High Altitude Balloon Launch and Recovery A

Design Group 14

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Executive Summary

MDP #14 was given the task of designing a balloon system capable of carrying scientific payloads to a given height for a given time. The Susquehanna Astronomical Society (SAS) requires a means of testing satellite radio transmission before sending the satellites into space. The project was given several requirements from Industry Advisor Alex Harvilchuck and must conform to the codes and standards put forth by the FAA for unmanned balloon regulations. From these requirements a design was researched, conceptualized and designed. MDP #14 is responsible for all parts of the balloon system above the experimental payload.

The requirements for the project were categorized in two ways: safety and performance. Safety requirements were mainly laid out by the FAA regulations regarding unmanned balloons. These require two independent forms of payload cut-down, the payload must be radar reflective and the system must land safely without being a hazard to persons on the ground. The current design employs a radio controlled electronic cut down device that will release the payload if an emergency signal is sent to the device. The device will also have a barometrically controlled cut down device to prevent the balloon from reaching an altitude outside of the device's operating range. Both these systems mechanical parts have been fully designed and fabricated. The payload will be covered with Aluminized-Mylar to create a large radar cross-section. The parachute system will ensure the device descends at a set velocity. Finally the system will be designed such that the descent rate is not a hazard to any bystanders.

The performance requirements are just as important to meet as the FAA requirements. These requirements set a desired altitude range, an operating time and require most of the system’s parts to be retrievable after each flight. A 3000g balloon was chosen for the project in order to reach the desired 92,000 ft altitude. The supplier (*Kaymont*) has been identified and the next team will be able to order the balloon when ready for launch. A radio receiver/transmitter has been purchased and will be wired up by the next team. The power generation systems will be chosen such that all components can be run for the desired 4 hour flight time. This parachute system has been designed such that it will ensure the payload does not descend fast enough to harm the components of the flight.

Currently the device is in the fabrication and testing stages of the design phase. The radio controlled cut-down system and the parachute payload are both fully designed and fabricated. The barometric cut-down system is fully designed and 75% fabricated. The mechanical portion of the radio controlled cut-down device is complete and tested. The balloon has been chosen, the parachute has been purchased and in a working state. The team continuing this design will need to complete the electrical systems design and finish the fabrication and calibration of the barometric quick release.

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1. Introduction

The goal of this project is to create a balloon system for use in testing of satellite components before they are put into use for the Susquehanna Astronomical Society. In creating this design several requirements were formulated and finalized in order to steer the design in the best direction possible. Using these requirements along with the five step engineering design process the team has been able to generate a design conforming to all the given criteria, a design that should be satisfactory of the industry sponsor.

2. Requirements

The balloon system had two major subsets of requirements to adhere to during design. The project was given a specific set of design requirements from Susquehanna Astronomical Society setting desired operating conditions for the balloon such as desired altitude achieved and project runtime. The team also identified that the design would have to comply with the FAA regulations regarding unmanned weather balloon flights. These requirements were compiled into a requirements matrix show in Appendix E. After this process, derived requirements were generated and placed on the same matrix. These requirements were the main points of focus in design and were looked at after every stage of the design phase.

Each requirement was further categorized by different taxonomies including performance, reliability, health and safety and functionality. Doing such does allows the team to identify the rationale behind each requirement, and gives a better perspective on each requirement.

2.1. Performance

Performance capabilities are the requirements that are needed to solve the direct problem at hand, in this case raising a scientific payload to a designated height and then returning it back to ground safely. The device shall:

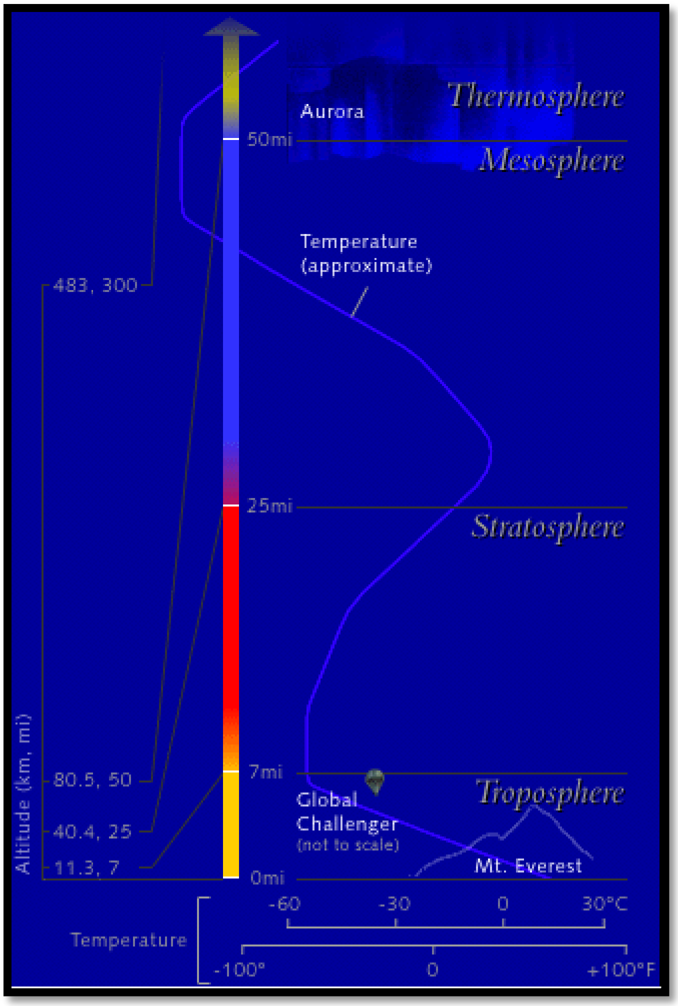


Figure 1. Properties of Layers of the Atmosphere

a) Elevate the payload to an altitude of 92,000 ft ±15,00ft. (Figure 1 shows temperature gradient throughout the atmosphere.)

b) Account for the fact that the balloon may pop inadvertently.

These requirements shall be tested and confirmed when the full system is complete and ready to launch.

2.2. Reliability

Reliability requires the design to work to maximum capability over its entire life cycle. The major reliability issue brought about in this problem is having all components of the design functional after flight termination. This will be solved by a properly designed parachute system which will limit the speed at which the payload will land on the ground. They also require the payload containers to be resilient. Boat foam has been seen to fit this description as it is relatively tough as well as being temperature resistant. The parachute will also be contained in the payload and shall be properly packed and stored until released through a door in the container. The parachute shall be hung in such a way that it will be ready to retard descent at any time during the flight without having to be released at fall.

2.3. Health and Safety

Health and safety requirement set standards for the safe use of the device. These requirements are mostly comprised of the FAA regulations for unmanned balloons. Unmanned balloons are governed by Title 14 Part 101 Subpart D of the Electronic Code of Federal Regulations [12]. Of these regulations applicable regulations are as follows:

a) 101.35 a1. No person may operate an unmanned free balloon unless it is equipped with at least two payload cut-down systems or devices that operate independently of each other;

b) 101.35 a3. The balloon envelope is equipped with a radar reflective device(s) or material that will present an echo to surface radar operating in the 200 MHz to 2700 MHz frequency range.

Regulations also state that the balloon cannot be a hazard to a person in the air or on the ground although it does not specifically state any regulations to ensure this. The balloon cannot legally or safely be launched without meeting all of the above regulations.

2.4. Functionality

Functionality describes features that do not directly affect the solution to the problem but are required for a successful design. The major additional feature required in this design is a 144 MHz radio transmitter. This radio transmitter will allow the ground station to track in balloon in air in order to properly locate the balloon's current, in air position. This tracking beacon will allow the ground station to determine whether the balloon is travelling too far from the launch site, or traveling into restricted airspace so the balloon's cut-down system can be activated. This component has been purchased and can be wired by the next team.

2.5. Selection Process

Table 1 tabulates the correlation between the mass of the payload and the diameter of the balloon needed to generate a moderate amount of life. The program utilized to propagate the relationship is shown in Appendix A. Formulation for the equations utilized is found in an external article [2].

Mass of Payload (kg)	Diameter of Balloon (m)
0	2.0
1	2.3
2	2.4
3	2.6
4	2.7
5	2.8
6	3.0
7	3.1
8	3.2
9	3.2
10	3.3

Table 1. Correlation between the Mass of Payload and the Diameter of Balloon

Figure 2 is a graphical representation of the data shown in the previous figure. The relationship is noticeably logarithmic. Note that the upper limit of the *total* payload is arbitrarily decreed to be 10 *kg* (22 *lbs*). The total payload includes that of the electronics payload placed in the responsibility of MDP #15 High Altitude Launch and Recovery B. For the intentions of the sponsors, the total payload should not exceed half this amount, 5 *kg* (11 *lbs*). Ideally, the payload weight should be minimized. However, optimization cannot be completed until finalized designs of the individual components are adjudicated.

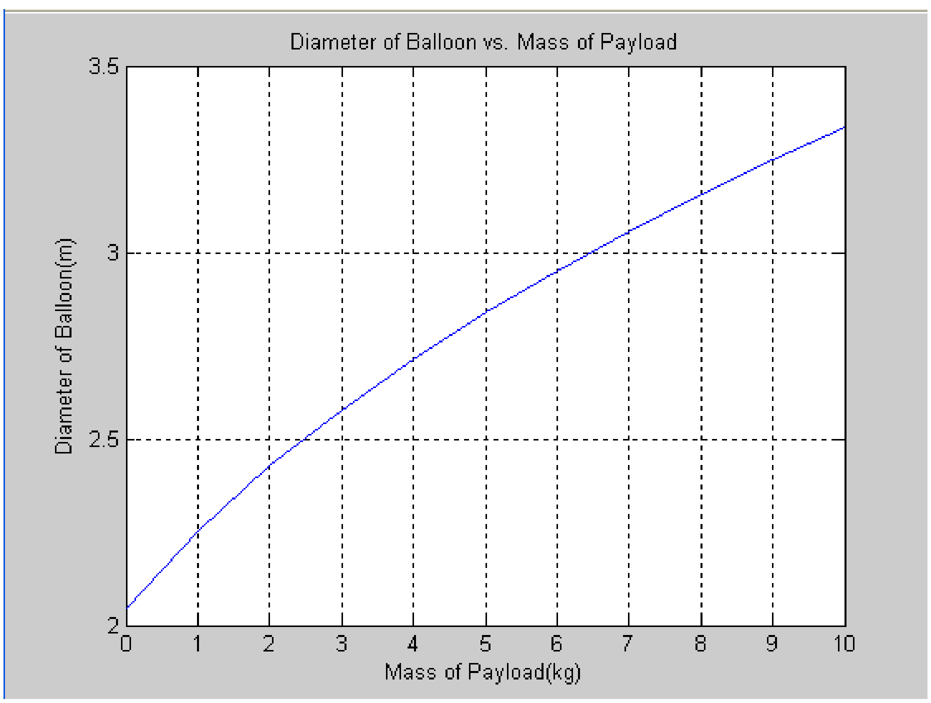


Figure 2. Graphical Representation of Balloon and Payload Correlation

The physical balloon was selected through an elimination process. The manufactured designs that fit the criteria described in 2.1. A majority of the other options are invalidated due to a high cost. Kaymont® balloons are noteworthy in that the institution is dedicated for meteorological-related research and are aligned with academic study. In addition to the models selected and shown in Table 2, Kaymont offers a selection of sounding balloons capable of high altitude flight [3]. The Kaymont models selected in comparison to other manufacturers are a representation of the bare minimum in size, cost, and capacity.

Manufacturer	Size	He Capacity	Lifting weight	Price
Kaymont	6ft.	117 ^{3}	2.8lbs.	$60.00
	7ft.	175.5 ft^3	3.76lbs.	N/A
Above & Beyond Balloons	7ft.	210 ft^3	5lbs.	$297.00
	10ft.	410 ft^3	14lbs.	$399.00
Advertising balloons company	7ft.	180 ft^3	N/A	$269.00
	8ft.	300 ft^3	N/A	$339.00

Table 2. Comparison between Various Potential Balloons

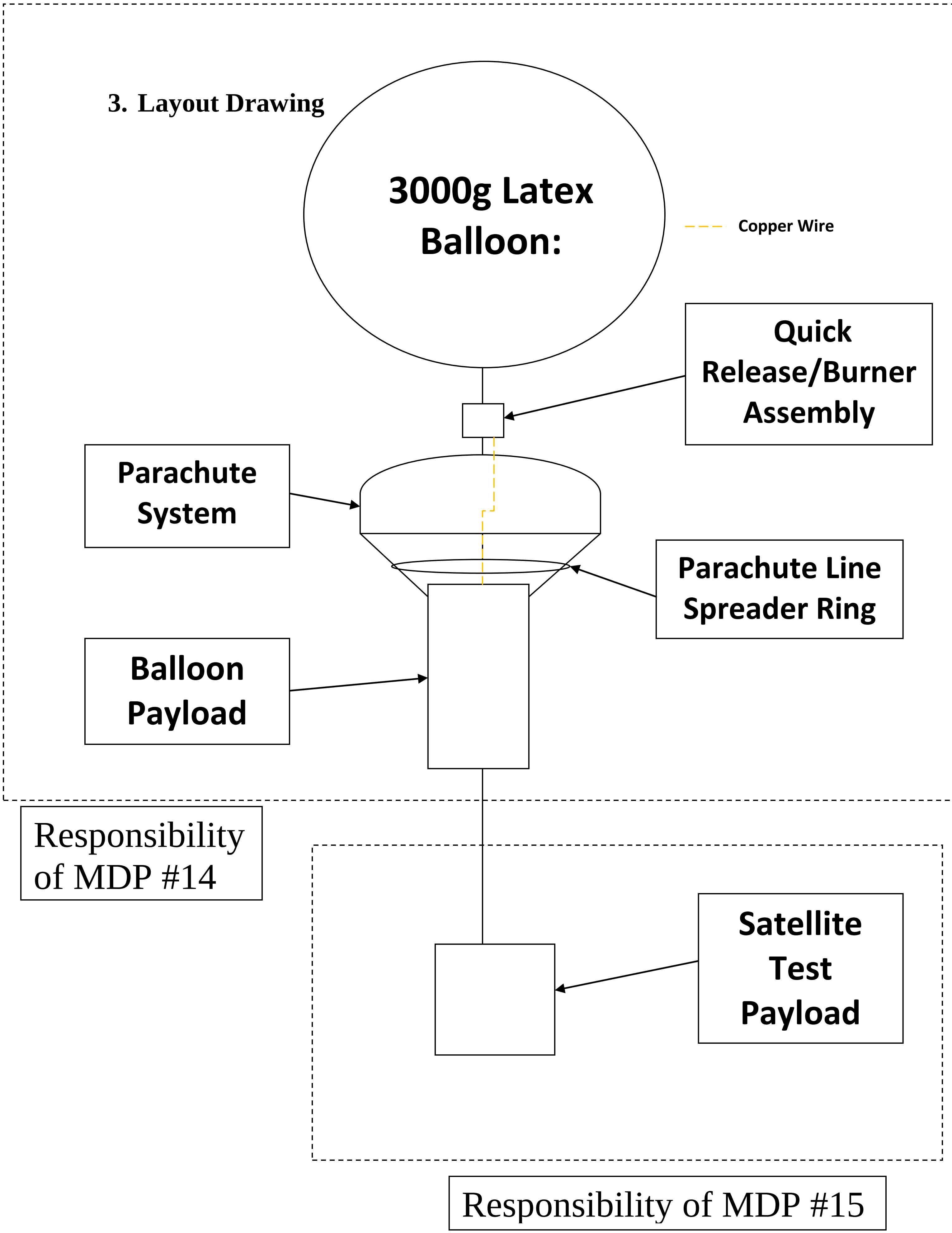
Table 3 identifies the various properties of the Kaymont cold weather line of balloons model TX3000. The TX line of latex balloons is treated with an unknown series of chemicals to permit functionality at temperatures below . Consequently, the nature of the highest caliber balloon still permits a payload of only approximately 2.3 *lbs*. However, the gross lift, identified as the recommended amount of lift to inflate the balloon to (the negative weight of the helium in the balloon) can be increased to compensate for a higher payload. Ultimately, there is a limit to the amount of additional helium that can be safely pumped into the latex container. The payload capacity can be maximized only until approximately 3.76 *lbs*. It is uncertain whether or not this value is the ultimate maximum or whether this is the recommended floor value. At the current time, the balloon choice has not been finalized. Kaymont will be contacted to inquire about for a customized high altitude latex balloon of a selected diameter.

Reference	KCI TX3000
Average Weight (gr)	3000
Neck Diameter (cm)	5
Neck Length (cm)	18
Flaccid Body Length more(cm)	357
Barely Inflated Diameter more(cm)	227
Payload (gr)	1050
Recommended Free Lift (gr)	1670
Nozzle Lift (gr)	2720
Gross Lift (gr)	5720
Diameter at Release (cm)	212
Volume at Release (m^3)	4.97
Rate of Ascent (m.min)	320
Diameter at Burst (cm)	1331
Bursting Altitude (km)	38.3
Bursting Pressure (hPa)	3.5

Table 3. Properties of Kaymont Model TX3000

In the previous table, average weight represents the weight of the un-inflated balloon. The nozzle lift is the Gross Lift minus the average weight of the balloon, or the negative weight of the filled balloon and the recommended free lift is the difference between the Nozzle Lift and the Payload weight.

3. Layout Drawing



4. Electronics Systems

4.1. Electronic Cut-Down Device

In order to ensure the balloon system does not pass into restricted air space the device must have a means of flight termination controlled by the balloon ground team. To achieve this, an electronic system was designed to receive a radio abort signal from the ground station, which once received, will cut the nylon rope above all system components except the balloon. This mechanism utilizes nichrome wire which heats up when current is passed through it. Once the system is cut the parachute system will engage ensuring the device's safe descent. This system is an emergency only device and is designed in such a way that the ground team will not lose any critical system parts other than the balloon when activated.

The emergency cut down system is a relatively simple series of electronics and mechanical parts. When flight termination is desired the ground team will send a signal to the radio receiver stored in the parachute payload box. Once this signal is processed the receiver will close a relay passing voltage and current through a wire from stored batteries and leads the power to the cut down device. At this point the wire is crimped into the yellow part of the loop connectors shown in the Figure 3. Nichrome wire will be crimped into the other loop connector and looped in a spiral fashion through the ceramic sleeve in the middle of the aluminum plate. The nylon balloon cable will be passed in the middle of the nichrome spiral.

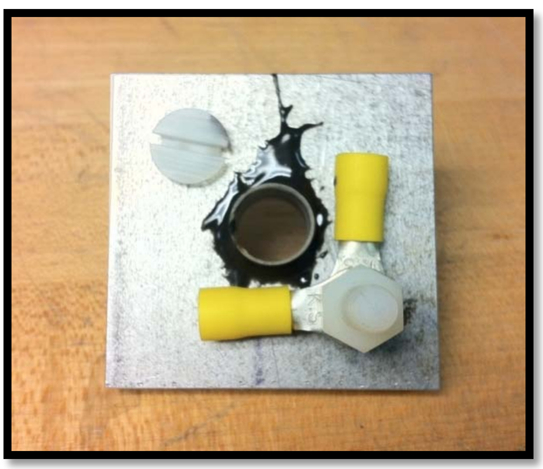


Figure 3. Completed Mechanical Design

If the system is not engaged the balloon system will proceed until the balloon pops at which point the barometric release will engage releasing the nylon cord through the burner assembly and commencing descent. If the ground team does engage this radio controlled device the nichrome will heat up and burn though the nylon cord releasing the balloon and dropping the payload and all its components.

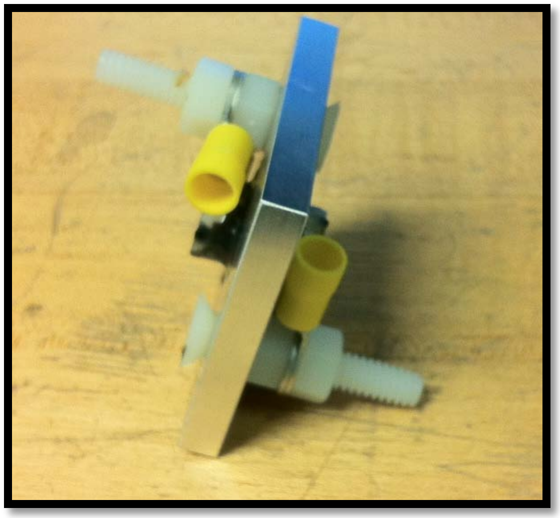


Figure 4. Burner Assembly Side View

Currently Industry Advisor Alex Harvilchuck has chosen a radio receiver to be used in this cut-down system. Next semester the team can wire and assemble the device using insulated copper wire attached the nichrome wire. Once assembled different battery configurations can be tested for best functionality and weight.

5. Barometric Quick Release System

5.1. Purpose

The quick release system is a barometrically activated apparatus that serves as one of the two cut-down devices onboard the high altitude balloon. Ultimately, the system serves two principle purposes.

1. Preventing the payloads from being entangled by shreds of the burst balloon and transitively, ensuring proper deployment of the parachute release.
2. Counting among the number of cut-downs required by the FAA.

Original conception of the quick release is accredited to Edge of Space Sciences [7]. The decision to include a similar apparatus was attributed by the essential success of past Edge of Space Science balloon launches. Fundamentally, the scope and intent of these past trials are nearly identical to that of High Altitude Balloon Launch and Recovery and as a result, the quick release mechanism was adopted as a requirement by the sponsors.

5.2. Mechanism and Design

The barometric quick release mechanism is dependent on an aneroid cell, a capsule of beryllium and copper alloy sensitive to extreme variations in atmospheric pressure. The inside of the apparatus is devoid of air, i.e. a vacuum. This device is prevented from collapsing as a result of external pressure by a high coefficient spring. Typical utilization of the capsule is found in barographs and weathering instrumentation. Figure 5 depicts a series of standard aneroid capsules in a barograph assembly.

Figure 5. Typical Barograph Aneroid Cell Assembly

The aneroid capsule employed by the High Altitude Balloon Launch and Recovery is salvaged from the Radiosonde Weather Data Transmitter as advised by Mike Manes of Edge of Space Science [8]. Herbach and Rademan Inc. ®, the company that sells the scrapped weathering instruments, offers the complete instrumentation set consisting of electronics Package, temperature sensor, barometric pressure sensor, humidity sensor, and water activated battery [9] .Two of these devices were purchased. The assembled package is shown in Figure 6.

Figure 6. Radiosonde Weather Data Transmitter

The barometric pressure sensor denoted by H&R Inc. ® is identified as the aneroid cell. For the intentions of the High Altitude Balloon Launch and Recovery, the remainder of the components is not necessary – analogous devices are designed to compensate.

The aneroid cell is nested within a salvaged weather transmitter shown in Figure 7. The essential purpose of the compartment is fundamentally identical to that of the quick release mechanism. The difference lies in that the Radiosonde Weather Data

Transmitter incorporates barometric control into an electronic cut-down device whereas the quick release is entirely mechanical. Electronic cut-down will be apportioned into an independent system discussed in 4.1.

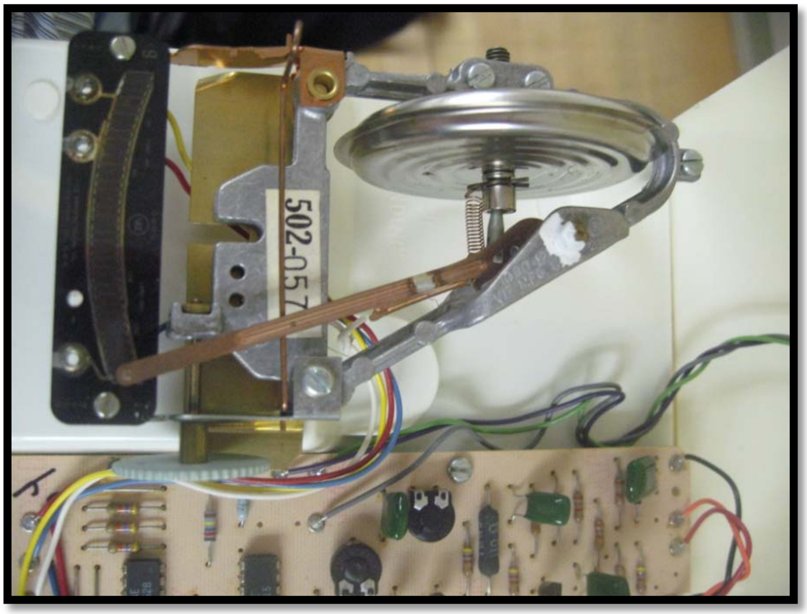


Figure 7. Aneroid Capsule Compartment

Figure 8 shows the salvaged aneroid cell that was detached from the aforementioned compartment. The overall shape and size is similar and possibly identical that of the aneroid apparatus shown in Figure 5. Note the threaded central recess shaft.

Figure 8. Salvaged Aneroid Capsule

Figure 9 shows the jaw and housing assembly of Mike Manes's original design, the conceptual sketches of which are shown in Appendix B. The rotational left jaw is responsible for the actual payload release. The jaws are kept at a passive open position by an overextended helical spring. The spring equilibrium force is hindered by tension transferred by lift force generated by the balloon.

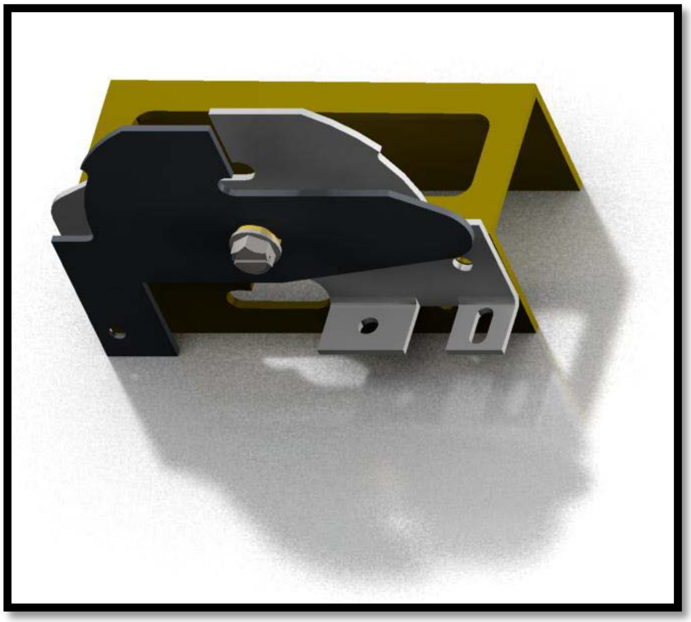


Figure 9. EOSS Jaw Assembly with Aneroid Housing

Ideally this would be sufficient for the purposes of a quick release system. However, the upper levels of the troposphere are known for high velocity wind currents [10]. Consequently, a failsafe locking mechanism was included in the Edge of Space Science and the High Attitude Balloon Launch and Recovery design [11]. This so-called "arming mechanism" ensures that the balloon travels through at least the limits of the troposphere before the quick release mechanism is deployed. The EOSS design features a rotational locking arm and a single rotational jaw. Modifications are done on the EOSS template to incorporate a translational locking arm and consequently two rotational jaws. The primary reasoning being that the EOSS quick release was designed for a lower payload loading with a maximum of 10 *lbs*. The expected requirement loading is at a maximum of 15 *lbs*. Figure 10 shows the final modified design.

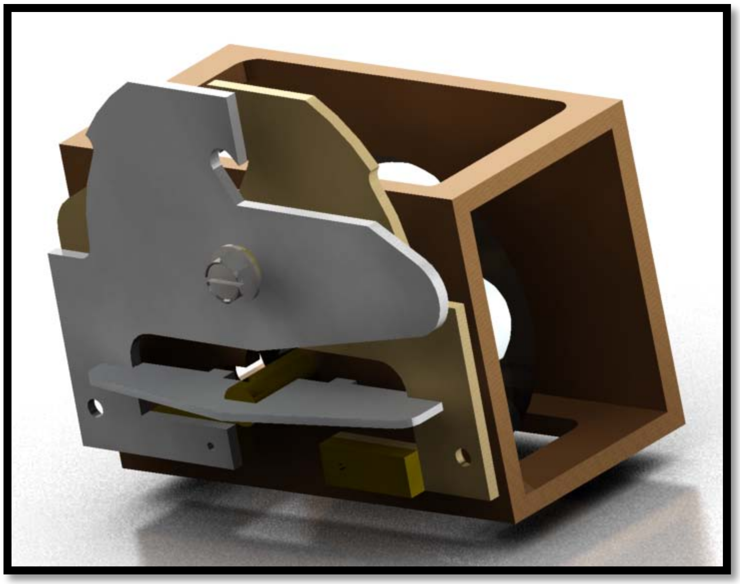


Figure 10. Modified Quick Release System

Aside from the aforementioned differences, the new aneroid housing and jaw assembly is composed of a thicker material that of 0.125 *in.* aluminum as opposed to the original 0.0625 *in*.

In the inertial state, the jaws are kept from opening by two locks, the physical locking arm wedged between the two jaws and lifting tension from the balloon. Figure 11 shows a schematic of the quick release in its inertia state. The tension spring is constantly pulling the jaws apart. This releasing moment is counterbalanced by the locking arm and lifting force.

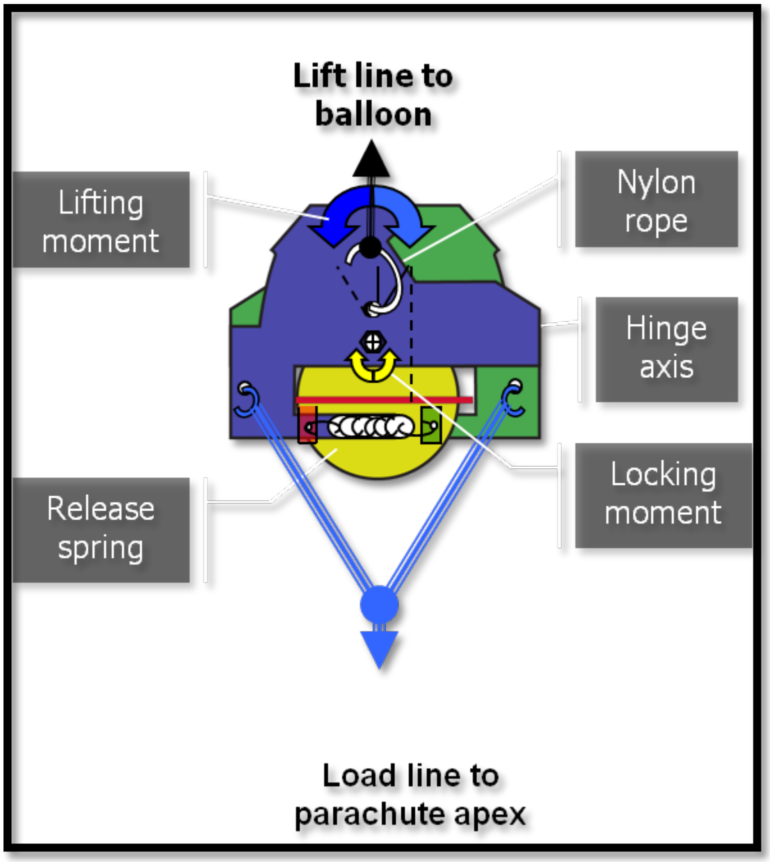


Figure 11. Schematic of Quick Release Mechanism in Inertia State

Release is done in three steps.

1. Once the aneroid cell expands past 4 *mm* bidirectional, i.e. laterally along its rotational axis in both directions, or 2 *mm* unidirectional, this translational force is directed on the barometric pin and consequently the locking arm is pushed out of the way (out of the page in the previous schematic). The quick release is now in unlocked position. The expected ambient pressure that this is achieved is at 0.5 *psi* at an altitude of 70,000 *ft*.
2. The payload system is still allowed to ascend. However, once the lifting tension is released, once the balloon pops, the tension spring s free to compress, forcing the jaws to open. The expected altitude that this occurs is at 90,000 *ft*.
3. The sudden loss of lifting moment prompts the lift line of nylon rope to sag through the jaws, removing the unnecessary scraps of balloon and therefore preventing interference with the remainder of the retrieval system. Figure 12 shows a schematic of the quick release in its released state.

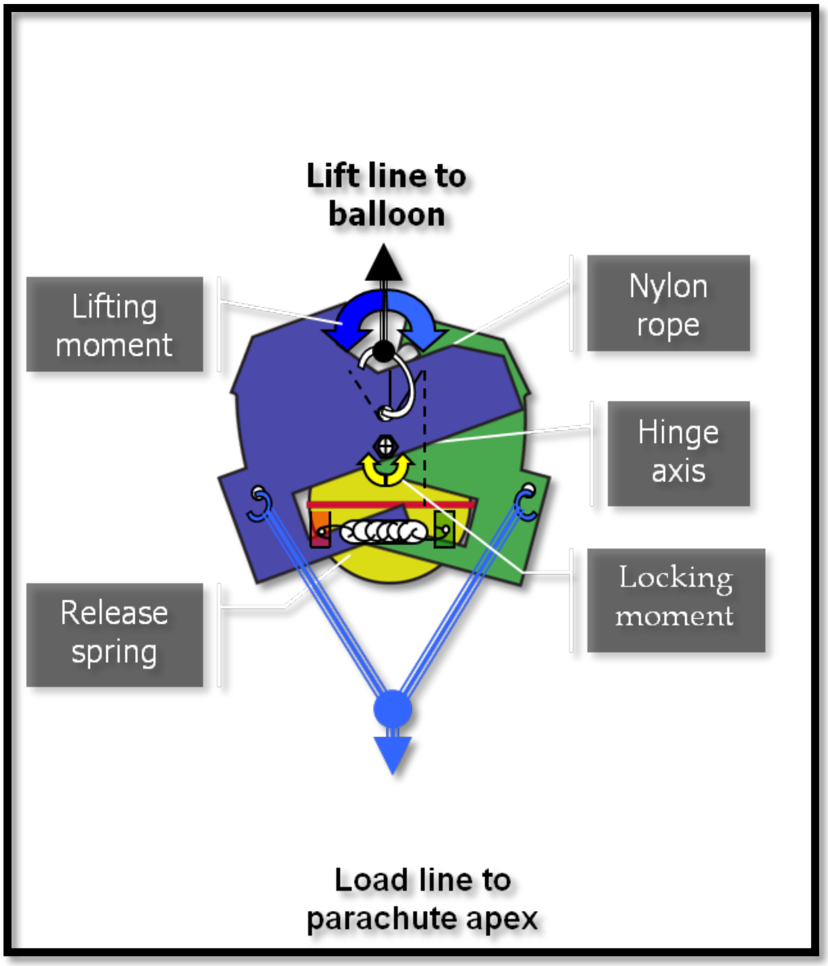


Figure 12. Schematic of Quick Release in Released State

5.3. Assembly

Full assembly of the barometric quick release is less obvious than other components. The following steps are taken in order:

1. Arrange the right and left jaws such that the central hole is aligned. The counter-sinks must be facing in the same direction. For all purposes, the sides with counter-sinks will be referred as the back. The right jaw should be behind the left jaw. Align a no. 8 nylon washer between the two jaws. The washer will act to mitigate frictional forces between the aluminum jaws.
2. Align and insert an 18-8 Stainless Steel Hex Washer Head Slotted Machine Screw through the central holes of the jaws from the front. Place a no. 8 split washer between the screw and the left jaw. Refer to Figure 13.
3. Place a no. 8 thin flat washer against the back of the right jaw and a no. 8 nylon washer behind it.

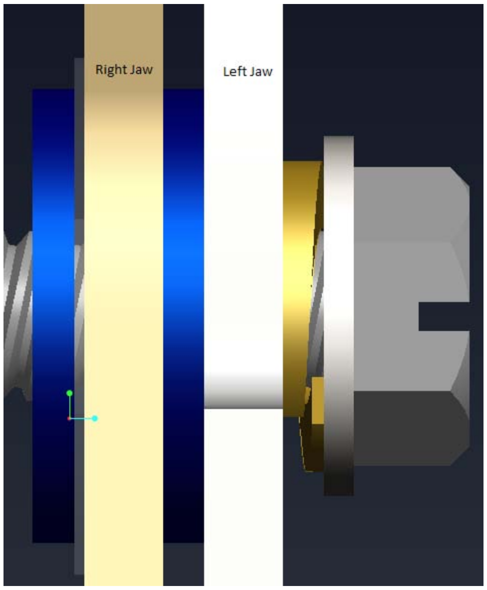


Figure 13. Jaw Assembly

4. The jaw apparatus should now be shafted through the matching hole in the aneroid housing with a no. 8 wavy washer. The ends should be capped with a no. 8 thin flat washer and a no. 8 nylon washer in order. Cap the screw with an Aluminum Nylon-Insert Hex Locknut. See Figure 14.
5. Attach a spring plate on the front of the left jaw and a spring plate behind the right jaw. Apply adhesive on the contact surfaces. Take care not to obstruct the bores.
6. Lightly thread the aneroid cell through the central matching 10-32 hole. The extent of the threading will be calibrated in a later step.
7. Slide the locking arm into the barometric pin such that angled side facing in the same direction as the flat surface of the pin. Attached a 2-56 Black Nylon Pan Head Slotted Machine Screw through the matching holes and cap it with a Zinc-Plated Steel Machine Screw Hex Nut.

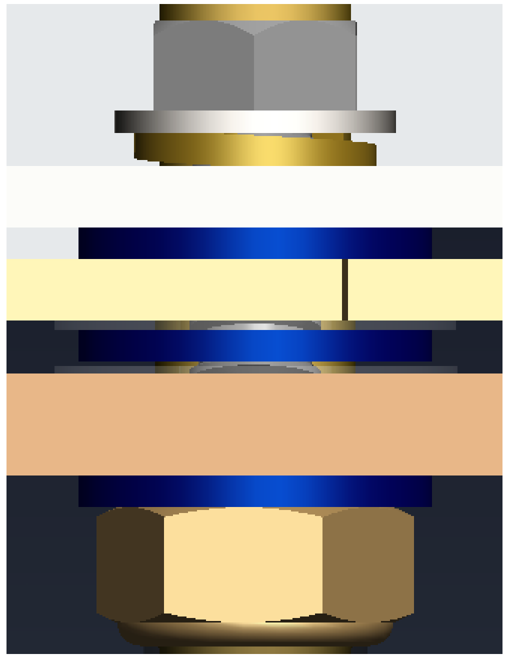


Figure 14. Jaw Attachment through Aneroid Housing

8. Applying a moderate amount of pressure, snap the barometric pin and the aneroid cell together.
9. Ideally, the aneroid cell must be calibrated such that it expands the required 2 *mm* to unlock the locking arm. However, in the event that a pressure chamber is unavailable, this step, unfortunately, will have to be skipped.
10. Apply adhesive to the connection point between the barometric pin and the aneroid cell.

The calibration step must be done before application of the adhesive. At the conclusion of the quick release assembly, the follow steps are taken to attach to the other key components:

1. The quick release device while in locked position, the default position on ground level) needs to be ensured that the barometric pin and aneroid cell must be intact.
2. The balloon nylon wire must be hooked through the .094 *in* radius hooks on the right and left jaws.
3. The bottom payload is attached to the two 0.115 *in* diameter countersinks on the two jaws.

6. Parachute Deployment System

When the payload descends, it cannot exceed a velocity deemed to be unsafe to not only the payload, but to anything within the vicinity of the landing site. The payload must not fall faster than 10 *ft/s* when it approaches the ground. In addition, it is essential that the parachute is guaranteed to deploy and open.

6.1. Deployment Design

The parachute deployment system is separated into three main components: the cord-spreading ring, the apex ring, and the parachute itself.

What dictates an accurate prediction of a parachute's descent velocity is its diameter. In order to determine what diameter our parachute should have, we utilized Equation 1.

$$D = \sqrt{\frac{8mg}{\pi \rho C_D v^2}} \tag{1}$$

Assumptions of the payload weight and parachute's coefficient of drag had to be made; thus, using a weight of 15 *lbs* and a drag coefficient of 1.5 - the drag coefficient of a dome-shaped parachute without an apex - the minimum diameter for a parachute to fall no faster than 10 *ft/s* has to be approximately 11 *ft*.

A function of velocity, derived from Equation 1, was also implemented in a custom MATLAB program written to determine the descent velocity up to 140,000 ft. The density of air decreases as the balloon ascends. The lower density air provides less of a drag force than air closer to the ground. Using NASA's equations, the air density up until 140,000 ft was estimated and a graph of the predicted descent velocity versus height was produced, as seen in Figure 15[12].

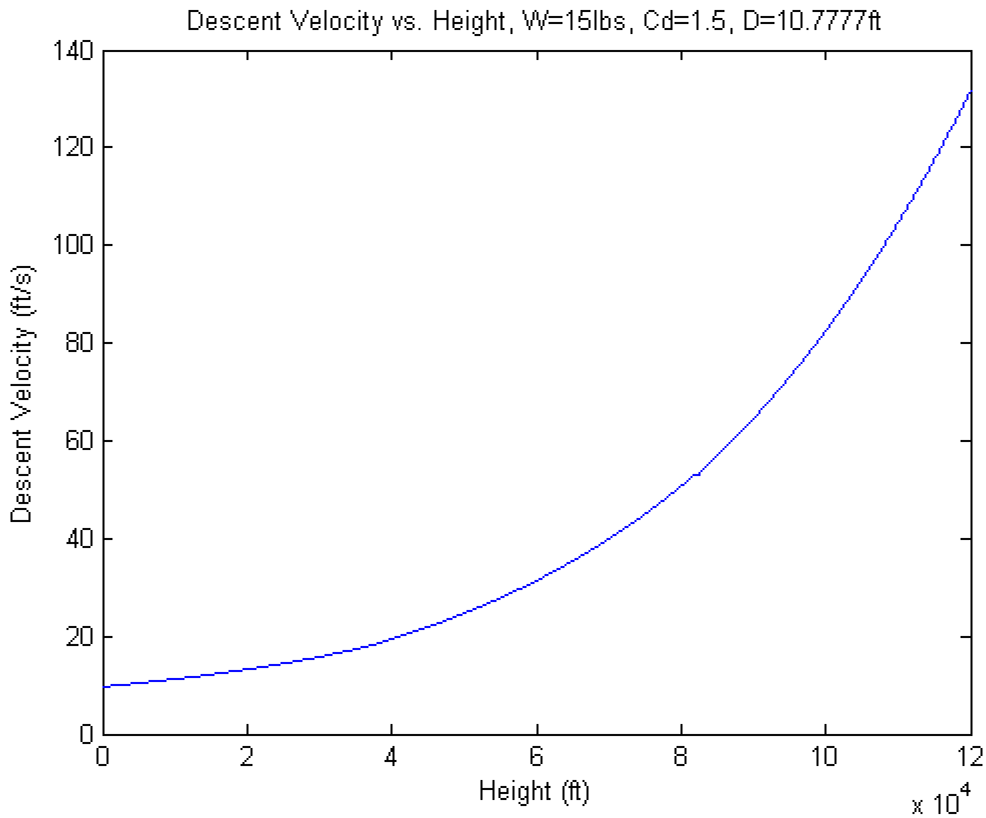


Figure 15. Correlation between Descent Velocity and Altitude

The type of parachute that has the highest drag coefficient of 1.5 is the dome parachute. Yet, most commercially available dome parachutes are either 25 ft in diameter or are made for human use and thus are expensive. After browsing various parachute supply websites, cargo parachutes measuring 15 *ft* in diameter were discovered at the Omaha Army Surplus store. It was one of the few that had a relatively small diameter, was cheaper to purchase, and was still usable [13].

In addition, the parachute needs to inflate fully without fail during the descent. The deployment system will utilize a cord-spreading ring and apex ring, as shown in Figure 16.

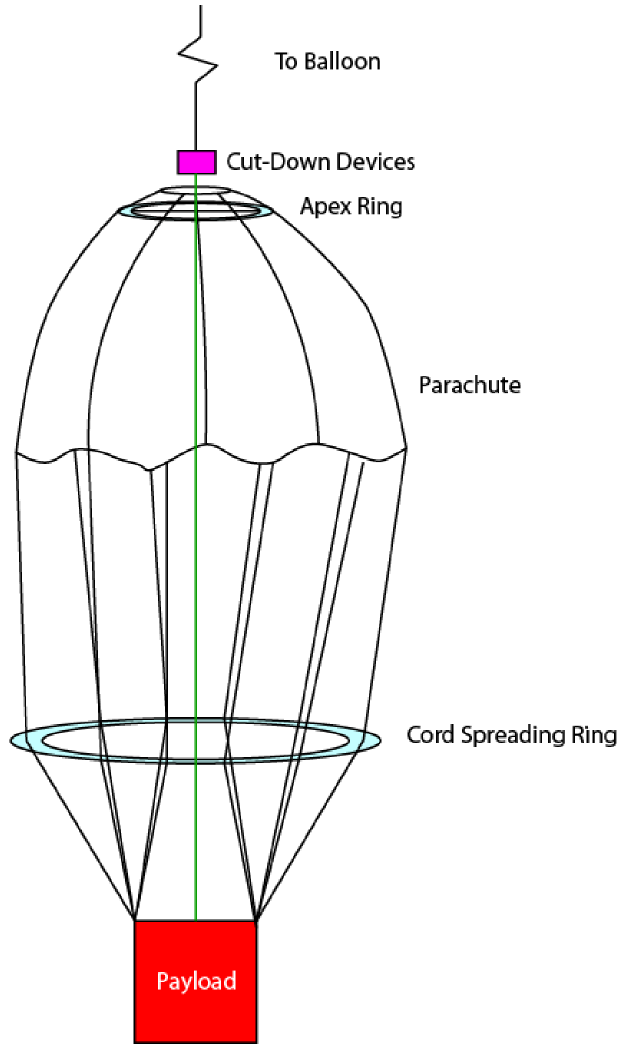


Figure 16. Parachute Deployment System

The apex ring is attached to the parachute at the apex. It is connected directly to the cut-down devices and payload via a nylon rope that is slightly larger than the combined length of the parachute cords and radius (approximately 25 feet) forcing the parachute to stretch out to its full length during ascent. Since the parachute is in this vertical position during ascent, there is no need for a deployment mechanism, eliminating the concern that the parachute will not deploy correctly. The apex ring also serves as an intermediary between the payload and cut-down devices, preventing the cut-down devices from interacting with the parachute.

As shown in Figure 17, the Apex Ring has a hole in the middle where a Female-Female connector rod is placed. The rod is allowed to translate and rotate in the hole, but is held in place by eyebolts and washers at both ends. The eyebolts connect to the payload and cut-down devices.

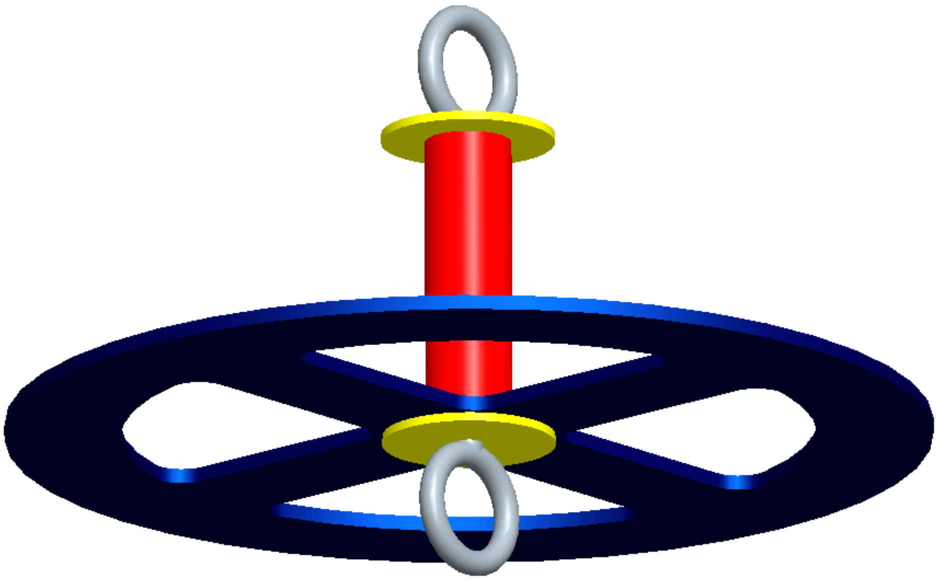


Figure 17. Apex Ring

The cord-spreading ring is used to ensure that the cords do not get tangled during the balloon's flight. In addition, the cord-spreading ring forces the parachute to remain slightly open, guaranteeing that air will flow into and inflate the parachute during descent. Additionally, small drilled balls are located evenly on the ring to prevent the parachute cords from being frayed by the ring's holes, as shown in Figure 18.

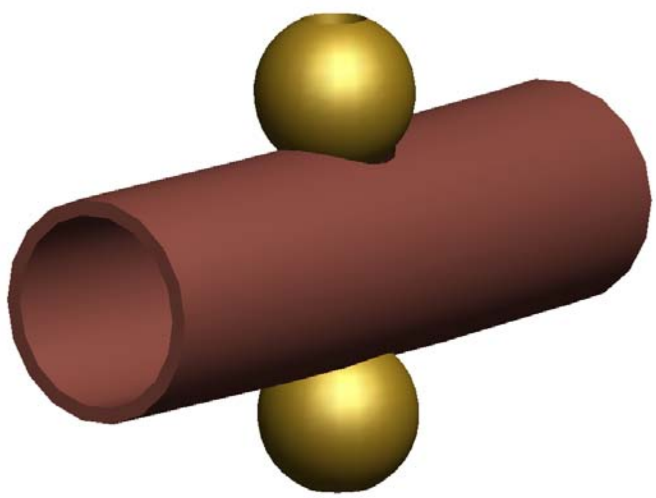


Figure 18. Section Cut of Cord Spreading

7. Testing

Test matrices were devised and can be seen on the attached CD copy of this report. MDP14001 and MDP14004 are complete and passed with satisfactory results. MDP14002 is the weight of the system test and can only be completed once the entire design is complete. MDP14003 was deemed unsafe for campus and thus was not performed. As a replacement MDP14004 was updated to include the parachute opening testing. MDP14005 and MDP14006 shall be completed once the barometric quick release is fully assembled and complete.

7.1. Electronic Cut-Down Device

MDP14001 was the burner assembly test and was performed in the lab by John Donovan. The test confirmed that the assembly is capable of burning through the nylon rope that will attach the balloon to the barometric quick release in a time of around 12 seconds.

7.2. Barometric Quick Release

The barometric quick remain to be tested. Calibration of the disarming apparatus should be completed at this phase, which is done prior to full assembly of the quick release. The aneroid cell must be able to expand past the 2*mm* necessary to release the locking arm. The disarming apparatus will be calibrated to a threshold of to approximately 35 Torr. Calibration adjustment will be made by rotating the aneroid cell and its #10-32 shaft in the threaded housing 1/4 turn at a time and locking it with the jam nut.

7.3. Parachute Ground Testing

Ground tests of the parachute were done to measure three things: the distance, under normal atmospheric conditions, the parachute would open, the drag force produced and the drag coefficient required to produce that drag force.

The drag force produced, at a speed of approximately 20 *ft/s*, was more than our 30 *lbf* scales could measure, resulting in a minimum known drag coefficient of 0.7. The distance the parachute opened was 80 *ft*.

8. Conclusion

The mechanical components for this design are all fully designed and nearly fully fabricated. The electrical systems will need to be designed and completed for the balloon payload system is useable. The barometric quick release also must be assembled and calibrated to the sensitivity of the aneroid cell. The next team will also need to order the balloon from Kaymont. With these complete the balloon system should be a successful, complete project.

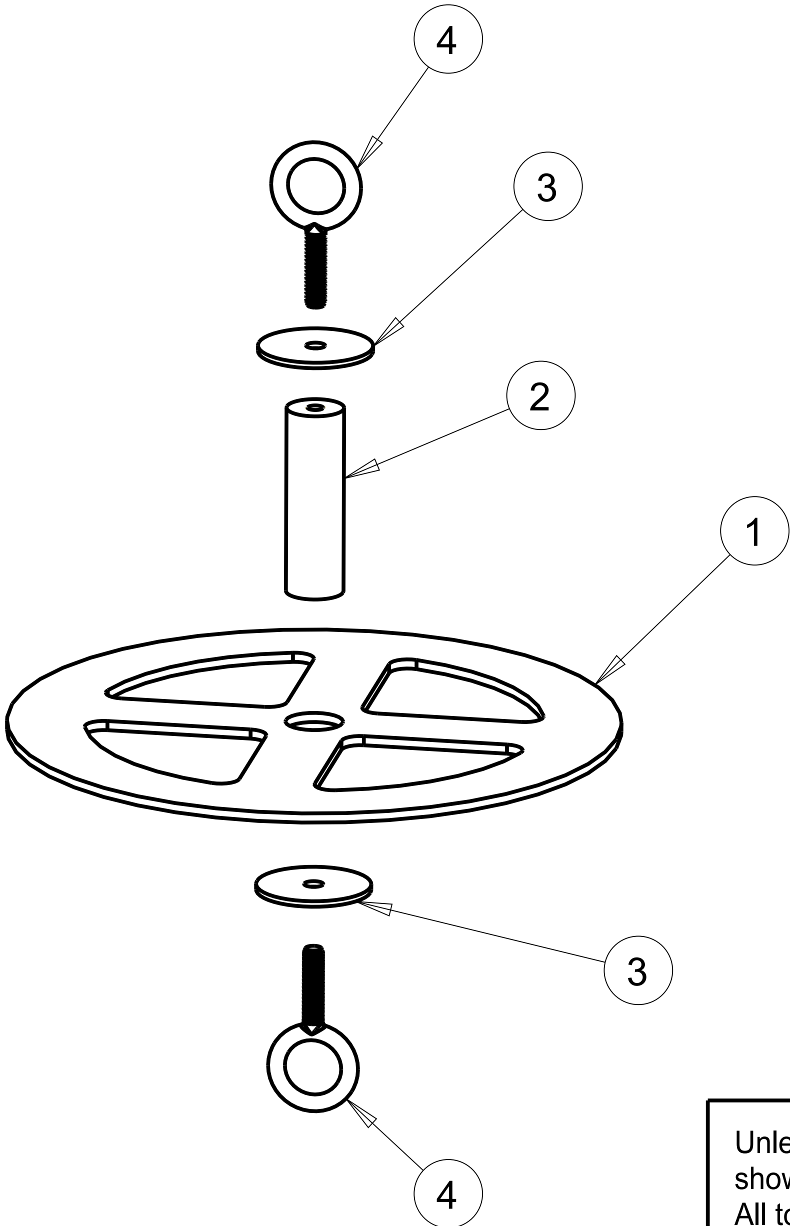
Appendix A Computer Code

```
%% Computes Correlation between Balloon Dimension and Mass of Payload

h=28000;
T=-38+273;rho=1.472;
m=0:10;
m_b=3;
sg=.1308;
B=rho-rho*sg*rho;
r=((m_b+m).*4./(B*3*pi)).^(1/3);
plot(m,2.*r)
grid on
xlabel('Mass of Payload(kg)')
ylabel('Diameter of Balloon(m)')
title('Diameter of Balloon vs. Mass of Payload')
```

```
%This code plots the expected descent velocity versus height of the
payload
%given the drag coefficient of the parachute and the weight of the
payload.
%It will determine the minimum diameter parachute required for a safe
fall
%and use that parachute in the calculations to determine the speed of
%descent for the duration of the trip.
clear
clc
W = input('Input the payload weight in pounds: ');
Cd = input('Input the drag coefficient: ');
h=2500; %This height is the maximum height we want the safe fall to be
T=59-0.00356*h;
P=2116*((T+459)/518.6)^5.256;
p = P/(1718*(T+459.7));
A=W/(50*Cd*p);
D = sqrt(4*A/pi);
disp(['The minimum required diameter for the parachute is
',num2str(D),' feet.']);
A= pi*D^2/4;
for h=10:10:120000
    if h > 82345
        T = -205.05+0.00164*h;
        P = 51.97*((T+459.7)/389.98)^(-11.388);
    elseif h>36152 && h<82345
        T=-70;
        P=473.1*exp(1.73-0.000048*h);

    elseif h<36152
        T=59-0.00356*h;
        P=2116*((T+459)/518.6)^5.256;
    else
```

```
        P=0;
    end
        p = P/(1718*(T+459.7));
        i=h/10;
        V(i)=sqrt(2*W/(Cd*p*A));
end
height = 10:10:120000;
plot(height,V);
title(['Descent Velocity vs. Height, W=',num2str(W),'lbs,
Cd=',num2str(Cd),', D=',num2str(D),'ft']);
xlabel('Height (ft)');
ylabel('Descent Velocity (ft/s)');
```

Appendix B CAD Drawings

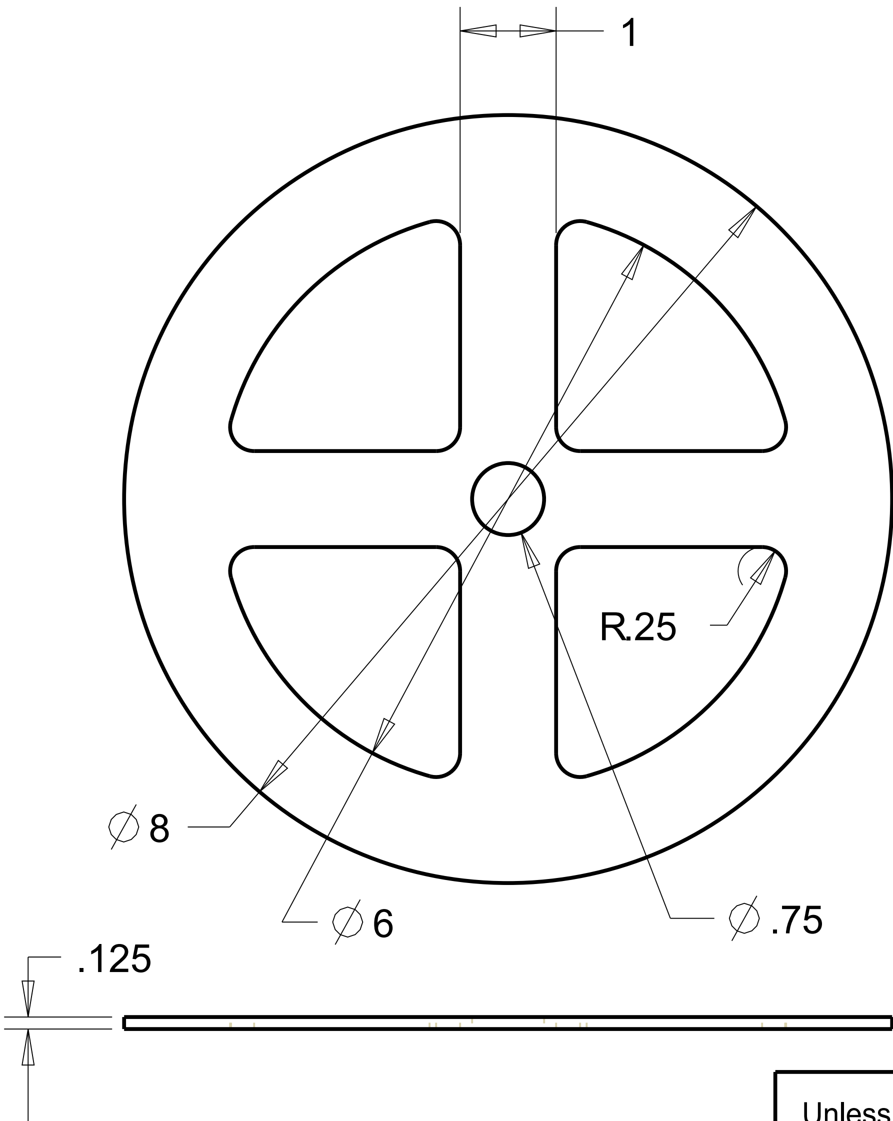


REVISIONS

Item	Part Name	Material	Qty
1	Apex Ring	Lexan	1
2	2.5"x3/4" ∅ Spacer	Ceramic	1
3	Washer	Steel	2
4	1/4-20 Eyebolt	Steel	2

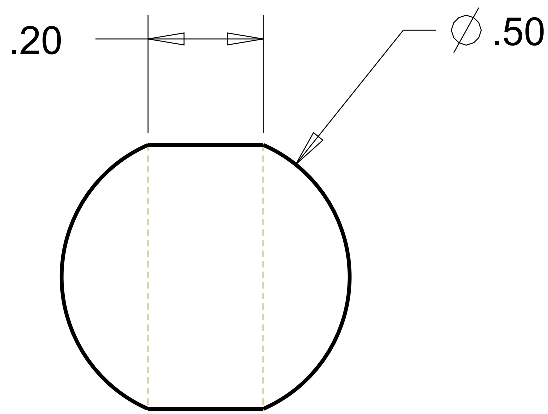
Unless otherwise shown: All tolerances ±0.1 of last decimal given.	Binghamton University Mechanical Engineering Department
	Apex Ring Assembly
	No.:
All dimensions in.	DRWN By: Chris Troiano Date: 24 Feb 2011

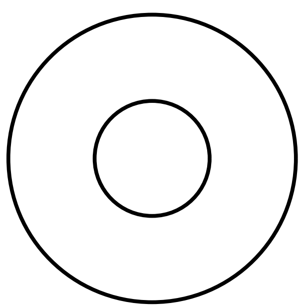
REVISIONS

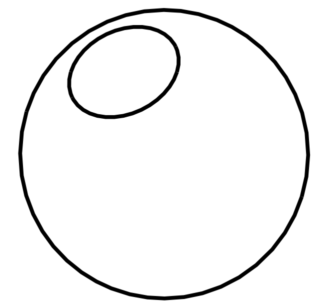


Unless otherwise shown: All tolerances ±0.1 of last decimal given.	Binghamton University Mechanical Engineering Department Apex Ring
	No.:
All dimensions in.	DRWN By: Chris Troiano — Date: 24 Feb 2011

REVISIONS







Unless otherwise shown:
All tolerances ±0.1 of last decimal given.

All dimensions in.

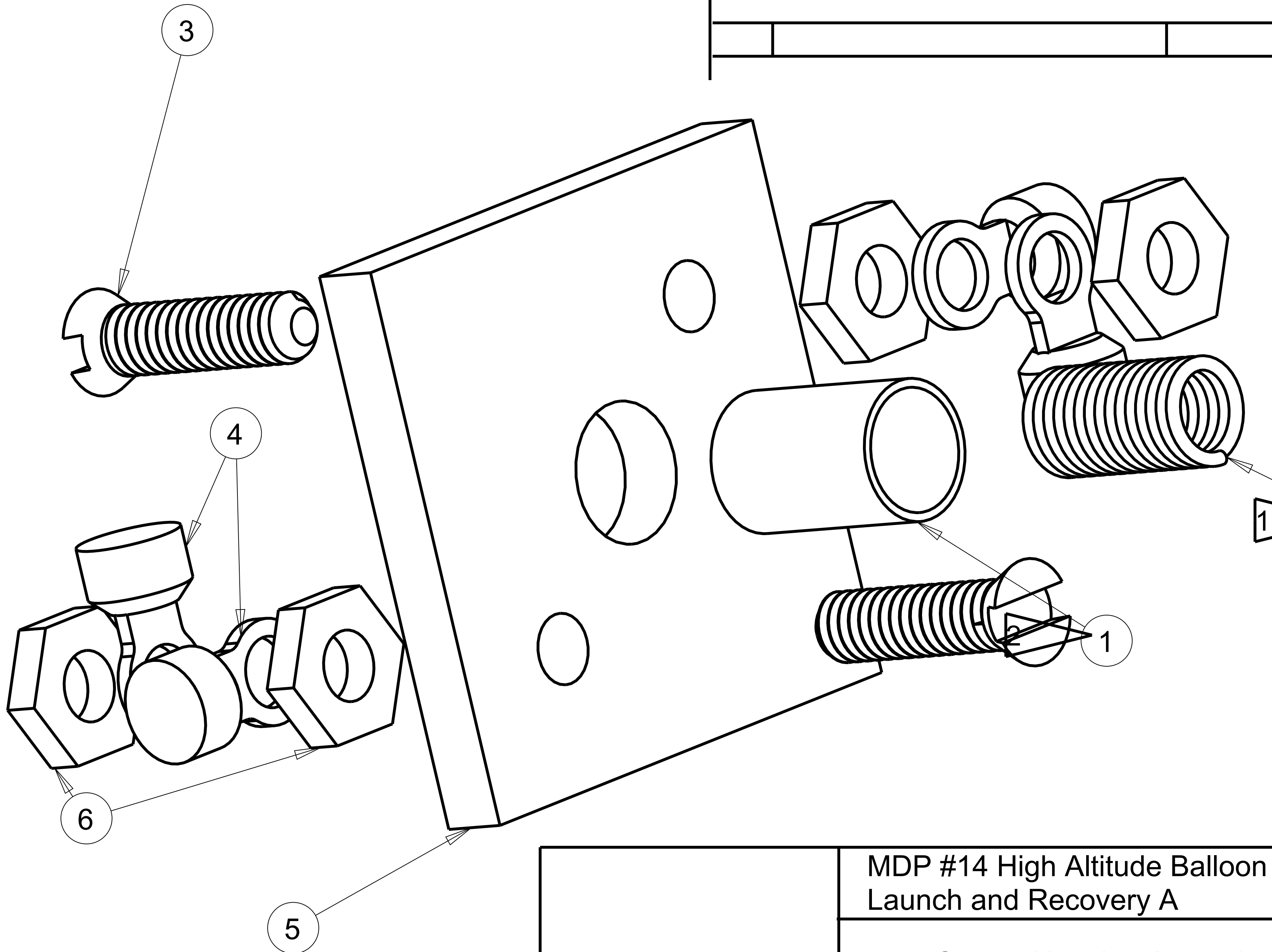
Binghamton University
Mechanical Engineering Department

Hula Hoop Ball

No.:

DRWN By: Chris Troiano

Date: 24 Feb 2011



MDP #14 High Altitude Balloon Launch and Recovery A				
Sleeve Housing Assembly				
Units: in, lbf, degrees	Size A	Scale: 2:1	Drawn By: John Donovan	Rev A
Date:	Signed:		Sheet 1 of 2	

ASSEMBLY NOTES:

1 NICHROME IS TO BE LOOPED AROUND A 1/4-20 BOLT FOR EVEN LOOPING. THEN INSERT LOOP INTO SLEEVE AND CRIMP ENDS OF WIRE TO ONE TERMINAL RING ON EACH SIDE OF HOUSING.

2 EPOXY INTO HOUSING WITH CERAMIC TO METAL EPOXY.

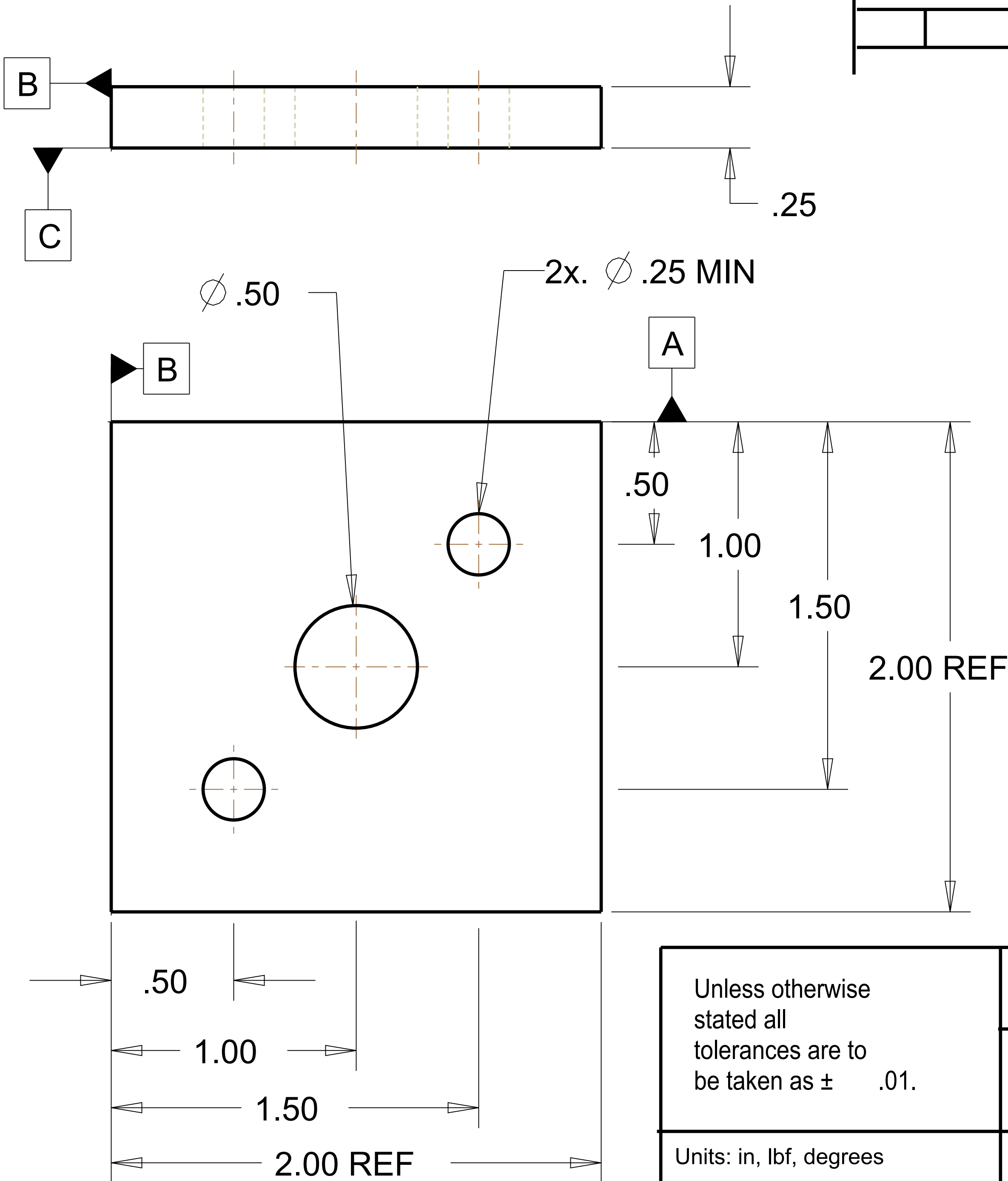
ITEM	DESCRIPTION	MTL	QTY
1	BURNER SLEEVE	Glass-Mica Ceramic	1
2	Nichrome Wire	NICHROME	1
3	1/4-20UNC-1/2 BOLT	NYLON	2
4	TERMINAL RING		4
5	BURNER HOUSING	AL 6061	1
6	1/4-20UNC NUT	NYLON	

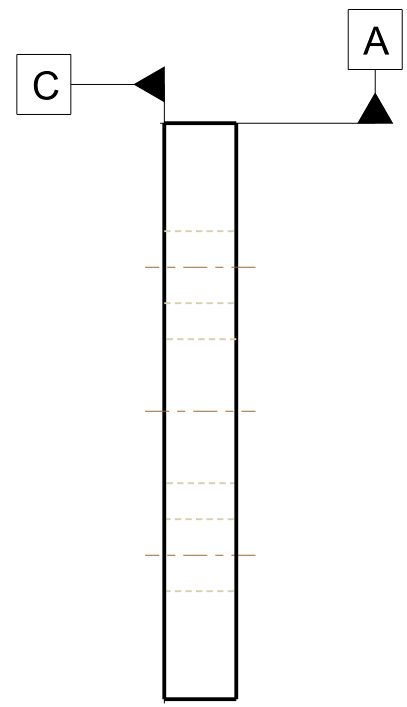
MDP #14 High Altitude Balloon Launch and Recovery A

Sleeve Housing Assembly

Units: in, lbf, degrees

Size A	Scale: 2:1	Drawn By: John Donovan	Rev A
Date:	Signed:	Sheet 2 of 2	



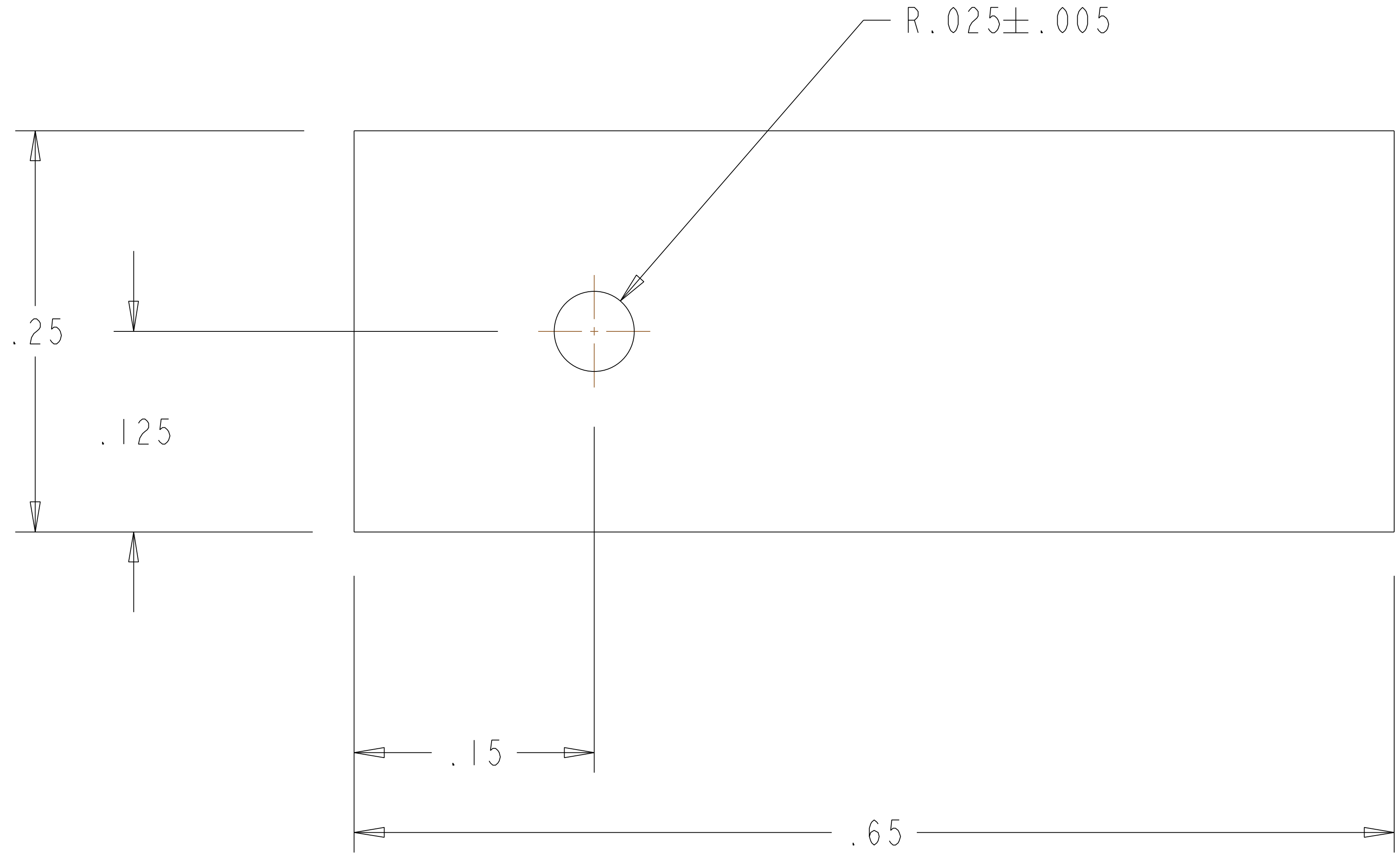


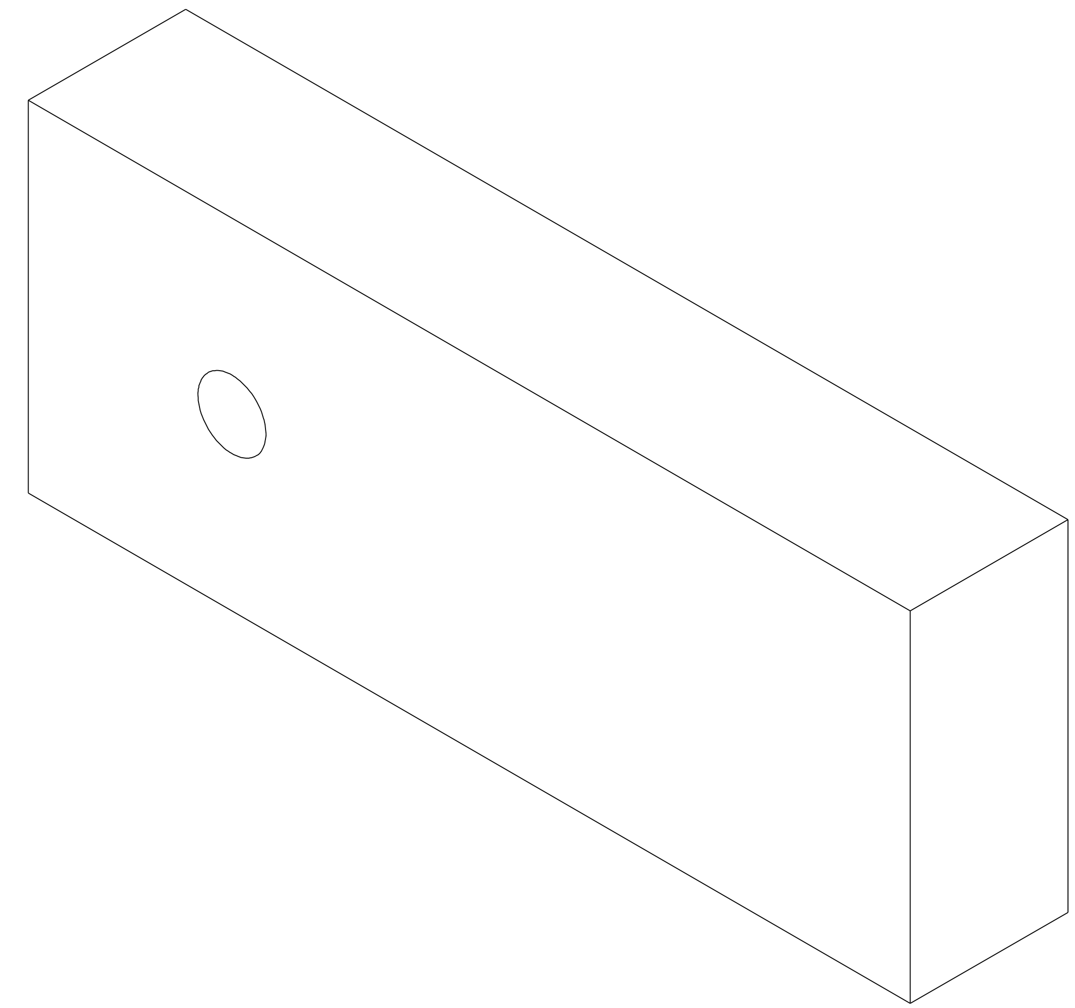
NOTE:
1) MATERIAL: AL6061

Unless otherwise stated all tolerances are to be taken as ± .01.	MDP #14 High Altitude Balloon Launch and Recovery A Burner Housing			
Units: in, lbf, degrees	Size A	Scale: 3:2	Drawn By: John Donovan	Rev A
	Date:	Signed:	Sheet 1 of 1	

Item	Part Name	Material	Qty
1	Spring Plate	6061-T6 Gauge 9 .1144 Al	2

REVISIONS			
A	Design for MDP14	PL	02/28/2011
B	Release for checking	PL	03/03/2011





Unless otherwise specified all tolerances shown are ±0.01 of the last decimal shown

All dimensions shown in inches

Peter Lin

Binghamton University: Watson School of Engineering
Department of Mechanical Engineering

Spring Plate

B Size SCALE 10.000

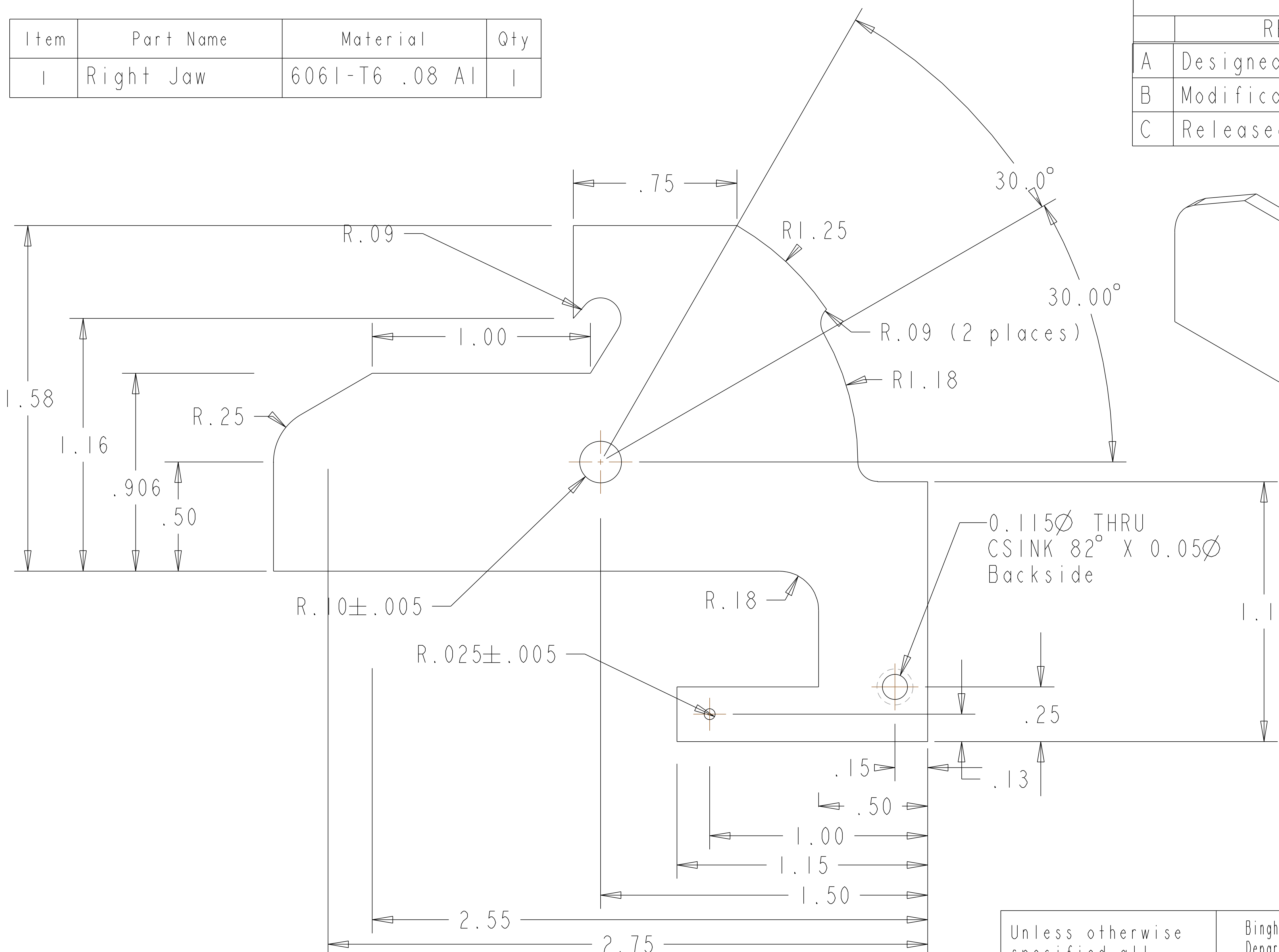
02/27/2011 Revision B Sheet 06 of 08

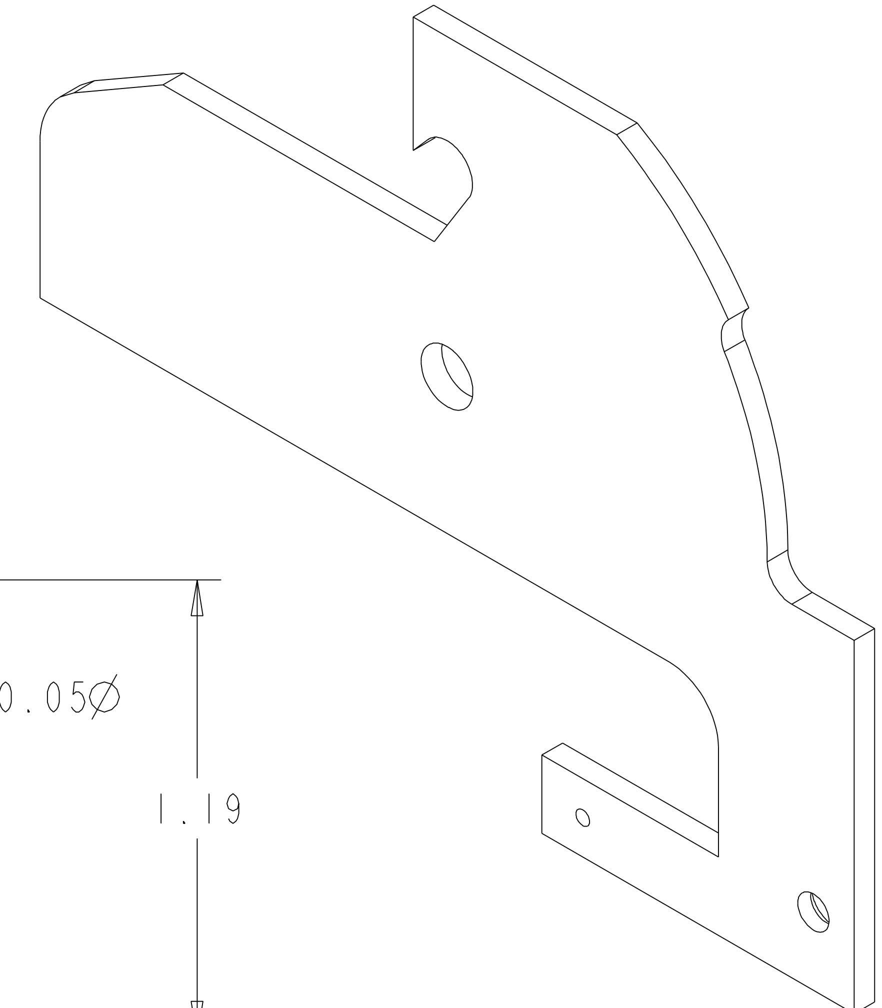
NAME:PLIN1 OBJECT:SPRING_PLATE DATE:03-Mar-11 21:42:26

NAME:PLIN1 OBJECT:RIGHT_JAW DATE:08-Mar-11 14:10:22

Item	Part Name	Material	Qty
1	Right Jaw	6061-T6 .08 Al	1

	REVISIONS		
A	Designed by Mike Manes	PL	02/19/2011
B	Modification for MDP14	PL	02/28/2011
C	Released for checking	PL	03/03/2011

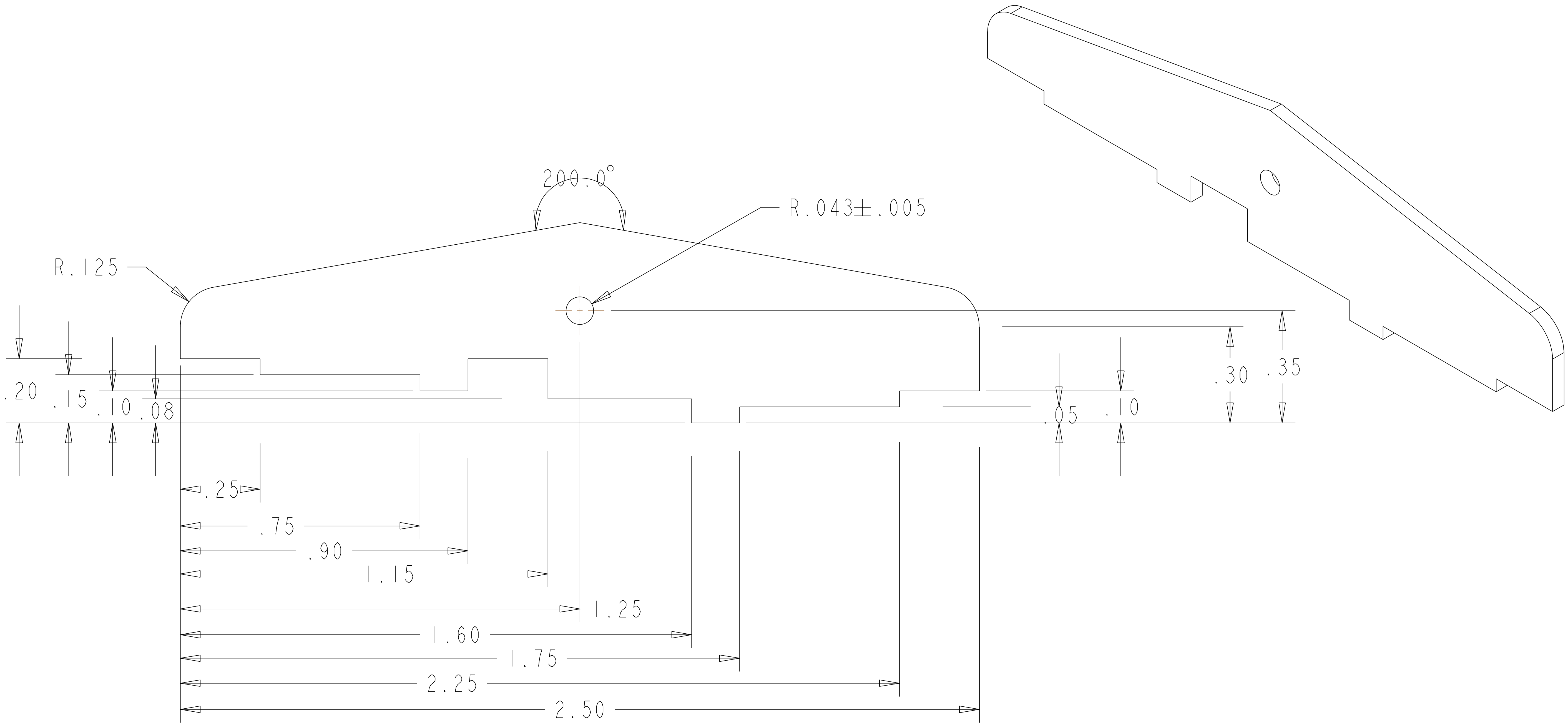




Unless otherwise specified all tolerances shown are ±0.01 of the last decimal shown	Binghamton University: Watson School of Engineering Department of Mechanical Engineering		
	Right Jaw		
All dimensions shown in inches	B Size	SCALE 2.000	
Peter Lin	02/19/2011	Revision C	Sheet 01 of 08

Item	Part Name	Material	Qty
1	Locking Arm	6061-T6 16 Gauge .05 Al	1

	REVSISIONS		
A	Design by Mike Manes	PL	02/19/2011
B	Modification for MDP14	PL	02/28/2011
C	Release for checking	PL	03/03/2011

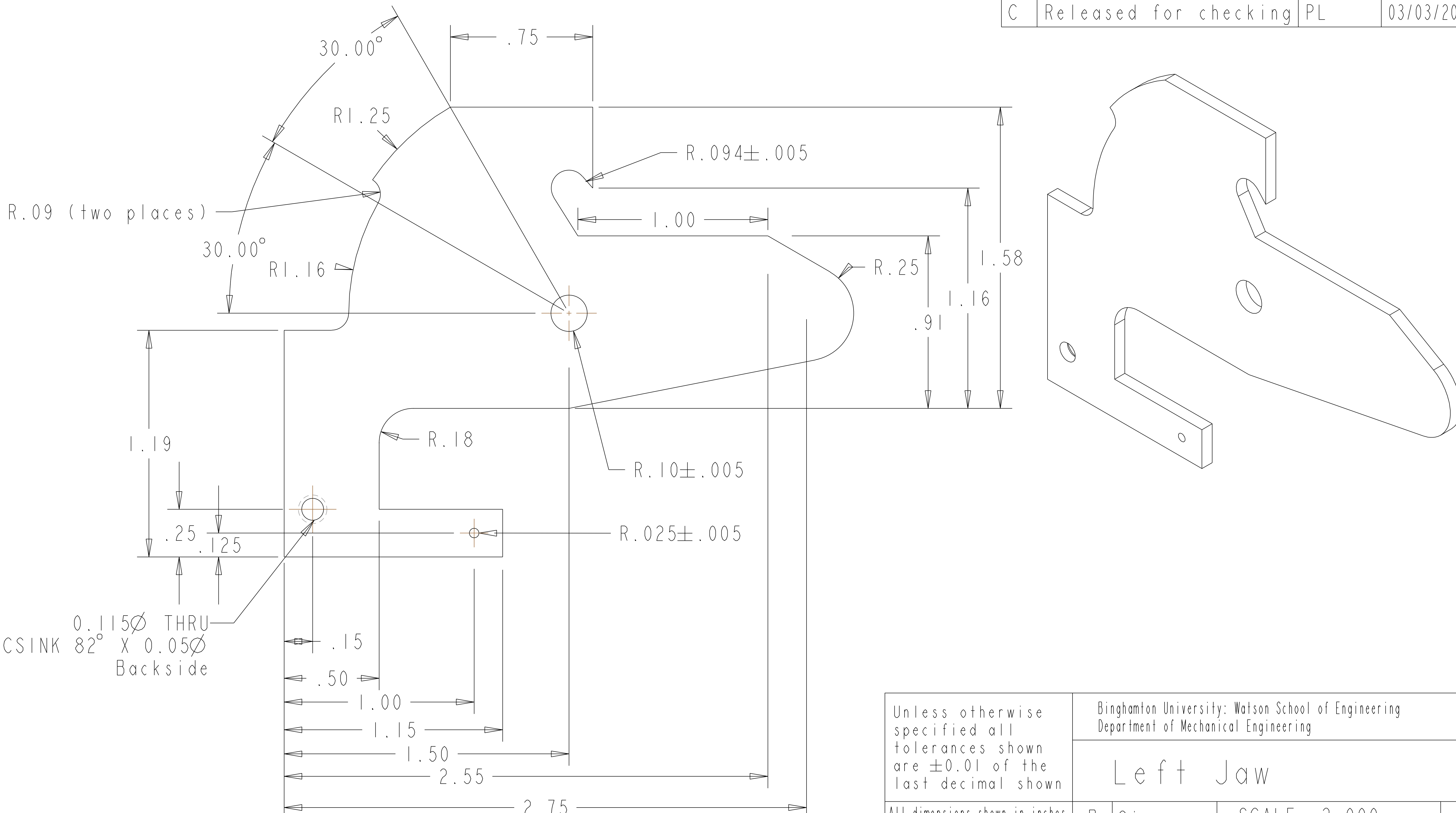


Unless otherwise specified all tolerances shown are ±0.01 of the last decimal shown	Binghamton University: Watson School of Engineering Department of Mechanical Engineering
	Locking Arm
All dimensions shown in inches	B Size | SCALE 3.000
Peter Lin	02/21/2011 | Revision C | Sheet 04 of 08

NAME:PLIN1 OBJECT:LOCKING_ARM DATE:08-Mar-11 14:11:04

Item	Part Name	Material	Qty
1	Left Jaw	6061-T6 .08 Al	1

	REVISIONS		
A	Designed by Mike Manes	PL	02/19/2011
B	Modification for MDP14	PL	02/28/2011
C	Released for checking	PL	03/03/2011

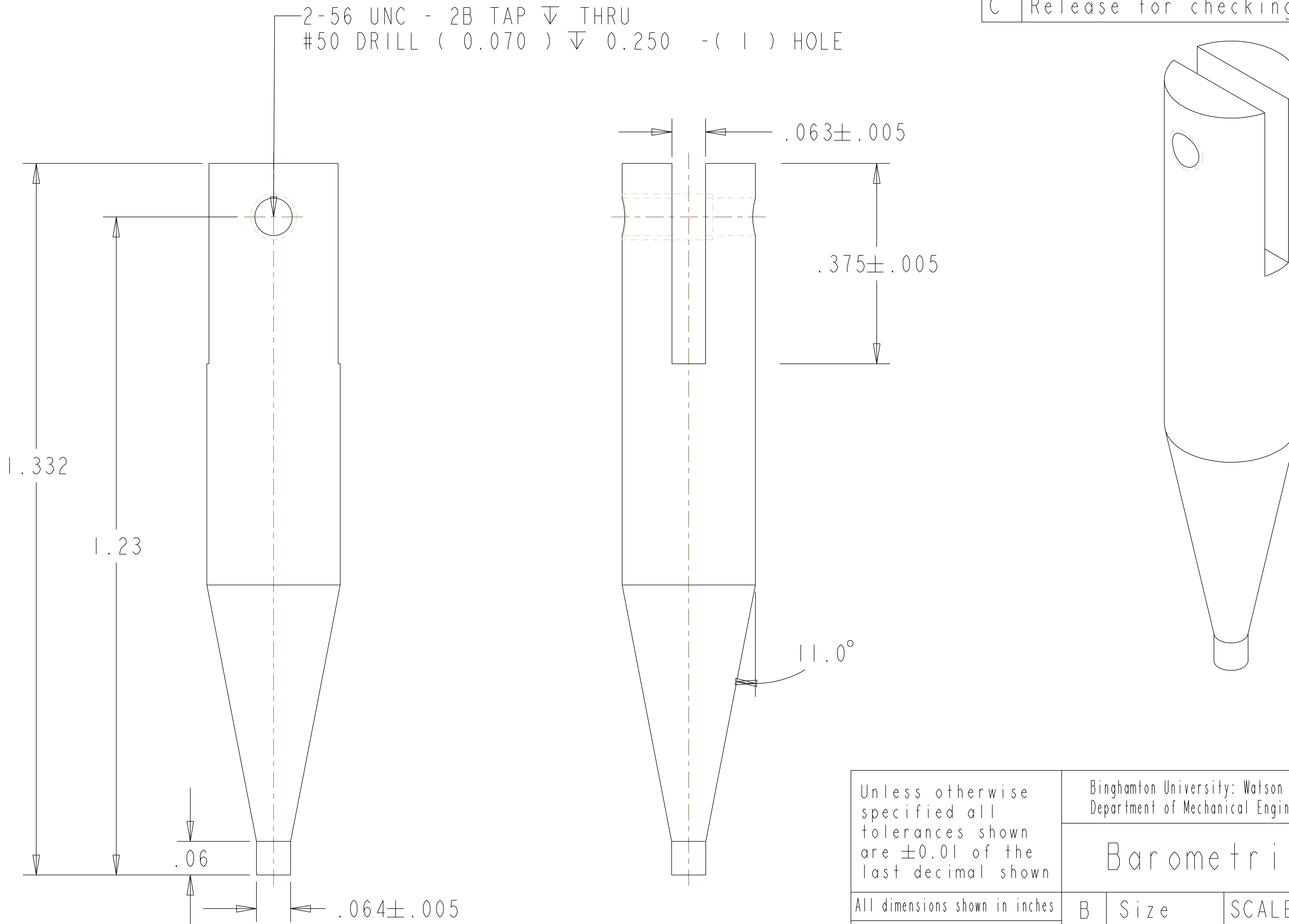


Unless otherwise specified all tolerances shown are ±0.01 of the last decimal shown	Binghamton University: Watson School of Engineering Department of Mechanical Engineering			
	Left Jaw			
All dimensions shown in inches	B	Size	SCALE 2.000	
Peter Lin	02/19/2011	Revision C	Sheet 02 of 08	

NAME:PLIN1 OBJECT:LEFT_JAW DATE:08-Mar-11 14:13:05

Item	Part Name	Material	Qty
1	Barometric Pin	1/4Ø Al	1

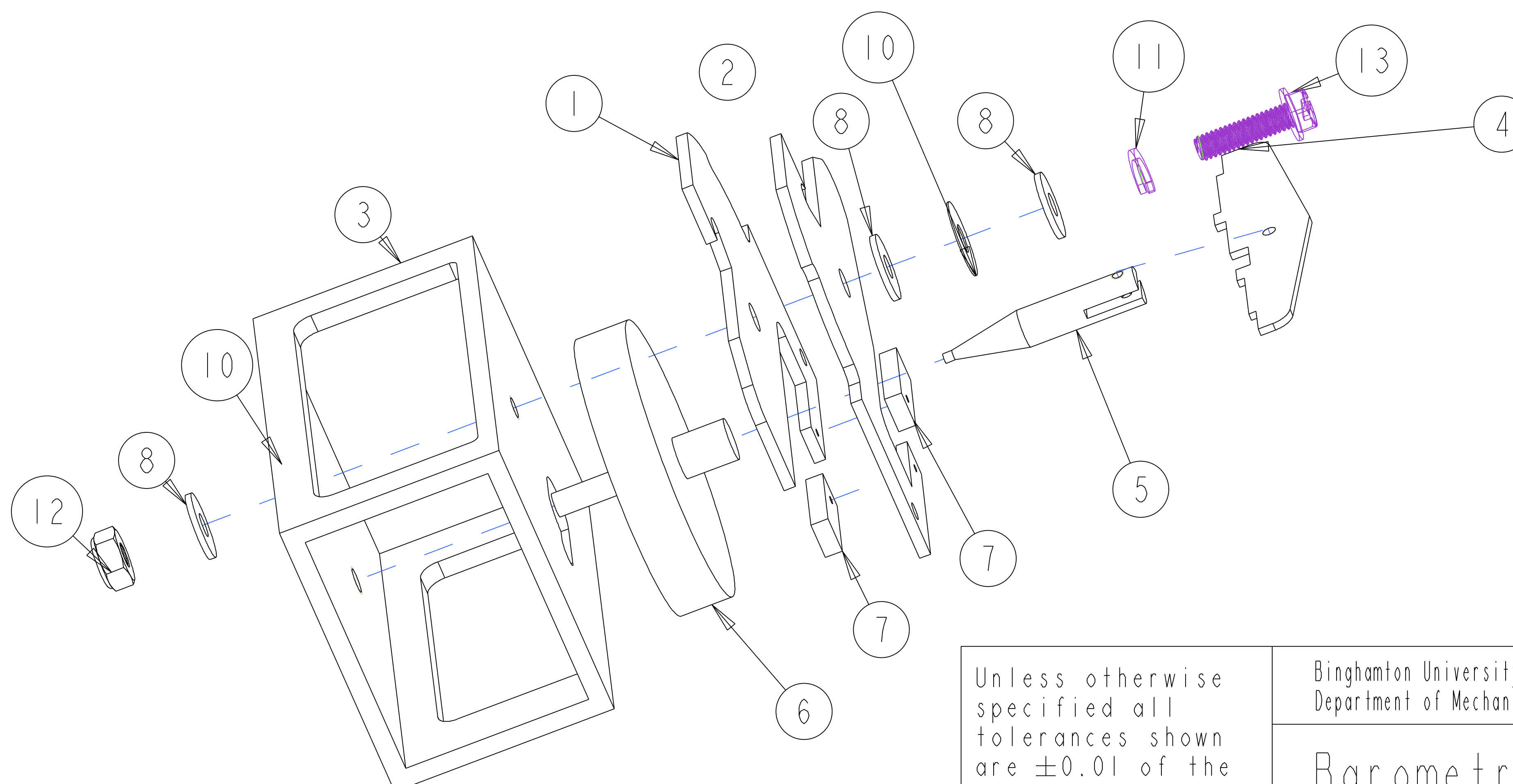
	REVISIONS		
A	Design by Mike Manes	PL	02/19/2011
B	Modification for MDP14	PL	02/28/2011
C	Release for checking	PL	03/03/2011



Unless otherwise specified all tolerances shown are ±0.01 of the last decimal shown	Binghamton University: Watson School of Engineering Department of Mechanical Engineering			
	Barometric Pin			
All dimensions shown in inches	B	Size	SCALE 5.000	
Peter Lin	02/19/2011	Revision C	Sheet 05 of 08	

Item	Part Name	Material	Qty	Item	Part Name	Material	Qty
1	Right Jaw	6061-T6 Al	1	11	No.8 0.01 Split Washer	Al	1
2	Left Jaw	6061-T6 Al	1	12	No.8 Nylock Nut	Al	1
3	Aneroid Housing	5052 Al	1	13	8-32 3/4 Hex Head	Al	1
4	Locking Arm	6061-T6 Al	1	14			
5	Arming Pin	Brass	1	15			
6	Aneroid Cell	Be & Cu Alloy	1	16			
7	Spring Plate	6061-T6 Al	2	17			
8	No.8 0.04 Flat Washer	Al	3	18			
9	No.8 0.04 Wavy Washer	Al	1	19			
10	No.8 0.01 Thin Washer	Al	2	20			

	REVISIONS		
1	Original design by Mike Manes	12/21/2010	
2	Modification by MDP14	02/01/2011	
3	Released for Checking	02/24/2011	



Note: Wavy washer not shown in assembly

Unless otherwise specified all tolerances shown are ±0.01 of the last decimal shown

All dimensions shown in inches

Peter Lin

Binghamton University: Watson School of Engineering
Department of Mechanical Engineering

Barometric Quick Release

B

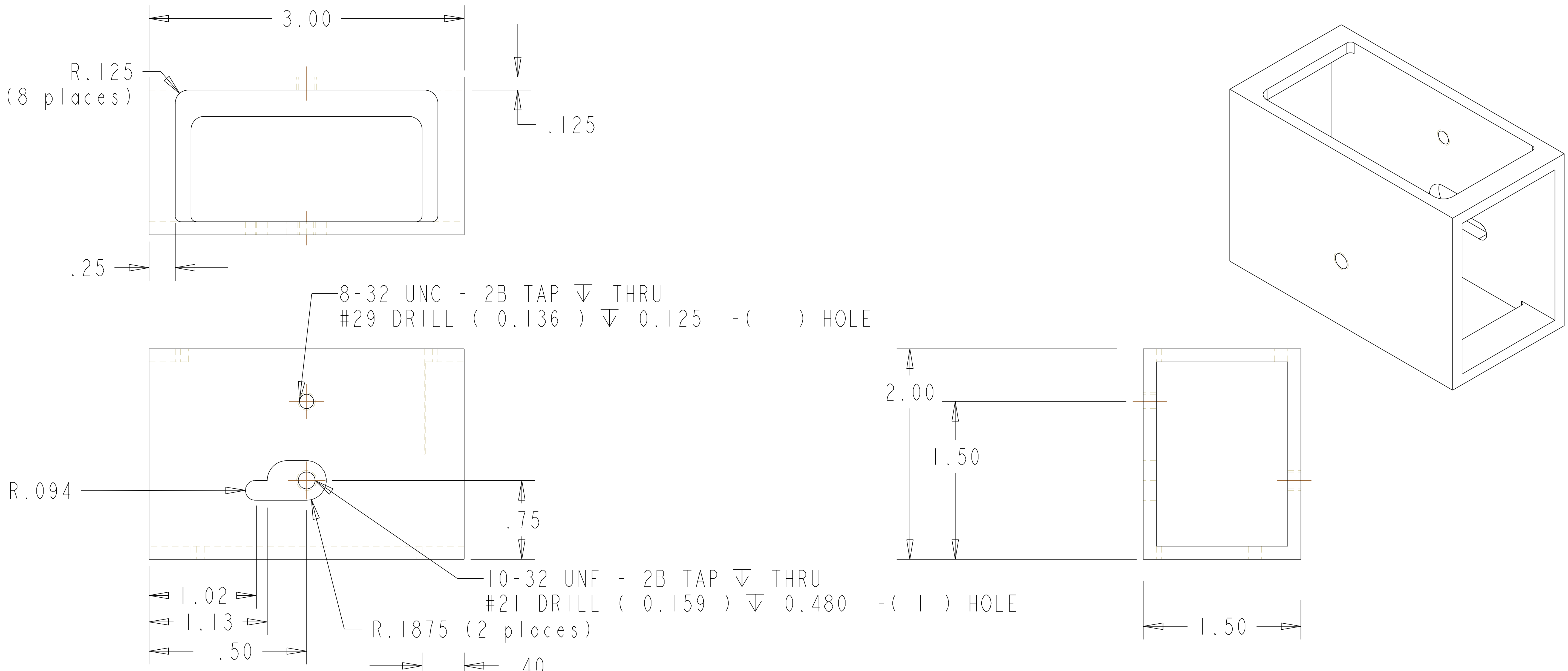
02/24/2011

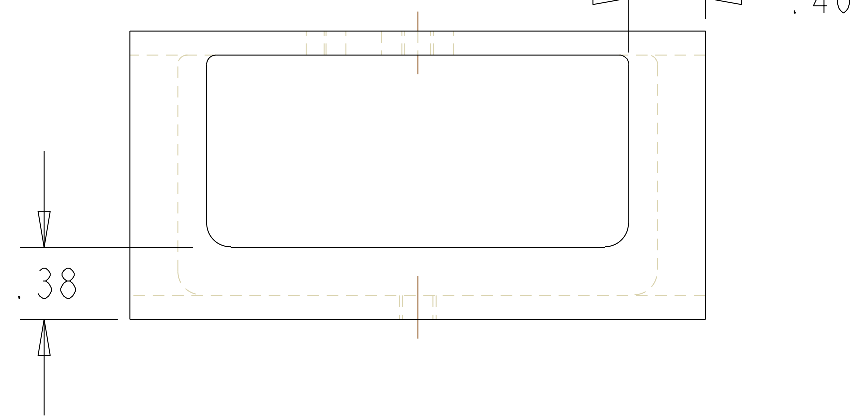
Sheet 06 of 08

NAME:PLIN1 OBJECT:ASSEMBLY_EXPLOSION DATE:09-Mar-11 12:38:37

Item	Part Name	Material	Qty
1	Aneroid Housing	5052 1 3/4 X 2 X .125 wall Al tubing	1

	REVISIONS		
A	Design by Mike Manes	PL	02/19/2011
B	Modification for MDP14	PL	02/28/2011
C	Release for checking	PL	03/03/2011

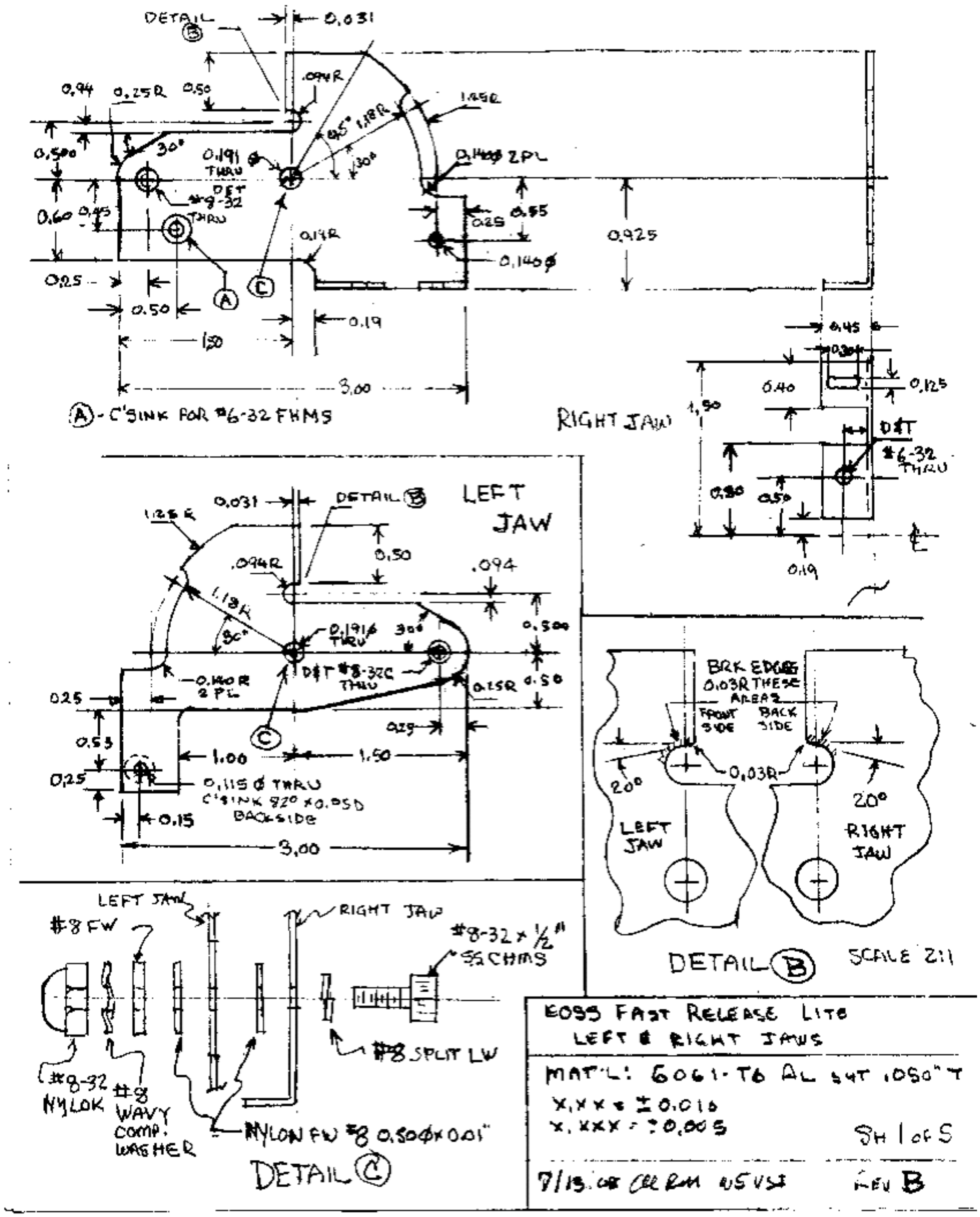


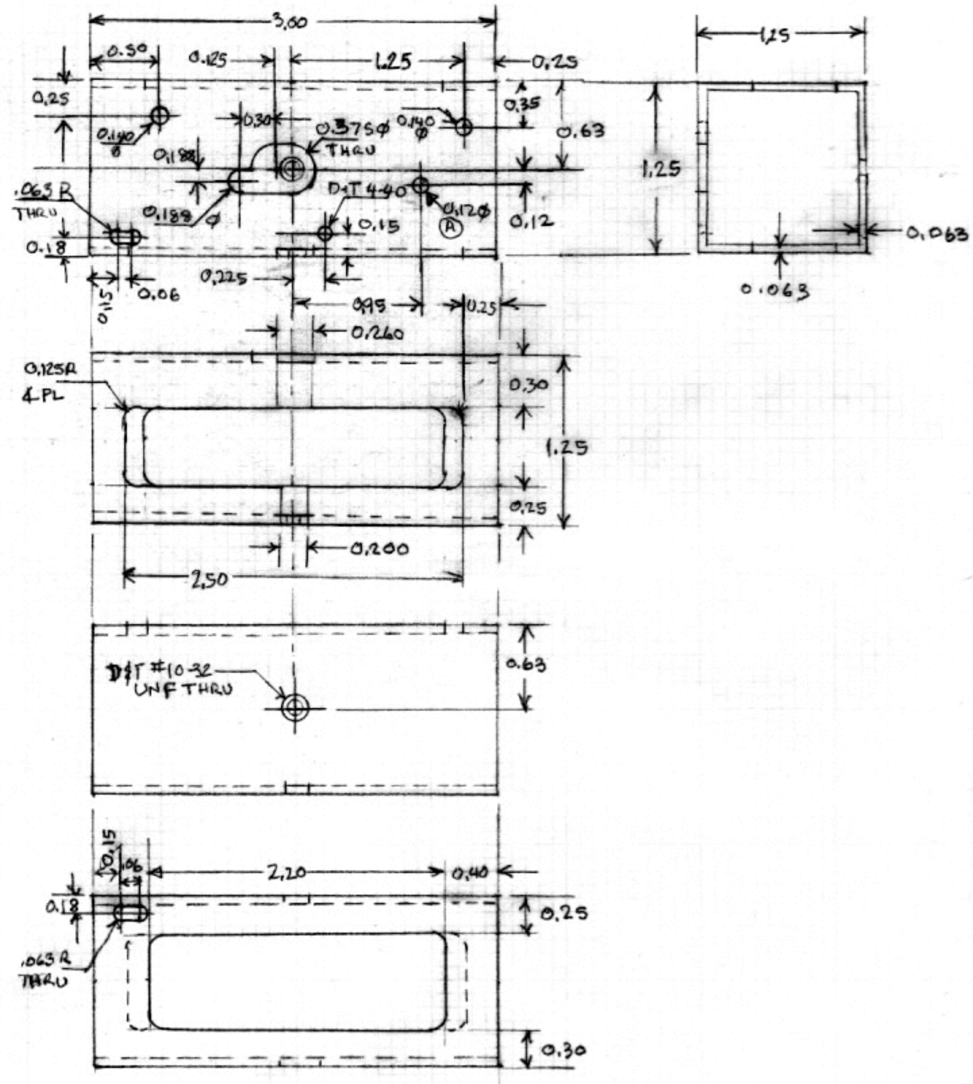


Unless otherwise specified all tolerances shown are ±0.01 of the last decimal shown	Binghamton University: Watson School of Engineering Department of Mechanical Engineering		
	Aneroid Cell Housing		
All dimensions shown in inches	B Size	SCALE 1.000	
Peter Lin	02/19/2011	Revision C	Sheet 03 of 08

NAME:PLIN1 OBJECT:ANEROID_HOUSING DATE:17-Mar-11 14:58:50

Appendix C Sketches





NOTES:

(A) RADIUS HOLE EDGES 0.02R MIN

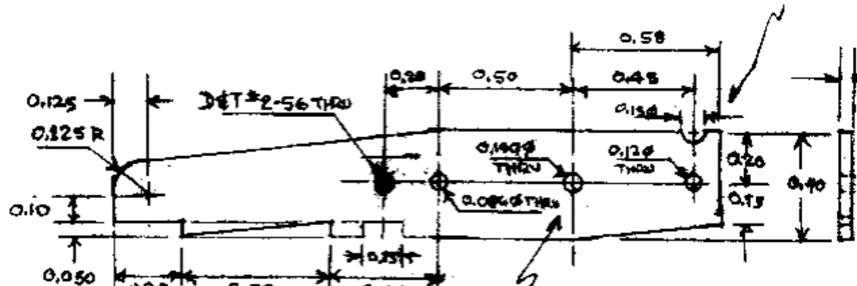
EOSS FAST RELEASE LITE
ANAEROID HOUSING

MAT'L: 1.25" × 1.25" × 0.063" 5052 AL EXTR.

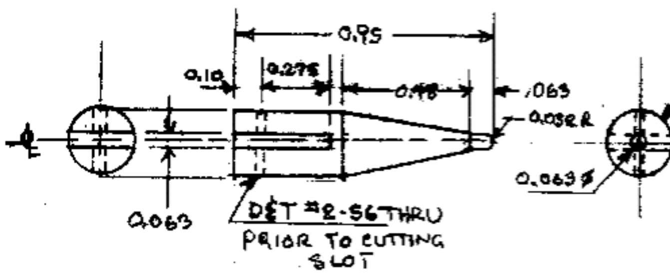
X.XX ± 0.010" SCALE 1:1

X.XXX ± 0.005 SH 2 OF 5

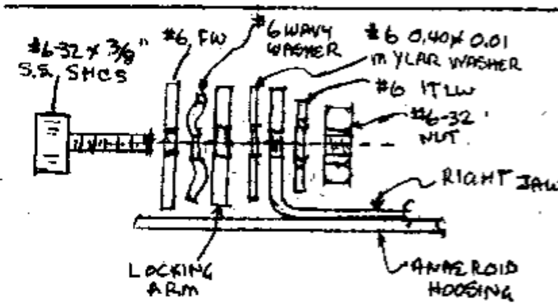
7/13/08 [signature] W5VSI REV B



LOCKING ARM
SCALE 2:1
MAT'L: 6061-T6 0.060" AL SHT

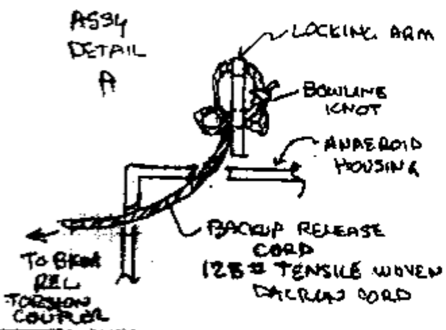


BARO ARMING PIN
SCALE 2:1
MAT'L: FREE MACH. BRASS
1/4" ROD STOCK

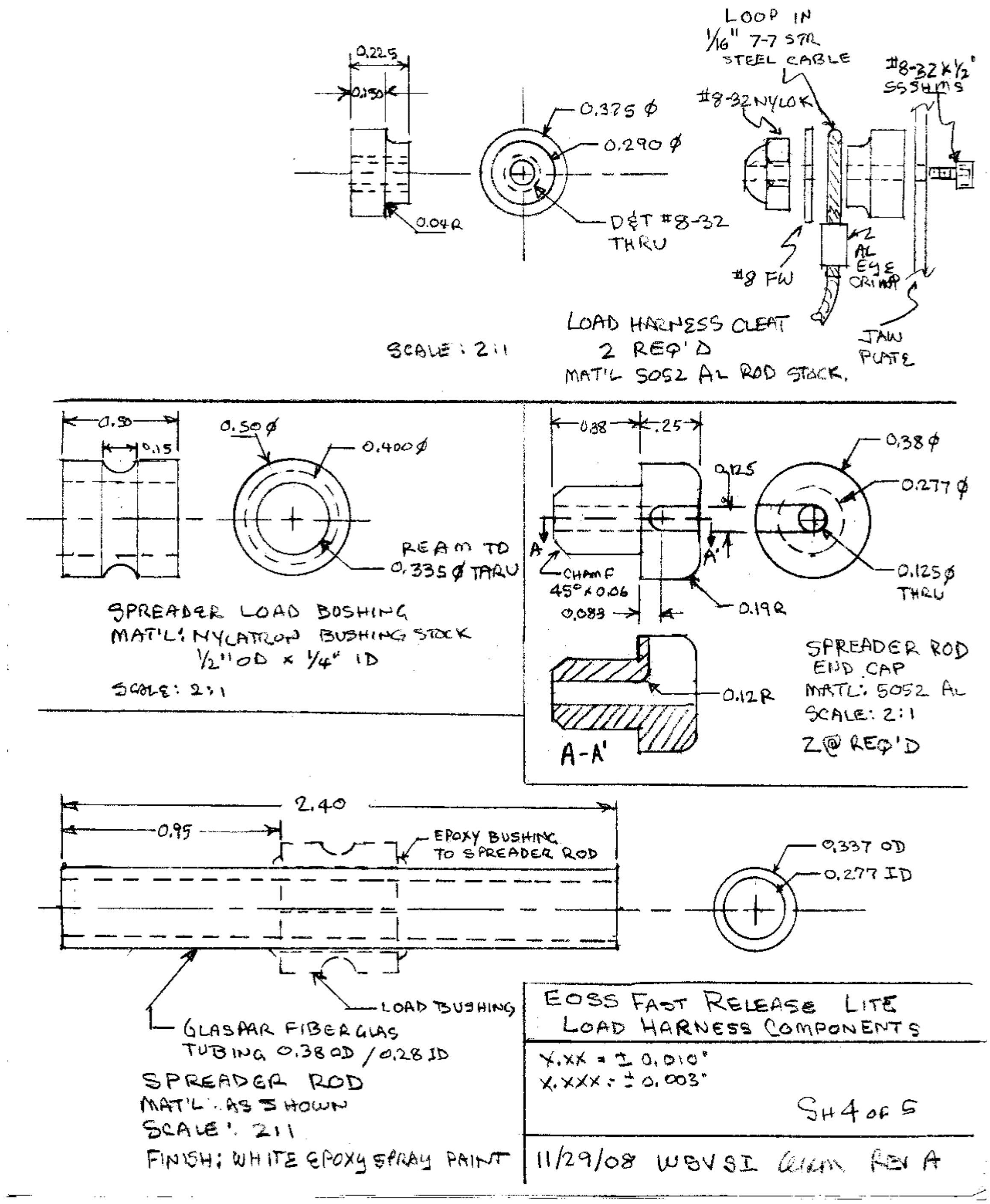


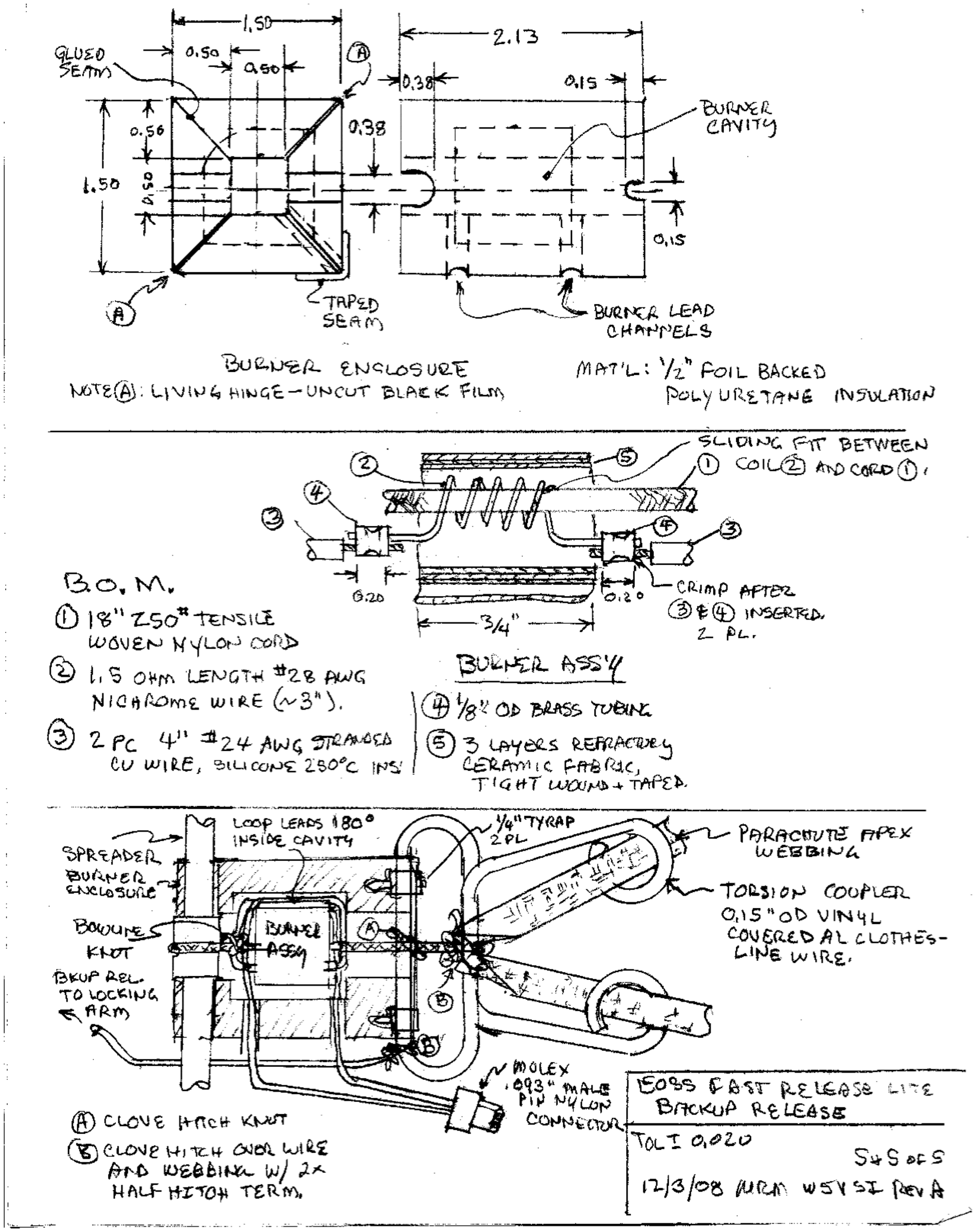
ASS'Y DETAIL B

TIGHTEN SCREW TO MIN LASH
& FREE AXIAL MOVEMENT LESS 1/8 TURN.
LOCK ADJUSTMENT W/ NUT



EOSS FAST RELEASE LITE ARMING COMPONENTS
MAT'L: AS SHOWN X.XX = ± 0.010" X.XXX = ± 0.005" SH3 of 5
11/25/08 WSVSI [illegible] REV A


LOOP IN 1/16" 7-7 STR STEEL CABLE
#8-32 x 1/2" SS SHIMS
0.225
0.150
0.375 ø
0.290 ø
#8-32 NYLOK
D&T #8-32 THRU
0.04R
#8 FW
AL EYE CRIMP
JAW PLATE
LOAD HARNESS CLEAT
2 REQ'D
MAT'L 5052 AL ROD STOCK.
SCALE: 2:1
0.50
0.15
0.50 ø
0.400 ø
REAM TO 0.335 ø THRU
SPREADER LOAD BUSHING
MAT'L: NYLATRON BUSHING STOCK
1/2" OD x 1/4" ID
SCALE: 2:1
0.38
.25
0.125
0.38 ø
0.277 ø
0.125 ø THRU
A
A'
CHAMF 45° x 0.06
0.083
0.19R
0.12R
A-A'
SPREADER ROD END CAP
MATL: 5052 AL
SCALE: 2:1
2@ REQ'D
2.40
0.95
EPOXY BUSHING TO SPREADER ROD
0.337 OD
0.277 ID
LOAD BUSHING
GLASPAR FIBERGLAS TUBING 0.38 OD / 0.28 ID
SPREADER ROD
MAT'L: AS SHOWN
SCALE: 2:1
FINISH: WHITE EPOXY SPRAY PAINT
EOSS FAST RELEASE LITE
LOAD HARNESS COMPONENTS
X.XX = ± 0.010"
X.XXX = ± 0.003"
SH 4 OF 5
11/29/08 WB8SI
REV A



1.50
0.50
0.50
GLUED SEAM
Ⓐ
0.56
0.38
1.50
0.50
TAPED SEAM
Ⓐ
2.13
0.38
0.15
BURNER CAVITY
0.15
BURNER LEAD CHANNELS
BURNER ENCLOSURE
NOTE Ⓐ: LIVING HINGE—UNCUT BLACK FILM
MAT'L: ½" FOIL BACKED POLYURETANE INSULATION
SLIDING FIT BETWEEN ① COIL ② AND CORD ①.
0.20
0.20
CRIMP AFTER ③ & ④ INSERTED. 2 PL.
3/4"
BURNER ASS'Y
B.O.M.
① 18" 250# TENSILE WOVEN NYLON CORD
② 1.5 OHM LENGTH #28 AWG NICHROME WIRE (~3").
③ 2 PC 4" #24 AWG STRANDED CU WIRE, SILICONE 250°C INS'
④ 1/8" OD BRASS TUBING
⑤ 3 LAYERS REFRACTORY CERAMIC FABRIC, TIGHT WOUND + TAPED.
LOOP LEADS 180° INSIDE CAVITY
1/4" TYRAP 2 PL
PARACHUTE APEX WEBBING
SPREADER
BURNER ENCLOSURE
BOWLINE KNOT
BURNER ASSY
BKUP REL. TO LOCKING ARM
TORSION COUPLER 0.15" OD VINYL COVERED AL CLOTHES-LINE WIRE.
MOLEX .093" MALE PIN NYLON CONNECTOR
Ⓐ CLOVE HITCH KNOT
Ⓑ CLOVE HITCH OVER WIRE AND WEBBING W/ 2X HALF HITCH TERM.
EOSS FAST RELEASE LITE BACKUP RELEASE
TOL ± 0.020
S4 S OF S
12/3/08 MRM W5YSI Rev A

Appendix D Budget

Item #	Item Name	P/N (if applicable)	Cost / unit	Quantity	Total Cost
1	Burner Assembly		$60.00	1	$60.00
2	Parachute Design		$75.00	1	$75.00
3	Barometric Quick Release	10047, TLS81110047	$60.00	1	$60.00
5	Pro-E (Wildfire 5.0) License (school owns)		$5,000.00	0	$0.00
4	Radiosonde Weather Data Transmitter		$9.95	1	$9.95
6	Wellington 10047 Rope 3/16"x 50'' Solid Braid Nylon		$28.95	1	$12.00
7	Aluminum Cell Bar Stock		$20.00	1	$20.00
8	Hula-Hoop		$6.00	1	$20.00
9	10' x 10' Sheet Aluminized Mylar		$15.00	1	$15.00
10	Ceramic Sleeve		$40.00	1	$40.00
11	¼-20 Nylon Nut		$.50	4	$2.00
12	¼-20 Nylon Bolt		$1.00	2	$2.00
13	Carabiners		$11.00	2	$22.00
				Total	**$195.00**

Appendix E Schedule

		Week of			2-Feb	9-Feb	16-Feb	23-Feb	2-Mar	9-Mar	16-Mar	30-Mar	6-Apr	13-Apr	27-Apr	4-May	11-May
Task Name	Subtask	Responsible Party															
Payload Quick Release System	Redesign	Lin	Exp		25%	50%	100%										
			Act		20%												
	Manufacture		Exp					10%	25%	60%	100%						
			Act														
	Test		Exp									30%	60%	100%			
			Act														
Quick Opening Parachute System	Redesign	Troiano	Exp		20%	50%	100%										
			Act		20%												
	Manufacture		Exp					20%	50%	100%							
			Act														
	Test		Exp								10%	40%	70%	100%			
			Act														
Cut Down/Payload	Redesign	Donovan	Exp		50%	75%	100%										
			Act		25%												
	Manufacture		Exp					20%	50%	75%	100%						
			Act														
	Test		Exp									30%	60%	100%			
			Act														
Assembly		Team	Exp												100%		
			Act														
Project Documentation	Formatting/Layoutting	Team	Exp														
			Act		`												
	Writing	Team	Exp							25%	75%	100%					
			Act		`												
	Editting	Team	Exp								10%	20%	40%	75%	85%	95%	100%
			Act														
	Binding	Team	Exp										25%	50%	75%	95%	100%
			Act														

Appendix F Requirements Matrix

Taxonomy	Customer Signoff	Requirement Number	Requirement	Derived Requirements
Performance		1	Shall reach at lease 92000ft±15000ft.	
		2	The system must operate in Stratoshpere	Must operate to temperatures of -20 degrees C
		3	Shall release payload after reaching desired height and/or after balloon explodes.	
		4	Payload shall fall without any damages after being released.	The system shall be mounted in an enclosure to provide recovery of the system
Health and Safety		5	Shall satisfy FAA requirements.	Balloon can not, "be hazard to other persons or their property," while launching or landing. (Title 14-Section 101.7b)
				Must be equipped with at least two payload cut down systems that act independently of one another in accordance with FAA regulation Title 14 - Section 101.35a.
				Trailing antennas must break with less than 50 lbs of force at any point, or must be covered with colored streamers. (Title 14-Section 101.35c)
		6	Payload shall be retrievable.	Apparatus must communicate with ground trailer.
Functionality		7	Shall have battery life for at least 4 hours	

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