Case Rocket Team - Phalanx and Aegis

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Case Rocket Team is an undergraduate student rocketry team from Case Western Reserve University in Cleveland, Ohio. It aims to participate in the 2021 Intercollegiate Rocket Engineering Competition (IREC) at the Spaceport America in New Mexico. The team's rocket is competing in the 10,000 ft Commercial-Off-The-Shelf (COTS) category and is notable for an included active apogee adjustment system through the use of aerodynamic braking flaps, and the ability to eject its payload. The team's payload is designed to guide itself to a predesignated landing target through the use of a parafoil. The team's goal is to successfully compete in the competition, and demonstrate the feasibility of the vehicle and payload design for future competitions.

I. Nomenclature

AGL	=	Above Ground Level
AWG	=	American Wire Gauge
BOM	=	Bill of Materials
CAD	=	Computer-Aided Design
cal	=	caliper

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CNC	=	Computer Numerical Control
$COTS$	=	Commercial Off-the-Shelf
$E-Bay$	=	Electronics Bay
$ESRA$	=	Experimental Sounding Rocket Association
FDM	=	Fused Deposition Modeling
FEA	=	Finite Element Analysis
ft	=	feet
GPS	=	Global Positioning System
HD	=	High-Definition
IMU	=	Inertial Measurement Unit
in	=	inch
$IREC$	=	Intercollegiate Rocket Engineering Competition
JST	=	Japanese Solderless Terminal
lb	=	pound
lbf	=	pound-force
$LiPo$	=	Lithium-Ion Polymer Battery
$LoRa$	=	long range
m	=	meter
mAh	=	milliamp hour
mph	=	miles per hour
N	=	Newton
$NACA$	=	National Advisory Committee for Aeronautics
PID	=	Proportional, Integral, Derivative
PLA	=	polylactic acid
s	=	second
SA	=	Spaceport America
SDL	=	Space Dynamics Laboratory
$SRAD$	=	Student Researched and Developed

II. Introduction

Case Rocket Team is an interdisciplinary team of undergraduate students from Case Western Reserve University in Cleveland, Ohio established in 2013. The team is made up of Aerospace, Chemical, and Mechanical engineers, as well as Computer Science majors. Case Rocket Team is proud to present a launch vehicle and functional payload, Phalanx and Aegis respectively. The team is organized under a single Team Lead, who is responsible for managing the competition and supervising two main sub teams, the Aerostructures and Payload teams. The Aerostructures team is responsible for designing, building, and testing the launch vehicle in its entirety. The Payload team is responsible for designing, building, and testing the payload in its entirety. This organization is shown below in Figure 1.

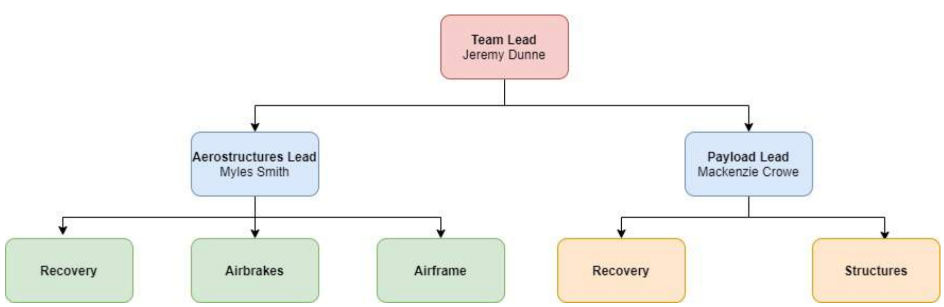

Fig. 1 Team Structure

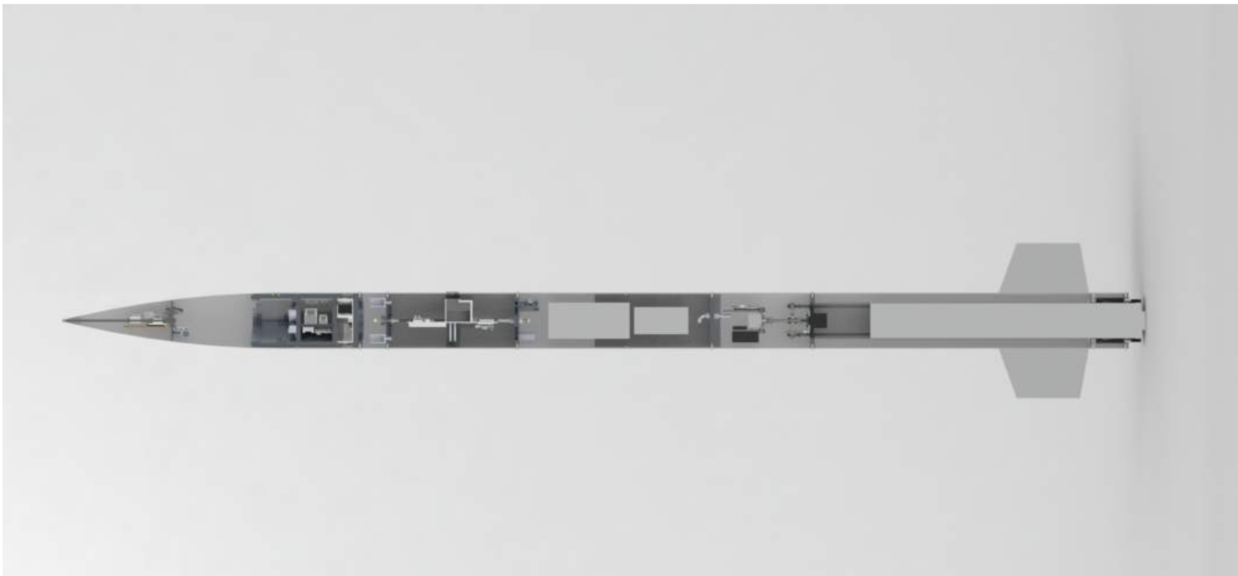

Fig. 2 Section View of Phalanx and Aegis

III. System Architecture Overview

Figure 2 depict the launch vehicle's flight ready mode configuration. Phalanx, the launch vehicle, is composed of five unique parts: the nose cone, upper section, ebay, recovery section, and lower section. The nose cone is independently recovered to permit clean separation and ejection of the payload which is stored in the upper section directly under the nose cone. The recovery and lower section of the launch vehicle are designed to separate at apogee to facilitate recovery. As such, the main and drogue parachutes are stored in the recovery section, directly beneath the e-bay and above the lower section. The lower section shares space with the 98mm Cesaroni M1450 motor, and an airbrake system which deploys aerodynamic braking flaps beneath the fins. The airbrake and motor assembly are designed to be easily removable from the lower section to facilitate testing, replacement, and inspection of the airbrake system. Table 5 displays general characteristics of the launch vehicle, Phalanx.

Name of Parameters	Value of Parameters
Vehicle Weight	35.37 lb
Launch Weight	63.3 lb
Length	119.8 in
Diameter	6.17 in
Fin Root Chord	10 in
Fin Tip Span	17.17 in
CG Location (from tip)	73.79 in

Table 1 Launch Vehicle Parameters

Name of Characteristic	Value of Characteristic
Apogee	11026 ft
Max Velocity	889 ft/s
Max Acceleration	244 ft/s^2
Time to Apogee	26.7 s
Flight Time	170s
Velocity Under Drogue	87 ft/s
Ground Hit Velocity	20.7 ft/s
Velocity off Rail	86.7 ft/s
CP Location (from tip)	87.87 in
Stability During Flight	2.28 cal
Stability off Rail	1.71 cal

Table 2 Flight Characteristics

A. Propulsion Subsystem

The rocket is propelled by a Cesaroni M1450 motor containing 4830 grams (170.4 ounces) of composite propellant. The motor has a peak thrust of 2416.35 N (543.2 lbf) and a burn time of 6.87s. The thrust curve for the motor is provided as Figure 3.

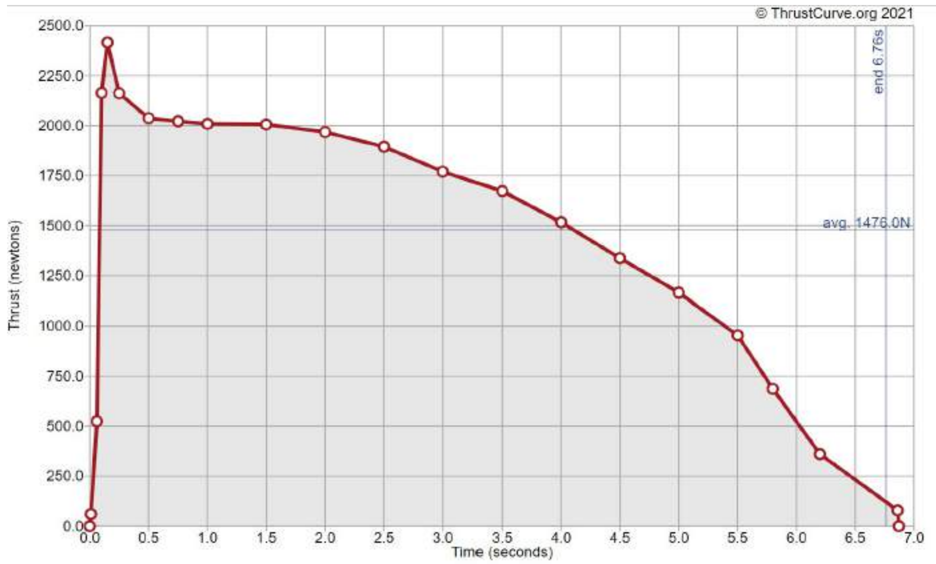

Fig. 3 Cesaroni M1450 Thrust Curve

This motor was selected as it brings the rocket to an apogee above 10,000 ft while still limiting its velocity to Mach 0.80, avoiding unnecessary aerodynamic stresses caused by the transonic region. This motor was also selected to maximize the coast phase of the launch vehicle, decreasing the required airbrake flap sizing as discussed later in the report. The motor is housed in a Cesaroni Pro98 4G motor casing placed inside the motor tube in the lower section. The motor mount is secured to the rocket with two 0.5 in thick aluminum centering rings and a 0.5 in thick thrust plate. The motor and its casing are held in the motor tube by an Aeropack 98 mm motor retainer attached to the thrust plate to distribute the load into the fiberglass airframe. Simulations run using OpenRocket provided a velocity off the rail of 86.7 ft/s and a minimum stability of 1.71 cal off the rail, showing that the rocket is always stable according to IREC requirements. Figure 4 above displays the simulated flight characteristics of the launch vehicle. The desired apogee was set above the competition goal of 10,000 ft in order to accommodate for overestimates in OpenRocket simulations and allow the airbrakes system to decrease the apogee of the vehicle to the 10,000 ft target.

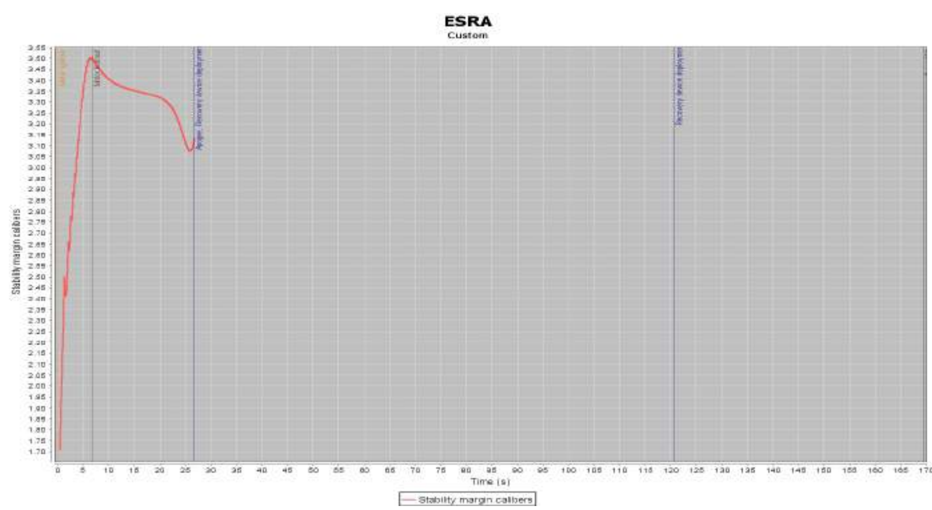

Fig. 4 Launch Vehicle Stability

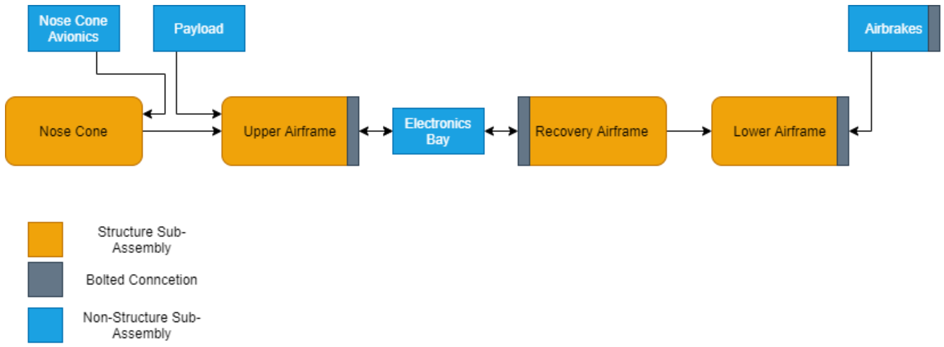

Fig. 5 Vehicle Block Diagram

B. Aero-structures Subsystems

The aerostructure of Phalanx is comprised mainly of COTS 6.17" OD G12 Fiberglass airframe tubing divided into five main sections, a 52" lower section, a 22" recovery section, a 18" upper section. The e-bay is located in between the upper and recovery sections, with a 1.5" camera band used to locate arming devices and secures a transparent section for an on-board camera. The upper section is responsible for containing the payload through the use of a payload attachment ring. Figure 5 illustrates a functional approach to how the rocket interfaces and integrates with other sections.

1. Lower Section

The lower section of the rocket houses the motor tube, fins, airbrakes subsystem, and a coupler used to join the lower section to the recovery section. Four trapezoidal fins were attached to the airframe through two part epoxy and strengthened through the use of tip-to-tip fiberglass layup. The fins were designed to be surface mounted as the airbrakes subsystem would interfere with a through-the-wall fin method and prevent the airbrakes and motor assembly from being easily removed. Tip-to-tip fiberglass layup was used to strengthen the fins and mitigate any strength losses over the through-the-wall method.

Since the rocket travels at high speeds, fin flutter analysis was conducted to ensure the stability of the fins in flight. This analysis utilizes a series of equations from Peak of Flight report "How To Calculate Fin Flutter Speed" by Howard(2011)[1].

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

$$S = \frac{1}{2}(c_r + c_t)b$$

$$AR = \frac{b^2}{S}$$

$$\lambda = \frac{c_t}{c_r}$$

where Vf is the flutter velocity in ft/s, G is the shear modulus of the material in psi, AR is the aspect ratio of the fin, P is the pressure at the flight altitude in psi, is the chord ratio, t is the thickness of the fin in inches, b is the semi-span in inches, ct is the tip chord length in inches, and cr is the root chord length in inches. These equations also utilize atmospheric models for pressure and temperature in the troposphere that vary linearly with altitude up to 36,152 ft

$$T = 59 - 0.00356h$$

$$P = 2116 * (\frac{T + 459.7}{518.6})^{5.256}$$

where h is altitude of the rocket in flight in ft, T is temperature in degrees Fahrenheit, and P is pressure in psf. The pressure in psf must be converted to psi before being utilized in the flutter velocity equation. The parameters used in calculating the fin flutter velocity are the fin thickness of 0.125 in, semi-span of 5.5 in, root chord of 10 in, tip chord of 7 in, shear modulus of G10 fiberglass of 892,857 psi, altitude of max velocity of 8,728 ft, a maximum velocity of 872.8 ft/s, and a specific heat ratio of air of 1.4. With these parameters it was determined that the fin flutter velocity was 1,286 ft/s. With the maximum velocity of the rocket's flight at 873 ft/s, this leaves a 413 ft/s margin. The rocket will perform its flight without any concern for fin flutter as its flight velocity is much lower than the fin flutter velocity even at the maximum flight velocity.

The airbrakes module, which is integrated into the motor tube, slides into the lower end of the tube and attaches to the airframe with radial bolts through the fiberglass airframe. Since the thrust plate interfaces with the body tube, no significant forces from the motor are transmitted through the motor tube or the airbrakes assembly. A 14 in internal coupler was installed using epoxy in the top of the lower section. A 0.5 in aluminum bulkhead was secured in the coupler section through several bolts through the airframe. This bulkhead contains a U-Bolt used to connect shock cord between the recovery and lower section during recovery.

2. Recovery Section

The recovery section consists of the 18 in recovery body tube, drogue chute, main chute, and shock cord. The main chute is stored in an SRAD deployment bag which is attached to the SRAD Tendie Descendie, a pyrotechnic recovery device used for dual deployment. The Tendie Descendie is described in specific detail later in the report. The recovery tube is sized so that during recovery, the main parachute's deployment bag remains in the tube to prevent premature main deployment. Four nylon shear pins are used to secure the recovery section to the coupler on the lower section and are designed to shear during the apogee pyro event. Four button head bolts are used to attach the recovery tube to the lower e-bay bulkhead.

3. E-Bay

The e-bay coupler is 14 in long and has a diameter of 6 in. The e-bay contains all of the electronic components for the rocket mounted on a 0.125 in thick acrylic sled. The sled itself is bolted onto two mounts. These slide onto the threaded rods and are secured in place with nuts. The two bulkheads that seal the e-bay are made out of 6061-T6 aluminum and are 0.5 in thick. The bulkheads are keyed to align the camera window and access holes for the arming devices. Two ejection charge wells for the nose cone are attached to the upper bulkhead. Two charge wells for the lower body tube and the Tendie Descendie are mounted on the lower bulkhead. Additionally, the camera band wraps around the middle of the e-bay, providing access to the screw switches used to arm the electronics. The e-bay is rendered below in both its assembled and disassembled states in Figure 6 and Figure 7, respectively.

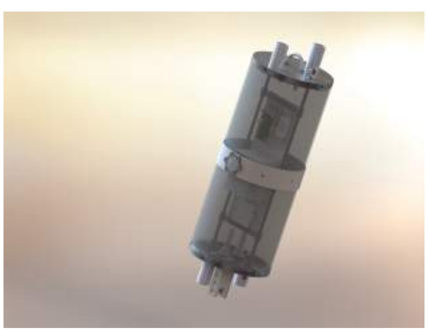

Fig. 6 E-Bay Render

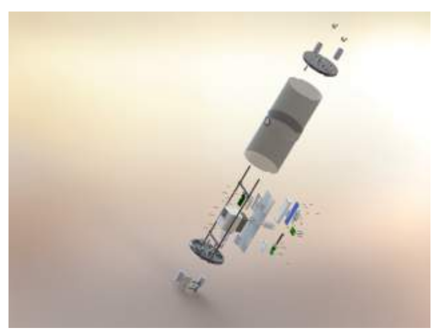

Fig. 7 Exploded E-Bay Render

There were several changes made to this e-bay during the design phase. The most noticeable design decision was making the sled "float" on the threaded rods rather than have it fit into a slot in the upper and lower bulkheads. By eliminating the large slot in each bulkhead, the e-bay became significantly more pressure sealed against the recovery pyrotechnics, decreasing the possibility of premature recovery due to pressure increases. Another significant decision was securing one bulkhead in place on the threaded rods. Previous designs involved sliding the rods through each bulkhead, the coupler, and the fully wired e-bay before securing it in place on each end. Now, one bulkhead is attached to the rods with lock nuts, making assembly much easier. The e-bay for Phalanx is also keyed. There are two notches cut into each end of the coupler with a corresponding spot on each bulkhead that fits into the notch. Previous e-bays were difficult to assemble as the coupler could rotate about the bulkhead, and the key design eliminates that issue.

Additionally, one key is larger than the other, so the e-bay cannot be installed in the wrong orientation. The camera slot is sealed with a window made out of a thin polyethylene terephthalate plastic sheet. The team attempted securing the window with adhesives, but it was not as secure or pressure sealed as desired. Instead, a thin gasket is clamped between the window and coupler, secured with a radial bolt pattern.

4. Upper Section

The upper section consists of an 18 in section of airframe tubing. A payload attachment ring is installed to secure the payload during the launch and coast phases of flight. The ring has four corners mounted on it that are used to interface with the payload and is secured in the tube with four radial bolts through the airframe. This ring ensures clean separation of the payload from the vehicle during ejection at apogee.

Fig. 8 Payload Attachment Ring

Fig. 9 Payload Installed in Upper Section

5. Nose Cone

The nose cone is a COTS 6 in 5:1 Ogive Fiberglass nose cone. Initially, the nose cone had been designed to attach to a shock cord that connected to the rest of the airframe. During testing, it was found that the payload's recovery system would frequently become tangled with the nose cone. As such, the nose cone's recovery system was designed to be completely independent from the rest of the rocket. By separating the systems, the complications that arose have been mitigated. In test rockets, the functionality of the nose cone in ensuring smooth payload deployment has been verified to be effective and reliable. Unlike other bulkheads in the rocket, the bulkhead in the nose cone is 0.125 in thick bulkhead. From drogue deployment, there is an expected maximum force of 6.8 lbf. From the main deployment there is a maximum expected force of 6.9 lbf. Due to the small force from parachute deployment, the size of the bulkhead was reduced from the standard sizes to save weight.

Fig. 10 Nose Cone Render

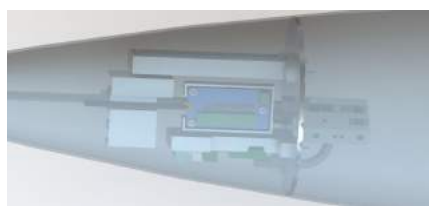

Fig. 11 Nose Cone E-Bay

6. Airbrakes

The airbrakes subsystem is designed to reduce the rocket's apogee to 10,000 feet. Utilizing a linear actuation system consisting of a stepper motor, encoder, and flight computer, the airbrakes subsystem uses actuation tubing that spans the length of the motor tube to deploy flaps at the base of the rocket. Shown in Figure 12, the linkage system translates linear vertical motion to angular flap deployment. The airbrakes subsystem has a maximum deployment angle of 82°.

The airbrakes subsystem has its own avionics bay housed at the top of the airbrakes. This avionics bay contains the flight computer, the stepper controller board, and the batteries necessary to power the computers and motors. The flight computer uses a combination of barometric pressure data and acceleration data to constantly update the predicted apogee. After motor burnout, the flight computer deploys the airbrakes flaps to an angle determined by the algorithm described in Figure 13. Constant adjustments are made in the deployment angle of the flaps to reach the desired 10,000 ft apogee. The airbrakes subsystem is armed by two screw switches that are mounted to the sled housing the flight computer and stepper driver. They are accessible by holes drilled into the lower body tube that line up with the screws.

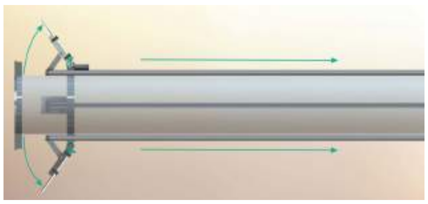

Fig. 12 Airbrake Deployment Mechanism

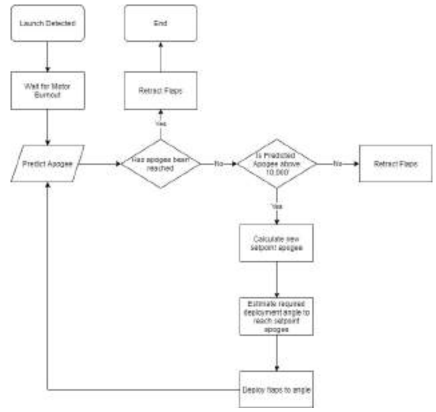

Fig. 13 Airbrake Algorithm

(a) Flaps and Actuation

The fundamental design of the airbrakes subsystem is centered around flaps located at the bottom of the rocket and below the fins. This flap placement ensures they deploy below the center of pressure. Thus, increased drag from the flaps brings the center of pressure further away from the center of mass. Not only does this prevent the rocket from losing stability during the coast phase, it will often increase the stability. Furthermore, if the flaps were located above the fins there would be a significant amount of turbulence around the fins. By designing the flaps to be below the fins, potential problems are avoided while preserving the function of the Airbrakes.

In order to account for inconsistency in our launch profile, the flaps were sized to reduce the apogee 10000 ft. By running SolidWorks Flow Simulations on an analogous model, the team was able to model the approximate drag coefficient of the flaps as a function of deployment angle. The team used Python to find the flap dimensions needed to decrease the rocket's apogee to 10000 ft. The script uses Newton's Method to find the required flap surface area that would cause enough drag to decrease Phalanx's apogee to 10000 ft. In each iteration of Newton's Method, the script performs a linear interpolation of user given data to calculate the rocket's drag coefficient. The flap width is calculated using the arc length formula with a given curve angle (ie. 23 degrees) and the vehicle's diameter. The flap width and the required flap surface area are then used to calculate the flap height. The flap width is viewed as a fixed constraint to decrease structural concerns. The script gave a width of 1.24 in and a height of 3.22 in for Phalanx. Phalanx's flaps are oversized to 3.5 in in height to account for simulation error and general caution.

The primary improvement over previous airbrakes models lies in the design of the actuation system. In previous systems, a downwards translation of the actuation tubing enabled deployment. This design was reversed for a few reasons. First, upwards translation allowed for a steeper deployment angle and therefore thinner flaps. Second, upwards translation allowed the location of the hinge to be moved into the bulkhead, reducing the manufacturing complexity and possible sources of error as shown in Figure 14.

(b) Upper Module

The upper module houses the linear actuation system for the airbrakes subsystem. Shown in Figure 15, the stepper bulkhead, bolted to the upper centering ring, supports the encoder bulkhead upon which the airbrakes avionics bay sits. The linear carriage, which connects the four actuation tubing, sits between the two bulkheads. By driving a lead screw that sits between it and the encoder, the stepper motor translates the linear carriage via the threaded bushing located at its center. Moving along the two linear actuation rods, the linear carriage conveys the linear motion to the four actuation tubes, driving the flaps located below, as depicted in Figure 16. This system ensures smooth, consistent translation of the actuation tubes and precise flap deployment.

Engineered into this system are multiple methods of precision adjustment. For example, the limit switch on the stepper bulkhead allows the system to determine a precise home for undeployed flaps and the threaded studs at the top of the actuation tubing allow for individual adjustment of effective tube lengths to account for imprecise actuation tubing lengths. Taken together with the linear actuation system, the design of the airbrakes

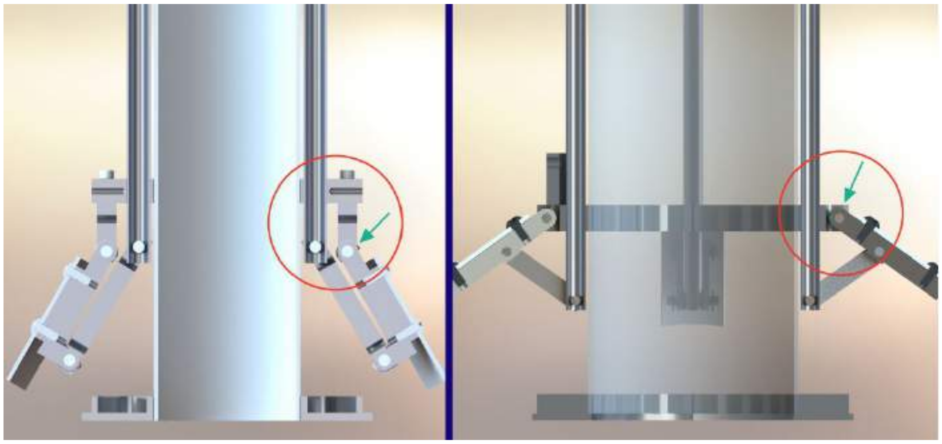

Fig. 14 Airbrake Hinge Mechanism

upper module guarantees stable, precise, and effective flap deployment.

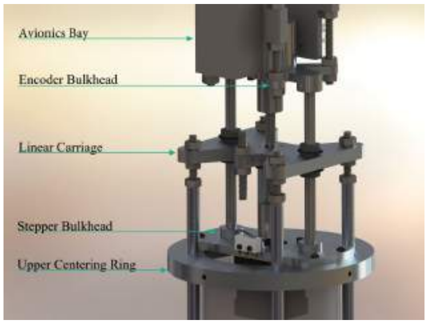

Fig. 15 Airbrake Upper Module

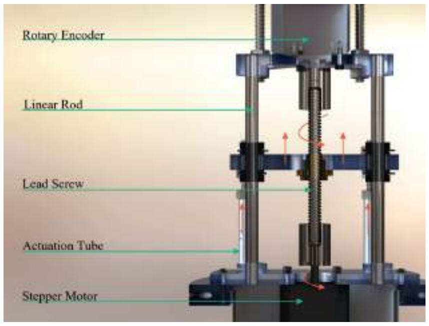

Fig. 16 Airbrake Upper Module Section View

(c) Airbrake Avionics Bay

The airbrakes avionics bay rests on the encoder bulkhead, suspended by four threaded rods, as depicted in Figure 17. One 3D printed sled houses the airbrakes flight computer and the stepper driver. The other houses the batteries for the motor and flight computers.

The recovery scheme for this rocket has the lower body tube, which encloses the airbrakes and the motor tube, separating from the rest of the rocket. Rather than running wiring from the electronics bay across many feet of shock cord, the decision was made to design a separate airbrakes avionics bay from the rest of the electronics. This decision simplified the wiring system, and significantly reduced the complexity of the airbrakes subsystem.

The stepper motor battery is a 1500 mAh 3S LiPo and the flight computer battery is a 150 mAh 1s LiPo. They are oversized to let their respective parts idle for up to 12 hours on the pad, and function actively for over 45 minutes.

7. Manufacturing Methods

(a) Airframe Tubing

All airframe body tubes were made using COTS 6.17 in G12 Fiberglass tubing. The most common features added to the tubing involved drilling clearance holes for bolts and other hardware passing through the airframe. These holes were laid out using a combination of radial jigs to align angles and optimal hole locations measured from assembled components. Airframe tubing was bonded together using laminating epoxy resin and allowed to cure at room temperature over a period of 24 hours before handling.

(b) Bulkheads

Given the weight relief and unique design of several bulkheads in the rocket, CNC milling was selected

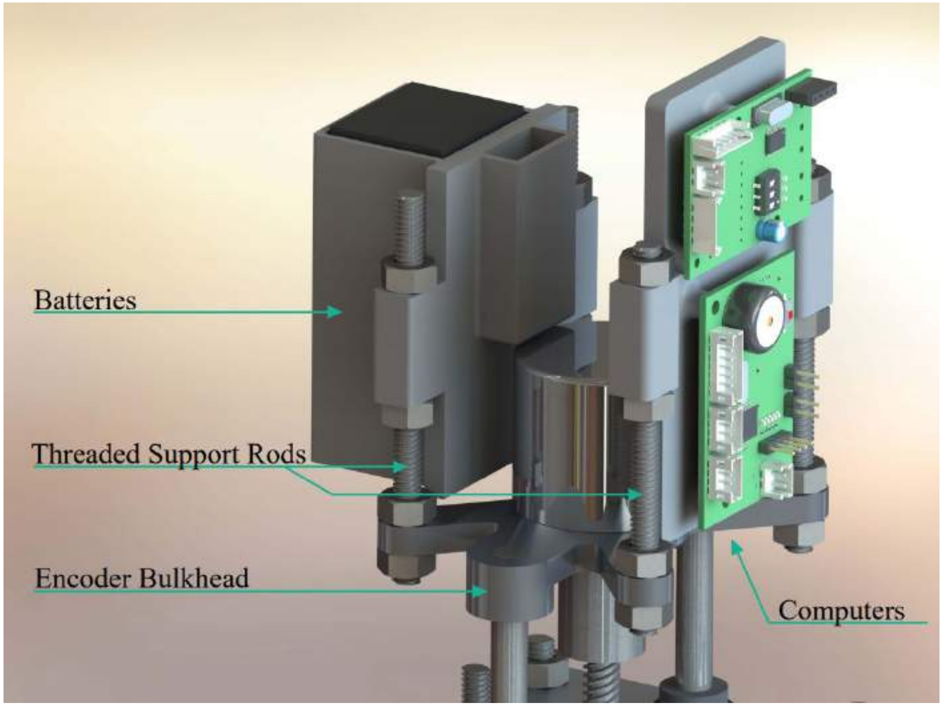

Fig. 17 Airbrake Avionics

as the manufacturing method for most first and second operations on parts. Using a fixture designed to accommodate circular blanks, the bulkheads were milled out using a 3-axis HAAS CNC Super Mini Mill. Figure 18 shows the fixture setup used on the CNC mill before running and Figure 19 shows various bulkhead parts following the first operation. All bulkheads were made of 6061-T6 aluminum, as detailed in Appendix VI.

Secondary operations and some primary operations were performed using a combination of manual mills, lathes, and drill presses. Where applicable, machining jigs were designed and manufactured to simplify operations and increase accuracy of parts, as well as to streamline the manufacturing process.

(c) E-Bay Components

Complex geometry parts located in the e-bay, such as flight computer holders, battery holders, and camera holders were 3D printed using conventional desktop FDM printers. Most parts were 3D printed using PLA plastic. Other more conventional parts were manufactured using a combination of waterjet cutting, manual machining, and CNC machining.

(d) Airbrakes Components

The centering rings and bulkheads within the airbrakes module were cut using the waterjet. Secondary operations like milling and drilling were then performed on the parts. The threaded rods and actuation tubing were cut to length. The flaps were cut by hand in the body tube.

C. Recovery Subsystems

The launch vehicle is recovered in two separate portions, the nose cone and lower vehicle. The nose cone is designed to be independently recovered to minimize the opportunity for a deploy-able payload to tangle with the shock cord or the launch vehicle during deployment. Because of this, the launch vehicle's recovery is kept completely independent of the payload and upper section.

(a) Lower Vehicle

The rocket body tubes are recovered using dual deployment and one continuous line of shock cord. Figure 20 shows the recovery scheme of the lower section. As shown in Figure XX, the parachutes and the main chute deployment bag are located in the recovery tube. At apogee, the lower body tube and recovery tube separate and a 36 in drogue chute deploys. The rocket descends under drogue at 78.3 ft/s, meeting ESRA's requirements. At 1250 ft above ground level, the Tendie Descendie releases the 84 in main chute. The rocket descends under

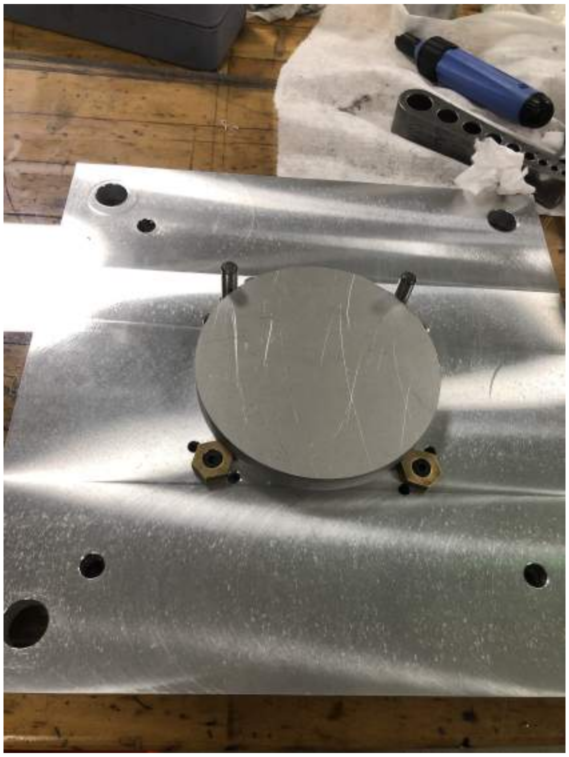

Fig. 18 Machining Jig

Fig. 19 Machined Bulkheads

its main chute until ground hit at 20.6 ft/s. The Tendie Descendie is screwed into the e-bay bottom bulkhead and consists of a base and ejector plate as shown in Figure 21.

The decision to have a body tube dedicated to vehicle recovery was based on two unsuccessful flight attempts of a 4.5 in diameter rocket, Spargarita, where the vehicle recovery system was in the upper body tube. From the flight attempts, it was apparent that having the payload pull the rocket drogue chute out of the upper body tube was unreliable. During the first flight attempt, the payload drogue chute shroud lines tangled with the nose cone shock cord, so the rocket drogue chute did not fully deploy. Recovery success is unknown for the second flight attempt because the vehicle was not recovered. Additionally, it was difficult to properly size the main deployment bag to fit through the payload ring.

The Tendie Descendie accomplishes the same goal as the COTS Tender Descender except it is designed to be secured to a bulkhead instead of hanging in-line with the parachutes. The Tendie Descendie holds onto a short length of shock cord, securing the main chute inside the nose cone. At a specified altitude, the securement pin is blown out by a small black powder ejection charge in the center of the Tendie Descendie and the main chute is free to be pulled out of the tube and deploy as shown in Figure 22. The Tendie Descendie is sized to withstand any deployment forces the rocket experiences. Running a Solidworks FEA simulation, it was found that the Tendie Descendie could withstand 1000 lbf with a minimum factor of safety of 4.6, far exceeding the forces this rocket is expected to experience.

The method of the lower body tube and recovery tube separating to release the drogue chute has been proven successful in two flight attempts of a 4.5 in diameter rocket, Once More. The separation of the tubes and the placement of the drogue chute in the coupler between the tubes guarantees drogue chute deployment. Furthermore, there are no obstructions in the tube, so when released from the Tendie Descendie, the main chute can easily deploy as well.

The parachute sizes were determined through Open Rocket simulations to meet the ESRA requirements for descent and ground hit velocity. A 36 in drogue chute slows the vehicle to 78.3 ft/s for main chute deployment. A 84 in main chute allows for a ground hit velocity of 20.6 ft/s.

Phalanx uses 60 ft of 0.625 in tubular nylon shock cord with a sewn loop on each end. The length from the e-bay u bolt to the main chute quick link is 16 ft to account for the length of the recovery tube and for the

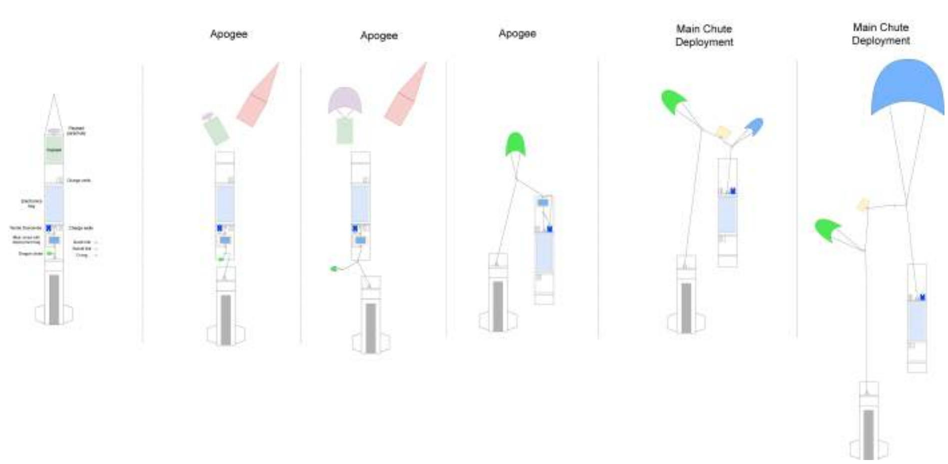

Fig. 20 Launch Vehicle Recovery Diagram

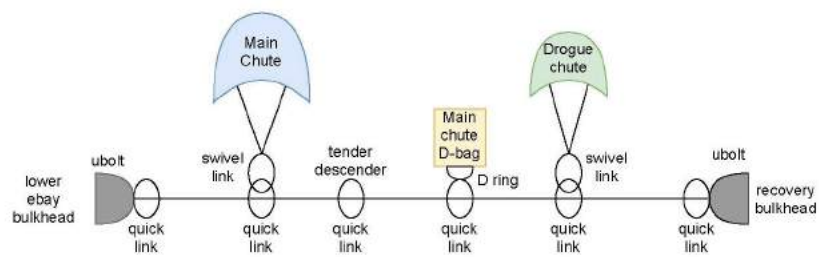

Fig. 21 Launch Vehicle Recovery Layout

main chute to completely come out of the tube. The length from the main chute quick link to it's deployment bag is 14 ft to allow the main chute to come out of the deployment bag. Between the main chute and its deployment bag is a knot for the Tendie Descendie which is 13 in from the deployment bag. The length from the deployment bag to the drogue chute quick link is 8 ft, which accounts for the tube length and drogue chute deployment. The length from the drogue chute quick link to the u bolt on the recovery bulkhead is 20 ft so that the lower section hangs below the upper section.

Black power sizing was mathematically calculated from the density of 4F black powder and will later be confirmed with ejection tests. Because all of the recovery events in the rockets rely on using shear pins, the shear strength of a shear pin drives the calculation. After solving for a required force to shear all of the pins, the pressure for the tube can then be determined, which then leads to a necessary amount of black powder. Then from the mass needed as well as the density, the volume of the charge well can be determined. An example of these calculations is depicted below in Figure 23.

For Phalanx, preliminary calculations were done to estimate the amount of black powder needed in each charge well, the results of which are summarized in Table 2 below. These calculations were verified through recovery testing of the vehicle.

The recovery electronics are located in the vehicle's electronics bay. The primary recovery flight computer is a Raven4 Altimeter with an RRC3 Sport as the secondary. Two different brands of COTS flight computers were chosen to increase redundancy and reliability. The Raven4 provides both barometric and accelerometer data, whereas the RRC3 provides only barometric data. A Featherweight GPS is also installed in the e-bay to facilitate tracking and recovery of the launch vehicle.

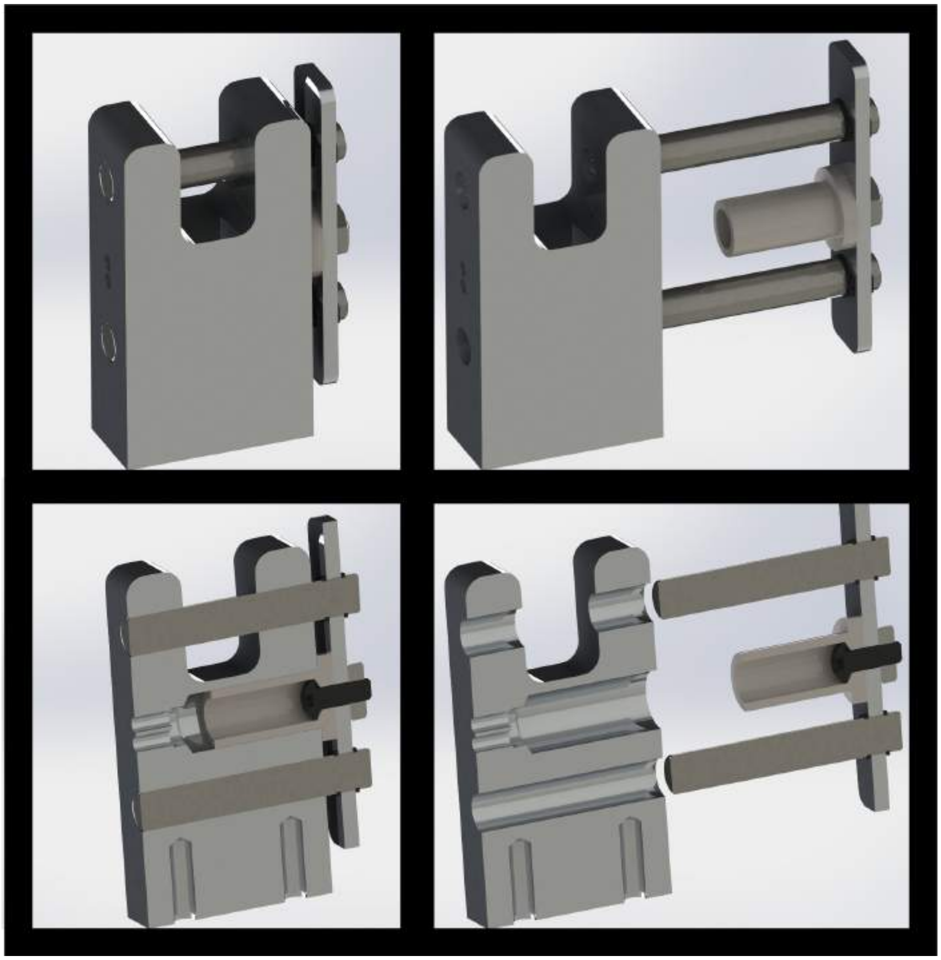

Fig. 22 Tendie Descendie Render

Inputs			
Rocket	Rocket Diameter	6.17	in
	Length of Tube	25	in
Shear Bolts	Number of Shear Bolts	4	
	Bolt Minor Diameter	0.0641	in
	Safety Factor	3	

Constants			
Nylon	Nylon Tensile Strength	12000	psi
	Nylon Shear Strength	7200	psi
4F Black Powder	Combustion T	3307	Degrees Rankine
	Combustion Gas Constant	265.92	(in-lbf)/(lbm-R)
	Density	0.0336	lb/in^3

Calculated Values			
Rocket	Reference Area	29.89924414	in^2
	Reference Volume	747.4811036	in^3
Shear Bolts	Bolt Cross Sectional Area	0.003227051828	in^2
	Bolt Shear Force	23.23477316	lbf
	Required Total Force	92.93909264	lbf
	Desired Total Force	278.8172779	lbf
	Desired psi	9.32522831	psi
4F Black Powder	Charge Weight	0.007926372799	lb
		3.598573251	g

USER GUIDE:
Only edit the values with GREEN backgrounds
Constants are PURPLE and calculations are BLUE
Charge weight is calculated using the Ideal Gas Law
Nylon shear strength is assumed to be 60% of the tensile strength
Calculated volume of charge well should be no more than 200% required volume

NOTES:
Safety factor to be determined from experimentation
Solving for needed bulkhead force rather than an arbitrary chosen force on bulkhead

Volume of Charge Well		
Diameter	0.5	in
Height	1.75	in
Calculated Volume	0.3436116965	in^3
Required Volume	0.2359039524	in^3
Upper Volume Estimate	0.4718079047	in^3

Fig. 23 Black Powder Calculations

Table 3 Black Powder Charges

System	Amount of Black Powder (grams)	Expected Force (lbf)
Tendie Descendie (main recovery)	0.3	—
Tendie Descendie Nano (nose cone recovery)	0.3	—
Upper Body Tube	3.3	279
Lower Body Tube	3.6	279 in

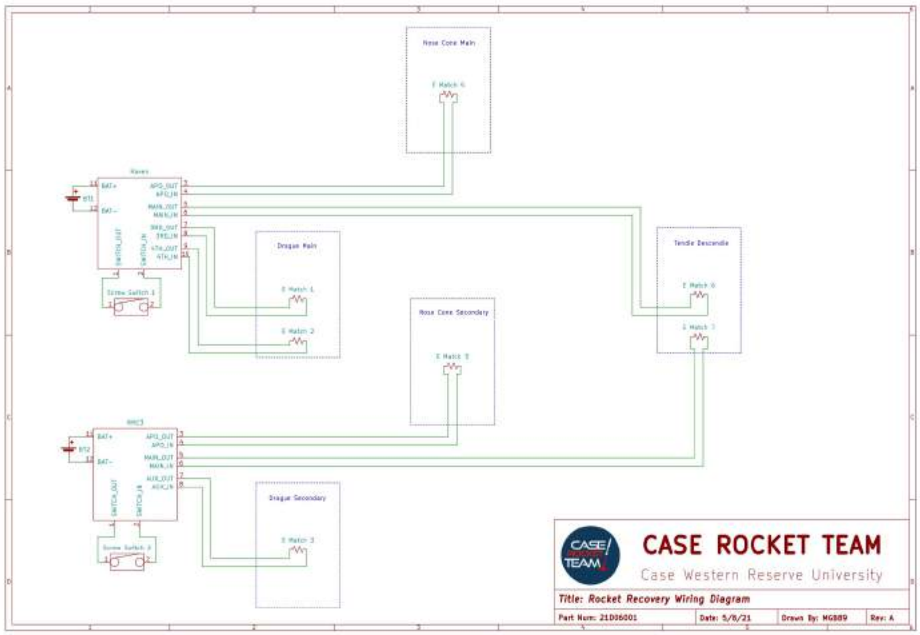

Fig. 24 Launch Vehicle Recovery Wiring Diagram

At apogee, the Raven4 apogee output fires e-match 4 in a charge well on the upper e-bay bulkhead which ejects the nose cone. For redundancy, the RRC3 apogee output fires e-match 5 in the second charge well on the upper e-bay bulkhead. After nose cone ejection, the Raven4 3rd output fires e-match 1 in the drogue main charge well on the lower e-bay bulkhead. At the same time, the Raven4 fourth output fires e-match 2 in the same charge well for further redundancy. If both e-matches fired by the Raven4 or the Raven4 itself fails, the RRC3 aux output is programmed to fire e-match 3 in the drogue secondary charge well on the lower e-bay bulkhead shortly after the Raven4 fires for more redundancy. At 1250 ft, the Raven4 main output fires e-match 6 in the Tendie Descendie charge well. For redundancy, the RRC3 fires e-match 7 shortly after e-match 6 is fired. This wiring scheme is shown in Figure 24.

Both the RRC3 and the Raven4 are armed with screw switches that are mounted to the e-bay sled. The screw switches are accessible through two holes in the camera band and are mounted on stand-offs so that the screw is close to the edge of the coupler.

(b) Nose Cone

The nose cone recovery subsystem is designed to minimize payload deployment interference and ensure successful nose cone recovery. It features dual deployment of a drogue and then main chute, handled by a Tendie Descendie Nano. At apogee, the nose cone separates from the upper body tube and the 10 in drogue chute deploys. The nose cone then descends at 81 ft/s. At 500 ft above ground level, the Tendie Descendie Nano releases the 24 in main chute, and the nose cone coasts to the ground at 23 ft/s.

The Tendie Descendie Nano accomplishes the same goal as the COTS Tender Descender, except it bolts to a bulkhead instead of hanging in-line with the parachutes. The Tendie Descendie Nano holds onto a short length of shock cord, securing the main chute inside the nose cone. At a specified altitude, the securement pin is blown out by a small black powder ejection charge in the center of the Tendie Descendie Nano and the main chute is free to be pulled out of the tube and deploy as shown in Figure 25. Its small size allows for weight-saving at the cost of strength, but it is still more than strong enough to account for the small deployment

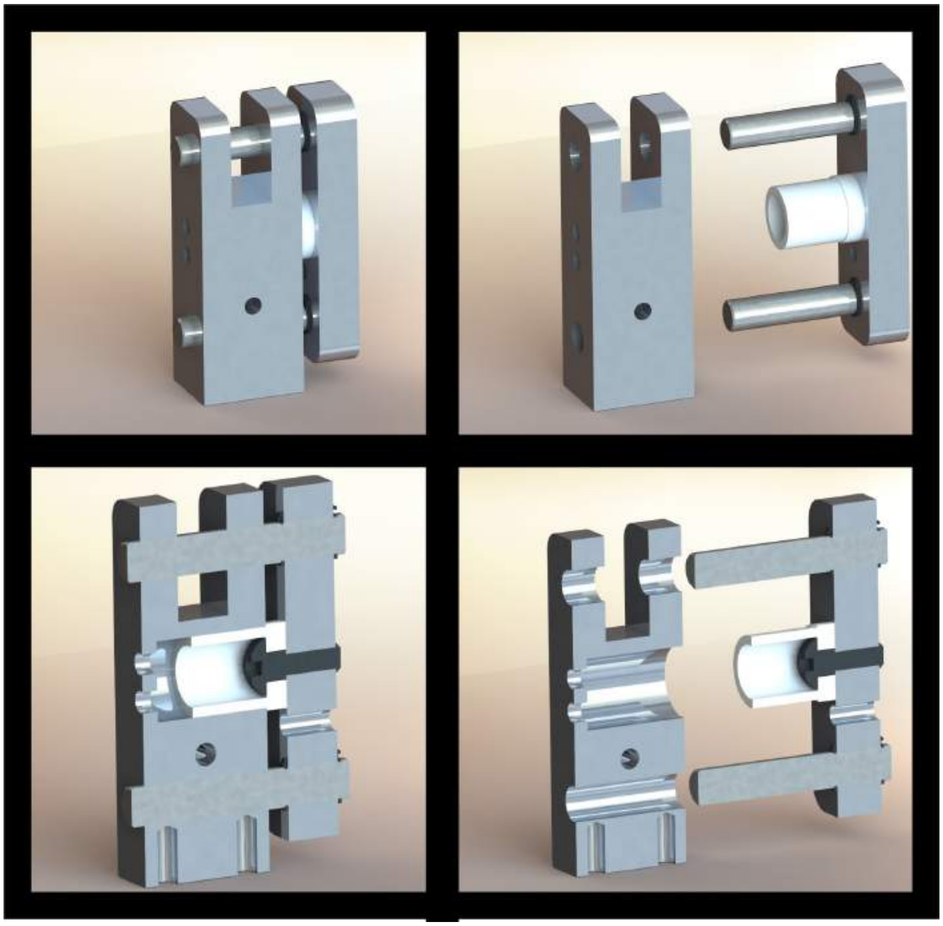

Fig. 25 Tendie Descendie Nano Render

force of the nose cone's parachutes.

The estimated mass of the nose cone is 3.6 lbs. Using the drag equation and comparing velocity to parachute area, the parachutes were sized as a 10 in drogue and a 24 in main for descent velocities of 81ft/s and 23 ft/s, respectively.A detailed diagram of the recovery system for the nose cone can be found in Figure 26. A detailed diagram of the recovery layout can be found in Figure 27.

The nose cone features dual-redundancy to ensure that the main chute deploys. There are two independent flight computers, a Raven 4 and RRC3 Sport. For redundancy, each flight computer has their own e-matches to deploy the Tendie Descendie Nano. A Featherweight GPS is included to facilitate tracking the nose cone during and after landing. A detailed wiring diagram can be found in Figure 28.

The nose cone is armed by two screw switches located at the base of the nose cone. A shield is installed surrounding the switch and wires to prevent tangling or snagging of the components with the recovery hardware. The screw switch is located near the base of the nose cone to minimize any pressure effects with holes on the leading surface of the nose cone geometry.

D. Payload Subsystem

1. Motivation

The payload is a rapid-recovery test vehicle for scientific experiments. Often on the field, the recovery of a launch vehicle is a time and labor intensive process. For small items or payloads that are time sensitive, issues with recovery can cause unintended consequences or failures. The use of guided parafoil recovery allows for a compact method of recovery with the goal of targeting a location on the ground. This allows a ground team to identify a primary recovery location

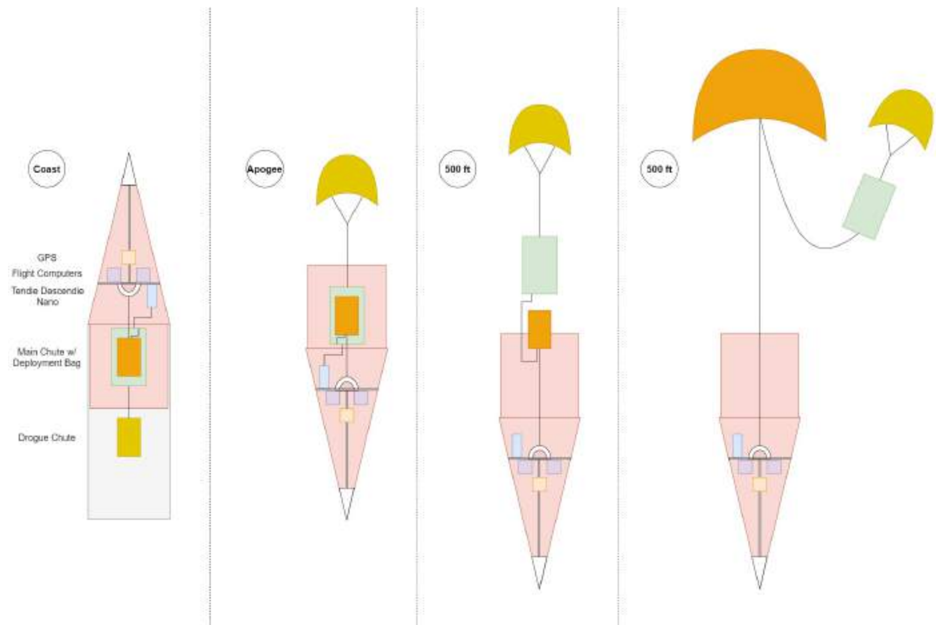

Fig. 26 Nose Cone Recovery Diagram

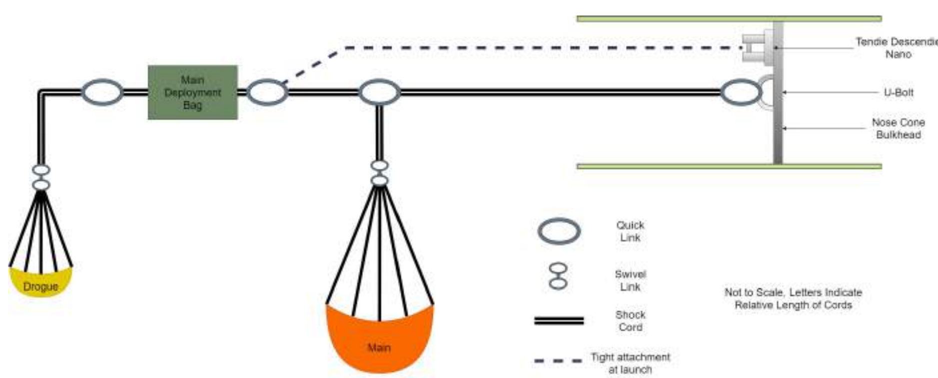

Fig. 27 Nose Cone Recovery Layout

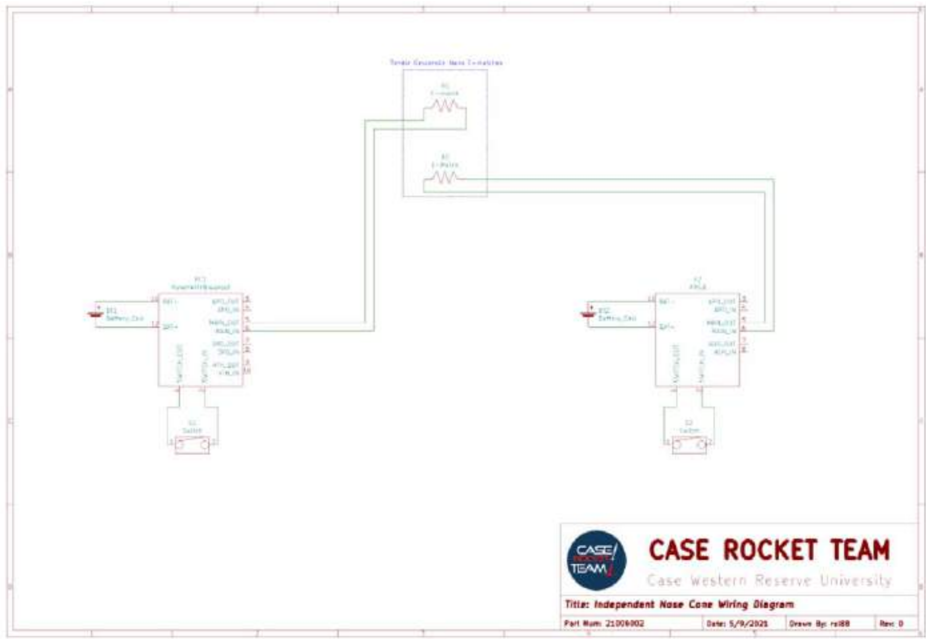

Fig. 28 Nose Cone Wiring

Fig. 29 Aegis Payload

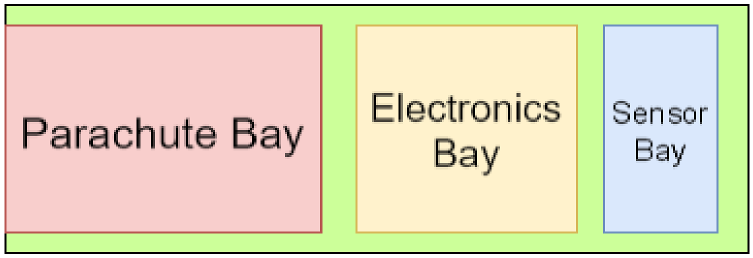

Fig. 30 Payload Layout

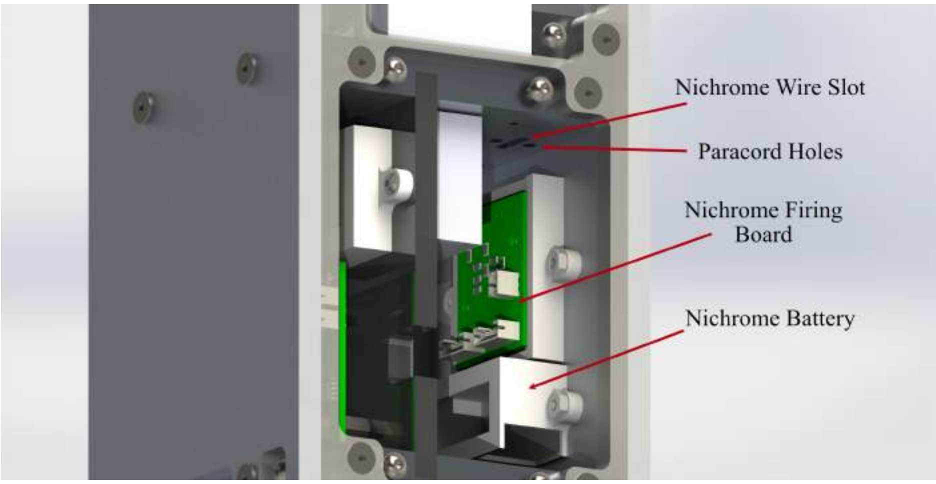

Fig. 31 Nichrome Wire Cord Cutter Mechanism

and be there in preparation of landing, as opposed to being required to follow the vehicle visually or track a GPS signal.

2. Structure

The payload is broken down into three primary subsystems: the Parachute Bay, housing the recovery hardware; the Electronics Bay, housing the avionics; and the Sensor Bay, housing scientific experiments and instruments. This layout can be seen in Figure 30.

(a) Electronics Bay

The electronics bay houses the main flight computer, the backup flight computer, the nichrome firing board, and the main computers' antennas, as well as the batteries necessary for powering all of the electronics. During flight, the main board is responsible for triggering parafoil deployment at the correct altitude, after which it uses the payload's parafoil control servos to steer the payload to the desired landing area on the ground. The backup board is only responsible for ensuring that the parafoil deploys and does not have the ability to control any other parts of the payload. Should either the main board or the backup board fail, the remaining functioning board will still send a signal to the nichrome firing board. The nichrome firing board has an input connection from each board, a battery connection, and two nichrome screw terminals. The board input connections have two separate signal pins corresponding to the two nichrome wires. If the nichrome firing board receives a signal from either board, it will apply the battery's voltage across the corresponding nichrome wire.

The main board has two antennas: a LoRa antenna and a GPS antenna. The GPS allows the main board to properly guide itself to the landing zone, while the LoRa allows for communication with the payload for the purpose of collecting real-time telemetry data.

Most of the electronics bay components are mounted on an acrylic sled, which slides in and out of the electronics bay and is held in place by an acrylic shield on either side. The nichrome firing board and nichrome battery are mounted on the inside of the frame.

Throughout testing, getting the nichrome wire to consistently deploy proved to be a problem. The team

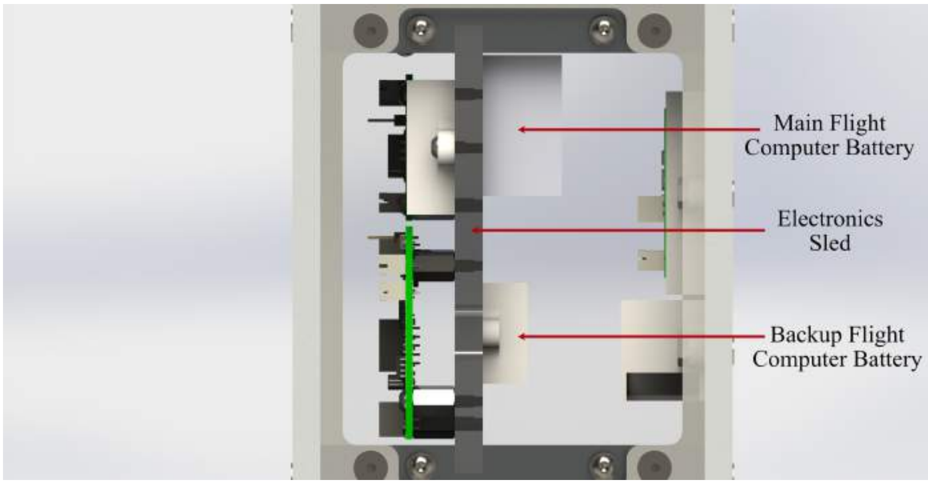

Fig. 32 Electronics Sled Inside the Electronics Bay

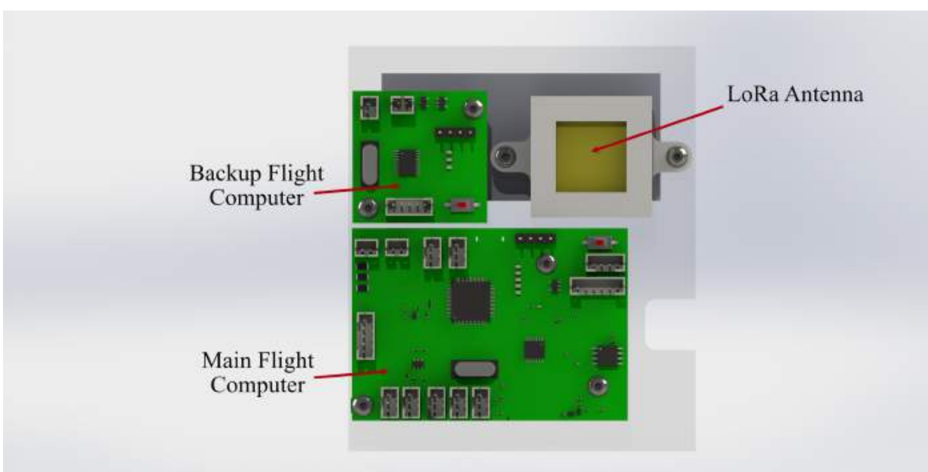

Fig. 33 Payload Flight Computers

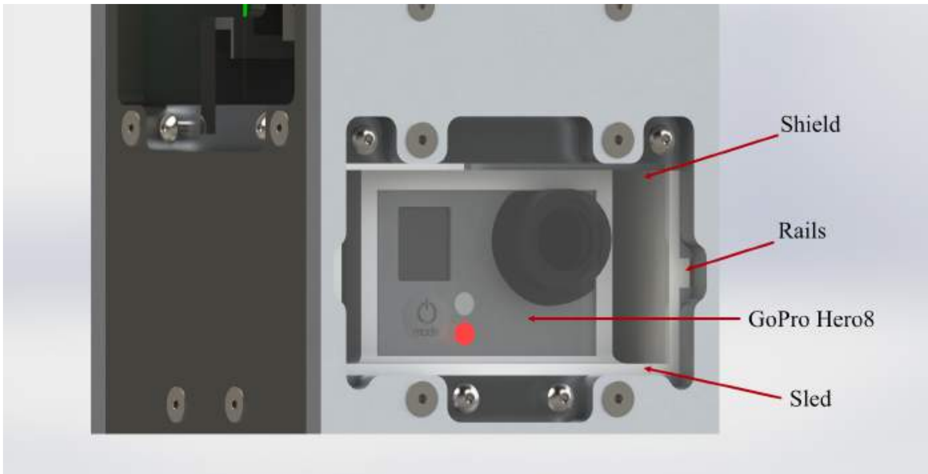

Fig. 34 Sensor Bay Exterior

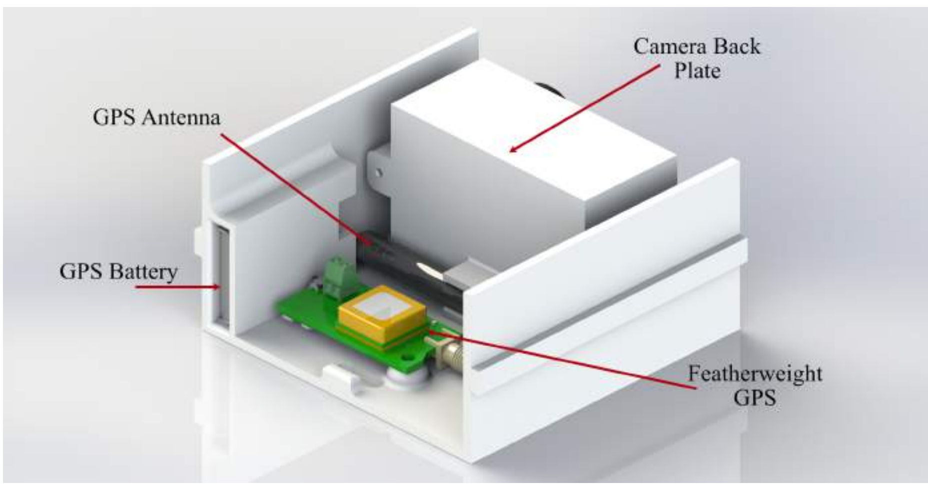

Fig. 35 Sensor Bay Interior

experienced failures caused by the nichrome coming loose, wires coming loose from the altimeter used for testing, and the altimeter not detecting flight. Thus, in order to ensure parafoil deployment, the team made several design decisions. The first was having a backup board, the sole purpose of which is to trigger the nichrome firing board in case the main board fails to do so. There are also two separate nichrome wires, either of which can trigger parafoil deployment, as well as continuity checks built into the main and backup boards. Finally, all of the wires terminate in JST connectors to prevent wires from easily coming loose.

Most of the electronics bay components are mounted on the sled for easy assembly. The nichrome firing board and nichrome battery are mounted directly to the frame because it is easier to set them up independently Additionally, mounting them to the frame leaves more space on the sled for the other components.

(b) Sensor Bay

The purpose of the sensor bay within the payload is to house a sensor that can collect data while being easy to install and remove from the payload. The current configuration for the payload houses a GoPro Hero 8 camera, a Featherweight GPS module, and a 400 mAh 1S battery. The camera is mounted on a 3D printed sled housed between the payload frame plates. Two acrylic shields screw into the middle bulkhead covering the front and back of the sensor bay for retaining the 3D printed sled. They allow for ease of installation and are transparent for the camera.

The most significant decision made with the sensor bay was separating it from the electronics bay in the first place. This eliminated issues found early in development while assembling the payload, where all components

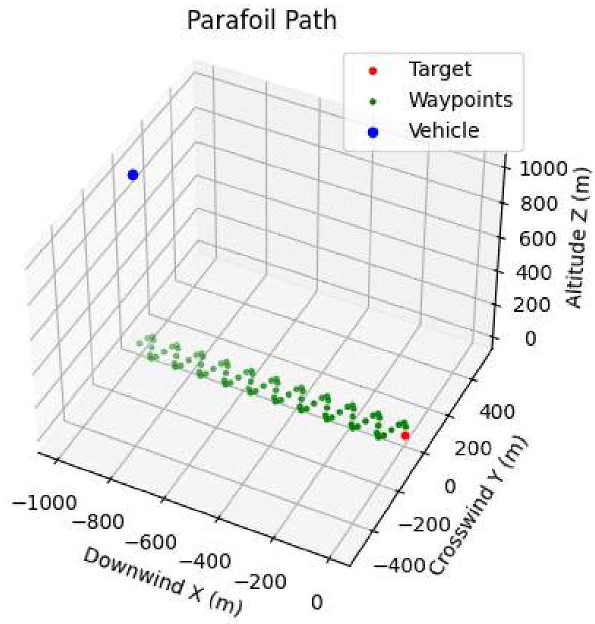

Fig. 36 Payload Guidance Waypoints

needed to be removed to access the flight computers. Now the flight computers, nichrome firing board, and their batteries can be easily accessed without removing every piece of electronics.

For the sensor bay, a GoPro Hero 8 video camera was selected for its ability to record long periods of HD footage so that recovery events such as ejection and main chute deployment can be examined after launch. With the modular nature of the sensor bay, different scientific instruments or experiments can be easily swapped in and out in the future.

(c) Parachute Bay

The payload's software handles the path generation, path following, and parafoil servo controls used to autonomously navigate the payload towards its predesignated target. The software uses data collected from the GPS, IMU, and altimeter to estimate its current location, heading, and wind speed.

After the parafoil is deployed, the flight computer determines a point between it and the target coordinates, around which it will hold a circular pattern. To maintain this holding pattern, the payload uses a PID controller using the distance from the center of this path as the process variable. The payload remains in this holding pattern until the vehicle is facing towards the target and the estimated time until landing is with a predefined range where an acceptable path is possible, then it moves to the pathing phase.

Once the payload enters into the final descent, a sinusoidal path, expressed as a set of evenly spaced out coordinates, is generated. This path makes sure to avoid turns smaller than 230 ft in radius, which is the minimum turning radius of the vehicle. Then the payload follows these waypoints using a pure pursuit algorithm until it has landed.

While testing different possible guidance methods in simulations, the team found that breaking up guidance into multiple stages achieved better results than all purpose methods that were active throughout the entire process. Additionally, a lack of processing power constrained the complexity of any guidance method, making multistage methods the best option.

The first stage, which is the holding pattern, is intended to maintain the desired distance from the target until final descent. The team used a circular holding pattern implemented with a PID controller because of its simple implementation and the low computational power required to operate. In the future, a figure eight pattern may be preferable, as the literature notes that this pattern avoids stalling that may occur when the vehicle holds a turn for long periods of time[2]. In the approach towards the target, the team opted for a sinusoidal pattern

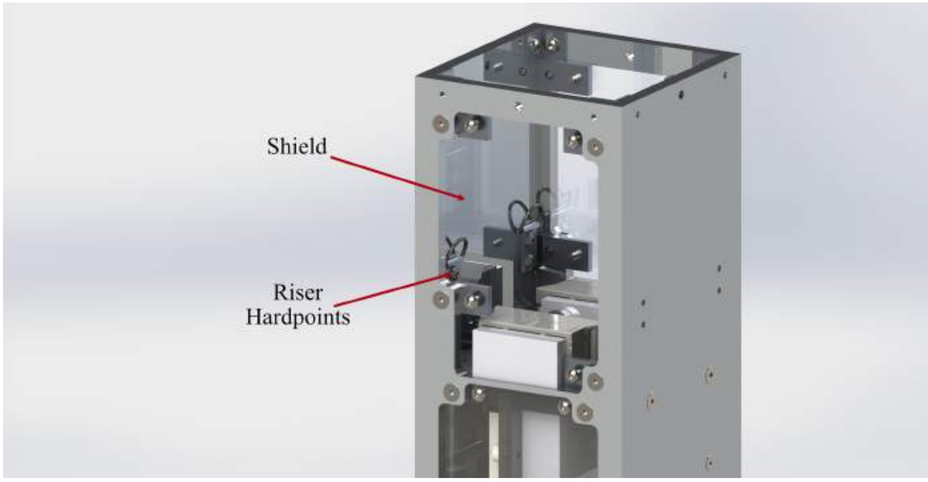

Fig. 37 Parachute Bay Exterior

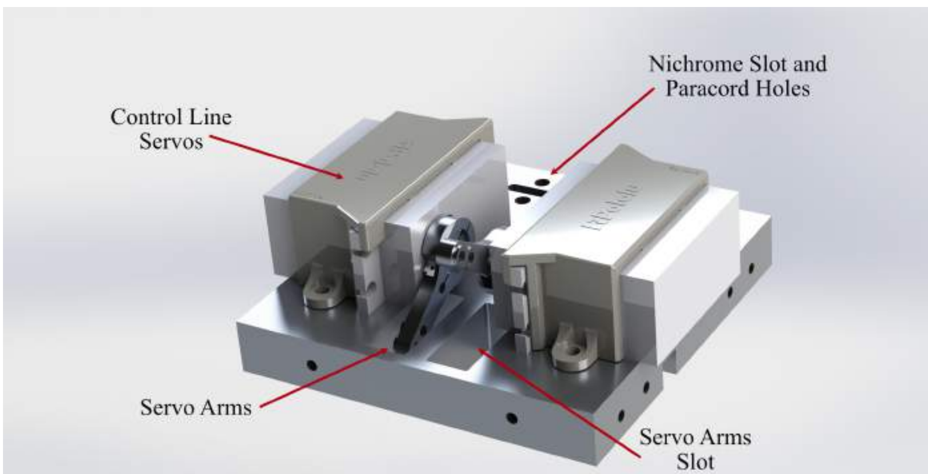

Fig. 38 Control Line Servos

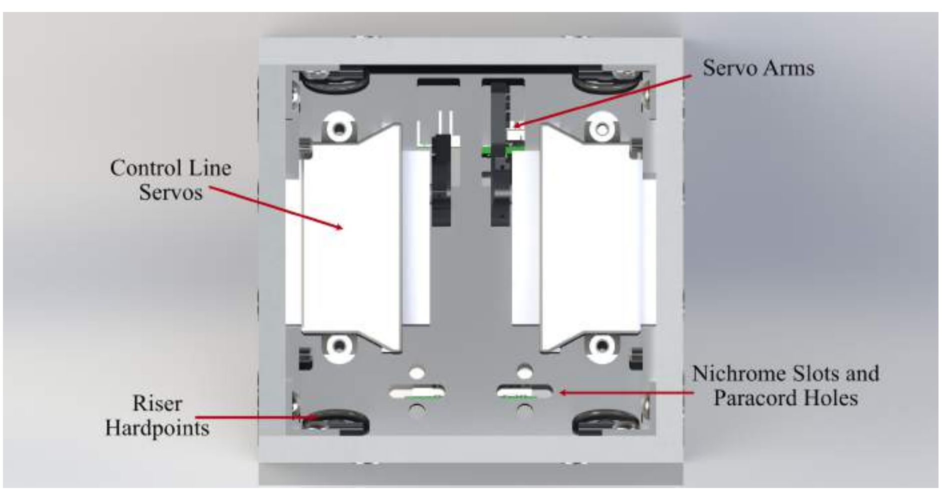

Fig. 39 Parachute Bay Top View

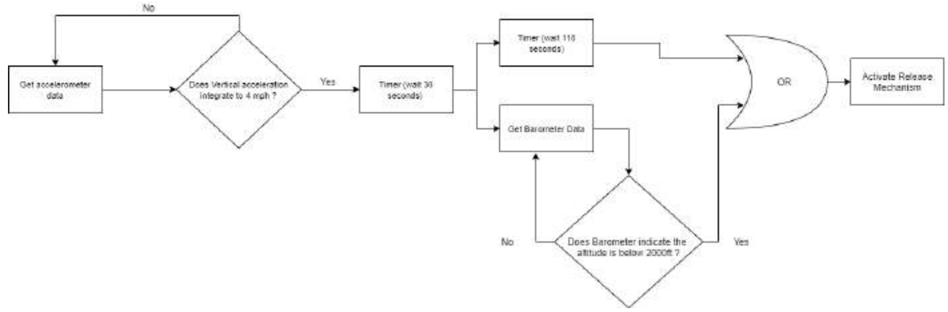

Fig. 40 Payload Control Algorithm

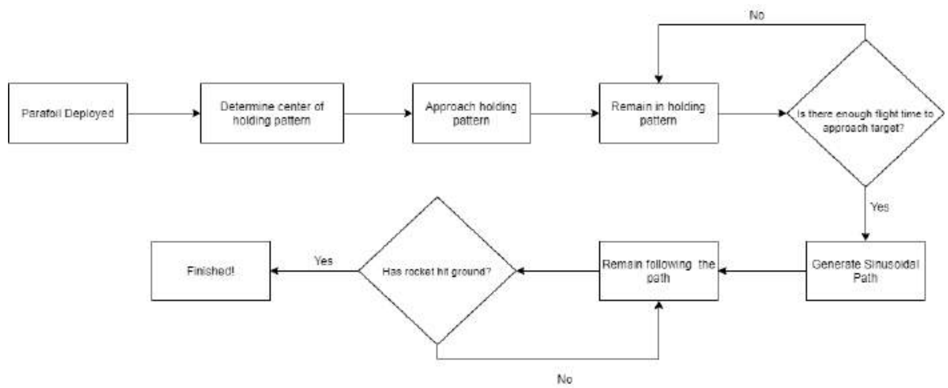

Fig. 41 Payload Guidance Algorithm

because it was similarly easy to calculate compared to other patterns and allowed for easy modification of the arc length of the path. The path length can be easily adjusted based on the amplitude and frequency of the curves, which provides more versatility for where the payload begins the pathing phase. Additionally, the team used path pursuit to follow the curve because it has low computational requirements and responded better in simulations than alternative methods like PID control.

3. Payload Recovery

The payload is designed to be recovered from the rocket as a separate entity. Since it will be ejected from the rocket at apogee, it features a dual deployment system with the payload falling at 80 ft/s under a 12 in SRAD elliptical drogue chute deployed at apogee. At a height of 2000 feet AGL, the onboard flight computer will trigger the nichrome wire cord cutter mechanism to release the deployment bag containing the SRAD parafoil as described in detail later in this section. Once the parafoil and its lines have been fully pulled out of the bag by the drogue chute, the slider holding the suspension and cascade lines together will start to move to the base of the lines, allowing the parafoil to fully inflate. Once fully inflated the vehicle will fall at 18 ft/s.

The nichrome wire cord cutter mechanism is a loop of 32 AWG nichrome wire looped around a thin piece of braided nylon cord. The nichrome wire is connected to the screw terminal of the nichrome firing board. The cord runs through two small holes in the upper bulkhead The cord runs through one hole, around, and out of the other hole, connecting to a link on the bottom of the parafoil deployment bag. This directly connects the cord to the payload. The cord is tied short to keep the deployment bag as close to the bulkhead as possible. As seen in Figure 29, when the firing board is activated at 2000 feet AGL, current flow through the nichrome wire heats it up rapidly, melting through the cord, separating it. The drogue parachute then pulls the parafoil deployment bag upwards, pulling the cord out of the bulkhead and separating the parafoil bag from the payload. Additionally, a small slot, seen in Figure 29, is used to create a small gap for the nichrome wire. This gap prevents the nichrome from making contact with the metal bulkhead.

The payload recovery design was based on two unsuccessful flight attempts using two alternative methods and test articles. The two test payloads, The Lime and Key Lime, each acted as a dual-deployment test platform with two

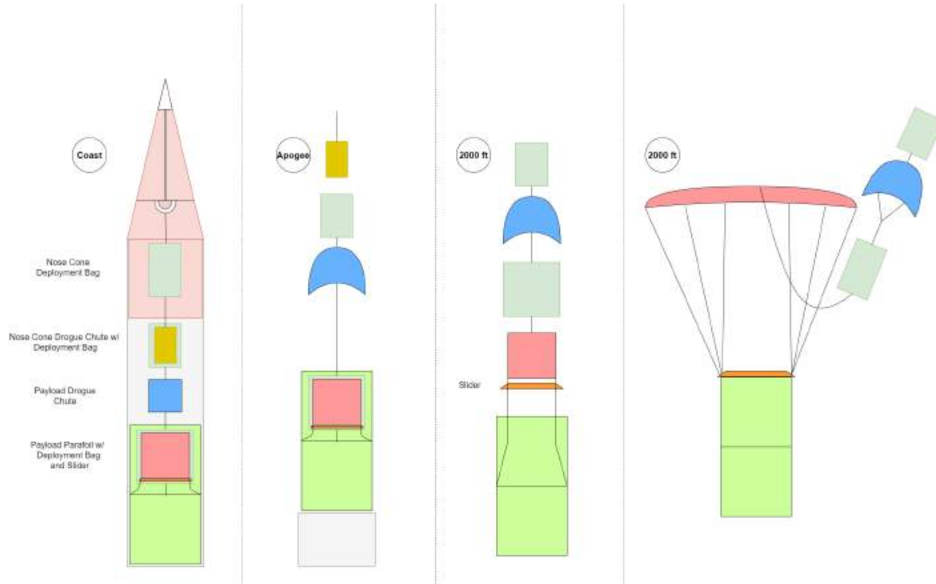

Fig. 42 Payload Recovery Diagram

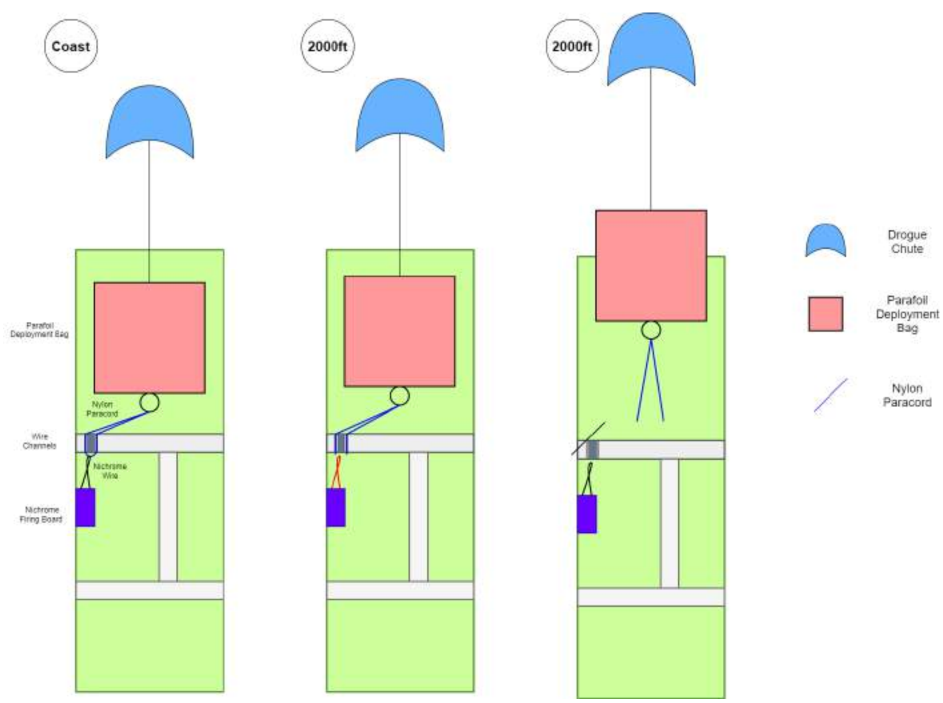

Fig. 43 Nichrome Cord Cutter Mechanism Diagram

elliptical parachutes attached to the top bulkhead. The Lime used a deployment bag that was fully removed from the parachute bay. This was to allow the team to more easily tie the paracord onto the bag. However, the main parachute fell out of the deployment bag and thus deployed above the desired altitude. Key Lime was modified to move the deployment bag completely inside the parachute bay with the paracord connected to the top of the bag. While extensive stress testing seemed to indicate this method would prevent early separation, the forces in flight managed to dislodge the bag and flip it around, again causing an early separation.

Additionally, both flights were found to have unsuccessfully burned through the paracord. Initially, it was suspected that this was due to the mounting of the Raven 4 altimeter used to test dual-deployment, as it had not detected a launch. However, the altimeter did not detect launch on the second attempt as well. This was likely due to a correction the altimeter attempted to make for acceleration while being prepared for launch. This assessment is based on dozens of tests conducted on the two test articles using the Raven to trigger the separation. In testing, the Raven correctly activated the nichrome while running in a simulation. One change between the two test payloads, however, was the introduction of the slot for the nichrome. This was used to correct a grounding error seen in testing where the nichrome would occasionally contact the metal bulkhead. When activated, the current would then transfer from the wire to the bulkhead. The gap allowed for the nichrome to be looped around the wire without making physical contact with the rest of the payload.

These tests led to the team tweaking the design of the payload recovery system to require that the deployment bag be completely contained inside the payload, with the paracord tied to the bottom of the bag. This paracord is sized to keep the deployment bag as close to the bulkhead as possible. The paracord is looped through two holes on the bulkhead, with the nichrome wire looped around the paracord. This wire then sits inside the air gap to prevent contact with the bulkhead. When activated, the nichrome melts the paracord, allowing the force of the drogue parachute to remove the parafoil deployment bag.

4. Parafoil

(a) Design

The parafoil was designed using the wind tunnel program XFOIL to determine the lift characteristic of the chosen NACA 4418 airfoil segment under various angles of attack. This was used to calculate the various impacts on the coefficients of lift and drag for the wing, those calculations being automated through a Python script written by the team[2]. The various components of drag on the wing are shown in Figure 30. Through several design iterations, a wing with a 40 in span and 20 in chord, an aspect ratio of 2, with a set 5° angle of attack was chosen as they led to a descent velocity of 18 ft/s and a glide ratio of 2.7:1 horizontal to vertical. This is advantageous to the mission profile as its descent speed is slow enough for the competition rules without taking an unnecessary amount of time to descend, potentially delaying other launches or recovery efforts. This glide ratio also lessens the potential for the vehicle to drift excessively far from the launch site if it encounters a problem and descends uncontrolled.

(b) Manufacturing

The parafoil is manufactured in two phases: sewing the canopy and attaching the lines. The canopy components were made by creating a set of cardboard templates and then using the tip of a soldering iron to cut the ripstop nylon fabric along the edge of the template, leaving a flat piece in the desired shape. The assembly of the canopy can be seen in Figure 46. This step is broken down into three actions. Firstly, the skin segments are brought together to form the bottom skin. The ribs are then attached to it by pinning the edge of each rib in place. When the pins are removed, the parafoil conforms to the shape of the ribs. These ribs are then sewn onto the top skin, completing the full canopy.

The braided nylon lines are then sized based on the line length calculated in the initial design equations. This determines how far away the payload should be away from the wing. Next, the payload center of mass needs to be located at one quarter the length of the wing chord away from the leading edge. With these two specifications set, the lines could be laid out. They need to connect to the ribs each one quarter of the chord length apart from each other, starting from the leading edge. The front two suspension lines will then meet and join into one cascade line which is then tied onto the risers. This is repeated with the rear two suspension lines. This line layout is shown in Figure 47. Each cell of the parafoil has a set of lines on either side as shown in Figure 48. A test article with all lines attached is shown in Figure 49.

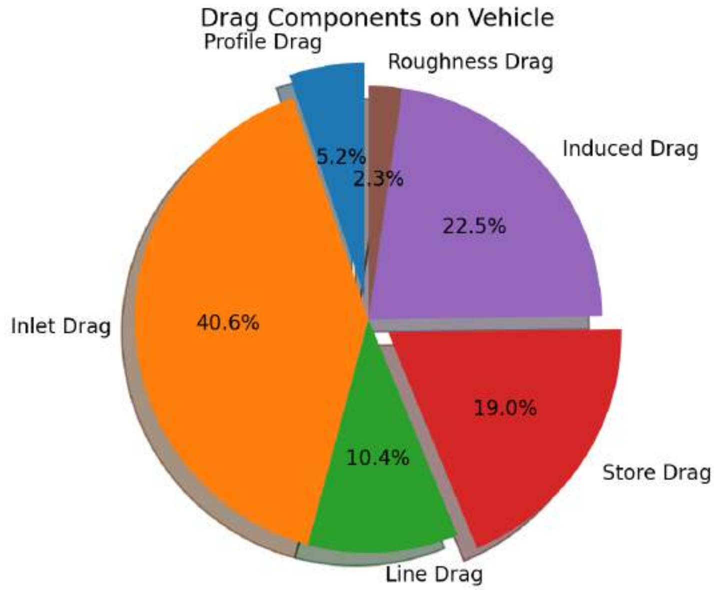

Fig. 44 Drag Analysis on the Parafoil

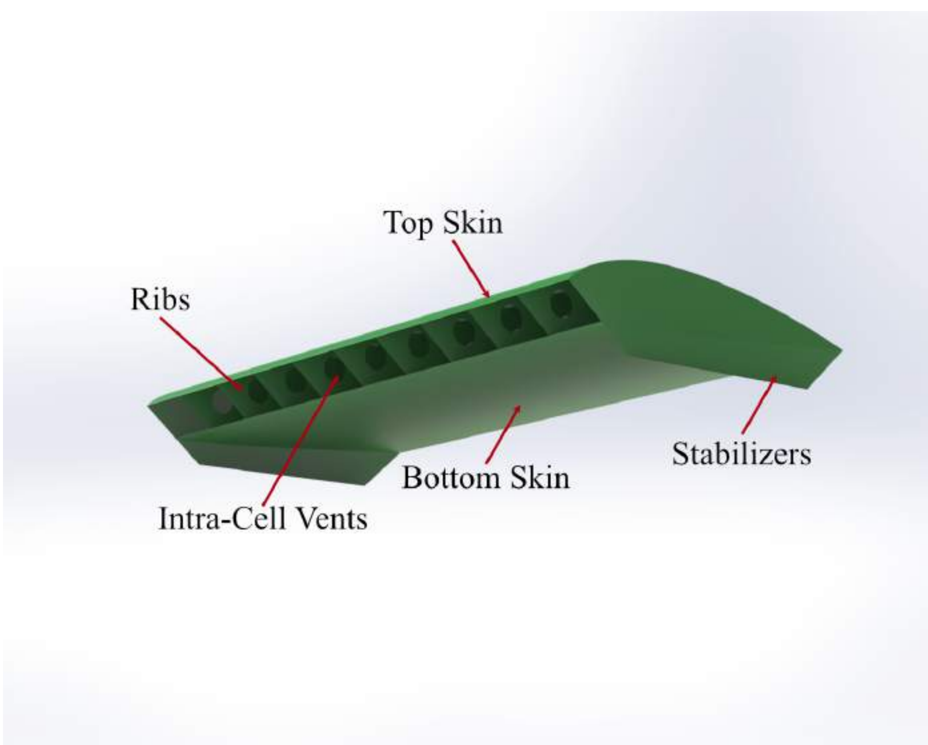

Fig. 45 Parafoil Full Design

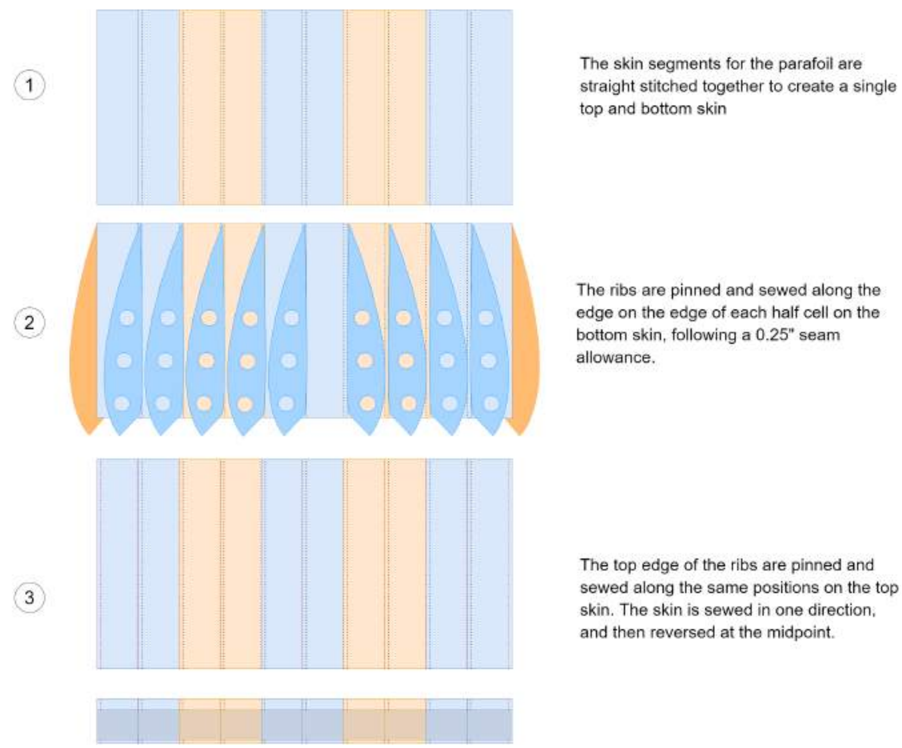

Fig. 46 Parafoil Canopy Assembly

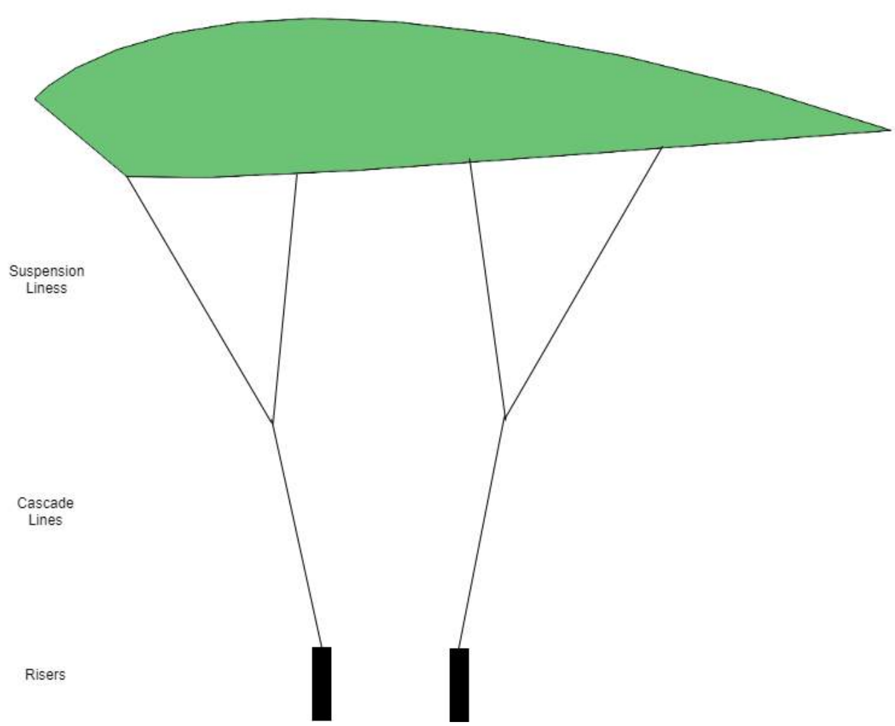

Fig. 47 Parafoil Lines Side Profile

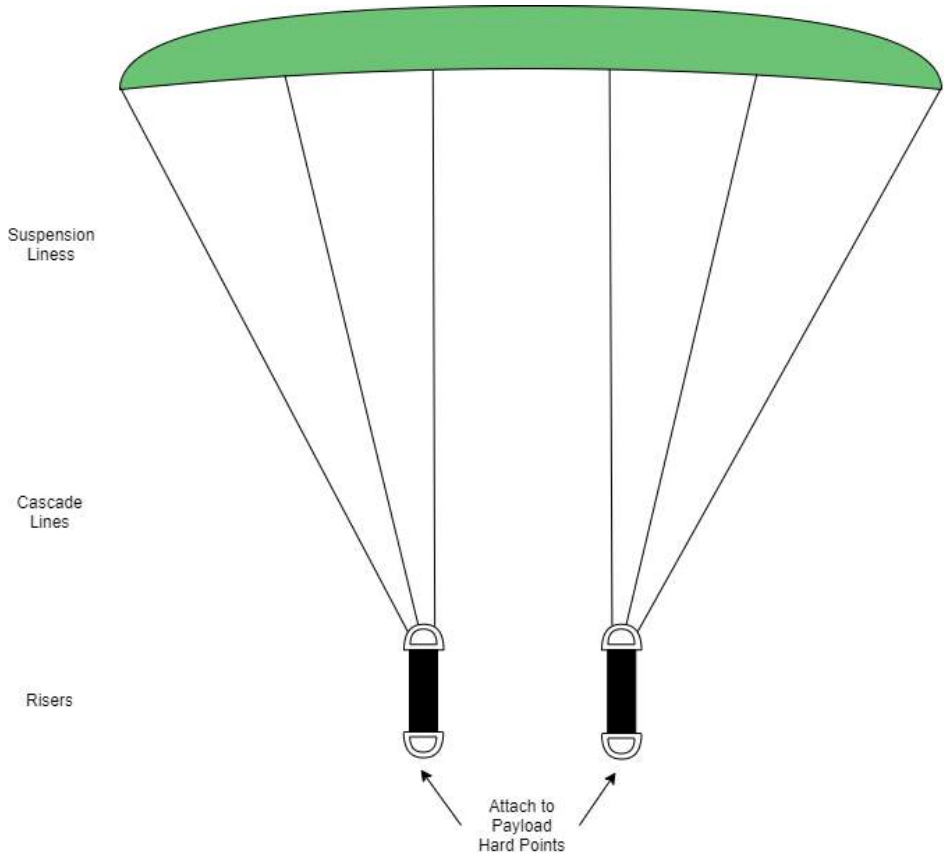

Fig. 48 Parafoil Lines Front Profile

Fig. 49 Parafoil Test Article

5. Payload Manufacturing

The payload's frame is made from 0.25 in 6061 aluminum plate that was cut into shape using a waterjet. Finishing operations included using a mill to drill the hole pattern and then tapping said holes. Both the bottom and middle bulkheads are made of 0.5 in 6061 aluminum plate stock, cut using a waterjet, with finishing work done with a mill to cut the slots and drill the hole pattern which were then tapped. The top bulkhead was made of 0.5 in A36 steel plate stock also cut using the waterjet and then drilled and tapped on a mill. The electronics bay sled and the frame side shields are made of 0.125in acrylic sheet that was cut into shape using a laser cutter. All of the electronics mounts used in the electronics bay and sensor bay were 3D printed using PLA filament.

6. Conclusions and Lessons Learned

By designing and constructing a payload for the SDL Payload challenge and its requirements, the team learned a great deal about the design considerations and operations of a deployable payload. To reach the final iteration of the payload the team designed multiple prototypes that were iterated on to improve on shortcomings found in each prototype. Some of the key lessons learned include the importance of workability and ergonomic design in the payload, as well how vital wire management in the electronics bay are to consistent operation of recovery mechanisms. In addition, integration of guidance via servo-controlled parafoil has revealed many meaningful interactions with other modules of the payload such as the parachute bay and electronics bay.

Ergonomics were found to be very important in both assembly and testing of the payload, as in previous iterations of the payload the electronics bay could only be accessed by removing the frame plates of the payload. This was found to be very cumbersome and often resulted in wires being caught in the frame plates as it was being reassembled. This was an issue particularly for the nichrome firing mechanism as it contained multiple delicate components connecting to screw terminals that could be damaged if pulled taut as the payload was being reassembled. This was remedied in the final iteration of the payload by allowing access to the electronics bay sled through screw on acrylic windows installed on the left and right sides of the payload. These windows not only allow inspection of electronic components without disassembling the payload, but allow the electronics bay sled to be removed, wired, and reinserted easily. The servo-controlled parafoil also presented design challenges that had to be solved, such as having the servos, which had to be routed up to the risers mounted in the parachute bay, while still having them connected to the main board mounted in the electronics bay. The solution resulted in the servos being mounted in the parachute bay using servo brackets rather than in the electronics bay sled like in previous iterations. The only change that had to be made to accommodate this was to have a slot in the parachute bay bulkhead for servos to be able rotate below the horizontal and route servo power cables to the main board.

Designing this payload has allowed the team to gain knowledge on how to successfully design, construct, and launch a deployable payload that can fulfill a task of our choosing such as guiding a payload to a designated destination in order to facilitate a timely recovery.

IV. Mission Concept of Operations Overview

The concept of operations is detailed for each key subsystem below in Table 50. More detailed concepts of operations are included for the nose cone, payload, and airbrakes in Sections (b), (c), and (d), respectively.

(a) General Concept of Operations
The general concept of operations covers all events from the time the team begins to assemble the rocket until the rocket is recovered. The exact timeline of each event will be determined on launch day, but the general process will always be the same.

(b) Detailed Nose Cone Concept of Operations
In addition to assembling the rocket as a whole, the avionics bay for the nose cone must also be assembled. After the avionics are assembled on the sled, the sled is then screwed into the tip of the nose cone and the recovery system can be packed. It is important to note that the deployment bag for the nose cone drogue parachute is attached to the payload, so both the payload and nose cone must be added to the rocket at the same time. During flight, the altimeters will monitor the flight events and deploy the main parachute at the appropriate time, ensuring safe recovery of the nose cone. After it has landed, it will be tracked via GPS like the rocket and recovered.

(c) Detailed Payload Concept of Operations
The payload will be assembled independently of the rocket. The paracord will be looped around the top bulkhead and connected to the bottom of the parafoil deployment bag. It is important to note that the deployment

	Assembly	Launch Pad	Motor Ignition	Powered Ascent	Unpowered Ascent	Apogee	Descent Under Drogue	Descent Under Main	Landing and Ground Operations
End of Phase Criteria	Rocket is assembled but unarmed, ready to be taken to the pad	Rocket is armed, safety checks and electronics checks are complete	Smoke is visible beneath the rocket	Rocket motor reaches burn out	Rocket reaches maximum altitude	Rocket begins to descend	Main parachute deploys at 1250 ft AGL	Rocket lands on the ground	Rocket is recovered by team
Rocket Airframe	Electronics bay is assembled and wired. Body tubes are assembled and attached with fasteners. Parachutes are packed in the rocket.	Cameras are turned on. GPS signal is verified with ground station. All avionics are armed through switches and checked for continuity. E-match igniter is installed in motor mount.	Rocket begins to accelerate from the ground, Ravens detect flight	Rocket clears the launch rail with a speed of 86 ft/s and continues to accelerate	Rocket continues to ascend while coasting	Ravens detect apogee and fire ejection charges for the nose cone and payload as well as the recovery tube. Drouge parachute deploys and rocket slows to a speed of 91 ft/s.	Ravens continue to monitor flight until detecting an altitude of 1250 ft AGL, then fire an ejection charge within the Tendie Descendie to release the main chute and slow the rocket to a speed of 24 ft/s	Rocket continues to descend under main	Rocket lands on the ground, team locates rocket through the GPS system, inspects for damages, and diserms all electronics
Nose Cone	Nose cone electronics bay is assembled, wired, and installed. Nose cone parachutes are packed.	GPS signal is verified with ground station. All avionics are armed.	——	——	——	Nose cone is ejected from rocket body, nose cone drogue parachute deploys	Nose cone main chute deploys	Nose cone lands on ground	Nose cone is recovered by team
Payload	Payload electronics bay is assembled, wired, and avionics systems are turned on. Payload parachutes are packed. Payload is placed inside rocket.	GPS signal is verified with ground station.	We integrate all acceleration readings in the vertical axis until we reach 4 m/hr. Once we reach this threshold, we start a timer for 30 seconds.			The timer for 30 seconds counts down to when apogee is reached. After the timer ends, another timer for 118 seconds is started.	The payload is ejected and deploys the parafoil once the timer for 118 seconds ends or the barometeric pressure sensor below 2000 ft.	Once the parafoil is deployed, the location of the center of the circular holding pattern is decided. The payload follows this holding pattern by using PID controller.	Once the estimated flight time to the target reaches a certain value, a final path to the target is calculated, which is followed using the path pursuit algorithm.
Airbrakes	Slide airbrakes module into rocket with motor tube	All avionics are armed	——	——	Airbrakes sytem adjusts altitude to achieve target	——	Airbrakes retract	——	Airbrakes electronics are turned off

Fig. 50 Concept of Operations

bag must be oriented such that the parafoil will be pulled down and out of the bag.The nichrome wire will be wrapped around the paracord and connected to the nichrome firing board. During flight, the altimeters will monitor the flight events and deploy the drogue parachute at apogee. While under drogue, the altimeter will monitor for an altitude of 2000 ft AGL, deploying the parafoil deployment bag by activating the nichrome cord cutter mechanism. Once the parafoil is deployed, the payload maintains a circular holding pattern around a point near the landing coordinates by using data from the GPS and inertial measurement unit, IMU, to monitor its location and heading, and using a proportional-integral-derivative controller to correct for any deviations due to wind. The payload maintains this holding pattern until the vehicle is facing towards the target and is within an accepted range of distance from the target and altitude. Once the payload reaches this threshold, a final path to the target is generated. This is a sinusoidal wave with an arc length equal to the remaining horizontal distance that the vehicle can travel at its current altitude based on the glide ratio. A series of waypoints is generated along this path, which the vehicle then follows using a pure pursuit algorithm.

(d) Detailed Airbrakes Concept of Operations
The airbrakes will be assembled with the rest of the rocket. At the launch site, the flight computers and other electronics in the airbrakes avionics bay will be tested and turned on. During flight, it is crucial that the airbrakes do not actuate until after motor burnout. Once the rocket enters its unpowered ascent phase, the airbrakes algorithm will begin monitoring the altitude of the rocket and adjusting the actuation angle of the flaps to increase drag until apogee is reached. After reaching apogee, the airbrakes will return to inactivity and remain undeployed while the rocket descends and after it lands.

V. Conclusions and Lessons Learned

This year's Spaceport America Cup is the third ESRA IREC competition the Case Rocket Team has taken part in. Unfortunately, the Covid-19 pandemic has prevented the team from fully constructing the 6" diameter competition rocket, Phalanx, and the 3U cubesat form factor payload, Aegis.

Despite these challenges, the team continued to develop other systems in the rocket. For one, the airbrakes went through many design iterations. Between mounting changes and a holistic linkage redesign, the team improved significantly on the previous designs. Thinking outside of the box, the team was able to solve problems like chute tangling by making our nose cone recovery completely independent. As part of the manufacturing process, the team experimented with production techniques such as multi-use linkage plates allowing us to expedite our manufacturing process and shorten our overall timeline.

Though the full-scale rocket was not constructed, the team was able to take lessons from the two scale rockets that were built, Spargarita and Once More. The team experimented with ejecting the payload this year, posing an interesting challenge for the payload subteam who then developed the nichrome wire burn mechanism to release the payload's parachutes. Additionally, trial and error with the scale rockets gave the team more experience with more complex recovery schemes. After it was clear that the payload would be unable to pull out the drogue and main parachutes for the rocket, the team adapted and added a new body tube with the sole purpose of recovery. This added complexity resulted in the most recovery events the team has ever had when launching the test rocket Once More, and gave the team a new confidence in both ejecting the payload and recovering the rocket.

The team is looking forward to a new year of collaboration and innovation in the upcoming semesters. By utilizing everything discussed in this report, the team will design and manufacture a 6-inch rocket for next year's Spaceport America Cup. Despite a year of challenges, the team has seen an outpouring of involvement and enthusiasm, and is excited for what the future will bring.

VI. Acknowledgements

The Case Rocket Team would like to thank our university sponsors, Larry Sears and Sally Zlotnick Sears think[box], the Case Alumni Association, and the CWRU Undergraduate Student Government. We would also like to thank Dassault Systèmes for sponsoring copies of SolidWorks for the team.

We would like to thank Ben Ault for providing us with a launch site for certification and test launches as well as advising us in our payload deployment scheme. We also would like to thank Tripoli Mid Ohio for providing their launch site for us to test our scale rocket, Once More.

Finally, we would like to thank our advisor Dr. Paul Barnhart for supporting the team.

VII. References

[1]Howard, Z., "How To Calculate Fin Flutter Speed," *Peak of Flight*, Vol.219, 2011, pp. 1-6. [2]Lingard, S., "Basic Analysis of Ram-Air Parachute," *Precision Aerial Delivery Systems: Modeling, Dynamics, and Control*, 2015, pp. 73-125.

VIII. System Weights, Measures, and Performance Data Appendix

A. System weights

1. Overall Rocket Weights

Table 4 Overall Rocket Weights

Configuration	Weight (pounds)	Additional Comments
Launch Weight	63.3	
Vehicle Weight	35.37	
Descent Weight	31.7	

2. Subsystem Weights

Table 5 Subsystem Weights

Subsystem	Weight (pounds)	Additional Comments
Structure	20.88	Airframe, centering rings, and fins
Airbrakes	3.59	
E-Bay	4.7	
Recovery	5.78	
Motor	18.91	
Nose Cone	0.42	
Payload	9	

B. Measures

Table 6 Vehicle Measurements

Name of Parameter	Measurement	Additional Comments
Airframe Length	119.8 in	
Airframe Diameter	6.17 in	
Fin-Span	17.17 in	
Fin Root Chord	10 in	
Fin Tip Chord	7 in	
Fin Span	17.17	
Number of Stages	1	

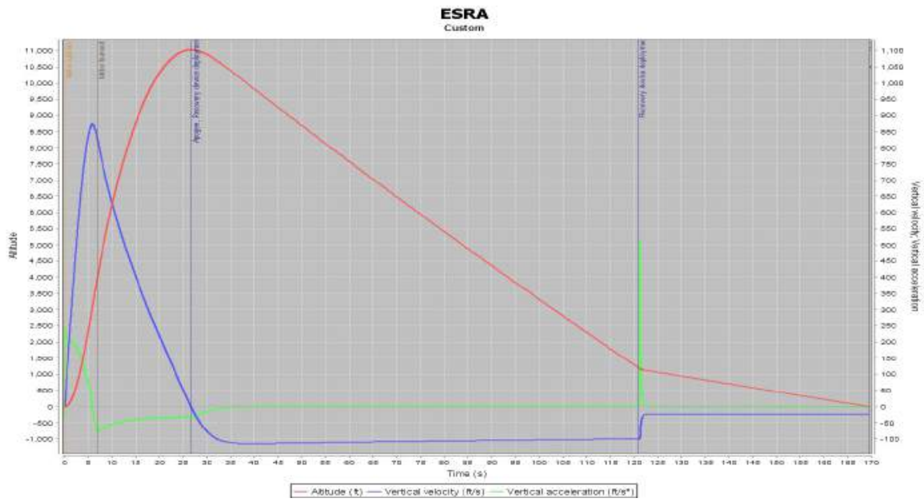

Fig. 51 Open Rocket Flight Path Simulation

C. Performance Data

Open Rocket was used to simulate Phalanx's flight path as shown in Figure 51. Table 7 contains the values used for the simulated launch condition, which were chosen to best match actual flight conditions at the SA Cup. Table 8 contains the results from the simulations. The results that pertain to events after apogee were found by adjusting the weight of the rocket and rerunning the simulation.

1. Simulation Information

Table 7 Simulation Parameters

Name of Parameter	Value of Parameter
Launch Location	Truth or Consequences, New Mexico
Longitude	-107 E
Latitude	33 N
Altitude	4595 ft
Wind Speed	4.47 mph
Launch Rail Length	17 ft
Temperature	85°F
Pressure	1011 mbar
Launch Angle	6° from vertical

2. Simulation Results

Table 8 Simulation Results

Name of Parameter	Measurement
Apogee	11026 ft
Velocity off Rail	86.7 ft/s
Max. Velocity	889 ft/s (Mach .80)
Max. Acceleration	244 ft/s2 (7.6G)
Time to Apogee	26.7 s
Flight Time	170 s
Ground Hit Velocity	20.7 ft/s
Velocity at Main Deployment	87.0 ft/s
Stability	2.28 cal
Min. Stability	1.71 cal

IX. Project Test Reports

A. Recovery System Testing

Once More, the team's test rocket, was designed and manufactured with the same processes and systems as Phalanx has. The primary differences are that all the systems were scaled to fit in a 4.5 in airframe and the payload used two parachutes instead of a parafoil because of space concerns.

1. Main Separation Ground Ejection Test

This test was performed on the ground prior to flight. It confirmed that in-flight ejection would occur with the specified amount of black powder and that the Raven4 would successfully deploy in-flight. It also provided evidence that the chutes would deploy in the correct order and shock cord tangling could be minimized.

Test 1	**Main Separation Ground Ejection**	
This test was performed on the 4.5" rocket Once More on the ground. The event triggering the ejection charge current from a Raven4 that ignited an e-match. The Raven4 was activated by computer software. 3.5 grams of 4f black powder were used.		
Event and Success Criteria		
1st Event - Detonation	PASS	4/17/21
2nd Event - Tube separation	PASS	4/17/21
2nd Event - Drogue chute out of tube	PASS	4/17/21
2nd Event - Drogue chute not tangled	PASS	4/17/21
2nd Event - Main chute remains in tube	PASS	4/17/21
System Analysis	Success	4/17/21

2. Nose Cone Separation Ground Ejection Test

This test was performed on the ground prior to flight. It confirmed that in-flight ejection would occur with the specified amount of black powder. It also provided evidence that the chutes would deploy in the correct order and shock cord tangling could be minimized.

Test 1	**Nose Cone Separation Ground Ejection**	
This test was performed on the 4.5" rocket Once More. The event triggering the ejection charge was current fed directly to an e-match. 2.5 grams of 4f black powder were used.		
Event and Success Criteria		
1st Event - Detonation	PASS	4/17/21
2nd Event - Tube separation	PASS	4/17/21
2nd Event - Nose Cone Drogue chute out of tube	PASS	4/17/21
2nd Event - Nose Cone Drogue chute not tangled	PASS	4/17/21
2nd Event - Nose Cone Main chute remains in tube	PASS	4/17/21
2nd Event - Payload drogue out of tube	PASS	4/17/21
2nd Event - Payload chutes not tangled	PASS	4/17/21
System Analysis	Success	4/17/21

3. Tendie Descendie Ground Deployment

This test was performed on the ground prior to flight. It confirmed that the Tendie Descendie could deploy successfully with the specified amount of black powder and that the pin could release smoothly while under load.

Test 1	**Tendie Descendie Ground Deployment**		
This test was performed on the Tendie Descendie with a suspended weight. The event triggering the ejection charge was current fed directly to an e-match. .5 grams of 4f black powder were used.			
Event and Success Criteria			
1st Event - Detonation		PASS	4/17/21
2nd Event - Pin release		PASS	4/17/21
2nd Event - Pin linkage remains attached via string		FAIL	4/17/21
2nd Event - Simulated mass drops without interference		PASS	4/17/21
System Analysis		Failure	4/17/21

Test 2	**Tendie Descendie Ground Deployment**		
This test was performed on the Tendie Descendie with a suspended weight. The event triggering the ejection charge was current fed directly to an e-match. .35 grams of 4f black powder were used.			
Event and Success Criteria			
1st Event - Detonation		PASS	5/1/21
2nd Event - Pin release		PASS	5/1/21
2nd Event - Pin linkage remains attached via string		PASS	5/1/21
2nd Event - Simulated mass drops without interference		PASS	5/1/21
System Analysis		Success	5/1/21

4. Tendie Descendie Nano Ground Deployment

This test was performed on the ground prior to flight. It confirmed that the Tendie Descendie Nano could deploy successfully with the specified amount of black powder and that the pin could release smoothly while under load.

Test 1	**Tendie Descendie Nano Ground Deployment**	
This test was performed on the Tendie Descendie Nano with a suspended weight. The event triggering the ejection charge was current fed directly to an e-match. .15 grams of black powder were used.		
Event and Success Criteria		
1st Event - Detonation	PASS	5/1/21
2nd Event - Pin release	PASS	5/1/21
2nd Event - Pin linkage remains attached via string	PASS	5/1/21
2nd Event - Simulated mass drops without interference	PASS	5/1/21
System Analysis	Success	5/1/21

5. Nichrome Burn Test

Test 1	**Nichrome Burn Test**	
This test was performed on the Key Lime payload. The event triggering the burn was current released into a 30mm length of 30 AWG nichrome wire by a Raven4 altimeter. This was set up to burn through a test length of nylon paracord with a simulated force.		
Event and Success Criteria		
1st Event - Nichrome wire becomes hot	PASS	4/15/21
2nd Event - Paracord burned through	PASS	4/15/21
2nd Event - Paracord released from payload	PASS	4/15/21
System Analysis	Success	4/15/21

Test 2	**Nichrome Burn Test**	
This test was performed on the Key Lime payload. The event triggering the burn was current released into a 30mm length of 34 AWG nichrome wire by a Raven4 altimeter. This was set up to burn through a test length of nylon paracord with a simulated force.		
Event and Success Criteria		
1st Event - Nichrome wire becomes hot	PASS	4/17/21
2nd Event - Paracord burned through	PASS	4/17/21
2nd Event - Paracord released from payload	PASS	4/17/21
System Analysis	Success	4/17/21

6. Payload Parachute Deployment Test

Test 1	**Payload Parachute Deployment Test**		
This test was performed on the Key Lime payload. The event triggering the parachute release is a simulated force of the inflation of the drogue parachute. This force was set up to pull a deployment bag out of the parachute bay. This release would then after a given length pull the second eliptical chute from the deployment bag.			
Event and Success Criteria			
1st Event - Drogue is pulled taught upwards.		PASS	4/15/21
2nd Event - Main deployment bag is fully ejected		PASS	4/15/21
2nd Event - Main parachute lines pulled out of straps		PASS	4/15/21
2nd Event - Main parachute pulled to full length		PASS	4/15/21
3rd Event - Main parachute is removed from deployment bag		PASS	4/15/21
3rd Event - Deployment bag pulled to full length		PASS	4/15/21
3rd Event - Lines do not tangle		PASS	4/15/21
System Analysis		Success	4/15/21

Test 2	**Payload Parachute Deployment Test**		
This test was performed on the Key Lime payload. The event triggering the parachute release is a simulated force of the inflation of the drogue parachute. This force was set up to pull a deployment bag out of the parachute bay. This release would then after a given length pull the second eliptical chute from the deployment bag.			
Event and Success Criteria			
1st Event - Drogue is pulled taught upwards.		PASS	5/1/21
2nd Event - Main deployment bag is fully ejected		PASS	5/1/21
2nd Event - Main parachute lines pulled out of straps		PASS	5/1/21
2nd Event - Main parachute pulled to full length		PASS	5/1/21
3rd Event - Main parachute is removed from deployment bag		PASS	5/1/21
3rd Event - Deployment bag pulled to full length		PASS	5/1/21
3rd Event - Lines do not tangle		PASS	5/1/21
System Analysis		Success	5/1/21

7. Full Deployment Test

Test 1	Full Payload Deployment Test		
This test was performed on the Key Lime payload. The event triggering the parachute release is a release of current into the 30 AWG nichrome wire by a Raven4 altimeter and a force simulating drogue parachute inflation. The nichrome was set up to burn a length of paracord attached to the bottom of a deployment bag. The force was set up to pull up on a deployment bag. This release would then after a given length pull the second eliptical chute from the deployment bag.			
Event and Success Criteria			
1st Event - Drogue is pulled taught upwards.		PASS	4/17/21
1st Event - Nichrome wire becomes hot		PASS	4/17/21
2nd Event - Paracord burned through		PASS	4/17/21
2nd Event - Paracord released from payload		PASS	4/17/21
2nd Event - Main deployment bag is fully ejected		PASS	4/17/21
2nd Event - Main parachute lines pulled out of straps		PASS	4/17/21
2nd Event - Main parachute pulled to full length		PASS	4/17/21
3rd Event - Main parachute is removed from deployment bag		PASS	4/17/21
3rd Event - Deployment bag pulled to full length		PASS	4/17/21
3rd Event - Lines do not tangle		PASS	4/17/21
System Analysis		Success	4/17/21

Test 2	Full Payload Deployment Test		
This test was performed on the Key Lime payload. The event triggering the parachute release is a release of current into the 34 AWG nichrome wire by a Raven4 altimeter and a force simulating drogue parachute inflation. The nichrome was set up to burn a length of paracord attached to the bottom of a deployment bag. The force was set up to pull up on a deployment bag. This release would then after a given length pull the second eliptical chute from the deployment bag.			
Event and Success Criteria			
1st Event - Drogue is pulled taught upwards.		PASS	5/1/21
1st Event - Nichrome wire becomes hot		PASS	5/1/21
2nd Event - Paracord burned through		PASS	5/1/21
2nd Event - Paracord released from payload		PASS	5/1/21
2nd Event - Main deployment bag is fully ejected		PASS	5/1/21
2nd Event - Main parachute lines pulled out of straps		PASS	5/1/21
2nd Event - Main parachute pulled to full length		PASS	5/1/21
3rd Event - Main parachute is removed from deployment bag		PASS	5/1/21
3rd Event - Deployment bag pulled to full length		PASS	5/1/21
3rd Event - Lines do not tangle		PASS	5/1/21
System Analysis		Success	5/1/21

8. Full System Test Flight

Test 1	Once More Test Flight 1	
This test flight was a full system test of the entire rocket. The rocket went to roughly 4900ft and all of the recovery systems were active. Additionally, there was a test payload that was in flight ready mode and set up to be deployed.		
Event and Success Criteria		
1st Event - Ignition and liftoff	PASS	4/17/21
2nd Event - Upper ejection charge detonation	PASS	4/17/21
2nd Event - Nose Cone deployment	PASS	4/17/21
2nd Event - Nose Cone drogue deployment	PASS	4/17/21
2nd Event - Payload Separation	PASS	4/17/21
2nd Event - Payload drogue deployment	PASS	4/17/21
3rd Event - Lower ejection charge detonation	PASS	4/17/21
3rd Event - Lower airframe separation	PASS	4/17/21
3rd Event - Airframe drogue chute deployment	PASS	4/17/21
4th Event - Payload nichrome activation	FAIL	4/17/21
4th Event - Payload main cute deployment	FAIL	4/17/21
5th Event - Airframe main chute deployment	PASS	4/17/21
6th Event - Nose Cone main chute deployment	PASS	4/17/21
7th Event - Nose Cone successful recovery	PASS	4/17/21
7th Event - Payload successful recovery	PASS	4/17/21
7th Event - Airframe successful recovery	PASS	4/17/21
System Analysis	Success	4/17/21

Test 2	Once More Test Flight 2	
This test flight was a full system test of the entire rocket. The rocket went to roughly 4800ft and all of the recovery systems were active. Additionally, there was a test payload that was in flight ready mode and set up to be deployed.		
Event and Success Criteria		
1st Event - Ignition and liftoff	PASS	5/1/21
2nd Event - Upper ejection charge detonation	PASS	5/1/21
2nd Event - Nose Cone deployment	PASS	5/1/21
2nd Event - Nose Cone drogue deployment	UNKNOWN	5/1/21
2nd Event - Payload Separation	PASS	5/1/21
2nd Event - Payload drogue deployment	PASS	5/1/21
3rd Event - Lower ejection charge detonation	PASS	5/1/21
3rd Event - Lower airframe separation	PASS	5/1/21
3rd Event - Airframe drogue chute deployment	PASS	5/1/21

4th Event - Payload nichrome activation	FAIL	5/1/21
4th Event - Payload main cute deployment	FAIL	5/1/21
5th Event - Airframe main chute deployment	PASS	5/1/21
6th Event - Nose Cone main chute deployment	FAIL	5/1/21
7th Event - Nose Cone successful recovery	FAIL	5/1/21
7th Event - Payload successful recovery	PASS	5/1/21
7th Event - Airframe successful recovery	PASS	5/1/21
System Analysis	Success	5/1/21

X. SRAD Propulsion System Testing

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XI. SRAD Pressure Vessel Testing

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XII. Hazard Analysis Appendix

A. Explosives

The rocket is powered by a Cessaroni M1450. The motor contains non-toxic propellant and does not require a breathing apparatus to handle. The motor will always be stored at room temperature and away from anything that would be able to ignite the propellant. Additionally, the safety data sheet will be available to all team members handling the motor so that they are aware of the hazards.

The rocket will also contain six black powder charges. The 4F black powder is in small quantities to limit the potential risk. The black powder will also be stored in a dry container at room temperature and kept away from anything that could ignite it. When measuring the charges before launch, small amounts will be measured by using plastic vials and stored in the vials until it is time to pack the charge wells. Additionally, the safety data sheet will be provided to all team members handling black powder.

The safety data sheets for both the motor and the black powder are included at the end of this appendix.

B. Fiberglass

The airframe, couplers, and nose cone of the rocket are manufactured from G12 fiberglass. While fiberglass can be machined with common manufacturing methods, special care must be taken to ensure the fiberglass dust is mitigated. Any team member working with machining fiberglass will be required to wear safety glasses as well as respirators. If using machines rather than hand tools, the machine must be protected through the use of tarps or similar methods. When sanding, wet sanding will be used to limit the amount of dust released into the air.

C. Launch Hazards

While the rocket is preparing to launch, all safety guidelines outlined by Tripoli will be followed. This includes but is not limited to rules like remaining 200 ft away from the rocket on the rail and waiting 90 seconds to approach the rocket after an unsuccessful launch attempt. To ensure all rules are followed in full, the team members responsible for launch will review the rules regularly leading up to the launch as well as the day of the launch to familiarize themselves with them.

SDS – Pro-X® Rocket Motor Reload Kits Page 1/7 Version 4.00
Revision Date. 2015-06-01

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SAFETY DATA SHEET

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Pro-X® Rocket Motor Reload Kits & Fuel Grains

1.0 PRODUCT / COMPANY IDENTIFICATION

Product Name: Pro24, Pro29, Pro38, Pro54, Pro75, and Pro98 Rocket Motor Reload Kits
Synonyms: Rocket Motor, Hobby Rocket Motor, HPR Reload Kit
Part Numbers: Reload kits: P24R-Y-#G-XX, P29R-Y-#G-XX, P38R-Y-#G-XX, P54R-Y-#G-XX, P24R-Y-#GXL-XX, P29R-Y-#GXL-XX, P38R-Y-#GXL-XX, P54R-Y-#GXL-XX,
Propellant grains: P75AC-PG-XX, P98AC-PG-XX, P98AC-MB-PG-XX
Where: Y = reload type (A = adjustable delay, C = C-slot)
# = number of grains &
XX = propellant type

Product Use: Solid fuel motor for propelling hobby rockets

Manufacturer / Supplier: Cesaroni Technology Inc.
P.O. Box 246
2561 Stouffville Rd.
Gormley, Ont.
Canada L0H 1G0

Telephone Numbers:
Product Information: Tel: +1-905-887-2370 Fax: +1-905-887-2375
24 Hour Emergency Telephone Number: Tel: +1-613-996-6666 (CANUTEC)

2.0 HAZARDS IDENTIFICATION

Signal Word: **Warning** GHS Pictogram:

Hazard Statement: H204 Fire or Projection Hazard

Precautionary Statements

P210	**Keep away from heat/sparks/open flames/hot surfaces. No smoking**
P250	**Do not subject to grinding/shock/friction.**
P370+P380	**In case of fire: Evacuate Area.**
P372	**Explosion risk in case of fire.**
P373	**DO NOT fight fire when fire reaches explosives.**
P401	**Store in accordance with local/regional/national regulations.**
P501	**Dispose of in accordance with local/regional/national regulations.**

Emergency Overview:
There articles contain cylinders of ammonium perchlorate composite propellant, encased in inert plastic parts. The forward closure also contains a few grams of black powder. ProX Rocket motor reload kits are classified as explosives, and may cause serious injury, including death if used improperly. All explosives are dangerous and must be handled carefully and used following approved safety procedures under the direction of competent, experienced personnel in accordance with all applicable federal, state and local laws and regulations. Avoid inhaling exhaust products.

General Appearance:
Cardboard tubes contain various plastic parts. Inside the plastic tube are cylinders of composite propellant (rocket fuel). The forward closure also contains a small quantity of black powder. All parts are odourless solids.

Potential Health Effects:

Eye:
Not a likely route of exposure. May cause eye irritation.

Skin:
Not a likely route of exposure. Low hazard for usual industrial/hobby handling.

Ingestion:

Goex Powder, Inc.

Material Safety Data Sheet

MSDS-BP (Potassium Nitrate)

Revised 3/17/09

PRODUCT INFORMATION	
Product Name	Black Powder
Trade Names and Synonyms	N/A
Manufacturer/Distributor	GOEX Powder, Inc.(DOYLINE, LA) & various international sources
Transportation Emergency	800-255-3924 (24 hrs – CHEM TEL)

PREVENTION OF ACCIDENTS IN THE USE OF EXPLOSIVES

The prevention of accidents in the use of explosives is a result of careful planning and observance of the best known practices. The explosives user must remember that he is dealing with a powerful force and that various devices and methods have been developed to assist him in directing this force. He should realize that this force, if misdirected, may either kill or injure both him and his fellow workers.

WARNING

All explosives are dangerous and must be carefully transported, handled, stored, and used following proper safety procedures either by or under the direction of competent, experienced persons in accordance with all applicable federal, state and local laws, regulations, or ordinances. ALWAYS lock up explosive materials and keep away from children and unauthorized persons. If you have any questions or doubts as to how to use any explosive product, DO NOT USE IT before consulting with your supervisor, or the manufacturer, if you do not have a supervisor. If your supervisor has any questions or doubts, he should consult the manufacturer before use.

HAZARDOUS COMPONENTS				
Material or Components	%	CAS NO.	TLV	PEL
Potassium nitrate	70-76	007757-79-1	NE	NE
Charcoal	8-18	N/A	NE	NE
Sulfur	9-20	007704-34-9	NE	NE
Graphite[1]	Trace	007782-42-5	15 mppct (TWA)	2.5 mg/m³
N/A = Not assigned NE = Not established				

[1] Not contained in all grades of black powder.

1

P.O. Box 659, Doyline, LA 71023-0659, (318) 382-9300
www.goexpowder.com

001092

XIII. Risk Assessment Appendix

A. Airframe Risk Matrix

#	Risk	Chance	Consequence	Mitigation
1	Altimeters fail during boost	2	5	redundancy, ensure proper wiring by checking beep codes, check manuals for proper amounts of power from batteries
2	Battery shorts in e-bay	1	5	testing batteries prior to use, use safety critical wiring, appropriately sizing batteries, check all wire connections prior to launch
3	Motor failure during launch	2	5	buying back-ups to have ready, visually inspect motor prior to launch, correctly intall motor retainer and visually inspect before launch
4	Main parachute does not deploy from parachute bag	1	5	testing fit of parachute bag, pack properly in bag to ensure deployment, dry run of all recovery steps to ensure it will work
5	Drogue chute does not deploy from parachute bag	1	5	testing removal of parachute from bag, proper packing to ensure deployment
6	The fiberglass or epoxy in the fin attachment cracks	1	4	testing strength of lay-up, have people experienced in lay-up attach the fins to the body tube, visually inspect fins for issues prior to launch
7	Nose cone ejection fails	2	5	make sure ejection sizing is correct, redundancy in ravens to time ejection, test fit of nose cone in body tube to make sure it is not too tight
8	Airbrakes fire during burn	2	3	only enable if confident in code
9	Airbrakes overshoot target apogee too much	3	1	only enable if confident in code
10	Bolts in airframe shear	2	4	perform calculations for size and number of bolts and design with a factor of safety of at least 2, run simulations on potential problem areas
11	the GPS system fails or does not communcicate with ground station	4	2	test gps prior to launch, ensure batteries stay charged
12	Shock cord breaks	2	4	verify strength of shock cord, verify length is appropriate enough, verify connections to u-bolts are strong before launch
13	E-matches do not ignite black powder	3	4	multiple charge wells for redundancy, mutltiple e-matches for redundancy
14	Coast time too short so airbrakes arent effective	2	2	run simulations to make sure coast time is sufficient for effective airbrake usage

Chance \ Consequences	1	2	3	4	5
5	9				
4		11			
3		8		13	
2		14		10, 12	1, 3, 7
1				6	2, 4, 5

Risk Factor	
High	Will cause a signifigant impact on system performance
Moderate	May cause an impact on system performance
Low	Little to no impact on system performance

B. Payload Risk Matrix

#	Risk	Chance	Consequence	Mitigation
1	Main battery runs out of power	2	4	Properly charging the battery, making sure it does not go through too many cycles, ensuring proper connections
2	Nichrome firing battery runs out of power	2	4	Properly charging the battery, making sure it does not go through too many cycles, ensuring proper connections
3	Servos break under force of parafoil	1	4	Testing the loads prior to, checking loads upon servo, limit extreme forces on the servos
4	Control line breaks	2	3	Not straining the nylon lines, proper attachment on both ends, not tangling the lines
5	Cascande line breaks	2	1	Using robust materials, proper manufacturing and proper connections to suspension lines
6	Suspension line breaks	2	5	Using robust materials, proper manufacturing
7	Drogue separates from payload	1	5	Ejection deployment testing, calculating loads on drogue, proper packing
8	Camera runs out of battery or fails to record	1	1	Proper installation, ensuring battery is charged before launch
9	Parafoil does not deploy	4	5	Ensuring testing of deployment, properly building and packing the parafoil
10	Hardpoint bolt shears	1	5	inspecting the quality of the bolts, and assembling them correctly, and making proper threads
11	PID controller is not tuned properly	3	4	Test and tune it in simulation
12	Software runs into error and stops responding	3	3	Put in error handling for likely errors
13	Bolts connecting spool to the servo shear at deployment	1	4	Check shear calcualtions for the bolt with the force at deployment
14	Parafoil enters stall	2	4	Make sure that the other servo has been sent to neutral before starting turning servo, do not actuate both servos at once
15	Parafoil enters spiral due to overturning	1	4	Add in software based limiters on bank angle and servo angle
16	Parafoil seams rip under load	1	5	Use high strength stitches and thread, do not overstitch nylon
17	Wind overtakes parafoil control ability	1	2	Only fly vehicle within set wind threshold. Make sure vehicle is tuned properly within that threshold

		Consequences				
		1	2	3	4	5
Chance	5					
	4					9
	3			12	11	
	2	5		4, 3	1,2,14	6
	1	8	17		3,13,15	5,10,16

Risk Factor	
High	Will heavily affect the operation of the system
Moderate	May affect the operation of the system
Low	Little to no affect the operation of the system

XIV. Assembly, Preflight, and Launch Checklists Appendix

A. Final Assembly

1. a) Electronics Bay Final Assembly
    - ❏ Place e matches in charge wells according to rocket recovery wiring diagram, slide coupler over e matches as necessary
    - ❏ Fill charge wells with appropriate amount of black powder and seal with recovery wadding and tape
    - ❏ Wire e matches into appropriate channels on the Raven and the RRC3
    - ❏ Connect altimeter switches to the altimeters, ensure they are in the off position
    - ❏ Connect the altimeter batteries to the altimeters
    - ❏ Check altimeters for continuity, if not continuous in all of the correct channels, check wiring until beep codes indicate it is correct and continuous
    - ❏ Turn on GoPro Hero8, connect it to phone bluetooth
    - ❏ Connect GPS battery to GPS, turn it on
    - ❏ Check base station connection to GPS
    - ❏ Line up recovery coupler with keys in bulkheads and appropriate camera window/switch access locations
    - ❏ Tighten upper bulkhead onto the coupler with wing nuts

   b) Nose Cone Final Assembly
    - ❏ Attach parachutes and shock cords to bulkhead and Tendie Descendie Nano
    - ❏ Place e matches into Tendie Descendie Nano and pack with black powder and recovery wadding
    - ❏ Wire e matched into appropriate channels in flight computers
    - ❏ Connect screw switched to flight computers, ensure it is in the off position
    - ❏ Connect batteries to flight computers
    - ❏ Check flight computers for continuity, re-wire as necessary
    - ❏ Connect batteries to GPS, turn it on
    - ❏ Check base station connection to GPS
    - ❏ Slide nose cone electronics bay into tip of nose cone, tighten with nose cone tip

   c) Payload Final Assembly
    - ❏ Screw main board, backup board, LoRa antenna, main battery, and backup battery into their proper locations on the electronics bay sled
    - ❏ Plug LoRa antenna into the main board [using the proper adapter].
    - ❏ Connect the main battery to the main board using the main battery connector.
    - ❏ Connect the backup battery to the backup board using the backup battery connector.
    - ❏ Insert the GoPro into the sensor bay sled and screw on the backplate.
    - ❏ Connect the GPS to the antenna using the extension cable. Clip the antenna into the clip on the backplate and screw the GPS onto the standoffs.
    - ❏ Insert the GPS battery into the GPS battery pocket. Connect the GPS battery to the GPS using the GPS battery connector.

- ❑ Connect the GPS battery connector to the screw switch leads.
- ❑ Insert the sensor bay sled and screw on the front shield.
- ❑ Screw the nichrome batteries onto the front frame plate.
- ❑ Cut the nylon line and pass it through the holes in the top bulkhead.
- ❑ Wrap two lengths of nichrome around the nylon and insert the nichrome into the nichrome firing board.
- ❑ Screw the nichrome firing board onto the front frame plate.
- ❑ Connect the nichrome batteries to the nichrome firing board using the nichrome battery connector.
- ❑ Connect: the main board to the servos with the servo connectors, the main board to the nichrome firing board with a nichrome connector, the backup board to the nichrome firing board with the other nichrome connector, the main board to the main screw switch, the backup board to the backup screw switch.
- ❑ Test nichrome firing mechanism for continuity
- ❑ Slide in the electronics bay sled with the main battery facing the nichrome firing board. Screw on the electronics bay shield.
- ❑ Pack the parafoil into the parafoil deployment bag and connect the lines to the servos and hardpoints.
- ❑ Insert the parafoil deployment bag into the parachute bay and tie the deployment nylon through the D-ring on the bottom of the bag.
- ❑ Screw on the parachute bay shields.

d) Rocket Final Assembly

- ❑ Slide motor tube with airbrakes subsystem installed into lower body tube
- ❑ Install rail buttons on lower body and radial bolts to attach motor tube to airframe
- ❑ Feed main rocket recovery system through recovery tube and attach parachutes and shock cord to Tendie Descendie and u bolt on lower electronics bay bulkhead
- ❑ Attach recovery tube to bottom half of electronics bay with radial bolts after securing fire blanket beneath recovery systems
- ❑ Pack drogue chute and shock cord into open end of recovery tube, attach shock cord to u bolt on recovery bulkhead in lower body tube
- ❑ Slide electronics bay and recovery tube onto lower body tube, secure with four 2-56 nylon shear pins
- ❑ Place upper body tube over top half of electronics bay, secure with radial bolts
- ❑ Place payload into upper body tube, ensure it is supported by the payload ring and mounting corners
- ❑ Pack nose cone drogue parachute into deployment bag on the top of the payload, then slide nose cone onto rocket
- ❑ Secure nose cone with four 2-56 nylon shear pins

B. Preflight

a) Motor Installation

- ❏ Clean all components and inspect the grooves
- ❏ Apply lubricant on appropriate components
- ❏ Insert the smoke tracking grain into the tracking charge insulator
- ❏ Insert the tracking charge insulator into the forward closure
- ❏ Fit the shoulder of the nozzle into one end of the case liner tube
- ❏ Put the smaller o-ring onto the nozzle holder
- ❏ Push the nozzle holder onto the nozzle
- ❏ Put one propellant grain into the other end of the casing liner. While it is part way into the liner, put a spacer o-ring on the top face of the grain.
- ❏ Put another grain on top of the spacer with a space o-ring on top of it
- ❏ Install two larger o-rings onto the nozzle holder and forward closure
- ❏ Slide on the motor casing from the top of the casing liner
- ❏ Screw in nozzle retaining ring until it is exactly even with the end of the casing
- ❏ Fit forward insulating disk to the top of the liner
- ❏ Insert assembled forward closer into top of motor case, screw tight
- ❏ Slide entire motor assembly into motor tube
- ❏ Secure in thrust plate with motor retainer

b) Payload

- ❏ Check for GPS connection from module to base station
- ❏ Check GPS downlink to base station
- ❏ Listen to payload beep codes to ensure successful connections

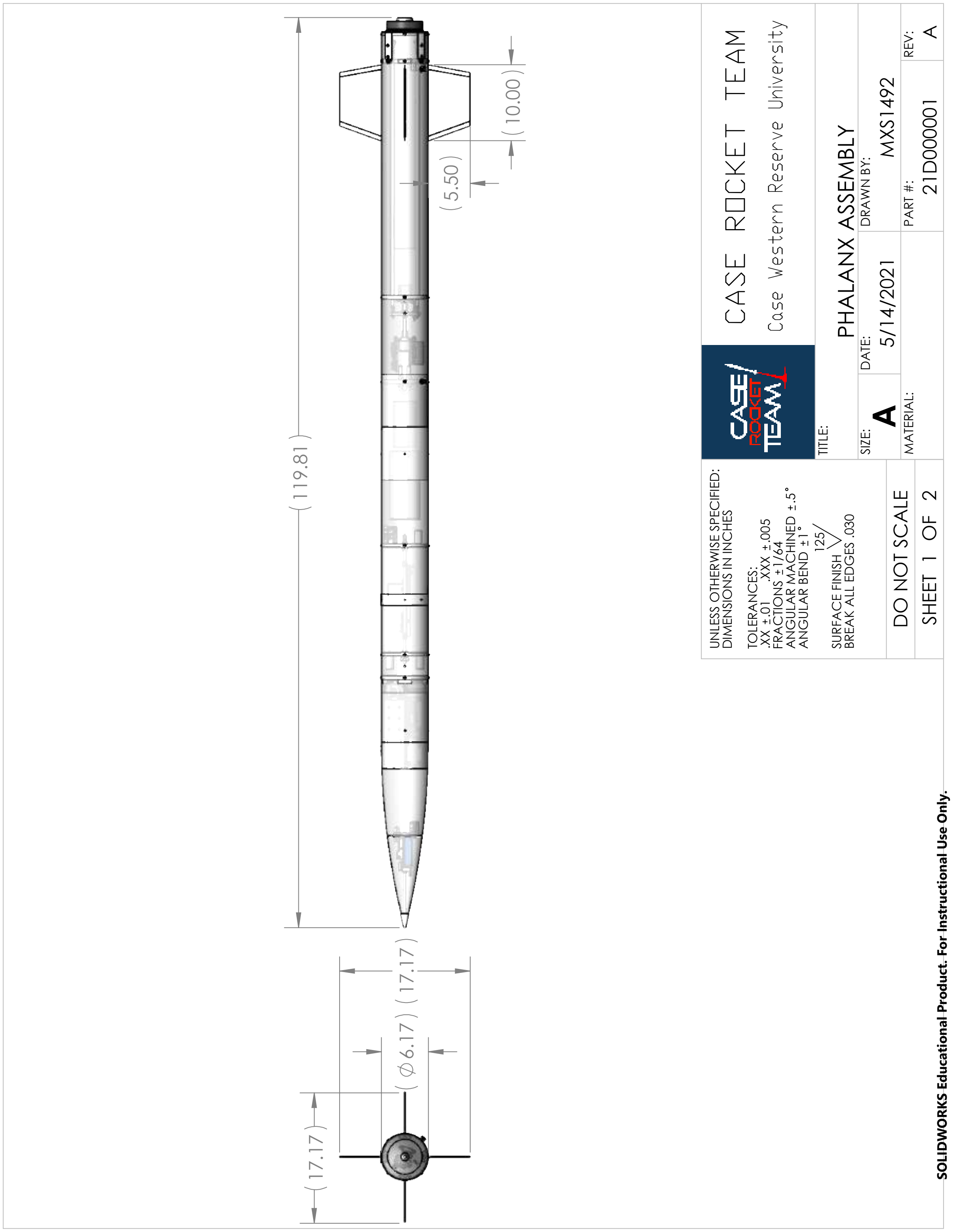
c) Final Checks

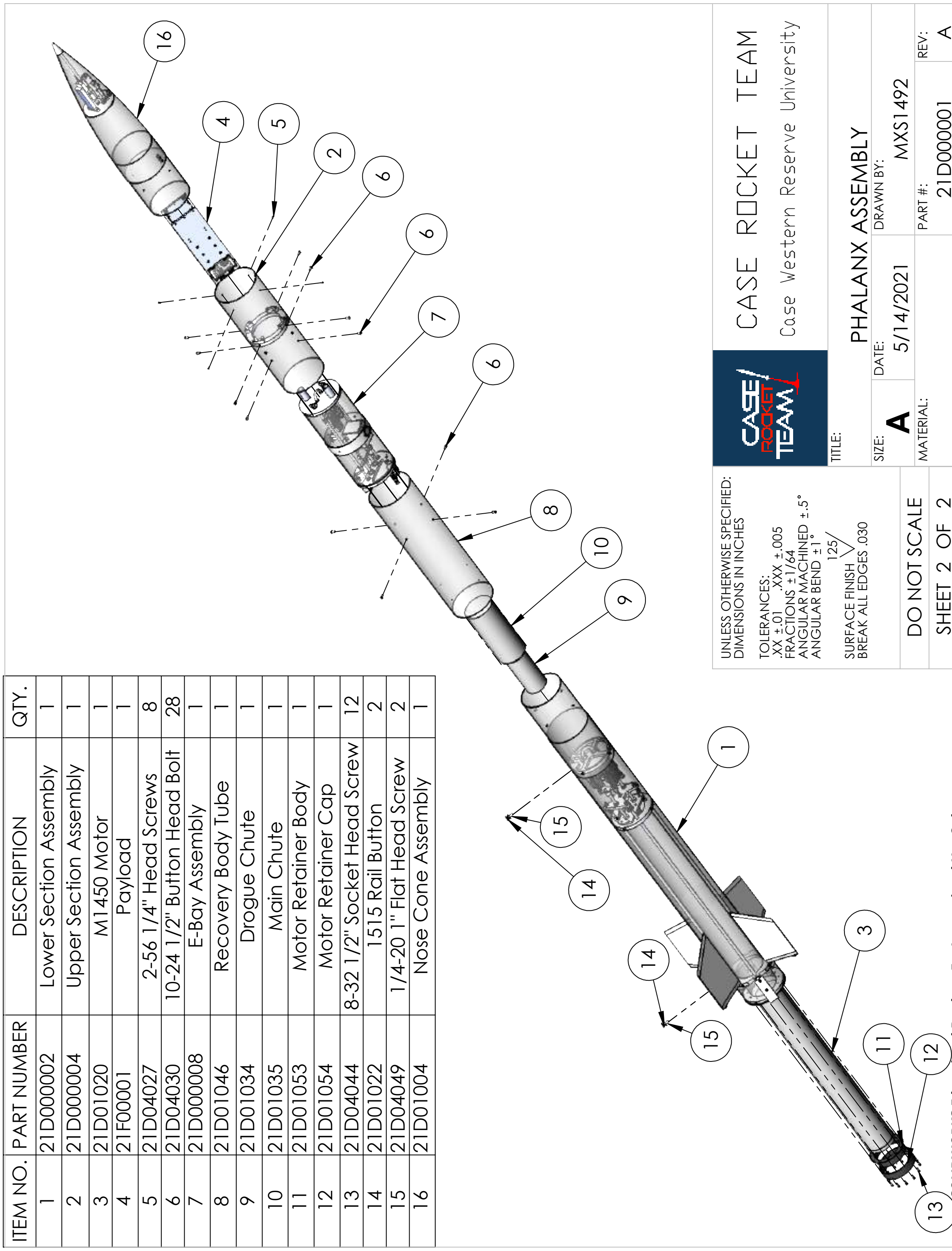
- ❏ Ensure all GPS systems are still communicating with base stations
- ❏ Ensure camera window is clear and camera is able to record
- ❏ Ensure rail buttons are tight and able to support the rocket
- ❏ Inspect all other components for damage or issues that may affect launch

C. Launch

- ❏ Slide rocket onto launch rail
- ❏ Start camera recording from phone
- ❏ Arm all electronics, listen to beep codes to ensure correct wiring
- ❏ Install e match igniter into motor
- ❏ Launch

XV. Engineering Drawings Appendix





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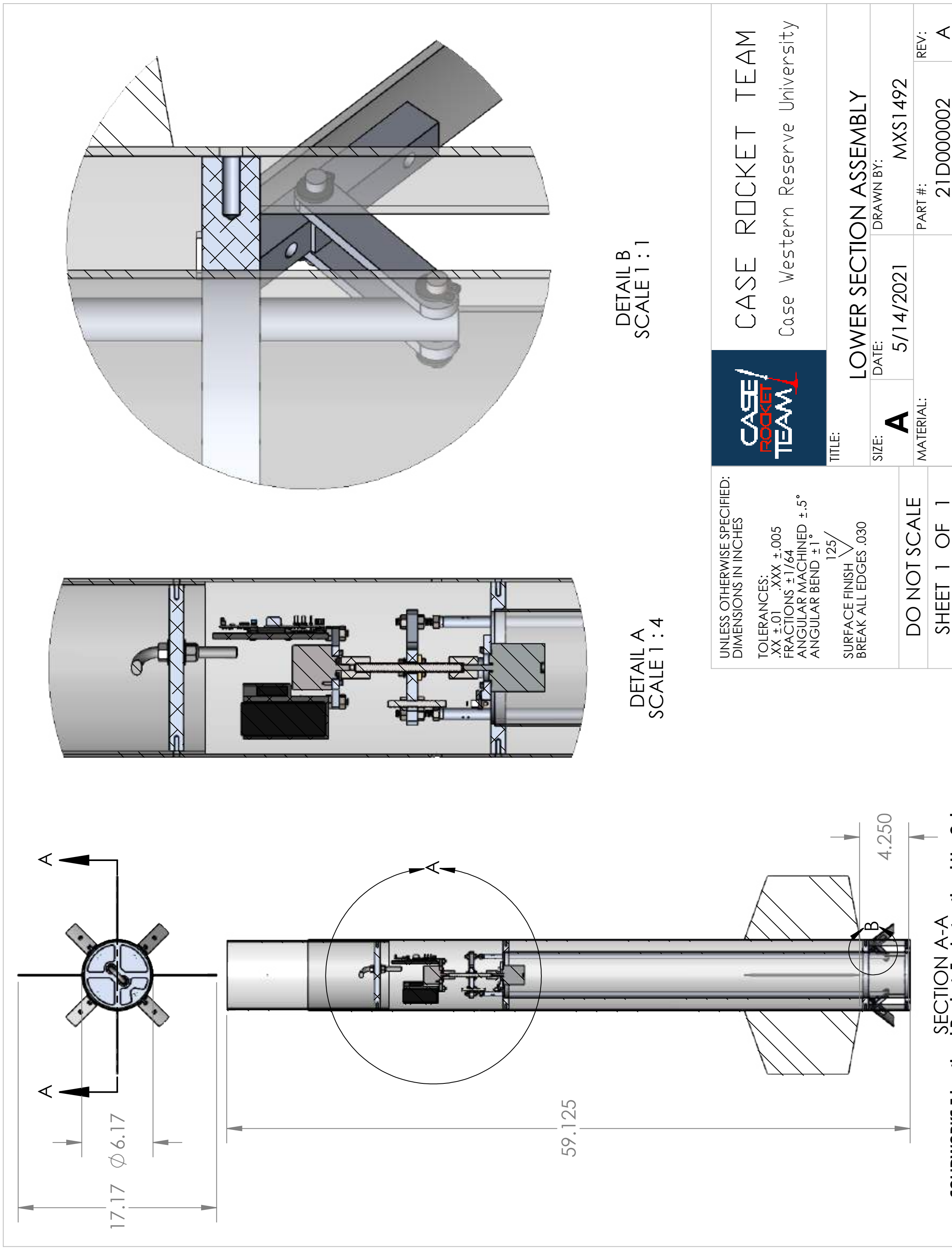
2	21D000004	Upper Section Assembly	1
3	21D01020	M1450 Motor	1
4	21F00001	Payload	1
5	21D04027	2-56 1/4" Head Screws	8
6	21D04030	10-24 1/2" Button Head Bolt	28
7	21D000008	E-Bay Assembly	1
8	21D01046	Recovery Body Tube	1
9	21D01034	Drogue Chute	1
10	21D01035	Main Chute	1
11	21D01053	Motor Retainer Body	1
12	21D01054	Motor Retainer Cap	1
13	21D04044	8-32 1/2" Socket Head Screw	12
14	21D01022	1515 Rail Button	2
15	21D04049	1/4-20 1" Flat Head Screw	2
16	21D01004	Nose Cone Assembly	1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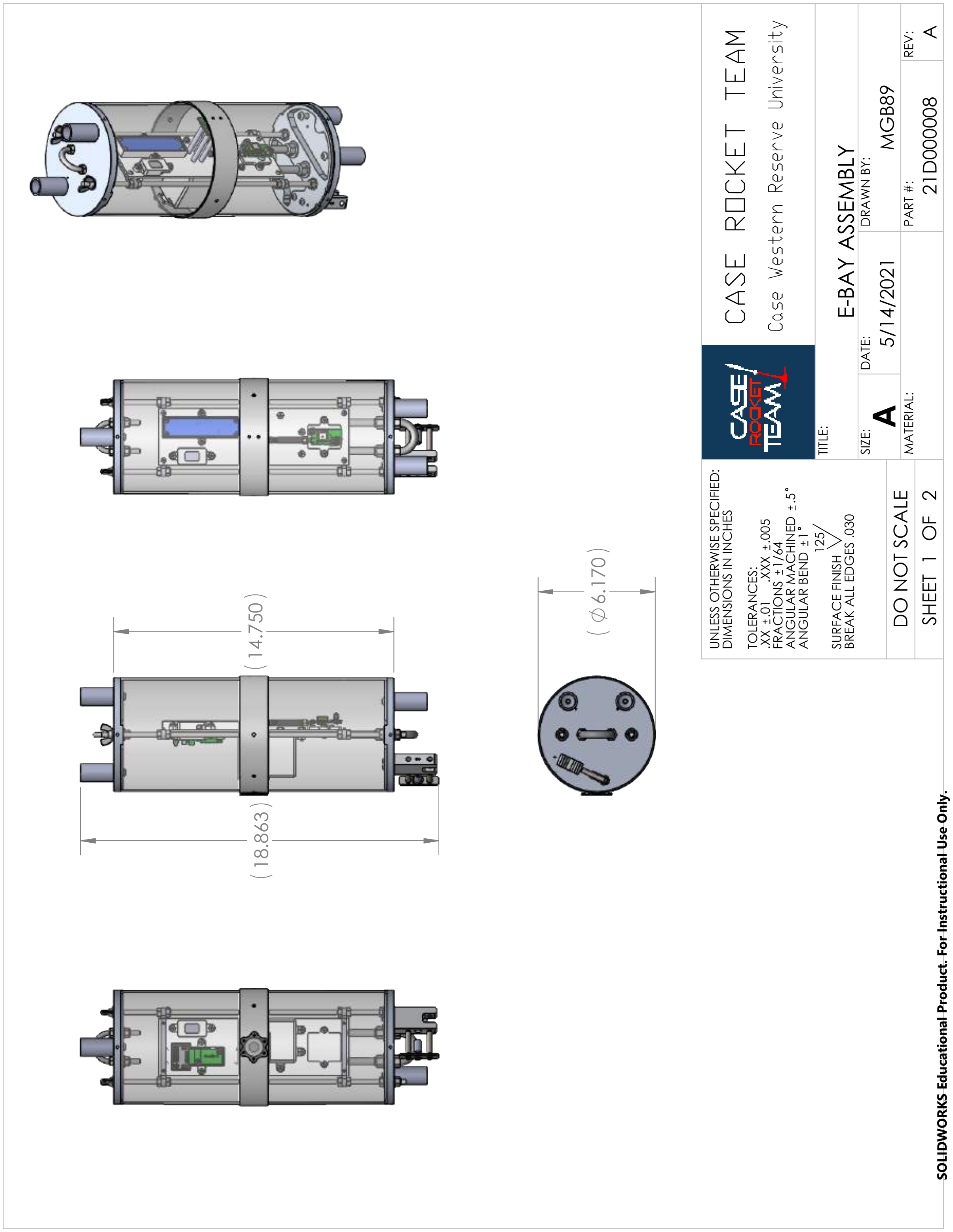

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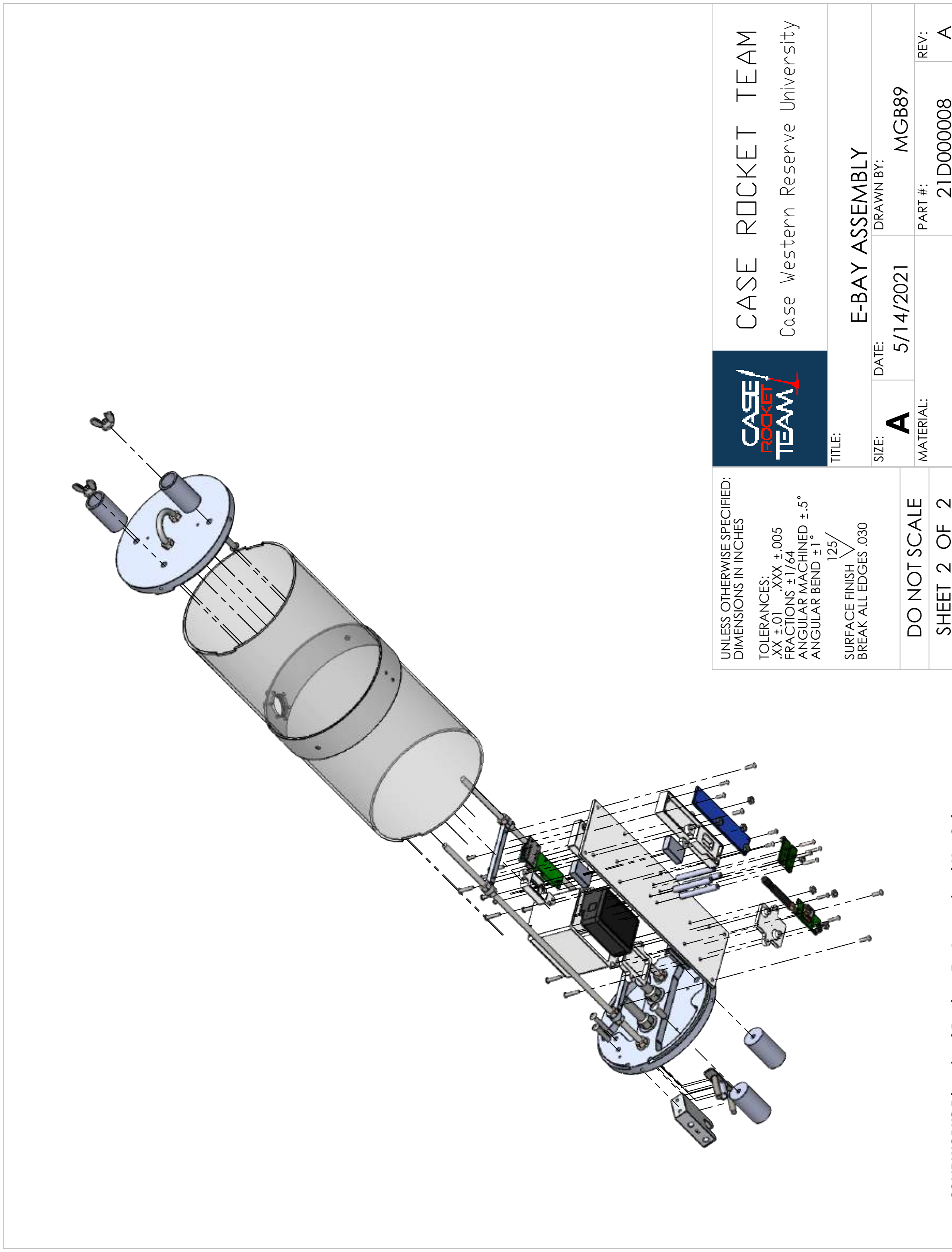
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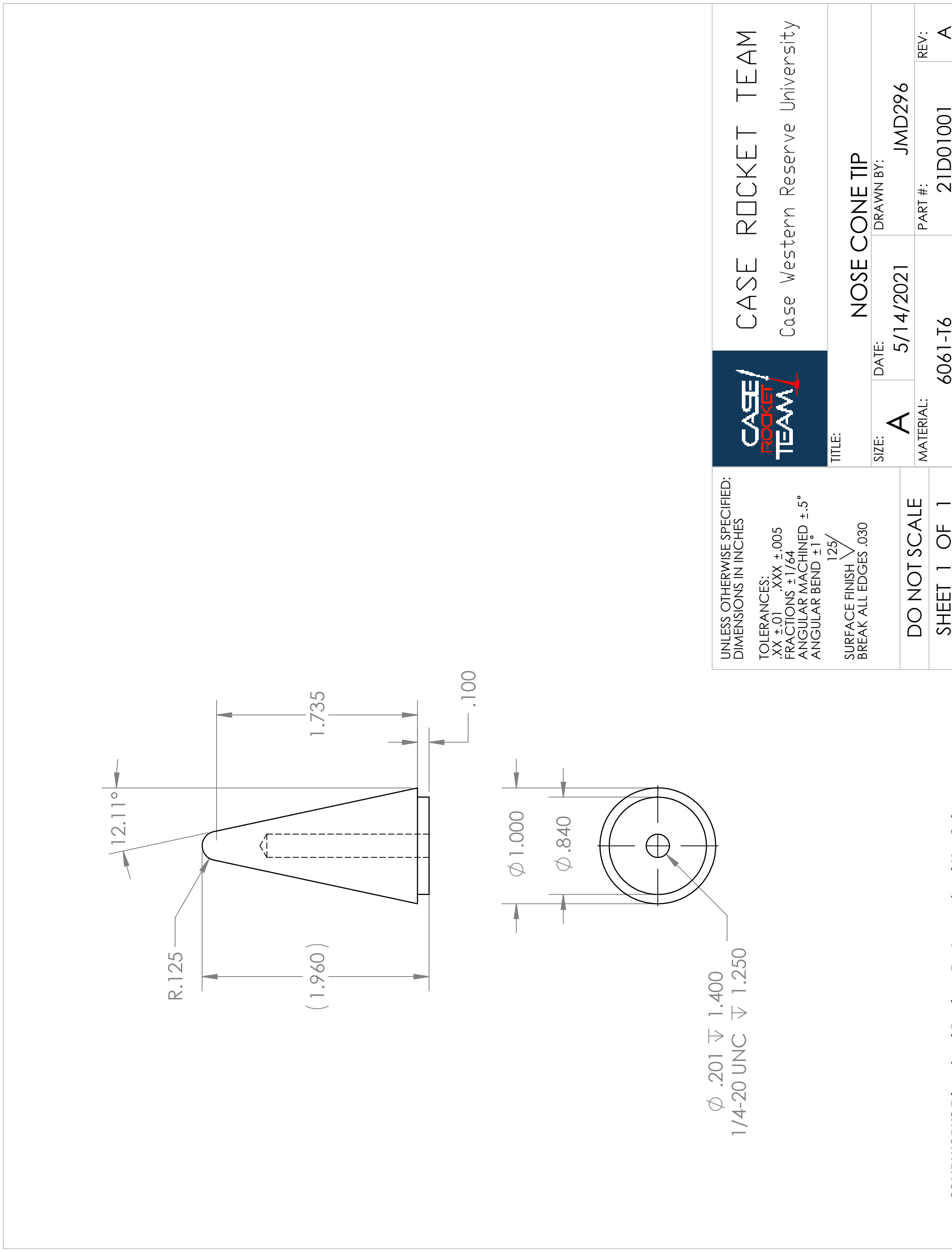

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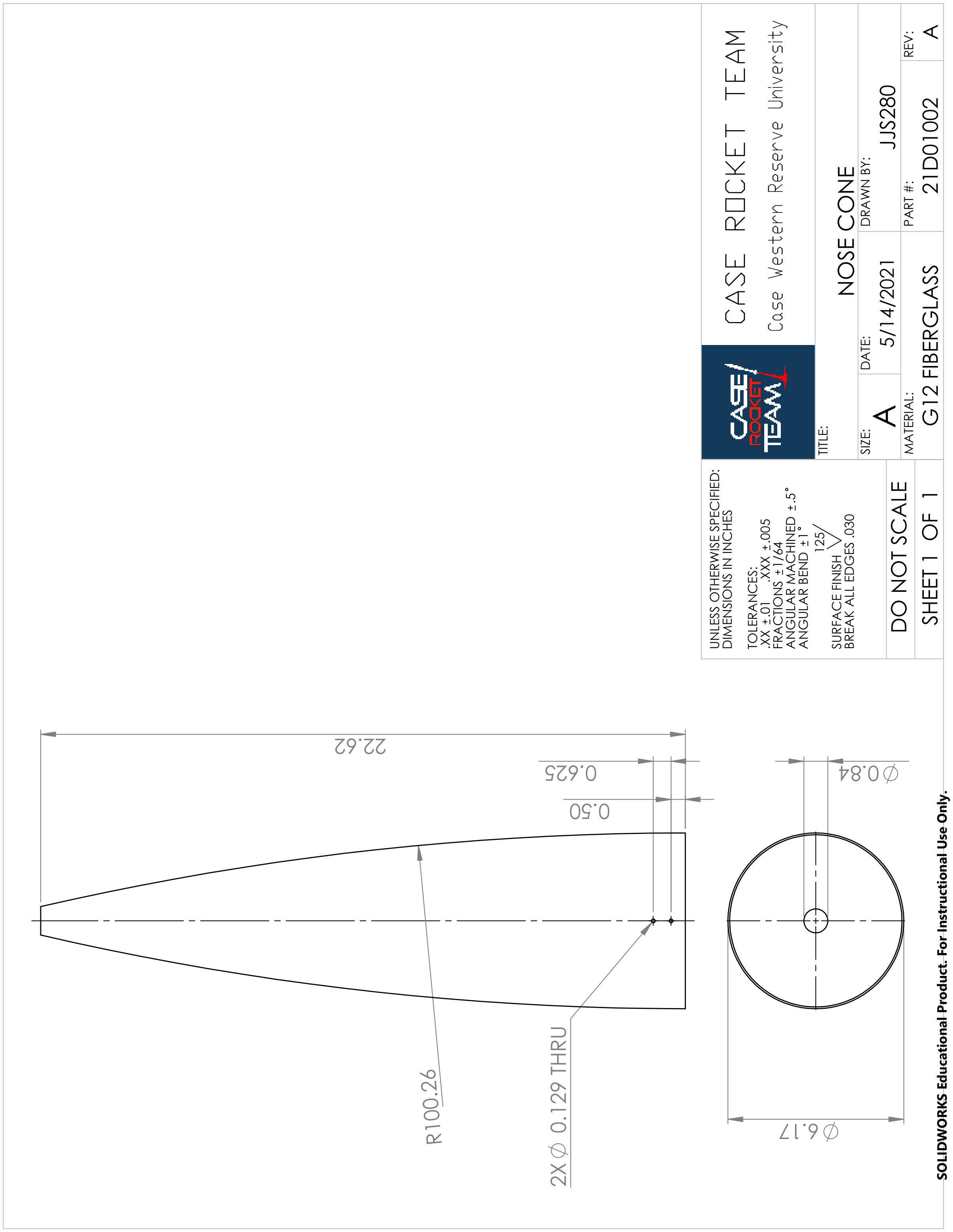
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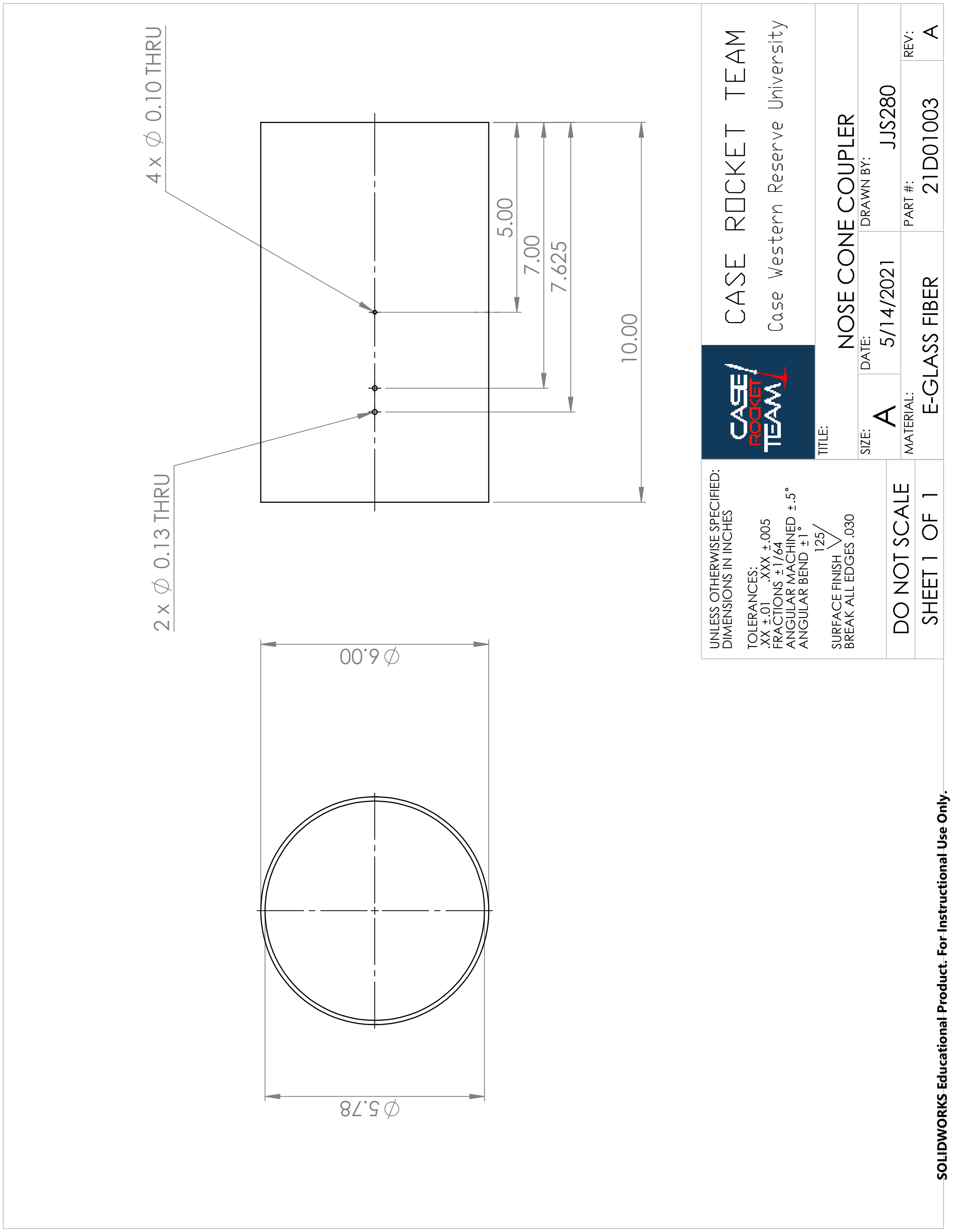
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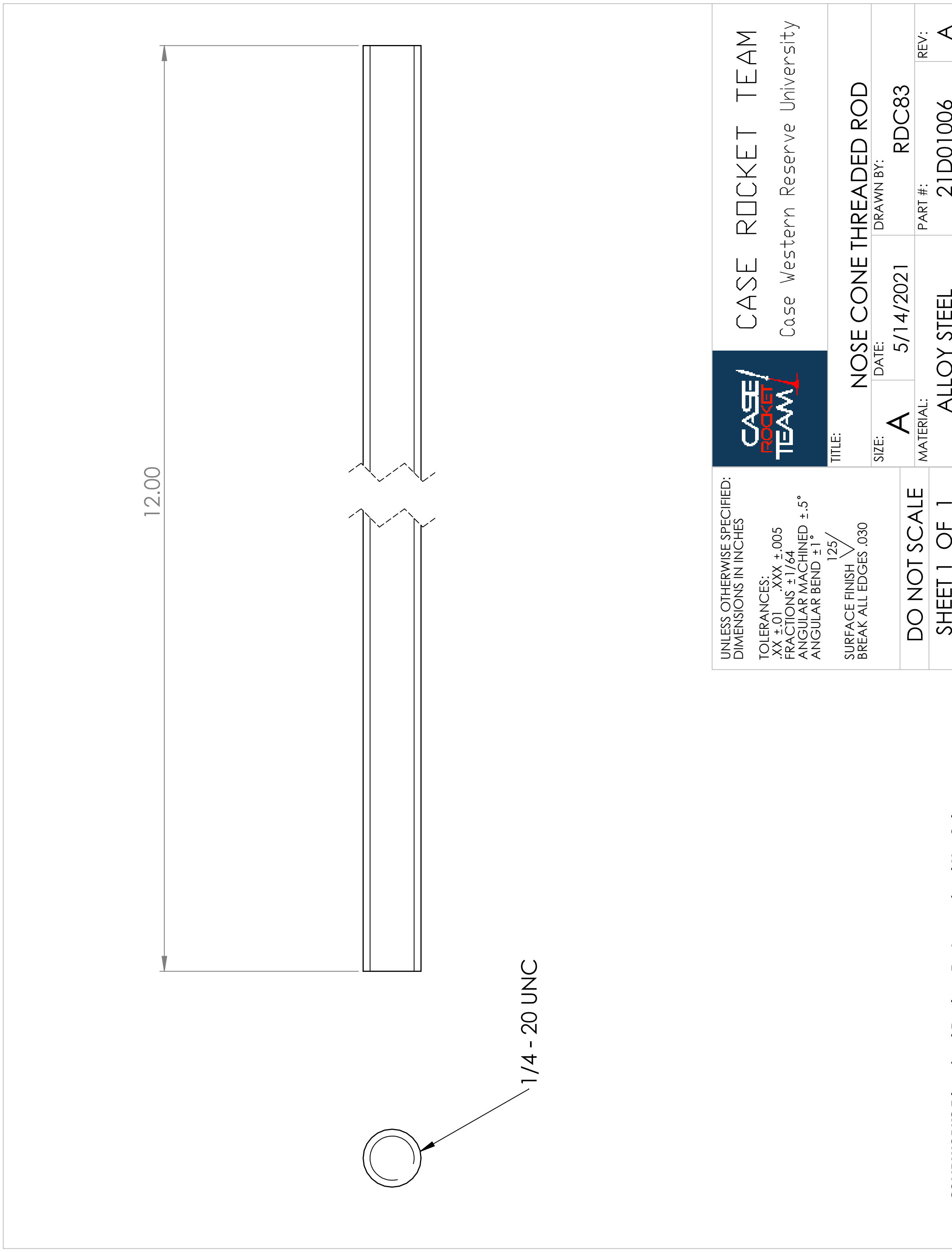
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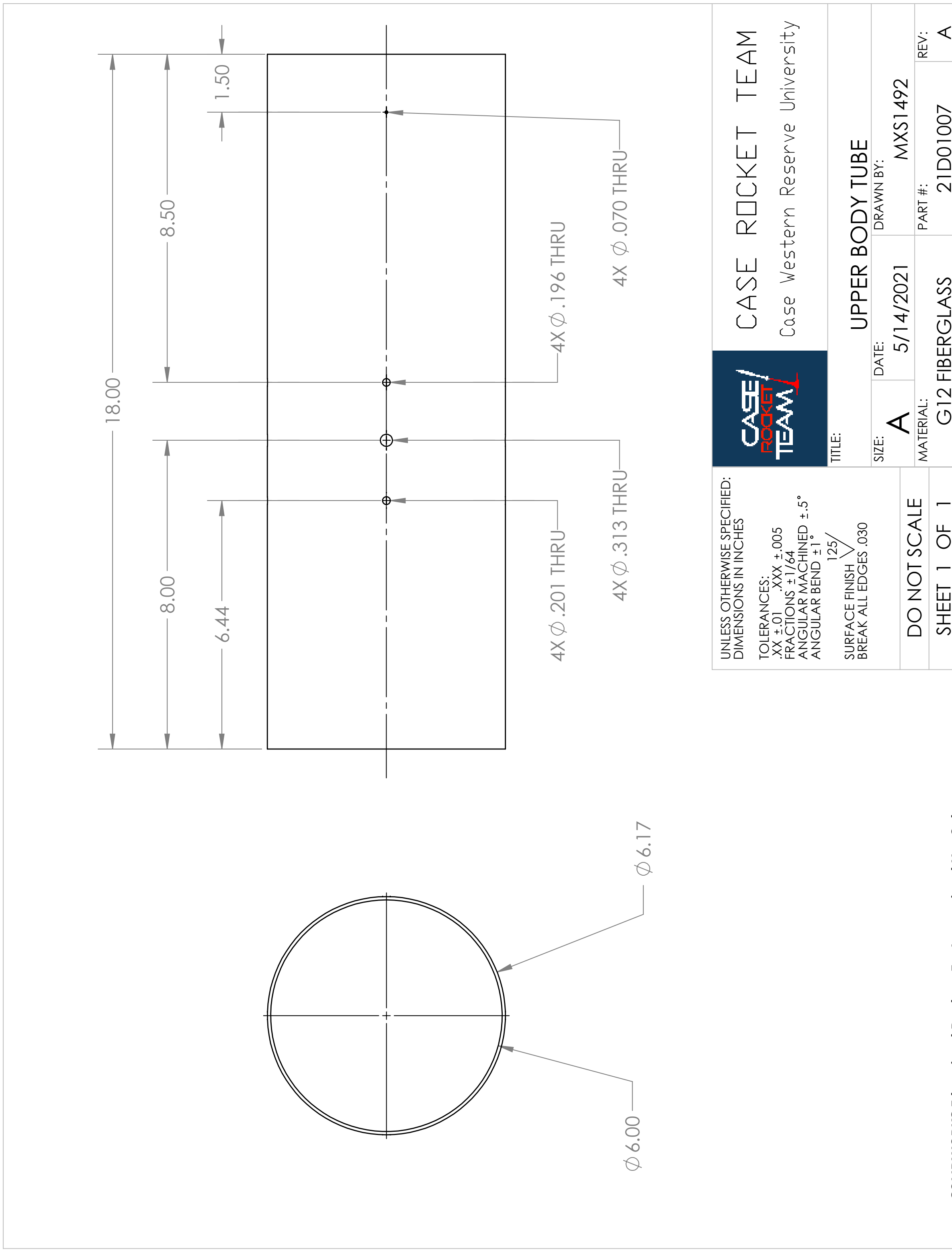
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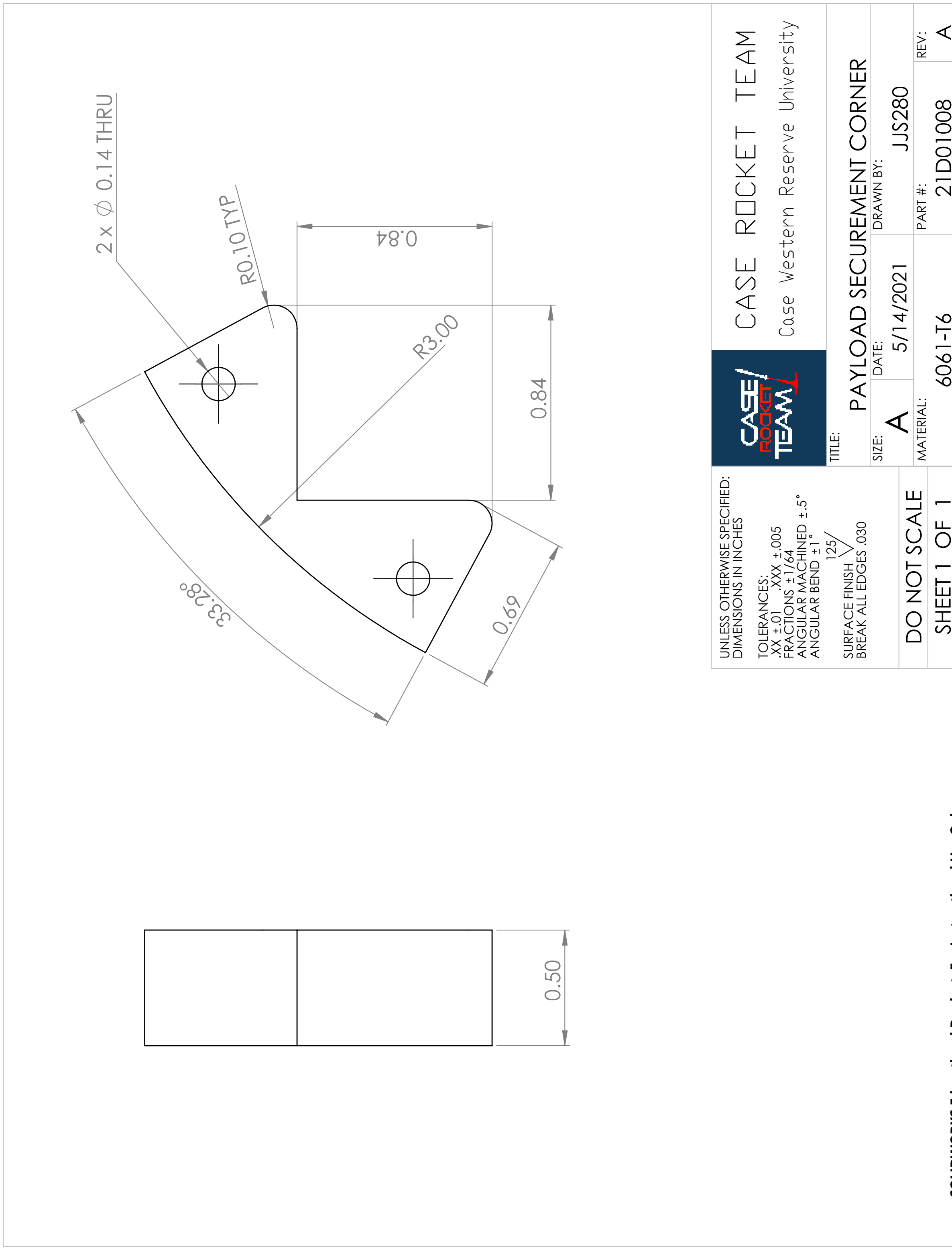
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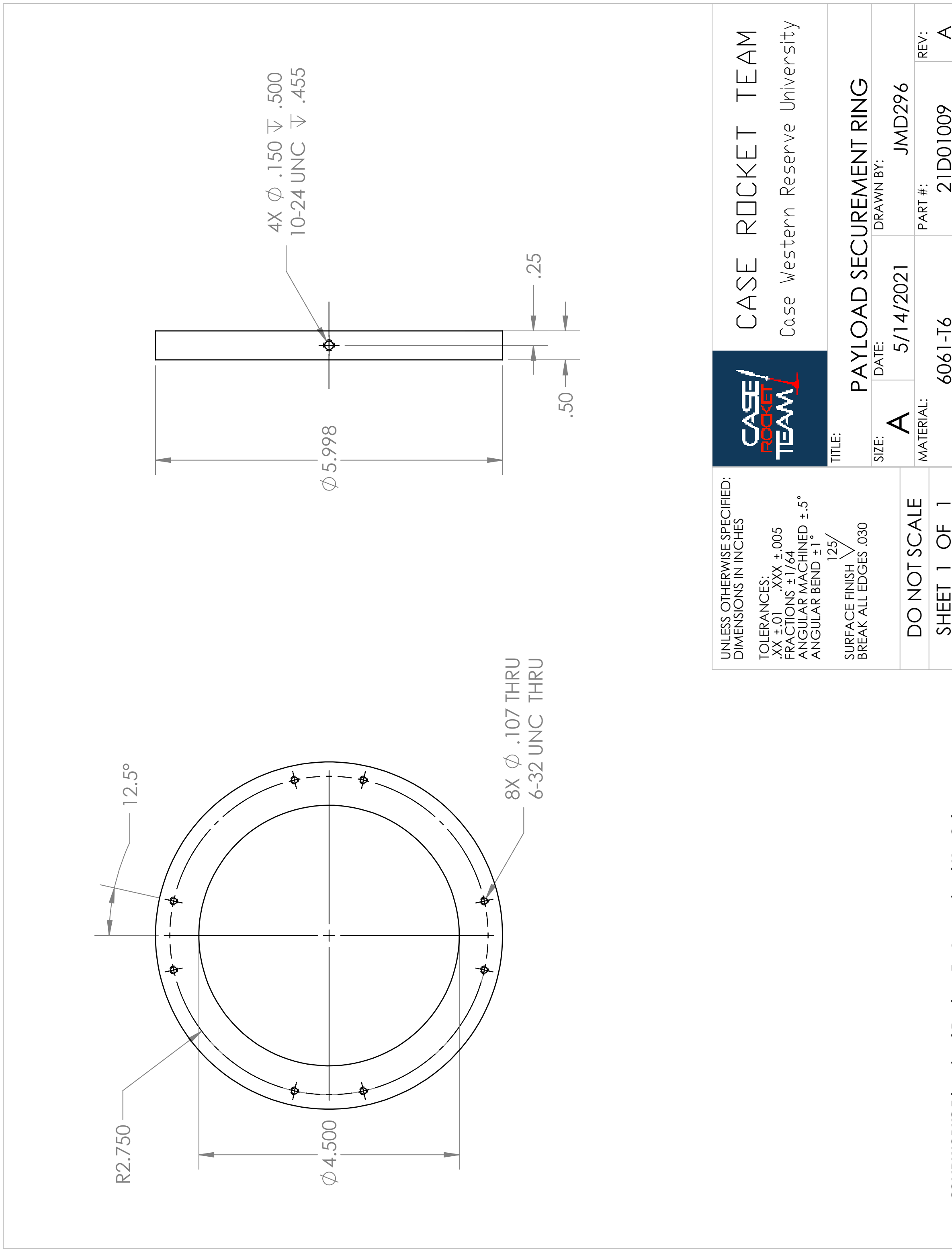
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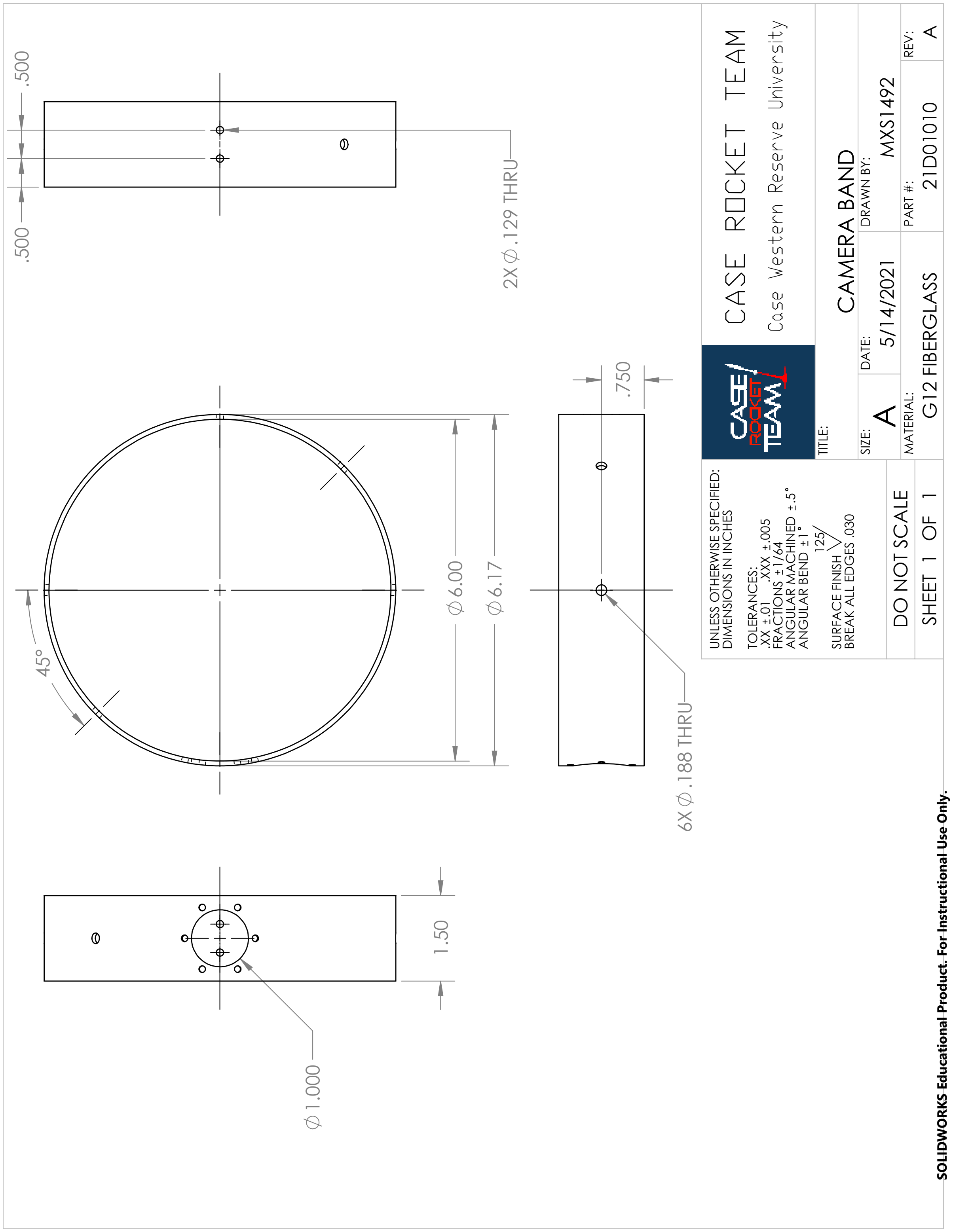
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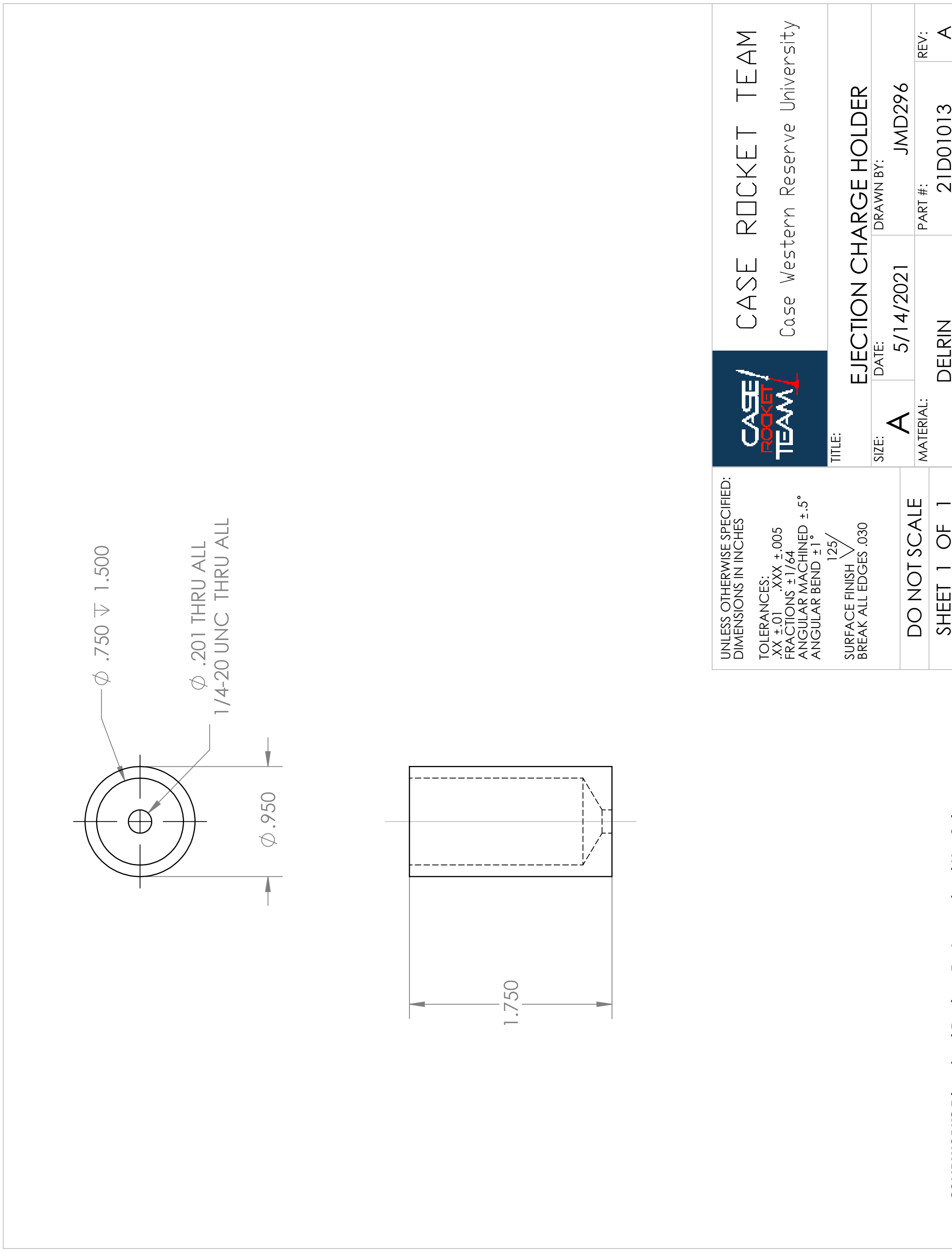
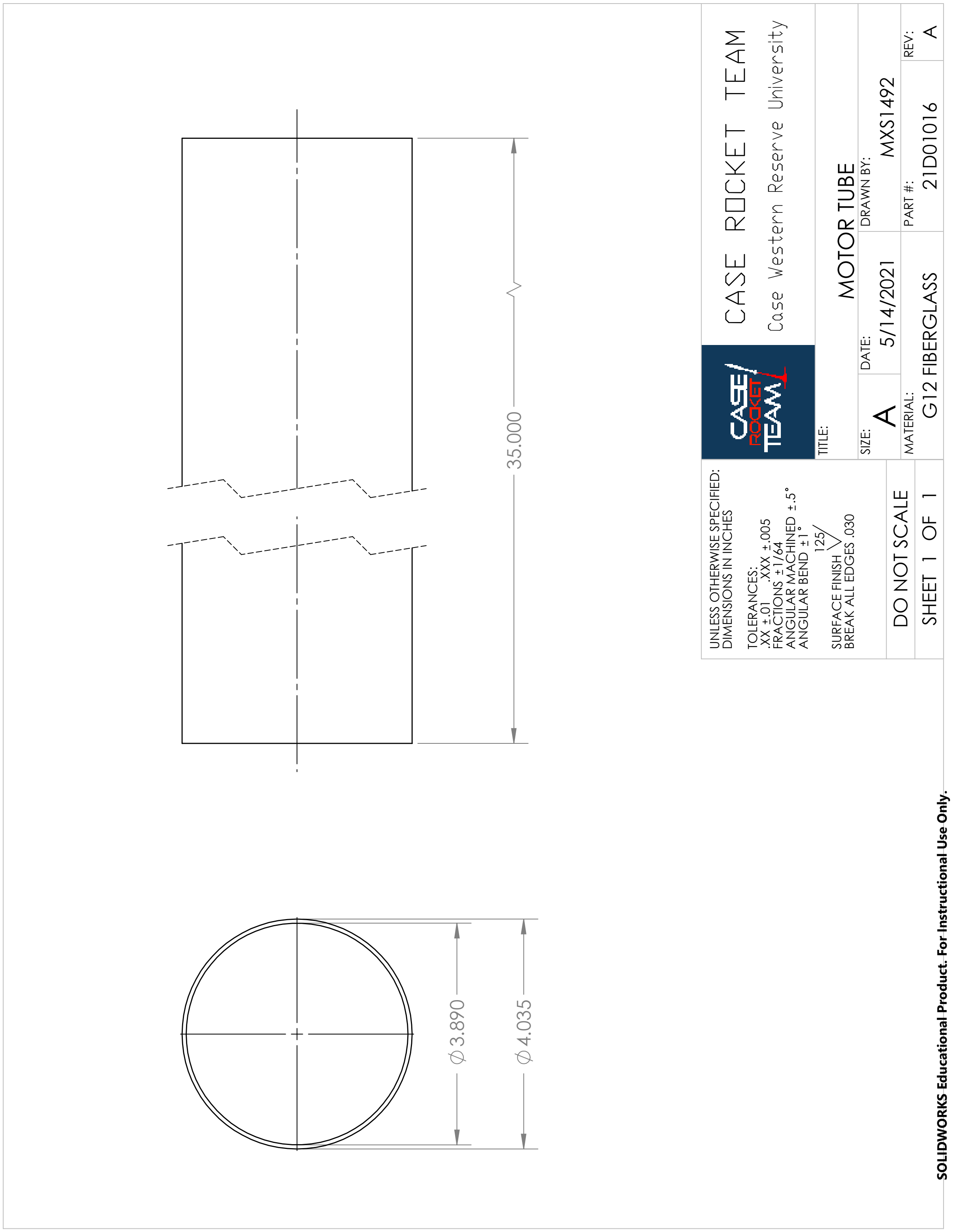
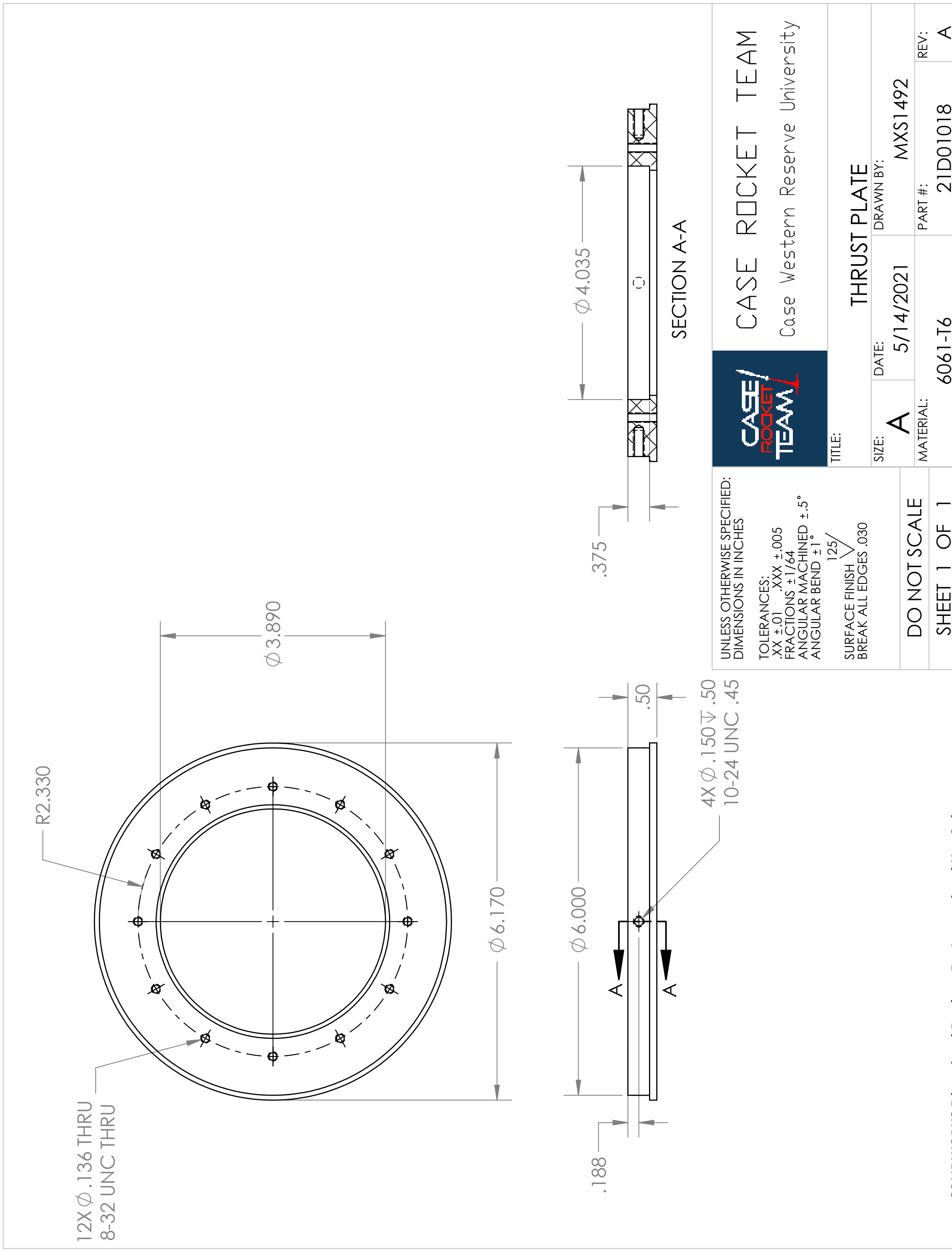
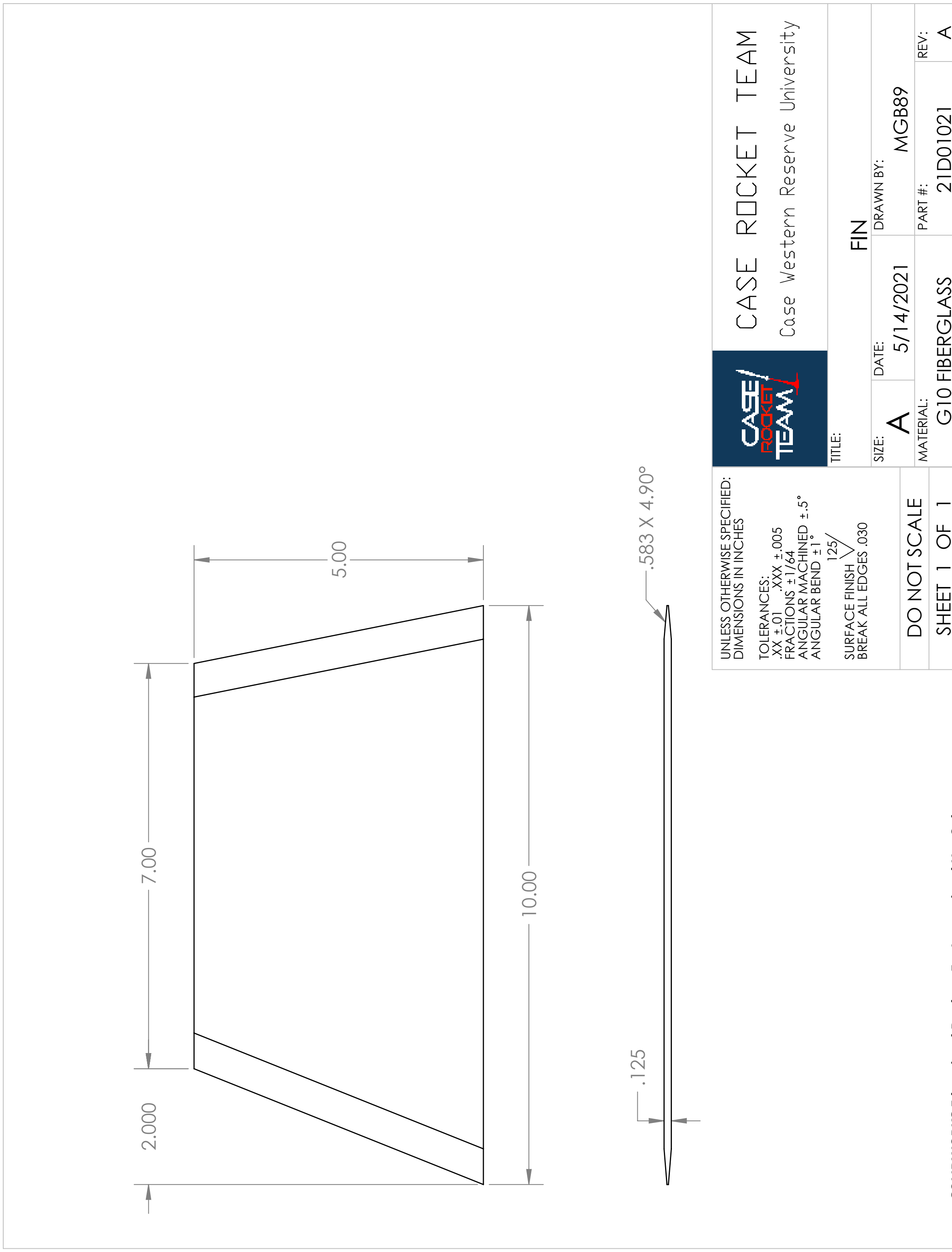
2X ∅.129 THRU
45°
∅6.00
∅6.17
.750
6X ∅.188 THRU
1.50
∅1.000
CASE ROCKET TEAM
Case Western Reserve University
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
TITLE:
CAMERA BAND
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MXS1492
REV:
A
MATERIAL:
G12 FIBERGLASS
PART #:
21D01010
DO NOT SCALE
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only.

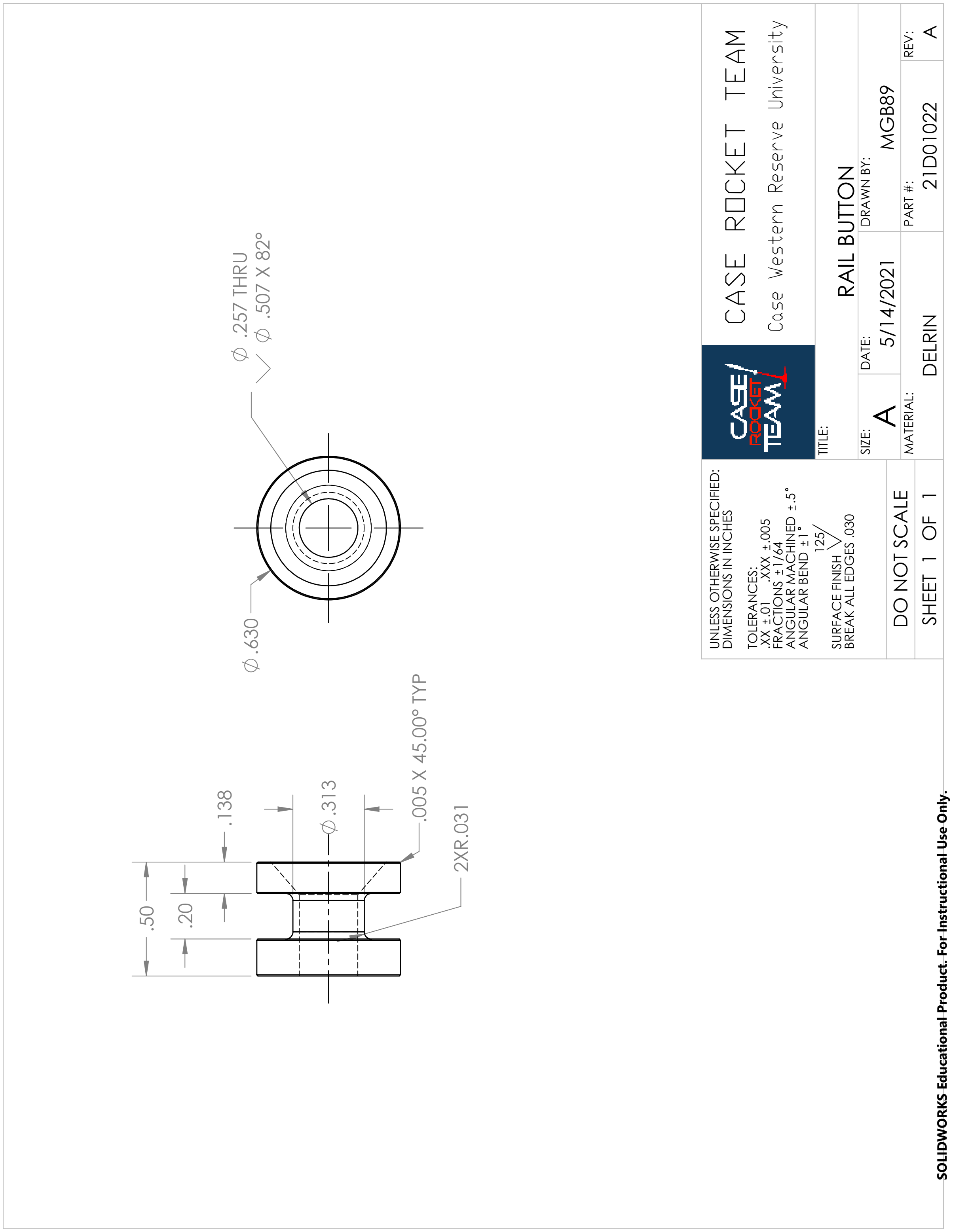

CASE ROCKET TEAM
Case Western Reserve University
TITLE:
EJECTION CHARGE HOLDER
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
JMD296
MATERIAL:
DELRIN
PART #:
21D01013
REV:
A
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
∅ .750 ↧ 1.500
∅ .201 THRU ALL
1/4-20 UNC THRU ALL
∅.950
1.750
SOLIDWORKS Educational Product. For Instructional Use Only.


35.000
⌀3.890
⌀4.035
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:
MOTOR TUBE
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MXS1492
MATERIAL:
G12 FIBERGLASS
PART #:
21D01016
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.



R2.330
12X ⌀.136 THRU
8-32 UNC THRU
⌀3.890
⌀6.170
⌀6.000
.188
.50
4X ⌀.150 ↧ .50
10-24 UNC .45
A
A
.375
⌀4.035
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 1 OF 1
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
THRUST PLATE
SIZE: A
DATE: 5/14/2021
DRAWN BY: MXS1492
MATERIAL: 6061-T6
PART #: 21D01018
REV: A
SOLIDWORKS Educational Product. For Instructional Use Only.


5.00
7.00
2.000
10.00
.125
.583 X 4.90°
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
125
SURFACE FINISH
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
FIN
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MGB89
MATERIAL:
G10 FIBERGLASS
PART #:
21D01021
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.


.50
.20
.138
∅.313
.005 X 45.00° TYP
2XR.031
∅.630
∅ .257 THRU
∅ .507 X 82°
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:
RAIL BUTTON
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MGB89
MATERIAL:
DELRIN
PART #:
21D01022
REV:
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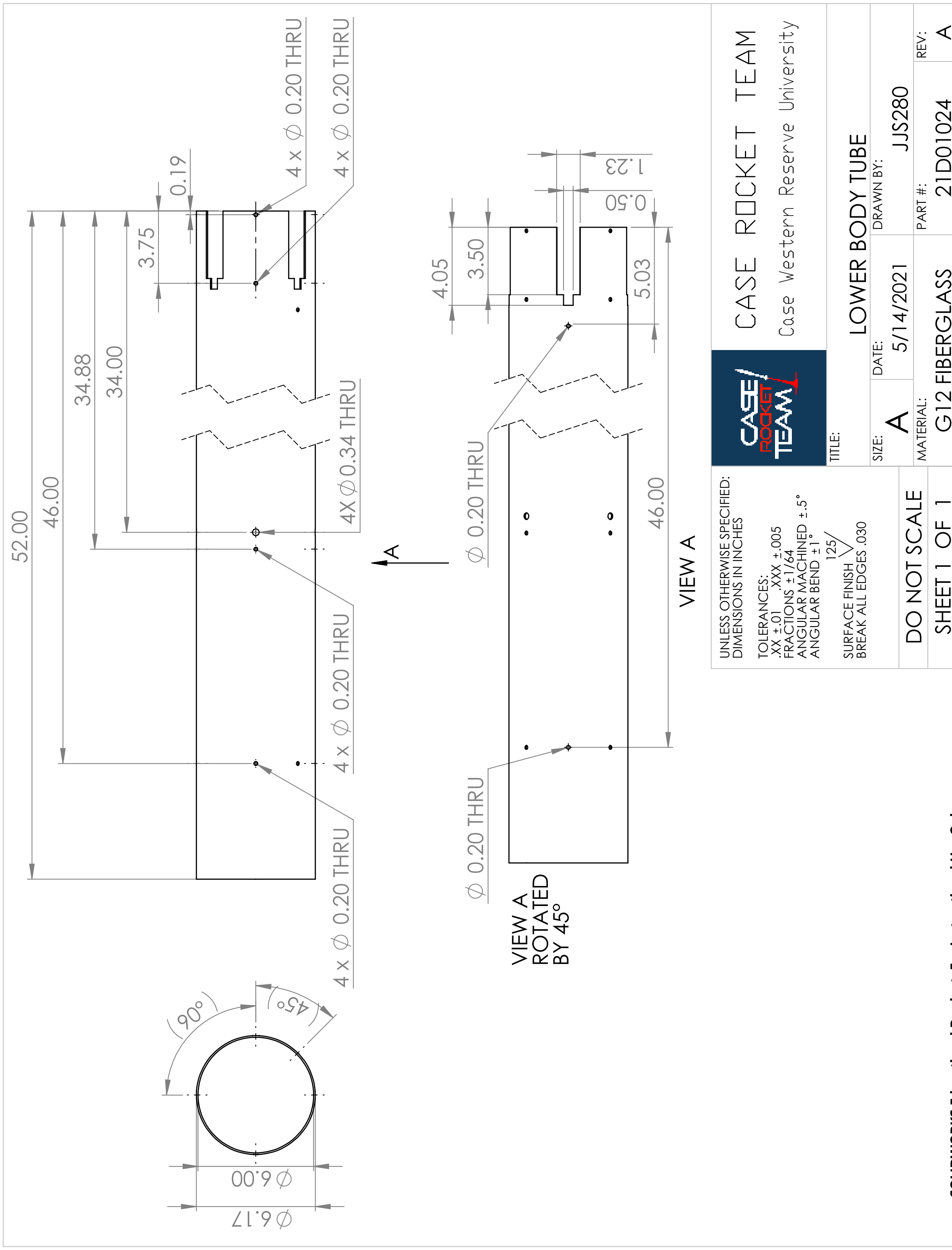
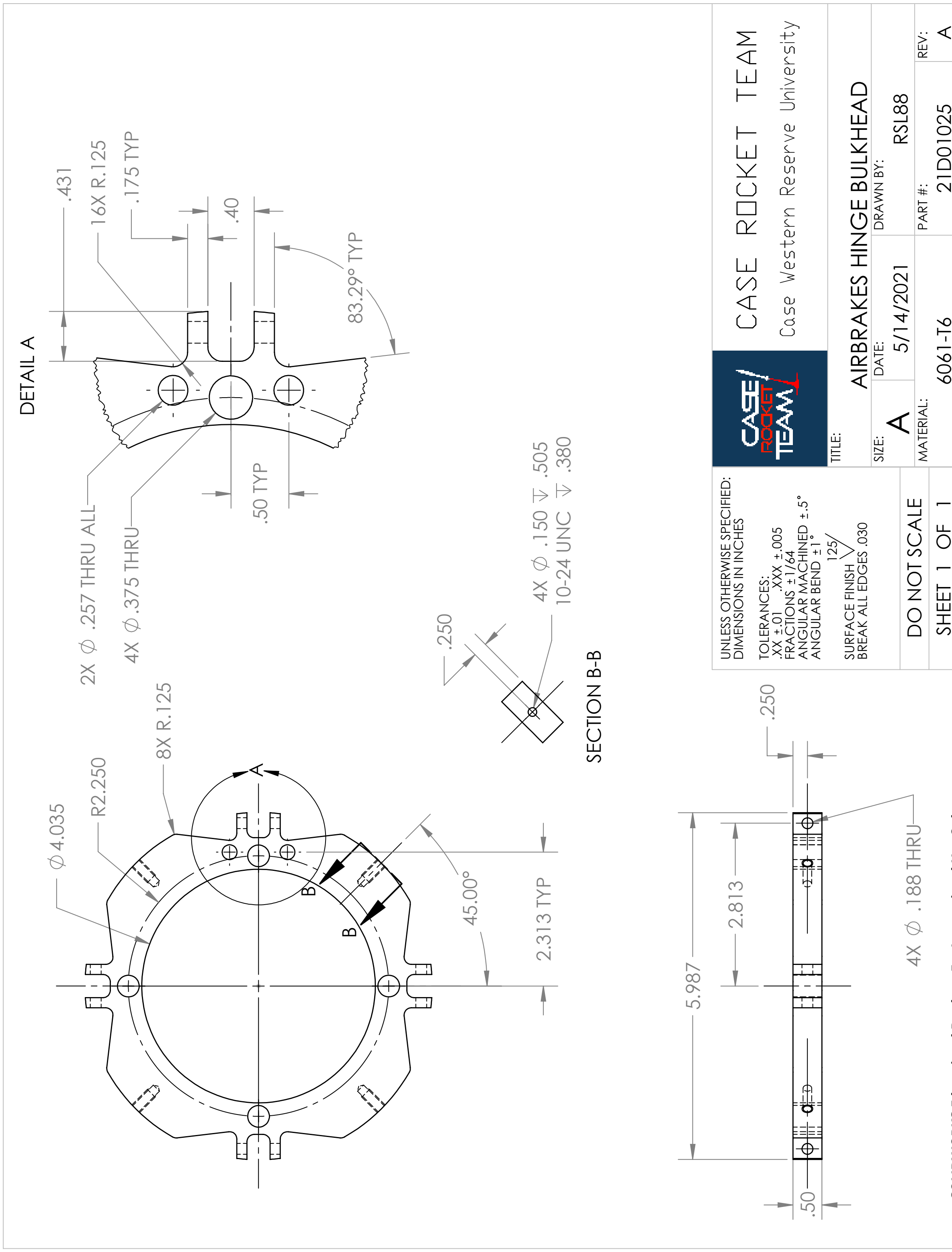
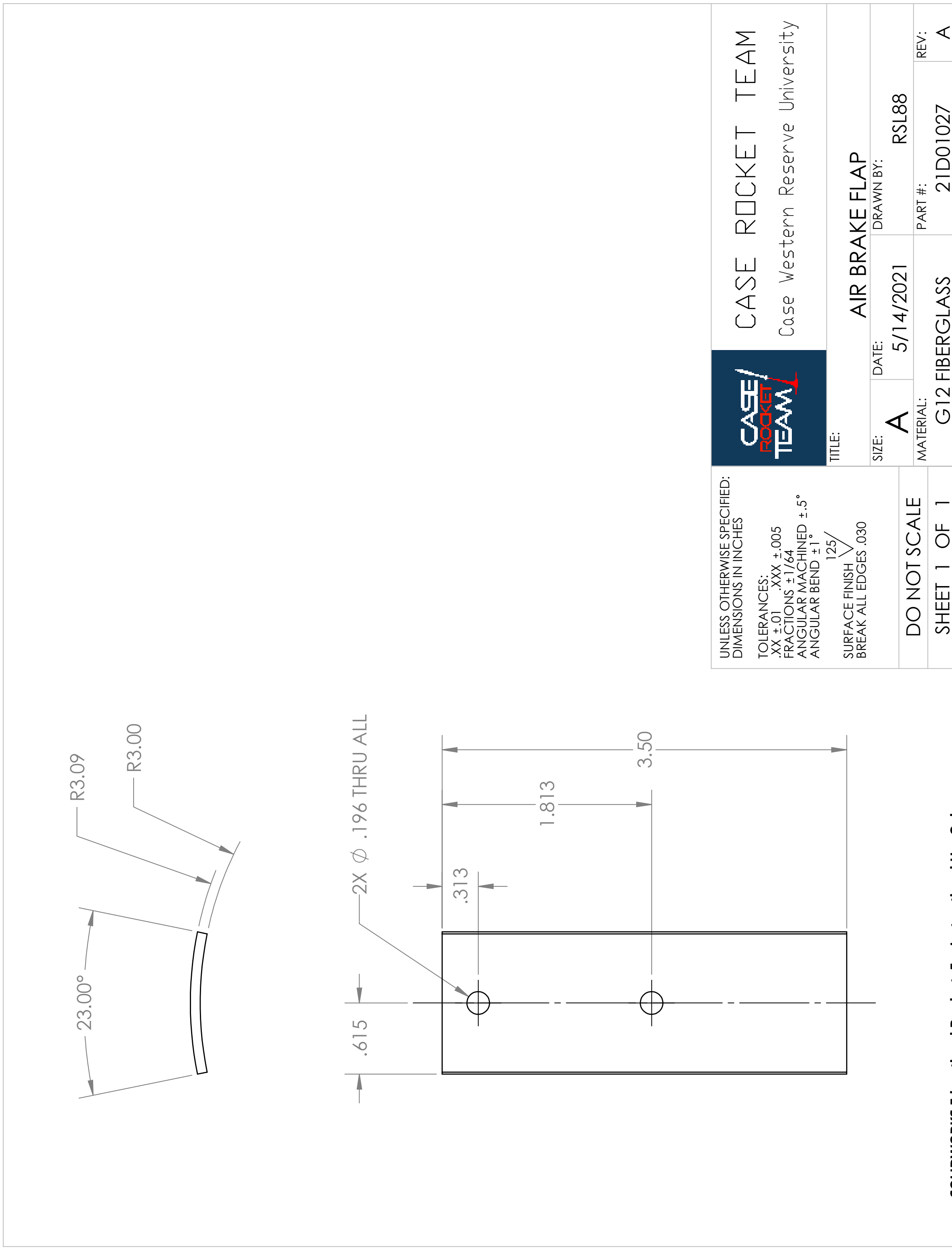
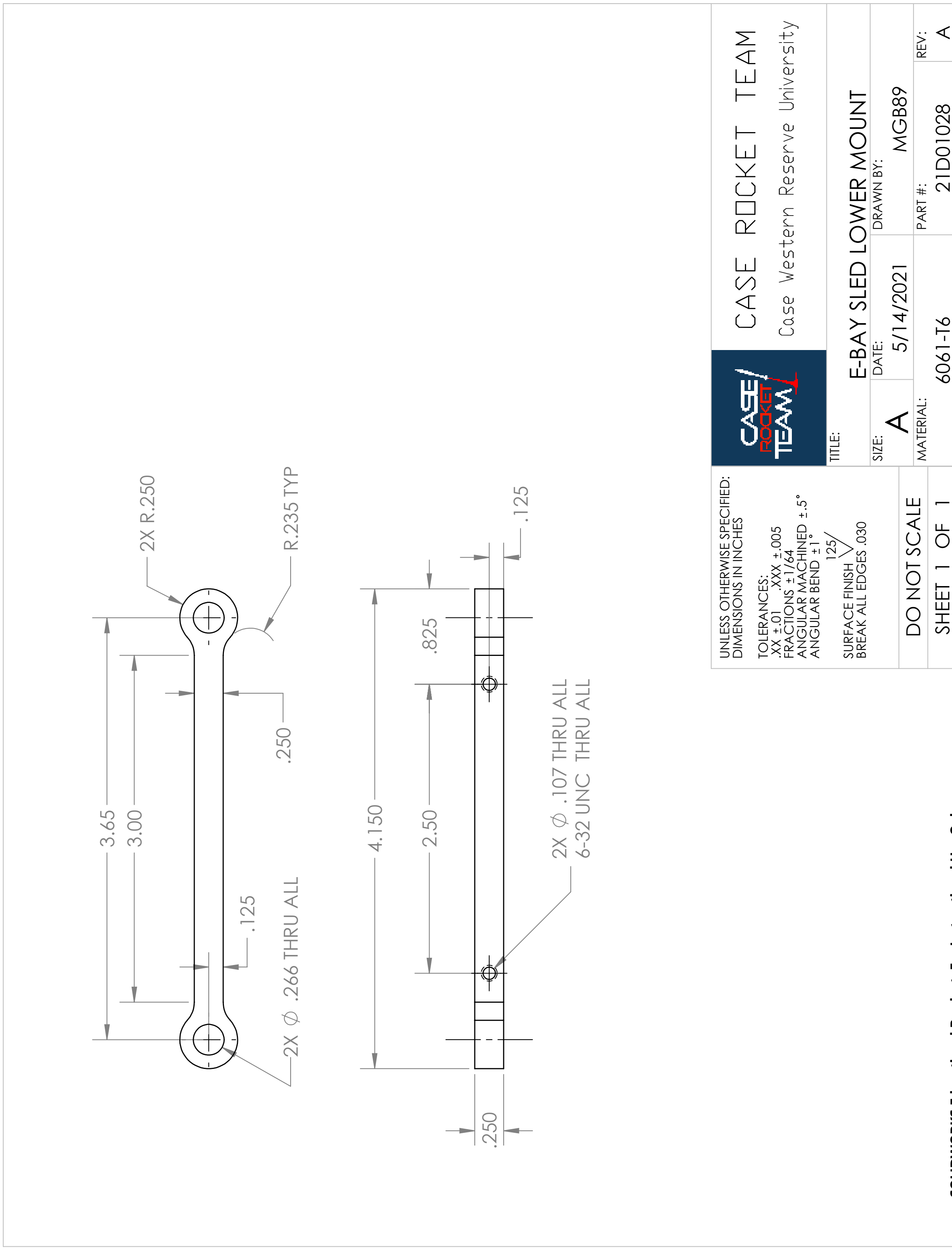
SOLIDWORKS Educational Product. For Instructional Use Only.



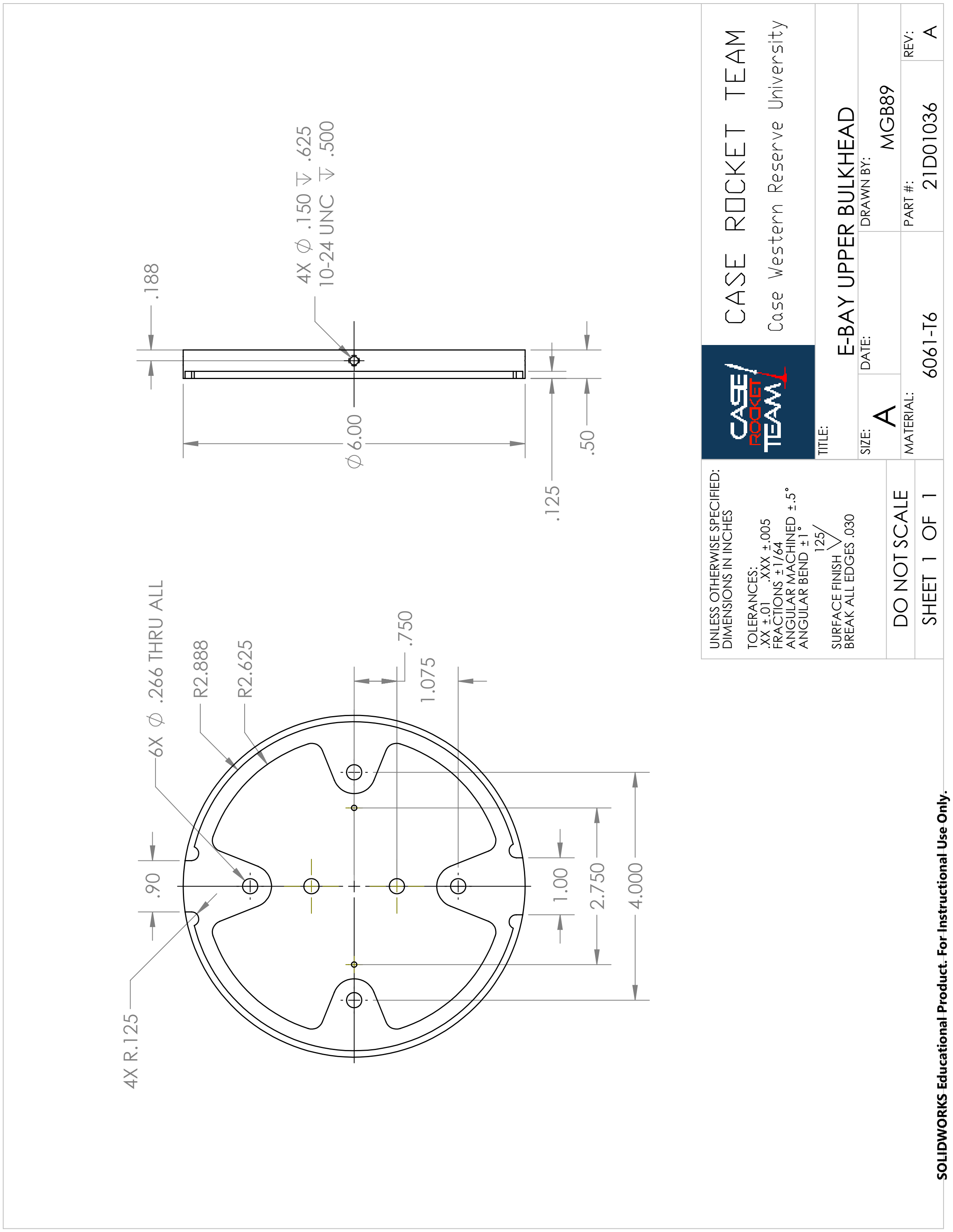
4 x Ø 0.20 THRU
4 x Ø 0.20 THRU
0.19
3.75
34.88
34.00
52.00
46.00
4X Ø 0.34 THRU
4 x Ø 0.20 THRU
4 x Ø 0.20 THRU
A
1.23
0.50
4.05
3.50
5.03
Ø 0.20 THRU
46.00
VIEW A
Ø 0.20 THRU
VIEW A ROTATED BY 45°
90°
45°
Ø 6.00
Ø 6.17
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
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 BODY TUBE
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
JJS280
MATERIAL:
G12 FIBERGLASS
PART #:
21D01024
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.


DETAIL A
.431
16X R.125
.175 TYP
.40
83.29° TYP
2X ∅ .257 THRU ALL
4X ∅ .375 THRU
.50 TYP
4X ∅ .150 ↧ .505
10-24 UNC ↧ .380
.250
SECTION B-B
∅4.035
R2.250
8X R.125
A
B
B
45.00°
2.313 TYP
5.987
2.813
.250
4X ∅ .188 THRU
.50
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:
AIRBRAKES HINGE BULKHEAD
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
RSL88
MATERIAL:
6061-T6
PART #:
21D01025
REV:
A

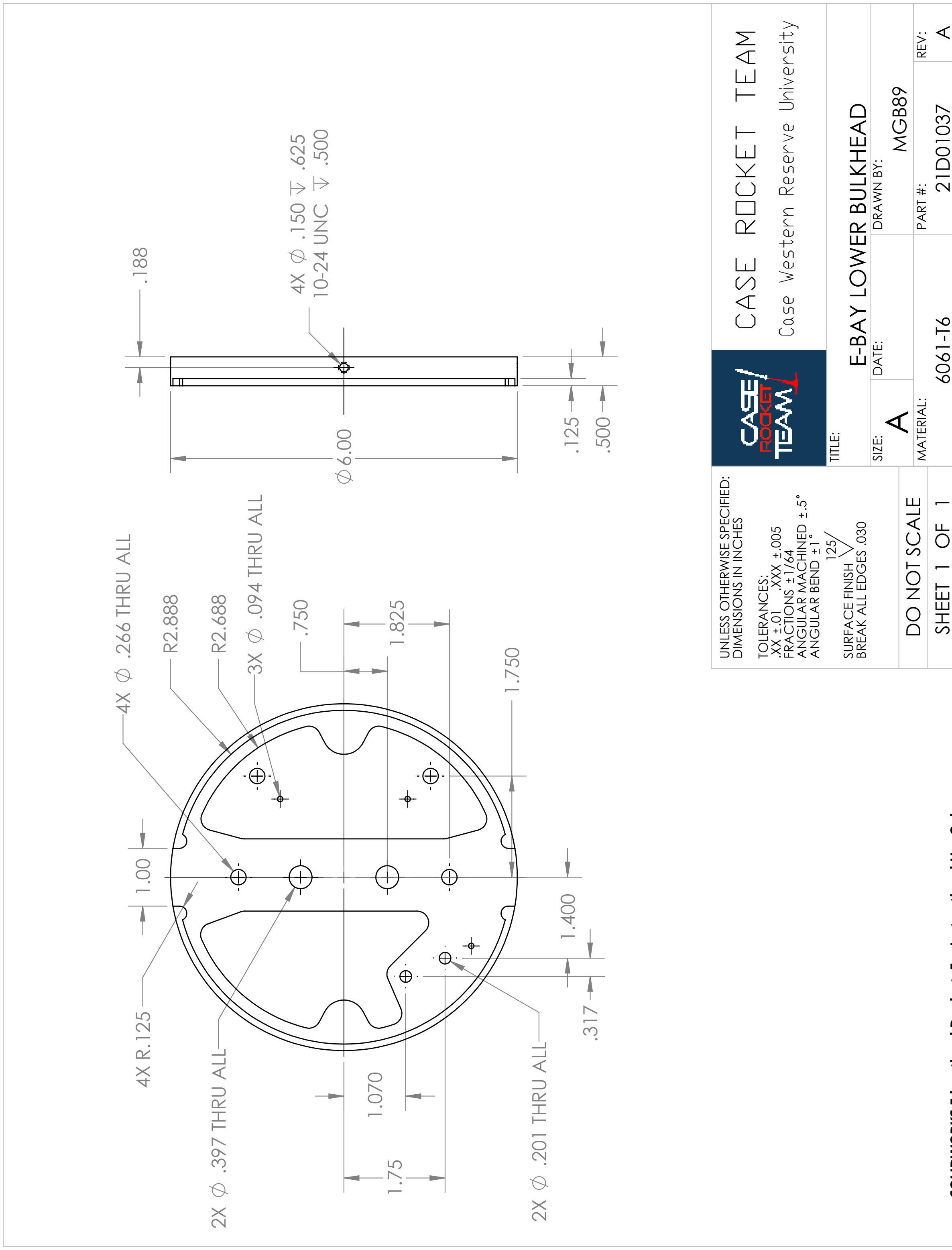

R3.09
R3.00
23.00°
.615
2X ⌀ .196 THRU ALL
.313
1.813
3.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
AIR BRAKE FLAP
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
RSL88
MATERIAL:
G12 FIBERGLASS
PART #:
21D01027
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.

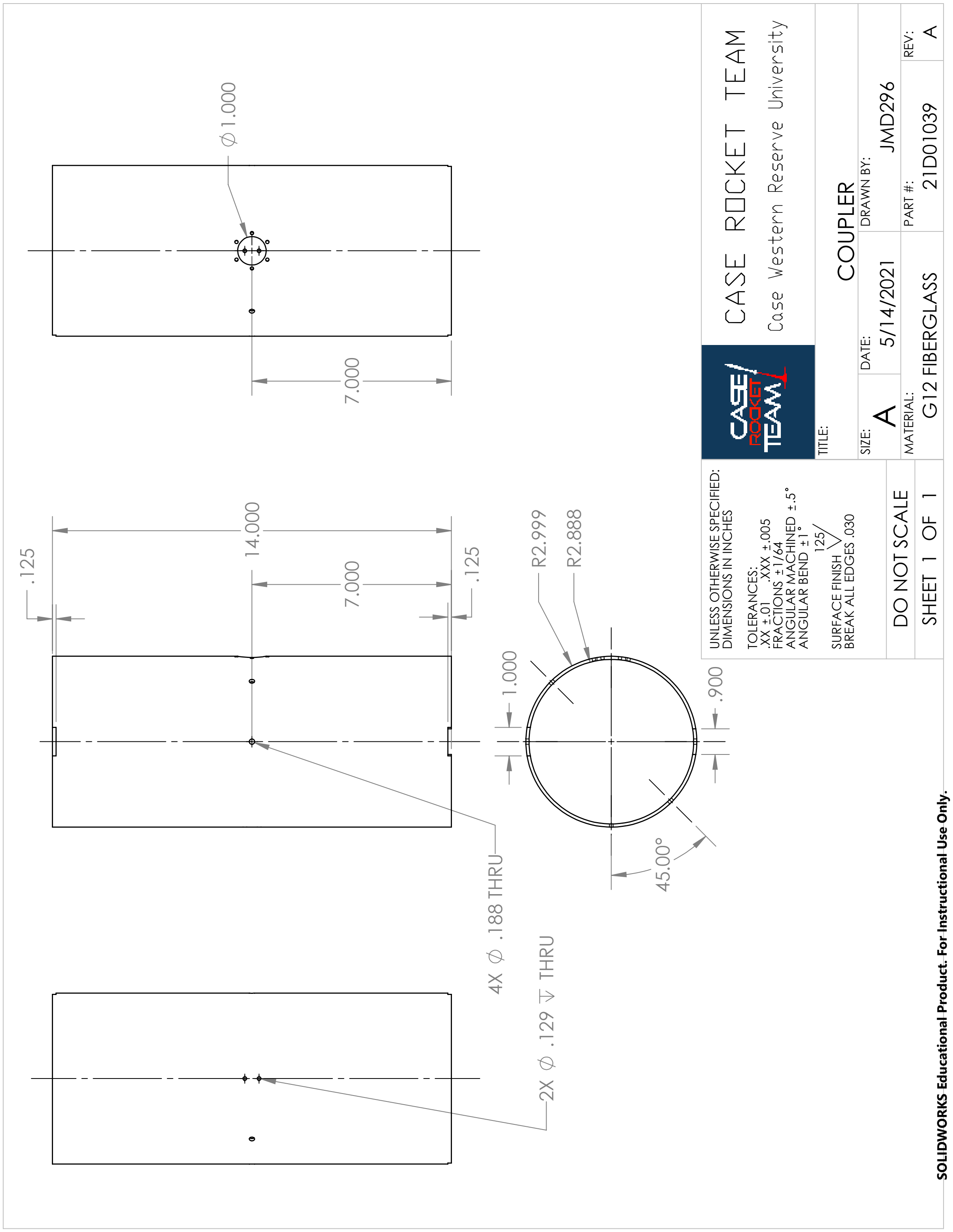


CASE ROCKET TEAM
Case Western Reserve University
TITLE:
E-BAY SLED LOWER MOUNT
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MGB89
MATERIAL:
6061-T6
PART #:
21D01028
REV:
A
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
2X R.250
R.235 TYP
3.65
3.00
.250
.125
2X ⌀ .266 THRU ALL
4.150
.825
2.50
.125
.250
2X ⌀ .107 THRU ALL
6-32 UNC THRU ALL
SOLIDWORKS Educational Product. For Instructional Use Only.

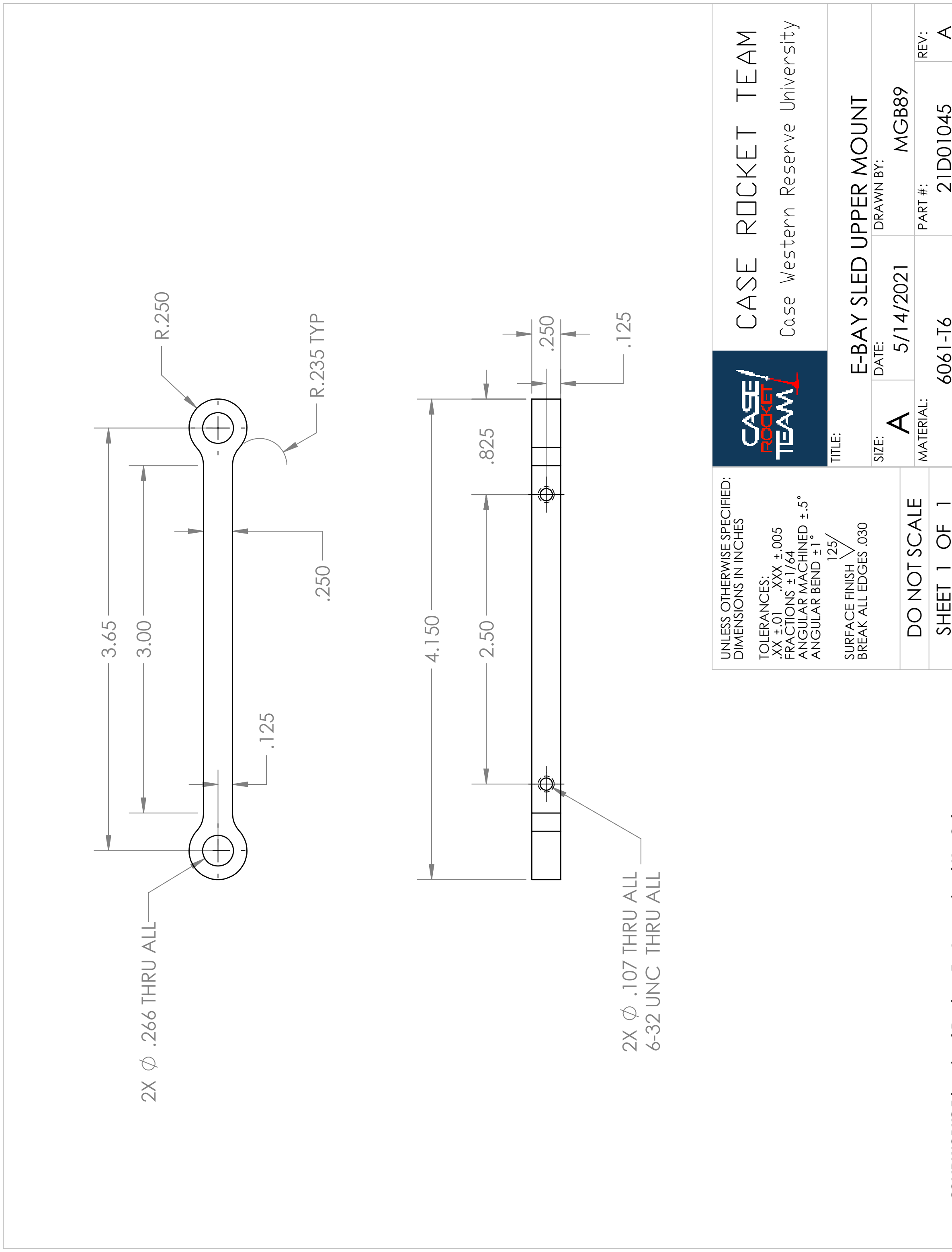


4X R.125
.90
6X ⌀ .266 THRU ALL
R2.888
R2.625
.750
1.075
1.00
2.750
4.000
⌀ 6.00
.188
4X ⌀ .150 ↧ .625
10-24 UNC ↧ .500
.125
.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
E-BAY UPPER BULKHEAD
SIZE:
A
DATE:
DRAWN BY:
MGB89
MATERIAL:
6061-T6
PART #:
21D01036
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.


4X ∅ .266 THRU ALL
R2.888
R2.688
3X ∅ .094 THRU ALL
.750
1.825
1.750
1.00
4X R.125
2X ∅ .397 THRU ALL
1.070
1.75
2X ∅ .201 THRU ALL
.317
1.400
.188
4X ∅ .150 ↧ .625
10-24 UNC ↧ .500
∅6.00
.125
.500
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 ROCKET TEAM
Case Western Reserve University
TITLE:
E-BAY LOWER BULKHEAD
SIZE:
A
DATE:
DRAWN BY:
MGB89
MATERIAL:
6061-T6
PART #:
21D01037
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.



Ø1.000
7.000
14.000
7.000
.125
.125
R2.999
R2.888
1.000
.900
45.00°
4X Ø .188 THRU
2X Ø .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:
COUPLER
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
JMD296
MATERIAL:
G12 FIBERGLASS
PART #:
21D01039
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.


R.250
R.235 TYP
3.65
3.00
.250
.125
2X ⌀ .266 THRU ALL
4.150
2.50
.825
.250
.125
2X ⌀ .107 THRU ALL
6-32 UNC THRU ALL
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:
E-BAY SLED UPPER MOUNT
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MGB89
MATERIAL:
6061-T6
PART #:
21D01045
REV:
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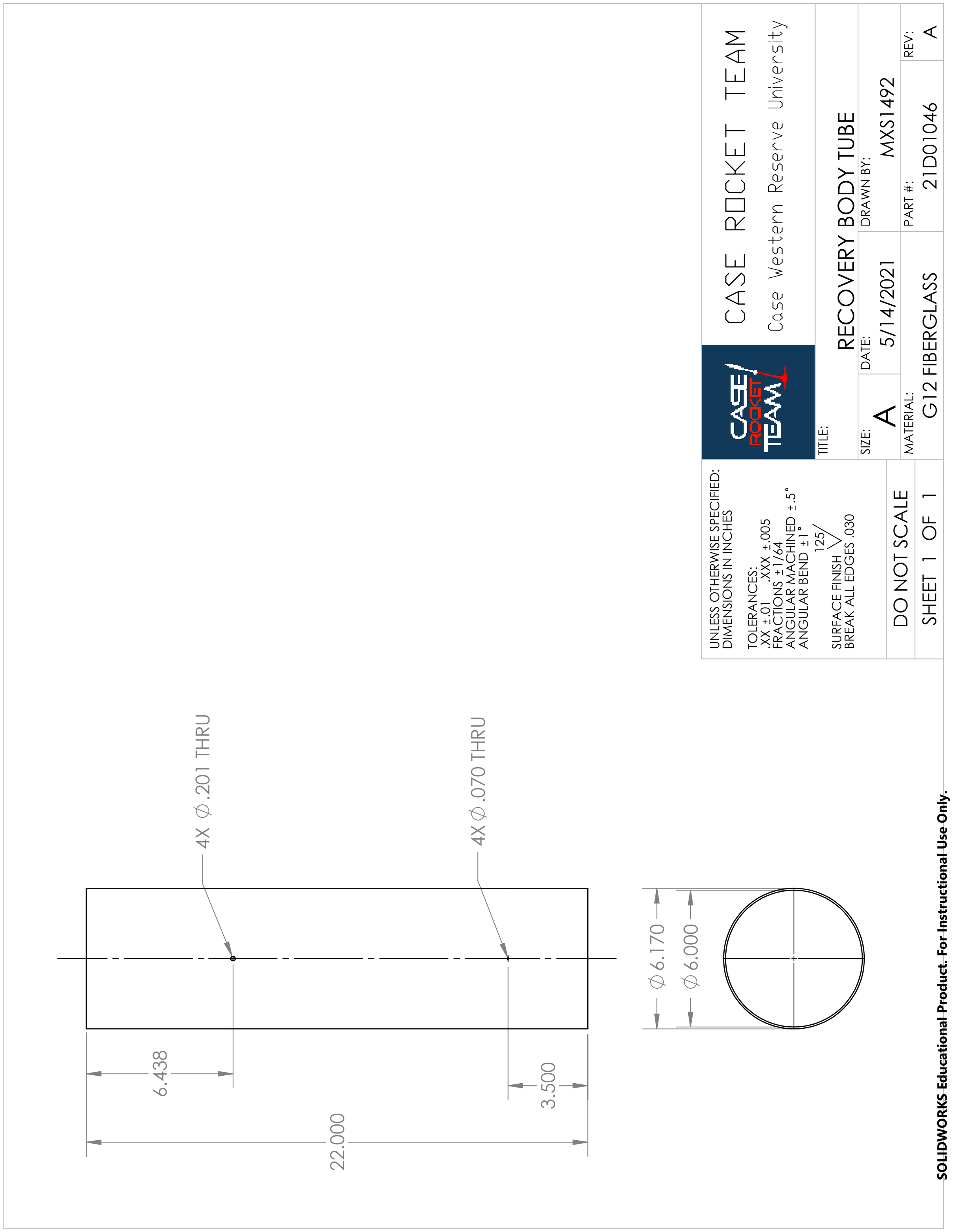
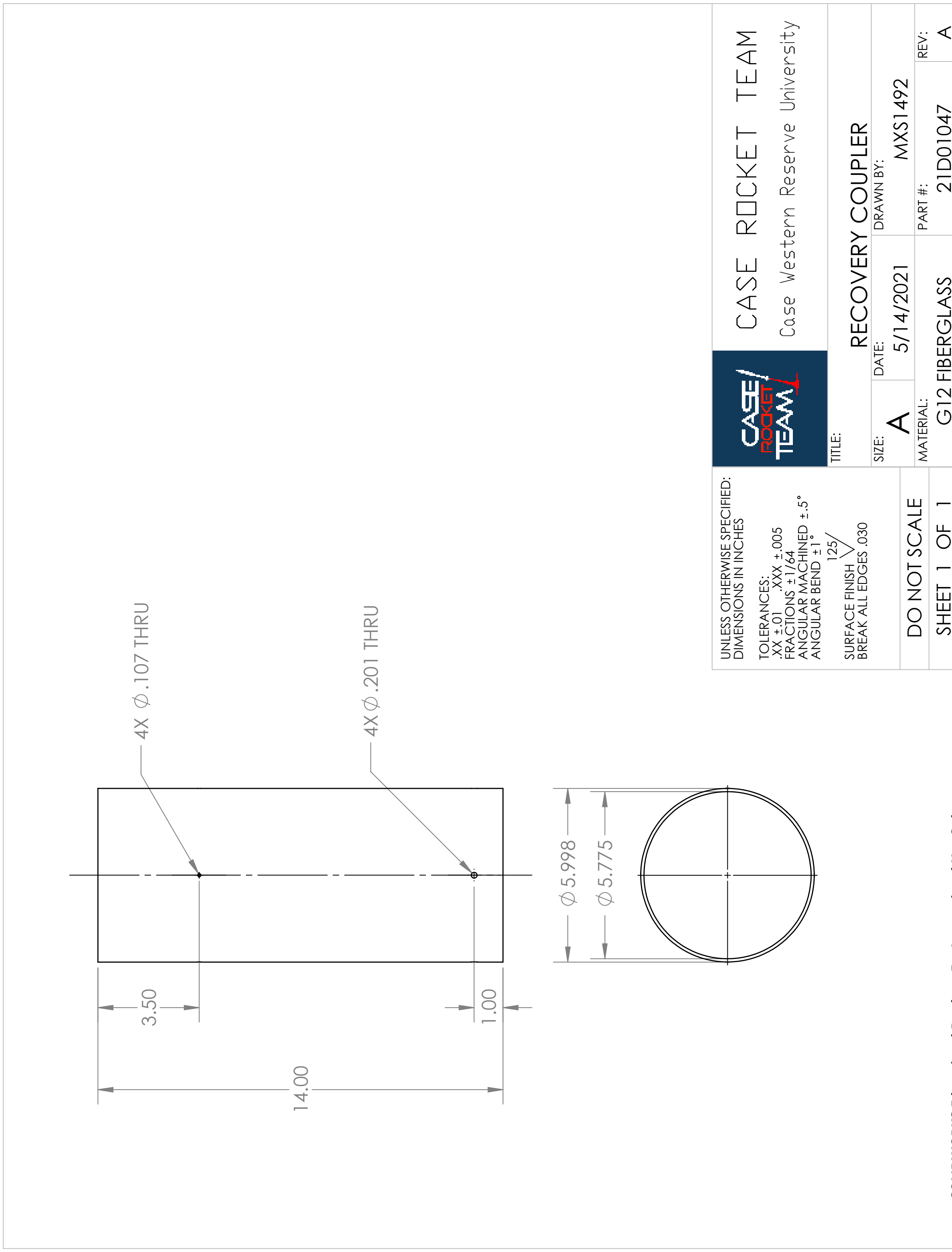
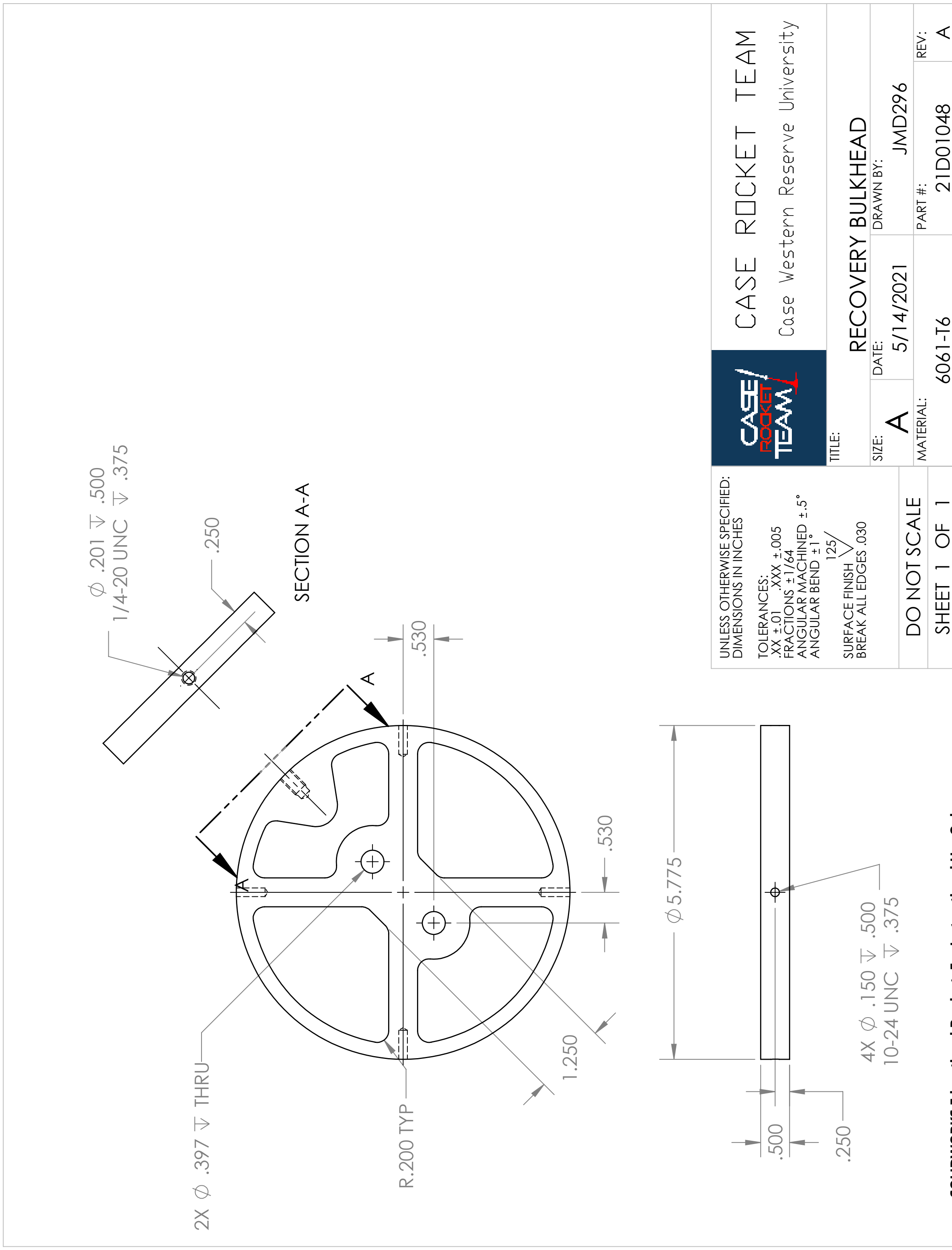
SOLIDWORKS Educational Product. For Instructional Use Only.



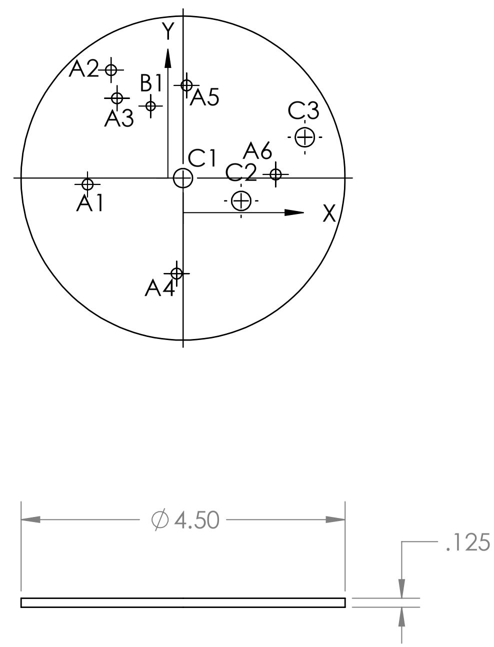
4X ∅.201 THRU
4X ∅.070 THRU
6.438
3.500
22.000
∅6.170
∅6.000
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
RECOVERY BODY TUBE
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MXS1492
MATERIAL:
G12 FIBERGLASS
PART #:
21D01046
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.



4X ∅.107 THRU
4X ∅.201 THRU
∅5.998
∅5.775
3.50
1.00
14.00
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:
RECOVERY COUPLER
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MXS1492
MATERIAL:
G12 FIBERGLASS
PART #:
21D01047
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.


Ø .201 ↧ .500
1/4-20 UNC ↧ .375
.250
SECTION A-A
A
A
.530
.530
2X Ø .397 ↧ THRU
R.200 TYP
1.250
Ø 5.775
.500
.250
4X Ø .150 ↧ .500
10-24 UNC ↧ .375
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 ROCKET TEAM
Case Western Reserve University
TITLE:
RECOVERY BULKHEAD
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
JMD296
MATERIAL:
6061-T6
PART #:
21D01048
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.

TAG	X LOC	Y LOC	SIZE
A1	-1.326	-.088	∅ .150 THRU
A2	-1.000	1.500	∅ .150 THRU
A3	-.917	1.109	∅ .150 THRU
A4	-.088	-1.326	∅ .150 THRU
A5	.050	1.287	∅ .150 THRU
A6	1.287	.050	∅ .150 THRU
B1	-.450	1.000	∅ .125 THRU
C1	.000	.000	∅ .266 THRU
C2	.808	-.317	∅ .266 THRU
C3	1.692	.567	∅ .266 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

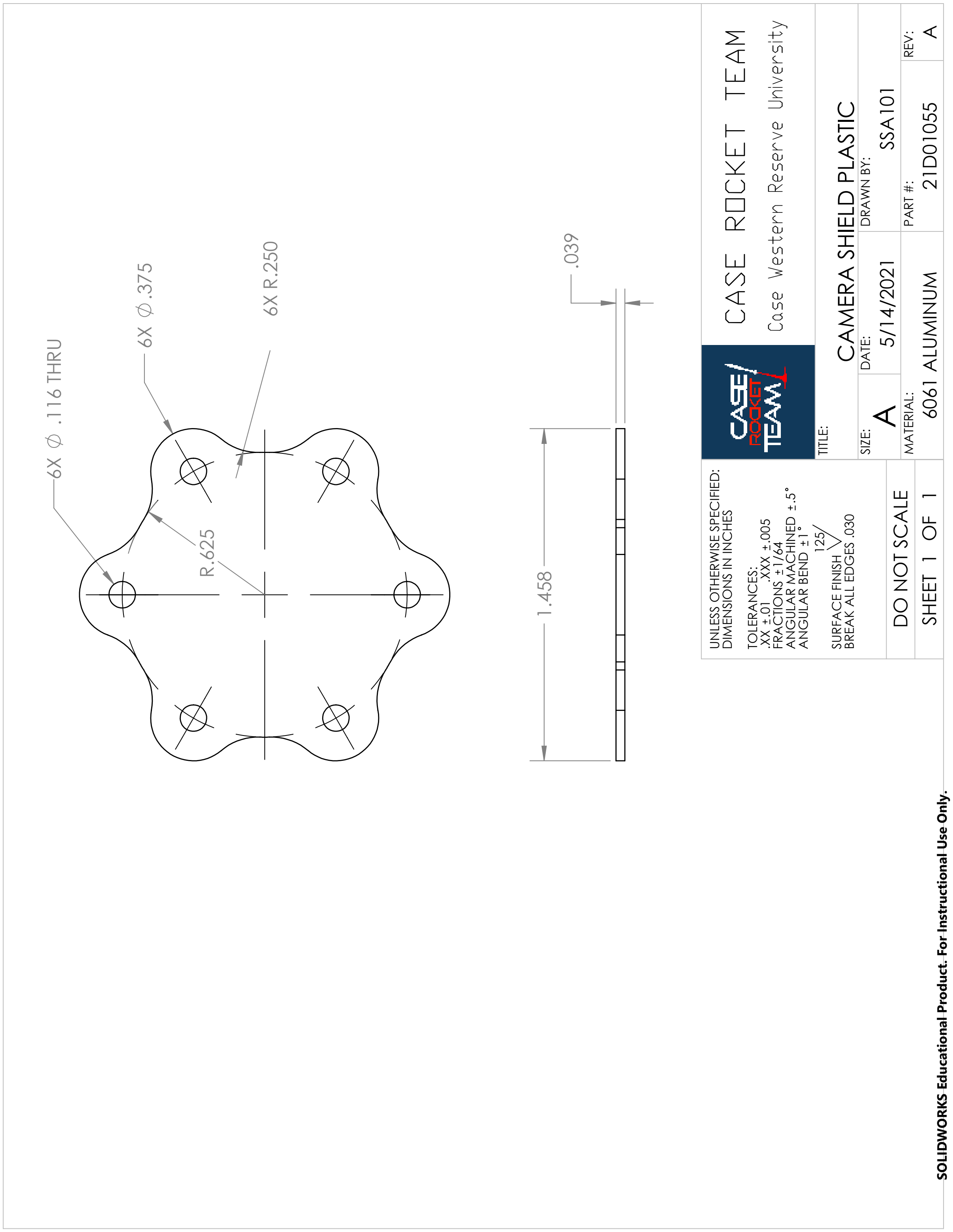
SHEET 1 OF 1

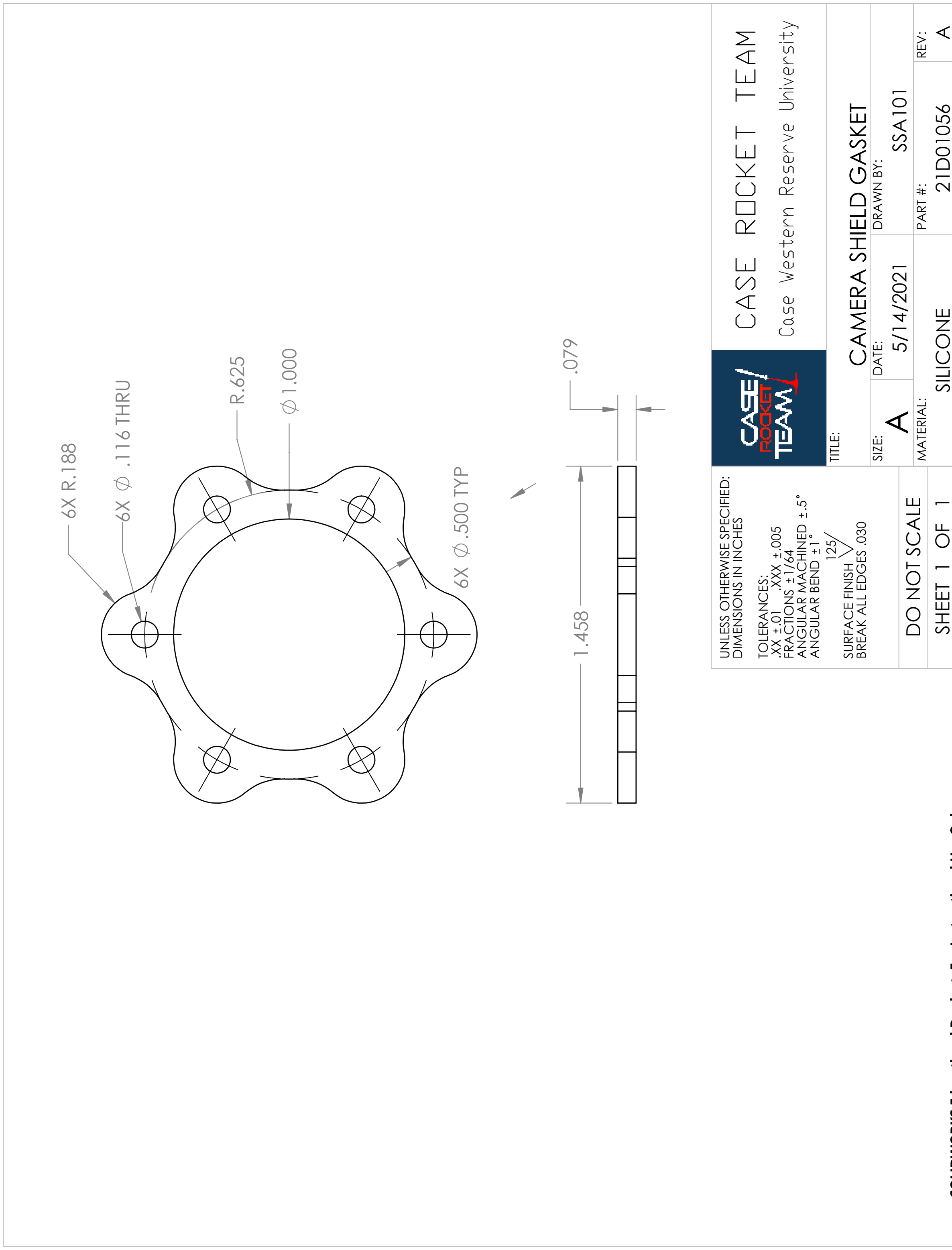
CASE ROCKET TEAM

Case Western Reserve University

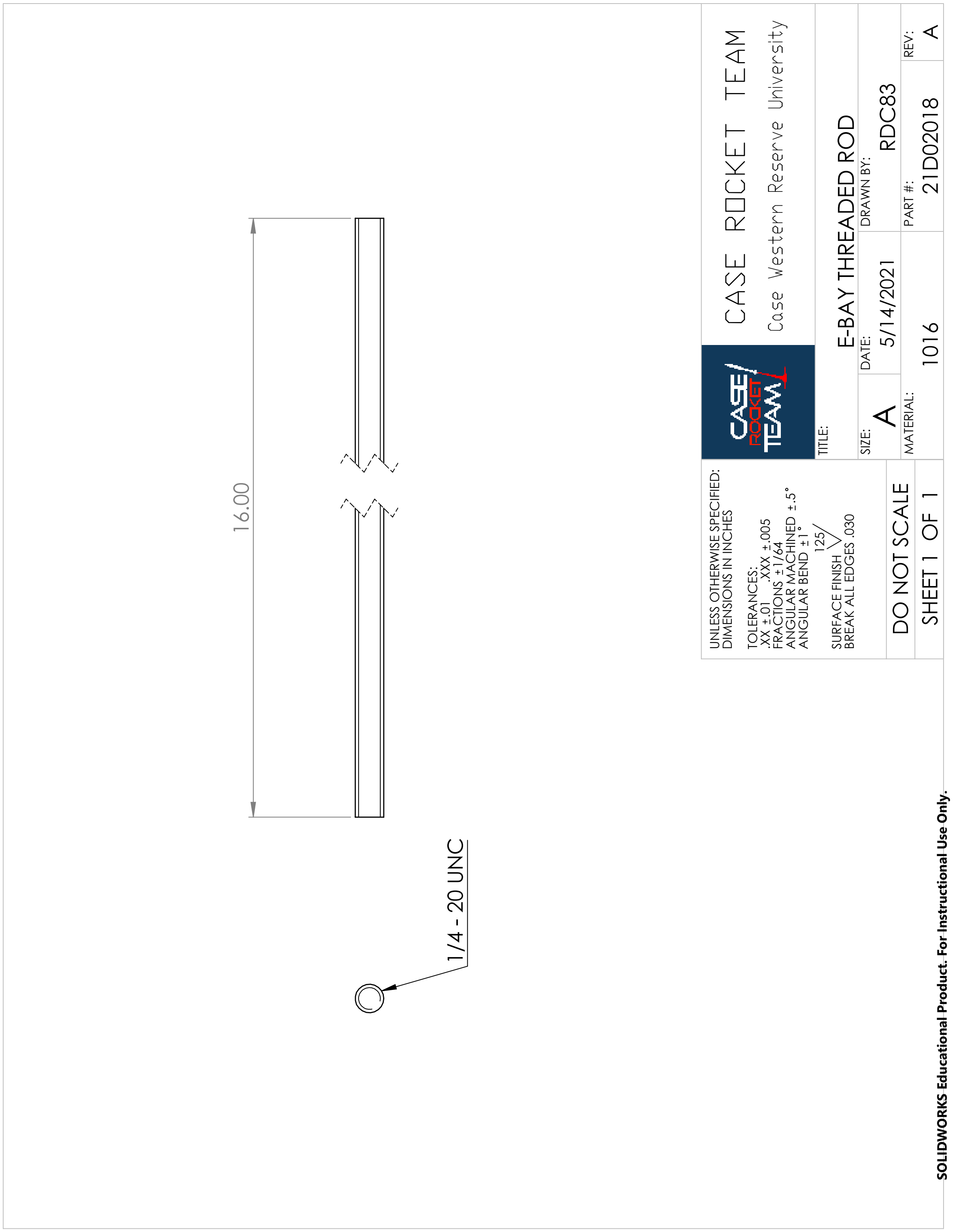
TITLE: NOSECONE BULKHEAD

SIZE:	DATE:	DRAWN BY:	
A	5/14/2021	MXS1492	
MATERIAL:		PART #:	REV:
6061-T6		21D01051	A

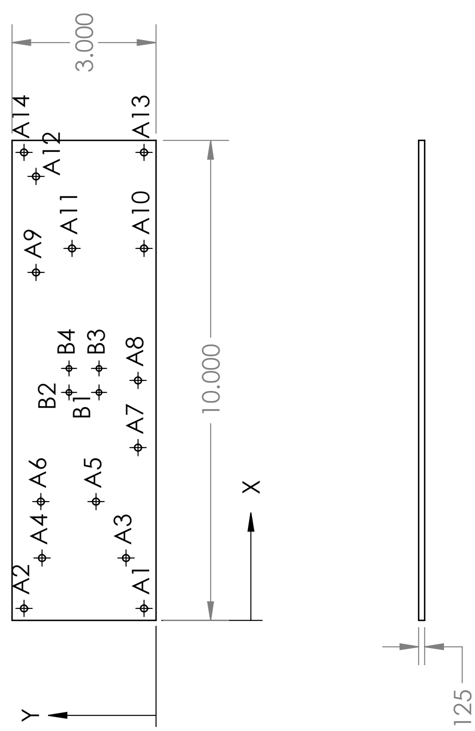

6X ⌀ .116 THRU
6X ⌀ .375
6X R.250
R.625
1.458
.039
CASE ROCKET TEAM
Case Western Reserve University
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
TITLE:
CAMERA SHIELD PLASTIC
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
SSA101
MATERIAL:
6061 ALUMINUM
PART #:
21D01055
REV:
A
DO NOT SCALE
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only.



6X R.188
6X ⌀ .116 THRU
R.625
⌀1.000
6X ⌀.500 TYP
.079
1.458
CASE ROCKET TEAM
Case Western Reserve University
CASE ROCKET TEAM
TITLE:
CAMERA SHIELD GASKET
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
SSA101
MATERIAL:
SILICONE
PART #:
21D01056
REV:
A
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
125
SURFACE FINISH
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only.


16.00
1/4 - 20 UNC
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 ROCKET TEAM
Case Western Reserve University
TITLE:
E-BAY THREADED ROD
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
RDC83
MATERIAL:
1016
PART #:
21D02018
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.

TAG	X LOC	Y LOC	SIZE
A1	.250	.250	∅ .144 THRU ALL
A2	.250	2.750	∅ .144 THRU ALL
A3	1.300	.625	∅ .144 THRU ALL
A4	1.300	2.375	∅ .144 THRU ALL
A5	2.475	1.250	∅ .144 THRU ALL
A6	2.475	2.400	∅ .144 THRU ALL
A7	3.600	.375	∅ .144 THRU ALL
A8	5.000	.375	∅ .144 THRU ALL
A9	7.250	2.500	∅ .144 THRU ALL
A10	7.750	.250	∅ .144 THRU ALL
A11	7.750	1.750	∅ .144 THRU ALL
A12	9.250	2.500	∅ .144 THRU ALL
A13	9.750	.250	∅ .144 THRU ALL
A14	9.750	2.750	∅ .144 THRU ALL
B1	4.750	1.188	∅ .116 THRU ALL
B2	4.750	1.813	∅ .116 THRU ALL
B3	5.250	1.188	∅ .116 THRU ALL
B4	5.250	1.813	∅ .116 THRU ALL



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

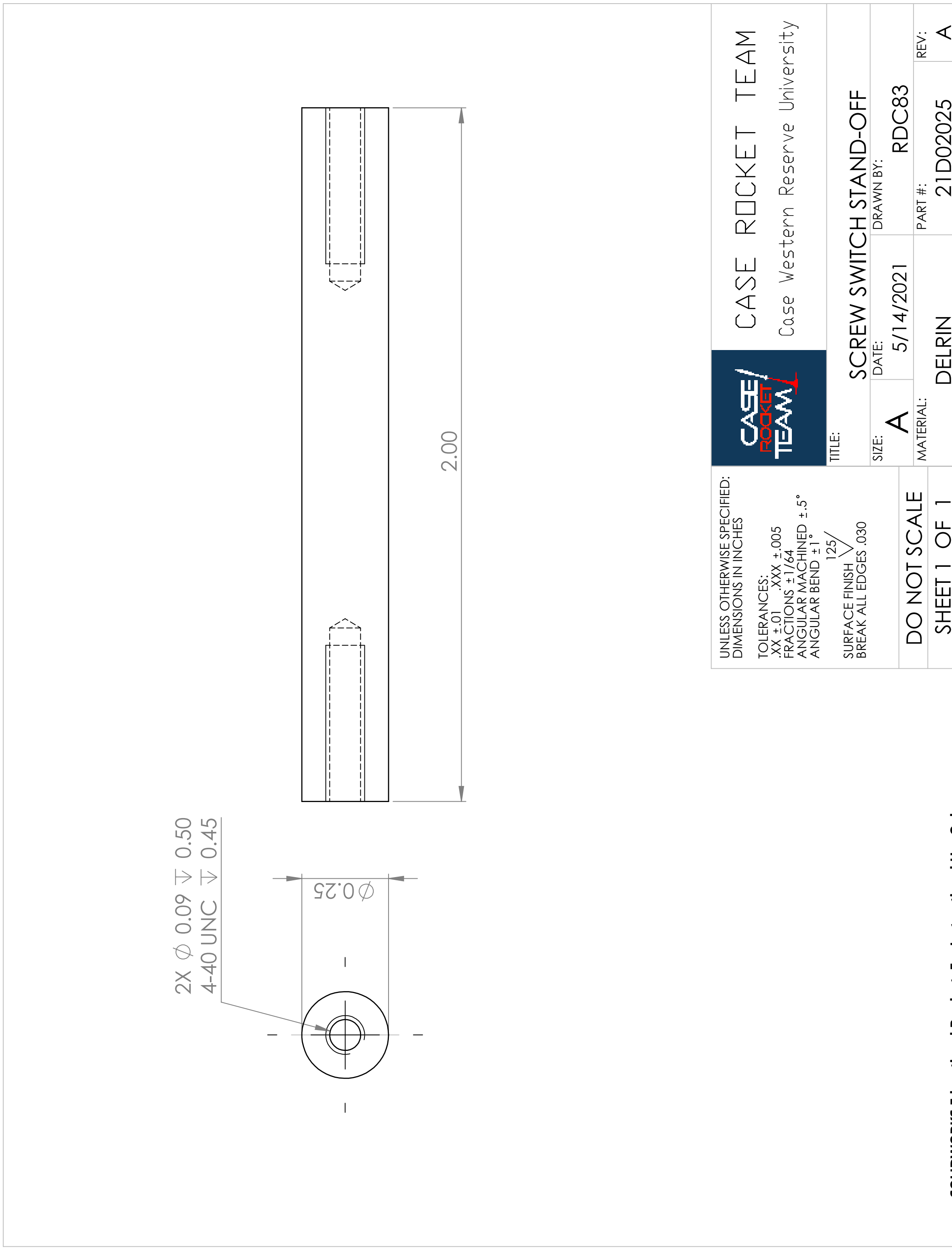
CASE ROCKET TEAM
Case Western Reserve University

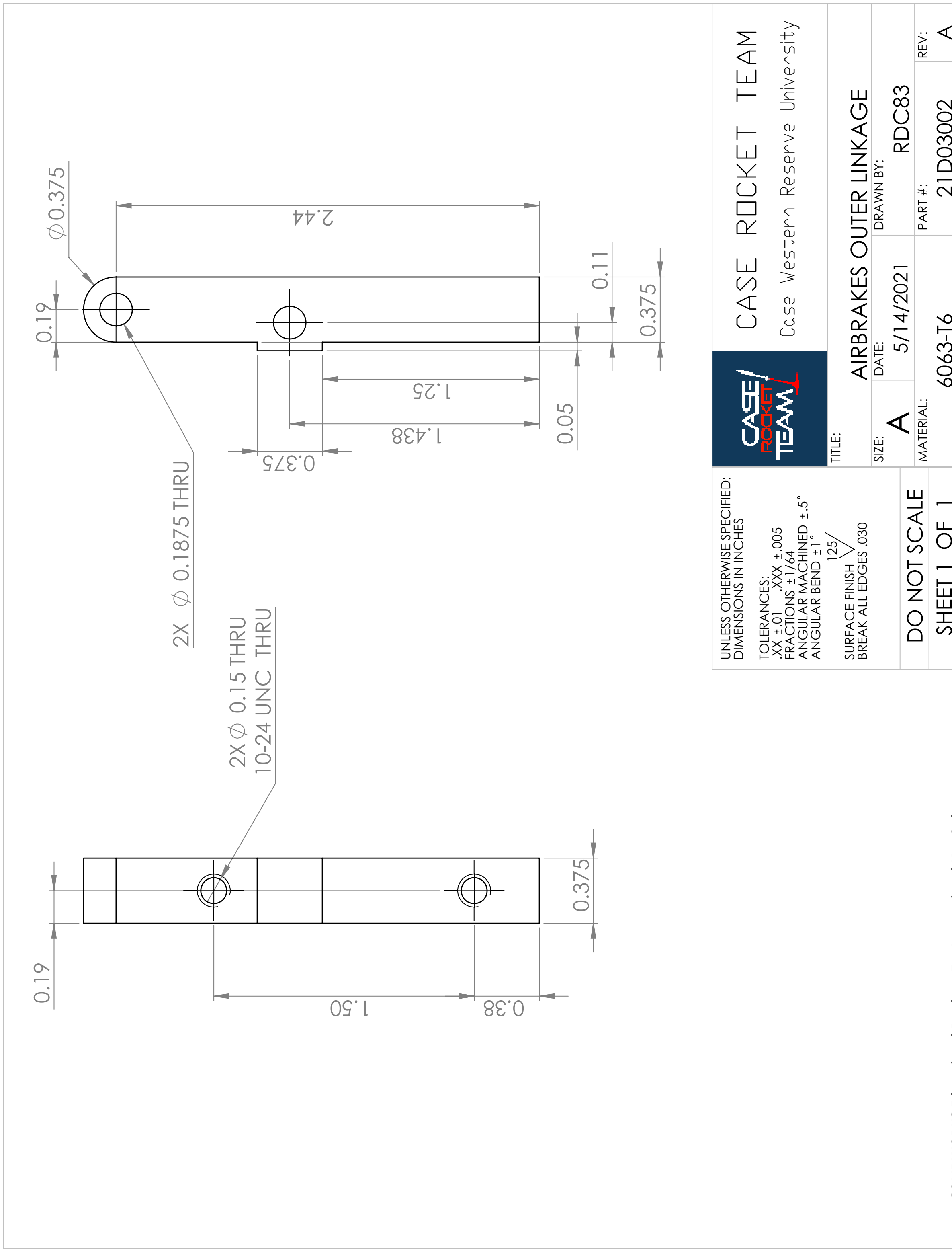
TITLE: E-BAY SLED

SIZE: A | DATE: 5/14/2021 | DRAWN BY: MGB89

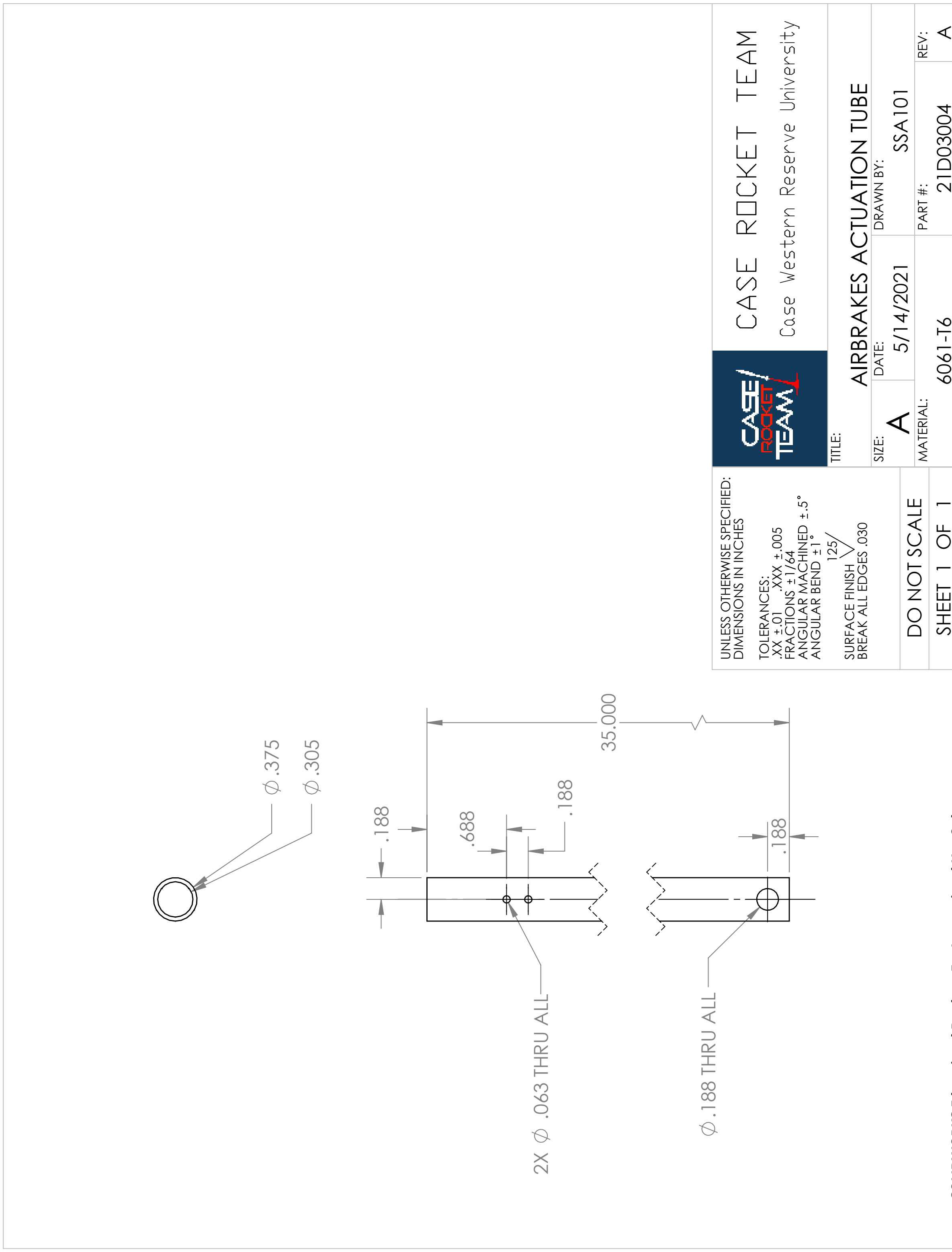
MATERIAL: ACRYLIC | PART #: 21D02022 | REV: A

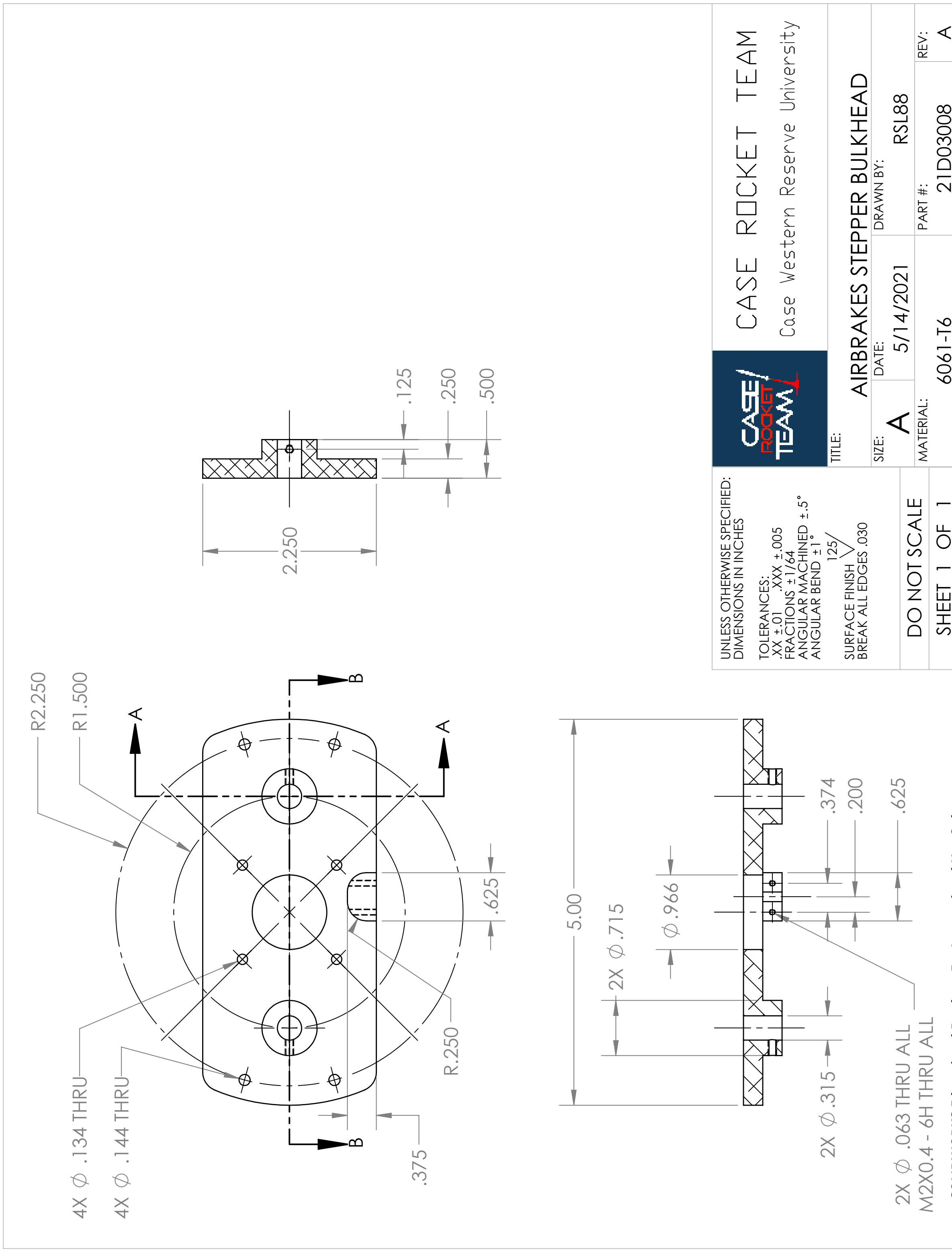
SOLIDWORKS Educational Product. For Instructional Use Only.

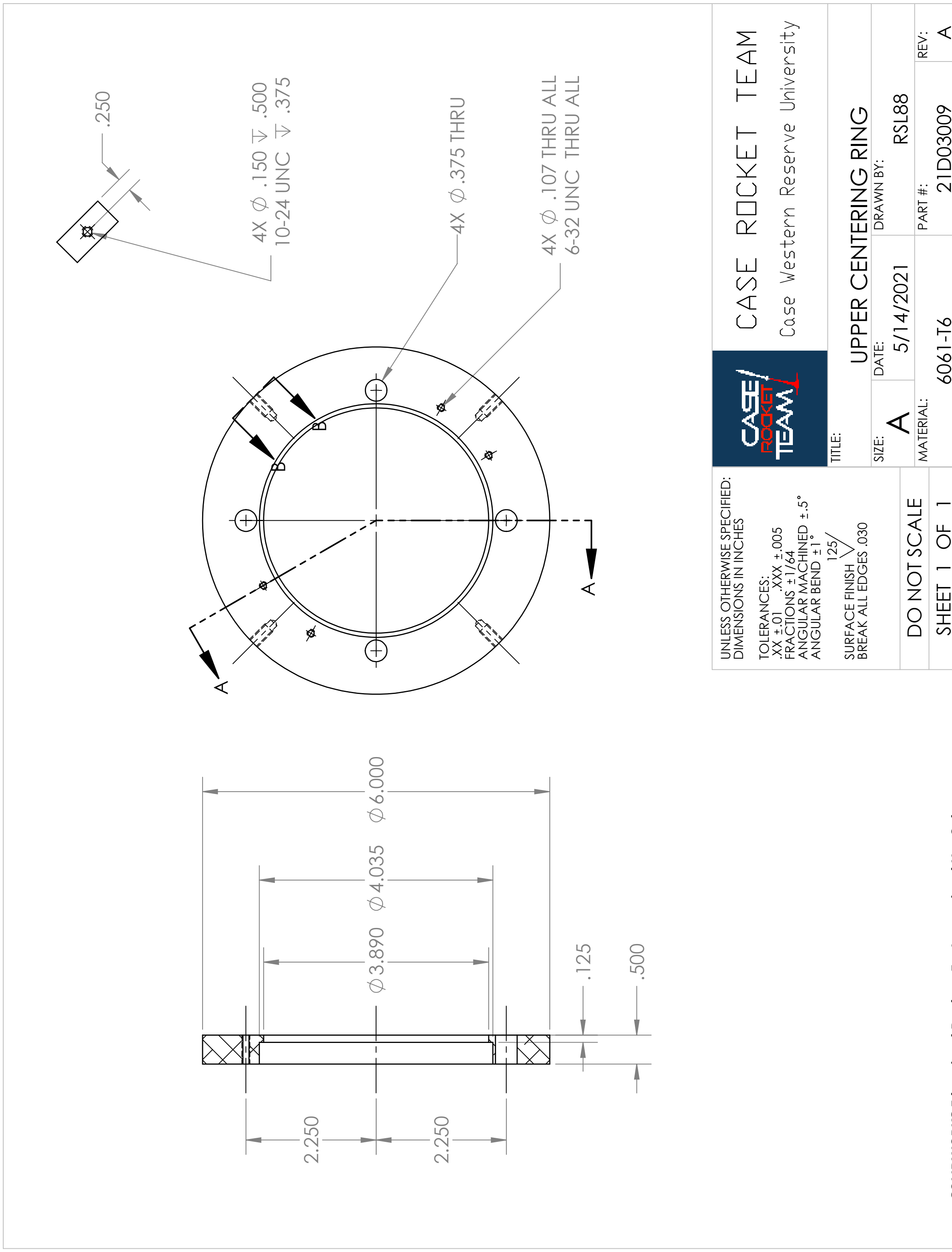

2X ∅ 0.09 ⊽ 0.50
4-40 UNC ⊽ 0.45
∅0.25
2.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
SCREW SWITCH STAND-OFF
SIZE: A
DATE: 5/14/2021
DRAWN BY: RDC83
MATERIAL: DELRIN
PART #: 21D02025
REV: A
DO NOT SCALE
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only.

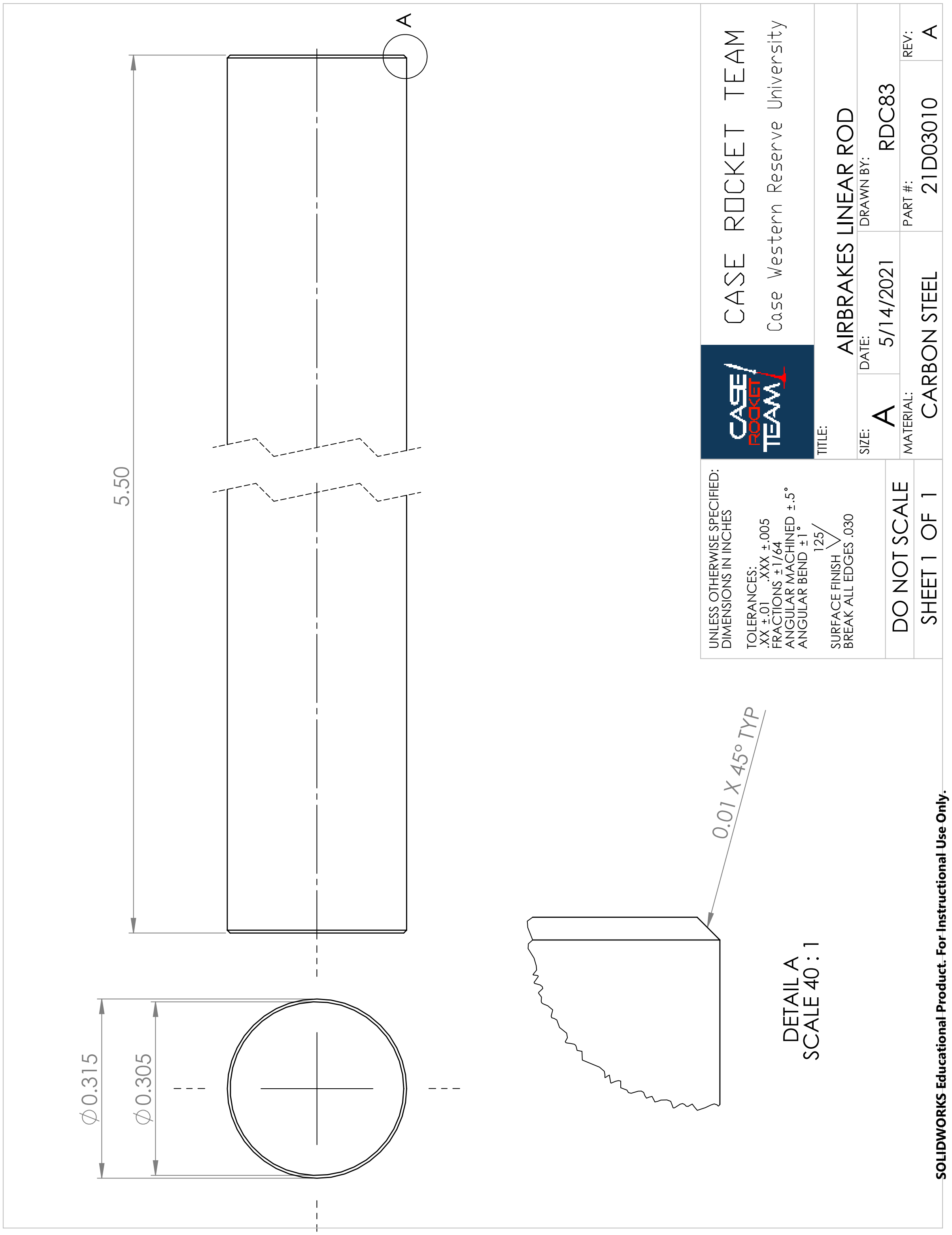


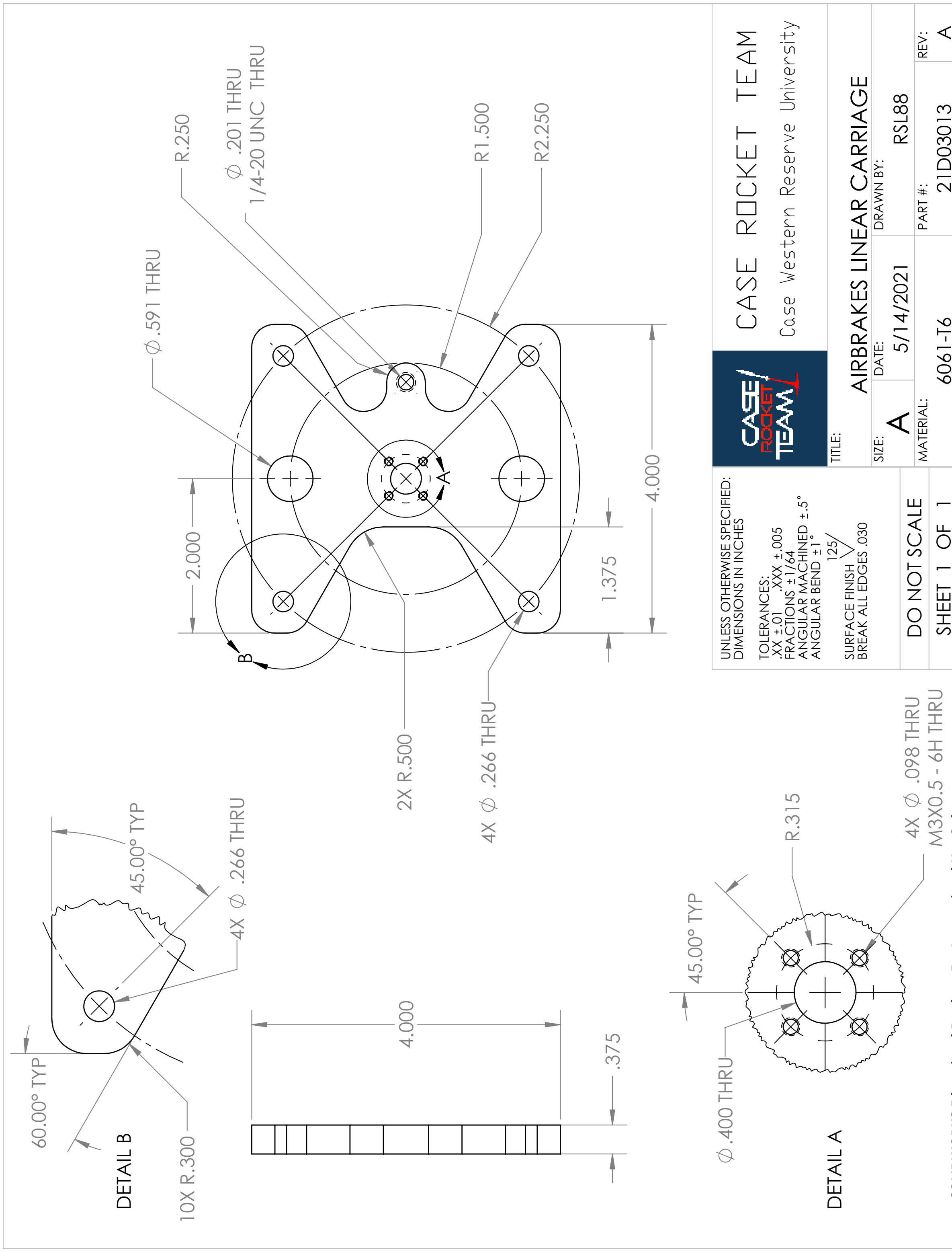
Ø0.375
2.44
0.19
0.11
0.375
1.25
1.438
0.05
0.375
2X Ø 0.1875 THRU
2X Ø 0.15 THRU
10-24 UNC THRU
0.19
0.375
1.50
0.38
CASE ROCKET TEAM
Case Western Reserve University
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
TITLE:
AIRBRAKES OUTER LINKAGE
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
RDC83
MATERIAL:
6063-T6
PART #:
21D03002
REV:
A
DO NOT SCALE
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only.


CASE ROCKET TEAM
Case Western Reserve University
TITLE:
AIRBRAKES ACTUATION TUBE
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
SSA101
MATERIAL:
6061-T6
PART #:
21D03004
REV:
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 1 OF 1
Ø.375
Ø.305
35.000
.188
.688
.188
.188
2X Ø .063 THRU ALL
Ø .188 THRU ALL
SOLIDWORKS Educational Product. For Instructional Use Only.


CASE ROCKET TEAM
Case Western Reserve University
TITLE:
AIRBRAKES STEPPER BULKHEAD
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
RSL88
MATERIAL:
6061-T6
PART #:
21D03008
REV:
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 1 OF 1
R2.250
R1.500
4X ∅ .134 THRU
4X ∅ .144 THRU
.375
R.250
.625
A
B
5.00
2X ∅.715
∅.966
2X ∅ .315
.374
.200
.625
2X ∅ .063 THRU ALL
M2X0.4 - 6H THRU ALL
2.250
.125
.250
.500
SOLIDWORKS Educational Product. For Instructional Use Only.


.250
4X ⌀ .150 ↧ .500
10-24 UNC ↧ .375
4X ⌀ .375 THRU
4X ⌀ .107 THRU ALL
6-32 UNC THRU ALL
A
A
B
B
⌀6.000
⌀4.035
⌀3.890
.125
.500
2.250
2.250
CASE ROCKET TEAM
Case Western Reserve University
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
TITLE:
UPPER CENTERING RING
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
RSL88
MATERIAL:
6061-T6
PART #:
21D03009
REV:
A
DO NOT SCALE
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only.


A
5.50
∅0.315
∅0.305
0.01 X 45° TYP
DETAIL A
SCALE 40 : 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:
AIRBRAKES LINEAR ROD
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
RDC83
MATERIAL:
CARBON STEEL
PART #:
21D03010
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.


Ø .591 THRU
R.250
Ø .201 THRU
1/4-20 UNC THRU
R1.500
R2.250
2.000
1.375
4.000
A
B
2X R.500
4X Ø .266 THRU
60.00° TYP
45.00° TYP
4X Ø .266 THRU
DETAIL B
10X R.300
4.000
.375
45.00° TYP
R.315
Ø .400 THRU
4X Ø .098 THRU
M3X0.5 - 6H THRU
DETAIL 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 1 OF 1
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
AIRBRAKES LINEAR CARRIAGE
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
RSL88
MATERIAL:
6061-T6
PART #:
21D03013
REV:
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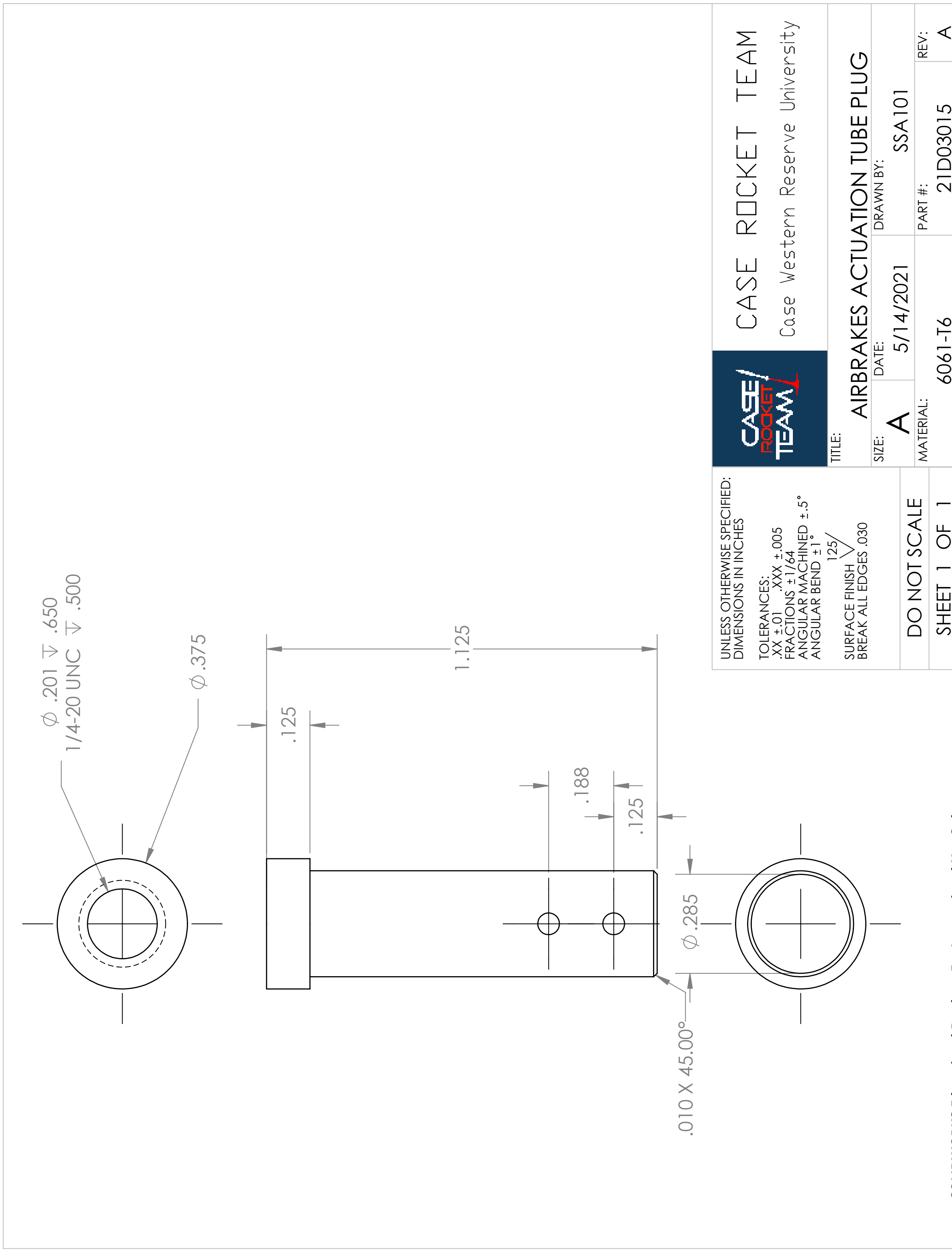
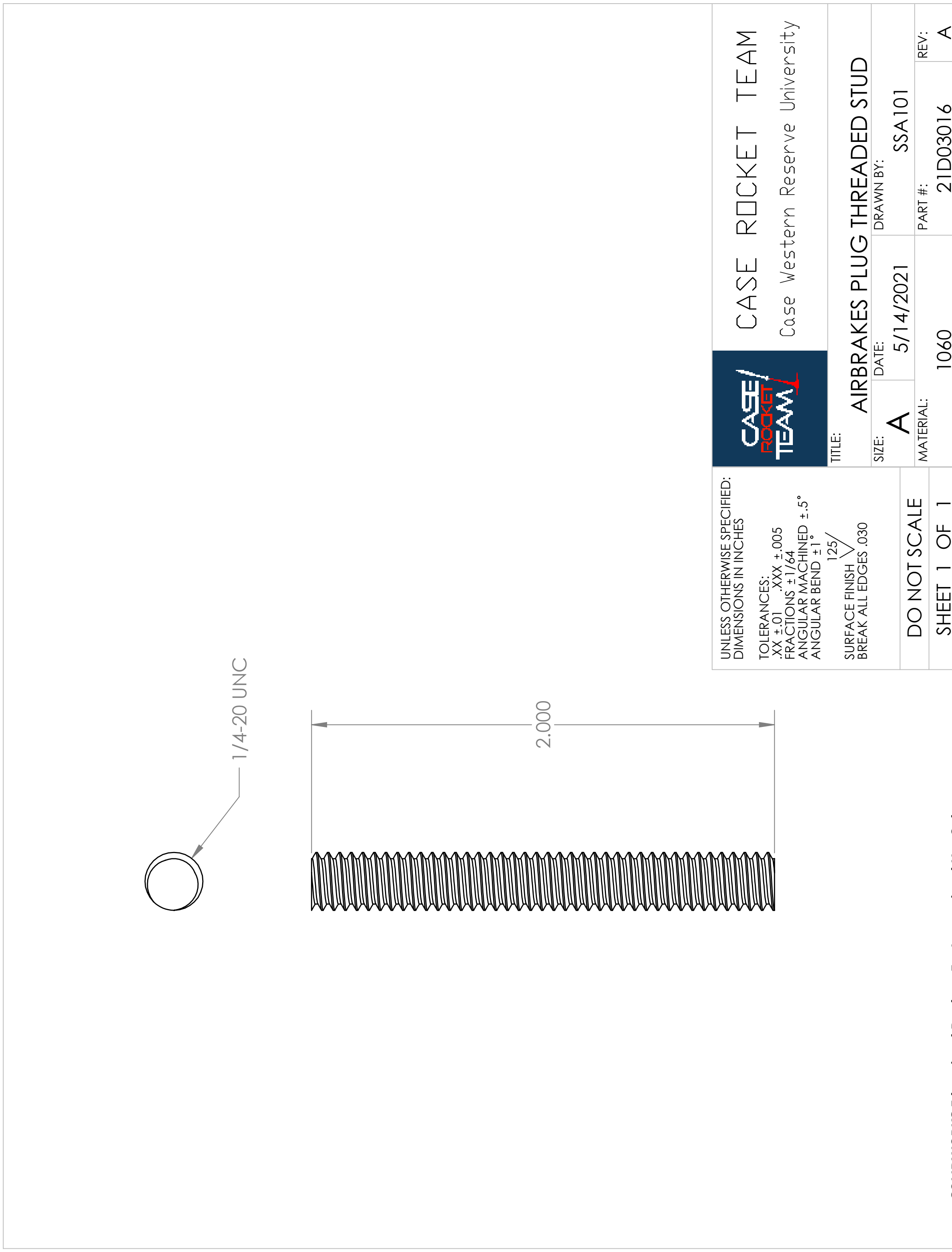
SOLIDWORKS Educational Product. For Instructional Use Only.


CASE ROCKET TEAM
Case Western Reserve University
TITLE:
AIRBRAKES ACTUATION TUBE PLUG
SIZE: A
DATE: 5/14/2021
DRAWN BY: SSA101
MATERIAL: 6061-T6
PART #: 21D03015
REV: 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 1 OF 1
∅ .201 ↧ .650
1/4-20 UNC ↧ .500
∅ .375
1.125
.125
.188
.125
∅ .285
.010 X 45.00°
SOLIDWORKS Educational Product. For Instructional Use Only.


1/4-20 UNC
2.000
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 ROCKET TEAM
Case Western Reserve University
TITLE:
AIRBRAKES PLUG THREADED STUD
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
SSA101
MATERIAL:
1060
PART #:
21D03016
REV:
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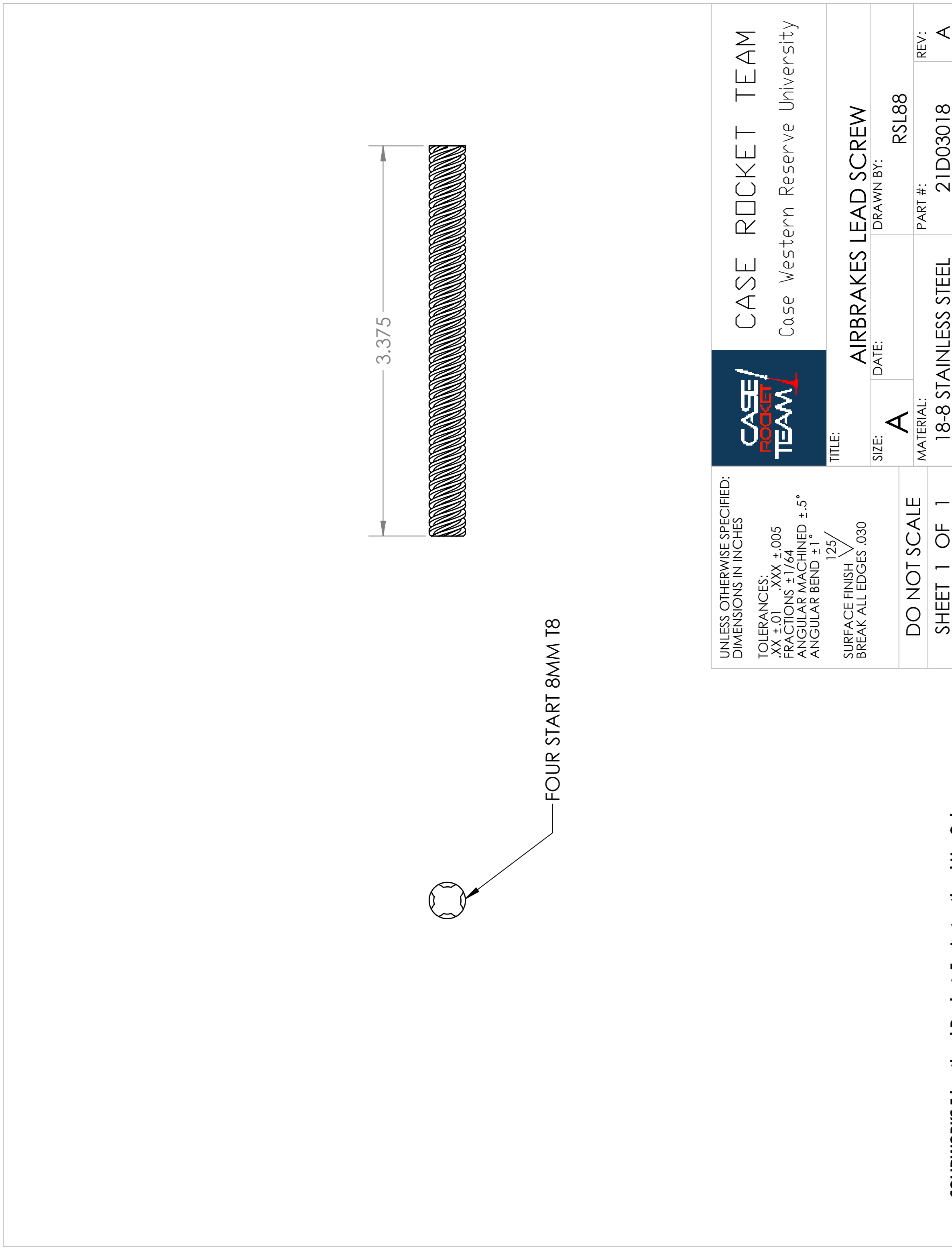
SOLIDWORKS Educational Product. For Instructional Use Only.



3.375
FOUR START 8MM T8
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
125
SURFACE FINISH
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
CASE ROCKET TEAM
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
AIRBRAKES LEAD SCREW
SIZE:
A
DATE:
DRAWN BY:
RSL88
MATERIAL:
18-8 STAINLESS STEEL
PART #:
21D03018
REV:
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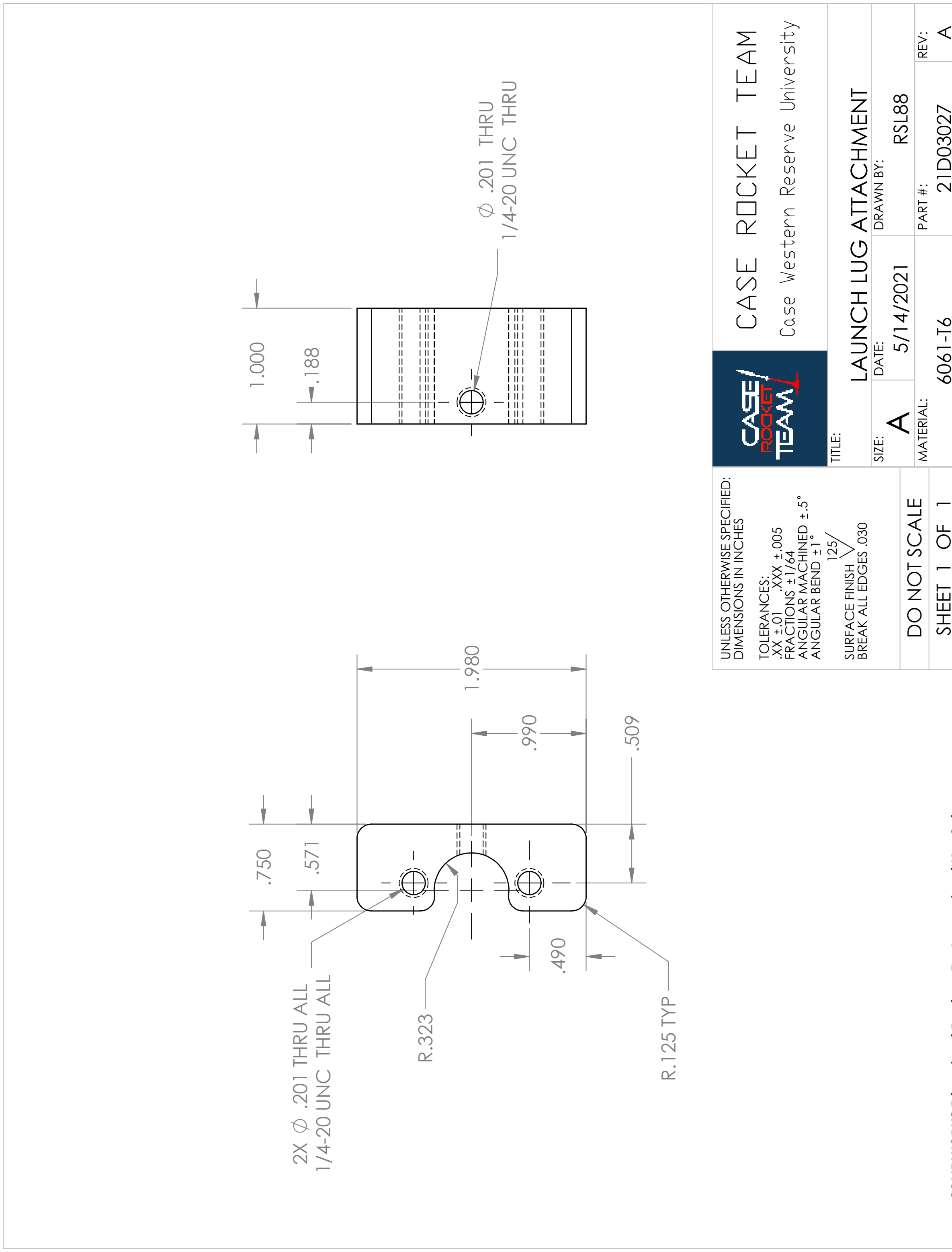
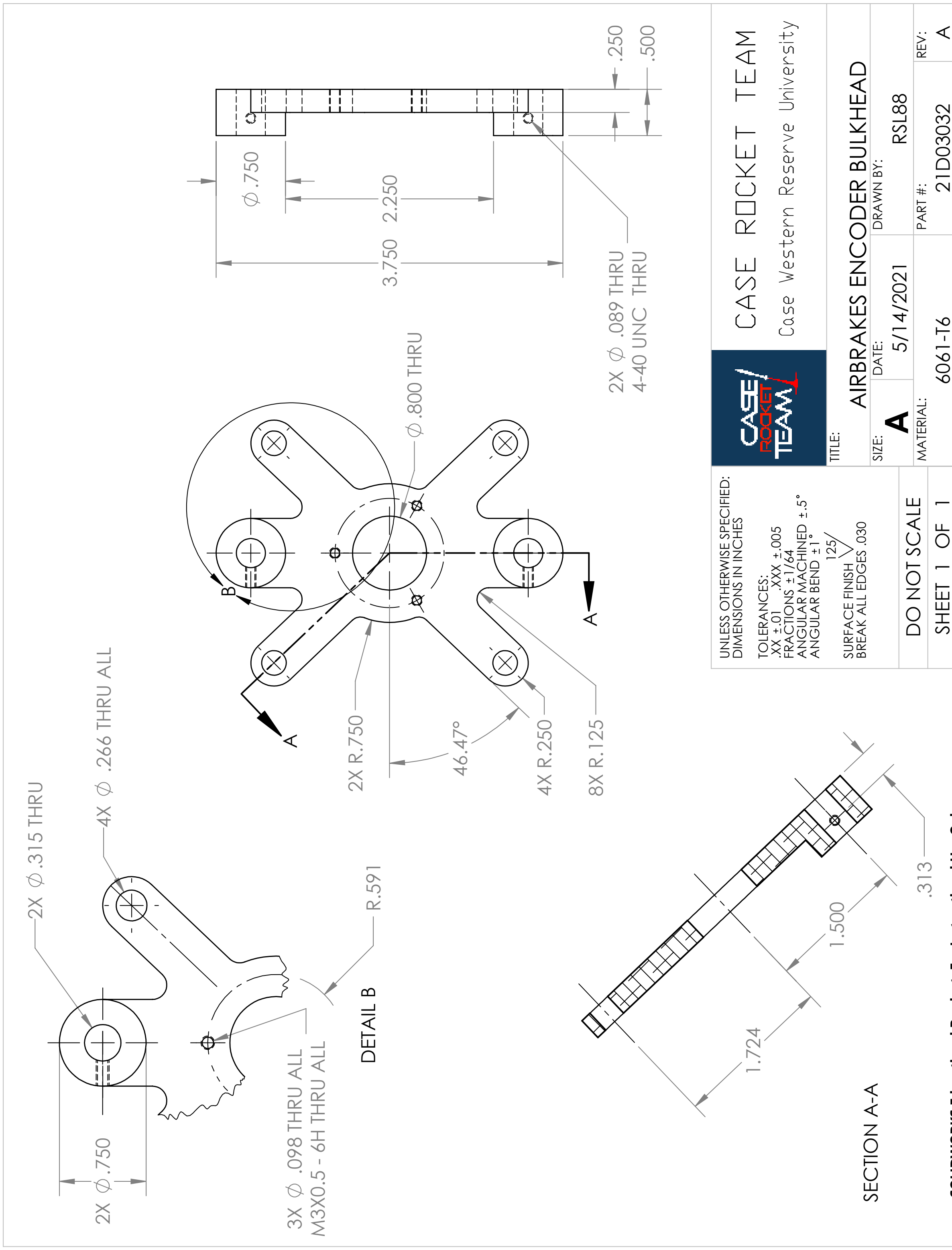
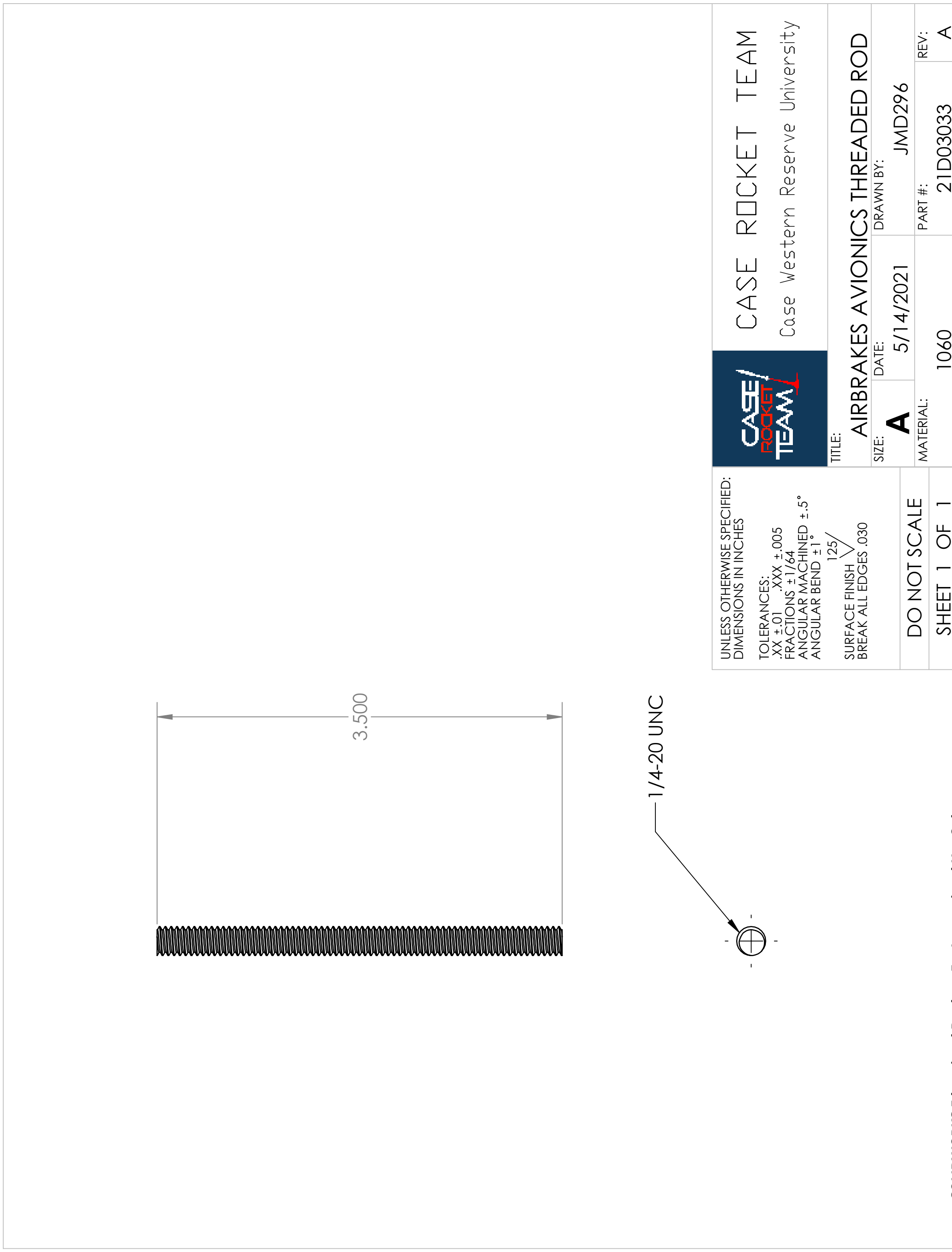
SOLIDWORKS Educational Product. For Instructional Use Only.

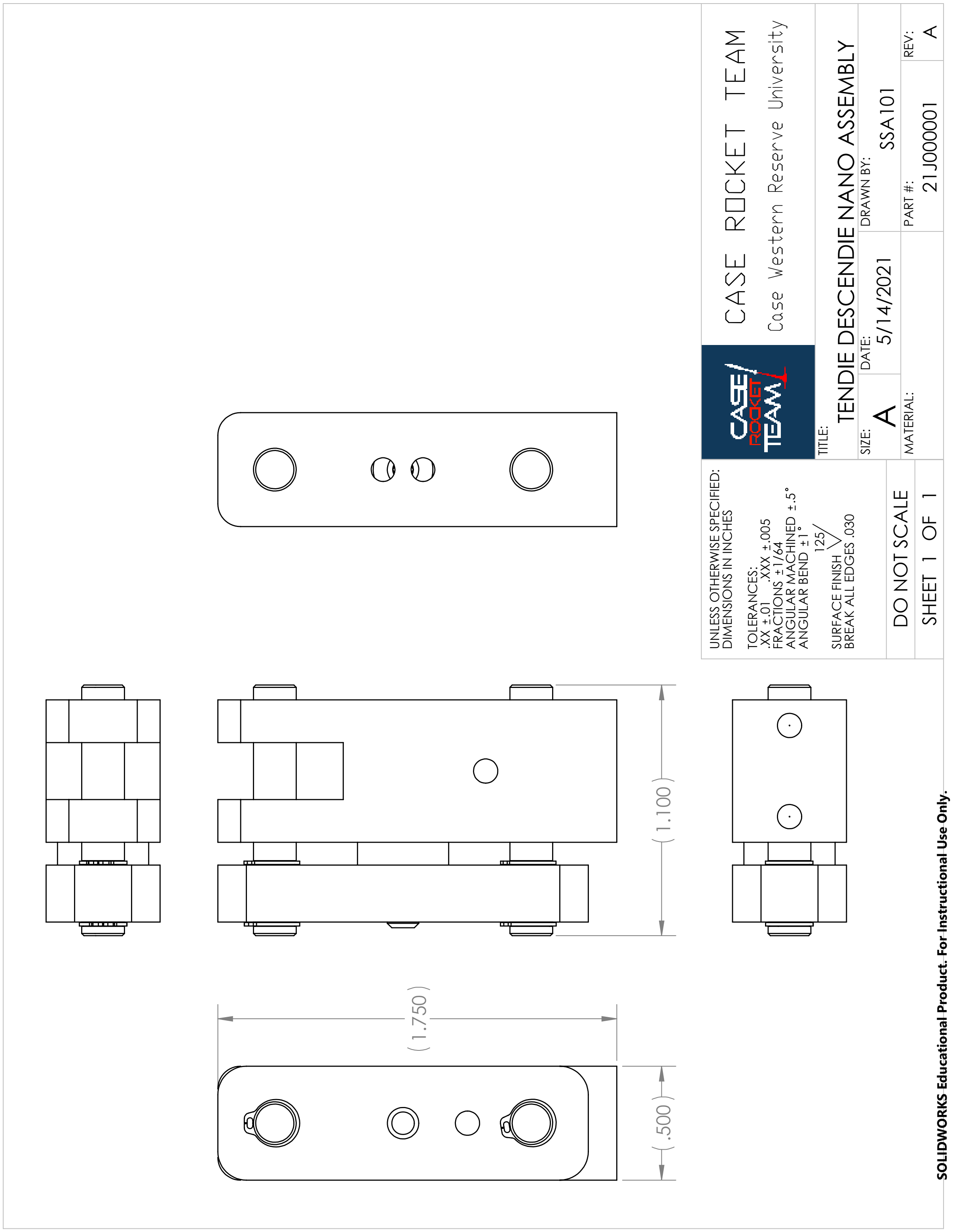


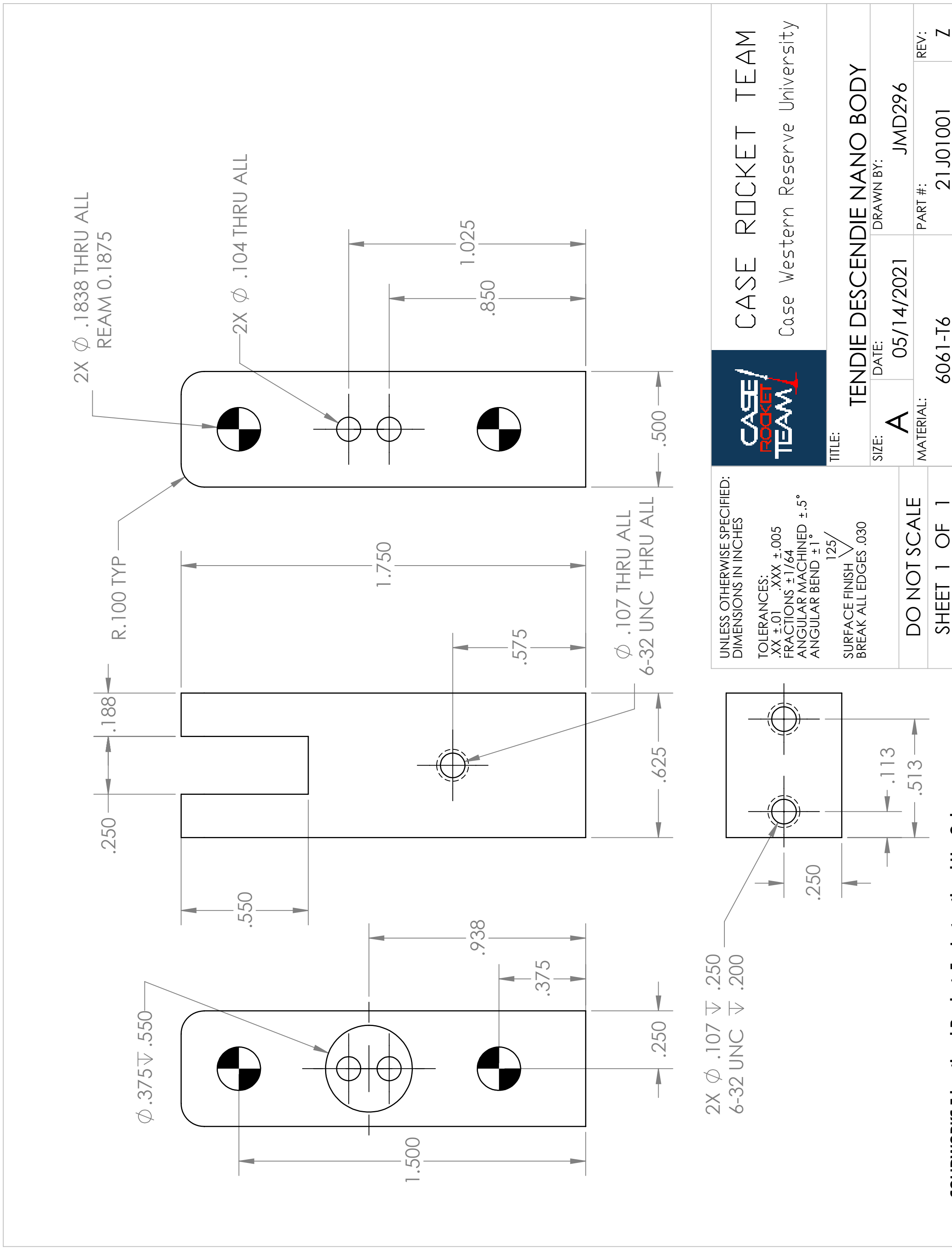
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
LAUNCH LUG ATTACHMENT
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
RSL88
MATERIAL:
6061-T6
PART #:
21D03027
REV:
A
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
⌀ .201 THRU
1/4-20 UNC THRU
1.000
.188
1.980
.990
.509
.750
.571
.490
2X ⌀ .201 THRU ALL
1/4-20 UNC THRU ALL
R.323
R.125 TYP
SOLIDWORKS Educational Product. For Instructional Use Only.



CASE ROCKET TEAM
Case Western Reserve University
TITLE:
AIRBRAKES ENCODER BULKHEAD
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
RSL88
MATERIAL:
6061-T6
PART #:
21D03032
REV:
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 1 OF 1
.250
.500
⌀.750
2.250
3.750
2X ⌀ .089 THRU
4-40 UNC THRU
⌀ .800 THRU
2X R.750
46.47°
4X R.250
8X R.125
2X ⌀ .315 THRU
4X ⌀ .266 THRU ALL
R.591
2X ⌀.750
3X ⌀ .098 THRU ALL
M3X0.5 - 6H THRU ALL
DETAIL B
1.724
1.500
.313
SECTION A-A
SOLIDWORKS Educational Product. For Instructional Use Only.


3.500
1/4-20 UNC
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:
AIRBRAKES AVIONICS THREADED ROD
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
JMD296
MATERIAL:
1060
PART #:
21D03033
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.


CASE ROCKET TEAM
Case Western Reserve University
TITLE:
TENDIE DESCENDIE NANO ASSEMBLY
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
SSA101
PART #:
21J000001
REV:
A
MATERIAL:
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
(1.100)
(1.750)
(.500)
SOLIDWORKS Educational Product. For Instructional Use Only.


2X ⌀ .1838 THRU ALL
REAM 0.1875
2X ⌀ .104 THRU ALL
1.025
.850
R.100 TYP
.500
1.750
.575
⌀ .107 THRU ALL
6-32 UNC THRU ALL
.188
.250
.625
.550
.938
.375
⌀ .375 ↧ .550
.250
1.500
2X ⌀ .107 ↧ .250
6-32 UNC ↧ .200
.250
.113
.513
CASE ROCKET TEAM
Case Western Reserve University
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
TITLE:
TENDIE DESCENDIE NANO BODY
SIZE:
A
DATE:
05/14/2021
DRAWN BY:
JMD296
MATERIAL:
6061-T6
PART #:
21J01001
REV:
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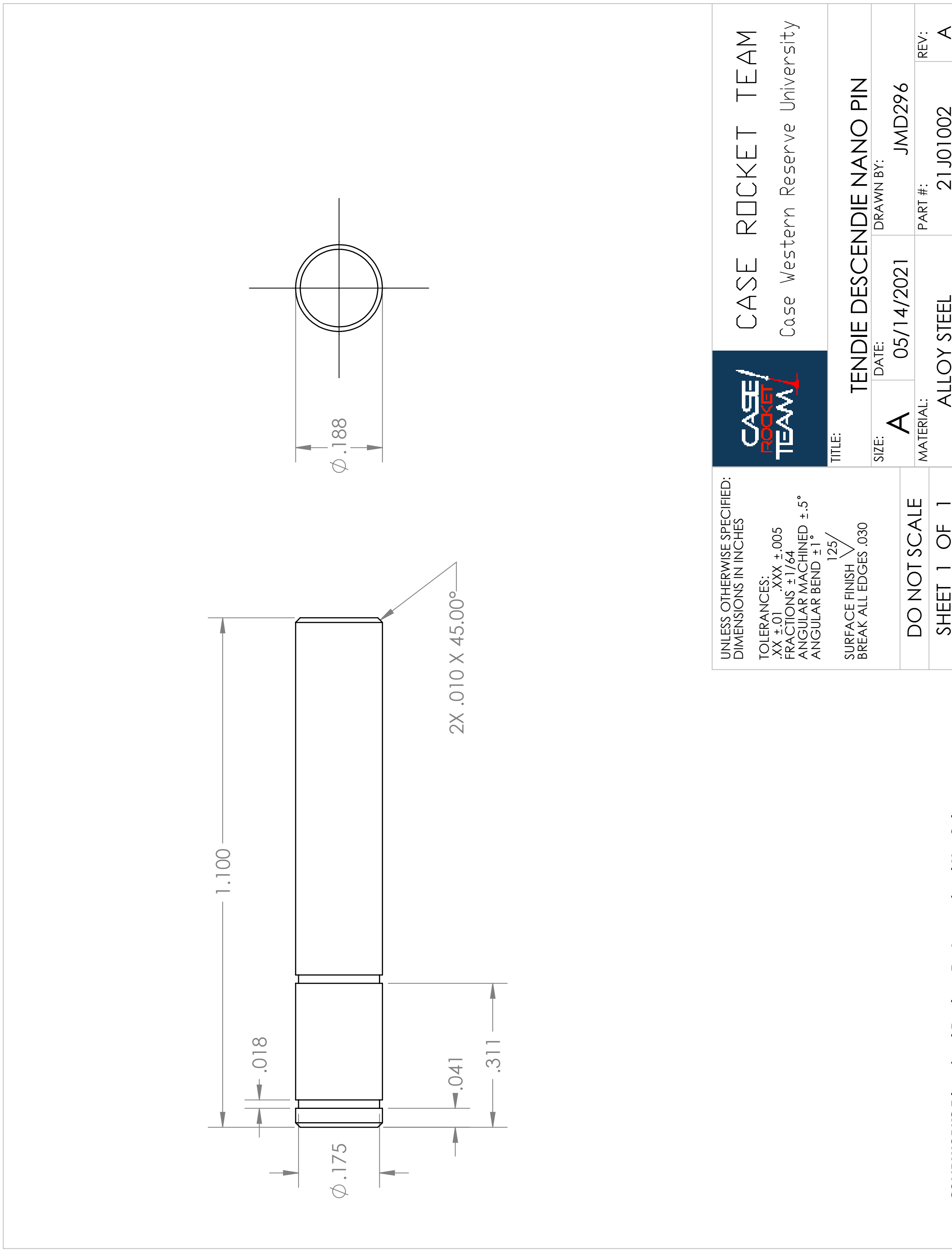
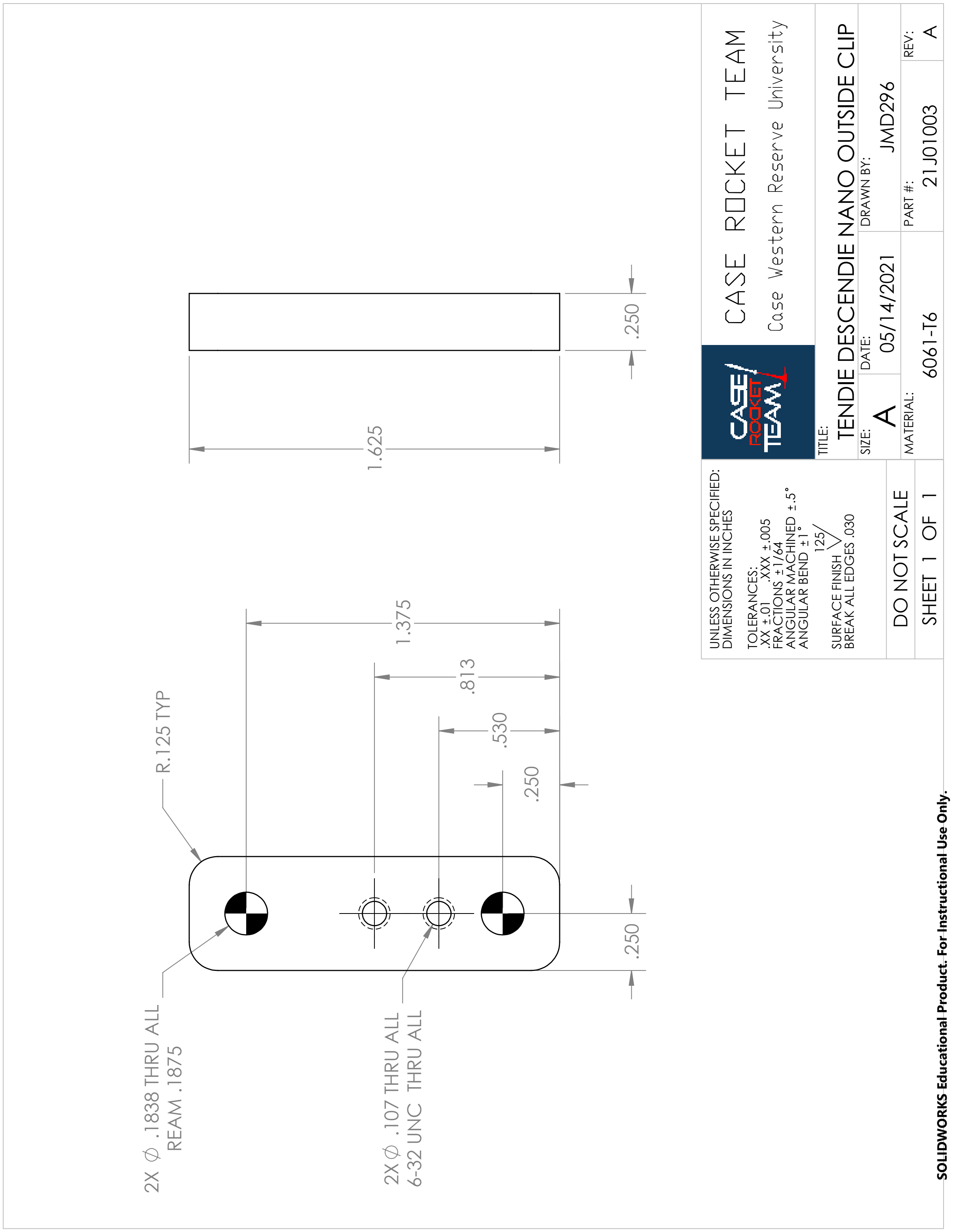
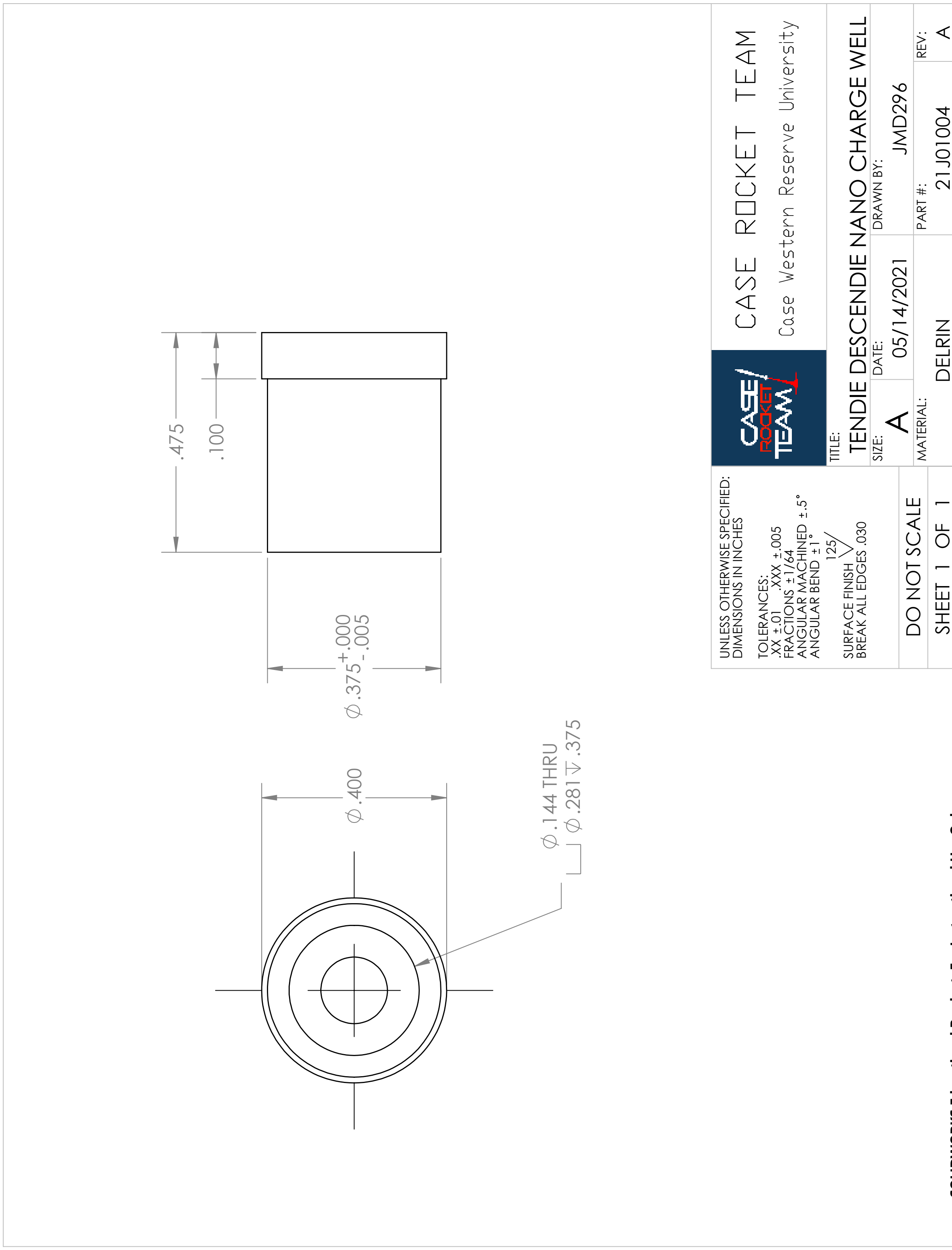
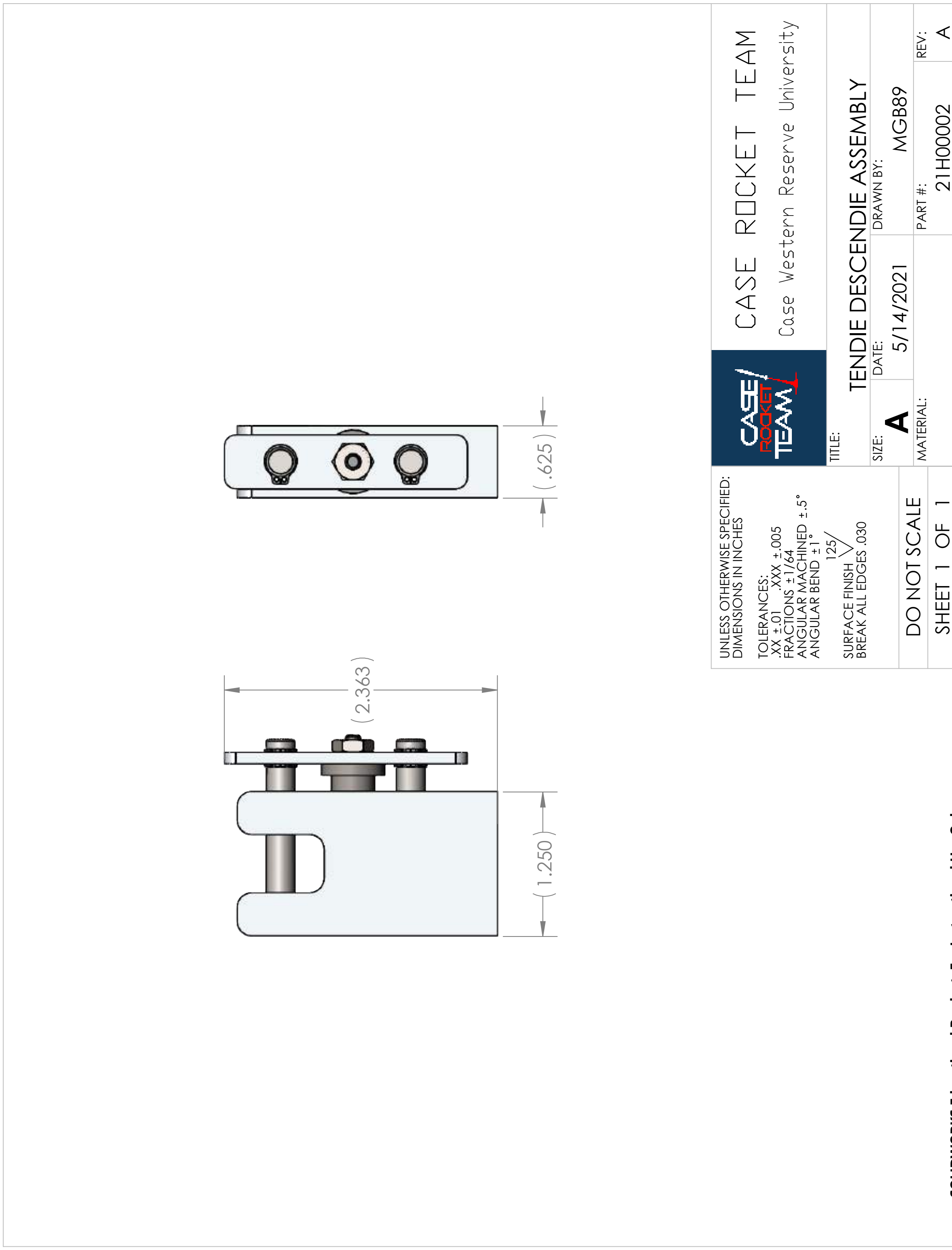
SOLIDWORKS Educational Product. For Instructional Use Only.


CASE ROCKET TEAM
Case Western Reserve University
TITLE:
TENDIE DESCENDIE NANO PIN
SIZE:
A
DATE:
05/14/2021
DRAWN BY:
JMD296
MATERIAL:
ALLOY STEEL
PART #:
21J01002
REV:
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 1 OF 1
Ø.188
2X .010 X 45.00°
1.100
.018
.041
.311
Ø.175
SOLIDWORKS Educational Product. For Instructional Use Only.

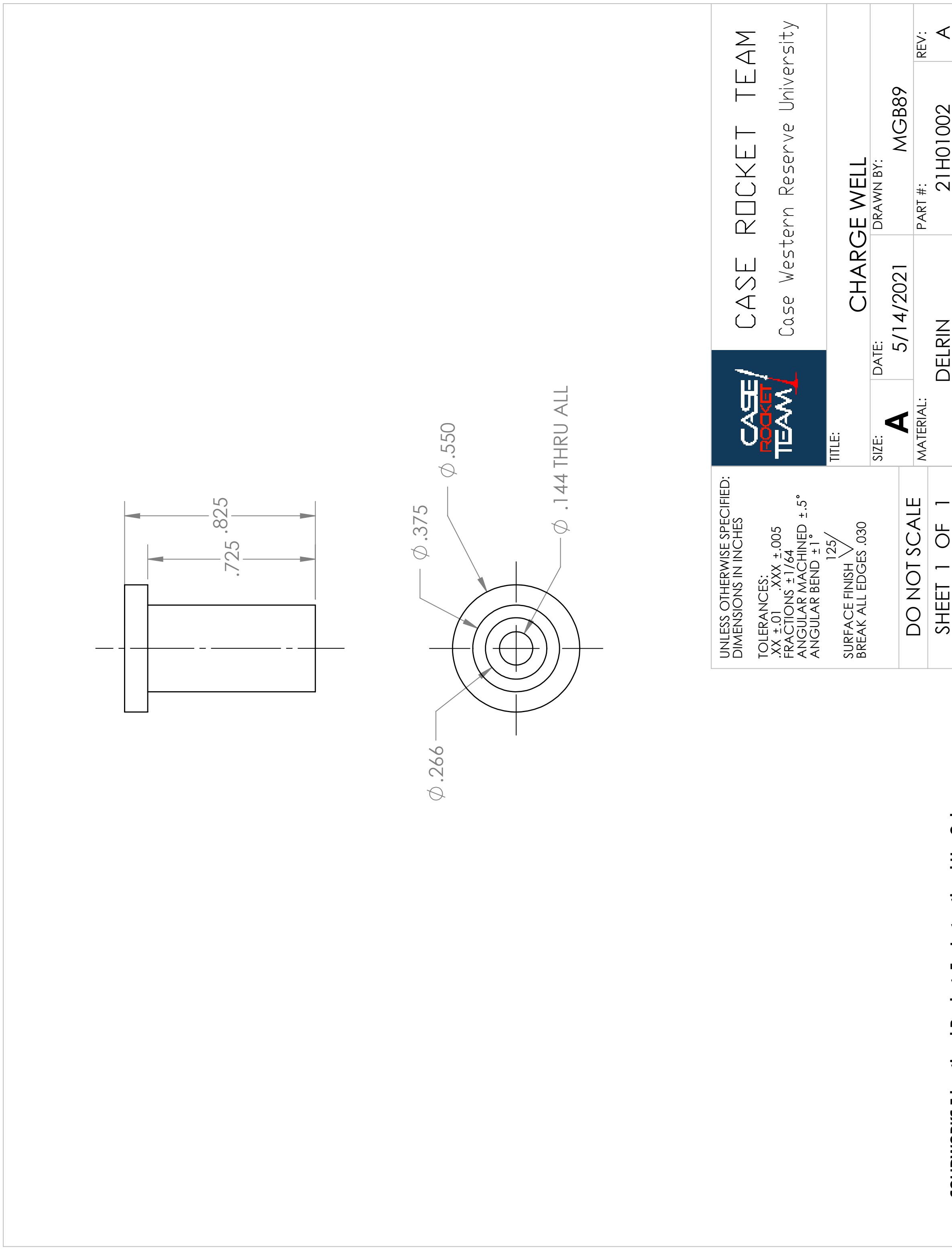


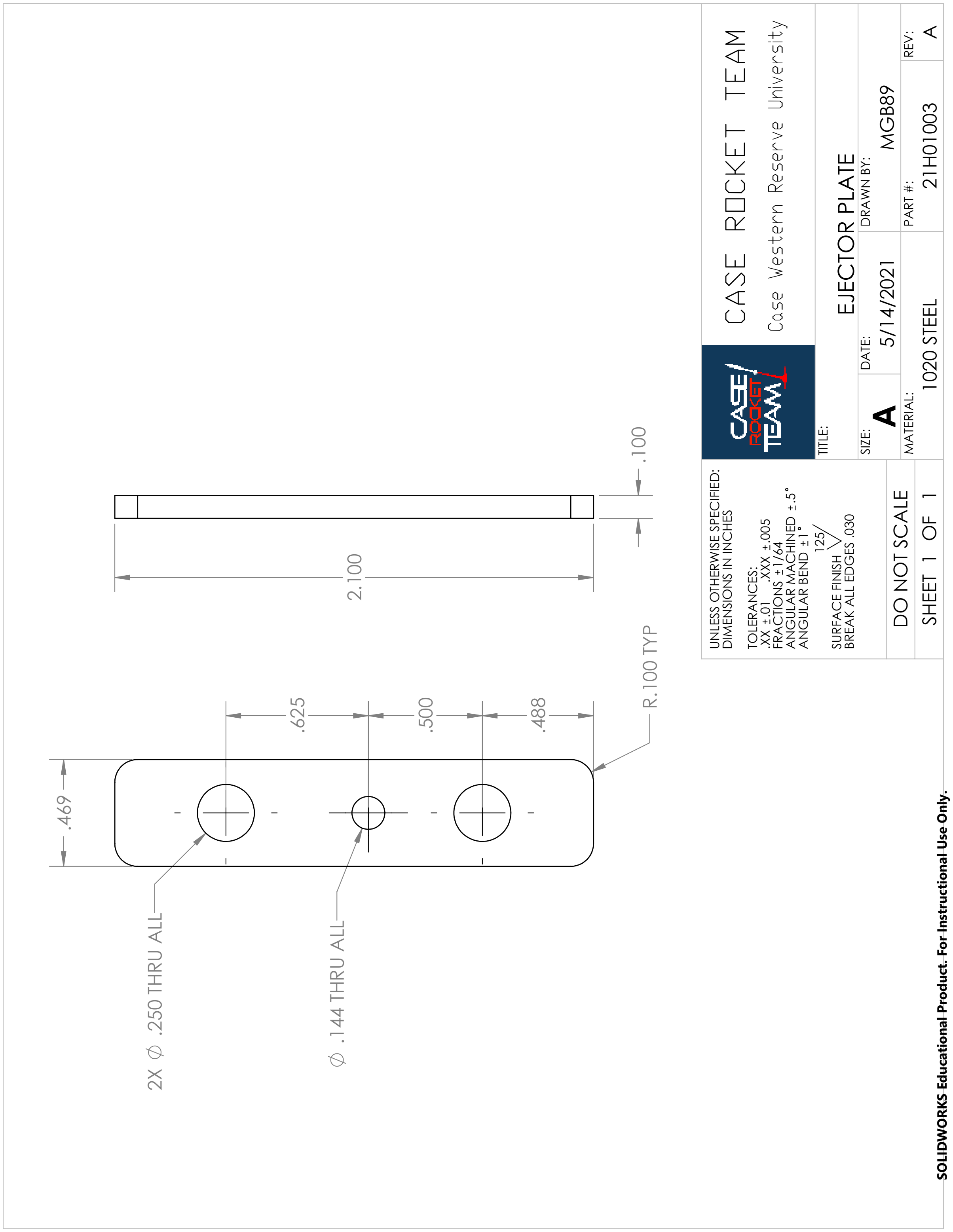
2X ∅ .1838 THRU ALL
REAM .1875
2X ∅ .107 THRU ALL
6-32 UNC THRU ALL
R.125 TYP
1.375
.813
.530
.250
.250
1.625
.250
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
TENDIE DESCENDIE NANO OUTSIDE CLIP
SIZE:
A
DATE:
05/14/2021
DRAWN BY:
JMD296
MATERIAL:
6061-T6
PART #:
21J01003
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.

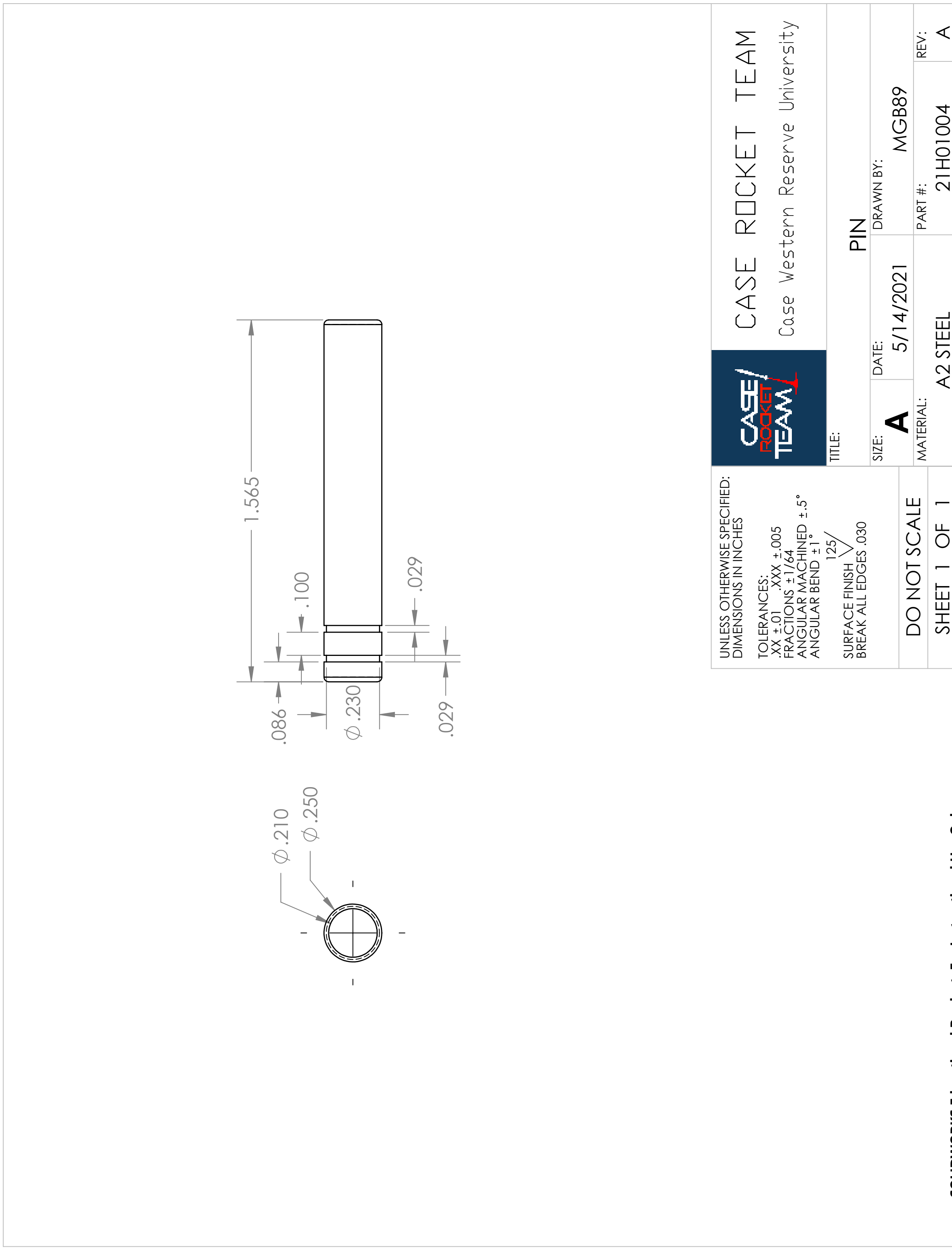

.475
.100
⌀.375 +.000 -.005
⌀.400
⌀.144 THRU
⌀.281 ↧ .375
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
CASE ROCKET TEAM
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
TENDIE DESCENDIE NANO CHARGE WELL
SIZE:
A
DATE:
05/14/2021
DRAWN BY:
JMD296
MATERIAL:
DELRIN
PART #:
21J01004
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.



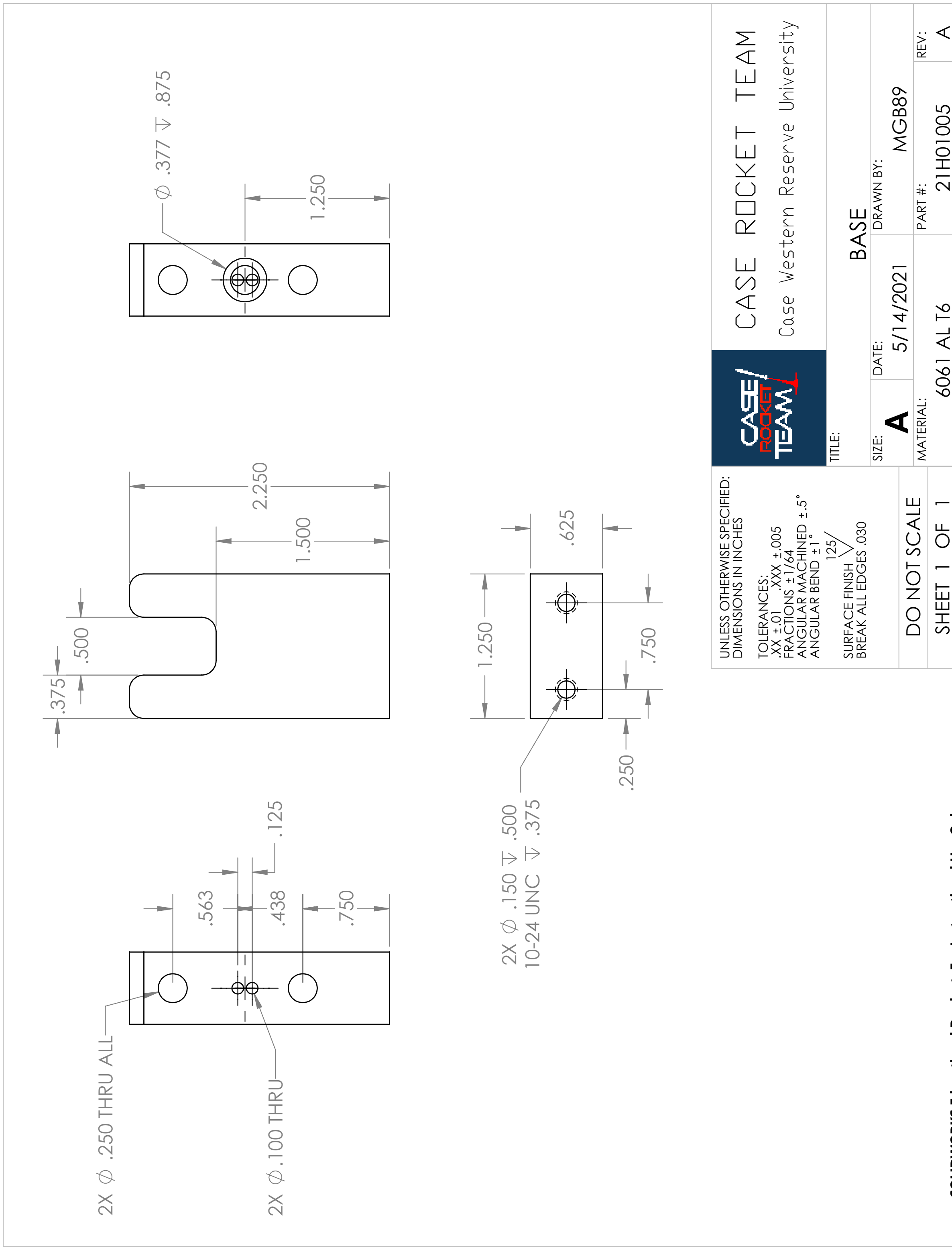
(.625)
(2.363)
(1.250)
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
TENDIE DESCENDIE ASSEMBLY
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MGB89
MATERIAL:
PART #:
21H00002
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.


.825
.725
⌀ .375
⌀ .550
⌀ .144 THRU ALL
⌀ .266
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
125
SURFACE FINISH
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
CASE ROCKET TEAM
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
CHARGE WELL
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MGB89
MATERIAL:
DELRIN
PART #:
21H01002
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.

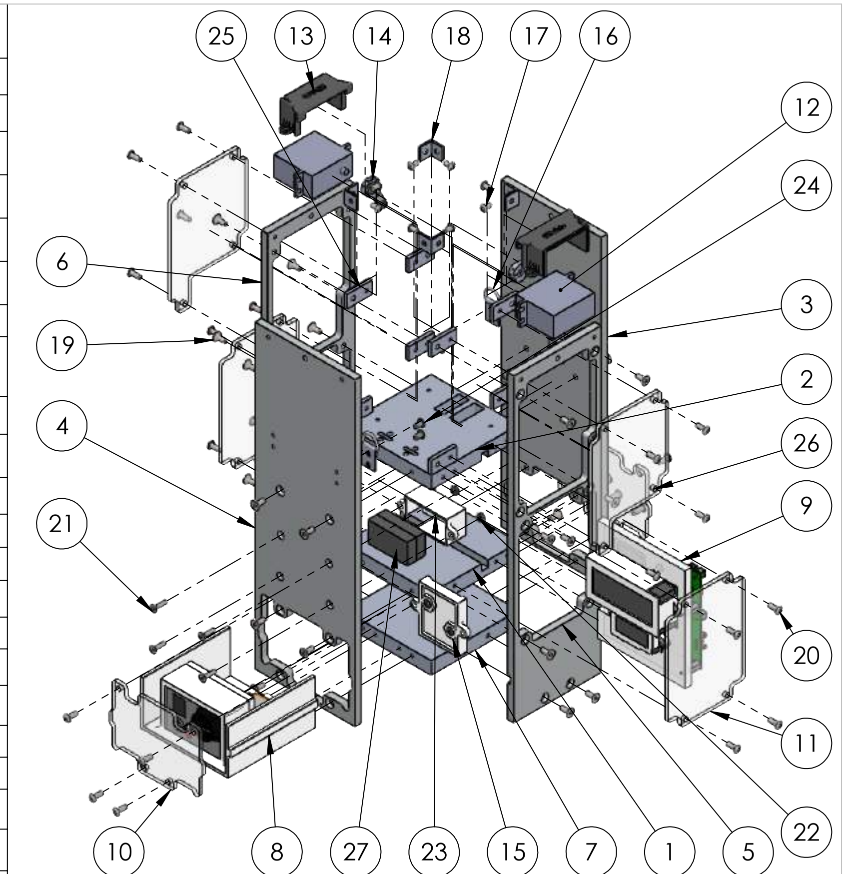

CASE ROCKET TEAM
Case Western Reserve University
TITLE:
EJECTOR PLATE
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MGB89
MATERIAL:
1020 STEEL
PART #:
21H01003
REV:
A
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
2X ∅ .250 THRU ALL
∅ .144 THRU ALL
R.100 TYP
.469
.625
.500
.488
2.100
.100
SOLIDWORKS Educational Product. For Instructional Use Only.



1.565
.100
.029
.086
Ø.230
.029
Ø.210
Ø.250
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:
PIN
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MGB89
MATERIAL:
A2 STEEL
PART #:
21H01004
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.


Ø .377 ↧ .875
1.250
2.250
1.500
.500
.375
1.250
.625
.750
.250
2X Ø .150 ↧ .500
10-24 UNC ↧ .375
.563
.438
.125
.750
2X Ø .250 THRU ALL
2X Ø.100 THRU
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
BASE
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MGB89
MATERIAL:
6061 AL T6
PART #:
21H01005
REV:
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 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	21F01049	Middle Bulkhead	1
2	21F01003	Top Bulkhead	1
3	21F01001	Rear Frame Plate	1
4	21F01047	Front Frame Plate	1
5	21F01048	Right Frame Plate	1
6	21F01002	Left Frame Plate	1
7	21F01009	Bottom Bulkhead	1
8	21F00002	GPS/Camera Sensor Bay Sled	1
9	21F00003	Electronics Bay Sled	1
10	21F01024	Sensor Bay Shield	2
11	21F01026	Electronics Bay Shield	2
12	21F02025	Control Line Servo Motor	2
13	21F02041	Servo Bracket	2
14	21F01028	Servo Horn	2
15	21F00005	Nichrome Board Sled	1
16	21F00006	Riser Hardpoint	4
17	21F01036	#6-32 1/4" Button Head Bolt	8
18	21F01038	L Channel	4
19	21F01043	#6-32 3/8" 82° Flat Head Bolt	32
20	21F01042	#6-32 3/8" Button Head Bolt	24
21	21F01030	#4-40 1/2" 100° Flat Head Bolt	4
22	21F01044	#4-40 Hex Nut	4
23	21F02040	Nichrome Battery Mount	1
24	21F01017	#6-32 1/4" Button Head Bolt	8
25	21F01045	Parachute Shield Attachment	8
26	21F01046	Parachute Bay Shield	2
27	21F02050	1s LiPo Battery	3



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

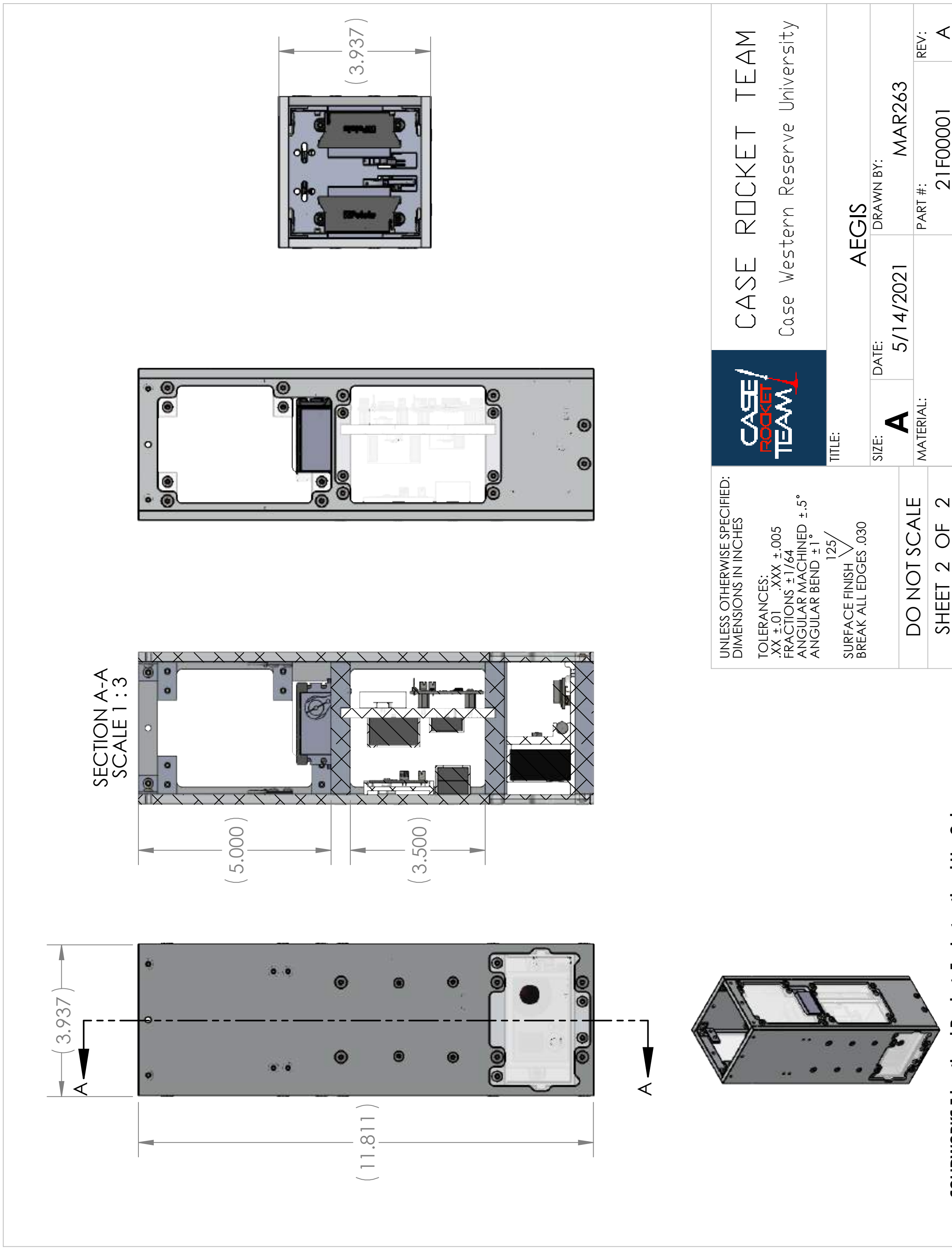
DO NOT SCALE

SHEET 1 OF 2

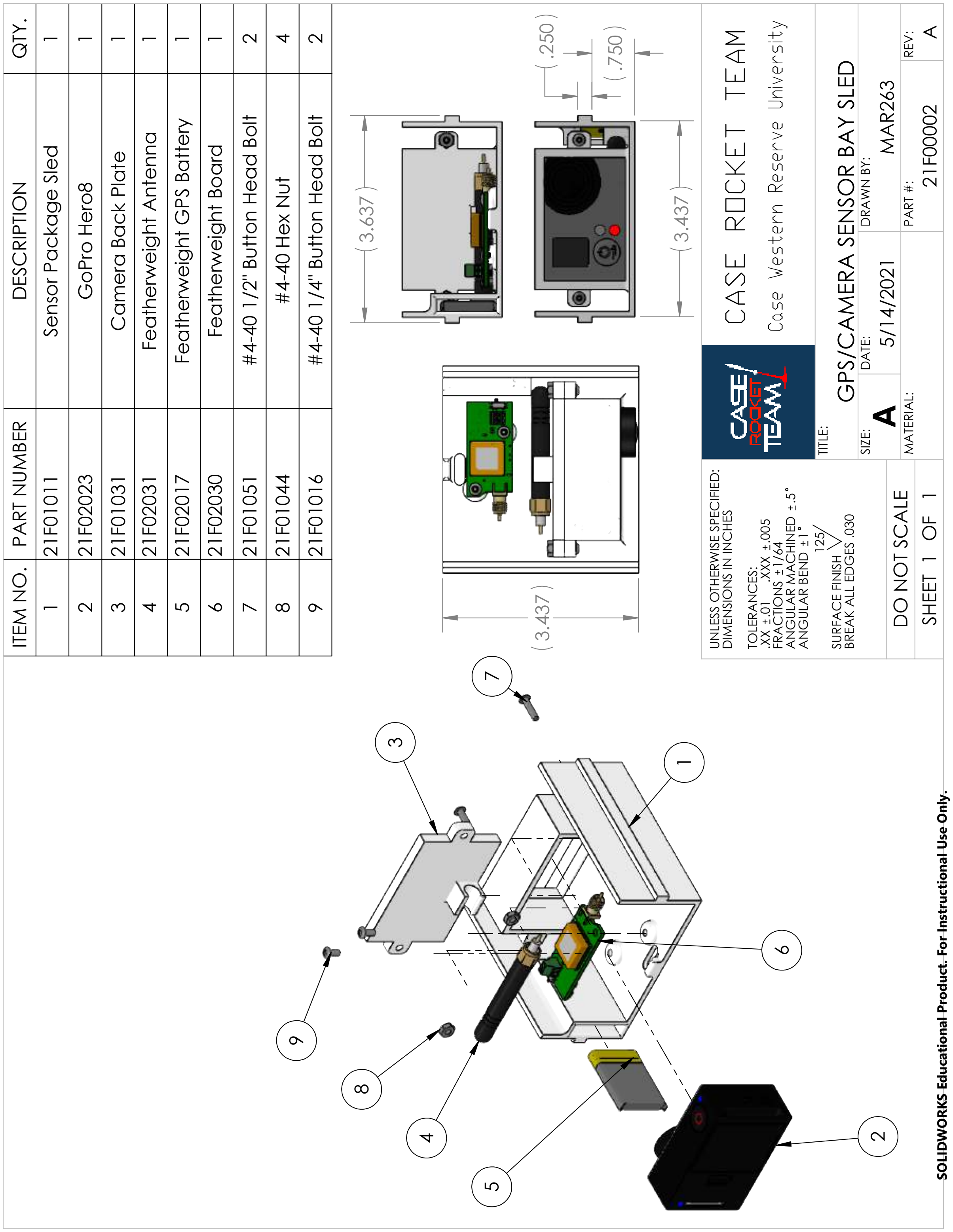
CASE ROCKET TEAM

Case Western Reserve University

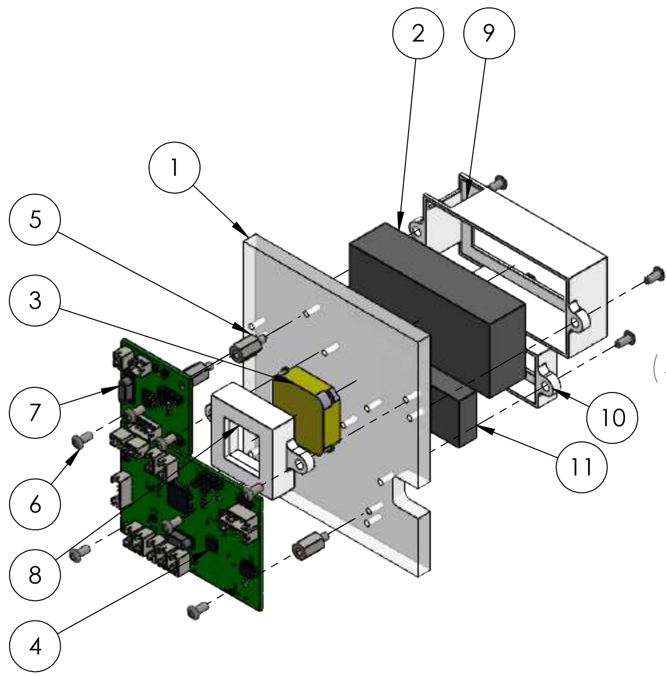
TITLE: AEGIS			
SIZE: A	DATE: 5/14/2021	DRAWN BY: MAR263	
MATERIAL:		PART #: 21F00001	REV: A



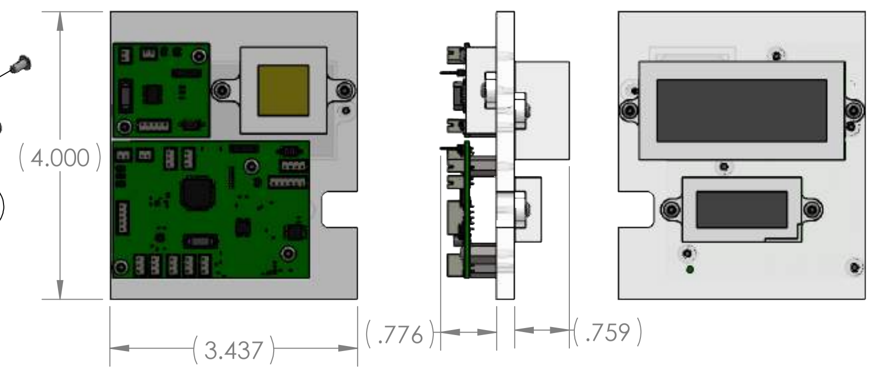
(3.937)
SECTION A-A
SCALE 1 : 3
(5.000)
(3.500)
(3.937)
A
A
(11.811)
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
AEGIS
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MAR263
PART #:
21F00001
REV:
A
MATERIAL:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 2 OF 2
SOLIDWORKS Educational Product. For Instructional Use Only.



ITEM NO.
PART NUMBER
DESCRIPTION
QTY.
1 21F01011 Sensor Package Sled 1
2 21F02023 GoPro Hero8 1
3 21F01031 Camera Back Plate 1
4 21F02031 Featherweight Antenna 1
5 21F02017 Featherweight GPS Battery 1
6 21F02030 Featherweight Board 1
7 21F01051 #4-40 1/2" Button Head Bolt 2
8 21F01044 #4-40 Hex Nut 4
9 21F01016 #4-40 1/4" Button Head Bolt 2
(3.637)
(.250)
(.750)
(3.437)
(3.437)
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:
GPS/CAMERA SENSOR BAY SLED
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MAR263
MATERIAL:
PART #:
21F00002
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	21F01004	Electronics Sled	1
2	21F02027	Main Flight Board Battery	1
3	21F02021	GPS LoRa Antenna	1
4	21F02034	Main Flight Board	1
5	21F01015	#4-40 3/8" Standoff	5
6	21F01016	#4-40 1/4" Button Head Bolt	11
7	21F02039	Backup Flight Board	1
8	21F02044	Patch Antenna Retainer	1
9	21F02048	Main Battery Mount	1
10	21F02049	Backup Battery Mount	1
11	21F02050	1s LiPo Battery	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: ELECTRONICS SLED

SIZE: A | DATE: 5/14/2021 | DRAWN BY: MAR263

MATERIAL: | PART #: 21F00003 | REV: A

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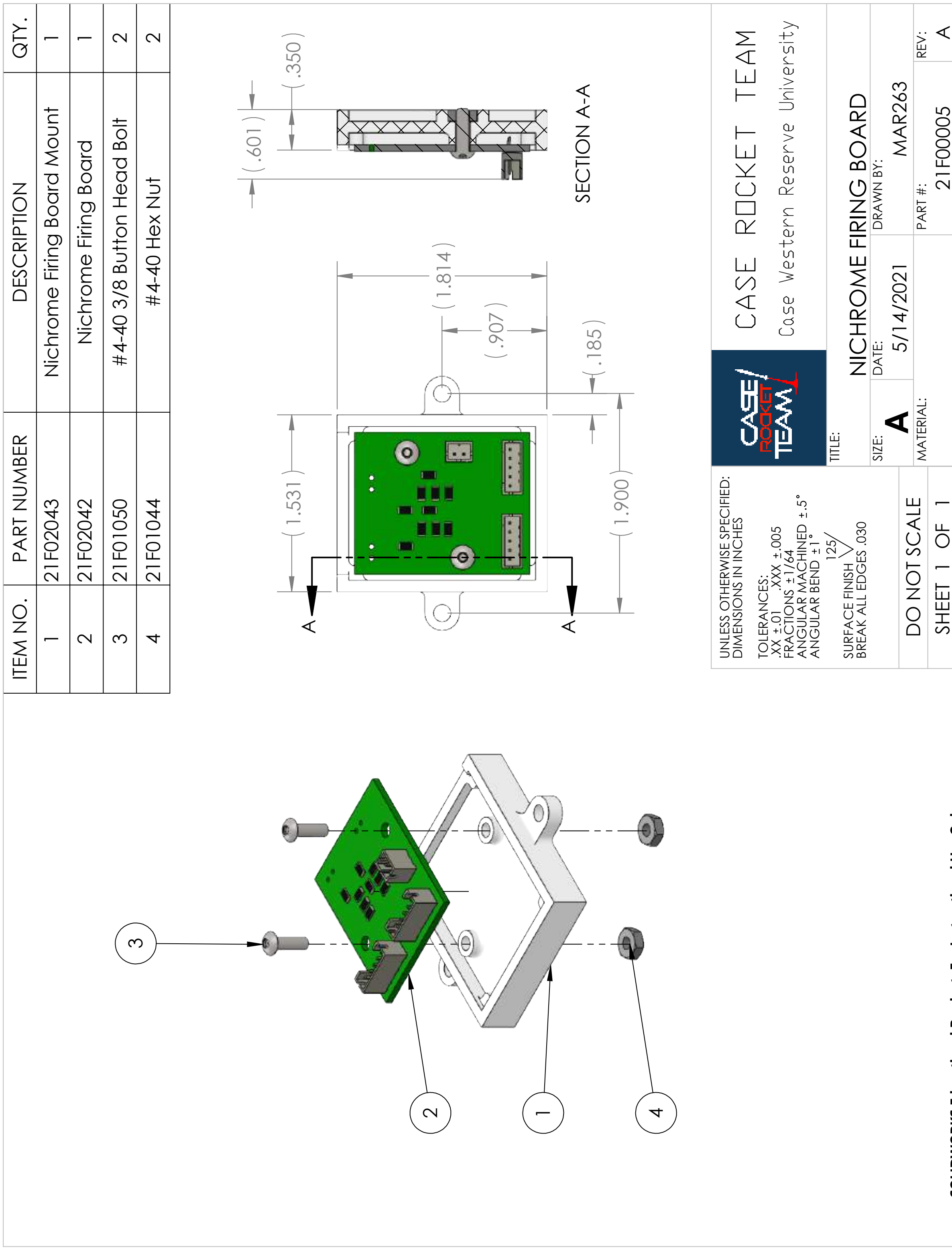
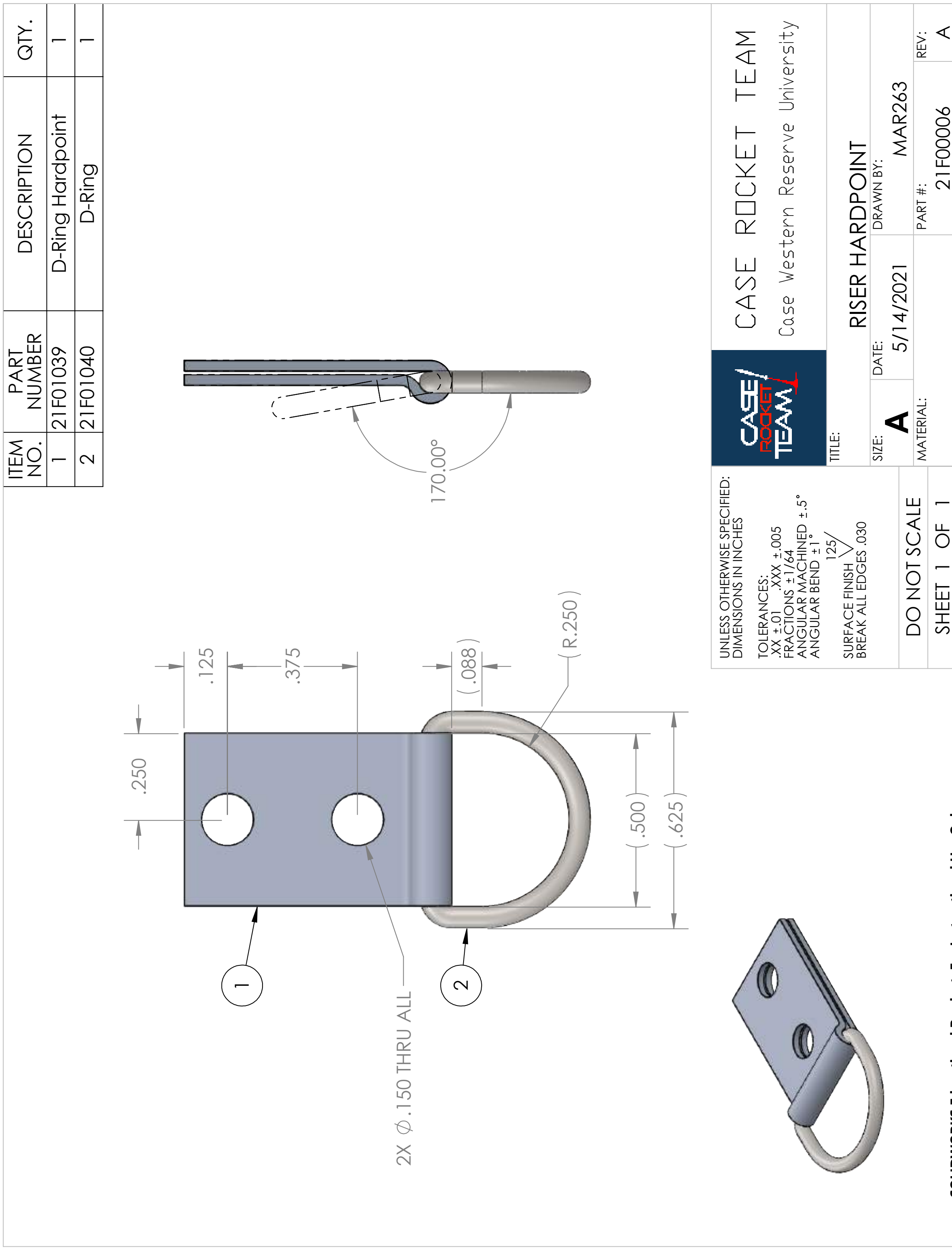
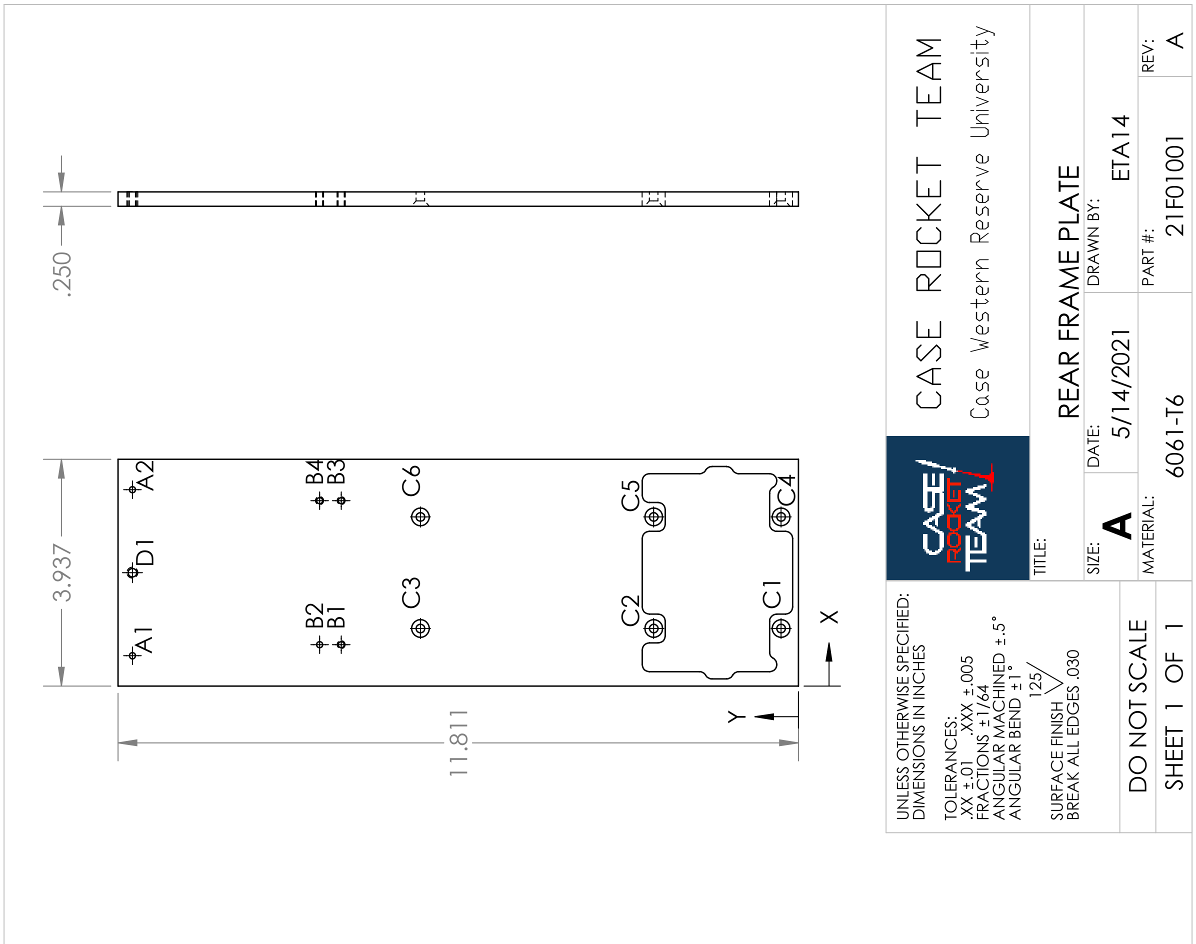


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	21F02043	Nichrome Firing Board Mount	1
2	21F02042	Nichrome Firing Board	1
3	21F01050	#4-40 3/8 Button Head Bolt	2
4	21F01044	#4-40 Hex Nut	2

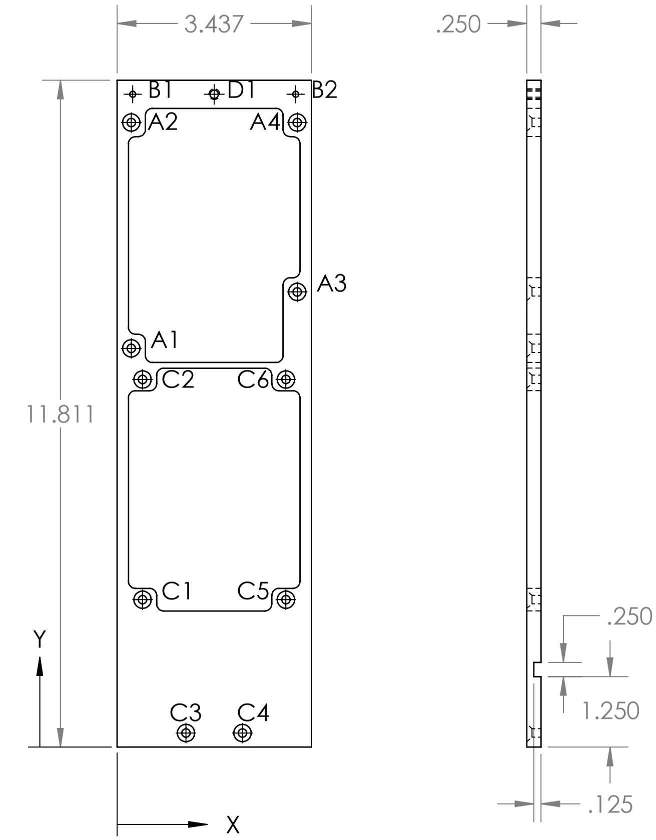


ITEM NO.
PART NUMBER
DESCRIPTION
QTY.
1
21F01039
D-Ring Hardpoint
1
2
21F01040
D-Ring
1
170.00°
.250
.125
.375
(.088)
(R.250)
(.500)
(.625)
2X ∅.150 THRU ALL
1
2
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
RISER HARDPOINT
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MAR263
MATERIAL:
PART #:
21F00006
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.



TAG	X LOC	Y LOC	SIZE
A1	.527	11.561	Ø .107 THRU ALL 6-32 UNC THRU ALL
A2	3.410	11.561	Ø .107 THRU ALL 6-32 UNC THRU ALL
B1	.719	7.936	Ø .107 THRU 6-32 UNC THRU
B2	.719	8.311	Ø .107 THRU 6-32 UNC THRU
B3	3.219	7.936	Ø .107 THRU 6-32 UNC THRU
B4	3.219	8.311	Ø .107 THRU 6-32 UNC THRU
C1	1.000	.300	Ø .150 THRU ALL ∨ Ø .307 X 82°
C2	1.000	2.511	Ø .150 THRU ALL ∨ Ø .307 X 82°
C3	1.000	6.561	Ø .150 THRU ALL ∨ Ø .307 X 82°
C4	2.937	.300	Ø .150 THRU ALL ∨ Ø .307 X 82°
C5	2.937	2.511	Ø .150 THRU ALL ∨ Ø .307 X 82°
C6	2.937	6.561	Ø .150 THRU ALL ∨ Ø .307 X 82°
D1	1.969	11.561	Ø .150 THRU 10-24 UNC THRU

TAG	X LOC	Y LOC	SIZE
A1	.250	7.061	∅ .150 THRU ⌵ ∅ .307 X 82°
A2	.250	11.061	∅ .150 THRU ⌵ ∅ .307 X 82°
A3	3.187	8.061	∅ .150 THRU ⌵ ∅ .307 X 82°
A4	3.187	11.061	∅ .150 THRU ⌵ ∅ .307 X 82°
B1	.277	11.561	∅ .107 THRU ALL 6-32 UNC THRU ALL
B2	3.160	11.561	∅ .107 THRU ALL 6-32 UNC THRU ALL
C1	.450	2.611	∅ .150 THRU ALL ⌵ ∅ .307 X 82°
C2	.450	6.511	∅ .150 THRU ALL ⌵ ∅ .307 X 82°
C3	1.219	.250	∅ .150 THRU ALL ⌵ ∅ .307 X 82°
C4	2.219	.250	∅ .150 THRU ALL ⌵ ∅ .307 X 82°
C5	2.987	2.611	∅ .150 THRU ALL ⌵ ∅ .307 X 82°
C6	2.987	6.511	∅ .150 THRU ALL ⌵ ∅ .307 X 82°
D1	1.719	11.561	∅ .150 THRU ALL 10-24 UNC THRU ALL



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

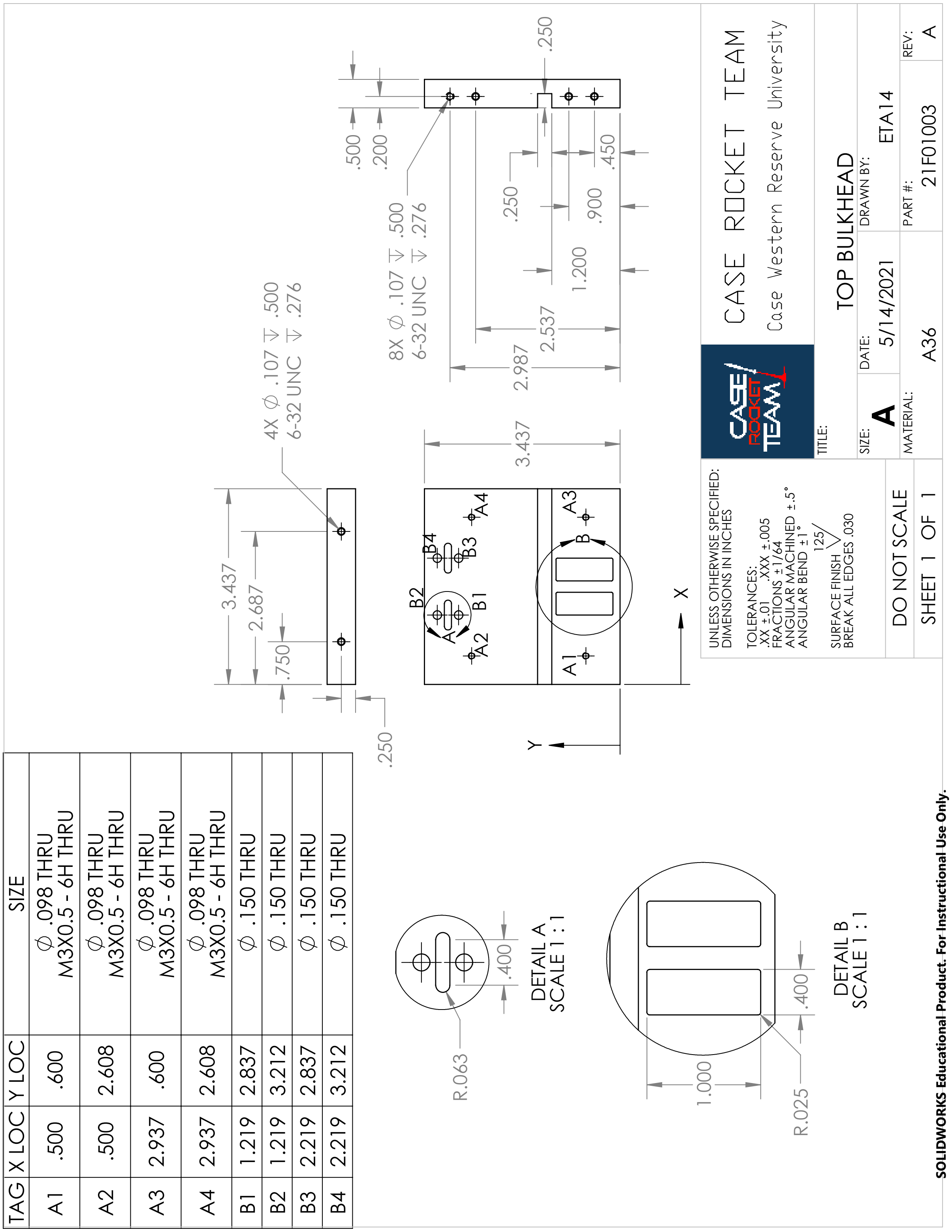
CASE ROCKET TEAM

Case Western Reserve University

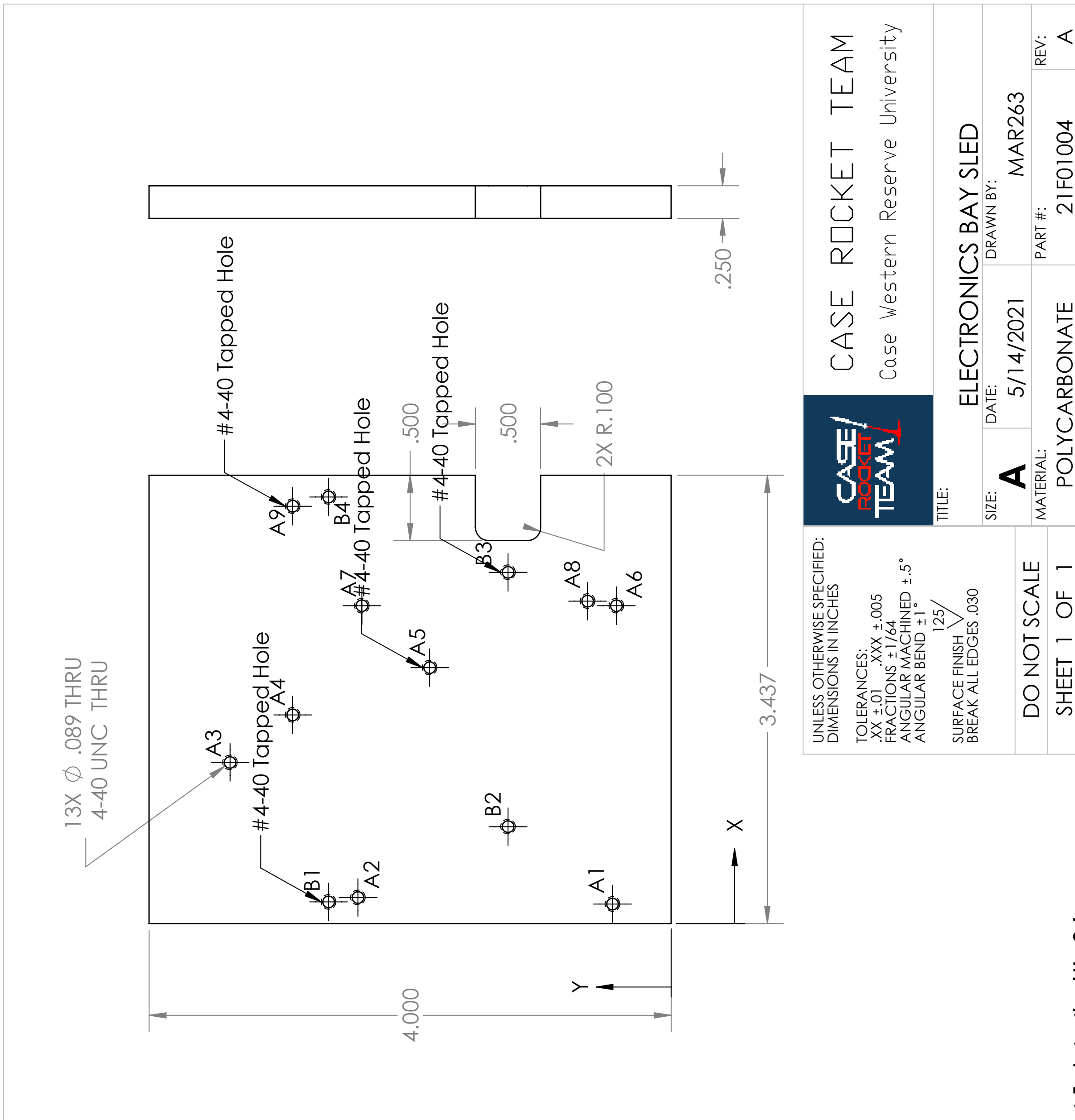
TITLE: LEFT FRAME PLATE

SIZE: A | DATE: 5/14/2021 | DRAWN BY: ETA14

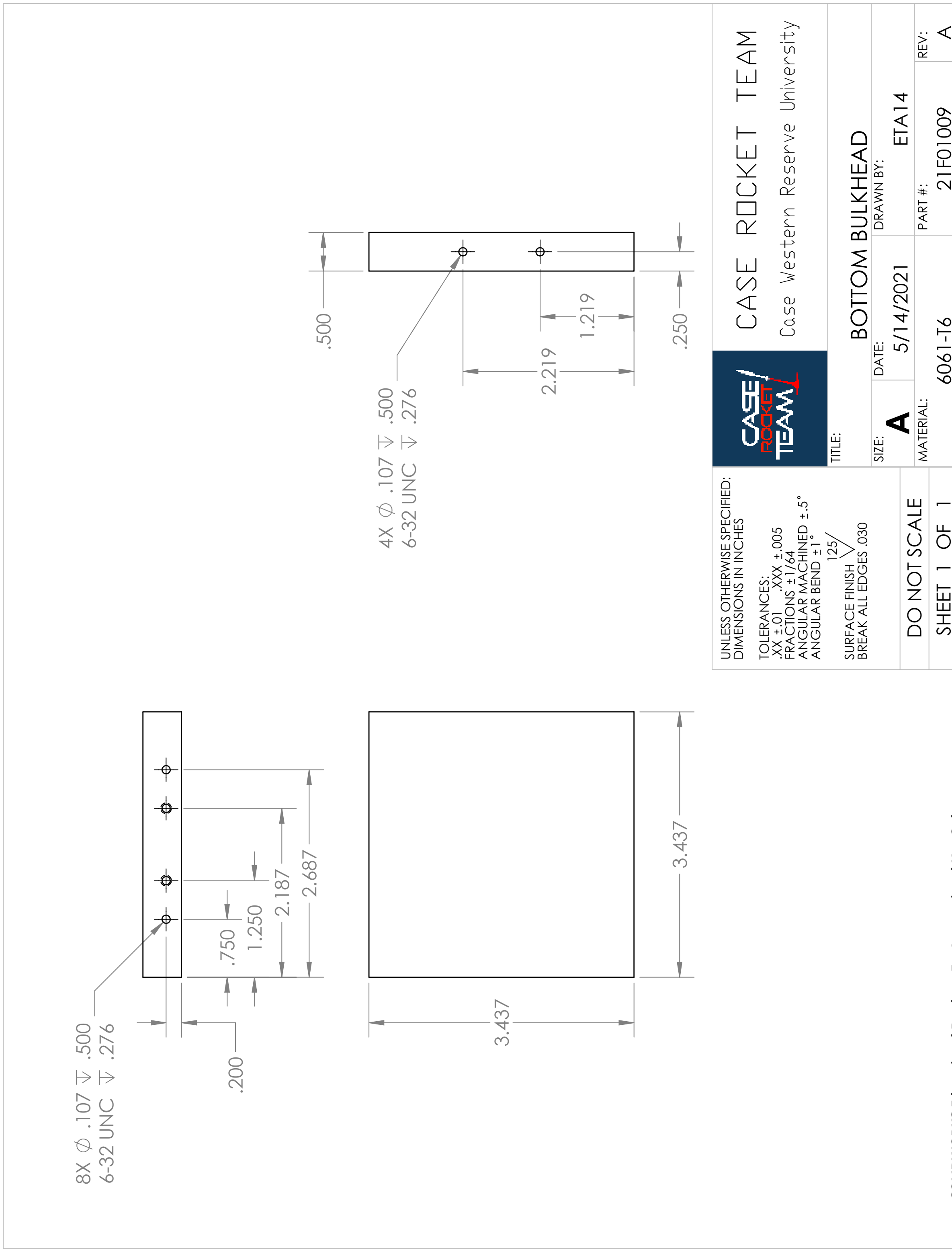
MATERIAL: 6061-T6 | PART #: 21F01002 | REV: A

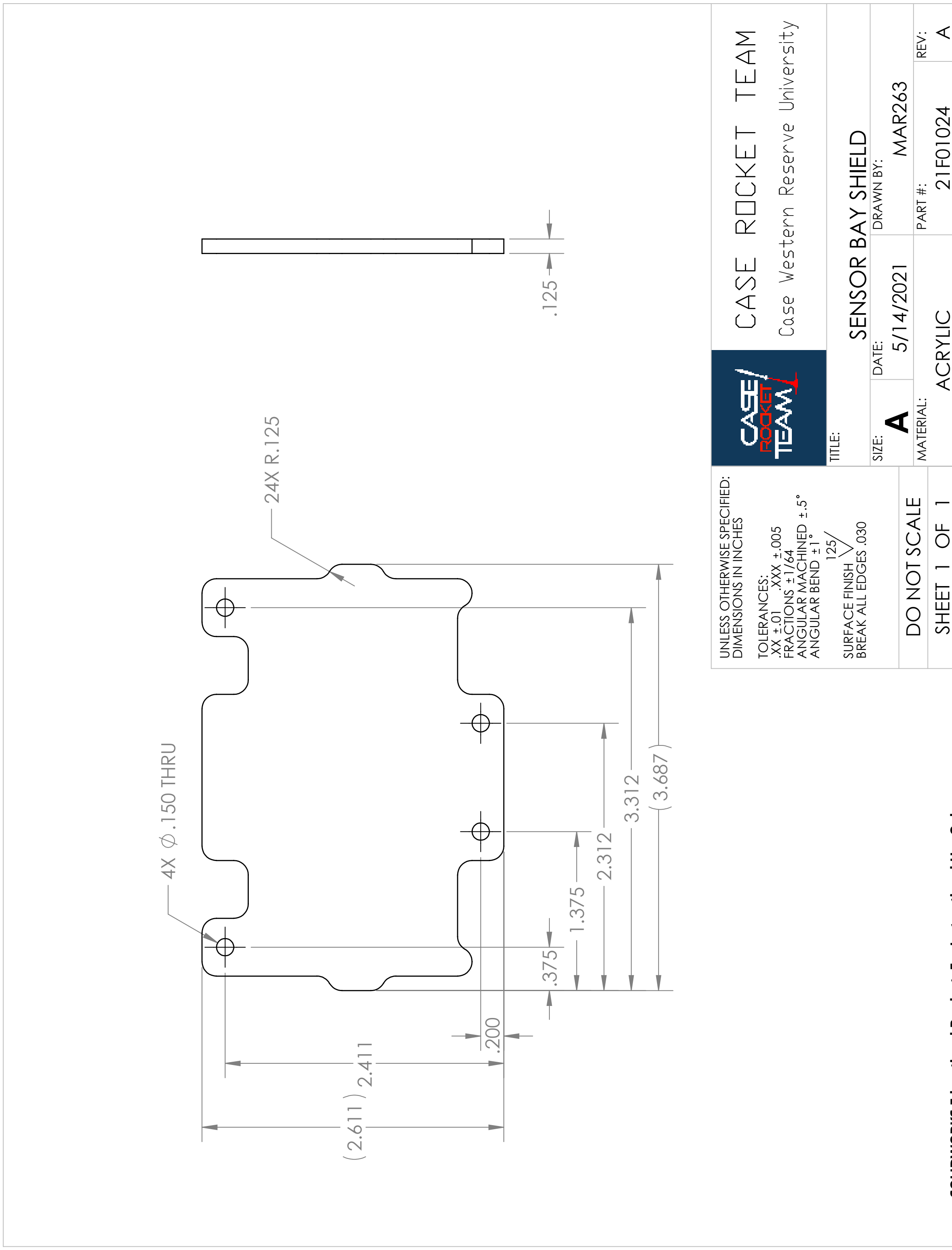


TAG	X LOC	Y LOC	SIZE
A1	.500	.600	Ø .098 THRU M3X0.5 - 6H THRU
A2	.500	2.608	Ø .098 THRU M3X0.5 - 6H THRU
A3	2.937	.600	Ø .098 THRU M3X0.5 - 6H THRU
A4	2.937	2.608	Ø .098 THRU M3X0.5 - 6H THRU
B1	1.219	2.837	Ø .150 THRU
B2	1.219	3.212	Ø .150 THRU
B3	2.219	2.837	Ø .150 THRU
B4	2.219	3.212	Ø .150 THRU

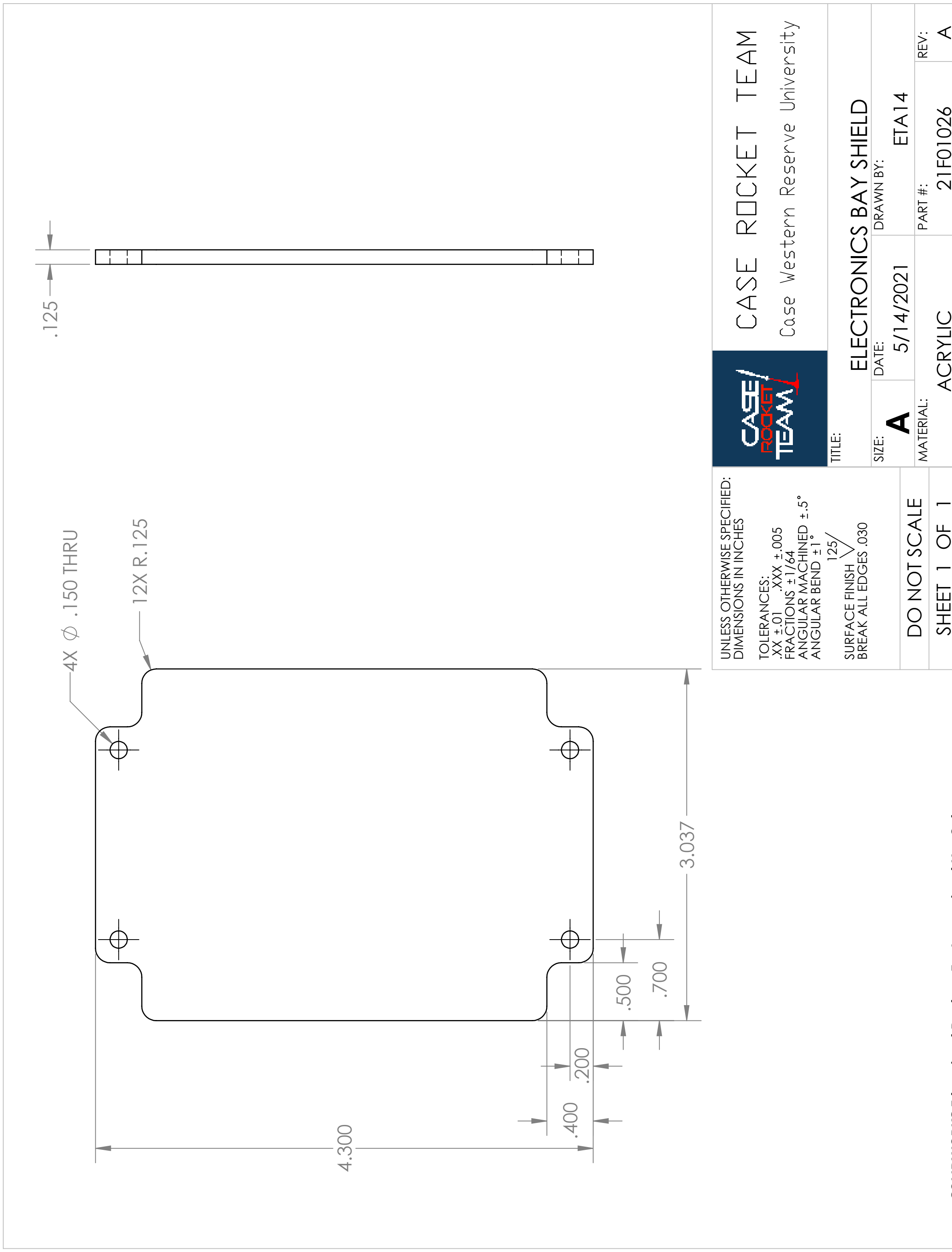


TAG	X LOC	Y LOC
A1	.150	.450
A2	.200	2.400
A3	1.235	3.380
A4	1.600	2.900
A5	1.962	1.851
A6	2.437	.420
A7	2.437	2.370
A8	2.472	.641
A9	3.200	2.900
B1	.166	2.625
B2	.744	1.250
B3	2.694	1.250
B4	3.271	2.625

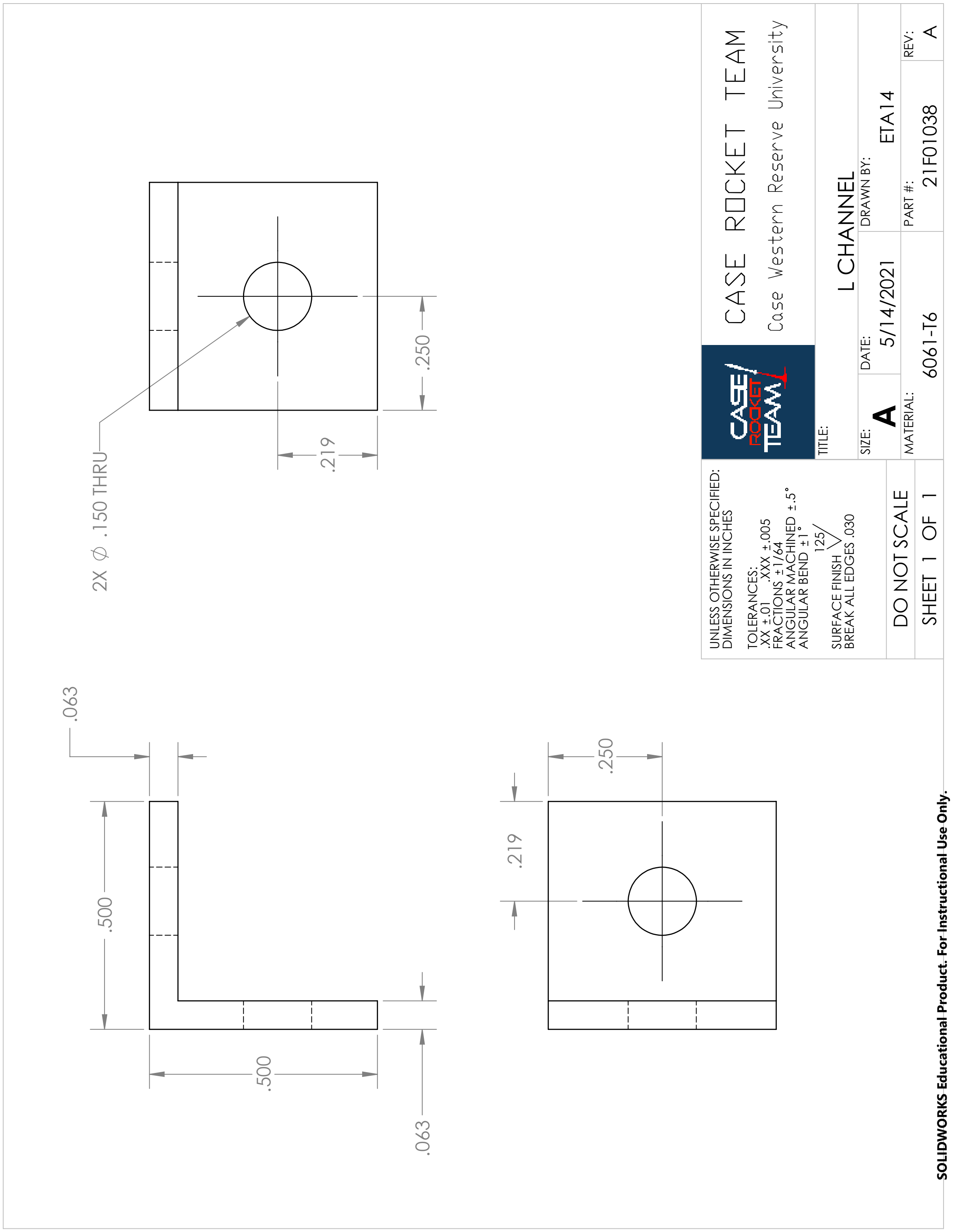

CASE ROCKET TEAM
Case Western Reserve University
TITLE:
BOTTOM BULKHEAD
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
ETA14
MATERIAL:
6061-T6
PART #:
21F01009
REV:
A
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
4X ⌀ .107 ↧ .500
6-32 UNC ↧ .276
8X ⌀ .107 ↧ .500
6-32 UNC ↧ .276
.500
.250
1.219
2.219
.200
.750
1.250
2.187
2.687
3.437
3.437
SOLIDWORKS Educational Product. For Instructional Use Only.



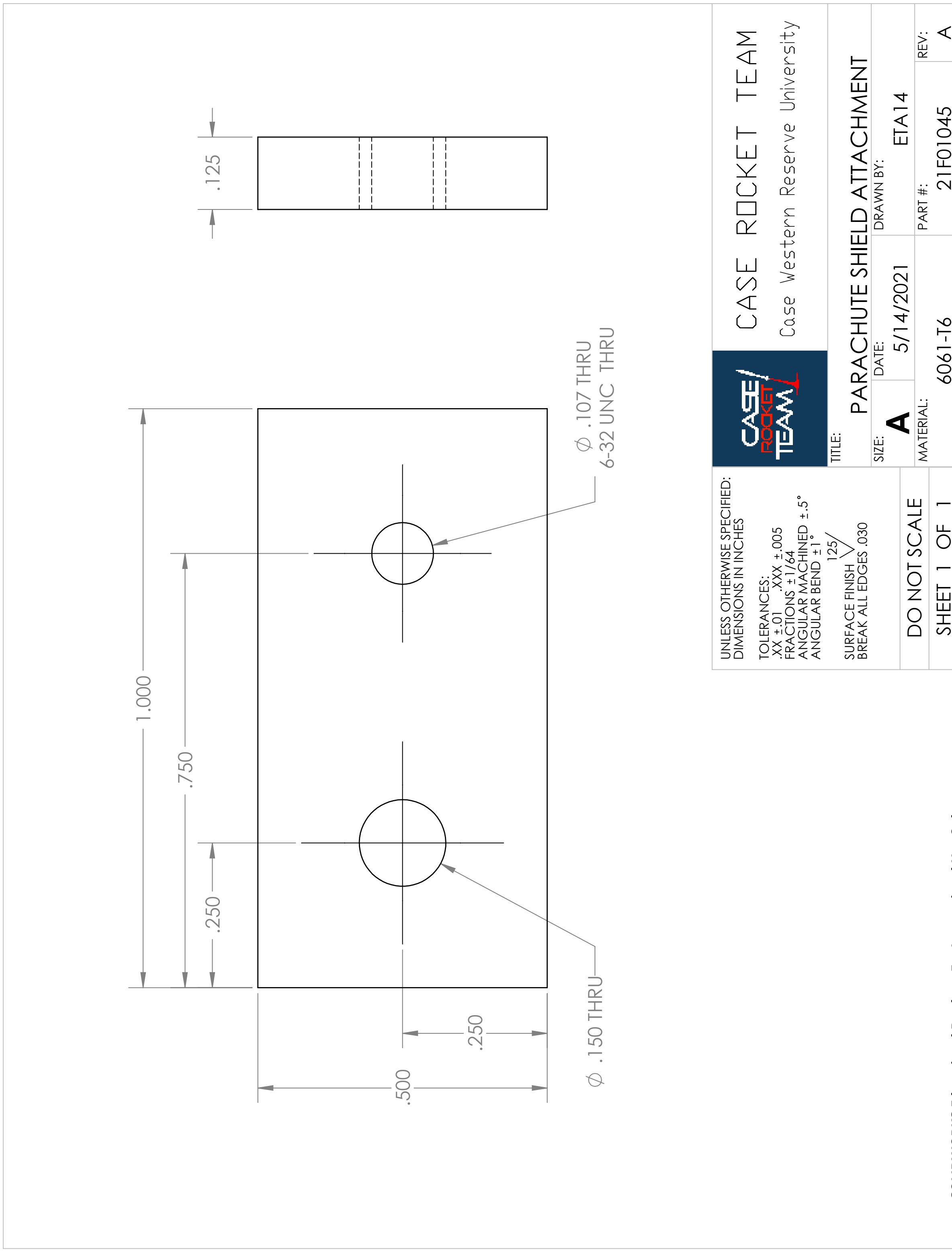
24X R.125
4X ∅.150 THRU
.125
.375
1.375
2.312
3.312
(3.687)
.200
2.411
(2.611)
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
CASE ROCKET TEAM
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
SENSOR BAY SHIELD
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MAR263
MATERIAL:
ACRYLIC
PART #:
21F01024
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.



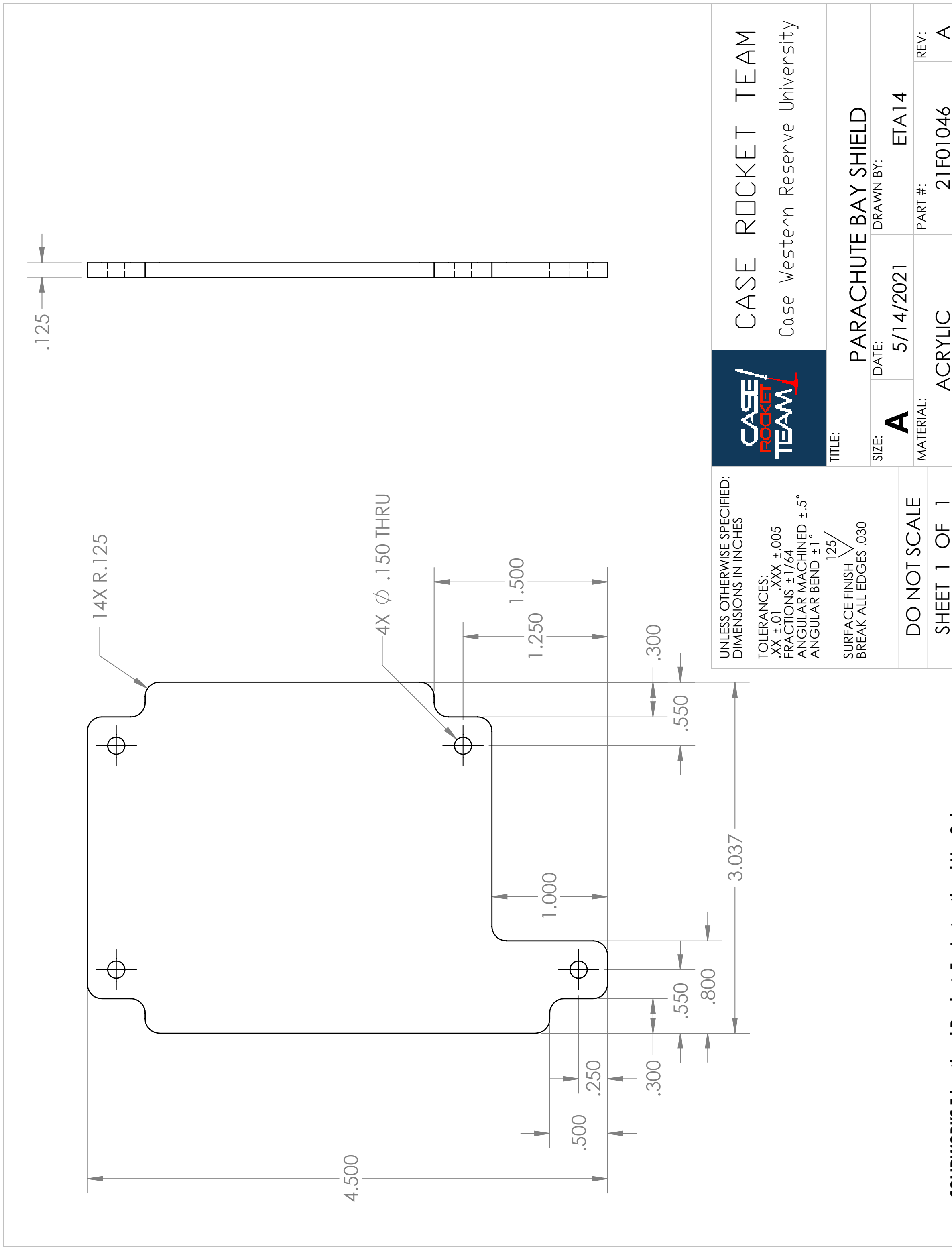
.125
4X ⌀ .150 THRU
12X R.125
3.037
.500
.700
.200
.400
4.300
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
CASE ROCKET TEAM
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
ELECTRONICS BAY SHIELD
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
ETA14
MATERIAL:
ACRYLIC
PART #:
21F01026
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.



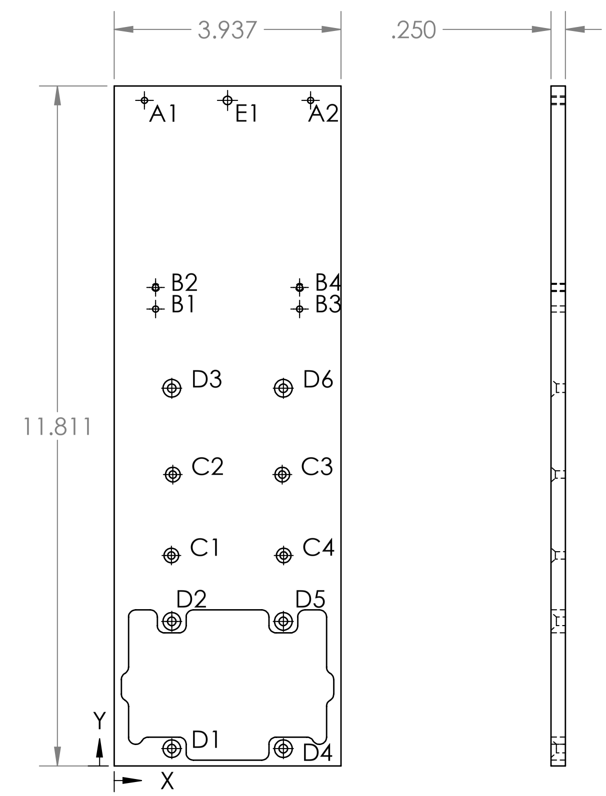
2X ∅ .150 THRU
.250
.219
.063
.500
.500
.063
.250
.219
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
CASE ROCKET TEAM
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
L CHANNEL
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
ETA14
MATERIAL:
6061-T6
PART #:
21F01038
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.



.125
1.000
.750
.250
.250
.500
∅ .107 THRU
6-32 UNC THRU
∅ .150 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 ROCKET TEAM
Case Western Reserve University
TITLE:
PARACHUTE SHIELD ATTACHMENT
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
ETA14
MATERIAL:
6061-T6
PART #:
21F01045
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.


.125
14X R.125
4X ⌀ .150 THRU
1.500
1.250
.300
.550
3.037
1.000
.550
.800
.300
.250
.500
4.500
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:
PARACHUTE BAY SHIELD
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
ETA14
MATERIAL:
ACRYLIC
PART #:
21F01046
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.

TAG	X LOC	Y LOC	SIZE
A1	.527	11.561	Ø .107 THRU ALL 6-32 UNC THRU ALL
A2	3.410	11.561	Ø .107 THRU ALL 6-32 UNC THRU ALL
B1	.719	7.936	Ø .107 THRU 6-32 UNC THRU
B2	.719	8.311	Ø .107 THRU 6-32 UNC THRU
B3	3.219	7.936	Ø .107 THRU 6-32 UNC THRU
B4	3.219	8.311	Ø .107 THRU 6-32 UNC THRU
C1	.994	3.656	Ø .129 THRU ALL ⌵ Ø .255 X 82°
C2	1.019	5.061	Ø .129 THRU ALL ⌵ Ø .255 X 82°
C3	2.919	5.061	Ø .129 THRU ALL ⌵ Ø .255 X 82°
C4	2.944	3.656	Ø .129 THRU ALL ⌵ Ø .255 X 82°
D1	1.000	.300	Ø .150 THRU ALL ⌵ Ø .307 X 82°
D2	1.000	2.511	Ø .150 THRU ALL ⌵ Ø .307 X 82°
D3	1.000	6.561	Ø .150 THRU ALL ⌵ Ø .307 X 82°
D4	2.937	.300	Ø .150 THRU ALL ⌵ Ø .307 X 82°
D5	2.937	2.511	Ø .150 THRU ALL ⌵ Ø .307 X 82°
D6	2.937	6.561	Ø .150 THRU ALL ⌵ Ø .307 X 82°
E1	1.969	11.561	Ø .150 THRU 10-24 UNC 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

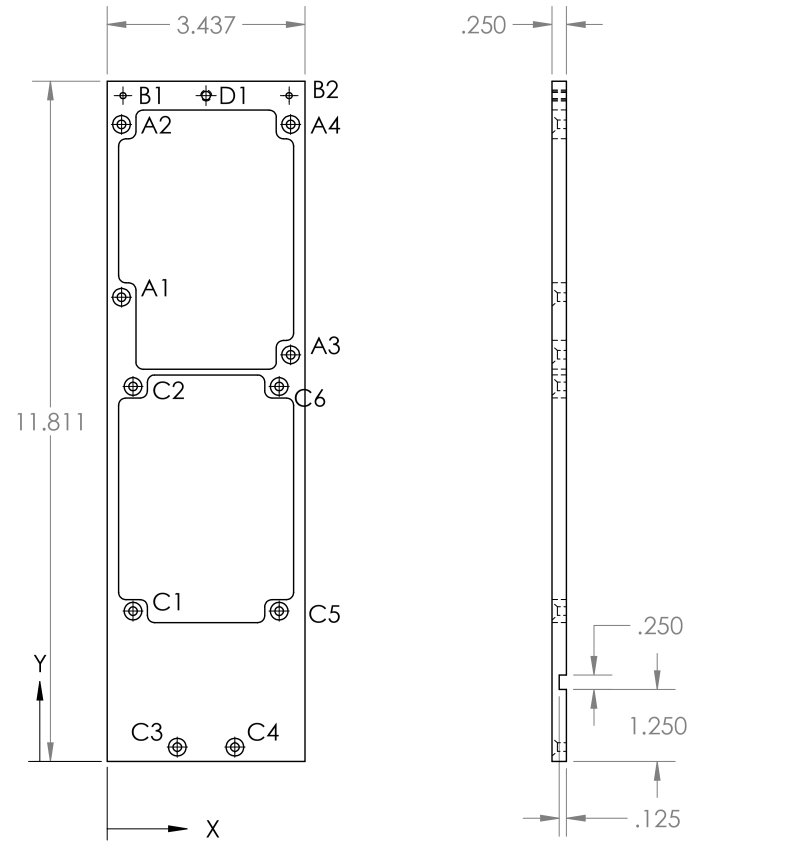
Case Western Reserve University

TITLE: FRONT FRAME PLATE

SIZE: A | DATE: 5/14/2021 | DRAWN BY: ETA14

MATERIAL: 6061-T6 | PART #: 21F01047 | REV: A

TAG	X LOC	Y LOC	SIZE
A1	.250	8.061	∅ .150 THRU ⌵ ∅ .307 X 82°
A2	.250	11.061	∅ .150 THRU ⌵ ∅ .307 X 82°
A3	3.187	7.061	∅ .150 THRU ⌵ ∅ .307 X 82°
A4	3.187	11.061	∅ .150 THRU ⌵ ∅ .307 X 82°
B1	.277	11.561	∅ .107 THRU ALL 6-32 UNC THRU ALL
B2	3.160	11.561	∅ .107 THRU ALL 6-32 UNC THRU ALL
C1	.450	2.611	∅ .150 THRU ALL ⌵ ∅ .307 X 82°
C2	.450	6.511	∅ .150 THRU ALL ⌵ ∅ .307 X 82°
C3	1.219	.250	∅ .150 THRU ALL ⌵ ∅ .307 X 82°
C4	2.219	.250	∅ .150 THRU ALL ⌵ ∅ .307 X 82°
C5	2.987	2.611	∅ .150 THRU ALL ⌵ ∅ .307 X 82°
C6	2.987	6.511	∅ .150 THRU ALL ⌵ ∅ .307 X 82°
D1	1.719	11.561	∅ .150 THRU ALL 10-24 UNC THRU ALL



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

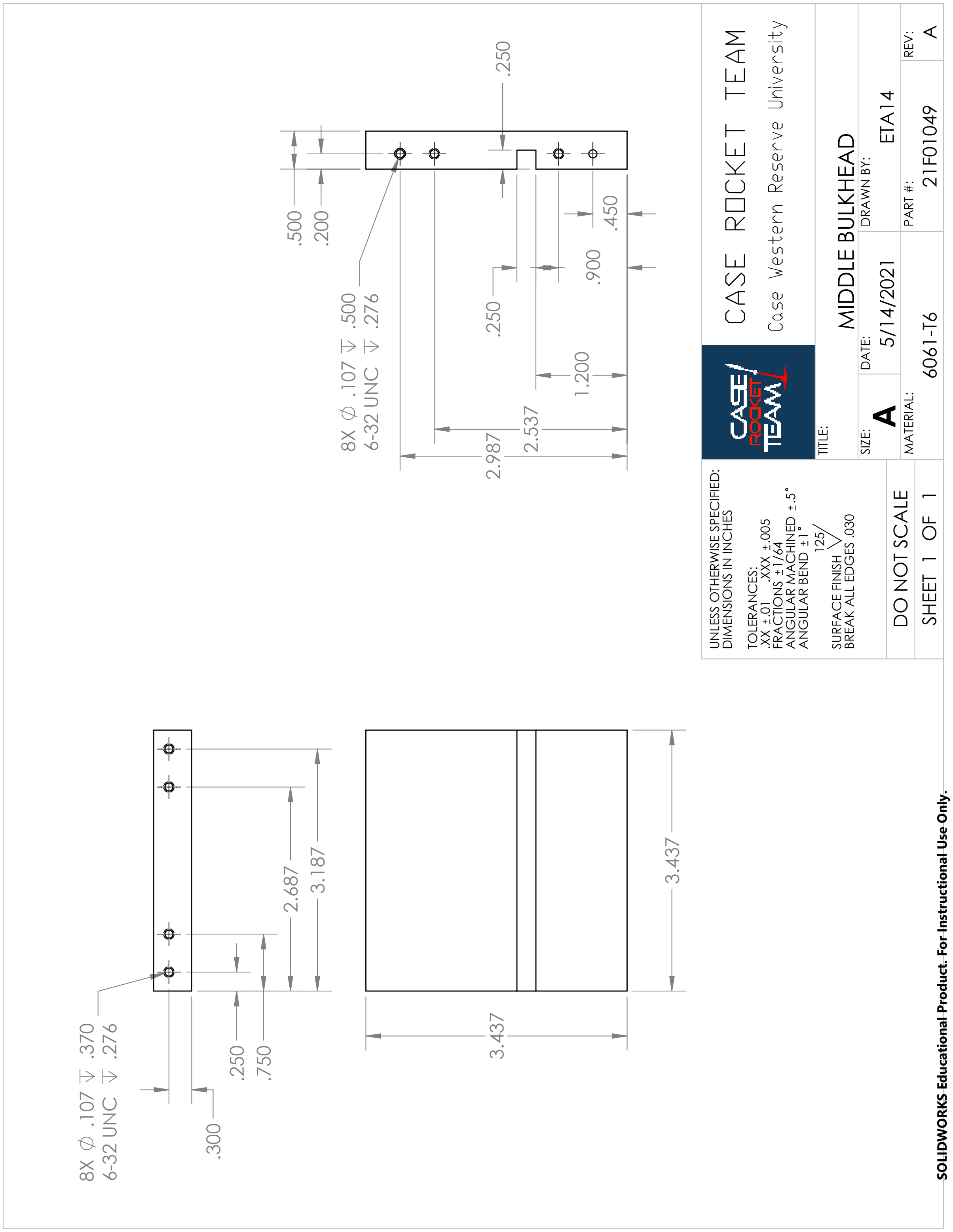
CASE ROCKET TEAM

Case Western Reserve University

TITLE: RIGHT FRAME PLATE

SIZE: A | DATE: 5/14/2021 | DRAWN BY: ETA14

MATERIAL: 6061-T6 | PART #: 21F01048 | REV: A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Case Western Reserve University
TITLE:
MIDDLE BULKHEAD
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
ETA14
MATERIAL:
6061-T6
PART #:
21F01049
REV:
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 1 OF 1
8X ∅ .107 ⊽ .500
6-32 UNC ⊽ .276
8X ∅ .107 ⊽ .370
6-32 UNC ⊽ .276
.250
.500
.200
.450
.900
.250
1.200
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2.987
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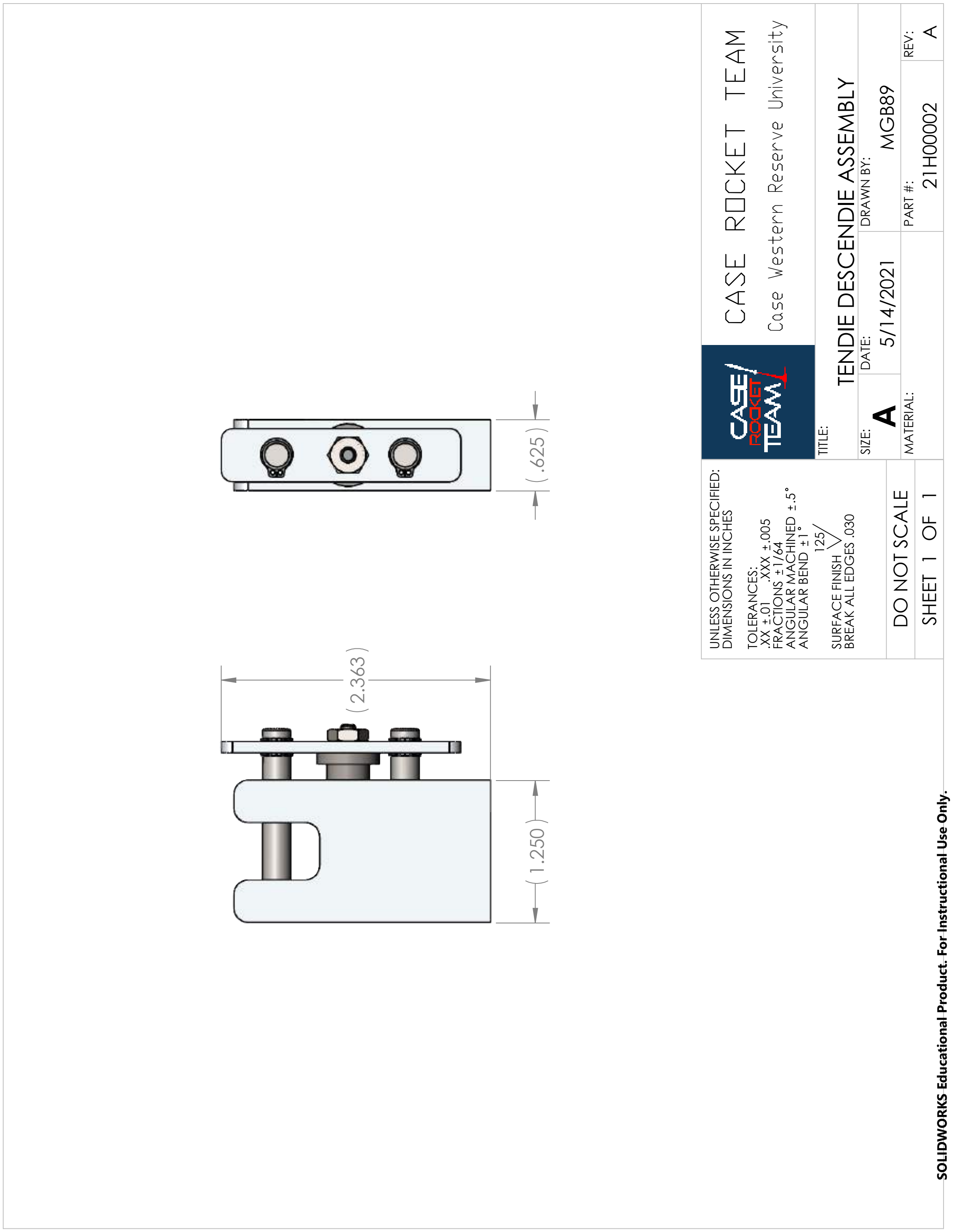
.250
.750
2.687
3.187
3.437
3.437
SOLIDWORKS Educational Product. For Instructional Use Only.



CASE ROCKET TEAM
Case Western Reserve University
TITLE:
TENDIE DESCENDIE ASSEMBLY
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MGB89
MATERIAL:
PART #:
21H00002
REV:
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 1 OF 1
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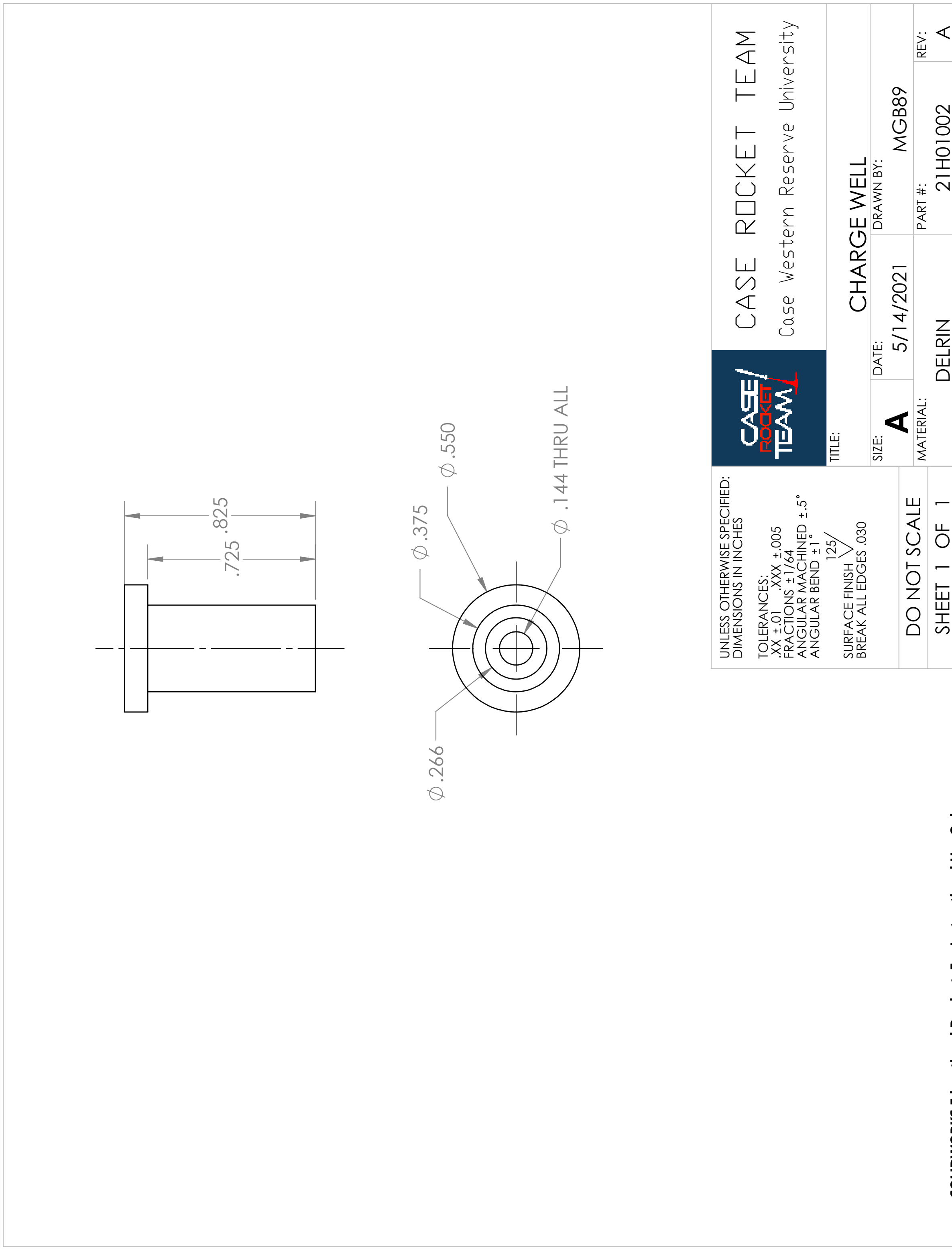
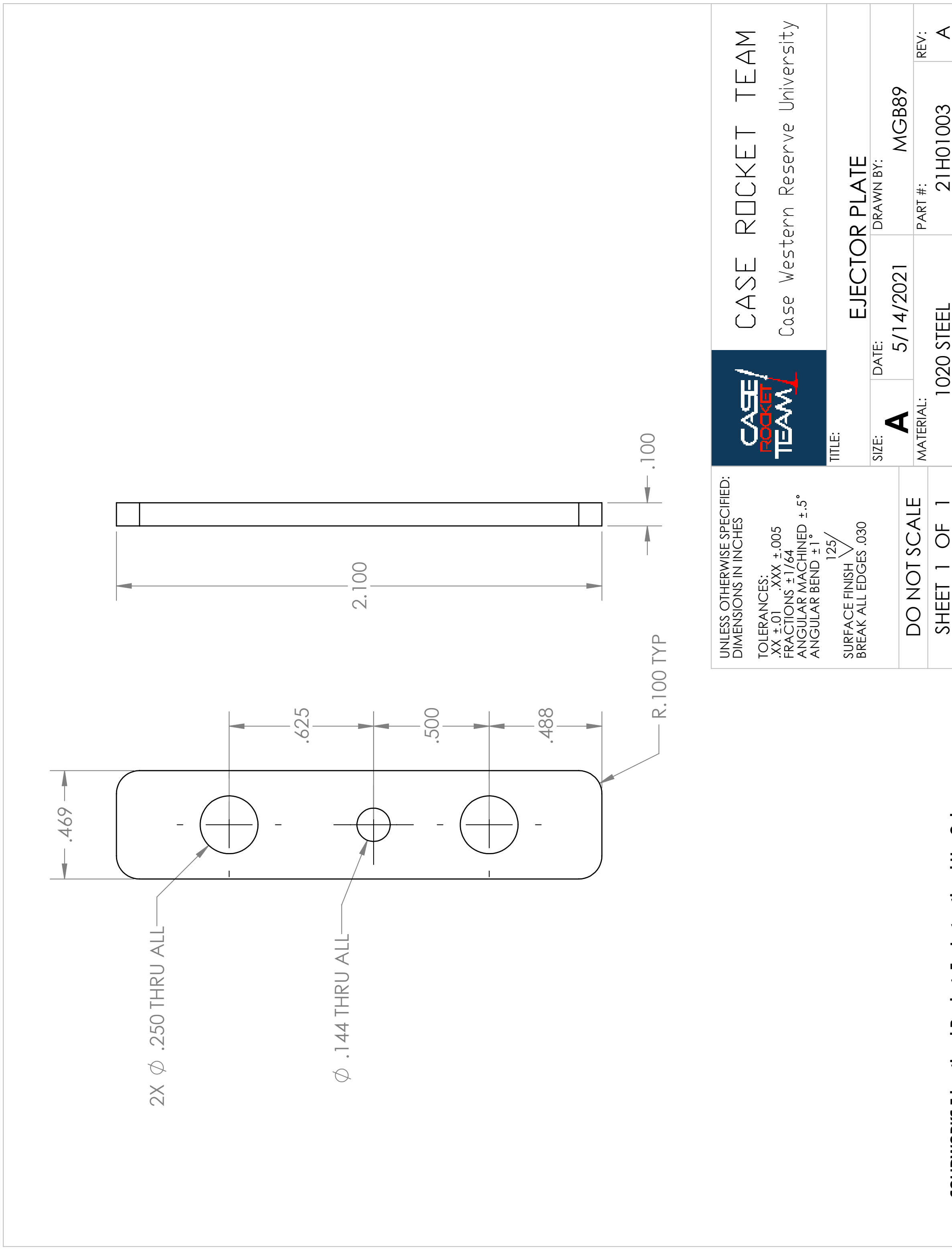
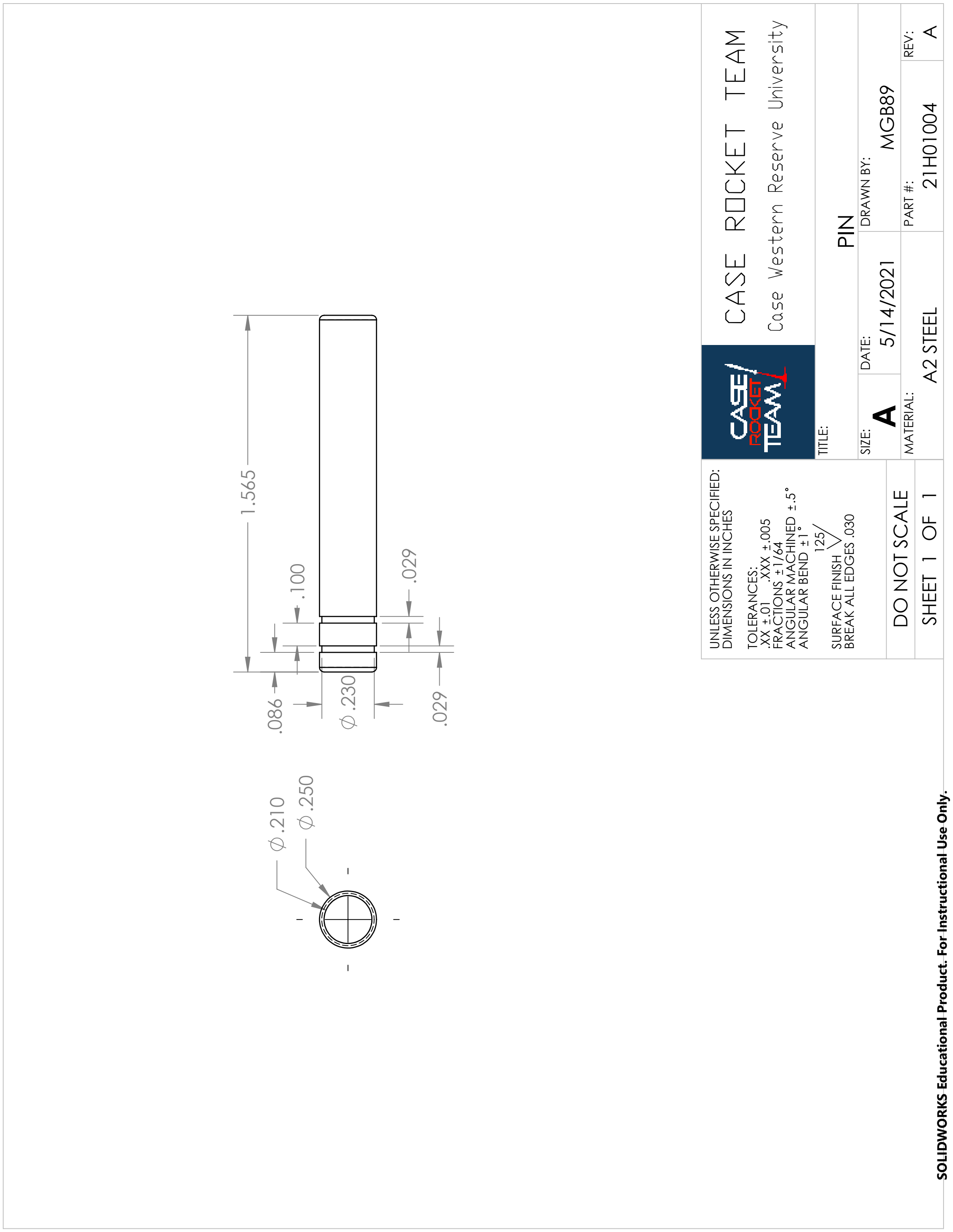
(2.363)
(1.250)
SOLIDWORKS Educational Product. For Instructional Use Only.

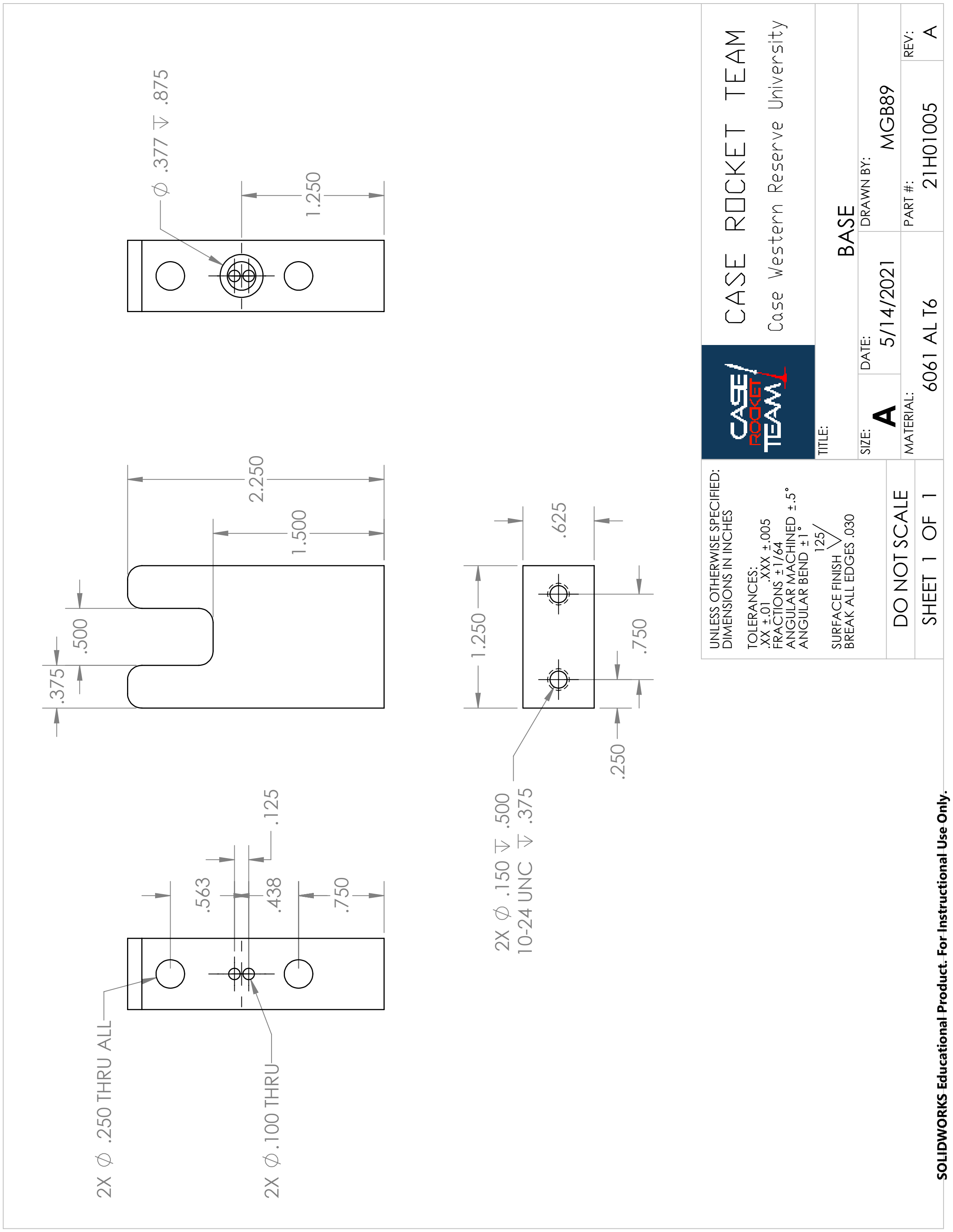


.825
.725
Ø .375
Ø .550
Ø .144 THRU ALL
Ø .266
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
CHARGE WELL
SIZE: A
DATE: 5/14/2021
DRAWN BY: MGB89
MATERIAL: DELRIN
PART #: 21H01002
REV: A
SOLIDWORKS Educational Product. For Instructional Use Only.

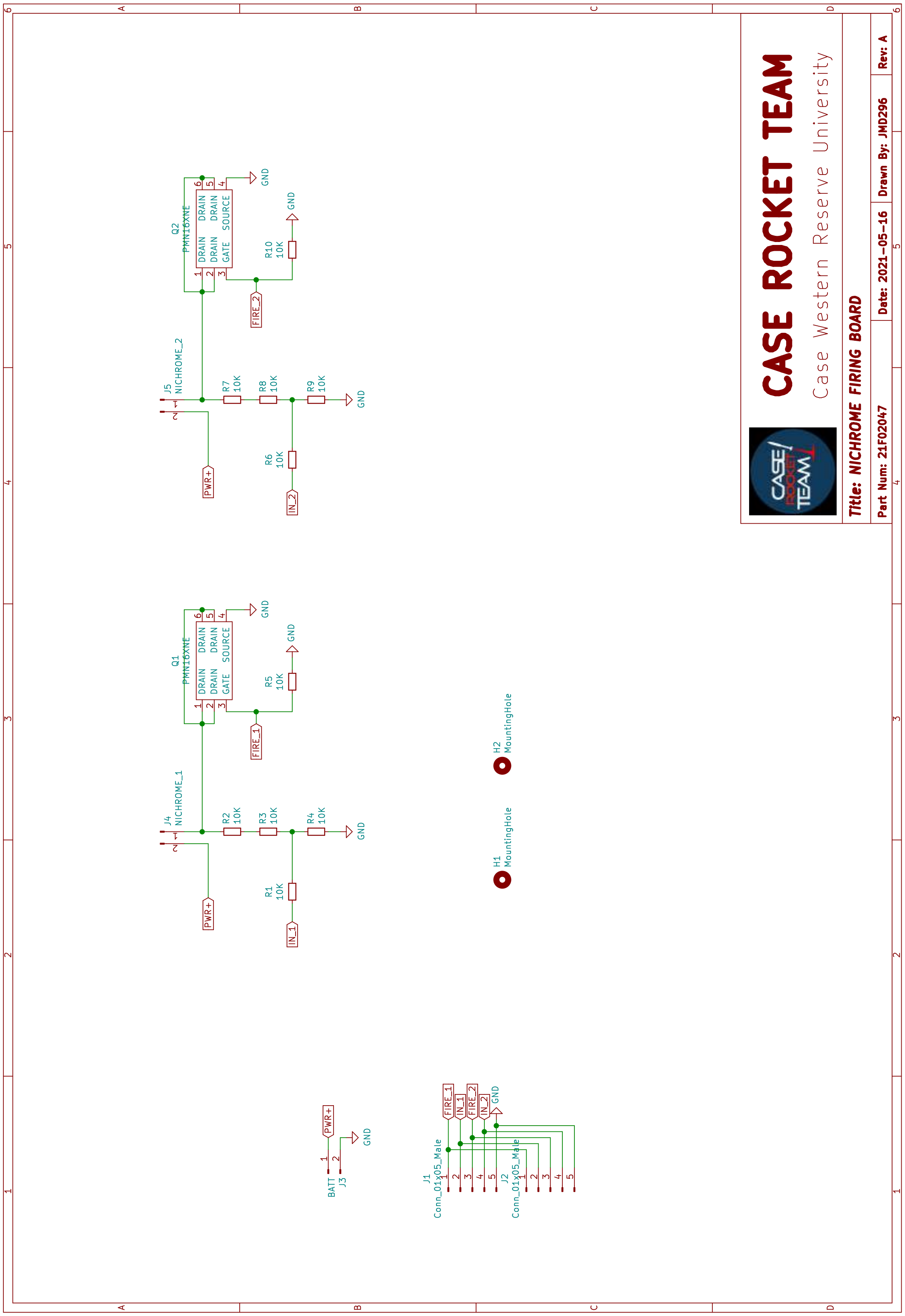


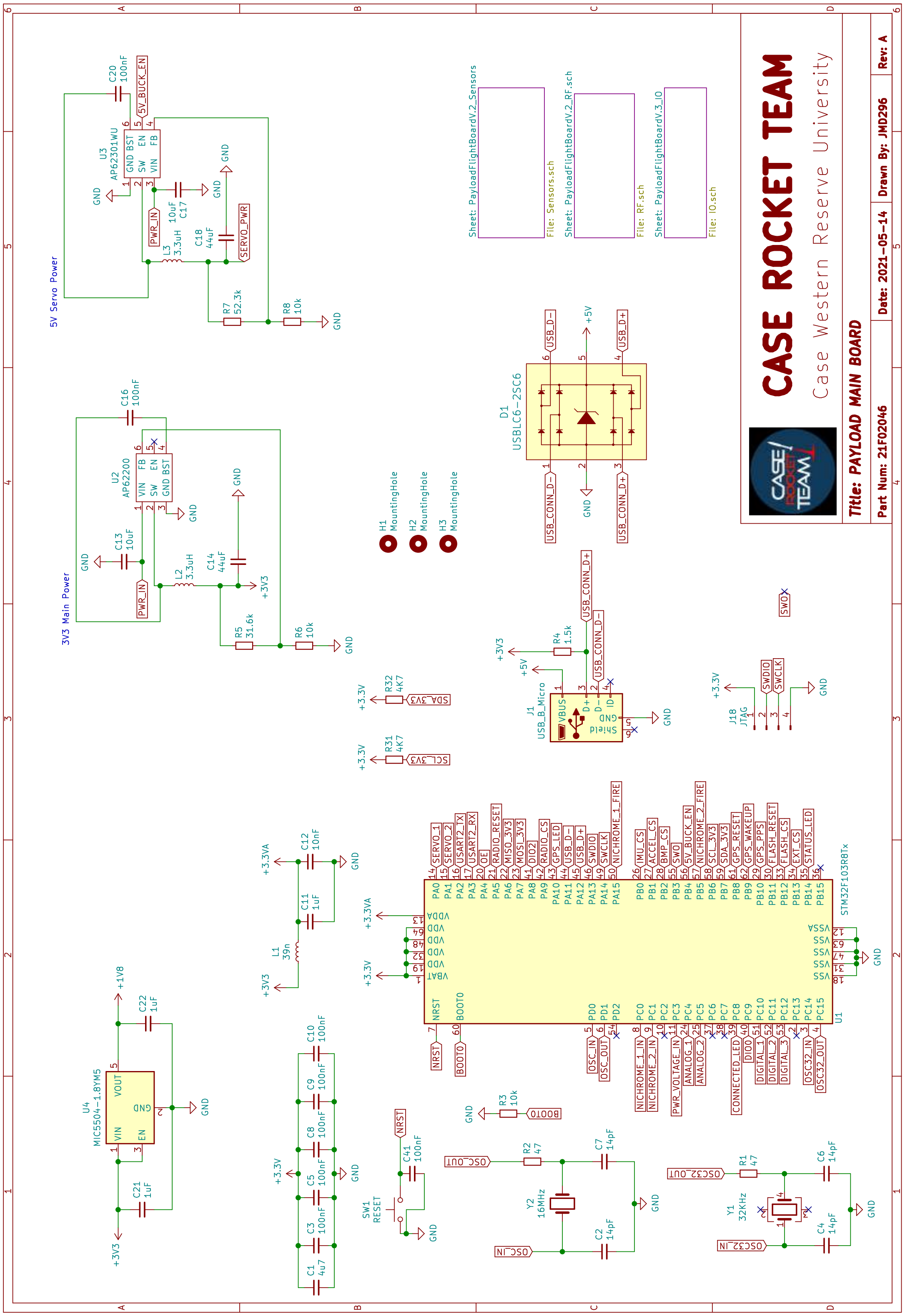
2X ∅ .250 THRU ALL
∅ .144 THRU ALL
.469
.625
.500
.488
R.100 TYP
2.100
.100
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
EJECTOR PLATE
SIZE: A
DATE: 5/14/2021
DRAWN BY: MGB89
MATERIAL: 1020 STEEL
PART #: 21H01003
REV: A
SOLIDWORKS Educational Product. For Instructional Use Only.

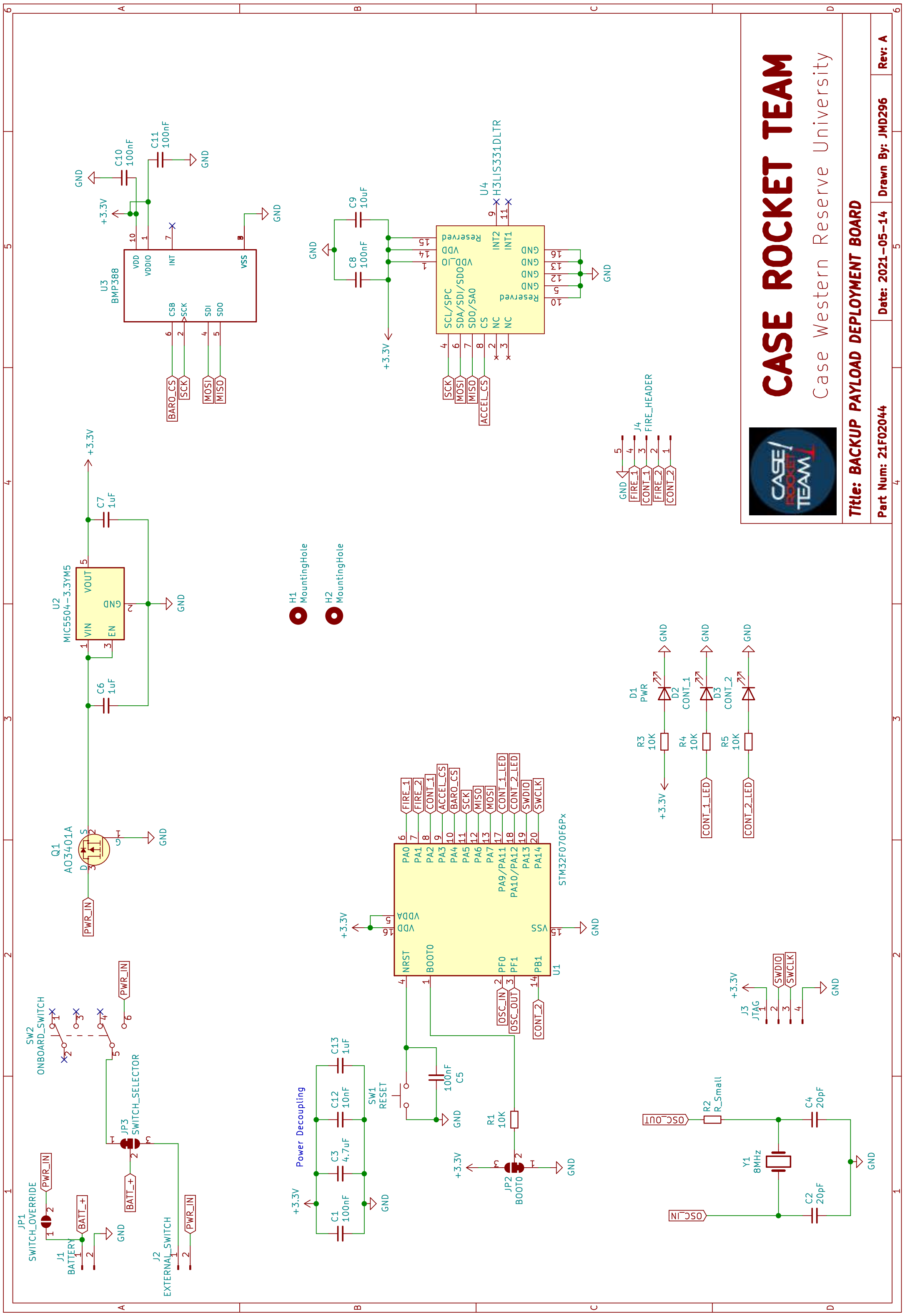

1.565
.100
.029
.086
⌀.230
.029
⌀.210
⌀.250
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS IN INCHES
TOLERANCES:
.XX ±.01 .XXX ±.005
FRACTIONS ±1/64
ANGULAR MACHINED ±.5°
ANGULAR BEND ±1°
SURFACE FINISH 125
BREAK ALL EDGES .030
DO NOT SCALE
SHEET 1 OF 1
CASE ROCKET TEAM
Case Western Reserve University
TITLE:
PIN
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MGB89
MATERIAL:
A2 STEEL
PART #:
21H01004
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.



2X ⌀ .250 THRU ALL
2X ⌀.100 THRU
.563
.438
.750
.125
2X ⌀ .150 ↧ .500
10-24 UNC ↧ .375
.375
.500
1.250
1.500
2.250
.625
.750
.250
⌀ .377 ↧ .875
1.250
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:
BASE
SIZE:
A
DATE:
5/14/2021
DRAWN BY:
MGB89
MATERIAL:
6061 AL T6
PART #:
21H01005
REV:
A
SOLIDWORKS Educational Product. For Instructional Use Only.


CASE ROCKET TEAM
Case Western Reserve University
Title: NICHROME FIRING BOARD
Part Num: 21F02047
Date: 2021-05-16
Drawn By: JMD296
Rev: A


CASE ROCKET TEAM
Case Western Reserve University
Title: PAYLOAD MAIN BOARD
Part Num: 21F02046
Date: 2021-05-14
Drawn By: JMD296
Rev: A
5V Servo Power
3V3 Main Power
Sheet: PayloadFlightBoardV2_Sensors
File: Sensors.sch
Sheet: PayloadFlightBoardV2_RF.sch
File: RF.sch
Sheet: PayloadFlightBoardV3_IO
File: IO.sch
STM32F103RBTx


CASE ROCKET TEAM
Case Western Reserve University
Title: BACKUP PAYLOAD DEPLOYMENT BOARD
Part Num: 21F02044
Date: 2021-05-14
Drawn By: JMD296
Rev: A
U3 BMP388
U4 H3LIS331DLTR
U2 MIC5504-3.3YM5
Q1 AO3401A
U1 STM32F070F6Px
SW2 ONBOARD_SWITCH
JP3 SWITCH_SELECTOR
JP1 SWITCH_OVERRIDE
J1 BATTERY
J2 EXTERNAL_SWITCH
JP2 BOOT0
SW1 RESET
Power Decoupling
H1 MountingHole
H2 MountingHole
J4 FIRE_HEADER
J3 JTAG
Y1 8MHz
D1 PWR
D2 CONT_1
D3 CONT_2

XVI. Airframe Bill of Materials

Item Number	Part Number	Description	Quantity	Material	P/M	Manufacturing Methods
1	21D000001	Rocket Assembly	1			
2	21D000002	Lower Body Tube Assembly	1			
3	21D000004	Upper Body Tube Assembly	1			
4	21D000006	Airbrakes Assembly	1			
5	21D000008	E-Bay Assembly	1			
6	21D01001	Nose Cone Tip	1	6061-T6	M	Turn, drill
7	21D01002	Nose Cone Body	1	G12 Fiberglass	P	Drill
8	21D01003	Nose Cone Coupler	1	G12 Fiberglass	P	Drill
9	21D01004	Nose Cone Assembly	1			
10	21D01006	Nose Cone Threaded Rod	1	Zinc Plated Steel	P	Cut to length
11	21D01007	Upper Body Tube	1	G12 Fiberglass	P	Cut to length, drill
12	21D01008	Payload Securement Corner	4	6061-T6	P	Waterjet
13	21D01009	Payload Securement Ring	1	6061-T6	P	Waterjet, tap
14	21D01010	Camera Band	1	G12 Fiberglass	P	Cut to length, drill
15	21D01013	Ejection Charge Holder	4	Delrin	M	Turn, drill, tap
16	21D01016	Motor Tube	1	G12 Fiberglass	P	Cut to length
17	21D01018	Thrust Plate	1	6061-T6	M	CNC mill, drill, tap
18	21D01019	Motor Tube Subassembly	1			
19	21D01020	M1450 Motor	1		P	
20	21D01021	Fin	4	G10 Fiberglass	M	Waterjet, grind
21	21D01022	Rail Button	2	Delrin	P	
22	21D01024	Lower Body Tube	1	G12 Fiberglass	P	Cut to length, drill
23	21D01025	Airbrakes Hinge Bulkhead	1	6061-T6	M	CNC mill, drill, tap
24	21D01027	Flap	4	G12 Fiberglass	M	Cut
25	21D01028	E-Bay Sled Lower Mount	1	6061-T6	M	Waterjet, drill, tap
26	21D01034	Drogue Chute	1	Nylon	P	
27	21D01035	Main Chute	1	Nylon	P	
28	21D01036	E-Bay Upper Bulkhead	1	6061-T6	M	CNC mill, drill, tap
29	21D01037	E-Bay Lower Bulkhead	1	6061-T6	M	CNC mill, drill, tap
30	21D01039	E-Bay Coupler	1	G12 Fiberglass	P	Cut
31	21D01045	E-Bay Sled Upper mount	1	6061-T6	M	CNC mill, drill, tap
32	21D01046	Recovery Body Tube	1	G12 Fiberglass	P	Cut to length, drill
33	21D01047	Recovery Coupler	1	G12 Fiberglass	P	
34	21D01048	Recovery Bulkhead	1	6061-T6	M	CNC mill
35	21D01049	Nose cone T3 GPS Mount	1	PLA	M	3D print
36	21D01050	Nosecone Raven Mount	1	PLA	M	3D print
37	21D01051	Nose cone Recovery Bulkhead	1	6061-T6	M	Waterjet
38	21D01052	Nosecone Battery Mount	1	PLA	M	3D print
39	21D01053	Motor Retainer Body	1	6061-T6	P	
40	21D01054	Motor Retainer Cap	1	6061-T6	P	
41	21D01055	Camera Shield Plastic	1	PETG	M	Laser cut
42	21D01056	Camera Shield Gasket	1	Rubber	M	Laser cut
43	21D01057	Nose cone RRC3 Mount	1	PLA	M	3D print
44	21D01058	Missileworks T3 Model	1		P	
45	21D02002	Raven4 Model	2		P	
46	21D02005	1s Lipo Battery	3		P	
47	21D02006	1s Lipo Battery Mount	2	PLA	M	3D print
48	21D02007	GoPro Hero 8 Black	1		P	

49	21D02008	GoPro Mount	1	PLA	M	3D print
50	21D02009	Featherweight GPS	1		P	
51	21D02010	Featherweight GPS Battery	1		P	
52	21D02011	GPS and Battery Mount	1	PLA	M	3D print
53	21D02018	E-Bay Threaded Rod	2	Zinc Plated Steel	P	Cut to length
54	21D02021	Raven4 Breakout Board	2		P	
55	21D02022	E-Bay Sled	1	Acrylic	M	Laser cut
56	21D02023	Featherweight GPS Mount	1	PLA	M	3D print
57	21D02024	Featherweight GPS Battery Mount	1	PLA	M	3D print
58	21D02025	Screw Switch Stand-offs	4	Delrin	M	Turn, drill, tap
59	21D02026	Screw Switch	2		P	
60	21D02027	RRC3 Mount	1	PLA	M	3D print
61	21D02028	RRC3 Model	1		P	
62	21D03002	Outer Linkage	4	6061-T6	M	Waterjet, drill, tap
63	21D03004	Actuation Tube	4	6061-T6	M	Cut to length, drill
64	21D03006	Rotary Encoder	1		P	
65	21D03007	NEMA 17 Stepper Motor	1		P	
66	21D03008	Stepper Bulkhead	1	6061-T6	M	CNC mill, drill, tap
67	21D03009	Upper Centering Ring	1	6061-T6	M	CNC mill, drill, tap
68	21D03010	Linear Rod	2	Carbon Steel	P	Cut to length
69	21D03011	Linear Bearing	2		P	
70	21D03012	Lead Screw Nut	1	Copper	P	
71	21D03013	Linear Carriage	1	6061-T6	M	CNC mill, tap
72	21D03014	Inner Linkage	8	6061-T6	M	Waterjet
73	21D03015	Actuation Tube Plug	4	6061-T6	M	Turn, drill, tap
74	21D03016	Plug Threaded Stud	4	Zinc Plated Steel	P	
75	21D03018	Lead Screw	1	Stainless Steel	P	Cut to length
76	21D03019	5-8 mm coupler	2	Aluminium	P	
77	21D03022	Limit Switch Threaded Stud	1	Zinc Plated Steel	P	Cut to length
78	21D03027	Launch Lug Attachment	1	6061-T6	M	CNC mill, drill, tap
79	21D03028	Flight Controller	1		P	
80	21D03029	Stepper Motor Controller	1		P	
81	21D03030	Avionics Sled	1	PLA	M	3D print
82	21D03031	Battery Sled	1	PLA	M	3D print
83	21D03032	Encoder Bulkhead	1	6061-T6	M	CNC mill, drill tap
84	21D03033	Avionics Sled Supports	4	Zinc Plated Steel	P	Cut to length
85	21D04002	1/4-20 Nylon Locknut	3	Zinc Plated Low-Strength Steel	P	
86	21D04004	1/4" Washer	13	18-8 Stainless Steel	P	
87	21D04005	4-40 1/4" Hex Nut	2	Zinc Plated Low-Strength Steel	P	
88	21D04007	4-40 3/4" Button Head Bolt	8	Zinc Plated Alloy Steel	P	
89	21D04008	1/4-20 Wing Nut	2	18-8 Stainless Steel	P	
90	21D04012	1/16" x 3/8" Coil Pin	8	1060-1090 Spring Steel	P	
91	21D04013	1/4-20 Hex Nut	48	Grade 5 Medium-Strength Steel	P	

92	21D04014	6-32 3/8" Button Head Bolt	2	Black-Oxide Stainless Steel	P	
93	21D04015	6-32 3/4" Button Head Bolt	26	18-8 Stainless Steel	P	
94	21D04016	6-32 Hex Nut	1	Zinc Plated Low-Strength Steel	P	
95	21D04019	10-24 1" Button Head Bolt	2	18-8 Stainless Steel	P	
96	21D04021	10mm M3 Socket Head Screw	11	Black-Oxide 18-8 Stainless Steel	P	
97	21D04022	3/16" Dowel Pin	12	Alloy Steel	P	
98	21D04023	3/16" Retaining Ring	24	Black-Phosphate 1060-1090 Spring Steel	P	
99	21D04025	15mm Retaining Ring	4	Black-Phosphate 1060-1090 Spring Steel	P	
100	21D04027	2-56 1/4" Head Screws	8	Nylon	P	
101	21D04030	10-24 1/2" Button Head Bolt	28	Black-Oxide Alloy Steel	P	
102	21D04031	Limit Switch	1		P	
103	21D04032	4-40 Set Screw	4	18-8 Stainless Steel	P	
104	21D04033	M2x0.4 10 mm Button Head Bolt	2	Black-Oxide Alloy Steel	P	
105	21D04034	M3x0.5 8mm Socket Head Screw	3	Black-Oxide 18-8 Stainless Steel	P	
106	21D04035	M3x0.5 Hex Nut	17	Class 8 Medium-Strength Steel	P	
107	21D04036	M3x0.5 10mm Button Head Bolt	17	Black-Oxide 18-8 Stainless Steel	P	
108	21D04038	M3x0.5 14mm Button Head Bolt	2	Passivated 18-8 Stainless Steel	P	
109	21D04040	6-32 1/2" Button Head Bolt	4	Black-Oxide 18-8 Stainless Steel	P	
110	21D04041	1/4"-20 Button Head Bolt	4	Zinc Plated Alloy Steel	P	
111	21D04043	1/4-20 1.5" U-Bolt	1	Steel	P	
112	21D04044	8-32 1/2" Socket Head Screw	12	Black-Oxide Alloy Steel	P	
113	21D04045	3/8-16 1.25" U-Bolt	2	Steel	P	
114	21D04046	3/8-16 Hex Nut	4	Grade 5 Medium-Strength Steel	P	
115	21D04047	3/8-16 Nylon Lock Nut	4	Zinc Plated Low-Strength Steel	P	
116	21D04048	3/8" Washer	6	18-8 Stainless Steel	P	
117	21D04049	1/4-20 1" Flat Head Screw	2	Black-Oxide Alloy Steel	P	
118	21H00001	Ejector plate Assembly	1			
119	21H00002	Tendie Descendie Assembly	1			
120	21H01002	Charge Well	1	Delrin	M	Turn, drill
121	21H01003	Ejector Plate	1	6061-T6	M	Waterjet
122	21H01004	Pin	2	Alloy Steel	P	Cut to length
123	21H01005	Base	1	6061-T6	M	Mill
124	21H02002	6-32 Hex Nut	1	Zinc Plated Low-Strength Steel	P	

125	21H02005	1/4" retaining ring	2	Black-Phosphate 1060-1090 Spring Steel	P	
126	21J000001	Main Assembly	1			
127	21J01001	Main Body	1	6061-T6	M	waterjet, mill, drill, tap
128	21J01002	Pin	2	Steel	M	waterjet, drill
129	21J01003	Outer Clip	1	6061-T6	M	waterjet, drill, tap
130	21J01004	Charge Well	1	Delrin	P	
131	21J02001	3/16 Retaining Ring	2	Black-Phosphate 1060-1090 Spring Steel	P	
132	21J02002	#6-32 3/8" Screw	2	Black-Oxide Alloy Steel	P	

XVII. Payload Bill of Materials

Item Number	Part Number	Description	Quantity	Material	P/M	Manufacturing Methods
1	21F00001	Main Assembly	1			
2	21F00002	Sensor Bay Sled (Camera)	1			
3	21F00003	Electronics Bay Sled	1			
4	21F00005	Nichrome Board Sled	1			
5	21F00006	Riser Hardpoint	4			
6	21F01001	Rear Frame Plate	1	6061-T6	M	Waterjet, mill
7	21F01002	Left Frame Plate	1	6061-T6	M	Waterjet, mill
8	21F01003	Top Bulkhead	1	A36	M	Waterjet, mill
9	21F01004	Electronics Bay Sled	1	Polycarbonate	M	Waterjet, mill
10	21F01009	Bottom Bulkhead	1	6061-T6	M	Waterjet, mill
11	21F01011	Sensor Package Sled	1	PLA	M	3D print
12	21F01013	#6-32 3/8" Button Head Bolt	24	18-8 Stainless Steel	P	
13	21F01015	#4-40 3/8" Standoff	5	18-8 Stainless Steel	P	
14	21F01016	#4-40 1/4" Button Head Bolt	13	18-8 Stainless Steel	P	
15	21F01017	#6-32 1/4" Button Head Bolt	8	18-8 Stainless Steel	P	
16	21F01024	Sensor Bay Shield	2	Acrylic	M	Laser cutter
17	21F01026	Electronics Bay Shield	2	Acrylic	M	Laser cutter
18	21F01028	Servo Arm	2	6061-T6	P	
19	21F01030	#4-40 Flat Head 100 1/2" Bolt	4	18-8 Stainless Steel	P	
20	21F01031	Camera Back Plate	1	PLA	M	3D print
21	21F01036	#6-32 1/4" Button Head Bolt	8	18-8 Stainless Steel	P	
22	21F01038	L Channel	4	6061-T6	M	Drill press
23	21F01039	D-Ring Hardpoint	4	6061-T6	M	Bending, drill press
24	21F01040	D-Ring	4	18-8 Stainless Steel	P	
25	21F01042	#6-32 3/8" Button Head Bolt	24	18-8 Stainless Steel	P	
26	21F01043	#6-32 3/8" 82 Flat Head Bolt	32	18-8 Stainless Steel	P	
27	21F01044	#4-40 Nut	10	18-8 Stainless Steel	P	
28	21F01045	Parachute Shield Attachment	8	6061-T6	M	Drill press
29	21F01046	Parachute Bay Shield	2	Acrylic	M	Laser cutter
30	21F01047	Front Frame Plate	1	6061-T6	M	Waterjet, mill
31	21F01048	Right Frame Plate	1	6061-T6	M	Waterjet, mill
32	21F01049	Middle Bulkhead	1	6061-T6	M	Waterjet, mill
33	21F01050	#4-40 3/8" Button Head Bolt	2	18-8 Stainless Steel	P	
34	21F01051	#4-40 3/8" Button Head Bolt	2	18-8 Stainless Steel	P	
35	21F02017	Featherweight GPS Battery	1		P	
36	21F02021	GPS LoRa Antenna	1		P	
37	21F02023	GoPro Hero 8	1		P	
38	21F02025	Control Line Servo Motor	2		P	
39	21F02027	Main Flight Board Battery	1		P	
40	21F02030	Featherweight Board	1		P	
41	21F02031	Featherweight Antenna	1		P	
42	21F02034	Competition Flight Board	1		P	
43	21F02039	Backup Board	1		P	
44	21F02040	Nichrome Battery Mount	1	PLA	M	3D print
45	21F02041	Servo Bracket	2		P	
46	21F02042	Nichrome Firing Board	1		P	
47	21F02043	Nichrome Board Mount	1	PLA	M	3D print
48	21F02044	Patch Antenna Retainer	1	PLA	M	3D print
49	21F02048	Main Battery Mount	1	PLA	M	3D print
50	21F02049	Backup Battery Mount	1	PLA	M	3D print
51	21F02050	1s LiPo Battery	3		P	