Case Rocket Team - Aurora and DogBone
Team 206 Project Technical Report for the 2026 IREC

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The Case Rocket Team is an undergraduate rocketry team from Case Western Reserve University in Cleveland, Ohio, competing in the 30,000 ft AGL Commercial-Off-The-Shelf category of the 2026 International Rocket Engineering Competition. CRT has designed and built a rocket, Aurora, and a payload, DogBone, to compete in this year's competition. Aurora features an entirely custom composite airframe manufactured by the team. The payload, DogBone, is a 3U CubeSat that tests the dampening properties of a new polymer produced by a research lab in the CWRU Department of Macromolecular Science and Engineering. The team's custom flight computer, Sirin, will connect with a base station to transmit live data and GPS position. Aurora is the first IREC rocket with strain gauges across the airframe and fins to measure the rocket through flight and to inform future composite design. The team's ultimate goal is to elevate the performance of CRT rockets in the 30K COTS category from the previous three years, demonstrating CRT's ability to continually innovate and reach new heights.

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I. Nomenclature

AGL	=	above ground level
$APRS$	=	Automatic Packet Reporting System
CAD	=	computer aided design
CAM	=	computer aided manufacturing
C_d	=	coefficient of drag
CNC	=	computer numerical control
$COTS$	=	commercial off-the-shelf
CRT	=	Case Rocket Team
$CWRU$	=	Case Western Reserve University
$dBFS$	=	Decibels relative to full scale
DC	=	direct current
$DTEG$	=	Design, Test, & Evaluation Guide
$e-bay$	=	Electronics Bay
$ECEF$	=	Earth-Centered, Earth-Fixed
$ESKF$	=	Error-State Kalman Filter
$ESRA$	=	Experimental Sounding Rocket Association
FEA	=	finite element analysis
FoS	=	factor of safety
ft	=	feet
g	=	grams
$GPIO$	=	general purpose input/output
GPS	=	global positioning system
Hz	=	hertz
hr	=	hour
ID	=	inner diameter
$in,"$	=	inches
IMU	=	inertial measurement unit
$IREC$	=	International Rocket Engineering Competition
lbs	=	pounds
lbf	=	pounds-force
LED	=	light-emitting diode
$Li-ion$	=	lithium-ion (Battery)
mAh	=	milliamp hours
MDF	=	medium-density fibreboard
MHz	=	megahertz
m	=	meters
mm	=	millimeters
N	=	newtons
NAR	=	National Association of Rocketry
Ns	=	newton-seconds
ORK	=	OpenRocket simulation software
OD	=	outer diameter
$PETG$	=	polyethylene terephthalate glycol
PLA	=	polylactic acid
RAS	=	RASAero II simulation software
RF	=	radio frequency
s	=	seconds
SDR	=	software defined radio
$SRAD$	=	student researched and developed
TRA	=	Tripoli Rocketry Association
UNC	=	Unified National Coarse
V	=	volts

II. Introduction

The Case Rocket Team is an undergraduate aerospace design team at Case Western Reserve University, consisting of members from a wide variety of disciplines. CRT is an extracurricular group and is fully student-led. The team is responsible for all planning and funding, although many on-campus resources are utilized. The IREC team is led by Competition Lead Rohan Rajappan and is composed of four subteams: Aerostructures, led by Robbie Shepherd and Alexander Stone; Payload, led by Jacob Gotthelf and Veronica Talan; Avionics, led by Brian Lujan and Alex Porter; and Measurements, led by Ian Dvorin and Luke Stephenson. Arlo Wheeler led CNC machining under both Aerostructures and Payload.

Aerostructures was responsible for simulation, design, manual manufacturing, and composite fabrication of the rocket airframe. Aerostructures oversaw the recovery system and design of the electronics bay in the rocket. Aerostructures also led the integration and assembly of the rocket. CNC Manufacturing was responsible for designing all CAM files and performing CNC operations for multiple machined components on both Aurora and DogBone. Payload was responsible for the design, manufacturing, and testing of the scientific payload for the 3U CubeSat payload for the Space Dynamics Laboratory competition. Avionics was responsible for the design and implementation of the SRAD flight computer, Sirin, and the wiring for the electronics. Avionics also took on the goal of live telemetry, which involves using the team's Base Station. Measurements was responsible for designing, testing, and implementing a strain gauge system within the rocket.

The team is competing in the 30,000 ft AGL apogee with COTS solid propulsion category. The airframe is made of an entirely SRAD composite airframe composed of carbon fiber and fiberglass, depending on the component. The nose cone is made of fiberglass for RF transparency as the main electronics bay is housed inside of it. The 5:1 Von Karman Ogive was laid up by the team on a 3D printed, surface-prepared mold. The rest of the body is made of carbon fiber. The SRAD fin can is one of CRT's defining features. Since IREC 2023, the team has been manufacturing complex fin cans. This year, the fin can feature a 4.13° draft angle. The fins were made with a core of 0.25 in G10 fiberglass, laid up with 2 layers of carbon fiber, and were then waterjet cut and CNC manufactured to the correct profile. Four layers of a tip-to-tip strengthened the fins.

The payload, DogBone, is a scientific payload designed to determine the damping properties of a polymer currently being developed by a research lab in the Department of Macromolecular Science and Engineering at Case Western Reserve University. The payload is equipped with 4 accelerometers: two accelerometers are used as baseline measurements, and two accelerometers are covered in the polymer.

The objective of this year's entry into IREC 2026 is to have a fully successful flight in the 30,000 ft category and position the team to move into different categories. The team has not had a fully nominal rocket since winning the 10,000 ft category at IREC 2023. Since then, the team has branched out into new areas of SRAD composites, flight computers, and more. A successful launch this year will position the team to decide what category and improvements to pursue next.

This report was led and organized by Rohan Rajappan. Each subteam mentioned above was responsible for adding its own content. The Aerostructures leads, Robbie Shepherd and Alexander Stone, made further contributions to this paper beyond what was expected as leads. Every author on this paper contributed a minimum of one section. The majority of the paper was written in Google Docs and was transferred to Overleaf in its final stages.

III. System Architecture Overview

Aurora utilizes a Cesaroni O3400-P motor and is anticipated to reach an altitude of 32,519 ft AGL in Midland, Texas. Aurora features custom composite airframe components, a scientific payload, SRAD avionics with live telemetry capabilities, and a one-of-a-kind measurements subsystem utilizing strain gauges. To the team's knowledge, this is the first time in IREC history that strain gauges have flown on a competition rocket.

The airframe of Aurora is composed of 4 sections: the nose cone, recovery section, body tube, and fin can. The avionics bay resides in the nose cone and houses all electronics to control recovery events and track Aurora. The recovery section houses the recovery system of the rocket, as well as the upper camera electronics bay. The body tube houses the measurements electronics bay, DogBone, the propulsion system, and the lower camera electronics bay. Lastly, the fin can features an integrated boat tail to reduce drag and increase altitude.

Aurora is designed to separate at the intersection between the body tube and the nose cone, which is visible in Figure 1 where the fiberglass nose cone meets the carbon fiber coupler. The coupler remains attached to the body tube after separation. Aurora deploys as one recoverable section, with DogBone attached to a bulkhead throughout the entire flight. Aurora will remain under drogue after deployment until 1,500, at which point the SRAD Tendie Descendie Duo will fire to release the main parachute. The specific vehicle characteristics can be found in Appendix A.

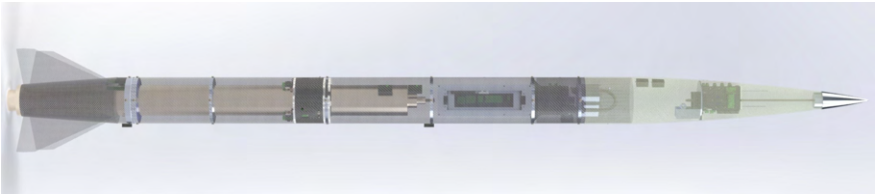


Fig. 1 Render of Aurora. The airframe is rendered as translucent to show the internal components of the rocket, including DogBone, the various electronics bays, and the motor.

A. Airframe

The airframe of Aurora is made entirely of SRAD composites. The nose cone is made of fiberglass, chosen for its RF transparency, as all transmitting electronics are housed in the nose cone. The rest of the airframe, consisting of the coupler, body tube, and fin can, is made from carbon fiber. The nose cone tip is made of 6061 aluminium, which is designed by the Case Rocket Team and manufactured by ProtoSpace Mfg. The nose cone has a widest OD of 5.900 in, and a widest ID of 5.750 in. The ID of the body tube is also 5.750 in. This ID was chosen to be about the smallest ID that could reasonably accommodate the size of the payload, and was further constrained by the fact that the team already owned a mandrel with an OD of 5.750 in that was long enough to manufacture the body tube. The OD of the body tube is 5.872 in, and the OD of the and fin can (at its widest) is 5.898 in. The OD of the coupler is 5.734 in, and the ID of the coupler is 5.560 in. Fully assembled, the airframe has a nominal length of 107.1 in.

Three nylon #2-56 shear pins connect the coupler to the nose cone; these two components will separate at apogee to allow the recovery system to deploy. All other connections in the airframe - coupler to body tube, body tube to interface centering ring, and interface centering ring to fin can - are mechanically fastened connections, each with four #10-24 UNC $\times$ 0.375 in alloy steel bolts to allow for efficiency of integration due to conformity of exterior bolt size. The only exceptions are the two air-foiled 1515 rail buttons, one screwed into the motor retention bulkhead and the other screwed into the lower side of the interface centering ring, which are affixed with 1/4"-20 UNC $\times$ 1 in countersunk bolts.

1. COTS vs SRAD Airframe Components Trade Study

As the team entered its third year of manufacturing the entire airframe out of custom composites, it was deemed worthwhile to examine the pros and cons of making SRAD airframe components compared to buying them COTS. In order to do so, a full trade study was conducted to compare the benefits and drawbacks of making SRAD custom composite tubes, couplers, and a nose cone for Aurora, versus buying COTS fiberglass tubes, couplers, and a nose cone from Wildman Rocketry. The trade study compared strength, cost, apogee simulation, and other specific benefits of each option, then weighed each category and gave both COTS and SRAD components a score out of 10 in each category. The trade study found that SRAD components received a higher score than COTS components, and thus recommended that the airframe of Aurora should be made from SRAD components. The full trade study can be found in Appendix H.

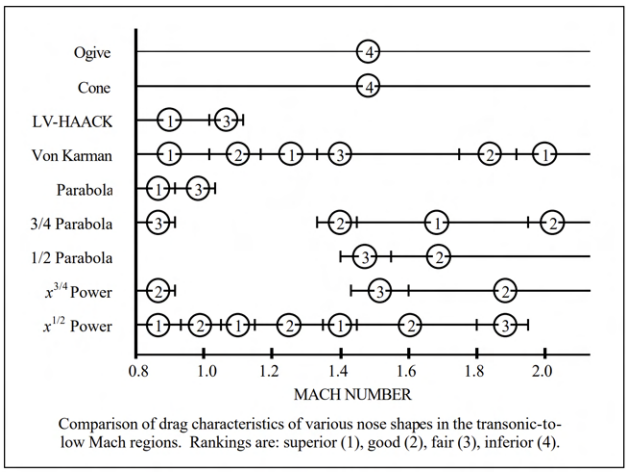


Fig. 2 Ranked comparison of drag Characteristics of various nose cone shapes. Reprinted from "The Descriptive Geometry of Nose Cones", Gary A. Crowell Sr., 1996 [1]

2. Nose Cone

This year, the team chose a Von Karman Ogive (also referred to as an LD-Haack with C=0) nose cone for the second year in a row. Over the past few years, the team has grown its experience in manufacturing composite parts with complex geometries, providing the confidence this year to manufacture the team's largest complex composite component yet. Both an $x^{\frac{1}{2}}$ power series shape and a Von Karman shape were considered for the nose cone of the team's IREC 2025 rocket, Helios, and ultimately a 4:1 Von Karman shape was chosen based on simulations of the rocket at the competition launch site. Additional research was conducted this year to further investigate the findings of last year; namely, the graph shown in Figure 2 was used to compare different nose cone shapes, particularly in the transonic region of flight. After the Von Karman shape was chosen, both a 4:1 and 5:1 fineness ratio were considered and tested in simulations. These simulations showed that despite the increase in mass that comes with the larger 5:1 fineness ratio, it still resulted in a greater altitude. Thus, a 5:1 Von Karman shape was chosen.

The nose cone has a diameter of 5.900 in and a length of 36.00 in. This length includes a 6 in straight section that the coupler slides into. Both the Von Karman shape and straight section were fabricated as one component from three layers of heavy fiberglass sleeve laminated with PRO-SET LAM-135 Epoxy Resin and 229 Hardener, hand laid-up over a custom 3D-printed mandrel. The nose cone tip geometry was researched and designed by the team, with a diameter of 2.145 in and a length of 6.526 in. The nose cone tip is designed to maintain the Von Karman shape of the nose cone, matching the curve seamlessly at the interface of the nose cone composite and nose cone tip. Once designed and CAD modelled by the team, the part was manufactured by ProtoSpace Mfg.

3. Nose Cone Avionics Bay

The Aurora avionics bay is located in the fiberglass nose cone due to RF transmission requirements. The assembly consists of a bulkhead, threaded rod, nose cone tip, eye nut, and 3D printed housing. Black powder ejection charges used to deploy recovery systems sit beneath the waterjet cut 1/8 in 7075-T6 aluminum bulkhead. This bulkhead has a slot so the avionics bay assembly can be inserted into the nose cone without colliding with the strain gauge modules epoxied to the interior of the nose cone. This slot mates with the male clocking notch epoxied into the nose cone, so the rotational orientation of the integrated nose cone assembly is constant.

Past competition rockets have had multiple avionics bays and employed a sled design with components bolted to both sides of a sheet of polycarbonate. For the purpose of optimizing Aurora for altitude performance, design decisions were made to minimize drag on the airframe. One result of this is reducing the overall height of the rocket. Due to volume requirements for payload, the measurements system, and the camera electronics bays, a single avionics bay with very high component density was required. A polycarbonate sheet sled design with components bolted to both sides is not suited for these requirements, so a 3D printed housing was created to concentrate all avionics components in the nose cone.

The housing is made of PETG due to the material's favorable properties, especially pertaining to impact strength

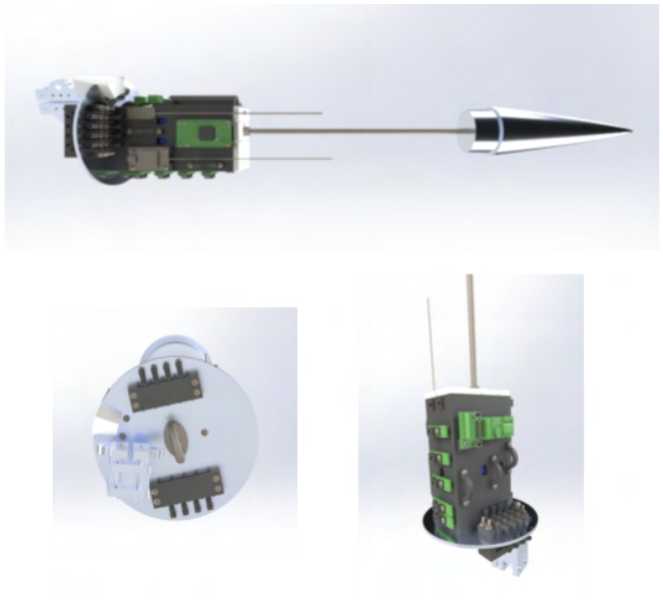


Fig. 3 Renders of nose cone electronics bay and bulkhead assembly.

and thermal resistance. Affixed to the housing are five Li-ion batteries, a TeleGPS, an ElvinBeacon, a Blue Raven, an EasyMini, and the team's SRAD flight computer, Sirin. Due to the tear-out strength limitations of threading 3D prints, heat-set inserts were used to bolt the Blue Raven, Easy Mini, TeleGPS, Sirin, Sirin antenna cover, cable management grommets, and screw switches to the housing. Excluding Sirin, which required 2-56 UNC heat set inserts, all components bolted to the housing used #4-40 heat set inserts. Since the housing was 3D printed, the geometry was designed to eliminate support structures and have a clean surface finish. This involved using 45-degree chamfers on overhangs on the heat-set insert standoffs.

The inside of the housing has five holes for the five 2600 mAh capacity 18650 Li-ion batteries. Each battery powers one of the five avionics bay components, which are affixed to the outside of the housing by fasteners or hot glue. Once the batteries have been inserted into the housing, a battery cover is bolted to the top of the housing. While battery capacity for some avionics components is unnecessarily large, every electronic component in Aurora is powered by 18650 batteries. Standardizing batteries makes integration, repairs, and replacements straightforward. For wiring flexibility, there are multiple options to route battery wires. There are slots in the cover to route wires through the top of the housing and there are also holes in the sides of the housing that allow battery wires to be routed through the walls of the housing.

Hot glue was also used to affix avionics components to the avionics bay housing. On the housing, an outcropping shaped like an "L" is used as a locating feature for the Elvin Beacon, a small beeper device that is designed to be used with tiny screws that aren't compatible with widely available heat-set inserts. The solution was to use the "L" shaped locating feature and a drop of hot glue to secure the beeper. The Sirin antenna is first hot-glued to the Sirin antenna cover, then that subassembly is bolted to the housing.

The Blue Raven and EasyMini are used for dual redundancy deployment. Apogee and main charges are wired through two sets of terminal blocks on opposing sides of the housing to make cable wiring management easier. The wiring is very clean, easy to follow, and easy to repair, if necessary.

The recovery force acting on the nose cone avionics bay bulkhead was calculated to be 140 lbf. SolidWorks FEA analysis was used to determine that the minimum FoS for this loading scheme is 2.1. The full results of this FEA analysis can be found in Appendix G. According to hand calculations, at main deployment, the 1/4"-20 threaded rod, held in tension, was determined to have a FoS of 31.41 and the eye nut was determined to have a FoS of 4.55.

COTS screw switches are used to power on and power off all avionics bay components. Screw switches were chosen over key and magnetic switches due to their resistance to vibration and high G-forces. To ensure redundancy, each avionics component has its own battery and screw switch for full redundancy. A failure point for a screw switch can occur when, after being screwed out to disconnect the circuit, the bolt continues getting screwed out and is eventually separated from the assembly. 3D printed screw switch covers are bolted to the COTS screw switch assembly to prevent

this.

Screw switch holes were accurately drilled in the nose cone by removing the screw switches, replacing them with 3D printed LED holders and LEDs, powering them on, and then fully inserting the avionics bay assembly into the nose cone. The light from the LEDs shone through the opaque fiberglass material of the nose cone, so accurate screw switch holes could be marked and later drilled after removing the avionics bay.

4. Recovery Section

The recovery system of Aurora is housed inside the nose cone and coupler, between the nose cone avionics bay bulkhead and the recovery bulkhead. The recovery bulkhead is bolted through the body tube and coupler with four #10-24 $\times$ 0.375 in alloy steel bolts. A 1/2"-13 stainless steel U-bolt is affixed to the recovery bulkhead with four 1/2"-13 stainless steel nuts. One end of the recovery lines attach to this U-bolt with a quick link. The upper camera avionics bay is also affixed to the top side of this bulkhead with four #4-40 $\times$ 0.5 in alloy steel bolts, residing underneath the U-bolt. The nose cone avionics bay bulkhead is held in place in the nose cone via a threaded rod that screws into the nose cone tip. The other end of the recovery lines attach to the eye nut on the underside of this bulkhead with a quick link. The entire recovery system, including the deployment bag and parachutes, resides in this section during the flight until apogee, when the nose cone separates, and the drogue is released. The main parachute is later released at 1500 ft using the SRAD Tendie Descendie Duo, which is bolted to the E-bay bulkhead via two #10-20 $\times$ 0.5 in alloy steel bolts.

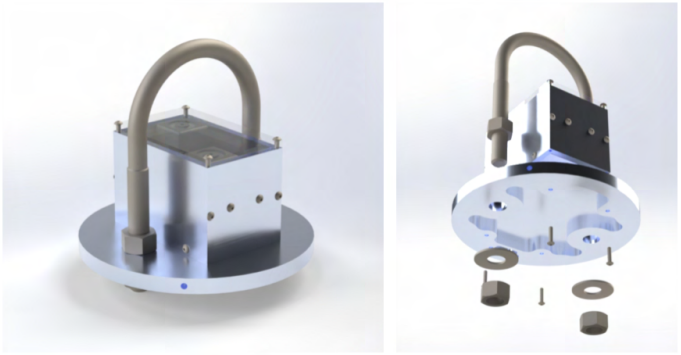


Fig. 4 Renders of the recovery bulkhead assembly, including the upper camera electronics bay, fully assembled (left) and in an exploded view (right).

5. Camera Electronics Bays

Upper Camera Electronics Bay The upper camera electronics bay (e-bay) houses 2 SQ11 cameras to film parachute deployment and inflation. SQ11s were chosen for their high temperature rating, low cost, and small size. These are powered by 2 18650 Li-ion batteries (one each), along with a boost converter to produce the 5V USB output used by the cameras. Due to the custom connector in the SQ11, the supplied cable had to be used. This cable was longer than needed, so in order for it to fit, the outer insulation of the USB cable was stripped (each wire remained fully insulated). This e-bay is located below the recovery U-bolt, in order to capture footage of parachute deployment, and so that it does not add any height to the rocket. The outer walls are constructed of 0.1875 in 6061-T6 aluminum, and the top is 0.25 in polycarbonate. This robust construction was chosen due to the e-bay's proximity to the floating charges when integrated. Additionally, it was discovered during our first ejection testing that the floating charges also deposit a large amount of soot on the polycarbonate lid. As a mitigation, 2 layers of Saran Wrap are applied to the polycarbonate lid before launch. The Saran wrap is then rolled around a Kevlar thread, which is affixed to the lower end of the recovery line. Further ejection testing revealed that this technique was sufficient to produce footage with an unobstructed view, more than sufficient to observe parachute deployment, and diagnose any potential off-nominal results in the recovery system.

Lower Camera Electronics Bay The lower camera e-bay houses 3 RunCam Split 4 v2 cameras. These were chosen due to their small size, high reliability, and the split design allows for better heat management and more freedom in mounting position. Each Split 4 v2 is powered by a 18650 Li-ion battery, along with a boost converter to produce

5V, as the camera only accepts 5-20 VDC. In the interest of thermal management, this e-bay also includes 3 20 mm fans, producing 1 ft^3/minute of airflow, directed as the main processor on the Split 4 v2 PCB. Heat transfer is further enhanced via the use of a COTS copper heat sink with preapplied thermal adhesive, allowing it to be in good thermal contact with the main processor. The lower camera e-bay also features adjustable screw switch mounts. Motivated by past difficulties aligning screw switch holes in carbon fiber tubes, the adjustable screw switch mounts allow 0.125 in of bidirectional travel in 2 axes, reducing the need for later filing of the holes. To not add additional height to the rocket, the e-bay is positioned to wrap around the motor inside Aurora's body tube. A section of Wildman G12 4 in the airframe was used to act as an insulator and centering ring. The e-bay is affixed in the rocket using 4 #10-24 $\times$ 0.375 in alloy steel bolts, which bolt into the 6061-T6 bulkheads on the top of the e-bay.

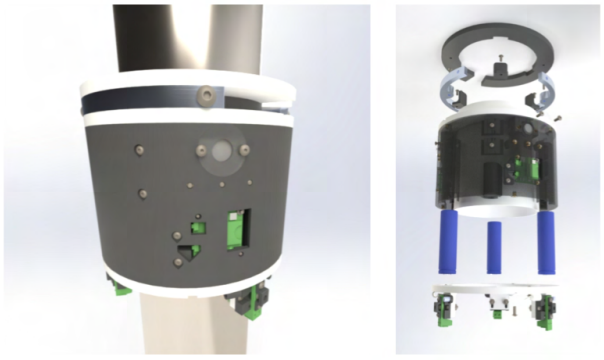


Fig. 5 Renders of the lower camera e-bay assembly fully assembled (left) and in an exploded view (right).

6. Body

The body tube of Aurora is a 56.75 in long tube fabricated from five layers of 3K carbon fiber sourced from Soller Composites. 3K carbon fiber was chosen for the desired thickness and for flexibility when compared to 6K carbon fiber. The measured dimensions of the body tube are 5.872 in OD, 5.750 in ID, .061 in thickness.

The body tube houses the measurements electronics bay, payload, Cesaroni O3400-P motor, and the lower camera electronics bay. There are four different bulkheads that are located in the body tube that house the different electronics bays, payload, and motor, as well as attach to the recovery system. There is also a centering ring between the lower camera e-bay and the bottom of the body tube, as well as an interface centering ring at the bottom of the body tube to attach the body tube and fin can together. These are all attached radially via four #10-24 $\times$ 0.375 in alloy steel bolts. The bolts are all spaced 90 degrees apart to create radial symmetry. One of the airfoiled 1515 rail buttons is attached to the bulkhead that retains the motor using a 1/4"-20 $\times$ 1 in countersunk screw.

The airfoiled 1515 rail buttons, purchased from Apogee Rockets, were chosen for their advantage in drag reduction. The rail buttons provide a 47.3% reduction in drag compared to standard circular rail buttons, which we pushed further to a 51.2% reduction in drag by rounding the top edge of the rail button via sanding [2].

7. Fin Can

This fin can is 14.25 in long, having a 2.25 in section of cylindrical section followed by a 12 in conical section. This features a 4.13°draft angle which tapers the cylindrical section down from 5.898 in OD and 5.605 in ID to 4.165 in OD and 3.895 in ID. The fins were placed completely on the conical section in order to make manufacturing a flush fit between the fins and the boat tail significantly more feasible and accurate than in previous designs. Both the 2.25 in and 12 in sections were manufactured as one piece. 6K carbon fiber sleeve from Soller Composites was used to create the boat tail as it provided a stiff wall for the fins to be tacked to.

The fins were manufactured out of a 0.25 in sheet of G10 fiberglass sourced from RockWest Composites. The fins were tacked to the boat tail using a 3D printed jig and superglue. To strengthen the bond, fillets made out of E6209 structural epoxy were added once the superglue had fully cured. Once the fins were fully attached, tip-to-tips were performed using three layers of carbon fiber, two layers of 6K and one layer of 3K. The final fin thickness was measured at .375 in. For more information on the manufacturing processes of the fin, please refer to Section III.A.8.

Before the start of fin manufacturing, the team conducted experimental shear modulus determination testing following ASTM D7078 standards. The testing aimed to determine the shear modulus of two woven composite materials: 3K carbon fiber laid up over G10 fiberglass, and a pure 6K carbon fiber composite. The testing report can be found in Appendix B.B. Though the testing was successful, shear modulus was not used to calculate fin flutter values, as the software used, AeroFinSim, does not take shear modulus as a parameter in calculating fin flutter. Still, the testing was useful for informing future design decisions, as shear modulus values were found for both composite materials. Additionally, many challenges were encountered during the process of manufacturing a pure 6K carbon fiber plate thick enough for competition rocket fins, which will inform future design-for-manufacturing decisions. The team intends to conduct further manufacturing and strength testing in future years.

Fin flutter calculations were performed using AeroFinSim [3] to ensure the fins would withstand the aerodynamic loads placed on them during flight that cause fin flutter and divergence. In order to account for the worst-case scenario, fin flutter was calculated at the altitude of max Q, which was found to be 8,000 ft above sea level from simulations. Additionally, the material CCRP T300 FBRT-934 7-MILL was used in the calculation, because it was the material most similar to the material used to manufacture the fins that resulted in the lowest fin flutter velocity. From these inputs, a flutter velocity of Mach 3.43 and a divergence velocity of Mach 5.36 were calculated. This results in a fin flutter FoS of 1.87 based on Aurora's maximum velocity of Mach 1.84, which exceeds the DTEG Section 8.2.2 requirement of a minimum fin flutter FoS of 1.5 [4]. A table of AeroFinSim calculations can be found in Appendix A.

Dynamic stability analysis was also performed to further confirm the safety of the fin dimensions. The main parameter studied was CNalpha, which quantifies the magnitude of the restoring force per unit angle of attack. The general rule-of-thumb used in amateur rocketry is that CNalpha should be above 10 for all Mach numbers the rocket will see in flight [5]. From RASAero II simulations, a minimum CNalpha value of 10.6 was found for the range of Mach numbers Aurora will see in flight. A graph of CNalpha can be found in Appendix A.

8. Manufacturing

Airframe Tubing All body tubes were fabricated by hand using carbon fiber laminated with PRO-SET LAM-135 Epoxy Resin and 229 Hardener. The main body tube was manufactured on a steel mandrel with an OD of 5.750" and a length of 70" out of 3K twill weave carbon fiber. The coupler tube was manufactured on a 3D printed mandrel, printed out of PLA. The same surface prep was used for both mandrels.

All tubular mandrels were surface prepped using the same procedure. First, the mandrel was wiped down completely with acetone, then multiple layers of Partall Coverall Film were applied, spread across the tube, and polished until an even surface finish was reached. The polish was finished, once glossy and shiny. This process was done once for each mandrel. On the day of each layup, Crown Dry Graphite Lubricant 8076 was sprayed in a thin layer, so light was reflected off of the surface. Once this dried, a layer of mylar was wrapped around the metal, and secured with flash tape along the seam to be tight enough to conform to the shape of the mandrel while still being able to slide off of the mandrel. Mylar was used because it did not create wrinkles in the surface prep that would transfer to the inside of the tubes, and prevented the epoxy from bonding to the mandrel.

The coupler tube was made of five layers of 6K twill weave carbon fiber on a mandrel that was 3D printed out of PLA and surface prepped.

For the main body tube, the layers of carbon fiber were rolled from one long piece of carbon fiber that was cut to be 60" wide and 100" long. Once the mandrel was fully surface prepped, it was placed on a jig that kept the mandrel level and steady, and allowed for the mandrel to be rotated as the carbon fiber was laid on it. The mylar was coated with a layer of epoxy, then the edge of the sheet of carbon fiber was lined up with the seam of the mylar to ensure the proper alignment. As the jig was rotated, the carbon fiber was pressed into the layer of epoxy, and more epoxy was applied on top for the next layer to be pushed into. This process was repeated for the rest of the layers, paying attention to the alignment of the edges as the jig was rotated. The final layer received a thick layer of epoxy which was smoothed over the entire surface to ensure that every layer was fully saturated. See Figure 6 for a picture of how this was done.



Fig. 6 Body tube layup.

After 24 hours, the tubes were removed from the mandrels. The Mylar was then removed from the inside of the tube. To finish, both ends of the tube were cut off with a horizontal bandsaw to remove frayed edges. Each end was cut to be 0.25 in greater than the desired final length, and then sanded to fit precisely with other components.

Nose Cone The nose cone was fabricated using sleeves of fiberglass, laid up over a 3-D printed mandrel. The mandrel was made of several segments made of PLA, glued together with superglue. Gaps between the segments were filled with 3M Bondo Original, and then sanded smooth. The mandrel was then coated with Fiberglast 683 gelcoat, Partall Paste Mold Release Wax, and Partall Coverall Film (PVA). 3 different sizes (3", 4", 6") of heavy fiberglass sleeve were used to accommodate the change in diameter of the nosecone. 3 layers of fiberglass sleeve were laminated onto the mandrel, using PRO-SET LAM-135 Epoxy Resin and Hardener 229. The layering, locations, and sizes of the sleeves are shown in Fig. 7, where blue represents the 3" sleeves, red the 4", and purple the 6". This diagram was used as a reference when performing the layup. Care was taken to avoid disturbing the PVA film by using minimal pressure/brushing to apply epoxy. The composite was left to cure for 24 hours, after which the mandrel was removed. The mold mostly released after being soaked in water, with only a small section near the tip needing to be broken out. The nose cone composite was then cut with a horizontal bandsaw and sanded to length. The nose cone had an excessive amount of voids, possibly due to the lack of pressure used when applying the epoxy, and one of the large voids was filled with Aeropoxy ES6029 structural epoxy. The 3M Bondo Original was used to fill in some of the smaller divots/voids.

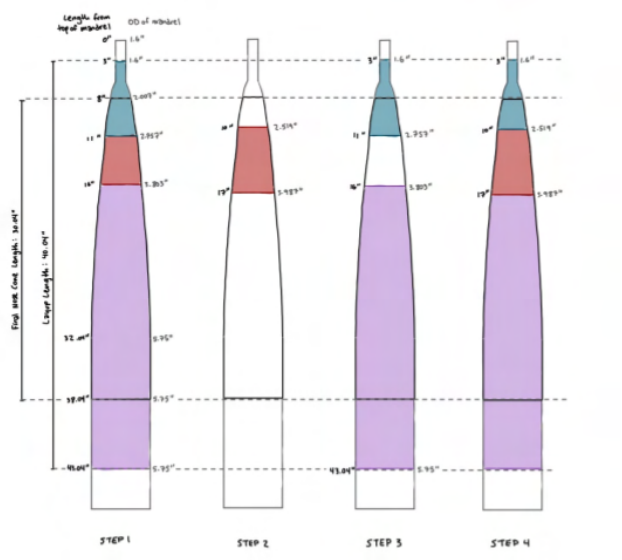


Fig. 7 Fiberglass sleeve layering sequence and locations for the nose cone layup.

Boat Tail The boat tail was manufactured using 6K carbon fiber sleeves placed on 3d printed mandrels, printed using PLA filament. Five 6" diameter carbon sleeves cut to 30" were used instead of carbon sheets in order to accommodate the variable diameter of the boat tail. The mandrel was printed in multiple pieces and then super glued together. The seams were sanded and then 3M Bondo Short Strand Fiberglass Reinforced Filler was used to fill in and smooth the remaining cracks. Once these seams were sanded smooth, Partall Coverall Film was used to make the surface completely smooth. Then, Crown Dry Graphite Lubricant 8076 was sprayed onto the mandrel. Once that dried, Mylar was wrapped around the mandrel in three sections, one for each cylindrical portion and one for the central conical section. These pieces were taped in place with flash tape.

Each layer of carbon fiber sleeve was compressed to widen the diameter and placed over the middle of the mandrel. The first layer of sleeve was placed on the mandrel before any epoxy so the sleeve could be adjusted to the proper position on the mandrel. Once the sleeve was properly placed, a thick layer of epoxy was applied to ensure the entire layer was soaked through. Once this was complete, the next layer was compressed and placed over the mandrel, then carefully placed in line with the previous layers. After each layer was placed, epoxy was spread over the surface, paying careful attention to not over-manipulate the layer to where the fibers were out of alignment, or the edges were not aligned with the previous layer. Throughout this process, the mandrel was held and rotated by team members.

Once the layup was complete, the boat tail was left to set for 24 hours. After this time, the composite was able to be slid off the mandrel. The composite was cut to size using a band saw. It was cut 2.5 in from where the conical section transitioned into the cylindrical section, and then sanded down to be 2.25 in. The narrower side was cut to size by measuring 3.75 in from the end of the composite, and then it was sanded another 0.25 in.



Fig. 8 Manufacturing process for the boat tail.

Fins The fins used on Aurora were fabricated by laminating 2 layers of 6K carbon fiber weave over each side of a 0.25 in thick G10 fiberglass sheet with PRO-SET LAM-135 Epoxy Resin and 224 Hardener. Each layer of carbon fiber was carefully cut into 24.5 in × 24.5 in squares, slightly oversized for the 24 in x 24 in G10 fiberglass sheet to ensure the sheet was fully covered by the carbon fiber. Additionally, the carbon fiber sheets were cut such that weaves stacked each other at a 45-degree angle to ensure the composite layer had an increase in multi-axial strength. The G10 fiberglass sheet was sanded using 3000-grit sandpaper, then wiped down with acetone in preparation for the layup to increase the bonding surface area.

After completing the preparation of the G10 fiberglass surface, it was coated in epoxy and the first layer of carbon fiber was laid carefully on top, centered and evenly covering the sheet. The first layer was then coated in epoxy and the second layer was placed similarly when fully saturated. This procedure was repeated on the opposite face of the G10 fiberglass sheet.

Once the carbon fiber lamination was complete, the composite fin plate was immediately put through a vacuum bagging process to evenly compress the layers together as the epoxy cured. This process was prepared by placing down a layer of peel ply film firmly onto the composite to ensure it was soaked in epoxy. Perforated film was placed over the peel ply in the same manner. This layer was followed up by 2 layers of breather cloth placed on top. This preparation process was then repeated on the other side of the composite sheet.

Following the vacuum bagging preparation, the composite sheet was transferred to the prepared vacuum bag. Inside of the vacuum bag, the gasket connector was placed in the corner of the setup to minimize creasing on the composite fins. The vacuum bag was cut above the gasket connector to allow for a connection between the through-bag connector and the gasket connector. This setup was then sealed with double-sided sealant tape. The vacuum was turned on, and the setup was checked for air leaks before confirming a complete vacuum seal. The vacuum bag setup was then left to run for 24 hours to ensure the composite was fully set. After 24 hours, the vacuum was shut off, the vacuum cut, and the setup was removed from the bag. The layers of breather cloth, perforated film, and peel ply were removed from the composite.

Before cutting the fins, creases were identified on the fin plate and marked to avoid cutting fins with creases. 6 fins were cut from the composite plate using a waterjet, including 2 spare fins if needed. The 4 fins with the least imperfections were then selected to be beveled using a CNC machine. During these operations, the fins were each

clamped down onto a fixture plate using toe clamps and beveled using a ball nose diamond-coated end mill. Following the CNC operations, the fins were manually sanded smooth until ready to be placed on the fin can.

Fin Can Once the fins were beveled and ready to be tacked to the boattail, they were surface prepped by progressively wet sanding starting with 60 grit. During this process, these fins were periodically cleaned by wiping a shop towel over their surface with acetone, and then isopropyl alcohol. After this cleaning, water droplets were applied to various areas of the fin surfaces. This was to test if they were smooth enough to evenly disperse these droplets, which is done by strengthening their adhesive forces to disrupt the cohesion of the water. If these droplets still formed after one minute had passed, the fins were further wet sanded until either the test was passed or until 3000 grit was reached.

In order to make sure the fins were properly lined up during tacking, each fin was initially numbered with the part of the boattail it interfaced with the best. Lines were drawn on the boattail to mark areas the fins were going to be attached to, 90 degrees apart. A 3D printed fin can jig made of PLA was used to secure the fins in place to ensure they stayed straight during tacking. The tacking adhesive itself is a 30-second superglue that is applied to the interfacing edges of our fins first. Afterwards, the boattail was lined up and quickly pressed down into the jig until the tips of the fins were in line with the narrow end of the boattail. This setup tacked all the fins at once. The glue was left to cure for 24 hours to ensure that the tacking was structurally sound before the fin jig removal.

After this curing process, heat from 2 Wagner heat guns was used to melt the PLA jig off the fin can. This softened the PLA until it was able to be peeled away from the fin can. While small chunks of melted PLA stuck onto the fiberglass bevels of the fins, these were resolved using a combination of box cutters, pliers, and wet sanding to manually remove them.

After tacking, fillets were created using Aeroepoxy ES6029 structural epoxy mixed with glass bubbles, to smooth the boattail-fin transition, and to strengthen the fin. A mylar and paper towel skirt was taped around the boat tail, to avoid any epoxy that ran off bonding to other parts of the fin can. The outline of the fillets was masked using masking tape. For the first few fillets, this tape was left on, which made removal difficult, but it was removed after the epoxy started to gel on the latter ones. The area of the fin and boat tail that would be covered by the fillet was surface prepped again, progressively sanding from 120 grit to 2500 grit, and then cleaned with acetone and isopropyl alcohol (in that order), with the structural epoxy applied within 1 hour of completing surface prep. The structural epoxy was scooped onto the general area of the fillet, and smoothed with paddles dipped in isopropyl alcohol. The paddles were also used to scoop any epoxy that ran off the ends of the fillets back onto the fillet, until the epoxy gelled. The masking tape around the edges of the fillet was removed after the epoxy started to gel, typically after around an hour and a half. The fillets were allowed to cure for at least 12 hours, and then the fin can was rotated for the next set of fillets. After the fillets cured, they were filed and sanded into a concave profile.

In order to surface prepare for the tip-to-tip layups, the fin can was wet sanded starting with 2000 grit and going incrementally to 3000 grit sandpaper. After this surface prep, it was cleaned using acetone and isopropyl alcohol.

Breather cloth was taped onto the surrounding edges of the fin can to prevent the vacuum bag from popping in a later step. In addition to this, there were two 3D-printed end caps wrapped with peel ply that were taped to both ends of the boattail for preventing the vacuum bag from being sucked into its cavity. Stencils for the fillets, carbon fiber core, and the tip-to-tip were measured and sketched into CorelDraw to be laser cut. These stencils utilized 6K carbon fiber, along with an additional tip-to-tip layer of 3K 45 degree weave carbon fiber. A weight ratio of 3.5:1 grams of PRO-SET LAM-135 resin to LAM-229 Hardener was measured and mixed into plastic cups to create laminating epoxy.

Once this initial preparation was completed, a layer of laminating epoxy was lathered first with double-gloved hands onto the fillets. Afterwards, the carbon fiber for the fillets was laid on first, followed by more laminating epoxy to saturate it onto the fin can. The edges of these carbon fiber stencils were carefully smoothed out to fit the fin can profile and to get rid of any wrinkles causing air bubbles. This process was repeated for the 6K core, the 3K 45 degree weave tip-to-tip, and then the 6K tip-to-tip, making a total of four layers. During this layup, more cups of epoxy were measured and mixed if necessary to ensure each layer was saturated.



Fig. 9 Tip-to-tip layup. Core layer of carbon fiber before two more layers are added.

A layer of peel ply was added on top of the tip-to-tip and pressed carefully until it was fully saturated with epoxy. This layer would allow the vacuum bag to release after the layup was fully cured and ensure an even layer of epoxy saturation throughout its surface. Finally, the last layer to be added was breather cloth, which soaked up excess resin that was drawn out and prevented the vacuum bag itself from popping during the vacuum bagging process. At this point, the fin can is ready to be inserted into the tubular vacuum bag with the layup side facing upwards.

Double-sided sealant tape was used to seal the open ends of the vacuum bag shut to prevent air from escaping. A small hole was cut into the bag where the pump was going to be inserted, big enough to fit the tube but smaller than the frog it was attached to. Once everything was in place, the vacuum was slowly pulled to allow enough time to pull any wrinkles from forming on the breather cloth. The bag itself was attempted to be pulled apart to see if the vacuum was pulling properly. This test was deemed successful if the bagging layers couldn't pull apart. If it was still possible to pull the layers apart, the sealant tape was either pressed down further or added to plug gaps around these areas until they were fixed. Finally, it was allowed to pull at full capacity and run for 24 hours until the epoxy was fully cured. After this curing, the vacuum bag was cut open and the peel ply layer was peeled off the fin can to complete the layup. Any excess carbon fiber hanging off the edges or small creases of the fin were sanded down till smooth with 60 grit.

Machined Components The bulkheads and centering rings were constructed primarily from 3/8 in aluminum plates which were cut on a waterjet. Radial holes were drilled with a dividing head and then manually tapped. FEA found in Appendix G was used to determine the alloy of aluminum used for components. Most components were made of 6061 aluminum, but high load bearing components such as the recovery bulkhead (intended to undergo the force at main deploy) or the motor retention bulkhead (intended to withstand the full thrust force of the motor) were made of 7075 aluminum. FEA also informed weight relief design in order to minimize weight while maintaining an FoS of 2 in all load-bearing components. The magnitude of forces used in FEA simulations were determined primarily through hand calculations. The largest force each component will see during flight was used in FEA simulations. These forces primarily tended to be either the force of the thrust of the motor, or the force of the main parachute deploy.

Painting Once manufactured, the composite airframe components of Aurora were covered in slight ridges from the saturation and curing of epoxy within the carbon fiber. Both the body tube and nose cone were lightly sanded to prepare

for primer. The nose cone was treated in a slightly different manner. Since the nose cone was made using fiberglass sleeves, there were large bumps on the surface. As such, the nose cone was sanded heavily using an orbital sander. Finish 1 2K Urethane Primer was used as a thick layer to fill in the majority of pinholes and provide a smooth surface finish. The primer was then sanded to smooth out any imperfections and prepare for the sealer. The rocket was then sprayed with Autoborne 6013 Silver Sealer. This sealer acts as a primer and presents a silver base for the dye-based paints. Vinyls were cut out and used for stenciling and details. Createx Colors Candy2o transparent dyes and any additives were sprayed onto Aurora for coloring. The general painting scheme can be seen in Figure 10. The last layers sprayed on the rocket were multiple coats of Finish 1 FC720 Automotive Clear Coat. At this point in the process, the fin can was re-joined to the rocket to be sprayed. FC720 was sprayed on in many heavy layers to smooth out the surface. The fin can was sprayed with extra layers as it was a simpler choice to spray more layers of clear coat rather than covering it in laminating epoxy and sanding.



Fig. 10 General paint scheme for Aurora.

B. Propulsion

The propulsion system for Aurora consists of a Cesaroni O3400-P solid rocket motor. The motor contains 24.10 lbs of propellant, with a total mass of 37.13 lbs when assembled and inserted into the Cesaroni Pro98 motor casing. The motor has a total impulse of 21,062.2 Ns, a maximum thrust of 4,750.3 N, and a burn time of 6.2 s. The O3400-P was chosen for its large impulse and thrust capable of propelling Aurora to its target apogee, as well as its previous success on the team's IREC 2024 rocket, Event Horizon. The thrust curve for the O3400-P is shown in Figure 11. The motor is retained via a 3/8"-16 $\times$ 1.375 in bolt that the forward closure screws on to. The bolt is affixed to the motor retention bulkhead, screwed in with Loctite Threadlocker Red 271 to ensure the bolt does not rotate. The motor retention bulkhead is bolted into the body tube with three #10-24 $\times$ 0.375 in bolts and one 1/4"-20 $\times$ 0.75 in bolt that also affixes an airfoiled rail button to the body tube. Figure 12 illustrates the motor retention method with the motor retention bolt in the motor retention bulkhead and forward closure.

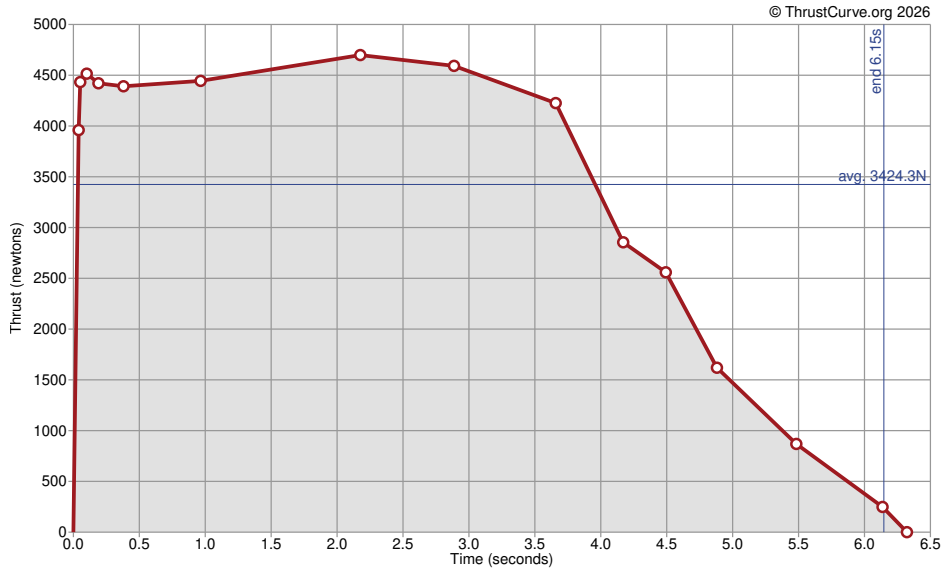


Fig. 11 Cesaroni O3400-P thrust curve. Reprinted from thrustcurve.org [6]

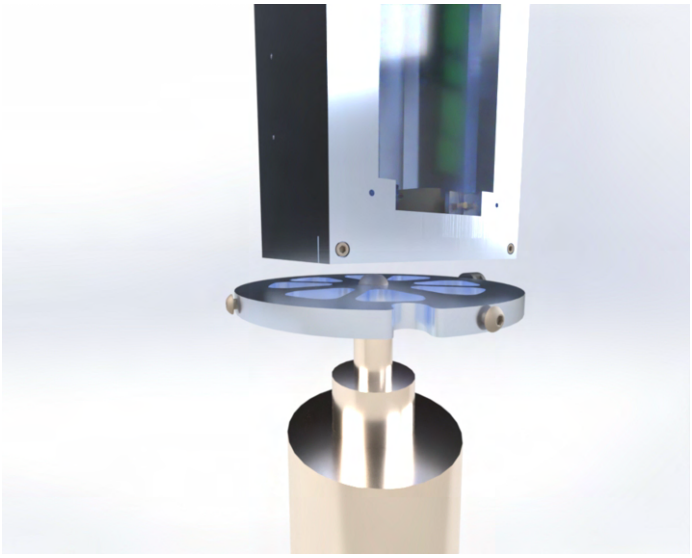


Fig. 12 Motor retention bulkhead with attached screw and motor casing. Note that the body tube is suppressed in this render for a clearer image.

C. Avionics

The nose cone electronics bay consists of two flight computers responsible for parachute deployments and three devices specifically designed for transmitting telemetry to our Base Station, equipped with specialized hardware and a mix of commercial and custom software for receiving and decoding this telemetry. Our flight computers are the Featherweight Blue Raven v1.0 and the EasyMini v3.0. Our transmitters consist of the COTS Altus Metrum TeleGPS, the SRAD Elvin Beacon (Not designed by the Case Rocket Team), and our own SRAD flight computer Sirin S1-R3. This combination of devices allows us to transmit two separate GPS locations, live flight data, and a beacon signal for direction finding.

D. Electronics Overview

Our electronics bay houses all five devices and their antennas on a 3D printed sled, each powered by their own individual 2600 mAh 18650 Li-ion batteries and each connected in series to a screw switch for easy disarming of all energetics and silencing of transmitters. Calculations shown below describe the battery life of each component in the nose cone e-bay. Our requirements stated that all electronics should have a minimum lifespan of 24 hours in order to aid in recovery and ensure functionality at the time of launch. This requirement was met by all components except for Sirin, due to its status as an ongoing SRAD project.

Component	Easy Mini	Blue Raven	TeleGPS	Elvin Beacon	Sirin
Current Draw (mA)	7.0	18.0	35.0	17.0	150.0
Runtime (hr)	371.4	144.4	74.29	152.9	17.33

Table 2 Electronics table showing runtimes and current draws of various electronics.

The general functionality of each device is as described:

1) Blue Raven - Serve as the primary flight computer, deploying the main and apogee parachutes and logging all flight data. This device uses a filtered stream from multiple sensors to record telemetry.
2) EasyMini - Serve as the secondary flight computer, igniting redundant charges one second after the ignition of the primary charges. This device logs flight data and relies solely on barometric pressure.
3) TeleGPS - Transmits GPS location via APRS packets once every 5 seconds. The TeleGPS is our only COTS transmitter and transmits on the 70cm band. The TeleGPS also logs GPS data which can be retrieved via USB post-flight.
4) Elvin Beacon - Transmit a beacon signal on the 1.25m band once every second. The sole purpose of this signal is to be received by Base Station at a high enough strength for direction finding to work. The Elvin Beacon was designed by the GitHub user ElvinC.
5) Sirin - Record flight data and transmit a combination of flight telemetry and GPS location. Sirin transmits twice every second on the 70cm band.

1. Architecture

Sirin (S1-R3) is the Case Rocket Team's SRAD flight computer. It is a 4-layer PCB consisting of a GPS, 6-axis 32G IMU for precise acceleration measurements, 3-axis 100G IMU for launch and event detection, barometer, 3-axis magnetometer, embedded flash chip, 440 MHz HAM LoRa radio, and a USB-C port for data streaming. Upon powering, Sirin transmits packets containing data from all of its onboard sensors, and in flight, Sirin logs this data on its flash.

Sirin is built on a STM32H753 programmable microcontroller capable of running several programs and advanced algorithms, such as our Error State Kalman Filter (ESKF) designed to combine the onboard measurements to create defined values for altitude, velocity, Earth-Centered, Earth-Fixed position (ECEF), and quaternion-represented orientation. Sirin's peripheral devices are split across two buses, SPI1 and SPI2. Splitting across two buses means that Sirin can write to both buses simultaneously.

Sirin's onboard software is written in Rust, a memory-safe alternative to C. Sirin uses the Embassy library (short for "embedded async") to manage asynchronous communication between its components. Embassy includes several useful frameworks for interfacing over SPI and USB channels, allowing the team to quickly write software to interface with new components following redesigns of the PCB. Embassy also utilizes Rust's ownership properties to simulate multi-threaded processing, allowing a seamless union of sensor data.

The code for Sirin is open source and maintained by the Case Rocket Team. This allows Sirin to be programmed for various other tasks that may utilize the sensors differently or interface with separate SPI devices via Sirin's GPIO ports. However, for typical flight operations, Sirin is programmed to follow the following flight loop:

1) Check for external commands sent via radio or USB (most commonly for querying flights, rebooting the device, or ground ejection testing).
2) Take updated measurements from both IMUs, barometer, and magnetometer.
3) Create a "nominal state" (notably containing a calculated altitude) by passing these measurements through the ESKF.
4) Check launch conditions and initiate Flight Mode if launch is detected.
    1) While in flight, log every sensor measurement to the flash.

Parachute	Diameter (in)	Shape	Max Descent Rate (ft/s)
Drogue	25	Ellipsoidal (C_D : 1.5)	152.0
Main	78	Toroidal (C_D : 1.84)	26.5

Table 3 Table containing the recovery design specifications.

2) If apogee is detected, deploy the apogee parachute.
    1) It is important to note that on Aurora, Sirin is not responsible for deployments. While it is capable of doing so, it has not had a full-scale test of this feature. A successful log of apogee on Aurora, once verified across COTS flight computers, is the final test for deployment capabilities.
3) If at or below our main deployment altitude, deploy the main parachute.
4) Upon the flight timer (15 minutes) finishing, leave Flight Mode.
5) Send an 'OutPacket' to the radio and flash, if not done already.

This loop runs 10 times a second, but data is logged at a longer frequency than that due to the time cost of logging and transmitting data. OutPackets sent to the radio and flash enter a queue of 32 packets, where the oldest packets will be dropped if the queue is full.

2. Data Format

Sirin uses a custom serialization/deserialization protocol in order to avoid various safety and optimization issues found in existing protocols. This is implemented via a set of custom "derive" macros called 'ToSong', 'FromSong', and 'SongSize' which can be used on any struct in Sirin's library. These convert data structures into a stream of bytes that can then be sent to the radio or flash for efficient storage and transmission. They are later reconstructed using the same macros.

Sirin's data formatting relies heavily on the following structs:

1) Data: This struct consists of raw measurements from all of Sirin's sensors.
2) State: This struct contains a general overview of the current state of Sirin, including time, flight mode, and its nominal state.
3) Nominal State: This contains the output of the ESKF containing all of the filter's calculated values.
4) OutPacket: This is a wrapper class for all types of packets that can be sent to different receivers on the board, typically the flash and radio. OutPackets have further wrapper classes underneath them to encode other critical information, like logging times, HAM radio callsigns, and device IDs.

3. Error-State Kalman Filter

Our primary data filter on Sirin is the Error State Kalman Filter. Kalman filters are only designed to work on linear objects, such as vectors. However rotations are SO(3) group objects, and we need to track the rotation of Sirin in order to interpret the linear acceleration readings. There are various methods of dealing with this issue, but they all hinge on the fact that rotations can be linearized for a small range around a rotation.

Our approach is based on this paper [7]. Essentially, we break up our state into a nominal state and an error state. The nominal state we treat nonlinearly and the error state we treat linearly. Since the error should be relatively small, we can treat it linearly without incurring a significant penalty. The nominal state is updated directly using integrated measurements from the IMU, and the error state is updated when we receive a measurement from another sensor such as the GPS, magnetometer, or barometer. The error state is then injected into the nominal state, thereby adjusting the estimation when data external to the IMU is received.

E. Recovery

Aurora will be recovered in one section. The parachutes are sized to fit within the descent rates outlined in Sections 6.3 and 6.4 of the DTEG [4]. The parachutes selected and relevant information are summarized in Table 3.

The drogue parachute deploys at apogee with a deployment force of 152.0 lbf . Aurora descends at a maximum rate of 153.0 ft/s under drogue force and reaches 89.2 ft/s at the time of main parachute deployment. The main parachute deploys at 1500 ft AGL with a deployment force of 1026 pounds. Both the drogue and main parachute deployment forces account for a shock factor of 2. Aurora descends with a maximum descent rate of 26.5 ft/s under main force and

achieves a touchdown velocity of 25.9 ft/s.

Aurora's recovery conceptual operations feature a single separation dual deploy setup. The rocket separates at the nose cone. The fiberglass nose cone and associated hardware form the upper body separated section and the nose cone coupler, main body tube and associated hardware form the lower body separated section. The two sections are connected via 348 in (29 ft) of 3/8" Tubular Kevlar recovery lines. The drogue parachute is attached to the recovery lines 128 in from the lower body and 75 in from the upper body during drogue descent. The main parachute is attached to the recovery line 145 in from the upper body during main descent. All recovery line lengths are calculated such that each parachute clears the upper and lower body by at least three times its length and the tip of the nose cone is always three ft from the top of the lower body.

The 3/8 in Tubular Kevlar has a manufacturer specified ultimate tensile load of 3600 pounds. The ends of the recovery lines attached to the U-bolt in the lower body and the quick link connected to the eye nut in the nose cone as well as the ends attached to the quicklinks that mount the parachutes are all sewn into loops using 1.5 in stitches of Bonded Kevlar Thread with a tensile strength of 135 pounds. These attachment points have a maximum tensile load of 3200 pounds as measured using an Instron Tensile Testing System [8].

Both the drogue and the main parachutes are housed in a Kevlar deployment bag during ascent. The drogue parachute and recovery lines that connect the drogue to the nose cone eye nut and the Tendie Descendie Duo are housed in one compartment of the deployment bag. The drogue parachute is also wrapped in a nomex fire blanket to prevent fire damage from the ejection charges. The main parachute and the recovery line that connect the main parachute to the drogue parachute and the lower body are housed in an adjacent compartment that is held closed by a Kevlar flap and a nylon strap. The nylon strap has a D-ring attached to the end which is connected to the Tendie Descendie Duo.

Tendie Descendie Duo The Tendie Descendie Duo is an SRAD, dual redundant, bulkhead mounted version of a Tender Descender. This is the team's fourth year utilizing this design which has operated successfully in IREC years 2023, 2024, and 2025.



Fig. 13 Tendie Descendie Duo.

The body was manually milled from 6061-T6 Aluminum square stock. The Tendie Descendie Duo plates were milled out on a Haas Mini Mill from a 6061-T6 Aluminum plate. The charge wells were milled from delrin stock also using the Haas Mini Mill. The charge wells are screwed on to the Tendie Descendie Duo plates using two #4-40 UNC ×

0.375 in screws and two quarter in diameter, one in long dowel pins are pressfit into the Tendie Descendie Duo plates. The dowel pins are designed to slip fit into the holes in the Tendie Descendie Duo body.

A Brunian Link [9] is put in a loop of 3/8 in Tubular Kevlar and attached to the Tendie Descendie Duo using the pins that pass through the slot of the body. The Brunian Link allows the Tendie to have dual redundancy since only one of the pins has to eject fully for the Kevlar loop to be released. The other end of the Kevlar loop is fed through the D-ring on the deployment bag and the quick link connecting the main parachute to the recovery line. The other end of the Kevlar loop is quicklinked to the eye nut on the E-bay bulkhead. Aircraft cables connect the plates to the quick link on the eye nut to keep the plates attached to the rocket after deployment.

The charge wells in the Tendie Descendie Duo are filled with 0.1 g of black powder. Each charge is detonated independently by its own flight computer both at 1500 ft AGL.

Parachute Construction The main parachute was constructed of twelve panels (gores) of ultra-low-porosity ripstop nylon. The gores were cut in six batches of two from large sheets of nylon using a CNC router with a drag knife attachment. To ensure precise cuts from the drag knife, the sheets were temporarily adhered to a board of MDF with spray adhesive. After removing the gores from the MDF, they were washed with acetone and placed in a water bath to remove spray adhesive and MDF residue. The gores were sewn together with flat felled seams and the exposed edges were hemmed using heavy duty thread. The 1/4 in Spectra Microline parachute lines were sewn onto the end of the flat felled seams.

The drogue parachute consisted of eight panels of ultra-low-porosity ripstop nylon cut in two batches of four with the CNC router and drag knife. The nylon sheets were adhered to the MDF board, washed and sewn in the same manner as the main parachute. T11 Nylon Chord was used for the drogue parachute lines.

All of the gores used in both parachutes were designed using a custom gore generation software [10].

Black Powder Sizing The three #2-56 UNC nylon shear pins at the separation joint require 69.7 lbf to break. Employing a factor of danger of 3 means the charge wells need to generate 209.1 lbf. With an internal diameter of 5.75 in, 209.1 lbf corresponds to 8.05 psi. The approximate unoccupied volume in the recovery chamber is 168 in^3, which accounts for the upper camera E-bay, recovery system, and Tendie Descendie Duo. Using the Ideal Gas Law, the required mass of black powder was calculated to be 1.656 g, which was rounded to 2 g. Given that drogue deployment requires an energetic separation, another factor of danger was applied, producing a 4.5 g mass of black powder for the primary charge. The backup charge was set to have a mass of 5 g of black powder.

Aurora employs floating vinyl charges to separate the rocket. To manufacture the charges, a two in piece of one in diameter vinyl tube was carefully sealed on one side using hot glue extruded approximately half a quarter of an in into the vinyl tube. Once the glue had cooled, 4.5 g of black powder was measured out and poured into the tube. An ematch, with approximately three ft of wire, was placed roughly in the middle of the black powder. The top of the black powder was packed with a cellulose insulation wadding and the end of the tube was sealed with a half in thick cap of hot glue. The cellulose insulation wadding was used to safely tamp the black powder down and prevent hot glue from coming into contact with the black powder when the charge was being sealed. This process was repeated for the 5 g backup charge.

Bolt and Thread Shear To ensure the recovery system stays intact at main deploy, a series of hand calculations were performed assuming a force of about 1,200 lbf. Since the main parachute line is mounted to a U-Bolt, a 1/2"-13 bolt was specified with a rating to 2,250 lbf, giving a factor of safety of 2.04. With the recovery bulkhead being mounted to the body tube with 4 #10-24 UNC $\times$ 0.375 in bolts, a shear area using the minor diameter was found to be 0.0152 in^2 per bolt. With the manufacturer specified tensile strength of 120,000 psi and a common conversion to shear strength of 60%, the estimated shear strength of each bolt was found to be approximately 72,000 psi. Using these values,the radial bolts in shear were found to have a FoS of 3.98. Further, for the bulkhead in shear, subtracting the area taken by the minor diameter of the radial threads from the thickness of the bulkhead, a shear area of 0.0184 in^2 per bolt was found. Using the standardized shear strength for 7075-T6 Aluminum of 48,000 psi, a FoS of 3.21 was determined. In conjunction with FEA performed on the face of the bulkhead, the design of weight relief and material selection for the recovery bulkhead was optimized to reduce weight while still ensuring a reliable, robust recovery system.

Drag Separation The equation used to find the drag separation is

$$N = \frac{M_1 D_2 - M_2 D_1}{M_1 + M_2},$$

[11], and the relevant values were found using Open Rocket. The point in flight that was analyzed is the point of motor burnout because that is when drag would have been greatest. After carefully weighing the different components of the rocket, the upper portion of the rocket was found to weigh 9.94 lbs and the lower section was 38.16 lbs. Then simulations in Open Rocket were used to find that the predicted drag force on the lower and upper portion was 174.8 lbf and 55.2 lbf respectively. Evaluating the expression gave 7.67 lbf which means the two components were in compression, so there is no drag separation and the nylon shear pins won't experience any shear stress. To remain absolutely certain that the rocket will not drag or pressure separate, three #2-56 UNC nylon shear pins were added to the separation joint.

F. Telemetry

1. Base Station

Telemetry is received from Aurora via our Base Station. Base Station is a commercial mini-desktop computer housed in a custom-made casing and equipped with two software-defined radios (SDR), a HackRFOne and a KrakenSDR. The SDRs receive RF data before, during, and after flight of the rocket and on the HackRFOne specifically, allow us to demodulate and deserialize signals into both APRS packets and Sirin's custom telemetry protocol. The signal broadcasted from the Elvin Beacon is picked up by the KrakenSDR via a 30-foot directional antenna set up at our Base Station where we can determine the direction the signal is coming from relative to the antenna.

Base Station has three semi-isolated software networks running on it to interpret data from our three transmitters. A custom Python script running on Base Station takes the USB handle of the HackRFOne and using SDR libraries, directly interprets the IQ data received. This data is then forwarded to two locations: the software SDRSharp and our custom telemetry visualization app. The KrakenSDR operates completely isolated from this network, having its own proprietary software for configuring the device and receiving data.

In SDRSharp, we are able to isolate different signals on our frequency range and forward data coming from the TeleGPS into the software Dire Wolf, which decodes its APRS packets and gives us raw GPS coordinates. KrakenSDR's software works similarly to this, with the only difference being it receives its data directly from the KrakenSDR. This is then interpreted natively by the software where we can then get a visualization within 10 degrees of the direction that all signals on the selected frequency are coming from.

Our telemetry visualization app receives raw bytes demodulated by the initial Python script, where a Tauri-based Node.js application reconstructs them into Sirin's packet scheme. From here, this data is used to visualize the orientation, location, and altitude of the rocket while also giving real-time flight information like GPS location, packet health, and even predicted apogee.

G. Payload

1. Introduction and Motivation

DogBone is designed to evaluate the vibrational damping of an experimental impact-resistant polymer developed by a lab at CWRU's campus. The theory is that this material will reduce the intense vibrations that are felt by components on a rocket by allowing the polymer to absorb them. It will record and store accelerometer data from two accelerometers. One accelerometer will be encased in polymer and the other will not. Vibrations will be compared on how they differ once the payload is recovered and download the data, allowing us to verify the polymer's effectiveness.

In addition to overall effectiveness, by including a thermometer to measure temperature over time, temperature's effect on this damping will be clasified. The polymer has best energy absorption properties at temperatures close to -50 degrees Celsius, which is close to what the outside air temperature is expected to be at our apogee.

The experiment was made in collaboration with a Case Western Reserve University lab run by Zachary Baierl. The trilayer damping system uses SIBS 103T on the outside and butyl rubber in the middle. SIBS is a thermoplastic elastomer with hard polystyrene end blocks and a soft polyisobutylene mid-block, so it feels like rubber during use but can be processed as a plastic when heated. Butyl rubber is a soft, airtight elastomer based on isobutylene with a little isoprene, known for strong damping and flexibility. The bilateral polymer design has vibration damping, which comes from internal friction. Both SIBS and butyl convert part of the mechanical vibration into heat instead of passing it straight through. The multilayer design amplifies this effect and makes the trilayer a very effective vibration-damping material.

2. Frame

The frame of DogBone has a 3U CubeSat form factor that encloses the components. The frame consists of six aluminum panels. All frame plates are made from 0.375” thick 6061-T6 aluminum plate. The frame is assembled using #4-40 UNC socket head bolts. Additionally, the lower frame plate uses two #10-24 UNC .875" bolts to attach to the payload retention bulkhead, which is secured to the airframe of Aurora via radial bolts. The outlines of all frames were cut out using a waterjet then placed on a CNC mill to machine pocket weight reliefs and engrave sponsor names. Upon the completion of these manufacturing processes, panels were drilled and hand-tapped for the appropriate screws. Additionally the payload features a polycarbonate window which was cut on a waterjet and inserted into a pocket in the frame plate.

There are two variants and two iterations of the accelerometer mounts: one iteration was using aluminum plates to constrain the accelerometer and the other used 3D-printed holders. For the aluminum plate design one aluminum plate was screwed directly into the frame and the other had a layer of polymer in between the plate and the frame. Both had the accelerometer constrained by 4 screws into the aluminum plate. The 3D-printed design fully contains the accelerometer via a pocket that fully surrounds the accelerometer. The variance in these comes from one holder having a pocket sized exactly to the accelerometer to hold it tight and the other having 0.1” of extra space to be filled by the polymer. Both designs were tested by mounting them to the frame and using a vibratory massage gun (40-60Hz) to simulate launch conditions. From the data captured on the accelerometers, the 3D-printed versions of the accelerometer mounts gave better results as they showed more damping. Therefore the decision was to to fly the 3D printed mounts.

The battery holder is designed to capture an 18650 Lithium Ion battery. The design consists of a holder that mounts to the frame using #4-40 UNC screws and a cap that captures the battery from escaping upward. This is manufactured via 3D printing using PETG as the filament.

The screw switch is a component designed to hold a screw switch up to the frame of the payload to allow easy accessibility. It also captures the screw for the switch to prevent it from backing out too far and falling into the payload assembly. We manufacture this piece via 3D printing using PETG as the filament. Heat set inserts were then inserted into printed holes for them, which are used.

In addition to the main microcontroller, many breakout boards were needed for the electronics. To hold them in place, a mount for the boards to screw into was manufactured via 3D printing using PETG as filament. Once printed, heat set inserts were installed to allow the boards to screw in. This will allow the buck converter, ESP32-WROOM microcontroller, breakout SD cart, and thermometer to stay affixed during flight.

3. Theory of Operations

The screw switch is a component designed to hold a screw switch up to the frame of the payload to allow easy accessibility. It also captures the screw for the switch to prevent it from backing out too far and falling into the payload assembly. We manufacture this piece via 3D printing using PETG as the filament. Heat set inserts were then inserted into printed holes for them, which are used. The experiment will begin when a screw switch is screwed in. This will start a circular buffer that cycles every 2 seconds. The buffer will store data at 1600 Hz until launch is detected. Launch is detected if both accelerometers detect more than 10 Gs for more than 10 straight datapoints. Once launch is detected, the accelerometers and thermometer will start storing data at 1600 Hz onto the breakout SD card. This will continue for 10 minutes. Once the payload is recovered, the system will be hooked up to a computer and the data will be read off and analyzed.

4. Electronics

The electronics were all developed around the high-frequency vibrations that are being measured. The accelerometers picked to measure these were the KX134 breakout boards because of their high G survivability and high sampling rate. To match these and allow for easier integration, the microcontroller designed to control all of the components was the ESP32-WROOM. In addition to having two cores and being 3.3V, the microcontroller has a built-in QWIIC connector which allows for simple I^2C connection with the accelerometers. The thermometer was chosen for the same reason, it is QWIIC compatible allowing easy daisy-chaining with the accelerometers. Not everything is I^2C, though; the breakout SD card where the data is stored needed to be soldered using SPI communication.

5. Electronic Architecture and Power Distribution

DogBone uses an 18650 3500 mAh Li-ion battery. The 18650 battery was chosen because it is the most commonly used rechargeable battery and therefore easy to design around and integrate. The decision to use a 3500mAh cell was because it will provide a large margin of safety in terms of runtime of the electronics if the rocket sits on the pad while the electronics are on for a long time. Calculations show that the electronics should be able to run for up to 12 hours on the pad without risking running out of battery in flight.

The battery must be stepped down to 3.3 before powering the electronics. By splicing and soldering, the battery runs through the screw switch and then to a buck converter before powering the electronics through the microcontroller.

6. Testing

The electronics were tested in many small segments culminating in a full-scale vibrational test. The first electronics test was to verify that the accelerometers could store meaningful data and that the launch detection could work which was somewhat successful. The data was stored well but it required a different way of transferring data onto the computer, which is when PuTTY started getting used. PuTTY reads data off of the serial monitor when the microcontroller is hooked up and saves it as a csv to analyze later.

The second test was to determine which accelerometer mount to use. Having narrowed it down to two options; the aluminum "cracker" and the PETG enclosure. The Aluminum mount allowed for a more realistic fully rigid connection to the accelerometers. The PETG mount, however, enclosed the accelerometers from all directions, allowing damping from three different axis. Both were fixed in a set with and without the polymer against a metal plate. This plate was then vibrated at around 40-60HZ using a massage gun for 30 seconds. Measuring the magnitude of the vibrations from each, the metal mount showed no damping and the PETG showed slight damping. Overall the PETG mount was chosen, as it's damping effectiveness is expected to increase at higher frequencies and lower temperatures.

The final test was a full-length flight simulation test with the battery connected. The accelerometers in the PETG mount were quickly accelerated to mimic launch, and then, on the metal plate, were vibrated with the massage gun for the full ten minutes. Once again, the data was read from PuTTY, and saved/analyzed. This resulted in another small damping result, proving the effectiveness of our design.

H. Measurements Subsystem

Custom composite materials benefit CRT because of their low weight, high strength, and customization. In the past few years, the team has run into issues justifying the number of layers for a part. One of the largest struggles is determining a requirement. The team currently does not know the magnitude of forces on the airframe during flight or the reaction of the airframe. As such, implementing a strain gauge system would benefit future rockets built by the team by setting strict requirements. This year, Aurora contains 14 strain gauges spread across the entire rocket. This includes 2 in the nose cone, 4 in the coupler, 2 in the body tube, 2 in the fin can, and 4 in the fins, totaling 14 strain gauges [12]. Details about the design decisions, procedure, operations, and lessons learned are found in the team's extended abstract.

IV. Mission Concept of Operations Overview

A. Aurora Concept of Operations

Integration Prior to launch, the rocket is assembled and integrated following the integration checklist shown in Appendix E. First, the nose cone electronics bay is fully assembled with flight computers, GPS, and batteries. Wired connections are made and tested via tug tests and continuity checks. The nose cone electronics bay is then taken to an energetics table, where vinyl tube charges are assembled and wired up to the electronics bay. Charge wells in the Tendie Descendie Duo are also loaded, and the packed recovery system is attached to the nose cone electronics bay bulkhead. With the nose cone electronics bay fully completed, it is then clocked and installed into the nose cone, held in place with the nose cone tip. Simultaneously, the lower camera electronics bay is installed into the body tube, followed by the centering ring. Measurements wires are then connected between the body tube and the fin can, and the fin can is affixed to the body tube via the interface centering ring. The payload and the measurements electronics bay are also affixed to the payload/measurements bulkhead - with the payload following its own assembly procedures as detailed in Section IV.B - and this bulkhead is integrated into the rocket. During this integration, wires from the strain gauges throughout the rocket are connected to the measurements e-bay. Also at this time, the upper camera e-bay is turned on and affixed to the recovery bulkhead. The coupler and recovery bulkhead are then attached to the body tube, making sure to connect the measurements wires through the VGA connector in the bulkhead. The recovery section is attached by a quick link and the Tendie Descendie Duo to the E-bay bulkhead and by a quick link to the U-bolt on the recover bulkhead. The two vinyl tube charges are taped to the side of the nose cone coupler. Prior to taping the charges to the coupler, they are held in a 3D printed holder that secures them in case of an accidental detonation. 2-4 layers of Saran Wrap are applied to the polycarbonate lid of the upper camera E-Bay. Extra material is left hanging over one end of the lid, and this excess material is then wrapped around a Kevlar thread. This Kevlar thread is then tied around the shock cord, such that the Saran Wrap is removed (producing a clear view of parachute deployment) upon the ejection charge firing. With the recovery system fully attached, the nose cone is then placed over the coupler, and affixed in place with shear pins. The motor is then installed inside the body tube, screwing onto the motor retention bolt and tightened until the lip of the motor casing is flush with the bottom of the fin can. To ensure quality of work and completeness, the integration checklist has written verification by both whomever completed the task and a supervising integration lead.

Arming Arming beings once the rocket is brought out onto the launch pad. While the rocket is horizontal on the rail, the TeleGPS, Sirin, and ElvinBeacon screw switches will all be turned on to allow each system ample time to connect to the Base Station and acquire GPS fixes. The TeleGPS connection must be checked by connecting to the Base Station. The ElvinBeacon and Sirin can both be checked using handheld HAM radios. While those are connecting, the lower camera electronics bay fans (three total) and the measurements electronics bay will be turned on via screw switches.

Once all appropriate signals have been received, the rocket will be positioned vertically on the launch rail. The EasyMini and BlueRaven will be turned on via their respective screw switches. The EasyMini and BlueRaven have unique sequences of beeps when turned on. Once all are confirmed to be on and functional, an igniter will be placed inside of the motor, completing the arming process.

Ignition After the rocket is fully armed and all personnel are a safe distance away from the rocket, as dictated in Tripoli Safety Information [13], the rocket is checked for continuity. After confirming continuity, ignition starts when a FIRE signal is sent to the igniter, and concludes when the propulsion system comes up to chamber pressure.

Liftoff Liftoff begins after ignition when at the vehicle's first motion, and concludes when the vehicle is free of the launch rail. At this time, the measurement electronics bay detects launch via an accelerometer and begins storing data. The payload has a circular buffer that stores the past 2 seconds of data and continuously erases it until launch is detected via accelerometers, and data begins to continuously be stored.

Powered Ascent Powered ascent begins when the rocket leaves the launch rail at 107 ft/s, with a stability of 2.52 body calibers (14.13%) according to RASAero II. This is when the barometric devices start taking data. Powered ascent lasts for the 6.2 seconds that the O3400 burns, and concludes once burnout has ceased. The rocket makes the transition from powered ascent to unpowered ascent at approximately 8000 ft AGL. After this, the rest of the flight is unpowered. The rocket will continue to climb for another 35 seconds, reaching an estimated apogee of 32,519 ft according to RasAero, where unpowered ascent concludes.

Apogee Apogee occurs once the rocket has stopped its ascent, estimated to occur approximately 38 seconds after ignition. The BlueRaven and EasyMini flight computers will detect apogee and will cause separation and ejection events. Once apogee is detected, the BlueRaven ignites the primary vinyl tube charge containing 4.5 grams of black powder to cause separation. The EasyMini is programmed to ignite the backup redundant vinyl tube charge of 5.0 grams one second after apogee is detected. Once one of the charges ignites, the three shear pins are broken and the pressure causes the nose cone to separate from the coupler and body tube. The force of ejection pulls the drogue parachute and associated recovery lines out of the deployment bag. The drogue inflates once it has been fully pulled out of the deployment bag. The force of deployment also removes the Saran wrap covering the polycarbonate upper camera E-bay shield via a length of Kevlar thread tied to the length of recovery line between the lower body and the drogue parachute. Apogee concludes once the rocket begins to have a negative acceleration.

Descent With Drogue Following the separation at apogee, Aurora initially falls at 153 ft/s. Under drogue, the descent rate slows to 89.2 ft/s as Aurora descends to 1500 ft AGL. At 1500 ft AGL, descent under drogue concludes and main deployment occurs.

Main Deployment Main deployment begins at 1500 ft AGL, when the BlueRaven and EasyMini each ignite one charge in the Tendie Descendie Duo. This releases at least one of the pins, which releases the recovery lines attached to the main parachute and the strap holding the main parachute compartment of the deployment bag closed. The force from the drogue parachute is now only applied to the quick link that the main parachute is attached to, so the main parachute is pulled out of the deployment bag, which is no longer held closed. Main deployment concludes when the main is fully released from the deployment bag.

Main Descent Descent under main begins once the main parachute has opened. The main parachute slows the descent of Aurora until the rocket contacts the ground at 25.9 ft/s, concluding main descent.

Ground Operations Once Aurora has touched down, the TeleGPS will transmit GPS signals to Base Station and the Elvin Beacon will transmit RF signals that can be tracked. The KrakenSDR that is attached to Base Station will be used to identify the direction of the signals, which will be communicated to the recovery team until Aurora is found and recovered.

Once Aurora is found, various pictures will be taken of the condition of the rocket before the rocket is touched. Once ample pictures have been taken and beep codes have been recorded, the various screw switches will be turned off and the recovery team will take the rocket back to the recovery tent where it will be assessed.

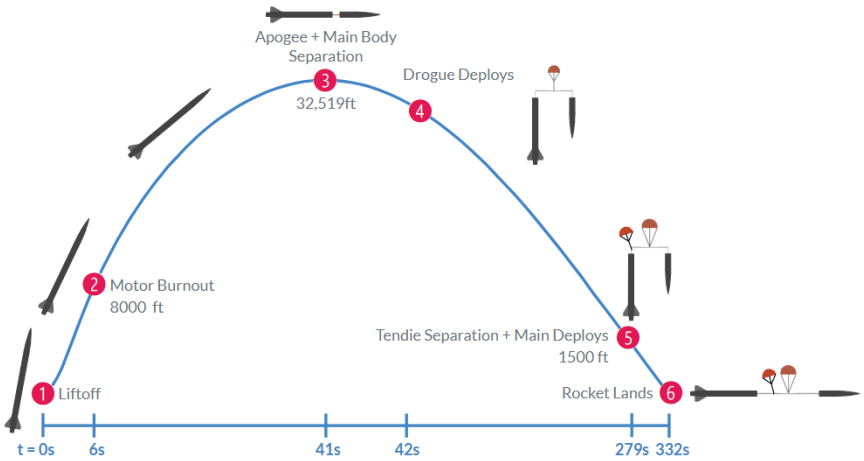


Fig. 14 Diagram of the Aurora mission concept of operations.

B. DogBone Concept of Operations

Integration The electronics will first be wired together outside of the housing and then integrated in. The majority of the electronics on DogBone are held on the electronics mount. This 3D-printed board will have the following components screwed into it: ESP32, Buck Converter, SD Card Breakout, and Thermometer. Once those are screwed in, one accelerometer will be put in a polymer pouch, and then both accelerometers will be fit into their respective 3D-Printed mounts. The battery will fit into its mount and the cover will get screwed in. In addition, the screw switch will be screwed into its mount. Finally, while the panels are unassembled, all of the mounts will be screwed into panels and the LED will be glued into its position. The panels will then be screwed together, and attached to the payload/measurement bulkhead in an orientation that lines the screw switch with a hole in the rocket.

Arming Once the rocket is on the rail and oriented horizontally, the payload system will be activated via screw switch. To verify the circuit has been closed, the LED which is illuminating the experiment will also be visible through the screw switch hole. It will begin its circular buffer and keep buffering until flight is detected.

Ignition With rocket ignition, once sustained acceleration is detected by the accelerometers, DogBone transitions from buffer to recording mode. It will store the accelerometers and thermometer data at a rate of 1600 HZ for the duration of the flight.

Ground Operations Upon recovery of Aurora and DogBone, the payload is manually powered down, via undoing the screw switch. Once the payload is returned from the recovery tent, the payload will be disassembled. A computer will be attached to the ESP32 via the Micro-USB port and via Arduino IDE and PuTTY, the data will be stored on the computer. Once all of the data has been collected, the magnitudes of the vibrations will be measured for each accelerometer. The data will be split into 3 second intervals, so the temperature at each section will be used to determine the temperature with the largest damping.

V. Conclusions and Lessons Learned

Creating Aurora and DogBone was some of the most complex, challenging work that the Case Rocket Team has taken on. From the start, the loftiest goal was to have a full test launch. Unfortunately, the team did not make this deadline. When looking back, there are a few lessons to be learned about the entire manufacturing process. The team started the academic year with a good pace and had the Ready for Manufacturing review in early January.

One issue that hindered progress was the equipment available. Many parts relied on using the waterjet or CNC mill. Unfortunately, both of these machines were in and out of service for the first few weeks of manufacturing. In future years, the team should create backup plans for any parts that require equipment that requires frequent service. An additional factor that became a huge roadblock during the manufacturing season for Aerostructures was experimenting with new manufacturing methods for Aurora. One such case was attempting to make fins of pure 6K carbon fiber, as they would have been both lighter and stiffer. A small-scale test had promising results, but proved difficult to work with and became extremely wavy after vacuum bagging when scaled up. This plate, which would have eventually become the fins, had to be scrapped, new material had to be ordered, and a new fin plate had to be manufactured. Although the rocket was still finished, this failure resulted in a large holdup that pushed back fin can manufacturing, which is the most intensive process in the entire rocket. In future years, full-scale tests should be run before the manufacturing season.

In regard to avionics, hardware choices during Sirin's design were difficult. Many of the sensors selected turned out to have high amounts of inaccuracy or inconsistency, hindering the production of the Error State Kalman Filter. These sensors would often get uncalibrated, have high noise levels, or occasionally output wildly incorrect values. A significant portion of time was spent attempting to get around these issues with software solutions. While some solutions have been effective, it took valuable time from important projects. These issues can be attributed to a lack of concern for the quality of components chosen over other factors such as cost, availability, and compatibility with the existing framework. For the next iteration of Sirin, component quality analysis will hold a much higher weight when choosing parts for the board.

Many of the scheduling decisions made in the fall semester were helpful when manufacturing the rocket and should be repeated in future years. The review framework followed included a system requirements review (SRR), conceptual design review (CoDR), preliminary design review (PDR), critical design review (CDR), and a ready for manufacturing (RFM). The SRR occurred in the first week of classes. All design reviews through the CDR were completed before the fall semester ended. Drawings were created over winter break, with RFM on the 15th of January. The team was able to start manufacturing months earlier than in previous years, which was essential when faced with equipment issues. In addition, stock was ordered before winter break, so the team did not have to spend any time waiting for it to arrive after RFM. This calendar, although tight, enabled the team to spring ahead in the second semester.

In order to facilitate transfer of knowledge to younger team members, team leads documented every single procedure in reference documents that live in CRT's Google Drive. Team leads were also instructed to allow younger members to help as much as possible with hands-on design and manufacturing so that they can gain those skills while also contributing to Aurora's design. Another factor that was emphasized this year was photos being taken, particularly during manufacturing processes. Many times, one person was a dedicated picture taker. This led to many photos from all angles, which allowed a comprehensive understanding to be gained from the aforementioned documentation and pictures combined.

A. System Weights, Measures, and Performance Data Appendix

A. Basic Rocket Vehicle Information

Characteristic	Measurement	Units	Notes
Number of stages	1	–	
Airframe length	107.14	in	
Airframe diameter	5.982	in	
Number of fins	4	–	
Fin semi-span	6.828	in	
Fin tip chord	2.25	in	
Fin root chord	11.25	in	
Fin thickness	0.375	in	
Center of gravity	69.21	in	At ignition, from tip
Center of pressure	85.77	in	At ignition, from tip
Launch rail length	12.69	ft	

Table 4 Overall rocket measures of Aurora.

Subsystem	Weight (lbs)
Full system on launch rail	69.66
Propellant	24.10
Empty motor case	13.03
Payload	10.4
Liftoff weight	69.66

Table 5 Overall rocket and subsystem weights of Aurora.

B. Propulsion Information

Motor type	COTS or SRAD?	COTS manufacturer and designation
Solid	COTS	Cesaroni Technology 21062O3400-P
Motor letter classification	**Average thrust (N)**	**Total impulse (Ns)**
O	3,416.7	21,062.2
Motor burn time (s)		
6.2		

Table 6 Propulsion information for Aurora.

C. Predicted Flight Data

1. RASAero II Simulation Information

Characteristic	Value	Units
Altitude	2,917	ft
Launch rail length	12.69	ft
Temperature	97	°F
Pressure	13.43	psi
Launch angle	6	°from vertical

Table 7 RASAero II simulation information.

2. OpenRocket Simulation Information

Characteristic	Value	Units
Longitude	-104	E
Latitude	31	N
Altitude	2,917	ft
Temperature	97.00	°F
Launch rail length	12.69	ft
Pressure	13.43	psi
Launch angle	6	°from vertical

Table 8 OpenRocket simulation information.

3. RASAero II and OpenRocket Simulation Results

Characteristic	Value (RAS)	Value (ORK)	Units
Liftoff thrust-weight ratio*	13.94	13.94	–
Rail departure velocity	–	107	ft/s
Target apogee	30,000	30,000	ft
Apogee	32,519	29,323	ft
Max velocity	2,076	1,997	ft/s
Max velocity	1.84	1.77	Mach
Max acceleration	521	509	ft/s^2
Max acceleration	16.2	15.82	G
Min stability	14.2	–	%
Min stability	2.51	–	Body calibers
Max stability	23.7	–	%
Max stability	4.30	–	Body calibers
Time to apogee	41	38.6	s
Flight time	329	344	s
Ground hit velocity	29.2	29.9	ft/s

Table 9 RASAero II and OpenRocket simulation results. Both simulations were performed with no wind. Note that the RASAero II simulations are used for official apogee, time to apogee, velocities, and accelerations. *calculated with initial thrust of 971.21 lbf [14].

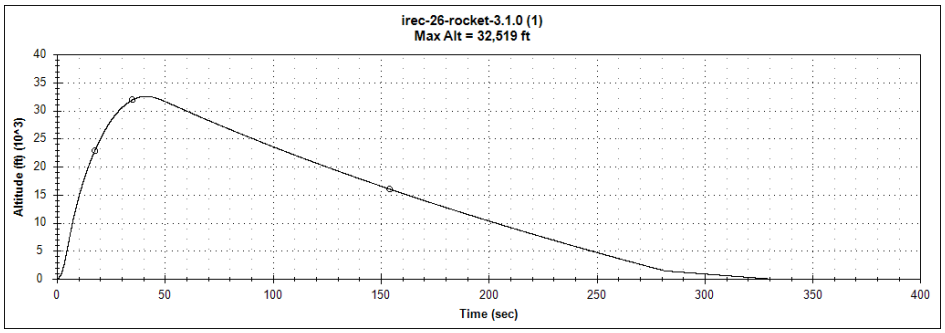


Fig. 15 Aurora RASAero II altitude graph.

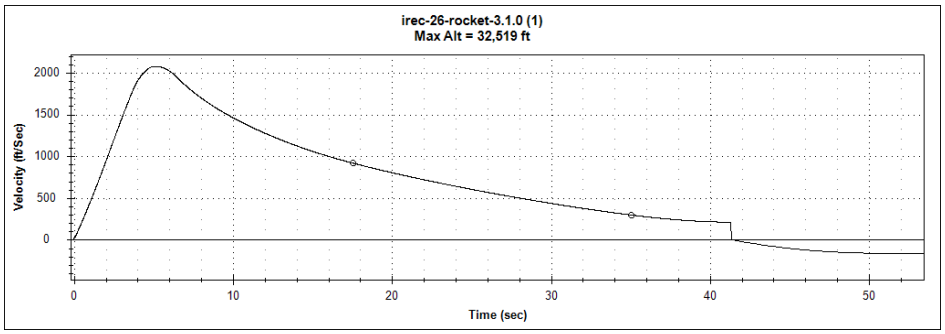


Fig. 16 Aurora RASAero II velocity graph.

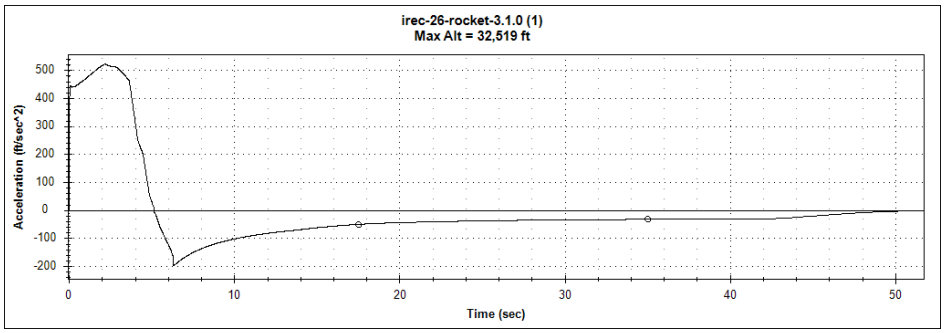


Fig. 17 Aurora RASAero II acceleration graph.

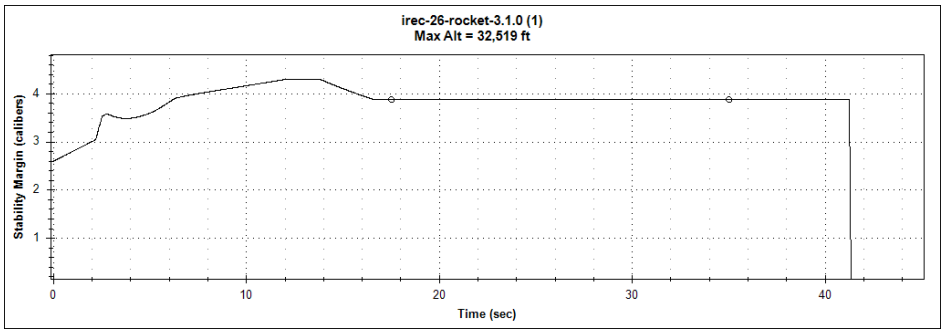


Fig. 18 Aurora RASAero II stability graph.

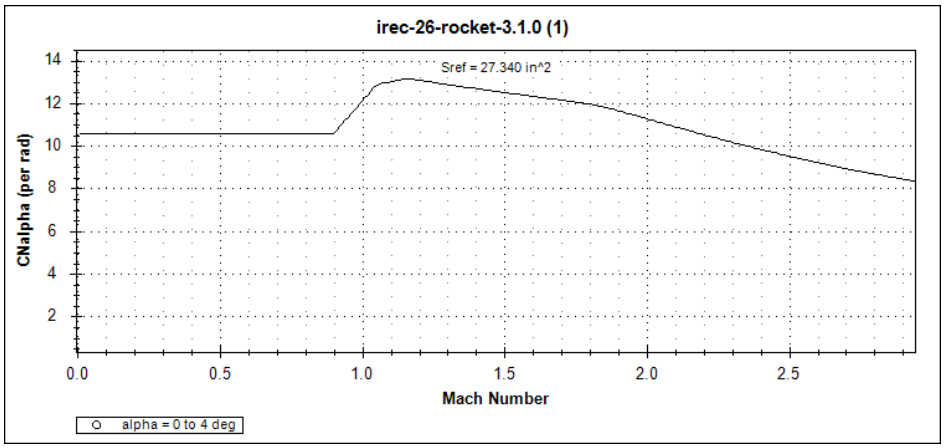


Fig. 19 Aurora RASAero II CNAlpha graph. Note that Aurora is anticipated to reach up to Mach 1.84.

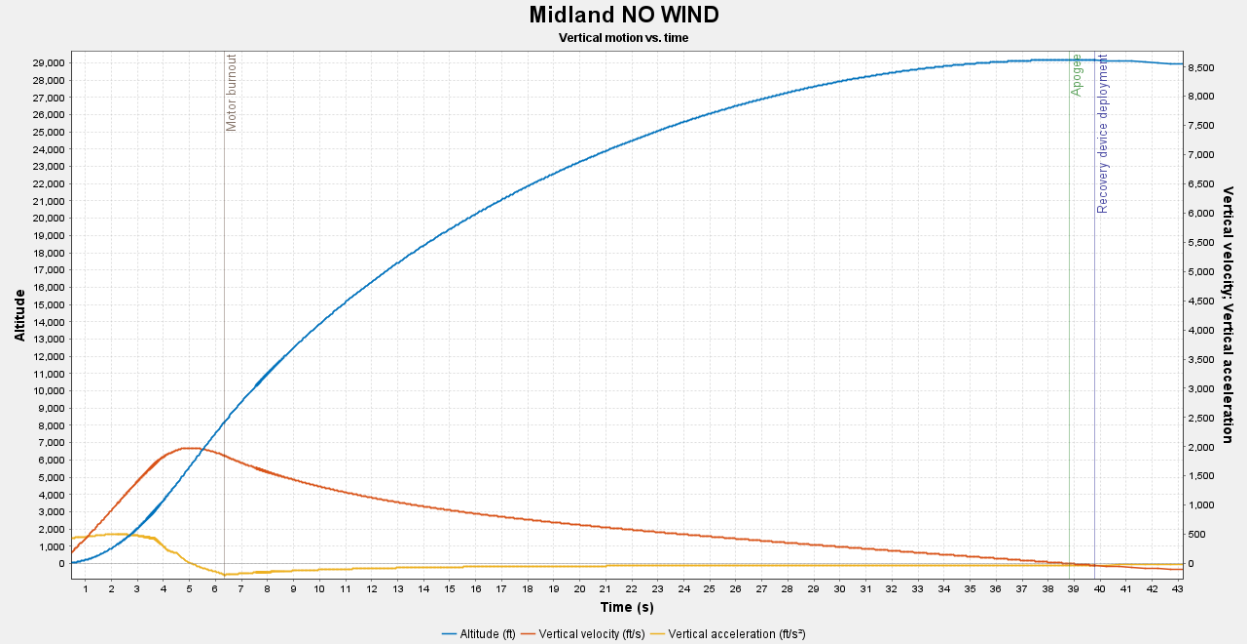


Fig. 20 Aurora OpenRocket flight profile graph.

4. AeroFinSim Fin Flutter Analysis

Characteristic	Value	Units
Fin flutter Velocity	3.43	Mach
Fin divergence Velocity	5.36	Mach
Flutter FoS	1.86	–
Divergence FoS	2.91	–

Table 10 AeroFinSim simulation Results.

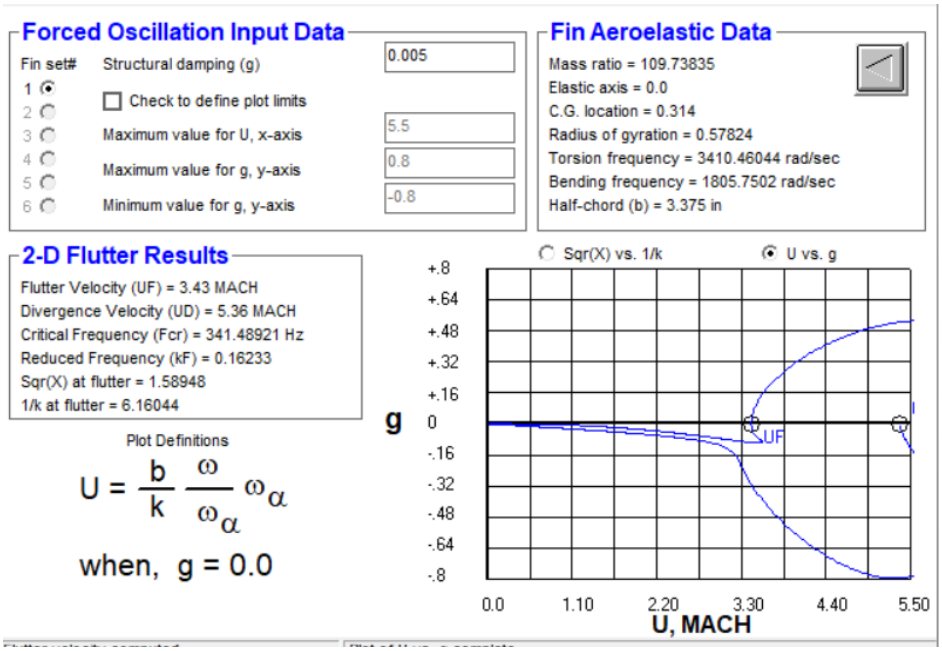


Fig. 21 Aurora FinSim Results.

5. Recovery Information

Altimeters Used

Flight Computer	COTS or SRAD
BlueRaven	COTS
EasyMini	COTS
Redundancy level	Dual

Table 11 Altimeters used on Aurora.

Drogue Parachute Information

Characteristic	Value	units
Primary deployment charge	BlueRaven	NA
Backup deployment charge	EasyMini	NA
Deployment altitude	32,519	ft
Max descent rate	152	ft/s
Min descent rate	89.2	ft/s

Table 12 Drogue parachute information.

Main Parachute Information

Characteristic	Value	units
Primary deployment charge	BlueRaven	NA
Backup deployment charge	EasyMini	NA
Deployment altitude	1500	ft
Max Descent rate	26.5	ft/s
Min Descent rate	25.9	ft/s

Table 13 Drogue parachute information.

Parachute Shock Cords

Characteristic	Value	units
Ultimate tensile strength	3,600	lbf
Length from drogue to body tube	128	in
Length from drogue to nose cone	75	in
Length from main to nose cone	145	in

Table 14 Shock cord information. Note all shock cord is 3/8 in tubular Kevlar.

Mechanical Links

Characteristic	Value	units
Ultimate Load	8,500	lbf

Table 15 Mechanical link information. Note that these quicklinks are used to attach all shroud lines to shock cord and shock cord to the airframe.

B. Project Test Reports Appendix

A. Recovery System Testing

1. Vinyl Tube Charge Testing

Test 1	**Vinyl Tubing Charge Test**		
Floating charges were a new idea that needed to be tested this year. The charges were made by cutting vinyl tubing, filling with black powder, an electronic match, cellulose insulation, and sealing with hot glue. These were detonated remotely using a BlueRaven. Two tests were done to ensure repeatability.			
Event	**Success Criteria**	**Result**	**Date**
Detonation	Successful detonation of charge	PASS	4/28/2026
	System Analysis	PASS	4/28/2026
Testing Notes			
These worked incredibly well and were able to be handled in a way that was significantly safer than previous years' alternatives. Most of the black powder combusted from both iterations of the test proving repeatability.			

2. Main Body Ejection Testing

Test 2	**Main Body Ejection Test**		
This test was performed in order to ensure that both separation occurs once the vinyl charges are ignited, and also to confirm that drogue deploys on separation without tangling. This test was performed while the entire rocket was integrated with everything except for the measurements electronics bay to get as accurate of a result as possible. It was performed outdoors and on the ground. After previous vigorous separations with 5g of black powder, 4.5 was chosen as it was also able to separate the nose cone from the body tube as well as shear the three shear pins.			
Event	**Success Criteria**	**Result**	**Date**
Detonation	Successful detonation of charge	PASS	4/23/2026
Tube Separation	Nose cone completely separates from the body tube and through all shear pins	PASS	4/23/2026
Drogue Deployment	Drogue parachute deploys without tangles and holes from embers	PASS	4/23/2026
Main Chute Stowed	Main chute does not deploy and stays stowed in the deployment bag	PASS	4/23/2026
	System Analysis	PASS	4/23/2026
Testing Notes			
Multiple tests were conducted before everything was successful. Used less black powder than calculated in initial test, as 5.0g was deemed to be a large amount of black powder by the Flyer of Record. This led to the first test using 4.5g of black powder, which was successful. The main parachute line was fully under tension from the 4.5g ejection and the main did not come out of the deployment bag. Since the separation was vigorous, 4.5g will be used for the main deployment charge and 5.0g will be used for the redundant.			

3. Tendie Descendie Duo Ejection Testing

Test 3	**Tendie Descendie Duo Ejection Test**		
The SRAD Tendie Descendie Duo used in Aurora controls the deployment of the main parachute. To verify that the pins from the Tendie Descendie Duo would separate, a test with one of the Tendie plates under load was performed. Black powder was poured into the delrin charge well, filling it fully.			
Event	**Success Criteria**	**Result**	**Date**
Detonation	Successful detonation of charge	PASS	4/28/2026
Tendie Descendie Duo Separation	Pins from the Tendie Descendie Duo separated from Tendie Descendie Duo body	FAIL	4/28/2026
	System Analysis	FAIL	4/28/2026
Testing Notes			
Neither pin ejected when the charge well was ignited. Before the competition, a new body will be CNC manufactured to take out the source of error when manufacturing by hand. This is an accurate workaround because in previous years this design has worked. Additionally, this new part will be adequately tested under load to ensure that the main parachute deploys.			

4. Main Parachute Deployment Testing

Test 4	**Main Parachute Deployment Test**		
In order to confirm the construction and packing method of the main parachute in the deployment bag, a test simulating the deployment conditions was done. The packed parachute was quicklinked to one person through a belt, while another held the deployment bag. The person attached to the parachute ran up wind to simulate deployment.			
Event	**Success Criteria**	**Result**	**Date**
Parachute exits deployment bag	The parachute leaves the deployment bag without significant resistance and there are no tears in the deployment bag and main parachute.	PASS	4/17/2026
Parachute Inflates	Parachute inflates within 3 seconds of deployment	PASS	4/17/2026
	System Analysis	PASS	4/17/2026
Testing Notes			
The parachute inflated two seconds after fully exiting the deployment bag. Neither the parachute nor the deployment bag sustained any damage.			

5. Recovery Line Strength Testing

Test 1	**Kevlar Line Rocket Attachment Point Test**		
These tests were done to determine the optimal attachment design between the recovery lines and the rocket. Small test articles of 3/8" Tubular Kevlar with either knots or sewn loops on either side are mounted to a Instron Universal Testing System and loaded until failure.			
Event	**Success Criteria**	**Result**	**Date**
Sewn Loop Test Article	The test article withstands a load of at least twice the expected load during main deployment.	PASS	10/21/2025
Knotted Test Article	The test article withstands a load of at least twice the expected load during main deployment.	FAIL	10/21/2025
	System Analysis	PASS	10/21/2025
Testing Notes			
The sewn loop test articles withstood a load of about 3200 lbf while the knotted test articles withstood only 1200 lbf. Given that the expected load during main parachute deployment is about 1000 lbf, the sewn loops were chosen to connect the kevlar lines to the rocket.			

Test 2	**Kevlar Line Parachute Attachment Point Test**		
These tests were done to determine the optimal attachment design between the recovery lines and the quicklinks that hold the parachutes. Small test articles of 3/8" Tubular Kevlar with either knots or sewn attachment points in the middle of the test article are mounted to a Instron Universal Testing System and loaded until failure.			
Event	**Success Criteria**	**Result**	**Date**
Sewn Attachment Point Test Article	The test article withstands a load of at least twice the expected load during main deployment.	FAIL	11/25/2025
Knotted Test Article	The test article withstands a load of at least twice the expected load during main deployment.	FAIL	11/25/2025
	System Analysis	FAIL	11/25/2025
Testing Notes			
The sewn attachment point test articles withstood a load of 500 lbf while the knotted test articles withstood 1800 lbf. Since neither design met the success criteria, the recovery line was segmented and the attachment points from Test 1 were used.			

B. Fin Shear Modulus Determination

Test 1	**Fin Shear Modulus Determination**		
Using old plates used for constructing fins and a new solid carbon fiber plate, shear modulus was determined to see which would be optimal for the fins			
Event	**Success Criteria**	**Results**	**Date**
Shear modulus for both types of fins obtained	A clean graph and csv file is obtained that can be used to determine shear modulus	PASS	2/7/2026
	System Analysis	PASS	2/7/2026
Testing Notes			
Fin shear moduli were determined and could be used to inform future decisions. The jig can also be used if new materials for fins are to be tested in the future.			

C. SRAD Propulsion System Testing

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D. SRAD Pressure Vessel Testing

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E. SRAD GPS Testing

1. GPS Tube Testing

In the 2024-25 academic year, the Case Rocket Team performed tube testing to determine the effect a carbon fiber tube has on the tracking signal strength of a Featherweight GPS. The team determined a negligible signal strength difference between no carbon fiber and a carbon fiber coupler combined with a fiberglass nose cone [15]. These results were a large factor in determining both the placement of tracking solutions and nose cone material.

2. Long Range GPS Testing

Due to its criticality to recovery operations, this form of testing was conducted for all transmitters on Aurora. The team performed long-range testing of all transmitters' radios spanning 3 miles over open water. Testing proved the ability to receive data with the team's current Base Station configuration at this distance. While packet reception was unreliable at points during testing, this was due to misconfiguration of the software and the antenna hardware, which has since been fixed. Mid-range testing was also performed at a distance of approximately 0.5 miles with line of sight, and the transmitter was elevated 75 ft above the ground. This testing showed a TeleGPS signal strength of 30 dBFS and an Elvin Beacon signal strength of 45 dBFS. Using this data on the log-distance path loss model, radio reception far exceeds the needs of the rocket's worst-case drift scenario, with telemetry reception being limited to approximately 6 miles due to the curvature of the earth and antenna height.

F. SRAD Avionics System Testing

While other telemetry solutions have had previous proven success, Sirin is still a project in development with the Case Rocket Team and has been the focus of multiple tests. The primary structure of the device has remained relatively unchanged since its inception, but it has undergone various iterations of component replacements, board redesigns, and functionality improvements. Historically, two new iterations have been produced before each IREC. For IREC 2026, the team opted to produce one iteration and focus our efforts on flight-readiness testing. This entailed tests on the following features:

1) GPS
2) Long-range Radio
3) Error-State Kalman Filter (ESKF)
4) Logging
5) Apogee Detection
6) Test flight

1. GPS

Sirin S1-R3 replaced the GPS from the previous iteration, S1-R2, due to reliability issues with the device. Upon reprogramming Sirin to interface with the new GPS, testing was performed at various locations across the country in several different weather conditions. In every outdoor scenario, Sirin was able to reliably connect to satellites, create a packet containing its ECEF position, and display it in logged data.

2. Error-State Kalman Filter (ESKF)

The ability of the ESKF to determine our heading was done by using a live data visualization of the rotational basis vectors in the world frame, along with the acceleration (gravity) and the magnetic field for reference. The visualization showed a strong consistency between the estimated orientation on the display and the physical motion of Sirin under nominal conditions. However, it was observed that when Sirin was moved in sharp increments, the heading estimation degraded. This suggests that the implementation of the ESKF may have limitations at high angular velocities, but this was deemed to be a minor issue as it would only affect operation of the filter outside of conditions expected in flight. These results confirm that the ESKF is able to reliably and accurately determine Sirin's heading in real time, which is crucial for reliable telemetry.

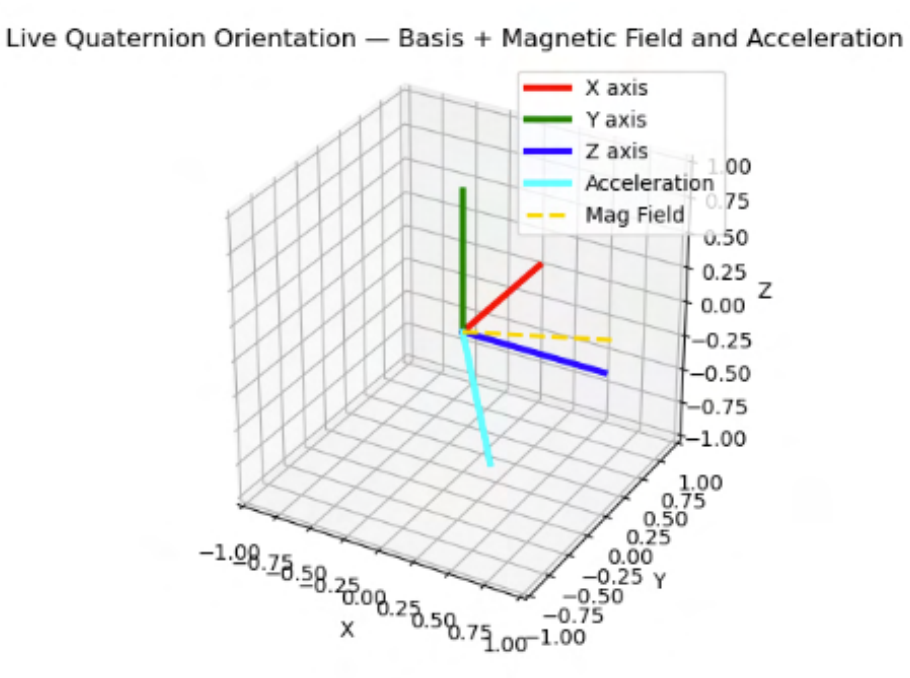


Fig. 22 Methodology of Kalman Filter.

3. Long-range Radio

The details for this section can be found in Section B.E.

4. Logging

To test Sirin's logging capabilities, the device was forced into Flight Mode, causing Sirin to log as many new data entries as possible for the duration of the flight timer. Review of this logged data showed that in some flights, data from far outside the flight timestamp was included in the logs. In every scenario, the full flight was logged with accurate data at the desired frequency.

5. Apogee Detection

This test was the precursor to a full-scale test launch. In order to simulate apogee detection, Sirin was inserted into a protective casing with pressure ports and launched 50+ ft into the air. An onboard white light indicated whether Flight Mode had been entered and an external LED was attached to represent an e-match being fired. The casing was launched at various speeds, angles, and from several positions. In all tests, the device detected apogee and illuminated the LED within a meter of the true apogee.

6. Test Flight

A partial test flight was performed in November with the intention of testing measurement, logging, and deployment capabilities. At the time, GPS, radio, and the ESKF had not been completed. Due to other complications with the rocket, there was no separation, and the rocket came down on a ballistic trajectory. The secondary flight computer was obliterated, but Sirin survived with minimal damage and recoverable flight data. By cross-referencing the flight measurements with each other as well as footage of the flight, the team determined that most measurements had been accurate. The rocket had an apogee of approximately 4200 ft and a top speed of Mach 0.8, ultimately reaching a terminal velocity of 275 ft/s during descent. A log of deployments was also kept, showing Sirin fired the ejection charges at the desired times in flight. Upon collision, power was lost, and Sirin stopped logging any further data.

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C. Hazard Analysis Appendix

Explosives and Energetics Aurora is powered by a Cesaroni O3400-P solid motor. This motor is safe to be handled without the use of a breathing apparatus because it is powered by a non-toxic propellant. The motor will be properly stored near room temperature and kept away from ignition sources, and the motor will be handled only under the supervision of those with a TRA or NAR L3 certification.

This project requires the use of black powder charges to initiate various in-flight events. As such, all black powder is carefully handled on a designated table isolated from potential ignition sources during the process of Aurora's assembly. During assembly and integration, any components of the rocket containing black powder will be moved to a designated black powder table and remain there. All members handling black powder are required to wear eye protection and gloves. Unused black powder will be treated as waste and disposed of into soil. At all times, members have access to the Safety Data Sheet.

Composites Manufacturing The manufacturing of the airframe utilized 2 main composite materials. Carbon fiber twill weave and sleeve were used for the majority of the airframe construction, including the body tube, coupler, boat tail, fin layups, and tip-to-tip layups on the assembled fin can. Fiberglass was also used in the form of fiberglass sleeves to manufacture the nose cone and G10 fiberglass sheets as the core layer for the fins.

When performing composite surface preparation and post-processing tasks, wet-sanding, half-face respirators, gloves, eye-protection, and open-air spaces were used to minimize exposure to composite dusts. During hand layups to laminate composites, double-layered nitrile gloves were used in a large, well-ventilated area to prevent the risk of epoxy poisoning. In order to minimize the risk of fumes resulting from an exothermic reaction, epoxy resin and hardener were mixed in small batches of no more than 45 g total. The laminated fins were cut on a water-jet using a high water level to prevent aerosolizing the composite particulates.

Launch Hazards All guidelines listed by TRA [13], NAR [16], and National Fire Protection Association 1127 [17] will be strictly adhered to in preparation for launch. As such, only select members will prepare for launch out on the launch pad, each of whom will be made aware of necessary safety protocols. The rocket will be driven to the pad with no electronics armed, and each procedure will be carried out safely according to a specific launch checklist. At the launch site, members will adhere to all guidelines and decisions made by the Range Safety Officer.

D. Risk Assessment Appendix

A. Aurora Risk Assessment Matrix

CONOPS Phase	Failure Mode	Effect	Causes of Failure	Mitigation	Severity	Occurence	Prevention	Risk Priority Number	Occurence After Prevention	Risk After Prevention Priority Number
Integration	Sirin flight parameters improperly entered before flight	GPS tracking is dysfunctional/doesn't work	Sirin improperly programmed	Use integration checklist and ensure proper coding, have redundant GPS	5	2	1	10	1	5
	GPS Fix not obtained before launch / radio data not received	No GPS fix / telemetry from Sirin or TeleGPS	Antenna / SDR software misconfiguration	Radio testing within airframe before launch, have redundant GPS	2	3	3	18	2	12
Arming	Errors are unwrapped in flight software	Sirin code terminates, failure of telemetry	Unsafe coding / lack of error handling	Error-safe programming	3	2	1	6	1	3
	Main Ebay batteries run out of charge before we launch	All mission critical electronics fail	Insufficent battery capacity	Ensure battery life lasts as long as we could be in quarantine, do not turn on flight computers until rocket is vertical	5	3	1	15	1	5
	Cameras run out of charge before we launch	We do not get any footage of the launch	Insufficent battery capacity	Ensure battery life lasts as long as we could be in quarantine	1	3	1	3	1	1
Ignition	Motor explodes	Rocket explodes	Defect, or blockage of exhaust	Ensure proper motor assembly with flyer of record, inspect motor grains before integrating	5	2	2	20	1	10
Liftoff	Rocket in understable off the rod	Rocket flies in an unpredictable manner and veers off course	Rocket innacurately simulated	Have multiple people double-check simulation parameters before launch	5	2	1	10	1	5
Ascent	Fin flutter and divergence	Rocket unable to fly properly, forces risk breaking rocket in-flight	Aerodynamic forces	Finsim analysis with FoS, measure shear modulus	4	3	3	36	2	24
	Motor retention bolt unthreads from motor retention bulkhead	Motor falls out of rocket	Vibrations cause motor to unscrew	Red loctite the threaded rod into the motor retention bulkhead.	4	2	1	8	1	4
	Motor retention bolt unthreads from forward closure	Motor falls out of rocket	Vibrations cause motor to unscrew	Blue loctite the threaded rod to the forward closure.	4	2	1	8	1	4
Apogee	Floating charges fail to ignite	No seperation, rocket comes down balistic	E-match gets crushed, charge not built properly	Ejection testing, follow integration checklist	5	2	2	20	1	10
	Ejection charges do not cause seperation	No seperation, rocket comes down balistic	Not enough black powder/not fully packed inside	Ejection testing, ensure enough black powder in charges	5	3	2	30	1	10
	Floating charges burn through parachute and/or shroud lines	Rocket comes down balistic	Floating charge goes off near recovery lines	Ejection testing to find the optimal way to pack the recovery subsystem.	5	2	2	20	1	10
	Shear pins do not break	Rocket does not seperate, comes down ballistic	Shear pins too strong	Ejection testing, ensure low FOS from hand calcs	5	2	2	20	1	10
	Nosecone threaded rod unscrews from nosecone tip	Ejection charges go off early, rocket may or may not seperate (properly or improperly), come down ballistic	The threaded rod is no longer in the nose cone tip, and the e-bay falls	Blue loctite the threaded rod to nosecone tip	5	2	1	10	1	5
	Ematch terminal connections fail	Failure of all ejection charges	Improperly tightened screw terminals	Stress testing of solder joints	4	2	2	16	1	8
	EasyMini does not output electrical signal	Rocket doesn't separate, comes down ballistic	Electrical connection fails	Continuity checks and tug tests prior to launch, check EasyMini turns on before connecting to energetics, ejection testing, have redundant flight computer	5	2	1	10	1	5
	EasyMini does not output electrical signal	Rocket doesn't separate, comes down ballistic	Product defect	Ejection testing, verify firing capabilities of each flight computer	5	2	2	20	1	10
	EasyMini outputs electrical signal too early	Separation occurs too early, drogue deploys too early, larger than nominal force would mean drogue can get ripped off and then the main parachute doesn't deploy, rocket doesn't hit altitude and/or comes down ballistic separated	EasyMini thought the rocket launched when going from horizontal to vertical when putting it on the rail so false detection of altitude	Use integration checklist and ensure proper coding, don't turn on the screw switches until the rocket is fully integrated and vertical on the rail	4	3	2	24	1	8
	EasyMini outputs electrical signal too early	Charge fires too early, so separation occurs too early, drogue deploys too early, larger than nominal force would mean drogue can get ripped off and then the main parachute doesn't deploy, rocket doesn't hit altitude and/or comes down ballistic separated	EasyMini programmed incorrectly	Use integration checklist and ensure proper coding	4	2	2	16	1	8
	EasyMini outputs electrical signal too early	Charge fires too early, so separation occurs too early, drogue deploys too early, larger than nominal force would mean drogue can get ripped off and then the main parachute doesn't deploy, rocket doesn't hit altitude and/or comes down ballistic separated	Product defect	Ejection Testing	4	1	2	8	1	8
	EasyMini outputs electrical signal too late	Charge fires too late, rocket comes down ballistic for a little while which is a lot of forces on the rocket, this could impact the u-bolt or cause the rocket to not separate	EasyMini programmed incorrectly	Use integration checklist and ensure proper coding, have redundant flight computer	5	2	2	20	1	10
	EasyMini outputs electrical signal too late	Charge fires too late, rocket comes down ballistic for a little while which is a lot of forces on the rocket, this could impact the u-bolt or cause the rocket to not separate	Product defect	Use integration checklist and ensure proper coding, have redundant flight computer	5	1	2	10	1	10
	BlueRaven does not output electrical signal	Rocket doesn't separate, comes down ballistic	Electrical connection fails	Continuity checks and tug tests prior to launch, check BlueRaven turns on before connecting to energetics, ejection testing, have redundant flight computer	5	2	1	10	1	5
	BlueRaven does not output electrical signal	Rocket doesn't separate, comes down ballistic	Product defect	Ejection testing, verify firing capabilities of each flight computer	5	1	2	10	1	10
	BlueRaven outputs electrical signal too early	Separation occurs too early, drogue deploys too early, larger than nominal force would mean drogue can get ripped off and then the main parachute doesn't deploy, rocket doesn't hit altitude and/or comes down ballistic separated	BlueRaven thought the rocket launched when going from horizontal to vertical when putting it on the rail so false detection of altitude	Use integration checklist and ensure proper coding, have redundant flight computer, don't turn on the screw switches until the rocket is fully integrated and vertical on the rail	4	3	2	24	1	8
	BlueRaven outputs electrical signal too early	Charge fires too early, so separation occurs too early, drogue deploys too early, larger than nominal force would mean drogue can get ripped off and then the main parachute doesn't deploy, rocket doesn't hit altitude and/or comes down ballistic separated	BlueRaven programmed incorrectly	Use integration checklist and ensure proper coding	4	2	2	16	1	8
	BlueRaven outputs electrical signal too early	Charge fires too early, so separation occurs too early, drogue deploys too early, larger than nominal force would mean drogue can get ripped off and then the main parachute doesn't deploy, rocket doesn't hit altitude and/or comes down ballistic separated	Product defect	Ejection testing	4	1	2	8	1	8

CONOPS Phase	Failure Mode	Effect	Causes of Failure	Mitigation	Severity	Occurence	Prevention	Risk Priority Number	Occurence After Prevention	Risk After Prevention Priority Number
	BlueRaven outputs electrical signal too late	Charge fires too late, rocket comes down ballistic for a little while which is a lot of forces on the rocket, this could impact the u-bolt or cause the rocket to not separate	BlueRaven programmed incorrectly	Use integration checklist and ensure proper coding, have redundant flight computer	5	2	2	20	1	10
	BlueRaven outputs electrical signal too late	Charge fires too late, rocket comes down ballistic for a little while which is a lot of forces on the rocket, this could impact the u-bolt or cause the rocket to not separate	Product defect	Ejection testing, have redundant flight computer	5	1	2	10	1	10
Descent with Drouge	Drogue descent rate is too fast	Could lead to a larger force on the rocket's main deployment	Inaccurate math to midland conditions for worst case scenario	Have math for worst case scenario	3	2	2	12	2	12
	Drogue descent rate is too slow	Cause the rocket to drift further away	Inaccurate math to midland conditions for worst case scenario	Calculate the worst case scenario drift	1	2	2	4	2	4
	Recovery lines get tangled	Parachute doesn't inflate, possible collision between nosecone and lower body during flight, main potentially does not deploy	Improper packing	Ensure proper packing of recovery system	4	2	2	16	1	8
	Drogue does not deploy	Main does not deploy properly or at all, rocket comes down ballistic	Improper packing	Ensure proper packing of recovery system	5	2	2	20	1	10
Main Deployment	Main does not deploy	Rocket comes down too fast	Improper packing	Ensure proper packing of recovery system	3	2	2	12	1	6
	Main deploys too late	Rocket comes down too fast	Tendie doesn't separate fully/properly	Ejection testing	3	2	2	12	1	6
	Recovery lines break during main deployment	Rocket comes down too fast and in two different pieces (potentially ballisitc depending on where breakage occurs)	Forces from main deployment	Strength test recovery lines, do analysis on deployment testing to obtain accurate deployment forces	4	3	3	36	1	12
	Tendie does not seperate	Main does not deploy properly or at all, rocket comes down too fast	Not enough black powder, slide sticking, e-match getting crushed, flight computer error	Ejection testing, have dual redundant tendie descendie	3	2	2	12	1	6
	Payload/measurements/bulkhead bolts shear/fail	Payload or measurements seperates from retention bulkhead	Forces from main deployment	Run sims/FEA prior to launch	2	2	1	4	1	2
Main Descent	Main descent rate is too fast	Could lead to a larger force on the rocket's ground touch speed. This creates more force and more likely for components to break on ground hit	Inaccurate math to midland conditions for worst case scenario	Have math for worst case scenario	2	2	2	8	2	8
	Main descent rate is too slow	Cause the rocket to drift further away	Inaccurate math to midland conditions for worst case scenario	Have math for worst case scenario	1	2	2	4	2	4
	Recovery lines get tangled	Parachute doesn't inflate, possible collision between nosecone and lower body during flight	Improper packing	Ensure proper packing of recovery system	3	2	2	12	1	6
Ground Operations	TeleGPS does not transmit data	Unable to locate rocket	Electrical connection fails	Test TeleGPS prior to launch	3	2	2	12	1	6
	TeleGPS does not transmit data	Unable to locate rocket	Product defect	Test TeleGPS prior to launch	3	3	2	18	1	6
	TeleGPS signal is unretrievable	Unable to locate rocket	Conductive materials present between the user and the FeatherWeight module	Can track Sirin's live telemetry before ground hit to locate rocket	3	3	3	27	2	18
	Elvin Beacon does not output signal	Potentially unable to recover rocket because it can't be located	Electrical connection fails	Battery voltage and continuity checks prior to launch, ensure stable readings before launch, try to use GPS as backup to find rocket	1	2	2	4	1	2
	Elvin Beacon does not output signal	Potentially unable to recover rocket because it can't be located	Programmed incorrectly	Ensure stable readings before launch, try to use GPS as backup to find rocket	1	3	2	6	2	4
	Elvin Beacon does not output signal	Potentially unable to recover rocket because it can't be located	Product defect	Ensure stable readings before launch, try to use GPS as backup to find rocket	1	2	2	4	2	4

B. DogBone Risk Assessment Matrix

CONOPS Phase	Failure Mode	Effect	Causes of Failure	Mitigation	Severity	Occurence	Prevention	Risk Priority Number	Occurence After Prevention	Risk After Prevention Priority Number
Arming	Code fails to run	No data is collected	Code is improperly written or does not work	Test run code before hand within payload and ensure that no errors occur even under heavy vibrations	5	2	1	10	2	10
Ignition	Accelerometers fail to collect data	No data is collected on the polymers vibration mitigation.	Accelerometers are not secured properly	Secure accelerometers within polymers and screw the accelerometers into the accelerometer holder within the payload	5	2	2	20	1	10
	Accelerometers do not work	No data is collected on the polymers vibration mitigation.	Manufacturer defect	Test accelerometers beforehand within the payload by using a vibration table	5	2	1	10	1	5
Ascent	Wires disconnect during flight	Code doesn't run through electronic components and no data is collected	Wires are not properly secured	Ensure that all solders are done correctly test if solders can endure flight vibrations by using vibration table	5	2	3	30	1	15
	Temperature sensor fails to collect data	No data is collected on the temperatures that the polymer experiences during rocket flight	Temperature sensor is wired incorrectly	Test on ground before launch to ensure that temperature sensor connections and data collection are collected and stored when undergoing intense vibrations from a vibration table	3	2	1	6	2	6
	The polymer is ripped or torn inside of payload	Vibrational damping data would be inaccurate for dampening effects of polymer	Mount does not hold accelerometer well enough	Test mount to ensure it can withstand forces it will feel during flihgt	3	2	3	18	1	9
	Payload bolts shear completely	Payload frame falls apart and/or mounts and internal components become dislodged	Too much force for bolt to handle	Bolt calculations to ensure bolts will not shear	5	1	1	5	1	5
	Payload bolts are vibrated loose	Payload frame falls apart and/or mounts and internal components become dislodged	Not secured tight enough	Blue loctite all of the bolts that are holding the payload frame together	5	2	1	10	1	5
	Payload bolts break in half	Payload frame falls apart and/or mounts and internal components become dislodged	Too much force for bolt to handle	Ensure that payload threads are vertical when tapping and that bolts are tightened properly to prevent any tenstion from being applied to bolts	5	1	1	5	1	5
Ground Operations	SD card does not store data correctly after landing	No data is saved from the flight and the vibrational mitigation or temperature	Code is improperly written or does not work	Ensure that data is being saved to the SD card by testing code and simulating flight vibrations	5	2	1	10	3	15

E. Assembly, Preflight, Launch, Recovery, and Off-Nominal Checklists Appendix

Aurora Launch Checklist				
Pre-Launch Checklist				
Task	Steps	Verification	Member Sign Off	Lead Sign off
1.1.1 GPS working	1. Connect the GPS battery in the e-bay and activate the screw switch. 2. Turn on and connect the receiver for e-bay GPS. 3. Turn off screw switches, disconnect all batteries, and turn off GPS receivers.	Stand somewhere known with the GPS. Check the receiver to ensure that the location is accurate		
1.1.2 Battery Checks	1. Check all 14 18650 and 16340 batteries are charged to at least 4.0 V (3.4V for the 16340) using a DMM 2. Charge any that are not charged	Check batteries with DMM for 4.0 V (max should be around 4.2)		
1.1.3 Main Deployment Packing Check	1. Fully pack this with the previous step 2. Once 1.1.3 is complete, undo the connection to the Tendie Descendie Duo	Ensure lines are not tangled and that the parachute can inflate		
1.1.4 Main Electronics Bay Flight Computer Programming	Program BlueRaven Program EasyMini Calibrate BlueRaven	**BlueRaven** *Apo:* Flight Time > TVal Time: TVal Time = 25s Pressure Increasing		

		Velocity < Vel1: Vel1 = 400 ft/s Time Delay: 0s *Main:* Flight Time > TVal Time: TVal Time = 25s Height Above Pad < AGL3: AGL3 = 1500 ft Pressure Increasing Velocity < Vel1: Vel1 = 400 ft/s **EasyMini** Main Deploy Altitude: 1500 ft Apo Delay: 1s Apo Lockout: 25s Check BlueRaven app to see if Blueraven is calibrated		
1.1.5 Main Electronics Bay Altimeter Firing Sequence Verification	1. Connect E-matches to proper channels 2. Run a simulated flight	**Blue Raven** Apo charge fires shortly after simulated apo Main fires shortly after 1500 ft **EasyMini** Apo Charge fires +1s after blue raven fires Main fires at 1500 ft		
1.1.6 Upper Camera Ebay Test	1. Ensure that 2 18650 are charged to at least 4.0 V using a DMM 2. Plug both batteries into boost converters and	1. Make sure that the camera records video 2. Watch video to see if video is clear and that we can see footage of drogue deployment		

	then plug the boost converter outputs into both cameras 3. Turn on cameras 4. Bolt cover onto upper camera ebay 5. Place saran wrap on plate such that some is laying off the edges, then wrap kevlar thread into excess saran wrap 6. Adhere kevlar thread to recovery line (ask Arlo what he thinks is the best way to do this) 7. This is going to be happen at the same time as the ejection test			
1.1.7 Black Powder Ejection Testing	1. Connect an e-match to the screw terminal for the correct port (we have the BR and EM labeled, traced the wires to ensure the vinyl tubing is attached to apo for each) 2. Make a vinyl charge and keep the ematch on the outside 3. Fully install the electronics bay with the nose cone by screwing it into the nose cone tip and put it on top of the body tube following clocking lines (body tube must have recovery bulkhead	1. Make sure that the shear pins all sheared 2. Nose cone should separate > 2 feet and < 10 feet away from the body 3. Drogue comes out of the nose cone 4. Parachutes are not sticking out at all from the nosecone. 5. Parachutes come out with no tangles when pulled 6. Ensure that the main parachute did not and will not inflate 7. If any of this process fails, add more/less powder until all requirements are fulfilled		

	+ U-bolt + upper camera ebay +cable attached to it) 4. Tape the upper portion of the measurements wires down into the nose cone using duct tape 5. Insert shear pins to secure orientation 6. Angle the tubes upward away from everyone for safe ejection 7. Activate the BlueRaven using a screw switch, then connect via bluetooth on the phone app 8. Run flight simulation, BACK AWAY 10 ft and put on hearing protection and safety glasses (wait inside and watch from a window if not enough headphones), and wait for ejection			
1.1.8 Tendie Descendie Duo Ejection Testing	Insert an E-match into the Tendie Descendie Duo and seal the wire with tape Pour black powder into the Delrin charge well of the pin assembly Insert pin assembly into the body with a quick link on the upper pin Suspend e-bay assembly so the upper bulkhead	1. Ensure that the Tendie Descendie Duo pins come out of the Tendie Descendie Duo body 2. Ensure that the pin didn't get lost, the aircraft cable should be dangling and 3. The suspended weight should be released		

	points downward Suspend a heavy weight (>10 lbs) from the Tendie Descendie Duo quick link			
1.1.9 Nose Cone measurement gauges	1. Set up measurement modules inside an extra tube (just the modules, no electronics should be inside) 2. Tape the extra tube together to create a pressure vessel 3. Blow up a vinyl charge in a worst case scenario (right on top of the modules) to see if they shatter/break	1. Make sure that the modules have not fractured at all from the blast		
2 - Main Electronics Bay				
1.2.1 Battery Checks	Check 18650 batteries for nominal charge using DMM	Check batteries with DMM for 4.0 V (max should be around 4.2)		
1.2.2 Battery Connections to Components	Connect EasyMini to battery Verify EasyMini powers on Disconnect EasyMini from battery Connect BlueRaven to battery Verify BlueRaven turns on Disconnect BlueRaven from battery Verify BlueRaven connects	Batteries are in their housing BlueRaven, EasyMini, and TeleGPS, Sirin, and Elvin Beacon can all be turned on using screw switches. BlueRaven and easymini both beep once turned on. TeleGPS is special, pick up this signal using HAM radio. The Sirin and Elvin beacon will have red lights that can not be seen. Both signals must be confirmed by Base Station. Make sure after everything is turned off, all LEDs are off		

	Connect TeleGPS to Battery Verify TeleGPS turns on Verify TeleGPS connects Disconnect TeleGPS from battery Connect Sirin to battery Verify Sirin turns on Disconnect Sirin from battery **Ensure all Connections Disconnected**	and base station can not connect.		
1.2.3 Component Connections and Continuity	Connect all flight computer channels to correct bulkhead connections Use a DMM to verify continuity **Disconnect all Connections**	**EasyMini:** EasyMini main 1,2, no cross continuity EasyMini apo to 3,4, no cross continuity **BlueRaven:** BlueRaven main 7,8, no cross continuity BlueRaven apo 5,6, no cross continuity		
1.2.4 Wire Connection Tests and Organization on the Nose Cone Ebay	Ensure all wires have been twisted together. Ensure that all connections will not come out during flight	All wires are observed to be twisted. All connections stay connected after being tug-tested		
1.2.5 Electronic Match Set-up	Strip ends of 4 E-matches Wrap electrical tape around the end with the igniter of e-matches for the Tendie Descendie Duo Pull the two taped e-matches through the	**EasyMini:** 1,2 to main floating charge 3,4 to main Tendie Descendie Duo well **BlueRaven:** 7,8 to backup floating charge		

	Tendie Descendie Duo and place the two non-taped e-matches into the floating charges Place the vinyl tubing into the charge boxes.	5,6 to backup Tendie Descendie Duo well		
1.2.6 Measure out Black Powder	Insert all proper measurements of black powder into individual containers using the funnel **Ensure that all containers are labeled** 4.5 grams in primary 5 grams in secondary	Visually inspect the amount of black powder in each vial.		
1.2.7 Final Battery Voltage Check	Check batteries for nominal charge using DMM Charge any batteries that are <4 Volts	Check all fourteen 18650 and the two 16340 batteries for a charged voltage of at least 4.0 using a DMM.		
1.2.8 Current Testing	Using a DMM, check the current through the screw terminals **Current must be less than 100mA**	Current readings are less than 100mA		
ENSURE ALL SCREW SWITCHES OFF AT THIS POINT				
1.2.9 Tendie Descendie Duo Packing	Wrap a small amount of electrical tape around an ematch and cut to around 6.5 inches Pour black powder into the delrin well in pin assembly until full. Push an ematch through the charge well cover. Turn e-bay on its side so Tendie Descendie Duo	Electronic matches are installed Pin restrains loop Link does not detach when pulled and the link is not frayed Visually inspect amount of black powder in each vial. Tendie Descendie Duo		

	can be pushed into the body Attach the quicklink at the end of the recovery line to the eye nut on e-bay Tie Brunnian link to backward facing Tendie Descendie Duo pins Lube the actual Tendie Descendie Duo pins with superlube Push out temporary Tendie Descendie Duo plates with back plates with charge wells Repeat for second Tendie Descendie Duo charge well.	charge wells are flush with Tendie Descendie Duo body and brunnian link still does not detach when pulled		
1.2.10 Pack Vinyl Charge (see internal reference doc for more information)	Cut 2” section of vinyl tubing and hot glue one side shut Pour black powder into vinyl tubing and place an ematch in the rough center of the black powder Fill in remaining volume with dog barf, packing tightly Cover in more hot glue and wait till it dries	All black powder vials are empty All e-matches are inside charge wells, with their heads covered in black powder Top of charge well feels solid when pushed on Hot glue Wires cannot be caught or tangled.		
1.2.11 Final Assembly	Connect batteries Connect all Stripped ends of e-matches to apo of blueraven and easymini, tighten screws and verify they pass the tug test. Insert main e-bay into	All electronics are off Connections pass the tug test by two(+) people The main E-bay is not loose and does not rattle. The nose cone tip should also be flush with the nose cone		

	Nose cone, making sure the clocking notch is set Blue Loctite Nose Cone tip Place charges in the vinyl tube charge holder			
3 - Upper Camera Ebay				
1.3.1 Check Batteries	Make sure the two 18650 batteries has a charge of at least 4.0 V with a DMM	Check with a DMM, charge if not charged		
1.3.2 Connect Camera to Battery	Connect Cameras to batteries using JSTs but ensure that upper camera ebay is still off via LEDs. Make sure that this is one of the last things you do as this turns on the cameras and they never turn off.	Check to ensure that all of the LEDs around the exterior are off.		
1.3.3 Attach to bulkhead	Attach the upper camera ebay to the recovery bulkhead using 4 #4-40 UNC .5” bolts (there is a tap stuck in one of them), also make sure that the clear plate is on top. Make sure the U-Bolt is pushed down as far as possible and bolt it down using washers on the underside.	Make sure the entire bulkhead is secure and the U-Bolt and upper camera ebay can not translate or rotate.		
1.3.4 Attach seran wrap and kevlar strand	2-4 layers of Saran Wrap are applied to the polycarbonate lid of the upper camera E-Bay. Extra material is left hanging over one end of the lid, and this excess material is then wrapped around a Kevlar thread.	Ensure that the Saran Wrap completely covers the polycarbonate plate. Lightly pull on the kevlar threads to ensure that it pulls off the Saran Wrap when pulled on.		

	This Kevlar thread is then tied around the shock cord, such that the Saran Wrap is removed (producing a clear view of parachute deployment) upon the ejection charge firing.			
4 - Lower Camera Ebay				
1.4.1 Check Batteries	Make sure the three 18650 batteries have a charge of at least 4.0 V with a DMM. Make sure the three 16340 batteries have a charge of at least 4.0 V with a DMM.	Check with a DMM, charge if not charged		
1.4.2 Connect Batteries to Cameras	Connect Cameras to 18650s using JSTs but ensure that lower camera ebay is still off via LEDs. Connect Fans to 16340s using JSTs but only do this once the integration checklist is almost complete.	Check to ensure that all of the LEDs around the exterior are off. Check to make sure that you can hear the fans		
1.4.3 Attach to bulkhead	Bolt into the lower camera ebay bulkheads using 4 #4-40 UNC 0.3125" bolts.	Ensure that the lower camera ebay can not translate or rotate on the bulkhead		
5 - Payload				
1.5.1 Check Batteries	Make sure the singular 18650 battery has a charge of at least 4.0 V with a DMM	Check with a DMM, charge if not charged		
1.5.2 Connect Batteries to Payload	Connect payload to batteries using JSTs but ensure that payload is still off via red LED being off	Check to ensure that the LED on the exterior is off.		
1.5.3 Attach to bulkhead	Attach to measurements payload bulkhead using 4 #10-24 UNC 0.875” bolts on the underside .	Ensure that the payload can not move on the bulkhead laterally or rotationally.		

6 - Measurements Ebay				
1.6.1 Check Batteries	Make sure the four 18650 batteries have a charge of at least 4.0 V with a DMM	Check with a DMM, charge if not charged		
1.6.2 Connect Batteries to Measurements Ebay	Connect measurements ebay to batteries using JSTs but ensure that measurements is still off via no beeping	Check to ensure that no beeping can be heard		
1.6.3 Attach Measurements to their modules via wires	Connect measurements ebay to batteries using JSTs but ensure that measurements is still off via no beeping	Do a tug test to ensure connection		
1.6.4 Attach measurements ebay to bulkhead	Attach the measurements Ebay to the payload measurements bulkhead using 4x #8-32 threaded rods and cap nuts	Make sure that neither the payload or measurements ebay can move laterally or rotationally.		
7 - Recovery Packing & Integration				
1.7.1 Pack main parachute into deployment bag	Fold parachute Untangle lines Weave lines into deployment bag Put canopy in dbag Roll up recovery line and put into deployment bag Attach main parachute quicklink to recovery line	Parachute fits in deployment bag without stressing the deployment bag The entire length of lines are fully secured in the deployment bag Quicklink at the end of the recovery line can reach the lower d-ring		
1.7.2 Prepare deployment bag	Attach quicklink at the end of the recovery line to the lower d-ring and the eye nut on the ebay Feed the Tendie Descendie Duo loop	The deployment bag is folded over on itself		

	through the parachute quicklink and the upper d-ring Attach the Tendie Descendie Duo loop to the quicklink at the end of the recovery line			
1.7.3 Pack drogue parachute	Attach drogue to fire blanket using quicklink Fold drogue Wrap drogue in fire blanket Attach recovery line Roll up recovery lines on either side and tape to fire blanket	Lines are not tangled Drogue is full covered by fire blanket Drogue does not fall out when handled but is not compressed		
8 - Final integration Minus Motor and Fincan				
1.8.1 Put in the motor retention bulkhead	Bolt motor retention bulkhead into body tube using 4 #10-24 0.375” bolts. NOTE FOR ALL BULKHEADS: They are clocked so that the measurements wire hole is to the right of the clocking line, keep that in mind for all sequential bulkheads.	Ensure that the motor retention bulkhead can not translate or rotate		
1.8.2 Put in the lower camera ebay	Connect fans to 16340s, check if they are on via listening. Bolt Lower Camera Ebay into body tube using 4 #10-24 0.375” bolts.	Ensure that the lower camera ebay can not translate or rotate. Listen to hear that each fan is on.		
1.8.3 Put in Centering Ring	Bolt centering ring into body tube using 4 #10-24 0.375” bolts	Ensure that the centering ring can not translate or rotate		

1.8.4 Put in the payload measurements bulkhead	Bolt payload measurements bulkhead into body tube using 4 #10-24 0.375” bolts	Ensure that the centering ring can not translate or rotate		
1.8.5 Attach the various cables to the measurement Ebay	Plug in the DB25 to the measurements on ebay. Plug in the JST connections from the coupler modules. Plug in the VGA cable to the measurements on ebay.	Do a tug test for each to ensure that everything is connected.		
1.8.6 Put in the recovery bulkhead	Bolt recovery bulkhead into body tube using 4 #10-24 0.375” bolts	Ensure that the recovery bulkhead can not translate or rotate		
1.8.7 Attach nose cone	Attach the VGA cable to the recovery bulkhead Tape the vinyl charges to the sides of the upper camera ebay Slide the dBag down so that it sits on the side of the U-Bolt that does not have the Tendie Descendie Duo Slide the nose cone down the coupler along the clocking line Press fit 3 #2 shear pins into the shear pin holes	Do a tug test Make sure that the vinyl charges will not move around in flight Make sure that all the shear pins go relatively flush with the surface of the nose cone.		
9 - Motor Integration				
1.9.1 Assemble Motor	Follow all manufacturer’s steps precisely Inspect grains for crystallization	Motor is securely assembled No significant distortion within the grains		
1.9.2 Inspect Motor	Inspect nozzle for any blockage	Nozzle is clear		
1.9.3	Attach Body Tube to	The fin can and Body Tube		

Attach fin can to Body Tube	interface centering ring, ensuring alignment along clocking line. Connect the measurements cable from the modules in the fincan to the cable in the body tube Use 4 #10-24 0.375” bolts to secure the body tube to the interface centering ring. Attach a 15-15 rail button on the hole that is visually larger using a countersink #1/4-20 1” bolt Ensure proper clock	are securely attached Tug test Rail button is attached to bolt Clocking line marks match up Paint scheme matches up Check tightness of bolts with hex key		
1.9.4 Attach motor rocket	Slide the motor up through the fincan and thread onto the bolt in the motor retention bulkhead using blue loctite.	Ensure that the motor can not spin easily using your hands.		
1.9.5 Final Check Before Safety	Inspect entire rocket for clocking Ensure all bolts tightened	All paint should match up All bolts should be tightened All mechanisms should be integrated		

Launchpad Checklist				
Hardware to Bring: **Safety Glasses, Small Screwdrivers from Red Milwaukee Kit, Stethoscope?**				
1 - Horizontal Mounting and Activation				
Task	Steps	Verification Method	Member Sign	Lead Sign
2.1.1 Install Rocket onto rail	Slide rocket onto rail	Rocket slides without interference		

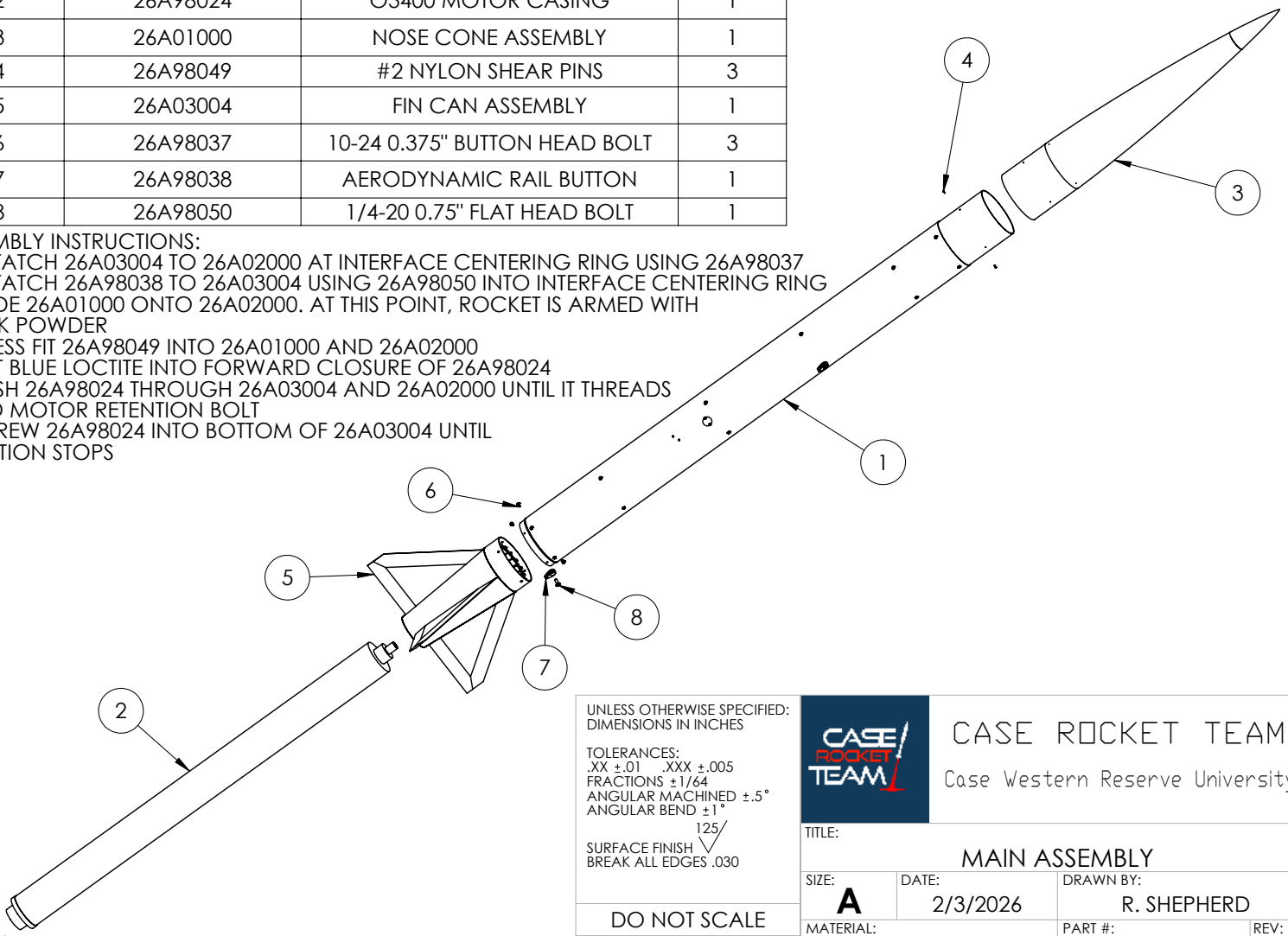
2.1.2 Activate TeleGPS	Screw in TeleGPS screw switch	Ensure TeleGPS is communicating with base station.		
2.1.3 Activate Sirin	Screw in Sirin screw switch	Ensure Sirin is communicating with HAM radio.		
2.1.4 Activate ElvinBeacon	Screw in ElvinBeacon screw switch	Ensure ElvinBeacon pulse is picked up on handheld radio Ensure ElvinBeacon is communicating with base station		
2.1.5 Lower Camera Ebay Screw switches to turn on fans	Screw in lower camera Ebay screw switch x3	Ensure all LED lights are visible through screw switch holes		
2.1.6 Lower Camera Ebay power buttons	Push in buttons on each of the three cameras	Ensure all LED lights are visible through button holes		
2.1.7 Activate measurement subsystem	Screw in the measurements screw switch	Ensure that you can hear a buzzer inside the rocket		
2.1.8 Arm DogBone	Screw in payload screw switch	Ensure LED is visible from screw switch hole		
2.1.9 Mount rocket vertically	Tilt launch rail 4 degrees into the wind	Rocket should be vertical on launch rail with a slight angle		
2 - Flight Computer Activation				
Task	Steps	Verification Method	Member Sign	Lead Sign
ENSURE PEOPLE ARE HOLDING THE LADDER BEFORE CLIMBING UP KEEP HEAD AWAY FROM ROCKET, USE A STETHOSCOPE				
2.2.1 Activate EasyMini	Screw in EasyMini screw switch	Listen for EasyMini to start beeping		
2.2.2 Check EasyMini beep codes for continuity	Listen for EasyMini beep codes Count beeps	First set of beeps should have 4, indicating enough voltage Second set of beeps should have 3 to indicate that main and apo are active		

2.2.3 Activate BlueRaven	Screw in BlueRaven screw switch	Listen for beeping from BlueRaven to begin		
2.2.4 Check BlueRaven beep codes for continuity	Listen for Blueraven beep codes Count number of tones and pitch (low and high)	High beep means Raven4 is on 4 High beeps for voltage 3 high beeps followed by 1 low beep for channel connection		
3 - Igniter Installation				
Task	Steps	Verification Method	Member Sign	Lead Sign
2.3.1 Insert Igniter	Strip leads of igniter Insert igniter into motor	Igniter is as far into the motor as possible Igniter ends are visible from bottom of the rocket		
2.3.2 Check Alligator Clips	Touch alligator clips together	**No spark from alligator clips**		
2.3.3 Connect Alligator Clips	Connect alligator clips to igniter leads	Ensure clips are freely attached to leads.		
4 - Final Steps				
Task	Steps	Verification Method	Member Sign	Lead Sign
ENSURE ALL PERSONNEL HAVE LEFT LAUNCHPADS				
2.4.1 Check igniter continuity	Perform continuity check on launch controller	Launch controller visual confirmation		
2.4.2 Launch	Ignite motor using igniter	Motor ignites Rocket leaves the rail		

F. Engineering Drawings Appendix

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A02000	BODY TUBE ASSEMBLY	1
2	26A98024	O3400 MOTOR CASING	1
3	26A01000	NOSE CONE ASSEMBLY	1
4	26A98049	#2 NYLON SHEAR PINS	3
5	26A03004	FIN CAN ASSEMBLY	1
6	26A98037	10-24 0.375" BUTTON HEAD BOLT	3
7	26A98038	AERODYNAMIC RAIL BUTTON	1
8	26A98050	1/4-20 0.75" FLAT HEAD BOLT	1

ASSEMBLY INSTRUCTIONS:
1) ATTATCH 26A03004 TO 26A02000 AT INTERFACE CENTERING RING USING 26A98037
2) ATTATCH 26A98038 TO 26A03004 USING 26A98050 INTO INTERFACE CENTERING RING
3) SLIDE 26A01000 ONTO 26A02000. AT THIS POINT, ROCKET IS ARMED WITH BLACK POWDER
4) PRESS FIT 26A98049 INTO 26A01000 AND 26A02000
5) PUT BLUE LOCTITE INTO FORWARD CLOSURE OF 26A98024
6) PUSH 26A98024 THROUGH 26A03004 AND 26A02000 UNTIL IT THREADS ONTO MOTOR RETENTION BOLT
7) SCREW 26A98024 INTO BOTTOM OF 26A03004 UNTIL ROTATION STOPS



1 QUANTITY 1

SOLIDWORKS Educational Product. For Instructional Use Only.

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 2

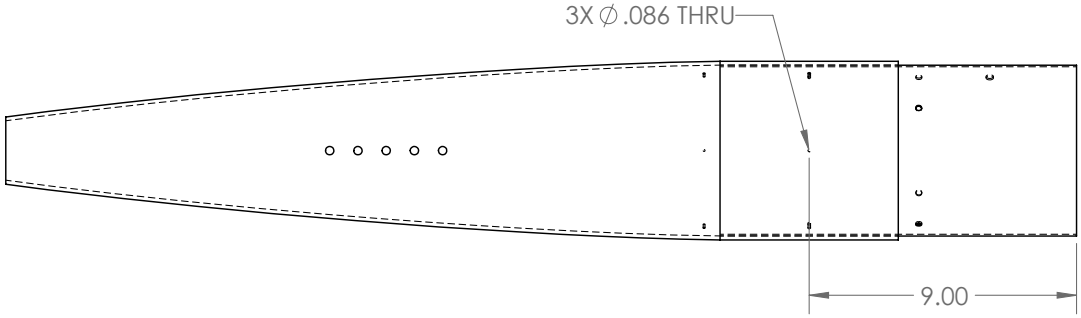
CASE ROCKET TEAM
Case Western Reserve University

TITLE: MAIN ASSEMBLY

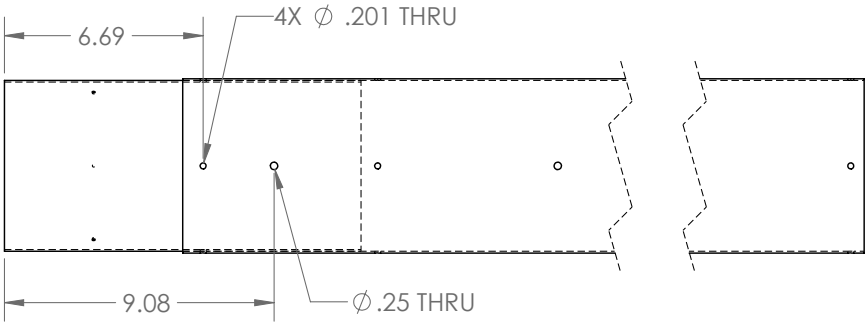
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NOTE: DRILL 3X ∅.086 THRU HOLES IN NOSE CONE AND COUPLER USING JIG 26A96032.
CLOCKING DOES NOT MATTER.



NOTE: DRILL 4X ∅ .201 THRU AND ∅.25 THRU HOLES IN COUPLER AND BODY TUBE USING JIG 26A96032



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 2 OF 2

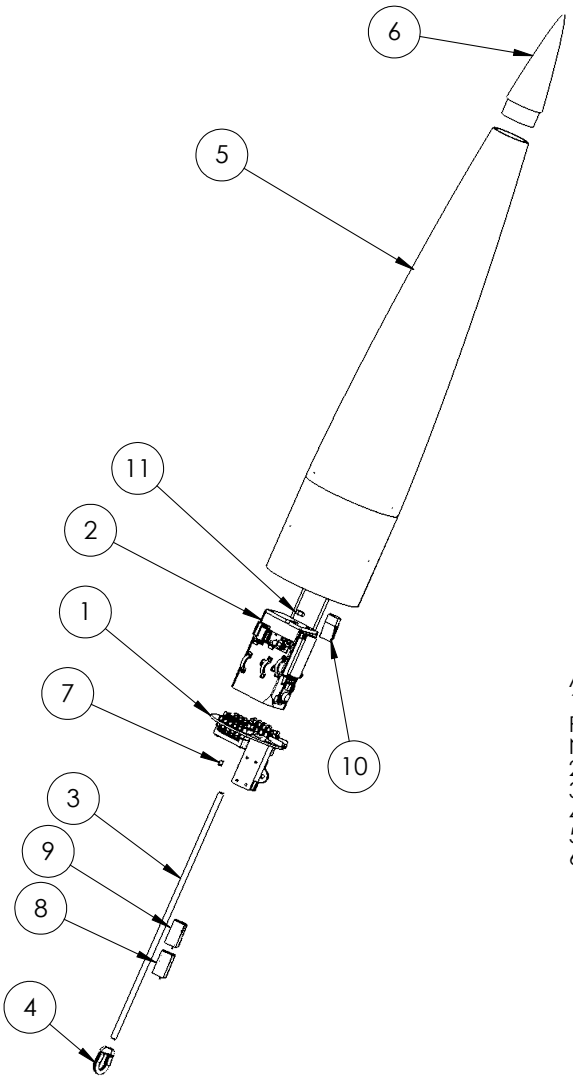
CASE ROCKET TEAM

Case Western Reserve University

TITLE: MAIN ASSEMBLY			
SIZE: A	DATE: 2/3/2026	DRAWN BY: R. SHEPHERD	
MATERIAL:		PART #: 26A00000	REV: D

1 QUANTITY 1

SOLIDWORKS Educational Product. For Instructional Use Only.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A01037	EBAY BULKHEAD SUBASSEMBLY	1
2	26A01036	EBAY SLED SUBASSEMBLY	1
3	26A01003	NOSE CONE THREADED ROD	1
4	26A98010	1/4-20 EYE NUT	1
5	26A01019	NOSE CONE	1
6	26A01020	NOSE CONE TIP	1
7	26A98040	4-40 0.25" BUTTON HEAD BOLT	1
8	26D00006	LOWER NOSE CONE STRAIN GAUGE MODULE IN HOLDER	1
9	26D00007	UPPER NOSE CONE STRAIN GAUGE MODULE IN HOLDER	1
10	26A01034	CLOCKING NOTCH (MALE)	1
11	26A98051	1/4-20 HEX NUT	1

ASSEMBLY INSTRUCTIONS:
1) EPOXY 26D00006, 26D00007, AND 26A01034 TO 26A01019 WITH PROSET LAM 135/224, AND USE RAIL GUIDES TO ATTACH THE STRAIN GAUGE MODULES IN A CLOCKED POSITION RELATIVE TO THE NOTCH IN THE EBAY BULKHEAD
2) SLIDE 26A01003 THROUGH 26A01036 AND 26A01037
3) SECURE 26A01036 IN PLACE WITH 26A98010 (USE RED LOCTITE) AND 26A98051
4) STOP ROTATION OF 26A01036 BY SCREWING IN 26A98040
5) LINEUP CLOCKING NOTCH AND INSERT ASSEMBLY INTO 26A01019
6) SECURE ASSEMBLY IN PLACE BY SCREWING 26A01020 ONTO 26A01003 (USE BLUE LOCTITE)

1 QUANTITY: 1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 2

CASE ROCKET TEAM

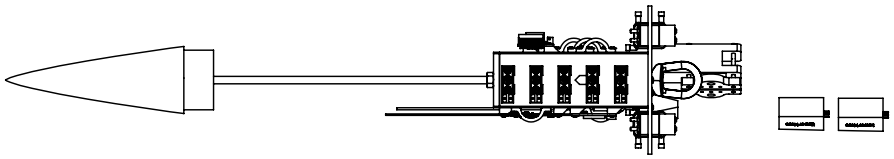
CASE WESTERN RESERVE UNIVERSITY

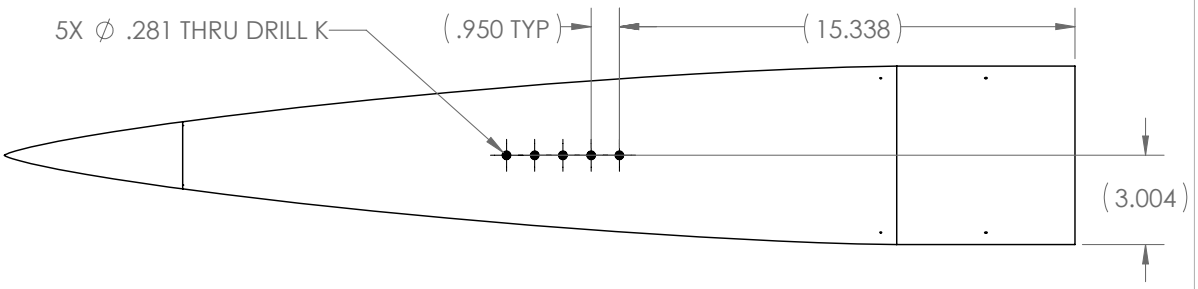
TITLE: NOSE CONE ASSEMBLY

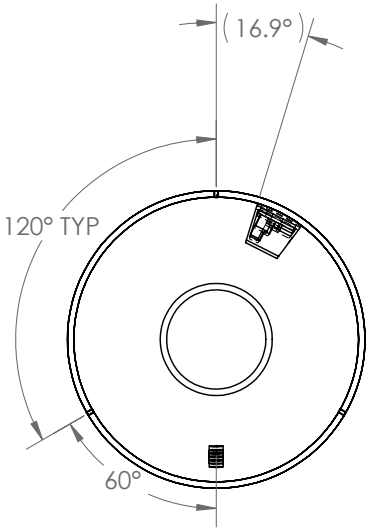
SIZE:	DATE:	DRAWN BY:	QUANTITY:
A	1/21/2026	D. COHEN	1

MATERIAL:	PART #:	REV:
	26A01000	C

SOLIDWORKS Educational Product. For Instructional Use Only.







1. DRILL ∅.281 HOLES WITH LOCATING FEATURE OF SCREW SWITCH HOLES FROM EBAY SLED AFTER PUTTING TOGETHER FULL NOSE CONE ASSEMBLY

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

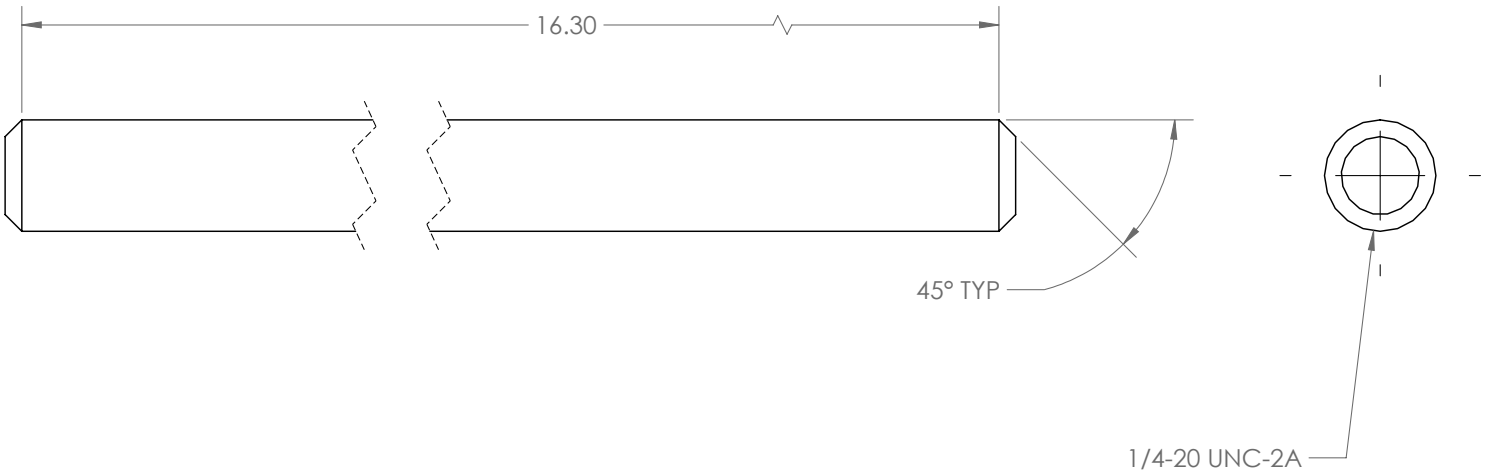
SHEET 2 OF 2

CASE ROCKET TEAM

Case Western Reserve University

TITLE: NOSE CONE ASSEMBLY			
SIZE: A	DATE: 1/21/2026	DRAWN BY: D. COHEN	
MATERIAL:		PART #: 26A01000	REV: C

SOLIDWORKS Educational Product. For Instructional Use Only.



1. QUANTITY: 1
2. FROM MCMASTER-CARR: 3313N128

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

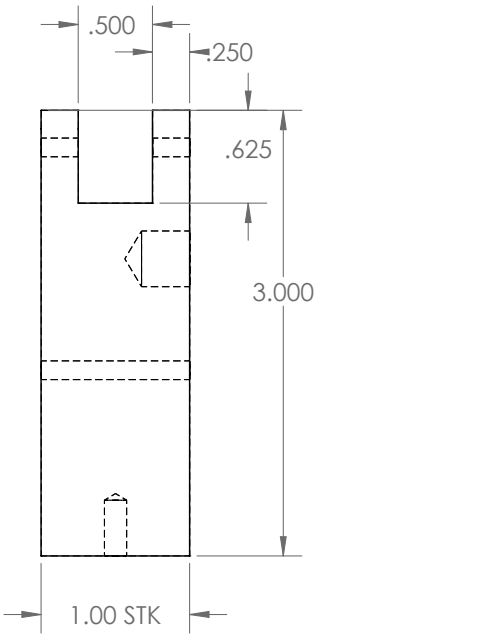
SHEET 1 OF 1

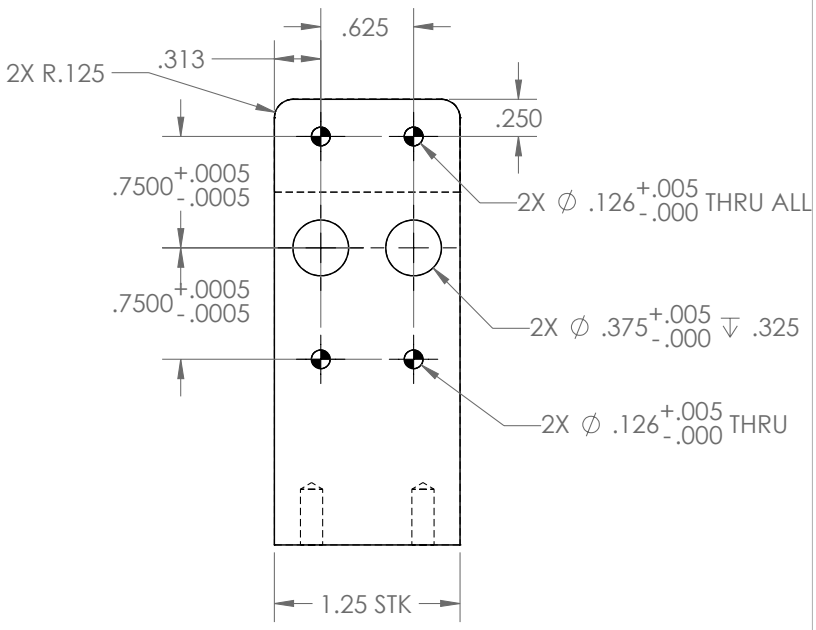
CASE ROCKET TEAM

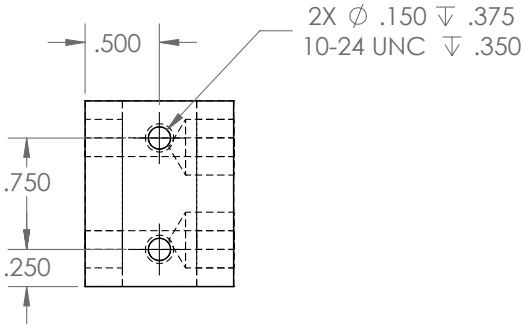
CASE WESTERN RESERVE UNIVERSITY

TITLE: NC THREADED ROD			
SIZE: A	DATE: 1/2/2026	DRAWN BY: R.DAI	
MATERIAL: HIGH-STRENGTH STEEL		PART #: 26A01003	REV: D

SOLIDWORKS Educational Product. For Instructional Use Only.







1. QUANTITY:1
2. USE BLANK 26A96040

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

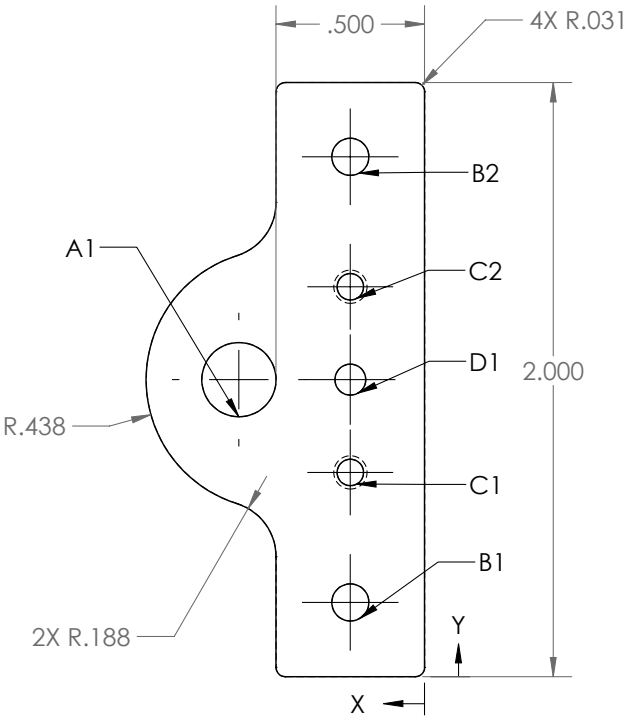
DO NOT SCALE

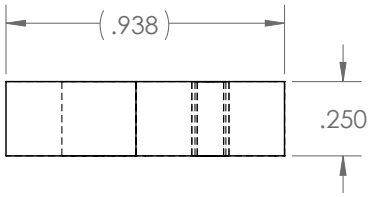
SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: TENDIE BODY			
SIZE: A	DATE: 1/17/2026	DRAWN BY: G. MCBRIDE	
MATERIAL: 6061-T6		PART #: 26A01010	REV: E





TAG	X LOC	Y LOC	SIZE
A1	.625	1.000	∅ .250 THRU
B1	.250	$.2500^{+.0005}_{-.0005}$	∅ $.1245^{}_{.1240}$ THRU
B2	.250	$1.7500^{+.0005}_{-.0005}$	∅ $.1245^{}_{.1240}$ THRU
C1	.250	.688	∅ .089 THRU 4-40 UNC THRU
C2	.250	1.313	∅ .089 THRU 4-40 UNC THRU
D1	.250	1.000	∅ .104 THRU

1. QUANTITY: 2
2. USE BLANK 26A96070

SOLIDWORKS Educational Product. For Instructional Use Only.

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

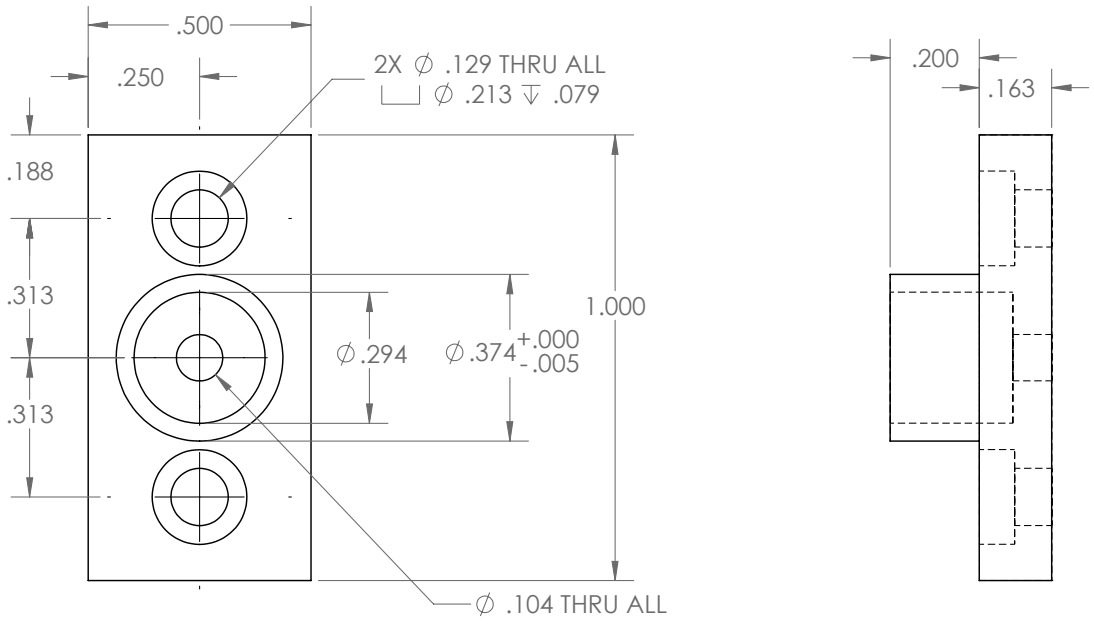
DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM
Case Western Reserve University

TITLE: TENDIE PLATE

SIZE:	DATE:	DRAWN BY:	
A	1/17/2026	G. MCBRIDE	
MATERIAL:		PART #:	REV:
6061-T6		26A01011	E



1. QUANTITY: 2
2. USE BLANK 26A96071

SOLIDWORKS Educational Product. For Instructional Use Only.

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

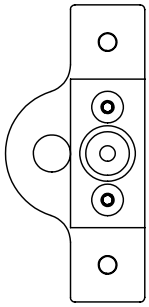
SHEET 1 OF 1

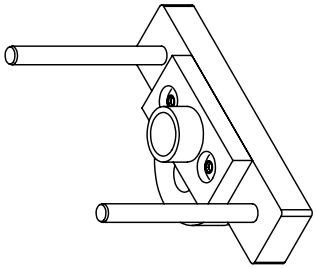
CASE ROCKET TEAM

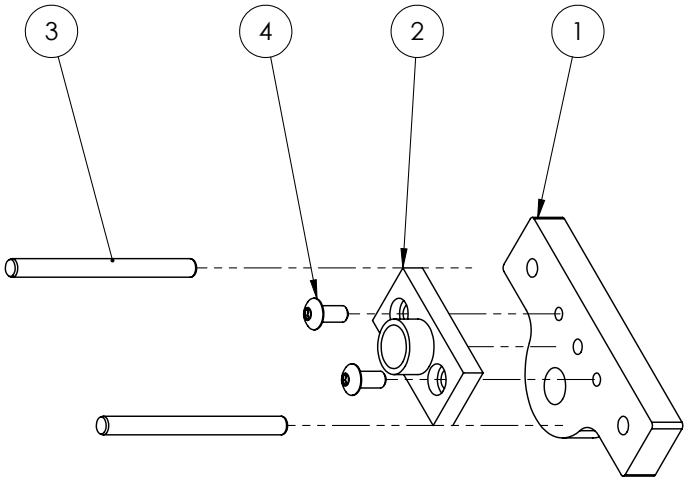
Case Western Reserve University

TITLE:			
TENDIE CHARGE WELL			
SIZE:	DATE:	DRAWN BY:	
A	1/16/2026	G. MCBRIDE	
MATERIAL:		PART #:	REV:
DELRIN		26A01012	E

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A01011	TENDIE PLATE	1
2	26A01012	TENDIE CHARGE WELL	1
3	25A98027	TENDIE ROD	2
4	26A98040	4-40 0.25" BUTTON HEAD BOLT	2







1. QUANTITY: 2
2. CHECK FIT OF 25A98027 IN 26A01011
3. TENDIE RODS PRESS FIT INTO TENDIE PLATE

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

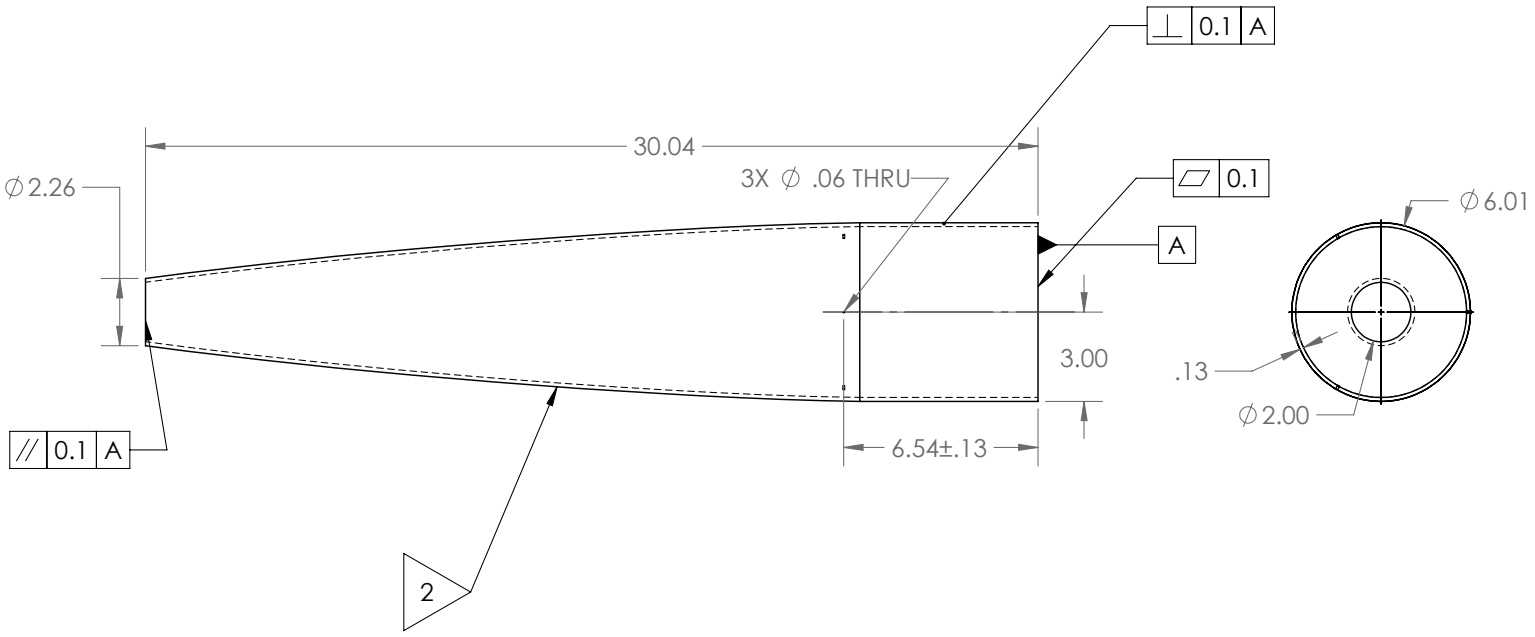
CASE ROCKET TEAM

Case Western Reserve University

TITLE: TENDIE PLATE SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	1/17/2026	G. MCBRIDE

MATERIAL:	PART #:	REV:
	26A01013	E



1. QUANTITY 1
2. VON KARMAN PROFILE
3. PERFORM LAYUP ACCORDING TO INTERNAL DOCUMENT

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

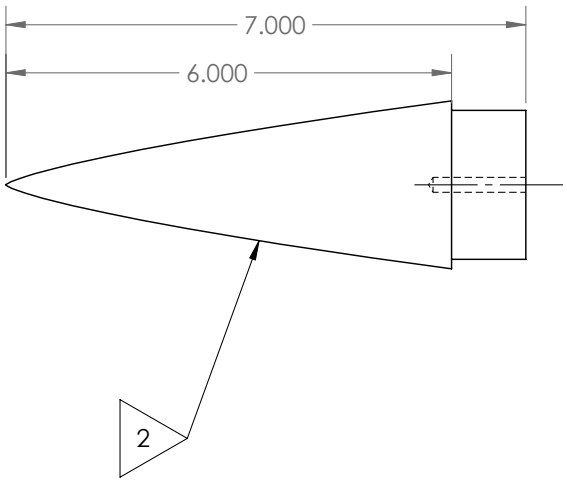
DO NOT SCALE

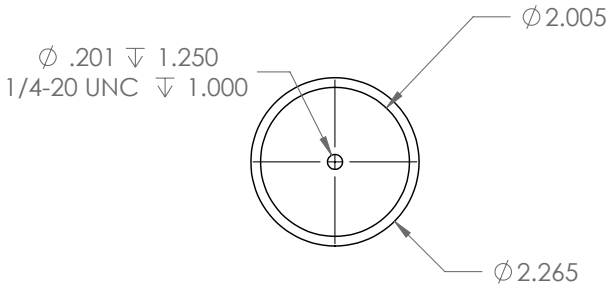
SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: NOSECONE		
SIZE: A	DATE: 2/2/2026	DRAWN BY: A. STONE
MATERIAL: HEAVY FIBERGLASS SLEEVE FROM SOLLER	PART #: 26A01019	REV: F





1. QUANTITY 1
2. VON KARMAN PROFILE

SOLIDWORKS Educational Product. For Instructional Use Only.

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

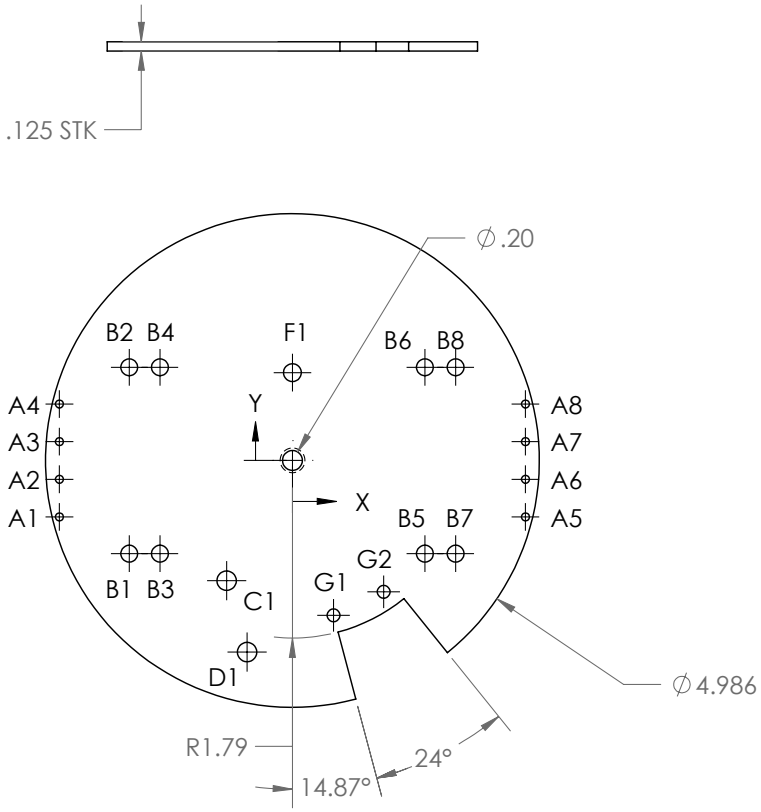
SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: NOSE CONE TIP			
SIZE: A	DATE: 1/30/2026	DRAWN BY: A. STONE	
MATERIAL: 6061-T6		PART #: 26A01020	REV: G

TAG	X LOC	Y LOC	SIZE
A1	-2.35	-.57	∅.080 THRU
A2	-2.35	-.19	∅.080 THRU
A3	-2.35	.19	∅.080 THRU
A4	-2.35	.57	∅.080 THRU
A5	2.35	-.57	∅.080 THRU
A6	2.35	-.19	∅.080 THRU
A7	2.35	.19	∅.080 THRU
A8	2.35	.57	∅.080 THRU
B1	-1.65	-.94	∅.170 THRU
B2	-1.65	.94	∅.170 THRU
B3	-1.34	-.94	∅.170 THRU
B4	-1.34	.94	∅.170 THRU
B5	1.34	-.94	∅.170 THRU
B6	1.34	.94	∅.170 THRU
B7	1.65	-.94	∅.170 THRU
B8	1.65	.94	∅.170 THRU
C1	-.66	-1.21	∅.196 THRU
D1	-.46	-1.93	∅.196 THRU
F1	-.00	.89	∅.180 THRU
G1	.42	-1.56	∅.129 THRU
G2	.92	-1.33	∅.129 THRU



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: EBAY BULKHEAD

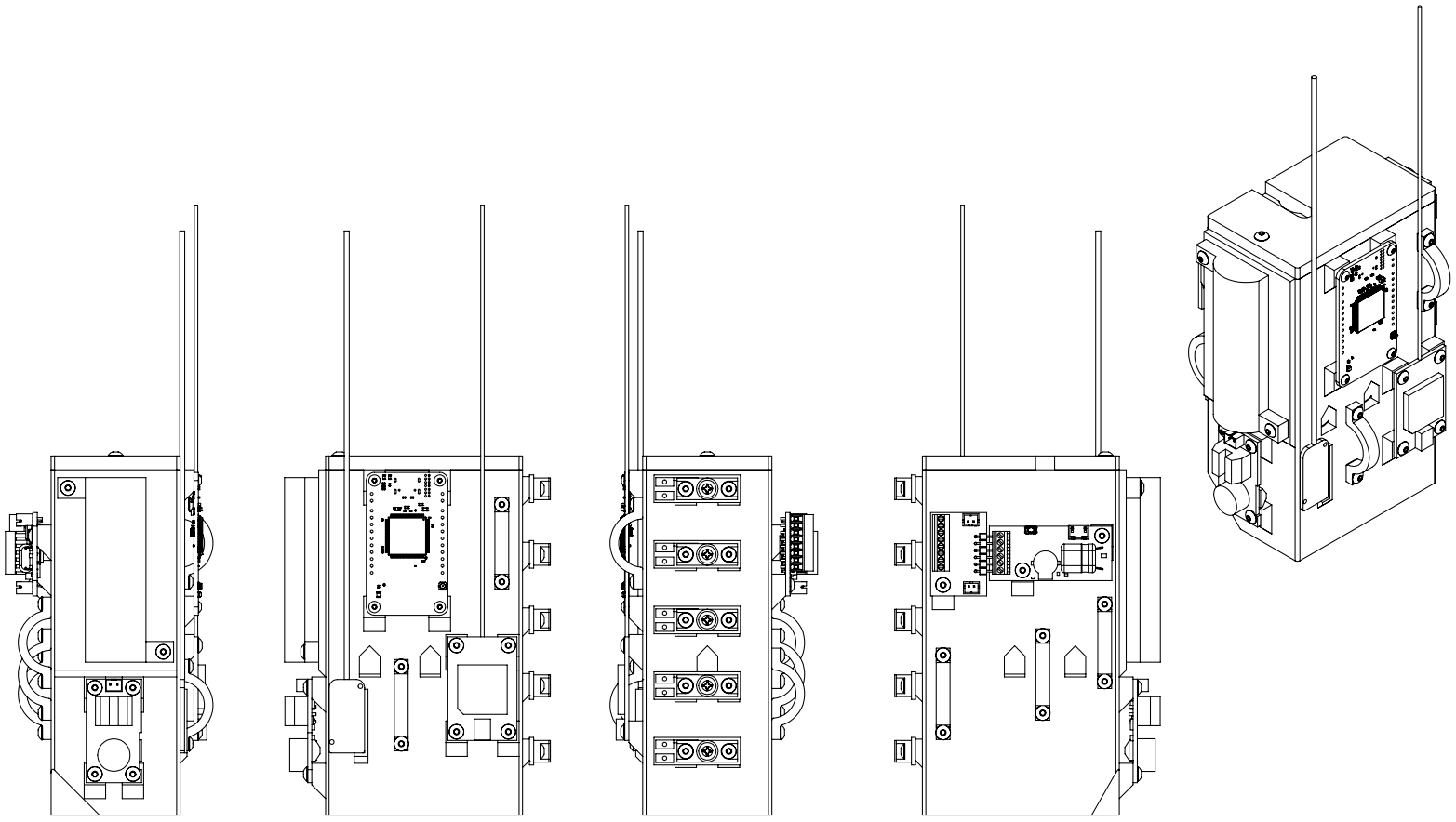
SIZE:	DATE:	DRAWN BY:
A	1/18/2026	S. CHURELCHULUUN

MATERIAL:	PART #:	REV:
7075-T6	26A01031	G

1 QUANTITY: 1

2 USE BLANK 26A96043

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 7

CASE ROCKET TEAM

CASE WESTERN RESERVE UNIVERSITY

TITLE:

EBAY SLED SUBASSEMBLY

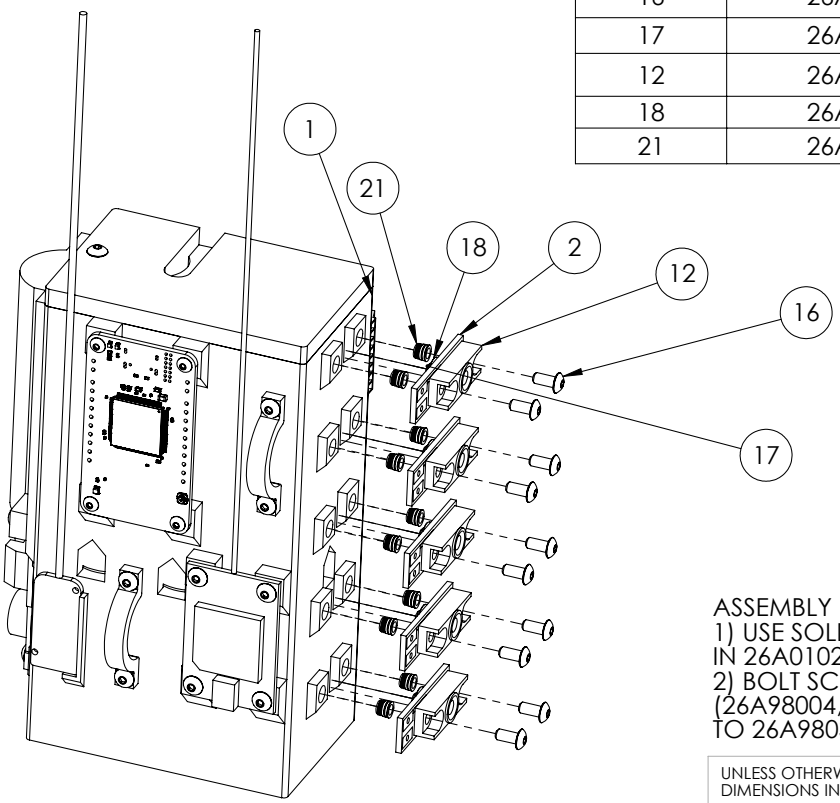
SIZE:	DATE:	DRAWN BY:	QUANTITY:
A	1/21/2026	D. COHEN	1

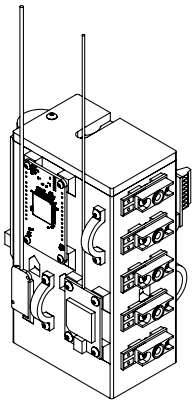
MATERIAL:	PART #:	REV:
	26A01036	C

1 QUANTITY: 1

SOLIDWORKS Educational Product. For Instructional Use Only.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
9	26A01022	EBAY SLED	1
2	26A98004	SCREW SWITCH	5
16	26A98040	4-40 0.25" BUTTON HEAD BOLT	10
17	26A98070	6-32 0.1875" PAN HEAD BOLT	5
12	26A02024	SCREW SWITCH COVER	5
18	26A98071	6-32 PEM NUT	5
21	26A98039	4-40 HEAT SET INSERT	10





ASSEMBLY INSTRUCTIONS:
1) USE SOLDERING IRON TO INSTALL 26A98039 IN 26A01022
2) BOLT SCREW SWITCH SUBASSEMBLY (26A98004, 26A02024, 26A98070, AND 26A98071) TO 26A98039 WITH 26A98040

1. ENSURE HEAT SET INSERTS ARE FLUSH WITH THE EBAY SLED SURFACE AND CHECK THAT COMPONENTS CAN BE BOLTED ON

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 2 OF 7

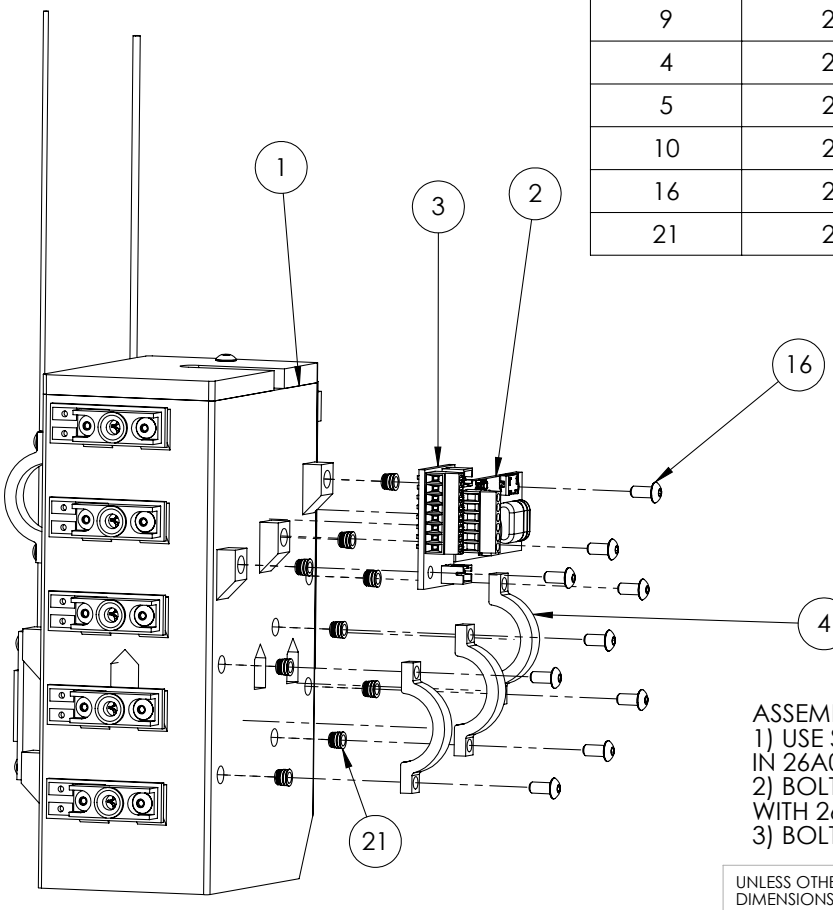
CASE ROCKET TEAM
Case Western Reserve University

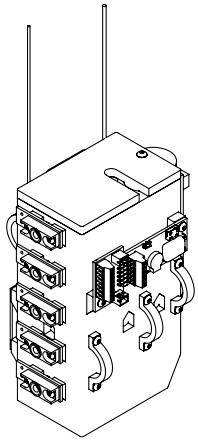
TITLE: EBAY SLED SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:	
A	1/21/2026	D. COHEN	
MATERIAL:		PART #: 26A01036	REV: C

SOLIDWORKS Educational Product. For Instructional Use Only.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
9	26A01022	EBAY SLED	1
4	26A98005	RAVEN4 ALTIMETER	1
5	26A98006	RAVEN4 BREAKOUT	1
10	26A01026	WIRE HOLDER	3
16	26A98040	4-40 0.25" BUTTON HEAD BOLT	9
21	26A98039	4-40 HEAT SET INSERT	9





ASSEMBLY INSTRUCTIONS:
1) USE SOLDERING IRON TO INSTALL 26A98039 IN 26A01022
2) BOLT 26A98005 AND 26A98006 TO 26A98039 WITH 26A98040
3) BOLT 26A01026 TO 26A98039 WITH 26A98040

1. ENSURE HEAT SET INSERTS ARE FLUSH WITH THE EBAY SLED SURFACE AND CHECK THAT COMPONENTS CAN BE BOLTED ON

SOLIDWORKS Educational Product. For Instructional Use Only.

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 3 OF 7

CASE ROCKET TEAM

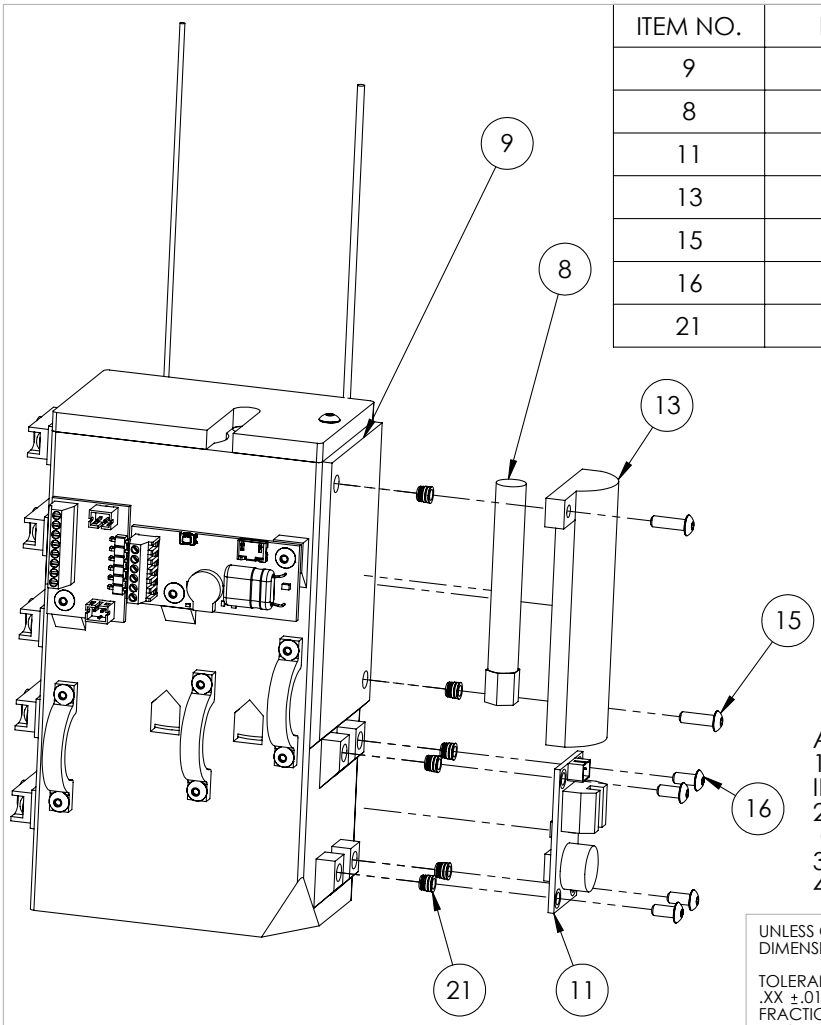
Case Western Reserve University

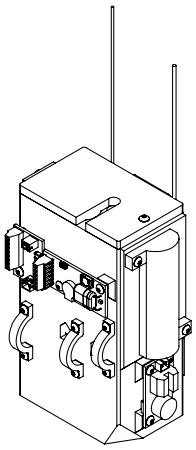
TITLE: EBAY SLED SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	1/21/2026	D. COHEN

MATERIAL:	PART #:	REV:
	26A01036	C

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
9	26A01022	EBAY SLED	1
8	26A98036	SIRIN ANTENNA	1
11	26A98001	EASY MINI	1
13	26A01021	SIRIN ANTENNA COVER	1
15	26A98042	4-40 0.375" BUTTON HEAD BOLT	2
16	26A98040	4-40 0.25" BUTTON HEAD BOLT	4
21	26A98039	4-40 HEAT SET INSERT	6





ASSEMBLY INSTRUCTIONS:
1) USE SOLDERING IRON TO INSTALL 26A98039 IN 26A01022
2) ATTACH 26A98036 TO 26A01021 WITH A DROP OF HOT GLUE
3) BOLT 26A01021 TO 26A98039 WITH 26A98042
4) BOLT 26A98001 TO 26A98039 WITH 26A98040

1. ENSURE HEAT SET INSERTS ARE FLUSH WITH THE EBAY SLED SURFACE AND CHECK THAT COMPONENTS CAN BE BOLTED ON

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

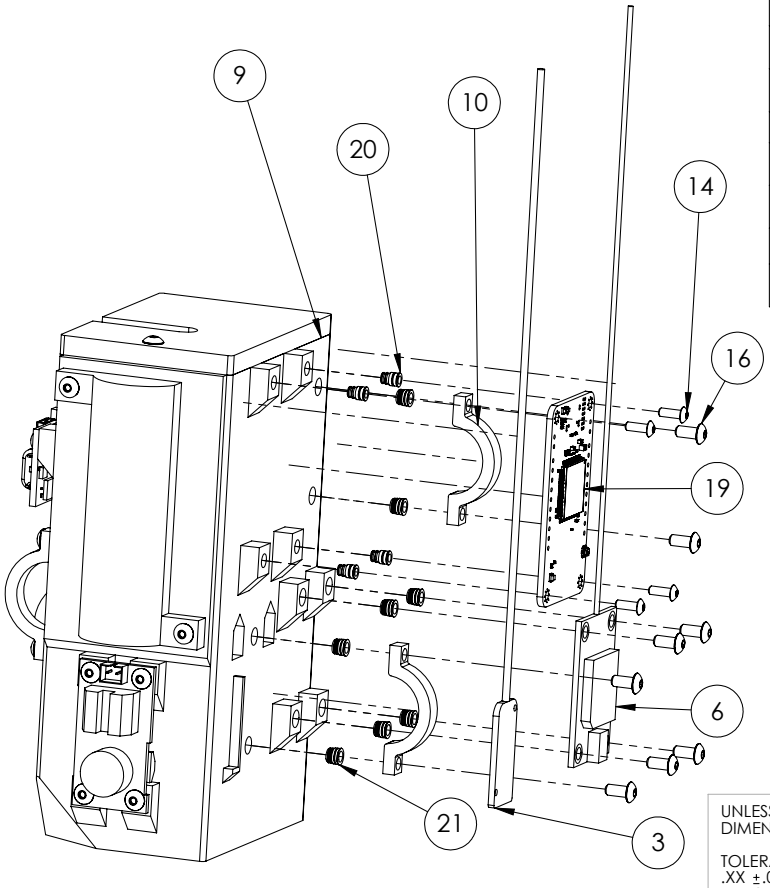
SHEET 4 OF 7

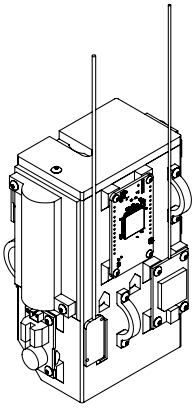
CASE ROCKET TEAM
Case Western Reserve University

TITLE: EBAY SLED SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:	
A	1/21/2026	D. COHEN	
MATERIAL:		PART #: 26A01036	REV: C

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
9	26A01022	EBAY SLED	1
3	26A98003	ELVIN BEACON	1
6	26A98007	TELEGPS	1
10	26A01026	WIRE HOLDER	2
14	26A98062	2-56 0.25" BUTTON HEAD BOLT	4
16	26A98040	4-40 0.25" BUTTON HEAD BOLT	8
19	26A01024	SIRIN	1
20	26A98061	2-56 HEAT SET INSERT	4
21	26A98039	4-40 HEAT SET INSERT	8





ASSEMBLY INSTRUCTIONS:
1) USE SOLDERING IRON TO INSTALL 26A98039 AND 26A98062 IN 26A01022
2) ATTACH 26A98003 TO 26A01022 WITH A DROP OF HOT GLUE AND USE THE L-SHAPED OUTLINE AS A LOCATING FEATURE
3) BOLT 26A01026 TO 26A98039 WITH 26A98040
4) BOLT 26A98007 TO 26A98039 WITH 26A98040
5) BOLT 26A01024 TO 26A98061 WITH 26A98062

1 ENSURE HEAT SET INSERTS ARE FLUSH WITH THE EBAY SLED SURFACE AND CHECK THAT COMPONENTS CAN BE BOLTED ON

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 5 OF 7

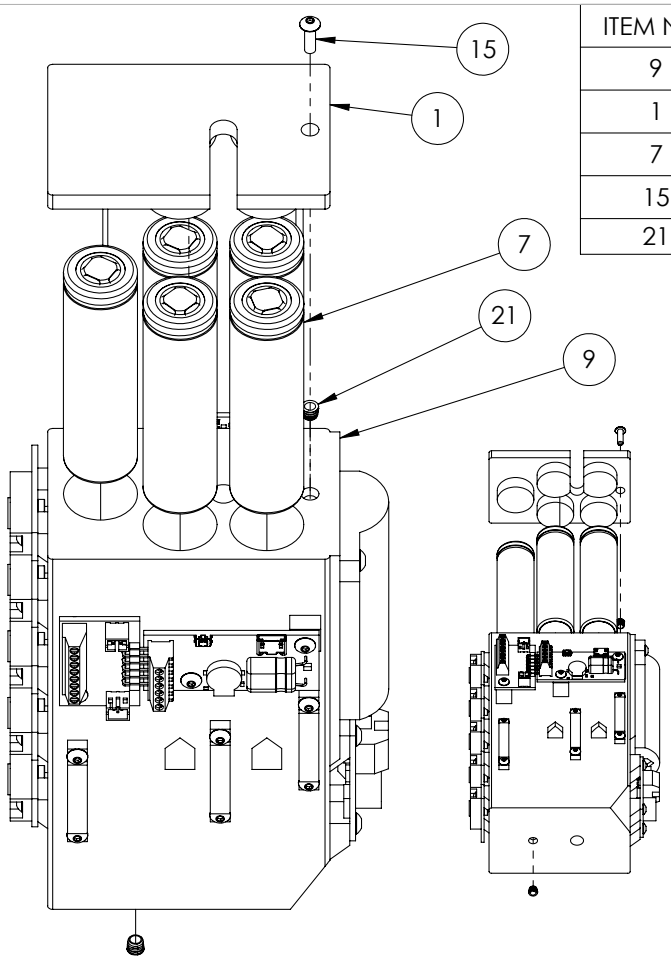
CASE ROCKET TEAM
Case Western Reserve University

TITLE: EBAY SLED SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	1/21/2026	D. COHEN

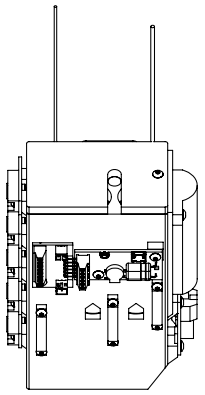
MATERIAL:	PART #:	REV:
	26A01036	C

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ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
9	26A01022	EBAY SLED	1
1	26A01029	BATTERY COVER	1
7	26A98008	18650 LI-ION BATTERY	5
15	26A98042	4-40 0.375" BUTTON HEAD BOLT	1
21	26A98039	4-40 HEAT SET INSERT	2

ASSEMBLY INSTRUCTIONS:
1) USE SOLDERING IRON TO INSTALL 26A98039 IN 26A01022
2) THREAD 26A98008 WIRES THROUGH CUTOUTS IN 26A01022 WITH TWEEZERS
3) DROP 26A98008 INTO 26A01022
4) INSERT 26A01029 INTO 26A01022, COVERING 26A98008
5) BOLT 26A01029 INTO 26A01022 WITH 26A98042



1 ENSURE HEAT SET INSERTS ARE FLUSH WITH THE EBAY SLED SURFACE AND CHECK THAT COMPONENTS CAN BE BOLTED ON

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 6 OF 7

CASE ROCKET TEAM
Case Western Reserve University

TITLE: EBAY SLED SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:	
A	1/21/2026	D. COHEN	
MATERIAL:		PART #: 26A01036	REV: C

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ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A01029	BATTERY COVER	1
2	26A98004	SCREW SWITCH	5
3	26A98003	ELVIN BEACON	1
4	26A98005	RAVEN4 ALTIMETER	1
5	26A98006	RAVEN4 BREAKOUT	1
6	26A98007	TELEGPS	1
7	26A98008	18650 LI-ION BATTERY	5
8	26A98036	SIRIN ANTENNA	1
9	26A01022	EBAY SLED	1
10	26A01026	WIRE HOLDER	5
11	26A98001	EASY MINI	1
12	26A02024	SCREW SWITCH COVER	5
13	26A01021	SIRIN ANTENNA COVER	1
14	26A98062	2-56 0.25" BUTTON HEAD BOLT	4
15	26A98042	4-40 0.375" BUTTON HEAD BOLT	3
16	26A98040	4-40 0.25" BUTTON HEAD BOLT	31
17	26A98070	6-32 0.1875" PAN HEAD BOLT	5
18	26A98071	6-32 PEM NUT	5
19	26A01024	SIRIN	1
20	26A98061	2-56 HEAT SET INSERT	4
21	26A98039	4-40 HEAT SET INSERT	35

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 7 OF 7

CASE ROCKET TEAM

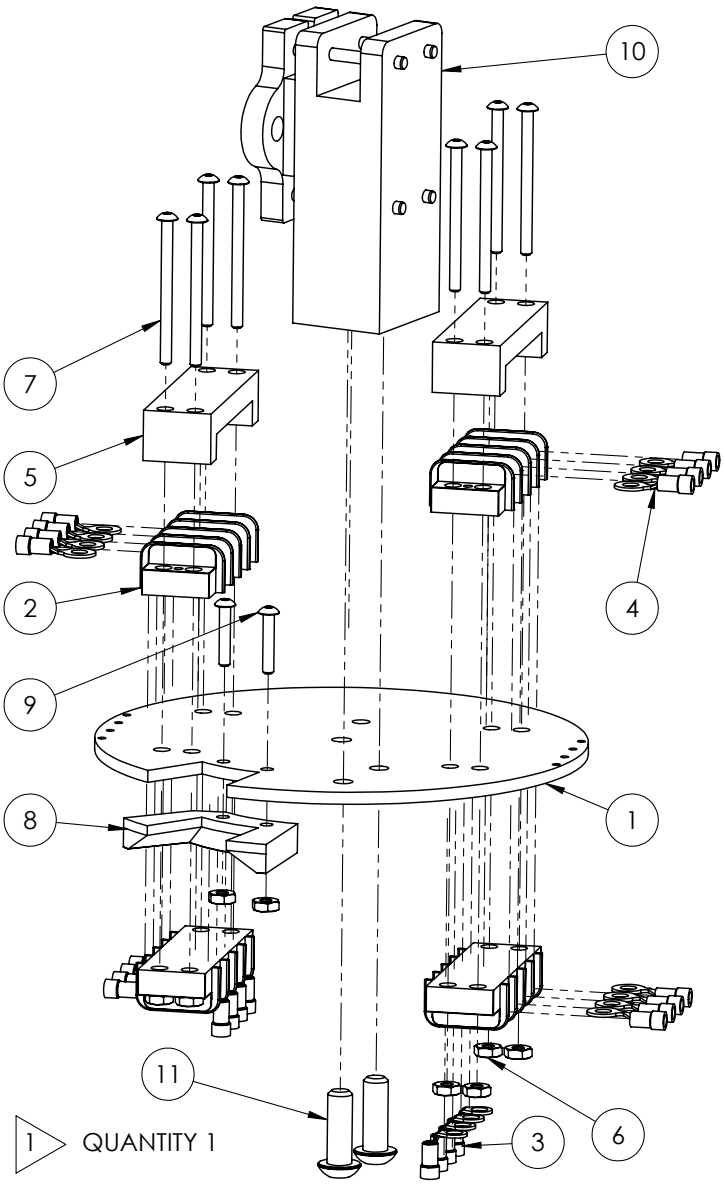
Case Western Reserve University

TITLE: EBAY SLED SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	1/21/2026	D. COHEN

MATERIAL:	PART #:	REV:
	26A01036	C

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ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A01031	EBAY BULKHEAD	1
2	26A98016	300V AC/300V DC TERMINAL BLOCK	4
3	26A98026	90 DEGREE RING TERMINALS	8
4	26A98027	STRAIGHT RING TERMINALS	16
5	26A01015	TERMINAL BLOCK COVER	2
6	26A98045	4-40 HEX NUT	10
7	26A98072	4-40 1.5" BUTTON HEAD BOLT	8
8	26A01035	CLOCKING NOTCH (FEMALE)	1
9	26A98064	4-40 0.625" BUTTON HEAD BOLT	2
10	26A01014	TENDIE DESCENDIE SUBASSEMBLY	1
11	26A98022	1/4-20 0.75" BOLT BUTTON	2

ASSEMBLY PLAN:

1. BOLT 26A01035 TO 26A01031 USING 26A98064
2. SCREW IN 26A98026 AND 26A98027 TO 26A98016
3. ATTACH EBAY WIRES TO 26A98026
4. ATTACH CONNECTING WIRES THROUGH 26A01031 TO 26A98027
5. BOLT ON 26A01015 USING 26A98072 AND 26A98045
6. SCREW ON 26A01014 USING 26A98022

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°

SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

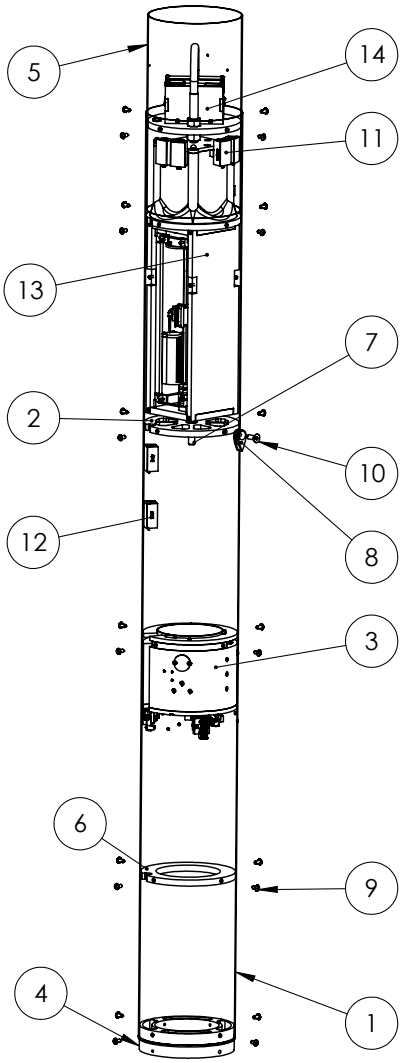
Case Western Reserve University

TITLE: EBAY BULKHEAD SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	1/6/2026	Z. KAO

MATERIAL:	PART #:	REV:
	26A01037	F

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ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A02001	BODY TUBE	1
2	26A02002	MOTOR RETENTION BULKHEAD	1
3	26A02015	LOWER CAMERA EBAY MAIN ASSEMBLY	1
4	26A02016	INTERFACE CENTERING RING	1
5	26A02023	COUPLER	1
6	26A02006	CENTERING RING	1
7	26A98023	3/8"-16 1.375" MOTOR RETAINING BOLT	1
8	26A98038	AERODYNAMIC RAIL BUTTON	1
9	26A98037	10-24 3/8" BUTTON HEAD BOLT	23
10	26A98050	1/4-20 3/4" FLAT HEAD BOLT	1
11	26D00005	COUPLER STRAIN GAUGE MODULE IN HOLDER	4
12	26D00002	BODY TUBE STRAIN GAUGE MODULE IN HOLDER	2
13	26A02040	PAYLOAD/MEASUREMENTS SUBASSEMBLY	1
14	26A02041	RECOVERY BULKHEAD SUBASSEMBLY	1

ASSEMBLY INSTRUCTIONS:
1) SECURE 26A02015 INTO 26A02001 WITH 26A98037
2) SECURE 26A02006 INTO 26A02001 WITH 26A98037
3) SECURE 26A02016 INTO 26A02001 WITH 26A98037
4) EPOXY 26D00002 TO 26A02001, USE RAIL GUIDES TO ALIGN STRAIN GAUGE MODULES TO BE CLOCKED RELATIVE TO THE NOTCHES IN BULKHEADS
5) THREAD 26A98023 INTO 26A02002 WITH RED LOCTITE
6) SECURE 26A02002 INTO 26A02001 WITH 26A098037
7) SECURE 26A98038 ONTO 26A02001 WITH 26A98050
8) SECURE 26A02040 INTO 26A02001 WITH 26A98037
9) EPOXY 26D00005 INTO 26A02023
10) SECURE 26A02041 AND 26A02023 INTO 26A02001 WITH 26A98037

1. QUANTITY 1
2. ENSURE MEASUREMENTS WIRE HOLES ARE CLOCKED
3. ENSURE 1/4-20 HOLES FOR RAIL BUTTONS ARE CLOCKED

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DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°

SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

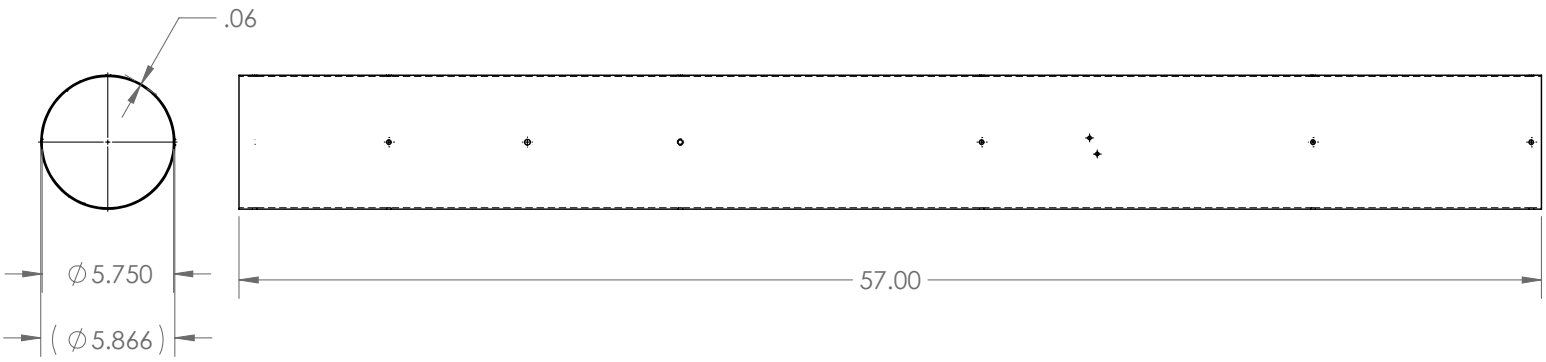
SHEET 1 OF 1

CASE ROCKET TEAM
Case Western Reserve University

TITLE: BODY TUBE ASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	1/31/2026	R. SHEPHERD

MATERIAL:	PART #:	REV:
	26A02000	D



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 2

CASE ROCKET TEAM

Case Western Reserve University

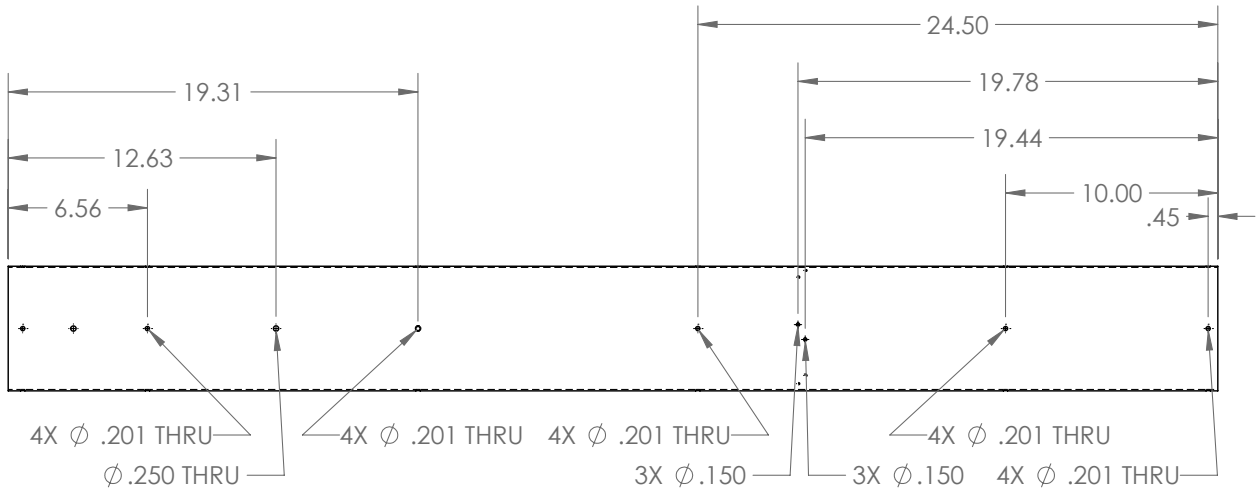
TITLE: MAIN BODY TUBE

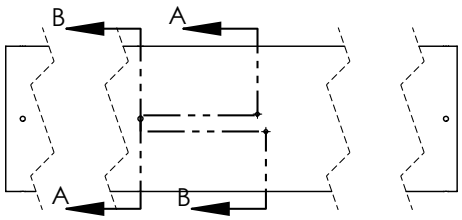
SIZE:	DATE:	DRAWN BY:
A	1/14/2026	Z. KAO

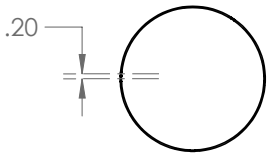
MATERIAL:	PART #:	REV:
3K CF WEAVE	26A02001	E

1 QUANTITY 1

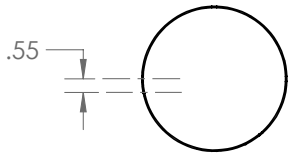
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SECTION A-A



SECTION B-B

1. QUANTITY 1
2. RADIAL HOLES NOT DIMENSIONED ARE DRILLED IN ASSEMBLY

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

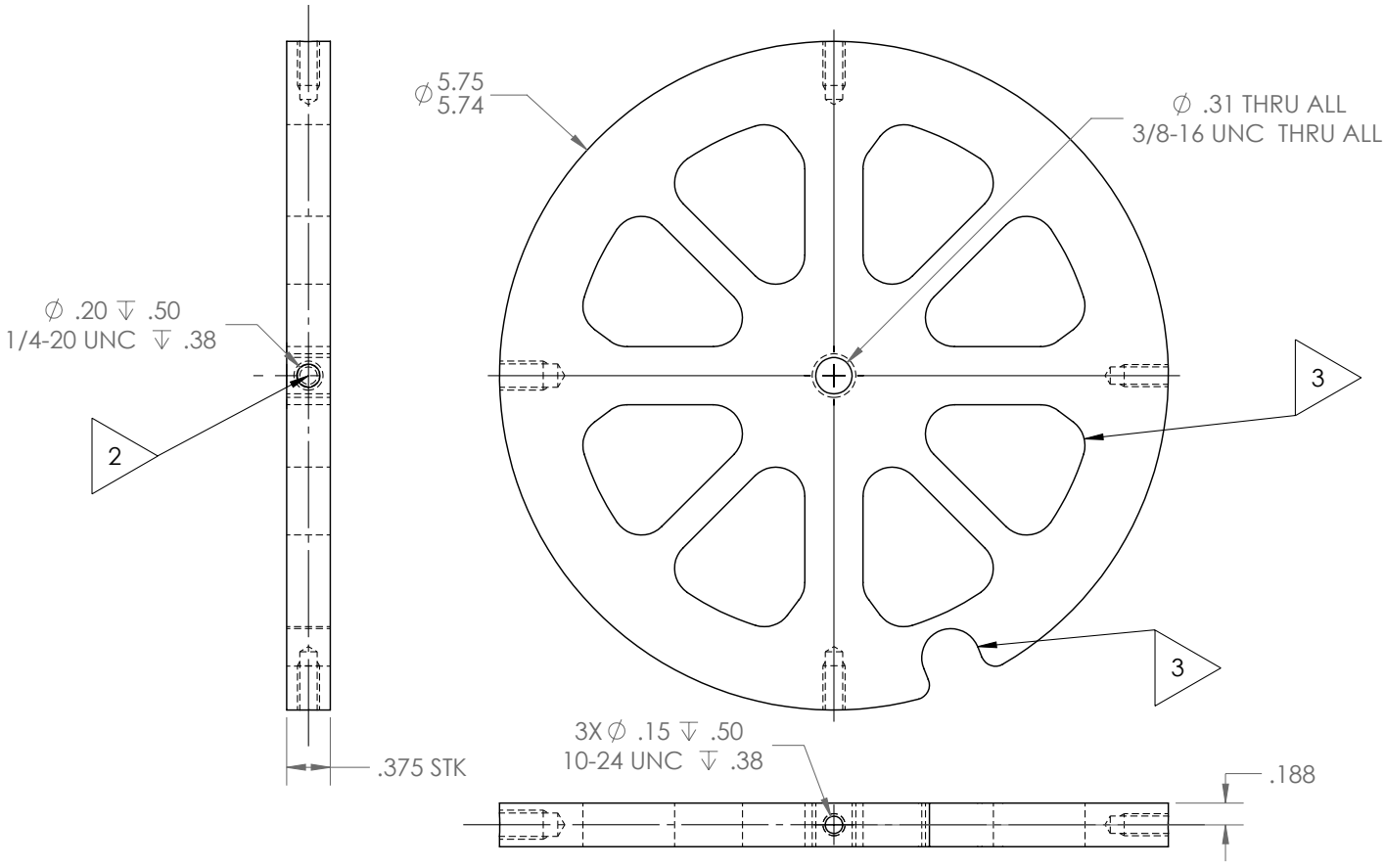
SHEET 2 OF 2

CASE ROCKET TEAM

Case Western Reserve University

TITLE: MAIN BODY TUBE			
SIZE: A	DATE: 1/31/2026	DRAWN BY: Z. KAO	
MATERIAL: 3K CF WEAVE		PART #: 26A02001	REV: E

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1. QUANTITY 1
2. ONLY ONE HOLE IS 1/4-20
3. MACHINE TO CAD MODEL
4. USE BLANK 26A96035

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DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

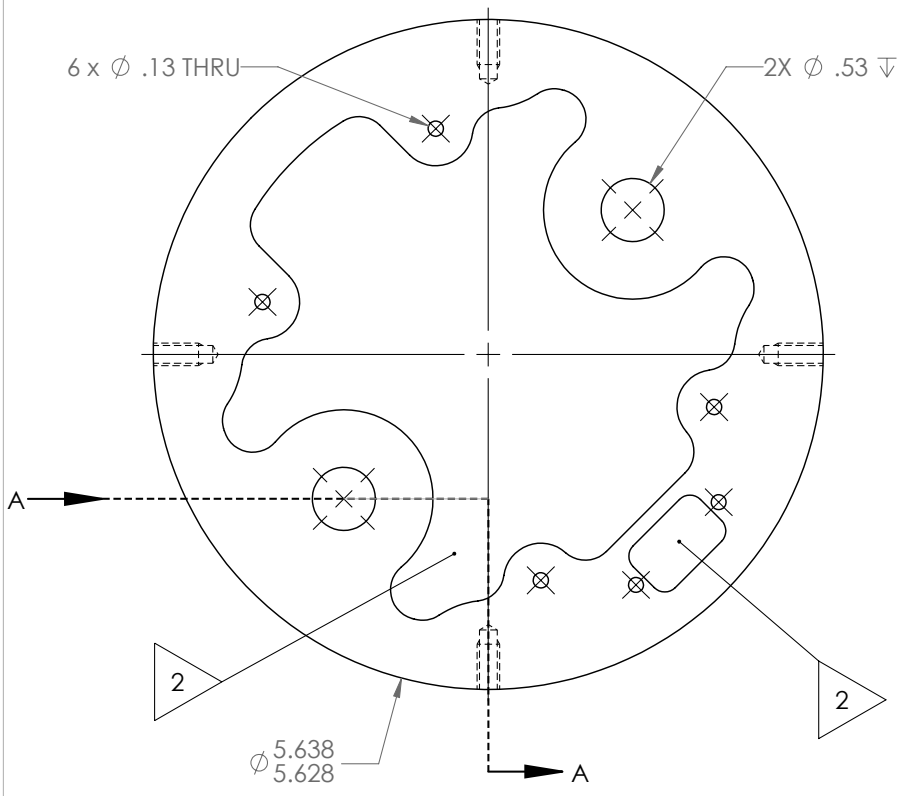
CASE ROCKET TEAM

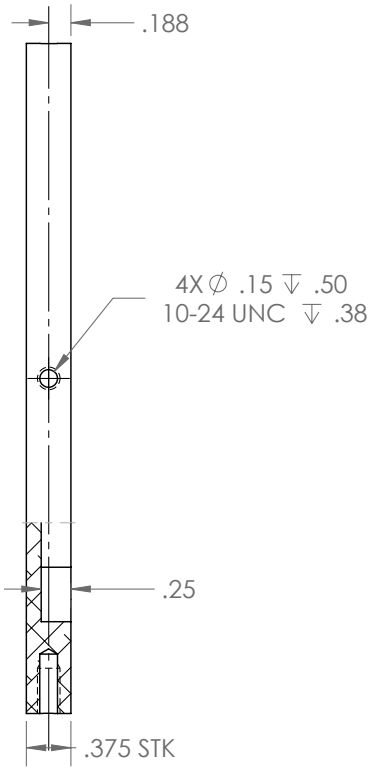
Case Western Reserve University

TITLE: MOTOR RETENTION BULKHEAD

SIZE:	DATE:	DRAWN BY:
A	1/18/2026	J TAN

MATERIAL:	PART #:	REV:
7075-T6	26A02002	G





SECTION A-A

1. QUANTITY 1
2. MACHINE TO CAD MODEL
3. USE BLANK 26A96042

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DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

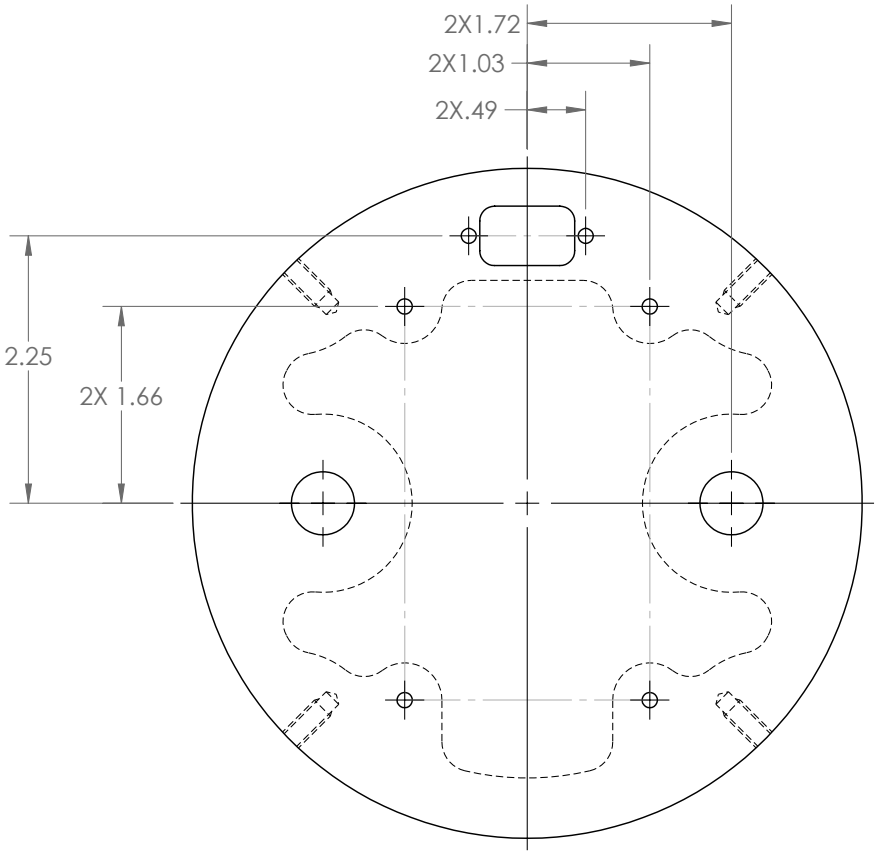
DO NOT SCALE

SHEET 1 OF 2

CASE ROCKET TEAM

Case Western Reserve University

TITLE: RECOVERY BULKHEAD			
SIZE: A	DATE: 1/18/2026	DRAWN BY: J. TAN	
MATERIAL: 7075-T6		PART #: 26A02003	REV: G



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 2 OF 2

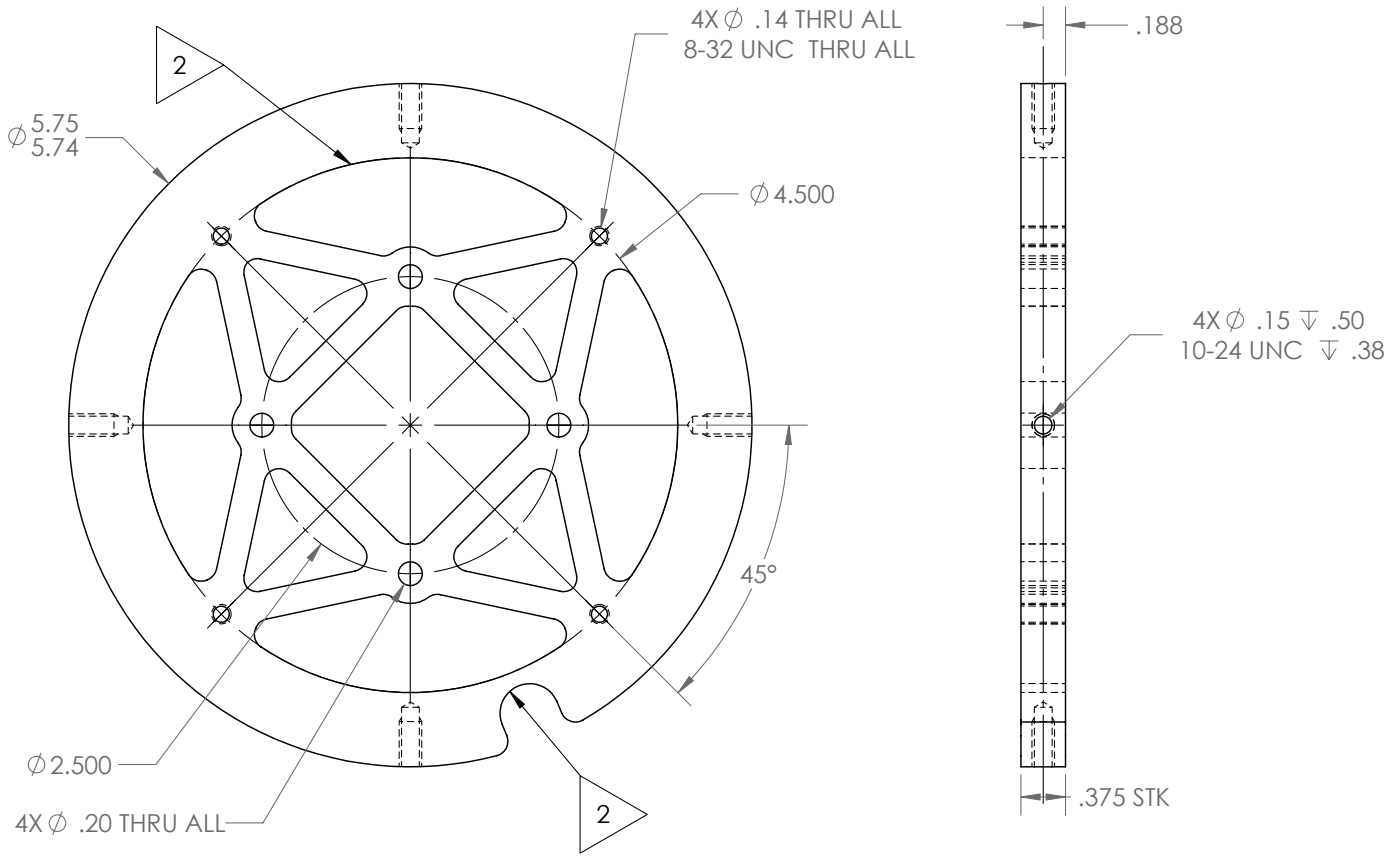
CASE ROCKET TEAM

Case Western Reserve University

TITLE: RECOVERY BULKHEAD			
SIZE: A	DATE: 1/18/2026	DRAWN BY: J. TAN	
MATERIAL: 7075-T6		PART #: 26A02003	REV: G

1. QUANTITY 1
2. USE BLANK 26A96042

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1. QUANTITY 1
2. MACHINE TO SOLID BODY
3. USE BLANK 26A96037

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

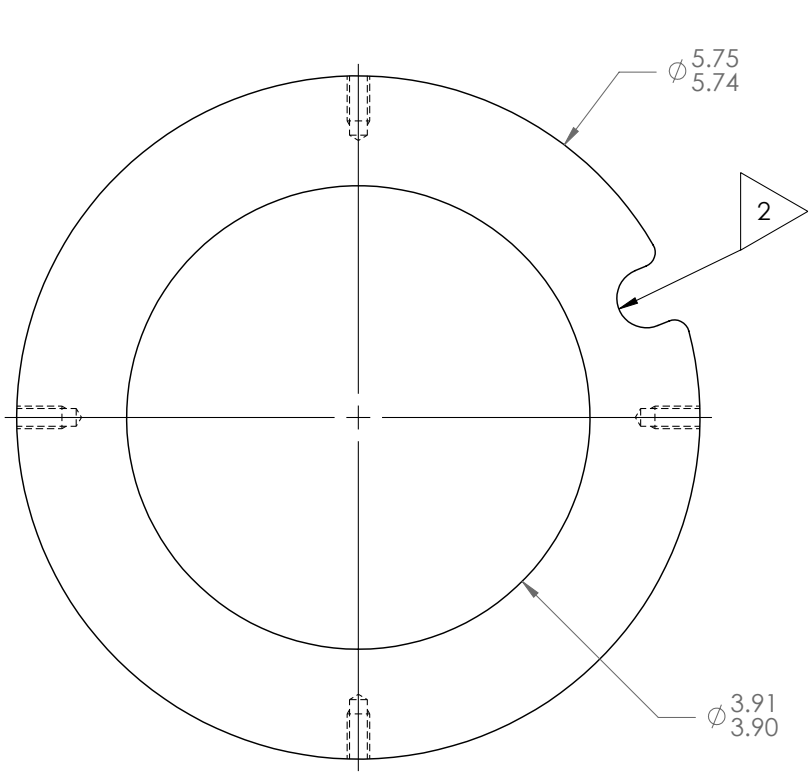
SHEET 1 OF 1

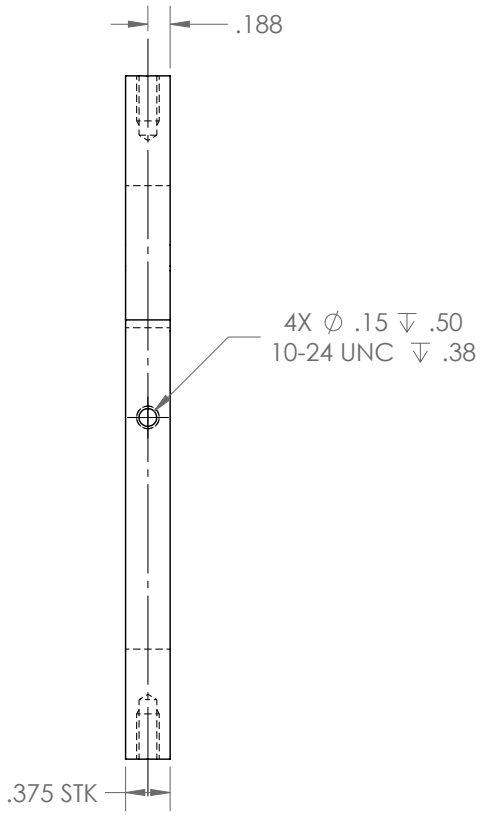
CASE ROCKET TEAM

Case Western Reserve University

TITLE:
PAYLOAD/MEASUREMENTS BULKHEAD

SIZE:	DATE:	DRAWN BY:	
A	1/18/2026	J. TAN	
MATERIAL:		PART #:	REV:
6061-T6		26A02004	F





1. QUANTITY 1
2. MACHINE TO SOLID BODY
3. USE BLANK 26A96037

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

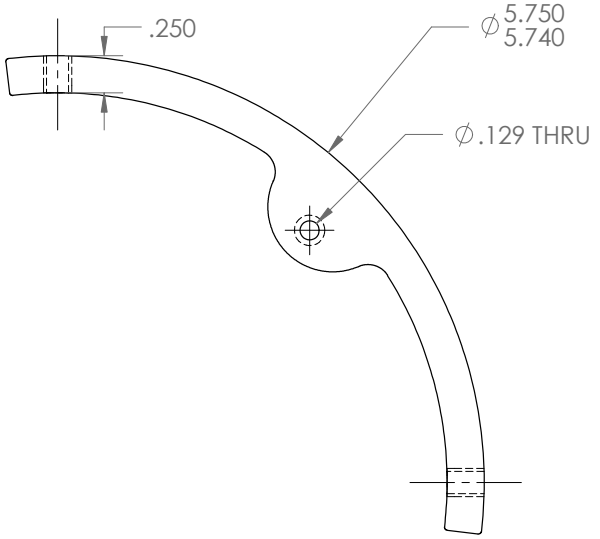
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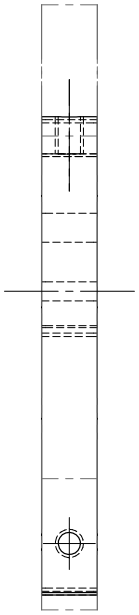
SHEET 1 OF 1

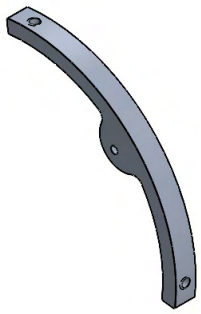
CASE ROCKET TEAM

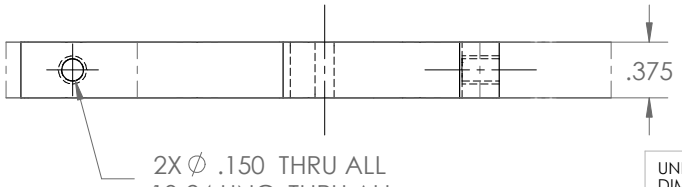
Case Western Reserve University

TITLE: CENTERING RING			
SIZE: A	DATE: 1/18/2026	DRAWN BY: J. TAN	
MATERIAL: 6061-T6		PART #: 26A02006	REV: E









1. QUANTITY: 2
2. MACHINE TO CAD MODEL
3. USE BLANK 26A96038
4. USE JIG 26A96069

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

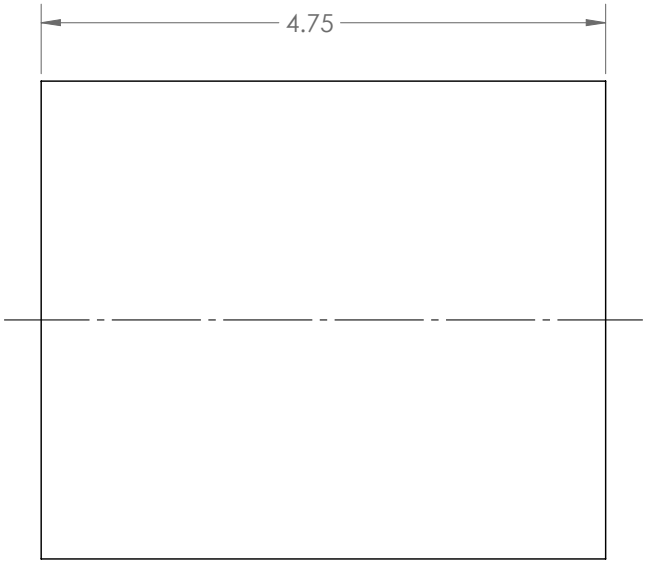
SHEET 1 OF 1

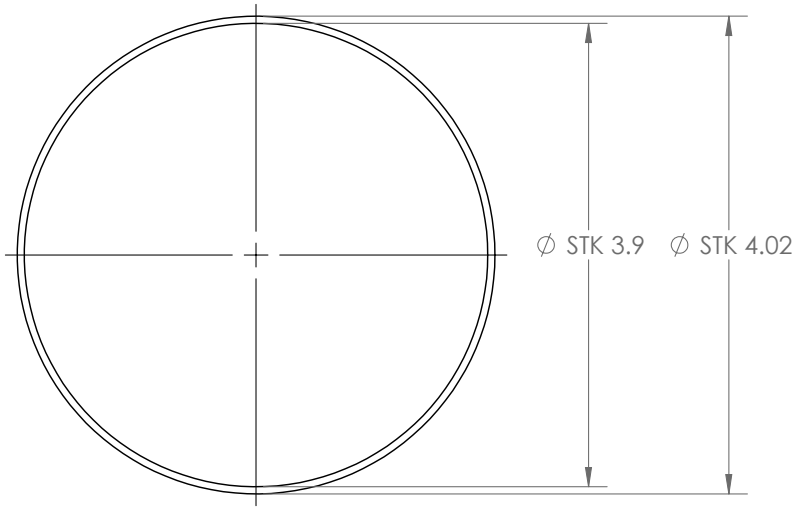
CASE ROCKET TEAM

Case Western Reserve University

TITLE: CAMERA LOWER BULKHEAD

SIZE:	DATE:	DRAWN BY:	
A	1/11/2026	C. DIAZ	
MATERIAL:		PART #:	REV:
6061-T6		26A02009	E





1. QUANTITY 1
2. PURCHASE FROM WILDMAN ROCKETRY

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

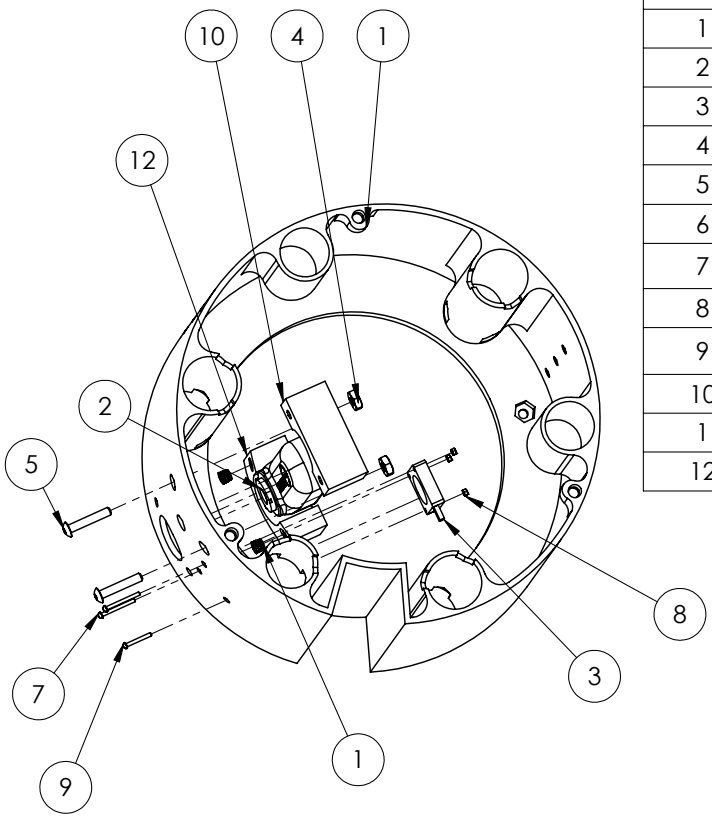
SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: CAMERA INSULATOR			
SIZE: A	DATE: 1/31/2026	DRAWN BY: R. PAPPALARDO	
MATERIAL: G12 FIBERGLASS		PART #: 26A02010	REV: B

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ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A02007	CAMERA MAIN COMPARTMENT	1
2	26A98021	RUNCAM THUMB	1
3	26A98028	FAN, 16MMX16MMX4.5MM	1
4	26A98045	4-40 HEX NUT	3
5	26A98064	4-40 0.625" BUTTON HEAD BOLT	2
6	26A98041	4-40 0.3125" BUTTON HEAD BOLT	1
7	26A98054	00-90 0.5" ROUND HEAD BOLT	2
8	26A98052	00-90 HEX NUT	3
9	26A98053	00-90 0.375" ROUND HEAD BOLT	1
10	26A02037	CAMERA HOLDER	1
1	26A98039	4-40 HEAT SET INSERT	2
12	26A02038	CAMERA MOUNT	1

ASSEMBLY INSTRUCTIONS:
1) INSTALL 2X 26A98039 INTO 26A02038(PERMANENT)
2) HOT GLUE 26A98021 INTO 26A02038(SEMI-PERMANENT)
3) BOLT 26A02038 INTO 26A02007
4) BOLT 26A02037 INTO 26A02007
5) BOLT 26A98028 INTO 26A02007, ENSURING THE AIRFLOW IS POINTING AT THE COOLING VENTS OF 26A98021
6) REPEAT 3 TIMES IN TOTAL

1. QUANTITY 1
2. ENSURE ALL HARDWARE IS RECESSED IN OR FLUSH WITH THE OUTSIDE OF THE MAIN COMPARTMENT
3. THE CAMERA AND FAN COMPONENTS NEED TO BE REPEATED 3 TIMES, ONLY ONE SET IS SHOWN FOR CLARITY

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 6

CASE ROCKET TEAM

Case Western Reserve University

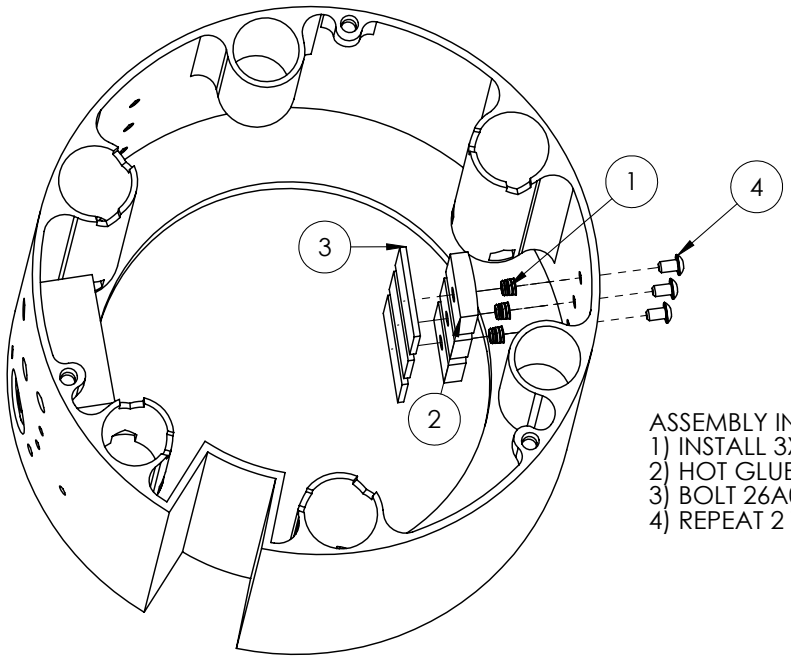
TITLE: CAMERA MAIN COMPARTMENT SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	2/3/2026	R. PAPPALARDO

MATERIAL:	PART #:	REV:
	26A02013	E

SOLIDWORKS Educational Product. For Instructional Use Only.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A98039	4-40 HEAT SET INSERT	3
2	26A02036	BOOST CONVERTER MOUNT	3
3	26A98032	BOOST CONVERTER, 5V OUT	3
4	26A98055	4-40 0.1875" BUTTON HEAD BOLT	3



ASSEMBLY INSTRUCTIONS:
1) INSTALL 3X 26A98039 IN 26A02036(PERMANENT)
2) HOT GLUE 26A98032 ONTO 26A02036(SEMI-PERMANENT)
3) BOLT 26A02036 INTO 26A02007
4) REPEAT 2 TIMES IN TOTAL

1. UNLESS OTHERWISE NOTED, THE BOM ONLY LISTS PARTS WHICH ARE NEW TO THE ASSEMBLY ON THIS SHEET
2. THE BOOST CONVETER COMPONENTS NEED TO BE REPEATED 2 TIMES, ONLY ONE SET IS SHOWN FOR CLARITY

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°

SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 2 OF 6

CASE ROCKET TEAM

Case Western Reserve University

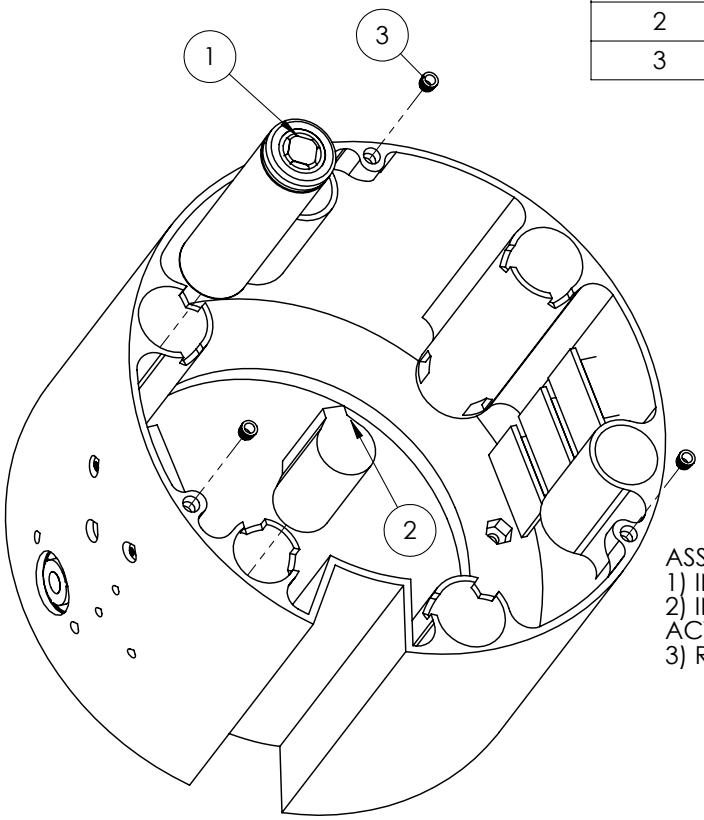
TITLE:
CAMERA MAIN COMPARTMENT SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	2/3/2026	R. PAPPALARDO

MATERIAL:	PART #:	REV:
	26A02013	E

SOLIDWORKS Educational Product. For Instructional Use Only.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A98008	18650 LI-ION BATTERY	1
2	26A98012	16340 LI-ION BATTERY	1
3	26A98039	4-40 HEAT SET INSERT	3



ASSEMBLY INSTRUCTIONS:
1) INSTALL 3X 26A98039 INTO 26A02007(PERMANENT)
2) INSTALL 26A98008 AND 26A98012 INTO 26A02007(NO FURTHER ACTION NEEDED, THEY WILL BE RETAINED BY THE UPPER BULKHEAD)
3) REPEAT BATTERIES 3 TIMES IN TOTAL

1. THE BATTERY COMPONENTS NEED TO BE REPEATED 3 TIMES, ONLY ONE SET IS SHOWN FOR CLARITY

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 3 OF 6

CASE ROCKET TEAM

Case Western Reserve University

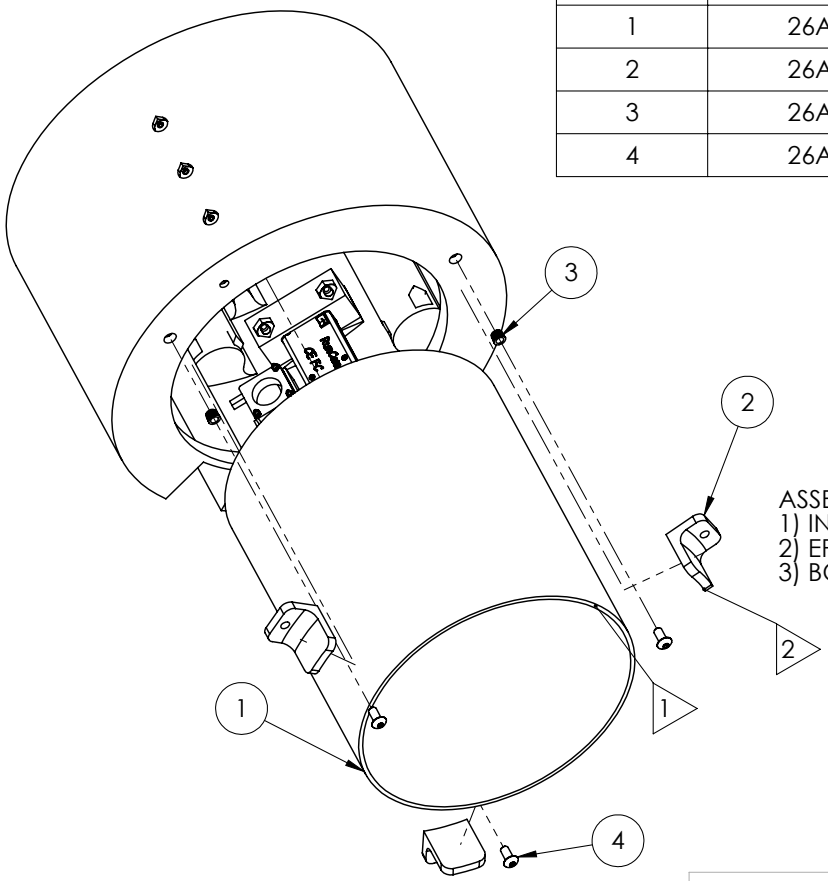
TITLE: CAMERA MAIN COMPARTMENT SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	2/3/2026	R. PAPPALARDO

MATERIAL:	PART #:	REV:
	26A02013	E

SOLIDWORKS Educational Product. For Instructional Use Only.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A02011	CAMERA INSULATOR MOUNT	3
2	26A02010	CAMERA INSULATOR	1
3	26A98039	4-40 HEAT SET INSERT	3
4	26A98040	4-40 0.25" BUTTON HEAD BOLT	3



ASSEMBLY INSTRUCTIONS:
1) INSTALL 3X 26A98039 IN 26A02007(PERMANENT)
2) EPOXY 26A02011 ONTO 26A02010(SEE BELOW, PERMANENT)
3) BOLT 26A02010 INTO 26A02007

1. THE BOND BETWEEN THE INSULATOR AND THE MOUNTS IS LAMINATING EPOXY, BOTH SURFACES SHOULD BE HAND SANDED TO 320 GRIT AND WIPED WITH ACETONE BEFORE BONDING. THE MOUNTS SHOULD BE BOLTED TO THE MAIN COMPARTMENT WHILE BONDING TO ENSURE PROPER ALIGNMENT.
2. ENSURE ALL NECESSARY WIRE MANAGEMENT IS ATTENDED TO BEFORE INSTALLING THE INSULATOR.

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

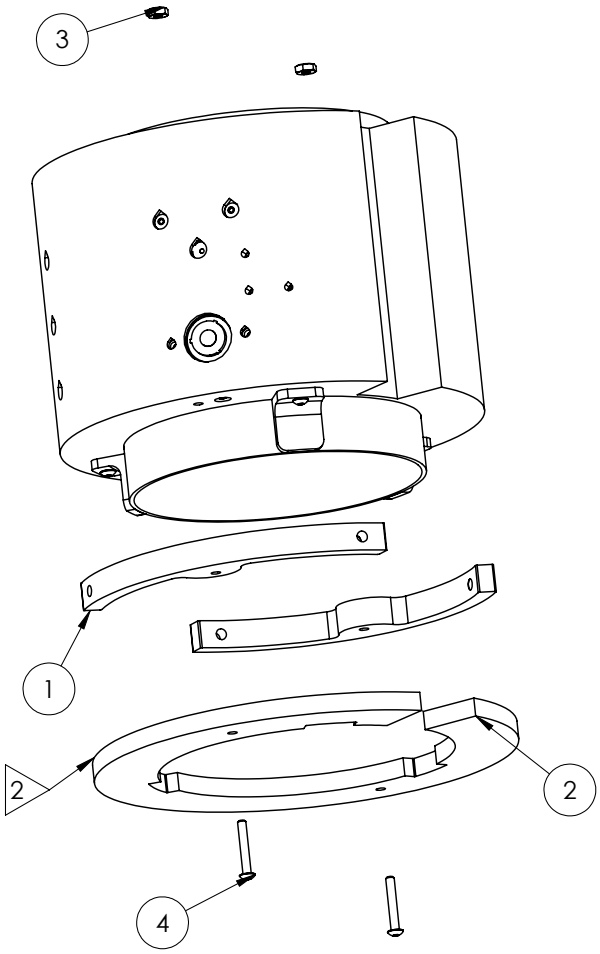
DO NOT SCALE

SHEET 4 OF 6

CASE ROCKET TEAM
Case Western Reserve University

TITLE: CAMERA MAIN COMPARTMENT SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:	
A	2/3/2026	R. PAPPALARDO	
MATERIAL:		PART #: 26A02013	REV: E



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A02009	CAMERA LOWER BULKHEAD	2
2	26A02020	BALLAST PLATE	1
3	26A98045	4-40 HEX NUT	2
4	26A98046	4-40 0.75" BUTTON HEAD BOLT	2

ASSEMBLY INSTRUCTIONS:
1) BOLT THE DESIRED NUMBER OF 26A02020(SEE BELOW) AND 2X 26A02009 INTO 26A02007

1. THIS STEP COULD OCCUR BEFORE INSTALLTING THE INSULATOR IF PREFERRED.
2. THE NUMBER OF BALLAST PLATES CAN BE CHANGED BASED ON THE DESIRED FLIGHT PROFILE. EACH 0.25" THICK BALLAST PLATE IS ~0.86 LB.

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

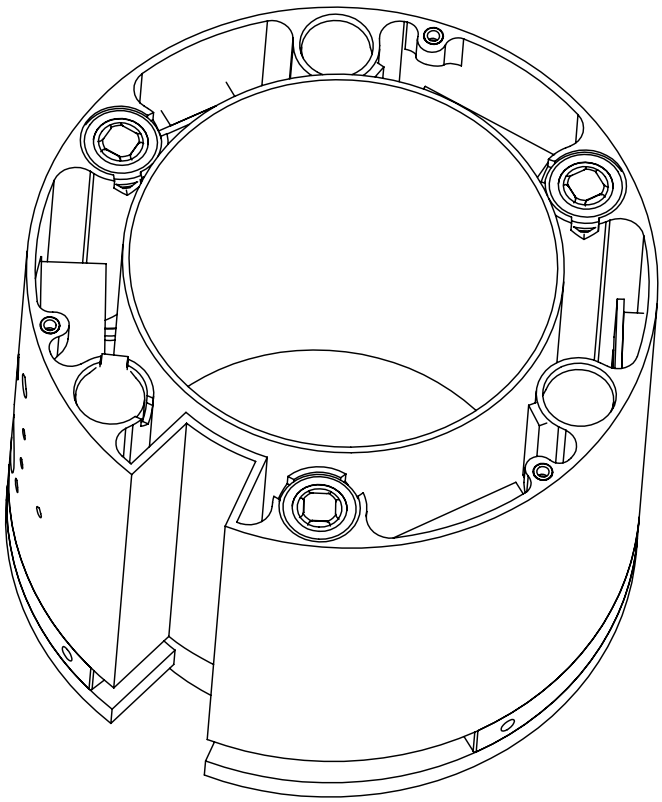
DO NOT SCALE

SHEET 5 OF 6

CASE ROCKET TEAM
Case Western Reserve University

TITLE:
CAMERA MAIN COMPARTMENT SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:	
A	2/3/2026	R. PAPPALARDO	
MATERIAL:		PART #:	REV:
		26A02013	E



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A02007	CAMERA MAIN COMPARTMENT	1
2	26A02009	CAMERA LOWER BULKHEAD	2
3	26A02010	CAMERA INSULATOR	1
4	26A02011	CAMERA INSULATOR MOUNT	3
5	26A98008	18650 LI-ION BATTERY	3
6	26A98012	16340 LI-ION BATTERY	3
7	26A98021	RUNCAM THUMB	3
8	26A98028	FAN, 16MMX16MMX4.5MM	3
9	26A02020	BALLAST PLATE	1
10	26A98045	4-40 HEX NUT	11
11	26A98064	4-40 0.625" BUTTON HEAD BOLT	6
12	26A98041	4-40 0.3125" BUTTON HEAD BOLT	5
13	26A98039	4-40 HEAT SET INSERT	18
14	26A98054	00-90 0.5" ROUND HEAD BOLT, BRASS	6
15	26A98052	00-90 HEX NUT, BRASS	9
16	26A98053	00-90 0.375" ROUND HEAD BOLT	3
17	26A98040	4-40 0.25" BUTTON HEAD BOLT	3
18	26A98046	4-40 0.75" BUTTON HEAD BOLT	2
19	26A02036	BOOST CONVERTER MOUNT	6
20	26A98032	BOOST CONVERTER, 5V OUT	6
21	26A98055	4-40 0.1875" BUTTON HEAD BOLT	6
22	26A02037	CAMERA HOLDER	3
23	26A02038	CAMERA MOUNT	3

1. THIS SHEET SHOWS THE MAIN COMPARTMENT SUBASSEMBLY OMITTING THE CAMERA SHIELDS, WHICH ARE INSTALLED LATER

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°

SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 6 OF 6

CASE ROCKET TEAM

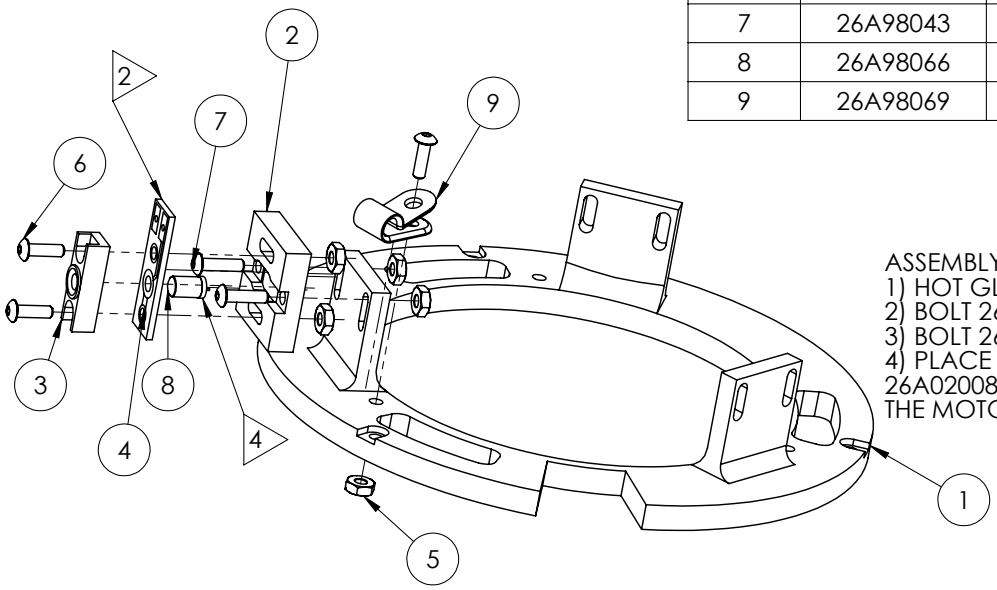
Case Western Reserve University

TITLE:
CAMERA MAIN COMPARTMENT SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:	
A	2/3/2026	R. PAPPALARDO	
MATERIAL:		PART #:	REV:
		26A02013	E

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ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A02008	LOWER CAMERA E-BAY UPPER BULKHEAD	1
2	26A02025	SCREW SWITCH MOUNTING PLATE	1
3	26A02024	SCREW SWITCH COVER	1
4	26A98004	SCREW SWITCH	1
5	26A98045	4-40 HEX NUT	5
6	26A98042	4-40 0.375" BUTTON HEAD BOLT	3
7	26A98043	4-40 0.4375" BUTTON HEAD BOLT	2
8	26A98066	RED LED	1
9	26A98069	0.1875" ID NYLON P-CLAMP	1



ASSEMBLY INSTRUCTIONS:
1) HOT GLUE 26A98066 ONTO 26A02025(SEMI-PERMANENT)
2) BOLT 26A98004 AND 26A02024 ONTO 26A02025
3) BOLT 26A02025 ONTO 26A02008
4) PLACE ALL WIRES IN 26A98069, BOLT 26A98069 ONTO 26A02008, AND ENSURE NO WIRES WILL INTERFERE WITH THE MOTOR

1. QUANTITY 1
2. THE SCREW SWITCH POSITION IS ADJUSTABLE +/- 0.125", ADJUST TO ALIGN WITH THE HOLES DRILLED IN THE BODY TUBE
3. THIS ONLY SHOWS ONE SET OF COMPONENTS, THE FULL ASSEMBLY AND BOM IS ON THE NEXT SHEET
4. THE LED IS HOT-GLUED TO 26A02025, ALL OTHER CONNECTIONS ARE BOLTED

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

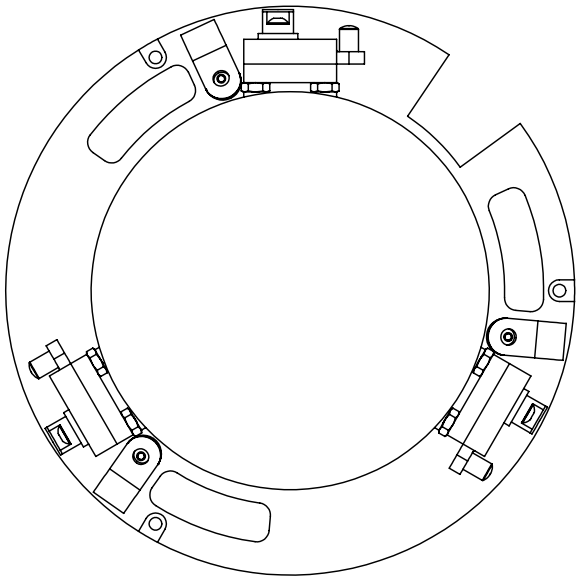
SHEET 1 OF 2

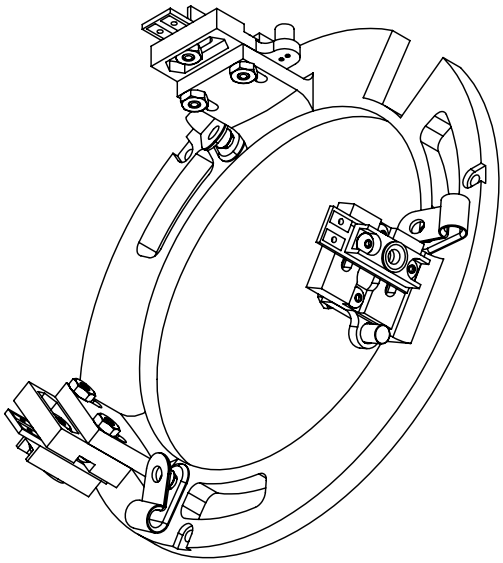
CASE ROCKET TEAM
Case Western Reserve University

TITLE:
CAMERA UPPER BULKHEAD SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	1/19/2026	R. PAPPALARDO

MATERIAL:	PART #:	REV:
	26A02014	E





ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A02008	LOWER CAMERA E-BAY UPPER BULKHEAD	1
2	26A02025	SCREW SWITCH MOUNTING PLATE	3
3	26A02024	SCREW SWITCH COVER	3
4	26A98004	SCREW SWITCH	3
5	26A98045	4-40 HEX NUT	15
6	26A98042	4-40 0.375" BUTTON HEAD BOLT	9
7	26A98043	4-40 0.4375" BUTTON HEAD BOLT	6
8	26A98066	RED LED	3
9	26A98069	0.1875" ID NYLON P-CLAMP	3

ASSEMBLY INSTRUCTIONS:
1) REPEAT PREVIOUS INSTRUCTIONS THREE TIMES TOTAL
2) ADJUST 26A98004 POSITION AS NECESSARY TO ALIGN WITH THE HOLES IN THE BODY TUBE

1. QUANTITY 1

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 2 OF 2

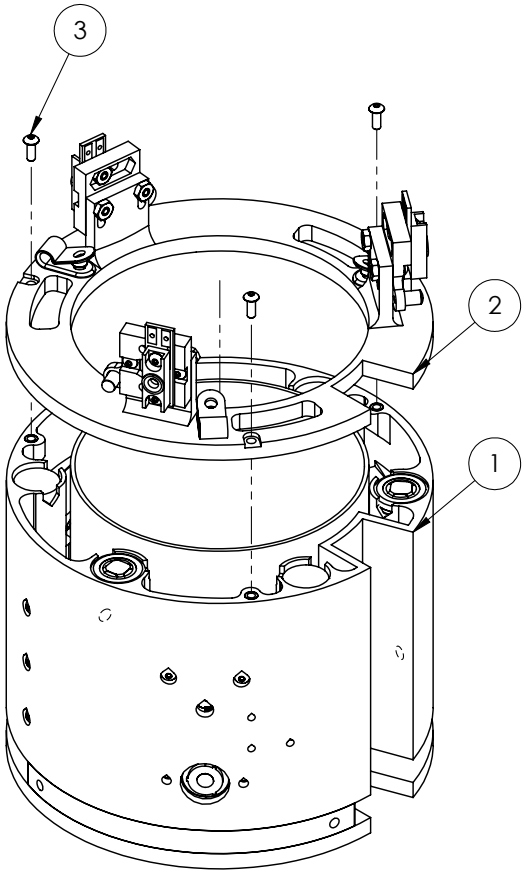
CASE ROCKET TEAM
Case Western Reserve University

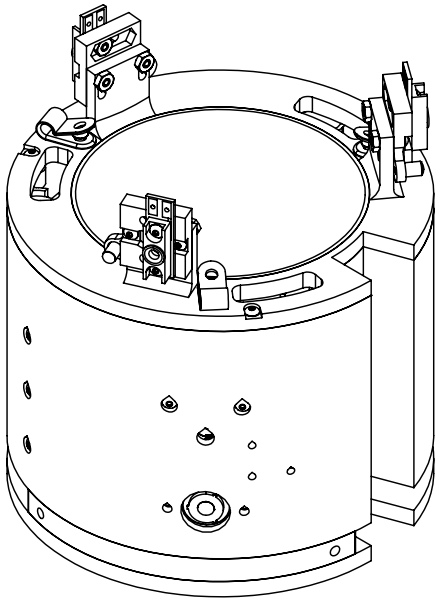
TITLE:
CAMERA UPPER BULKHEAD SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	1/19/2026	R. PAPPALARDO

MATERIAL:	PART #:	REV:
	26A02014	E

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A02013	CAMERA MAIN COMPARTMENT SUBASSEMBLY	1
2	26A02014	CAMERA UPPER BULKHEAD SUBASSEMBLY	1
3	26A98041	4-40 0.3125" BUTTON HEAD BOLT	3





ASSEMBLY INSTRUCTIONS:
1) BOLT 26A02014 INTO 26A02013

1. QUANTITY 1
2. BEFORE FINAL INSTALLATION, MAKE SURE THAT ALL WIRES ARE CONTAINED IN THE MAIN COMPARTMENT OR THE P-CLAMP, AND CAN'T INTERFERE WITH THE MOTOR

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

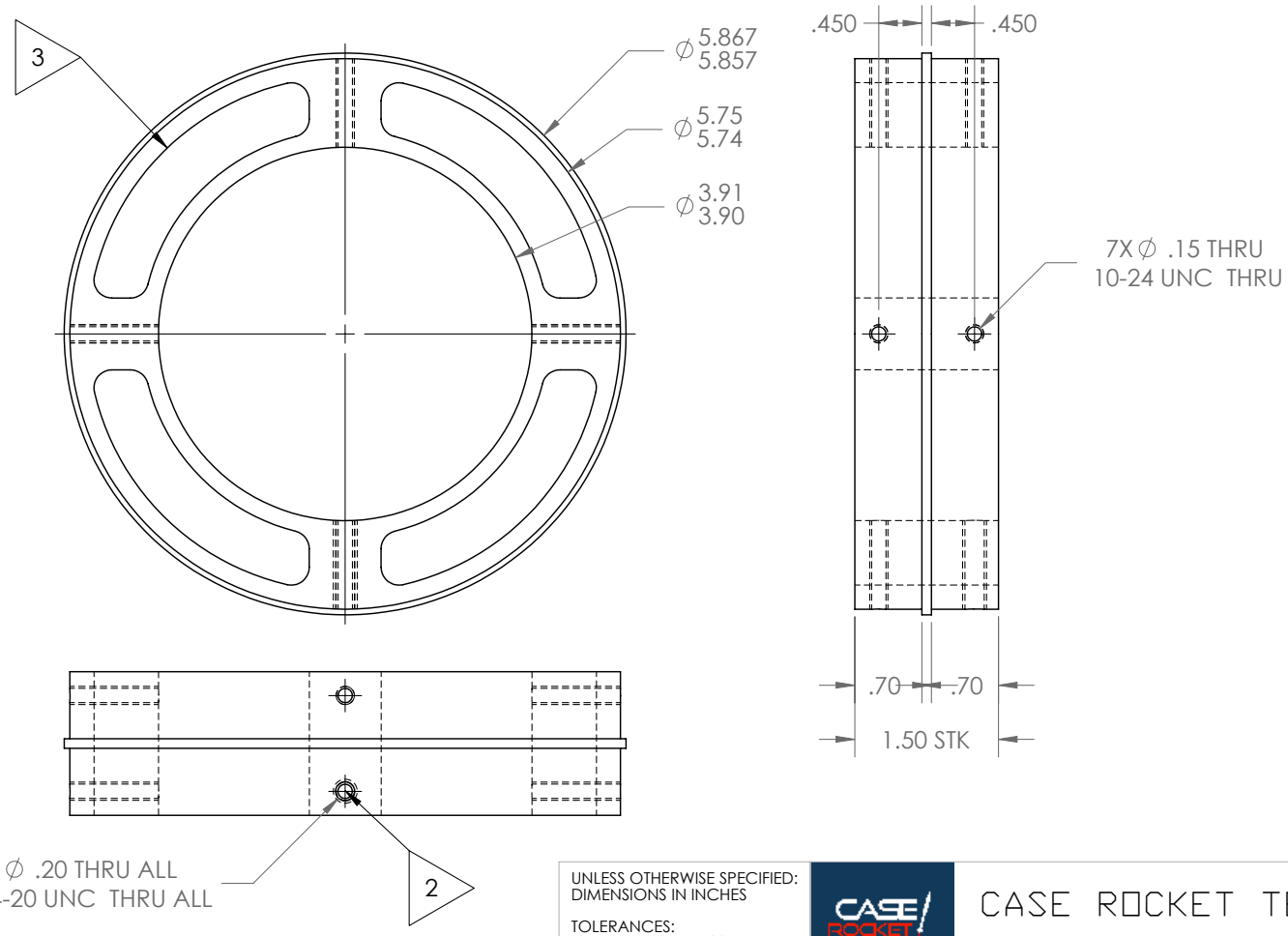
CASE ROCKET TEAM
Case Western Reserve University

TITLE: LOWER CAMERA E-BAY ASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	1/19/2026	R. PAPPALARDO

MATERIAL:	PART #:	REV:
	26A02015	E

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1. QUANTITY 1
2. ONLY ONE HOLE IS 1/4-20, REST ARE 10-24
3. MACHINE TO CAD MODEL
4. USE BLANK 26A96036

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

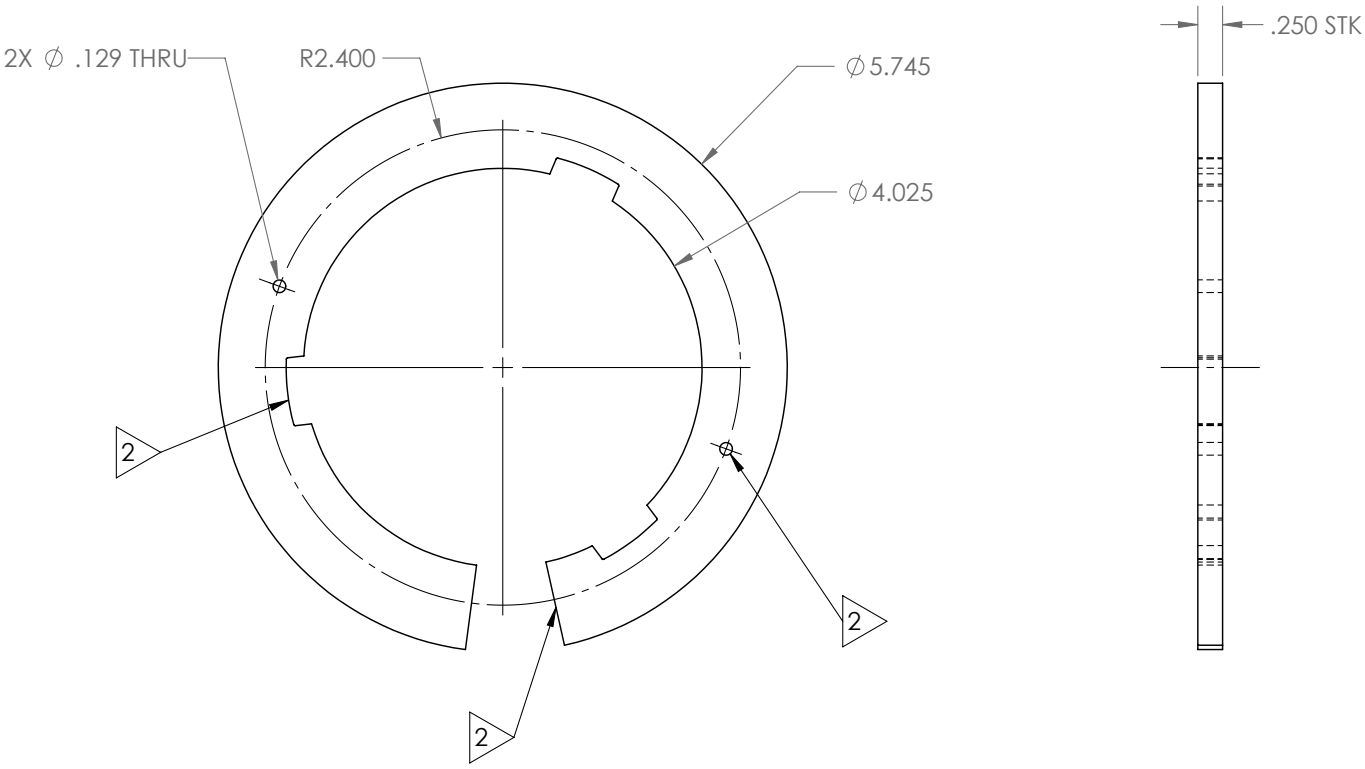
SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: INTERFACE CENTERING RING

SIZE:	DATE:	DRAWN BY:	
A	1/20/2026	J. TAN	
MATERIAL:		PART #:	REV:
6061-T6		26A02016	F



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: BALLAST PLATE

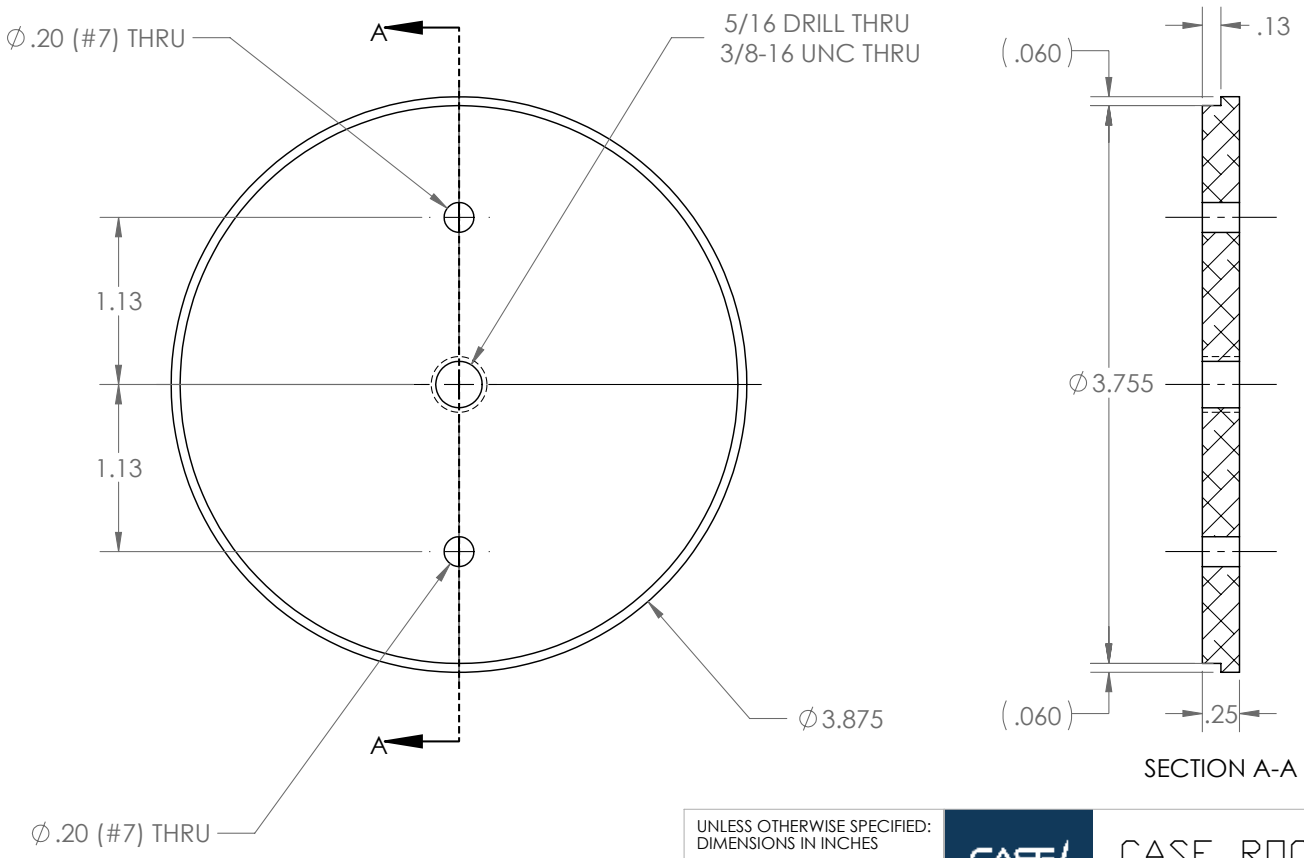
SIZE:	DATE:	DRAWN BY:
A	1/20/2026	A. STONE

MATERIAL:	PART #:	REV:
AISI 1015 STEEL	26A02020	E

1 QUANTITY 1

2 MACHINE TO CAD MODEL

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SECTION A-A

1. QUANTITY: 2
2. USE BLANK 26A96041

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

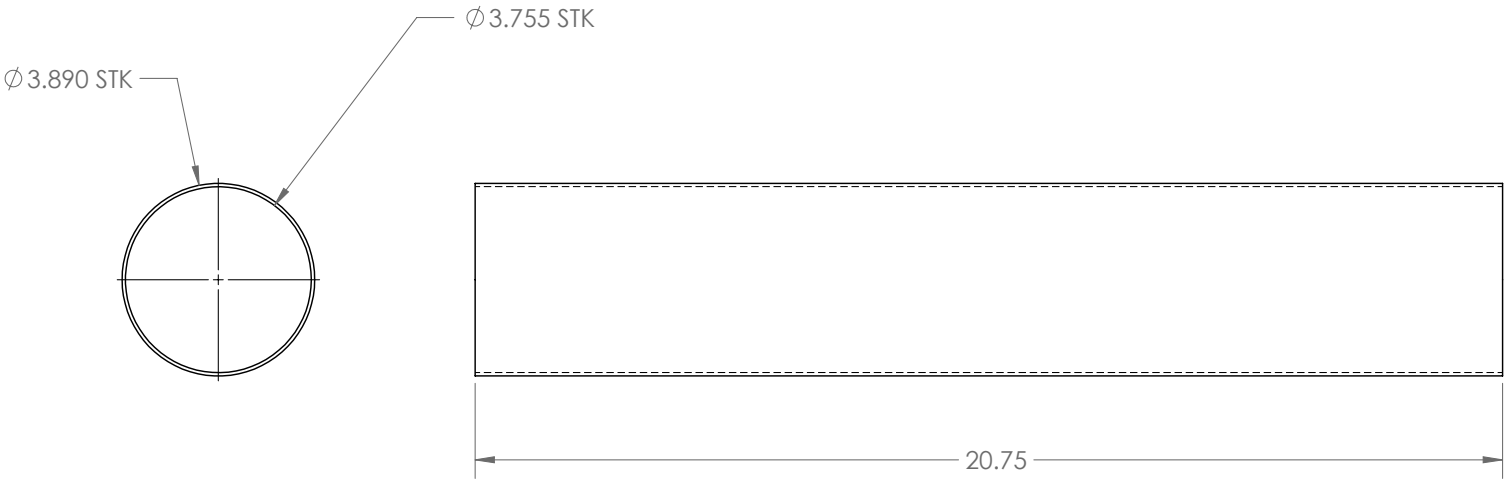
DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: LOW LAUNCH BULKHEAD			
SIZE: A	DATE: 1/20/2026	DRAWN BY: S. CHURELCHULUUN	
MATERIAL: 6061-T6		PART #: 26A02021	REV: I



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: LOW LAUNCH COUPLER TUBE

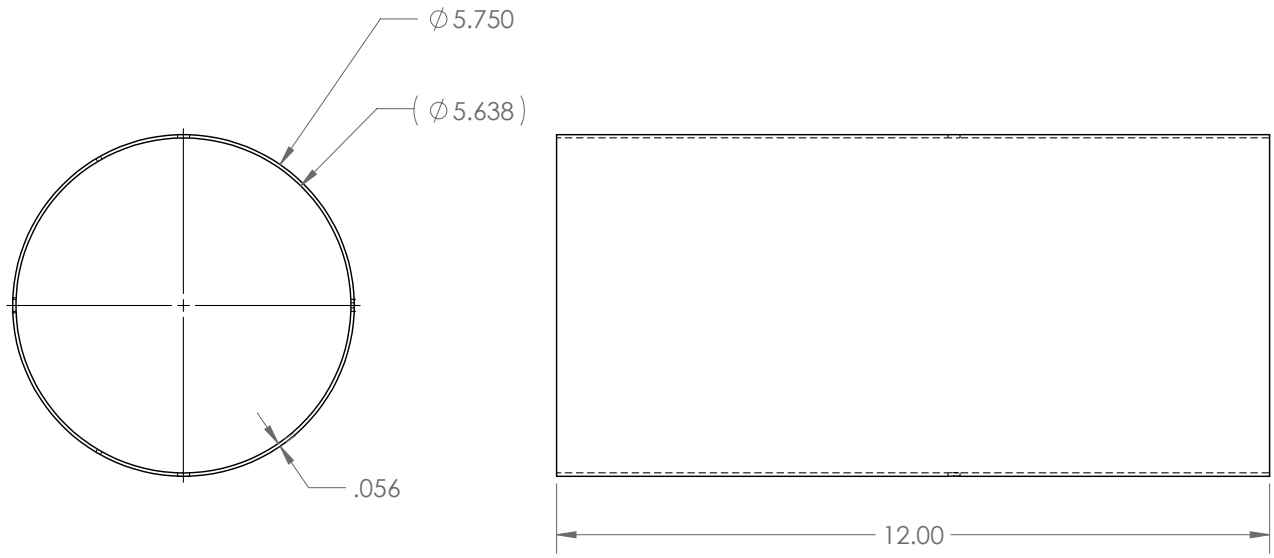
SIZE:	DATE:	DRAWN BY:
A	1/18/2026	S. CHURELCHULUUN

MATERIAL:	PART #:	REV:
G12 FIBER GLASS	26A02022	D

1 QUANTITY: 1

2 FROM WILDMAN

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

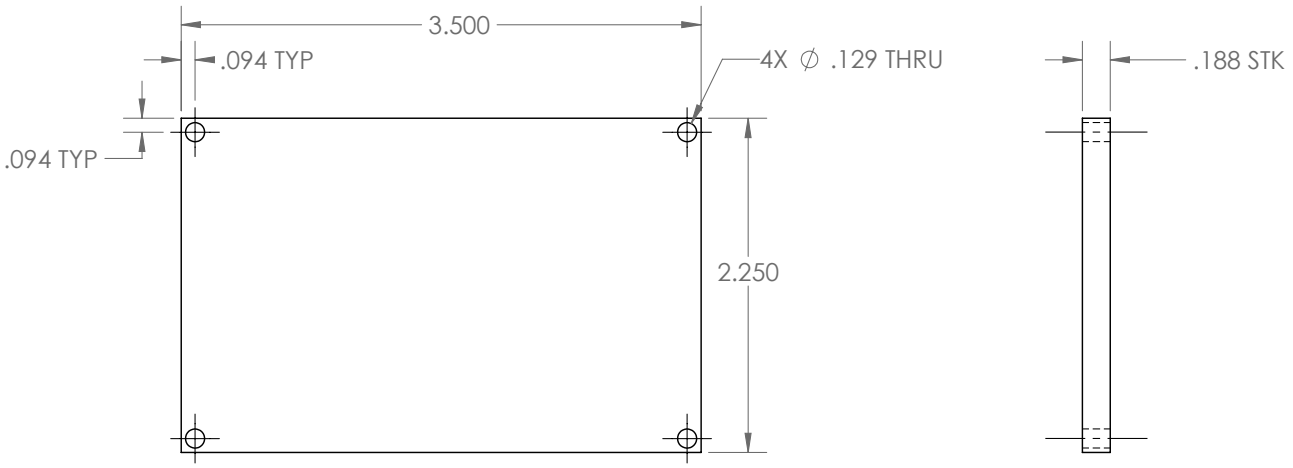
TITLE: MAIN COUPLER

SIZE:	DATE:	DRAWN BY:
A	12/30/2025	Z. KAO

MATERIAL:	PART #:	REV:
3K CF WEAVE	26A02023	F

1. QUANTITY 1

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DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: UPPER CAMERA LID

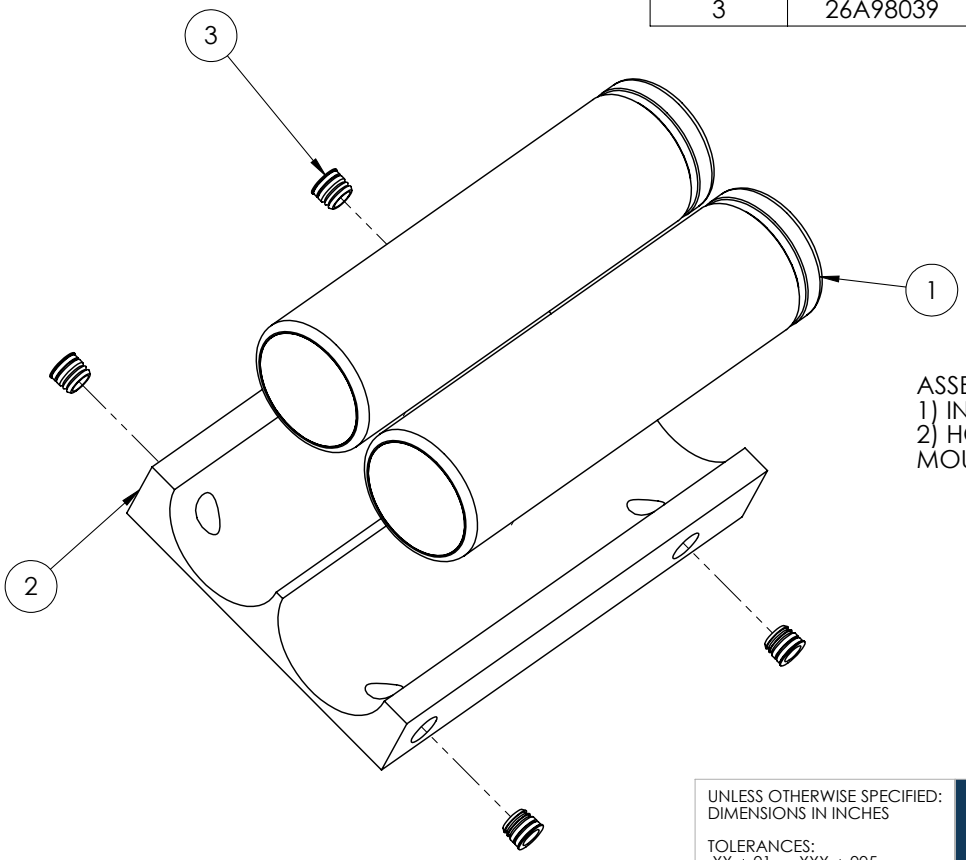
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A	1/21/2026	A. STONE

MATERIAL:	PART #:	REV:
CLEAR PC	26A02028	E

1 QUANTITY 1

SOLIDWORKS Educational Product. For Instructional Use Only.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A98008	18650 LI-ION BATTERY	2
2	26A02026	UPPER CAMERA E-BAY BATTERY MOUNT	1
3	26A98039	4-40 HEAT SET INSERT	4



ASSEMBLY INSTRUCTIONS:
1) INSTALL 4X 26A98039 INTO 26A02026(PERMANENT)
2) HOT GLUE 2X 26A98008 INTO THE BATTERY MOUNT(SEMI-PERMANENT)

1. QUANTITY 1
2. CONNECTIONS ARE NOT PERMANENT

UNLESS OTHERWISE SPECIFIED

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 4

CASE ROCKET TEAM

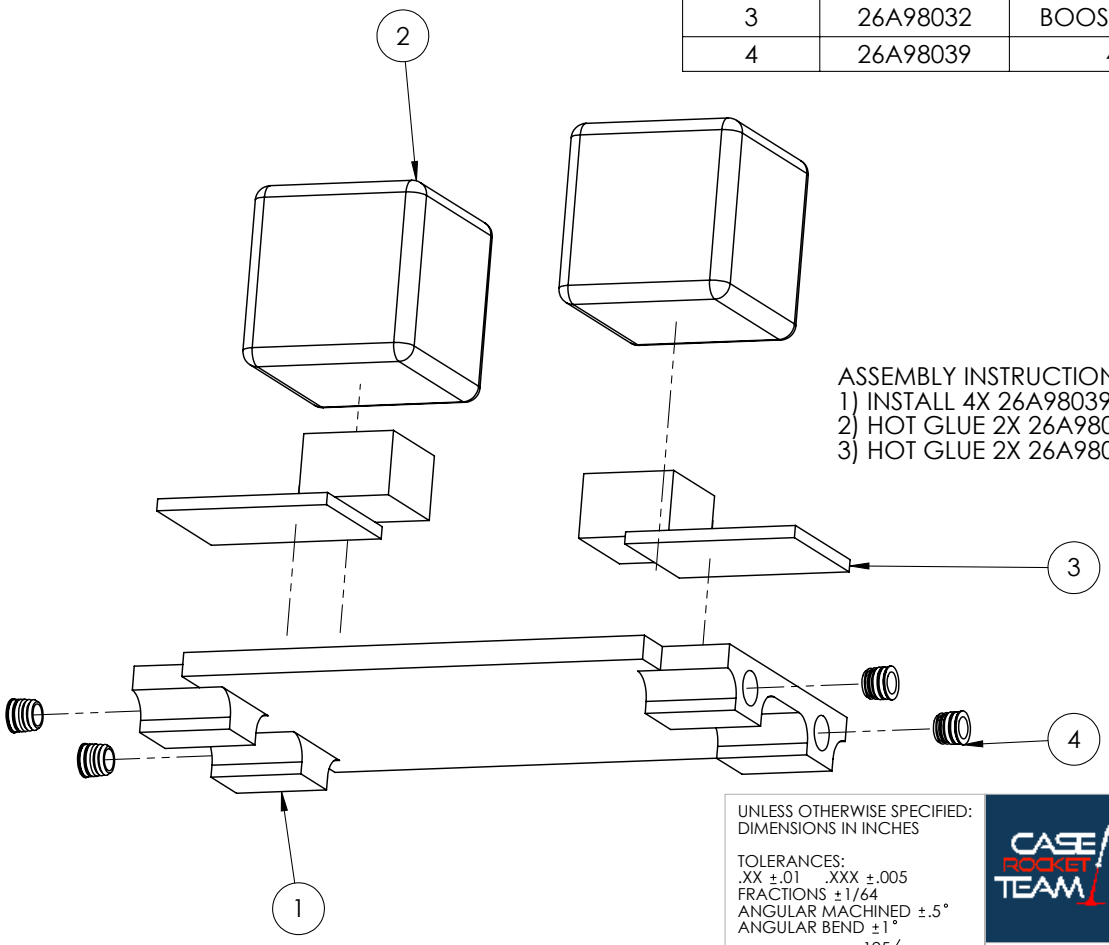
Case Western Reserve University

TITLE: UPPER CAMERA E-BAY ASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	1/19/2026	R. PAPPALARDO

MATERIAL:	PART #:	REV:
	26A02030	E

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A02027	UPPER CAMERA E-BAY INSERT PLATE	1
2	26A98033	SQ11 CAMERA	2
3	26A98032	BOOST CONVERTER, 5V OUTPUT	2
4	26A98039	4-40 HEAT SET INSERT	4



ASSEMBLY INSTRUCTIONS:
1) INSTALL 4X 26A98039 INTO 26A02027(PERMANENT)
2) HOT GLUE 2X 26A98033 ONTO 26A02027(SEMI-PERMANENT)
3) HOT GLUE 2X 26A98032 ONTO 26A02027(SEMI-PERMANENT)

1. QUANTITY 1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 2 OF 4

CASE ROCKET TEAM
Case Western Reserve University

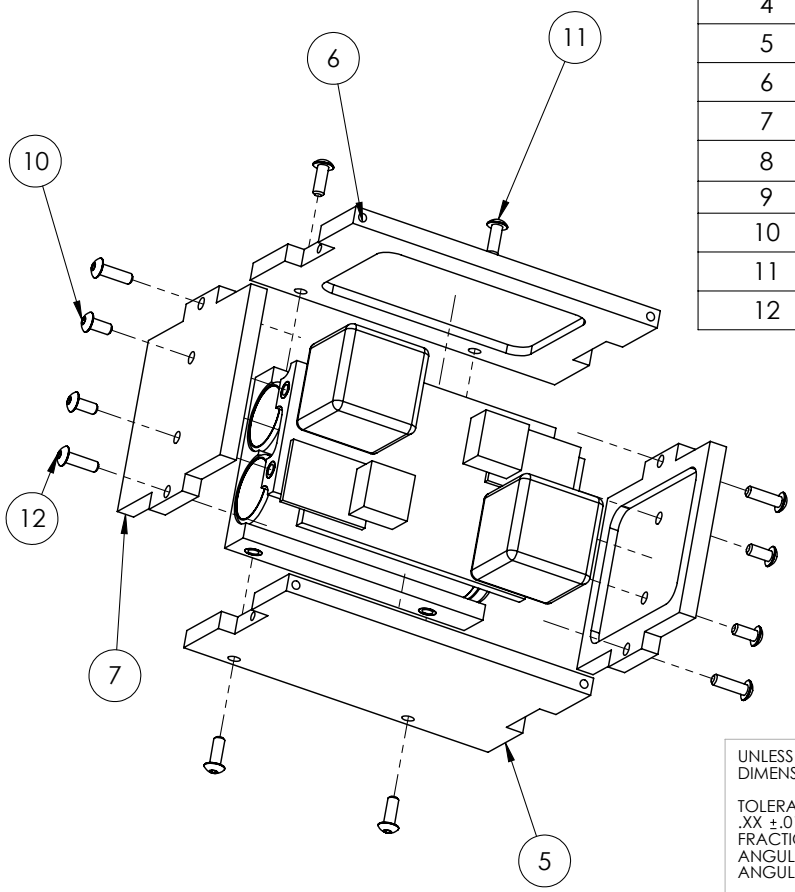
TITLE: UPPER CAMERA E-BAY ASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	1/19/2026	R. PAPPALARDO

MATERIAL:	PART #:	REV:
	26A02030	E

SOLIDWORKS Educational Product. For Instructional Use Only.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A02027	UPPER CAMERA E-BAY INSERT PLATE	1
2	26A98008	18650 LI-ION BATTERY	2
3	26A98033	SQ11 CAMERA	2
4	26A98032	BOOST CONVERTER, 5V OUTPUT	2
5	26A02034	UPPER CAMERA E-BAY BIG PLATE A	1
6	26A02034	UPPER CAMERA E-BAY BIG PLATE B	1
7	26A02035	UPPER CAMERA E-BAY LITTLE PLATE	2
8	26A02026	UPPER CAMERA E-BAY BATTERY MOUNT	1
9	26A98039	4-40 HEAT SET INSERT	8
10	26A98040	4-40 0.25" BUTTON HEAD BOLT	4
11	26A98041	4-40 0.3125" BUTTON HEAD BOLT	4
12	26A98042	4-40 0.375" BUTTON HEAD BOLT	4



ASSEMBLY INSTRUCTIONS:
1) BOLT 2X 26A02035 INTO 26A02027
2) BOLT 2X 26A02034 INTO 26A02026

1. QUANTITY 1
2. BALLOONS ARE ONLY APPLIED TO PARTS WHICH ARE NEW ON THIS SHEET

SOLIDWORKS Educational Product. For Instructional Use Only.

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

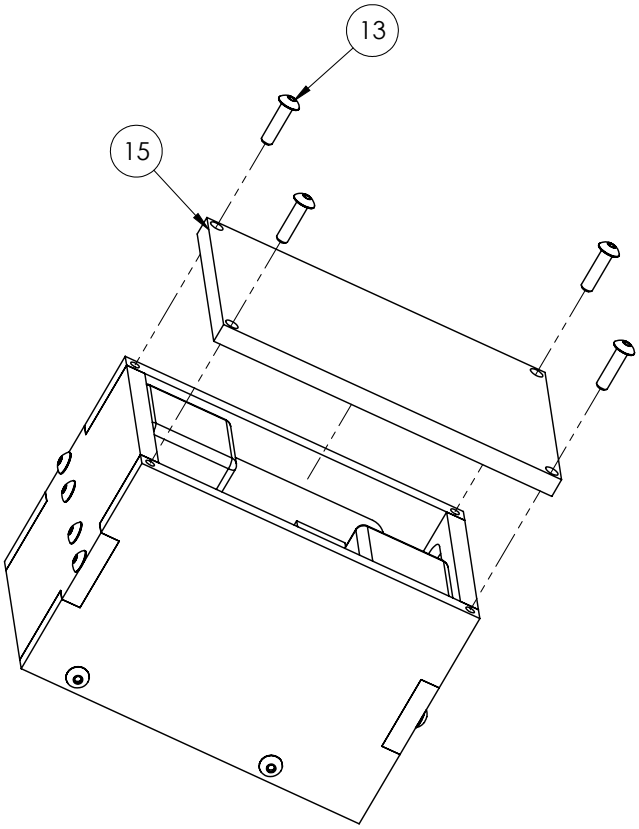
SHEET 3 OF 4

CASE ROCKET TEAM
Case Western Reserve University

TITLE: UPPER CAMERA E-BAY ASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	1/19/2026	R. PAPPALARDO

MATERIAL:	PART #:	REV:
	26A02030	E



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A02027	UPPER CAMERA E-BAY INSERT PLATE	1
2	26A98008	18650 LI-ION BATTERY	2
3	26A98033	SQ11 CAMERA	2
4	26A98032	BOOST CONVERTER, 5V OUTPUT	2
5	26A02034	UPPER CAMERA E-BAY BIG PLATE A	1
6	26A02034	UPPER CAMERA E-BAY BIG PLATE B	1
7	26A02035	UPPER CAMERA E-BAY LITTLE PLATE A	2
8	26A02026	UPPER CAMERA E-BAY BATTERY MOUNT	1
9	26A98039	4-40 HEAT SET INSERT	8
10	26A98040	4-40 0.25" BUTTON HEAD BOLT	4
11	26A98041	4-40 0.3125" BUTTON HEAD BOLT	4
12	26A98042	4-40 0.375" BUTTON HEAD BOLT	4
13	26A98043	4-40 0.4375" BUTTON HEAD BOLT	4
14	26A02028	UPPER CAMERA E-BAY LID	1

ASSEMBLY INSTRUCTIONS:
1) BOLT 26A02028 INTO 26A02034
2) ENSURE ALL BOLTS ARE TIGHT, AND NO VISIBLE GAPS IN THE WALLS ARE PRESENT

1. QUANTITY 1
2. BALLOONS ARE ONLY APPLIED TO PARTS WHICH ARE NEW ON THIS SHEET

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DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

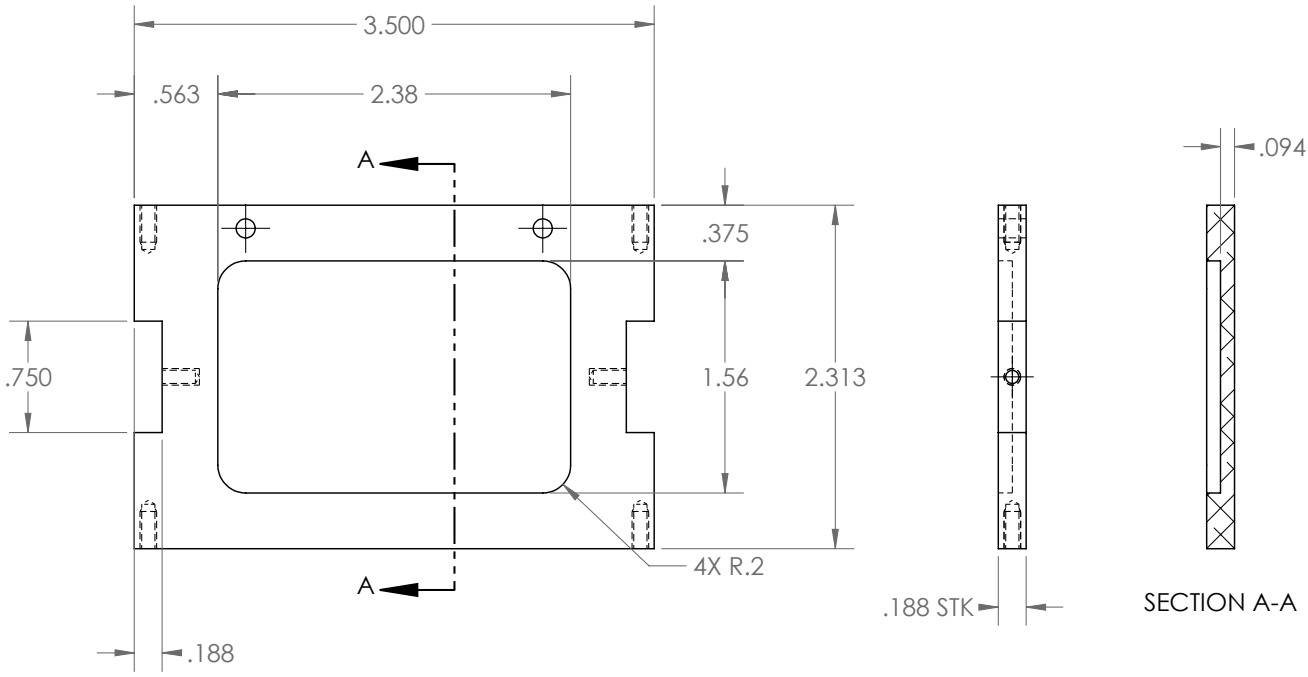
SHEET 4 OF 4

CASE ROCKET TEAM
Case Western Reserve University

TITLE: UPPER CAMERA E-BAY ASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	1/19/2026	R. PAPPALARDO

MATERIAL:	PART #:	REV:
	26A02030	E



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 2

CASE ROCKET TEAM

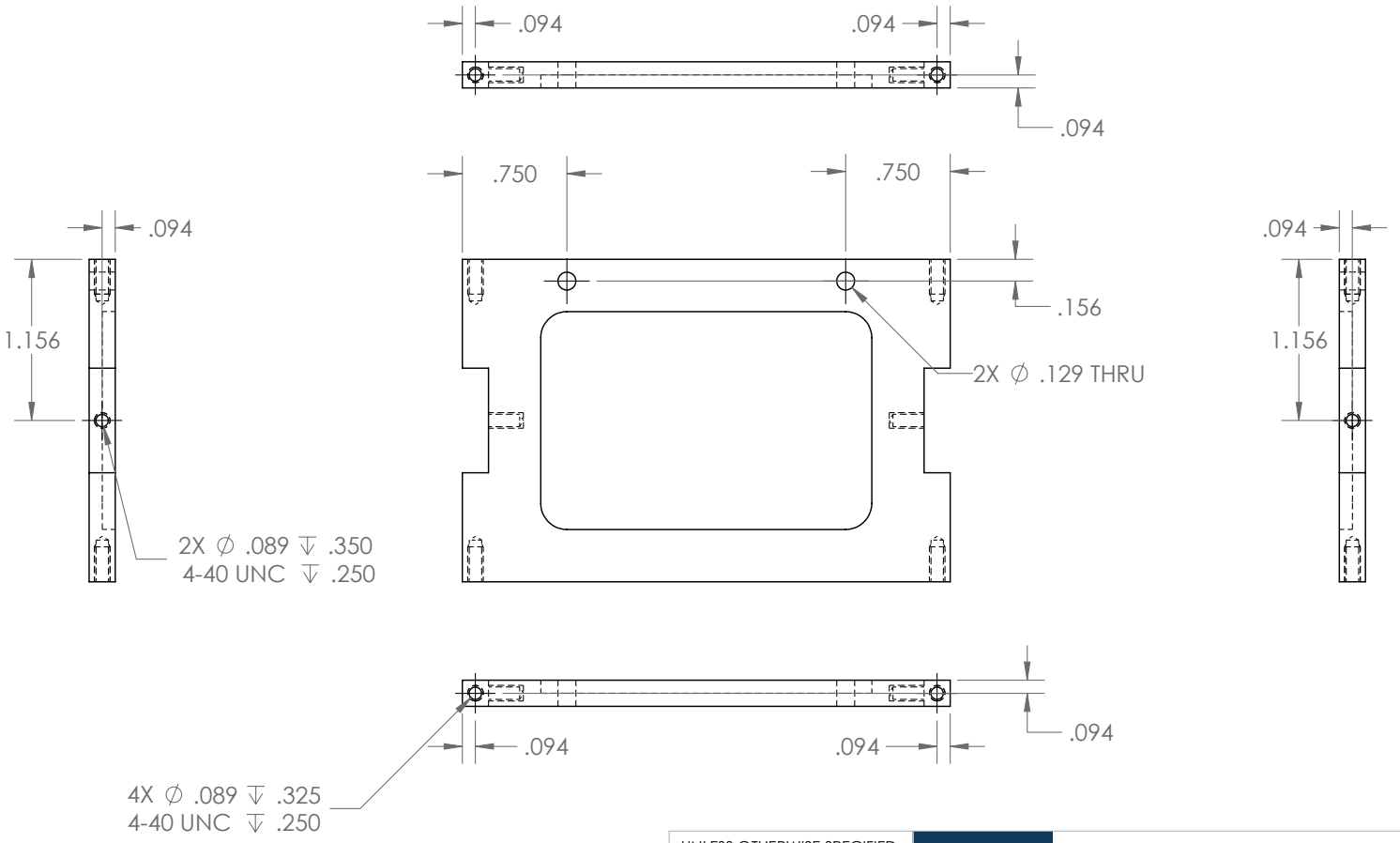
Case Western Reserve University

TITLE: UPPER CAMERA E-BAY BIG PLATE

SIZE:	DATE:	DRAWN BY:	
A	12/30/2025	Z. KAO	
MATERIAL:		PART #:	REV:
6061-T6		26A02034	E

1. QUANTITY 2
2. USE BLANK 26A96039

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 2

CASE ROCKET TEAM

Case Western Reserve University

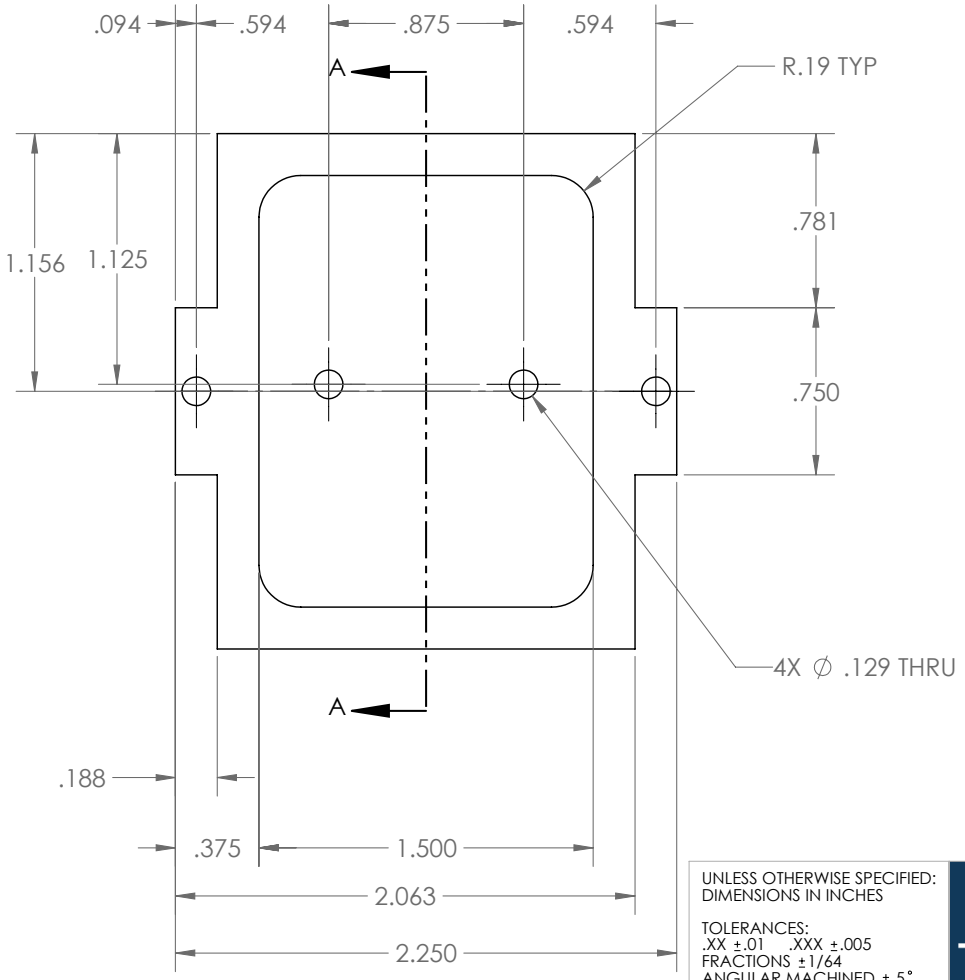
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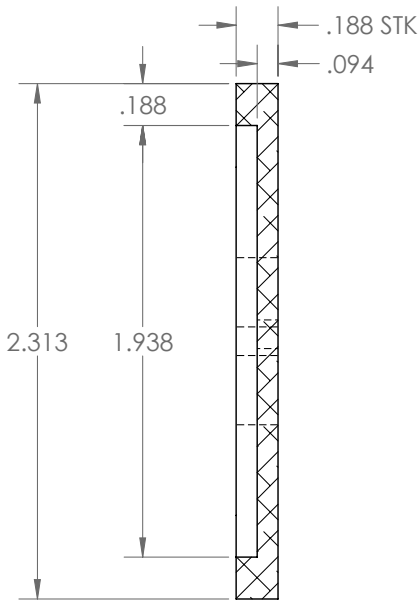
SIZE:	DATE:	DRAWN BY:
A	12/30/2025	Z. KAO

MATERIAL:	PART #:	REV:
6061-T6	26A02034	E

1. QUANTITY 2
2. USE BLANK 26A96039

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SECTION A-A

1. QUANTITY 2
2. USE BLANK 26A96039

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

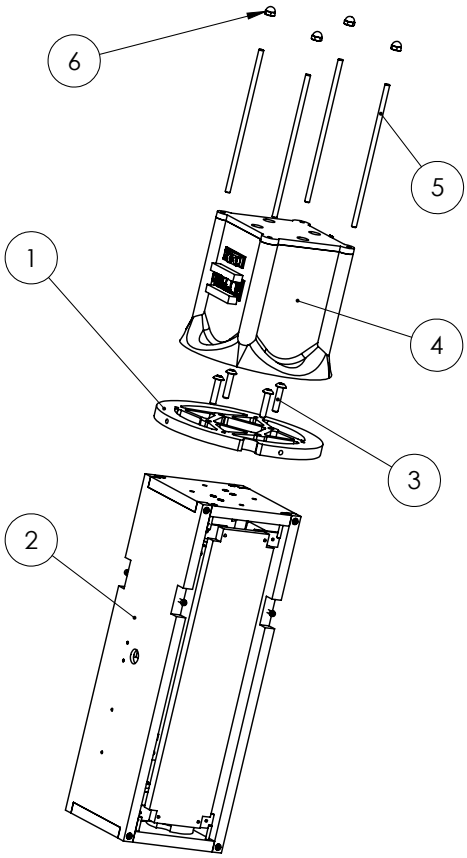
SHEET 1 OF 1

CASE ROCKET TEAM
Case Western Reserve University

TITLE: UPPER CAMERA E-BAY LITTLE PLATE			
SIZE: A	DATE: 12/30/2025	DRAWN BY: Z. KAO	
MATERIAL: 6061-T6		PART #: 26A02035	REV: G

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ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A02004	PAYLOAD/MEASUREMENTS BULKHEAD	1
2	26B000	PAYLOAD ASSEMBLY	1
3	26A98073	10-24 7/8" BUTTON HEAD BOLT	4
4	26D00001	MEASUREMENTS EBAY ASSEMBLY	1
5	26A98059	8-32 5" THREADED ROD	4
6	26A98060	8-32 CAP NUT	4



ASSEMBLY INSTRUCTIONS:
1) SECURE 26B000 ONTO 26A02004 USING 26A98073 WITH BLUE LOCTITE
2) THREAD 26A98059 INTO 26A02004 WITH BLUE LOCTITE
3) PLACE 26D00001 OVER 26A98059 AND ONTO 26A02004
4) SCREW 26A98060 ONTO 26A98059

1 QUANTITY 1

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM
Case Western Reserve University

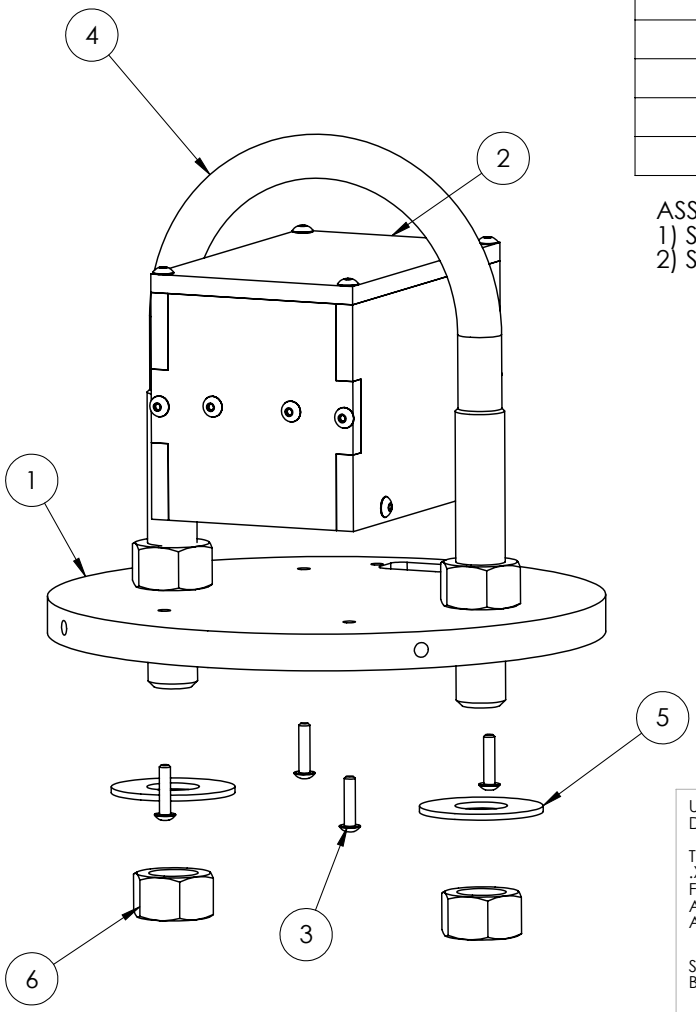
TITLE: PAYLOAD/MEASUREMENTS SUBASSEMBLY

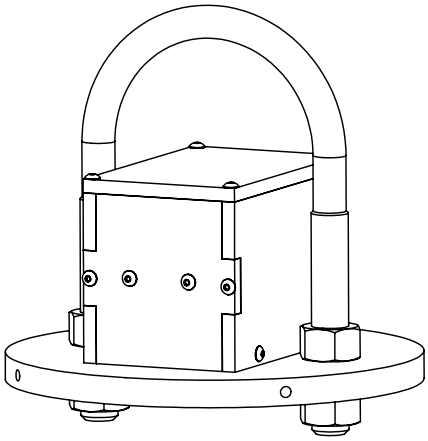
SIZE:	DATE:	DRAWN BY:
A	1/31/2026	R. SHEPHERD

MATERIAL:	PART #:	REV:
	26A02040	D

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A02003	RECOVERY BULKHEAD	1
2	26A02030	UPPER CAMERA EBAY SUBASSEMBLY	1
3	26A98047	4-40 0.5" BUTTON HEAD BOLT	4
4	26A98025	1/2"-13 U-BOLT	1
5	26A98085	1/2"-13 WASHER	2
6	26A98086	1/2"-13 NUT	4

ASSEMBLY INSTRUCTIONS:
1) SECURE 26A02030 ONTO 26A02003 WITH 26A98047
2) SCREW 26A98025 ONTO 26A02003 USING 26A98085 and 26A98086





1 QUANTITY 1

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DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

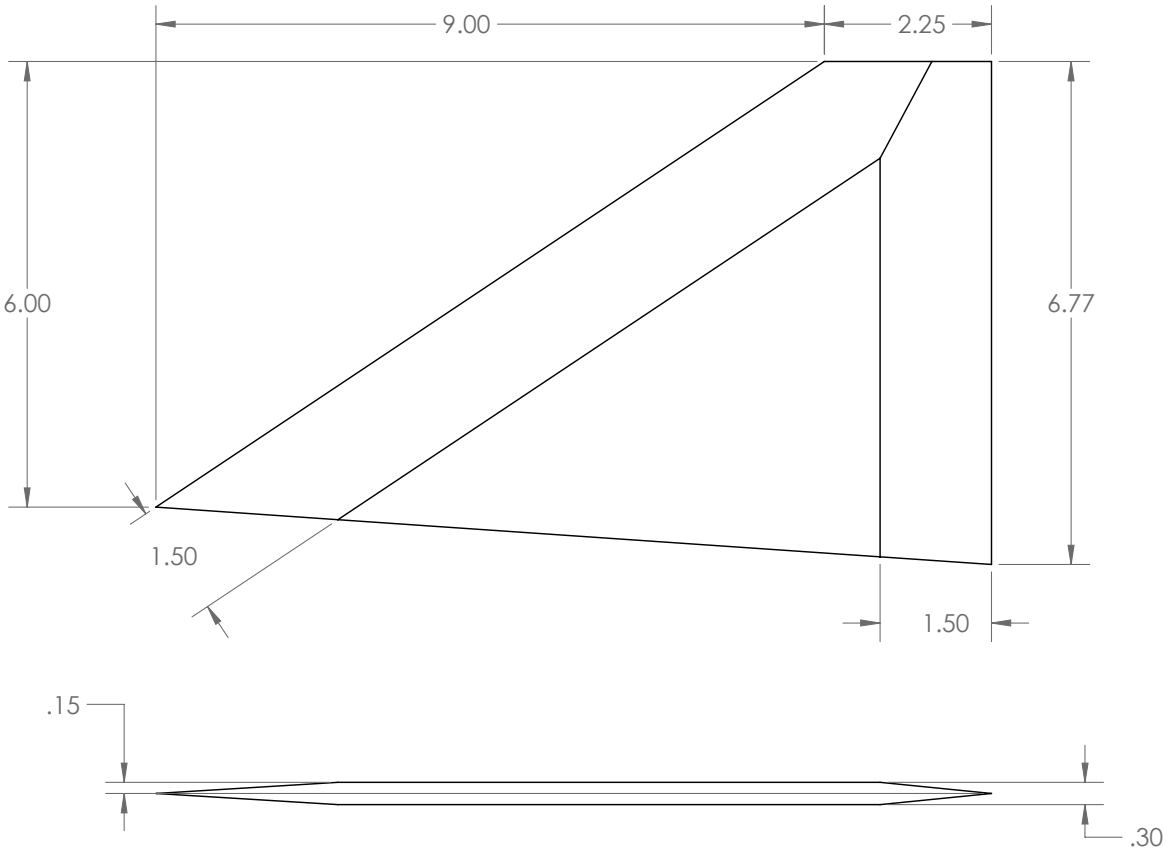
SHEET 1 OF 1

CASE ROCKET TEAM
Case Western Reserve University

TITLE:
RECOVERY BULKHEAD SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	1/31/2026	R. SHEPHERD

MATERIAL:	PART #:	REV:
	26A02041	E



1. QUANTITY 4
2. FOR MANUFACTURING REFER TO INTERNAL REFERNCE DOCUMENT
3. MADE OUT OF FIBERGLASS CORE WITH CARBON FIBER LAID UP ON BOTH SIDES

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

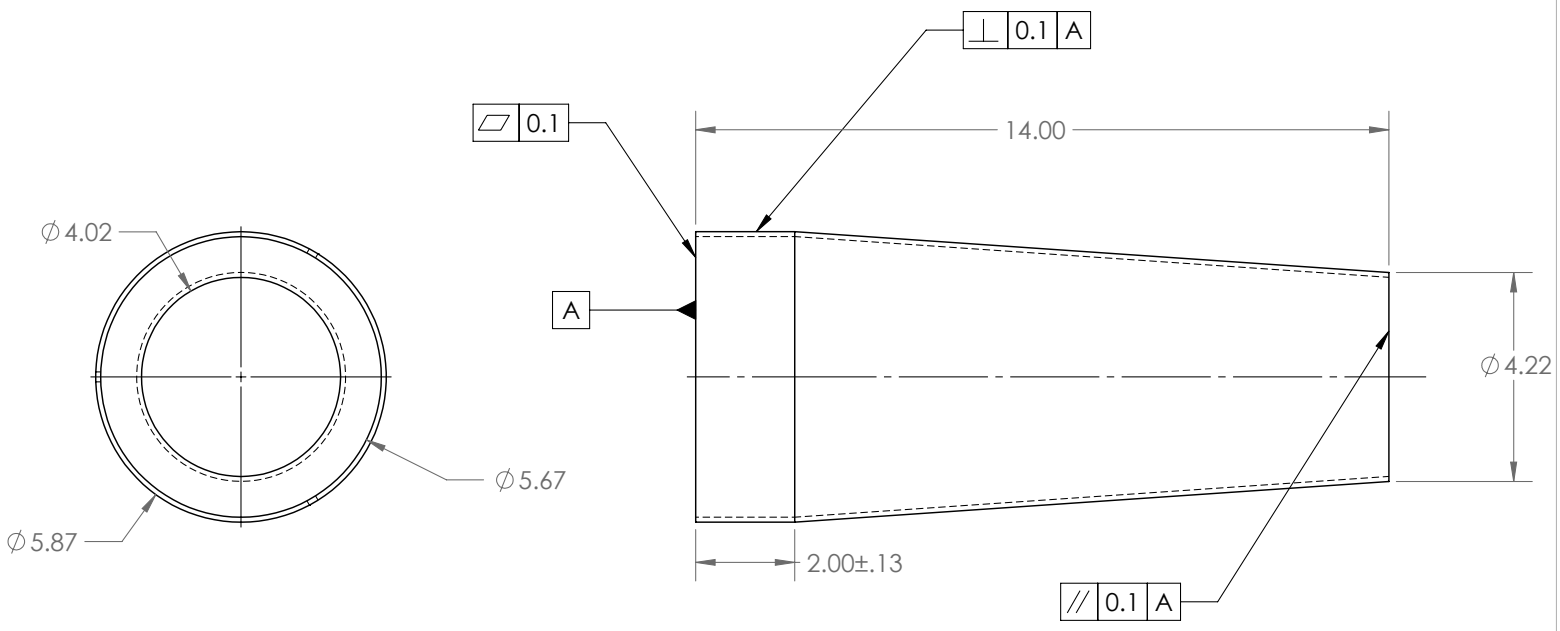
DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: FIN		
SIZE: A	DATE: 1/21/2026	DRAWN BY: K. FIGUEROA
MATERIAL: 3	PART #: 26A03001	REV: E



1. QUANTITY 1
2. LAID UP FOLLOWING INSTRUCTIONS ON INTERNAL REFERENCE DOCUMENT

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DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

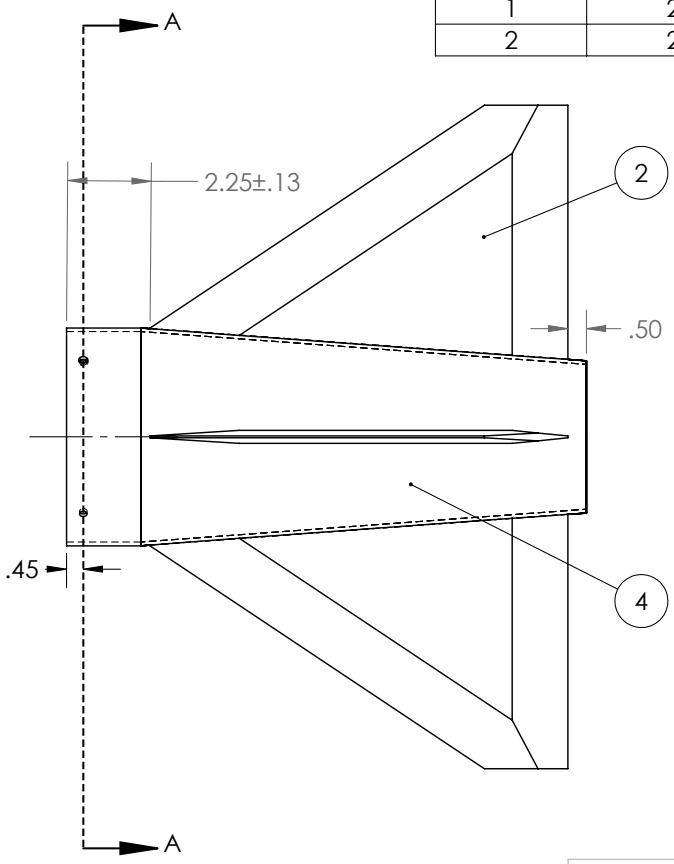
SHEET 1 OF 1

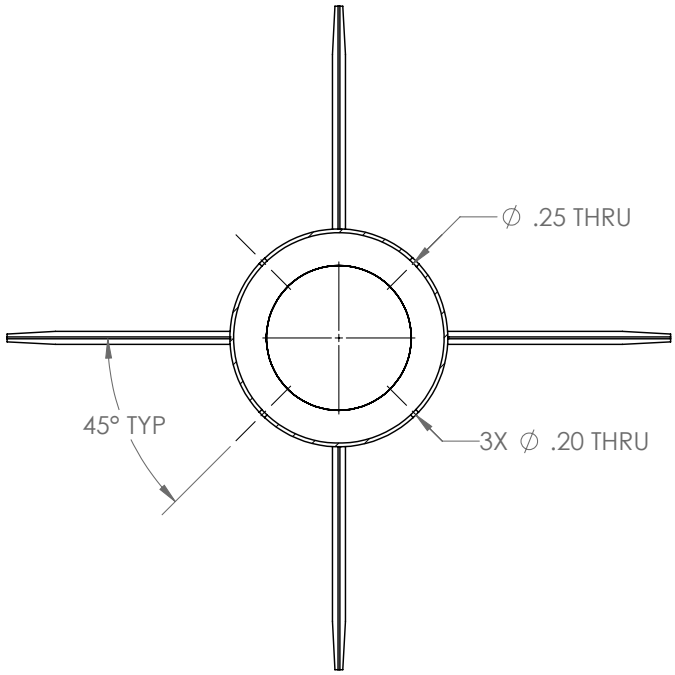
CASE ROCKET TEAM

Case Western Reserve University

TITLE: BOATTAIL			
SIZE: A	DATE: 1/21/2026	DRAWN BY: K. FIGUEROA	
MATERIAL: 6K CARBON FIBER		PART #: 26A03002	REV: E

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A03002	BOATTAIL	1
2	26A03001	FIN	4





SECTION A-A

1. QUANTITY 1
2. TACK FINS AND LAY FILLETS ACCORDING TO INTERNAL REFERENCE DOCUMENTS

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

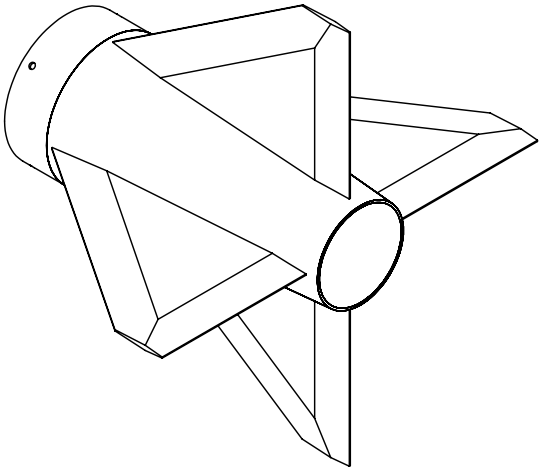
CASE ROCKET TEAM
Case Western Reserve University

TITLE: FINCAN SUBASSEMBLY

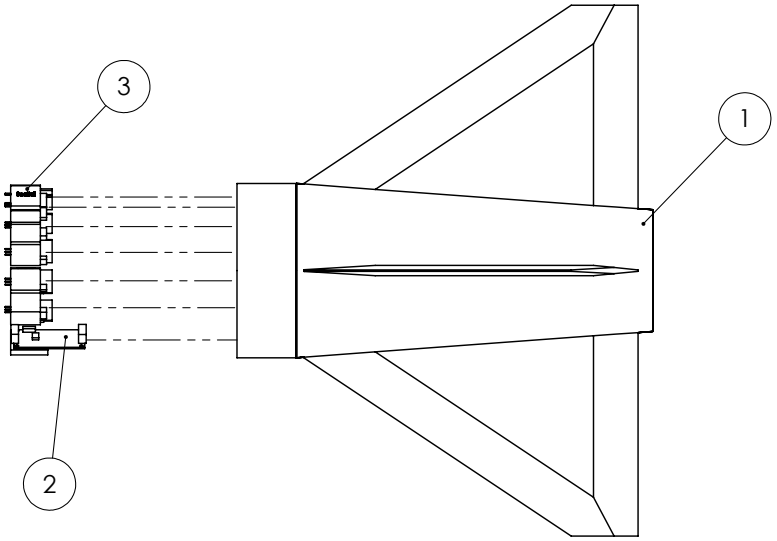
SIZE:	DATE:	DRAWN BY:
A	1/22/2026	K. FIGUEROA

MATERIAL:	PART #:	REV:
	26A03003	E

SOLIDWORKS Educational Product. For Instructional Use Only.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A03003	FINCAN	1
2	26D00004	BOATTAIL ANALOG TO DIGITAL CONVERTER	1
3	26D00003	BOATTAIL STRAIN GAUGE MODULE	6



1. QUANTITY 1
2. ATTACH MEASUREMENTS SYSTEM FOLLOWING INTERNAL REFERENCE DOCUMENT
3. PERFORM TIP TO TIP FOLLOWING INTERNAL REFERENCE DOCUMENT

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 2

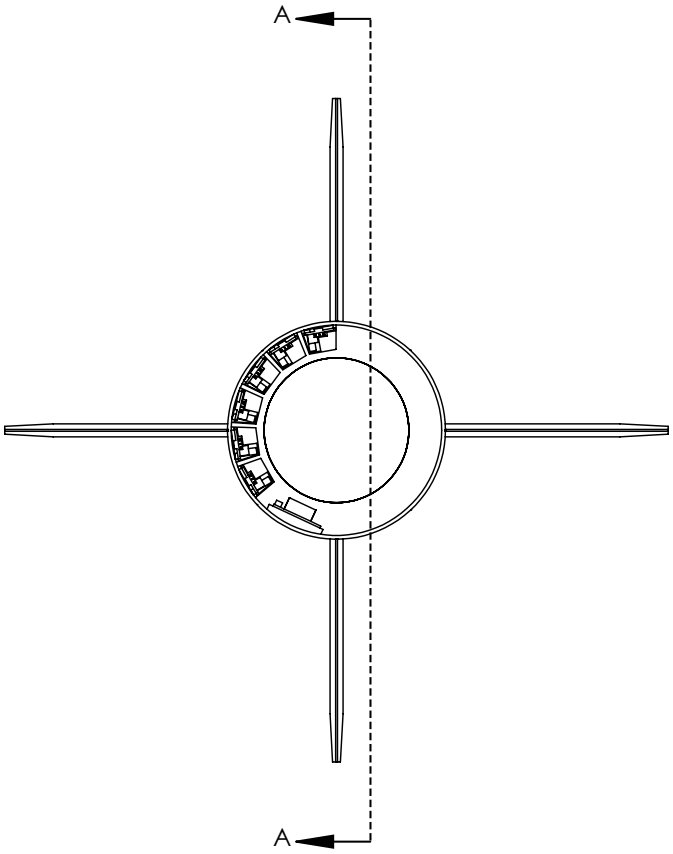
CASE ROCKET TEAM

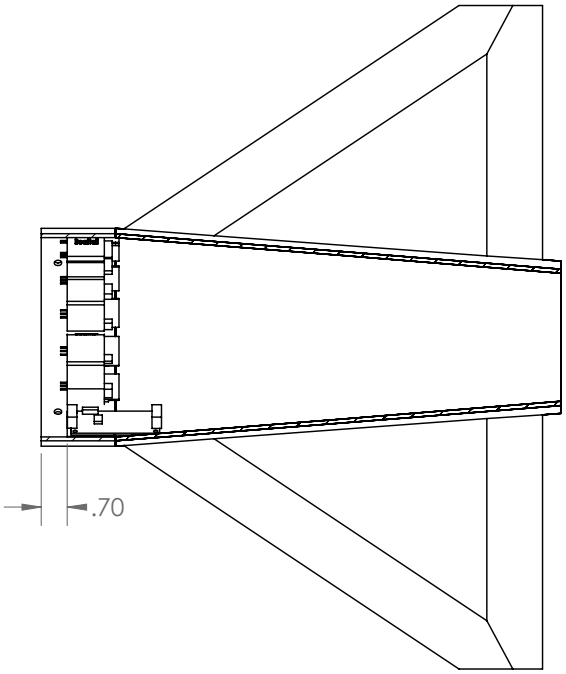
Case Western Reserve University

TITLE: FINCAN SUBASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	2/2/2026	A. STONE

MATERIAL:	PART #:	REV:
	26A03004	F





SECTION A-A

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 2 OF 2

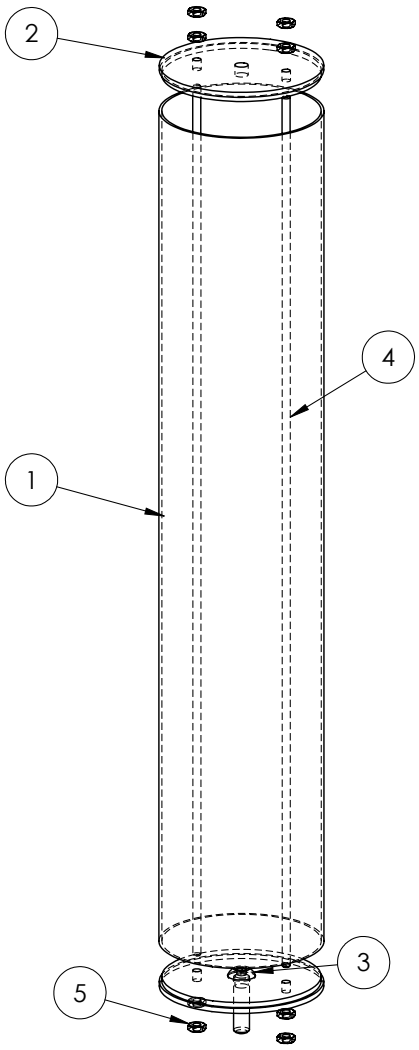
CASE ROCKET TEAM

Case Western Reserve University

TITLE: FINCAN SUBASEMBLY

SIZE:	DATE:	DRAWN BY:	
A	2/2/2026	A. STONE	
MATERIAL:		PART #: 26A03004	REV: F

SOLIDWORKS Educational Product. For Instructional Use Only.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A02022	LOW LAUNCH COUPLER TUBE	1
2	26A02021	LOW LAUNCH COUPLER BULKHEAD	2
3	26A98023	3/8-16 X 1.375" BUTTON HEAD BOLT	1
4	26A98067	LOW LAUNCH COUPLER THREADED ROD	2
5	26A98057	10-24 X 0.125" HEX NUT	8

ASSEMBLY INSTRUCTIONS:

1. THREAD 26A98023 INTO LOWER 26A02021 USING RED LOCTITE
2. THREAD 2X 26A98057 EACH ONTO 2X 26A98067 ~0.125" FROM END
3. SLIDE 2X 26A98067 THROUGH HOLES OF LOWER 26A02021, WITH SIDE WITH NUTS SAME AS THREAD OF 26A98023
4. SLIDE 26A02022 OVER 26A98067, ENSURING LIP OF LOWER 26A02021 IS ENGAGED WITH INNER DIAMETER OF 26A02022
5. ADD UPPER 26A02021 TO OPPOSITE SIDE OF 26A02022, PUTTING BOTH INSTANCES OF 26A98057 THROUGH RESPECTIVE HOLES OF UPPER 26A02021
6. USE REMAINING 26A98057 TO CLAMP INSTANCES OF 26A02021 TOGETHER

1. QUANTITY 1

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

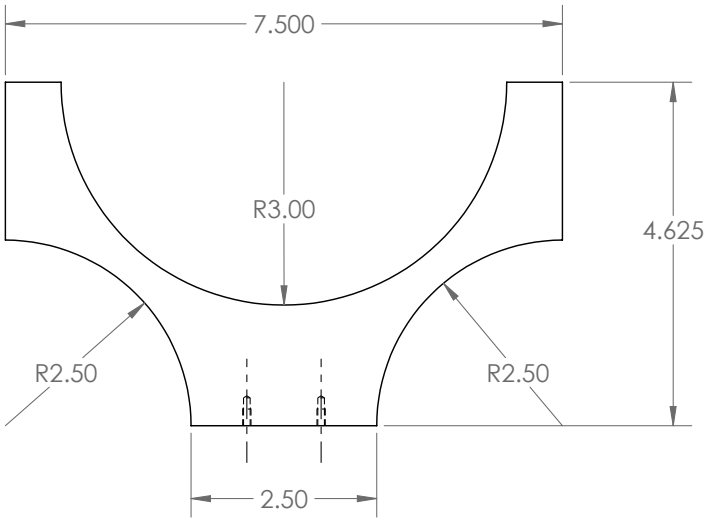
CASE ROCKET TEAM

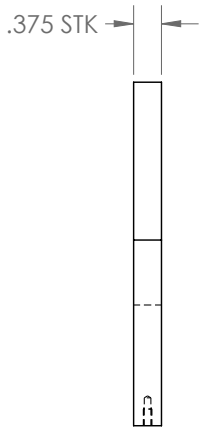
Case Western Reserve University

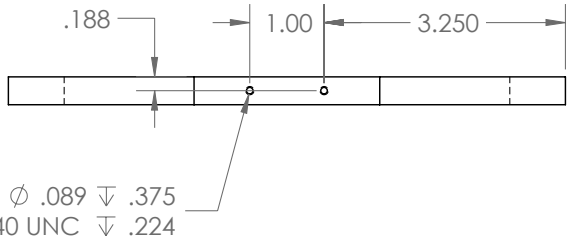
TITLE: LOW LAUNCH COUPLER ASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	1/20/2026	J. TAN

MATERIAL:	PART #:	REV:
	26A04000	F







1. QUANTITY 1
2. USE BLANK 26A96042

SOLIDWORKS Educational Product. For Instructional Use Only.

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

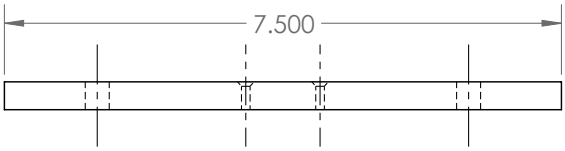
DO NOT SCALE

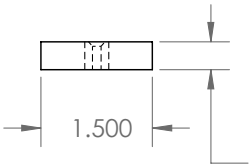
SHEET 1 OF 1

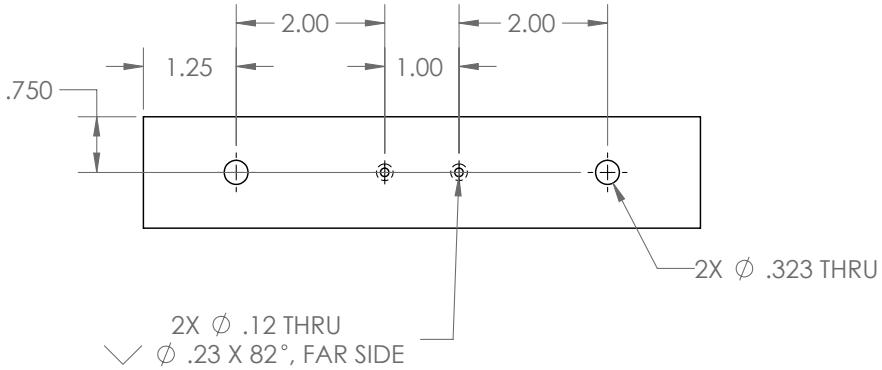
CASE ROCKET TEAM

CASE WESTERN RESERVE UNIVERSITY

TITLE: TUBE HOLE DRILLING JIG HOLDER			
SIZE: A	DATE: 1/1/2026	DRAWN BY: R.DA	QUANTITY: 1
MATERIAL: 6061-T6		PART #: 26A96025	REV: F







1. QUANTITY 1
2. USE BLANK 26A96042

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

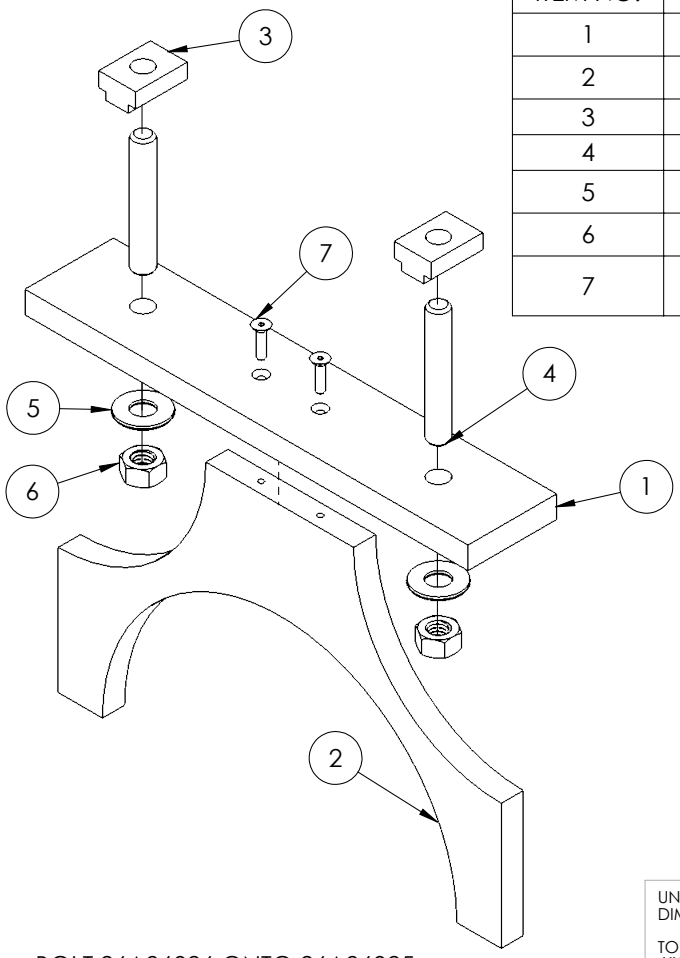
CASE ROCKET TEAM

CASE WESTERN RESERVE UNIVERSITY

TITLE: TUBE HOLE DRILLING JIG BASE			
SIZE: A	DATE: 1/2/2026	DRAWN BY: R.DAI	QUANTITY: 1
MATERIAL: 6061-T6		PART #: 26A96026	REV: F

SOLIDWORKS Educational Product. For Instructional Use Only.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A96026	TUBE HOLE DRILLING JIG BASE	1
2	26A96025	TUBE HOLE DRILLING JIG HOLDER	1
3	26A96028	5/16-18 T-SLOT NUT	2
4	26A96031	5/16-18 THREADED ROD	2
5	26A96029	5/16-18 STAINLESS STEEL WASHER	2
6	26A96030	5/16-18 STAINLESS STEEL HEX NUT	2
7	26A96027	4-40 1/2" HEX SOCKET FLAT HEAD SCREW	2



1. BOLT 26A96026 ONTO 26A96025
   SCREW THE SLOT NUTS ONTO THE END OF THE THREADED RODS
   PUT THE THREADED RODS THROUGH THE LARGER HOLES ON THE SIDES OF 26A906026
   FASTEN THE RODS EACH WITH A 5/16-18 HEX NUT, ON TOP OF A WASHER

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

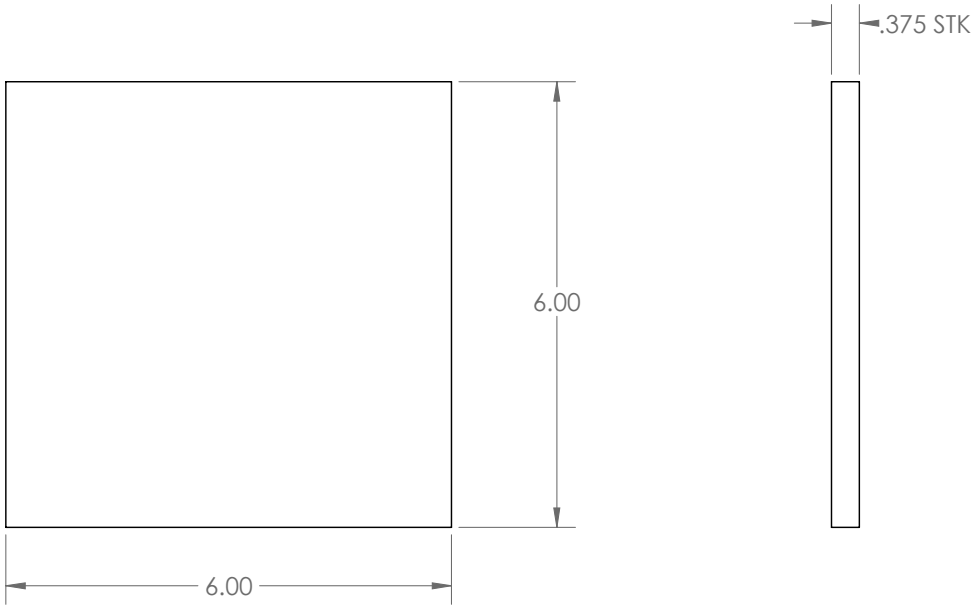
CASE WESTERN RESERVE UNIVERSITY

TITLE:
TUBE HOLE DRILLING JIG ASSEMBLY

SIZE:	DATE:	DRAWN BY:	QUANTITY:
A	01/30/2026	R.DAI	1

MATERIAL:	PART #:	REV:
	26A96032	E

SOLIDWORKS Educational Product. For Instructional Use Only.



1. QUANTITY 1
2. FOR MOTOR RETENTION BULKHEAD (26A02002)

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

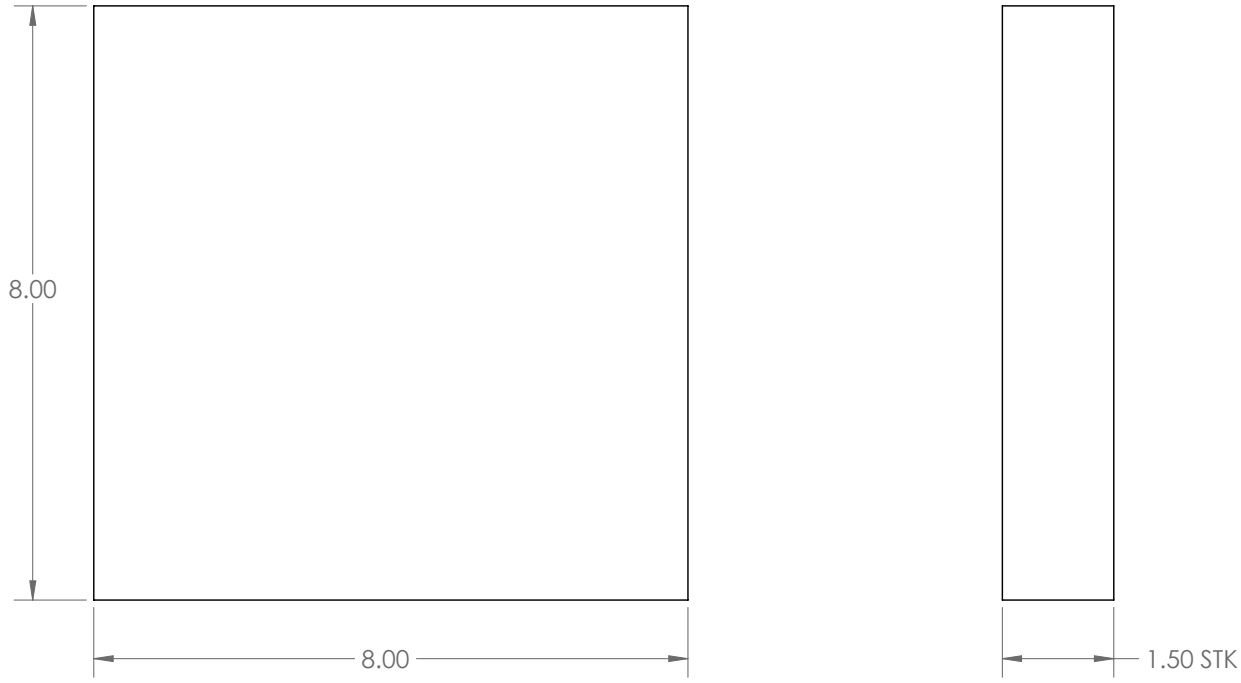
DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: 6"x6"x0.375" BLANK (6061)			
SIZE: A	DATE: 1/31/2026	DRAWN BY: R. SHEPHERD	
MATERIAL: 6061-T6		PART #: 26A96035	REV: D



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

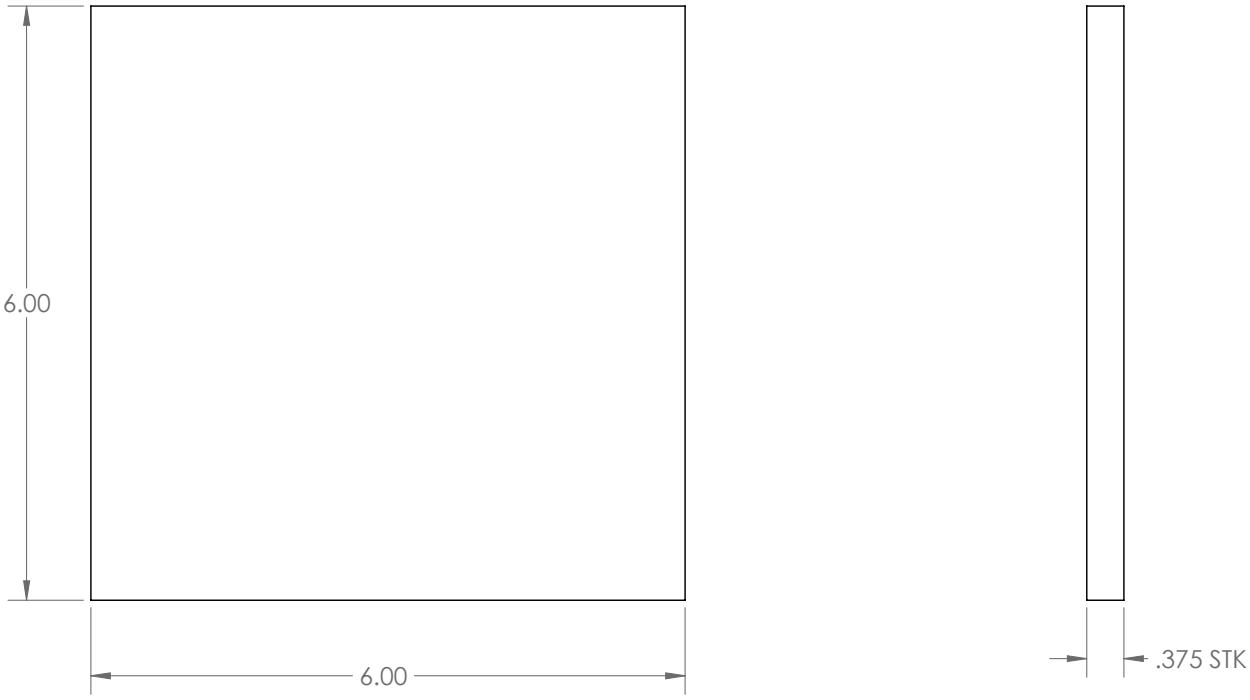
CASE ROCKET TEAM

Case Western Reserve University

TITLE: 8"x8"x1.5" BLANK (6061)			
SIZE: A	DATE: 1/18/2026	DRAWN BY: J. TAN	
MATERIAL: 6061-T6		PART #: 26A96036	REV: B

1. QUANTITY 1
2. BLANK FOR INTERFACE CENTERING RING (26A02016)

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1. QUANTITY 2
2. BLANK FOR PAYLOAD/MEASUREMENTS BULKHEAD (26A02004) AND CENTERING RING (26A02006)

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

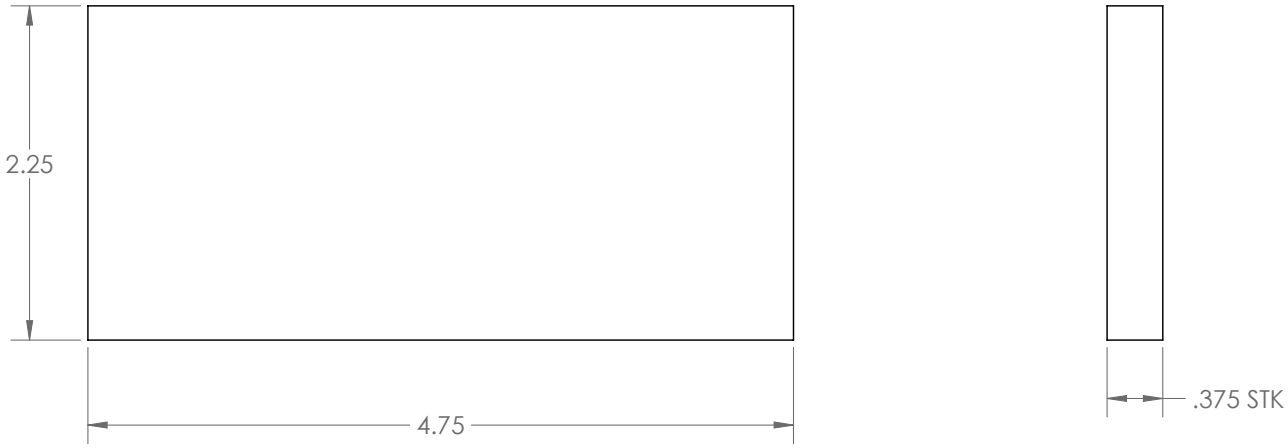
DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: 6"x6"x0.375" BLANK (6061)			
SIZE: A	DATE: 1/18/2026	DRAWN BY: J. TAN	
MATERIAL: 6061-T6		PART #: 26A96037	REV: B



1. QUANTITY 2
2. FOR LOWER CAMERA EBAY BULKHEAD (26A02009)

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

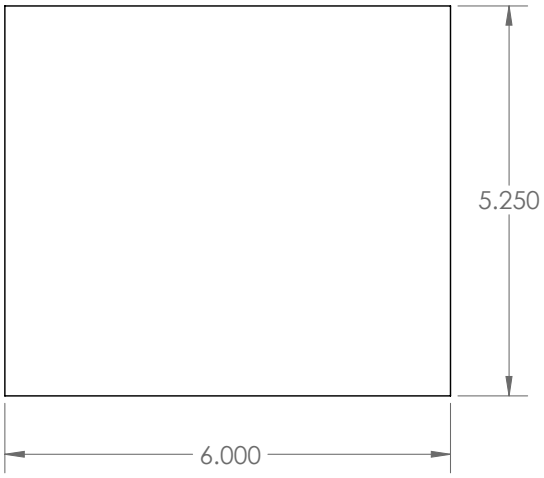
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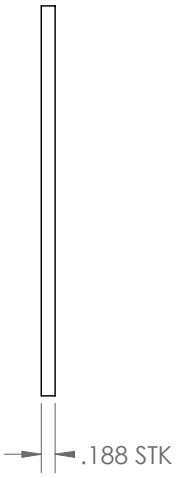
SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: 4.75"x2.25"x0.375" (6061)		
SIZE: A	DATE: 1/18/2026	DRAWN BY: J. TAN
MATERIAL: 6061-T6	PART #: 26A96038	REV: B





1. QUANTITY 1
2. FOR UPPER CAMERA EBAY BIG PLATES (26A02034) AND LITTLE PLATES (26A02035), MAKES TWO OF EACH

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

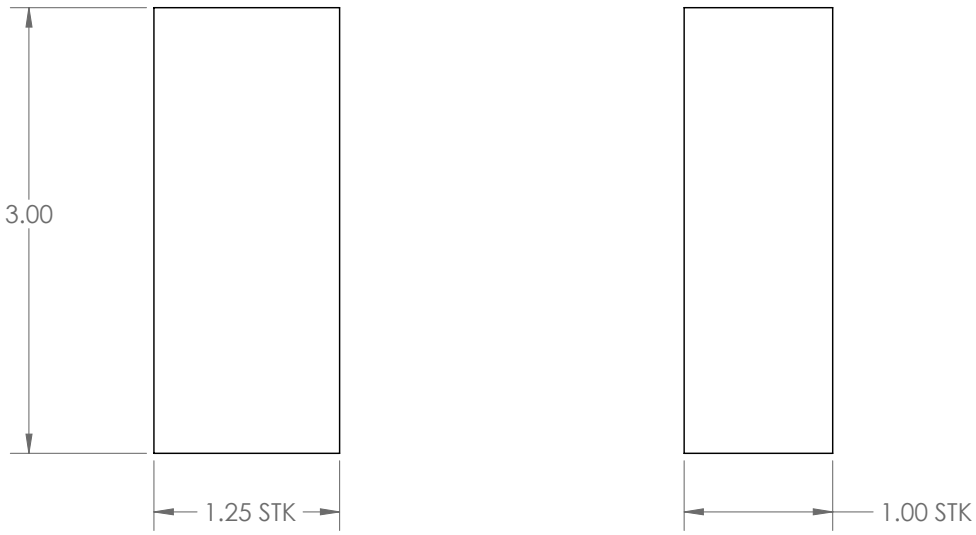
DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: 6"x5.25"x0.1875" (6061)			
SIZE: A	DATE: 1/31/2026	DRAWN BY: R. SHEPHERD	
MATERIAL: 6061-T6		PART #: 26A96039	REV: C



1. QUANTITY 1
2. FOR TENDIE BODY (26A01010)

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

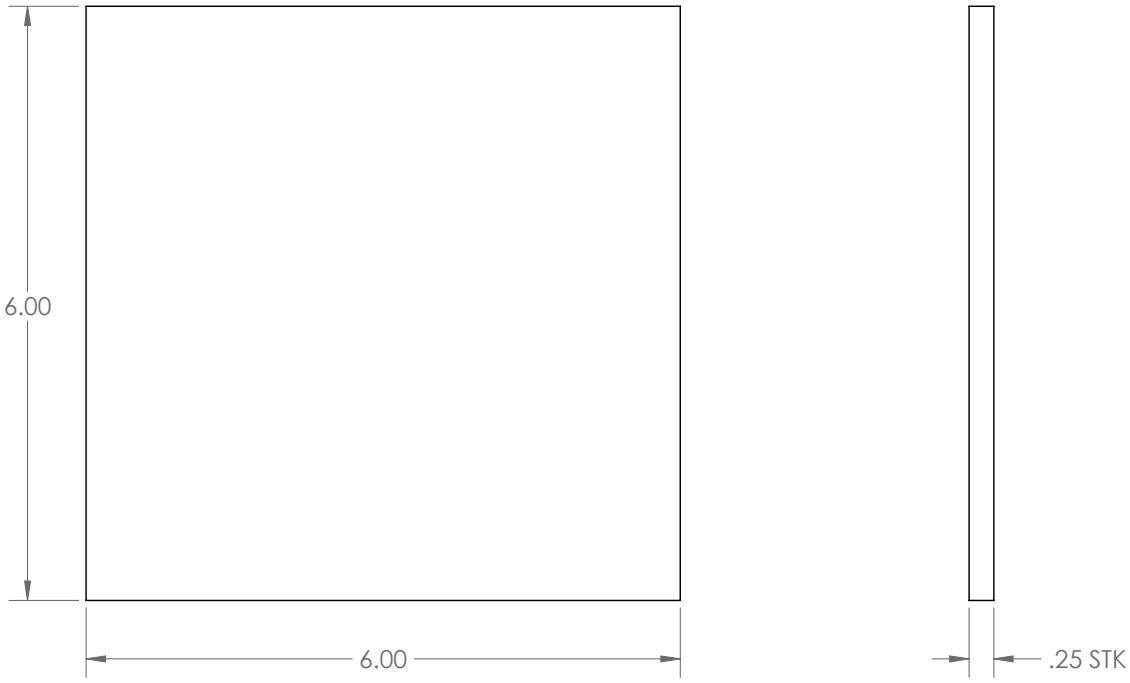
DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: 1.25"x1"x3" (6061)			
SIZE: A	DATE: 1/18/2026	DRAWN BY: J. TAN	
MATERIAL: 6061-T6		PART #: 26A96040	REV: C



1. QUANTITY 2
2. FOR LOW LAUNCH COUPLER BULKHEADS (26A02021)

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

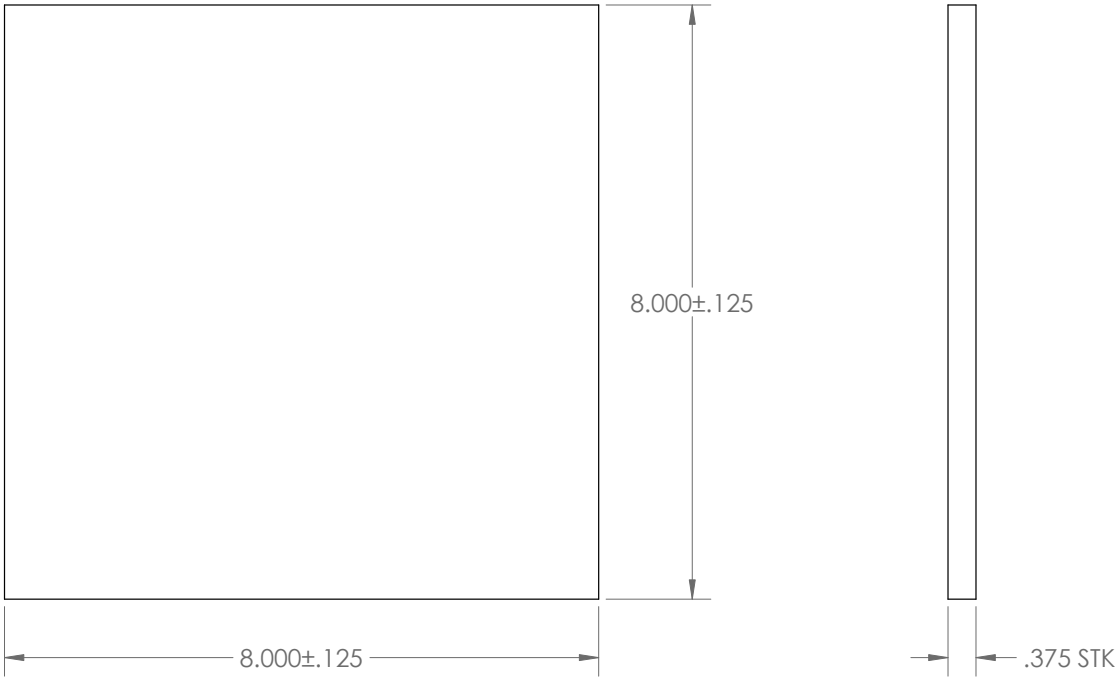
DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: 6"x6"x0.25" (6061)			
SIZE: A	DATE: 1/18/2026	DRAWN BY: J. TAN	
MATERIAL: 6061-T6		PART #: 26A96041	REV: B



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

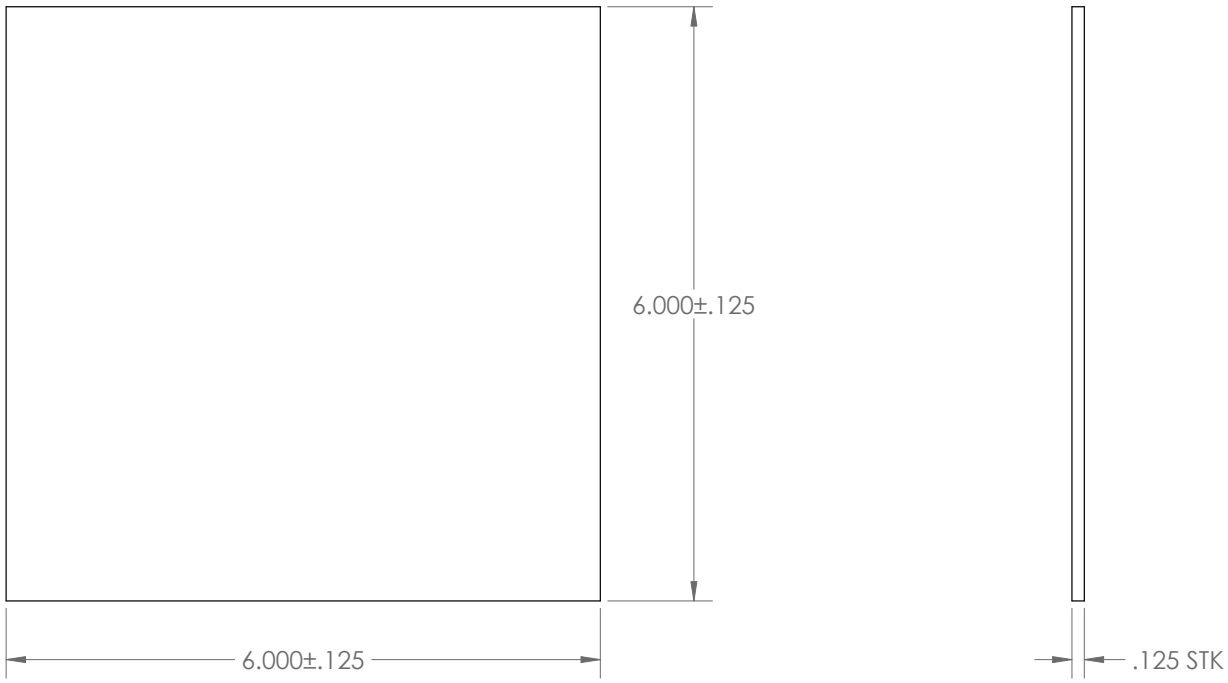
TITLE: 8"x8"x0.375" (7075)

SIZE:	DATE:	DRAWN BY:
A	1/12/2026	C. DIAZ

MATERIAL:	PART #:	REV:
7075-T6	26A96042	E

1. QUANTITY 1
2. FOR RECOVERY BULKHEAD (26A02003), MAKES ONE

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1. QUANTITY 1
2. FOR NOSE CONE EBAY BULKHEAD (26A01031), MAKES ONE

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

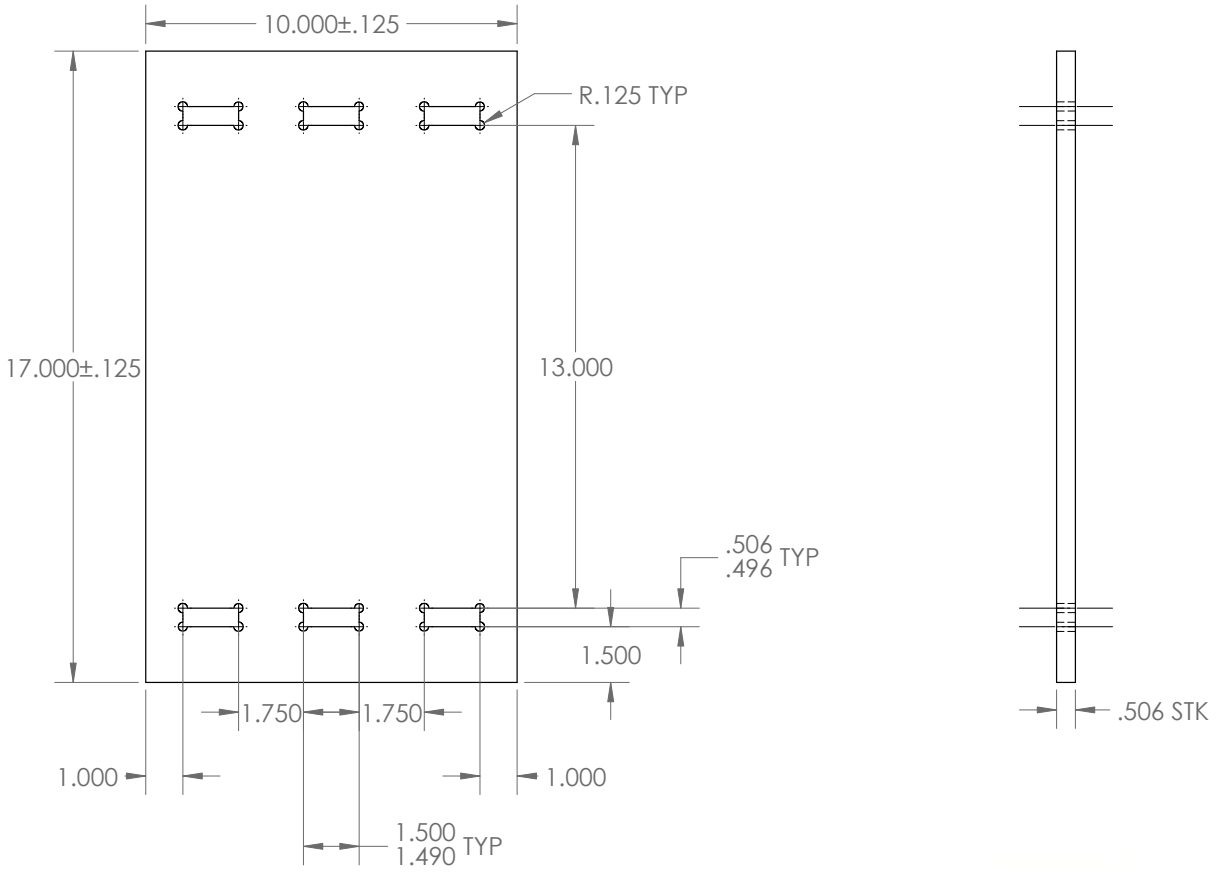
DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: 6"x6"x0.125" (7075)			
SIZE: A	DATE: 1/12/2026	DRAWN BY: C. DIAZ	
MATERIAL: 7075-T6		PART #: 26A96043	REV: E



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

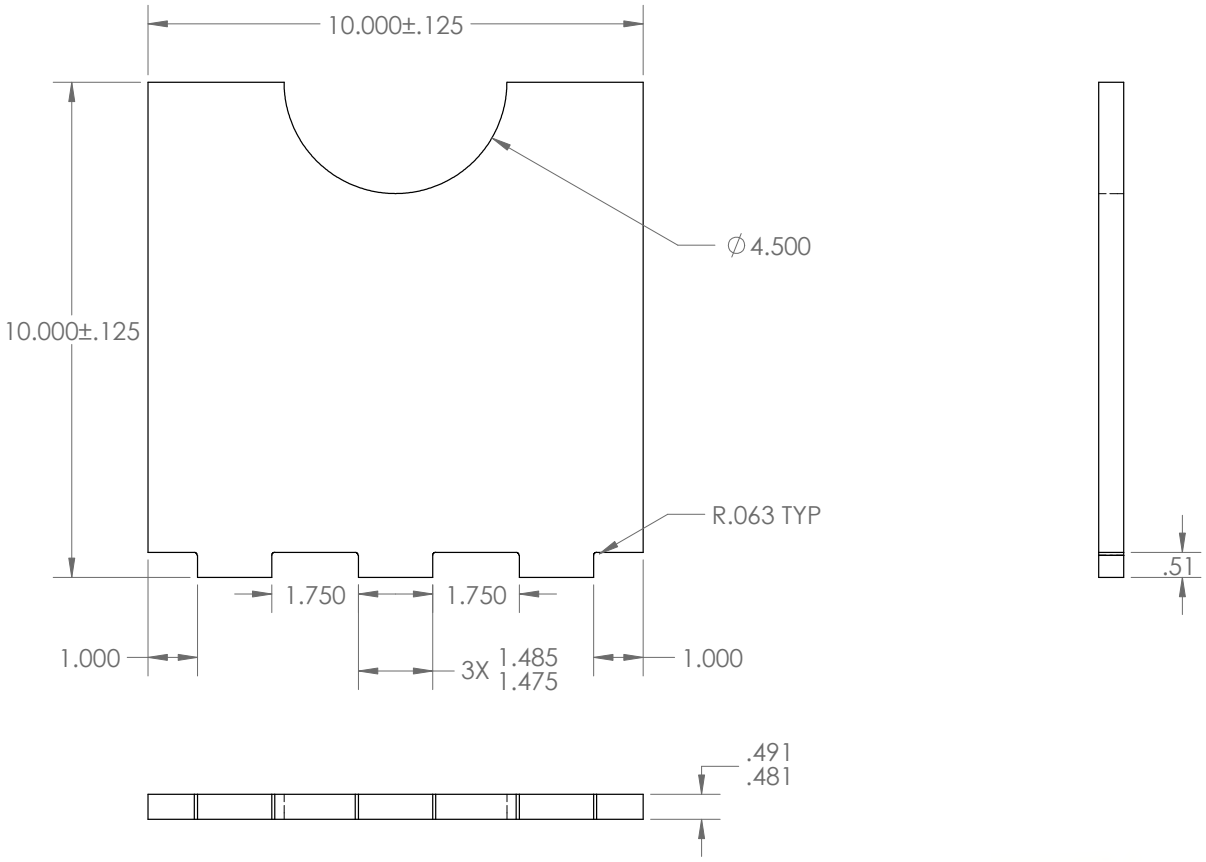
TITLE: FINCAN JIG BASE

SIZE:	DATE:	DRAWN BY:
A	1/13/2026	C. DIAZ

MATERIAL:	PART #:	REV:
PLYWOOD	26A96065	D

1 QUANTITY: 1

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

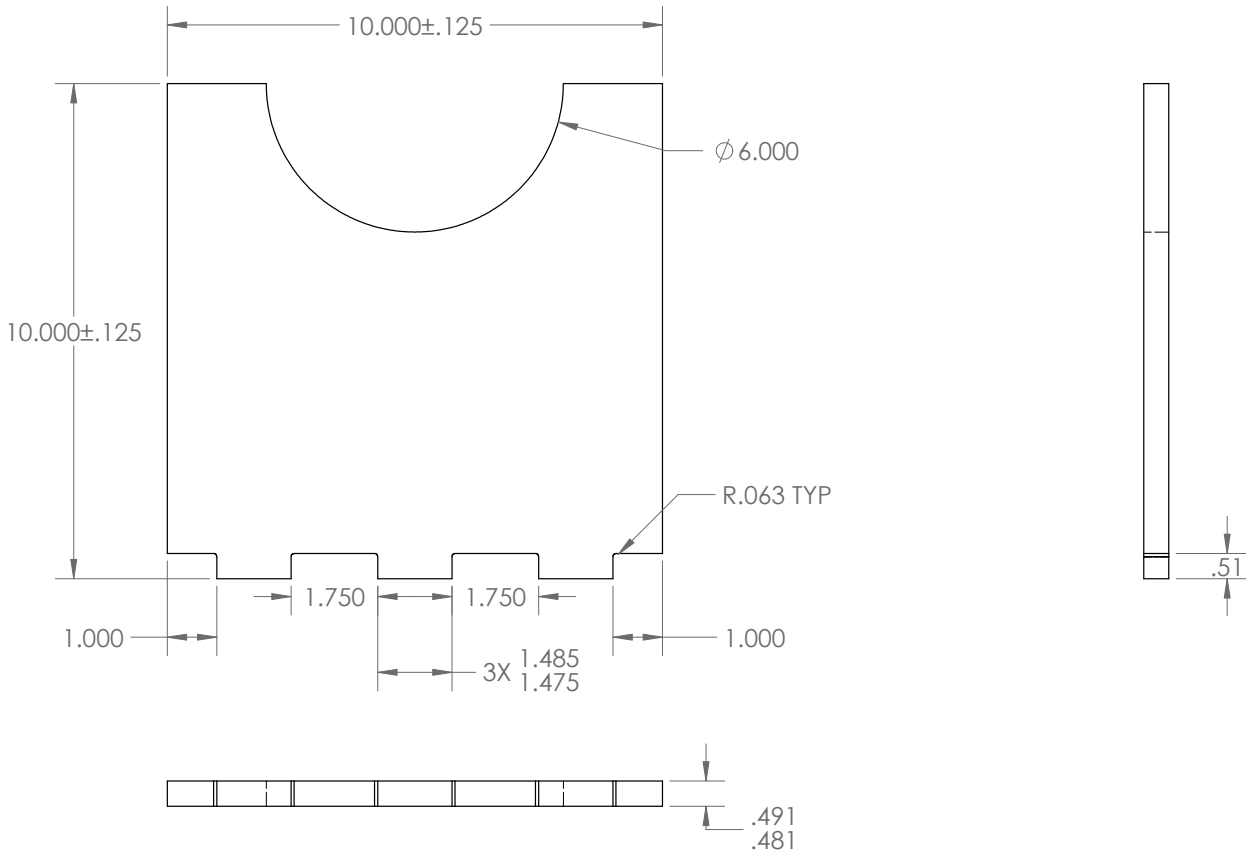
TITLE: FINCAN JIG FRONT

SIZE:	DATE:	DRAWN BY:
A	1/13/2026	C. DIAZ

MATERIAL:	PART #:	REV:
PLYWOOD	26A96066	D

1 QUANTITY: 1

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: FINCAN JIG BACK

SIZE:	DATE:	DRAWN BY:
A	1/13/2026	C. DIAZ

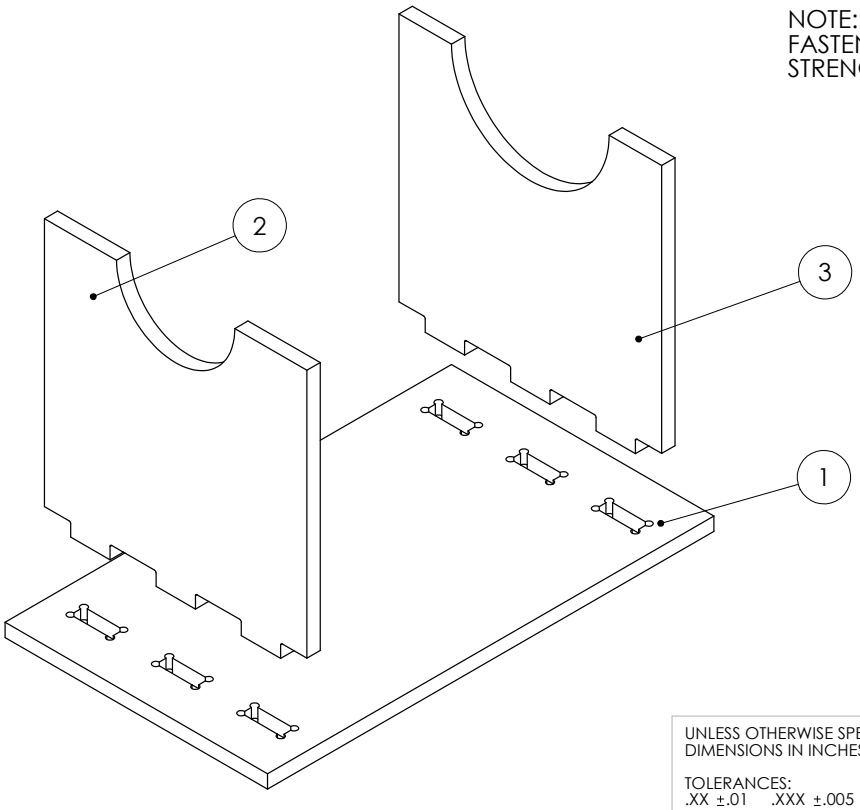
MATERIAL:	PART #:	REV:
PLYWOOD	26A96067	D

1 QUANTITY: 1

SOLIDWORKS Educational Product. For Instructional Use Only.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	26A96065	FINCAN JIG BASE	1
2	26A96066	FINCAN JIG FRONT	1
3	26A96067	FINCAN JIG BACK	1

NOTE: SLOTS SANDED TO FIT, ATTACHED WITH WOOD GLUE, FASTEN NAILS THROUGH BASE PLATE FOR ADDITIONAL STRENGTH



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

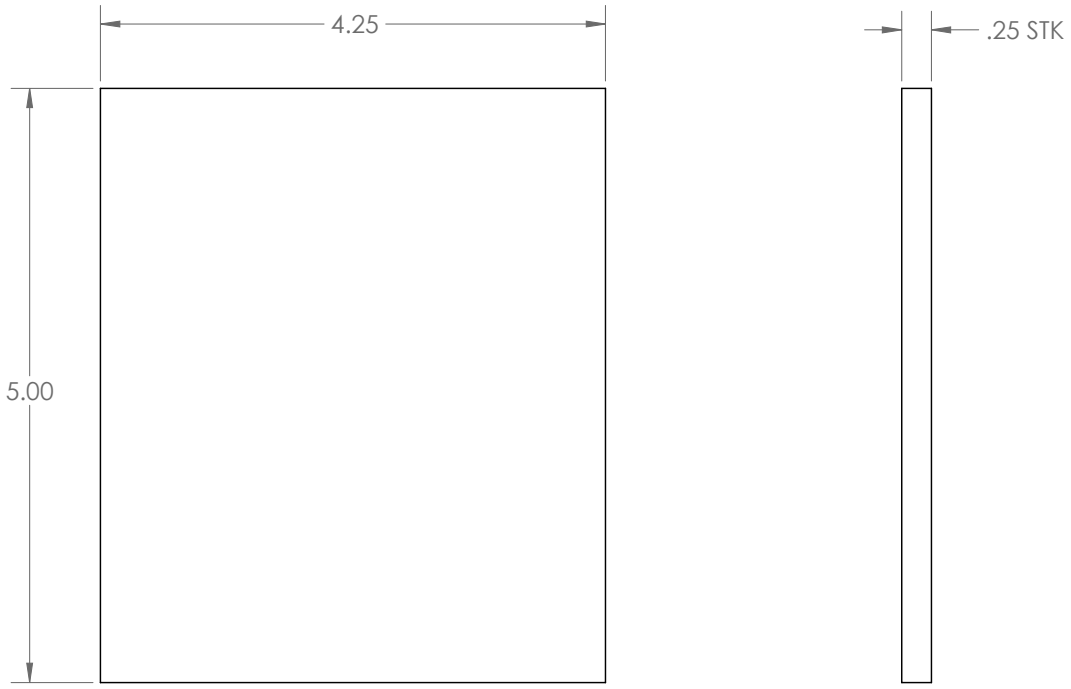
TITLE: FINCAN JIG ASSEMBLY

SIZE:	DATE:	DRAWN BY:
A	1/13/2026	C. DIAZ

MATERIAL:	PART #:	REV:
	26A96068	F

1 QUANTITY: 1

SOLIDWORKS Educational Product. For Instructional Use Only.



1. QUANTITY 1
2. FOR TENDIE PLATES (26A01011), MAKES TWO

SOLIDWORKS Educational Product. For Instructional Use Only.

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

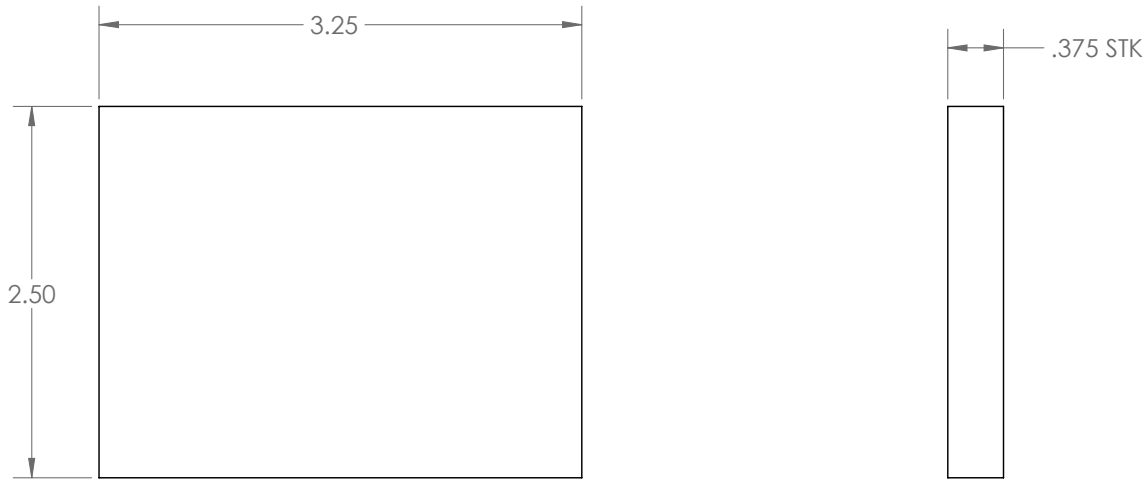
DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: 5"x4.25"x0.25" (6061)		
SIZE: A	DATE: 1/18/2026	DRAWN BY: J. TAN
MATERIAL: 6061-T6	PART #: 26A96070	REV: B



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

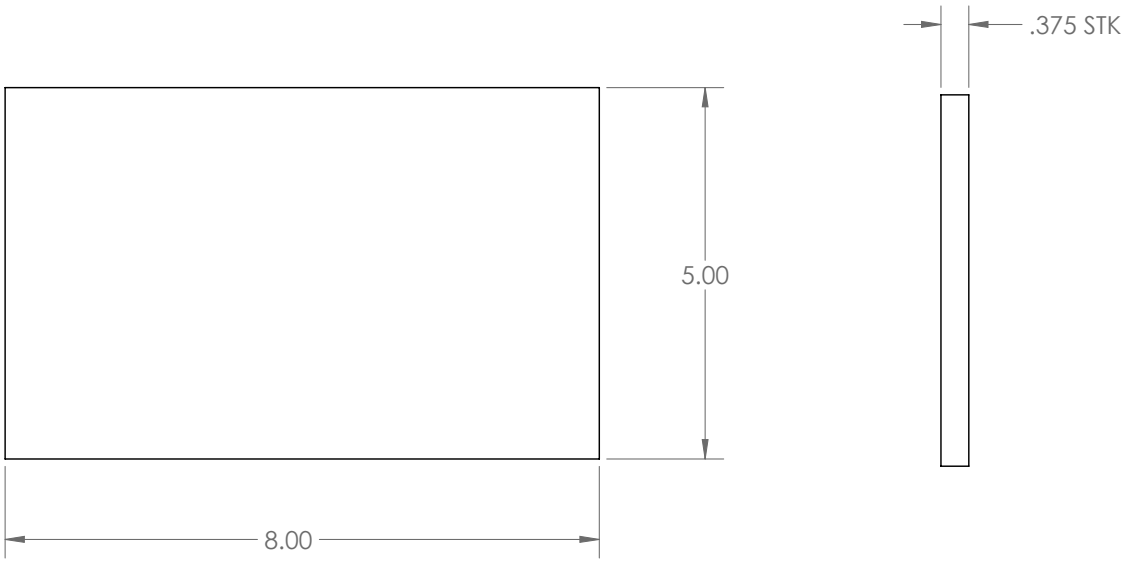
TITLE: 3.25"x2.5"x0.375" (DELRIN)

SIZE:	DATE:	DRAWN BY:
A	1/18/2026	J. TAN

MATERIAL:	PART #:	REV:
DELRIN	26A96071	B

1. QUANTITY 1
2. FOR CHARGE WELLS (26A01012), MAKES FOUR WELLS

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1. QUANTITY 1
2. USED FOR HOLE MILLING TUBE SUPPORT (26A96025)

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

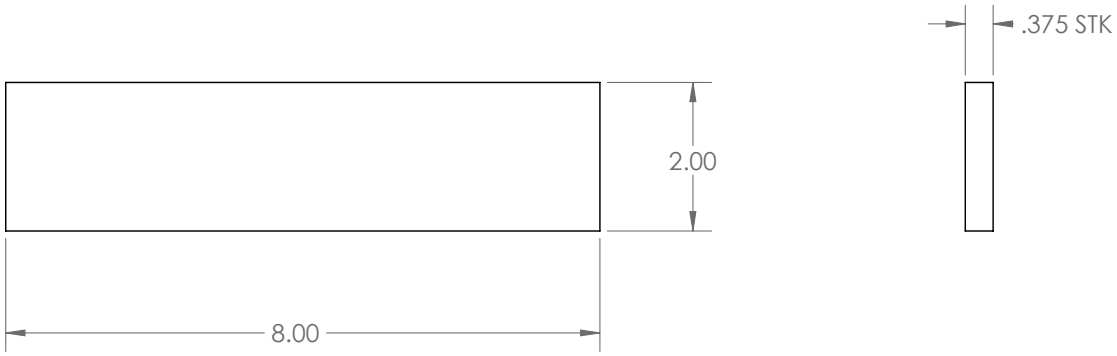
DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: 8"x5"x0.375" (6061)			
SIZE: A	DATE: 1/31/2026	DRAWN BY: R. SHEPHERD	
MATERIAL: 6061-T6		PART #: 26A96086	REV: B



1. QUANTITY 1
2. FOR HOLE MILLING BASE PLATE (26A96026)

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DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
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BREAK ALL EDGES .030

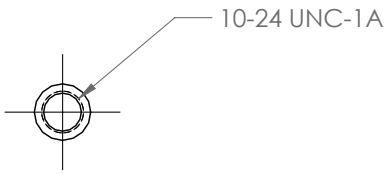
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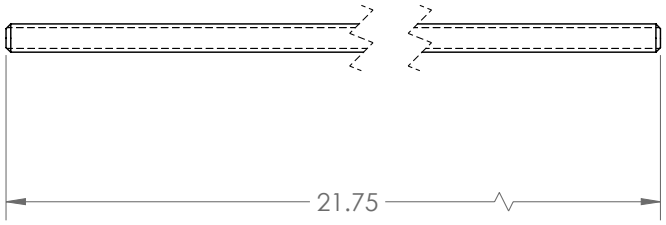
SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: 8"x2"x0.375" (6061)			
SIZE: A	DATE: 1/31/2026	DRAWN BY: R. SHEPHERD	
MATERIAL: 6061-T6		PART #: 26A96087	REV: B





1. QUANTITY: 2
2. FROM MCMASTER-CARR: 98790A011

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DIMENSIONS IN INCHES

TOLERANCES:
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FRACTIONS ±1/64
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ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

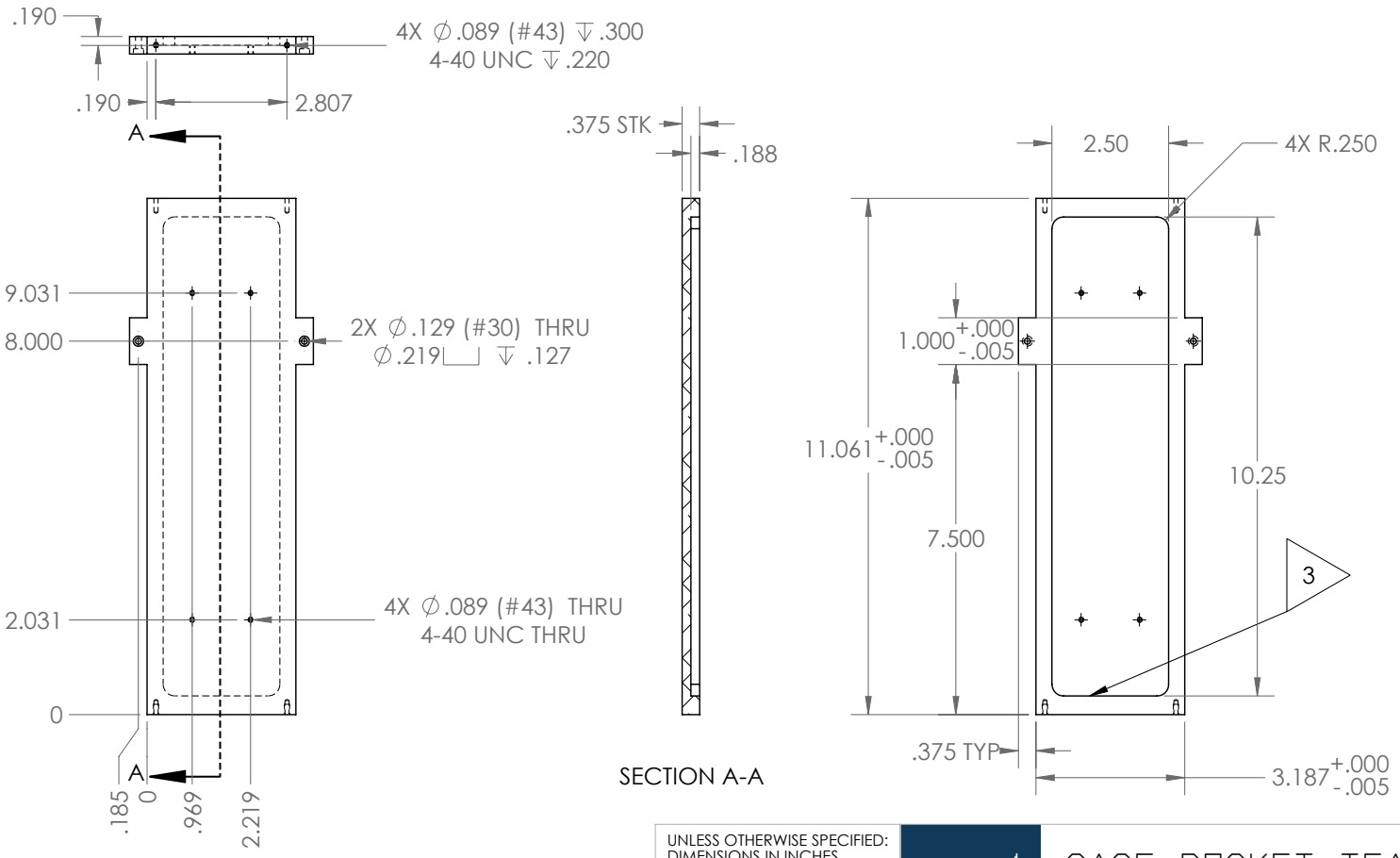
DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: LOWER LAUNCH THREADED ROD			
SIZE: A	DATE: 2/2/2026	DRAWN BY: S. CHURELCHULUUN	
MATERIAL: LOW STRENGTH STEEL		PART #: 26A98067	REV: E



1. QUANTITY 1
2. USE BLANK 26B038
3. MACHINE TO CAD MODEL

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DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

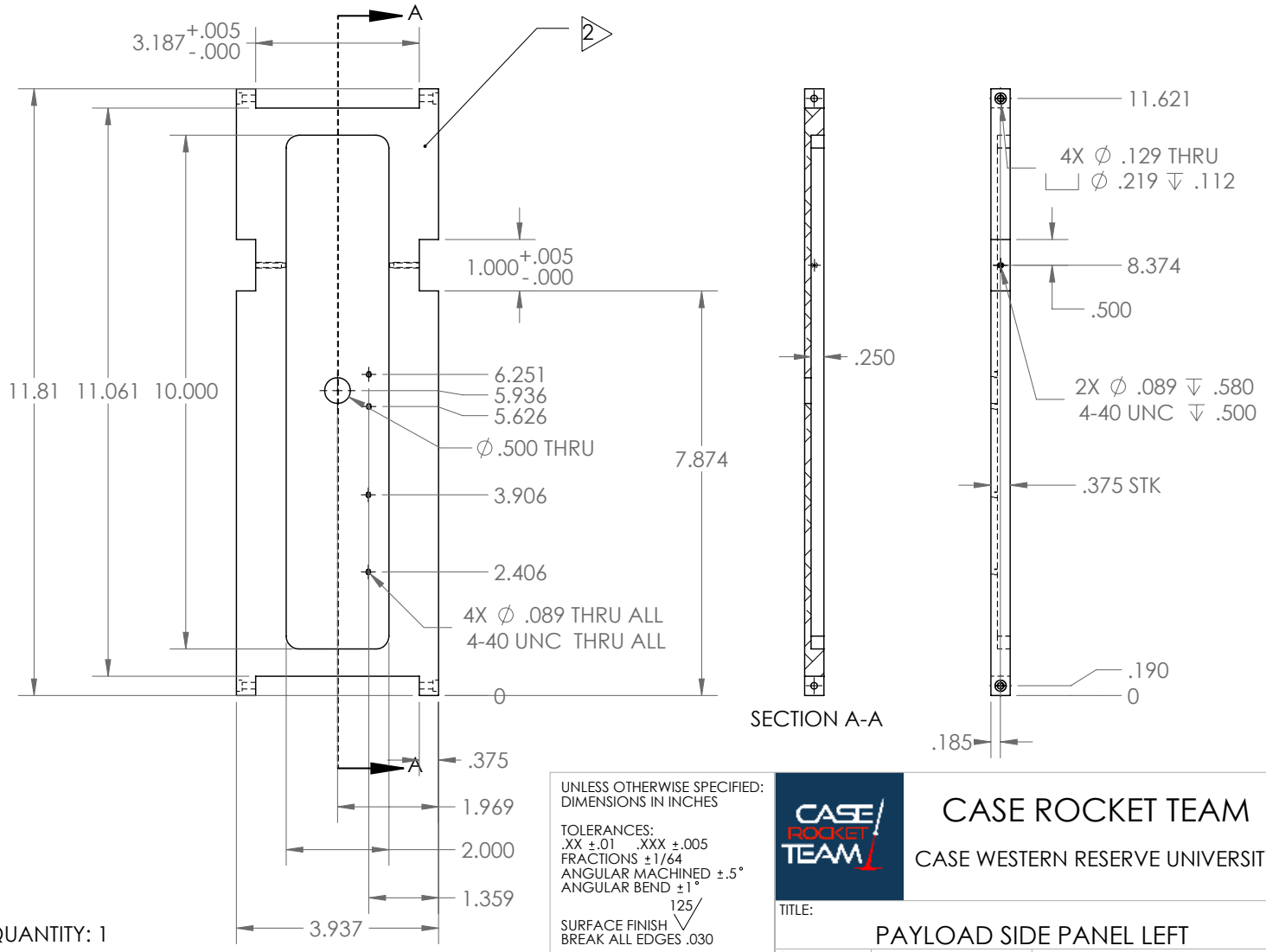
DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: SIDE PANEL 1			
SIZE: A	DATE: 1/29/2026	DRAWN BY: A.KNOBLACH	
MATERIAL: AL 6061 T6		PART #: 26B001	REV: C



1 QUANTITY: 1

2 MACHINE FROM CAD MODEL USING BLANK (26B039)

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DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

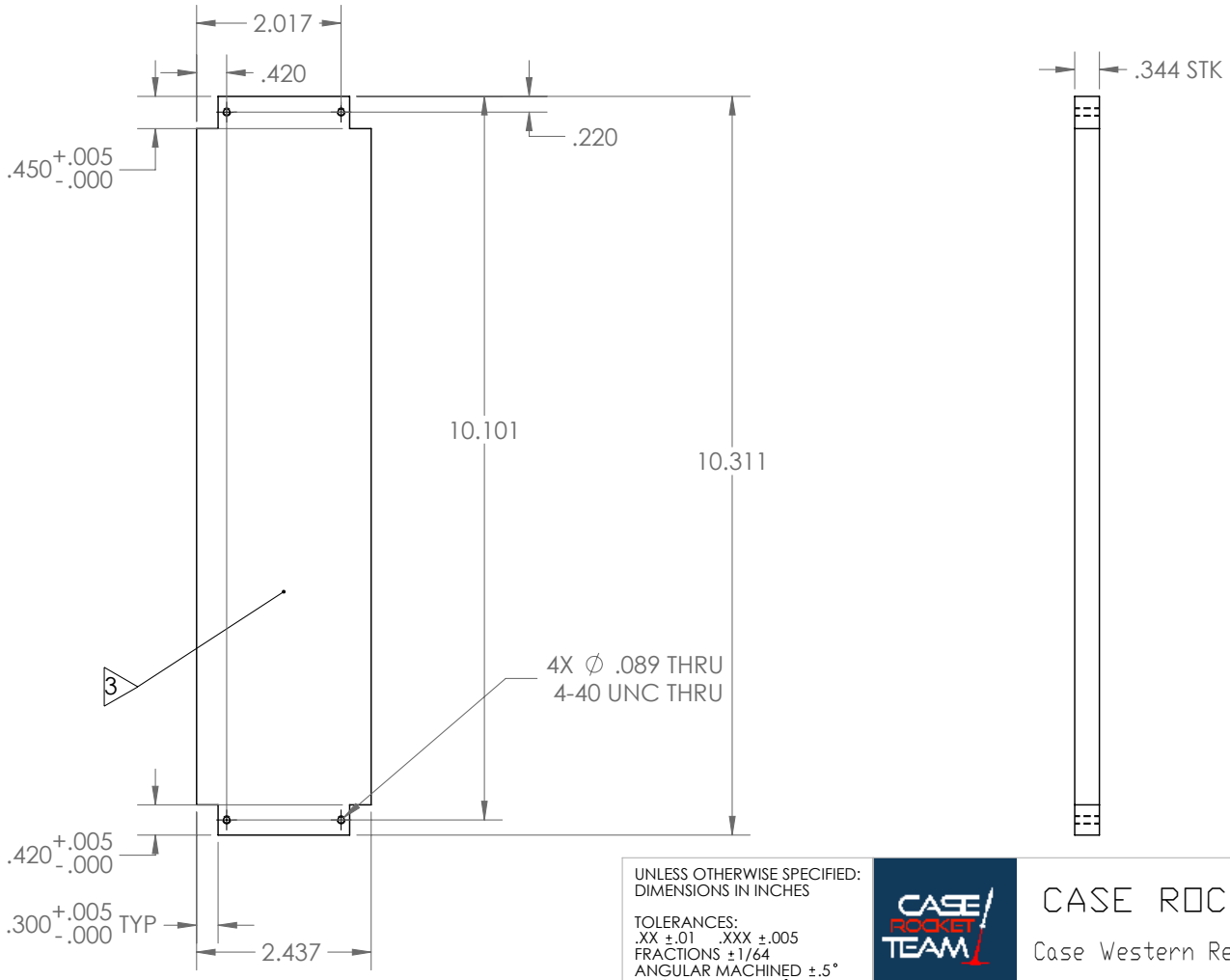
DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

CASE WESTERN RESERVE UNIVERSITY

TITLE: PAYLOAD SIDE PANEL LEFT			
SIZE: A	DATE: 12/28/2025	DRAWN BY: VJT14	
MATERIAL: AL 6061 T6		PART #: 26B003	REV: D



1. QUANTITY 1
2. USING WINDOW PANEL BLANK (26B041)
3. MACHINE TO CAD MODEL

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

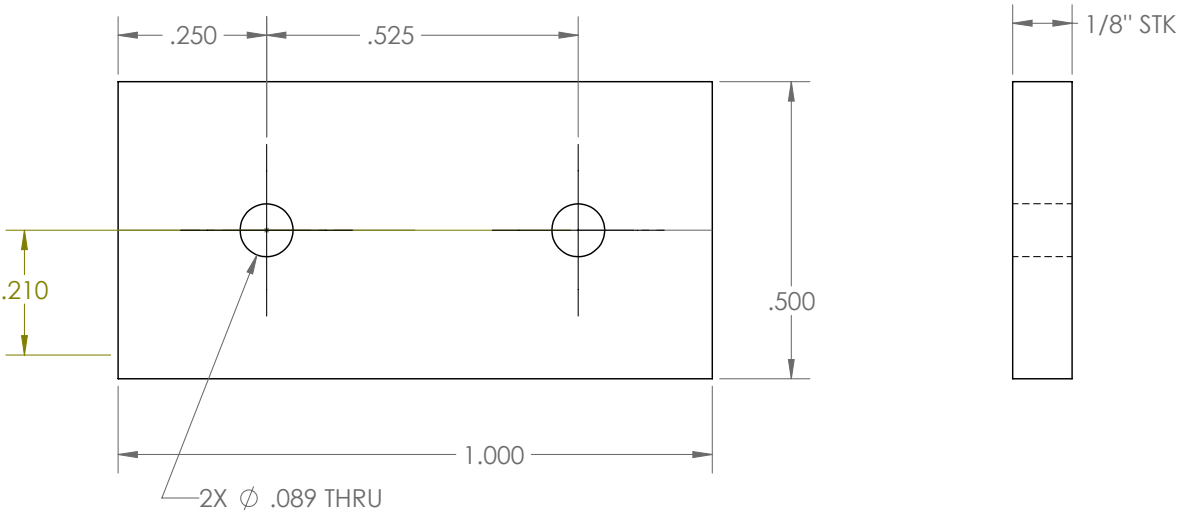
DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

TITLE: WINDOW PANEL			
SIZE: A	DATE: 1/17/2026	DRAWN BY: E. QUAN	
MATERIAL: CLEAR POLYCARBONATE		PART #: 26B028	REV: C



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

Case Western Reserve University

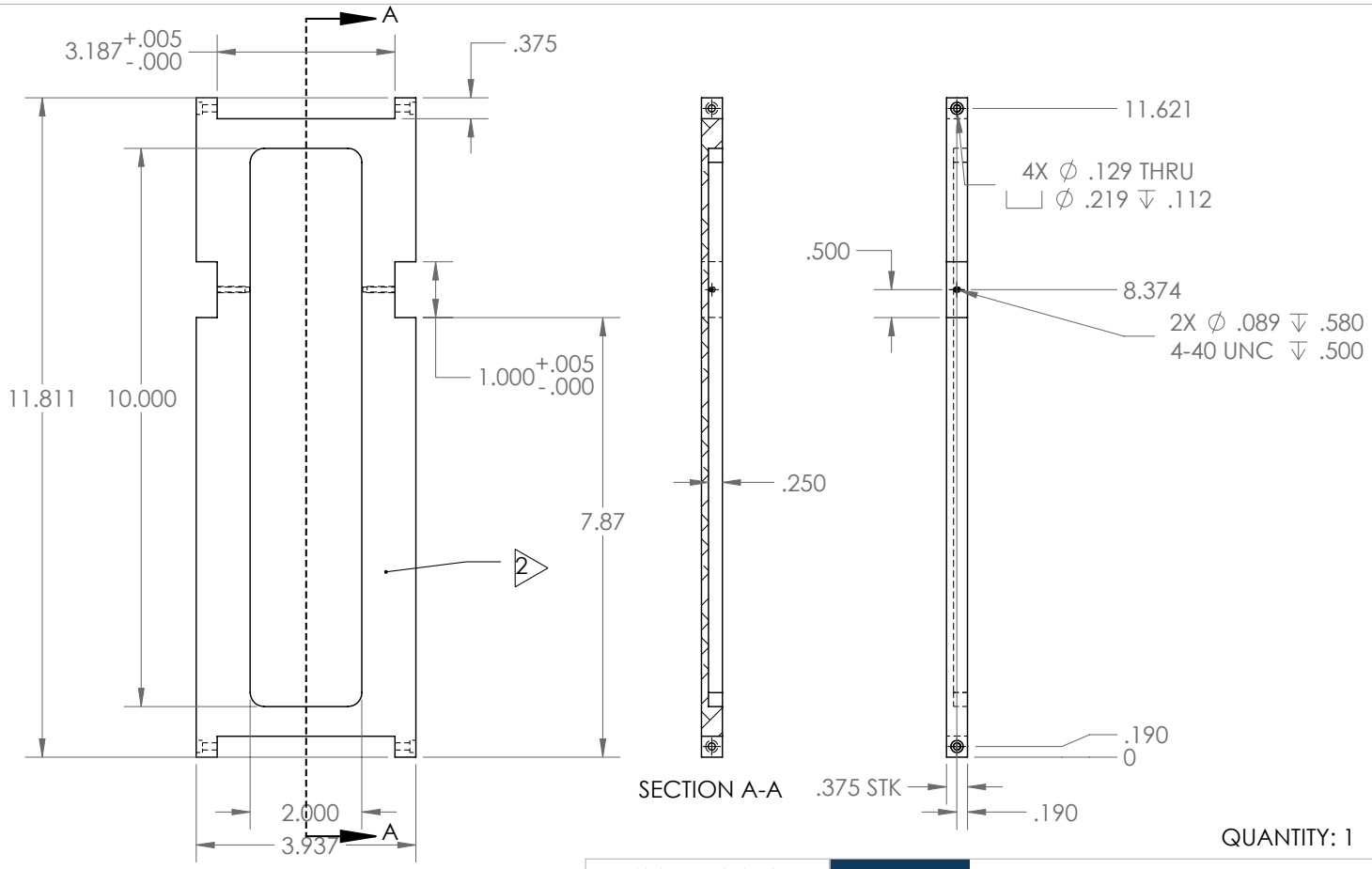
TITLE: BRACKETS FOR POLYCARB PANEL

SIZE:	DATE:	DRAWN BY:
A	1/29/2026	E. QUAN

MATERIAL:	PART #:	REV:
AL 6061-T6	26B029	C

1. QUANTITY 4
2. USING BRACKETS FOR POLYCARB PANEL BLANK (26B040)

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QUANTITY: 1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES

TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030

DO NOT SCALE

SHEET 1 OF 1

CASE ROCKET TEAM

CASE WESTERN RESERVE UNIVERSITY

TITLE: PAYLOAD SIDE PANEL RIGHT			
SIZE: A	DATE: 12/28/2025	DRAWN BY: VJT14	
MATERIAL: AL 6061 T6		PART #: 26B033	REV: E

1 QUANTITY: 1

2 MACHINE FROM CAD MODEL USING BLANK (26B039)

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G. Finite Element Analysis Appendix

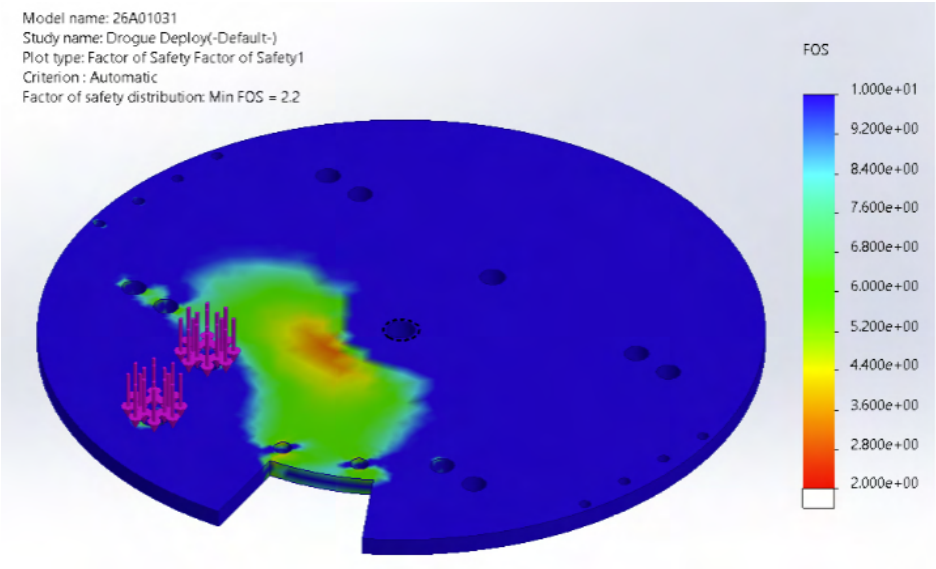


Fig. 23 Nose cone bulkhead FEA at drogue deploy. FoS: 2.2.

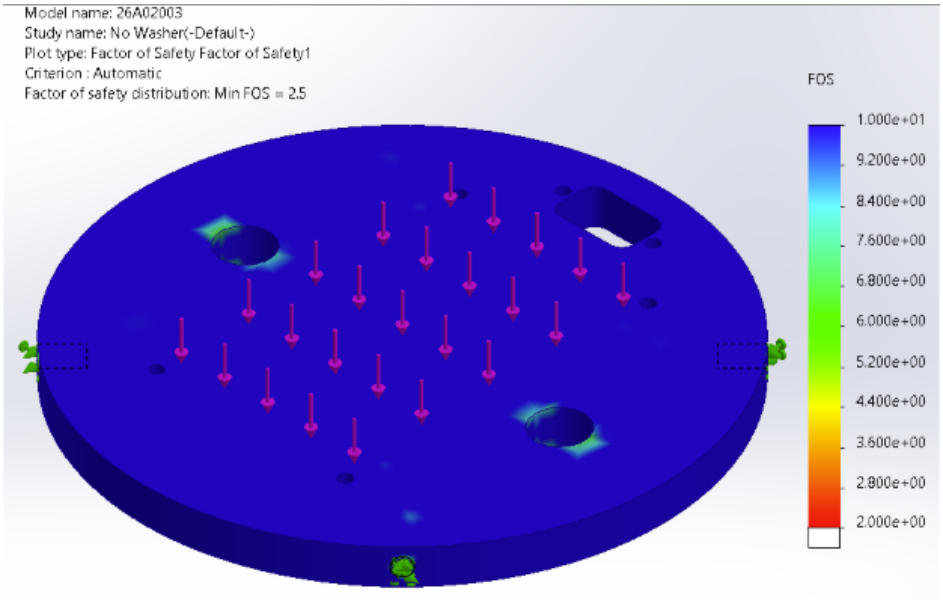


Fig. 24 Recovery bulkhead FEA at main deploy. FoS: 2.5.

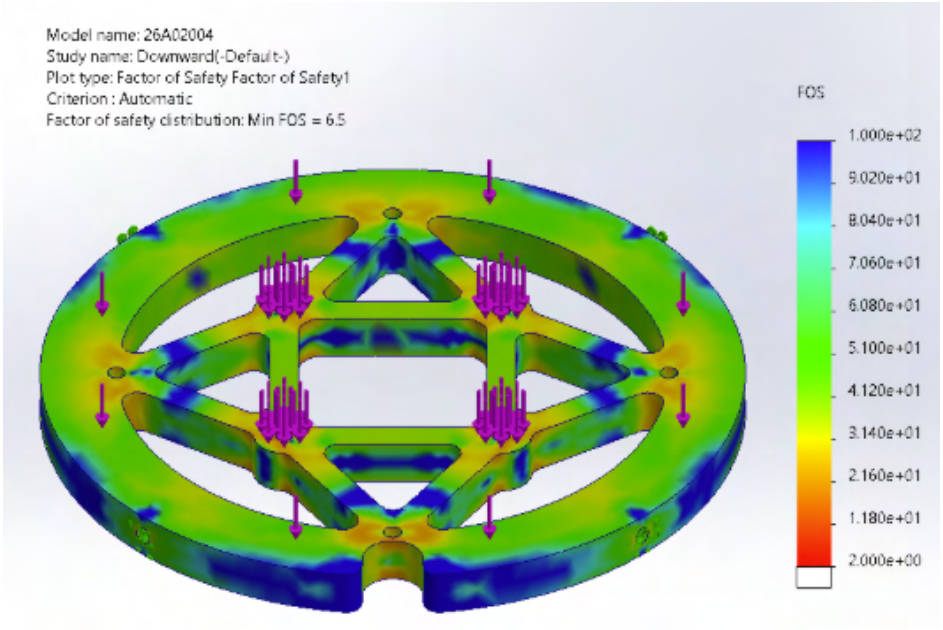


Fig. 25 Payload/Measurements bulkhead FEA at main deploy. FoS: 6.5.

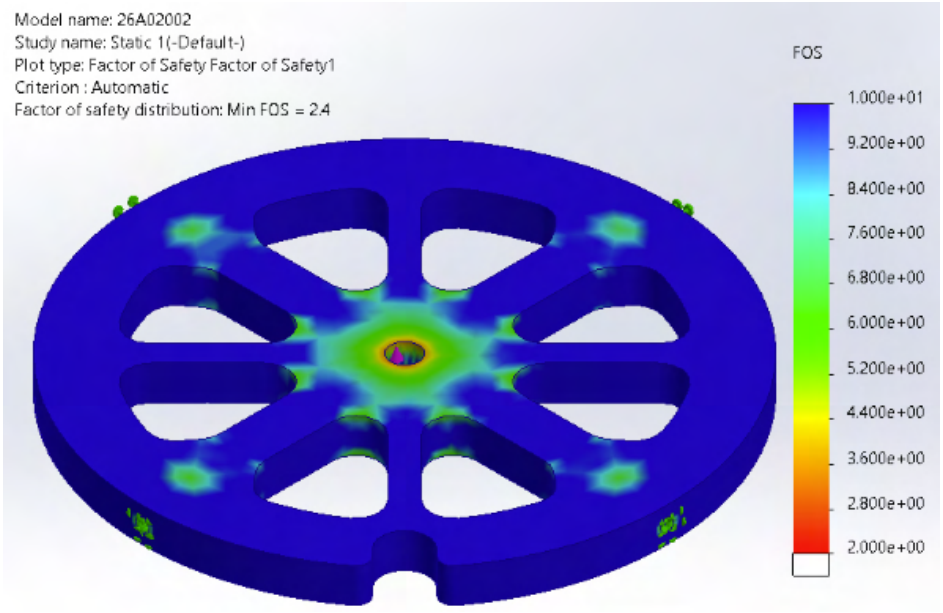


Fig. 26 Nose cone bulkhead FEA at drogue deploy. FoS: 2.4.

H. COTS vs SRAD Airframe Components Trade Study

Case Rocket Team: COTS vs SRAD Airframe Components Trade Study

Robbie Shepherd, Alex Stone
Ahmed Al-Juhaishi, Remy Dai, Kyle Lim, Ryan Pappalardo, Ian Voelkel

This trade study compares the benefits and drawbacks of making our own custom composite tubes, couplers, and nose cone for the 2026 IREC competition rocket, versus buying COTS fiberglass tubes, couplers, and nose cone from Wildman Rocketry. We compare strength, cost, apogee simulation, and other benefits for each option. We conclude by assigning point values to each relevant category, from which we calculate a final score to determine a recommendation. Based on a final score of 59/100, we recommend that the Case Rocket Team use SRAD composite tubes with the same diameters as the IREC 2025 rocket, Helios, to construct the 2026 IREC competition rocket.

Strength Testing Comparison:

The strength test done used a three point bending jig pictured below (Fig 1.). The goal was to test the overall strength of the tubes and compare our SRAD tubes to bought Wildman tubes. Unfortunately, due to the jig being used, the tubes were not tested to failure because the tubes bottomed out before breaking. Strain gauges were not used.

Layers	Thickness (inch)	Max Deflection (mm)	Max Force (N)
6 Layer CF #1	0.0732	7.57	3,384.71
6 Layer CF #2	0.0668	7.87	3,224.13
6 Layer CF #3	0.0748	9.95	3,761.83
Wildman (fiberglass)	0.085	15.40	3,959.00

*Note: This data was taken from tubes that were made from new members doing layups for the first time, which can explain some of the inconsistencies. Also, 6 layer fiberglass lay-ups were measured to withstand ~40% of the force the CF could at the same deflection.

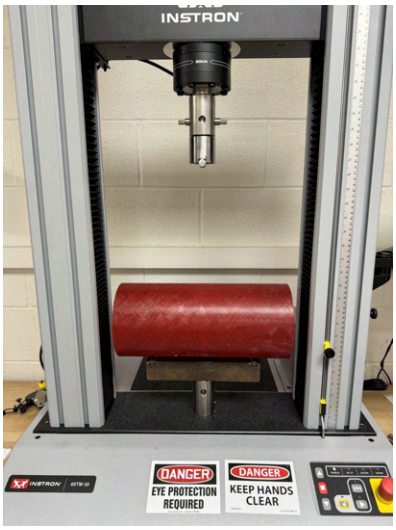


Fig 1. A Wildman coupler tube being strength tested in the Instron machine.

The measurements for the above Wildman tube are based on lengths from other tubes used.
Length of tube: 15 inch
The lengths for the jig are 8.5 inches between the two cylinders and the width of the jig is 2 inches.

Wildman Flexural Modulus:

The following calculations were done using the collected data from the Wildman tube strength testing done by us, with equations based on U Penn[1] and Special Chem[2]:

$$\sigma = M_y/I$$

$$\delta = F * L^3/(48 * E * I) \rightarrow E = F * L^3/(48 * \delta * I)$$

Moment Forces

$$M = 890.0186/2 * 8.5/2 = 1891.29\ N$$

Distance from tube surface to center

$$y = h/2 = 6/2 = 3\ inches$$

Polar moment of inertia

$$I = \pi/4(3^4 - 2.915^4) = 6.91\ in^4$$

Max flexural stress

$$\sigma = 821.02\ PSI$$

[1] "Example 2: Cylindrical Three Point Bending." University of Pennsylvania Perelmen School of Medicine, n.d. https://www.med.upenn.edu/pcmd/assets/user-content/documents/Biomechanics/Example2.pdf.
[2] "Flexural Modulus: Units, Formula & Material Table." Accessed April 30, 2026. https://www.specialchem.com/plastics/guide/stiffness.

Young's Modulus

$$E = 9995\,psi$$

Or

$$E = FL/(4 * b * h^3 * d) = 2658psi\ (Special\ Chem)$$

The values calculated for the flexural modulus are not close the 2.75*10^6 measurement that Wildman provides. Knowing this, no conclusions can confidently be made about the data other than the fact that under ~3000 N, the six layer CF tubes displace less when compared to the bought Wildman tubes. It is worth noting that none of the tubes were tested to failure due to limitations, and it is also worth noting that strain was not measured in this experiment.

Cost Comparison (not including boat tail cost*):
*we assume we will be making our boat tail either way

We do a cost comparison using the materials needed to construct the IREC 2025 rocket, Helios, as an example, since we know how much we spent on those composites last year.

Buying tubes and nose cone from Wildman:

- Based on the Helios OpenRocket, we would need to get one 60" tube and one 30" tube of G12 - 6.0, two 12" couplers, and a 6.0" nosecone, which would cost around $760
    - This is based on the Wildman website[3]
- This does not include the boat tail/fins
- As a plus, buying the nose cone comes with a nose cone tip

Making tubes and nose cone:

- Based on 2024-25 IREC Composites purchase list[4], the total cost minus boattail sleeve material and vacuum bag sealant tape is $983.68
    - Thinking in terms of this year, this cost would vary likely, because it does not consider the materials we still have from last year, including leftover CF, epoxy, and layup materials (we do not need to buy more spray bottles, etc)
        - After taking inventory of current stock, we have leftover 3k CF weave, 6k CF weave, and fiberglass sleeve valued at a total of $371.60[5]
    - Epoxy costs will likely also be split with Composites R&D for 2025-26

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[3] Wildmanrocketry.Com. "Airframe Fiberglass." Accessed April 30, 2026. https://wildmanrocketry.com/collections/fiberglass-1.

[4] Google Docs. "IREC Composite Manufacturing Purchase List." Accessed April 30, 2026. https://docs.google.com/spreadsheets/u/1/d/1uTGI_4Om87Y8vIAmCccaBX6caT0hiAxEKf2kKUWIJuM/edit?usp=sharing&usp=embed_facebook.

[5] Google Docs. "Aerostructures Inventory 2025-26." Accessed April 30, 2026. https://docs.google.com/spreadsheets/u/1/d/1Ch27RMIlMW30mrCZCWT-OKClewwFbDw9PMM9cLnt0tY/edit?usp=sharing&usp=embed_facebook.

- Based on the 2024-25 IREC Mandrel purchase list[6] and the quote[7] for machining the coupler mandrel, the prices of mandrels (buying them and also CNC lathing the coupler mandrel) in total was $675.35
    - If we used the same diameter tubes, we wouldn't have this cost - something to consider in the design process this year
- Based on the 2024-25 IREC Metal Stock purchase list[8], the stock for the nose cone tip was $75.89

Flight Simulation:

If using Wildman Fiberglass body tubes, couplers, and nose cone, we are restricted to a minimum diameter of 6.17" OD (because there is no smaller diameter that we can buy that can still accommodate a 3U Cubesat payload). We simulate this diameter on a conceptual design for the 2026 IREC rocket, and compare it to a similar conceptual design (both designs use the same recovery system, and are as identical as possible other than the intended differences of COTS vs SRAD tubes, coupler, and nose cone). Apogees are taken from RasAero II.

Outer Diameter	**Apogee**
5.982" - 5.862"	32,075 ft
6.17"	30,524 ft

Mass Calculations:
COTS Wildman fiberglass tubes are heavier than SRAD carbon fiber tubes. The Wildman website[9] cites their tube density as **.**07-.076 lbs/in^3. We used .07 in our simulations in order to simulate with the lowest possible weight, and therefore the best possible outcome. Below are some of the calculations to find the weight of the COTS tubes:

For comparison - Lower body tube density from Helios:

$$V = \pi(R^2 - r^2) * h$$
$$V = \pi((5.86/2)^2 - (5.75/2)^2) * 55.5$$
$$V = 56.69\ in^3$$
$$M = 3.65\ lbs$$
$$D = M/V = 3.65/56.69 = 0.064\ lbs/in^3$$

[6] Google Docs. "IREC Mandrel Stock." Accessed April 30, 2026. https://docs.google.com/spreadsheets/u/1/d/16LpKfWeukIfGj0VsTR8XSd_MvtASpiXQ4ud63MGC1sU/edit?usp=sharing&usp=embed_facebook.
[7] Trim Tool and Machine Inc. "Quote." Google Docs, January 29, 2025. https://drive.google.com/file/u/1/d/15-bXFTsnWasnPIH9peR31D_ln-_yFpin/view?usp=sharing&usp=embed_facebook.
[8] Google Docs. "'25 Metal Stock (and Tubes) Purchase List." Accessed April 30, 2026. https://docs.google.com/spreadsheets/u/1/d/1nNip2s8oOcAPCYbLkTZAAhKoFPXorbG3TFOGgVz67lo/edit?usp=sharing&usp=embed_facebook.
[9] Wildmanrocketry.Com. "G12-6.0." Accessed April 30, 2026. https://wildmanrocketry.com/products/g12-6-0.

COTS body tube:

$$V = \pi(R^2 - r^2) * h$$

$$V = \pi((6.17/2)^2 - (6/2)^2) * 59.25 = 96.28\ in^3$$

$$M = 96.28 *.07 = 6.74\ lbs$$

COTS coupler:

$$V = \pi((5.998/2)^2 - (5.82/2)^2) * 9 = 14.87\ in^3$$

$$M = 14.87 *.07 = 1.041\ lbs$$

Wildman nose cone weight:

- Based on Wildman Von Karman 5-1 6" nose cone[10]
- Robbie called Wildman: weight is 4.9 lbs with tip, but without coupler
    - Coupler is calculated above

Mass differences in bulkheads, centering rings, and boattail that arise from an increase in diameter were also accounted for. Full masses and other details of the two designs compared in this section can be found in the OpenRocket files rms-COTS_tubes-2.6.0.ork and rms-helios_inspired-3.5.0.ork, located in the CRT Google Drive[11].

Benefits of Buying Tubes:

- Time frame
    - Buying tubes (especially the nose cone) is faster since we don't have to spend a few GBs prepping the mandrel/mold, cutting CF/fiberglass, doing the actual layup etc.
    - They also would probably have to be sanded a lot less since the surface is already fairly smooth. The sanding process for custom tubes often takes 2 weeks to a month of GBs, depending on how many people are working on it. We would still have to sand to parallel/perpendicular but less overall time.
- Radio transparent
    - Since the Wildman tubes (that we generally use) are fiberglass, the entire rocket would be radio transparent.
    - However, radio transparency for our body tubes was not deemed important for our IREC rocket this year as we will have a radio transparent nose cone either way for transmitting GPS, and the ebay is planned to be in the nose cone or nose cone coupler.
- Cost
    - If the spill over materials from last year is taken out of the picture, buying our tubes would cost less than making all of our own tubes.
- Known Strength
    - Wildman's tube strength data is publicly available and would be more consistent than data of our own tubes.

---

[10] Wildmanrocketry.Com. "FNC6.0-FW-MT." Accessed April 30, 2026. https://wildmanrocketry.com/products/fnc6-0-5-1vk-fw-mt.

[11] Google Drive. "OpenRocket - Case Rocket Team." Accessed April 30, 2026. https://drive.google.com/drive/u/1/folders/1HVcqOiEcLHOx7mrIO-jkNwvlBab8Kvqz.

    - Using this data could allow us to be more confident in our rocket withstanding the loads experienced during flight when compared to our mystery strength tubes.
- Thinner
    - To get tubes of similar strengths (from the data above, again take with a grain of salt), the bought tubes are a little bit less thick on average when compared to the carbon fiber tubes.

Benefits of Making Tubes:

- Weight
    - The custom composite tubes that we make weigh less than Wildman fiberglass tubes. Below, the weight difference between using Wildman tubes vs Helios' composite tubes is calculated (Wildman tubes are almost double the weight), and this weight difference contributes to the overall apogee the rocket achieves.
- Custom sizes
    - When ordering from Wildman, we are restricted to the diameters of tubes they make, and there are only options every half-inch (5.5, 6, etc).
    - When making our own tubes, we have a wider option of diameters, restricted only by the mandrel diameter we can purchase[12,13] (though we could CNC lathe these to any custom diameter if we wanted to).
        - This allows us to further optimize the diameter of our rocket.
- Experience
    - The creation of custom composite tubes is a great experience for the members of Case Rocket Team to gain, and is a useful skill to cite in internship applications/job interviews.
- New members
    - The opportunity to create custom composite tubes is a great draw-in for new members, helping to expand the membership of the Case Rocket Team.
- Advancing the capabilities of the team
    - Pushing ourselves to work on more advanced/complex projects advances the scope and capabilities of the Case Rocket Team. We should always be striving to be better and better. Specifically, using our custom composite tubes on a real competition rocket allows them to be put to the real test under the conditions they are intended to withstand.
- IREC points
    - "ESRA places special significance on projects which leverage SRAD in a particular aspect, either to enhance the team's understanding of that subject, or to develop technology necessary for achieving a longer-term performance goal" (RRD 2.8.1.3)
    - According to the Design Implementation Rubric (RRD Appendix B), the "SRAD Components" score is worth up to 50 available points (in the Design and Quality Decisions category, out of 120), with 45-50 points being awarded for "High use of SRAD components, which are clearly chosen to achieve design or strategic goals." This is a bit

[12] "Drawn Over Mandrel Tubing - DOM Tubing Supplier | Industrial Tube and Steel Corporation." Accessed April 30, 2026. https://www.industrialtube.com/drawn-over-mandrel/#product-listing.
[13] "Steel DOM Round Tubing | Midwest Steel & Aluminum." Accessed April 30, 2026. https://www.midweststeelsupply.com/store/steeldomroundtubing.

of an arbitrary score rating that are based on what the judges think so no causation can be linked for making SRAD tubes specifically.

- Of the 40 highest ranking teams in the design category, we saw that 30 of them opted for SRAD tubes while only 10 bought their own. We also believe some of them stood out due to having more sophisticated designs, such as in component configurations, air brakes, or housing.[14]
- https://www.soundingrocket.org/uploads/9/0/6/4/9064598/irec_rules_and_requirements_document_v_1.6_.pdf
- Even with this evidence, we can not confidently conclude that making SRAD tubes will make us score higher in the competition and therefore will not be graded in our rubric.

Final Scoring and Conclusion:

Categories of Importance	**COTS (/10)**	**SRAD (/10)**
Time (15%) A lot less time is needed to manufacture the COTS tubes. The mandrel prep and actual layups days do not need to happen and can be utilized for other tasks. Both tubes however still need to be sanded to parallel and painted over.	8/10	3/10
Cost (15%) With all of the left over stock from previous years, the cost for buying materials from both comes out as roughly the same for the 2025-2026 rocket, if design choices are made such that mandrels are able to be reused from last year.	7/10	7/10
Flight Performance (60%) Overall apogee drops around 1500 feet due to weight and drag differences making COTS tubes have significantly less wiggle room, but still doable. In order to grade this on a scale we picked a range of 28,000 - 34,000 feet in RasAero. For every 600 feet the rocket goes up above the 28,000, it gets another point. This range was chosen because it was a realistic range of what expected apogees would look like for the 30k COTS category.	4/10	7/10
Customizability (10%)	1/10	2/10

[14] Google Docs. “SRAD Tubes Label.” Accessed April 30, 2026. https://docs.google.com/document/u/1/d/1wuEqFx0kpZesOSEtvH7z8BVUNKtd0ScwPWV5T687rCw/edit?usp=sharing&usp=embed_facebook.

For this year, since we plan on reusing mandrels, the customizability of SRAD is not as good as it could be. The only thing that can change is the thickness of the tubes themselves which is why they scored slightly higher.		
Total (100%):	**Score = 47.5**	**Score = 59**

Based on the final scoring, it is the recommendation of the authors that the Case Rocket Team construct their 2025-26 IREC competition rocket using SRAD composite tubes, with the same diameter as Helios.

Bibliography

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