Oregon State University 30k Rocket Team: Technical Report

Team 21 Project Technical Report for the 2018 Spaceport America Cup

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A sounding rocket has been designed, manufactured, tested, and integrated by students at Oregon State University to reach an altitude of 30,000 feet, deploy an experimental payload, and perform a safe recovery of both the rocket and the payload. The final goal of the project is to compete at the Spaceport America Cup 2018 in New Mexico and compete in the 30K SRAD Solid Motor category. The rocket is 13 feet long, weighing in at 106 lbs fully loaded, and has been simulated to an altitude of 28,401 ft and will be launched from a custom OSU launch rail. The propulsion system is a custom designed, O-class solid rocket motor. The airframe body tubes are sponsor donated. The nose cone, fins, bulkheads, and couplers are student built. The initial payload was designed to be a microgravity experiment, accelerating downwards by means of a propeller from apogee until a separate payload recovery system is deployed. During its descent, the system would create a microgravity environment for experiments contained inside. After an unfortunate loss of this payload during a test launch, a new payload has been designed and manufactured that is also deployable. The new payload will descend from apogee under drag from a drogue parachute, filming the ground below with a combination of an infrared camera and a standard camera lens to assist with wildfire tracking. The recovery of the rocket utilizes a dual deployment black powder system.

Nomenclature

OSU	=	Oregon State University
ESRA	=	Experimental Sounding Rocket Association
AIAA	=	American Institute of Aeronautics and Astronautics
30k	=	30,000 feet
ME	=	Mechanical Engineering
ECE	=	Electrical and Computer Engineering
CS	=	Computer Science
AGL	=	Above Ground Level

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I. Introduction

The Oregon State Experimental Sounding Rocket Association 30k Rocketry team is a student-led competition rocketry team that is a part of the OSU AIAA branch, which was founded in 2012. The OSU ESRA team consists of four mechanical engineering subteams (Propulsion, Structures & Integration, Aerodynamics & Recovery, and Payload) each with three ME students, one Electrical and Computer Engineering subteam with three ECE students, and one Computer Science subteam with three CS students. The 18 students that make up the subteams described above are all of senior standing in their respective majors. The senior students are assisted by underclassmen who wish to participate, as well as advised by faculty advisor Dr. Nancy Squires. The team, as described here, works to fulfill the project requirements as they relate to the individual requirements of each subteam. The Structures & Integration subteam is then responsible for efficient integrating the work of each subteam into the rocket.

II. System Architecture Overview

This section provides an overview of the OSU ESRA 30k Team's integrated launch vehicle and detailed descriptions of the propulsion, aero-structures, recovery, and payload subsystems.

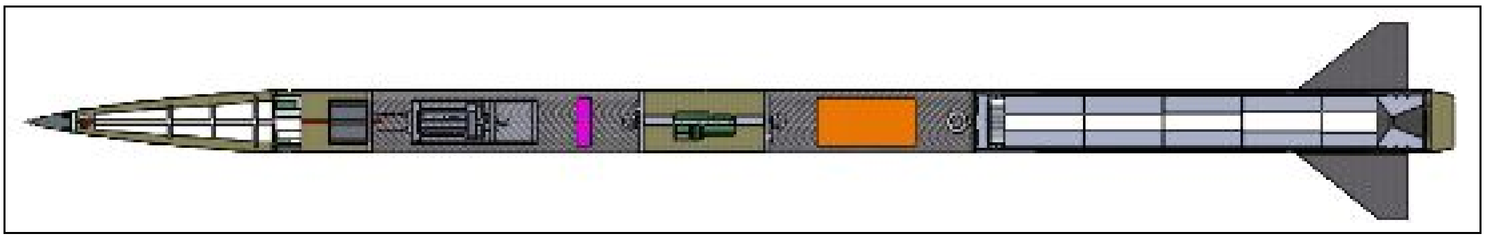

Figure 1: Fully integrated launch vehicle.

Figure 1., above, shows the fully integrated launch vehicle as it will be configured for the Spaceport America Cup launch. The launch vehicle can divided into four main sections. These sections are the nose cone, upper airframe, midaby coupler, and lower airframe. The lower airframe can be further broken up into an upper and lower section. The subsystem components housed in the different sections are listed below.

Nose Cone
- Rocket telemetry electronics
- Non-deployable payload

Upper Airframe
- Deployable payload
- Drogue parachute and ejection charges

Midbay Coupler
- Drogue and main parachute recovery system electronics
- Pi camera and pi camera electronics

Lower Airframe (upper section)
- Main parachute and ejection charges

Lower Airframe (lower section)
- Solid motor
- Fins

A. Propulsion Subsystem

The selected propulsion system is a student researched and designed (SRAD) solid rocket motor. The motor casing will be constructed from a 5.0” ID, 6.0” OD 6061-T6 aluminum tube. The alloy was selected because it has a high strength to weight, ratio, low cost compared to composites or specialty metals, and is widely available. The propellant is an ammonium perchlorate composite propellant (APCP) and is casted into 5 grains, all following BATES format. To protect the motor casing from the high heat of combustion, a filament wound, fire retardant fiberglass tube lines the inside of the casing. The propellant grains are glued in place inside the liner. The nozzle is machined from superfine isomolded graphite. The forward end of the motor is capped with an aluminum plug, held in place with 12 steel fasteners. The nozzle is held in place with a snap ring.

The motor casing is 46” long and has an inner diameter of 5.0”. The nominal wall thickness is 0.20”. This wall thickness gives a safety factor of 3.8 against yielding with a chamber pressure of 800 psi, assuming no thermal effects. The safety factor is based on the standard equations for a cylindrical pressure vessel that is thin walled.. The ends are thicker for two reasons. First, both the forward enclosure and nozzle retaining methods are stress concentrations. The second reason is ensuring concentricity with respect to the airframe. The outer diameter of the forward enclosure is approximately 0.010”-0.005” smaller than the inner diameter of the airframe 5.68”. The nozzle end is approximately 0.050” smaller to allow for a boat tail coupler to interface at the end. There is a raised ring that sit ⅓ from the bottom. Similar to the forward end, the ring is machined to a diameter of 5.675”. Again, the ring is to ensure concentricity.

The forward enclosure is manufactured from 6061-T6 aluminum. 12 3/8”-16 radial bolts will pass through the 0.380” holes in the motor casing to thread into the forward enclosure to hold it in. The forward enclosure is not bound in any one radial direction, so it is not possible for a gap to be introduced by tightening one bolt more than another. Two O-ring grooves are machined into the forward enclosure to ensure a proper seal against the chamber walls. Two O-ring grooves were chosen for redundancy. The O-rings are high temperature, silicone O-rings from McMaster Carr. There is a threaded area at the top to allow a threaded eye bolt to thread in and anchor the main parachute chords.

The fasteners used for the forward enclosure assembly are black oxide steel hex driven screws from McMaster Carr. The screws are threaded 3/8”-16. The screws have a tensile strength of 170 ksi the strongest available on McMaster Carr. The diameter and number bolts was determined from assuming the internal chamber pressure is distributed across an equivalent area of a cross section of the casing. Meaning that there is an equivalent force of 15,800 lbf pushing against the forward enclosure. The force experienced by each bolt would be 1,310 lbf. It is assumed that the fasteners are of uniform diameter equal to the minor diameter of the thread type, 0.3125” in this case. For the loading case described, there is a 22,760 psi shear stress being applied to each fastener. Steel retains approximately 57% of its tensile strength in shear so a 170 ksi bolt can withstand 98 ksi in shear. Thus the safety factor of the fasteners is 4.25 [1].

In amateur rocketry, the liners used in large motors are often convolute or filament wound paper, canvas, or fiberglass tubes. While not specifically for rocketry, the chosen liner is a 5.0” OD, 4.71” ID, 0.144” thick filament wound fiberglass tube with a fire retardant resin system.

There is a steel ring that interfaces between the aft end of the nozzle and the snap ring. The ring is used in conjunction with the snap ring to retain the nozzle within the pressure vessel during the motor fire. The increase in surface are between the snap ring and steel retaining ring prevents the brittle graphite from cracking during combustion. The snap ring groove geometry was selected based on criteria against yield from a snap ring manufacturer’s handbook.

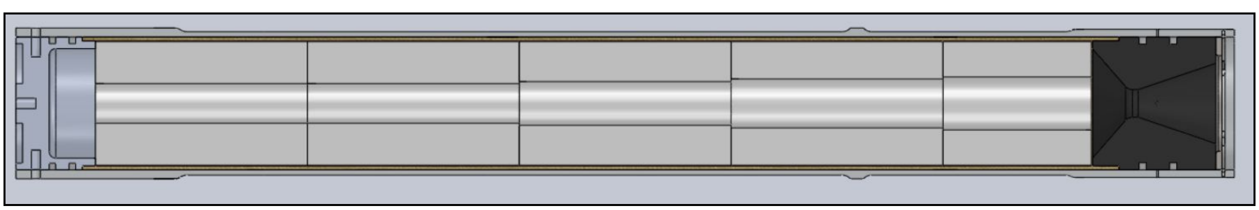

Figure 2: Motor tube cross-section model.

The propellant formulation in use is termed "Orange Koolaid" or simply "OK" by the team. The name represents its bright orange colored flame. OK is an APCP propellant that has a medium burn rate and utilizes unimodal ammonium perchlorate. The grain geometry is stepped BATES meaning the core diameter of the grain increases as the grain position becomes more aft. This is to allow a prolonged burn with smaller core sizes without compromising the core area to throat area ratio. The core diameters from forward to aft are 1.5", 1.5", 1.65", 1.85", and 2.0". The forward 4 grains are all 8" long and the most aft grain is 5" long. All grains are casted into a 4.625" ID, 4.70" OD casting tube.

Wireless Ignition System

The lists and descriptions that follow include all of the electrical components used in the wireless ignition system depicted below as well as a description of both the control and rocket ends of the system.

Control Box

The control box end of the ignition system is powered by a 7.4 volt Lipo battery. The system is powered on by inserting the key and turning it ninety degrees right. Next, the system is armed when the chrome switch is flipped. A red LED and a sound emitting buzzer turn on when the system is armed. To ignite the rocket the large red button is pressed and held down and Arduino Mega sends a signal to the XBee to transmit to the rocket box.

Component List:

- XBee Series 2 Transmitters
- Arduino Mega
- 7.5V Lipo Battery
- Sound Emitting Buzzer
- Push Button
- Red LED
- Chrome Switch
- Lock Switch

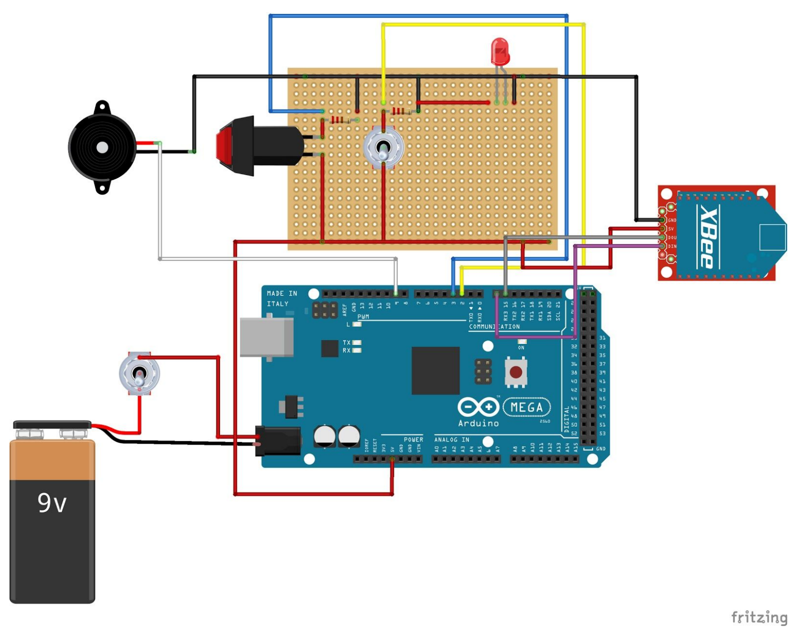

Figure 3: Control box schematic.

Rocket Box

The rocket end of the ignition system is powered by a 12 volt power supply that is plugged into a generator. The system is powered on by flipping one the first red switch. Next the system is armed when the second red switch is flipped. A red LED turns on when the system is armed. To ignite the rocket, a XBee receives a signal from the control end XBee transmitter. An Arduino Mega recieves the signal from the Xbee and sends a signal to a voltage relay to supply current to the igniter.

Component List:

- XBee Series 2 Transmitters
- Voltage Relay
- Arduino Mega
- 12V Power Source
- Generator
- Red LED
- 2 Red Switches

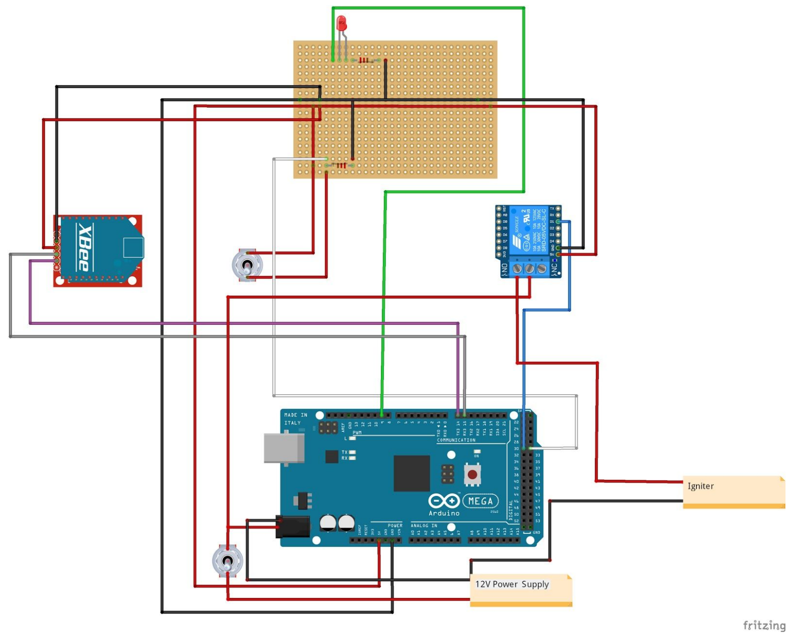

Figure 4: Rocket box schematic.

B. Aero-Structures Subsystems

The Aero-Structures subsystem is broken up into four sub-subsystems: airframe, nose cone, fins, and motor retention and boat tail. The design, manufacturing, and testing details for each sub-subsystem are described in the sections below.

Airframe:

The body tubes follow a layup schedule of [90/45/0/45/90] and was rolled and donated by our sponsor, Innovative Composites Engineering. Extra bands of material were wrapped at the ends known as patching to prevent zippering in the body tubes. The lower body tube is made out of Carbon Fiber while the upper body tube is made out of fiberglass. The use of RF transparent fiberglass in the upper body tube is to allow for communication with the payload, recovery system, and avionics housed in the upper airframe. A drawing for the specifications of the body tubes can be found in Appendix F. In order to validate the strength of the body tubes a compression test was performed in accordance to ASTM D695-15. With information gathered from the other subteams the max thrust produced by the motor is 7.5 kN and the max drag caused by the recovery system is 4 kN creating a max compressive force of 11.5 kN. From Figure 5, the compression test was taken far past the max compressive force of 11.5 kN. The little dips in the graph is due to the body tube sample being uneven at the edges. The higher local points at the edges broke as the body tube test sample is compressed.

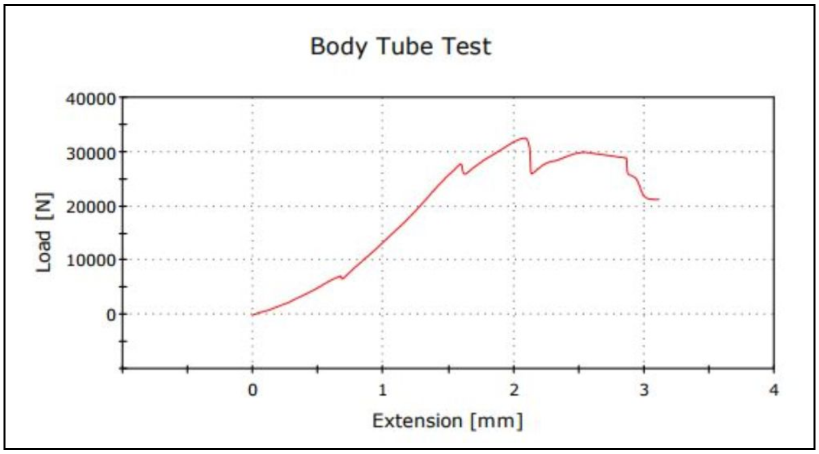

Figure 5: Body tube compression test data.

All couplers used to join the main structural components of the rocket are made out of Pre-impregnated Kevlar. Pre-impregnated Kevlar was chosen because the material is easy to use. A layup schedule of [90/45/-45/90]s was used for the three coupler tubes and was determined using Helius Composite Software. The coupler tubes were laid up and cured using Oregon State's Composite lab. An extra cut of the body tubes was used as a female mold for the couplers. The pre-impregnated plies were cut by hand. Specifications for the mid bay coupler can be found in Appendix F. The bulkheads used to enclose the mid bay coupler was machined out of G10 fiberglass using a Bridgeport CNC. A drawing of the model used to generate the G code can be found in Appendix F. An avionics ladder was 3D printed to mount electrical components and was secured within the mid bay coupler by running a threaded rod through the ladder. In order to test the strength of the bulkheads a testing sample was epoxied within a test body tube sample. Following ASTM D695-15, a load was applied to the testing sample. The epoxy failed rather than G10 fiberglass bulkhead at 8.5 kN. The graph for this test can be found in Figure 6. From these results, the bulkhead will be able to withstand the forces caused by the propulsion and recovery system.

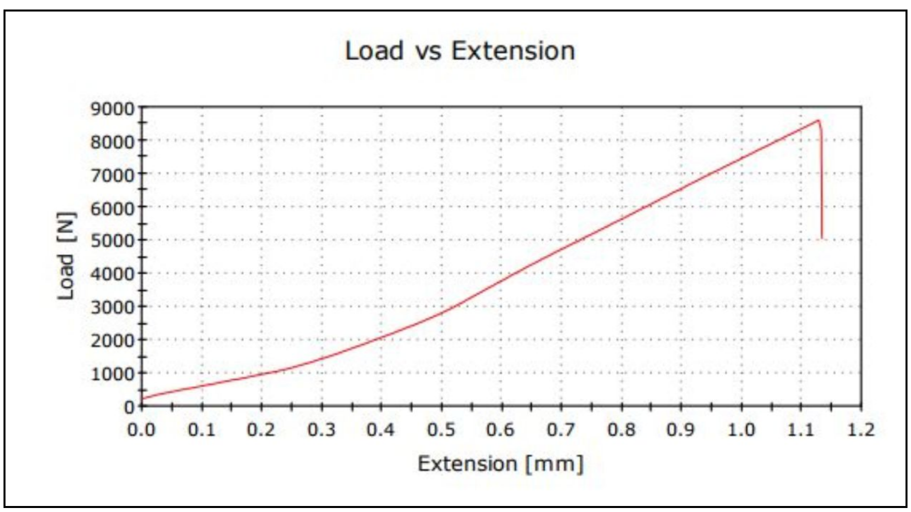

Figure 6: Motor bulkhead load test data.

The rail guide is screwed in by two screws into an aluminum hard point located within the body tube. The hard point is a 2"x1.5"x1/4" cube machined using Sharpe End Mill.

Nose cone:

The nose cone is a Von Karman Haack series profile, with a total length of 28 inches to provide the necessary internal volume to mount the avionics electronics. The Von Karman profile was selected for its performance in the high subsonic and transonic regions.

The primary structure of the nose cone was manufactured using prepreg Kevlar and fiberglass for their RF transparency. The Kevlar provides strong impact resistance to protect the avionics, and the fiberglass provides a sacrificial layer. The nose cone was laid up over an enamel-coated male mold using a layup schedule of [0/0/45/-45/0/0] for the prepreg Kevlar. The layup was finished with an additional fiberglass schedule of [0/0] to allow for post-processing on the outer surface. The Kevlar and fiberglass were vacuum bagged and cured at 275℉ for 6 hours in the autoclave. Once the nose cone was cured, the nose cone was removed from the male mold. Due to ridging, two additional layers of wet fiberglass were used to to protect the Kevlar prior to sanding. Once cured, the outer surface of the nose cone was sanded smooth on a lathe. The tip of the composite nose cone was parted off using a grind wheel, and the remaining nose cone body was sanded to final length.

The tip of the nose cone was machined from aluminum to provide good resistance against heating caused by shockwave formation at the tip of the rocket during flight. The aluminum tip of the nose cone was machined on a Haas CNC lathe. The aluminum tip of the nose cone is integrated into the primary structure using a steel centering ring. The steel centering ring follows the internal Von Karman profile of the nose cone and was machined on a Haas CNC lathe. The upper face of the steel ring is flush with the upper edge of the Kevlar and is held in place using epoxy. The shoulder of the aluminum nose cone tip sits flush to the upper face of the steel ring. The base of the aluminum tip slides through the steel ring until flush with the lower face. The aluminum tip is fastened to the nose cone using a washer, a G10 bulkhead, and a 2-inch eye-bolt. The G10 bulkhead rests on the lower face of the steel ring, and was machined to follow the internal Von Karman profile on a Bridgeport CNC. The washer is placed on the length of the eye-bolt and the eye-bolt is threaded into the aluminum tip from the inside of the nose cone. This assembly can be seen in Figure 7.

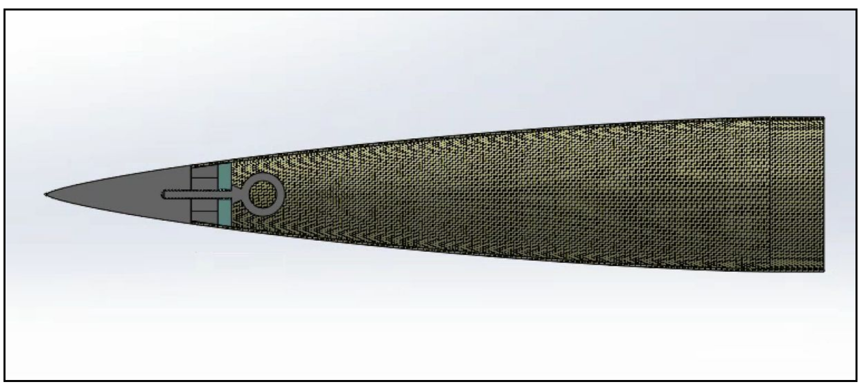

Figure 7: Section view of nose cone assembly

A length of spectra cord is anchored to the eye-bolt. The spectra cord runs through the primary structure of the nose cone and the lower G10 bulkhead which secures the tip to the nose cone to the upper body tube. The lower bulkhead is held in place with a clamp around the spectra cord.

The nose cone houses an avionics ladder which slides onto the spectra cord. The primary function of the avionics ladder is to house one of the GPS antennas used to locate the rocket during flight and recovery. The base of the nose cone has an integrated Kevlar coupler which allows for the nose cone to interface correctly with the upper body tube. The outer edge of the nose cone is flush with the taper in the upper body tube.

Fins:

The fin design began with determining their basic geometry which was first done by researching traditional fin design and narrowing down the results based on which ones could be applied to this rocket. Then the selected geometries were modeled in OpenRocket to see what their effect on the rocket stability and altitude would be. Through this process the clipped delta fin geometry was chosen. To determine the final dimensions of the fins, initial measurements of root chord, span, and tip chord were chosen as starting points and then the iterated until fins with optimal aerodynamics were produced. This process was done for both a three and four fin rocket design. The final fin dimensions determined through this process are as follows: Root Chord =11.38 in.,Tip Chord =.845 in., Span =6in. The thickness of the fins is equal .217 in. with a bevel taper length of .39 in. and an edge length is equal to .0625 in.

The fins consist of three materials: a G10 fiberglass frame, Nomex honeycomb core, and prepreg T800 carbon fiber skin. The use of three materials reduces the risk of fin flutter as each material has a different resonance frequency, which prevents the fins from vibrating at a single frequency to the point of failure [2]. A carbon fiber honeycomb sandwich design was selected because it is strong but lightweight. The G10 fiberglass frame adds weight but provides an aerodynamic leading edge and impact resistance.

The G10 frame was machined on a Bridgeport CNC. A drawing of the of the model used to generate the G code can be found in Appendix F. The inner section of the frame was used as a stencil to cut out the honeycomb core. The carbon fiber plies were cut on a ply cutter. A drawing of the DXF file used to cut out the plie can be found in Appendix F. The layup schedule for the fins is [0/45/-45/90/c/90/-45/45/0]. A symmetric, quasi-isotropic layup schedule was selected to prevent warping and provide equal strength in all directions in the plane of the part [3]. The fins were vacuum bagged and cured at 270℉ for 2 hours in an autoclave. Once the fins were cured, the fin edges were beveled using a table saw.

3-point bend tests were performed on a set of test fins on an Instron machine. Three fins were tested following ASTM C393 standards and a plot of force versus displacement for the three fins can be seen in Figure 8. The fins withstood an average maximum force of 2.24 kN. After the fins were tested the four fins for the rocket were manufactured.

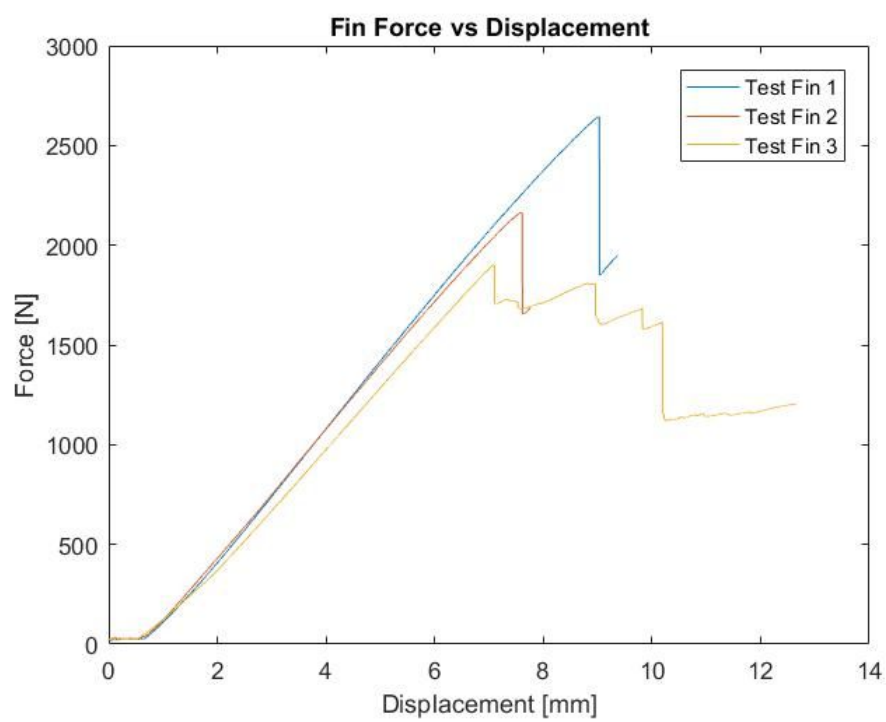

Figure 8: Plot of force vs displacement for fin 3-point bend tests

The fins are are attached to the airframe with epoxy fillets and reinforced with tip-to-tip layup. To align the fins and hold them in place while they were attached, a fin alignment guide was machined out of the aluminum. The fins were aligned against the lower airframe using the guide and the fins were attached with an initial set of epoxy fillets as seen in Figure 9. After the initial fillets cured the lower body tube with the fins was laid horizontally on a stand and thick epoxy fillets were applied as seen in Figure 10.

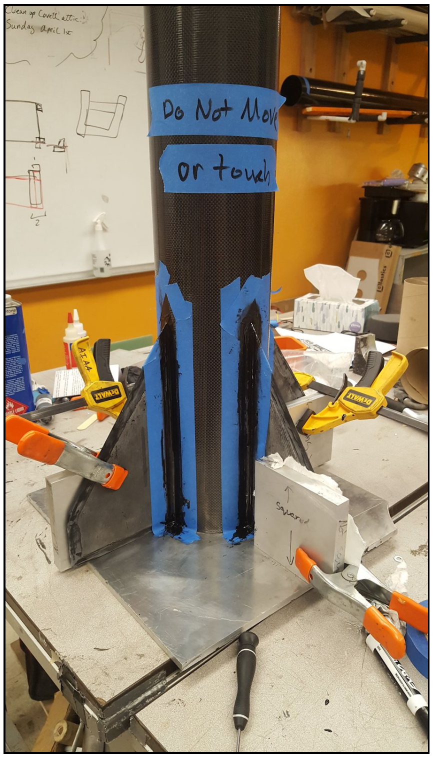

Figure 9: Fin alignment and initial attachment

Figure 10: Epoxy fillet process for fins

The epoxy fillet were allowed to fully cure for two days and then the fins were reinforced with a tip-to-tip layup. A tip-to-tip layup was selected because it increases the stiffness of the fins and the attachment points which prevents fin flutter and reduces the chance of the fins breaking during flight or on impact. The layup schedule for the tip-to-tip integration is $[90_4]$ with three plies of prepreg Kevlar and one ply of prepreg twill carbon fiber on top. The plies were cut on a ply cutter and drawings of the DXF files used to cut out the plys can be found in Appendix F. For the layup the plies are laid up from the tip of one fin to the base of the fin, around the body tube to the base of the next fin, and up to the tip of the other fin. The end of the airframe and the fins were vacuum bagged and cured at 235℉ for 8 hours in an autoclave. Once the tip-to-tip layup was cured, the fin edges were trimmed to remove any excess material and epoxied to prevent delamination.

Motor Retention and Boat Tail:

The motor is retained at the upper and lower end of the the motor casing. The forward enclosure rests against a ⅜" thick G10 bulkhead that is epoxied into the airframe. There is a clearance hole at the center of the bulkhead for a ½"-13 eye bolt that screws into the forward enclosure and holds the motor against the bulkhead. The main parachute shock cord attaches to the eye bolt on the other side of the bulkhead. The bottom of the motor casing is secured radially to the airframe with four 10-32 steel screws. One of the four screws doubles the rail button.

To test the motor retention system a spare bulkhead was epoxied into an extra section of the carbon fiber airframe. Four radial holes were drilled into the airframe and a 6” section of extra motor casing tube. The section of motor casing tube was secured to the section of airframe with four 10-32 screws so that it rested against the bulkhead, similar to how the motor would be retained in the actual rocket. An Instron compression test was performed on the test section. The section of airframe acted as the base and 2” of the motor casing tube stuck out above the airframe and this was pressed on during the test. The retaining system started to fail at 16 kN. A plot of force versus displacement can be seen in Figure 11. The smaller dips in the graph are due to the uneven edge of the airframe section. Since the edge was not completely flat, the higher parts of the broke as it was compressed. The simulated maximum thrust, which is the maximum force on the retaining system, is about 7 kN so the retaining system has a safety factor of 2.3.

Figure 11: Plot of force versus displacement for motor retention system

The boat tail has a consistent section with a distance of 2 in. and a diameter of 5.68 in., then transitions to a conical shape which tapers to a 4.9 in. end diameter over a distance of 2.5 inches. A drawing of the boat tail can be found in Appendix F. Prepreg Kevlar and prepreg fiberglass are used for the boat tail. Kevlar was selected for its impact resistance as it will be protecting the end of the motor casing and nozzle. The fiberglass provides a sacrificial layer for sanding. The nose cone was laid up over an enamel-coated male mold using a layup schedule of [0/45/90/45/0] for the prepreg Kevlar. An additional fiberglass schedule of $[0_5]$ use laid up on top of the Kevlar to allow for post-processing on the outer surface. A drawing of the DXF file used to cut out the plie can be found in Appendix F. The boat tail interfaces with the airframe with a Kevlar coupler. The coupler slides between the motor casing and the airframe and is secured with the four radial screws.

C. Recovery Subsystems

The recovery systems utilize a 10 ft. diameter hemispherical toroidal main chute and a 3 ft. diameter hemispherical toroidal drogue chute with spill holes that measure ⅕ of the diameter of the chute itself. The hemispherical toroidal shape was selected for it’s relatively high coefficient of drag of approximately 2.2 as well it’s relatively low packing size in relation to it’s packed volume. The sizing of the parachutes was calculated using MATLAB code that can be seen in Appendix B. Each chute is composed of 12 zero porosity ripstop nylon gores and are sewn together with nylon thread. The inner and outer nylon shroud lines are attached to a nylon bridle which is made of tubular nylon webbing and a mix of nylon and kevlar thread. The bridle is attached to the shock cord using a steel swivel link.

The team designed and manufactured a prototype full CO2 ejection system that utilized a spring loaded spike to puncture a 38g CO2 cartridge. The system used an Arduino Uno and an XYZ servo motor to pull a steel pin that would in turn release the spring loaded spike and puncture the cartridge. However, the system could not be made to work reliably in ground testing and the idea was abandoned before the first full test launch.

The final ejection systems for the drogue and main chute ejection events utilize full black powder charges. The ejection event at apogee which deploys the drogue consists of a 14g black powder charge encased in ¼" surgical tubing with the ends closed with zip ties and triggered by an E-match. The primary E-match is triggered by pressure readings from a Stratologger. The backup system for this is a secondary 14g black powder charge also triggered by an E-match set on a time delay from the initial charge. The ejection system to deploy the main chute consists of a 12g black powder charge that is triggered by an E-match. The E-match is triggered by the pressure readings from a Stratologger at an AGL of 1500 ft. The backup trigger for this system is a secondary 12g black powder charge that is triggered by a separate Stratologger and triggers the charge at an AGL of 1250 ft.

Live GPS telemetry accompanies the parachute ejection systems as a critical component in rocket recovery. The GPS data is received from satellites and retransmitted as an APRS formatted packet in the 70cm band by a Beeline GPS 70cm 100mW in both the nose cone and deployable payload. Fundamental to the APRS format is the AFSK encoding which allows both data decoding when the signal is strong and direction finding with audio when the signal is weak. Direction finding capabilities therefore act as a redundant method to the GPS data. Student designed and built antennas are present at both the transmitting and receiving ends of the RF link to provide an optimal configuration for a given environment and other constraints. In the nose cone, a significant RF transparent section allowed a vertical dipole, providing a highly desirable omnidirectional radiation pattern. In the payload, space constraints and a heavily metal structure necessitated a deployable bazooka antenna that is deployed with the drogue.

Several antennas are present on the receiving end at the ground station where the data packets are de-modulated and converted to an audio signal. For each transmitter, there is a corresponding 5-element Yagi and vertical dipole. Yagi design incorporates 1'' and 0.5'' copper pipe as the boom and elements, respectively, along with a parallel capacitor to each half and a ferrite bead balun. This nonstandard matching network eliminates the mechanically worrying series capacitor present in the gamma match while maintaining several degrees of freedom and a complete overall network. The 5-element Yagi serves as the primary receive antenna as it exhibits high directionality and therefore allows a stronger signal for a given link path loss. The Yagi, however, must be pointed to within approximately 45 degrees to achieve any beneficial gain. The vertical dipole therefore serves as a redundant receive antenna which requires no pointing, only suffering at apogee due to the null off its axis. The two antennas together provide a more reliable receive system.

Received telemetry is parsed from four audio signals using Direwolf software running on four Raspberry Pi Zeroes. There are two parsers for signals from the rocket, and two parsers for signals from the payload. These parsers are connected to a database which stores telemetry data. Additionally, a computer is used to serve a web based application which displays this telemetry data during flight, specifically the altitude and location of both the payload and the rocket.

D. Payload subsystems

The OSU payload was originally planned to be a deployable microgravity experiment (Figure 12), which used a combination of a propeller and a reaction wheel to create a microgravity environment for experiments carried inside. However, this design was lost due to a loss of contact during the first test launch of the OSU ESRA rocket on May 13th, 2018. This report will describe the details of this original design as well as the redesigned payload that will be launched at the Spaceport America Cup in June.

Figure 12: Original 2018 OSU Payload

Original Payload:

The external structure of the original payload design consisted of a fiberglass body tube split into three sections - fin can (aft), main body (middle), and nose cone (front). These circular body tubes were 3.25” in diameter, and were manufactured in the OSU composites laboratory using Prepreg 7781 E-Glass in a $[0/+45/-45/90]_S$ layup schedule. The three sections were stacked together by means of two coupler tubes (made of the same fiberglass material) attached with epoxy to the inside surface of the forward side of the aft body tube and the forward side of the middle body tube. The tail end of the aft body tube also included a box fin - similar to the architecture of WWII bombs - that was constructed using a combination of 0.05” and ⅛” thick 6061 aluminum sheet metal. The 0.05” makes up the outer walls of the box fin, and is bent to an angle of 135° to match the surface of the four ⅛” thick clipped delta shaped fins that connect the box fin to the body tube. The box fin assembly is held together by 8 6-32 ½” steel socket head screws that are fastened with a lock nut on the inside area of the box fin, and then cut to an appropriate length. The box fin fits onto the body tube over a 0.05” thick steel sheet metal sleeve. The entire assembly is then attached to the body tube using rocket epoxy. Drawings for this part can be viewed in appendix F.

The internal structure of the payload is divided into 6 sections (from forward end moving aft: propeller motor bay, forward electronics bay, reaction wheel, experiment bay, aft electronics bay, parachute chamber) using five 6061-T6 aluminum bulkheads that line up with the 5 lines of screws that can be seen in Figure 12. Four of the bulkheads are ¼” thick, and connected to the body tube using 6 6-32 ½” socket head steel screws (two sets of 3, on each side). The 5th bulkhead (just above the forward end of the box fin assembly) is ½” thick and connected to the aft body tube using 8 6-32 ½” socket head steel screws, as well as a layer of epoxy around the edge. This thicker bulkhead in the rear (referred to as the “Parachute Bulkhead”), has an eye bolt threaded into a hold directly in its center that is used to attach the parachutes that will be used for payload recovery. Drawings for the aluminum bulkheads can be seen in Appendix F.

The ability for the payload to reach a state of true microgravity is achieved through use of a propulsion system in the form of a propeller mounted to the forward tip of the payload nose cone. If the body were to be dropped from apogee as an unpowered unit, the forces of drag would eventually become equal to the weight of the device, and the flight would be constrained to a “terminal velocity”. Thrust provided by the propeller allows a constant acceleration to be achieved, equal to the induced acceleration due to gravity.

To reach and maintain this impressive acceleration, a high-speed propeller and motor combination is necessary. As the payload reaches lower altitudes the air density will increase, and the propeller will have to spin even faster to maintain the proper acceleration. For this application, a GM folding propeller is used with dimensions of 10”✖23”. The propeller dimensions represent the diameter and the pitch, respectively (diameter✖pitch). The pitch is the distance that the propeller will be displaced in its axial direction during one full rotation. Therefore, one rotation of the chosen 10 inch diameter propeller will result in an axial displacement of 23 inches. The use of this propeller will allow the payload to reach a speed of 287.76 meters per second during its descent, with the propeller rotating at 29,555 rotations per minute, according to simulations.

The propeller motor must be capable of giving the chosen 10”✖23” propeller a rotational rate that is large enough to counteract the force of drag on the payload. The “Dr. Mad Thrust B3682” 1700 kv Electric Ducted Fan motor fits the specifications of this application due to its safe operating range of 38,000 RPM. Although calculations only call for around 30,000 RPM, it is likely that there will be unexpected turbulence during flight, requiring more thrust from the propeller. Accelerometers within the avionics bay will be able to sense the acceleration of the payload and adjust the propeller speed accordingly.

Because the aim of the payload is to reach a state of microgravity, it is desirable to prevent any outside forces from acting on the experiments inside. This includes centripetal forces that are induced on the body by the spinning propeller. In order to prevent centripetal forces from affecting the experiment, there must be a stability system to prevent spin, and a reaction wheel was chosen for this purpose because of its ease of manufacturing and implementation. A reaction wheel is simply a mass that can absorb rotational momentum from the payload by spinning in the opposite direction of the payload spin. Due to the fact that this system is simply a wheel and a motor, the necessary manufacturing is minimal. The math that governs the effectiveness of the reaction wheel is listed below:

$$I_w * \omega_w + I_p * \omega_p = 0 \tag{1}$$

Where I_w and I_p are the rotational inertias of the wheel and payload respectively, and ω_w and ω_p are the angular velocities of the reaction wheel and payload respectively.

In order to ensure that the reaction wheel can negate any rotational momentum caused by the propeller, the rotational momentum of the payload as a whole must be countered by the rotational inertia of the reaction wheel. If the wheel's inertia is too low than the reaction wheel motor will have to compensate by spinning to extreme speeds, and if the wheel's inertia is too high the motor will not be able to move the wheel at all. Neither of these outcomes are desirable. In order to accomplish a balance between these two points, the payload team designed a reaction wheel that is a balance of high inertia (I_w) and attainable rotational velocity (ω_w). The reaction wheel is machined from 6061-T6 aluminum stock. Drawings for this part can be seen in Appendix F.

A toroidal nylon parachute was chosen for the main payload parachute because it has the highest available drag coefficient out of the commercially available parachute designs. This is ideal because the payload size constraints make the implementation of large chutes difficult - it is desirable to find the chutes with the highest drag capacity for the amount of space they consume within the payload. In addition to this main parachute, the payload design includes a small 1 foot elliptical drogue chute. The elliptical style of parachute provides worse drag characteristics than toroidal chutes but they are also significantly cheaper, making them an ideal choice for the drogue chute. The chutes utilized in the recovery system are 3 feet (main chute) and 1 foot (drogue chute) in diameter. The drogue parachute is much smaller that the main so that it is not shredded by the extreme airspeed that the payload will experience during flight while the main chute is sized to ensure that our target descent velocity of 20 feet per second is met upon landing.

During recovery system deployment, both parachutes are anchored to a small bulkhead in the aft compartment via a long length of kevlar cord connected to a threaded eye-bolt. The main chute will be secured 6 feet up the paracord line while the drogue will be secured 3 feet higher than that. This cord is used to absorb as much energy as possible from the deployment to prevent excessive amounts of shock stress that could destroy the payload. When it is time for the parachute to deploy, a small black powder charge is ignited by an E-match and the ensuing increase in pressure within the aft compartment will break a series of tape strands, separating the tail cap from the payload and deploying the parachute. This tail cap is secured to the paracord line via a zip tie to prevent it from falling free from the payload. Black powder charges are small explosive charges that are often used to deploy recovery systems. These charges are often accompanied by E-matches which are a small explosive compound that ignite when exposed to an electrical current. Black powder charges and E-matches were chosen because they are cheap, easy to implement, and they are one of the most reliable deployment options available.

In addition to the initial black powder charge, there is also a second black powder charge contained within a metal casing that is used to cut a zip tie restraining the main parachute. This zip tie and black powder assembly is often referred to as a "cable cutter". The purpose of restraining the main parachute is to ensure that it does not deploy at the extreme speeds that the payload will be experiencing following its microgravity experiment. The main parachute's development is delayed until the velocity of the payload falls within the boundaries of a safe parachute deployment.

The electronic systems inside the original payload are attached to two electronics ladders (forward and aft) each consisting of 3D printed ABS plastic. Drawings for these "E-Ladders" can be viewed in Appendix F. The electronics system is divided between the two "E-Ladders." On the rear (smaller) ladder, there is a BeelineGPS telemetry module used for live GPS telemetry, several Stratologger flight controllers for recovery system deployment, a custom RF control board for wireless arm and disarm functionality, and several small Lipos to provide isolated power sources for the Stratologgers. On the forward (larger) ladder, there is are several sensors which provide data on acceleration, pressure, temperature, and more, an ESC which drives the propeller motor, a smaller motor driver board to drive the reaction wheel, and a Raspberry Pi Zero microcontroller which acquires sensor data, processes data, and controls both the main propeller motor and reaction wheel motor. The speed of the main propeller motor is increased or decreased based on acceleration data collected from sensors during flight while the speed of the reaction wheel motor is controlled based on gyroscope data. Both are fed into separate PID loops tuned to the individual motors. In order to ensure the motors are not spinning either after deployment of the parachutes or prior to separation, checks are put in place to ensure that the payload has fallen at least 300 ft and for at least two seconds before engaging the main propeller, and the propeller is shut off as soon as the significant pull of the drogue parachute is detected or 12 seconds has passed. Additionally, secured within the forward ladder structure is a 6S Lipo which provides power for all electronics except those in the recovery system.

New Payload:

As stated above, the original microgravity payload was lost during a test launch on May 13th, 2018 when the team lost communication with the payload shortly after it was deployed from the rocket at apogee. No data is available from that flight, and the payload was not found after a 7+ hour search of the launch/recovery area.

Due to constraints involving funding and time before competition, the team has designed a new payload shown below in Figure 13. that will be launched with the ESRA rocket at the Spaceport America Cup in June of 2018. The new payload will incorporate Infrared camera technology for wildfire tracking. The payload will fit the dimensions of a 3U CubeSat, measuring 10x10x34.5cm, and will be deployable. Once deployed from the rocket at the target altitude of 30,000 feet, the payload will descend with a deployed drogue parachute for stability as it records images and video of the ground below using a wide-view Infrared camera, as well as one standard wide-lens camera. The images and video captured during its descent can be used to identify and track down wildfires that are burning within view of the payload during its flight. This is a technology that can be used in industry to prevent injury/save lives due to wildfire risks. The payload will be deployed from the rocket and its descent will immediately be controlled by the drogue parachute, stabilized for image capture. Once the system has descended to an altitude of 2,000 feet, the main parachute will deploy, decreasing the velocity to below 25 ft/s before 1,500 feet, per SA Cup rules.

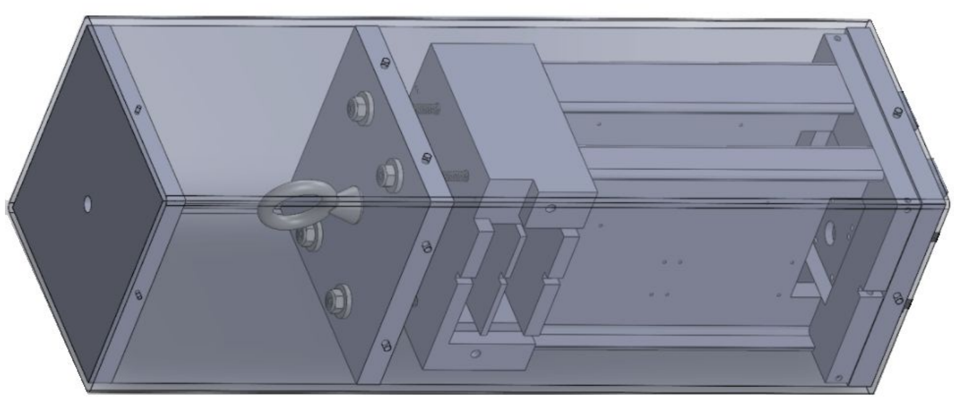

Figure 13: 2018 OSU Payload redesign.

This new payload design will make use of a combination of thin weave kevlar donated by Cytec Industries using a layup schedule of $[0/+45/90/-45/0/+45/90/-45/0/+45]_S$ to make the outer shell. The extra layers. compared to the fiberglass body tube layup of the first payload, makes up for the lack of thickness seen from the kevlar. This kevlar layup will then be reinforced using a thick weave kevlar donated by SpaceX along with layers of Prepreg 7781 E-Glass (leftover from the first payload). This outer shell “body tube” will now be one single structure with no sections or coupler tubes, and will have a 10cmx10cm square cross section, and a length just under 34.05cm (per 3U Cubesat dimensions). There will be two square G10 bulkheads, working together to add structural support and to divide the inside of the payload into three separate sections (from forward end, moving aft: Camera bay, electronics bay, parachute chamber). This new payload incorporates a modular design, meaning that the entirety of the internal components are connected in one continuous structure - including the bulkheads, electronics ladder assembly, electronic components, and parachutes - that will easily slide into the outer shell during integration. Once the internal structure is in place, it will be fastened using 12 6-32x1/2” socket head steel screws running through the outer shell and into the G10 bulkhead. There will be 8 screws fastened to the rear bulkhead to support the additional load from parachute deployment, and 4 screws (one on each face) fastened to the forward bulkhead that handles no significant structural load.

The same 3 foot main parachute and 1 foot drogue parachute will be used for the new payload. The drogue parachute will be deployed as the payload is ejected from the rocket, and therefore there will be no true freefall time for this payload. This allows the payload to stay in a stable, correctly oriented position to assure adequate video captured by the cameras. The main parachute will then be deployed at 2,000 ft AGL to ensure a reasonable descent velocity of below 25 ft/s before the payload passes through 1500 ft AGL.

The electronic systems inside the new payload are attached to a single electronics ladder of 3D printed ABS plastic. Drawings for the “E-Ladders” can be viewed in Appendix F. The electronics systems consist of a BeelineGPS telemetry module used for live GPS telemetry, several Stratologger flight controllers for recovery system deployment, a custom RF control board for wireless arm and disarm functionality, two Raspberry Pi Zero microcontroller boards to enable video recording and storage, several 1S lipos to provide isolated power for the recovery system, and a larger 2S lipo to power all other components.

The OSU ESRA rocket also features a non-deployable 1U cubesat that is located in the nsecone of the rocket. This payload will contain multiple microbiology experiments designed by OSU students, as well as highschool students from West Linn high school in West Linn, Oregon. This non-deployable payload will be made from G10 fiberglass, and will serve as a protective space for these experiments to be conducted during launch. The experiment inside will measure the effects of the significan G-forces at launch on the stress of plants that are included inside the non-deployable payload.

III. Mission Concept of Operations Overview

Our launch is separated into five different phases: Boost, Coast, Apogee Deployment, Rapid Descent, Main Descent and Retrieval. The subsystems which are responsible for the major events that occur in each of these phases and the nominal operations of them will be detailed in the sections below.

The boost stage begins when the ignition button is pressed, sending a signal to the igniter which starts the burn. We will reach a velocity of 142.5 ft/s when the rocket leaves the 32 foot tall launch rail. Our burn, from ignition to burnout lasts for a total of 6.6 seconds. During this burn we expect to reach a maximum acceleration of 15.27 G and achieve a maximum velocity of 1725 ft/s or mach 1.63. When we reach maximum velocity we also reach our maximum dynamic pressure meaning the rocket airframe is under its most violent forces during this phase. The stability of the rocket is also most important during this phase and is nominally greater than 1.9 for the entire boost phase. The end of the burn signifies the end of the boost stage and the beginning of the coast phase where the rocket will travel the majority of its predicted altitude.

The velocity and altitude at the beginning of the boost phase are equal to an expected 1659 feet per second and 7560 feet respectively. The rocket is predicted to coast for 33 seconds and 20841 feet until it reaches apogee at 28401 feet 39.6 seconds into its flight. During this phase the rocket maintains stable flight throughout even though it will be affected by high-speed winds the more altitude it gains. When it reaches apogee at a predicted 28401 feet the coast phase ends and the apogee deployment phase starts.

The primary drogue ejection charge is activated by E-match once the primary Stratologger detects apogee. This causes the nose cone and upper body tube, which were held together by shear pins, to be separated. The force which pushes on the payload to break the shear pins also pushes it, as well as the drogue parachute, out of the rocket. A redundant Stratologger simultaneously detects apogee, delaying an additional two seconds before a backup deployment charge is ignited causing the payload and the drogue parachute to be ejected from the rocket. To keep the parachutes safe from scorching from the detonation of the black powder charges nomex blankets and cellulose fibers are packed between the black powder charge and the drogue parachute. Involved in this phase are the ejection mechanism which is actuated by our electronics subsystems that have been using redundant Stratologger data which has been recording the entire flight profile, the payload system which was designed to be easily ejected from the rocket, and the drogue parachute/protection subsystems which need to keep the parachutes safe so upon ejection they can unfurl correctly. The drogue parachute and payload deploying marks the end of this phase and the beginning of the rapid descent phase.

The rapid descent phase starts at apogee and ends when the main parachute opens at 1500 feet. At the start of this phase the rocket has been separated into three components, the nose cone, the body tubes, and the drogue parachute. A spectra cord is connected on one end to a swivel link connected to an eye bolt mounted to the inside of the nose cone tip and a carabiner on the other end. That carabiner is also connected to a swivel link that the drogue parachute is attached to and a shock cord which is then connected to a swivel link which is attached to an eye bolt on located inside the upper body tube. During this phase the drogue parachute is used to slow the descent velocity to approximately 90 feet per second by the time the main parachute deploys. In the beginning of this phase the payload has opened its drogue parachute and the cameras are recording the ground and surroundings as the payload is descending back towards Earth. At 1500 feet AGL, at a predicted five and a half minutes into the mission, the main ejection charge is detonated by a Stratologger. The ejection charge separates the upper and lower body tubes, which are held together by shear pins, and pushes out the main parachute from the rocket so it can unfurl and ensure that the rocket lands safely on the ground. The redundant Stratologger unit fires a backup ejection charge at 1250 feet AGL to make sure that if the first charge fails, the main parachute will still be deployed, this time by pulling it out using the force of the separation between the upper and lower body tubes. The same parachute safety system used to ensure safety of the drogue parachute was used for the main parachute with the only difference being that the nomex and cellulose needs to be on either side of the parachute since there are black powder charges on either side.

The final phase of the mission is the main descent and retrieval. This is started with the main parachute ejection and unfurling at 1,500 feet and continues until the rocket is recovered. The series of connections used to connect the upper and lower body tubes, as well as the main parachute, is similar to the one detailed above to connect the nose cone and upper body tube upon ejection of the payload. Shock cord connects the upper body tube to a carabiner that is then attached to both the main parachute and the lower body tube. All connections to the airframe and parachute use a swivel link to relieve torsional effects. During this phase the rocket is very prone to drifting due to the low descent velocity and the large parachute attached to it. The rocket will land on the ground at an expected velocity of 15 feet per second in five connected pieces: nose cone, drogue parachute, upper body tube, main parachute, lower body tube. The rocket landing on the ground marks the beginning of the retrieval section of this phase where the team interprets telemetry data transmitted from the rocket and the payload and locates the rocket. When located the team will walk to the rocket to retrieve and inspect it for any damages. The retrieval marks the end of the mission.

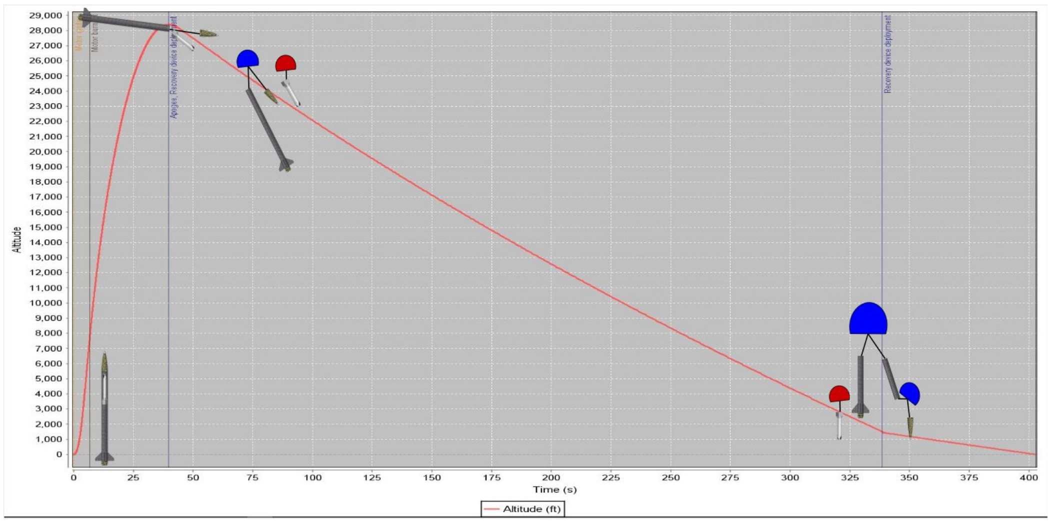

Figure 14: Recovery simulation data.

IV. Conclusions and Lessons Learned

The lessons learned and knowledge transfer are incorporated into the following sub-teams and divisions: Team Management, Propulsion, Structures and Integration, Aerodynamics and Recovery, and Payload. The team has concluded that the lessons learned and knowledge transfer are often intertwined and are therefore presented in no particular order.

Team Management:

- Schedule regular entire teams meetings to discuss updates and issues and don’t be afraid to schedule extra meetings if major issues arise
- Create a team Slack channel to share and discuss project information (both technical and logistics information)
- Create a team Google Drive and upload all research, analysis, CAD models, and documents (technical and logistics). This allows the current team to access all information regarding the project and it can be shared with future teams. This method of knowledge transfer has worked well for the current OSU ESRA 30k team and past OSU rocket teams
    - Be sure to actually upload all documents and to share Drive with next team.
- Communication between sub-teams is extremely important. Communicate early and communicate often. This helps clarify expectations for all teams and members, which makes everyone’s jobs easier. If you don’t know what the other teams are doing you don’t know what you’re doing.
- Schedule team bonding activities throughout the year (level 1 rocket kit builds, movie night, dinner, etc).

Propulsion:

- Characterize propellants with subscale testing much sooner than February.
- If possible, use a motor diameter that is compatible with widely available, off the shelf parts.
- When processing large batches of propellant (20+ lbs), separate into two batches before adding curative and packing.
- Let the propellant cool down after long mix sessions before adding curative, the lower temperature will increase working time of propellant after curative is added.
- Always check continuity of ignition system before attempting to fire.
- When ordering material for motor casings, request a Mill Test Report (MTR) from the manufacturer to ensure out of roundness and cylindricity is minimized.

Structures and Integration:

- Composite materials often took several weeks to arrive so they need to be selected and ordered early in the design process.
- Fixtures for machining and integration are important to consider the design process and may influence component design.
- Composites manufacturing is time consuming, but a well designed mock up can help to understand what shape of composite plies should be used.
- More research needs to be done on how to machine a consistent fin bevel.
- The nose cone and boat tail should be manufactured using a female mold to reduce post-processing and to better maintain tolerances for increased aerodynamics.
- It is beneficial to start integrations tests early, even if all the components are not fully manufactured. Early integration tests help find issues early on and improve integration efficiency.

Aerodynamics and Recovery:

- The CO2 recovery system could not be designed and manufactured to an acceptable degree of reliability to use in this years project but it is a promising system and a more refined system or a similar CO2 system could likely be successful with more research, design, and testing.
- Parachute manufacturing is laborious and time consuming but the knowledge from manufacturing them helps with packing and manipulating the chutes during integration and testing.
- A simple, reliable backup ejection system such as a full black powder system should be tested and finalized early in the process so that the team always has a reliable alternative.
- Flight simulations should be run simultaneously on different programs or platforms because each simulation software has its own strengths and weaknesses. This allows the team to normalize data and have alternative data when there are discrepancies.
- The aerodynamics of rockets, fins, nose cones, and parachutes are very well defined and verified by experimental and testing data as well as theoretical analysis so the design of these parts is largely reliant on finding appropriate sources and references and then testing and simulating the chosen designs.

Payload:

- All internal components of the payload should be made of RF transparent composite material. The amount of metal present in the design could have affected the GPS communication.
- Making an effective reaction wheel is not easy. The motor should be powerful enough to bring the reaction wheel up to speed quickly. A motor of that power requires significant amounts of space in the confines of the payload.
- Payload to rocket integration should be considered from the beginning of the design process.
- Communication with electronics teams is absolutely necessary and should be practiced early on in the project. ME students do not know the language of ECE and CS students, and vice-versa.
- The payload manufacture process should begin early. The payload testing process is complicated, laborious, and there needs to be as much time as possible dedicated to testing and verification of payload reliability.
- BUILD TWO PAYLOADS. Chances are one is going to get lost - if it is a deployable design. Budget for double the manufacture.
- Clearly define all possible failure modes of the payload before testing, and set rules for how these problems will be mitigated, if they arise.
- Place reliability over functionality. Flashy payloads are only great if they are reliable.

Appendix A: System Weights. Measures, and Performance Data

Spaceport America Cup

Intercollegiate Rocket Engineering Competition
Entry Form & Progress Update

Color Key — SRAD = Student Researched and Designed — v18.1

Must be completed accurately at all time. These fields mostly pertain to team identifying information and the highest-level technical information.

Should always be completed "to the team's best knowledge" , but is expected to vary with increasing accuracy / fidelity throughout the project.

May not be known until later in the project but should be completed ASAP, and must be completed accurately in the final progress report.

Date Submitted: 5/22/2018

Team ID: 21 — * You will receive your Team ID after you submit your 1st project entry form.

Country: Unites States of America

State or Province: Oregon

State or Province is for US and Canada

Team Information

Rocket/Project Name:	Daedalus* (Name has changed)
Student Organization Name	OSU ESRA 30k Rocketry Team
College or University Name:	Oregon State University
Preferred Informal Name:	
Organization Type:	Senior Project
Project Start Date	9/20/2017
Category:	30k – SRAD – Solid Motors

Projects are not limited on how many years they take

Member	Name	Email	Phone
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Alt. Student Lead	Devon Burson	bursond@oregonstate.edu	541-784-8245
Faculty Advisor	Dr. Nancy Squires	squiresn@engr.orst.edu	541-737-2337
Alt. Faculty Adviser	Dr. David Blunck	david.blunck@oregonstate.edu	541-737-7095

For Mailing Awards:

Payable To:	Nancy Squires
Address Line 1:	Oregon State University
Address Line 2:	Rogers Hall 306
Address Line 3:	2000 SW Monroe Ave
Address Line 4:	Corvallis, OR 97331-6001
Address Line 5:	

Demographic Data

This is all members working with your project including those not attending the event. This will help ESRA and Spaceport America promote the event and get more sponsorships and grants to help the teams and improve the event.

Number of team members

High School	2	Male	21
Undergrad	25	Female	6
Masters	0	Veterans	0
PhD	0	NAR or Tripoli	1

Just a reminder the you are not required to have a NAR, Tripoli member on your team. If your country has an equivelant organization to NAR or Tripoli, you can cant them in the NAR or Tripoli box. CAR from Canada is an example.

STEM Outreach Events

The OSU ESRA 30K Rocketry team is partnering with two high school students from West Linn High School, in West Linn, Oregon. The high school students will be designing an experiment that will be integrated into the non-deployable cubesat payload kept inside the nosecone of the rocket. Their work so far has been on an experiment involving capilary tubes, measuring the effects of the massive G-forces experienced at launch on their medical function - no live data will be collected due to space restrictions within the payload. These students plan to use their work on this project for their own portfolio moving forward in their highschool career and college search. We believe this is a wonderful opportunity for them to get a jump start on real-world engineering applications.

The OSU ESRA team is also partnering with students from OSU's microbiology department for the design of another technical experiment to be performed inside the non-deployable cubesat payload. This experiment will focus on plant stress dur to extreme heat conditions and G-Forces. Two Zinnia plants will be placed inside of the non-deployable cubesat payload, and heat sensors will be used to measure plant stress. The experiments will be completely self-contained, requiring no power from the rocket or payload. The experiments will abide by all SA Cup rules.

Rocket Information

Overall rocket parameters:

	Measurement	Additional Comments (Optional)
Airframe Length (inches):	148	
Airframe Diameter (inches):	ID: 5.68 OD: 5.78	
Fin-span (inches):	6	
Vehicle weight (pounds):	57	
Propellent weight (pounds):	32.3	
Payload weight (pounds):	11	Estimate Includes both the deployable and non-deployable payloads
Liftoff weight (pounds):	100.3	
Number of stages:	1	
Strap-on Booster Cluster:	No	
Propulsion Type:	Solid	
Propulsion Manufacturer:	Student-built	
Kinetic Energy Dart:	No	

Propulsion Systems: (Stage: Manufacturer, Motor, Letter Class, Total Impulse)

1st Stage: SRAD Solid, 32.3 pounds of aluminum-HTPB-AP composite propellant, O-Class, 26,500 Ns

Total Impulse of all Motors: 26,500 (Ns)

Predicted Flight Data and Analysis

The following stats should be calculated using rocket trajectory software or by hand.

Pro Tip: Reference the Barrowman Equations, know what they are, and know how to use them.

	Measurement	Additional Comments (Optional)
Launch Rail:	Team-Provided	
Rail Length (feet):	32	
Liftoff Thrust-Weight Ratio:	10.5	
Launch Rail Departure Velocity (feet/second):	142.5	
Minimum Static Margin During Boost:	1.96	*Between rail departure and burnout
Maximum Acceleration (G):	15.27	
Maximum Velocity (feet/second):	1,758	
Target Apogee (feet AGL):	30K	
Predicted Apogee (feet AGL):	28,401	

Payload Information

Payload Description:

The main payload will deploy at the rocket's peak altitude and accelerate downward due to a combination of gravity and a propeller mounted on the forward end. The goal is to overcome drag forces in order to induce a state of microgravity on experiments that are being conducted within the device. The experiments are the result of the ESRA team's partnership with OSU's microbiology department, and high school students from the West Linn-Wilsonville school district in Oregon (see STEM outreach section). The payload has a long and slender body as well as a box-shaped fin on the aft end. This payload will be held concentric within the rocket airframe using a ring of foam and the aft box fin that perfectly matches the inside diameter of the rocket body tube. The foam will deploy with the payload and be retained with the main rocket recovery system. The main payload will be recovered using its own recovery system consisting of two prachutes: a 1ft drogue chute deploying at apogee, and a 3ft toroidal parachute deploying around 2,000 feet - these will work to slow the paylaod to below 30 ft/s as it descends through 1,500 ft AGL. It is not likely that the payload will drift into WSMR. Both parachutes are deployed uding a black powder charge that will be tested within the next two weeks using both on-ground tests, and a simulation "Drop Test: of a full scale dummy payload - constructed of PVC Pipe and weighted equally to the actual payload. The main payload will also contain a reaction wheel internally, which will spin with an equal and opposite mass inertia to that of the spinning propeller, cancelling out any induces spin and increasing stability during descent. The secondary payload is non-deployable and non-functioning. It will be of 1U CubeSat dimensions of 10x10x10cm. This non-deployable payload will house another unspecified experiment. This payload will be integrated into the rocket airframe using a rigid connection in the rocket's mid bay. Both payloads have been designed and manufactured to comply with Section 7 of the IREC Design Test and Evaluation Guide.

The deployable microgravity payload described above was unfotunately lost during the test launch of Daedalus and Icarus Payload (V1) on 5/13/18 due to a loss of contact with the payload after deployment at apogee - it was never found. This unfortunate loss has given way to the design of a new payload that will be taken to the competition in June, which is described below

After an unfortunate loss of the deployable microgravity payload during a test launch (design as described in the ESRA progress reports), the OSU ESRA team has redesigned a new payload that will incorporate Infrared camera technology for wildfire tracking. The payload will fit the dimensions of a 3U CubeSat, measuring 10x10x~33cm, and will be deployable. Once deployed from the rocket at apogee, the payload will descend with a deployed drogue parachute as it records images and video of the ground below using a wide-view Infrared camera, as well as one standard wide-lens camera. The images and video captured during its descent can be used to identify and track down wildfires that are burning within view of the payload during its flight. This is a technology that can be used in industry to prevent injury/save lives due to wildfire risks. The payload will be deployed from the rocket and its descent will immediately be controlled by the drogue parachute, stablized for image capture. Once the system has descended to an altitude of 2,000 feet, the main parachute will deploy, decreasing the velocity to below 25 ft/s before 1,500 feet, per SA Cup rules.
Failure modes of the payload described above include: Failure to recover due to parachute not deploying, failure to recover due to loss of contact (no GPS or Yagi signal), failure to deploy from the rocket, damage at ground impact, and damage due to black powder charges (Payload parachute deployment).

Any Damage that would occur during deployment of the payload from the rocket will be assessed during on-ground deployment testing prior to actual flight, therefore this is not of concern at competition during flight. The deployment tests will verify that the payload is fully ejected from the rocket at apogee using black powder charges, and that the payload sustains no damage during that deployment.

The payload main parachute will be verified to completely deploy on-ground before the payload is placed into the rocket. if the payload parachute were to not deploy correctly, the payload would not reach a safe descent velocity and could cause danger. Testing procedures will prevent this from occuring.

STEM outreach experiments will still be included in the non-deployable cubesat payload

Payload Materials:

Fiberglass outer shell - Prepreg 7781 E-Glass purchased from fibreglast.com.
G10 Fiberglass bulkheads.
9.5" Steel 6-32 Threaded rods.
1/4-20 threaded eye bolt (parachute attachment).
1 ft Drogue and 3 ft toroidal Main Parachute purchased from fruitychutes.com.
<3g Black powder charges for main parachute deployment (Two for redundancy).
ABS Plastic fillament for 3D printed Electronics ladder.
Acryllic camera lens covers (for protection).

Recovery Information

The nosecone, upper body tube, and lower body tube are the recoverable portions of the rocket. The nosecone is linked to the upper body tube with Spectra cord and the upper and lower body tubes are linked with shock cord. The first ejection occurs at apogee and deploys drogue chute after separating the nosecone from the rocket. This event is triggered by a pressure reading from a Stratologger and utilizes a 14g black powder charge. The backup event trigger is also a 14g black powder charge that is based on a timer after the primary charge. The secondary ejection event separates the upper and lower body tubes and occurs at at AGL of 1500 ft. This even utilizes a 12g black powder charge and is activated by the pressure readings from a Stratologger. The backup trigger for this event is another 12g black powder charge that is activated at an AGL of 1250

1250
ft. based on the pressure readings from a separate Stratologger. Both parachutes are toroidal canopies with spill holes.

The recovery system for the Payload can be seen in the Payload section.

Planned Tests

* Please keep brief

Date	Type	Description	Status	Comments
10/25/17	Other	Payload Sub-Scale Drop Tests	Successful	Validation of box fin design
11/25/17	Ground	Antenna Prototype Test	Successful	Antennas work & perform well
11/27/17	Ground	Avionics Deployment Initial Test	Successful	Stratalogger only in vacuum bag, deployment signal lit LED at apogee
12/5/17	Ground	Sub Scale #1	Successful	
12/8/17	Ground	Simulate Full Rocket Flight	TBD	SImulates to target altitude
12/8/17	Ground	Telemetry Range Test	Successful	Extremely reliable up to ~6 miles
1/12/18	Ground	RF Transparent Surface Area Test	Successful	Validation of material selection for nose cone and body tube
1/14/18	Ground	Battery Power Test	Successful	Supplied 2kW peak representing payload propeller motor max power
1/19/18	Ground	Body Tube Compressive Strength Test	Successful	Body tube withstood 8 kN compressive force
1/27/18	Ground	Payload GPS Drive Tests	Successful	Validated working GPS systems
1/30/18	Ground	Sub Scale #2	Successful	Propellant formula characterized
2/1/18	Ground	Hydrostatic Verification	Successful	
2/2/18	Ground	Test Shock Line Energy Absorption	Successful	Validated shockline on Instron - ~1300lbs
2/2/18	Ground	Test Ejection Mechanism Springs	Successful	Spring was sufficient for puncturing CO2 cartridge
2/13/18	Ground	Sub Scale #3	Successful	Propellant formula characterized
2/16/18	Ground	Payload Thrust Verification	Successful	Validated adequate thrust
2/21/18	Ground	Fin Bending Test	Successful	l average load of 2.24kN, core shear ultimate stress (average): 2.52 MPa,
2/23/18	Ground	Payload to Rocket Integration Tests	Minor Issues	Payload fits inside the rocket cody tubes - Rocket not yet complete
3/2/18	Ground	Test Backup Recovery System	Successful	Black powder system verified
3/3/18	Ground	Full Scale Static Fire #1	Major Issues	CATO due to over pressurization
3/10/18	Ground	Wireless Arm/Disarm Testing	Minor Issues	ole > 500 ft in adverse conditions. Takes much longer to arm than desired
3/16/18	In-Flight	Drop Test Parachutes	Successful	Successful test launch recovery
3/16/18	Ground	COTS recovery system testing	Successful	Ejection signaled reliably at programmed altitude.
3/22/18	Ground	Body Tube Bending Test	Successful	Layup simulated to withstand 10 kN
3/22/18	Ground	Coupler Bending Test	Successful	Layup simulated to withstand 10 kN
3/23/18	Ground	Full Scale Static Fire #2	Major Issues	CATO due to over pressurization
3/24/18	Ground	Bulkhead Strength Test	Successful	Bulkhead withstood load of 7.5 kN
3/26/18	Ground	Payload Deployable Antenna Environment Testing	Successful	Telemetry acceptable before and reliable after deployment.
3/28/18	Ground	Payload Recovery System Ejection Test	Successful	Flawless ejection
3/28/18	In-Flight	Full-Scale Payload Drop Test	Major Issues	Unable to complete droip tests - no legal options. Test not necessary
3/31/18	Ground	Shear Pin Test	Successful	Black powder charge ejects nosecone and midbay shears pins
4/3/18	Ground	Sub Scale #4	Successful	Propellant formula characterized
4/6/18	Ground	Vibration Test Ejection Mechanism	Major Issues	Test no longer necessary
4/6/18	Ground	Test Coefficient of Drag for Parachutes	Minor Issues	Shroud lines need to be adjusted
4/29/18	Ground	Full Team Integration Test #1	Minor Issues	me components not fully manufactured, intregated as much as possible
4/7/18	Ground	Test Fitment of Recovery System	Successful	All parts integrated well
4/8/18	Ground	Sub Scale #5	Successful	Propellant formula characterized
5/4/18	Ground	Nose Cone Avionics Range Test	Successful	cture exhibits negligible impact on telemetry, signal heard > 4 miles away
4/13/18	Ground	Test Puncture Force of CO2 Canister	Successful	Chosen Spring was capable of puncturing CO2 cartridge
4/14/18	Ground	Cp and Cg Distance Test	Successful	Cp is 2.5 calibers below Cg on the rail
5/6/18	Ground	Full Team Integration Test #2	Minor Issues	Almost complete integration, minor issues with simple fixes
4/15/18	Ground	Mid Scale Static Fire	Successful	Tested a motor with the full diameter, and half the length of full scale
4/21/18	Ground	Full Scale Ground Test Ejection Mechanism - Main	Successful	Black powder charge ejects main chute
4/27/18	Ground	Full Scale Ground Test Ejection Mechanism - Drogue and Payload	Successful	Black powder charge ejections payload and drogue
4/27/18	Ground	Flight configuration deployment electronics testing	Successful	Black power and CO2 ejection electronics function as expected.
4/27/18	Ground	Flight configuration antenna testing (main and payload)	Minor Issues	Transmitter exhibited power issues. Sent back for repairs.
5/4/18	Ground	Flight configuration antenna testing (main and payload) #2		On ground, telemetry from > 2 miles for both main and payload.
5/10/18	Ground	Full Team Integration Test #3	Successful	Full integration in 4 hours
5/10/18	Ground	Full Scale Static Fire #3	Successful	Performed as expected
5/19/18	Ground	Black Powder Antenna Testing	Successful	Black power coating exhibits negligible impact on antennas.
5/28/18	Ground	NEW Payload Ejection Testing	TBD	
5/28/18	Ground	NEW Payload GPS Testing	TBD	
5/28/18	Ground	NEW Payload Parachute Deployment Testing	TBD	
5/28/18	Ground	NEW Payload Camera Testing	TBD	
5/13/18	In-Flight	Test Launch #1	Minor Issues	~25,000 ft, small propellant chuff, rocket recovered w/o damage, lost pa

Any other pertinent information:

Structures
Nose Cone: Materials - Pre-impregnated aramid with fiberglass overlay, steel tip; Dimensions - MAX OD 5.78", MIN ID 5.68", 23.5" L; Integration - forged steel eye bolt connected to steel tip will be attached to parachute with spectra cord. Coupler tube will align nose cone to the upper body tube. Coupler will extend 3" into nose cone and 6" into the upper airframe. Integration of avionics into nose cone - 3d-printed support structure will support antenna against the wall of the nose cone. Thru holes in the lover nose cone bulkhead will support the battery and transmitter for the antenna. There is sufficient RF transparent area to support radio transmission.
Body Tubes: The upper body tube will be made out of fiberglass to allow RF transparency since the payload sits there. The lower body tube will be made out of carbon fiber. There is not an immediate point above the motor tube which is RF transparent. There is a RF transparent point below the motor tube where a beacon can be placed. Both body tubes will have an ID of 5.68".
Bulkheads: The bulkheads will be 3/8" thick and machined out of G10 fiberglass. They will be for the nose cone and above the motor. The bulkheads mounting servos in the midbay will be machined out of 1/2" thick aluminum, they will serve to integrate the CO2 recovery system and avionics.
Couplers: The coupler tubes will be manufactured using pre-impregnated aramid. The coupler tube in the midbay will be 12" in length and extend 6" into each side of the airframe. The coupler tube connecting the nose cone and upper body tube will be 6" in length and will extend 3" into the nose cone and 3" into the upper airframe. The coupler tube located at the bottom of the rocket connecting the boat tail and lower body tube will be 4" in length, with 2" into both sides of the airframe.
Fins: 4 Fins; Dimensions - Root: 11.38", Tip: 2.845", Height: 6.00" (the height increased from 5.78" to 6.00" to increase the stability), Sweep Length: 8.535", Sweep Angle: 55.9 degrees, Thickness: ~1/8"; Materials - G10 fiberglass frame, aramid honeycomb core, carbon fiber skin; Integration - epoxy fillets and tip-to-tip layup. The tip-to-tip layup consists of three plies of pre-impregnated aramid and one ply of pre-impregnated twill carbon fiber.
Retaining Assembly: Aluminum motor casing is machined to have one ring with an OD of 5.68" (ID of airframe) that acts as a centering ring. The forward enclosure rests against a 3/8" thick G10 bulkhead epoxied into the lower body tube. A 1/2" -13 steel eye bolt goes through the center of the bulkhead and the forward enclosure screws onto the eye bolt to hold the motor against the bulkhead. A bottom retaining ring on the motor casing has 4 radial holes to mount the casing to the airframe with #10-32 steel screws.
Boat Tail: Materials - Pre-impregnated aramid with fiberglass overlay. Integration - The boat tail attachs to the airframe with a coupler that slides between the motor casing and the airframe. The coupler has 4 radial holes which line up with the radial holes on motor casing and in the airframe.

Avionics
Live telemetry will include GPS data and will use the 70cm licensed amateur band. There will be one transmitter module in the nose cone and another transmitter in the payload.
All antennas (transmit and receive) will be student designed and constructed. There will one antenna for each transmitter module in the rocket and payload, and a total of four ground station antennas, two for each transmitter. For each transmitter, there will be a high-gain Yagi alongside a simple whip which will act primarily as a backup.
The upper coupler tube in the rocket will contain a student designed sensor array, which will record and log sensor data from: accelerometer, barometer, thermometer, magnetometer, and gyroscope. The payload will record and log sensor data from: accelerometer, thermometer, and gyroscope.
Deployment will be done using an off-the-shelf module. Output from the off-the-shelf module will be compared against logged sensor data from student designed sensor board in real time to determine how well student setup compares to commercial.

Payload
The payload will use inertial measurement sensors to control the speed of a propeller to overcome drag, creating a minimal gravity environment for the onboard biology experiment. The sensor data will be logged and used to determine duration and effectiveness of the experiment design.

Appendix B: Project Test Reports

Rocket Recovery System Testing:

Recovery system testing was initially performed on the ground at the OSU propulsion lab. The rocket was assembled to simulate launch conditions including attaching the nose cone with avionics, inserting a dummy payload, installing the drogue parachutes and upper bulkheads, and installing the black powder charge. The lower body tube was attached with the empty motor tube, main chute, and black powder charge. The leads to the black powder charges were passed through vent holes in the body tubes and a Li-Po battery was used to ignite the E-matches. The rocket was secured on the ground using tie-downs and testing stands. Initial testing began at 8g of black powder for the drogue and main deployments and the charges were increased in increments of 2g until satisfactory ejection and separation was achieved. The final 14g and 12g charges for the drogue and main, respectively, were verified by this testing. A final ground test was conducted using the actual payload which was successfully ejected from the rocket.

The recovery system was also tested in flight conditions during the rocket test launch. Although the success of the individual recovery systems could not be analytically verified, the successful recovery of the rocket with minimal damage to the airframe or parachutes and separation of all parts of the rocket at recovery indicate that each recovery system was successfully activated and deployed during launch.

A simple wiring diagram demonstrating the redundancy of the recovery system electronics is seen in Figure 13 below. Two separate Stratologger units are mounted in the coupler section of the main rocket. Each Stratologger unit is connected to a completely isolated 3.7V Lipo to ensure that no component failures outside the recovery system may cause either Stratologger to fail due to power loss. One Stratologger is designated the primary Stratologger and is connected to the two e-matches designated for primary drogue and main ejection. The other Stratologger is similarly designated the redundant Stratologger and is connected to two separate e-matches designated for redundant drogue and main ejection. In this way, two fully isolated and redundant recovery systems are implemented.

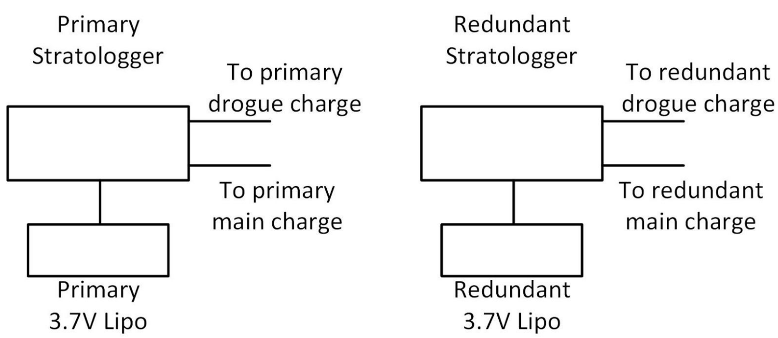

Figure 15: Wiring Diagram for Redundant Recovery System Electronics

Payload Recovery System Testing:

The payload recovery system for the microgravity payload that was lost consists of two parachutes: a 1 ft diameter elliptical drogue parachute, and a 3 ft diameter toroidal main parachute. The deployment of these parachutes takes place using a series of black powder charges that are set off using E-matches connected to the electronics equipment within the payload. The first black powder charge blows open the parachute retaining cap, deploying the drogue parachute and the main parachute restrained by the "cable cutter" assembly. When the correct altitude is reached for main deployment, a second black powder charge actuates the cable cutter, and the main parachute is allowed to fully develop.

The functions described here were thoroughly tested on May 2nd, 2018. The first black powder charge was ignited using E-matches connected to a battery, and both parachutes deployed completely out of the payload with no visible issues. The second black powder charge was lit separately, again using a battery, and the cable cutter assembly completely disconnected as expected, allowing the main parachute to develop had the payload been in flight. This testing procedure was conducted a minimum of 10 times to assure consistent results, and no system failure was encountered. The electronic components in charge of igniting the E-matches for the payload recovery system were tested separately and proved to be completely functional in detecting correct pressures.

The recovery system for the new IR camera payload will involve the same two parachute design, with the same size and type of parachutes. The drogue will be attached to the payload already deployed, and therefore no black powder charge is needed for drogue deployment. The main parachute will then be deployed using a single black poster charge that will blow open the end cap, and push the main parachute completely out of its compartment in the payload. Although the new payload design is not manufactured for testing yet, the test and validation of this recovery system is set to take place on June 1st, 2018.

SRAD Propulsion System Testing:

To comply with the rules set forth by IREC in the *Design, Evaluation, and Testing* Guide in section 2.4, the propulsion team conducted 4 static test fires.

i. The first test was conducted on March 3rd, 2018. At the time the motor configuration was slightly different than the final version. The motor was 6" shorter and used a different propellant mixture. Total propellant mass was 28.5 lbm, the expected burn time was about 6 seconds and the maximum operating pressure was expected to be 800 psi. Within about ¼ of a second the motor coming up to pressure, the propellant grains started to burn on the inhibited surfaces leading to a dramatic pressure spike. The pressure reached a pressure of 2250 psi at about ¾ of a second in into the burn and the casing failed. The motor casing was completely destroyed, the nozzle cracked in multiple locations, and the vertical thrust stand was destroyed.

ii. The second test was conducted on March 23rd, 2018. For this test, the motor was the full 46" and contained 33 lbm of propellant. As before, the expected burn time was 6 seconds and the expected maximum pressure was 680 psi. The propellant burned for ¾ of a second and reached a pressure of 1800 psi when the casing failed. The overpressurization is attributed to a propellant chemistry error that was unknown to the team at the time. As with the the first test, the result was a complete loss of hardware.

iii. The third test was conducted on April 15th, 2018. The propulsion team identifies this test as a 'Mid Scale' test. The motor that was used was the same diameter as the first two but only half the length. The reason for this is to risk a full motor casing and to ensure the casting method and propellant formulation. The propellant formulation was reverted to one that Oregon State had previously used. The expected burn time was 6 seconds and the expected maximum pressure was 680 psi. The actual burn time was 6.5 seconds and the maximum chamber pressure was 687 psi.

iv. The fourth and final static test was conducted on May 10th, 2018. This test used 33 lbm of propellant, the expected burn time was 6.5 seconds and the expected max pressure was 680 psi. The test resulted in a complete success; the motor burned for 7 seconds and reached a maximum pressure of 780 psi. The configuration of this test was replicated for the flight test.

SRAD Pressure Vessel Testing:

To comply with the rules set forth by IREC in the *Design, Evaluation, and Testing* Guide in section 4.2.4.1 all pressure vessels were tested hydrostatically before firing. The propulsion team uses another forward enclosure in place of the nozzle with everything else remaining the same during the test. The nozzle plug is put in first and then the assembly is filled with water. Once full, the forward enclosure is fastened in. The forward enclosure is used as the pressure tap where a grease gun hose is threaded in as well as a pressure transducer. The grease gun applies hydraulic pressure until the pressure transducer reads 1.5-1.8x max operating pressure. The pressure is held for at least 30 seconds.

Appendix C: Hazard Analysis

Material	Hazard	Mitigation Approach	Risk of Injury After Mitigation
Propellant Grains	Unwanted combustion	Isolate from flammables, oxidizers, sparking materials	Low
Ammonium Perchlorate	Unwanted combustion	Isolate from flammables, sparking materials, keep in separate smaller amounts	Medium
Aluminum Powder	Unwanted combustion, Health Risks due to exposure	Store in fuel magazine cabinet, Use in controlled environment while wearing proper PPE (gloves, mask, safety glasses)	Low
Zinc Powder	Unwanted combustion, Health Risks due to exposure	Store in fuel magazine cabinet, Use in controlled environment while wearing proper PPE (gloves, mask, safety glasses)	Low
MDI Isocyanate Curative	Health Risks due to exposure	Use in controlled environment while wearing proper PPE (gloves, mask, safety glasses)	Low
Black Powder	Unwanted combustion, Corrosive Residue	Store in manufacturer bottle until use, Clean residue with acetone	Low

		Team 21	OSU ESRA 30k Rocket Team	May 2018		
Mission Phase	**Sub-system**	**Hazard**	**Possible Causes**	**Risk of Mishap and Rational**	**Midigation Approach**	**Risk of Injury After Midigation**
Ignition	Propulsion	Motor fails to ignite	Faulty E-match	Low E-matches are simple, hard to fail	Use multiple E-matches	Low
			Bad continuity	Low Leads on ignition may not be hooked up properly	Test continuity before countdown	Low
Boost	Structures	Retaining Assembly Fail (Potential failure mode in all phases)	Failure of radial screws Failure of body tube and/or coupler tube Failure of epoxied bulkhead	Medium Epoxy not strong enough Not enough radial holes	Motor Retaining Test	Medium
		Coupler tube failure	Insufficient strength to withstand buckling	Medium Relatively long time spent in the transonic region of flight resulting in higher stresses on the coupler tubes	Coupler tubes made no less than 1.5 calibers of airframe	Medium
		Body tube failure	Insufficient strength to withstand buckling and compressive forces	Low Similar layup schedule to previous years along with patching to prevent zippering	Helius Composite Software testing and large safety factor	Low
	Propulsion	Overpressurization of Motor	Grains detach from liner and burn on inhibited sides	Very Low Grains are glued to the liner prior	Glue grains to liner	Very Low
			Pressure spike	Low, student built yet taken steps to mitigate risk of excessive or erosive burning and increased safety factor of motor.	Hydrostatic test, static test	Low
			Erosive burnining	Low, tapered propellant inner bore diameter, widened throat diam	Static test	Moderate
			Propellant Density	Low, calulate before use	Test multiple samples, take average	Low
		Nozzle Blowout	High stresses on the nozzle (thermal and mechanical)	Moderate, widened throat diameter	Static test	Moderate
	Payload	Internal components become disconnected	Excessive G-Forces from launch place loads on the electronics systems	High Electronics systems can only be ground tested. They may operate differenly under extreme loads	Use rigid connecions for all wires and components inside the payload	Medium
Coast	Structures	Fin Flutter (Potential failure mode in coast phase)	Delamination between carbon and G10 Honeycomb not stiff enough to resist flutter Integration technique to airframe fails	Delamination between carbon Honeycomb not stiff enough to Integration technique to airfram	Three point bending test verifies the layup schedule	Low
		Nose Cone Kevlar Melts (Potential failure mode in coast phase)	Heat experienced during flight melts resin	Low Aluminum tip will incur the majority of the heat	Anodized aluminum tip	Low
Apogee Deployment	Structures	Bulkhead Failure	Insufficient epoxy bond securing bulkhead Vacuum bagging tape seal is poor	Medium High ejection forces may exceed epoxy bond strength	Use rocket epoxy Tested with recovery forces applied Ensure clean coupler edges	Low
	Payload	Payload does not correctly deploy	Black powder charge does not fully deploy payload, or the payload gets stuck inside the body tube	Low Excessive payload deployment testing was conducted with no failures.	Use correct payload support system within the rocket body tubes to assure a smooth deployment	Medium
	Recovery	Drogue chute does not deploy	Avionics fails to trigger event, E-matches fail, Payload does not separate	Low Stratologgers and E-matches are robust, Black powder charges are sufficiently large	Use redundant systems, use large black powder charges	Medium

Rapid Decent	Payload	Payload does not maintain stability during flight after deployment	Excessive wind, or any broken parts during launch/deployment.	Medium The payload has been put through extensive grount testing, but nothing can simulate actual flight conditions.	Assure that external payload stability structure is secure and will not flutter at extreme speeds	Medium
Main Decent and Reterival	Structures	Nose cone breaks/cracks/dents on impact with the ground	Insufficient nose cone strength	Medium Implementation of Kevlar must be precise	Increase number of plies to in	Low
	Payload	Payload parachute does not deploy.	E-match failure, black powder charge does not ignite.	Low Excessive payload parachute deployment testing was conducted with no failures	Use reduntant black powder charges to assure a backup if failure occurs	High
	Recovery	Main chute does not deploy	Avionics fail to trigger event, E-matches fail	Low Stratologgers and E-matches are robust, Black power charges are sufficiently large	Use redundant systems, use large black powder charges	High

Appendix E: Assembly, Preflight, and Launch Checklists

*IMPORTANT: The payload checklist provided in this report corresponds to the microgravity payload (described earlier in this report) that was lost during a test launch. The new IR camera payload is currently being designed and therefore does not have an accurate checklist completed. An official checklist for the new payload will be emailed to competition officials as soon as it is finalized.

Aerodynamics & Recovery

Tooling Needed:

- ❏ Scissors
- ❏ Zip ties
- ❏ Scale
- ❏ Electrical/Gorilla tape
- ❏ Epoxy

Components Needed:

- ❏ Surgical tubing
- ❏ 4x Black powder charges
- ❏ Parachutes [drogue, main]
- ❏ 3x Shock cord
- ❏ Spectra cord
- ❏ 4x Nomex blanket
- ❏ Cellulose Fiber
- ❏ 6x Swivels
- ❏ Spare eye bolts
- ❏ Powder scoop
- ❏ 4x E-matches

Prepare main parachute:

- ❏ Inspect main parachute for damage
- ❏ Secure swivel connection to main parachute
- ❏ Attach fasteners to each side of shock cord
- ❏ Fold + tape the shock cord into sections of 4 folded bundles w/ tape and zip ties

Prepare drogue parachute:

- ❏ Inspect drogue parachute for damage
- ❏ Secure swivel connection to drogue parachute
- ❏ Attach fasteners to each side of shock cord
- ❏ Fold + tape the shock cord into sections of 4 folded bundles w/ tape and zip ties

Pre-Flight Checklist: Day of Launch

Prepare main parachute:

- ❏ Verify shock cord connection point
- ❏ Ensure fasteners attached to both ends of shock cord
- ❏ Fold main parachute
    - ❏ Lay parachute flat with 6 gores showing and shroud lines split into 2 groups
    - ❏ Tuck flat shroud lines up to 6” below top of chute
    - ❏ Hold bridle below bottom of chute
    - ❏ Fold chute top to bottom in 6” segments

    - ❏ Roll chute horizontally while keeping shroud lines separate
    - ❏ Wrap taut shroud lines around chute

<u>Prepare drogue parachute:</u>

- ❏ Verify shock cord connection point
- ❏ Ensure fasteners attached to both ends of shock cord
- ❏ Fold drogue parachute
    - ❏ Lay parachute flat with 3 gores showing
    - ❏ Tuck flat shroud lines up to 3” below top of chute
    - ❏ Hold bridle below bottom of chute
    - ❏ Fold chute top to bottom in 3” segments
    - ❏ Roll chute horizontally while keeping shroud lines separate
    - ❏ Wrap taut shroud line around chute

<u>Prepare black powder systems:</u>

- ❏ Ensure e-matches are securely placed in tubing
- ❏ Zip tie e-match into tubing
- ❏ Check continuity on ematches
- ❏ Epoxy end of tubing securing e-match
- ❏ Fill tubing with black powder
- ❏ Zip tie open end of tubing
- ❏ Epoxy open end of tubing
- ❏ Trim zip tie ends
- ❏ Connect e-match to stratologger
- ❏ Solder and heat shrink e-match to stratologger connection
- ❏ Secure charge to bulkhead

<u>Drogue Parachute Integration</u>

- ❏ Place the upper body tube connection end of shock cord through two nomex blankets
- ❏ Secure a black powder charge to the base of the upper body tube on the bulkhead
- ❏ Attach the upper body tube connection end of shock cord to a swivel link and connect that to the upper body tube eye bolt
- ❏ Add cellulose fibers which will be compressed by the pressure cap attached to the shock cord
- ❏ Place the redundant black powder charge on the other side of the pressure cap
- ❏ Place more cellulose that is compacted by the second nomex blanket on top of the pressure cap
- ❏ Attach the other end of shock cord to a carabiner
- ❏ Attach drogue parachute, which has a swivel link on it, to the same carabiner and insert into the body tube
- ❏ Tie the loose end of spectra cord to the same carabiner
- ❏ Make sure that no cord will get caught on the payload upon the payloads integration

<u>Main Parachute Integration</u>

- ❏ Put the shock cord through a nomex blanket
- ❏ Attach one end of shock cord to a swivel link attached to the lower body tube
- ❏ Attach black powder charge to the lower body tube bulkhead
- ❏ Place cellulose on top of the charge and add press it down with one of the nomex blankets
- ❏ Attach the other end of chock cord to a carabiner

- ❏ Attach main parachute with a swivel link attached to the same carabiner
- ❏ Attach a second shock cord with a nomex blanket attached to the carabiner
- ❏ Press down the second nomex blanket to the parachute and add cellulose on top
- ❏ Ensure the second black powder charge is attached to the upper body tube bulkhead
- ❏ Attach the other end of shock cord a swivel link connected to the eye bolt in the upper body tube bulkhead

Electronics

Nosecone:

- ❏ Check mounting screws on all electronics
- ❏ Check that all batteries are in holders and rods secured with nuts
- ❏ Check power connector for Beeline GPS
- ❏ Zip Tie Beeline GPS power connector to nearest standoff
- ❏ Plug in 7.4V Lipo
- ❏ While holding XT60 connector, zip tie through holes above 7.4V lipo to hold XT60 connector in place
- ❏ Check all antenna connections

Coupler:

- ❏ Check mounting screws on all electronics
- ❏ Check that Stratologger switches are in off position
- ❏ Check that all batteries (two 3.7V and one 7.4V are in holders, rods/screws secure
- ❏ Connect XT60 from 7.4V to main power harness
- ❏ Check that 3.7V Lipos are connected to the two Stratologgers
- ❏ Place ladder just outside tube at tail end of coupler
- ❏ Connect ematch wires coming from nose cone end of coupler to primary Stratologger
- ❏ Connect ematch wires coming from tail end of coupler to primary to redundant Stratologger
- ❏ Slide ladder into coupler several inches, then connect camera cable to pi zero camera port
- ❏ Slide ladder fully into coupler, dressing coax cables (one through hole in ladder, one alongside ladder), sliding until fit into bulkhead slots
- ❏ Connect both SMAs, horizontal antenna to arm-disarm board, vertical antenna to beacon
- ❏ Slot tail bulkhead onto ladder to secure

Payload :

- ❏ Check that 3.7V Lipos are connected to the two Easyminis and switches are in off position
- ❏ Plug in XT60 connector on forward ladder from 6S Lipo to ESC
- ❏ Connect reaction wheel wires to motor driver on forward ladder
- ❏ Slot reaction wheel onto forward ladder
- ❏ Slide interbay wires, reaction wheel, and forward ladder into central airframe tube
- ❏ Wait for payload to put in a bunch of screws
- ❏ Pull interbay wires towards boxfin end of central airframe tube
- ❏ Hold rear ladder just outside box fin tube and attach ematch wires to two Easyminis
- ❏ Connect interbay wires to arm-disarm board on rear ladder
- ❏ Slide rear ladder into box fin tube until slotted into parachute bulkhead, dressing both coax and 4 ematch wires
- ❏ Connect SMAs - deployable antenna SMA to Beeline GPS, horizontal epoxied antenna to arm-disarm board
- ❏ Slot upper bulkhead onto rear e-ladder, dressing interbay wire slack back to forward ladder
- ❏ Wait for payload to put in more screws
- ❏ Lift forward ladder back out to further dress interbay wire slack
- ❏ Connect propeller motor to 4mm bullet connectors on ESC
- ❏ Bring together prop motor and rest of tube

Ground Station:

- ❏ Dipole stands hammered into ground near table
- ❏ 0.25’’ audio cable for both dipoles connected and taken to table
- ❏ 0.25’’ audio cables into box at table, two 3.5’’ to CS
- ❏ On Yagi boxes, 0.25’’ audio cables attached and taken to table
  - ❏ 3.5mm to headphones
- ❏ 0.25’’ audio cables into box at table, two 3.5’’ to CS
- ❏ Turn on avionics temporarily, check audio levels at all inputs

Tools:

- ❏ 1.4mm & 2mm flat-head screwdriver
- ❏ Large flat-head screwdriver
- ❏ #1 phillips screwdriver
- ❏ Side Cutters
- ❏ Scissors
- ❏ Big & small pliers
- ❏ Needle Nose pliers
- ❏ Solder sucker
- ❏ 6’’ Crescent wrench
- ❏ Ruler
- ❏ Hammer
- ❏ Medium size vise grips
- ❏ Programmer for stratologger
- ❏ Programmer for beeline GPS/beacon
- ❏ USB to mini cable
- ❏ USB to micro adapter
- ❏ Raspberry Pi power cords
- ❏ Wire cutter (Big + small)
- ❏ Crimper
- ❏ Soldering iron
- ❏ Flashlight
- ❏ Multimeter
- ❏ Sharpies
- ❏ Tape

Backup Materials:

- ❏ 18 awg (black + red)
- ❏ 22 awg (all spare)
- ❏ F-F, F-M, M-M sq pin rainbow wire
- ❏ All crimps
- ❏ All clear heat shrink
- ❏ Zip Ties
- ❏ Extra 9V batteries
- ❏ Solder
- ❏ Assorted screws

Payload

Necessary Supplies and Tools

- 19 6/32 ½” Allen Head Screws
- 7 6/32 ¼” Allen Head Screws
- 6 6/32 ⅜” Allen Head Screws
- 4 M3 ½” screws (Prop Motor)
- Complete metric and standard allen key set
- Plumbers Putty (Parachute Bay)
- Blue Masking Tape Roll
- Straw
- Drill/Bits

Payload Assembly 1

- ❏ Fasten RXN Wheel to RXN wheel motor shaft and tighten set screws to stabilize.
- ❏ Attach FWD E-Ladder legs to RXN Wheel Bulkhead notches and connect RXN Motor leads to the FWD E-Ladder.
- ❏ Connect ESC to Battery (on FWD E-Ladder).
- ❏ Fasten RXN wheel bulkhead (with FWD E-Ladder legs connected to notches in RXN wheel bulkhead) into body tube in orientation marked by arrows. Use 6 6/32 ½” screws. The Wire notch goes opposite of the interbay wire connection to E-ladder.
- ❏ Insert straw around inter-bay wires, and pass through edge holes in the experiment and RXN Wheel bulkheads.
- ❏ Fasten Experiment Bulkhead into Body Tube.
    - ❏ Marked “1” Faces towards the RXN Wheel.
    - ❏ Use 6/32 ¼” Screws (Shortest). Watch for cross threading in bulkhead holes.
    - ❏ Do not tighten the screws until every screw is in place.
- ❏ Tape straw to inner wall of experiment bay.

Payload Recovery Preparation

- ❏ Obtain Fin Can Assembly.
- ❏ Install black powder charges into parachute bay.
    - ❏ Run E-match wires through the hole in the parachute bulkhead, going out of the parachute bay.
- ❏ Tie cable cutter around main parachute cover.
- ❏ Run cable cutter lead through the parachute bulkhead hole, into E-bay.
- ❏ Tie blue tape to the ends of cable cutter leads for identification.
- ❏ Apply plumbers putty to the outer edge of the parachute bulkhead on the side with the E-ladder notches - Use enough to seal the gap between the bulkhead edge and the body tube inner surface.
    - ❏ Apply plumbers putty to wire holes as well.
- ❏ Add dogbarf to parachute bay.
- ❏ Pack main parachute and place into parachute bay.
- ❏ Pack drogue parachute and place into parachute bay.
- ❏ Connect paracord to endcap.
- ❏ Install and tape the end cap.

Payload Assembly 2

- ❏ Insert rear E-ladder into notches in parachute bulkhead.
    - ❏ Connect antenna 1 and 2.

- ❏ Connect E-match wires to E-ladder components.
    - ❏ Connect inter-bay wires to E-ladder components.
- ❏ Insert rear E-bay bulkhead, placing the upper E-ladder legs into the slots on the bulkhead.
- ❏ Place **Petri dish experiments** onto rear E-bay bulkhead and add foam retainer.
- ❏ Attach body tube to tail tube over the rear coupler tube, and connect using screws into rear E-bay bulkhead.
    - ❏ Lift FWD E-Ladder up by ~2” (out of the notches in RXN Wheel bulkhead) to pull out slack in inter-bay wires. Leave the ladder in this position.
    - ❏ Use six 6/32 ½” screws to fasten the rear E-bay bulkhead/body tube.
- ❏ Fasten propeller motor onto nose bulkhead using M3 fasteners.
- ❏ Fasten propeller hub onto propeller motor using the set screws in the hub.
- ❏ Insert FWD E-ladder bulkhead into nose, around the propeller motor.
    - ❏ The ladder should still be in its ~2” shifted up position.
- ❏ Run wires from propeller motor through the hole in the FWD E-ladder bulkhead and attach to the ESC.
- ❏ Place FWD E-ladder back into the notches in the RXN Wheel bulkhead with the FWD E-ladder bulkhead attached.
- ❏ Place Nose section onto FWD coupler tube and attach with six 6/32 ⅜” screws.
- ❏ Place Propeller onto propeller hub and tighten until secure for flight.
- ❏ Check all screws, tighten until secure for flight.
- ❏ Inspect external payload surface for damage in preparation for flight.
- ❏ Prepare for rocket integration.

<u>Payload-Rocket Integration</u> (Work with Recovery Team)
- ❏ Place black powder charge into rocket.
- ❏ Pack dog barf and blankets/ rocket drogue parachute.
- ❏ Insert box fin support disk into body tube.
- ❏ Insert payload into body tube, box fin first and propeller folded, and guide into support disk.
    - ❏ While inserting payload, place payload supports along body tube.
- ❏ Perform any final pre-launch inspections.

<u>Payload Recovery</u>
- ❏ Once touchdown is confirmed, work with the ECE team to determine the location of the payload using the GPS.
- ❏ Locate payload.
- ❏ Make sure power is OFF.
- ❏ Determine the physical condition of the payload and proceed accordingly.

Propulsion

- ❏ Slide fiberglass liner into tube leaving forward enclosure end partially out
- ❏ Grease 2 O-rings
- ❏ Place 2 greased O-rings around forward enclosure
- ❏ Align Bolt Holes
- ❏ Push forward enclosure and fiberglass liner fully into motor casing
- ❏ Fasten all 12 screws
- ❏ Slide nozzle into motor casing, WITHOUT O-rings to ensure fit
- ❏ Remove Nozzle
- ❏ Screw motor assembly into forward bulkhead
- ❏ Wait for rest of team to integrate

- ❏ Align rail button and airframe holes
- ❏ Screw in rail button and airframe screws
- ❏ Grease 2 O-rings
- ❏ Place 2 greased O-rings around nozzle
- ❏ Place nozzle into motor casing
- ❏ Insert thrust ring and snap ring

- ❏ Integrate with launch rail
- ❏ Prepare ignition system
- ❏ Remove non-essential personnel
- ❏ Test to ensure ignition system is functioning properly
- ❏ Retreat
- ❏ Insert igniter
- ❏ Verify range is clear with RSO
- ❏ Connect ignition system leads to igniter
- ❏ Arm ignition system
- ❏ Go for countdown

Hangfire Procedure:

- ❏ Wait 10 minutes
- ❏ Have 1 person approach rocket
- ❏ Turn off ignition system and disconnect igniter
- ❏ Communicate with trigger side to test continuity
- ❏ Check again to ensure ignition system is disarmed
- ❏ Verify range is clear with RSO
- ❏ Connect ignition system leads to igniter
- ❏ Arm ignition system
- ❏ Go for countdown

Tools:

- ❑ Push rod
- ❑ Crescent wrenches
- ❑ Mallot
- ❑ Igniters
- ❑ Bone saw
- ❑ Gloves
- ❑ Paper towels
- ❑ Uncured propellant
- ❑ Ignition system
- ❑ Batteries
- ❑ Electrical tape
- ❑ Masking tape
- ❑ Walky talky
- ❑ Balsa wood stick
- ❑ Facemask
- ❑ Multimeter
- ❑ Extension cord
- ❑ O-rings, grease
- ❑ Grease
- ❑ 12x 3/8"-16 screws, hex keys
- ❑ Rail button, 3x 10-32 screws, hex keys
- ❑ Facemask
- ❑ Snap ring pliers
- ❑ Generator

CS

Ground Station:

- ❏ Both batteries have at minimum half charge
- ❏ WiFi network runs and can be connected to
- ❏ All four parsers start up and connect to network
- ❏ All four parsers are connected to an audio cable
- ❏ Database is running
- ❏ Web application is being served

During ECE Signal Check:

- ❏ Database is receiving lines
  - ❏ Payload
  - ❏ Rocket
- ❏ Altitude is received and plotting
  - ❏ Payload
  - ❏ Rocket
- ❏ GPS is received and plotting
  - ❏ Payload
  - ❏ Rocket

Structures & Integration

Bill of Materials

- ❏ Components
    - ❏ Lower body tube (x1)
    - ❏ Upper body tube (x1)
    - ❏ Nose cone (x1)
    - ❏ Nose cone tip (x1)
    - ❏ Upper nose cone bulkhead (x1)
    - ❏ Lower nose cone bulkhead (x1)
    - ❏ Midbay bulkheads (x2)
    - ❏ Nose cone avionics tower (x1)
    - ❏ Nose cone foam (x1)
    - ❏ Midbay avionics ladder (x1)
    - ❏ Boat tail (x1)
- ❏ Hardware
    - ❏ ¼” threaded rod (x1)
    - ❏ ¼” eye bolt nut (x2)
    - ❏ ¼” locknut (x2)
    - ❏ ¼” washer (x2)
    - ❏ ⅜” eye bolt (x1)
    - ❏ ⅜” washerm (x1)
    - ❏ #6 locknut (x9)
    - ❏ Shear pin (x9)
    - ❏ ½” eye bolt (x1)
    - ❏ ½” locknut (x1)
    - ❏ ½” washer (x1)
    - ❏ 10-32 screws (x3)
    - ❏ Rail button (x1)
    - ❏ Large zip ties (x4)
    - ❏ Sealant tape
- ❏ Tools
    - ❏ Structures tool box
        - ❏ Verify all tools are in tool box
    - ❏ Drill
    - ❏ Drill bits
    - ❏ File
    - ❏ Masking tape
    - ❏ Electrical tape
    - ❏ Gorilla tape
    - ❏ 5 min epoxy
    - ❏ Putty
    - ❏ Sand paper
    - ❏ Acetone
    - ❏ Shop towels

Component Inspection

- ❏ Inspect composite components for delamination and damage
  - ❏ Body Tubes (edges, rail guide, shear pin/air holes, clean of dust and dirt)
  - ❏ Coupler Tubes (edges, shear pin holes, clean of dust and dirt)
  - ❏ Nose Cone (inspect coupler joint)
  - ❏ Boat Tail (inspect coupler joint)
  - ❏ Lower Bulkhead (inspect epoxy fillet)
  - ❏ Fins (edges, tap test, wiggle test

Subsystem Verification (before subsystems are integrated into rocket verify subsystems are properly assembled/prepped)

- ❏ Nose Cone Avionics Assembly - EE
- ❏ CubeSat Payload Assembly - Payload
- ❏ Black Powder Charge Prep - Aero & Recovery
- ❏ Midbay Avionics Assembly - EE
- ❏ Motor Assembly - Propulsion
- ❏ Drogue Shock Cord Prep - Aero & Recovery
- ❏ Drogue Parachute Prep - Aero & Recovery
- ❏ Drogue Spectra Cord Prep - Aero & Recovery
- ❏ Deployable Payload Assembly - Payload, EE
- ❏ Main Parachute Prep - Aero & Recovery

Rocket Integration

- ❏ Nose Cone Integration
  - ❏ Tie spectra cord to one end of swivel
  - ❏ Attach free end of swivel to ⅜” eye bolt
  - ❏ Slide ⅜” washer then upper nose cone bulkhead onto ⅜” eye bolt
  - ❏ Set nose cone tip in upper nose cone ring and screw onto eye bolt assembly (one person holds the eyebolt in place inside of nose cone, a second person screws on nose cone tip.
  - ❏ Slide **nose cone avionics tower** onto spectra cord and center on mounting ring screws
  - ❏ Screw #6 lock nuts onto avionics tower retaining screws
  - ❏ Slide protective foam onto spectra cord until it rests against the the avionics tower
  - ❏ Zip tie **cubesat payload** to lower nose cone bulkhead (set on lip side, 2 sets of zip ties)
  - ❏ Slide lower nose cone bulkhead assembly onto spectra cord (so cubesat is inside nose cone) until it sits in the nose cone coupler
  - ❏ Tie off spectra cord at end of nose cone bulkhead

- ❏ Midbay Integration
  - ❏ Screw ¼” eye bolt onto ¼” threaded rod
  - ❏ Screw ¼” lock nut on threaded rod after eye bolt nut (eye bolt side)
  - ❏ Slide ¼” washer onto other side of threaded rod
  - ❏ Slide upper mid bay bulkhead onto threaded rod
    - ❏ Verify main and backup e-match wires are placed through correct holes
  - ❏ Slide threaded rod assembly through upper body tube until bulkhead lip rests on coupler tube (slot needs to face rail side)
  - ❏ Slide **midbay avionics ladder** partially onto threaded rod and connect upper e-match wires (main and backup) and pi camera connector

- ❏ Slide lower mid bay bulkhead onto threaded rod and connect lower e-match wires (main and backup)
    - ❏ Verify main and backup e-match wires are placed through correct holes
- ❏ Slide mindbay avionics ladder down the threaded rod so that the upper bracket sits in slot in upper bulkhead
- ❏ Slide lower mid-bay bulkhead down the threaded rod until the lip rests on the coupler tube and the lower bracket sits in slot
- ❏ Slide ¼" washer onto threaded rod
- ❏ Screw ¼" eye bolt nut onto threaded rod
    - ❏ verify eye bolt nut is tightened all the way
- ❏ Screw ¼" lock nut on threaded rod after eye bolt nut

❏ Drogue Parachute and Payload Integration (upper body tube)
- ❏ Place primary 14g black powder charge on top of lower mid-bay bulkhead
- ❏ Place three handfuls of dog barf in airframe
- ❏ Slide pressure cap so that it rests on the dog barf
- ❏ Place backup 14g black power charge on top of pressure cap
- ❏ Place three more handfuls of dog barf in airframe
- ❏ Verify parachute connections
- ❏ Place **drogue shock cord** in airframe
- ❏ Seat **drogue parachute** in airframe
    - ❏ Make sure tape is removed from parachute
- ❏ Place **drogue spectra cord** on top of drogue parachute
- ❏ Seat **deployable payload** in airframe so it rests on top of the spectra cord

❏ Nose Cone Coupler Integration
- ❏ Slide nose cone couple into body tube and secure with shear pins (x3)
    - ❏ Verify rail side of nose cone lines up with rail side of upper body tube

❏ Motor Integration Part I
- ❏ Screw ½" lock nut onto ½" eye bolt until it is at the top of the eye bolt threaded rod
- ❏ Place ½" eye bolt through clearance hole in motor retention bulkhead (from upper end of airframe)
- ❏ Slide **motor** into lower body tube and screw onto eye bolt, adjusting eye bolt so that the motor tube retaining holes line up with those on the body tube
    - ❏ Verify that the eye bolt is tightened all the way

❏ Main Parachute Integration Part II (lower body tube)
- ❏ Attach swivel to eye bolt in motor retention bulkhead
- ❏ Verify main parachute connections
- ❏ Place main 12g black powder charge on motor retention bulkhead
- ❏ Place 3 handfuls of dog barf in airframe
- ❏ Seat parachute in airframe
- ❏ Place 3 handfuls of dog barf in airframe
- ❏ Place backup 12g black powder charge on top of dog barf

❏ Body Tube Coupler Integration
- ❏ Slide upper body tube coupler tube into lower body tube and secure with shear pins (x6)

- ❏ Verify rail side of upper body tube lines up with rail side of lower body tube

- ❏ Motor Integration Part II
  - ❏ Integrate nozzle into motor
  - ❏ Slide boat tail coupler between motor tube and body tube so that holes line up
  - ❏ Secure airframe, boat tail, and motor tube with 10-32 retaining screws (x3 and one rail button)
    - ❏ Verify rail button is on rail side of airframe

Launch Rail Integration

- ❏ Confirm that the following pre-flight checklists are complete:
  - ❏ Propulsion
  - ❏ Aerodynamics & Recovery
  - ❏ Payload
  - ❏ Electronics
  - ❏ Structures & Integration
- ❏ Loosen all screws on launch rail and align t-slot rail to the bottom of the truss
- ❏ Hammer in connecting pins in the bottom truss and place top truss over
- ❏ Fixate the top rail
- ❏ Slide t-slot connectors over both rail
- ❏ Tighten all rail screws
- ❏ Align flame trench
- ❏ Ensure rail has been lubed with dry graphite spray
- ❏ Place all 4 outriggers in their respective spots on the trailer
- ❏ Attach guidewires to rail
- ❏ Hammer steaks at 120 degrees apart about 20 feet away from rail
  - ❏ 1st guidewire goes directly over the trailer
- ❏ **CAREFULLY** slide rail button and rail guide onto launch rail until rocket reaches end stop
  - ❏ **<u>NOTE 1</u>: Be extremely careful not to twist or lift rocket once the rail guides are on the rail**
  - ❏ **<u>NOTE 2</u>: Ensure guides do not snag at interface between rail sections**
- ❏ Raise launch rail
- ❏ Set appropriate launch angle
- ❏ Tighten turnbuckles on guidewires
- ❏ Move to propulsion launch checklist

Flight

- ❏ Confirm that the following pre-flight checklists are complete:
  - ❏ Propulsion
  - ❏ Aerodynamics & Recovery
  - ❏ Payload
  - ❏ Electronics
  - ❏ Structures & Integration
  - ❏ Launch Rail
- ❏ Arm electronics in payload and rocket
- ❏ ALL Team members/observers meet at ground station!
- ❏ Designate post-launch teams
- ❏ Equip each post-launch team with a radio
- ❏ Disperse all post-launch teams to appropriate locations (either ground station or lookout area)
- ❏ Confirm via radio that all post-launch teams are in position
- ❏ Confirm proper wind/weather conditions
- ❏ Confirm that ground station is ready for launch
- ❏ Give launch site the go ahead for launch
- ❏ Commence launch countdown over radio
- ❏ All ears to ground station (remains at GS) for GPS coordinates
  - ❏ Primary rocket recovery
  - ❏ Primary payload recover

<u>Hangfire Procedure</u>

- ❏ Wait 10 minutes
- ❏ Have 1 person approach rocket
- ❏ Turn off ignition system and disconnect igniter
- ❏ Communicate with trigger side to test continuity
- ❏ Check to ensure ignition system is disarmed
- ❏ Verify range is clear with RSO
- ❏ Connect ignition system leads to igniter
- ❏ Arm ignition system
- ❏ Go for countdown

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Appendix F: Engineering Drawing

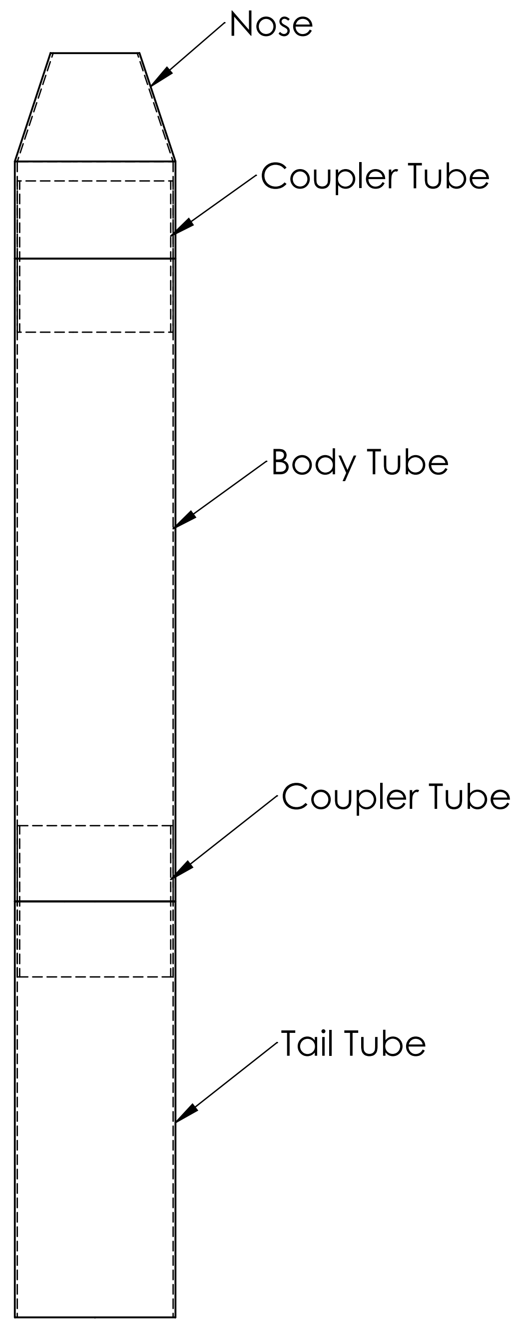
Acknowledgments

References

[1] Budynas, B.G. and Nisbett, J.K. *Shigley's Mechanical Engineering Design,* 9th ed. McGraw Hill, New York City, NY, 2014. pp.225

[2] Simmons III, J.R., "Aeroelastic Optimization of Sounding Rocket Fins," M.S. thesis, Department of the Air Force, Air Force Institute of Technology, Wright Patterson Air Force Base, OH, 2009.

[3] Joyce, P., "Common Lay-up Terms and Conditions," United States Naval Academy, 2003

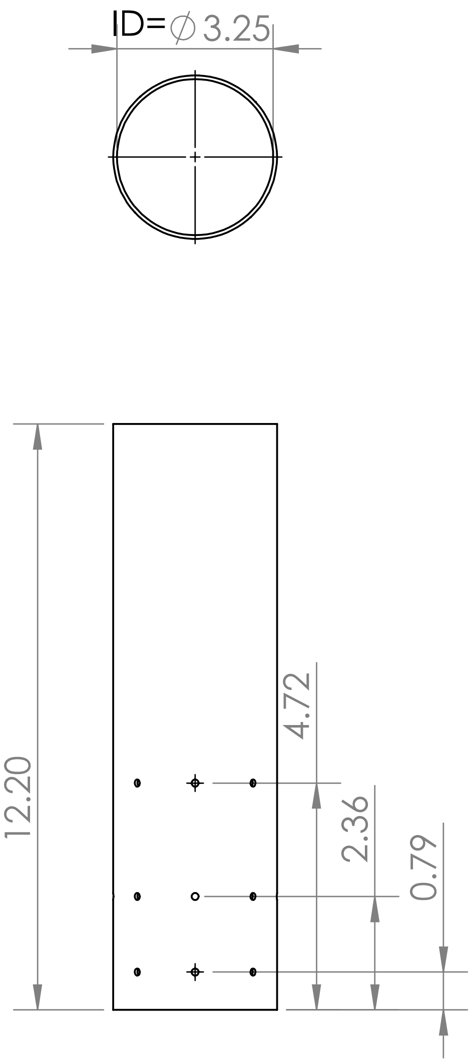


NOTE:

****NOTE:**

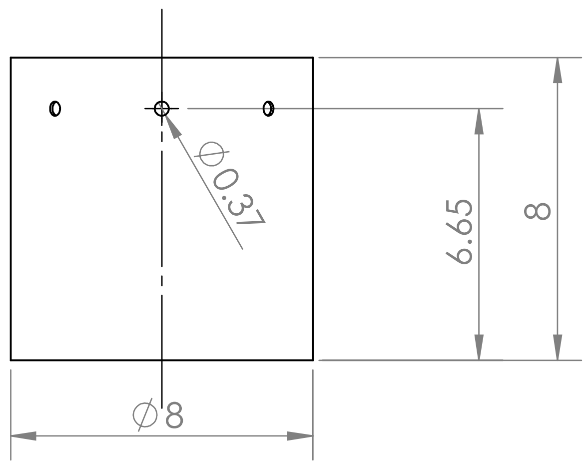
DO **NOT** permanently attach this assembly.
3 parts (nose, body w/ coupler, tail w/ coupler)
should slide together yet still be seperaable

Airframe Assembly

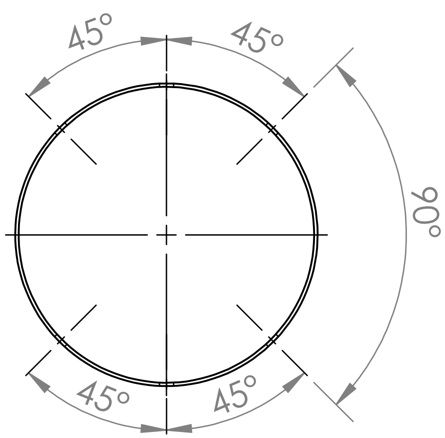


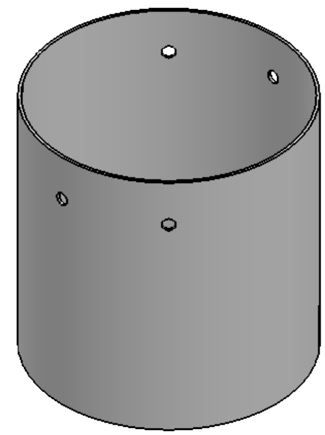
Body Tube
UNITS: Inches

Side View



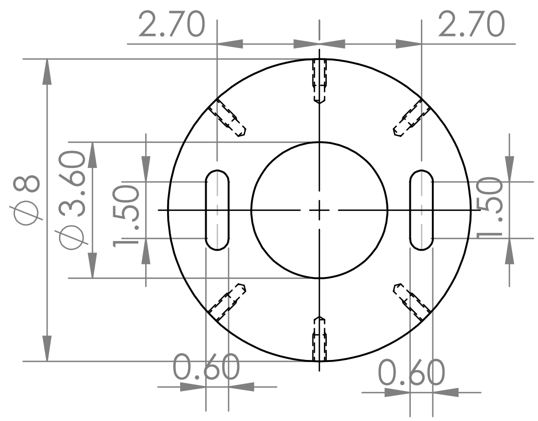
Top View: Hole Locations



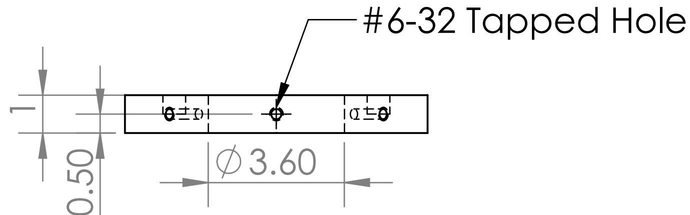


OSU ESRA 2017-18 Payload		
TITLE: Nose Coupler Tube		
SIZE A	UNITS: cm	REV
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

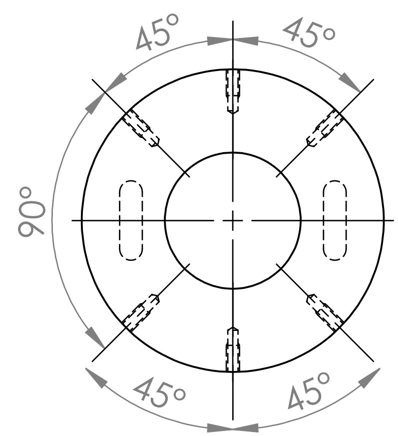
Top View

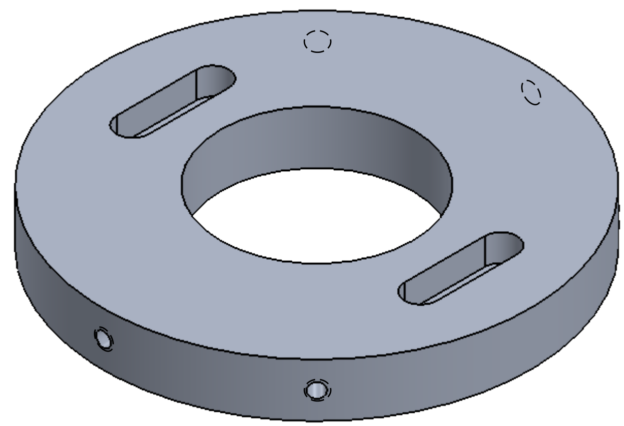


Side View

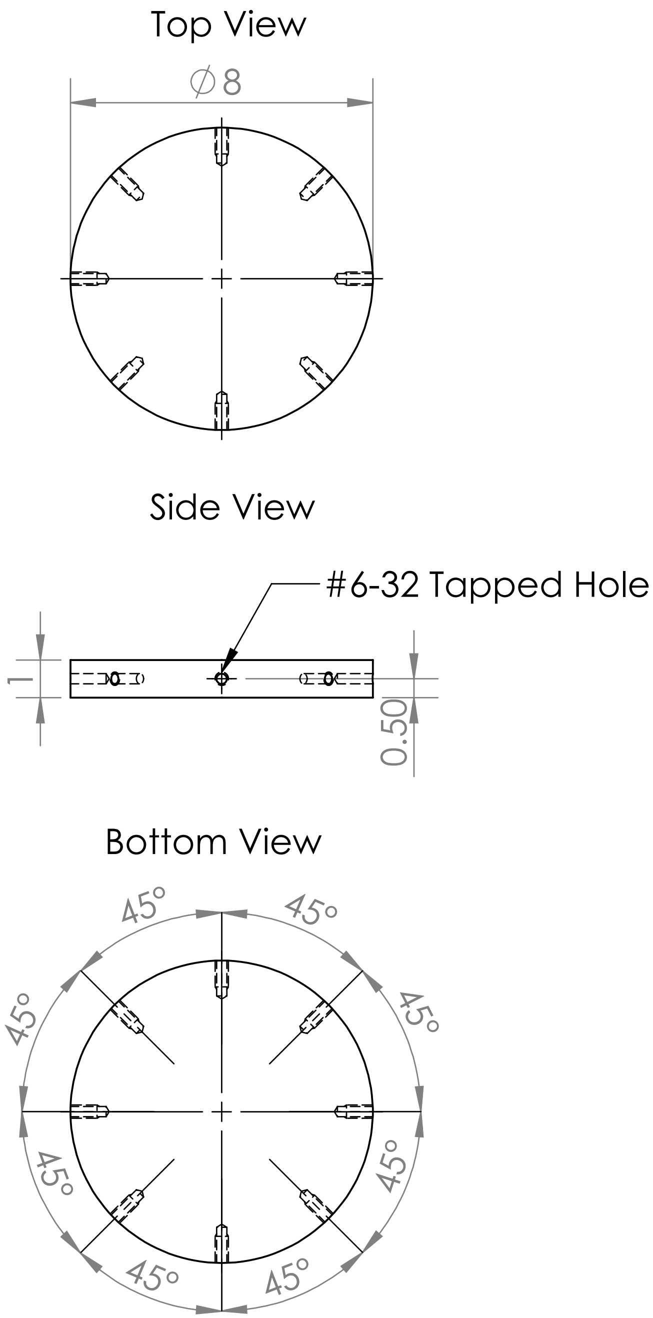


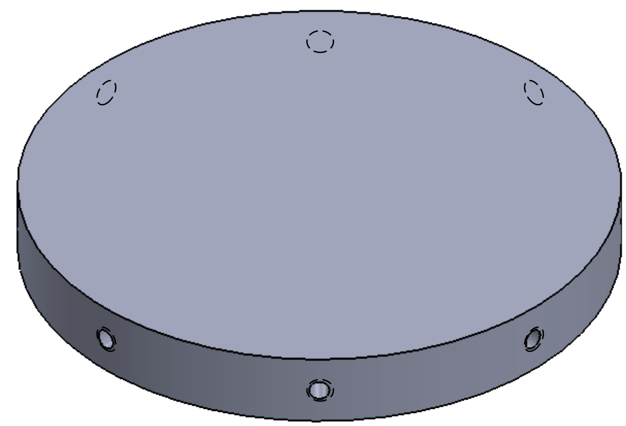
Bottom View



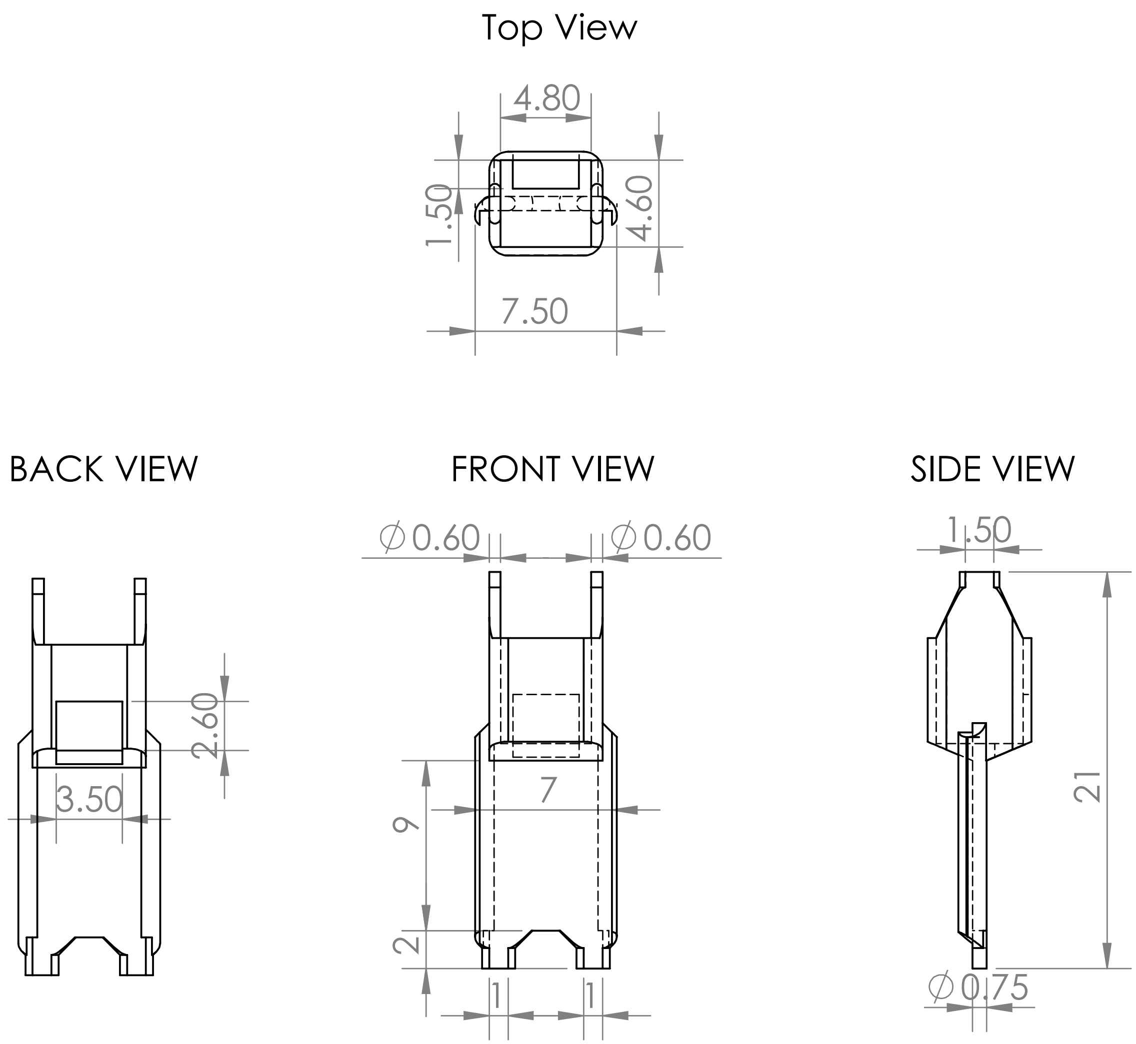


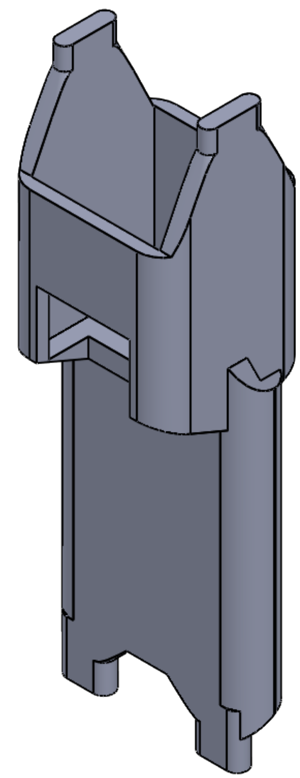
OSU ESRA 2017-2018 Payload		
TITLE: Electronics Bulkhead		
SIZE A	Units: cm	REV
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1



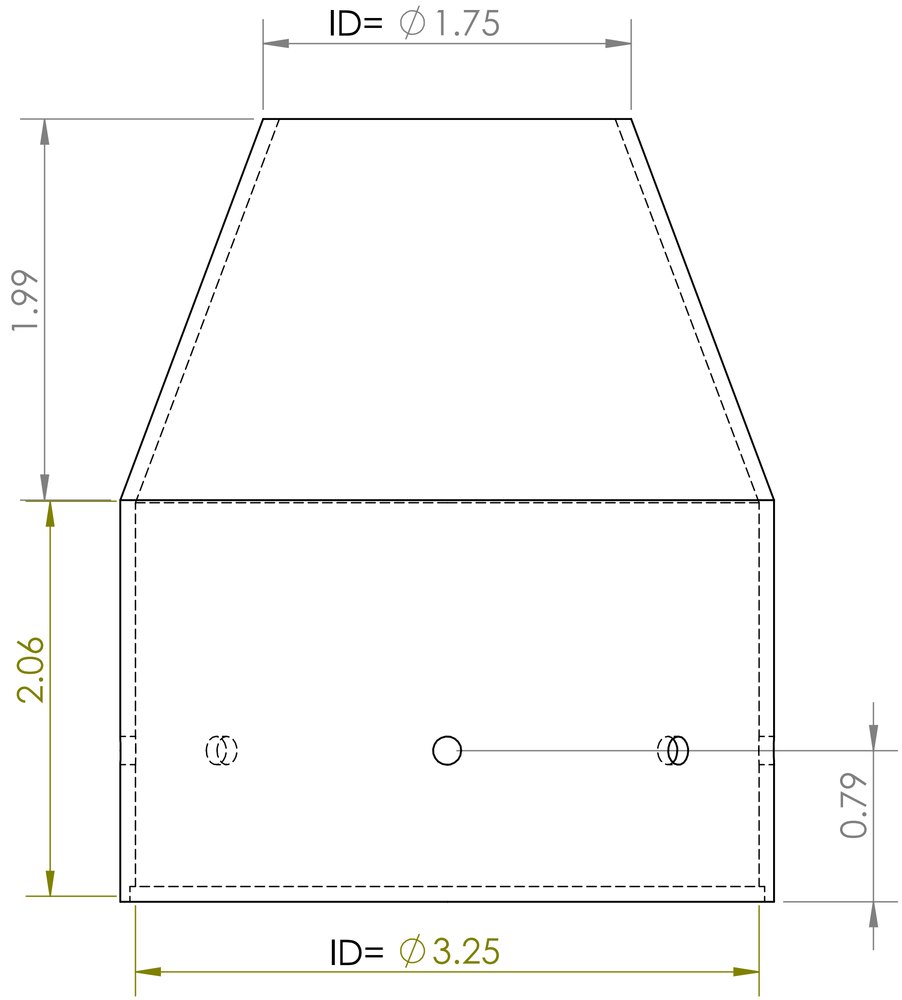


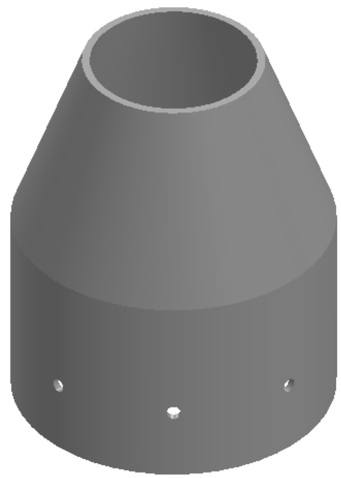
OSU ESRA 2017-2018 Payload		
TITLE: Experiment Bulkhead		
SIZE A	Units: cm	REV
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1





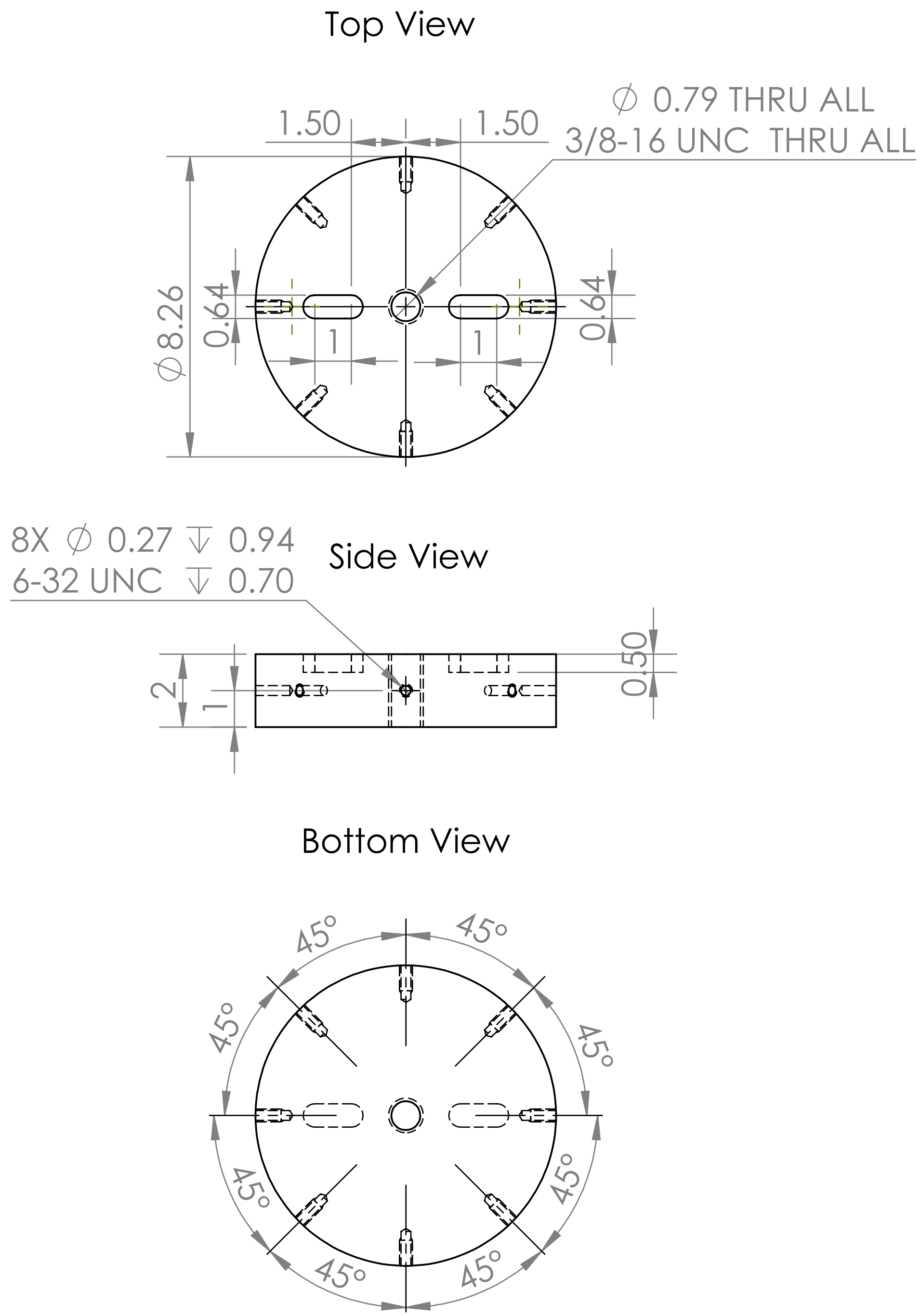
TITLE: Forward Electronics Ladder		
SIZE A	Units: cm	REV
SCALE: 1:4	WEIGHT:	SHEET 1 OF 1

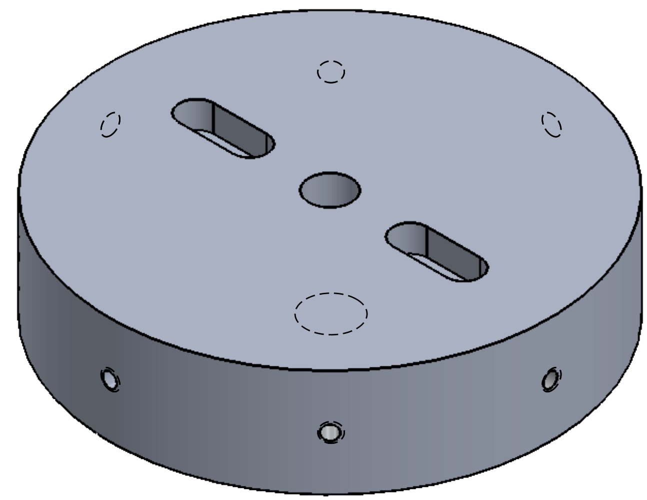




Nose

UNITS: Inches





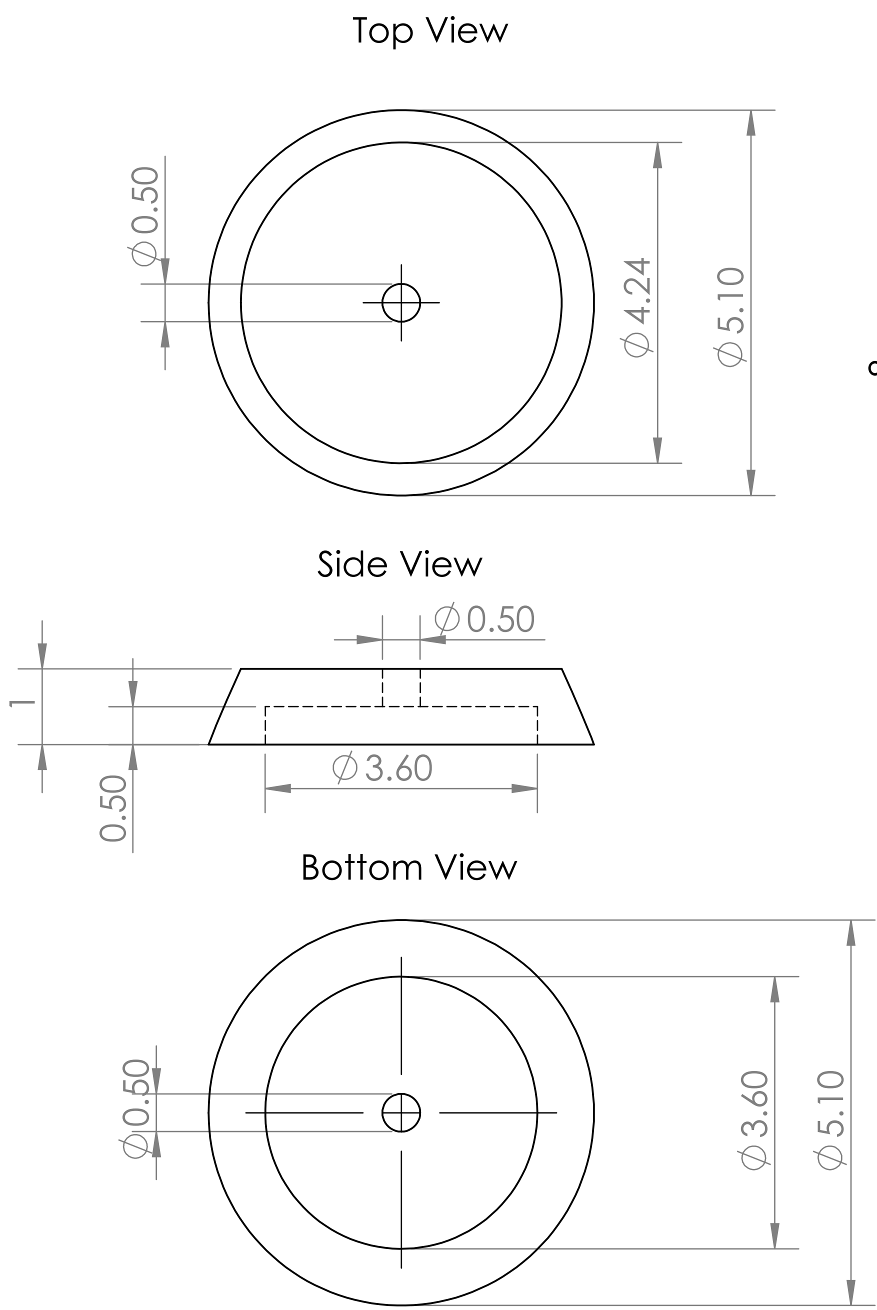
OSU ESRA 2017-2018 Payload

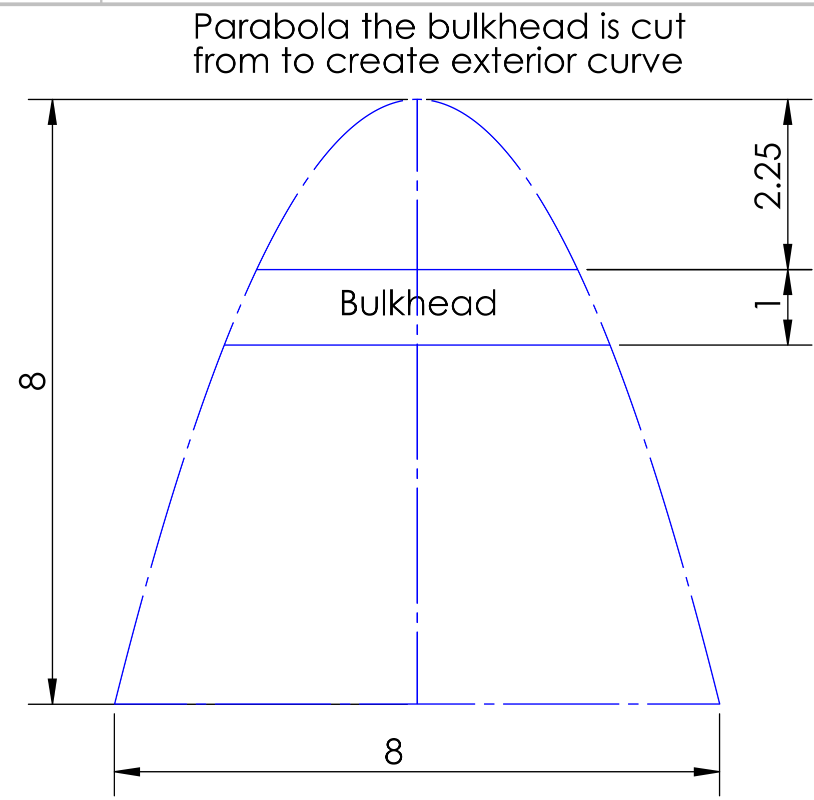
TITLE:

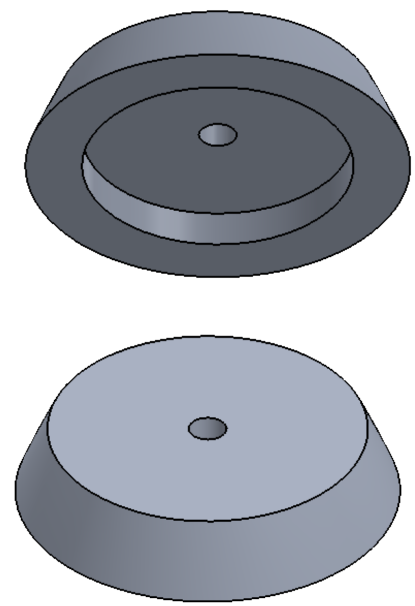
Parachute Bulkhead

SIZE		REV
A	Units: cm	

SCALE: 1:2	WEIGHT:	SHEET 1 OF 1





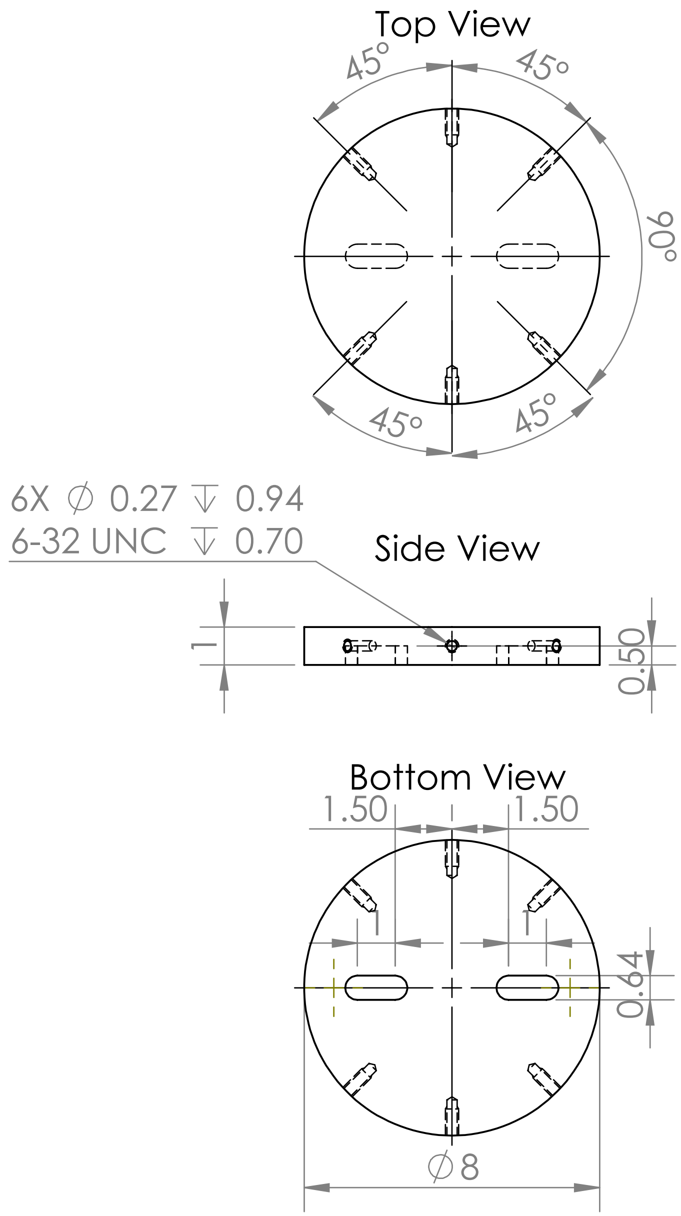


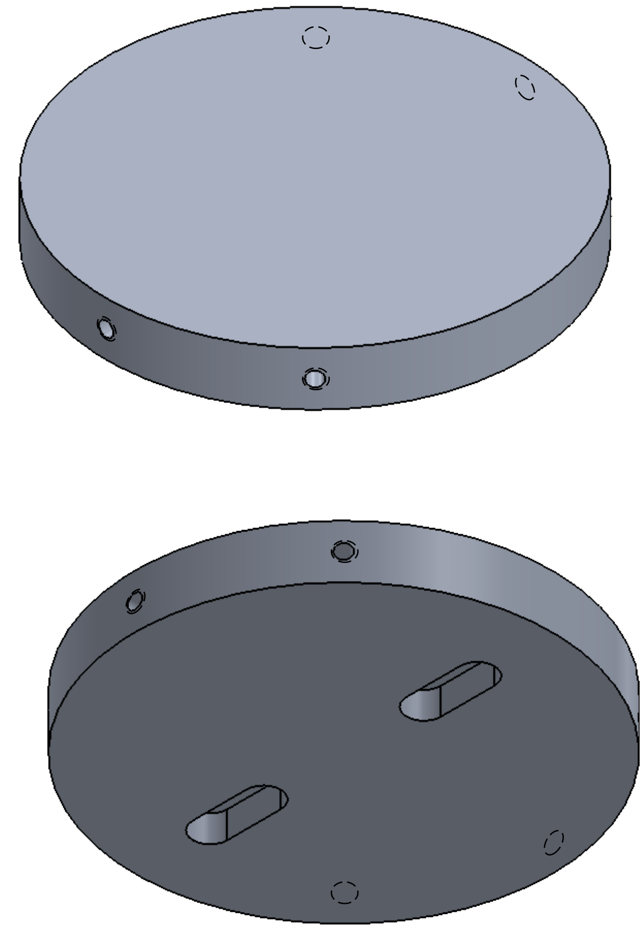
OSU ESRA 2017-2018 Payload

TITLE:

Propeller Motor Bulkhead

SIZE		REV
A	Units: cm	
SCALE: 1:1	WEIGHT:	SHEET 1 OF 1





OSU ESRA 2017-2018 Payload

TITLE:

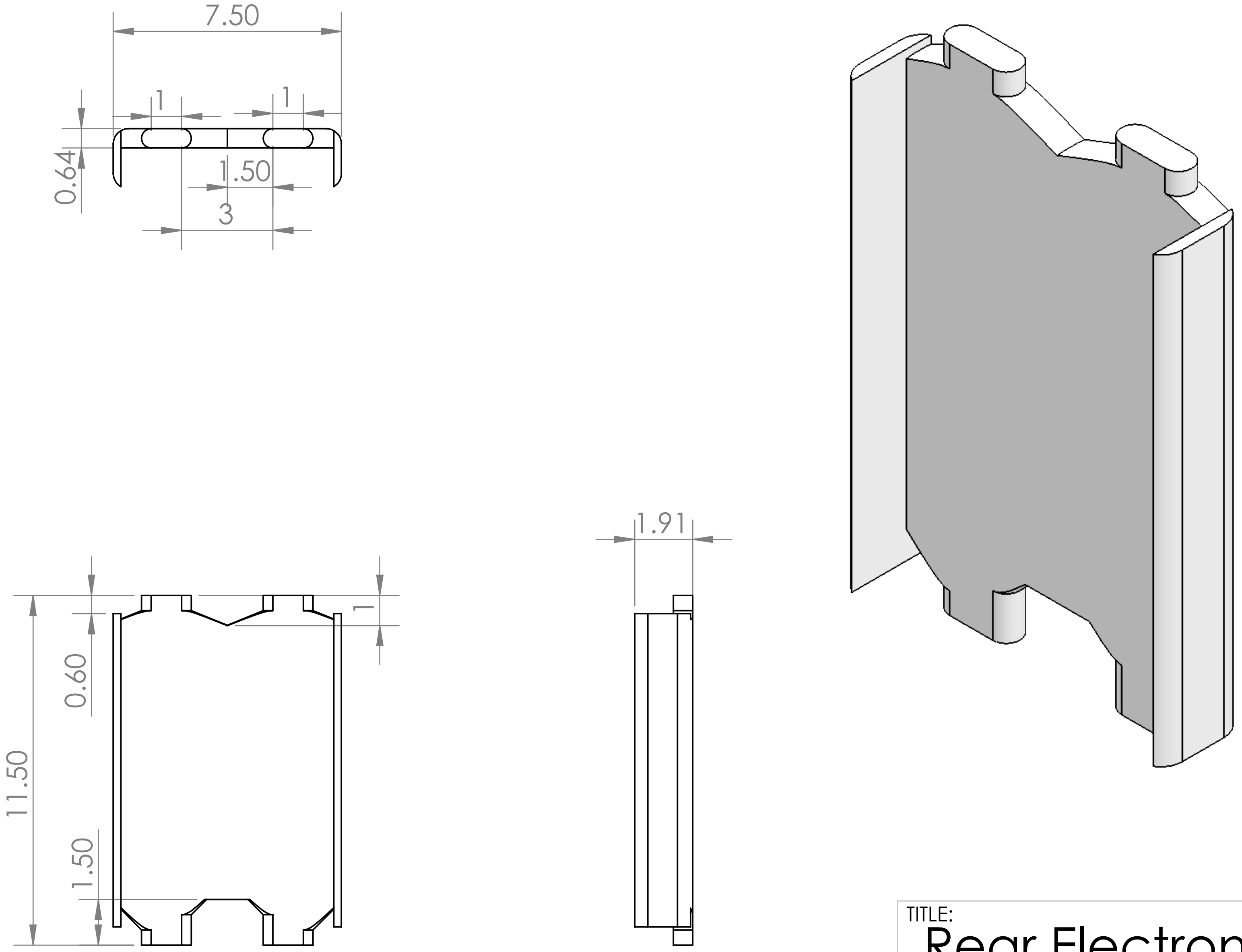
Rear Electronics Bulkhead

SIZE A

Units: cm

REV

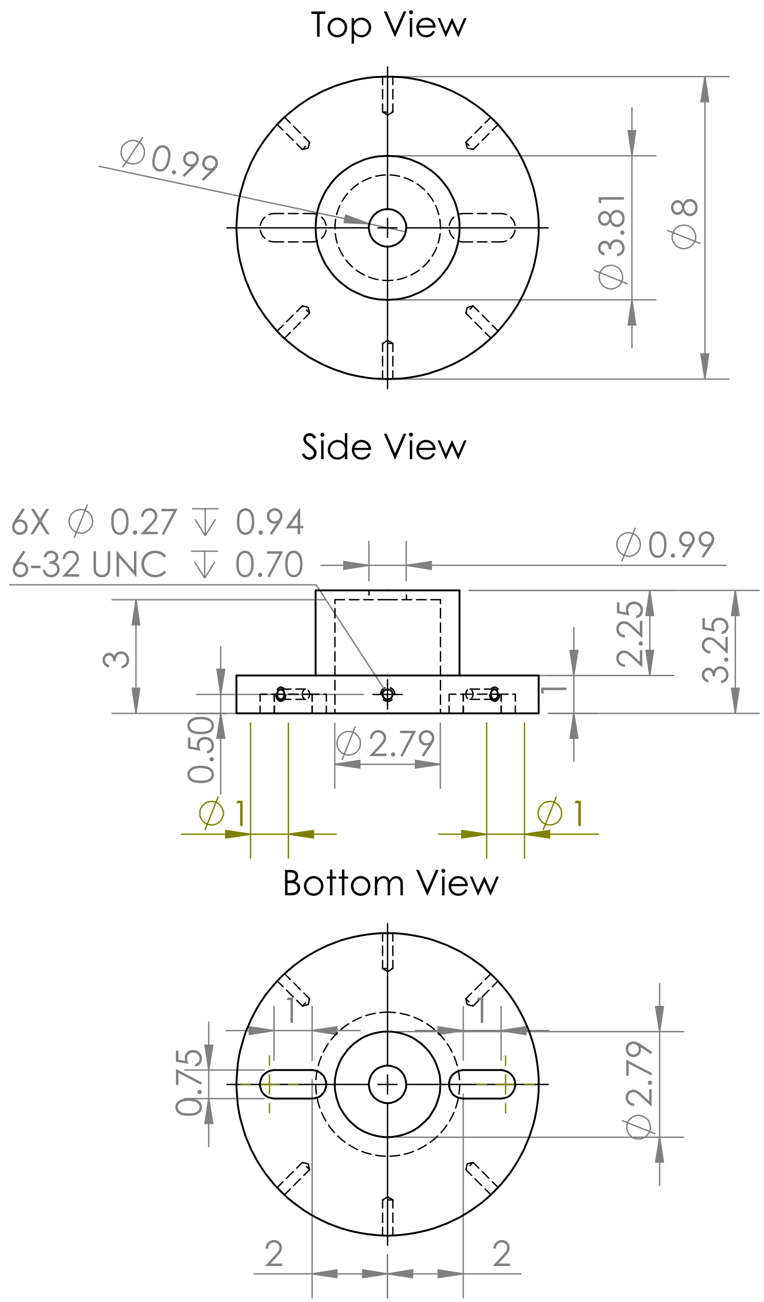
SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1

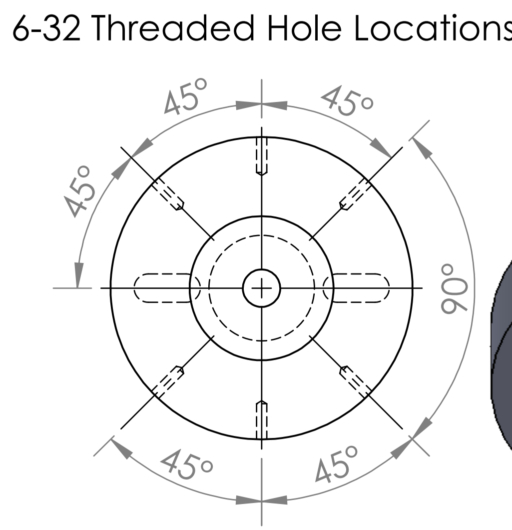


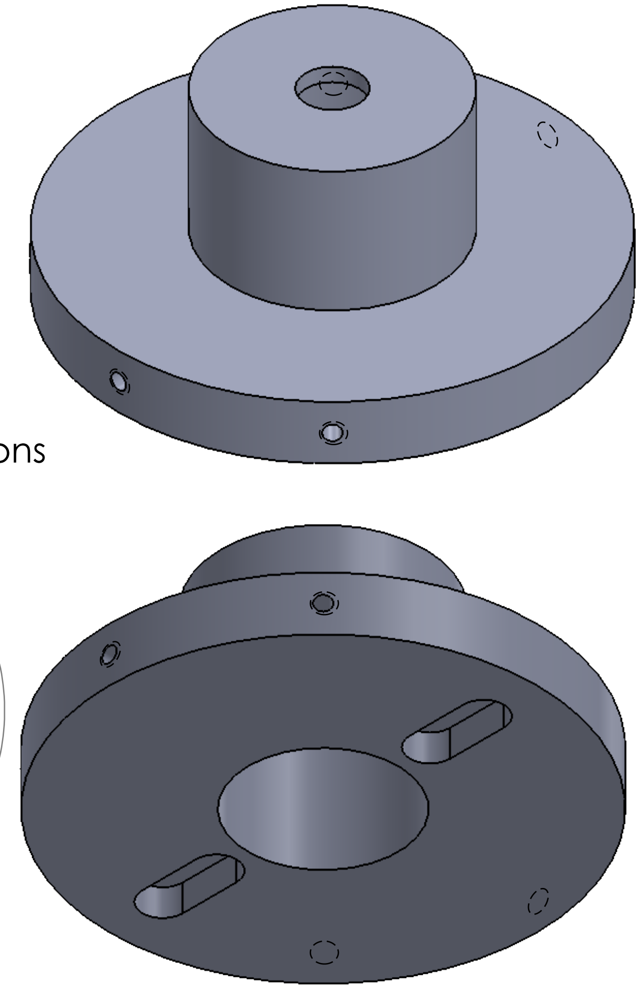
TITLE:
Rear Electronics Ladder

SIZE		REV
A	Units: cm	

SCALE: 1:2	WEIGHT:	SHEET 1 OF 1







OSU ESRA 2017-2018 Payload

TITLE:

Reaction Motor Bulkhead

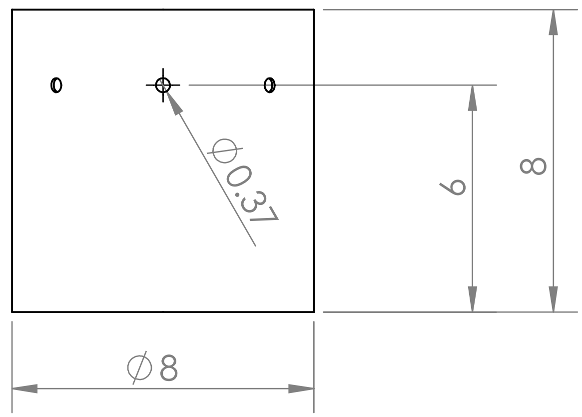
SIZE **A**

Units: cm

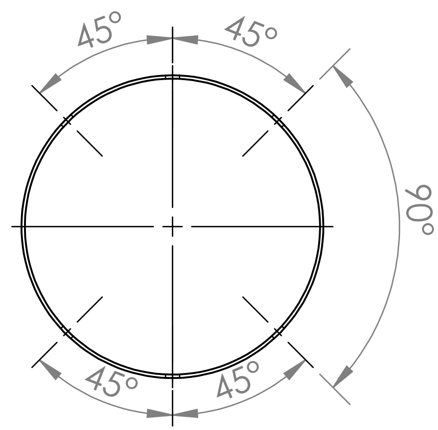
REV

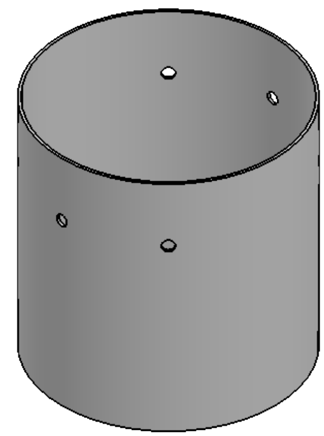
SCALE: 1:2 WEIGHT: SHEET 1 OF 1

Side View

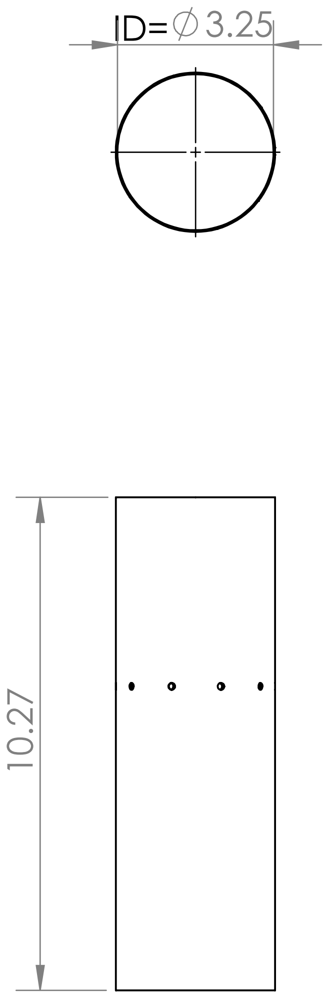


Top View: Hole Locations





OSU ESRA 2017-18 Payload		
TITLE: Tail Coupler Tube		
SIZE A	UNITS: cm	REV
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

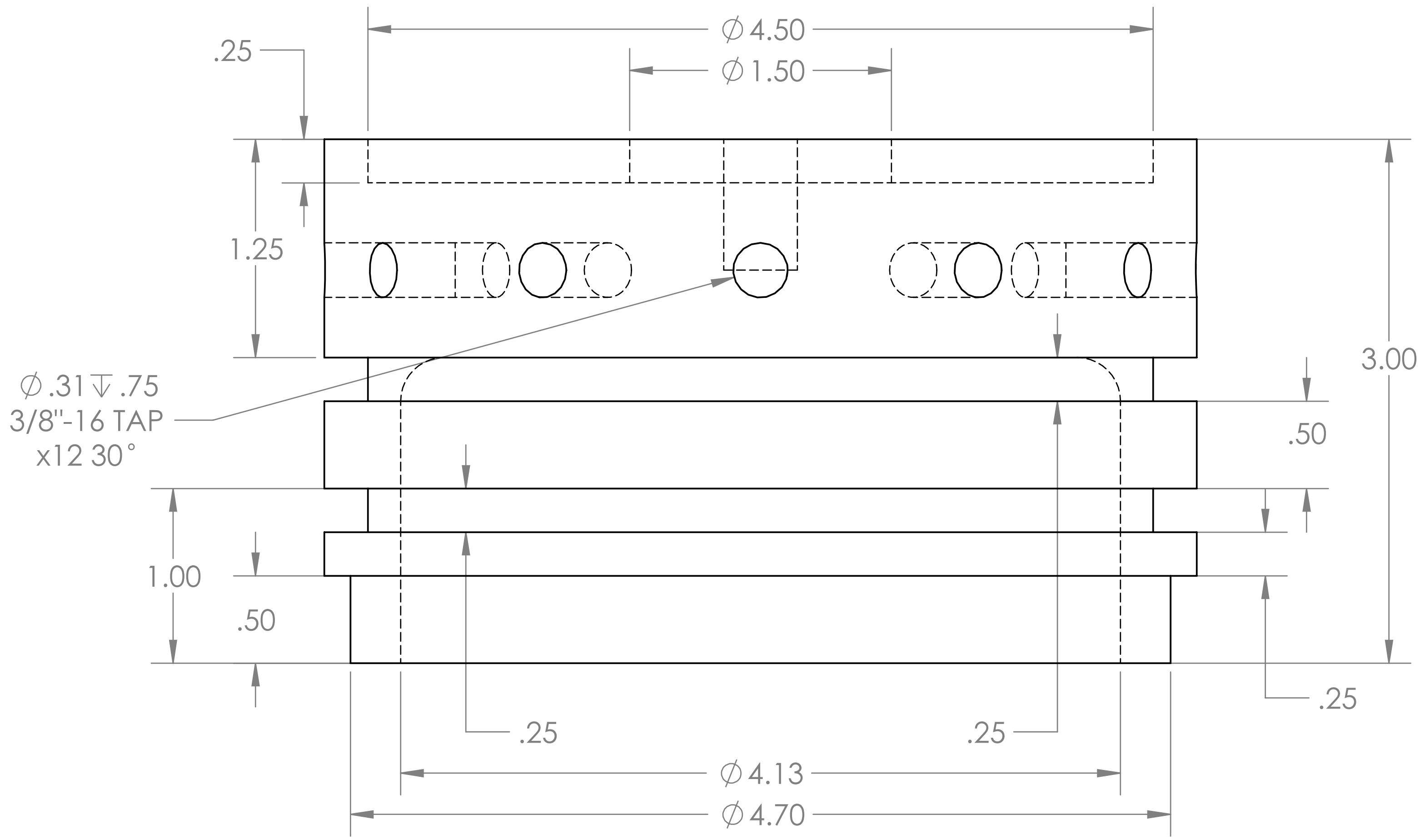


Tail Tube

UNITS: Inches

2 1

B B



A A

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

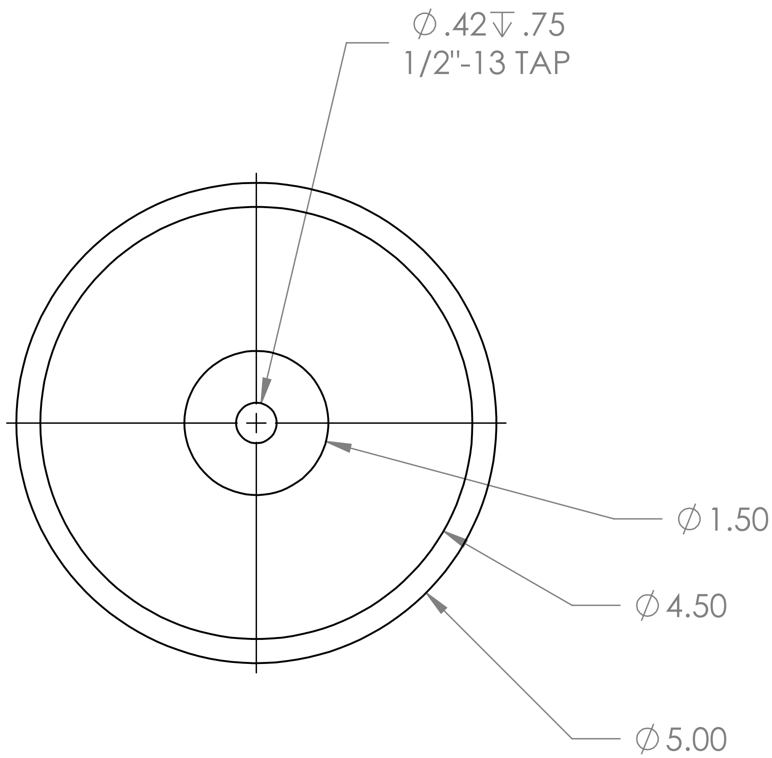
TITLE:

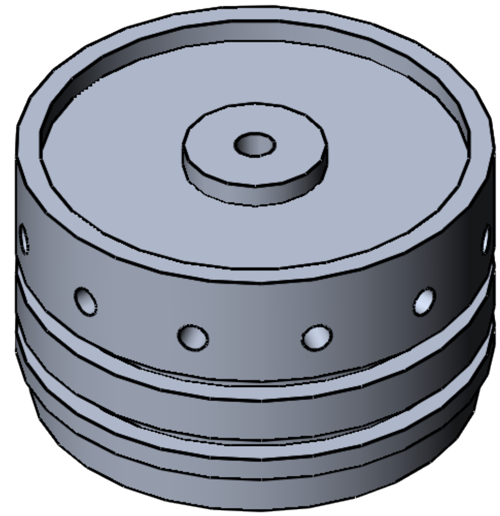
Fwd Encl.

SIZE	DWG. NO.	REV
A		2

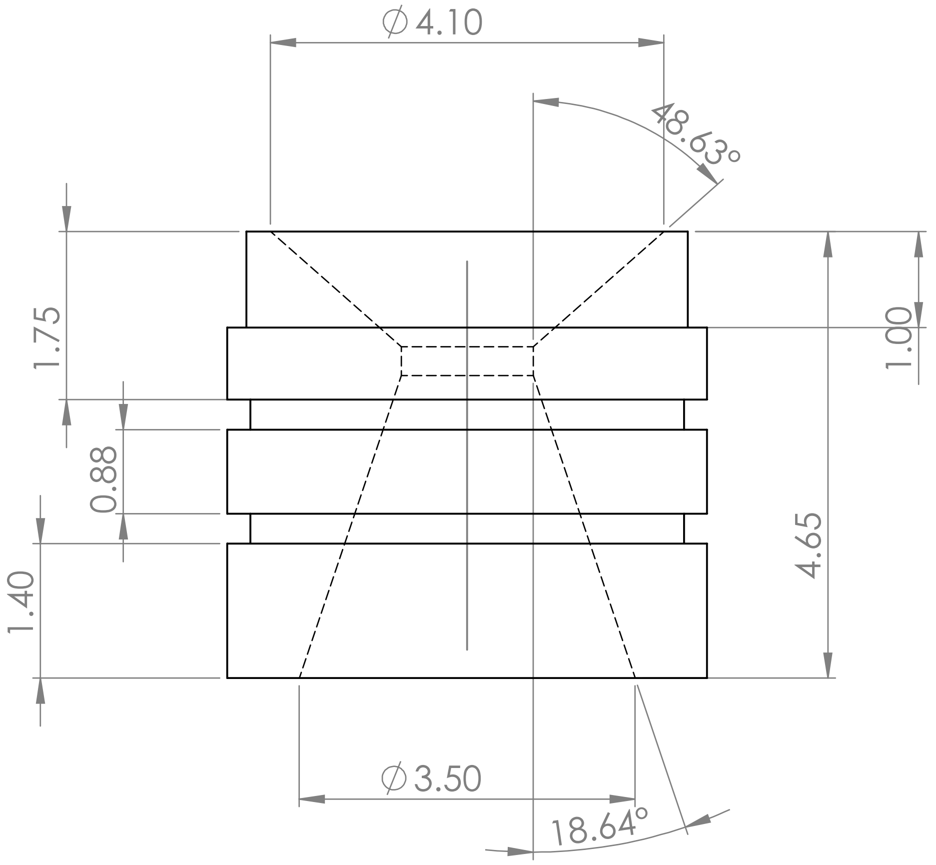
SCALE: 1:1	WEIGHT:	SHEET 1 OF 2

2 1

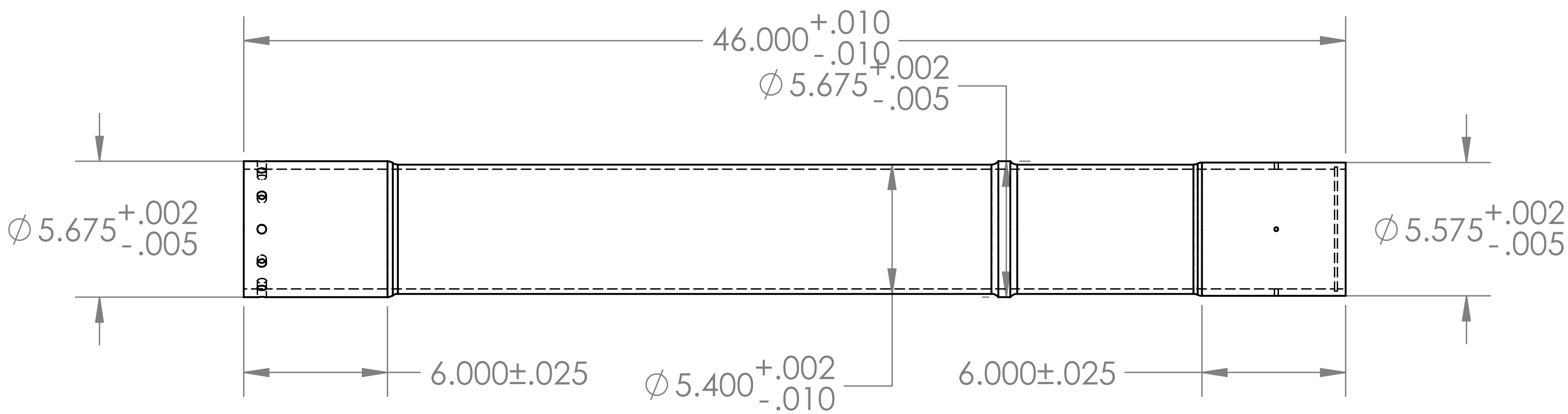




UNLESS OTHERWISE SPECIFIED:		NAME	DATE	OSU AIAA
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE: OSU MOTOR
	CHECKED			
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL	COMMENTS:			SIZE A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



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:		DEBURR AND BREAK SHARP EDGES		REVISION	
	NAME	SIGNATURE	DATE		TITLE: OSU 30k Nozzle	
DRAWN						
CHK'D						
APPV'D						
MFG						
Q.A				MATERIAL: Graphite	DWG NO. Nozzle	A4
				WEIGHT:	SCALE:1:2	SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
AL 6061-T6

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	MH	4/7/18
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

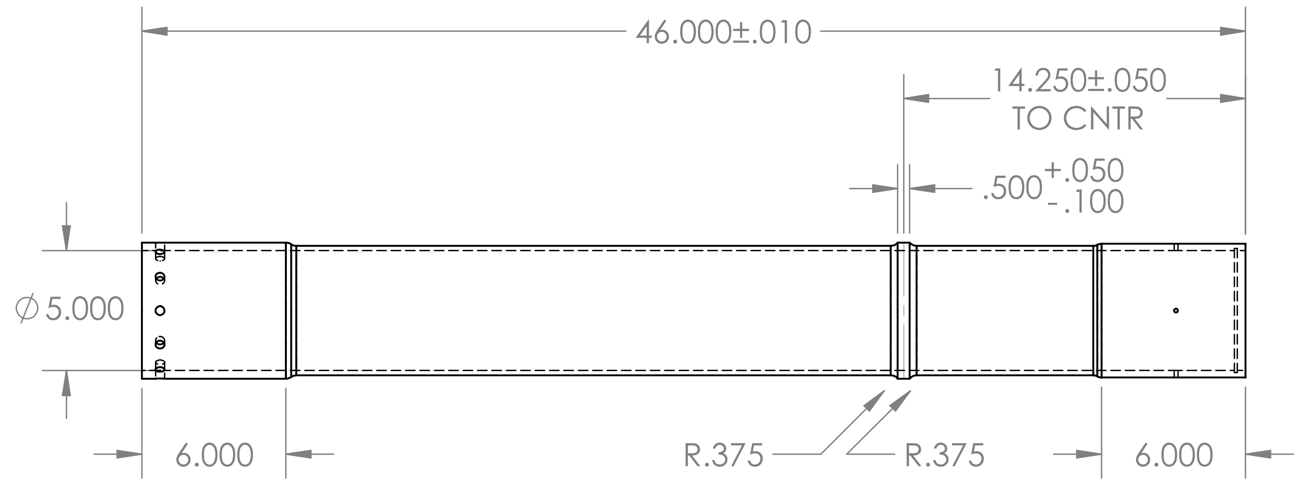
COMMENTS:

TITLE:

OSU MOTOR

SIZE	DWG. NO.	REV
A		3

SCALE: 1:8 WEIGHT: SHEET 1 OF 4



UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
AL 6061-T6

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	MH	4/7/18
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

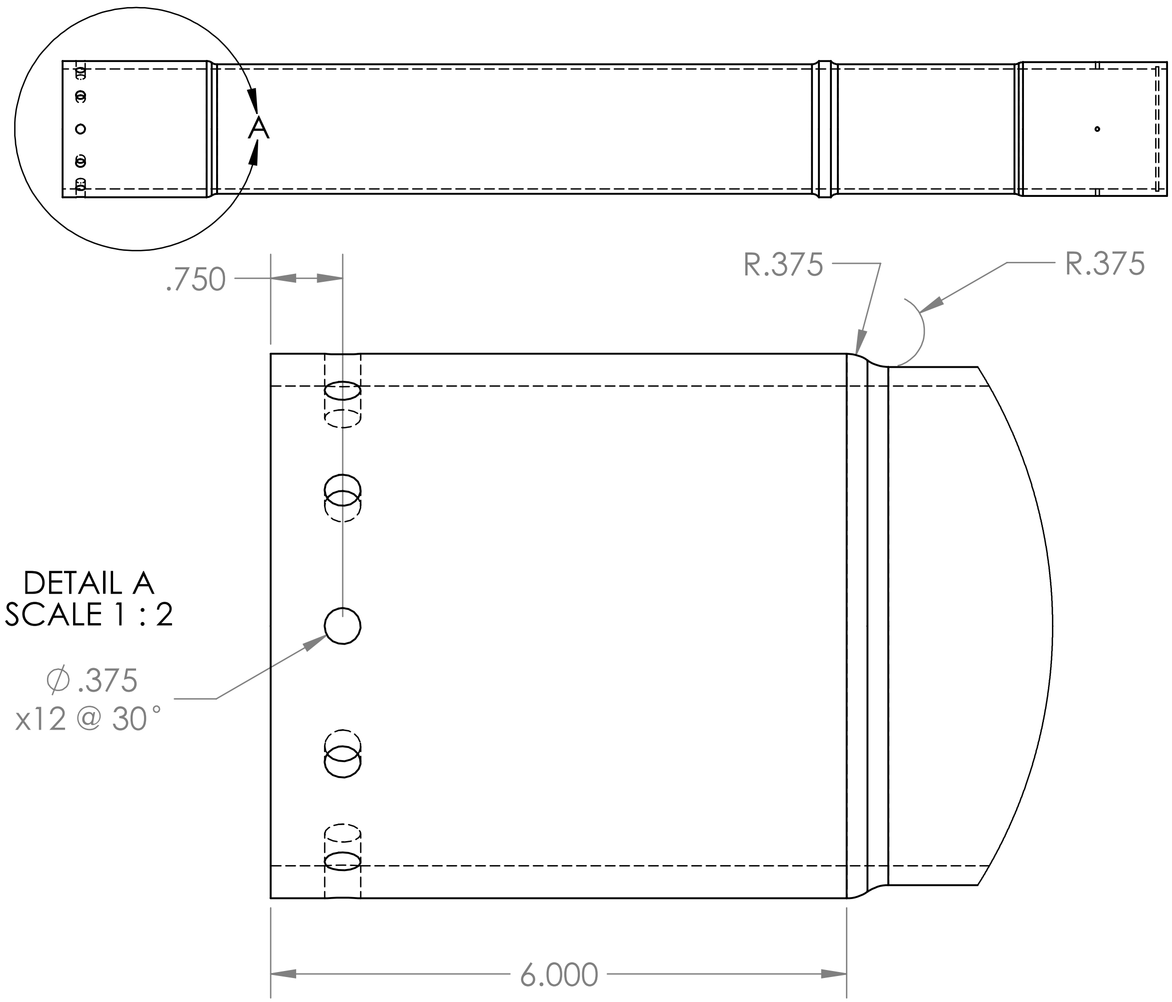
COMMENTS:

TITLE:

OSU MOTOR

SIZE	DWG. NO.	REV
A		3

SCALE: 1:8 | WEIGHT: | SHEET 2 OF 4



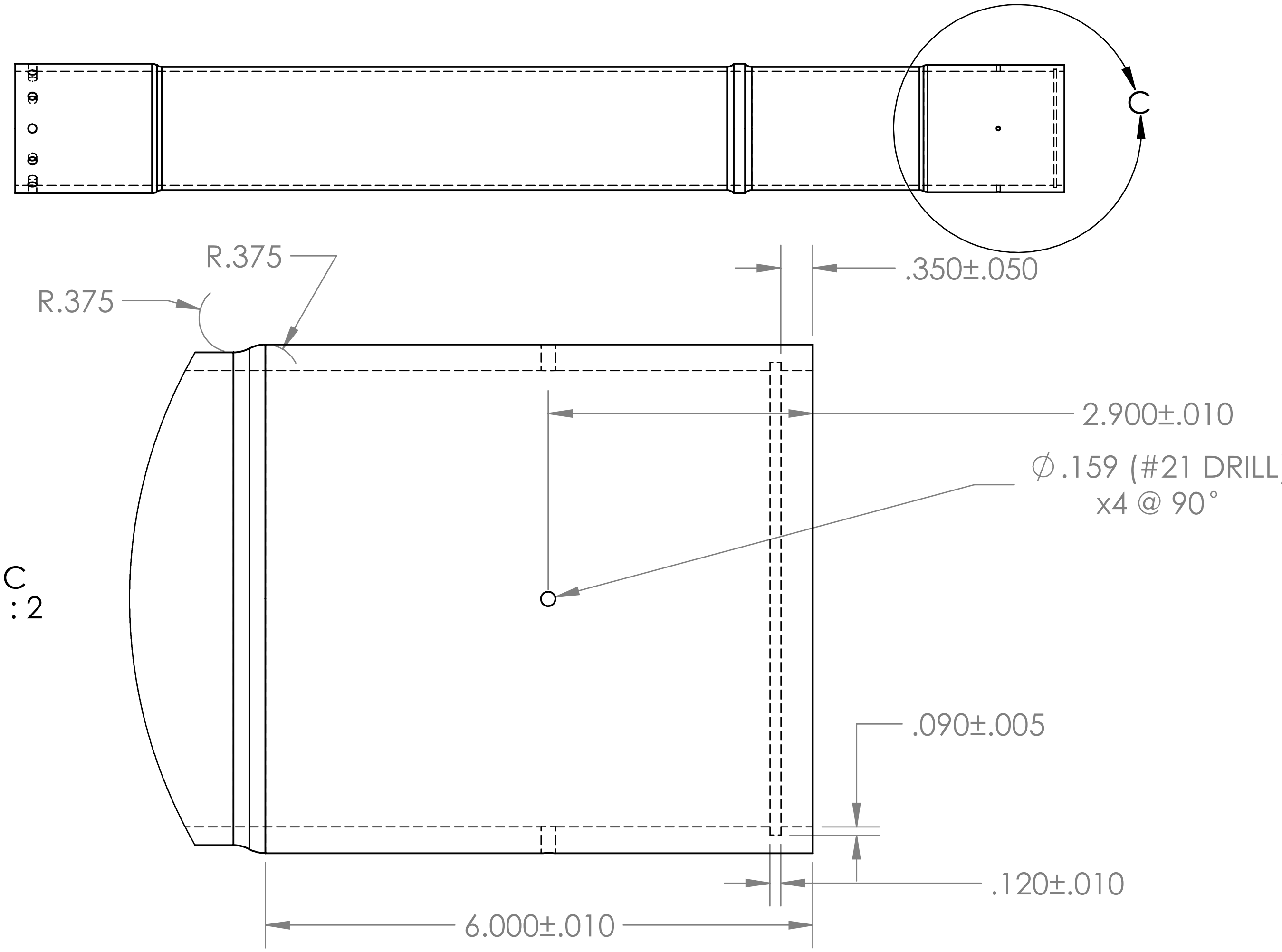
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	MH	4/7/18
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL AL 6061-T6	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

TITLE:

OSU MOTOR

SIZE A | DWG. NO. | REV 3

SCALE: 1:8 | WEIGHT: | SHEET 3 OF 4



DETAIL C
SCALE 1 : 2

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
AL 6061-T6

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	MH	4/7/18
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

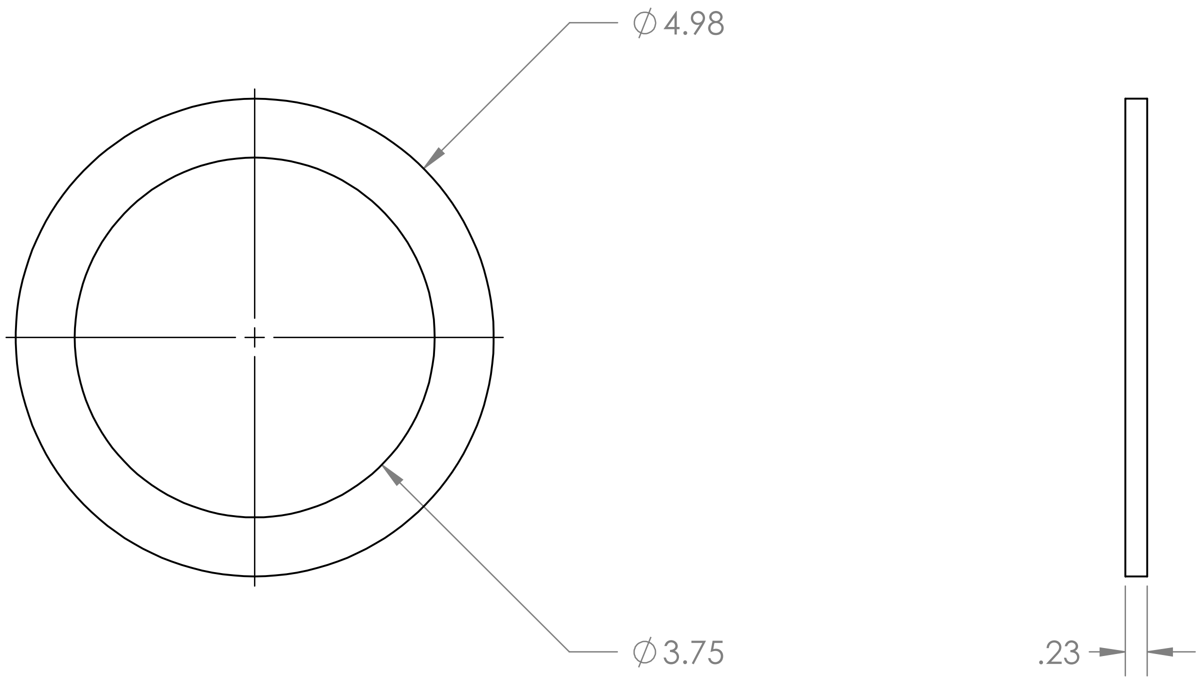
COMMENTS:

TITLE:

OSU MOTOR

SIZE	DWG. NO.	REV
A		3

SCALE: 1:8 WEIGHT: SHEET 4 OF 4



UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
0

FINISH

DO NOT SCALE DRAWING

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

COMMENTS:

TITLE:

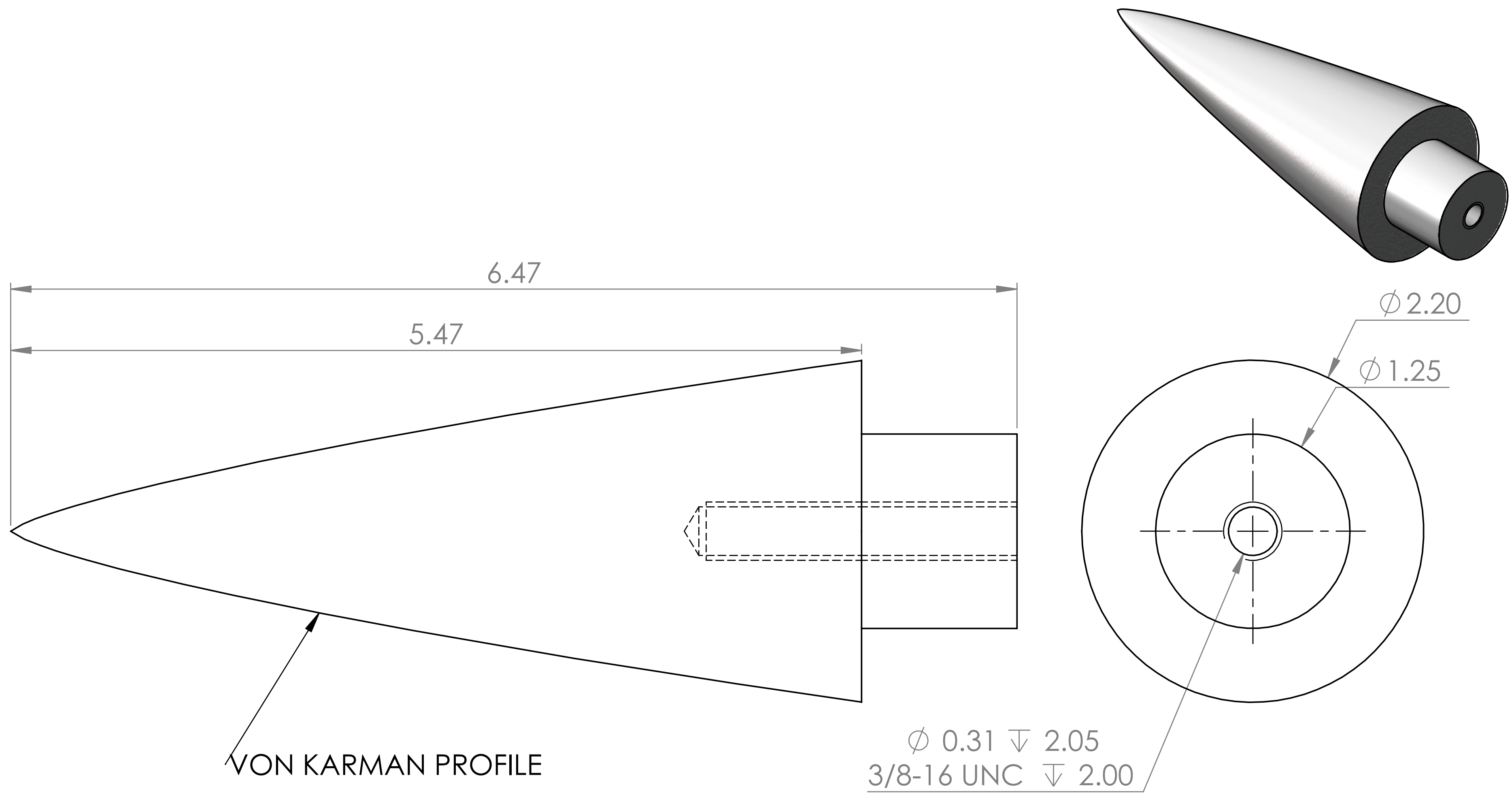
Noz. Retain. Ring

SIZE **A** DWG. NO. REV

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

2 1

B B



A A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	ESRA 30K 2017-18 STRUCTURES & INTEGRATION
		DIMENSIONS ARE IN INCHES TOLERANCES: DECIMAL .XX ±.010 DECIMAL .XXX ±.005 FRACTIONAL ±1/64 ANGULAR: ± 1°	DRAWN	MH	12/7/2017	TITLE: ALUMINUM NOSE CONE TIP
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL: ALUMINUM	COMMENTS: CNC LATHE, BREAK LEADING EDGE WITH SANDPAPER			SIZE A — DWG. NO. ALUMINUM NC TIP — REV 0
NEXT ASSY	USED ON	FINISH: POLISHED OUTER SURFACE				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:2 — SHEET 1 OF 1

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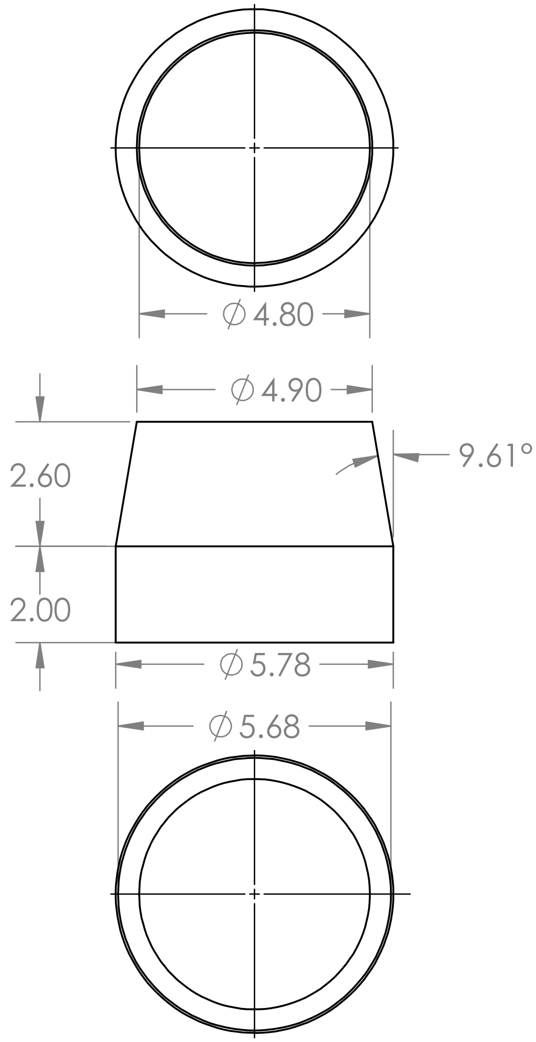
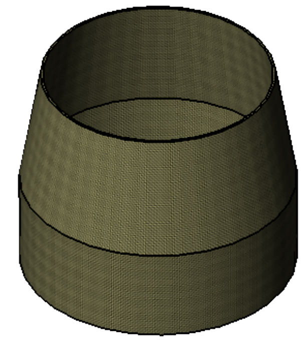
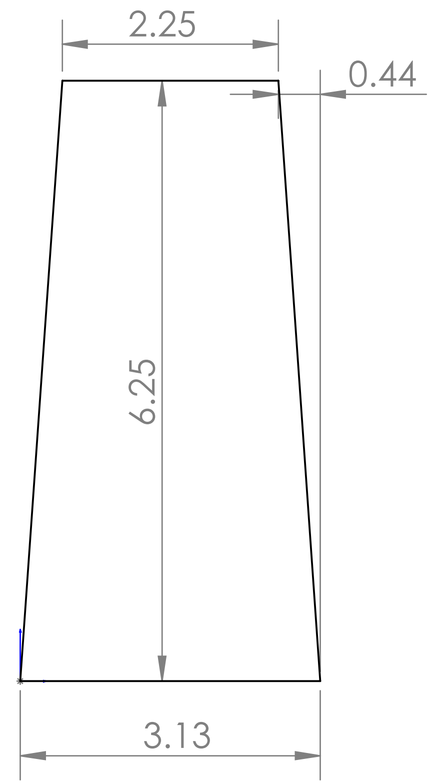
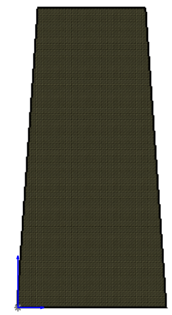
2 1



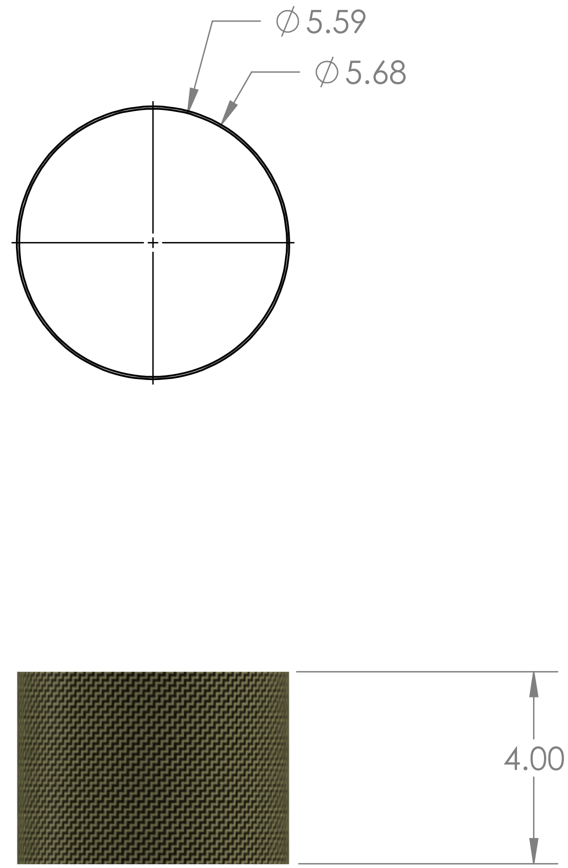


		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	ESRA 30K 2017-18 STRUCTURES & INTEGRATION
		DIMENSIONS ARE IN INCHES TOLERANCES: DECIMAL .XX ±.010 DECIMAL .XXX ±.005 FRACTIONAL ±1/64 ANGULAR: ± 1°	DRAWN	EF	11/10/17	BOAT TAIL
			CHECKED			
			ENG APPR.			
			MFG APPR.			
			Q.A.			
		INTERPRET GEOMETRIC TOLERANCING PER:	COMMENTS:			
		MATERIAL: ARAMID FIBER				SIZE **A**
NEXT ASSY	USED ON	FINISH: SMOOTH OUTER SURFACE				REV 0
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:4
						SHEET 1 OF 1

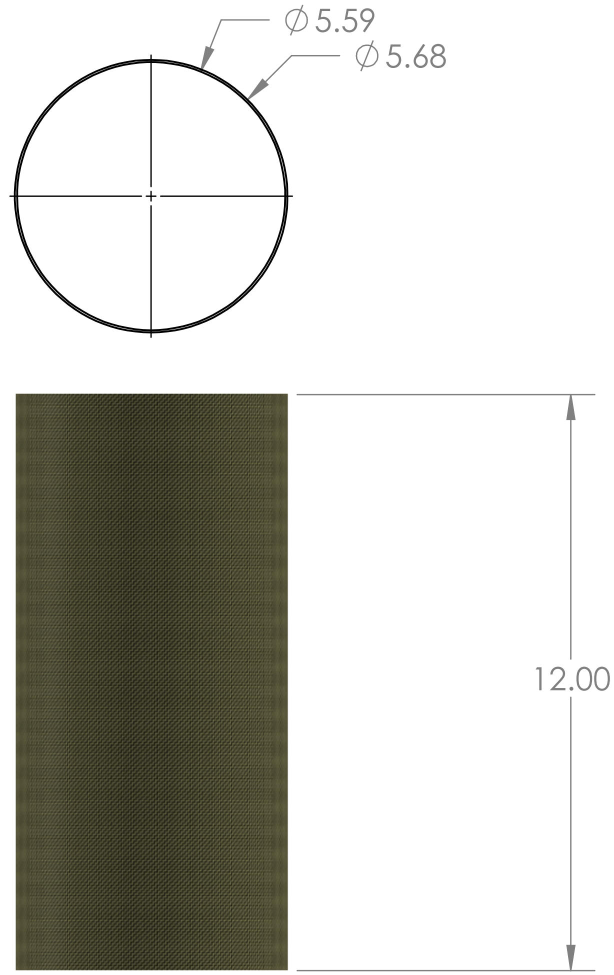




		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	ESRA 30K 2017-18 STRUCTURES & INTEGRATION
		DIMENSIONS ARE IN INCHES TOLERANCES: DECIMAL .XX ±.010 DECIMAL .XXX ±.005 FRACTIONAL ±1/64 ANGULAR: ± 1°	DRAWN	EF	4/30/18	
			CHECKED			BOAT TAIL PLY
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL: ARAMID FIBER	COMMENTS:			SIZE **A** REV 0
NEXT ASSY	USED ON					
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:2 SHEET 1 OF 1



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



PROPRIETARY AND CONFIDENTIAL

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

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

COMMENTS:

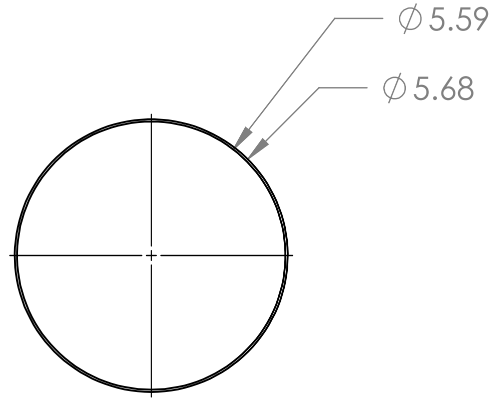
TITLE:

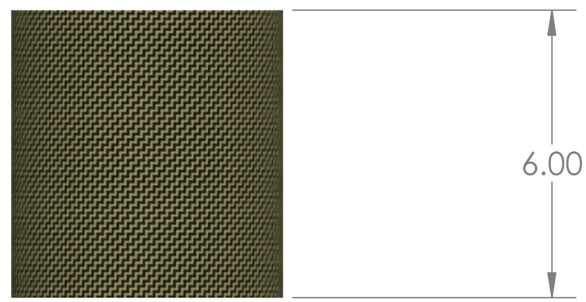
SIZE	DWG. NO.	REV
A	Coupler Mid	

SCALE: 1:4 WEIGHT: SHEET 1 OF 1

2 1

B B





A A

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

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TITLE:

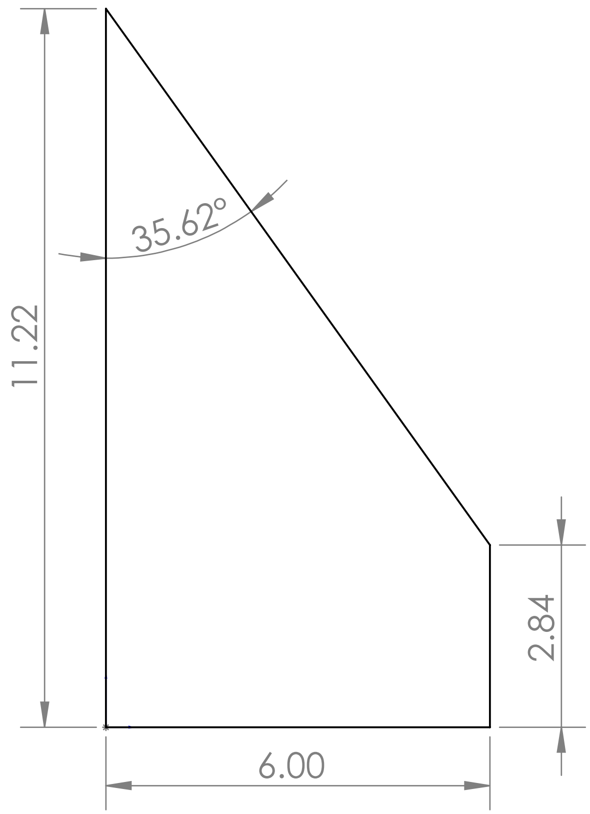
SIZE	DWG. NO.	REV
A	Coupler Nosecone	

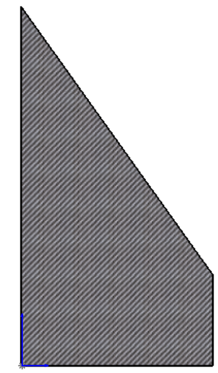
SCALE: 1:4	WEIGHT:	SHEET 1 OF 1

2 1

2 1

B B

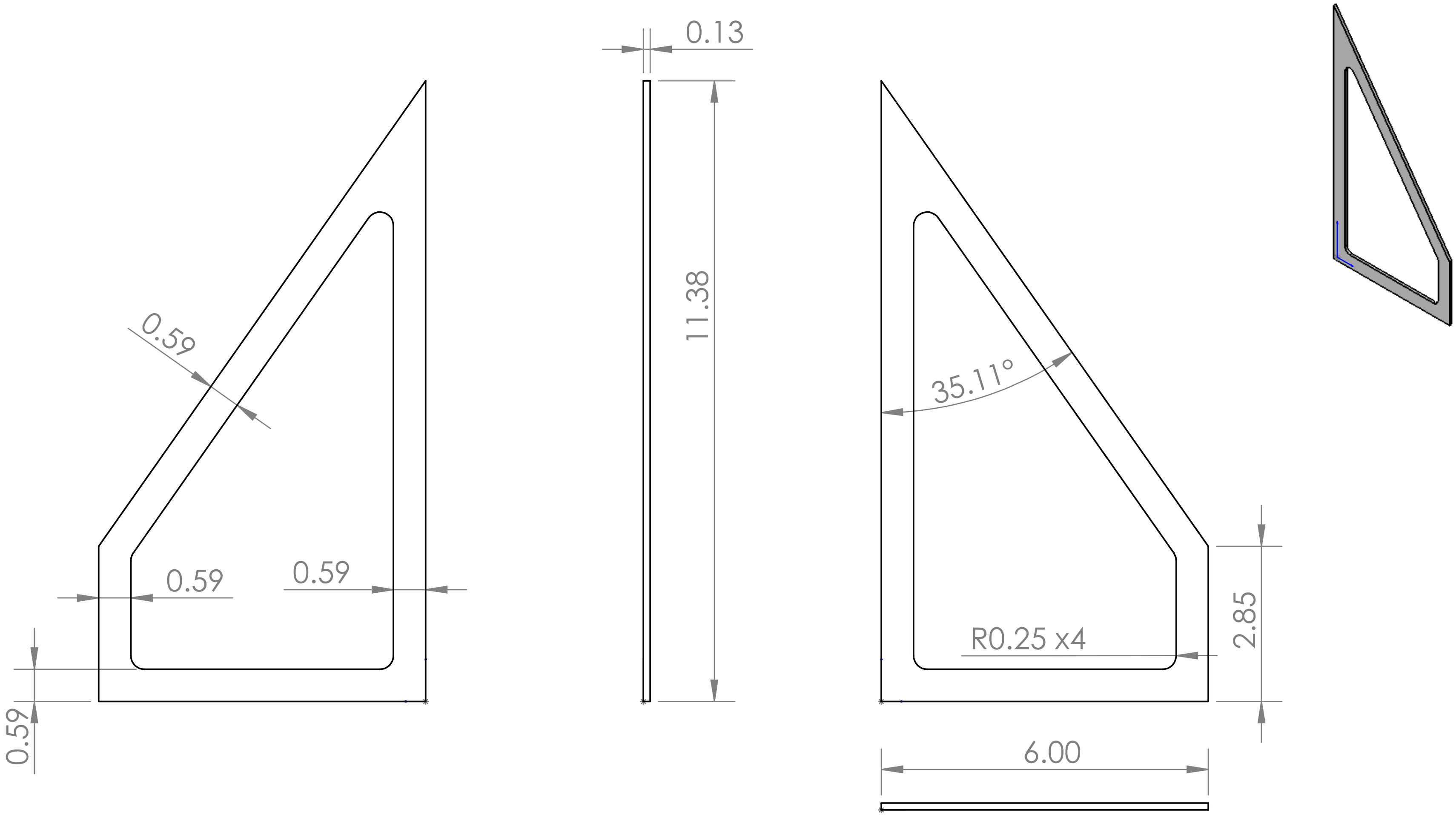




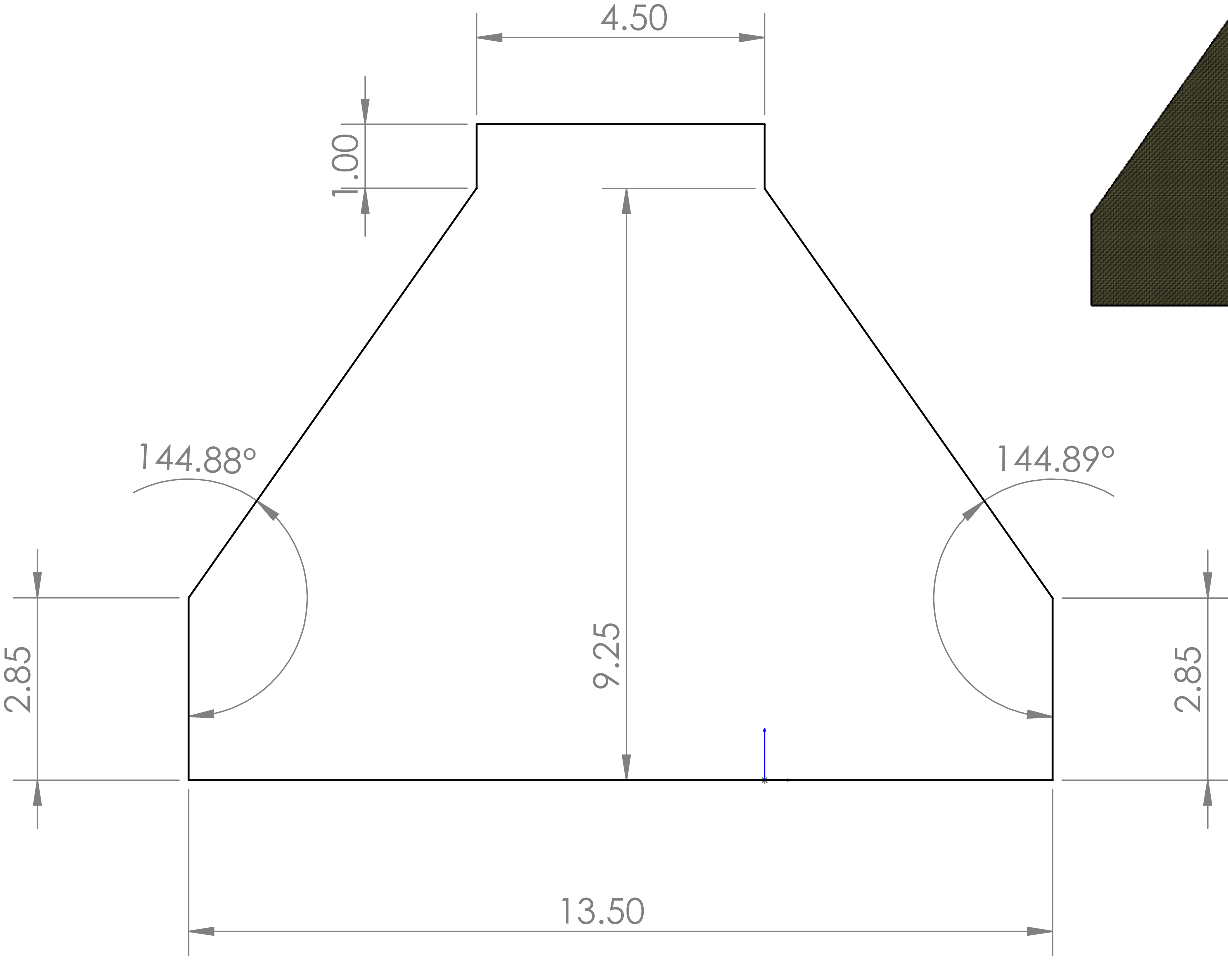
A A

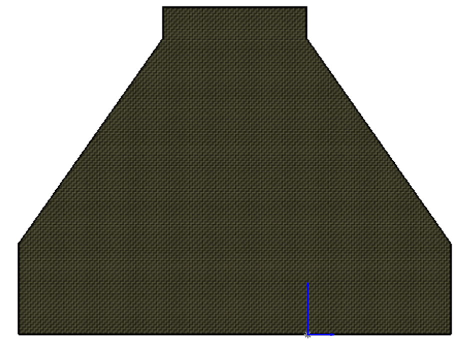
		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	ESRA 30K 2017-18 STRUCTURES & INTEGRATION
		DIMENSIONS ARE IN INCHES TOLERANCES: DECIMAL .XX ±.010 DECIMAL .XXX ±.005 FRACTIONAL ±1/64 ANGULAR: ± 1°	DRAWN	EF	11/16/17	FIN LAYUP PLY
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL: CARBON FIBER	COMMENTS:			SIZE A / REV 0
NEXT ASSY	USED ON					
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:3 / SHEET 1 OF 1

2 1

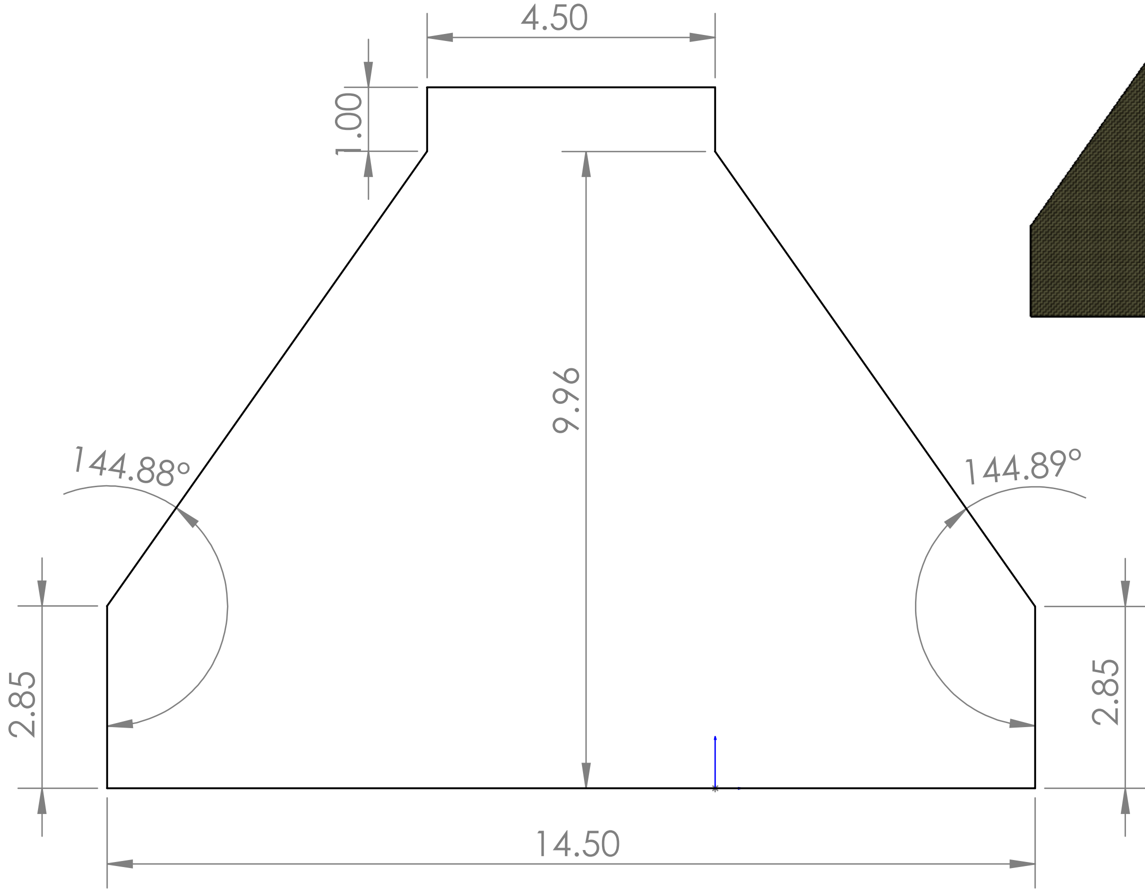


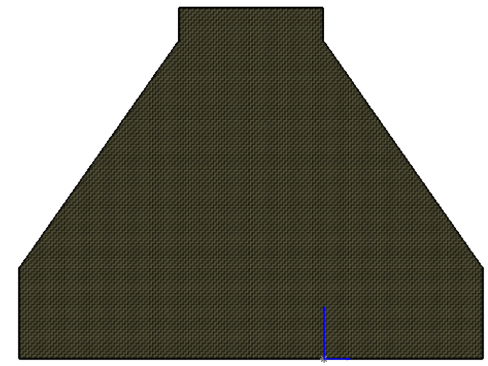
		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	ESRA 30K 2017-18 STRUCTURES & INTEGRATION
		DIMENSIONS ARE IN INCHES TOLERANCES: DECIMAL .XX ±.010 DECIMAL .XXX ±.005 FRACTIONAL ±1/64 ANGULAR: ±1°	DRAWN	EF	10/8/17	
			CHECKED			FIN FRAME
			ENG APPR.			
			MFG APPR.			
			Q.A.			
		INTERPRET GEOMETRIC TOLERANCING PER:	COMMENTS:			
		MATERIAL: G10 FIIBERGLASS				SIZE A — REV 0
NEXT ASSY	USED ON					
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:3 — SHEET 1 OF 1





		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	ESRA 30K 2017-18 STRUCTURES & INTEGRATION
		DIMENSIONS ARE IN INCHES TOLERANCES: DECIMAL .XX ±.010 DECIMAL .XXX ±.005 FRACTIONAL ±1/64 ANGULAR: ± 1°	DRAWN	EF	4/27/18	
			CHECKED			TIP-TO-TIP LAYUP PLY 1
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL: ARAMID FIBER	COMMENTS:			SIZE **A** — REV 0
NEXT ASSY	USED ON					
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:3 — SHEET 1 OF 1





		UNLESS OTHERWISE SPECIFIED:
		DIMENSIONS ARE IN INCHES TOLERANCES: DECIMAL .XX ±.010 DECIMAL .XXX ±.005 FRACTIONAL ±1/64 ANGULAR: ±1°
		INTERPRET GEOMETRIC TOLERANCING PER:
		MATERIAL: ARAMID FIBER
NEXT ASSY	USED ON	
APPLICATION		DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	EF	4/27/18
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

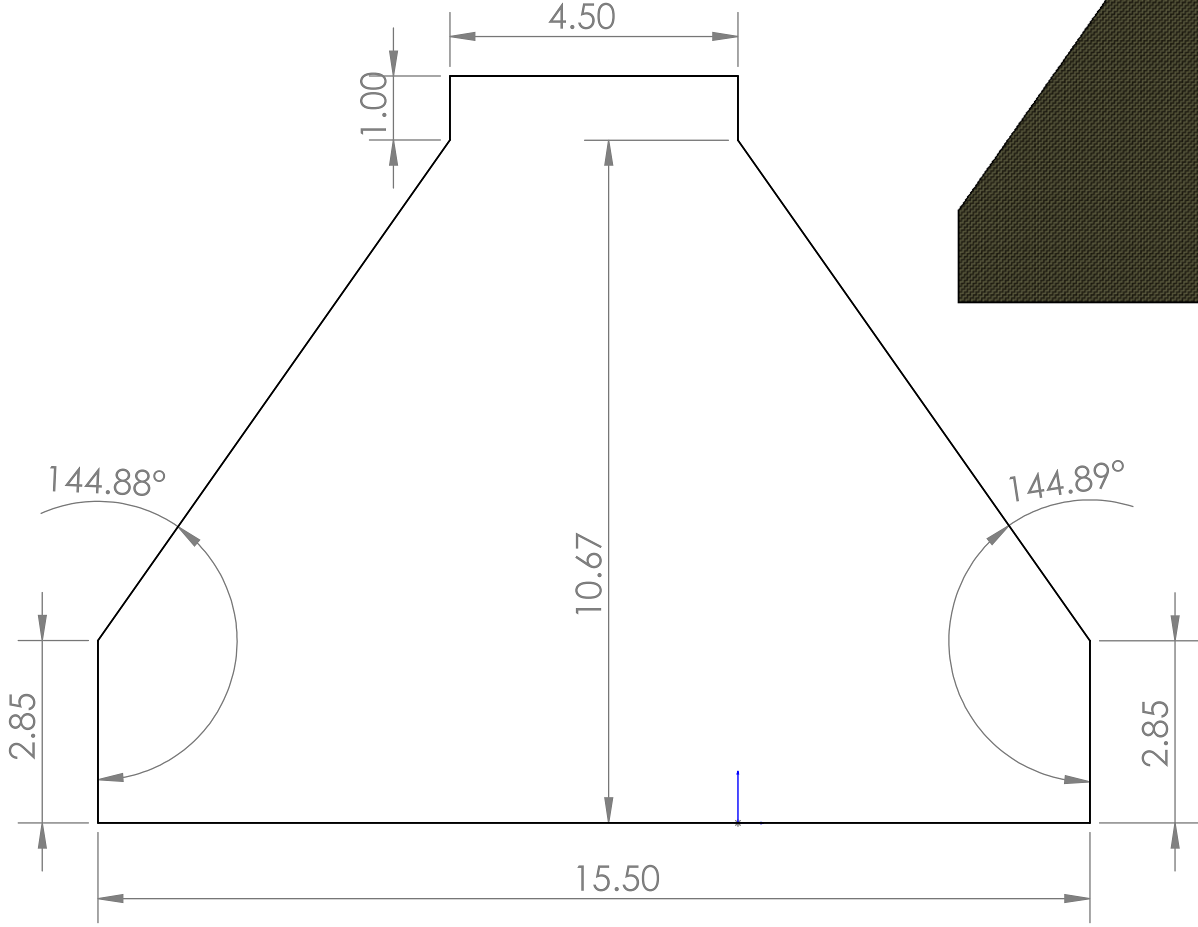
ESRA 30K 2017-18
STRUCTURES & INTEGRATION

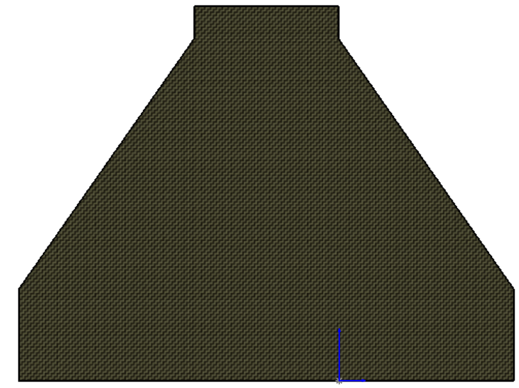
TIP-TO-TIP LAYUP PLY 2

SIZE		REV
A		0
SCALE: 1:3		SHEET 1 OF 1

2 1

B B





A A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: DECIMAL .XX ±.010 DECIMAL .XXX ±.005 FRACTIONAL ±1/64 ANGULAR: ± 1°	DRAWN	EF	4/27/18
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL: ARAMID FIBER	COMMENTS:		
NEXT ASSY	USED ON				
APPLICATION		DO NOT SCALE DRAWING			

ESRA 30K 2017-18
STRUCTURES & INTEGRATION

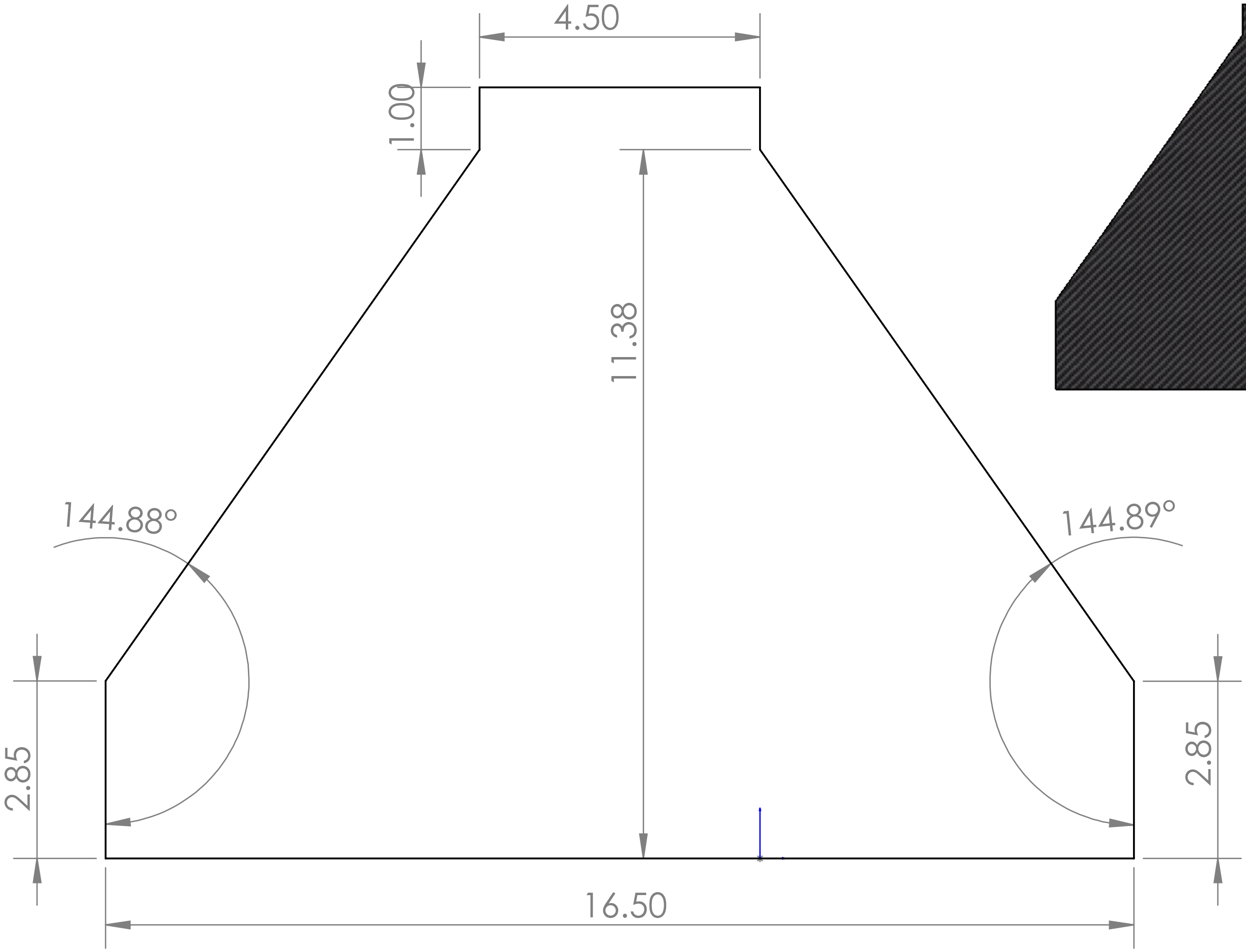
TIP-TO-TIP-LAYUP PLY 3

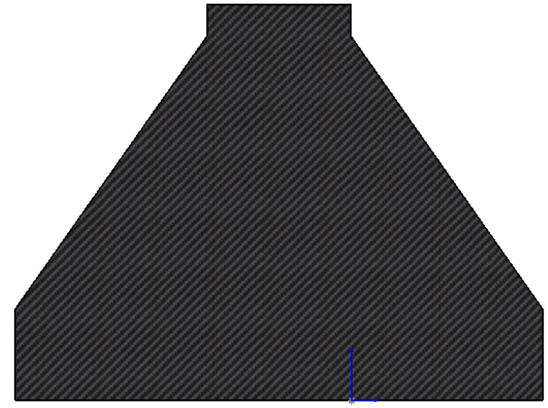
SIZE		REV
A		0
SCALE: 1:3		SHEET 1 OF 1

2 1

2 1

B B

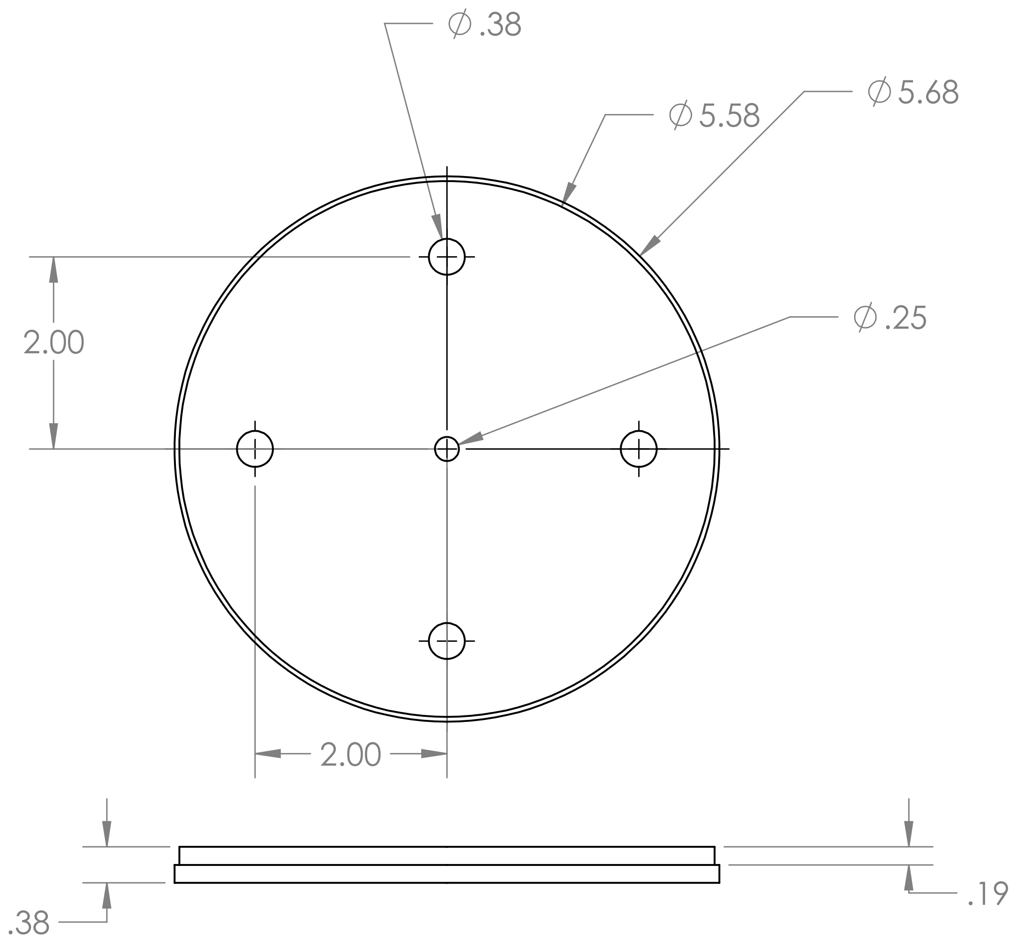




A A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	ESRA 30K 2017-18 STRUCTURES & INTEGRATION
		DIMENSIONS ARE IN INCHES TOLERANCES: DECIMAL .XX ±.010 DECIMAL .XXX ±.005 FRACTIONAL ±1/64 ANGULAR: ± 1°	DRAWN	EF	4/27/18	TIP-TO-TIP LAYUP PLY 4
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL: CARBON FIBER	COMMENTS:			SIZE A
NEXT ASSY	USED ON					REV 0
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:3 SHEET 1 OF 1

2 1



UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

NEXT ASSY	USED ON	
APPLICATION		

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

COMMENTS:

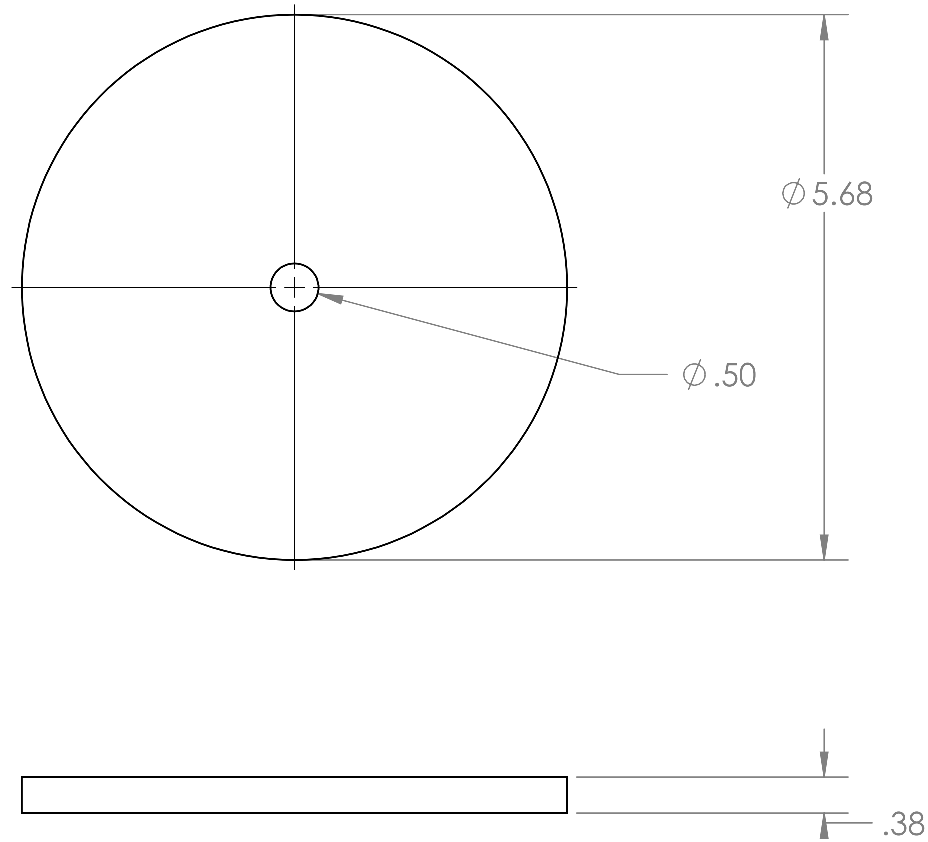
TITLE:

SIZE	DWG. NO.	REV
A	G10LBulk	

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

2 1

B B



A A

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

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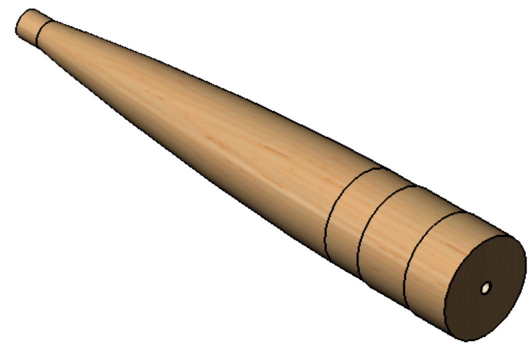
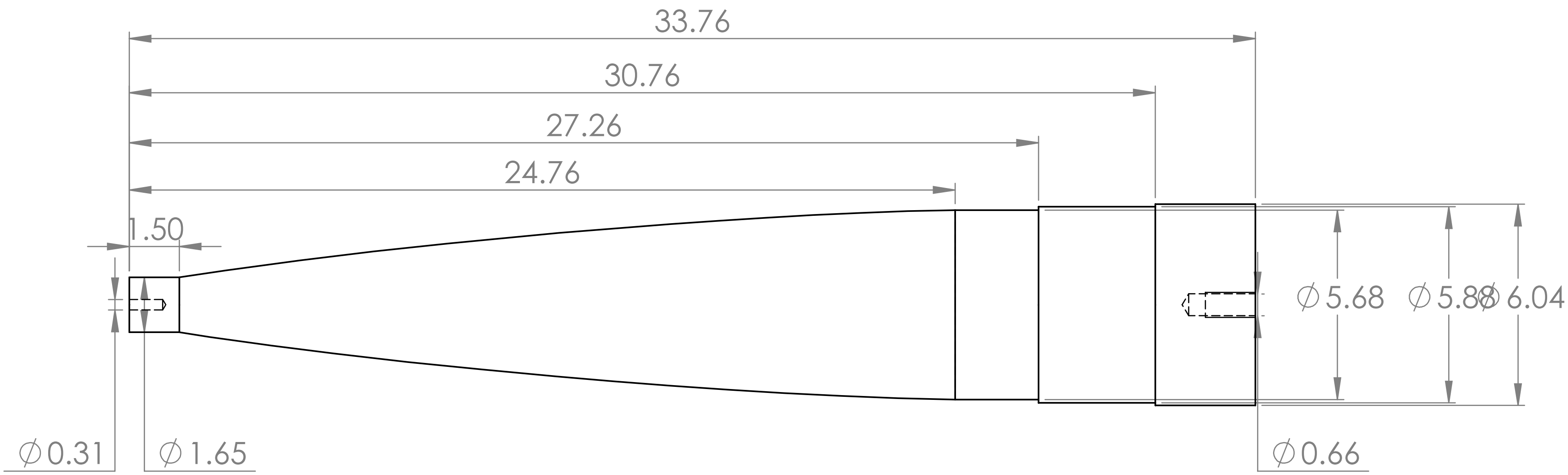
TITLE:

SIZE	DWG. NO.	REV
A	G10motorBulk	

SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

2 1





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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
DECIMAL .XX ±.010
DECIMAL .XXX ±.005
FRACTIONAL ±1/64
ANGULAR: ± 1°

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: WHITE EASTERN MAPLE OR CEDAR

FINISH: SMOOTH OUTER SURFACE, PERMANENT EPOXY

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	MH	12/7/2017
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS: CNC LATHE, TABLE SAW

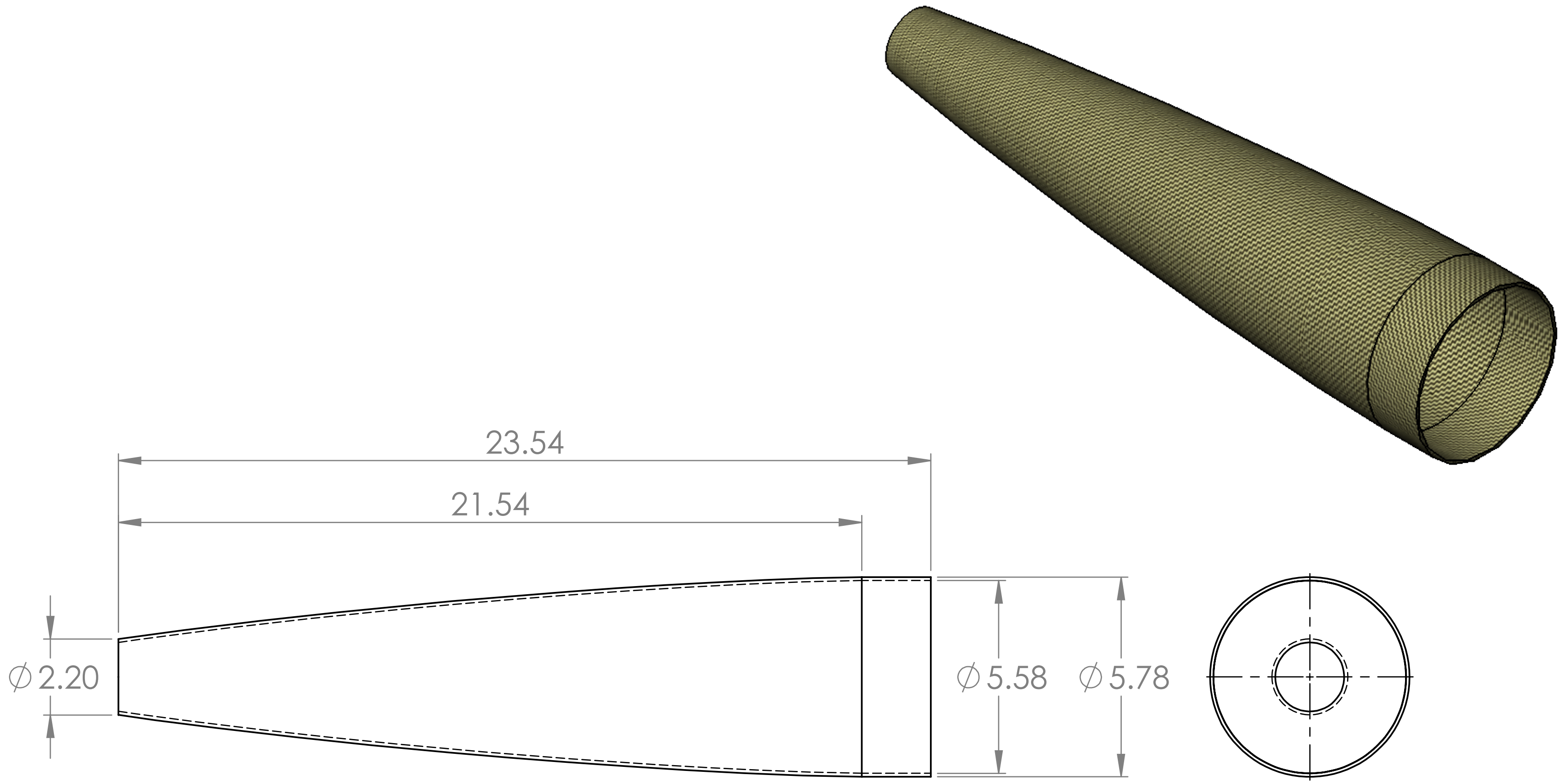
ESRA 30K 2017-18
STRUCTURES & INTEGRATION

TITLE:

VON KARMAN NOSE CONE MALE MOLD

SIZE	DWG. NO.	REV
A	NC MOLD	0

SCALE: 1:10 SHEET 1 OF 1



VON KARMAN NOSE CONE

ESRA 30K 2017-18
STRUCTURES & INTEGRATION

	NAME	DATE
DRAWN	MH	12/7/2017
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS: CNC LATHE

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
DECIMAL .XX ±.010
DECIMAL .XXX ±.005
FRACTIONAL ±1/64
ANGULAR: ± 1°

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: ARAMID FIBER

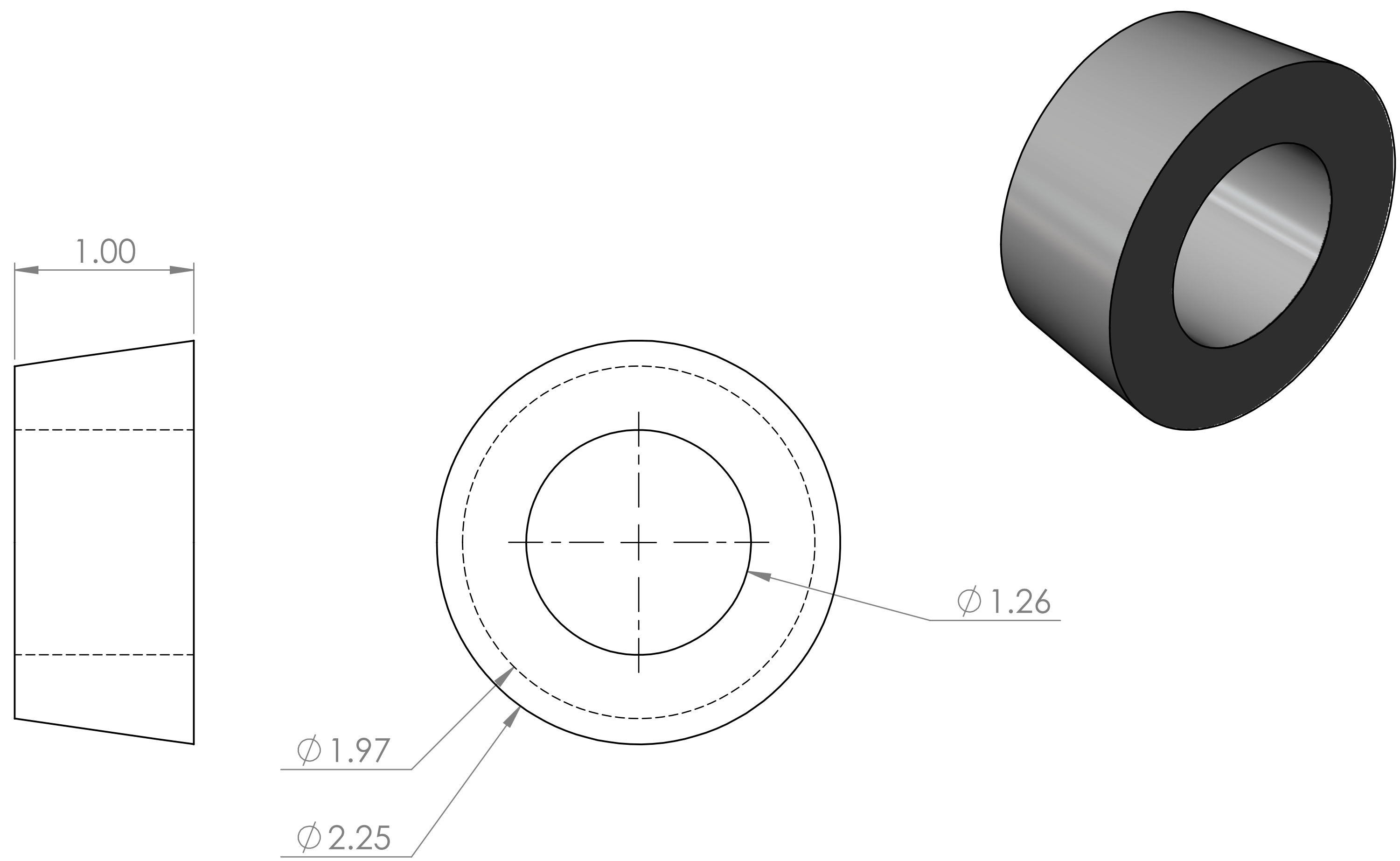
FINISH: SMOOTH OUTER SURFACE

DO NOT SCALE DRAWING

NEXT ASSY	USED ON
APPLICATION	

SIZE	DWG. NO.	REV
A	PRIMARY NC STRUCTURE	0

SCALE: 1:10 SHEET 1 OF 1



ESRA 30K 2017-18
STRUCTURES & INTEGRATION

TITLE:

STEEL NOSE CONE RING

	NAME	DATE
DRAWN	MH	12/7/2017
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS: LATHE OR MILL. DEBURR ANY SHARP EDGES, SAND OUTER SURFACE

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
DECIMAL .XX ±.010
DECIMAL .XXX ±.005
FRACTIONAL ±1/64
ANGULAR: ± 1°

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: ALUMINUM

FINISH: ROUGH OUTER SURFACE, SMOOTH INNER EDGE

DO NOT SCALE DRAWING

NEXT ASSY	USED ON
APPLICATION	

SIZE A | DWG. NO. STEEL NC RING | REV 0

SCALE: 1:1 | SHEET 1 OF 1