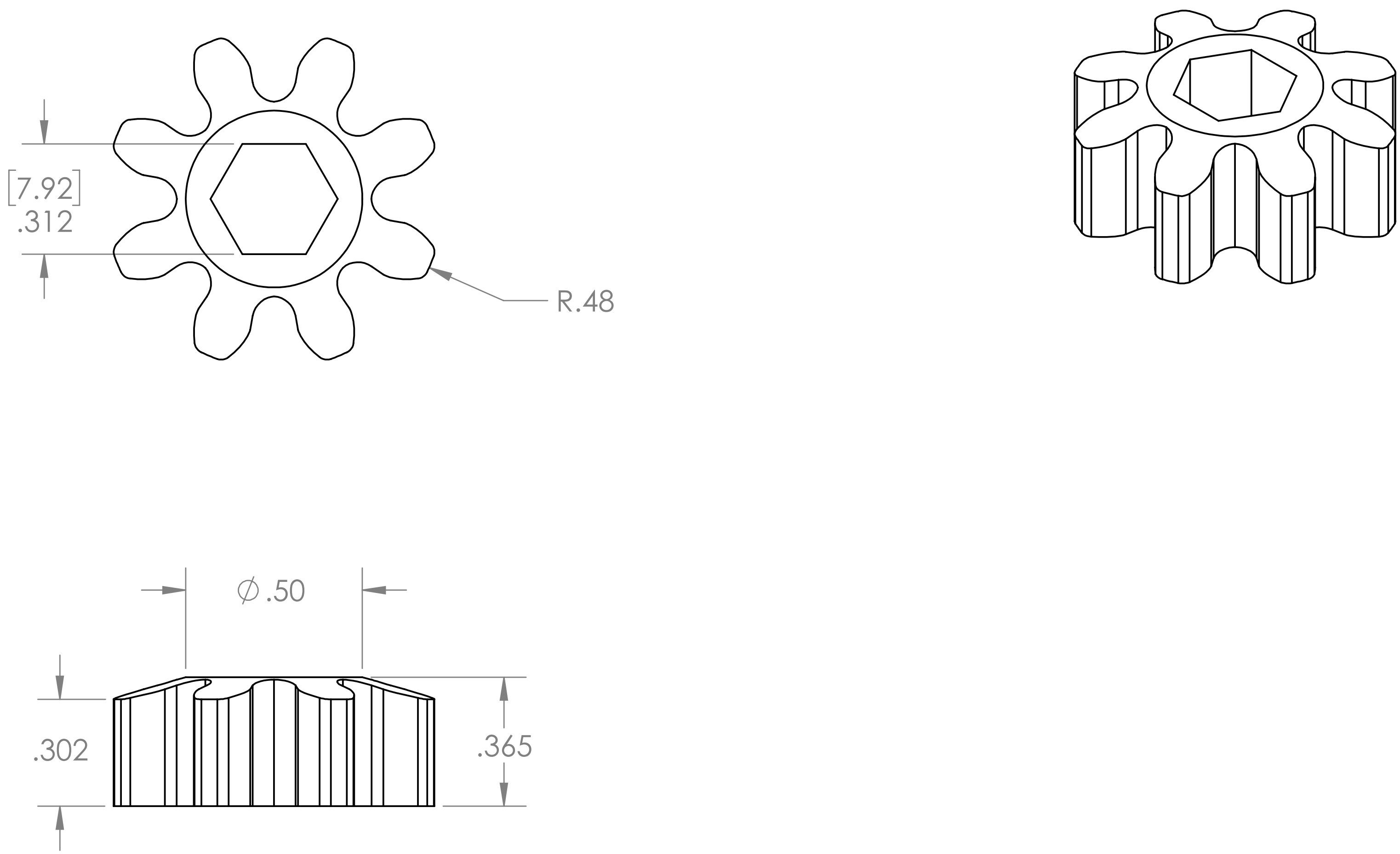
Arm Deployment Assembly

SIZE	DWG. NO.	REV
A	U22-2-1-500	

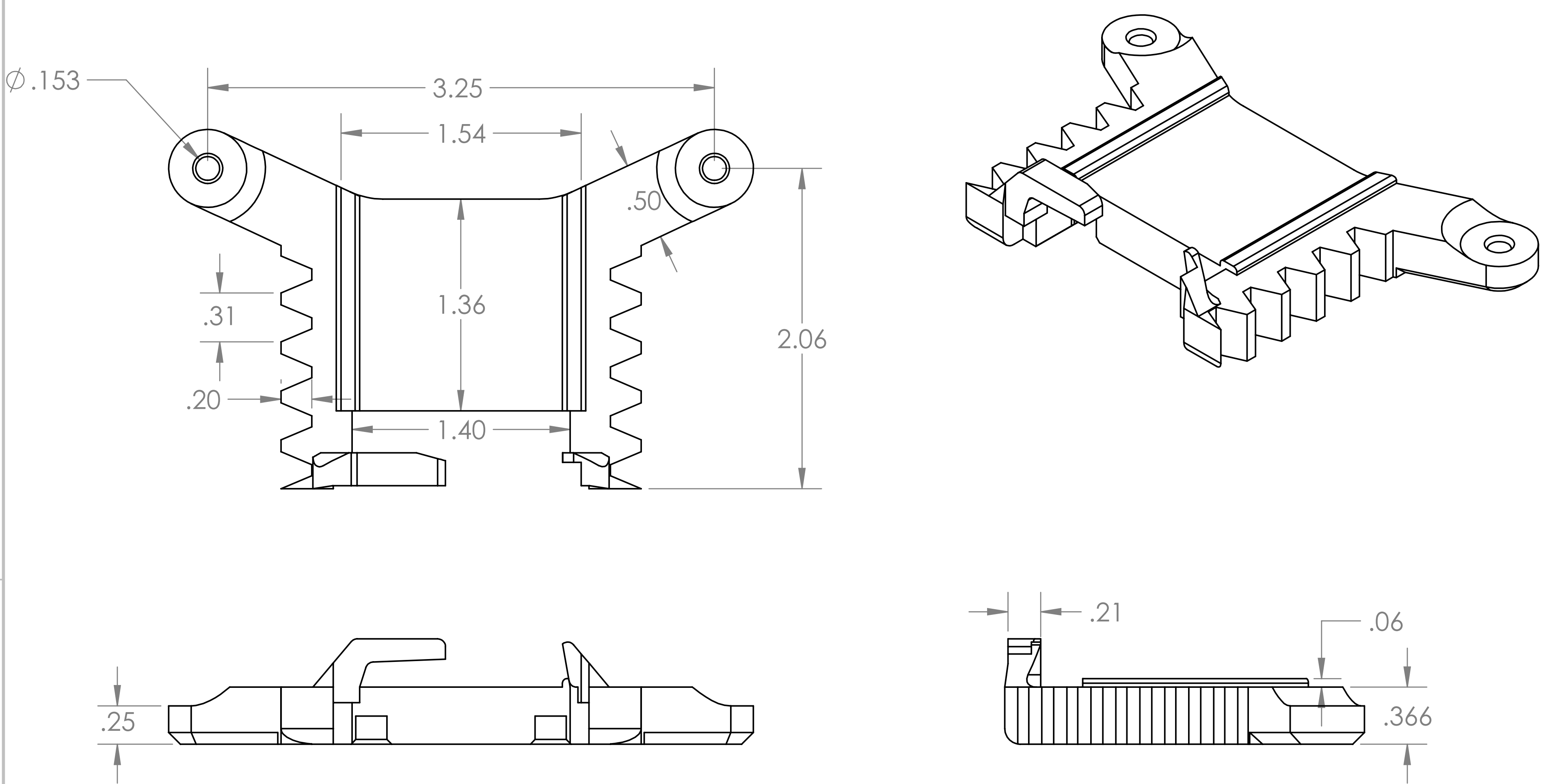
SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE: Bottom Plate		
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022			
	CHECKED	JR	5/12/2022			
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A	DWG. NO. U22-2-1-501	REV
MATERIAL Polycarbonate				SCALE: 1:1.5	WEIGHT:	SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022	Hex Profile Pinion
	CHECKED	JR	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A DWG. NO. U22-2-1-502 REV
MATERIAL Polycarbonate				SCALE: 2:1 WEIGHT: 0.03698990 SHEET 1 OF 1



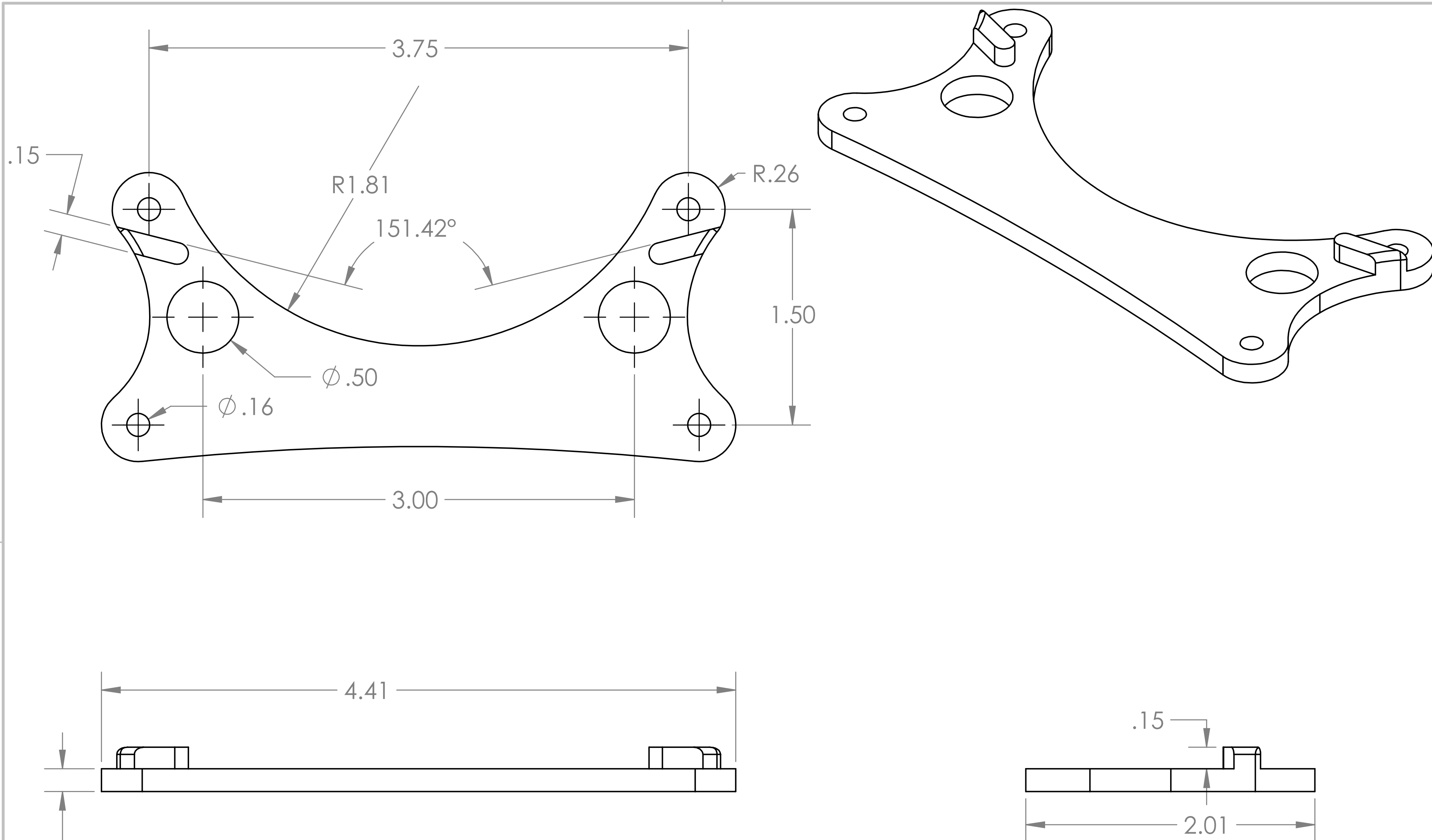
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL Polycarbonate			

HPRC WPI AIAA

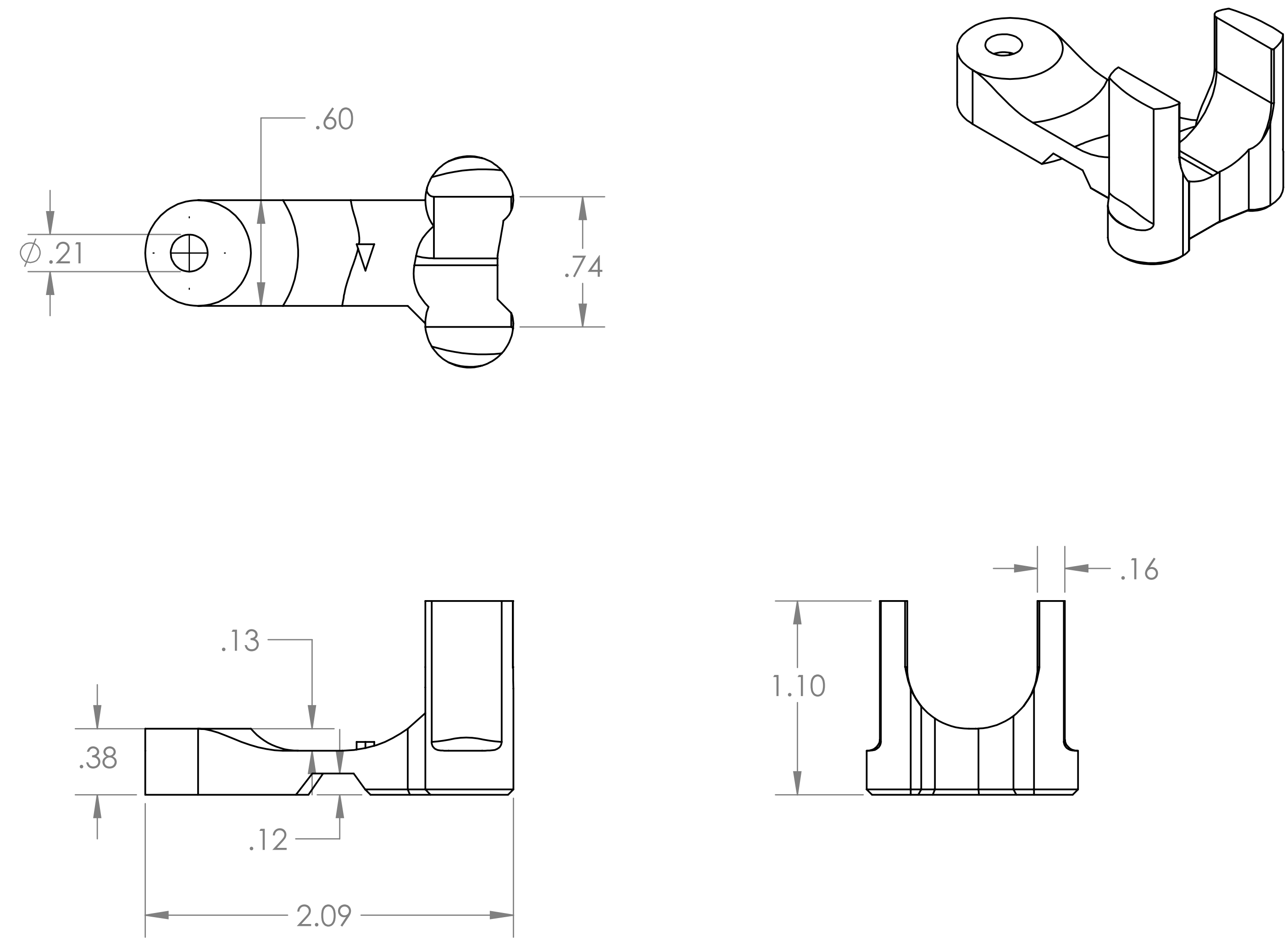
TITLE:

Wide Rack

SIZE	DWG. NO.	REV
A	U22-2-1-503	
SCALE: 1:1	WEIGHT:	SHEET 1 OF 1



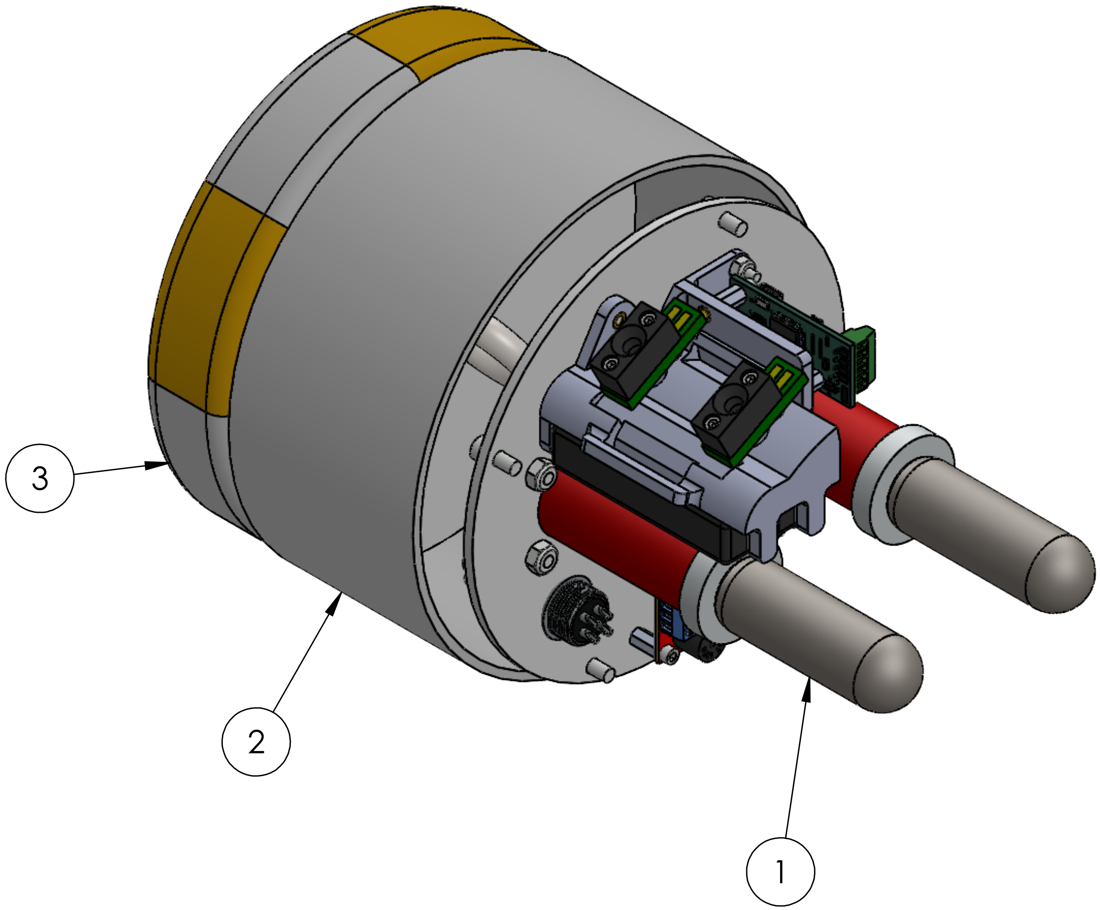
UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022	Top Plate
	CHECKED	JR	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A — DWG. NO. U22-2-1-505 — REV
MATERIAL Polycarbonate				SCALE: 1:1 — WEIGHT: — SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022	Lever Arm
	CHECKED	JR	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A — DWG. NO. U22-2-1-508 — REV
MATERIAL Polycarbonate				SCALE: 1:1 — WEIGHT: — SHEET 1 OF 1

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022	Standoff
	CHECKED	JR	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A — DWG. NO. U22-2-1-512 — REV
MATERIAL Polycarbonate				SCALE: 2:1 — WEIGHT: — SHEET 1 OF 1

ITEM NO.	PART NUMBER	QTY.
1	U22-2-2-100 (PAYLOAD RECOVERY BAY ASSEMBLY)	1
2	U22-2-2-200 (PAYLOAD PISTON ASSEMBLY)	1
3	Rocketman 9ft Ultralight Parabolic	1



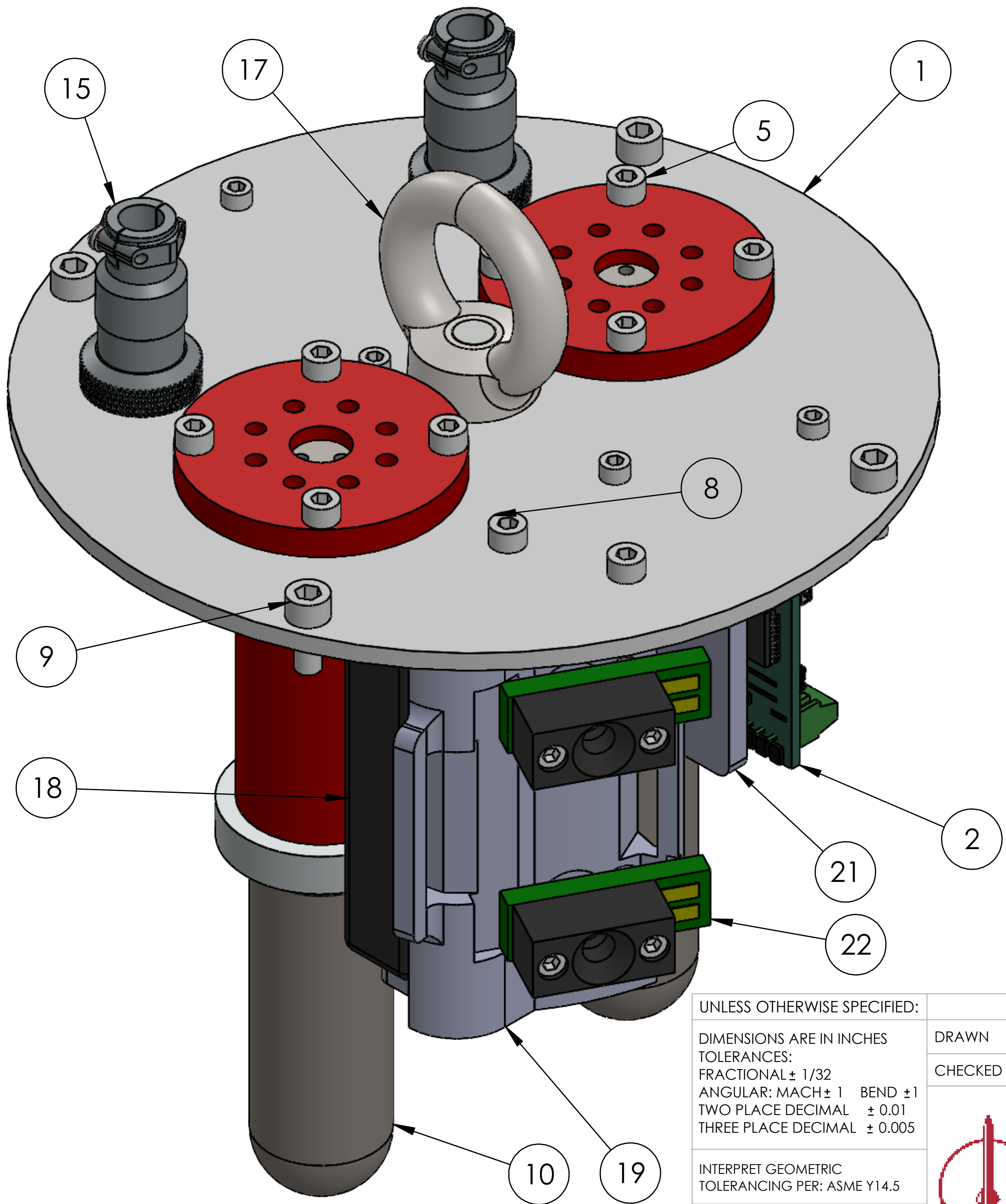
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL			

HPRC WPI AIAA

TITLE:
Payload Recovery Assembly

SIZE A | DWG. NO. U22-2-2-000 | REV

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



ITEM NO.	PART NUMBER	QTY.
1	U22-2-2-101 (BULKHEAD)	1
2	Raven 4	1
3	Stratologger CF	1
4	#4-40x0.250	6
5	#6-32x0.500	8
6	#4-40x0.375	4
7	#4-40x0.500	2
8	#6-32x0.250	2
9	#8-32x0.375	4
10	Eagle CO2 Ejection System	2
11	91780A529	6
12	#6-32x0.150	8
13	#6-32	8
14	#4-40	2
15	GX16 4 PIN	2
16	0.25-20x0.50	1
17	3112T31	1
18	Auline 450mah 2s Lipo	2
19	U22-2-2-103 (POWER SWITCH MOUNT)	1
20	#4-40x0.250	4
21	U22-2-2-102 (RAVEN MOUNT)	1
22	Screw Switch Assembly	2

UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL			

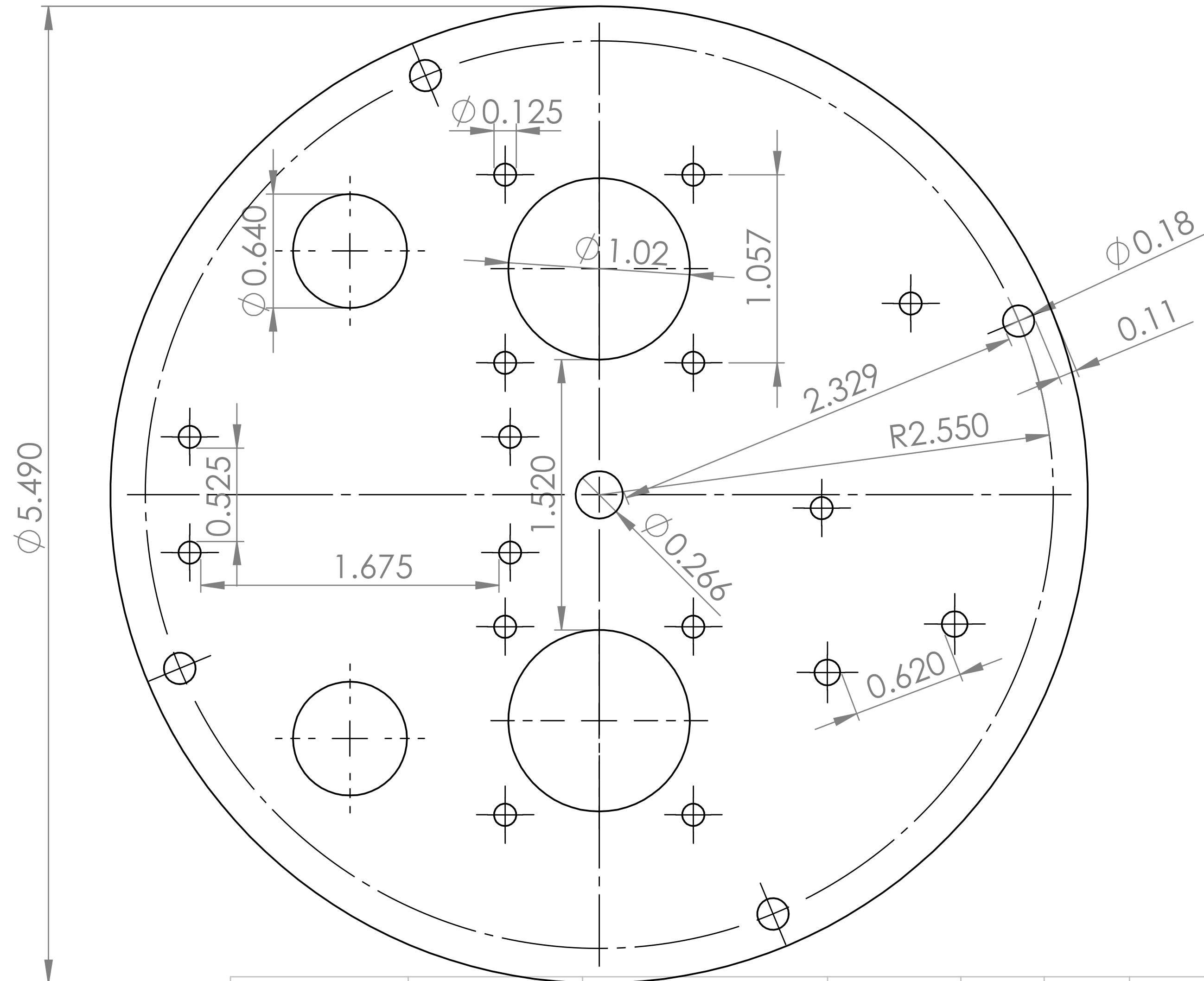
HPRC WPI AIAA

TITLE:
Payload Recovery Bay Assembly

SIZE	DWG. NO.	REV
A	U22-2-2-100	
SCALE: 1:1	WEIGHT:	SHEET 1 OF 1

2 1

B



B

A

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:

TITLE:

U22-2-2-101 (BULKHEAD)

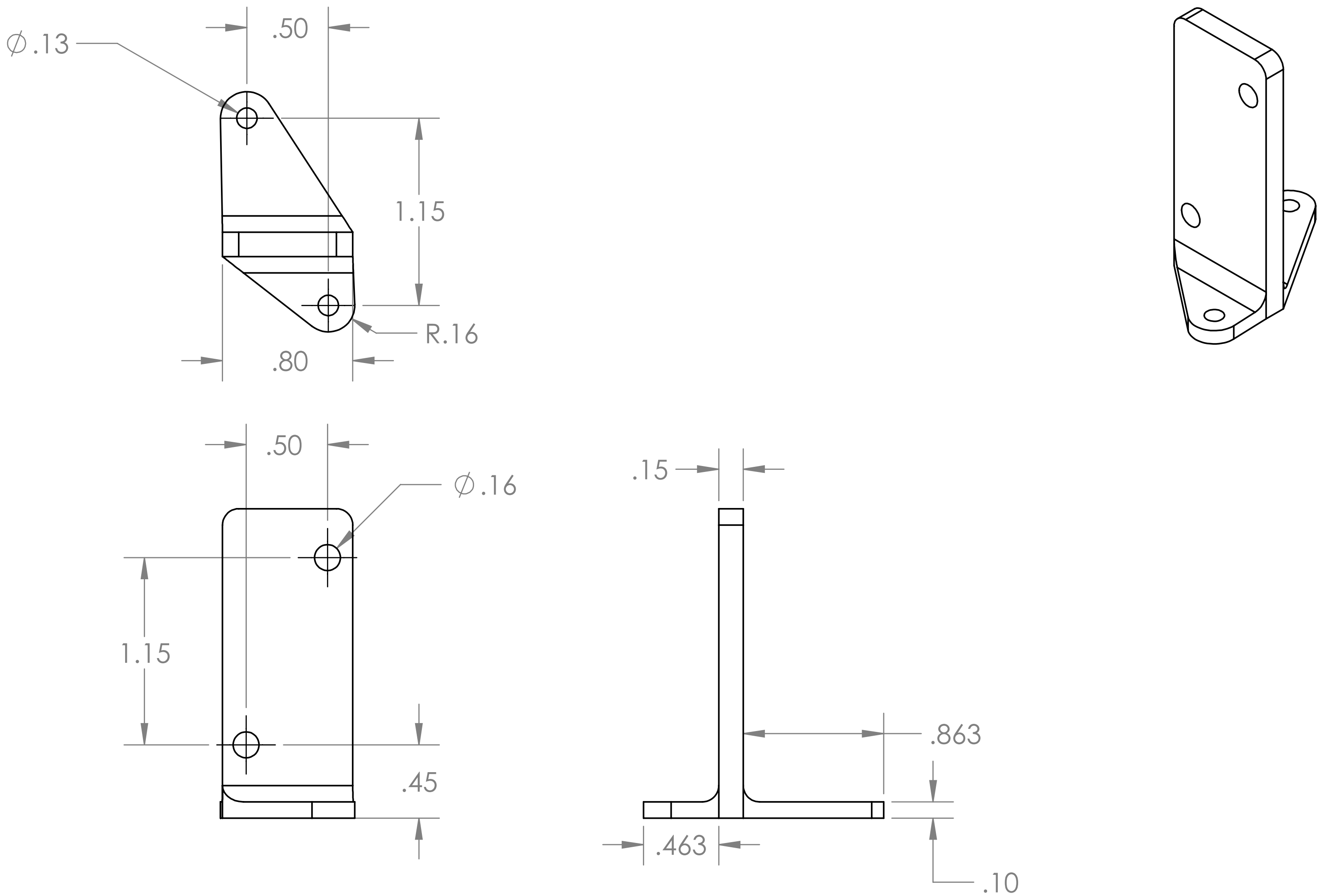
SIZE	DWG. NO.	REV
A		

SCALE: 1:1 WEIGHT: SHEET 1 OF 1

NEXT ASSY	USED ON
APPLICATION	

A

2 1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/32
ANGULAR: MACH ± 1 BEND ± 1
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5

MATERIAL
Polycarbonate

	NAME	DATE
DRAWN	CB	5/10/2022
CHECKED	JR	5/12/2022

HPRC WPI AIAA

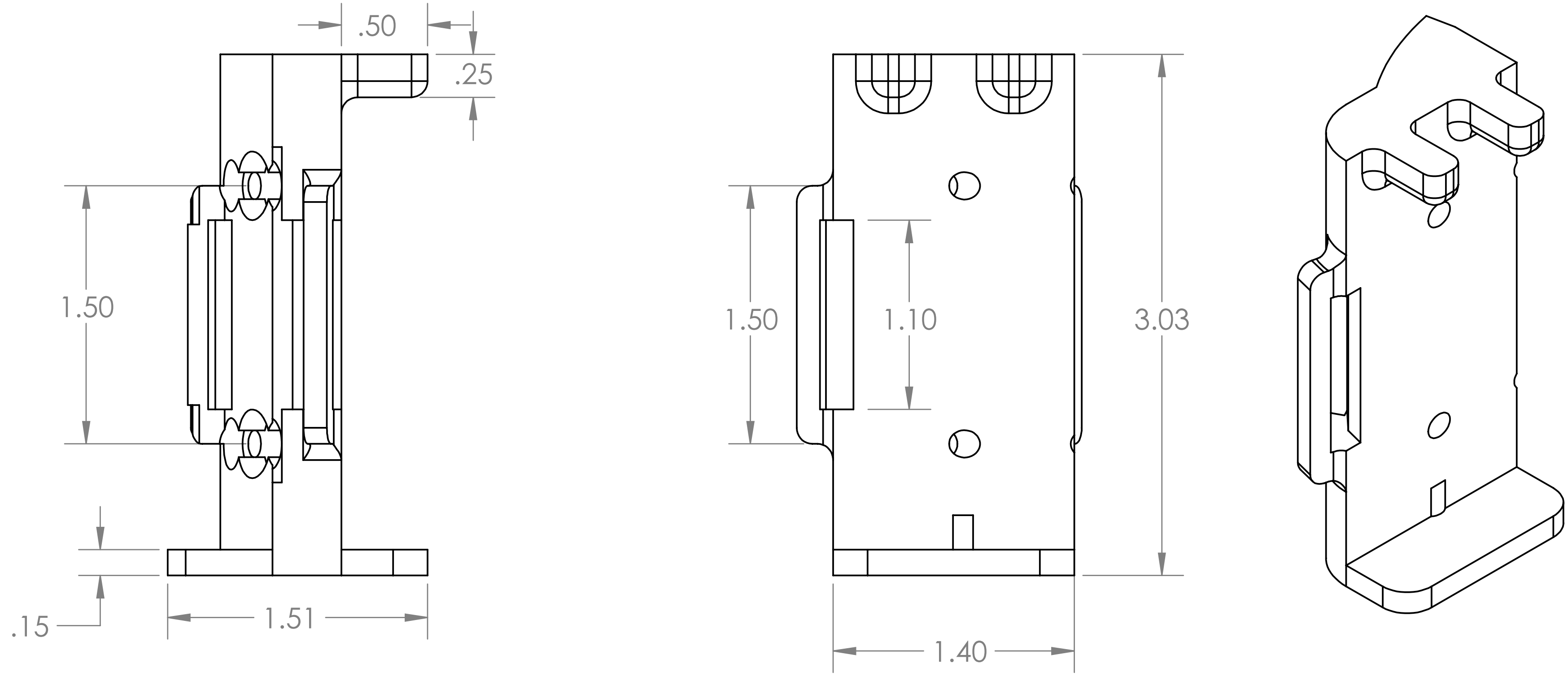
TITLE:
Raven Mount

SIZE A | DWG. NO. U22-2-2-102 | REV

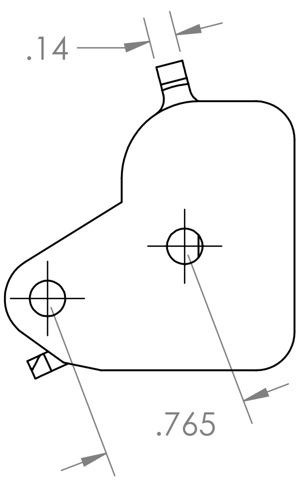
SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1

2 1

B B



A A



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL Polycarbonate			

HPRC
WPI AIAA

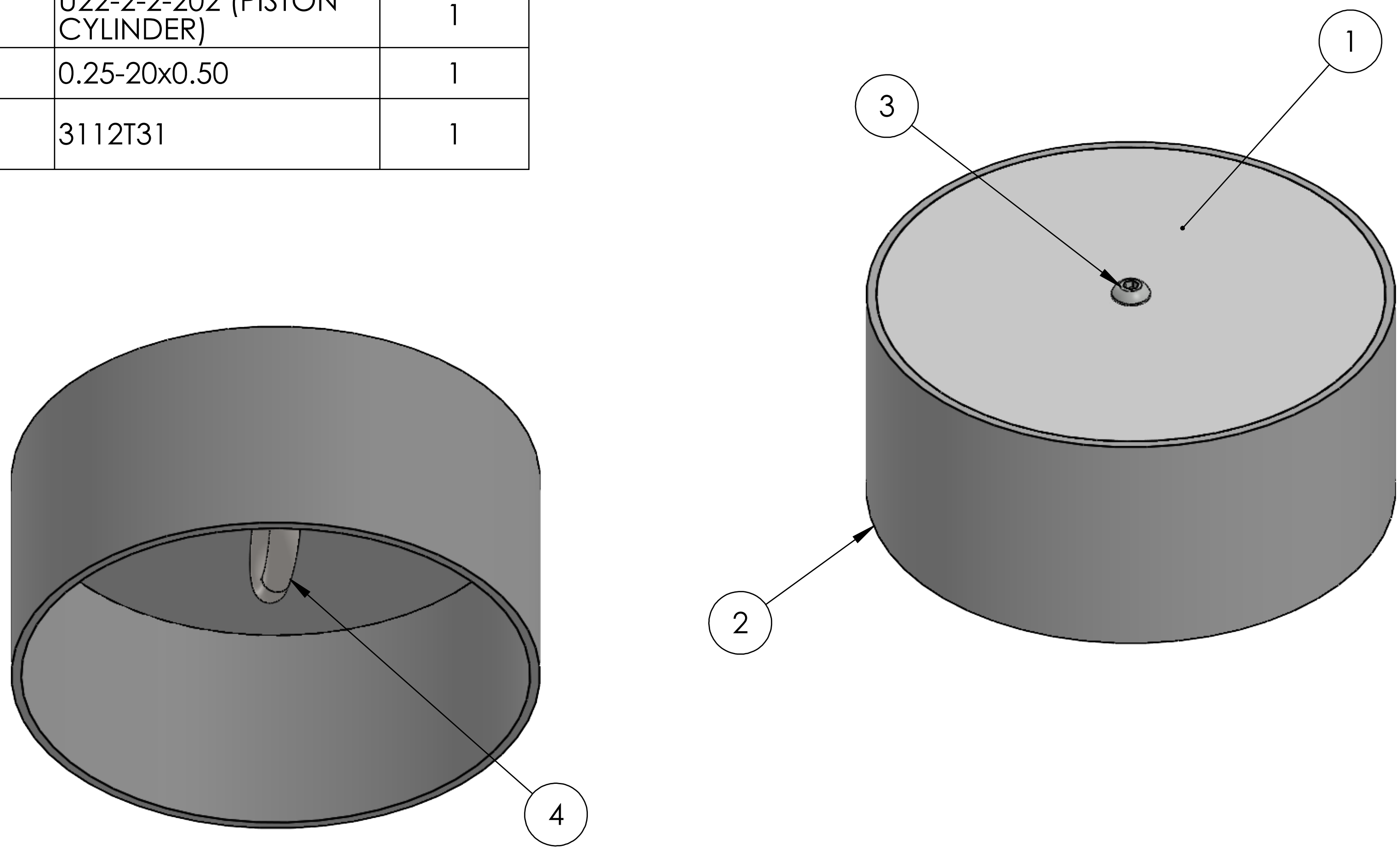
TITLE:

Power Switch Mount

SIZE	DWG. NO.	REV
A	U22-2-2-103	
SCALE: 1:1	WEIGHT:	SHEET 1 OF 1

2 1

ITEM NO.	PART NUMBER	QTY.
1	U22-2-2-201 (PISTON BULKHEAD)	1
2	U22-2-2-202 (PISTON CYLINDER)	1
3	0.25-20x0.50	1
4	3112T31	1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL			

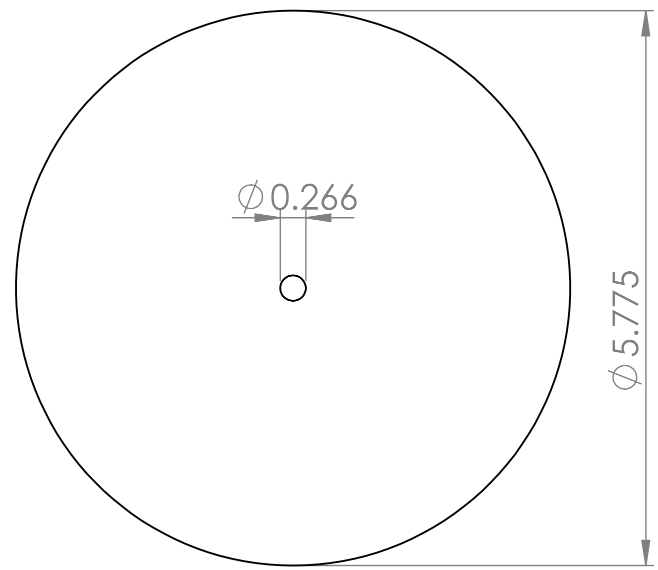
HPRC WPI AIAA

TITLE:

Payload Piston Assembly

SIZE	DWG. NO.	REV
A	U22-2-2-200	

SCALE: 1:2	WEIGHT:	SHEET 1 OF 1



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:

NEXT ASSY	USED ON
APPLICATION	

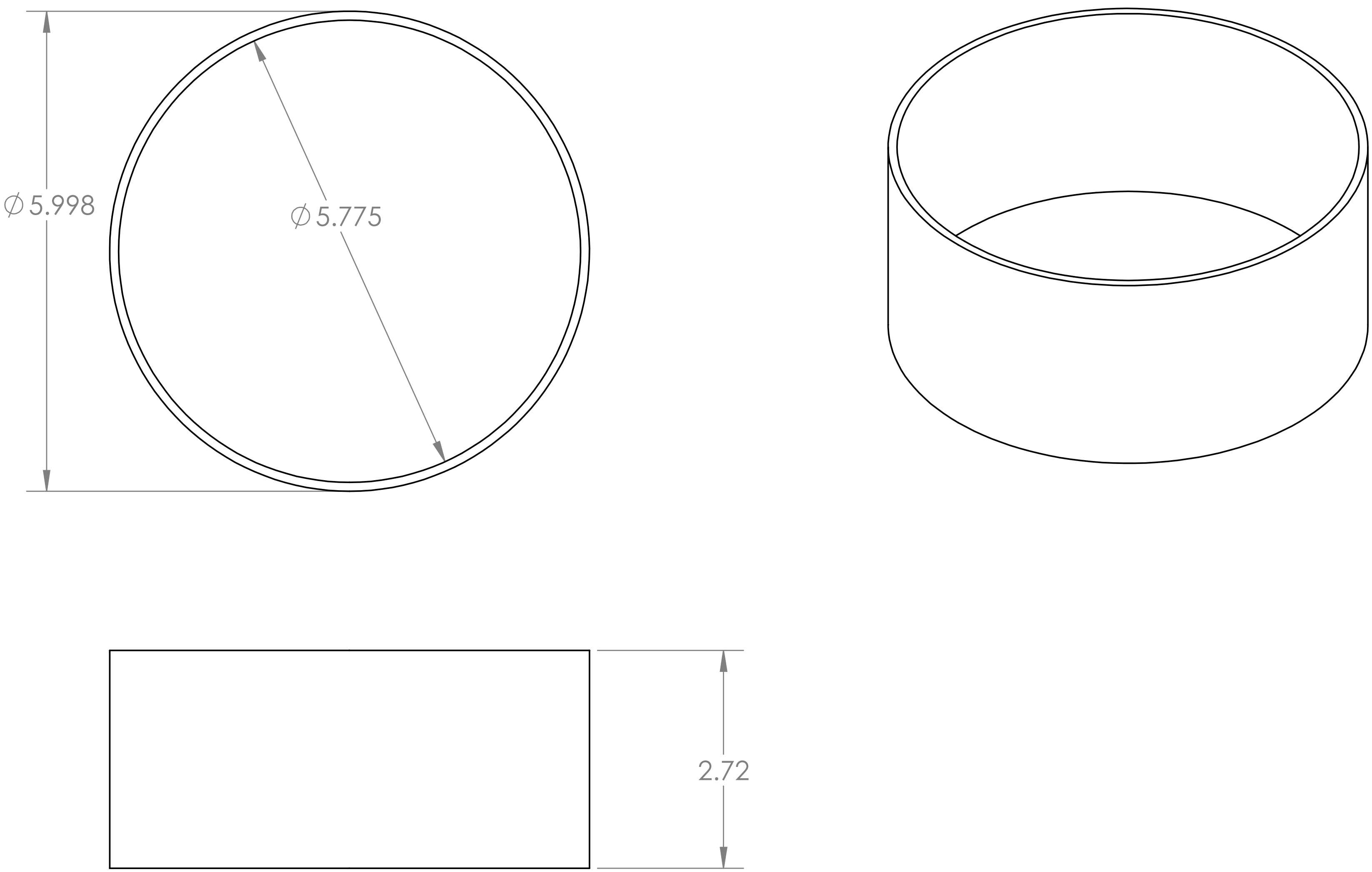
DO NOT SCALE DRAWING

TITLE:

U22-2-2-201 (PISTON BULKHEAD)

SIZE A | DWG. NO. | REV

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



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL Fiberglass			

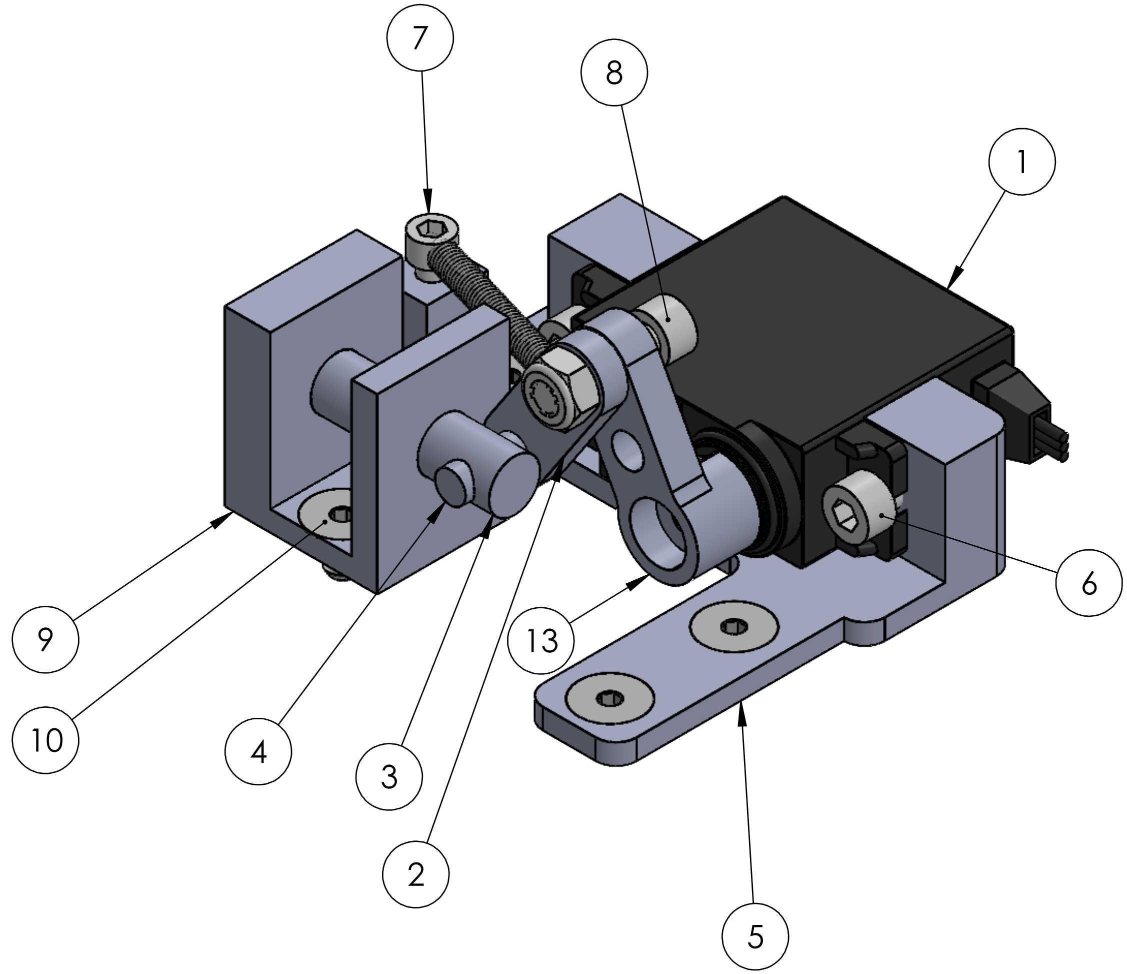
HPRC WPI AIAA

TITLE:
Piston Cylinder

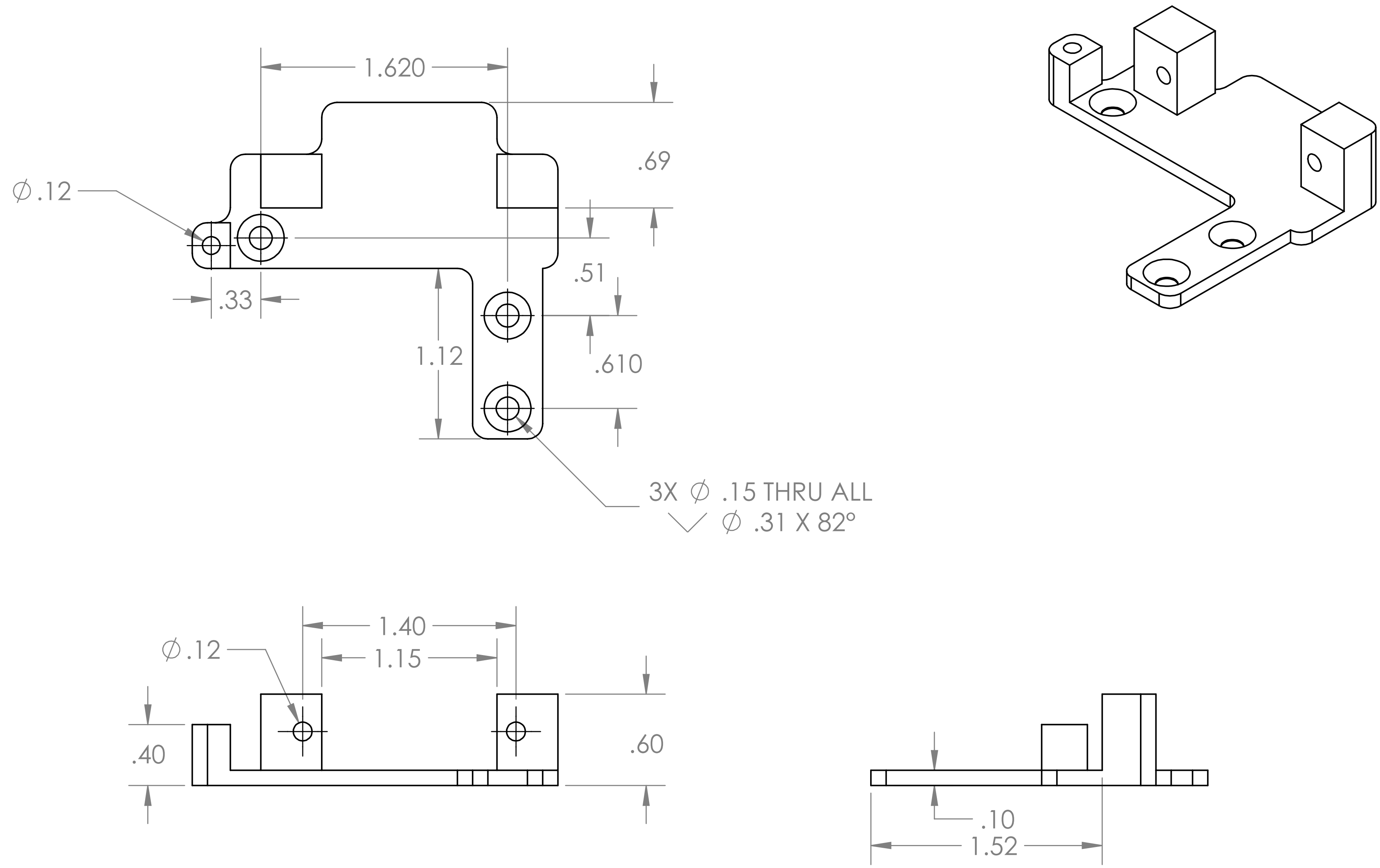
SIZE	DWG. NO.	REV
A	U22-2-2-202	

SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

ITEM NO.	PART NUMBER	QTY.
1	HS-5087MH	1
2	U22-2-2-304 (SERVO HORN CONNECTOR)	1
3	U22-2-2-305 (PIN)	1
4	U22-2-2-306 (CONNECTING PIN)	1
5	U22-2-2-301 (SERVO BASE)	1
6	#6-32x0.250	2
7	#4-40x0.375	1
8	#6-32x0.500	1
9	U22-2-2-302 (PIN HOLDER)	1
10	91263A512	5
11	5108N084	1
12	#4-40	1
13	U22-2-2-303 (SERVO HORN)	1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	TITLE: Parachute Release Assembly
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022	
	CHECKED	JR	5/12/2022	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA			SIZE A · DWG. NO. U22-2-2-300 · REV
MATERIAL				SCALE: 1.5:1 · WEIGHT: · SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL Polycarbonate			

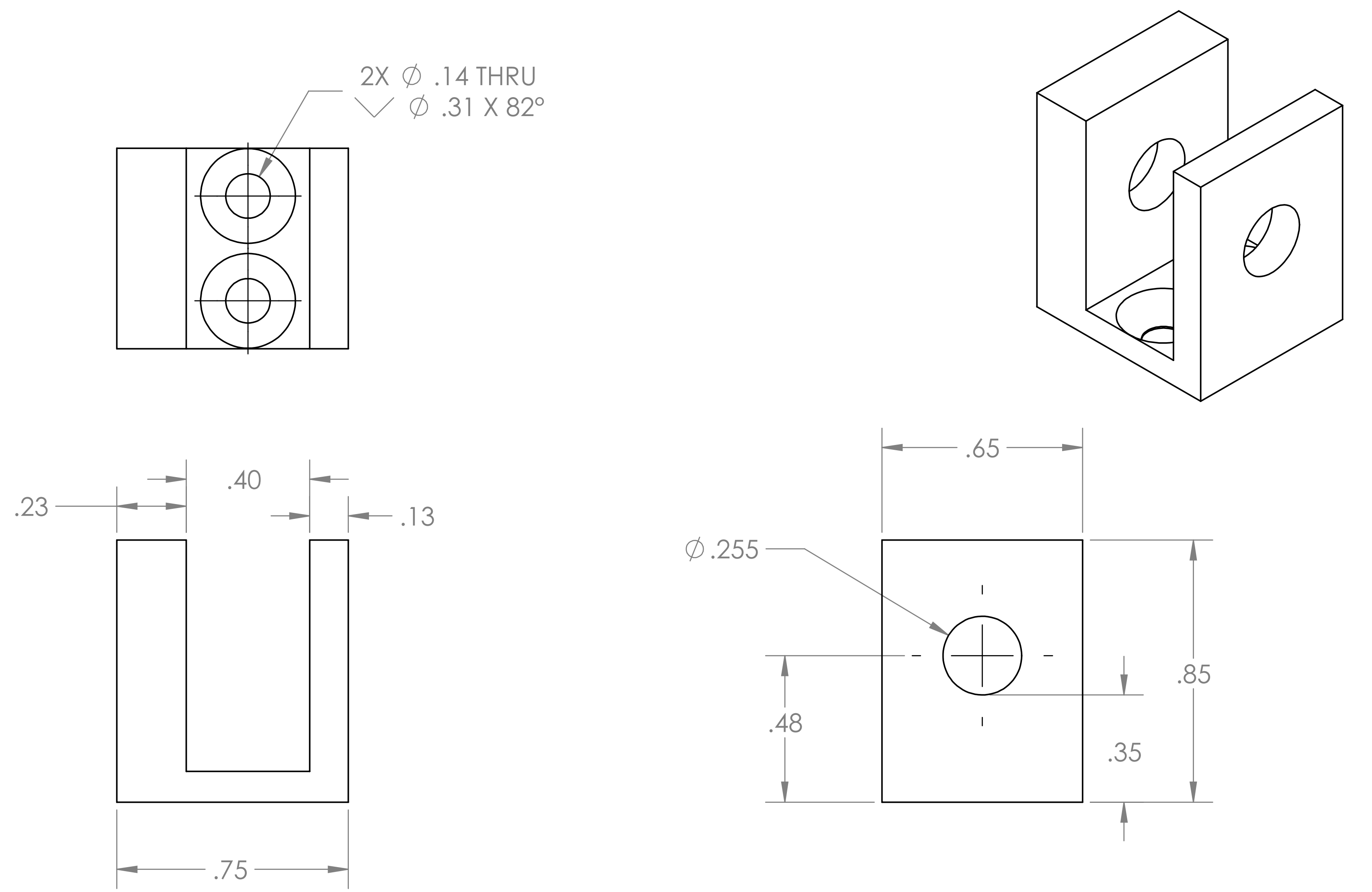
HPRC
WPI AIAA

TITLE:

Servo Base

SIZE	DWG. NO.	REV
A	U22-2-2-301	

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



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL 6061-T6 Aluminum			

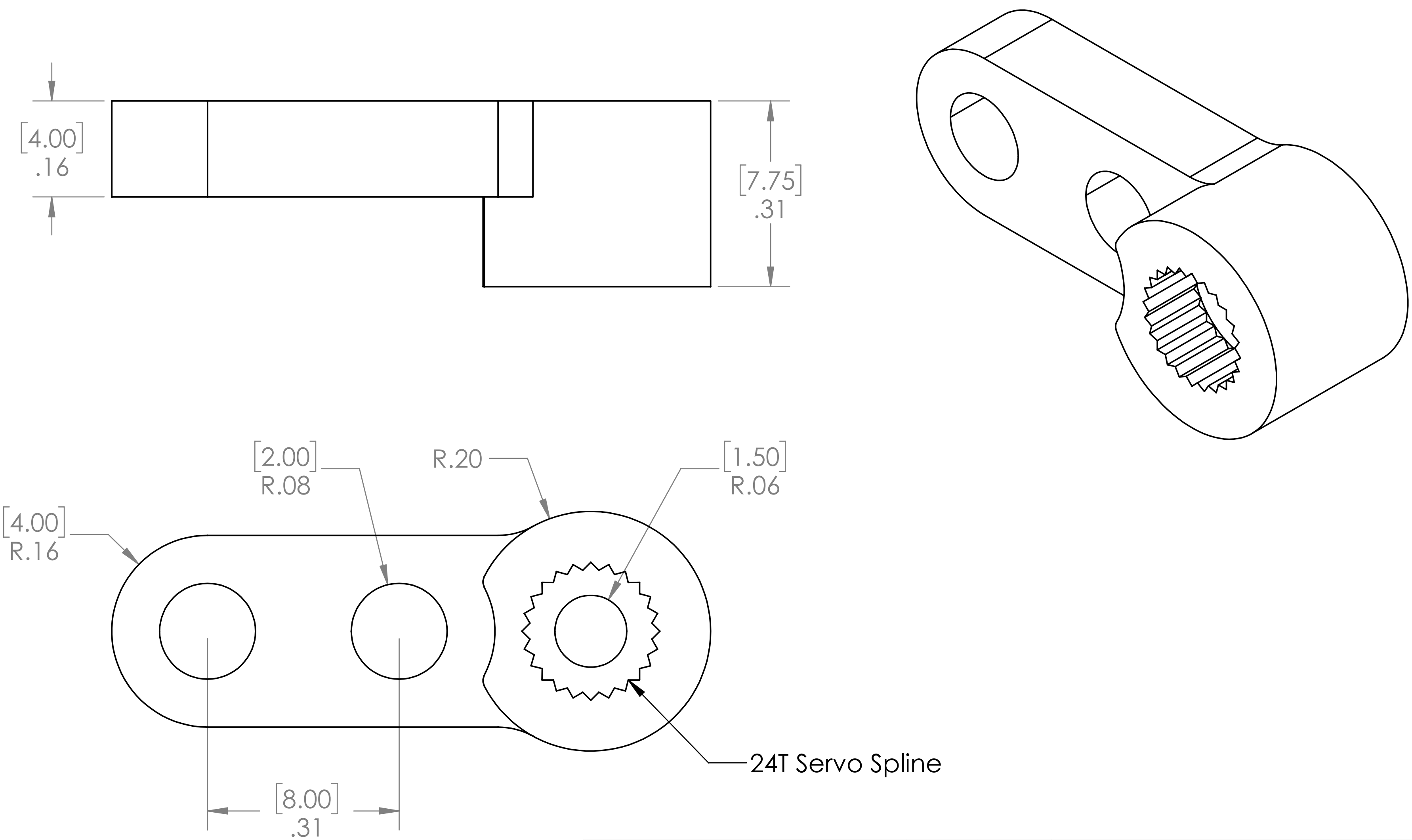
HPRC WPI AIAA

TITLE:

Pin Holder

SIZE	DWG. NO.	REV
A	U22-2-2-302	

SCALE: 2:1 WEIGHT: SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL Aluminum			

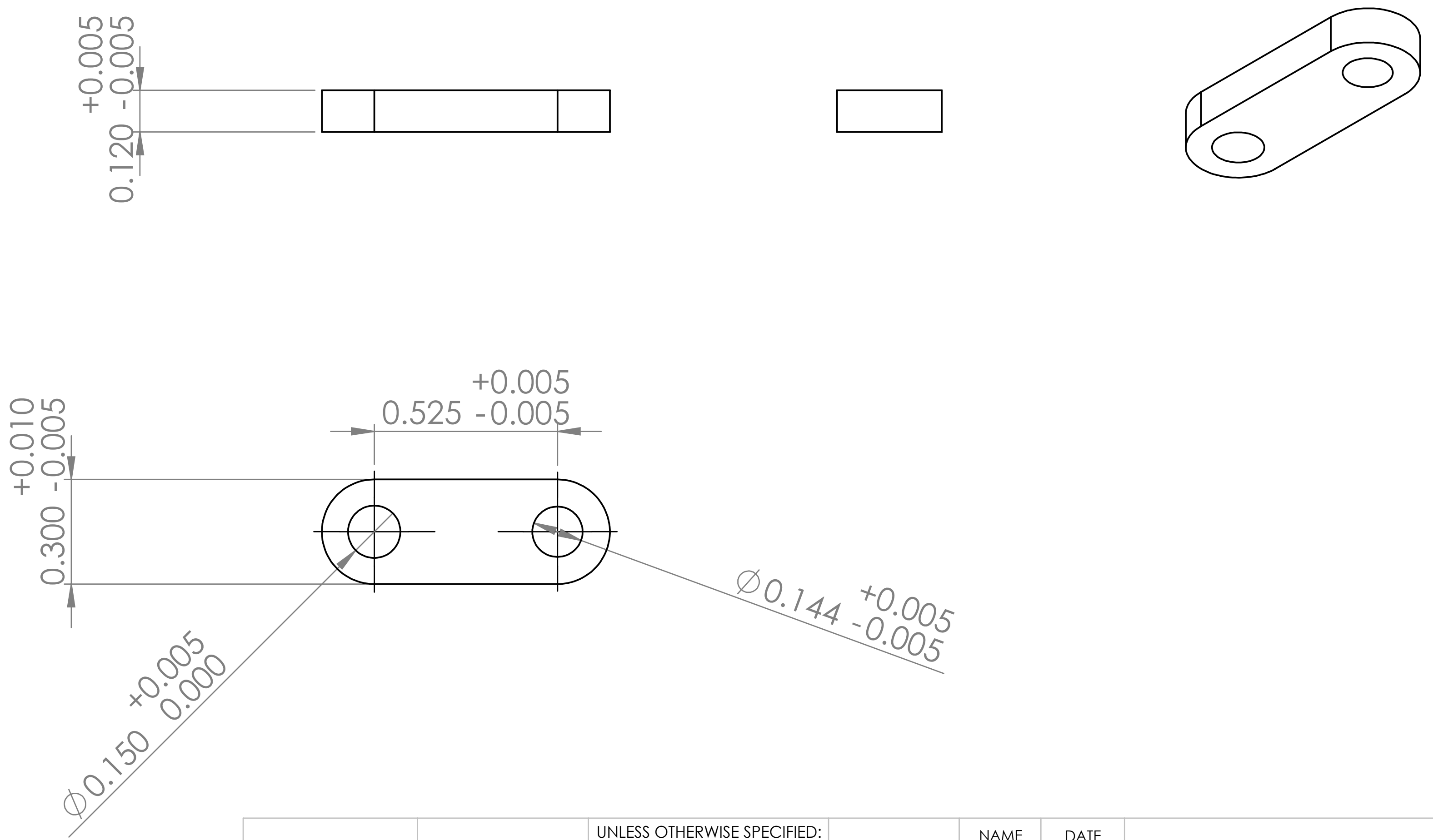
HPRC WPI AIAA

TITLE:

Servo Horn

SIZE	DWG. NO.	REV
A	U22-2-2-303	

SCALE: 4:1	WEIGHT:	SHEET 1 OF 1



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	LE	4/22/22	TITLE: SERVO HORN CONNECTOR
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL Aluminum	COMMENTS:			SIZE A · DWG. NO. U22-2-2-304 · REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 2:1 · WEIGHT: · SHEET 1 OF 1

PROPRIETARY AND CONFIDENTIAL

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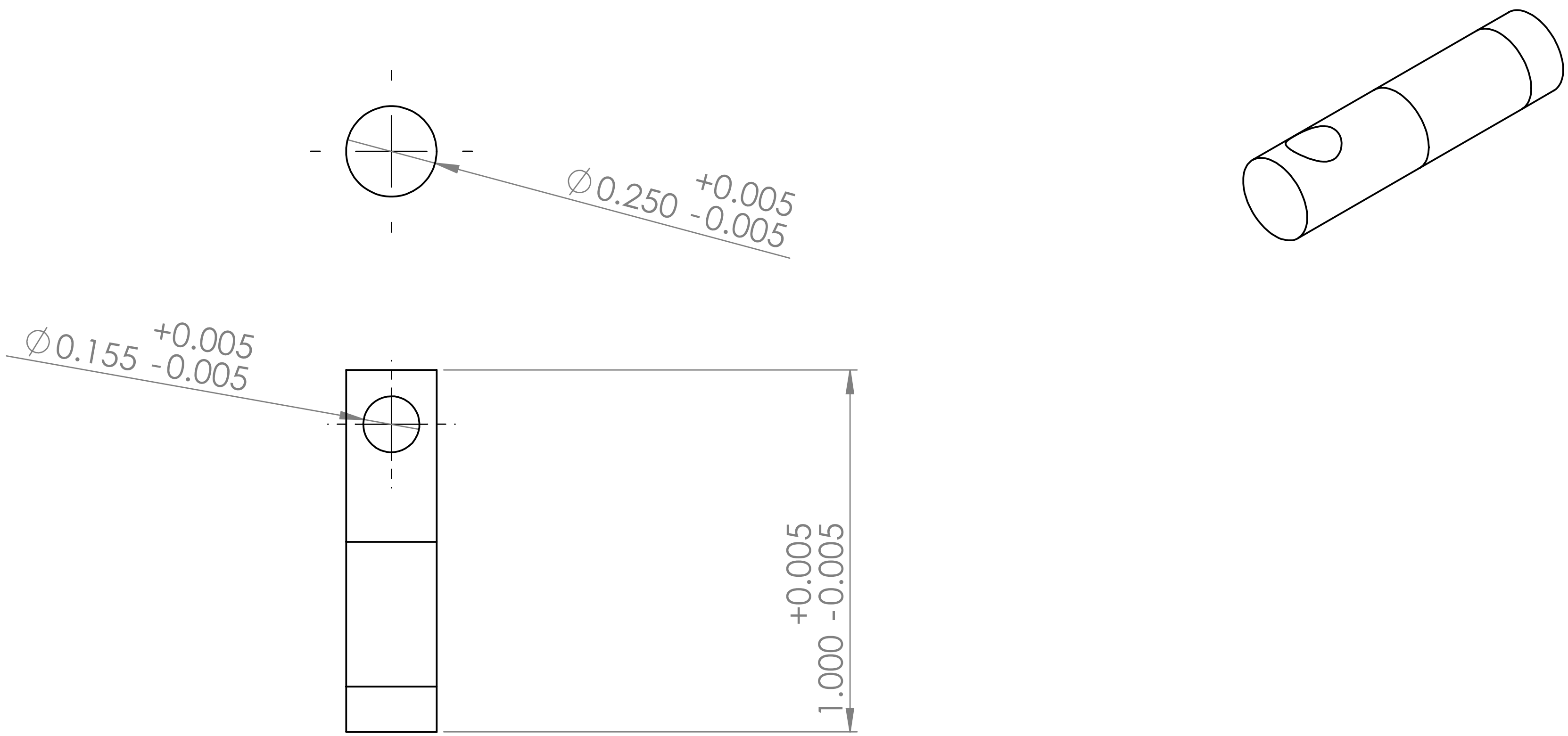
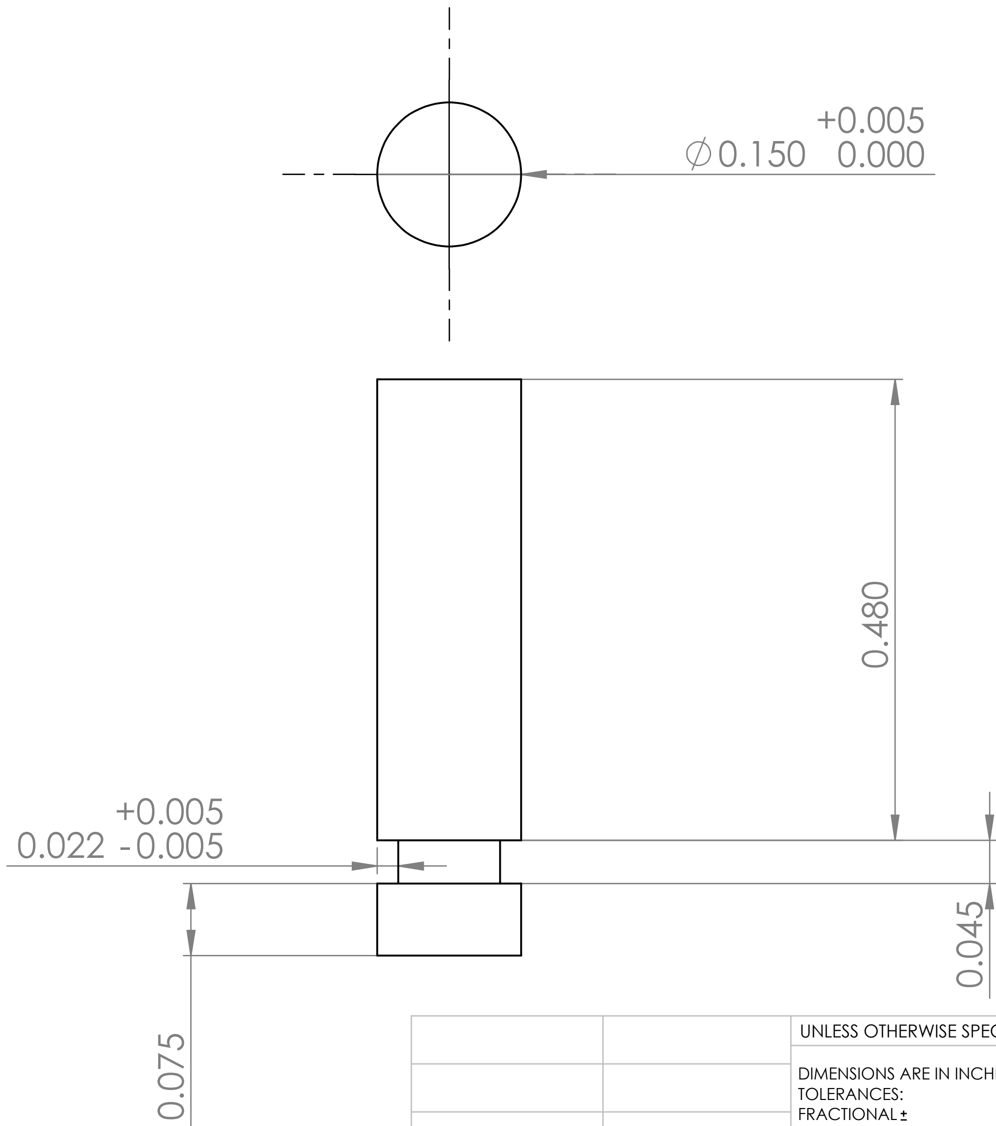
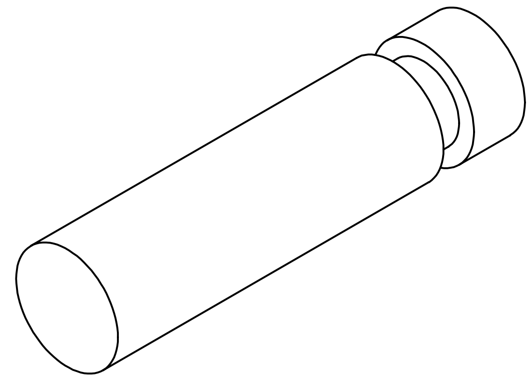


		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	LE	4/11/22	TITLE:
			CHECKED			PIN
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL Aluminum	COMMENTS:			SIZE A — DWG. NO. U22-2-2-305 — REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 2:1 — WEIGHT: — SHEET 1 OF 1





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NEXT ASSY | USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
Aluminum

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	LE	4/11/22
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

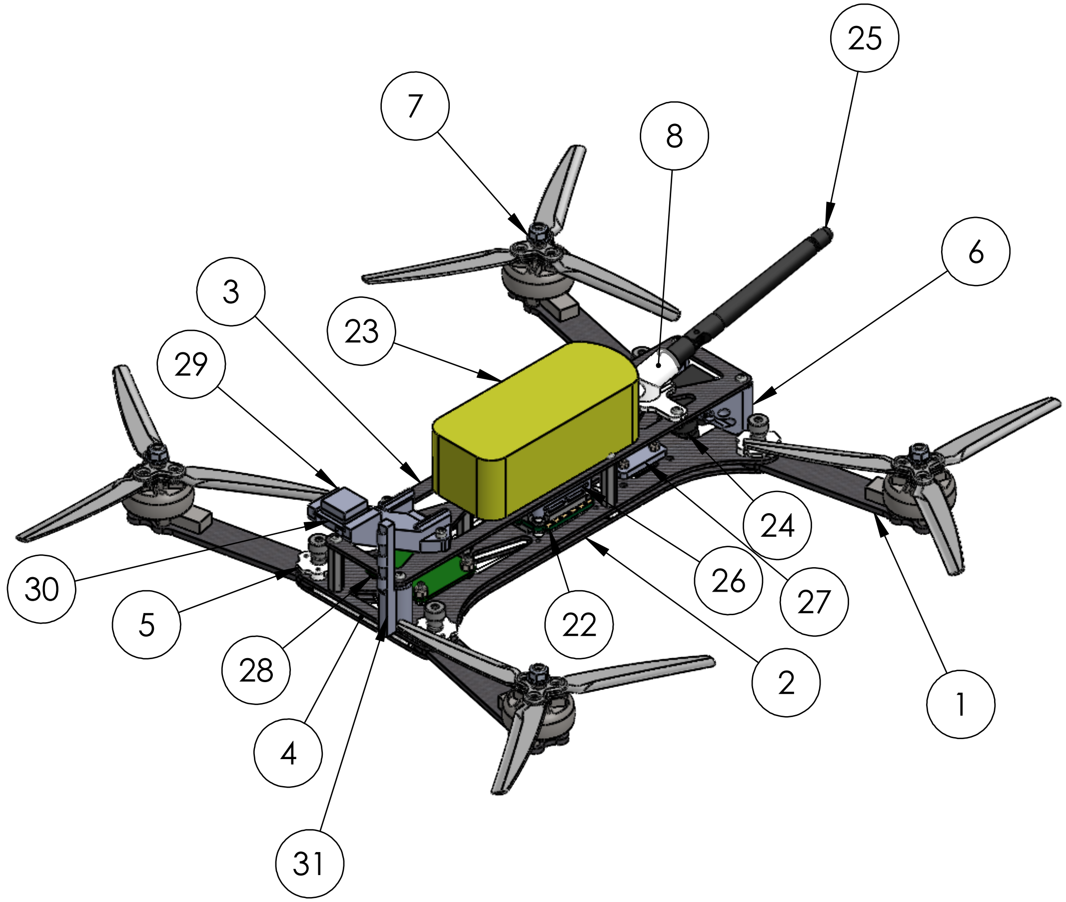
COMMENTS:

TITLE:
CONNECTING PIN

SIZE **A** | DWG. NO. U22-2-2-306 | REV

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

ITEM NO.	PART NUMBER	QTY.
1	U22-2-3-004 (QUAD ARM)	4
2	U22-2-3-001 (QUAD MAIN PLATE)	2
3	U22-2-3-002 (QUAD TOP PLATE)	1
4	U22-2-3-003 (QUAD MID PLATE)	1
5	U22-2-3-100 (QUADCOPTER ARM LOCKING ASSEMBLY)	4
6	U22-2-3-005 (RUNCAM SPLIT 4 MOUNT)	1
7	U22-2-3-200 (QUADCOPTER MOTOR ASSEMBLY)	4
8	U22-2-3-009 (ANTENNA MOUNT)	1
9	#4-40x0.250	7
10	#4-40x0.375	9
11	91306A657	16
12	91502A111	4
13	91502A108	4
14	92290A746	4
15	93625A101	4
16	94205A220	8
17	#4-40	4
18	#4-40x0.500	2
19	91780A167	7
20	93657A201	4
21	93657A203	12
22	Lumenier ELITE PRO 60A 2-6S BLHeli_32 4-in-1 ESC	1
23	Zippy Compact 1800mAh 6s 40c LiPo	1
24	Runcam Hybrid	1
25	Quater Wave 915 MHz Dipole Antenna	1
26	Lumenier LUX H7 HD Ultimate Flight Controller	1
27	Runcam Hybrid Board	1
28	Quad Microcontroller Board	1
29	U22-2-3-010 (GPS MOUNT) - Copy	1
30	MATEK M8Q-5883 GPS Module	1
31	U22-2-3-011 (ANTENNA MOUNT)	1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/32
ANGULAR: MACH ± 1 BEND ± 1
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5

MATERIAL

	NAME	DATE
DRAWN	CB	5/10/2022
CHECKED	JR	5/12/2022

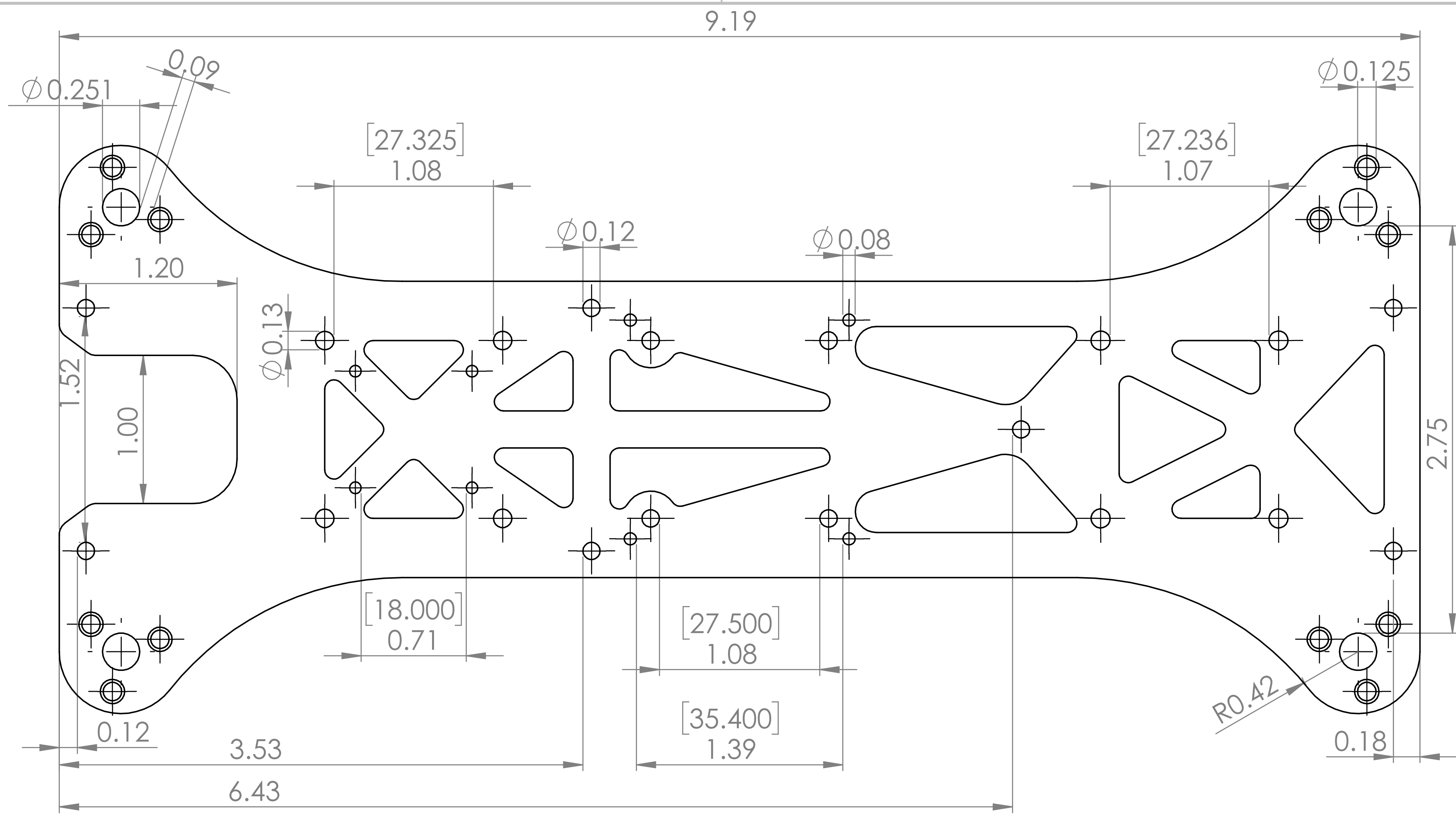
HPRC WPI AIAA

TITLE:

Quadcopter Assembly

SIZE A | DWG. NO. U22-2-3-000 | REV

SCALE: 1:3.5 WEIGHT: SHEET 1 OF 1



PROPRIETARY AND CONFIDENTIAL

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NEXT ASSY	USED ON
APPLICATION	

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:

TITLE:

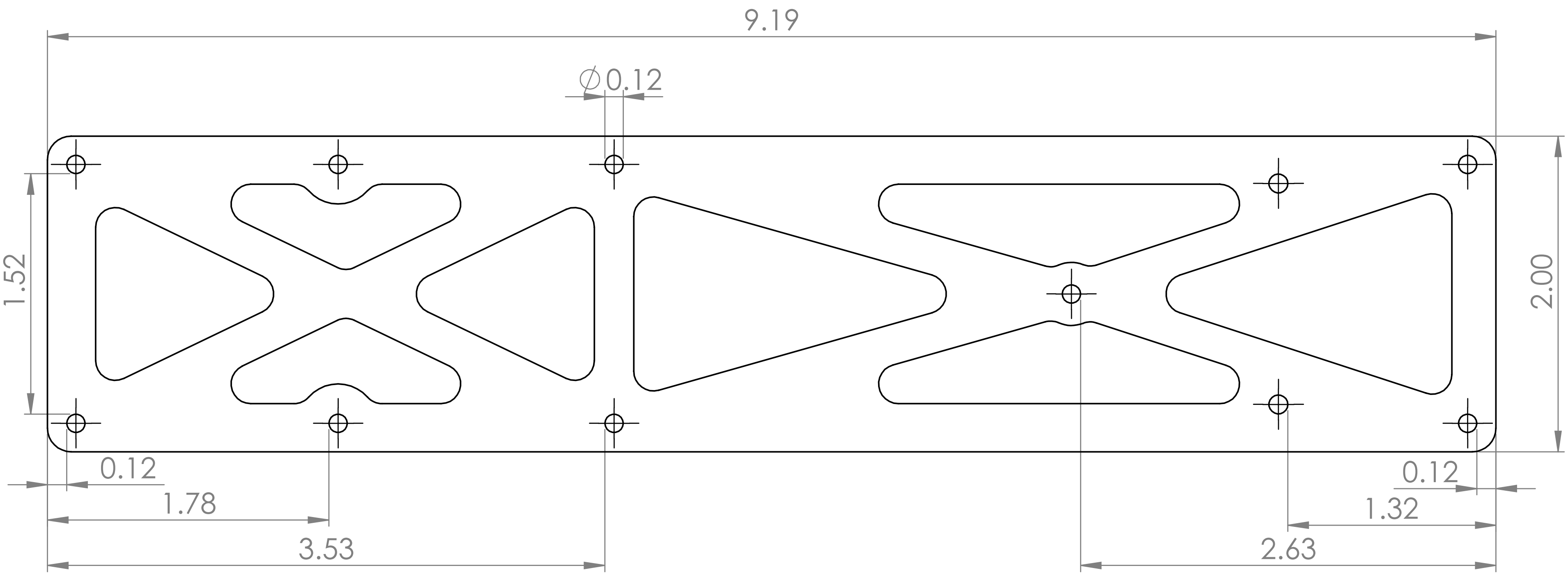
Quad Main Plate

SIZE	DWG. NO.	REV
A	U22-2-3-001	

SCALE: 1:1 WEIGHT: SHEET 1 OF 1

2 1

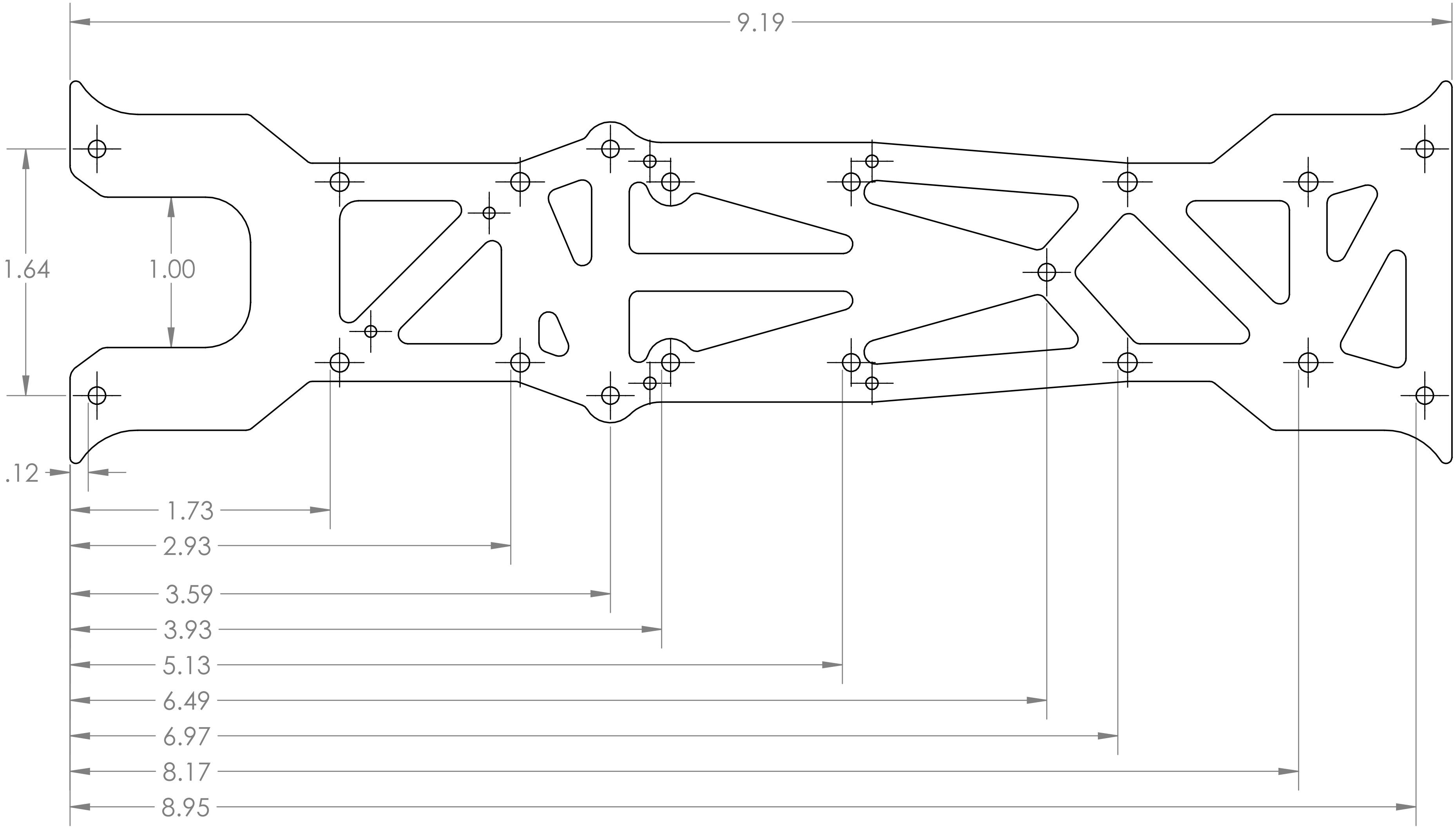
B B



A A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE: Quad Top Plate
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE A DWG. NO. U22-2-3-002 REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:1 WEIGHT: SHEET 1 OF 1

2 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL Plywood			

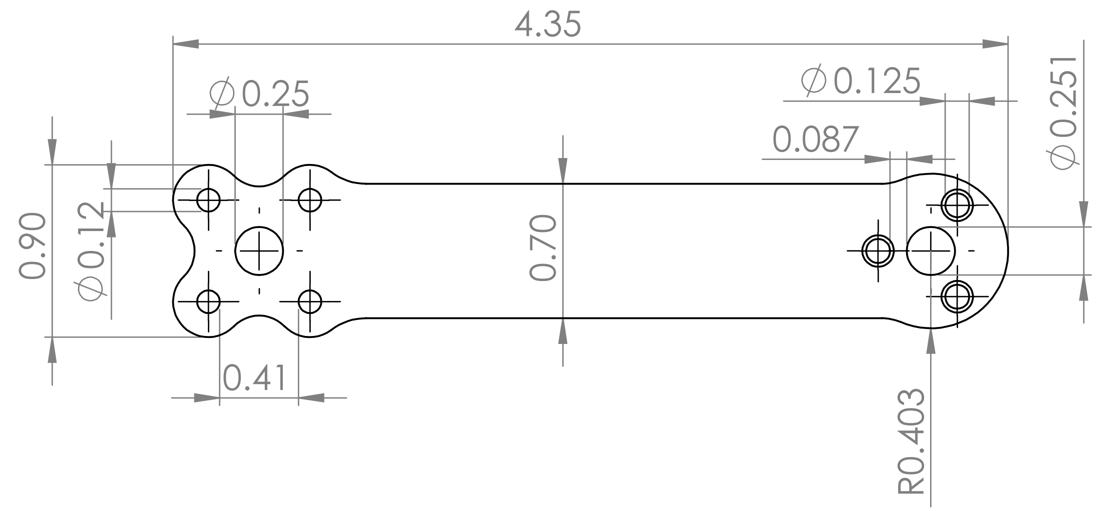
HPRC WPI AIAA

TITLE:

Quad Mid Plate

SIZE	DWG. NO.	REV
A	U22-2-3-003	

SCALE: 1:1	WEIGHT:	SHEET 1 OF 1



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE: Quad Arm
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE A DWG. NO. U22-2-3-004 REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:1 WEIGHT: SHEET 1 OF 1

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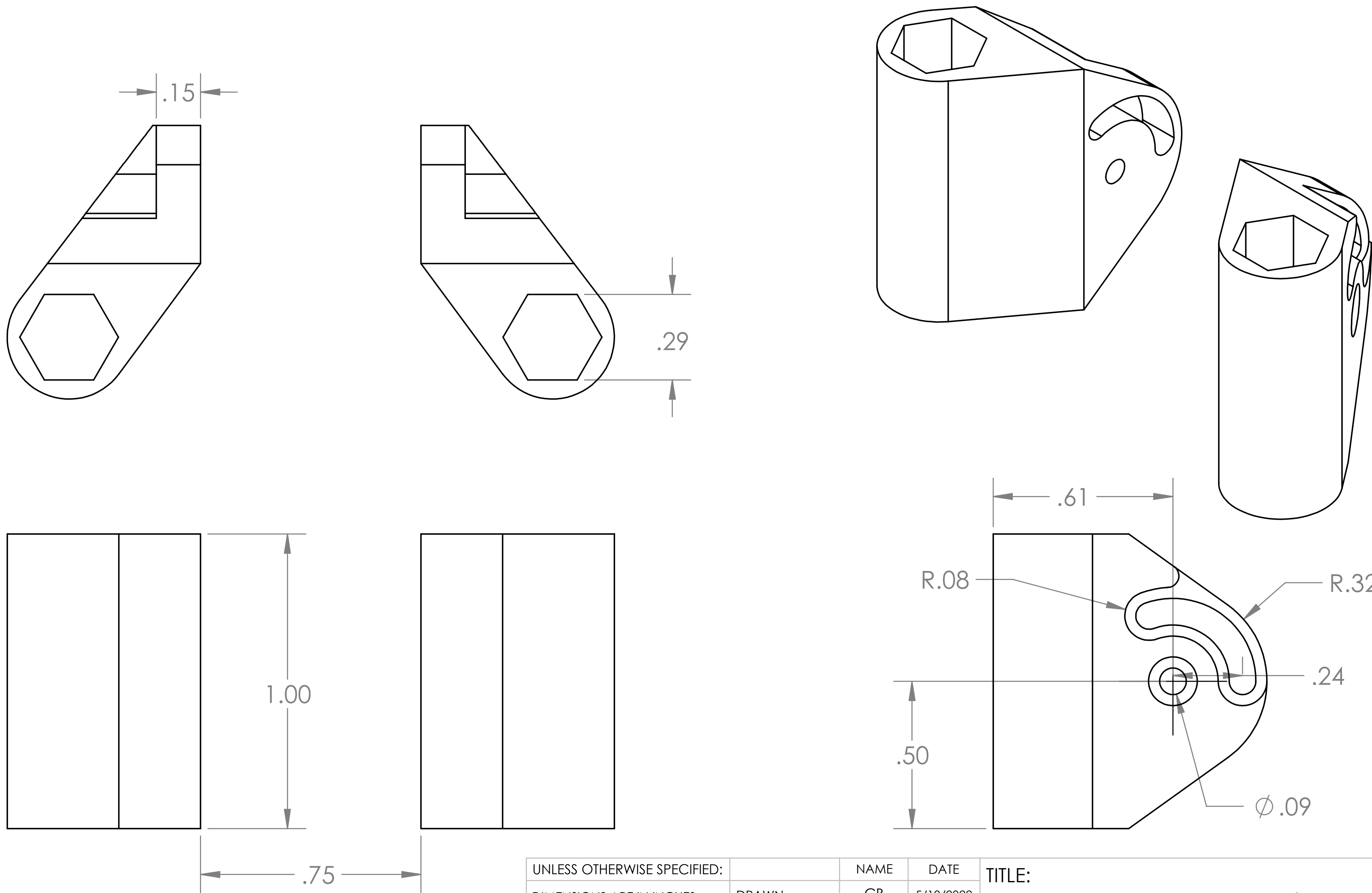


UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/32
ANGULAR: MACH ± 1 BEND ± 1
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5

MATERIAL
Polycarbonate

	NAME	DATE
DRAWN	CB	5/10/2022
CHECKED	JR	5/12/2022

HPRC WPI AIAA

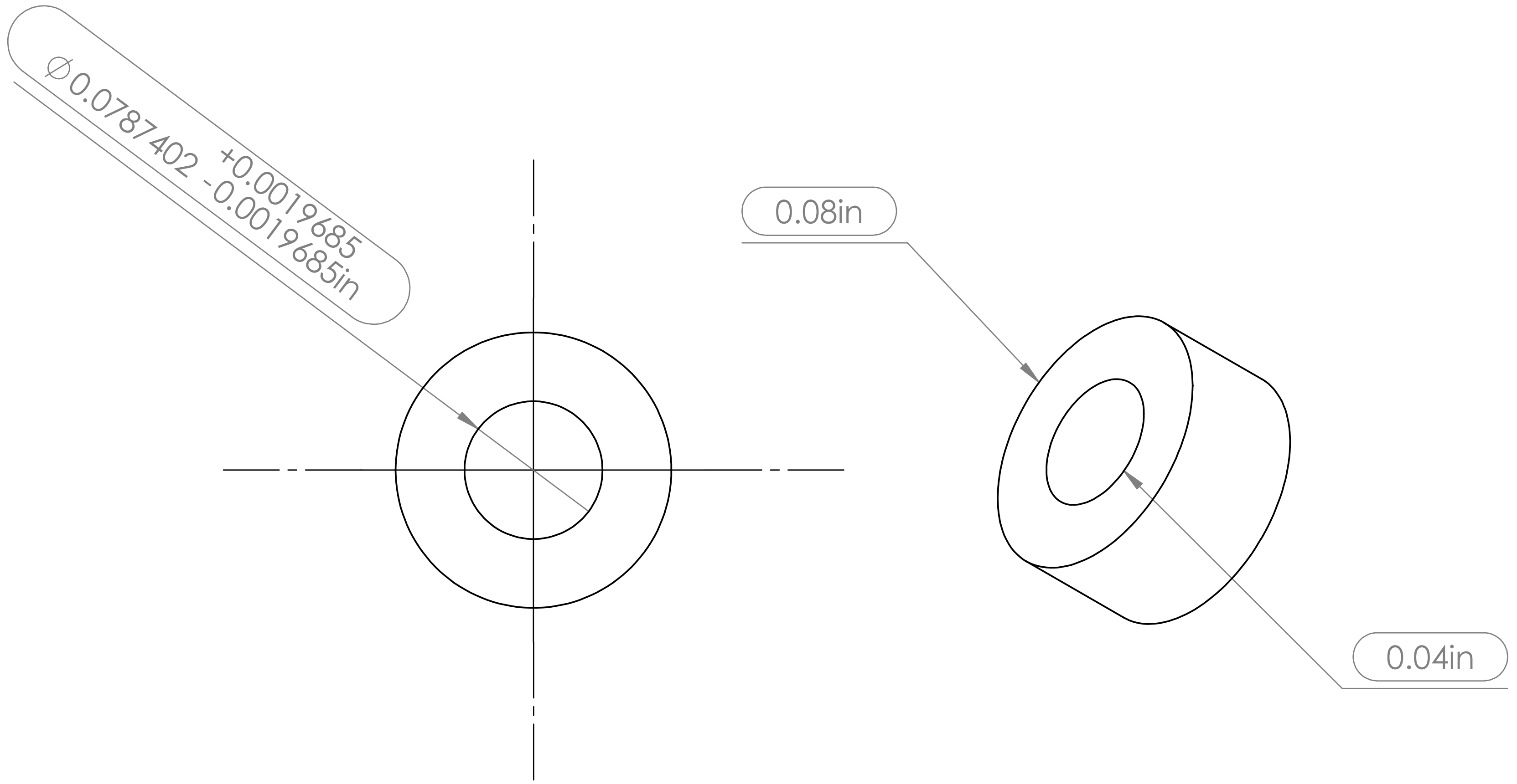
TITLE:
Runcam Split 4 Mount

SIZE A | DWG. NO. U22-2-3-005 | REV

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

2 1

B B



A A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
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			CHECKED			TITLE:
			ENG APPR.			ESC 2MM SPACER
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL Nylon 6/6 Plastic	COMMENTS:			SIZE A — DWG. NO. U22-2-3-007 — REV 1
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 10:1 — WEIGHT: — SHEET 1 OF 1

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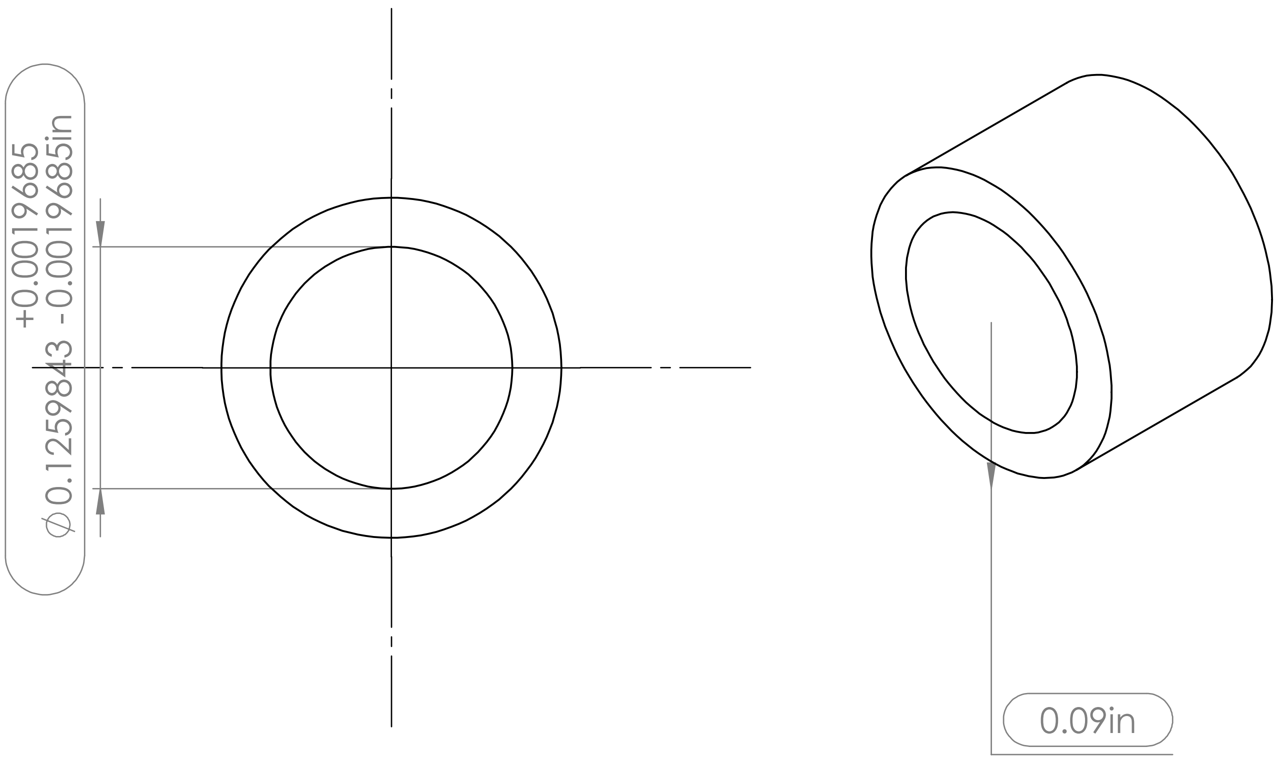
2 1

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	Skyler Cole	3/16/2022
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL Nylon 6/6 Plastic	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

PROPRIETARY AND CONFIDENTIAL

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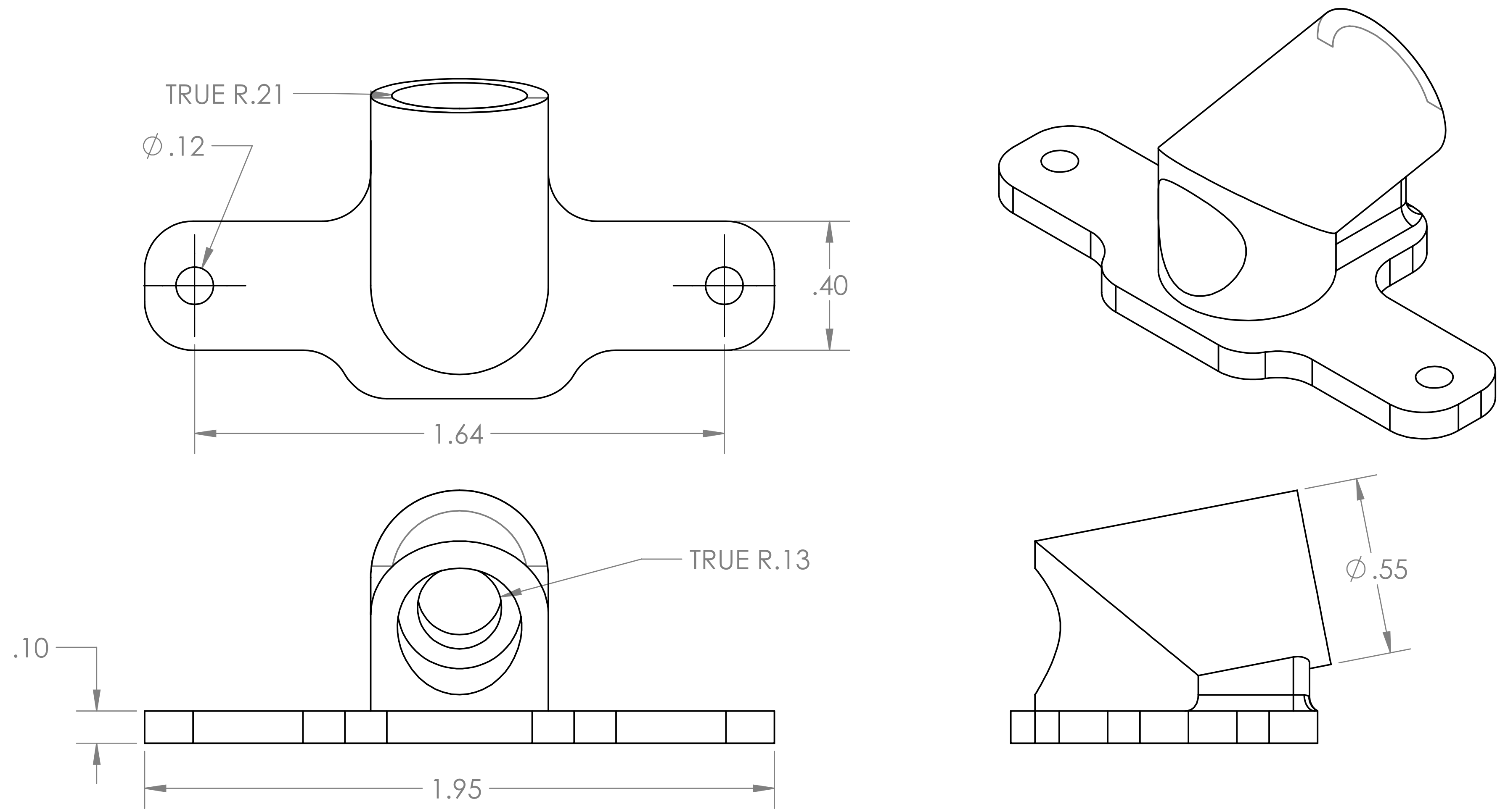
TITLE:

ESC 3MM SPACER

SIZE	DWG. NO.	REV
A	U22-2-3-008	1

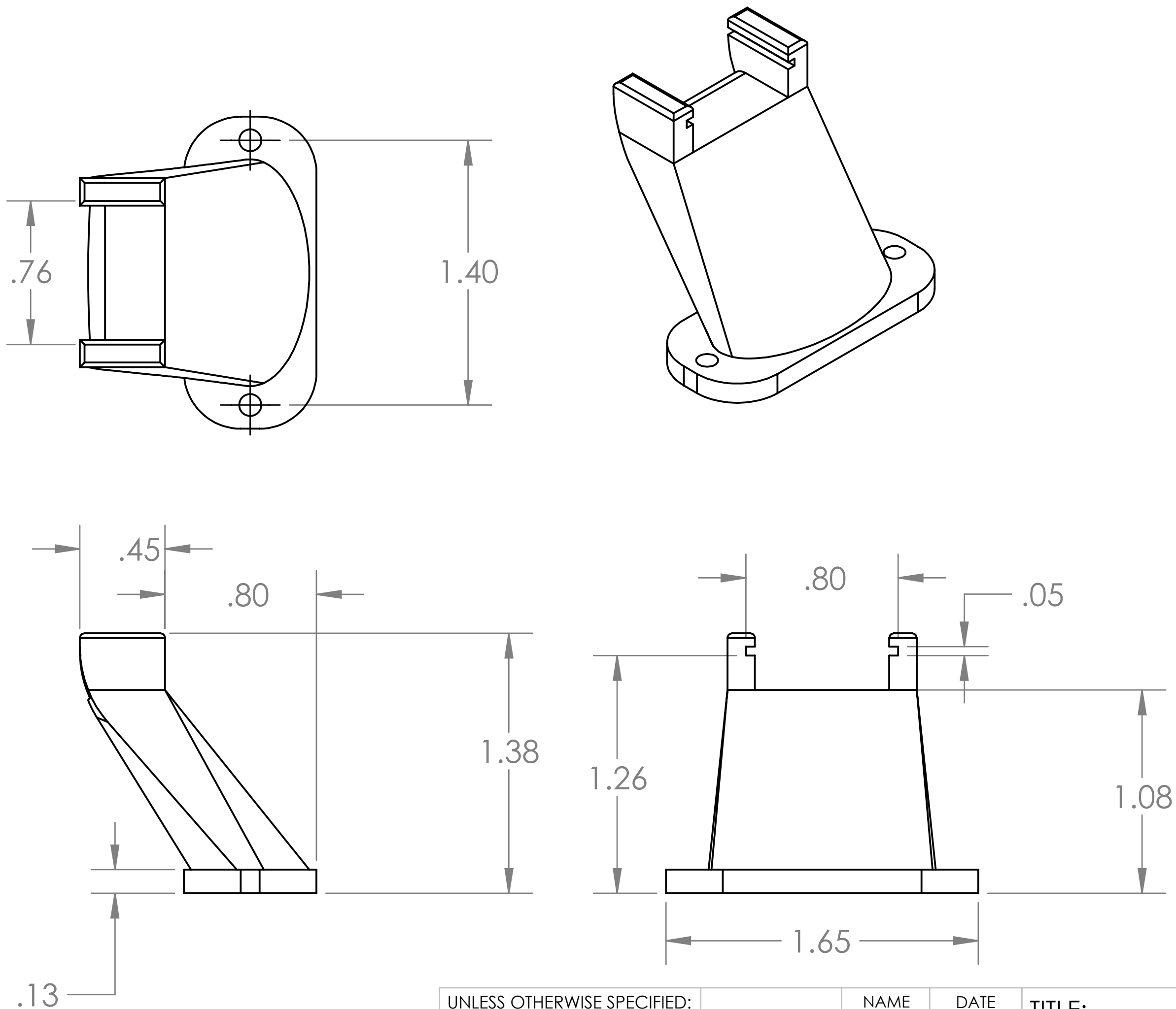
SCALE: 10:1 WEIGHT: SHEET 1 OF 1

2 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5	HPRC WPI AIAA		
MATERIAL Polycarbonate			

TITLE:		
Antenna Mount		
SIZE A	DWG. NO. U22-2-3-009	REV
SCALE: 2:1	WEIGHT:	SHEET 1 OF 1

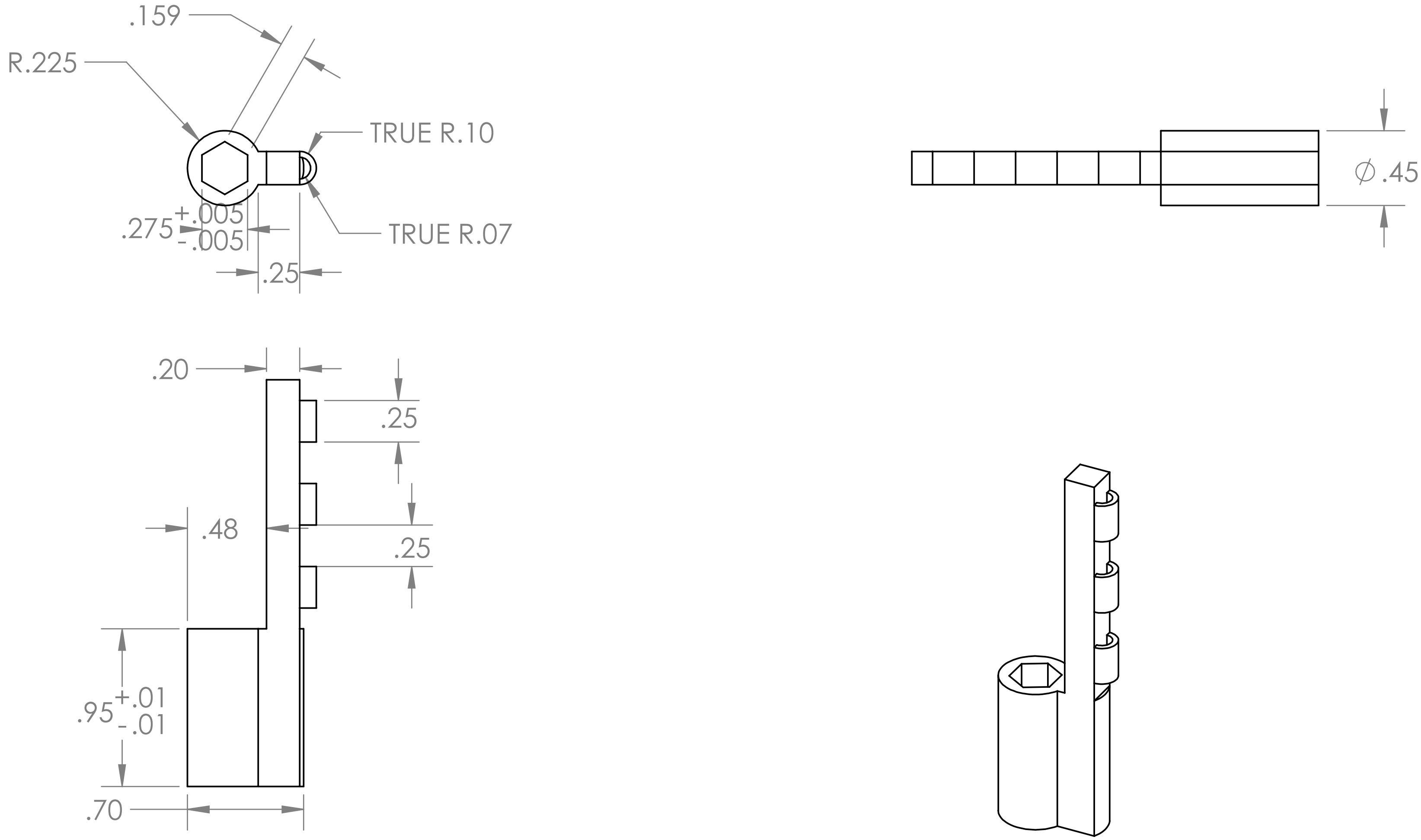


UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL Polycarbonate			

HPRC WPI AIAA

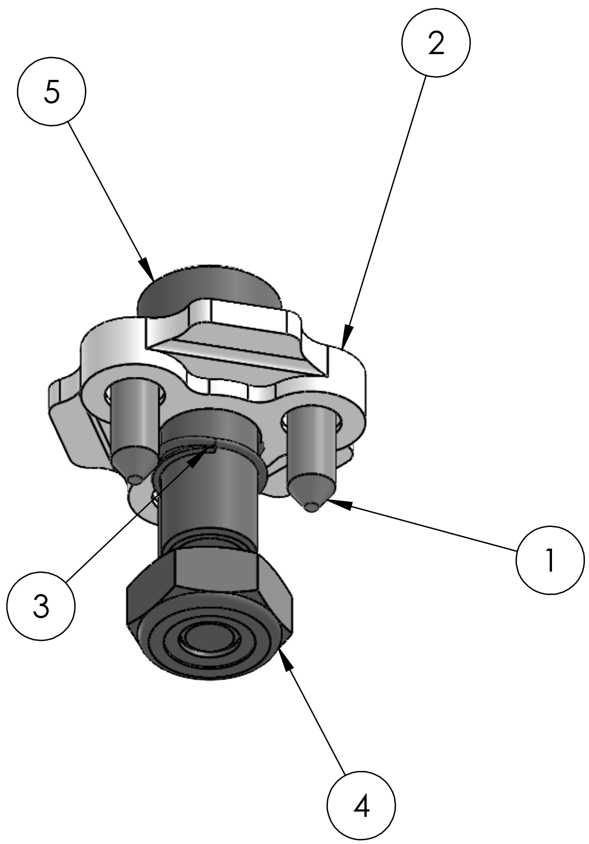
TITLE: **GPS Mount**

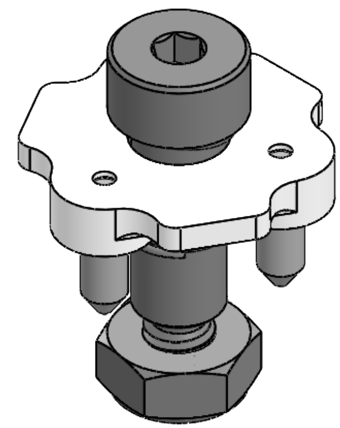
SIZE	DWG. NO.	REV
A	U22-2-3-010	
SCALE: 1:1	WEIGHT:	SHEET 1 OF 1



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	Hunter Crossman	4/13/2022	TITLE:
			CHECKED			Antenna Mount
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL Thermoplastic Polyurethane	COMMENTS:			SIZE A / DWG. NO. U22-2-3-011 / REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:1 / WEIGHT: / SHEET 1 OF 1

ITEM NO.	PART NUMBER	QTY.
1	U22-2-3-102 (QUADCOPTER LOCKING PIN)	3
2	U22-2-3-101 (QUADCOPTER LOCKING PIN CARRIER)	1
3	9657K265	1
4	90633A411	1
5	94035A539	1





UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL			

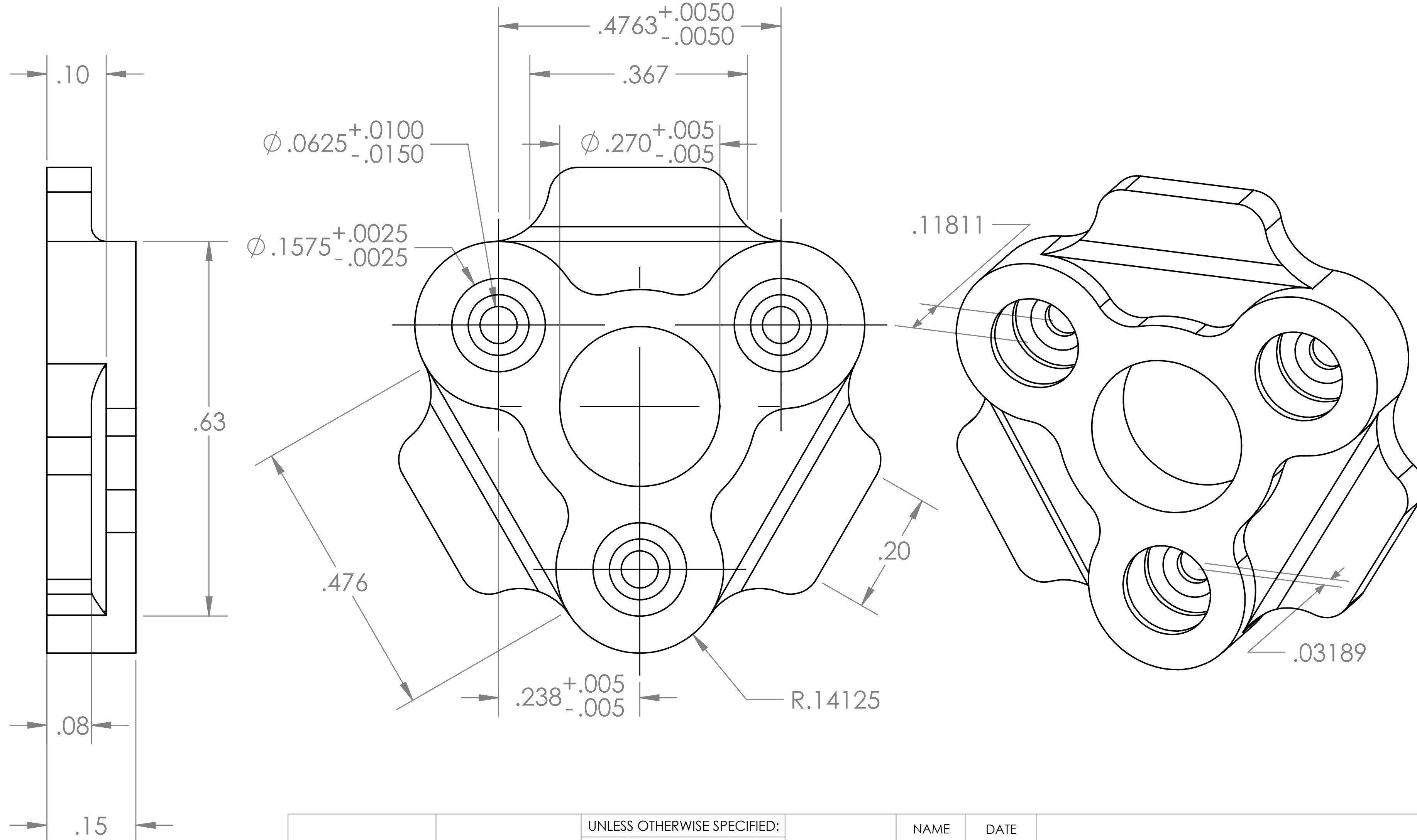
HPRC WPI AIAA

TITLE:

Quadcopter Arm Locking Assembly

SIZE	DWG. NO.	REV
A	U22-2-3-100	

SCALE: 2:1	WEIGHT:	SHEET 1 OF 1



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	Hunter Crossman	3/14/2022
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

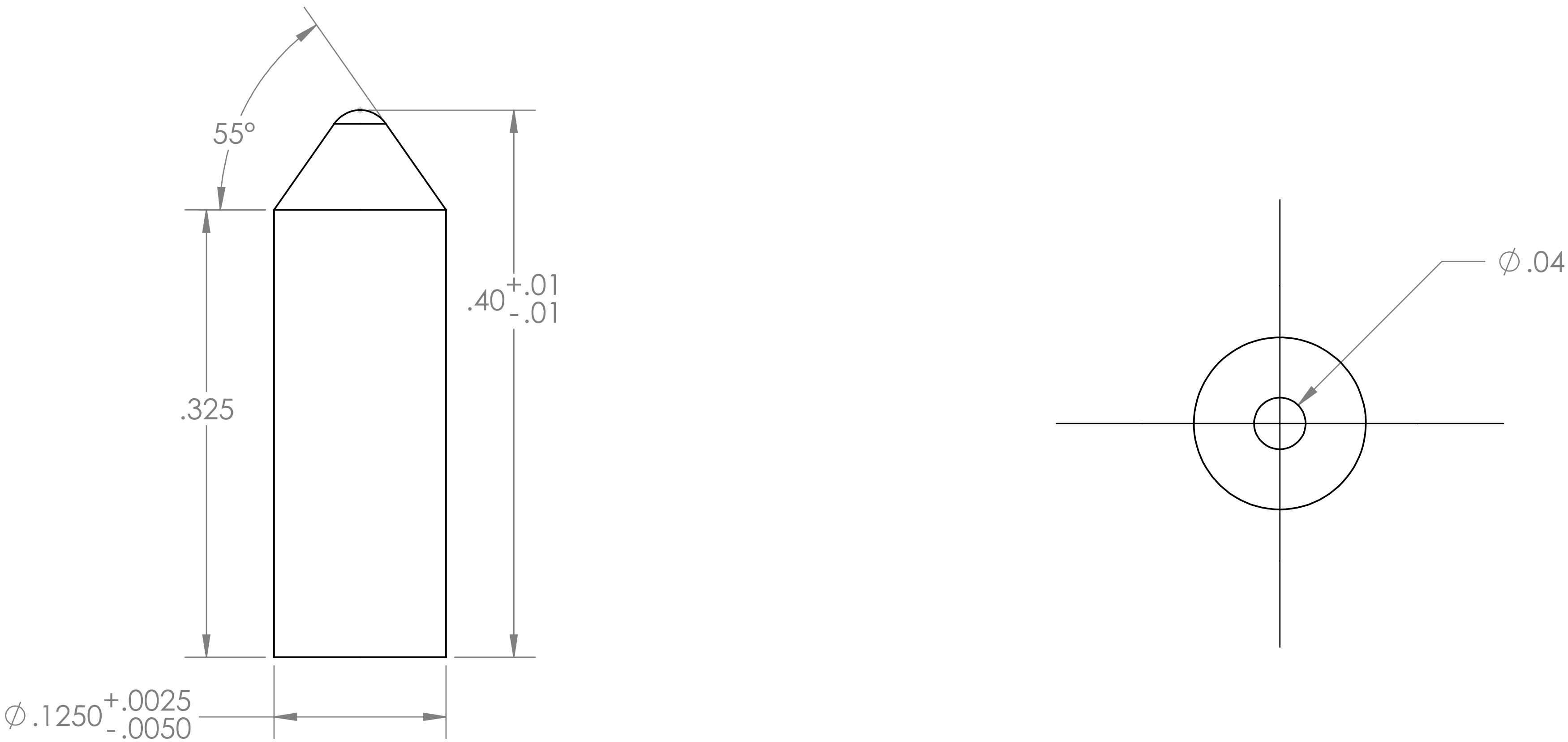
PROPRIETARY AND CONFIDENTIAL

TITLE:

QUAD PIN LOCKING CARRIER

SIZE	DWG. NO.	REV
A	U22-2-3-101	1

SCALE: 4:1 WEIGHT: SHEET 1 OF 1



		UNLESS OTHERWISE SPECIFIED:
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±
		INTERPRET GEOMETRIC TOLERANCING PER:
		MATERIAL 6061-T6 Aluminum
NEXT ASSY	USED ON	FINISH
APPLICATION		DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	Hunter Crossman	3/14/2022
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:
QUADCOPTER LOCKING PIN

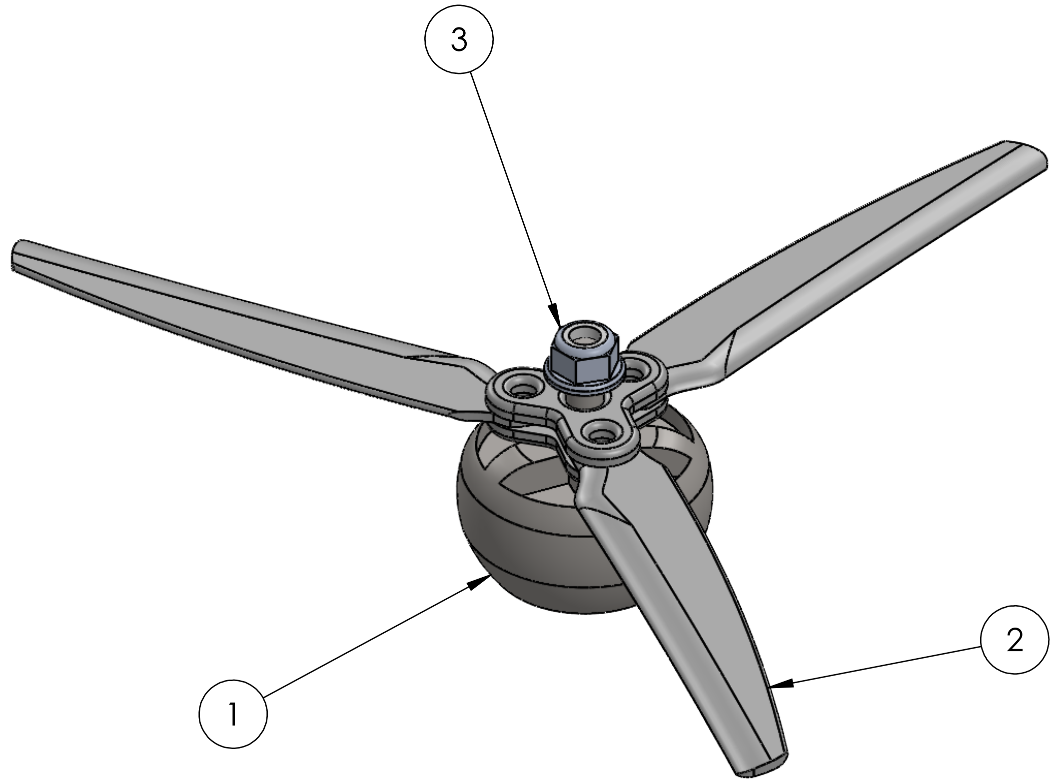
SIZE	DWG. NO.	REV
A	U22-2-3-102	1

SCALE: 8:1 | WEIGHT: | SHEET 1 OF 1

2 1

ITEM NO.	PART NUMBER	QTY.
1	Emax ECO II Series 2807 1500KV	1
2	Lumenier 6.7x3x3 Folding Propeller	1
3	MotorShaftNut	1
4	Luiminer Propeller Spring	1

B B



A A

UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 1/32 ANGULAR: MACH ± 1 BEND ± 1 TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.005	DRAWN	CB	5/10/2022
	CHECKED	JR	5/12/2022
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5			
MATERIAL			

HPRC WPI AIAA

TITLE:

Quadcopter Motor Assembly

SIZE	DWG. NO.	REV
A	U22-2-3-200	
SCALE: 1:1	WEIGHT:	SHEET 1 OF 1

2 1

Acknowledgments

The team's authors and members would like to thank the team's sponsors, Curtis Heisey our rocketry advisor, and the various WPI administrators that have given their time and resources to the team.

References

[1] Zachary Howard. "How To Calculate Fin Flutter Speed." Peak of Flight Newsletter, Jul 19, 2011, pp. 2–6.
[2] Iliopoulos, A., Steuben, J., and Michopoulos, J. "Determination of Anisotropic Mechanical Properties of G-10 Composite via Direct Strain Imaging." Polymer Testing, Vol. 50, 2016. https://doi.org/10.1016/j.polymertesting.2015.12.002.
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[4] Balanis, A., Constantine. "Antenna Theory: Analysis and Design." Wiley-Interscience, 2015.
[5] Knacke, T. W., Parachute recovery systems: Design manual, Para Publishing, 1992.