Project The Big One

Team 23 Technical Report for the 2018 IREC

Travis Moleski[1] , Tessa Berger[2], Jeremy Browne[3], Archie Scott[4], Brittany Hesson[5], Dylan Denner[6]
Ohio University, Athens, Ohio, 45701

I. Abstract

For the Second Annual Spaceport America Cup the Ohio University Rocket Design and Engineering Team will be launching project The Big One. This project will be competing in the 30,000 foot above ground level apogee with commercial off the shelf solid propulsion system category. Notable characteristics of The Big One include roll stabilized video capability as well as a mounted landing system for improved the sustainability and reusability of the vehicle. The project aims to capture roll stabilized video of the complete flight profile of the rocket (ascent, apogee, descent and landing) as a scientific payload. Normally, a camera would be mounted to a fixed position on the rocket body which would rotate with the rocket during flight resulting in unstable and sometimes disorienting video. To obtain stable footage, the camera is isolated inside the rocket airframe with the ability to spin independently from the rest of the rocket. A viewing window is also installed into the airframe of the rocket allowing for a 360 degree viewing angle for the camera as the rocket spins.

Nomenclature

CP = center of pressure
CG = center of gravity

[1] Mechatronics Engineer, Mechanical Engineering, 14213 St. Rt. 278 Nelsonville, Ohio, 45764.
[2] Payload Team Lead, Mechanical Engineering, 3B station St, Athens Ohio 45701
[3] Safety Officer, Mechanical Engineering, 166 N Lancaster St, Athens, Ohio, 45701
[4] Lead Engineer, Mechanical Engineering, 57 Stewart St. Athens Ohio, 45701
[5] Payload Team Lead, Mechanical Engineering, 315 Jennings Hill Road Marietta, Ohio 45750
[6] Lead Engineer, Computer Engineering and Applied Mathematics Engineering, 178 Marko Lane, Brooklyn Heights, Ohio, 44131

II. Members

Advisors:

- David Burnette Ph.D, Mechanical Engineering
- Jay Wilhelm Ph.D, Mechanical Engineering

Lead Engineers:

- Dylan Denner, B.S. Student, Computer Engineering and Applied Mathematics
- Archie Scott III, B.S. Student, Mechanical Engineering

Payload Team Leads

- Tessa Berger, B.S. Student, Mechanical Engineering
- Brittany Hesson, B.S. Student, Mechanical Engineering

Mechatronics Engineer:

- Travis Moleski, B.S. Student, Mechanical Engineering

Manufacturing Engineer:

- James (JC) Kraml, B.S. Student, Mechanical Engineering

Safety Officer:

- Jeremy Browne, B.S. Student, Mechanical Engineering

Landing Leg Team Lead:

- Alex Polacek, B.S. Student, Mechanical Engineering

Staging Team Lead:

- Eddie Mikalsen, B.S. Student, Mechanical Engineering

General Members:

- Caleb Saunders, B.S. Student, Mechanical Engineering
- Mitchel Brightman, B.S Student, Mechanical Engineering
- Nick Braun, B.S Student, Mechanical Engineering
- Erica Wright, B.S Student, Mechanical Engineering
- Jeremiah Creech, B.S Student, Mechanical Engineering
- Emily McGuire, B.S Student, Mechanical Engineering
- Lorenzo Fava, B.S Student, Mechanical Engineering

III. INTRODUCTION

The Ohio University Rocket Design and Engineering Team is a student led design team representing Ohio University from Athens, Ohio. Located in southeast Ohio, Ohio University has a total enrollment of 24,155 students at its Athens campus[1]. The Rocket Design Team specifically represents the Russ College of Engineering at Ohio University. The Rocket Design Team is comprised of 16 undergraduate students. There are 15 students representing the department of mechanical engineering and, one student representing the electrical engineering/computer science and mathematics department. Stakeholders for the Rocket Design Team include the Russ College of Engineering and the Ohio Space Grant Consortium.

A. Team Structure:

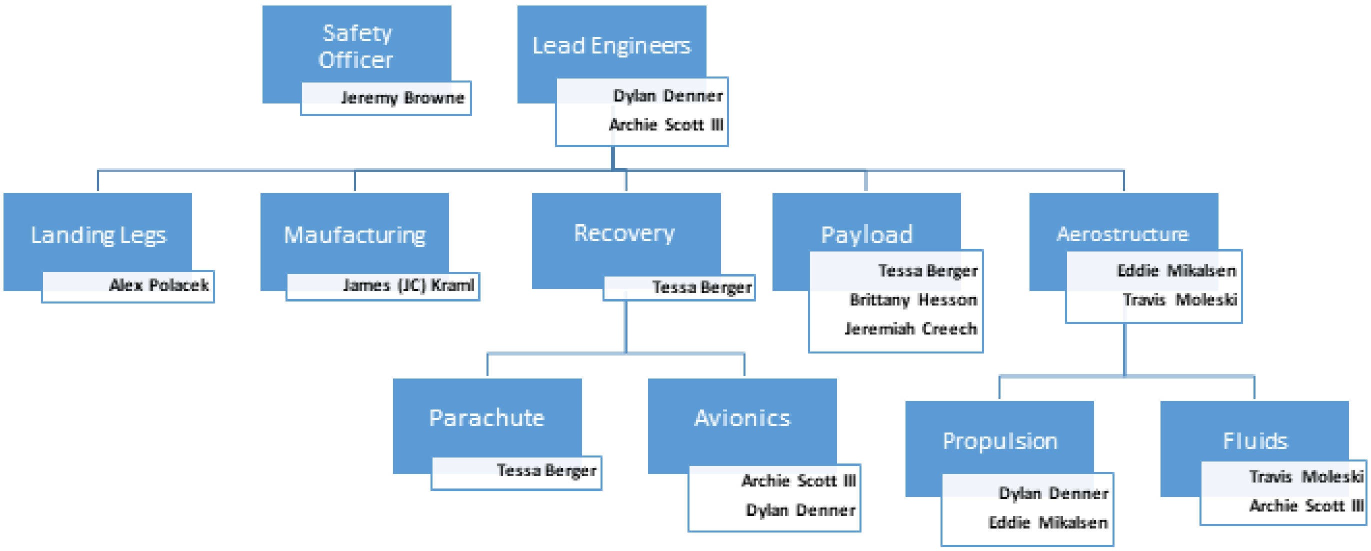


Figure 1. Team and sub team structure.

B. Team Management Strategies:

The team management strategies were developed in the fall semester to help insure project success. These strategies include effective and frequent communication. In order to achieve this goal, the Rocket Design Team was committed to being adaptive with regards to communication platforms. The team originally used email and GroupMe as its main communication platforms but after an open team discussion it was concluded that Slack and Google Drive would best suit the team's needs. Therefore, the Rocket Design Team now utilizes Google Drive, a shared university project folder and a Slack team with individual threads including #general, #landing_legs, #recovery, #technical_report, and #relevantresources.

Another team management strategy was to have frequent, informal meetings during the week. A general body team meeting was held every Sunday during the fall and spring semesters but along with these meetings, teams were encouraged to communicate effectively with their team to determine when to meet during the week. This was due to the collective understanding that every member's schedule changed on a week to week basis and it would be best to give the subteams the flexibility and freedom to coordinate their own meeting time.

A third method of team management strategy was to keep members interested and excited about the project, while being understanding of schedule conflicts. The Rocket Design Team invested into its members by splitting the cost of the materials needed for a student to get his or her level one high powered rocket certification. During the fall semester, and earlier development stages of the competition rocket, it was important to keep members excited and connected to the project. This was also achieved by being flexible with student's schedules during the initial planning stages in order to retain interest early in the project. This investment has paid off as all of the members that attempted their level one high powered rocket certification have remained on the project.

The last major team management strategy was to build up the responsibility given to each team member. During the fall semester, team members were given more instructions and direction with regards to assignments. This allowed team members to feel comfortable learning high powered rocketry. During the spring semester, the team members were given more freedom in terms of their assignments, this allowed students to be creative and leverage the skills they have acquired from their education. Each subdesign team was able to perform multiple tests and therefore go through multiple design iterations while still being supervised by the lead engineer to insure that the specification and quality criteria were met. This incremental responsibility was put into place in anticipation of the lead engineer being away from the team during the summer, while most ofthe team remained at school for classes, work, or both. Now the team works autonomously giving only a handful of updates throughout the week to the lead engineer.

IV. SYSTEM ARCHITECTURE OVERVIEW

A three dimensional model of the fully integrated launch systems shown in Figure 2, consists of the following components:

Rocket Structure

A. Fiberglass 4 inch standard-wall 4:1 Ogive nose cone
B. Fiberglass 4 inch airframe to act as a coupler between nose cone and payload
C. Payload
D. 4 inch to 6 inch 3D printed transition coupler (ABS plastic)
E. Fiberglass 6 inch airframe to store drouge and main parachute
F. Fiberglass 4 inch avionics bay
G. Fiberglass airframe with landing legs stored inside
H. Fiberglass 4 inch inner tube housing Aerotech N3300 and act as a mount for the landing legs
I. Fiberglass fins

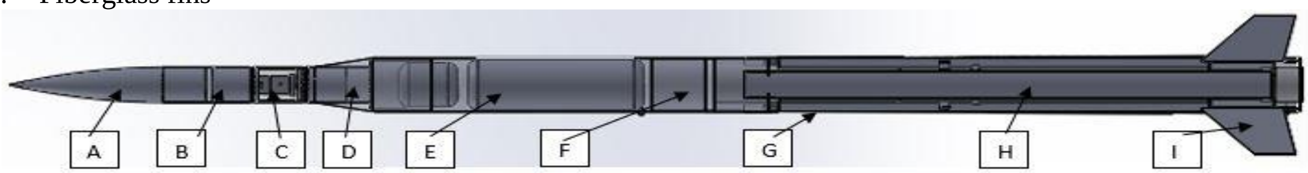


Figure 2. System model presenting internal subsystems

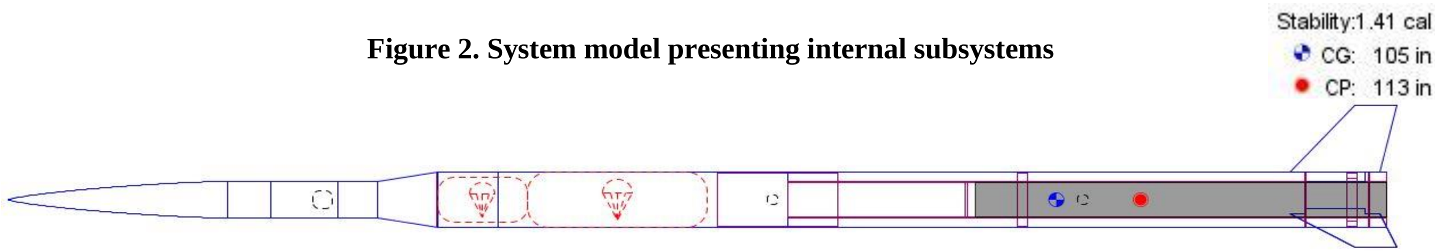


Figure 3. 2D model of launch vehicle and subsystems

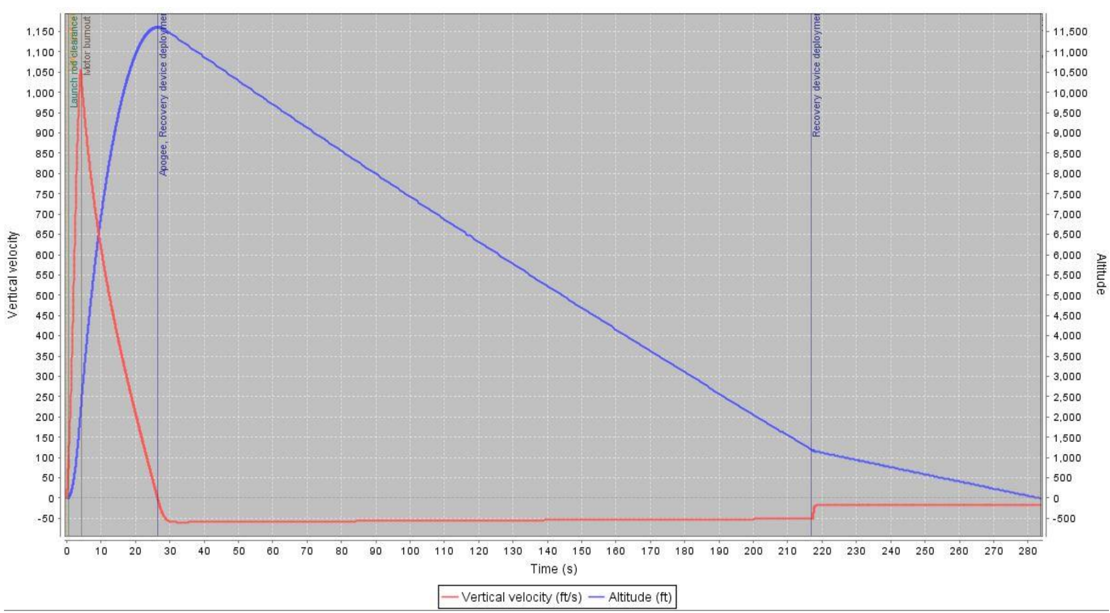


Figure 4. Launch simulation results presenting altitude and velocity

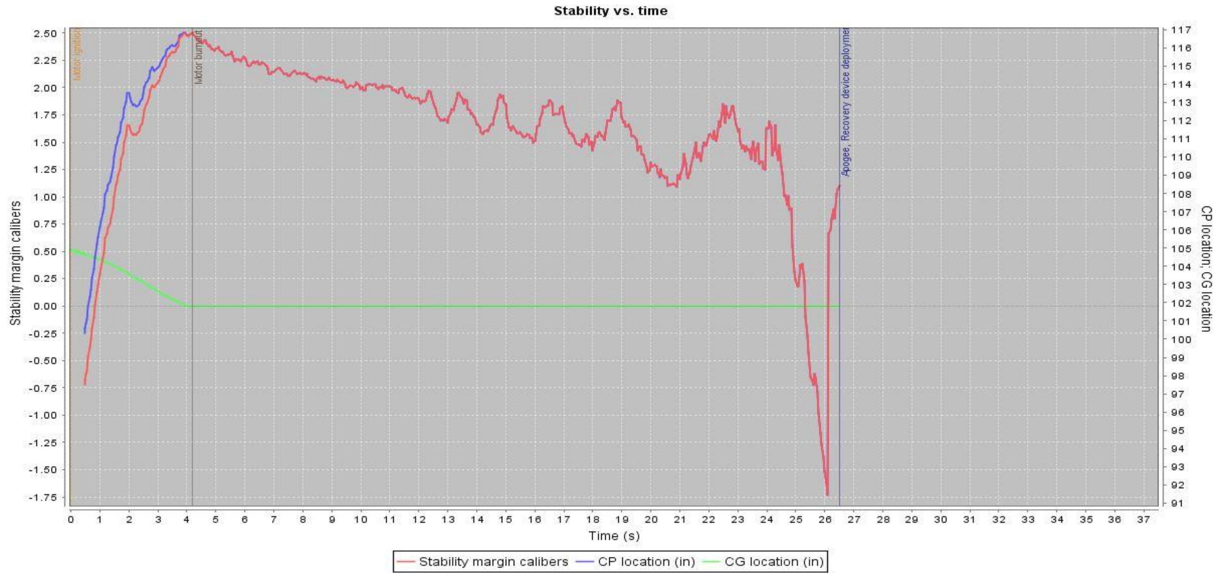


Figure 5. Launch simulation results representing stability

A. Aero-structures Subsystem:

Figure 5 represents a fully modeled 3D model of the final launch vehicle. All models were drawn in Solidworks and exported as .step and .igs files in order to perform finite element analysis (FEA) in external software. Table 1 presents a parts list for all subsystems and their respective materials and vendors. From left to right it

Figure 5. 3D model of launch vehicle.

Table 1. Each part of the launch vehicle and where it was purchased from.

Part name (top down)	Specification	Vendor
Nose Cone 4:1 Von Carmen	Fiberglass Filament Wound	Mad Cow Rocketry
Nose Cone payload connector	Fiberglass	Mad Cow Rocketry
Payload top	PVC	McMaster-Carr
Payload	Acrylic	McMaster-Carr
Payload Bottom	PVC	McMaster-Carr
Payload Transition Connector	Fiberglass	Mad Cow Rocketry
Transition Coupler 6" to 4"	ABS Plastic	3D printed at Ohio University

Airframe 6"	G12 Fiberglass	Mad Cow Rocketry
Coupler	G-12 Fiberglass	Mad Cow Rocketry
Body tube 4" OD	G-12 Fiberglass	Mad Cow Rocketry
Upper Leg mount	6061 Aluminum	McMaster-Carr
Upper leg mount pin	6061 Aluminum	McMaster-Carr
Actuator mount	ABS Plastic	3D printed at Ohio University
Magnetic Solenoid		Adafruit
Rib 1/8"	Fiberglass	McMaster-Carr
Spring mount	ABS Plastic	3D printed at Ohio University
Lower Leg Mount	6061 Aluminum	McMaster-Carr
Spring	Music Mire	McMaster-Carr
Lower Leg Pin	6061 Aluminum	McMaster-Carr
Centering ring	Fiber lass	McMaster-Carr
Gas Piston	15lb extension force	McMaster-Carr
Spring Plunger		McMaster-Carr
Leg Locking Eyelet	6061 Aluminum	McMaster-Carr
Top leg mount to Fiberglass	6062 Aluminum	McMaster-Carr
Fiberglass Leg	Fiberglass	Mad Cow Rocketry
Leg Reinforcements m	Fiberglass L-Bracket	McMaster-Carr
Cross member	3/8 " Carbon Fiber tube	Rockwest Composites
Crossmember leg mount	6061 Aluminum	McMaster-Carr
Fins	G-12 Fiberglass	McMaster-Carr

B. Leg Subsystem:

Design Parameters
The landing system for The Big One is designed to optimize strength, weight, and aerodynamic drag while ensuring reusability of the sounding rocket. This is done with three landing legs with independent suspensions systems on each, and by flush mounting the system when closed.


Figure 6. 3D model of landing leg subsystem.

Kinematics
Knowing that the optimal landing system for The Big One would be landing legs that lie flush to the airframe once collapsed, the next step was determining the linkages required to allow the leg to fold into the allotted space within the vehicle and deploy freely once released during descent. This was accomplished my modeling several different

configurations in MATLAB simulations and analyzing the movements of each. Shown below, in Figure 7 is the final kinematic diagram of a single landing leg to be built for use on the rocket.

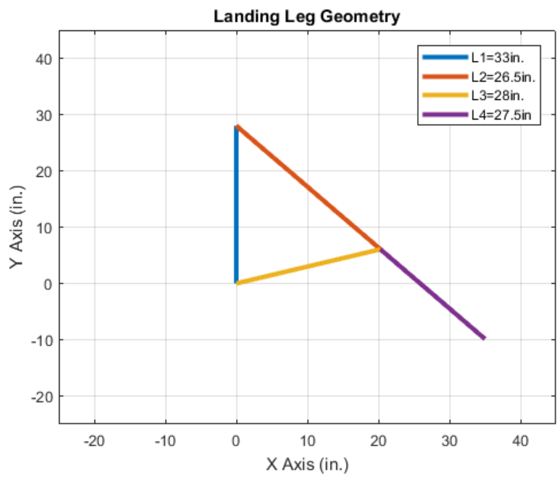


Figure 7. Kinematic simulation snapshot of single landing leg

Mounting

The landing system is attached to the rocket with the use of two brackets with the top bracket also acting as a centering ring for the motor tube. Due to the location of the rocket motor, mechanical through-wall fastening is not an option and therefore the system is fixed to the motor tube with adhesive.

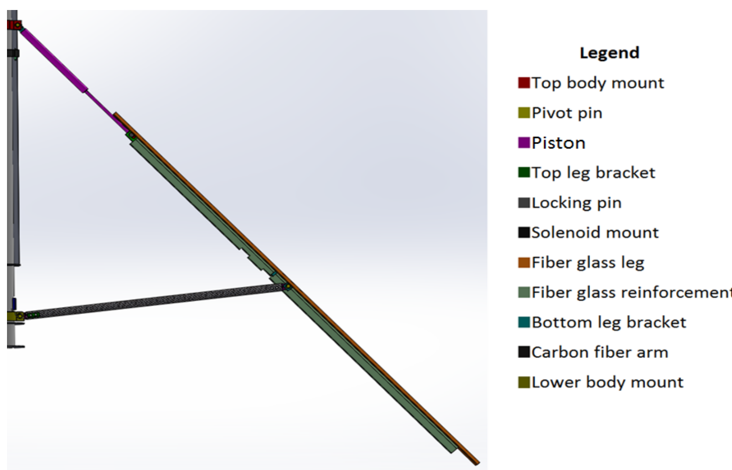


Figure 8. Kinematic simulation snapshot of single landing leg

Pivots

There are four moving joints on each leg with three of these joints being free to move while the fourth joint has the ability to lock. The fourth joint will only lock after deployment and when the leg is fully extended. Once locked, the fourth joint is effectively eliminated and will allow for the majority of the load upon impact to be taken by a gas spring piston mounted to the top of each leg. This piston will act as a dampener and is rated with a 15 lb extension force. Upon impact the three free joints will move to allow for easy compression of the dampener and at the same time eliminating unwanted strains on the joints. The rotation of the three joints will be made easy by the assistance of thrust bearings and washers. By using these bearings we can get a tighter fit that limits unwanted side to side motion that would otherwise result if the bearings were not implemented.

Piston

The pistons were all bought pre manufactured to allow for the smallest possible variance between one another providing an equal compression. This was done to ensure that upon landing we would not tip because one piston compressed more easily than another.

Deployment

Once The Big One is under parachute and in its decent back to Earth's surface, the landing legs will deploy at a predetermined altitude of 100 ft. This event is completed with the use of an Arduino microcontroller and electromagnetic solenoid. The microcontroller will take the altitude from a barometer and once desired altitude is achieved, a signal will be sent to a relay allowing a battery to activate the solenoid, releasing each landing leg. Two torsion springs mounted at the bottom of the leg will assist in deployment of each leg once released. The legs will also experience air pushing upward. This upward air will help push the legs open into their locking position.

Dynamics

Dynamic analysis of the landing system was also completed with the use of MATLAB. In order to determine the effects of ground impact on the landing leg system a program was written using the kinematics of the landing system at a maximum descent rate of 18 fps. This allowed for calculation of the maximum reaction forces on the shell of the landing leg, as well as the mounting brackets that secure the landing system to the motor tube of The Big One. Shown in Figure 9 are the reaction force of both the top and bottom mounting brackets. The mounts proved to be the point of interest under impact. As shown, the maximum reaction force occurs on the lower mounting bracket in the x direction. It is because of this buckling point that the cross member of this system was chosen to be made of carbon fiber due to the large strength to weight ratio of this material.

Finally, this program was also written to determine the maximum spring force needed as well as the required stroke of the gas spring. This resulted in a spring force value of 14.2 lbs and a compression length of 7.07 inches. Therefore, a gas spring with an extension force of 15 lbs and a stroke length of 7.87 inches was implemented. A safety factor of 1.5 was implemented on the load to account for atmospheric factors affecting the main parachute speed on during descent. These include changing wind speed and a lag in the set time for parachute ejection.

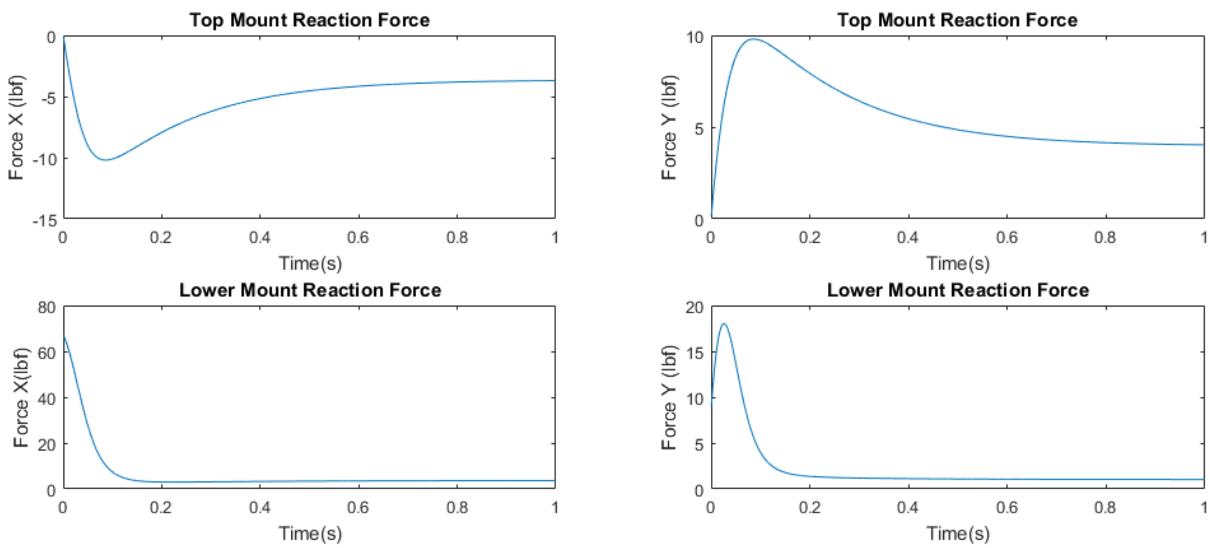


Figure 9. Reaction forces of landing legs on impact

Tipping Point

Calculations were also performed in order to determine the maximum angle, taken from the vertical, that The Big One could impact Earth's surface and still land upright without tipping. This evaluation is important in optimizing the length of the landing legs, the angle of deployment between landing leg and airframe, as well as the center of gravity of the rocket. All of these factor play a role in determining the likelihood of landing the rocket upright. Determining the angle at which the rocket would be expected to tip over is done by analyzing the angle at which the center of gravity of the rocket exceeds a theoretical line connecting the end points of two adjacent legs. This critical angle was found to be 25.17 degrees taken from the vertical. The MATLAB program used for calculating critical tip angle is shown in Figure 10. Figures 10 and 11 depict the variables and tipping point.

```
% Ohio University "The Big One" Tip Calculator
% Date: 4/111/18
clear all; close all; clc;
CG=48.93; % Center of gravity rocket post motor burn out, taken from the ground (in.)
LH=51.69; % Distance from ground to top leg mounting bracket
LL=69.18; % Leg Length (in.) from center line of rocket
aod=acosd(LH/LL); % Angle of deployment between leg and airframe (degrees)
LS=LL*sind(aod)% Leg span taken from rocket center line (in.)
delta=120; % Angle between legs (3 legs, theta=120 degrees)
TipL=LS*cosd(delta/2); % Theoretical distance from rocket center line to line connecting tip-
to-tip of adjacent landing legs
ThetaTip=atand(TipL/CG)
```

```
LS =
   45.9784
ThetaTip =
   25.1660
```

Published with MATLAB® R2017a

Figure 10. MATLAB code for tip calculations.

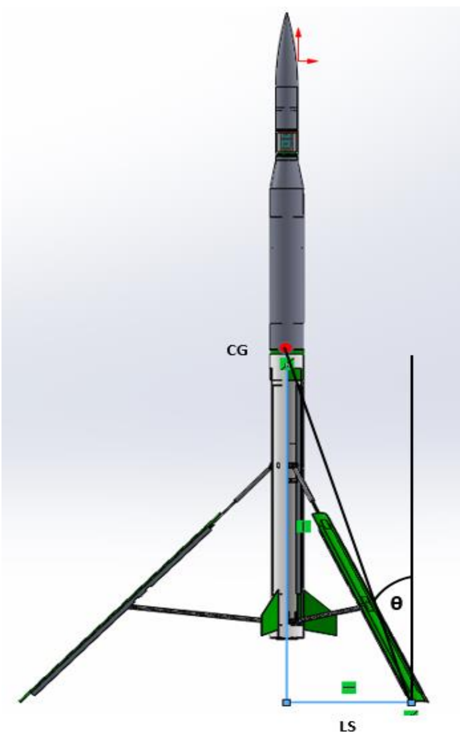


Figure 10. Launch vehicle tipping diagram side view.

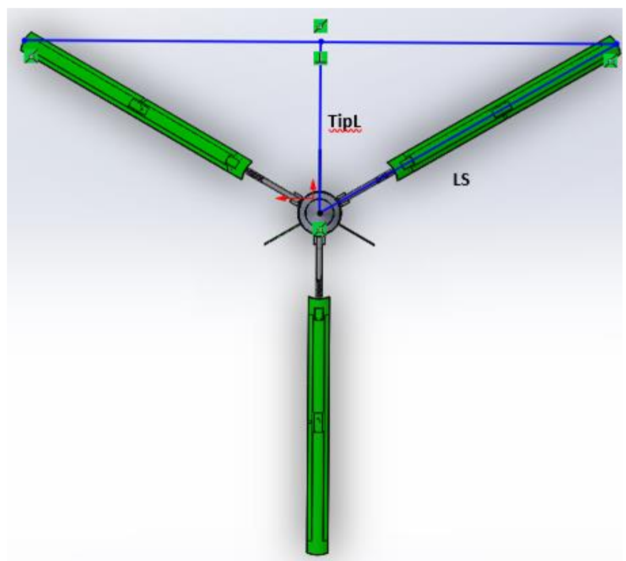


Figure 11. Launch vehicle tipping diagram top view.

Manufacturing
Most of the machining for the rocket was for the leg design. Machining took place in the Senior Design Lab and Lab 013 of Stocker Center at Ohio University. Machines used include a horizontal and vertical band saw, manual vertical mill, computer numerically controlled (CNC) lathe, and CNC three axis HASS mill. Several parts within the Ebay were 3D printed using a CR10 printer using ABS plastic which was available to students of Ohio University.

C. Propulsion Subsystem
The motor selected for the competition is an Aerotech N3300. The N3300 is a reusable 98 mm motor. The motor sits in a 4 inch tube. The aluminum rings that hold the legs on to the rocket also double as the centering rings for the inner tube.

The N3300 was selected because it is the largest motor that could be used in the rocket that does not allow the rocket to reach supersonic speeds.

D. Recovery Subsystems

Altimeters

To ensure that both parachutes deploy at minimal risk of charge malfunction, the recovery subsystem uses a dual altimeter configuration. An Atlus Metrum Telamega is used as the primary flight computer with a Raven3 as a redundant altimeter for the appogee events. The main parachute will be released by two Jolly Logic chute releases. The official altitude will be measured by the Telamega which again is serving as the primary flight computer. The Telamega flight computer is powered by a lithium ion battery and the Raven3 is powered by a 9V Duracell battery. Tracking of the rocket will be used via the Telamega, TeleDongle USB to RF interface and Arrow 440-3 Yagi handheld antenna.

Electronics Bay

The Telamega, Raven3, lithium ion battery and one 9 volt batteries will be secured to a 3D printed sled. Two ¼ inch 20 thread rods will secure the 3D printed sled in between the electronics bay bulk plates.

Pyrotechnic Charges

There will be four electronic matches used in the ejection of the main and drogue parachutes from the airframe of the launch vehicle. Both altimeters will have two electronic matches wired for two events. The first being an apogee event and the second being a redundant charge which will fire 2 seconds after apogee is detected.

Wiring

The wiring for each altimeter and key-switch is shown in Figures 12 and 13.

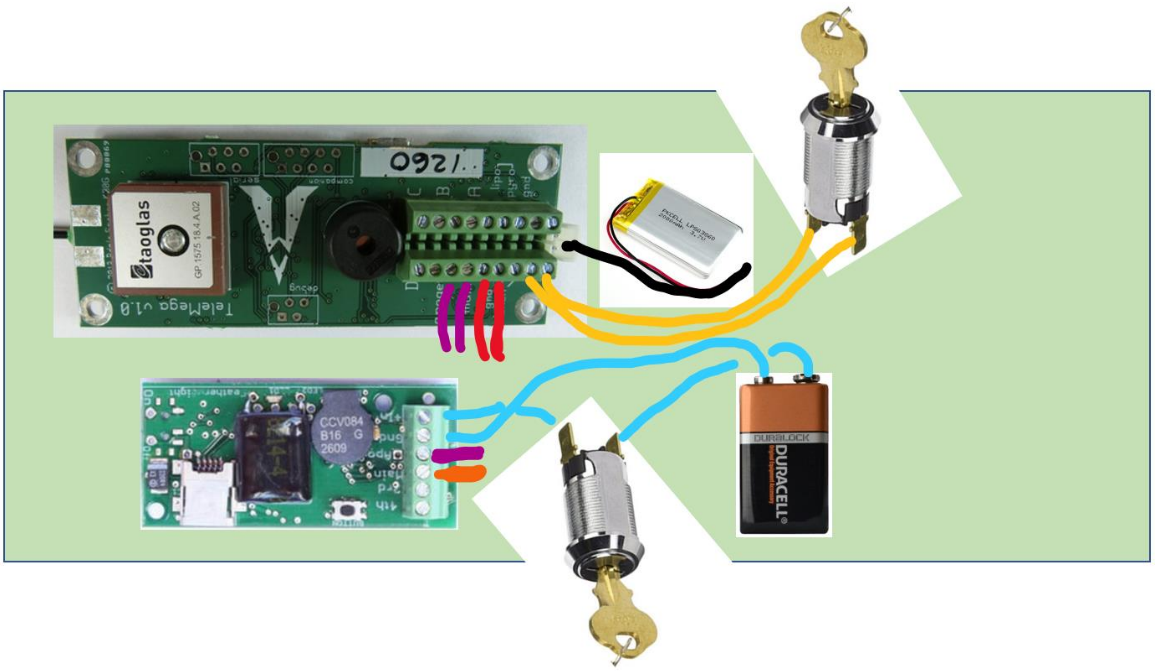


Figure 12. Wiring diagram inside of E-bay.

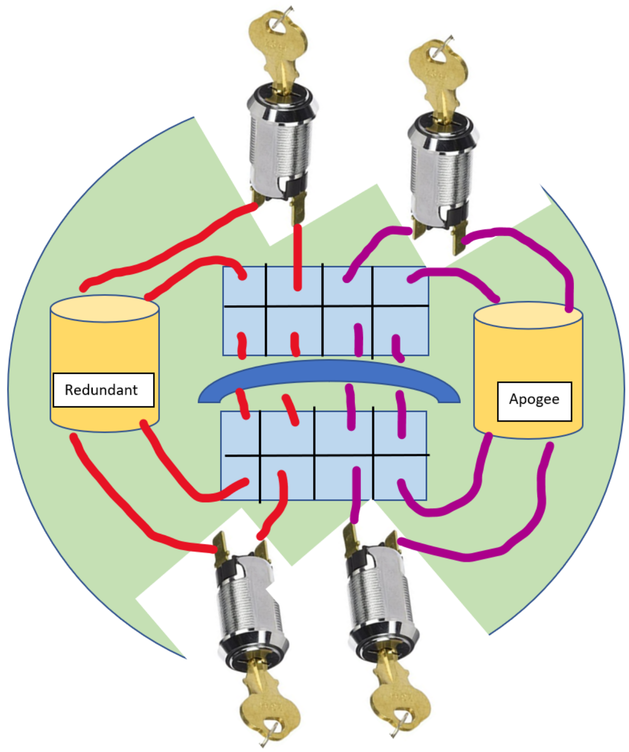


Figure 13. Wiring diagram on lid of E-bay

Charge Deployment

To provide the appropriate pressure that forces the drogue and main parachutes from the launch vehicle without causing overheating within the vessel, a black powder charge calculation is shown below to validate the desired outcome of the recovery stages.

$$Black\ Powder\ (grams): N = \frac{Pressure*Volume}{266\ in\frac{lbf}{lbm}*2847.33°F}\left(\frac{454grams}{1lbf}\right) \quad \textbf{(1)}$$

The ideal gas law is employed with the appropriate conversions, combustion gas constant for FFFF grade black powder, and combustion temperature. For a six-inch diameter tube and 150 lb. bulkhead force, the required pressure is 5.3 psi yielding a charge requirement of 3.87 grams for each redundant capsule at the top of the avionics bay.

D. Payload

Overview

The project's scientific payload is a passive system designed to obtain stable video footage during flight. Normally a camera would be mounted in a fixed position to the rocket causing the camera to spin with the rocket. Video taken this way is usually disoriented and hard to watch. To prevent this from happening the payload team designed a bearing system with a 360 degree window which will be harnessed inside the airframe.

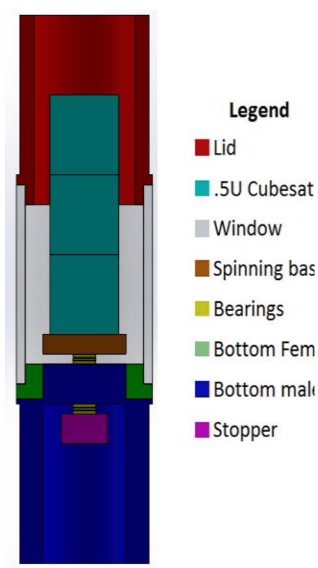


Figure 14. Section view of payload subsystem with parts labeled.

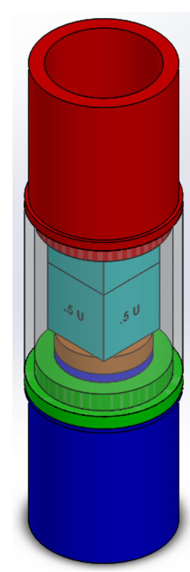


Figure 15. 3D model of payload subsystem.

Technical Objective

As a method of stabilization during flight, the rocket spins around its vertical axis. This is a good sign for the stabilization of the rocket but it an unfavorable condition for video recording. Since the payload team is trying to collect a video of flight, the more spinning that occurs the more disoriented the video becomes. Therefor a system that allows the camera to remain stable while the rocket spins around the vertical axis was created. The payload team had to design a system because the systems available commercially were for stabilization about multiple axes instead of just one axis.

Design

Many different design criteria were taken into consideration when choosing the materials to build the payload. The materials chosen had to be machinable, fit into the budget, be light, durable, and accessible. The most important and the most expensive part of the payload was the acrylic window. Extensive research went into selecting the right material for the window. The window itself is 5 inches tall and provides a 360 degree viewing port for the camera. The lid, bottom female and bottom male are made out of PVC. The spinning base was made out of steel, adding the necessary weight needed to make our design work. By using steel the payload team also helped add weight to the payload to help it reach the required 8.8 pounds needed for the competition. The spinning base rests on a thrust bearing and a washer to stabilize the spinning base while the rocket is in flight. Located on the other side of the spinning base, between the stopper and the bottom male, there is another thrust bearing and washer intended for the same purpose. Finally, the cubes used to achieve the 0.5 Cubesat form were 3D printed in our machine shop.

After deciding which materials to select for each part, the next challenge was putting the pieces together and ensuring they wouldn't move or come apart during flight. The lid and the bottom female parts are epoxied to the window. The bottom male piece threads to the bottom female piece to provide an easy way to remove the cubes and the camera. To ensure that the two pieces do not unthread during flight, a pin is placed through a hole that goes in both of the pieces. For the camera, it is attached to the spinning base with a threaded mount. When placed on the threaded mount the camera sits perfectly inside the bottom cube. The specific model camera that worked best for this design was the GoPro Hero 5 Session. This camera was the smallest camera that provided the video quality desired for the project. A battery pack will be housed in the top two cubes to ensure maximal battery life for the camera.

Failure Modes

With an uncertain amount of time on the launchpad with the camera running, the camera could die before it is launched. Also, the heat of the desert could cause the camera to overheat and stop recording.

V. MISSION CONCEPT OF OPERATIONS OVERVIEW

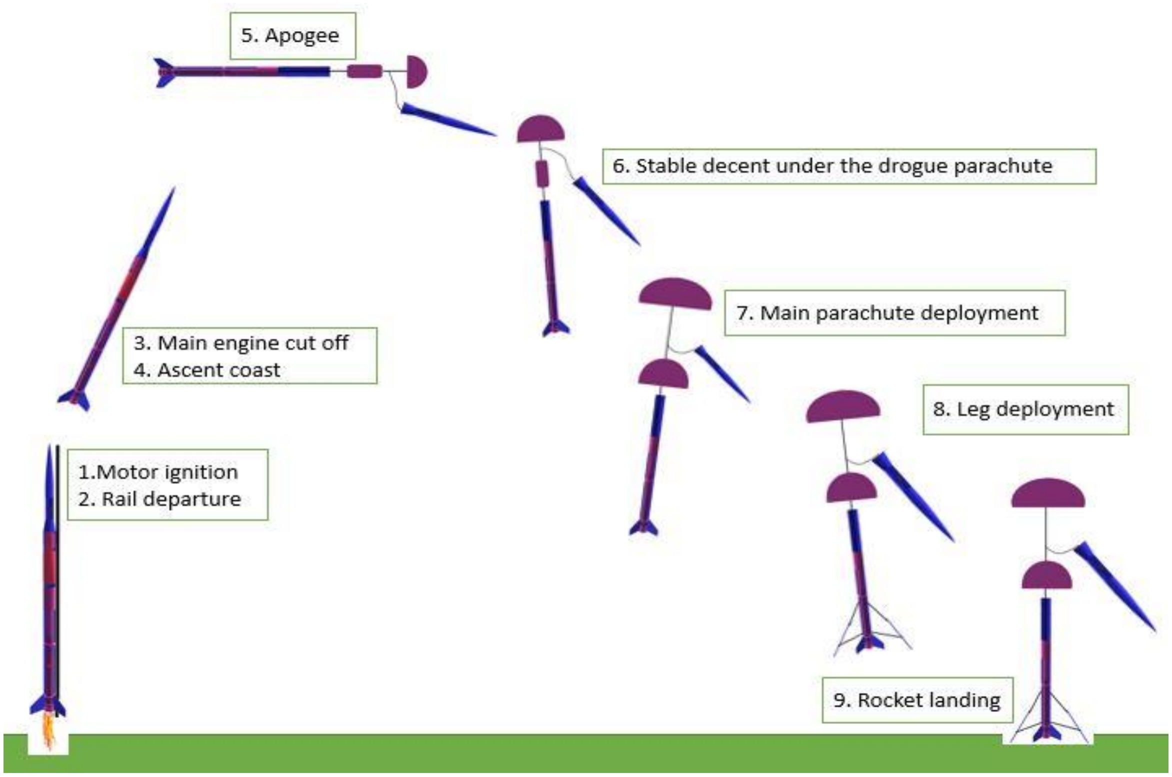


Figure 16. Overview of inflight operations

Mission Phases

1. **Motor Ignition**
2. **Rail departure**
3. **Main engine cut off**
4. **Ascent coast**
5. **Apogee**
6. **Stable decent under the drogue parachute**
7. **Main parachute deployment (1,200 feet)**
8. **Leg Deployment (700 feet)**
9. **Rocket landing**

Subsystems

- Aerotech N3300
- Landing legs
- Landing release solenoids
- Electronics bay
- Raven3 altimeter
- Telemega
- Main parachute
- JollyLogic chute release
- Drogue parachute
- Scientific payload
- Nose cone

Nominal operations during phases

1. *Motor Ignition*
   - ❑ Aerotech N3300: Motor ignited and producing thrust
   - ❑ Landing legs: Locked and stable in their aerodynamic position
   - ❑ Landing leg release solenoid: Locked and stable within the airframe
   - ❑ Electronics bay: Armed and structurally stable
   - ❑ Telemega altimeter: Armed with two ejection charges on standby
     - ❑ Apogee standby
     - ❑ Redundant apogee standby
   - ❑ Raven3: Armed with one ejection charge on standby
     - ❑ Apogee standby
     - ❑ Redundant apogee standby
   - ❑ Main parachute: Packed and secured in the airframe by the JollyLogic chute release, main parachute tether connected to the electronics bay
   - ❑ JollyLogic chute release: Locked in place securing the main parachute within the airframe
   - ❑ Drogue parachute: Packed within the airframe, connected to the drogue chute tether which is connected to the electronics bay
   - ❑ Scientific payload: Batteries fully charged, GoPro is active and recording
   - ❑ Nose cone: Securely connected to the airframe, connected to the drogue chute tether which is connected to the electronics bay

2. *Rail Departure*
   - ❑ Aerotech N3300: Motor ignited and producing thrust
   - ❑ Landing legs: Locked and stable in their aerodynamic position
   - ❑ Landing leg release solenoids: Locked and stable within the airframe
   - ❑ Electronics bay: Armed and structurally stable
   - ❑ Telemega altimeter: Armed with two ejection charges on standby
     - ❑ Apogee standby
     - ❑ Redundant apogee standby
   - ❑ Raven3: Armed with one ejection charge on standby
     - ❑ Apogee standby
     - ❑ Redundant apogee standby
   - ❑ Main parachute: Packed and secured in the airframe by the JollyLogic chute release, main parachute the electronics bay
   - ❑ JollyLogic chute release: Locked in place securing the main parachute within the airframe

- ❑ Drogue parachute: Packed within the airframe, connected to the drogue chute tether which is connected to the electronics bay
- ❑ Scientific payload: Batteries charged, GoPro is active and recording
- ❑ Nose cone: Securely connected to the airframe, connected to the drogue chute tether which is connected to the electronics bay

3. *Main Engine Cut Off*
- ❑ Aerotech N3300: Motor burned out
- ❑ Landing legs: Locked and stable in their aerodynamic position
- ❑ Landing leg release solenoids: Locked and stable within the airframe
- ❑ Electronics bay: Armed and structurally stable with drogue
- ❑ Telemega altimeter: Armed with two ejection charges on standby
  - ❑ Apogee standby
  - ❑ Redundant apogee standby
- ❑ Raven3: Armed with one ejection charges on standby
  - ❑ Apogee standby
  - ❑ Redundant apogee standby
- ❑ Main parachute: Packed and secured in the airframe by the JollyLogic chute release, main parachute tether connected to the electronics bay
- ❑ JollyLogic chute release: Locked in place securing the main parachute within the airframe
- ❑ Drogue parachute: Packed within the airframe, connected to the drogue chute tether which is connected to the electronics bay
- ❑ Scientific payload: Batteries charged, GoPro is active and recording
- ❑ Nose cone: Securely connected to the airframe, connected to the drogue chute tether which is connected to the main chute tether which is connected to the electronics bay

4. *Ascent Coast*
- ❑ Aerotech N3300: Motor burned out
- ❑ Landing legs: Locked and stable in their aerodynamic position
- ❑ Landing leg release solenoids: Locked and stable within the airframe
- ❑ Electronics bay: Armed and structurally stable with drogue and main parachute tethers
- ❑ Telemega altimeter: Armed with two ejection charges on standby
  - ❑ Apogee standby
  - ❑ Redundant apogee standby
- ❑ Raven3: Armed with one ejection charges on standby
  - ❑ Apogee standby
  - ❑ Redundant apogee standby
- ❑ Main parachute: Packed and secured in the airframe by the JollyLogic chute release, connected to the main parachute tether connected to the U-bolt anchor
- ❑ JollyLogic chute release: Locked in place securing the main parachute within the airframe
- ❑ Drogue parachute: Packed within the airframe, connected to the drogue chute tether which is connected to the electronics bay
- ❑ Scientific payload: Batteries charged, GoPro is active and recording
- ❑ Nose cone: Securely connected to the airframe, connected to the drogue chute tether which is connected to the main parachute tether which is connected to the electronics bay

5. *Apogee*
- ❑ Aerotech N3300: Motor burned out
- ❑ Telemega altimeter: Armed with 2 ejection charges on standby, two charges detonated
  - ❑ Apogee detonate
  - ❑ Redundant apogee detonate
- ❑ Raven3 altimeter: Armed with one ejection charge on standby, one charge detonated
  - ❑ Apogee detonate
  - ❑ Redundant apogee detonate
- ❑ Nose cone: ejected from airframe, connected to the drogue parachute and drogue tether which is connected to the electronics bay
- ❑ Drogue parachute: ejected from the airframe, connected to the drogue chute tether which is connected to the main parachute and then to the electronics bay
- ❑ Scientific payload: Batteries charged, GoPro is active and recording
- ❑ Main parachute: ejected from airframe and secured by JollyLogic chute release, connected to the main parachute tether connected to the electronics bay

- ❑ JollyLogic chute release: Locked in place securing the main parachute outside of the airframe
- ❑ Electronics bay: Armed and structurally stable

6. *Stable Descent Under The Drogue Parachute*
    - ❑ Aerotech N3300: Motor burned out
    - ❑ Telemega altimeter: Armed with two ejection charges on standby, two charges detonate
        - ❑ Apogee detonated
        - ❑ Redundant apogee detonated
    - ❑ Raven3 altimeter: Armed with one ejection charge on standby, one charge detonated
        - ❑ Apogee detonated
        - ❑ Redundant apogee detonated
    - ❑ Nose cone: ejected from airframe, connected to the drogue parachute and drogue tether which is connected electronics bay
    - ❑ Drogue parachute: ejected from the airframe and is fully inflated during descent, connected to the drogue chute tether which is connected the the electronics bay
    - ❑ Scientific payload: Batteries charged, GoPro is active and recording
    - ❑ Main parachute: ejected from airframe and secured by JollyLogic chute release, connected to the main tether connected to the electronics bay
    - ❑ JollyLogic chute release: Locked in place securing the main parachute outside of the airframe
    - ❑ Electronics bay: Armed and structurally stable

7. *Main Parachute Deployment (1,200 feet)*
    - ❑ Aerotech N3300: Motor burned out
    - ❑ Telemega altimeter: Armed with two ejection charges on standby, two charges detonated
        - ❑ Apogee detonated
        - ❑ Redundant apogee detonated
    - ❑ Raven3 altimeter: Armed with one ejection charge on standby, one charge detonated
        - ❑ Apogee detonated
        - ❑ Redundant apogee detonated
    - ❑ Nose cone: ejected from airframe, connected to the drogue parachute and drogue tether which is connected to the electronics bay
    - ❑ Drogue parachute: ejected from the airframe and is fully inflated during descent, connected to the drogue chute tether which is connected to the electronics bay
    - ❑ Scientific payload: Batteries charged, GoPro is active and recording
    - ❑ JollyLogic chute release: 1,200 feet sensed and chute release is unlocked
    - ❑ Main parachute: Released and fully inflated connected to the main tether connected to the electronics bay
    - ❑ Electronics bay: Armed and structurally stable supporting the main parachute tether

8. *Leg Deployment (700 feet)*
    - ❑ Aerotech N3300: Motor burned out
    - ❑ Telemega altimeter: Two charges detonated
        - ❑ Apogee detonated
        - ❑ Redundant apogee detonated
    - ❑ Raven3 altimeter: one charges detonated
        - ❑ Apogee detonated
        - ❑ Redundant apogee detonated
    - ❑ Drogue parachute: paritally inflated during descent, connected to the drogue chute tether connected to the main parachute tether which is then connected to the electronics bay.
    - ❑ Scientific payload:
    - ❑ Nose cone: ejected from the rocket and connected to the drogue chute tether.
    - ❑ Electronics bay: Armed and structurally stable supporting the main parachute tether
    - ❑ JollyLogic chute release: Unlocked and connected to main tether
    - ❑ Main parachute: Fully inflated connected to the main tether connected to the electronics bay
    - ❑ Scientific payload: Batteries charged, GoPro is active and recording
    - ❑ Landing leg solenoid: activated
    - ❑ Landing leg release: legs released and locked into place

9. *Rocket Landing*

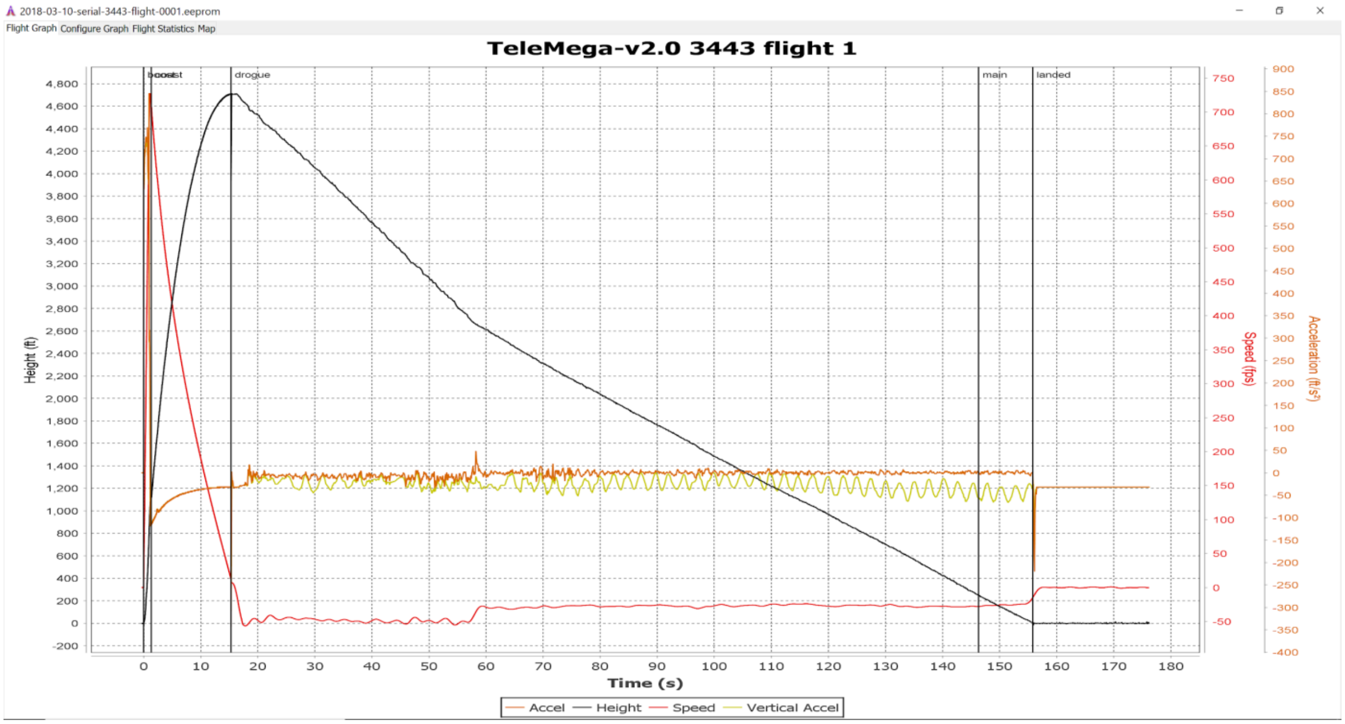
- ❑ Aerotech N3300: Motor burned out
- ❑ Telemega altimeter: Two charges detonated
  - ❑ Apogee detonated
  - ❑ Redundant apogee detonated
- ❑ Raven3 altimeter: one charges detonated
  - ❑ Apogee detonated
  - ❑ Redundant apogee detonated
- ❑ Electronics bay: Armed and structurally stable supporting the main parachute
- ❑ JollyLogic chute release: Unlocked and connected to main tether
- ❑ Main parachute: Fully inflated connected to the main tether connected to the U-bolt anchor
- ❑ Scientific payload: Batteries charged, GoPro is active and recording
- ❑ Landing leg solenoid: deactivated
- ❑ Landing leg release: legs released and locked into place

VI. Conclusion

As a second year team competing in this competition and as a relatively new organization, the Ohio University Rocket and Design Team has went through an extreme amount of change since the beginning of the 2017 fall semester. Taking on the task of developing a full mechanical landing leg system for this project proved to be a very difficult challenge for the team. These challenges however, helped the team and as individuals grow. Many new management strategies were picked up later in the year and successfully implemented. These will carry over into the next year and will help optimize the amount of time and effort put into future projects overall quality.

PROJECT TEST REPORTS APPENDIX

The following figures represent test flight data for a single stage level two rocket flown with the Telemega.



Flight data from Telemega

GPS tracking from Telemega

Notable Flight Values

Date	**2018-03-10**
Apogee	**4712 ft**
Max Speed	**727 ft/s**
Maximum boost acceleration	**845 ft/s^2**
Ascent Time	**14.0 = coast**
Drogue Descent Rate	**34 ft/s**
Main Descent Rate	**25 ft/s**
Descent Time	**9.5 = main**
Flight Time	**155.0 s**

THIS PAGE INTENTIONALLY LEFT BLANK

THIS PAGE INTENTIONALLY LEFT BLANK

HAZARD ANALYSIS APPENDIX

The Ohio University Rocket Team will adhere to the following safety plan to mitigate injury to any team member due to the inherent hazards presented by the rocket design and construction environment.

Launch Procedure:

All launches carried out by the Ohio University Rocket Team will be supervised by the team Safety Officer and will follow the Assembly, Prelaunch, and Launch checklists related to the rocket being prepared to launch. All personnel involved with the rocket launch must be familiar with these checklists. Any revisions must be reviewed and approved by the Safety Officer. These checklists will provide both a step-by-step guide to assembling the rocket and may refer to any sub-system checklists that are inherent to the design of the rocket. The safety officer will inspect the rocket after each checklist is completed to ensure safety.

NAR Safety Code and Compliance for High Power Rocketry:

The majority of members in the Ohio University Rocket Team are certified through the National Association of Rocketry (NAR). Therefore our club as a whole will obey the NAR safety code as well as the National Fire Protection Association (NFPA) 1127 code. Furthermore, all certified members will enforce each regulation. The following is our compliance with said code.

NAR Safety Code	Compliance
Certification. I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.	Only properly licensed members of the Ohio University Rocket Team will purchase, own, or fly any high power rocket motors within their certification.
Materials. I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.	All materials used in the rocket design will adhere to this code.
Motors. I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.	All rocket motors purchased by any individual of this team will be from certified and reputable sellers. No team member will make modifications to any rocket motor outside of seller's' recommendation/specs. Finally, all heat/ignition sources will be cleared from the storage area of the motor.
Ignition System. I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the “off” position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.	All rocket designs created by team will implement an electrical ignition system that will be set up only during launch prep or on the launch pad, depending on the desires of the Range Safety Officer present and the regulations of the launch. In addition, all electronics involved with ignition and ejection charges will feature a safety switch that will be in the ‘off’ position until the rocket is on the launchpad ready to launch.

Misfires. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 s after the last launch attempt before allowing anyone to approach the rocket.	The team will adhere to this code and the Range Safety Officer will have the final say on all Misfires.
Launch Safety. I will use a 5-s countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.	This code will be followed and the Range Safety Officer will have the final say on all Launch Safety considerations.
Launcher. I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.	This code will be followed and the Range Safety Officer will have the final say on all Launch Safety considerations.
Size. My rocket will not contain any combination of motors that total more than 40,960 N-s (9208 lbf-s) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.	All rockets designed by the Ohio University Rocket Team will follow these size restrictions.
Flight Safety. I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.	This code will be followed and the Range Safety Officer will have the final say on all Flight Safety considerations.
Launch Site. I will launch my rocket outdoors, in an open area	All team launches will be held at NAR/TRA hosted events. The Range Safety Officer will have the final say on all rocketry

where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-s, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).	safety considerations.
Launcher Location. My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.	This code will be followed and the Range Safety Officer will have the final say on Launcher location.
Recovery System. I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.	This regulation will be followed by all team members where all designs will be checked and approved by the team Safety Officer and Team President. At any launch the Range Safety Officer will have the final say on the recovery system of any rocket design.
Recovery Safety. I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.	All rockets designed by the Ohio University Rocket Team will have a Recovery Team whose sole job is to ensure the safe recovery of the rocket. A safety checklist, approved by the Safety Officer, will be used for every launch to ensure success.

Hazardous Material Handling:

The following is a list of hazardous materials used by the Ohio University Rocket Team in the construction of our rocket. Along with each material is a list of its intended uses, the required Personal Protective Equipment (PPE) , and the materials Safety Data Sheet (SDS). This is to ensure safe handling by each team member. No member will use any of these materials unless they have been trained in their proper use. If the use is by a new team member than he/she will be assisted and supervised by a more experienced team member.

Material: Fiberglass
Uses: Material chosen for the airframe, nose cone, and fins
PPE: Long-sleeved shirt, pants, closed toed shoes, goggles, gloves, mask
SDS: https://stars.berkeley.edu/assets/files/Fiberglass_MSDS.pdf

Material: Hodgdon Pyrodex - The muzzleloading propellant (gunpowder)
Uses: Used as the combustible for the ejection charges and tender descender.
PPE:
SDS: https://www.hodgdon.com/wp-content/uploads/2016/11/pyrodex-sds-sheet-2013.pdf

Material: West Systems 205 Fast Hardener
Uses: Mixed with 105 Epoxy Resin before application and used to bond multiple rocket components. Fin fillets.
PPE: Mask, gloves, goggles, apron
SDS: http://www.westsystem.com/wp-content/uploads/105-SDS.pdf

Material: West System 105 Epoxy Resin
Uses: Mixed with 205 Fast Hardener before application and used to bond multiple rocket components. Fin fillets.
PPE: Mask, gloves, goggles, apron
SDS:http://www.westsystem.com/wp-content/uploads/205-SDS.pdf

Transportation and Storage Procedures of Propellants and Explosives:

Ammonium perchlorate composite propellant (APCP) is the main component in amature rocket motors. In March of 2009 APCP was no longer listed as an explosive by the Bureau of Alcohol, Tobacco, Firearms and Explosives (BATFE) as decided by a ruling from the United States District Court for the District of Columbia. This effectively removed APCP from regulation under Federal explosives laws at 18 U.S.C., Chapter 40, allowing anyone to manufacture, import, purchase, distribute, or receive APCP without a license or permit. This allows the Ohio University Rocket Team to transport our rocket motor across the country by car. The storage of our rocket motor will adhere to the NAR safety code. Furthermore, our motor will be stored in the original packaging from the manufacture, in an area clear of any potential ignition sources, up to the moment of installation during launch prep.

The transport, storage, and purchase, of any purchase will be done only by team members who are certified to do so as described by 18 U.S. Code Chapter 40, and 27 CFR part 555.

Relevant links:

- APCP ruling: https://www.google.com/search?q=BATFE+letter+APCP&rlz=1C1CHBF_enUS722US722&oq=BATFE+letter+APCP&aqs=chrome..69i57j69i60.4231j0j7&sourceid=chrome&ie=UTF-8
- 18 US code chapter 40: https://www.law.cornell.edu/uscode/text/18/part-I/chapter-40
- 27 CFR part 555: https://www.law.cornell.edu/cfr/text/27/part-555

Plan for Hazard Recognition and Accident Avoidance

To ensure the safety of all team members, new members will be properly trained in the use of all hazardous materials and equipment by either more experienced members or by faculty who maintain the machines shops on campus. This may be accomplished by a mass training session or by a need to know basis. The workspaces available to the rocket team at Ohio University are as follows:

- Senior Design Lab in Stocker Center
- A hangar space in the Academic and Research Center (ARC), attaches to Stocker
- Multiple machine shops in the basement floor of Stocker

Student use of the machine shop is only permitted while the faculty member who runs said shop is present. Any student who wishes to use the equipment in the shop must first go through training with the faculty member with the particular machine of interest prior to use. Furthermore, the ARC hangar is available for use by students 24 hours a day 7 days a week. This room includes a closet space that the Russ College has allocated for the use of storing all of the materials, equipment, and tools that belong to the rocket team. The hazards inherent to these workspaces are listed as follows:

- Power tools
    - Battery powered drill
    - Dremel
    - Horizontal band saw
    - Manual vertical mill
    - Computer numerically controlled lathe (CNC)
    - CNC three axis mill
- Electrical components/devices in the case of making a circuit from scratch
- Saws, files, and hammers.

RISK ASSESSMENT APPENDIX

Hazard	Possible Causes	Risk of Mishap and Rationale	Mitigation Approach	Risk of Injury after Mitigation
Premature ignition of ejection charge(s)	Incorrect wiring of avionics	Medium: student built circuitry, multiple problems in the past with both the circuit and the altimeter	Triple check wiring of the avionics	Low
	Malfunction or damage to avionics components		Safely perform a check that the devices of the avionics set off a charge as intended	
	Coding for electronic device controlling charge is corrupted or incorrectly installed		Promote communication between teammates and onlookers to alert them to the presence of dangerous (combustible) materials	
	A heat source was brought near the ejection charge		To prevent injury. Do not point loaded ejection charges at anyone and designate a 'no-occupancy zone' where the ejection charges will be pointing during the duration of rocket assembly	
Landing Legs do not release	Actuator could not overcome friction of the pin slot	High; experimental design, budget and time constraints due to classes did not allow for extensive destructive testing	Ensure that pins can be easily pulled (oil/lubrication may be needed) and that the legs have enough of a kick from springs to descend	Low/Medium
	Torsional spring is not strong enough to deploy legs		Check the mechanics of the leg prior to launch	
	Transport damage to legs		The landing legs will be transported in a sturdy container to mitigate any damage from travel	
	Installation errors of legs		All parts will be accounted for so that the leg installation goes according to design	

Premature firing of Rocket motor	Heat source was brought near motor	Medium;	When motor is installed, ensure that all members and bystanders are aware of the presence of the motor so that the environment can be cleared of any heat sources or possible igniters.	Low
	Motor was not stored/handled safely		Do not point the exhaust end of the motor at anyone	
	Faulty motor		Purchase motor from reputable supplier	
Rocket deviates from nominal flight path, comes in contact with personnel at high speed	Problem with rail pins installation/design	Medium; rail pins will be extended from body due to the landing leg design.	Check length of each rail pin and ensure that the rocket does not have an excessive angle on the launch rail	Low
	Fin(s) detach from airframe		Check that each fin is securely mounted	
	Landing leg detaches from rocket or prematurely deploys		Check that each leg locked in place	
Rocket does not ignite when command is given (“hang fire”), but does ignite when team approaches to troubleshoot	Problem with ignition switch/circuitry	Medium; hard to predict if this is a motor production issue.	Disable launch system by turning off or physically disconnecting power source. Wait 60 s before allowing any team members to approach the launch pad.	Low
	Faulty motor		Purchase motor from reputable supplier	
Recovery system fails to deploy, rocket or payload comes in contact with personnel	Main parachute does not get ejected	High; Recovery is one of the most common things to go wrong with rocket builds. This design has many components that must perform correctly for the rocket to land intact.	Multiple tests on main parachute-release to ensure reliability	Low/Medium

ASSEMBLY, PREFLIGHT, AND LAUNCH CHECKLIST APPENDIX

AIAA Ohio University Rocket Design Team
Rocket Launch Prep Safety Procedures
***PRINT ONE COPY PER LAUNCH EXPECTED**

- **Pre-Assembly General Inspection**
  - Visually inspect
    - Structural stability of fins
    - Structural integrity of airframe
    - Structural integrity of tether lines
    - Structural integrity of parachutes
    - Structural integrity of nose cone
    - Structural integrity of motor, motor fit, retention
    - Ensure rail buttons are attached
    - Check functionality of JollyLogic
    - Check functionality of Telamega altimeter and all electrical components prior to installing
    - Check functionality of Reaven3 altimeter and all electrical components prior to installing
- **Pre-Assembly Landing Leg Inspection**
    - Ensure that all parts are accounted for before assembly
    - Check that each leg has full range of motion as intended
    - Check operation of locking mechanism
    - Check gas spring systems for leaks, fractures, damages or defects
    - Ensure all required hardware is intact and in proper location
    - Test release solenoids
    - Check electrical wiring is intact and properly assembled
    - Check electronics for frayed or exposed wires
- **Pre-Assembly Electronics Bay**
  - Visually inspect structural state of electronics bay
    - No exposed, or frayed wires
    - Wires are secure and in proper location
    - All bolts and nuts are present and adequately tightened
    - Visually inspect electronic matches are of good quality and intact
    - Check that bulk plates are secure
  - Check battery voltage using multi-meter
  - Configure Altimeters
- **Assembly of Electronics Bay**
  - Face shield on
  - Insert sled into electronics bay
  - Measure black powder
    - Mass of powder used __________g
  - Wire electronic matches
  - Announce loading of black powder
  - Load black powder for separation charges
  - Insert electronic matches
  - Load Dog Barf
  - Tape over separation charge capsule
  - Connect recovery
  - Insert electronics bay into booster stage rocket, screw into position
  - Pack parachutes
  - Booster Stage Assembly Complete
- **Assembly, Closing of Airframe and Collapsing of Landing Leg System**
  - Check LED for confirmation of power to leg deployment microcontroller
  - Retract solenoid shaft to allow for locking mechanism to fall into place
  - Fold a single leg at a time up into position

- Press locking button to cut power to solenoid and lock leg into closed positioning
- Repeat process for all three legs
- **Launch Rail Procedures**
    - Load rocket onto rail
    - Upright rocket
    - Check launch angle
    - Check stability of the rail
    - Power ON Telamega electronics
        - Listen for confirmation beeps from electronics
        - Verify settings and configuration using ground station
    - Power ON Raven3 electronics
        - Listen for confirmation beeps from electronics
    - Switch ON secondary safety ignition and separation switches for redundant electric match 1
    - Switch ON secondary safety ignition and separation switches for redundant electric match 2
    - Switch ON secondary safety ignition and separation switches for appogee electric match 1
    - Switch ON secondary safety ignition and separation switches for appogee electric match 2
    - Verify electric match continuity using ground station
- **Rocket assembly complete and ready for launch**

SAFETY OFFICER SIGNATURE:______________________________DATE:____/____/_______
TEAM LEAD SIGNATURE:_________________________________DATE:____/____/_______

References

[1]"Ohio University – Institutional Research Enrollment Statistics Spring 2016", *Ohio University* [online Portable Document Format], URL: https://www.ohio.edu/instres/enrollstats/Spring%202016%20FINAL%20ENROLLMENT%20STATISTICS.pdf [cited 24 May]

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: 5/25/2018

Team ID: 23

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

Country: United States

State or Province: Ohio

State or Province is for US and Canada

Team Information

Rocket/Project Name:	"The Big One"
Student Organization Name	Ohio University AIAA: Rocket Design and Engineering Team
College or University Name:	Ohio University, Athens Campus
Preferred Informal Name:	Astrocats
Organization Type:	Club/Group
Project Start Date	8/28/2017
Category:	30k – COTS – All Propulsion Types

Projects are not limited on how many years they take

Member	Name	Email	Phone
Student Lead	Dylan Denner	dd575213@ohio.edu	216-339-2315
Alt. Student Lead	Archie Scott III	as860414@ohio.edu	937-561-4886
Faculty Advisor	Jay Wilhelm	wilhelj1@ohio.edu	
Alt. Faculty Adviser	David Burnette	burnettd@ohio.edu	

For Mailing Awards:

Payable To:	OU AIAA: Rocket Design and Engineering Team
Address Line 1:	251 Stocker Center, Athens, OH 45701
Address Line 2:	Ohio University-Mechanical Engineering
Address Line 3:	
Address Line 4:	
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	0
Undergrad	12
Masters	1
PhD	0

Male	10
Female	3
Veterans	0
NAR or Tripoli	7

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

N/a

Rocket Information

Overall rocket parameters:

	Measurement	Additional Comments (Optional)
Airframe Length (inches):	133	
Airframe Diameter (inches):	6	Transition to 4 in nosecone
Fin-span (inches):	6	
Vehicle weight (pounds):	52.45	
Propellent weight (pounds):	27	
Payload weight (pounds):	8.8	
Liftoff weight (pounds):	88	
Number of stages:	1	Reduced to single stage
Strap-on Booster Cluster:	No	
Propulsion Type:	Solid	
Propulsion Manufacturer:	Commercial	
Kinetic Energy Dart:	No	

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

```
1st Stage: Aerotech Single Use/DMS, N3300 98MM DMS, N Class, 14041.0 Ns
```

Total Impulse of all Motors: 14041 (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:	ESRA Provide Rail	
Rail Length (feet):	17	
Liftoff Thrust-Weight Ratio:	8.43	
Launch Rail Departure Velocity (feet/second):	81.5	
Minimum Static Margin During Boost:	1.5	*Between rail departure and burnout
Maximum Acceleration (G):	10.4	Acceleration of second stage = 91
Maximum Velocity (feet/second):	1009	second stage =1355
Target Apogee (feet AGL):	30K	
Predicted Apogee (feet AGL):	11350	Mass may be added for landing legs

Payload Information

Payload Description:

The Ohio University Rocket Club has decided to implement a functional payload. The purpose of our payload is to capture stabilized video of the launch. In regards to the payloads design, we chose to use a passive system to help stabilize the camera. By using roller bearings we were able to stabilize a platform for our camera to rest on. This platform is made of heavy steel which requires more force to spin, in contrast with just mounting the camera itself. The camera used in our payload is a GoPro Hero 5 session, which was chosen based on its size and recording capabilities. This camera will capture video of the horizon, pointing perpendicular out of the rocket's air frame. After collecting the video, we plan on making a promotional video for the Ohio University Rocket Design Team as well as the Russ College of Engineering and Technology. By doing this we hope to inspire other students to join our organization as well as pursue a degree within the Russ College of Engineering and Technology.

As far as recovery of the payload goes, the payload will remain connected to the second stage of the rocket the entire time. So, it will be recovered with the second stage using its drogue and parachute. We have securely attached the camera, using a threaded camera mount, to ensure that the payload will not be harmed when returning back to the ground.

We have machined most of the parts for our payload ourselves. The payload consists of 5 main parts. The vessel itself is made of an acrylic window as well as a PVC top and bottom cap. The caps ensure that nothing from the inside of the rocket will interfere with our video. On the inside of the payload we have a plate that is attached to the bottom cap via our roller bearing design. The camera is attached to a mount that has a threaded end which is then mounted into the steel plate mentioned above. We plan on adding a battery pack to our payload in anticipation of a long wait on the launch rail. We also may add additional stabilization measures if we find it is needed.

Recovery Information

There will be one part of rocket that is being recovered. The stage will be flying with an Altus Metrum TeleMega and Raven3. The Telemega will serve as the primary altimeter and the Raven3 will serve as the redundant altimeter. For recovery, once the stage reaches apogee the primary altimeter will trigger a black power ejection charge to eject the drogue parachute. The main parachute will be bounded by a Jolly-Logic chute release. The Jolly-Logic chute release stage will deploy at 1,000 feet (AGL). Around 100 feet, an Arduino will send signals to relays to release our landing legs held in place by electromagnet solenoids. The rocket will be tracked using the TeleMega and Arrow Antennas Yagi3 antenna.

Planned Tests

* Please keep brief

Date	Type	Description	Status	Comments
10/7/17	In-Flight	Recovery and Electronics check out	Successful	Team level 1 certification flights
12/16/17	Ground	Two stage seperation sequence & charges	Successful	
3/10/18	In-Flight	Tele-mgea and telemetry check out	Successful	Tested Tele-mega with tracking
4/7/18	In-Flight	Two stage rocket flight	Major Issues	
4/7/18	In-Flight	Mach rocket flight	Minor Issues	Testing supersonic flight (mach 1.7)
5/25/18	Ground	ompetition rocket parachute and leg deployme	Minor Issues	

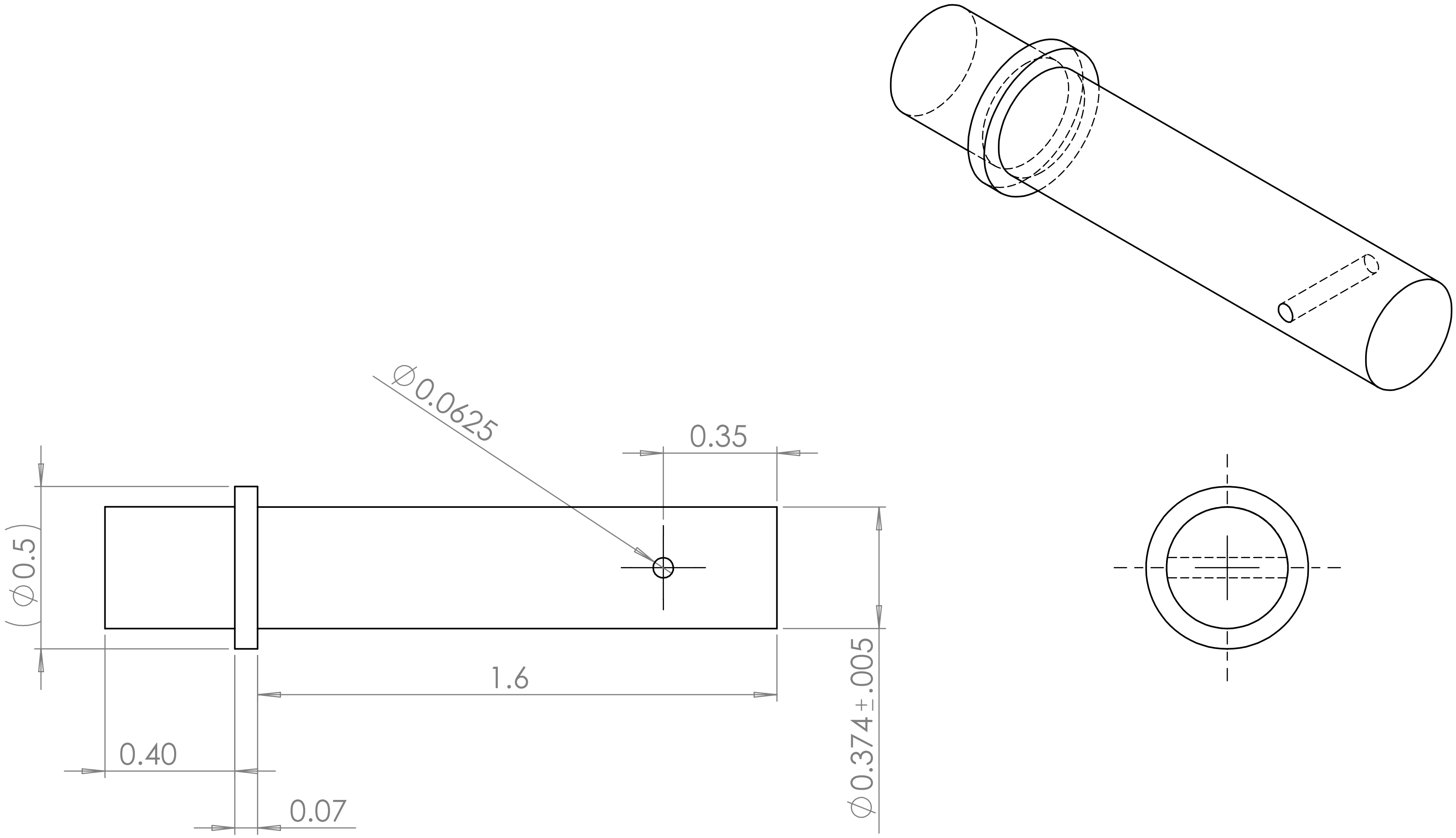
Any other pertinent information:

Continuing to progress off our 2017 design for landing legs, OURDT has re-evaluated and redesigned the construction of landing legs for our 2018 Spaceport America Cup competition rocket.

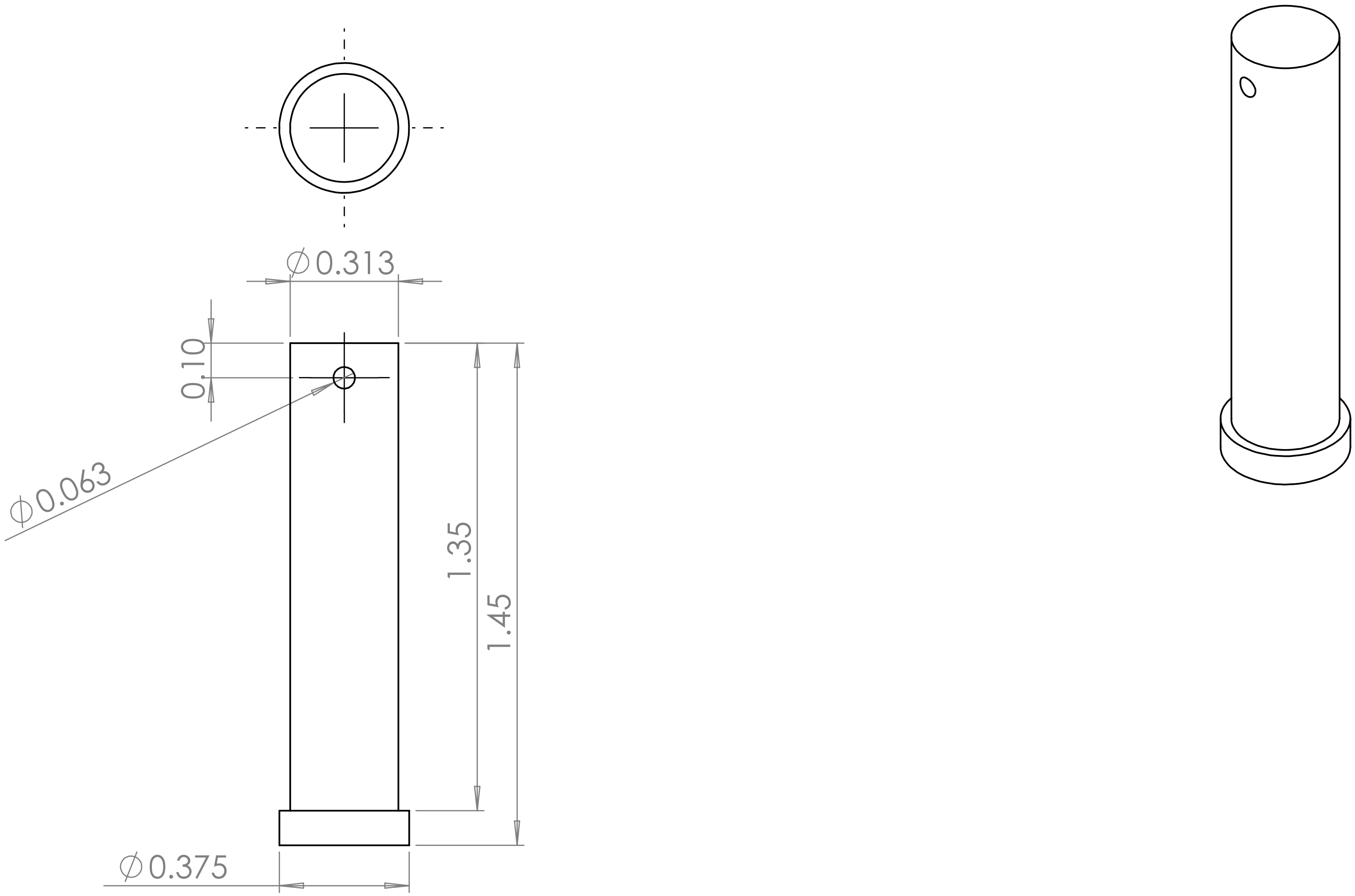
The body of the leg will be cut from the same material the airframe of the rocket is composed of. This allows us to reduce weight as well as aerodynamic drag by flush mounting the legs to the airframe. All mounting hardware for the legs will be machined out of 6061 Aluminum, supporting cross member used to prevent buckling will be made of fiberglass L brackets. The legs will be deployed by retracting electromagnet solenoids controlled by an Arduino taking altitude data. At a set-point of 100 feet, the Arduino will send signals to relays so the solenoids can be driven by 9 V batteries only when the desired deployment height is reached on descent. Once released, a torsion spring will produce the force required to extend and deploy the landing legs. Finally, a plunging lock pin will lock each leg into open position for impact.

Tip calculations have been completed to understand the greatest angle, taken from the vertical, that the rocket can approach the ground and be self-righted by the landing legs. Analyzing the angle at which the center of gravity exceeds the imaginary line connecting two end points of any adjacent legs, we've found the maximum self-righting angle to be 25.16 degrees. Any approach angle greater than 25.16 degrees, will result in the center of gravity exceeding the tipping point and the rocket will not land upright.

End of File



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE:
			CHECKED			regular pin
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL aluminum	COMMENTS:			SIZE A · DWG. NO. 001 · REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 2:1 · SHEET 1 OF 1



2 | 1 | B | A

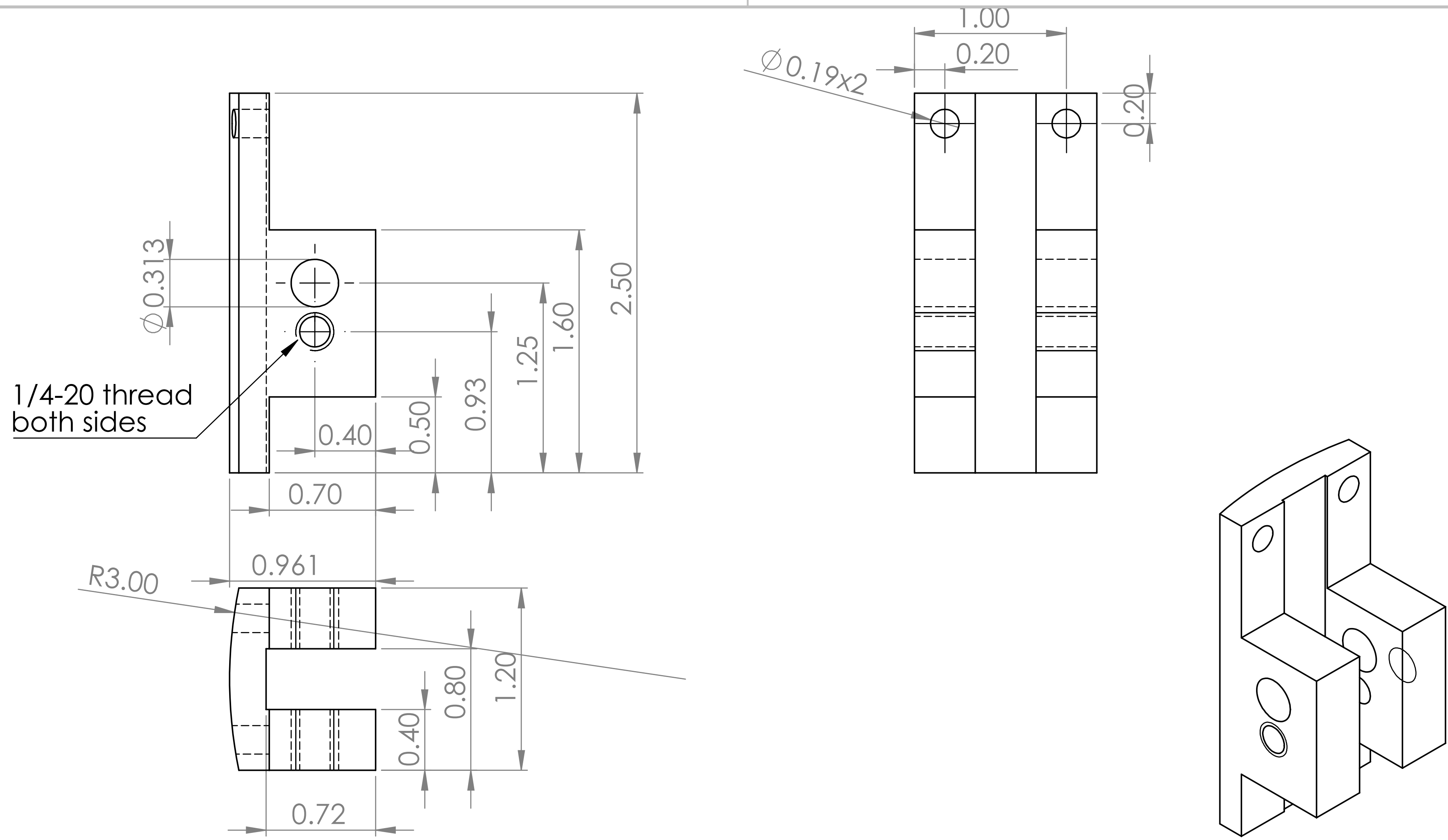
		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL aluminum	COMMENTS:		
NEXT ASSY	USED ON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

TITLE:

locking pin

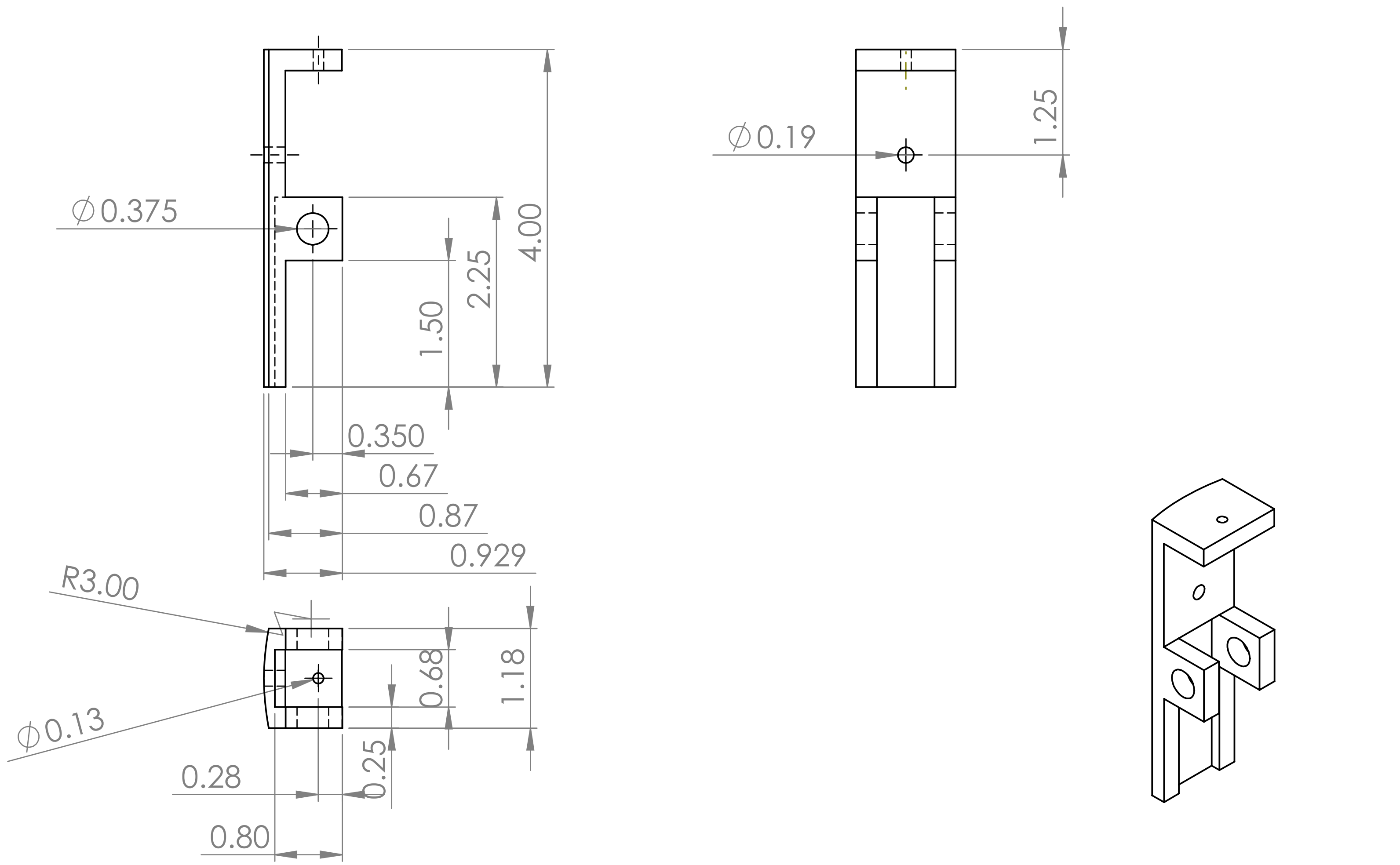
SIZE A | DWG. NO. 002 | REV

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

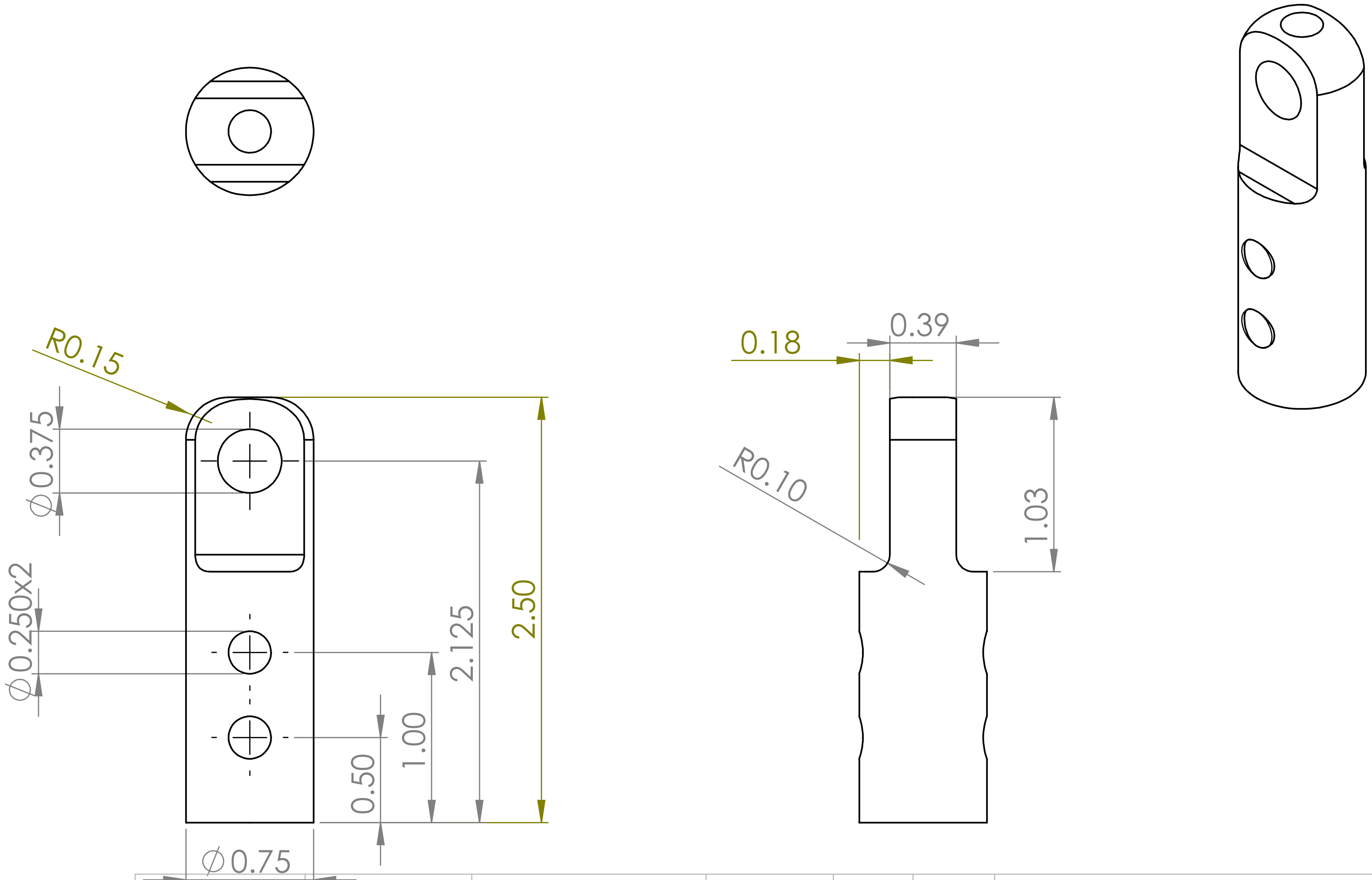


UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE:
	CHECKED			top leg bracket
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL aluminum	COMMENTS:			SIZE A — DWG. NO. 003 — REV
FINISH				
DO NOT SCALE DRAWING				SCALE: 1:1 — SHEET 1 OF 1

NEXT ASSY	USED ON
APPLICATION	



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



NEXT ASSY	USED ON
APPLICATION	

PROPRIETARY AND CONFIDENTIAL

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: aluminum

FINISH

DO NOT SCALE DRAWING

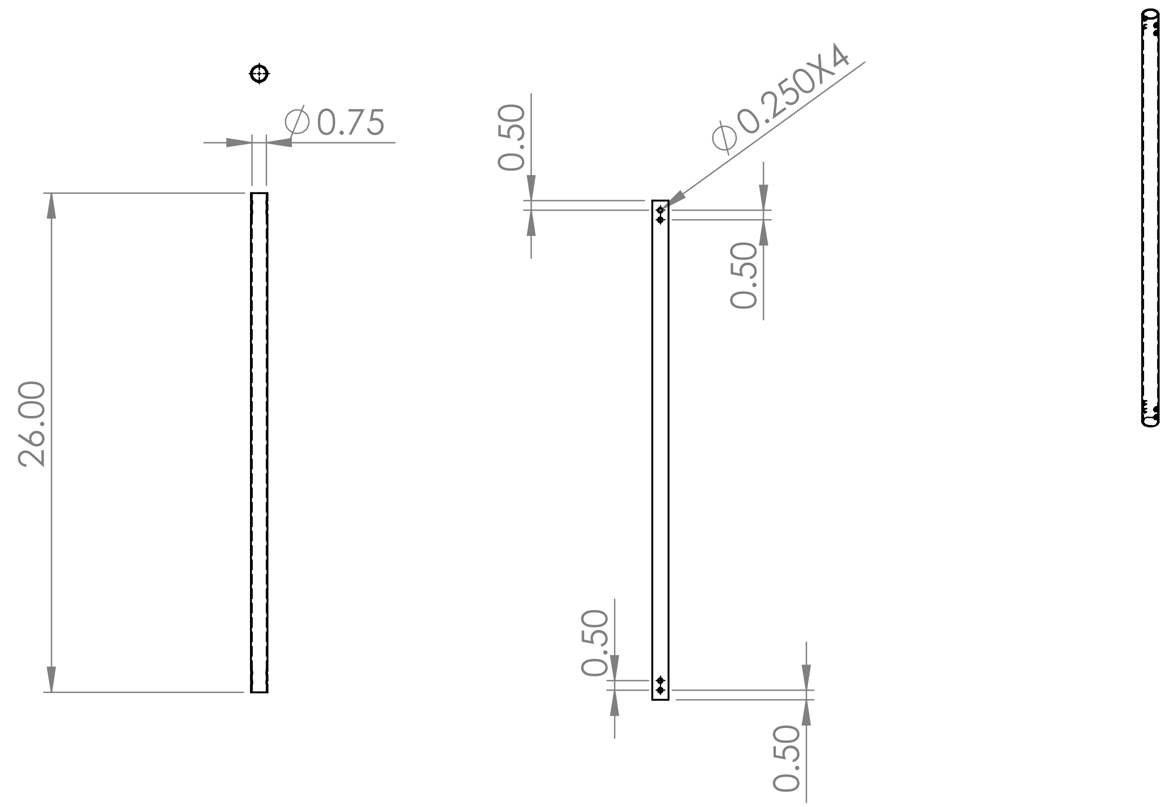
	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE: carbon fiber joint

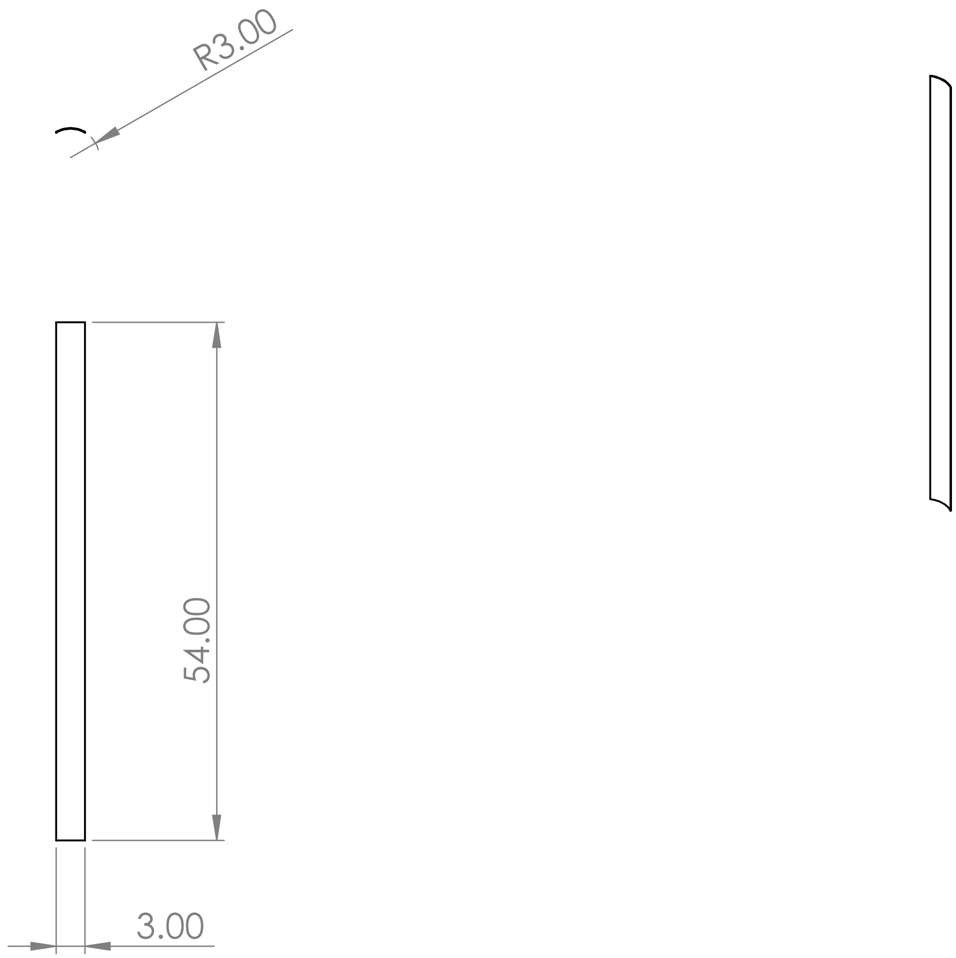
SIZE: A DWG. NO. 005 REV

SCALE: 1:1 WEIGHT: SHEET 1 OF 1

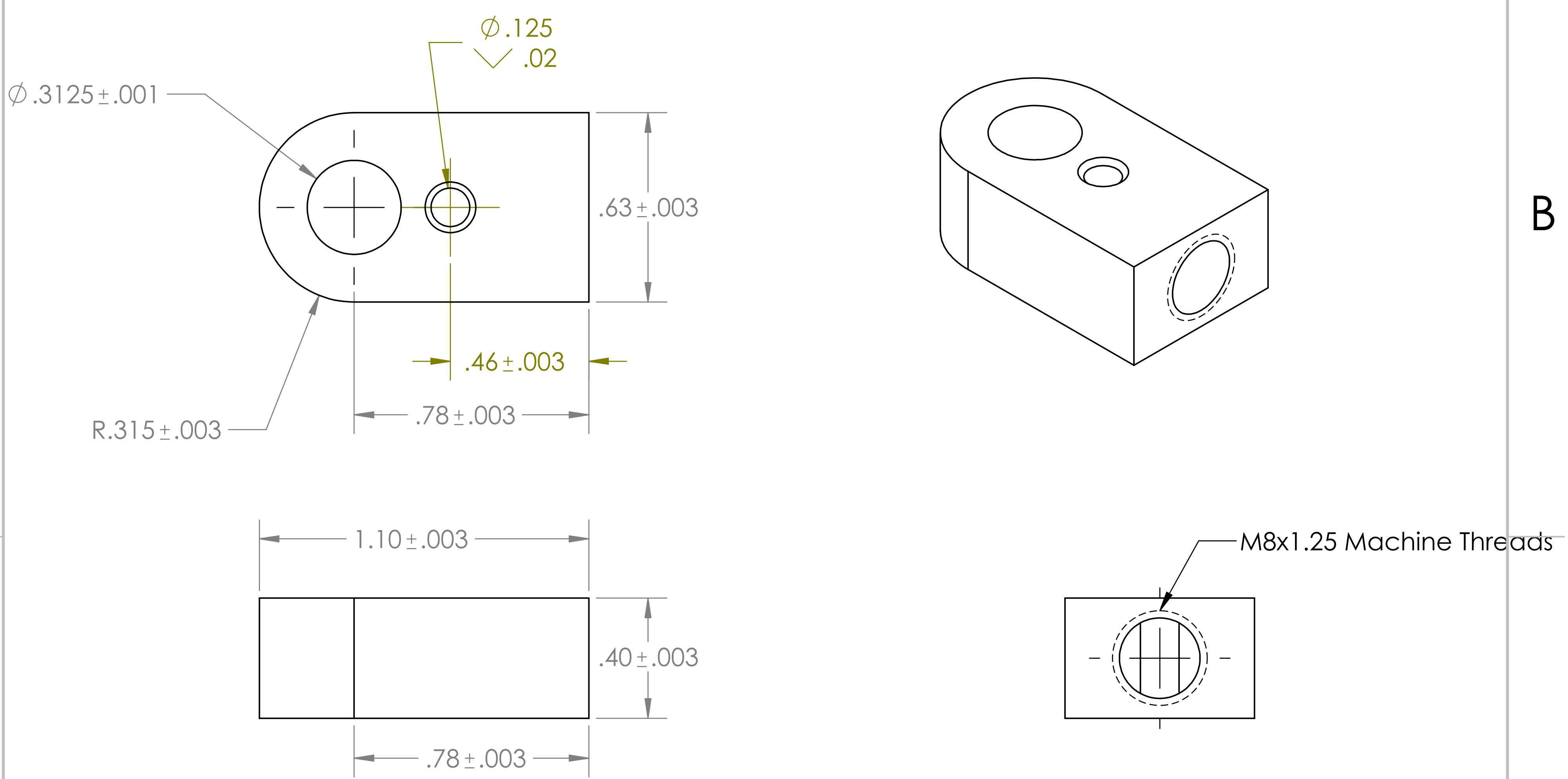


		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE:
			CHECKED			carbon fiber lef
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL carbon fiber	COMMENTS:			SIZE A · DWG. NO. 007 · REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:10 · WEIGHT: · SHEET 1 OF 1

PROPRIETARY AND CONFIDENTIAL



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			
			CHECKED			TITLE:
			ENG APPR.			fiber glass leg
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL fiber glass	COMMENTS:			SIZE A · DWG. NO. 008 · REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:20 · WEIGHT: · SHEET 1 OF 1

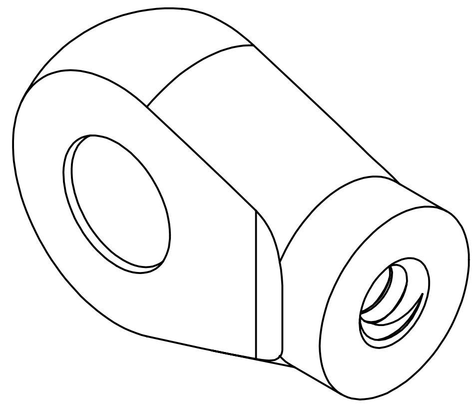


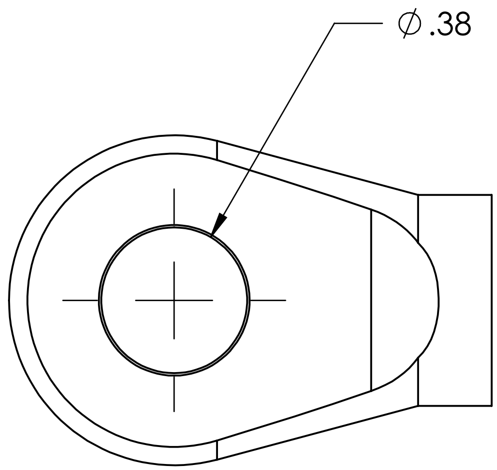
		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	JC Kraml	5/19/18
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL Aluminum	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

TITLE:

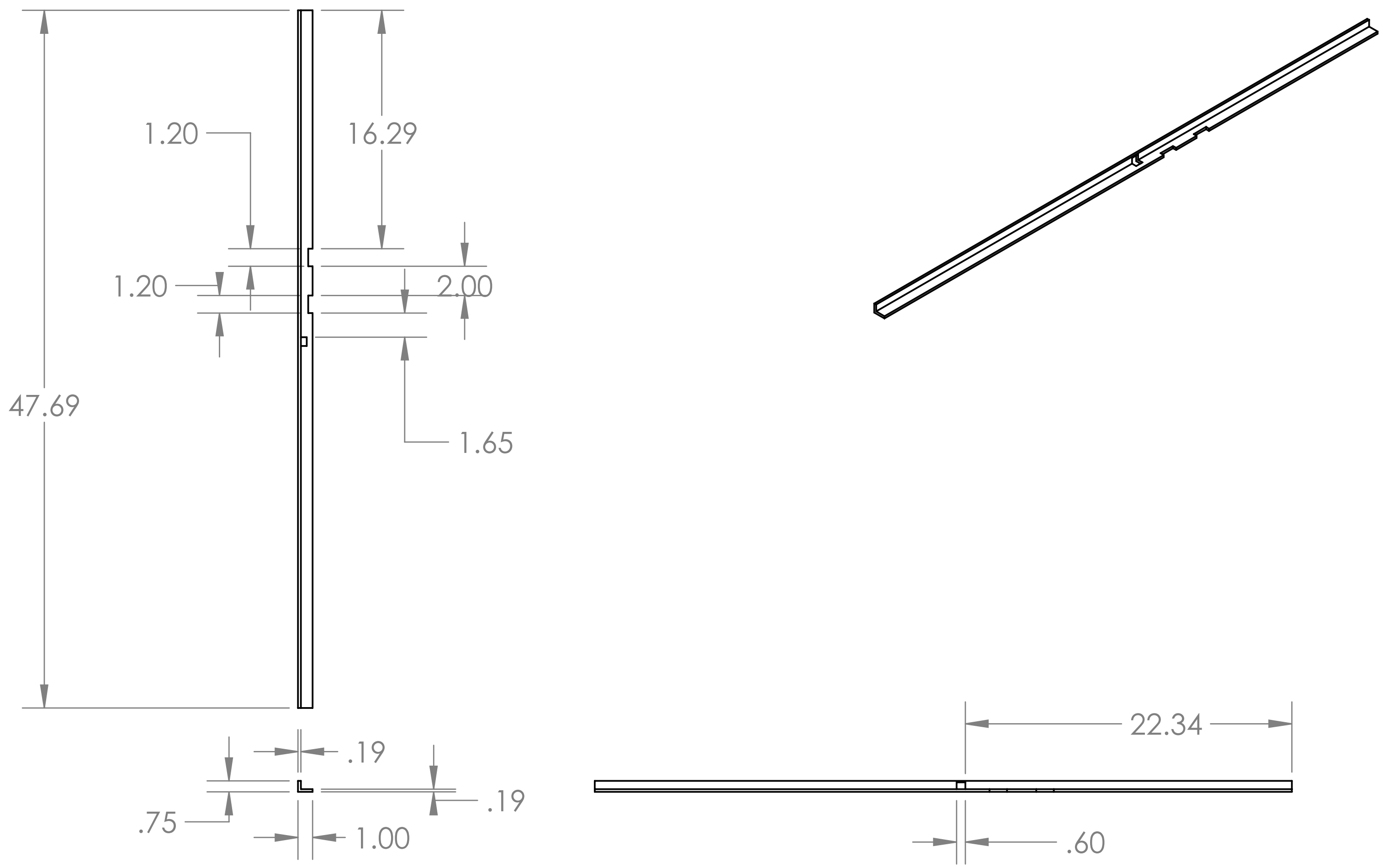
Piston Attachment

SIZE	DWG. NO.	REV
A	009	
SCALE: 2:1		SHEET 1 OF 1





		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE:
			CHECKED			
			ENG APPR.			
			MFG APPR.			Upper Eylet
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL Pre bought	COMMENTS:			SIZE A · DWG. NO. 011 · REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 2:1 · WEIGHT: · SHEET 1 OF 1



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

TITLE:

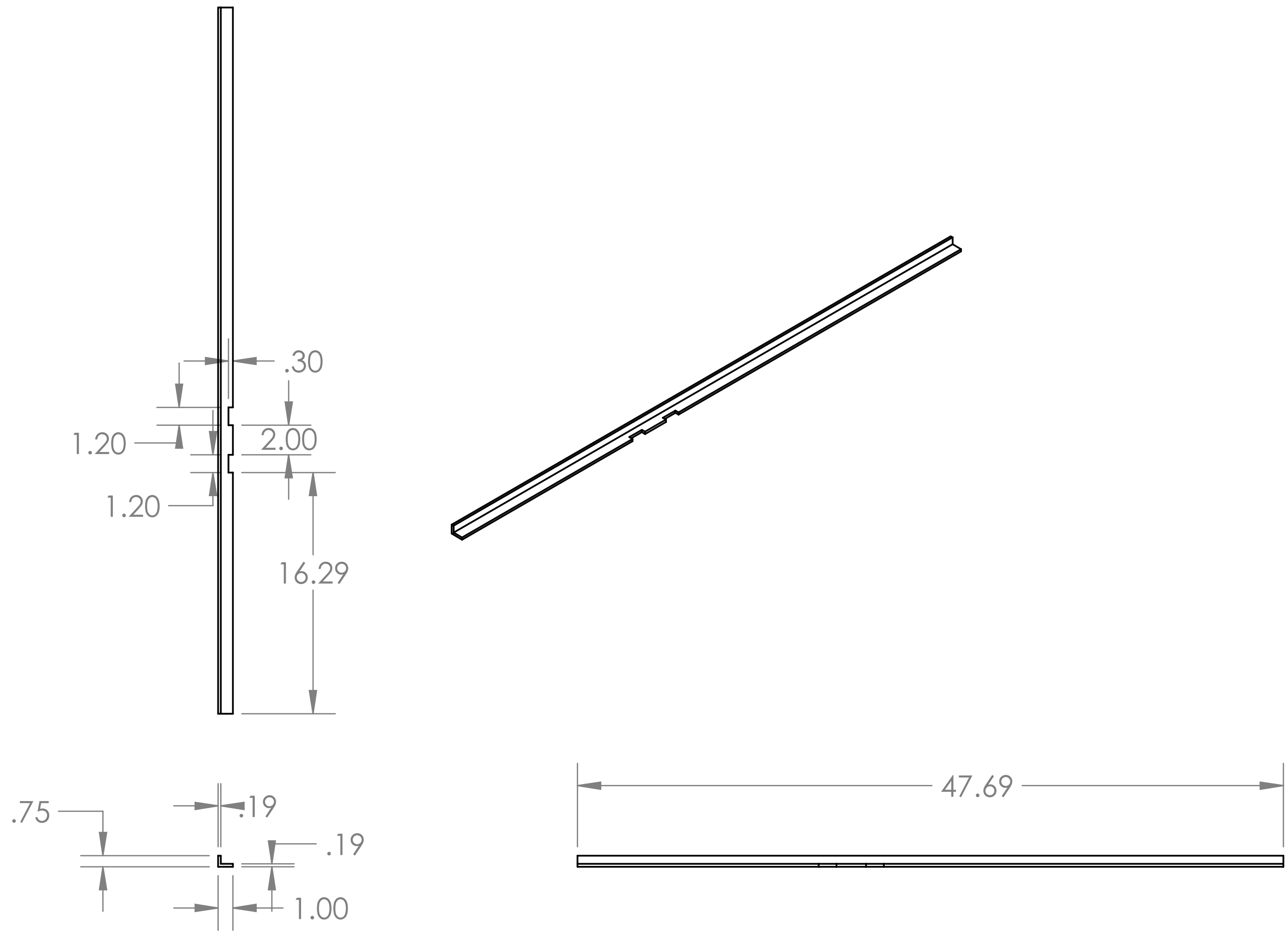
L Support with Entrance Holes

SIZE	DWG. NO.	REV
A	013	

SCALE: 1:12 WEIGHT: SHEET 1 OF 1

2 1

B B



A A

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
Fiber glass

FINISH

DO NOT SCALE DRAWING

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

COMMENTS:

TITLE:
L Bracket

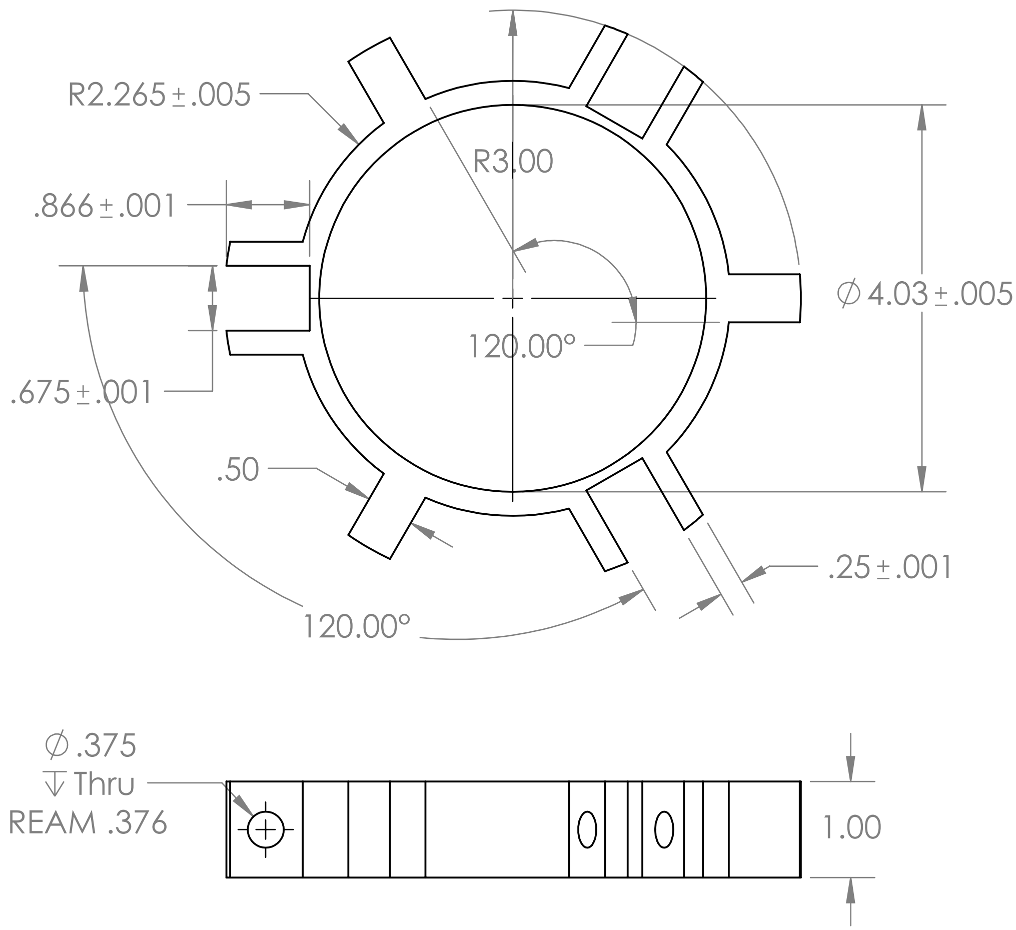
SIZE	DWG. NO.	REV
A	014	

SCALE: 1:12 SHEET 1 OF 1

PROPRIETARY AND CONFIDENTIAL

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

2 1



PROPRIETARY AND CONFIDENTIAL

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL Aluminum

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JC Kraml	5/19/18
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

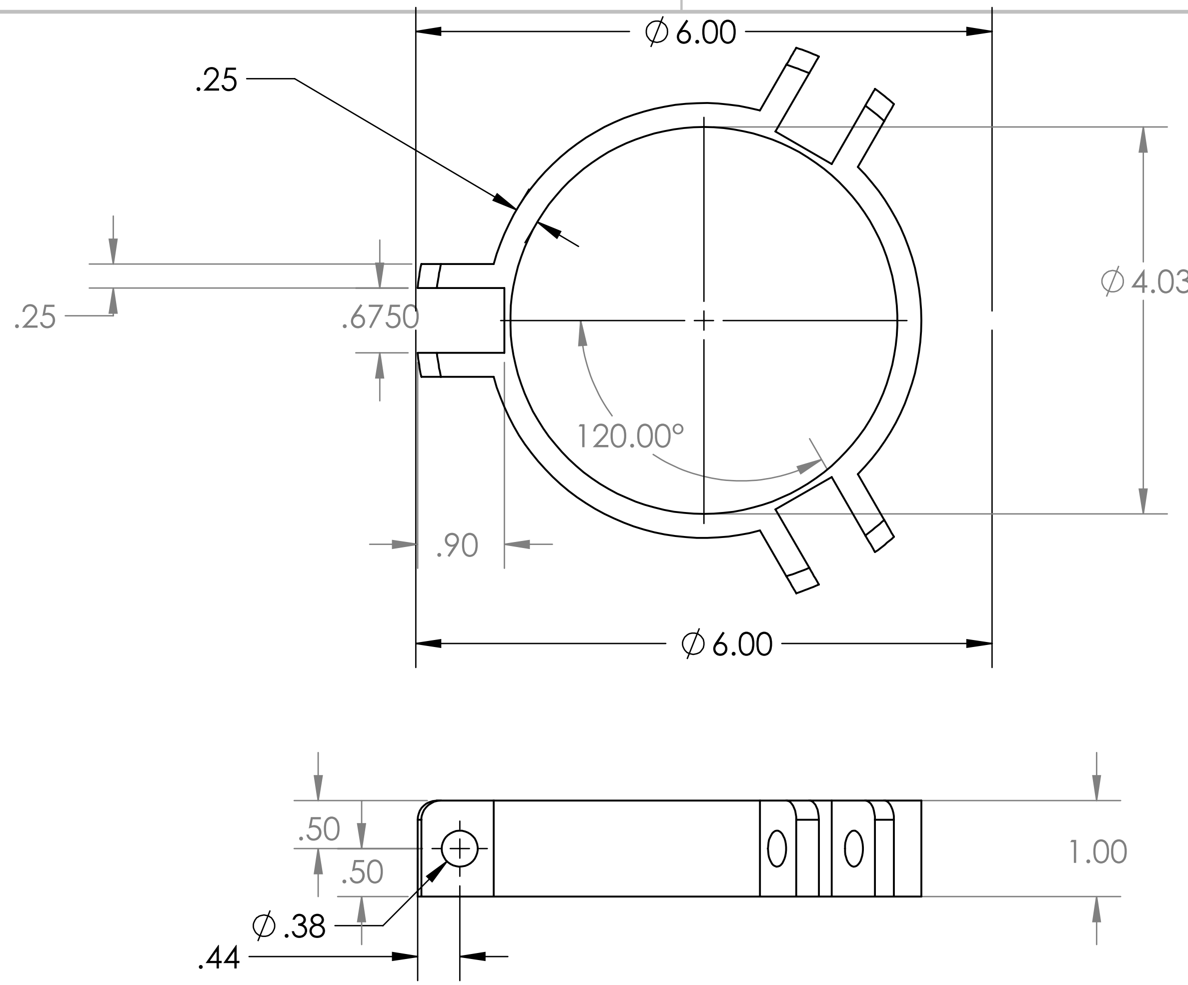
COMMENTS:

TITLE:

Upper Bracket

SIZE	DWG. NO.	REV
A	015	

SCALE: 1:2 WEIGHT: SHEET 1 OF 1



2 1

B B

A A

2 1

PROPRIETARY AND CONFIDENTIAL

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL Aluminum

FINISH

DO NOT SCALE DRAWING

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

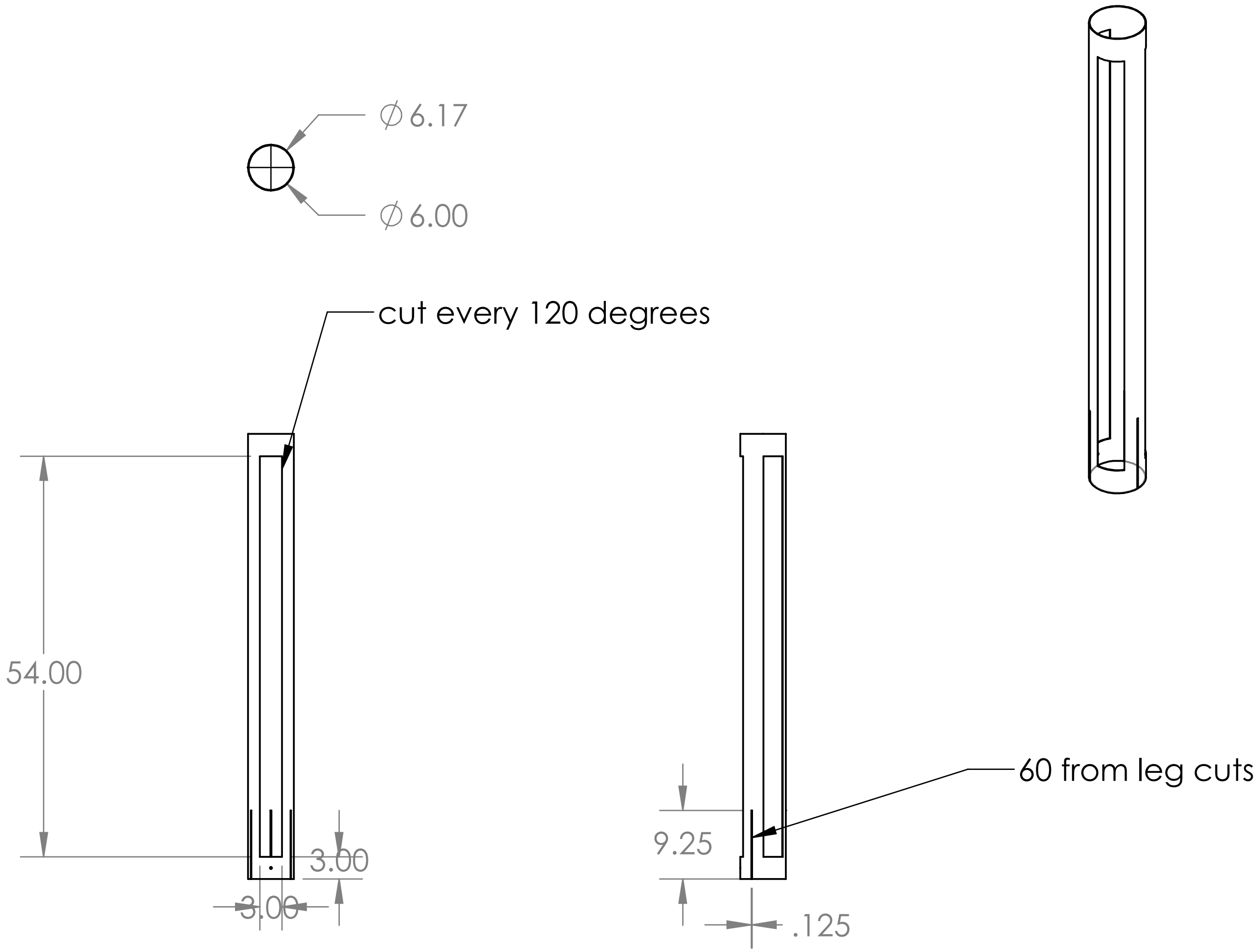
COMMENTS:

TITLE:

Lower Body Bracket

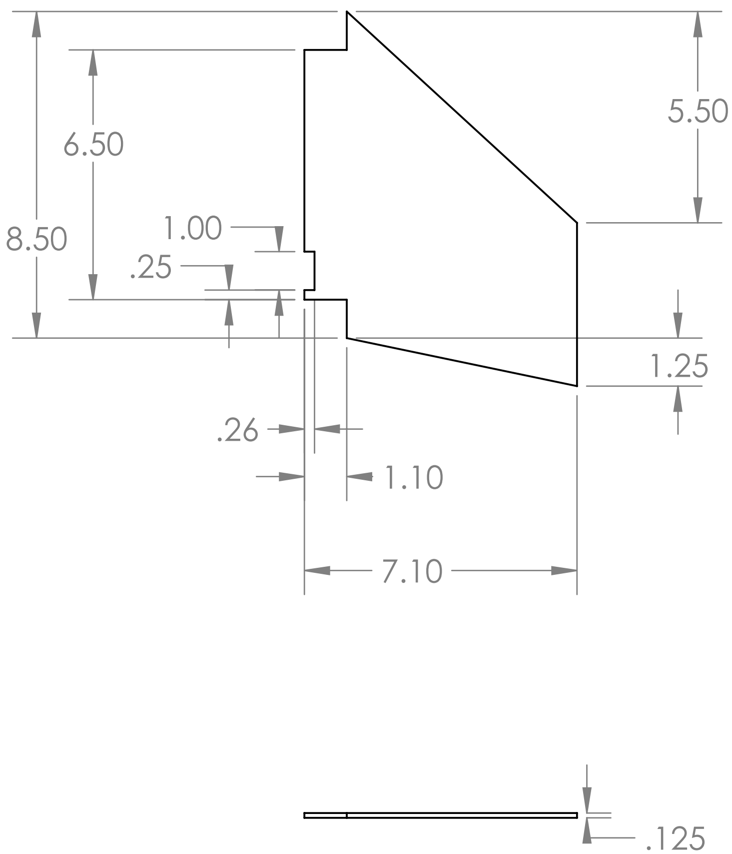
SIZE **A** DWG. NO. 016 REV

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

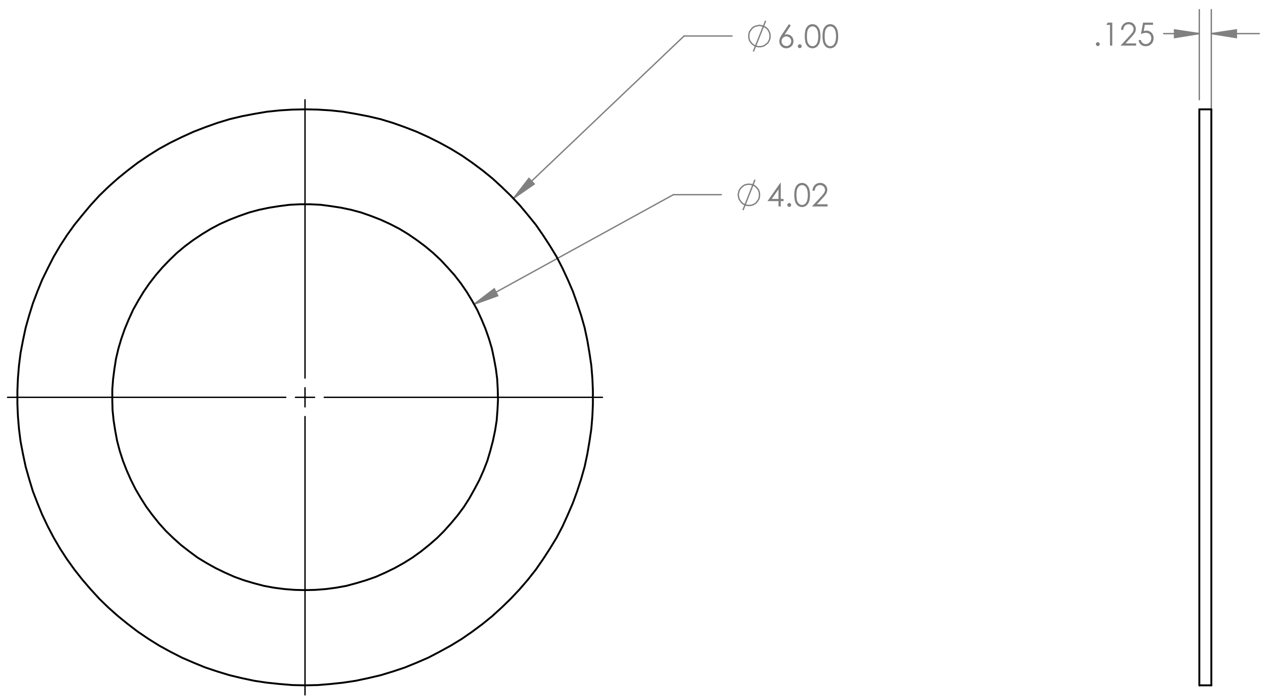


		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE:
			CHECKED			Body Tube
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL fiberglass	COMMENTS:			SIZE A · DWG. NO. 017 · REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:20 · WEIGHT: · SHEET 1 OF 1

PROPRIETARY AND CONFIDENTIAL



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE: Fin
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL Fiberglass	COMMENTS:			SIZE A / DWG. NO. 019 / REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:5 / WEIGHT: / SHEET 1 OF 1



PROPRIETARY AND CONFIDENTIAL

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

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
Fiberglass

FINISH

DO NOT SCALE DRAWING

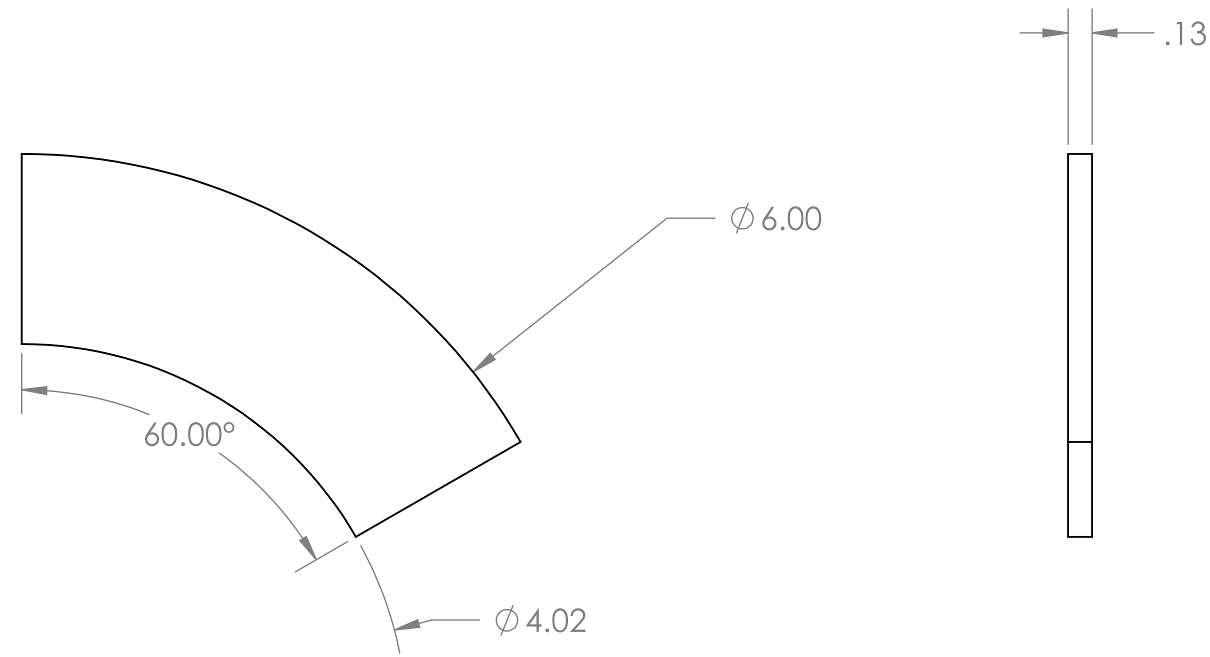
	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:
Centering Ring

SIZE	DWG. NO.	REV
A	020	

SCALE: 1:2 WEIGHT: SHEET 1 OF 1



PROPRIETARY AND CONFIDENTIAL

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

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 fiberglass

FINISH

DO NOT SCALE DRAWING

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

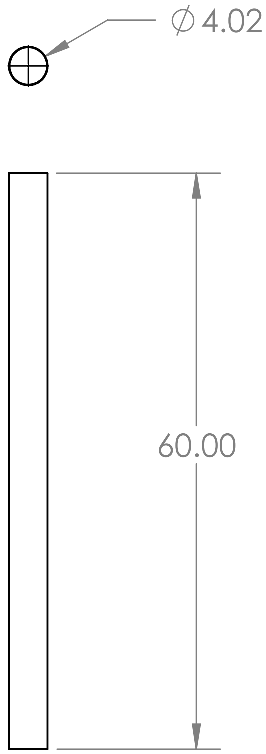
COMMENTS:

TITLE:

Centering Wedge

SIZE	DWG. NO.	REV
A	022	

SCALE: 1:1 WEIGHT: SHEET 1 OF 1



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

PROPRIETARY AND CONFIDENTIAL

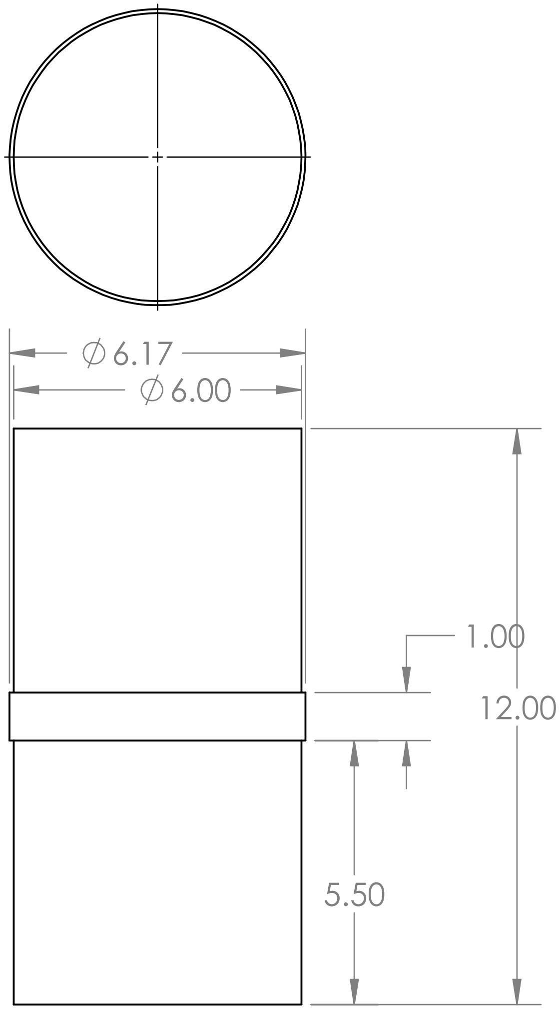
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

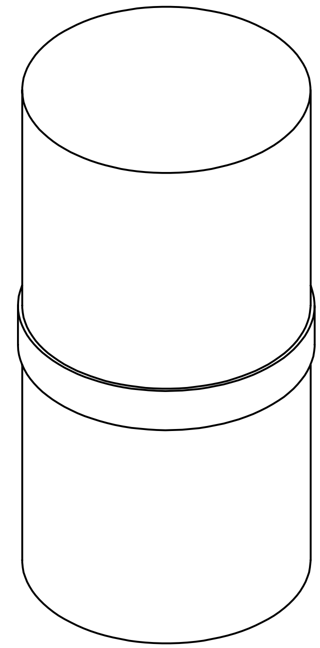
TITLE:

Motor Tube

SIZE	DWG. NO.	REV
A	023	

SCALE: 1:20 WEIGHT: SHEET 1 OF 1





NEXT ASSY	USED ON
APPLICATION	

PROPRIETARY AND CONFIDENTIAL

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: Fiberglass

FINISH

DO NOT SCALE DRAWING

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

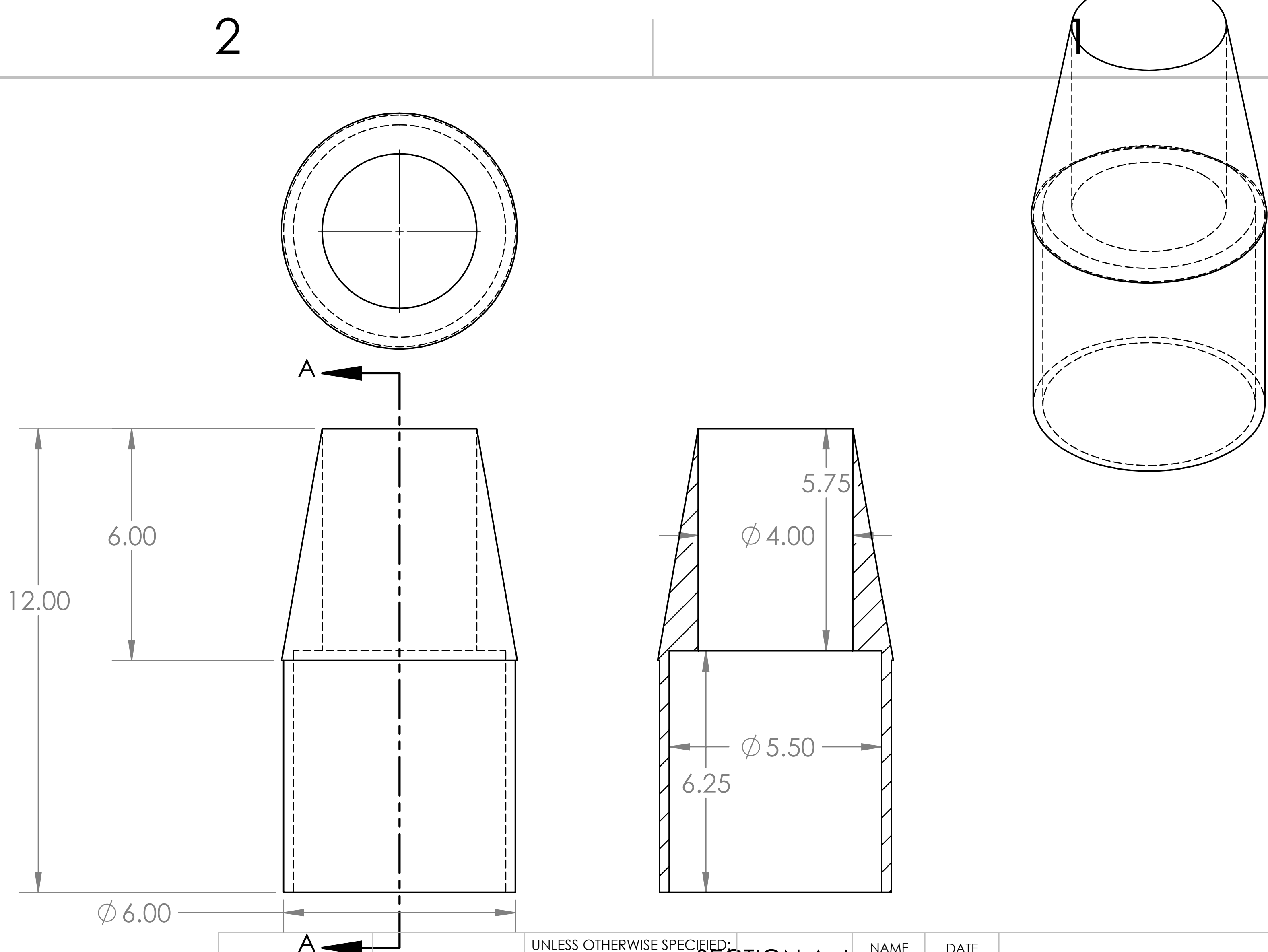
COMMENTS:

TITLE:

Ebay Cupler

SIZE	DWG. NO.	REV
A	024	

SCALE: 1:4 WEIGHT: SHEET 1 OF 1



NEXT ASSY	USED ON
APPLICATION	

PROPRIETARY AND CONFIDENTIAL

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
3D printed ABS

FINISH

DO NOT SCALE DRAWING

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

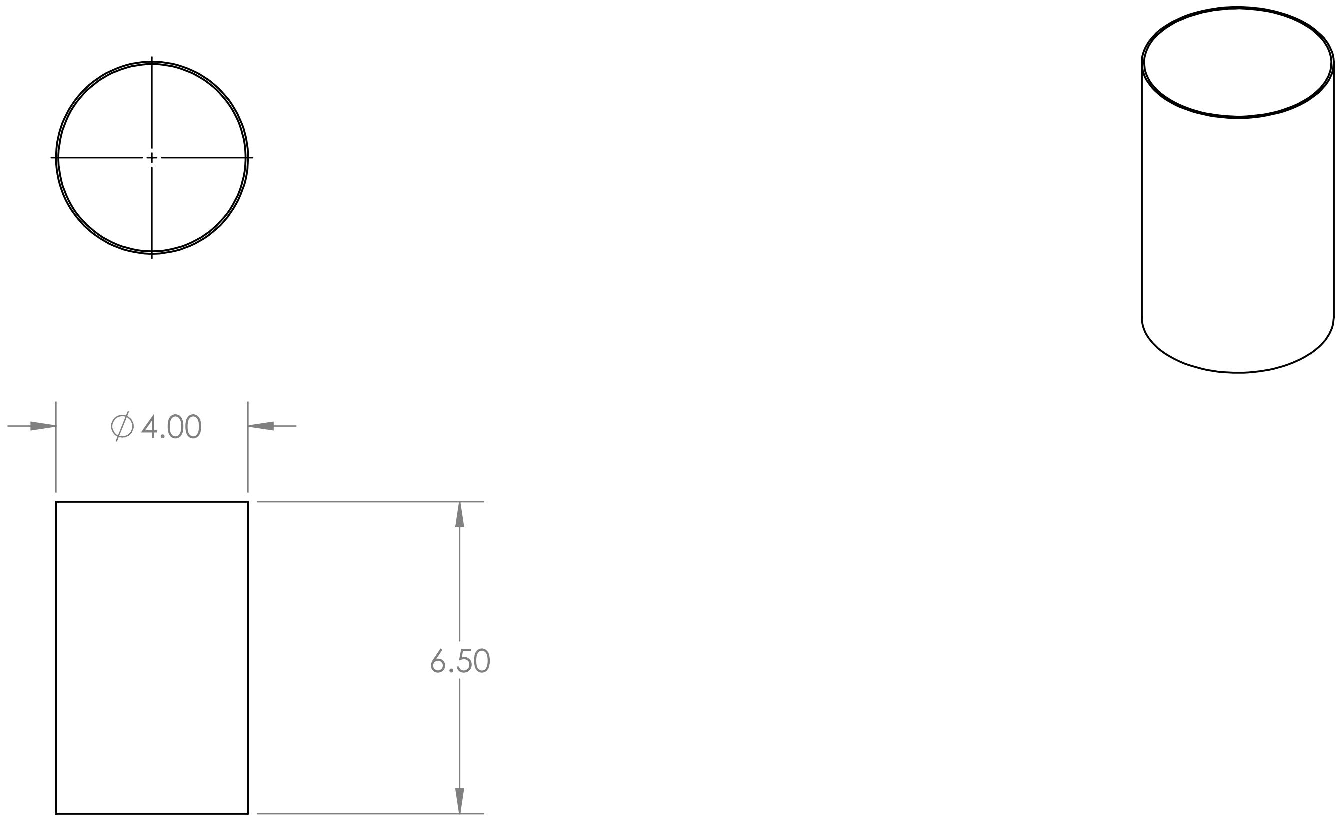
COMMENTS:

TITLE:

Transition Cupler

SIZE	DWG. NO.	REV
A	025	

SCALE: 1:4 WEIGHT: SHEET 1 OF 1



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

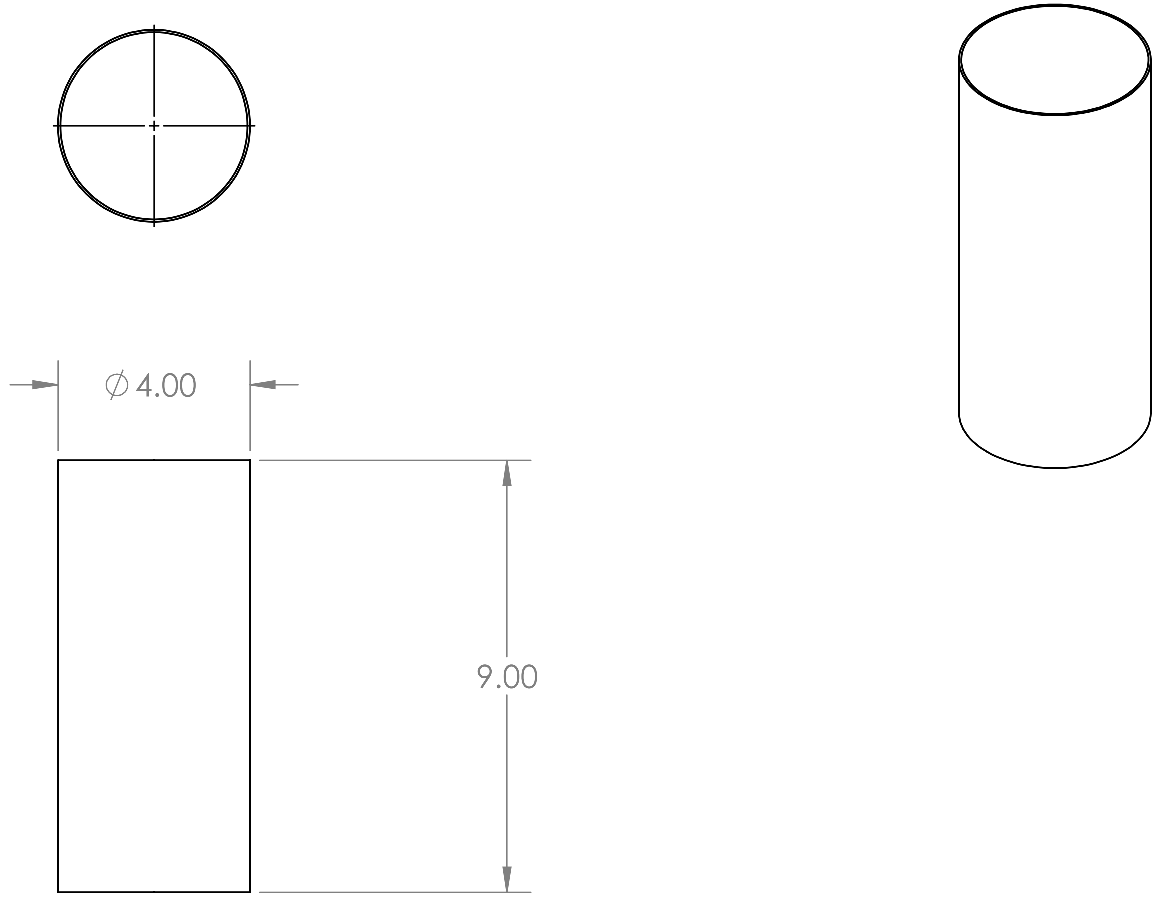
TITLE:

Transition Tubing

SIZE	DWG. NO.	REV
A	026	
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 Fiberglass	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

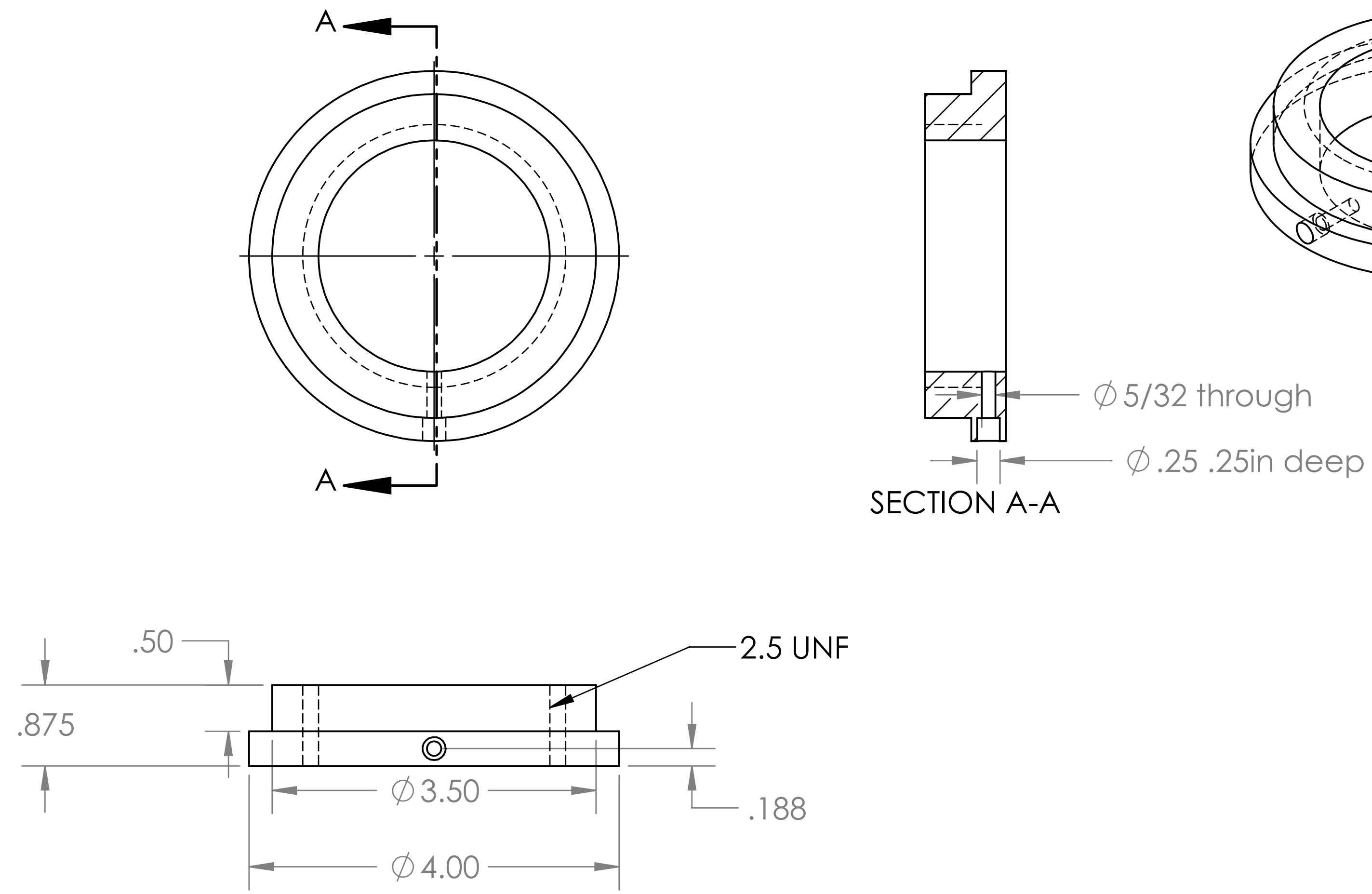
NEXT ASSY	USED ON
APPLICATION	

TITLE:

Tansition Tube

SIZE	DWG. NO.	REV
A	027	
SCALE: 1:4	WEIGHT:	SHEET 1 OF 1

2 1



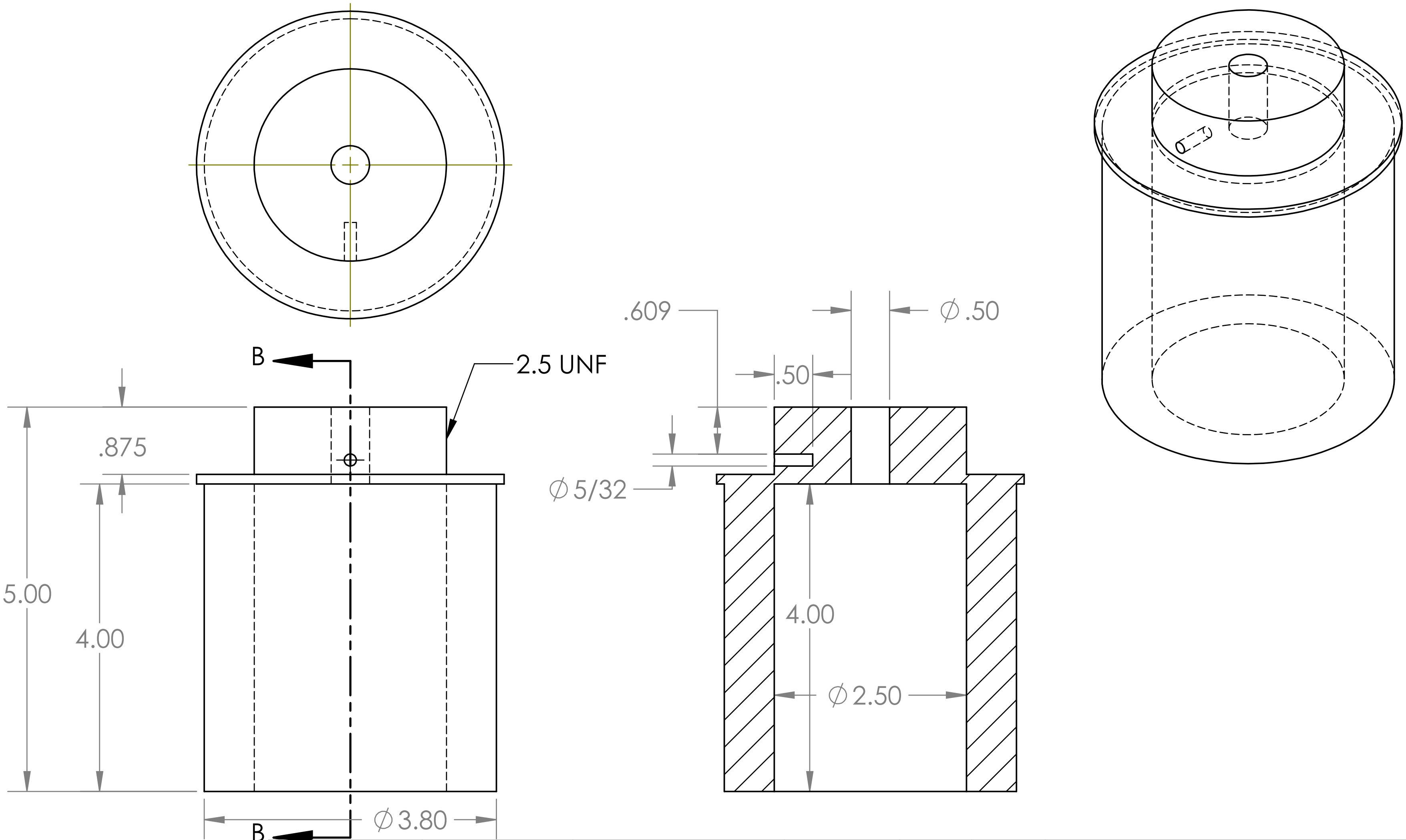
	UNLESS OTHERWISE SPECIFIED:		NAME	DATE
	DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
		CHECKED		
		ENG APPR.		
		MFG APPR.		
	INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
NEXT ASSY / USED ON	MATERIAL PVC	COMMENTS:		
APPLICATION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

TITLE:

Bottom female

SIZE A | DWG. NO. 028 | REV

SCALE: 1:2 | 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
PVC

FINISH

DO NOT SCALE DRAWING

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

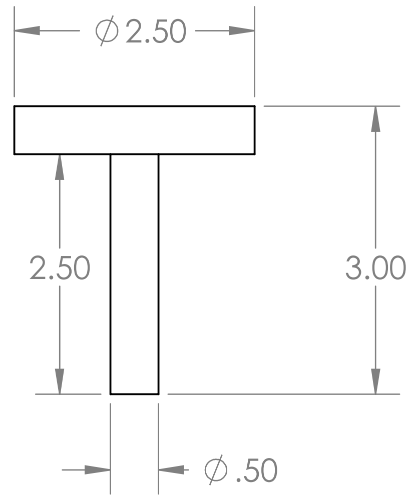
COMMENTS:

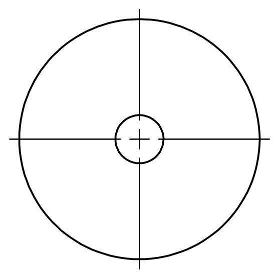
TITLE:

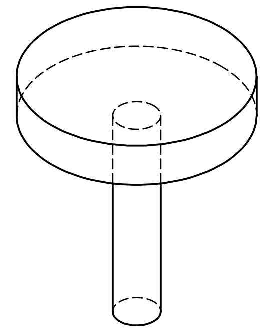
Bottom Male

SIZE	DWG. NO.	REV
A	029	

SCALE: 1:2 WEIGHT: SHEET 1 OF 1



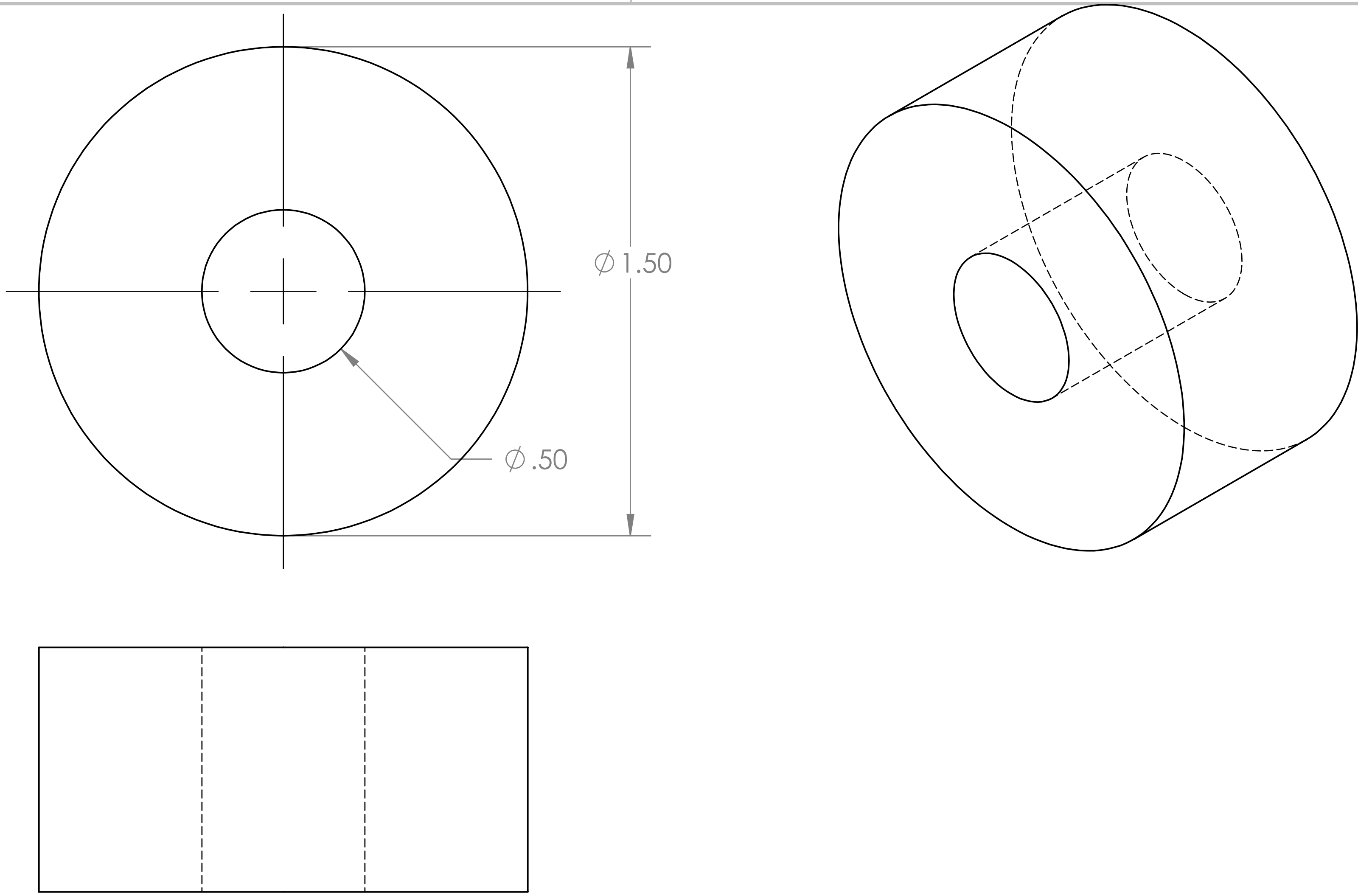




		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			
			CHECKED			TITLE:
			ENG APPR.			Spinner
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL Steel	COMMENTS:			SIZE A
NEXT ASSY	USED ON	FINISH				DWG. NO. 030
APPLICATION		DO NOT SCALE DRAWING				REV
						SCALE: 1:2
						WEIGHT:
						SHEET 1 OF 1

2 1

B B

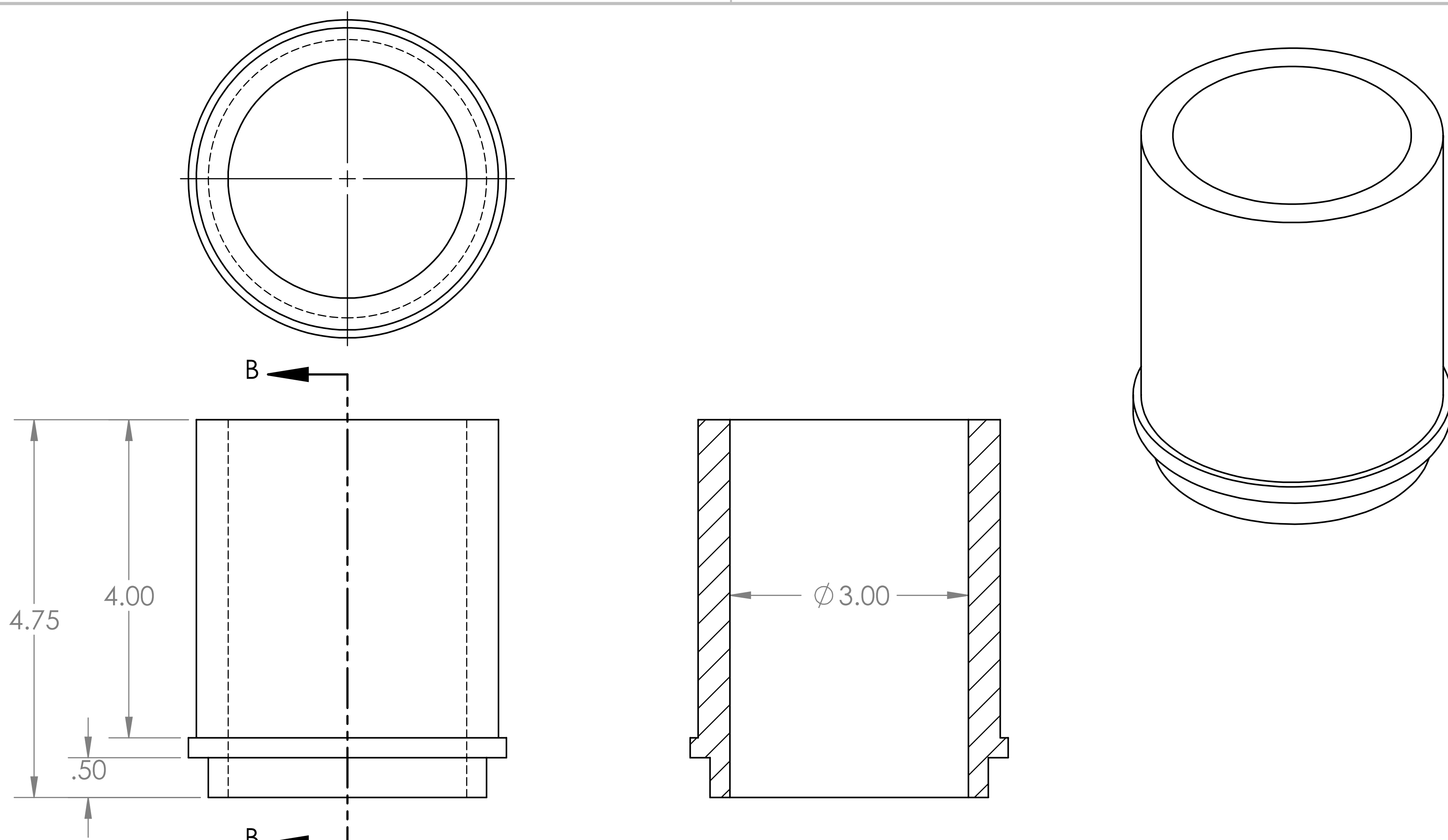


A A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE:
			CHECKED			Stopper
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL PVC	COMMENTS:			SIZE A · DWG. NO. 031 · REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 2:1 · WEIGHT: · SHEET 1 OF 1

PROPRIETARY AND CONFIDENTIAL

2 1



SECTION B-B

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL PVC

FINISH

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

COMMENTS:

TITLE:

Lid

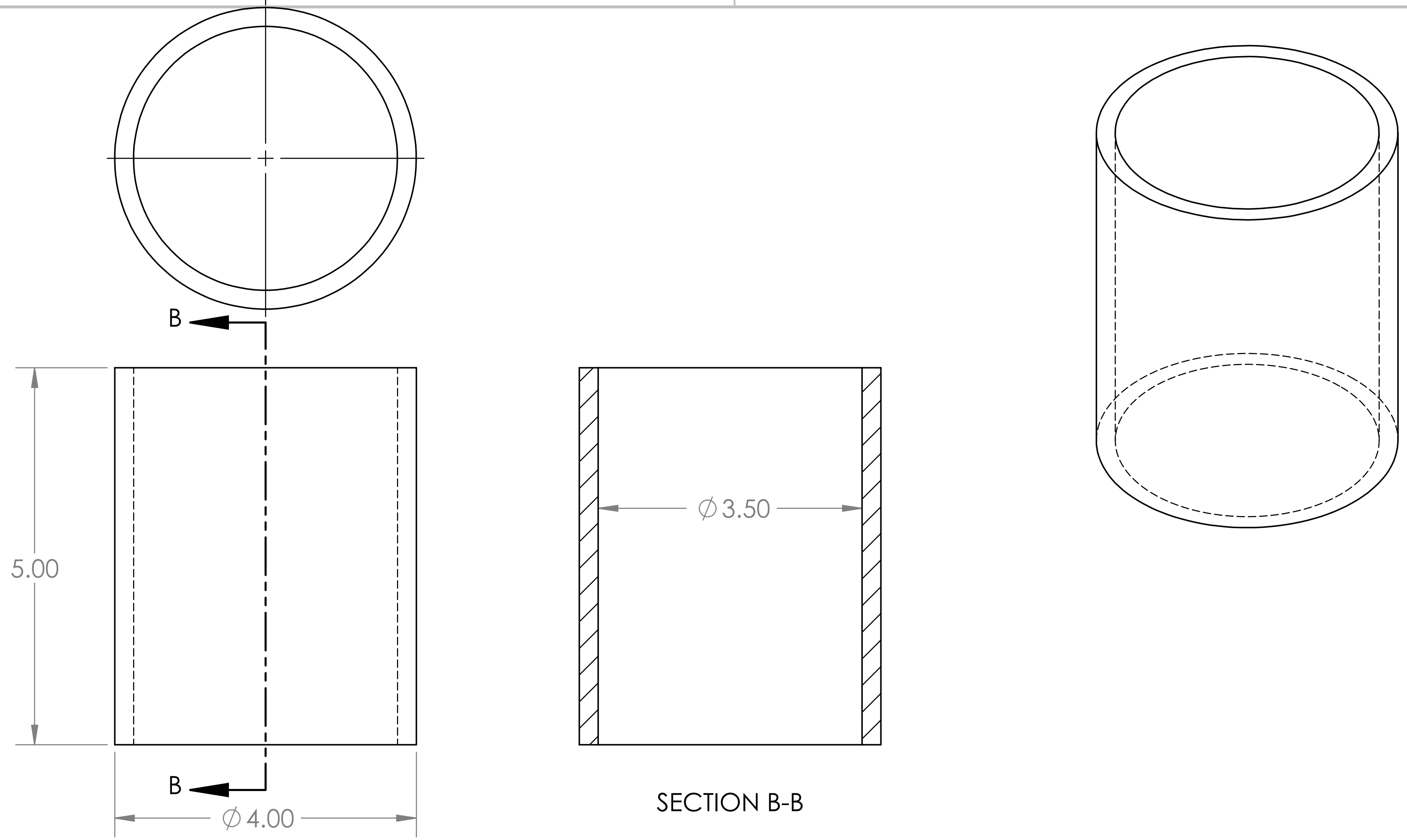
SIZE A DWG. NO. 032 REV

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

NEXT ASSY | USED ON

APPLICATION

DO NOT SCALE DRAWING



SECTION B-B

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 acrilic

FINISH

DO NOT SCALE DRAWING

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

COMMENTS:

TITLE:

Windo

SIZE A | DWG. NO. 033 | REV

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