Team 12

Memo

To: Mr. Edwin Anderson

From: ME 476c, Team 12

cc: Jeb Duncan, Eddie Hoopingardner, Bryon Cole Middlebrook, Michael Orrill

Date: December 13, 2013

Re: Laser Pointer Project Proposal

The purpose of this communication is to provide information pertaining to the final design choice and estimate of total cost for the Laser Pointer project.

Two design choices were presented, a hand held design with proximity and angle of departure detection, and a tripod mounted turret with joystick control. Of the two designs, the tripod mounted turret with joystick control was chosen as the final design.

The hand held design presented considerable design challenges which could not be overcome in the timeframe given. These issues were compounded by uncertainties in the unknown operators of the device. The design required the operator to modify settings to provide a safe operating environment. The design team decided that the risk of injury was excessive.

The tripod mounted turret with joystick control design was chosen for numerous reasons with the primary concern being safety. The tripod mounting provides a superior safe operation location without the need for operator adjustment. This design also allows for custom star gazing horizons to be fabricated to exclude tall buildings or elevated platforms reducing user error.

The total cost of fabrication and testing for the final design is $ 1393.90.

Remote Control Laser Pointer

By
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Team 12

Project Proposal

Submitted towards partial fulfillment of the requirements for
Mechanical Engineering Design I – Fall 2013

Department of Mechanical Engineering
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Nomenclature

a = Acceleration $[m/s^2]$
A = Area $[m^2]$
C_1 = tabulated value [22]
C_p = Specific Heat of Air $\left[\frac{kJ}{kgK}\right]$
D_0= Outermost diameter [m]
dt = Change in time [sec]
dv = Change in velocity [m/s]
E = Modulus of elasticity [Pa]
F = Force [N]
h = Height $[m]$
h = Heat transfer coefficient $[W/m^2K]$
k = Thermal conductivity $[W/mK]$
k_{ins}= Thermal conductivity of insulation $[W/mK]$
k_{shell}= Thermal conductivity of Delrin $[W/mK]$
Nu_D = Nusselt Number
r_0 = Radius of cylinder $[m]$
r_1 = Inner radius of cylinder $[m]$
r_2 = Outer radius of cylinder $[m]$
r_3= Outer radius delrin $[m]$
$R_{cond\ (cyl)}$ = Thermal resistance cylinder $[m^2K/W]$
R_{conv} = Thermal Resistance $[m^2K/W]$
Re = Reynolds Number
T_i= Initial Temperature [K]
T_O= Temperature of Interest [K]
T_∞= Ambient Temperature [K]
V_f = Final velocity $[m$/s]
V_O = Initial Velocity $[m$/s]
ε = Strain [m/m, Dimensionless]
σ = Stress [Pa]
ρ = Density of Air $\left[\frac{kg}{m^3}\right]$
$\theta^* = \frac{(T_0 - T_\infty)}{(T_i - T_\infty)}$
δ_1 = tabulated value [22]

Abstract

Edwin Anderson, the Support Systems Analyst for the NAU Physics department, currently gives guided talks of the night sky using a 5 mW laser. A 5 mW laser is not power enough to effectively direct the attention of large groups of people because people not in Mr. Anderson's immediate vicinity cannot see the beam. A 20 mW laser would be powerful enough to direct large groups of people, but is too dangerous to be used as a handheld pointing device because of the risk of causing blindness. Mr. Anderson has requested that a device be designed that will use a 20 mW laser to point out stellar bodies while eliminating the possibility of shining the beam into someone's eyes.

The design must be capable of moving the laser across the sky at a minimum speed of 24° per second while maintaining a resolution of 0.5°. The design must not be longer than 48" in order to fit into the back of Mr. Anderson's vehicle. In addition, the design must weigh less than 100 lbs. Five general concepts were generated and analyzed to see which one would best meet the needs of Mr. Anderson.

Concept 1 is a hand held device with integrated electronics that would automatically shut the laser off if either the laser is less than 6' from the ground or the angle of the laser to the horizontal is less than 30°. Concepts 2-5 each utilize the same basic design. Each would use a tripod that would mount an electronically controlled two axis turret. The laser would be mounted to the two axis turret. The method of controlling the turret is what distinguishes concepts 2-5. Concept 2 uses a tablet with an application that would allow the user to touch or input constellations or names of stars. The turret would then automatically point the laser to the user input star or constellation. Concept 3 uses a six axis controller that could be tilted to change the direction the laser is pointing. Concept 4 would use an infrared remote controller that could be pointed at the stars. The angle and direction that the controller is pointed would then be mimicked by the turret to point the laser. Concept 5 uses a joystick to manually control the direction and angle of the turret.

Concept 5 was chosen as the final design because of its simple design and relatively low cost. For this design, the laser would have an insulated case to ensure it stays within the lasers operating temperature range, even in cold winter conditions. In addition there would be a solenoid attached to the case to allow manual control of the laser power switch while using the joystick. A switch trigger will be installed to allow the device to function properly even if Mr. Anderson decides to use a different model laser with the power switch in a different location. To ensure the safety of everyone surrounding the device, a mechanical blind will be installed to block the laser if it were to drop below 30° from the horizontal.

Thermal analysis was conducted to make sure the laser would stay within operating temperatures during cold winter nights. This analysis was done at steady state to find the heat loss from the laser. Which was found to be 0.35 Watts at steady state. Transient analysis was conducted and showed that under extremely harsh conditions, it would take ~25 minutes for the laser to drop below operating temperatures beginning from room temperature. Because of the conservative approach taken in the analysis, it was concluded that the laser housing insulation will be sufficient in maintaining proper operating temperatures.

The cost of all the components can be found in Table 4.1. A total cost of $1393.90 is estimated to complete the design. Which is well below the allotted $3000.00 budget for this project. All objectives have been met for the current Fall 2013 semester and all tasks are on schedule for next semester. The final product will be completed in April 2014.

1.0 Introduction

1.1 Project Summary

Mr. Edwin Anderson, the Support Systems Analyst for the NAU Physics department has requested a device to aid him in safely directing the attention of groups of people toward individual stars and constellations. He currently points out stellar bodies by hand with a 5 mW laser which is not powerful enough for people to see that are not in his immediate vicinity. He wants to use a 20 mW laser so that larger groups of people can see what he is pointing out, however it is too powerful to be operated by hand. If the beam were to make contact with someone's eye, instant blindness could occur.

1.2 Operating Conditions

The design must be stable and comfortably operable in relevant weather conditions, i.e. typical Flagstaff winter night conditions. The laser will not operate if it becomes too cold. The main location of use will be the NAU observatory grounds, and other locations in and around flagstaff such as Buffalo Park, Heritage Square and various elementary schools. A primary concern with various locations are differing minimum angles for the laser. For example, if the system was to be used near buildings, the system must not allow the laser to be shined into windows.

1.3 Constraints

The system must point out stellar objects within a reasonable time while retaining a resolution of 0.5°. A reasonable time was determined by considering the case in which the laser moves a maximum amount, generally 120°, in five seconds. This equates to an angular velocity of 24° per second or 0.4189 radians per second. The system must be able to fit into a small car and able to be transported by a single adult. This means the final inclusive design must have fully collapsed dimensions no larger than 48" X 12" X 12" so that it can fit into the cargo compartment of Mr. Andersons Subaru Outback. The design and all components must weigh no more than 100 lbs.

1.4 Research

Several different types of technology were explored as a possible solution to the client's problem. The different technologies researched were the use of accelerometers and gyroscopes, motion tracking technology, tablet app software technology, and infrared detection technology.

Accelerometers were first researched due to their wide range of applications. These devices, wired and wireless, are useful in systems where impact force, vibrations, angle of tilt or inclination are needed. A Monnit wireless accelerometer is an example of a specific component considered and has dimensions of 1.77 x 1.04 x 0.785 inches, has a frequency of 900MHz and has a 250-300 feet non-line-of-sight range [1]. Both angle of tilt and acceleration forces are applicable to concept generation.

Motion detection is another technology explored as a possible solution providing technology. Motion detection technology has been used to capture real life motion for animated characters in movies and video games. This technology is applicable to this project by enabling the client to control an object motion monitoring, and translating that motion to another device that moves a laser. Xsens is a company that manufactures motion tracking devices and software. The system available from Xsens has features that include no line of sight occlusion, easy installation and calibration for software, real time preview of motion feedback, 17 motion trackers, and up to 500 feet wireless range [2].

Interactive applications for tablets was another technology researched as a possible solution to the client's need. The idea was to integrate the technology used for interactive constellation applications into a new software that enables a user to click on the constellation, satellite, or planet which would send a signal to a turret and redirect a laser to the corresponding location in the sky. Since the application tracks the sky in real-time, the software would be constantly updated with the correct location of the objects in the sky. Star walk is such an application, developed by Vito Technology, and specifically tracks 20,000+ objects in the night sky [3]. The app can locate constellations, stars, planets, and galaxies without needed an internet connection. This technology could be integrated with a new application for tablets that moves a laser pointer when a user taps on the object of interest.

Infrared Detection technology is an additional technology that may serve useful in creating a system for the client. Infrared can be used to track two LED emitters in space and translate the information into a line or vector. Johnny Lee, a graduate from Carnegie Mellon University, created a simple infrared tracking system from the Nintendo Wii controller and two LED emitters. The software created for this system converted the LED movement into digital code which moves an image on a TV screen giving the impression of a three dimensional environment for the user [4].

1.5 QFD

The section below presents and explains the quality function deployment (QFD) created for this report. Table 1.1 below depicts the QFD table.

Table 1.1 – Quality Function Deployment

Quality Function Deployment		Engineering Requirements					
		Insulation / Isolation	Weight	Cost	Height	Angle of Departure	Motor/Servo
Customer Requirements	Aesthetics			X			
	Stability				X		
	Controllablity			X			X
	Safety (no eye contact)				X	X	
	Inexpensive			X			X
	Long Lasting						X
	Operable in all temperatures	X					X
	Collapsible				X		
	Rapid Response						X
	One Person Mobility		X				
	High Resolution						X
	Units	R	kg	$	m	°	rad/sec
		10	W < 45.35	< 3000	1.9812	30	π rad in 5 sec
		Engineering Targets					

Definitions of each customer and engineering requirement are as follows:

Engineering Requirements

Insulation / Isolation – For operation of the laser, the temperature must be maintained at or above 40° Fahrenheit. To accomplish this temperature maintenance, the case in which the laser will be placed must be insulated. Insulation / Isolation pertains to the resistance associated with this insulation.

Weight – The client must be able to transport the device unaided by others. Thus, the weight of the system is of concern. The Weight requirement is associated with the transportability of the system and is to not exceed 45.35 kg.

Cost – There exists a cost constraint on the project. The Cost requirement is associated with this cost and is to not exceed $3000.00.

Height – For safety, the device must be located above the average eye level of the individuals in the star talk. Thus, the Height requirement is not to be lower than 1.9812 meters from ground level.

Angle of Departure – To further ensure safe operation, limitation of the laser beam departure angle is necessary. This angle must be limited to 30° from the horizontal.

Motor / Servo – During star talks, the client frequently tracks fast moving objects across the night sky. To accomplish this task, a motor / servo speed of π radians in 5 seconds is necessary.

Customer Requirements

Aesthetics – The final device must be appealing to the eye so as not to distract from the star talks.

Stability – The customer requires the system to not easily topple in standard operating conditions, including temperatures at or above 0° Fahrenheit. Since the star talks will not be given in windy conditions, wind velocity is neglected.

Controllability – The client must be able to easily control the system and guide the laser beam to stellar objects in an efficient manner. Thus controllability, encompasses the system’s capability to accomplish this rapid motion.

Safety – Safety is the primary concern and reason for this project, thus this requirement is the most important.

Inexpensive – The overall system must not exceed the client’s budget of $3000.00, thus the components must be relatively inexpensive to accomplish this requirement.

Long Lasting – For the client to invest money into this project, the system must be of a lasting design. Long lasting is the requirement that dictates the longevity of the system.

Operable In All Temperatures – The system must be capable of operating in typical all season Flagstaff weather conditions.

Collapsible – The client transports the system in a Subaru Outback with a limited storage compartment. Thus, the system must fit in the storage compartment after collapsing.

Rapid Response - During star talks, the client frequently tracks fast moving objects across the night sky. The system must be response to the operator in a timely fashion to be capable of stellar object tracking.

One Person Mobility - The client must be able to transport the device unaided by others.

High Resolution - The client must be able to easily control the system and guide the laser beam to within ½° of stellar objects in an efficient manner.

2.0 Concept Generation

This section introduces and explains the alternative design concepts that were considered for this project. Two of these concepts were chosen for analysis and are described in greater detail in this section, the decision matrix used in aiding the choice is shown in Table 2.1 on page 14.

2.1 Concept Alternatives

Concept 1 Hand Held

The handheld design will function much like the existing laser from a user stand point. The laser and all supporting electronics will be housed in an insulated cylinder, see Figure 2.1a

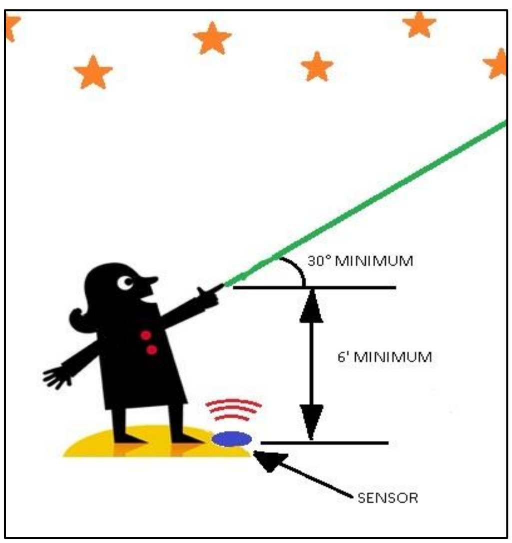


Figure 2.1a – Hand Held Design [5]

and 2.1b below. A system of gyroscopes and proximity sensors will ensure that the laser shuts off when pointed below an adjustable minimum angle or drops below a certain height. Concept 1 is thermally insulated to enable the laser to be used in Flagstaff winter conditions. For the thermal analysis see the thermal analysis section.

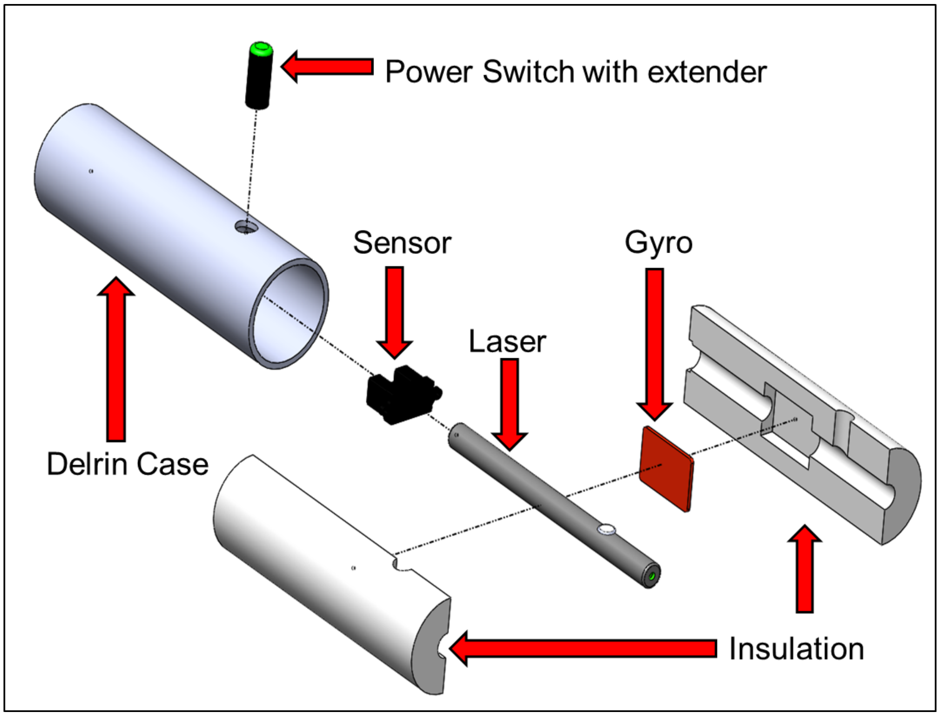


Figure 2.1b – Exploded View of Preliminary Design

As shown in the figure above, the proximity detector, gyroscope / accelerometer, and the laser are all contained in a two piece insulation shell. This shell will be inserted into a Delrin case which has been structurally analyzed in the structural analysis section. The design allows the user to remove the laser components for inspection and battery replacement, battery not shown for simplicity.

The power switch will be integrated into the circuitry of the gyroscope / accelerometer and sensor system. The switch will be activated by a switch extender. The switch extender is a mechanism which transfers force from the outer case, through the insulation shell and to the laser pointer's existing power switch. The signal from the power switch will be interrupted by the gyroscope / accelerometer circuitry so that at dangerous angles, the laser power is cut. By interrupting the power circuit, all safety features are contained in the programming of the device.

Concept 2-5 Overall Design

The next four concepts presented are composed of a similar overall design, the differences are focused on the control interface in which the user will operate the designed system.

The overall design for concepts one through four include an extendable tripod base, a two axis rotational turret, and the laser itself inside of an insulated enclosure and a control system for the user to aim the laser. The overall system design for concept 2 through 5 is displayed in Figure 2.2 below.

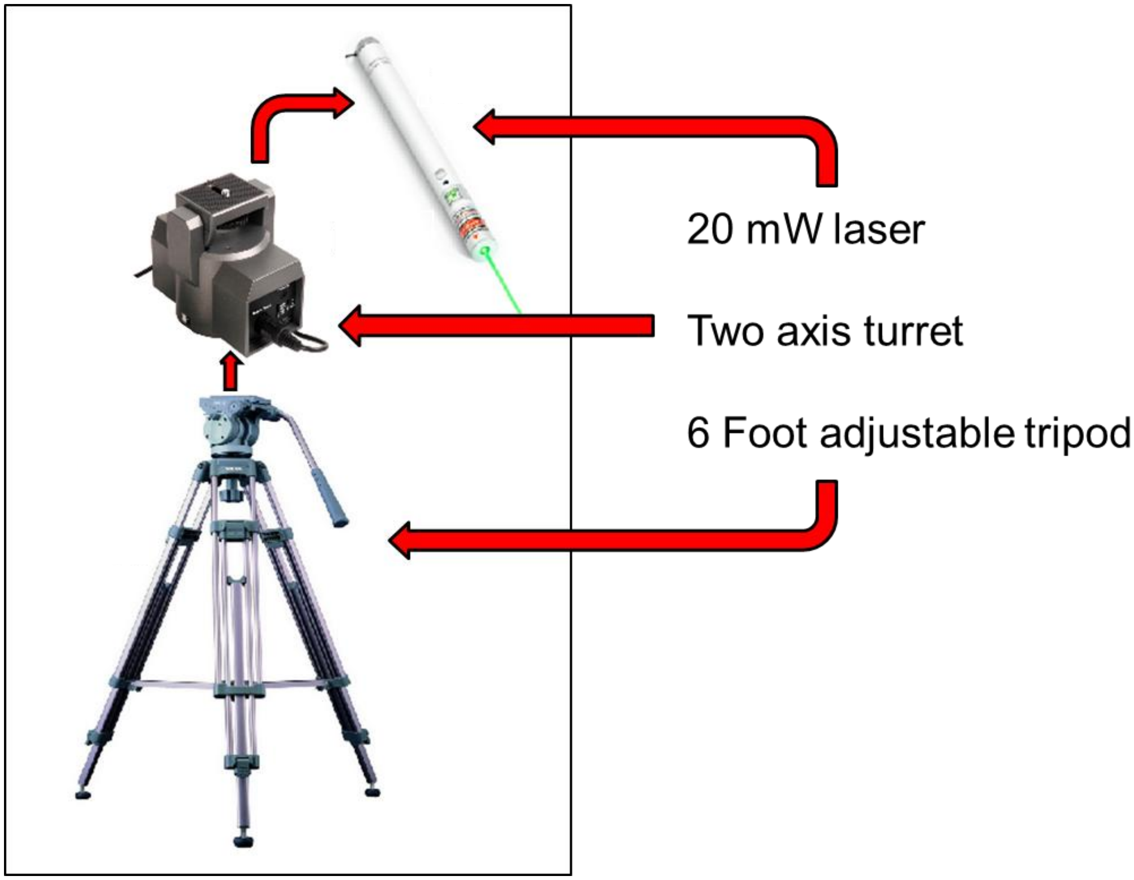


Figure 2.2 – Overall System for Concepts 2-5 [10],[11]

The tripod will to hold the laser at a minimum height of 6’5’’, the legs must be securely fastened to the ground with the use of spikes or something of equivalent strength and reliability. This feature is needed for high wind conditions or if someone were to walk into or trip over the legs the system would remain secure. The importance of this feature is twofold, first if the system were to fall over the laser could be shined into someone’s eyes, which is the main concern of the entire project. The second being avoiding damage to the equipment from fall impacts.

The two axis turret will be purchased, its control system modified. Many existing types are available. The turret will be used to physically aim the laser by moving in two spherical coordinate directions (i.e. theta and phi or a horizontal pan angle as well as a vertical elevation angle).

The laser’s enclosure will keep the laser within operating temperatures using insulation and will house the system responsible for toggling the laser on and off.

The purpose of the cylindrical blocks will be to block the laser from shining into a crowd at low angles. They will be mounted around the laser enclosure and interchangeable for differing minimum angles.

Concept 2 Tablet Control

A tablet computer with a star mapping application, Figure 2.3, will be modified so that the user may enter specific coordinates, or simply touch a stellar body on the screen and the system will communicate with the turret moving the laser to the specified location. The software for this control scheme could also make available an option for a pre-planned number of locations to point out, allowing the user to simply click through the stellar bodies he wished to speak about, keeping the option to pick a location manually intermittently.

Figure 2.3 – Tablet Computer Star Map Application [6]

Concept 3 Six Axis Smartphone Control

This control scheme uses six axis motion detection available in most smartphones that incorporate accelerometers. The phone itself will used as a point and click like remote control. The user will have control over toggles for on/off and follow/not follow, so that the user need not hold the phone, or six axis controller as seen in Figure 2.4, at the object to be pointed out constantly. He will be able to turn the laser on, move it into position, and have the laser stay there while he relaxes his arm, and turns the laser off as desired.

One advantage of designing this sort of control system is that there is already a considerable foundation of software and knowledge for developing custom applications like this one.

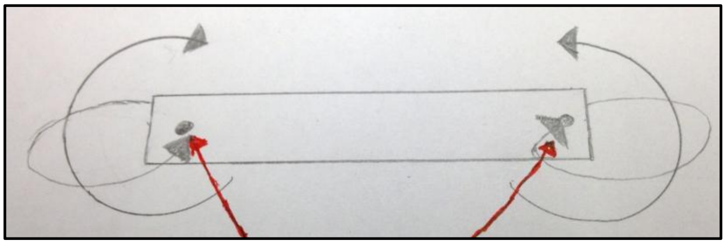


Figure 2.4 – 6 Axis Controller

Concept 4 Infrared Motion Sensing Control

Modern video game consoles, like Nintendo's Wii, have incorporated infrared motion sensing technology into their control schemes. This design concept aims to adapt and modify this existing technology to control our laser turret. For example a Wii remote, see Figure 2.5, would be used as a remote control and would be operated similarly to concept 3's six axis remote in the sense of point and click and toggling. However the system would function quite differently.

Two points in 3-D Cartesian coordinate space are needed to determine a line. The laser's location will serve as the origin and one point could be detected on the user's shoulder and another from his hand as he points to a stellar body. The distances from the turret to the two points would be determined and a line with angles relative the lasers current position can be calculated. The laser could then be moved into position by matching the angles acquired from the two points.

Figure 2.5 – Wii Remote and Sony Ball Controller [7],[8]

Concept 5 Joystick Control

This design incorporates a tripod and joystick, see Figure 2.6, controlled video camera turret to hold the laser at a safe height of 78 inches and move it into the desired positions. Similar to concept one, the laser itself will be housed in an insulated cylinder, this cylinder will then be mounted to the camera turret. There will also be a cylindrical blind, made likely from sheet metal that fits around the turret and blocks the laser if it should drop below a certain angle.

Figure 2.6 – Joystick Control [9]

2.2 Concept Selection

Table 2.1 is a design matrix consisting of the five potential design choices discussed above. The following paragraphs will describe how each category and weight pertains to each design alternative and why each score was chosen. This discussion will start with a description of what each design criteria entails, and how it can impact each design alternative. The weight, weight percent, score, and visual score will then be discussed, followed by the final design choice and rationale. Listed below are the individual criteria by which each design was assessed.

Table 2.1 – Decision Matrix

<table>
<tr><td>Weight</td><td>5</td><td>3</td><td>3</td><td>2</td><td>5</td><td>18</td><td rowspan="2"></td></tr>
<tr><td>Weight Percent</td><td>28%</td><td>17%</td><td>17%</td><td>11%</td><td>28%</td><td>100%</td></tr>
<tr><td>System Design</td><td>User Control</td><td>Mechanical Design</td><td>Manuverability</td><td>Cost</td><td>Electrical Design</td><td>Score</td><td>Visual score</td></tr>
<tr><td>Hand Held</td><td>5</td><td>1</td><td>5</td><td>5</td><td>3</td><td>3.8</td><td>||||||||||||||||||||||||||||||||||||||</td></tr>
<tr><td>Tablet Control</td><td>3</td><td>3</td><td>3</td><td>1</td><td>2</td><td>2.5</td><td>|||||||||||||||||||||||||</td></tr>
<tr><td>Smart Phone Control</td><td>5</td><td>3</td><td>3</td><td>3</td><td>2</td><td>3.3</td><td>|||||||||||||||||||||||||||||||||</td></tr>
<tr><td>Motion Sensor</td><td>4</td><td>3</td><td>3</td><td>3</td><td>1</td><td>2.7</td><td>|||||||||||||||||||||||||||</td></tr>
<tr><td>Joystick Control</td><td>2</td><td>3</td><td>3</td><td>5</td><td>5</td><td>3.5</td><td>|||||||||||||||||||||||||||||||||||</td></tr>
</table>

- ***User Control*** is the design criteria which describes the ease in which the operator can control the device against the backdrop of the night sky. A score of 1 would resemble a design that is difficult to place the laser where it is needed in the sky, as well as taking a long time to do so. A score of 5 would be a system that comfortably and quickly shines the laser to the desired location.
- ***Mechanical Design*** is the design criterion which describes any part in the system that is subjected to mechanical forces such as those due to acceleration, shear, and torque. A score of 1 would be a system that will be difficult to design and develop. A score of 5 would be a system that could be bought off the shelf and implemented with minimal effort.
- ***Maneuverability*** is the design criteria which describes the ability of the user to transport the device from one location to another without the need of assistance. This criterion also incorporates the ability of the design to be reduced in size for ease of transport in vehicles with small cargo compartments. A score of 1 would be a system that an adult would struggle to pick up and move around. A score of 5 would be a system that would be light and easy to carry.
- ***Cost*** is the design criterion which governs the feasibility of the potential design to remain at or below the project budget. A score of 1 would be a system that uses up all available funds to complete the project. A score of 5 would be a system that would be well under budget.
- ***Electrical Design*** is the design criterion which describes any electrical component in each design alternative. This encompasses any electric motors, servos, switches, accelerometers, etc. which may be present in each design. This criterion also includes any software that would need to be developed. A score of 1 would be a system which uses many servos and controllers that would must be coded. A score of 5 would be a system that requires no additional servos or switches.

Weight

The top row in Table 2.1 shows the weight assigned to each design criterion. The scale ranges from 1 to 5, with 1 being the least important and 5 being the most important. The weights of each design criteria starting with User Control and ending with Electrical Design are explained in detail below for each design alternative.

User Control

Due to the danger associated with a 20mW laser, the user must be able to have full control at all times. For instance, if an airplane were to fly toward the laser beam, the user must be able to move the laser or shut the beam off in a short time period. All of the design alternatives meet this requirement; however, some of the alternatives exhibit more control than others. The scoring rationale for each alternative concerning user control is as follows:

- **Hand Held** – This design alternative was given a score of 5 for user control. This alternative will be controlled with physical contact from the user, thus the user will have complete control of the system at all times.
- **Tablet Control** – This alternative was given a score of 3 for user control because the user will have to enter in coordinates or touch a different location on the screen. This act will take a few moments thus the user does not have complete and immediate control of the system.
- **Smart Phone Control** – This design was given a score of 5 due to the user motioning the laser with a smart phone. The user will have immediate movement capability thus complete control of the system.
- **Motion Sensor Control** – This design was given a score of 4 due to the motion sensor software lag time. This lag time would hinder rapid response of the laser thus the user would not have immediate control of the system.
- **Joystick Control** – This design was given a score of 2 because the user would have to move the laser by means of a joystick controller rather than pointing at a destination. The user would have to become acclimated to operating a joystick to maneuver the laser to a position within the specified accuracy of 0.5°.

Mechanical Design

The mechanical design criterion for each design alternative is as follows:

- **Hand Held** – This design must incorporate the laser, an angle sensing device, and a proximity detector, in one case or housing. This housing must be designed, analyzed, and constructed for the device to function properly. Since design and manufacturing are time intensive, the Hand Held design alternative was given a score of 1.
- **Tablet Control** – This design will have few components to be modeled, or machined, and a small non-structural housing for heat retention, thus this alternative was given a score of 3.
- **Smart Phone Control** – This design will have few components to be modeled, or machined, and a small non-structural housing for heat retention, thus this alternative was given a score of 3.
- **Motion Sensor Control** – This design will have few components to be modeled, or machined, and a small non-structural housing for heat retention, thus this alternative was given a score of 3.
- **Joystick Control** – This design will have few components to be modeled, or machined, and a small non-structural housing for heat retention, thus this alternative was also given a score of 3.

Maneuverability

The maneuverability of the device is a critical design parameter because the user must transport the device without the aid of other personnel. Scores for of each design alternative are as follows:

- **Hand Held** – This design consists of a case or housing with all system components mounted inside. Since the system must be light weight for the user to be able to lift the device one handed, the Hand Held design was given a score of 5.
- **Tablet Control** – This design consists of a tripod mounted laser turret and a tablet. Since these items can be easily carried by one person yet heavier than the Hand Held design, the Tablet Control design was given a score of 3.
- **Smart Phone Control** – This design consists of a tripod mounted laser turret and a smart phone. Since these items can be easily carried by one person yet heavier than the Hand Held design, the Smart Phone design was given a score of 3.
- **Motion Sensor Control –** This design consists of a tripod mounted laser turret and a motion sensing device. Since these items can be easily carried by one person yet heavier than the Hand Held design, the Motion Sensor design was given a score of 3.
- **Joystick Control** – This design consists of a tripod mounted laser turret with a joystick attached via cable. Since these items can also be easily carried by one person yet heavier than the Hand Held design, the Joystick Control design was given a score of 3.

Cost

The cost of each design must remain below the project budget of $3000. The cost parameter was evaluated by researching rough component costs for each design. The scores for each design are as follows:

- **Hand Held –** This design has some unknown costs associated with it; however, the overall cost was determined to be less than $1500, thus a score of 5.
- **Tablet Control –** This design requires a tablet computer to operate an app to control the laser. Tablets can be very expensive, thus the overall cost was determined to be the full budget of $3000 with an assigned score of 1.
- **Smart Phone Control –** This design requires a smart phone to operate an app based off of the accelerometers in the phone, thus the overall cost was determined to be $2500 with a score of 3.
- **Motion Sensor Control –** This design requires several motion sensors and a sensor reading device. The overall cost was preliminarily estimated to be $2500, thus given a score of 3.
- **Joystick Control –** This design requires few parts yielding a total cost of $1500 warranting a score of 5 for this design.

Electrical Design

Each design must use electronics to accomplish the project. This section describes the score and the rationale behind the score assigned to each design.

- **Hand Held** – This design will use accelerometers and a small digital logic controller to operate the on/off switch on the laser. These electronic components will be simplistic to construct, but difficult to make accurate, thus a score of 3 was assigned to the design.
- **Tablet Control –** This design will be difficult to write and integrate an app to control the laser. This difficulty is reflected in a score of 2.
- **Smart Phone Control** – This design will also be difficult to write and integrate an app to control the laser. This difficulty is reflected in a score of 2.
- **Motion Sensor Control –** This design will incorporate motions sensors and a receiving device with a currently unknown difficulty level of integration. The best estimate of electronic difficulty yielded a score of 1.

- **Joystick Control** – This design will consist of an on/off switching device for the laser mounted to the joystick, thus the simplicity of this design yielded a score of 5.

Weight Percent

The weight percent row is the percentage which the weight represents out of a total of 18.

Score

A score was assigned to each design concept parameter for each design alternative. The score column is the total weighted score for each design. The highest score is the best design based off of the design parameters.

Visual Score

The visual score is a bar graph visual representation of the score column and is included for fast visual reference only.

2.3 Chosen Designs for Analysis

The final design choices are based off of the values obtained in the decision matrix, Table 2.1. Based on the assigned values, the Hand Held design will be the best design choice to fulfill the project parameters. This design will be highly controllable, maneuverable, incur the least cost, and incorporate the fewest electronics. However, the electronics may prove to be too complex to reliably incorporate. The next best option is concept five, the tripod and turret design with a joystick controller. Both of these concepts were analyzed, this analysis is presented in the following section.

The housing containing the laser will be constructed of Delrin. A stock piece of Delrin will be machined to the specifications in the engineering drawings provided in Appendix A. The Northern Arizona University (NAU) machine shop will machine the case and the cap of the housing. The solenoid cover will be rapid prototyped in the NAU rapid prototyping lab from ABS. Figure 2.7 below shows the components of the proposed design.

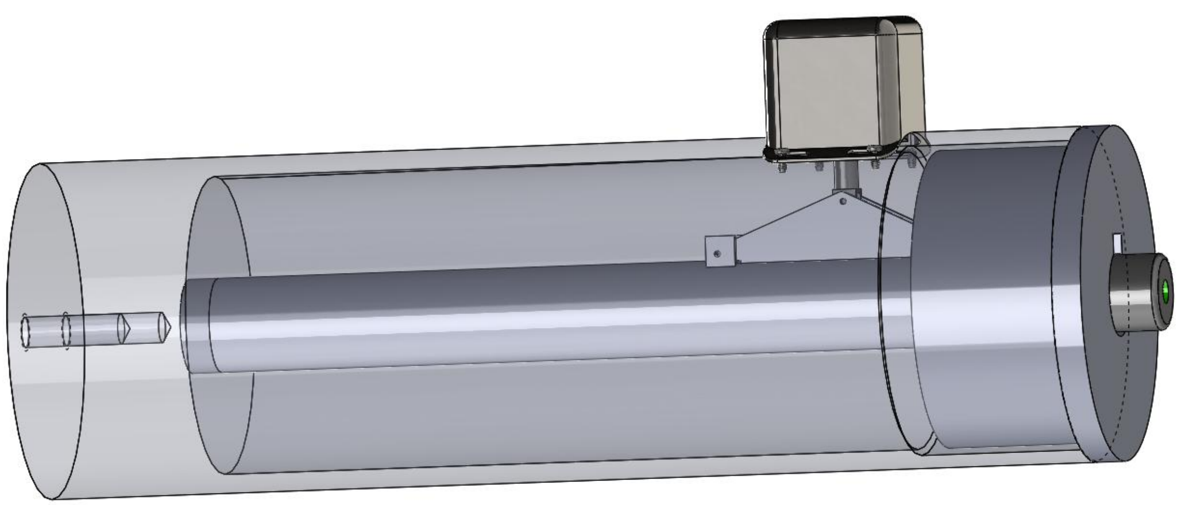


Figure 2.7 - Tripod Mounted Laser Housing

The image above shows the locations of the internal components for the design. Each of these components will be briefly described in the following paragraphs.

The outer case will be machined out of Delrin. Figure 2.8 below shows the solenoid mounting location and the hole necessary for the actuator to contact the switch ramp as well as the turret mounting holes. The solenoid will be mounted to the outer case with two M1.4 x 0.3 – T5 drive screws (not shown). These screws will be further analyzed when the mass of the solenoid is known. However, these screws are often used to install electrical components in soft metal, and thus will be more than adequate for the solenoid attachment in Delrin. The turret mounting holes are tapped with $\frac{1}{4}$ inch NCP threads. Bolts will be placed through the mounting slots on the turret assembly and into these holes. Grade 5 steel bolts are capable of 6.15E+05 $\frac{N}{m^2}$ of tensile stress. The mass and motion of the turret and laser assembly will not produce a fraction of this maximum stress. Also, the turret assembly is rated for 5 pounds (2.26796 kg). Consequently, no force analysis was conducted on these bolts or the turret assembly.

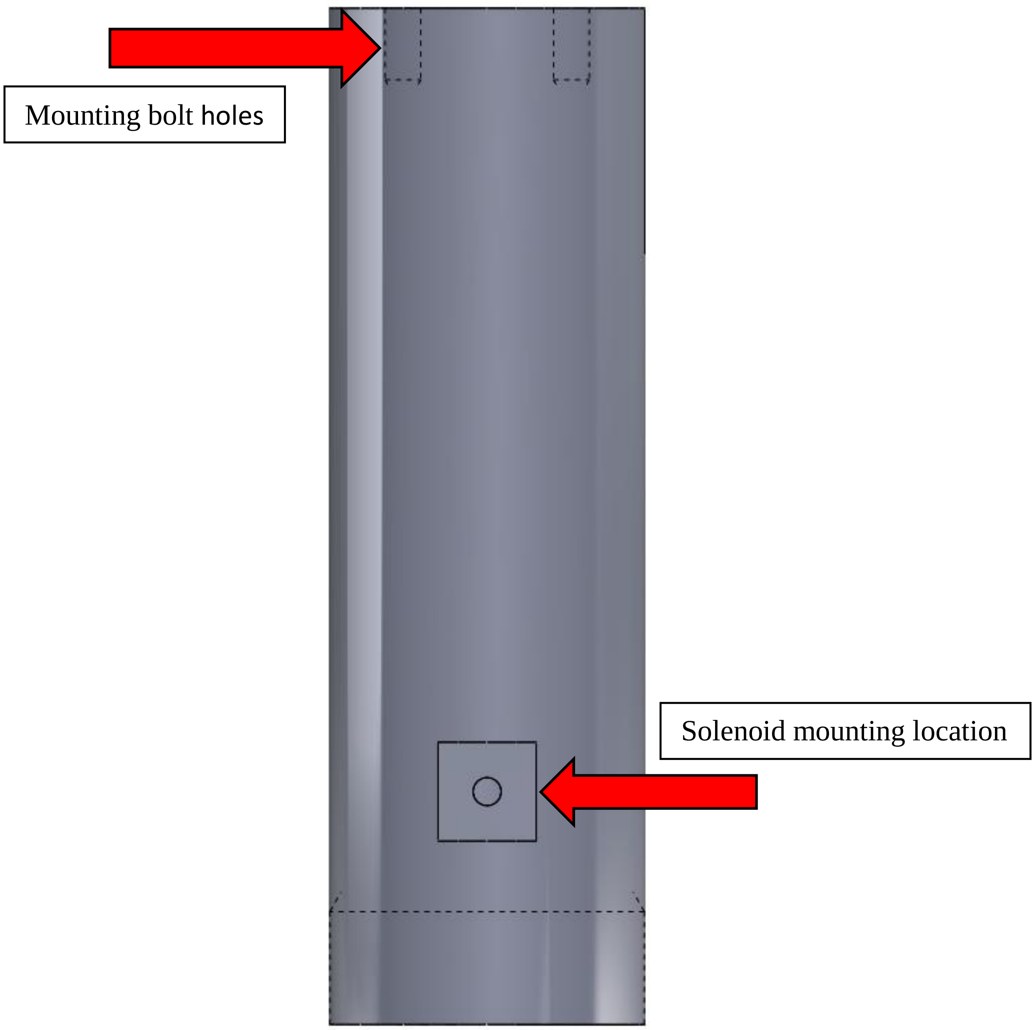


Figure 2.8 - Outer Case with Solenoid Mounting Location Shown

The inner tube rests in a recess in the bottom of the outer case. The recess is shown in Figure 2.9 below.

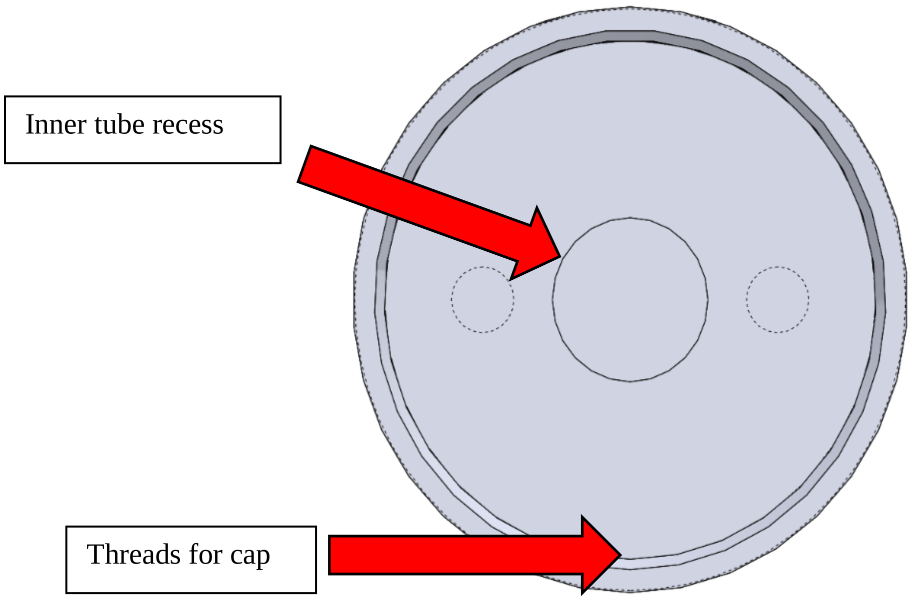


Figure 2.9 - Outer Case with Inner Sleeve Mount Cutout Shown

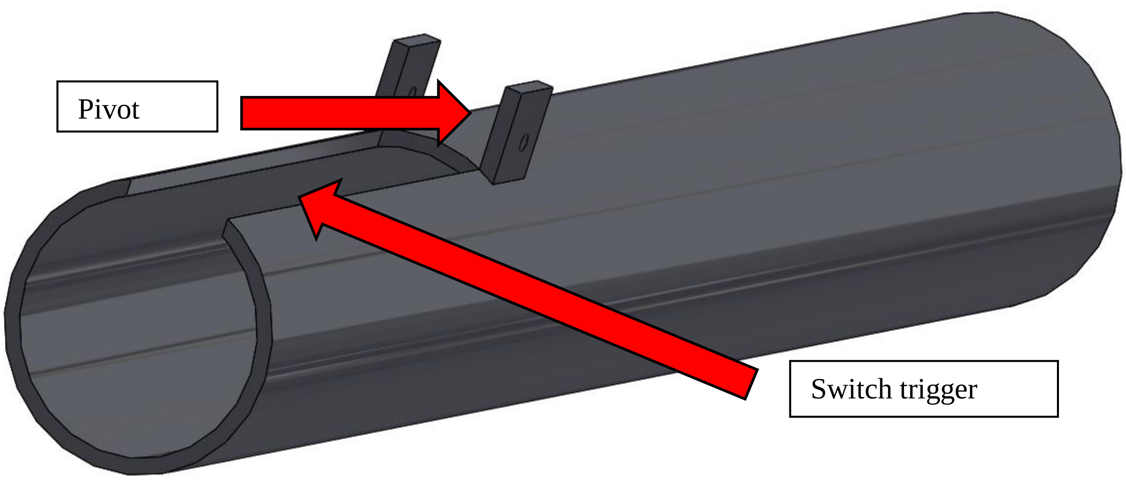


Figure 2.10 - Inner Tube with Switch Trigger Mounting Tabs

The inner tube is the compartment where the laser will be placed, see Figure 2.10 below. This compartment is designed such that a variety of laser models can be placed inside. It will be constructed from $\frac{1}{2}$ inch electrical conduit. This material is very inexpensive, strong, and easily machined. The inner tube will also contain pivot tabs, and a groove for the switch trigger, explained below.

The switch trigger is a device necessary to accommodate several laser models. Not all laser are designed with the power switch in the same location. Thus it is necessary to design an actuator capable of operating switches in various locations. The switch trigger distributes the

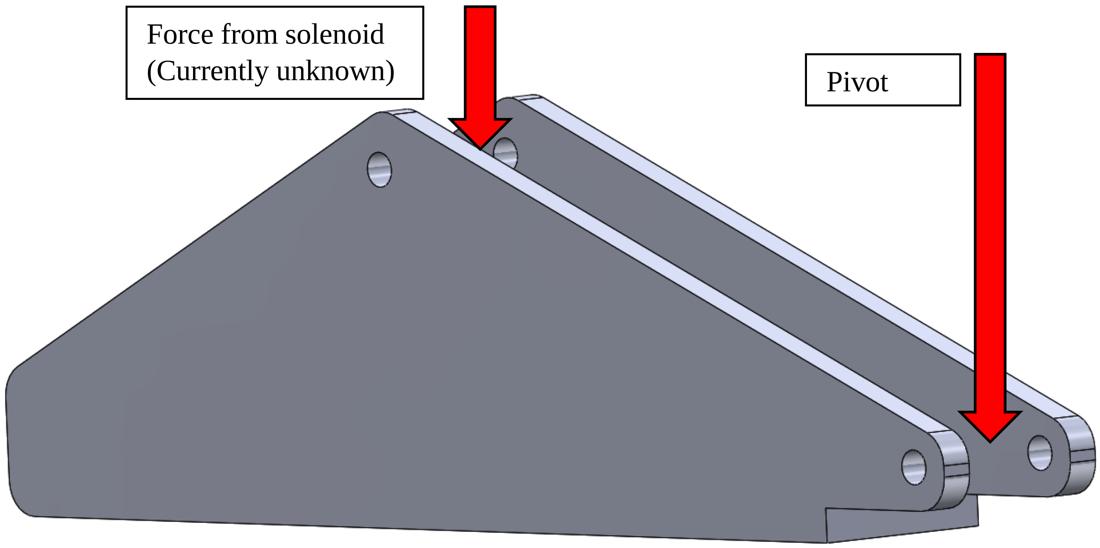
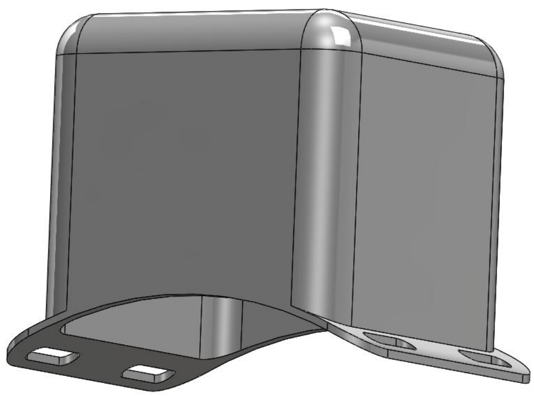


Figure 2.11 - Switch Trigger, with Pivot Side Facing

solenoid actuation over a longer functional distance. A specialized solenoid will be required for this application. A manufacture has been contacted for specifications; once received, force calculations can continue on the switch trigger and inner tube. Figure 2.11 below shows the switch trigger with the pivot point toward the viewer. The switch trigger pivots in the switch trigger groove via the pivot point tab pin welded to the inner tube. When the solenoid is inactive, the switch trigger will be elevated such that the power switch for the laser is not depressed. When the solenoid is actuated, the switch trigger will depress the power switch, turning on the laser.

The solenoid is not a weather resistant device. To ensure that the solenoid will remain operational in outdoor conditions, a cover must be designed and constructed. Figure 2.12 below shows the solenoid cover with the mounting slots visible. This cover has not yet been analyzed because various other covers are still being investigated. The cover design shown is representative of any electronics cover. If a purchased option cannot be found, then the design presented here will be rapid prototyped in the NAU rapid prototype lab. The rapid prototyping materials range between ABS, and polycarbonate. These materials will be tested and analyzed before making the final design choice.

Figure 2.12 - Solenoid Cover



To cap the internal components and support for the inner tube on the upper end, a Delrin cap was designed, see Figure 2.13 below. The cap is currently modeled with threads that match the outer case opening; however, the threads may be replaced with set screws for ease of access to the internal components. If the threads are replaced, the outer case will no longer have the step shown toward the opening. The step shown in Figure 2.13, is a result of the threads and would no longer be necessary. The determining factor in this decision will be the availability of the NAU machine shop to machine the necessary threads. A discussion with the machine shop operators will ensue in the week beginning on November 12th. Another design component in the cap is the switch groove. This groove is necessary for the power switch to enter the inner tube. This notch is aligned with the notch in the inner tube and the switch trigger.

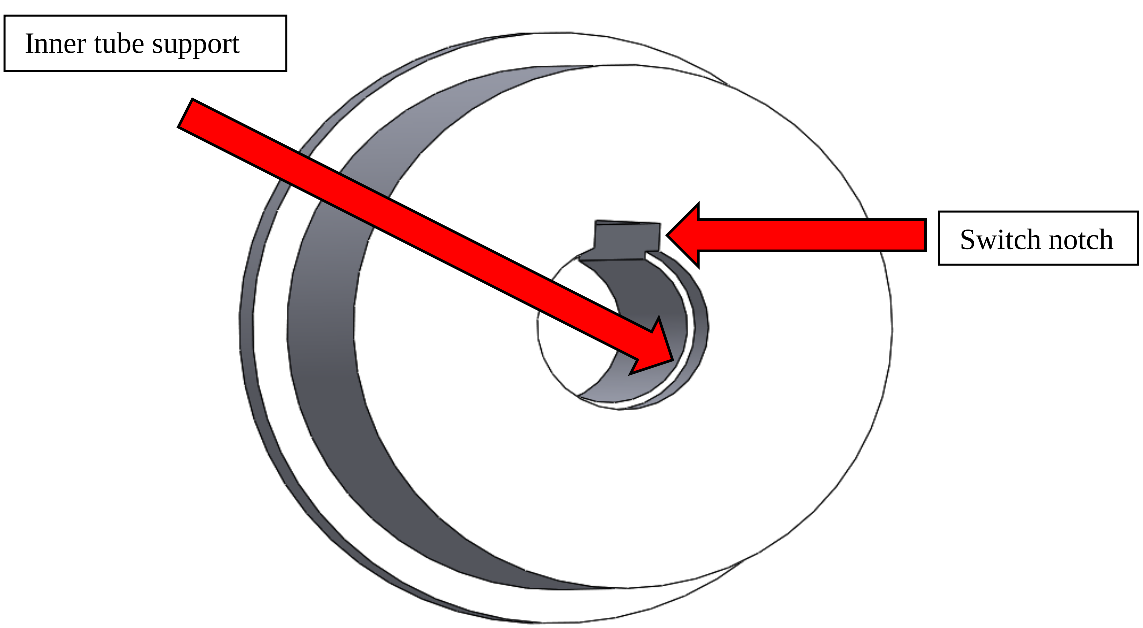


Figure 2.13 – Delrin Cap

The tripod for concept five will be a purchased component. This component is capable of height adjustment from 34 inches to 78 inches. This adjustability poses a potential safety concern for the laser operational height. One solution could be to remove the locking mechanisms and implement holes and pins to make only the operational height allowable. Mounting of the turret to the tripod will be accomplished via a camera quick connector capable of handling an 8 pound camera.

An image of the cylindrical blind is shown in Figure 2.14 below. Its purpose is to create a false horizon which will impose a lower limit on the angle that the laser may shine.

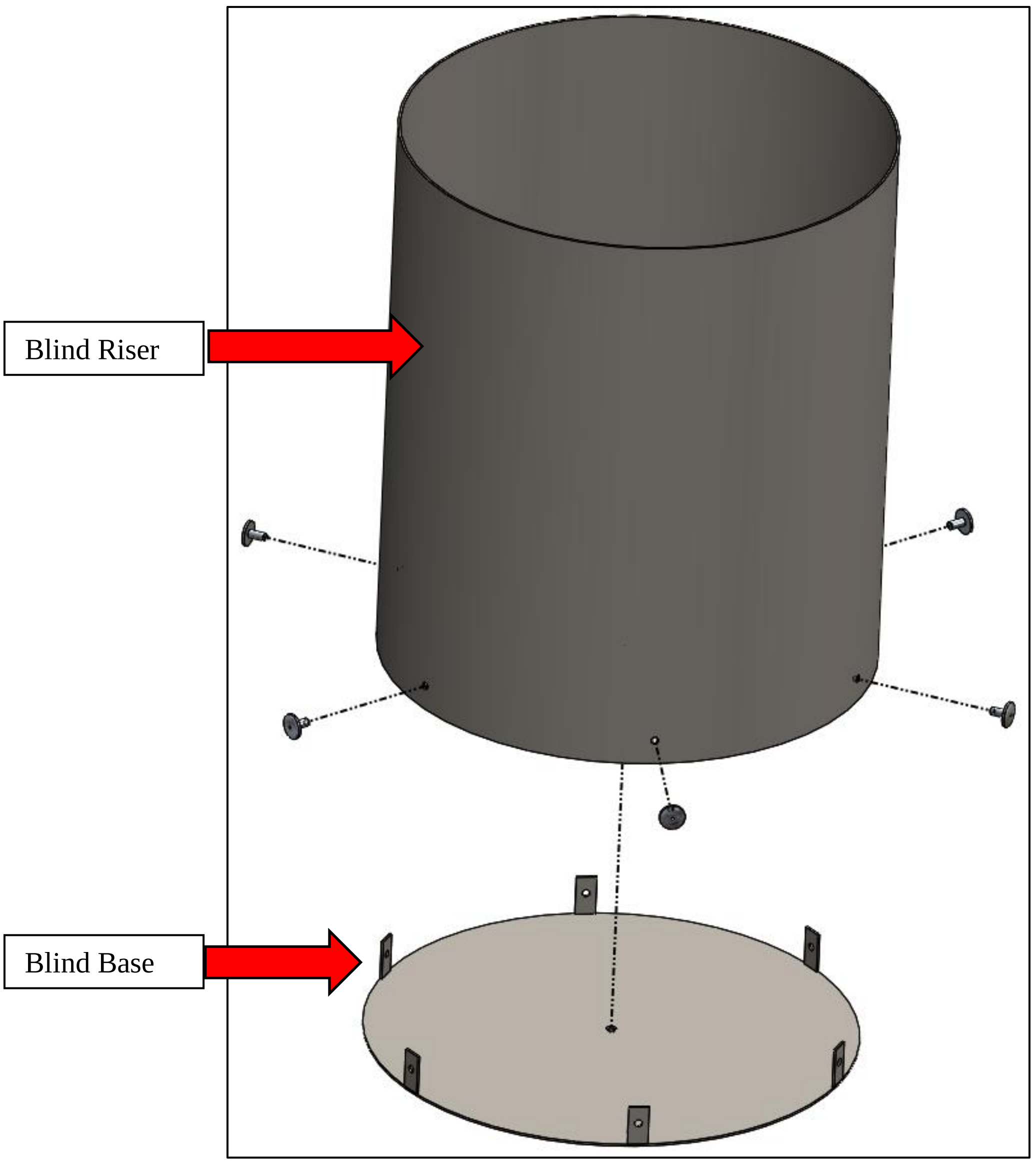


Figure 2.14 – Cylindrical Blind

Both designs will use a small electric heating element inside the laser housing to maintain the lasers temperature within operating limits.

Manufacturer specifications for the tripod and turret we have selected for concept 5 are shown below in Tables 2.2 and 2.3.

Table 2.2 – Turret Specifications

Physical		**Electrical**	
Dimensions (WxHxD)	10" x 14" x 4"	Power Supply	110-230 VAC to 12 DC 1000 MA
Weight	4.5 lbs.	Connector	5.5 X 2.1 center Pos.
Cable Length	12 Feet	**Capabilities**	
Mounting	Upright or Inverted	Slowest Speed	1 rev in 10 minutes
Mounting Plate	3" x 3" with 3/8" hole	Max Speed	4 RPM @ 12 V
Controls		Pan Revolution	360° +
2 Axis Thumbstick P/T	30/30 degrees	Tilt Revolution	360° +
Ramp	none	Capacity	5 ponds/2.3 kilos
Linear	none		
Logarithmic	fixed		
Speed Limit	0 to 100%		

Table 2.3 – Tripod Specifications

Overall Specifications	
Max height	78" (1.98 m)
Min height	31" (0.7874 m)
Folded length	34" (0.8636 m)
Center post adjustment	15" (0.381 m)
Weight	9 lb (4.08 kg)
Max Tripod load	25 lb (11.34 kg)

A picture of the exploded view of the complete housing for the tripod design can be found in Figure 2.15 below.

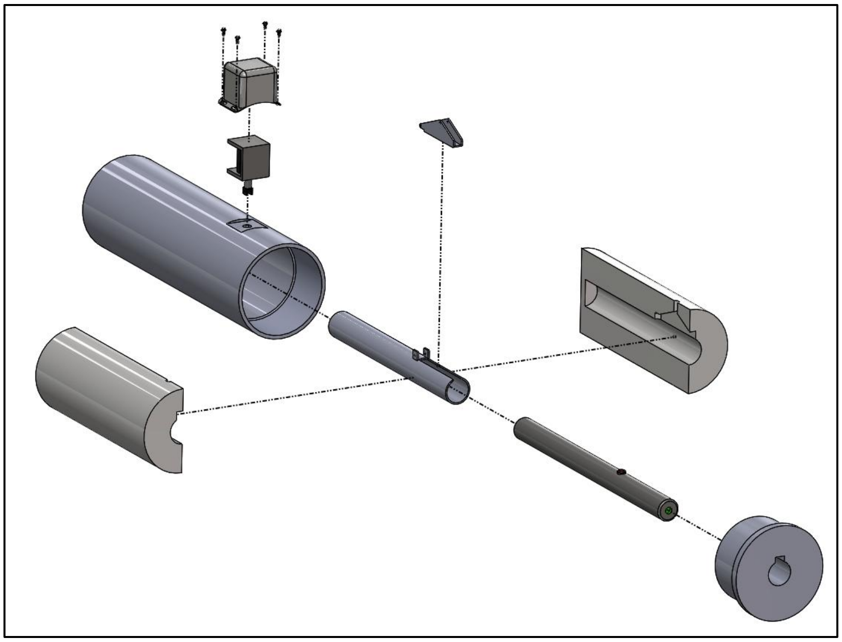


Figure 2.15 – Exploded View of Housing for Tripod Design

The tripod selected for concept 5 is shown in Figure 2.16 below.

Figure 2.16 – Camera Turret, Laser Mounting Slots Shown [10]

The tripod selected for concept 5 is shown in Figure 2.17 below.

Figure 2.17 – Tripod [11]

3.0 Engineering Analysis

Engineering analysis is required to fully understand the system being designed for our client, Mr. Anderson. Two designs have been proposed to our client for approval and both will be analyzed, the results of this analysis is presented in detail in this section. The analysis will investigate structural, fluid, and thermal effects on our designed systems and discuss the implications of our findings.

3.1 Structural Analysis

For concept 1, structural analysis consisted of developing a model that describes the event of dropping the devise from a height of six feet onto solid ground. The system must be able to withstand an impact with the ground sustaining minimal permanent deformation to the enclosure and no damage to internal electrical components. The results for this model are shown below.

3.1.1 Structural Results

Structural analysis was conducted for the outer casing of the handheld design using two different materials. The two options were 6061-O Aluminum and Delrin 100. The purpose of the structural analysis was to estimate the impact force the handheld unit would sustain if dropped from six feet (1.83m) and calculate whether or not the outer casing would undergo plastic deformation. First, the velocity that the unit hits the ground at from six feet was calculated using the kinematic equation, Equation 1, listed below.

$$V_f{}^2 = V_O{}^2 + 2 * a * h \quad (1)$$

Where:

V_f = Final velocity [m/s]
V_O = Initial Velocity [m/s]
a = Acceleration [m/s^2]
h = Height [m]

The calculation for the velocity just before impact when dropped from 6 feet is listed below.

$$V_f{}^2 = (0)^2 + 2 * \left(9.81\frac{m}{s}\right) * 1.83m$$

$$V_f = 5.99\frac{m}{s} \approx 6\frac{m}{s}$$

In order to calculate the force that is exerted at impact, the acceleration the unit undergoes during impact must be calculated. The equation for acceleration is listed below.

$$a = \frac{dv}{dt} \quad (2)$$

Where:

a = Acceleration [m/s^2]
dv = Change in velocity [m/s]
dt = Change in time [sec]

This calculation is only an estimation of the actual acceleration the unit would undergo. Therefore, it is assumed that the time is takes for the unit to go from 6 m/s to 0 m/s is 0.1 seconds. This is a rough estimate that was generated by dropping similar weighted objects from 6 feet on a hard concrete surface and estimating the time it took for the object to bounce.

$$a = \frac{(6-0)\,{}^{m}/_{s}}{(0-0.1)s} = 60\,{}^{m}/_{s^2}$$

Once the acceleration the unit undergoes during impact was calculated, the force was calculated using Newton's 2nd law of motion.

$$F = ma \quad (3)$$

Where:

F = Force [N]
m = Mass of object [kg]
a = Acceleration [m/s^2]

To make this calculation the mass of each option, Aluminum and Delrin, had to first be calculated. The volume of the outer case was calculated by modeling the case in SolidWorks and looking up the volume under the "material properties". Volume calculated and weight of each option is listed in Table 3.1 below.

Table 3.1 – Casing material properties

	Aluminum (6061-O)	Delrin (100)
Volume [cm^3]	117.6	117.6
Density [g/cm^3]	2.70	1.41
Weight [g]	317.4	165.7

In addition to these weights, each design option shares all other components. A list of the components and their respective weights is listed in Table 3.2 below.

Table 3.2 – Mass of components

Component	Mass [g]
Polystyrene (Expanded)	4.7
Gyro / Accelerometer	4.0
Proximity Detector	5.0
Heating Element	12.0
Batteries (2 x AAA)	23.0
Laser Pointer	26.0
Total	**74.7**

The weights were then totaled and forces calculated.

Aluminum case: $$F = (0.3921\ kg) * \left(60\ {}^{m}/_{s^2}\right) \approx 23.5\ N$$

Delrin case: $$F = (0.2404\ kg) * \left(60\ {}^{m}/_{s^2}\right) \approx 14.4\ N$$

For the Aluminum, any stress that exceeds .02% of the yield strength will cause plastic deformation. Using the known properties of Aluminum 6061-O, this stress was calculated using the relationship below.

$$\sigma = E\varepsilon \tag{4}$$

Where:

σ = Stress [Pa]
E = Modulus of elasticity [Pa]
ε = Strain [m/m, Dimensionless]

The modulus of elasticity for Aluminum is 68.9 GPa. Using this, the minimum stress to cause plastic deformation was calculated.

$$\sigma = (68.9\ GPa)(.0002) = 13.8\ MPa$$

For Delrin 100, the modulus of elasticity is not listed in any sources. The modulus of elasticity was estimated by analyzing the stress-strain curve of Delrin at room temperature (23°C) as seen in Figure 3.1 below.

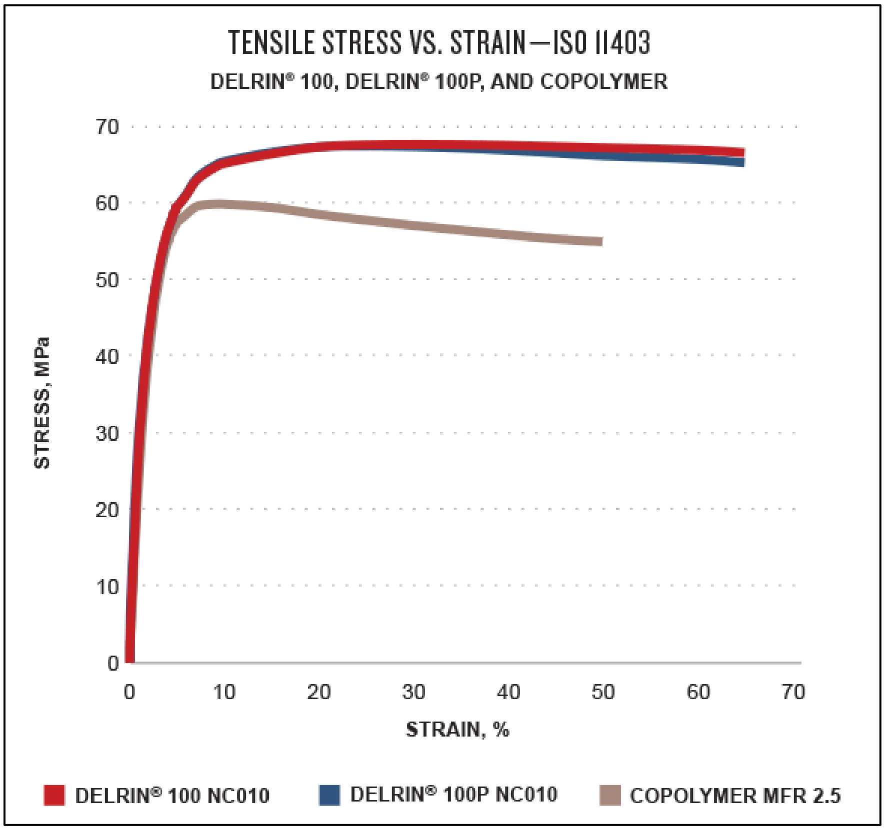


Figure 3.1 – Stress-Strain Curve Delrin 100 [21]

Listed below is the calculation for the modulus of elasticity.

$$E = \frac{(60\ MPa)}{(.03\ \frac{mm}{mm})} = 2\ GPa$$

The modulus of elasticity for Delrin was estimated to be 2 GPa. Using this information, the stress necessary to cause plastic deformation was calculated.

$$\sigma = (2\ GPa)(.0002) = 0.4\ MPa$$

Finally the actual stress the unit will undergo if dropped from six feet (1.83m) can be estimated. The way this is calculated is to calculate what area will undergo the stress when the unit is dropped and see if this is realistic. This area is calculated using the relationship to stress.

$$\sigma = \frac{F}{A} \tag{5}$$

Where:

σ = Stress [MPa]
F = Force [N]

$A =$ Area $[m^2]$

The area necessary to undergo stress is calculated for each Aluminum and Delrin. The force and stress used in the calculation were calculated above.

Aluminum: $$13.8\ MPa = \frac{(23.5\ N)}{A}$$

$$A = 0.017\ cm^2$$

Delrin: $$0.4\ MPa = \frac{14.4\ N}{A}$$

$$A = 0.36\ cm^2$$

These calculated areas represent the maximum area that the force from the impact can be spread across. If the same force is exerted on a smaller area, there will be plastic deformation. The area for the aluminum is significantly smaller than the area for the Delrin. Simply, the aluminum case is much stronger and less likely to plastically deform if dropped. If either unit is dropped and lands either on along the length of the unit or on the top of the unit, there will be no plastic deformation. However, there is a possibility of plastic deformation if the unit is dropped and lands on one of the corners along the top or bottom for both the aluminum and the Delrin. The conservativeness of these calculations needs to be taken into consideration to make any decisions about which material should be used.

A time of 0.1 seconds was assumed for the calculation of acceleration. This was assumed by dropping the unit on hard concrete. It is known that Mr. Anderson often conducts his guided talks in the forest or on grassy fields. This makes the calculation of 0.1 seconds for the unit to come to complete stop very conservative.

It also must be taken into consideration the type of stress the unit would undergo if it were dropped. All calculations were based on the tensile strength of Delrin and Aluminum. However, the yield strength of Delrin is almost double in compression than it is for tension; 60MPa in tension vs. 125MPa in compression. This can be seen in Figure 3.2 below.

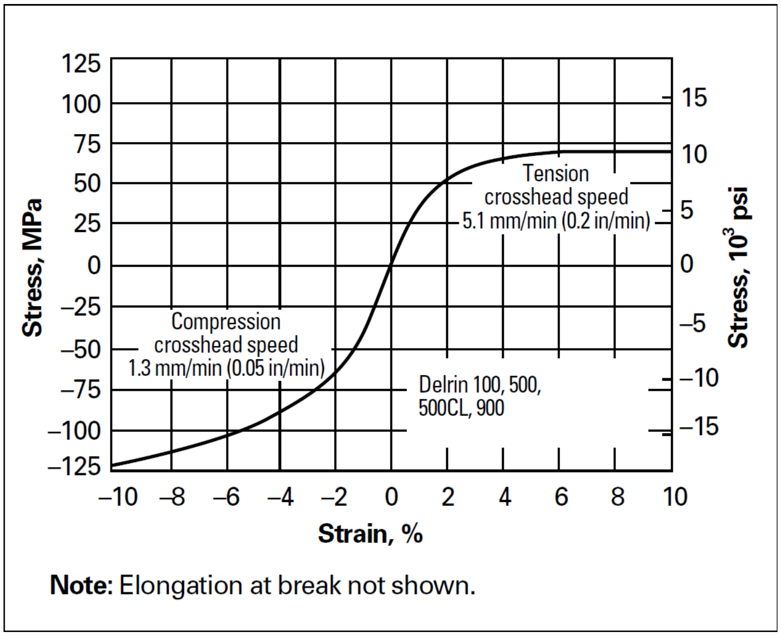


Figure 3.2 - Delrin Compressive and Tensile Stress Curve [19]

In conclusion, all estimates for the amount of stress needed to plastically deform the hand held unit when dropped from six feet are extremely conservative. This makes both the Aluminum and Delrin relatively equal candidates to be used in the final design. There is one material property that makes Delrin a much better choice than Aluminum and that is the thermal conductivity.

One of the main concerns with the hand held unit is keeping it above a certain temperature so the unit operates even in harsh winter environments. The thermal conductivity of Aluminum is significantly higher than Delrins; 237 vs 0.3 W/m*K. Since both materials are structurally sufficient for this design, but the ability for Delrin to act as an insulator is much better than Aluminum's, Delrin will be used as the casing for the final design.

3.2 Fluid Analysis

Fluid analysis would have consisted of calculations of a maximum endurable sustained wind speed needed to cause the tripod system to fall over. However our team reasoned that these wind conditions would be uncomfortable for attendees of the presentation as well as the instructor. If such conditions were present, the presentation would not occur and our system would not be in use, therefore these calculations were omitted.

3.3 Thermal Analysis

The laser must remain within operating temperatures at all times. For this reason thermal analysis was done for both concepts one and two on the laser housing. Both designs incorporate electric heating elements as well as insulation to regulate the temperature of the laser during operation. The important quantity is the heat loss through the housing under predicted worst case conditions. Once this value is determined the group can identify an adequate heating element to incorporate.

3.3.1 Thermal Results

Both design concepts involve surrounding a laser or a combination of the laser and the electrical components in insulation with an outer shell of material. The laser housing is been assumed to be equivalent in geometry for both concepts; the subsequent thermal analysis applies to both concepts and is considered at the worst case scenario (i.e. system exposed to cold air and wind conditions). The geometry has been simplified to a cylinder with a length equal or slightly longer than the length of the laser and variable radii for the insulation and outer shell. An Excel spreadsheet was created that determines total heat flow through our system while being able to change material type, geometry dimensions, and temperatures for operating conditions. The team chose Delrin to be the outer shell material and Polystyrene foam for insulation because they have relatively low thermal conductivities compared to other materials. Delrin was found to have a thermal conductivity of 0.3 $\left[\frac{W}{mK}\right]$ [15]. Polystyrene was found to have a thermal conductivity of 0.026 $\left[\frac{W}{mK}\right]$ [16]. The dimensions presented are an estimate of the needed thickness of our laser housing and can be altered if needed during construction. The laser operating temperature was determined using an average of the laser's specified operating temperature. The ambient temperature was assumed based on lowest temperatures seen in Flagstaff in which would be comfortable for a night sky presentation. Tables 3.3-3.5 show the chosen material properties and other variables described above.

Table 3.3 – Laser Housing Materials

Housing Material	**K (W/(m*K))**
LD PolyE	0.30
HD PolyE	0.48
PolyProp	0.20
Delrin	0.30
Insulation Material @270K	**K (W/(m*K))**
Polystyrene extruded	0.026
Blanket mineral fiber	0.040

Table 3.4 - Temperatures

Temp outside	**Deg F**	**Deg C**	**Kelvin**	**Appx Temp (K)**
	-5	-20.56	252.44	260.00
Temp laser functional	**Deg F**	**Deg C**	**Kelvin**	**Appx Temp (K)**
	32	0.00	273.00	280.00

Table 3.5 – Variable Dimensions for Laser Housing

K (insulation)	0.02600
K (housing)	0.30000
Length (in)	6.00000
r inner (in)	1.00000
r inner (in) insul	0.25000
r outer (in)	1.50000
r inner [m]	0.02540
r inner insul [m]	0.00635

r outer [m]	0.03810
Length [m]	0.15240

In order to calculate the convection from the outer shell surface to the ambient air, a heat transfer coefficient was determined. This coefficient was calculated using equation 7.54 from the textbook "Fundamentals of Heat and Mass Transfer", see Equation 6 below [21].

$$\overline{Nu_D} = 0.3 + \frac{0.62 Re_D^{\frac{1}{2}} Pr^{\frac{1}{3}}}{\left[1+\left(\frac{0.4}{Pr}\right)^{\frac{2}{3}}\right]^{\frac{1}{4}}}\left[1+\left(\frac{Re_D}{282{,}000}\right)^{\frac{5}{8}}\right]^{\frac{4}{5}} \qquad (6)$$

Where:

$Nu_D = \ Nusselt\ Number = 182.77$

$Re = Reynolds\ Number = \ 7.73 \times 10^4\ \left(based\ on\ 30\ \frac{mi}{hr}\right)$

$\mathrm{Pr} = \ Pradtl\ Number = \ .7205$

Once the average heat transfer coefficient was calculated, the equivalent resistances were calculated and used to determine the heat transferred from the system. Equations 7 and 8 were used to determine resistances from the surface of the laser to the ambient air.

$$R_{conv} = \frac{1}{hA} \qquad (7)$$

Where:

R_{conv} = Thermal resistance $[m^2K/W]$

h = Heat transfer coefficient $[W/m^2K]$

A = Surface area $[m^2]$

$$R_{cond\ (cyl)} = \frac{ln\frac{r_2}{r_1}}{2Lk\pi} \qquad (8)$$

Where:

$R_{cond\ (cyl)}$ = Thermal resistance for a cylinder $[m^2K/W]$

r_2 = Outer radius of cylinder $[m]$

r_1 = Inner radius of cylinder $[m]$

The total heat transfer in our system was found using Equation 9 below.

$$q = \frac{T_i - T_\infty}{\frac{1}{L\pi}\left[\frac{1}{hD_0} + \frac{ln\frac{r_2}{r_1}}{2k_{ins}} + \frac{ln\frac{r_3}{r_2}}{2k_{shell}}\right]} \qquad (9)$$

Where:

T_i= Initial Temperature [K]

T_∞= Ambient Temperature [K]

r_3= Outer radius delrin [m]

k_{ins}= Thermal conductivity of insulation $[\frac{W}{m^2}]$

k_{shell}= Thermal conductivity of Delrin $[\frac{W}{m^2}]$
D_0= Outermost diameter

Table 3.6 shows calculated heat transfer coefficients and total heat transfer for wind speeds ranging from 0 to 50 miles per hour.

Table 3.6 - Calculated h in cross flow

U air (mph)	U air (m/s)	Re	h bar	Nusselt	Q total
0	0.00	0.00E+00	0.09	0.30	0.06
5	2.24	1.29E+04	19.49	62.14	0.34
10	4.47	2.58E+04	29.02	92.54	0.34
15	6.71	3.86E+04	37.02	118.02	0.35
20	8.94	5.15E+04	44.23	141.01	0.35
25	11.18	6.44E+04	50.95	162.43	0.35
30	13.41	7.73E+04	57.33	182.77	0.35
35	15.65	9.02E+04	63.45	202.29	0.35
40	17.88	1.03E+05	69.37	221.17	0.35
45	20.12	1.16E+05	75.13	239.53	0.35
50	22.35	1.29E+05	80.75	257.46	0.35

The total heat transfer was determined to be 0.35 Watts when using a wind velocity of 30 mph, a heat transfer coefficient of $57.33\left[\frac{W}{m^2K}\right]$, and the parameters from Tables 3.2-3.4. Therefore, a heating element will be selected that can produce at least 0.35 Watts.

In order to validate our theoretical calculations, ANSYS was used to plot our temperature distribution for the conditions described above. Figure 3.3 below, shows the resulting temperature distribution.

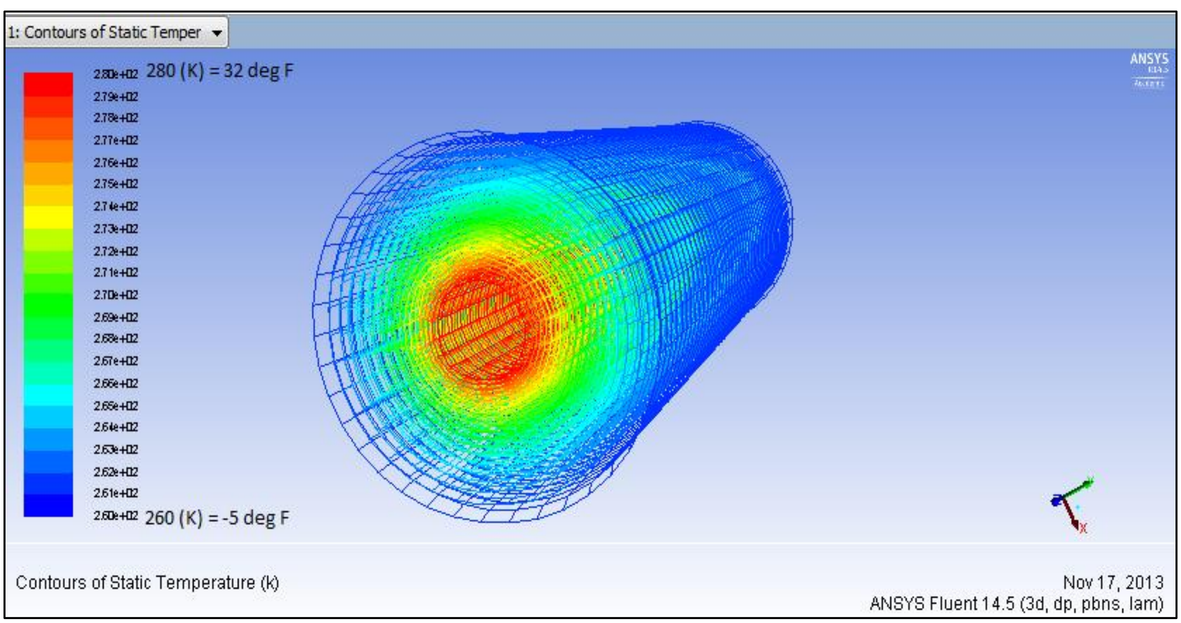


Figure 3.3 – Temperature Distribution

The temperature distribution shows the inner surface temperature of the laser at 280K, the appropriate operating temperature, and the ambient temperature at 260K. As seen in the figure, the insulated section retains more heat than the Delrin outer shell. This observation was expected due to the difference in equivalent thermal resistance between the outer shell and the insulation.

Equations 10 and 11 were used for the transient analysis.

$$F_o = \frac{\frac{k}{\rho C_p} * t}{r_0} \tag{10}$$

Where:

$k = Thermal\ conductivity\ of\ air\ \left[\frac{W}{mK}\right]$
$\rho = Density\ of\ air\ \left[\frac{kg}{m^3}\right]$
$C_p = Specific\ heat\ of\ air\ \left[\frac{kJ}{kgK}\right]$
$r_0 = Radius\ of\ cylinder\ [m]$

$$\theta^* = C_1 * exp(-\delta^2 F_o) * cos(\delta_1 x^*) \tag{11}$$

Where:

$\theta^* = \frac{(T_0 - T_\infty)}{(T_i - T_\infty)}$
C_1 = 1.1539
δ_1 = 1.0873

Transient conduction analysis was conducted to determine how long it takes for the laser temperature to drop below operating temperature. The average operating range for 20mW lasers in 32-95°F. Assuming the initial temperature of the laser is 70°F and the ambient temperature is worst case at -5°F, the laser will reach 32°F in 24.64 minutes. This is how long it takes for the temperature to reach the low end of the operating range. Additionally, when assuming the initial temperature of the laser is 70°F and the ambient temperature is worst case at -5°F, the laser will reach 50°F in 12.68 minutes. Additionally, when assuming the initial temperature of the laser is 70°F and the ambient temperature is 20°F (not worst case), the laser will reach 50°F in 16.16 minutes. The insulation alone is sufficient in our design only if the outside temperature is above the minimum operating temperature. Given the conservative nature of the above analysis, the need for a small heating element is still in question. The likely hood of a sky presentation occurring in such extreme conditions is low. This issue will be investigated further during the construction process.

3.4 Final Concept Selection

The tripod mounted turret with a joystick controller design was chosen for numerous reasons with the primary concerns being safety and reliability. The tripod will hold the laser at a safe height above the average person's eye level. This design also allows for custom artificial horizons to be fabricated to eliminate the possibility of the laser being shined into windows of buildings near the place of use.

4.0 Cost Analysis

This section pertains to the itemization and declaration of component, assembly, and testing costs for the final design concept. All costs incurred are listed in Table 4.1 below, with descriptions of all components in the following paragraphs. The following costs are based off of current known values and may be subject to change upon component arrival.

Table 4.1 – Cost Analysis with Grand Total

Component	Supplier	Part #	Cost [$]	Shipping [$]	Tax [$]	Total [$]
Davis and Sanford 78" Tripod	Amazon.com	N/A	189.95	21.95	0.00	211.90
RCA Cable	Amazon.com	N/A	12.15	7.25	0.00	19.40
.0589" Sheet Metal	Ace Hardware	N/A	30.99	0.00	2.62	33.61
PT5 Camera Turret	Camera Turret	PT5	839.00	22.00	0.00	861.00
Auxiliary Power Button	Camera Turret	N/A	0.00	0.00	0.00	0.00
Delrin Rod Stock 1'	McMaster Carr	8572K32	26.30	8.00	0.00	34.30
1/2" Electrical Conduit 5'	McMaster Carr	7126K11	1.55	8.00	0.00	9.55
Aluminum Stock 1 1/4" X 1' X 3/4"	McMaster Carr	8975K487	8.74	8.00	0.00	16.74
M1.4 X .3 - T5 Drive Screw	McMaster Carr	94209A111	9.38	3.25	0.00	12.63
Blind Rivet 3/16"	McMaster Carr	97525A485	10.34	3.55	0.00	13.89
Heater	Measurement Specialties	Custom	10.00	3.50	0.00	13.50
RCA Cable to Quick Connector	Radio Shack	N/A	7.50	4.50	0.00	12.00
Solenoid	Deltrol Controls	53648-81	40.00	12.00	3.38	55.38
Solenoid Cover	3-D Printer	N/A	0.00	0.00	0.00	0.00
Contingencies	Unknown	N/A	100.00	N/A	N/A	100.00
Grand Total [$]					**1393.90**	

Component – This column contains the description of the part for purchase. This list is as comprehensive as possible without possessing some of the components.

Supplier – This column displays where each component will be purchased.

Part # - Some of the components have part numbers or reference numbers from the supplier or manufacture. This column displays the reference number associated with the supplier listed in the Supplier column.

Cost – This column shows the cost as displayed on the supplier website, written estimate, or by phone for each supplier listed in in the Supplier column.

Shipping – Many of the components will incur shipping charges from the supplier to NAU. These incurred costs are listed in the Costs column.

Additions – One of the components includes additional charges due to modifications to the stock part on the supplier website. This additional cost is listed so that no discrepancies between listed price and Table 4.1 exist.

Tax – This column incorporates any local, federal, or state taxes incurred by the purchase of each component.

Total – This column is the summation of the Supplier, Part #, Cost, Shipping, and Additions columns for each component.

Component Descriptions

Davis and Sanford 78" Tripod – This item is the tripod on which all other components will be mounted. It will be modified such that it will only function at the maximum height of 78 inches to ensure a safe elevation for laser operation.

RCA Cable – The operation of the solenoid to depress the power switch on the laser pointer will be via two RCA ports on the side of the turret. The RCA cable will connect the RCA ports on the turret to the solenoid connector pins.

.0589" sheet metal – Safety dictates that the laser pointer beam be directed away from potentially dangerous directions. To ensure that this always occurs, a laser beam shield will be constructed from the sheet metal to prevent the laser from dropping below the desired elevation.

PT5 Camera Turret – The Camera turret is the device that will move the laser to the desired position. This is a single purchased component which will undergo minimal modification during assembly.

Auxiliary Power Button – Power must be supplied to the solenoid to operate the power switch on the laser pointer. This is the button, located on the joystick, which will accomplish the switch signal. This component will be installed by the camera turret manufacture as per the design request.

Delrin Rod Stock 1' – The case and cap which will house the laser pointer will be constructed of Delrin. These parts must be machined from a larger bulk stock, which is represented in the table and is one foot long from the supplier.

½" Electrical Conduit 5' – Within the Delrin case will reside a tube constructed from electrical conduit. The bulk material which the part will be manufactured will be five feet in length.

Aluminum Stock 1 1/4" X 1' X 3/4" – In order for the solenoid to depress the power switch on the laser pointer, an intermediate beam must transition the linear motion to a semicircular motion. This semicircular motion will come from a part machined from the aluminum listed in the table.

M1.4 X .3 - T5 Drive Screw – The solenoid cover must be fastened to the Delrin case. These screws will provide ample fastening strength.

Blind Rivet 3/16" – The laser beam shield consist of two parts, a base plate and a tubular shield. The shield will provide laser beam blockage while the base plate supports the shield. The blind rivets will be used to fasten the shield to the base plate.

Heater – For cold weather conditions, a heater will be installed in the inner tube where the laser pointer will mount.

RCA Cable to Quick Connector – In order to connect the RCA cables to the solenoid, some adaptors will be required. These quick connectors are the adaptors.

Solenoid – The solenoid will actuate when a button is depressed on the joystick controller. While the button is depressed, the solenoid will apply force to the switch trigger thus depressing the power button on the laser.

Solenoid Cover – To keep the solenoid clean and dry, a cover is necessary. This cover will be 3-D printed in the NAU fabrication lab from a G code which the group will develop.

Contingencies – This row is an additional cost which incorporates imposed costs that are unforeseen due to components not in the group's possession at the time of this report.

5.0 Conclusion

Problem description

Our client, Mr. Anderson, has requested a system that will use a 20 mW laser to aid him in pointing out stellar bodies during presentations of the night sky while eliminating the possibility of laser beam contact with anyone's eye. He currently uses a 5 mW laser for this purpose; which does not produce a powerful enough beam for people that are outside of his immediate vicinity to see clearly. Main design considerations are the usability and responsiveness of the system as well as the required operating temperature of the laser because it operates poorly when cold. The designed system must also fit into the cargo compartment of Mr. Anderson's Subaru Outback when fully collapsed, and weigh less than 100 lbs.

Concept generation/selection

Several concepts were generated as potential solutions to the client's problem. A handheld system using a system of gyroscopes and proximity sensors to detect when the laser is pointed below a preset critical angle or held below a critical height. This design would preserve the intuitive control of having the laser in your hand. Four other concepts were presented which all have the same overall design, a tripod camera mount and a 2-axix rotational video camera turret to direct the laser. Concepts two through five differ in the way the user will control the laser's position. Concept two would use a tablet computer with a star mapping application in which the user could touch stars on the screen or enter coordinates and the laser would move to the selected location. Concept 3 uses the 6-axis motion detection technology of a smartphone and an accompanying application to translate the motion of the smartphone directly to the laser. Concept 4 would utilize the infrared motion detection technology found in modern gaming console controllers such as Nintendo's Wii and Sony's PS3 to translate the motion of the users arm to the laser. Concept five uses a wired joystick to control the laser.

After discussing the concepts with Dr. Venkatraman of the Electrical Engineering Department here at NAU to determine the feasibility of each concept given the team's electrical and computational knowledge, concepts one and five were chosen for analysis.

Engineering analysis

Many of the components for our design are purchased off the shelf and are to be used well below the maximum recommended loading. For this reason the analysis for our design reduced to the housing for the laser, which the group will be developing for this project. A mathematical model was developed for the event of the devise being dropped from a height of six feet onto solid ground. The housing will need to be designed to withstand this sort of event with little to no permanent deformation and no damage to the internal laser or electronics. By using Delrin 100 as the material for the outer case not only will the handheld unit be capable of withstanding numerous impacts, it will contribute to insulating the laser to maintain sufficient operating temperatures.

The tripod design was going to be analyzed for the event of being toppled over by the strong winds. However, our team reasoned that if there were strong enough sustained winds to knock the tripod over, an audience would not be comfortable sitting and watching a presentation. Thus our system would not be in use in these conditions, therefore this portion of the analysis was omitted.

Thermal analysis was conducted on the laser housing for both concepts. The objective was to find the amount of heat leaving the system under worst case conditions which were determined to be a temperature of -20 °C or -5 °F and a wind speed of 13.4 m/s or 30 mph. Once this quantity of heat loss was determined an electrical heating element could be selected and installed to maintain the operating temperature of the laser. The resulting total heat transfer through our system was determined to be 0.35 Watts at worst case environmental conditions. With this information, a heating element that can produce at least 0.35 Watts is being considered for incorporation into the design.

Cost analysis

The costs incurred by the system design do not include labor costs, machine costs, or processing costs. This is because individuals in the group will perform all machining and rapid prototype work, thus the labor cost is neglected. All manufacturing of components will be completed in house, meaning at the NAU machine shop and by NAU personnel. The total system cost is well below the allotted $3000.00 budget at and will fulfill the design requirements will obeying all constraints.

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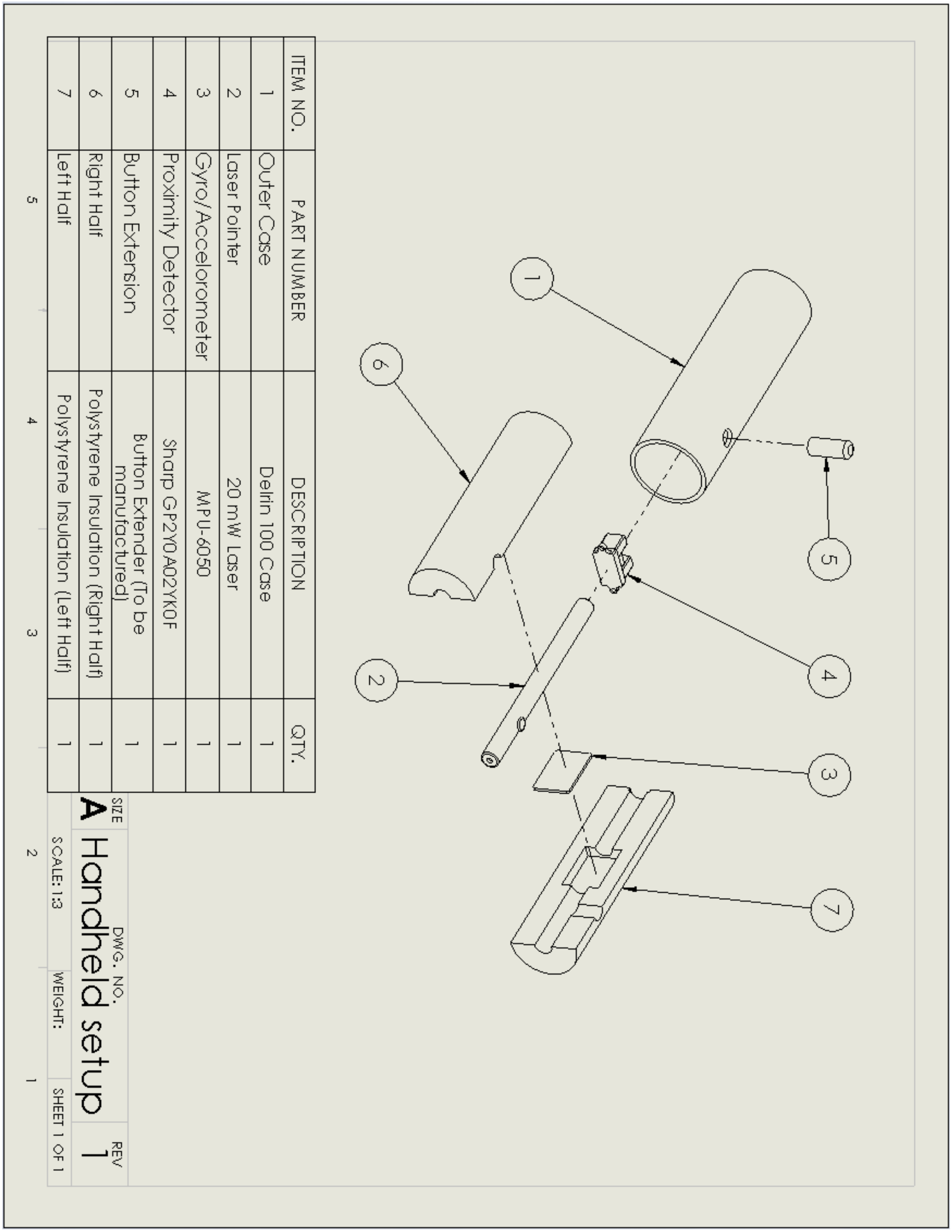
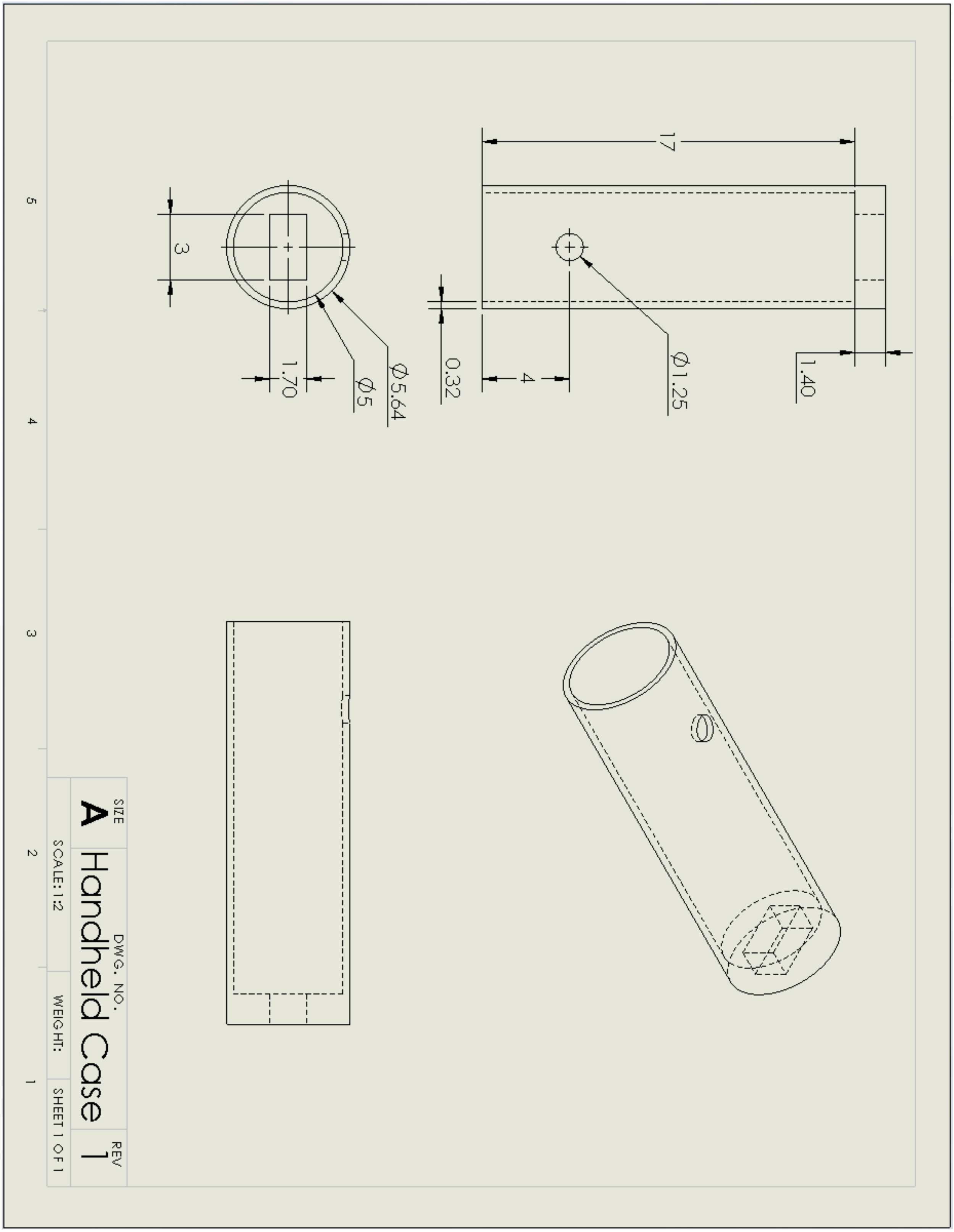
APPENDICIES

Appendix A: Engineering Drawings

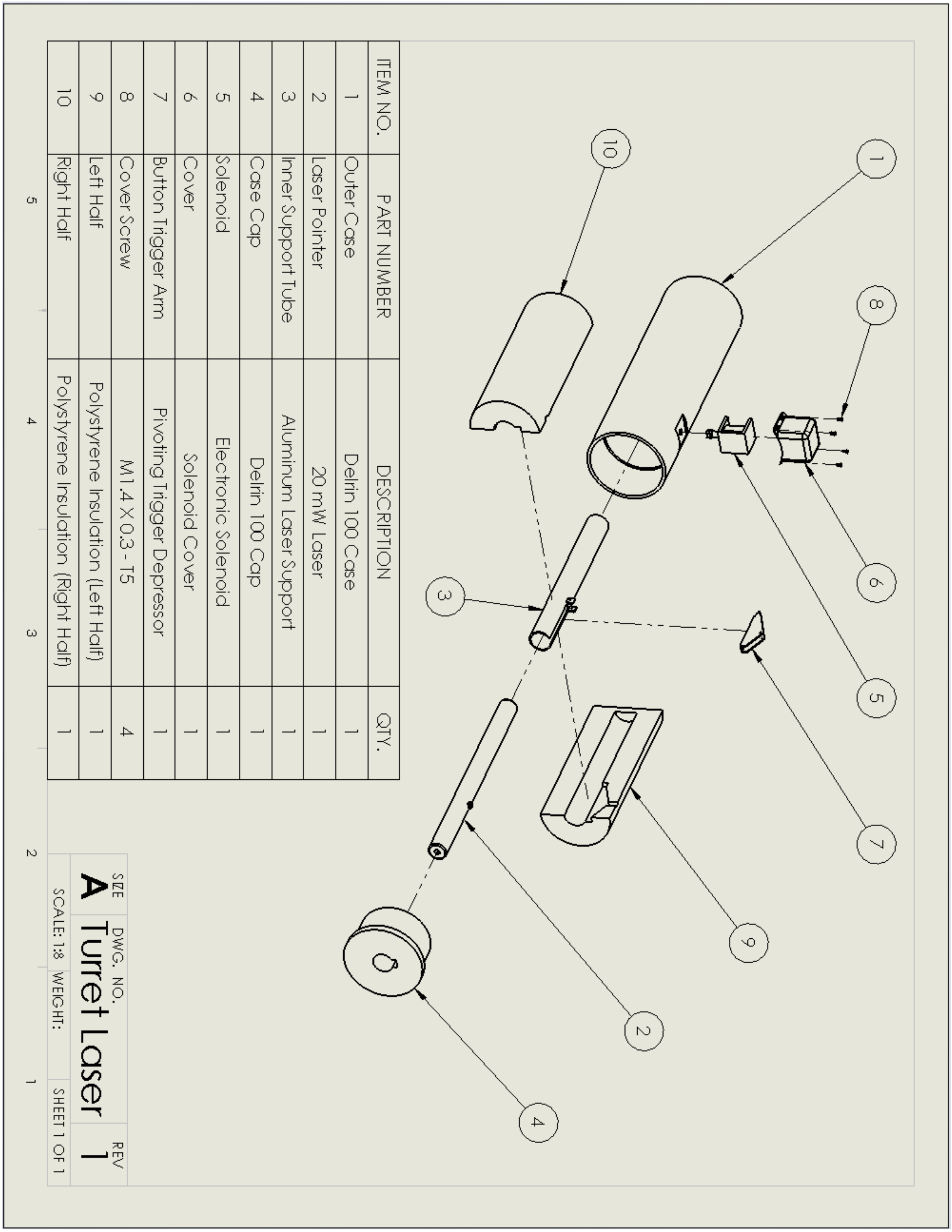
Concept 1 – Overall System Assembly



Concept 1 – Case Design

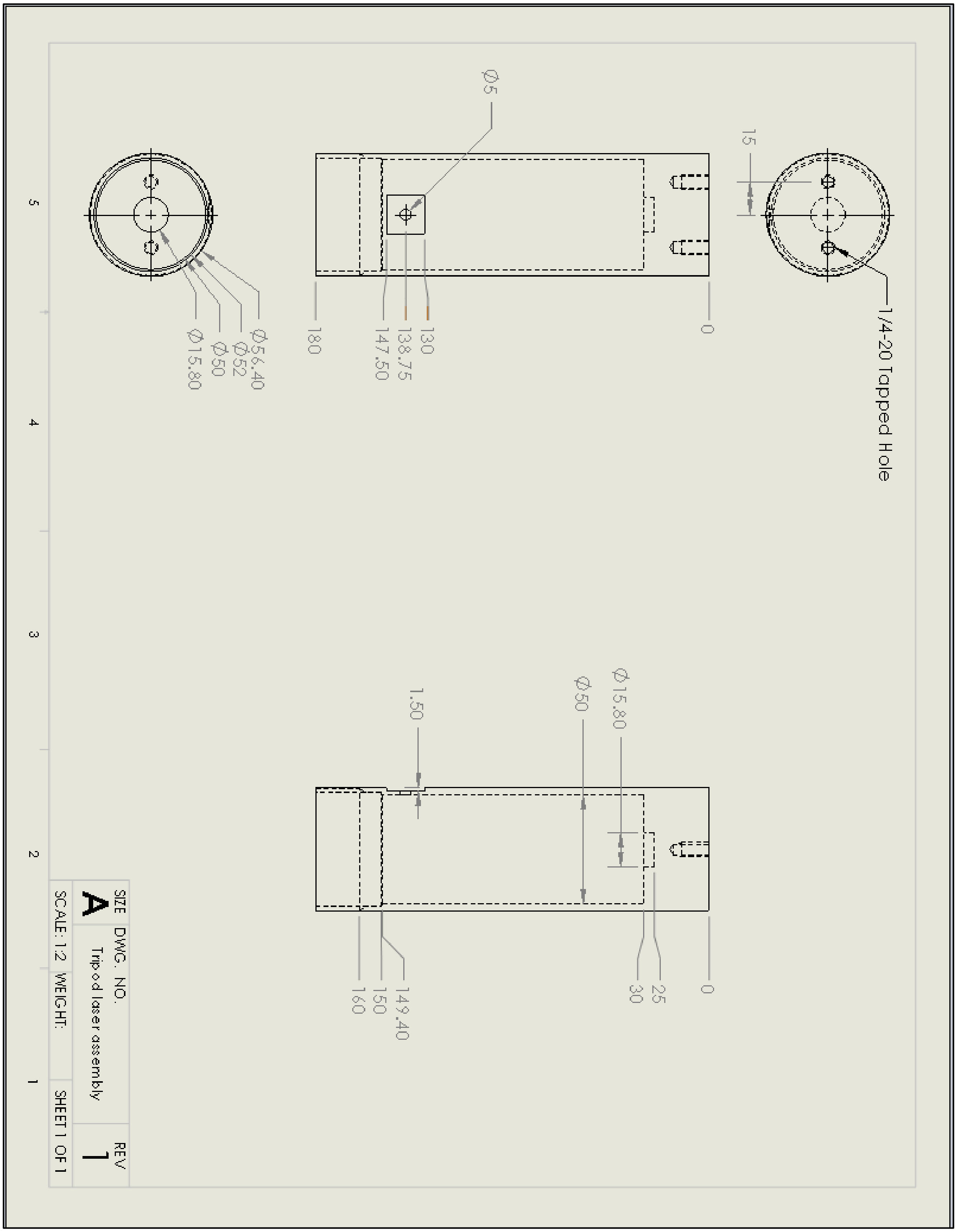


Concept 2 - Overall System Assembly

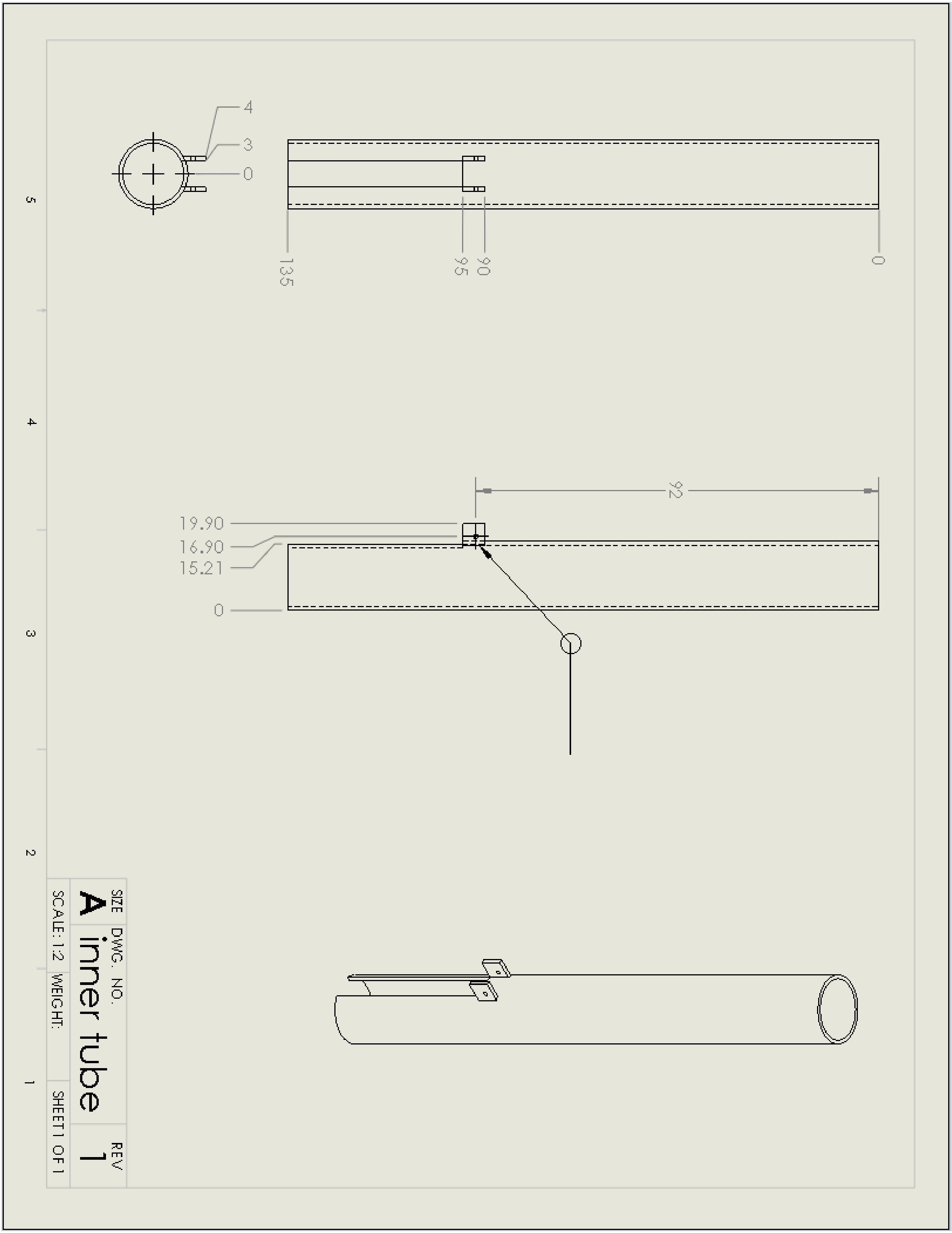


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Outer Case	Delrin 100 Case	1
2	Laser Pointer	20 mW Laser	1
3	Inner Support Tube	Aluminum Laser Support	1
4	Case Cap	Delrin 100 Cap	1
5	Solenoid	Electronic Solenoid	1
6	Cover	Solenoid Cover	1
7	Button Trigger Arm	Pivoting Trigger Depressor	1
8	Cover Screw	M1.4 X 0.3 - T5	4
9	Left Half	Polystyrene Insulation (Left Half)	1
10	Right Half	Polystyrene Insulation (Right Half)	1

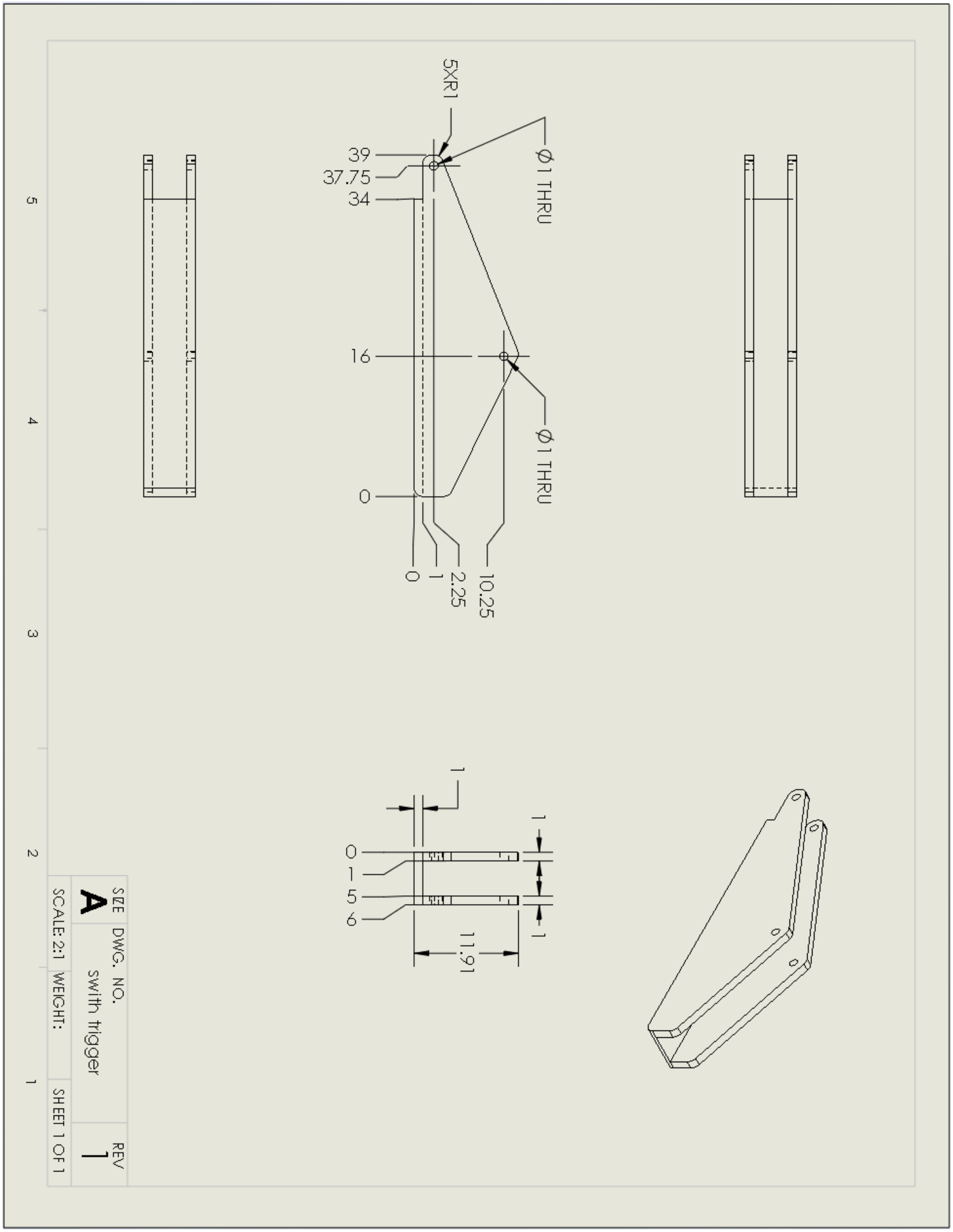
Concept 2 - Outer Case



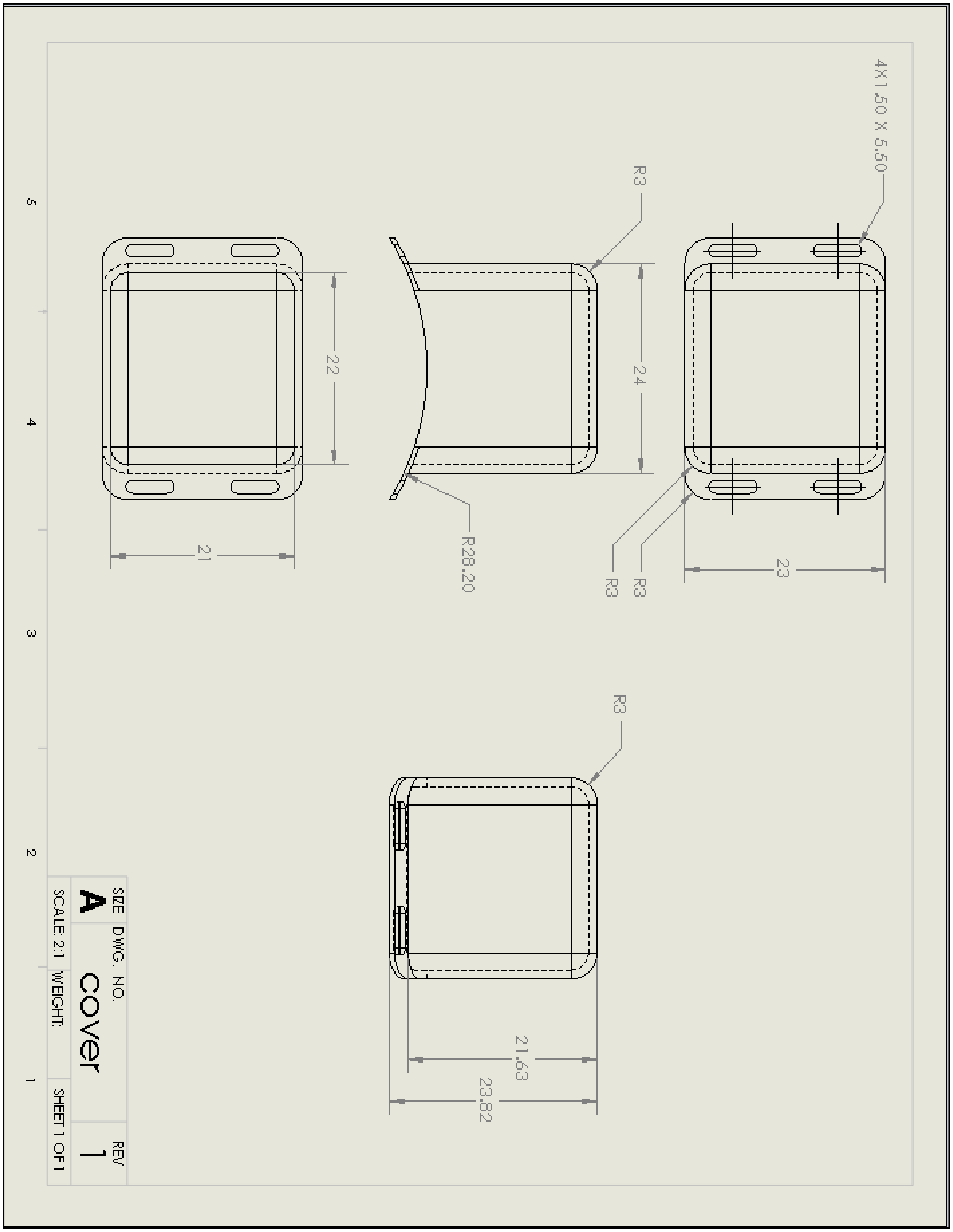
Concept 2 - Inner Tube



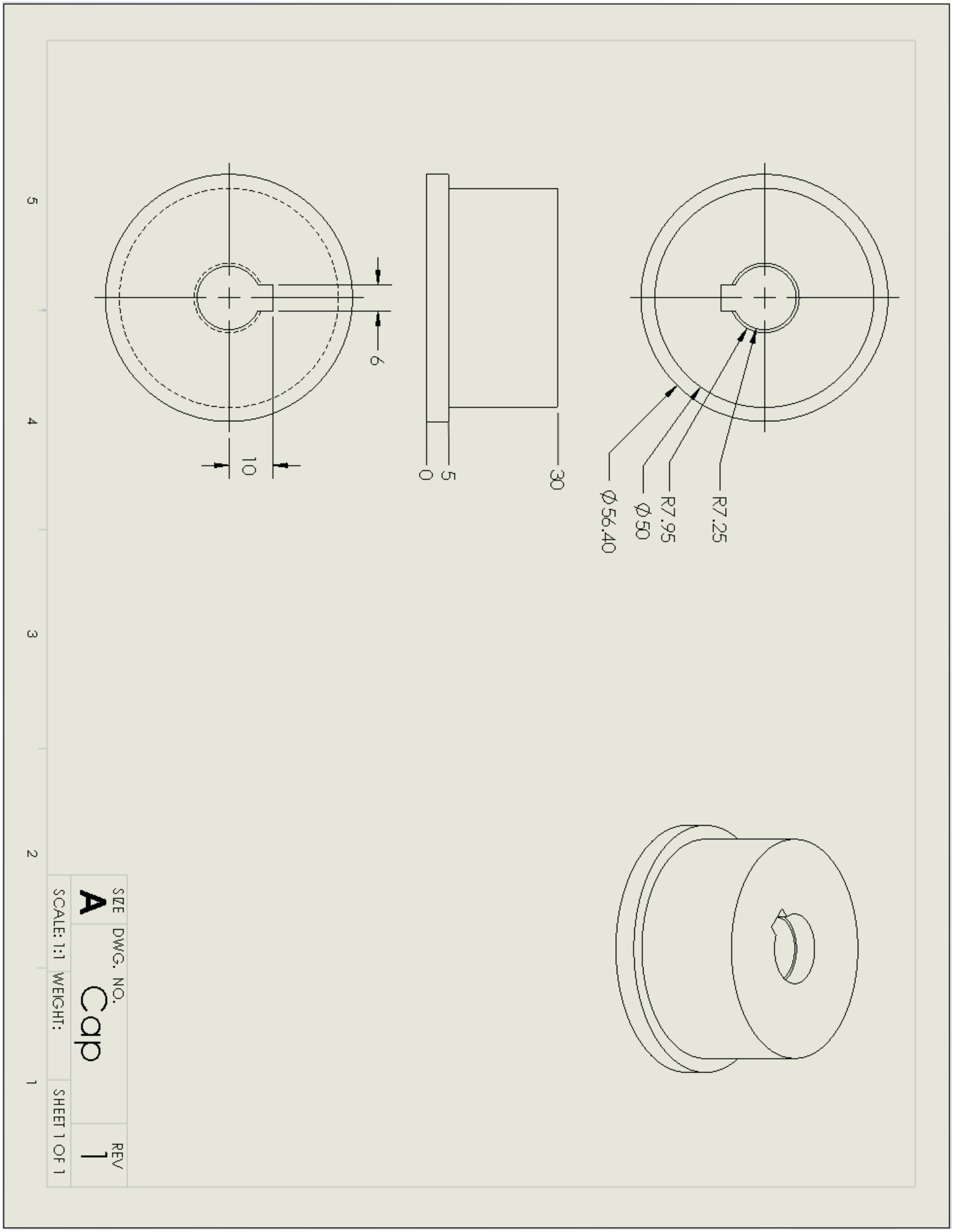
Concept 2 - Switch Trigger



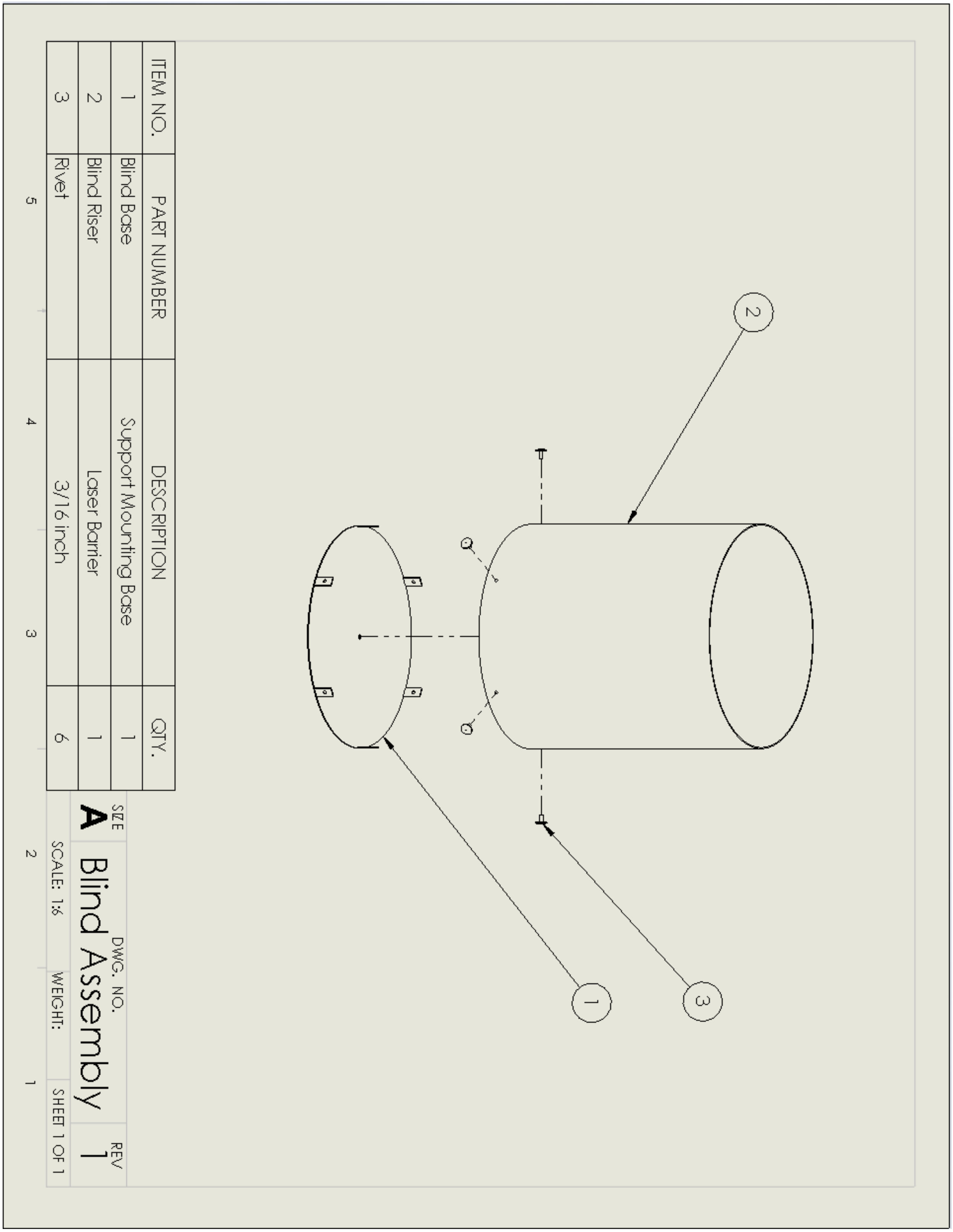
Concept 2 - Solenoid Cover



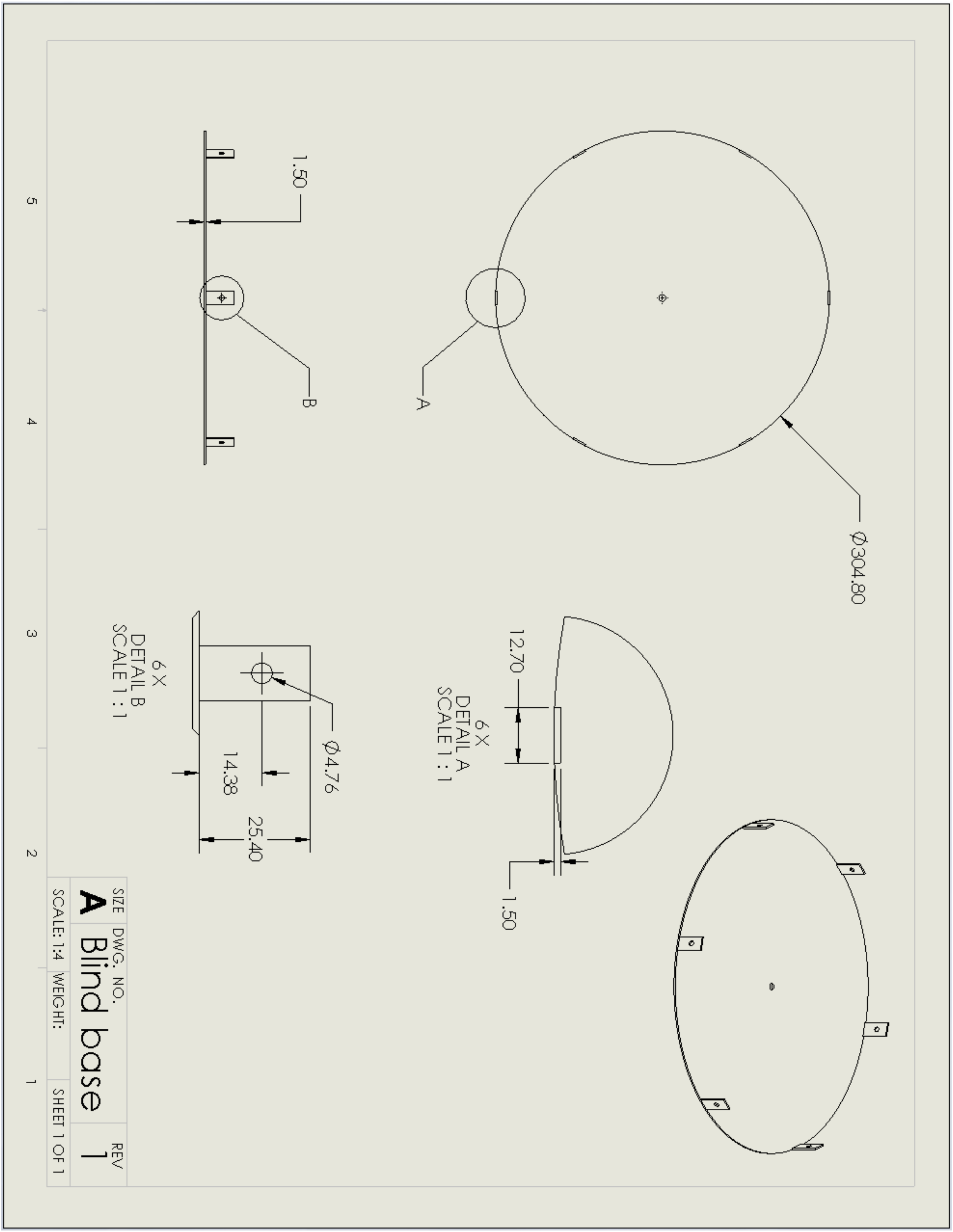
Concept 2 – Cap



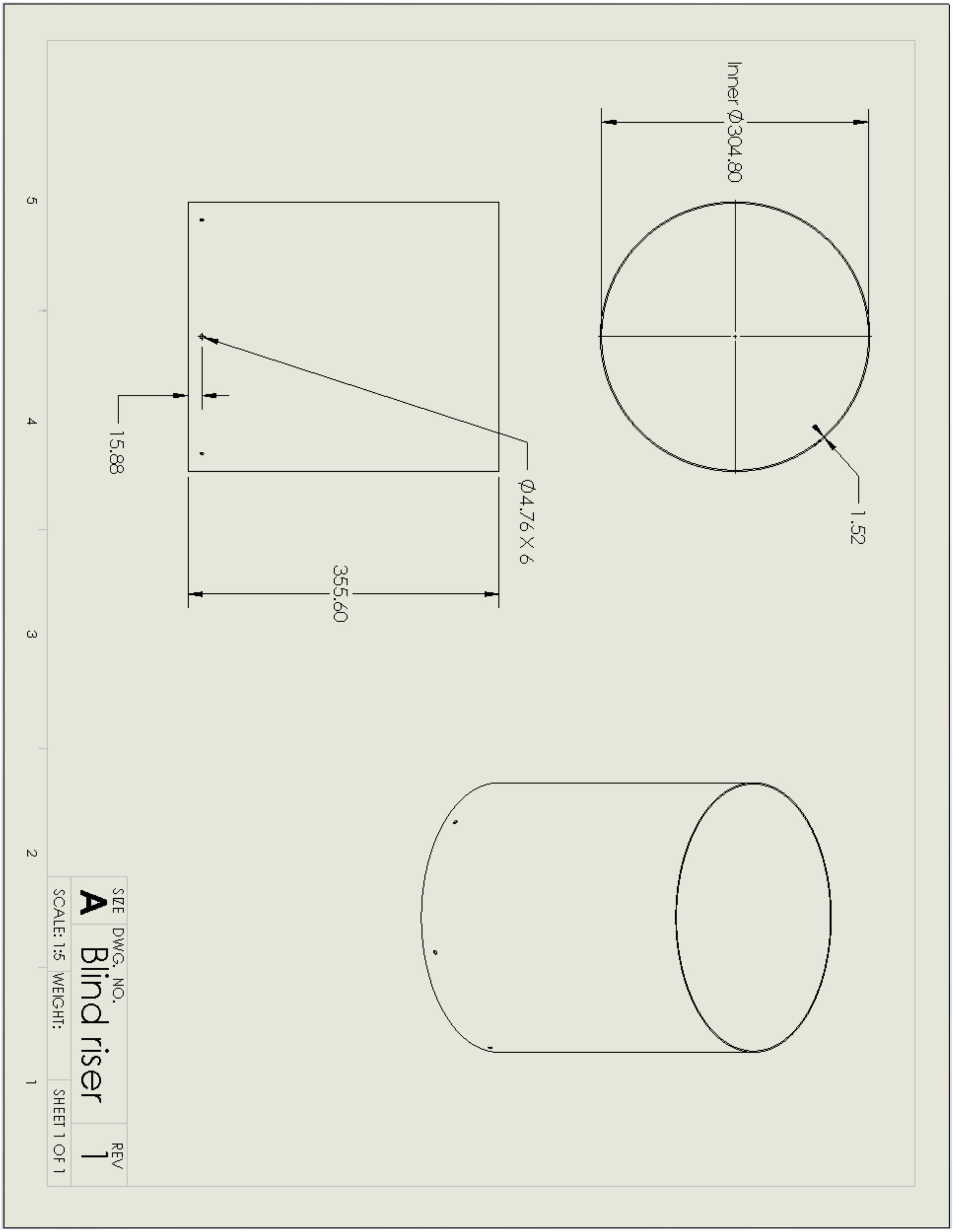
Concept 2 – Blind Assembly



Concept 2 – Blind Base

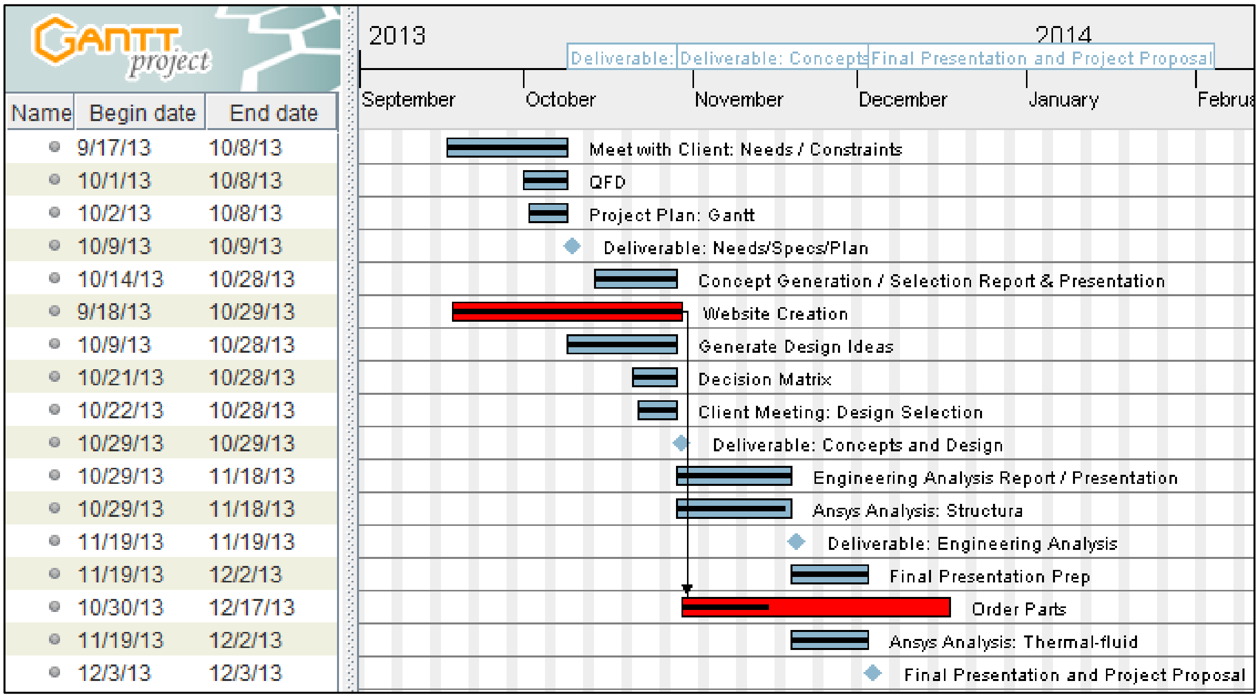


Concept 2 – Blind Riser



Appendix B: Project Planning

Appendix B1: Fall 2013 Gantt Chart



Name	Begin date	End date
	9/17/13	10/8/13
	10/1/13	10/8/13
	10/2/13	10/8/13
	10/9/13	10/9/13
	10/14/13	10/28/13
	9/18/13	10/29/13
	10/9/13	10/28/13
	10/21/13	10/28/13
	10/22/13	10/28/13
	10/29/13	10/29/13
	10/29/13	11/18/13
	10/29/13	11/18/13
	11/19/13	11/19/13
	11/19/13	12/2/13
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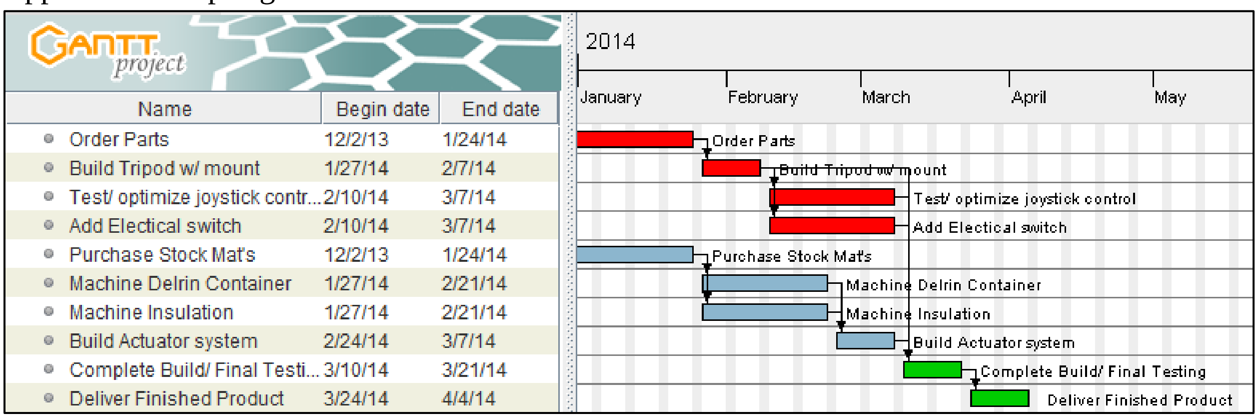
	11/19/13	12/2/13
	12/3/13	12/3/13

Appendix B2: Spring 2014 Gantt Chart



Name	Begin date	End date
Order Parts	12/2/13	1/24/14
Build Tripod w/ mount	1/27/14	2/7/14
Test/ optimize joystick contr...	2/10/14	3/7/14
Add Electical switch	2/10/14	3/7/14
Purchase Stock Mat's	12/2/13	1/24/14
Machine Delrin Container	1/27/14	2/21/14
Machine Insulation	1/27/14	2/21/14
Build Actuator system	2/24/14	3/7/14
Complete Build/ Final Testi...	3/10/14	3/21/14
Deliver Finished Product	3/24/14	4/4/14