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Legacy borehole project

Piper Connelly
Santa Clara University

Rhys Marks
Santa Clara University

Ronald Saavedra
Santa Clara University

SANTA CLARA UNIVERISTY

Department of Mechanical Engineering

I HEREBY RECOMMEND THAT THE THESIS PREPARED

UNDER MY SUPERVISION BY

Piper Connelly, Rhys Marks, Ronald Saavedra

ENTITLED

LEGACY BOREHOLE PROJECT

BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

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LEGACY BOREHOLE PROJECT

By

Piper Connelly, Rhys Marks, Ronald Saavedra

SENIOR DESIGN PROJECT REPORT

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Abstract

To assist scientists in their pursuit of important research of the subseafloor, the Legacy Borehole Project designed a unique structure that will be lowered to the ocean floor for data collection beneath the ocean floor. This derrick structure will provide support for a sensor package to access pre-existing boreholes, deep and narrow holes drilled into the Earth's crust beneath the sea floor. Our team has completed the second year effort of the three-year plan. In this paper we detail our work on the structure, which will be assembled on a ship's deck and lowered onto the borehole reentry cone with assistance from remotely operated vehicles (ROVs). When the sensor has completed its data sampling, the entire structure will be returned to the ship's deck. The design has been completed and approved and testing has been conducted, but it has not been possible to proceed with the manufacturing of the structure due to a loss of funding. A bolt pattern has been manufactured and tested, validating the bolt pattern choice. The full design and manufacturing details have been finalized and are ready for the third year team. It will be important for funding to be secure for this important work to be completed.

Acknowledgements

The authors wish to thank Dr. Christopher Kitts, Bill Kirkwood, and Dr. Geoff Wheat first and foremost for their advisement and guidance on this project; Dr. Timothy Hight for his advisement and support, and Don Maccubbin for his assistance in the Machine Shop.

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1 Introduction

1.1 Motivation

The Legacy Borehole Project is a three year project that has been undertaken by students at Santa Clara University to facilitate the exploration of the subseafloor biosphere. The project was originated in 2012 at the University of Alaska, Fairbanks (UAF) by geochemist and hydrogeologist Dr. Geoffrey Wheat, with the aim of engineering a system to collect data from the ocean floor, a remote environment that is "a potentially paradigm-shifting enigma to science."[1] Wheat spear-headed the Legacy Borehole Project and became its Principal Investigator because of a widely held expectation that scientific knowledge of the subseafloor (which is far removed from the photosynthetic world) may lead to understanding the origins of life on Earth and insights into life forms that are likely to exist in the similarly extreme conditions on other planets.

An explosion of interest in exploration of "the Earth under the sea" has sparked global engineering and scientific collaboration. Research teams are pursuing projects in the subseafloor biosphere because it is anticipated that it will yield knowledge that will advance pharmaceutical and energy technologies[2]. Past explorations have collected samples from boreholes using manned submersibles[3] and drilling operations[4]. The Legacy Borehole project intends

[1] Wheat, C. Geoffrey, Kathina Edwards, Bill Kirkwood, Chris Kitts, William Hug, and Everett Salas. "Dark Energy Biosphere Initiative- SubserfacE LifE Characterization (DEBI-SELECT)." Marine Science and Technology Foundation Grant Proposal. 4 May 2012.

[2] European Consortium for Ocean Research Drilling (ECORD). "Exploring the Earth Under the Sea: Science Plan for 2013 – 2023." http://www.iodp.org/science-plan-for-2013-2023

[3] Monastersky, Richard. "Dive Master: The US flagship submersible Alvin is getting a partial upgrade. But deep-sea exploration faces some rough water." Nature 489 (2012): 194-196. Web. 10 Oct. 2013.

[4] Consortium for Ocean Leadership, Inc. "Ocean Drilling Program: Final Technical Report 1983 - 2007." http://www.odp.tamu.edu/publications/ODP_Final_Technical_Report.pdf

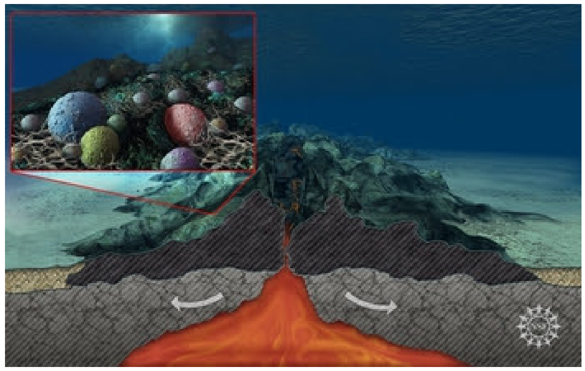

Fig. 1: Scientists have found that rocks beneath the seafloor are teeming with microbial life. Source: National Science Foundation, March 2015. Credit: Nicolle Rager-Fuller/NSF

to build upon the knowledge from those past research projects by using a new derrick and sensor system supported by more cost efficient remotely operated vehicles (ROVs).

1.2 Literature Review

There was much review of previous research and related projects completed during the first year of this project. The literature that was reviewed and collected by the first year's team outlines past efforts to observe variation in temperature, depth, and water composition collected from boreholes as a means of learning more about the ecosystem under the seafloor.

One of the earliest projects was the first of three international drilling projects that have continued to operate since 1975, the Deep Sea Drilling Project (DSDP), which began with research in the United Kingdom, Japan, Germany, the Soviet Union and France. The initial contract was signed in 1966 by the National Science Foundation (NSF) and the Regents of the University of California and was based out of Scripps Institution of Oceanography at the University of California, San Diego. Global Marine, Inc. conducted the drilling operations. Though originally for the benefit of large oil companies, the Deep Sea Drilling Project drilled 10 boreholes that became primarily focused on scientific research. The core samples retrieved were analyzed and provided scientific proof that continental drift occurred at rift zones, also known as the theory of continental drift[5].

Another related work that influenced the Legacy Borehole Project was the Oceans Drilling Program (ODP). Dr. Wheat was an influential scientist in the ODP, which left instruments in place to collect data over the course of two years. As described by the ODP website, their mission was to conduct "basic research into Earth processes by recovering sediment and rock samples from below the ocean floor and using the resulting holes to perform downhole measurements and experiments".[6]

According to ODP's Greatest Hits (1997), an informational text from the Joint Oceanographic Institutions, after the initial launch of ODP in the late 1980's a ship named JOIDES Resolution traveled around the world collecting geological information from the "boreholes". The inaugural expedition occurred in 1985. The ship was one of the first to drill in water depths over 5 kilometers. According to the informational pamphlet, the deepest hole that has been drilled reached 6926 feet (2,111 meters) below the seafloor. "ODP has collected over 138 km of core and has provided over 1,700 shipboard scientists with more than 1,000,000 samples for further laboratory study"/[7] While the specific data collected is not pertinent to the Legacy Borehole project, the huge strides that have been made in this specific field are impressive and generate excitement for future research projects. These research projects are important to the Legacy Borehole project because of the knowledge gained

[5] Becker, K., M.G. Langseth, and R.P. Von Herzen. "Deep crustal geothermal measurements, Hole 504B, Deep Sea Drilling Project Legs 69 and 70." J. Cann, M.G. Langseth (Eds.), Init. Rep. DSDP, U. S. Gov't Printing Office, Washington, D. C. (1983), pp. 223–236.

[6] ODP. "Ocean Drilling Program: Final Technical Report 1983 - 2007." Consortium for Ocean Leadership, Inc. Web. 28 Nov. 2013.

[7] Kappell, Ellen. ODP Legacy: ODP's Greatest Hits. Ocean Drilling Program National Science Foundation, 1 Nov. 1997. Web. 19 May 2015.

about the different ways to access the boreholes and the types of instruments needed.

1.3 Project Objectives

As stated in Wheat's original proposal, "the goal will be to enter existing 'legacy' boreholes with a sensor and sampling package that can sense and collect unaltered materials for microbial and geochemical characterization." [8] The first year of the three year Legacy Borehole Project centered around the broad-scope system design. Specifically, the first year's team completed design specifications for the sensor package, started conceptual design of the mechanical system and winch system, as directed by Dr. Wheat's proposal for the project.[9] The second year has focused on the conceptual design and mechanics of the system. Our team has completed a final design of the derrick and has tested a bolt pattern design for use by next year's team. Should the project continue for a third year, the team will accomplish the fabrication, testing, and implementation of this project.

1.4 Project Statement

Within the span of three years, the Legacy Borehole Project aims to "design, fabricate, and test a new automated borehole platform, equipped with a suite of physical and geochemical sensors and sampling capability, for assessing the chemical, hydrologic, and microbial conditions of the basaltic crust through the utilization of about 54 legacy boreholes worldwide". [10]

[8] Wheat, C. Geoffrey, Kathina Edwards, Bill Kirkwood, Chris Kitts, William Hug, and Everett Salas. "Dark Energy Biosphere Initiative- SubserfacE LifE Characterization (DEBI-SELECT)." Marine Science and Technology Foundation Grant Proposal. 4 May 2012.

[9] Ibid

[10] Wheat, C. Geoffrey, Kathina Edwards, Bill Kirkwood, Chris Kitts, William Hug, and Everett Salas. "Dark Energy Biosphere Initiative- SubserfacE LifE Characterization (DEBI-SELECT)." Marine Science and Technology Foundation Grant Proposal. 4 May 2012

As Wheat explains in the formal proposal for the project, the initial goal of the Legacy Borehole project is to gain an understanding of the motion of fluids through boreholes and what the connection is between the water flow and the chemical composition of the subseafloor. Another goal is to better understand "how the microorganisms that live in those fluids manage to generate energy and metabolism for growth".[11] The primary leads on the project include Dr. Wheat, Adjunct Researcher at Monterey Bay Aquarium Research Institute (MBARI), his team of staff scientists at the University of Alaska, Fairbanks (UAF), Dr. Bill Kirkwood, Senior Research and Development Engineer on staff at MBARI, and Dr. Christopher Kitts, Professor of Mechanical Engineering at Santa Clara University.

Fig. 2: Existig borehole with tilted and damaged reentry cone. Source: <http://www.mstfoundation.org/story/DEBI-SELECT>

[11] Brady, Maza. Cashman, Luke. Hicks, Erin. Richey, Meghan. Legacy Borehole Project. BS thesis. Santa Clara University, Santa Clara, 2014. Print.

2 Design of System

2.1 System Overview

The second year work of the Legacy Borehole Project required a thorough review of the efforts of the first year's team, multiple meetings, and communications with the clients for the project. Together, Dr. Christopher Kitts, Dr. Kirkwood, our student predecessors, and the UAF scientists, provided the information we needed to define more specific system requirements. The entire system is comprised of four main subsystems:

1. Derrick Structure - a truss structure, connected to two ROVs that will safely transport the sensor package from the ship's deck to the borehole.
2. Winch and Cable System - a hydraulic system designed to power and control the movement of the sensor package while inside the borehole.
3. Sensor Package - a package of scientific instruments that will collect data and transmit the data back to a graphical user interface (GUI).
4. Communication Interface - technology that makes possible interaction between scientists on the ship, ROVs, winch and cable system, etc.

While each subsystem has an extensive list of design requirements, it is expected that all will be completed within the three-year period. The derrick structure was the primary focus of our team's efforts this year.

2.2 Customer Needs

Our primary customers for this project are our sponsoring clients who will be using our sensor deployment system for scientific research and our academic "customers" at Santa Clara University. Our clients include Dr. Wheat, Dr. Kirkwood and Dr. Kitts and the student team who will be carrying on our work next year.

As our main customers, the scientists at UAF require tools to advance their study of the ecosystems in the boreholes. The derrick structure will facilitate their ability to take physical samples as well as make various scientific measurements of borehole environments. The customers have a need for a derrick structure that is safe, sturdy, and can be easily transported and stored. The customers require a system that is easy to assemble and operate.

At Santa Clara University Dr. Kitts was designated to be a co-principal investigator for this project and is our immediate customer. Dr. Kitts required our team to communicate with him on our progress on a regular basis and to keep him apprised of our interactions with the scientists. Also, come the end of the year, the next student team that will carry on this project will be our customers as well. We have supported the efforts of next year's students by providing documentation of our research in this report.

2.3 System Requirements

Based on thorough research and analysis of these customer's needs, a comprehensive list of system requirements is outlined below:

2.3.1 General System Functionality

1. The system must be able to be assembled on the deck of a marine vessel.
2. The system must handle between 1 C and 30 C temperatures.
3. The system must fully contain the sensor package and minimize any undesired movement.
4. The winch system must be able to stop the sensor package every meter at the beginning of the borehole and every 10 meters deeper into the borehole down to 1500 meters for data sampling.

5. The system must handle a broad range of geological disturbances in the boreholes.

6. The system must center the instrument package in the boreholes.

7. The system must be balanced and outfitted with proper flotation elements so as to stay upright during ascent and descent.

8. The system must fit within a standard 20' x 8' x 8.5' cargo container.

9. Damaged parts or components must be easily replaceable (standardized as much as possible).

2.3.2 Derrick Structure

1. The construction of the structure must be simple and it must be easily assembled on a boat.

2. The structure must be able to be assembled on its side and then lifted to an upright stance on the boat deck.

3. The structure must be able to be moved with cranes and taglines.

4. The structure must have a hole in the base for the passage of the instrument package.

5. The top of the derrick structure must have a hook for attaching to Medea (ROV helper).

6. The structure must be able to be broken down into pieces that fit inside a standard size shipping container (approximately 8' x 20' x 8.5').

2.3.3 Winch and Cable System

1. The winch system must be strong enough to raise and lower the approximately 500 lb instrument package.

2. The winch system must have precision control to stop every meter while lowering or raising the instrument package.
3. The winch system must be designed to prevent the tether from slipping out of place.
4. The winch must be securely connected to the base plate.
5. The winch must incorporate a designated 176 Moog slip ring.
6. The winch must incorporate a cable that will transmit power and data to and from the sensor package.
7. The winch and cable must be able to operate at a maximum depth of 6000m in seawater.
8. The fiber-optic cable must have 3 wires.

2.3.4 Base Plate and Alignment

1. The base plate must accommodate reentry cones of different shapes with diameters of between 10 and 18 feet.
2. To minimize the chance of the structure falling off the reentry cone, the shape of the reentry cone will be mapped before the deployment of the derrick and a pins will be configured in the three corners of the baseplate that are tailored to the shape of the reentry cone.
3. The alignment pin locations will be arranged with threefold radial symmetry from each corner of the triangular base plate. (See Figure 5)

2.3.5 Connections to Jason (Remotely Operated Vehicle) and Medea (ROV assist)

1. The structure must have a hook on its top that Medea can clasp onto.

2. The structure must be rigged to allow the ROV Jason to grip its side and adjust the position of the structure on the reentry cone.
3. The structure will utilize wet-mates to connect Jason to the pressure housing of the winch system.
4. The connection to Jason will provide both power and a real-time data connection from the subseafloor sensors to the surface.

2.4 System Summary

The Legacy Borehole project is designed to be implemented in the Pacific Ocean. The structure is meant to be assembled on the deck of a marine research vessel and placed in the water. Figure 3 shows a representation of the fully proposed deliverable being lowered into the depth of the ocean by two ROVs. The top ROV is controlled by the marine vessel. This ROV is used to latch on to the top of the structure and gently lower it to the reentry cone at the floor of the ocean. The bottom ROV is used to grab the side of the structure and center it on the reentry cone. Once the structure is positioned on the reentry cone, the lower ROV will connect to the structure through wet-mate plugs, which will give the sensors power and communicate to the command center on the marine vessel. After a connection is established, the instrument package will be lowered into the borehole and data will be collected.

Within the structure there are three main systems that must all work together in order to make the system successful (See Fig. 4 below). These three are the sensor package, the derrick structure, and the winch & cable system. The sensor package has yet to be fully designed, but its general physical characteristics are known. The components of the system in green represent structural elements that provide the overall structural support while blue shows parts that require electricity and control the sensor package. The characteristics of the sensor package informed the design of the derrick struc-

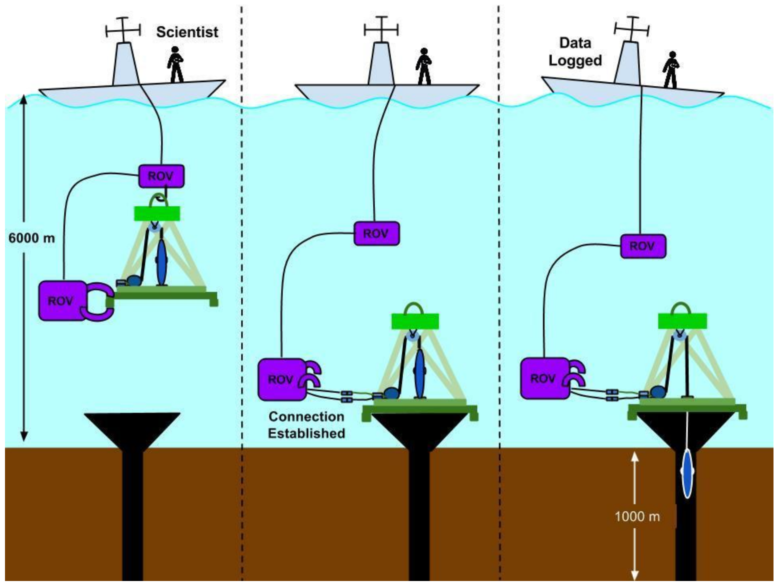

Fig. 3: Sketch of the derrick structure and instrument package deployment assisted by ROVs. The marine vessel controls the movement of the ROVs and collects data from the sensors on the instrument package once it has been lowered into the reentry cone. Source: Legacy Borehole project 2014

ture (depicted in green, in Fig. 4) as one of the structure's key functions is the safe transportation of the sensor package to and from the reentry cone. The winch and cable system (depicted in blue, in Fig. 4) facilitates the deployment of the sensor package from the derrick structure. On the top of the derrick is a hook to be used for control by the crane, which will lower the entire system into the ocean. The flotation device, also on top of the derrick, will allow the system to be more easily maneuvered in the water. Deployment of the sensor package will be accomplished by the pulley and winch system. The winch has been positioned at the bottom of the derrick structure because of its significant weight. This design is intended to assure greater stability and safety for the system. The winch then directs the tether around the pulley. An ROV provides the hydraulic power for the winch through the wet-mates. All of these elements were taken into consideration when designing the derrick structure.

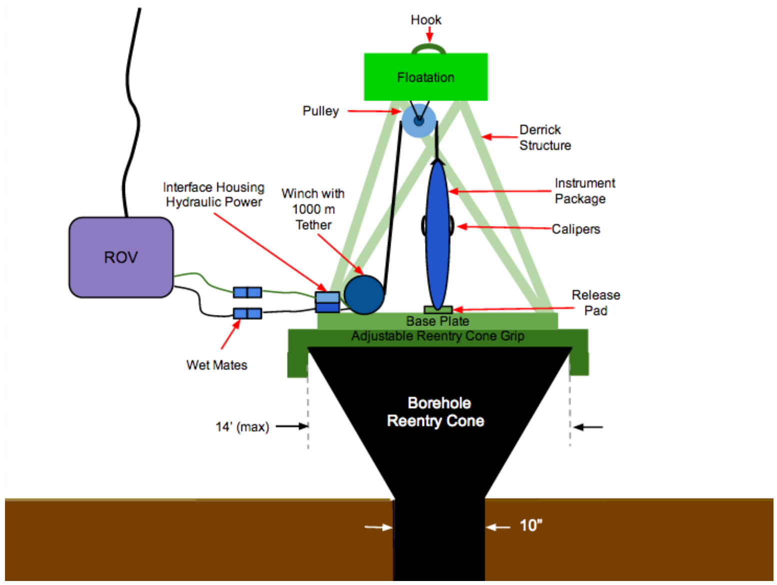

Fig. 4: A depiction of the s Subsystems of the structure. The components of the system in green represent structural elements that provide the overall structural support while blue shows parts that require electricity and control the sensor package. Source: Legacy Borehole project 2014.

Part II. Subsystem

3 Derrick Structure

3.1 Design Process

The year one team proposed a derrick structure with a triangular base and we continued with that design. The progression of three designs for the derrick is depicted below. Our first effort (Fig. 5) failed to take into consideration the volume of buoyant material required at the top of the structure. We revised the design to accommodate the buoyant material. This design is seen in the second image. Within this design is a consideration for the assembly and disassembly process, which, while it was rejected by the client, became an important transition to the third and final design (Fig. 6). The final design includes a satisfactory assembly process (see Appendix F) and all of the structural elements to accommodate the requirements of the client (Fig. 7).

Fig. 5: Initial derrick design

Fig. 6: Second derrick design, assembly process was not approved.

Fig. 7: Final derrick design met requirements of customer for buoyancy and assembly.

3.2 Assembly

The assembly of the derrick structure went through two modifications througout the tenure of the year 2 design of the Legacy Borehole project. Shown in Appendix F are the two procedures that display the assembly processes that have been created. The first is an assembly process that is suitable to ensure a safe assembly, however the customer chose a more traditional approach and approved the secondary assembly process shown in Appendix F.

3.3 Functionality and Requirements

Specifications that had to be considered in the design of the derrick structure included the 8 ft. height of the sensor package and an ability to support 1000 lbs. on land. The derrick structure must securely hold the weight of the sensor package and be large enough to provide protection and safe transportation. The structure must also be able to be assembled on the ship's deck and on its side and to withstand the conditions at the bottom of the ocean. The client required that the derrick be sized to fit inside a standard shipping container. See Appendix F for the assembly process.

3.4 Considered Alternatives

In year two of the project the discussion of options included whether the number of legs of the overall design of the derrick structure should be four with a square base or three with a triangular base. The square base design that was considered would be easier to manufacture, but the triangular base was determined to be superior because it provides three points of contact and thereby eliminates any possibility of rocking on top of the re-entry cone, regardless of size. For these reasons the client directed that we proceed with a triangular design.

It was originally requested that a ladder be incorporated into the derrick structure, but this request was withdrawn this year when the side assembly process was advanced by the client and a ladder was deemed unnecessary.

3.5 Material Choice

In most aquatic environments corrosion is a significant concern that would dictate material choice. There was an initial proposal by Dr. Wheat to build the derrick out of anodized aluminum, stainless steel or galvanized steel. Instead, Dr. Kirkwood advanced a change and directed that the derrick be built of low carbon steel. While this steel might develop surface rust, Kirkwood pointed out that it would have the advantage of being less expensive, both in terms of the cost of materials and the cost of fabrication.[12] Additionally, given that deployments would be for short periods of time, the exposures to the corrosive environment would be brief.

3.6 Finite Element Analysis

3.6.1 Testing Reasoning

Using ANSYS, finite element analysis software, the top enclosure of the derrick structure was analyzed in multiple design iterations. A Solidworks rendering was created for each design considered and then impulse finite element analysis was utilized. Impulse FEA was used in order to simulate both the initial contact between the crane of the ship interface and the structure being dropped. Figures 8 and 9, respectively, show the top enclosure of the final design experiencing the entire weight of the structure lifted up in an impulse. This gives the structure an increased factor of safety knowing that it will be lifted slowly in order to ensure safe transportation of the derrick

[12] Bird, Kenneth W. and Florian Mansfield. "Corrosion Protection." AccessScience, McGraw Hill Education, 1999.

structure. The finite element analysis test for each design is exactly the same despite the change in geometry for each design.

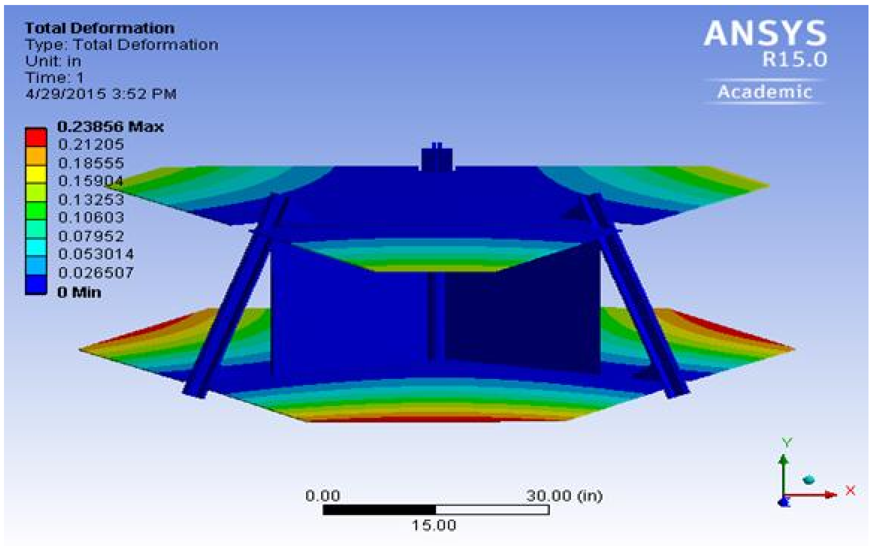

Fig. 8: Second design iteration of top enclosure subjected to an impulse load in finite element analysis. Color coding indicates value of deformation.

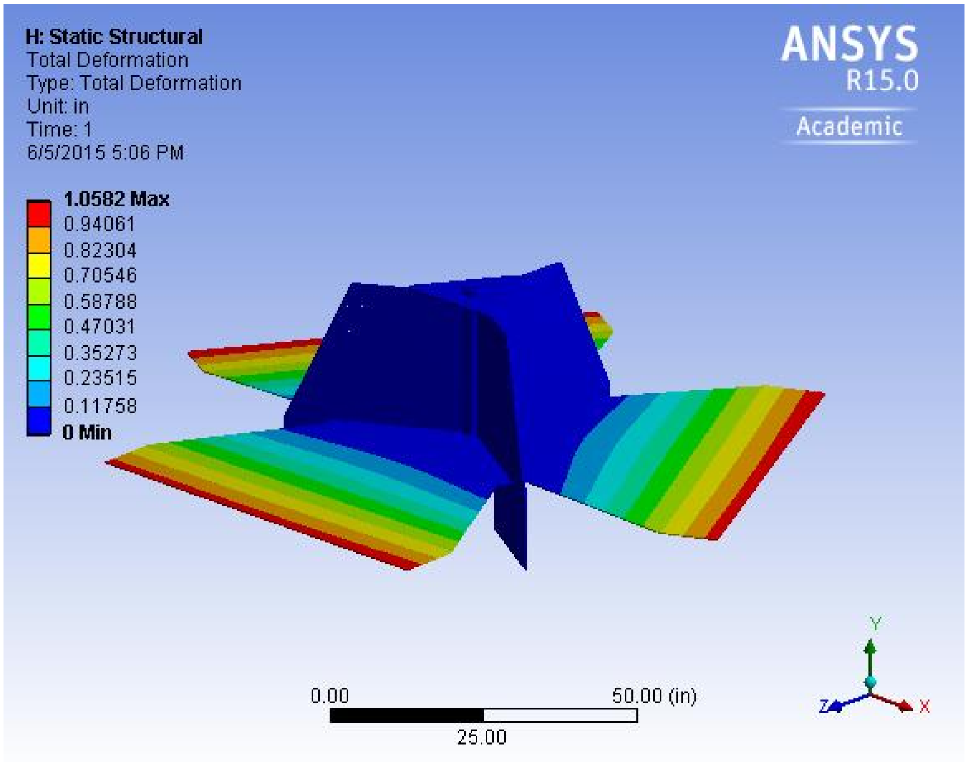

Fig. 9: Final design of top enclosure subjected to an impulse load in finite element analysis. Color coding indicates value of deformation.

3.6.2 Testing Results

The analysis results show that there is a significant jump in deformation from the first design to the third and final design. This deformation is due to an increase in the weight of the structure, and therefore an increase in the amount of force that it experiences when being lifted or dropped. The initial deformation shown is a sizeable amount yet it will be offset by the fact that the factor of safety of an impulse test shows a very extreme environment for the structure to experience. In the post-processing of the impulse FEA test, the weakest areas of the top enclosure include the fans that were added to accommodate for the buoyant material (syntactic foam). These fans will experience much less force when being lifted due to the fact that they have additional design constraints that include bolting them from the top and the bottom. A further report of the initial finite element analysis of the first design can be seen in Appendix H. The only difference between this report and the most recent findings are the geometric constraints and the temporary deformation results.

3.7 Calculations Discussion

While the finite element analysis is a helpful tool, basic hand calculations are also utilized to determine values such as critical buckling load and the buoyant force on the structure. These hand calculations are seen on the spreadsheet in Appendix I. In order to determine the critical buckling load on the T bars being used for the mid-beams, the following equations (1) & (2) are used.

$$P_{cr} = \frac{\pi^2 EI}{L^2} \tag{1}$$

Where E is the Modulus of Elasticity for steel at 29,000 ksi (199947.96 Mpa), I, is equal to the moment of inertia, and L is the 160.00 in (4.064 m) length of the T bar. Figure 10 shows the variables used for the dimensions describing the 4.00 in (10.16 cm) T bar.

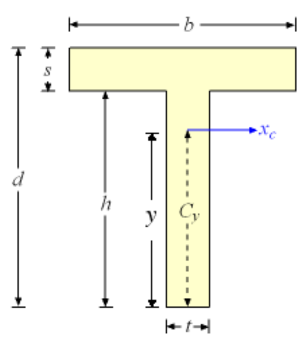

Fig. 10: Dimensions of a T bar used in the structural calculations. Source:< http://www.efunda.com/designstandards/beams/SquareTbeam.cfm>

	Values	Units
b	4.00	inches
t	0.25	inches
s	0.25	inches
d	4.00	inches
h	3.75	inches

Tab. 1: Values used in the calculations for the T bar and correspond to Figure 10.

Property	Amount	Units
Density	.28	lbs/in^3
Mass	2908.54	lbs
Volume	10455.61	in^3

Tab. 2: Physical properties of the basic steel structure without the winch and sensor package.

The moment of Inertia is 3.039 in^4 (126.492 cm^4), and is found using equation (2):

$$\frac{1}{3}[ty^3 + b(d-y)^3 - (b-t)(d-y-s)^3] \qquad (2)$$

Using the value found in Equation 2, the critical buckling load (Pcr) is found to be 33980.903 lbs (15413.50 kg). Considering the load of the top enclosure and the sensor package will be divided equally among the three midbeams, these calculations show that the midbeams will not experience any deformation due to buckling.

In order to determine how much syntactic foam should be used to make the structure buoyant, the properties in table 2 were needed:

In order to calculate the weight in sea water of the structure (not including the winch or sensor package), the following equation is used:

Weight in Seawater = (Density of Seawater – Density of Steel) x Volume of Steel)

Using the conversion factor of 1 g/cm^3 = 0.0361 lb/in^3:

= **(.0371 lb/in^3 - .2836 lb/in) x (10455.61 in^3)**

Weight in Sea Water = -2577.3079 lbs (1169.047 kg)

This means we would need to provide 2577.2 lbs (1169.047 kg) of lift from the syntactic foam to make the steel structure neutrally buoyant.

If we used syntactic foam with a density of 0.0139 lb/in^3 (.3848 g/cm^3), we can plug into the same equation to solve for the volume of foam needed:

Weight in Seawater = (Density of Seawater – Density of Syntactic) x Volume of Syntactic

2577.2 lbs = (.0371 – 0.0139) x Volume of Syntactic foam

Volume of Syntactic foam = 147945.1 in^3 =85.615 ft^3 (2.424 m^3)

This value found above is representative of the volume of syntactic foam that is needed in order to make the structure neutrally buoyant. Because the weight of the sensor and winch are not included in this value, our design has planned for approximate double the volume of foam. With these calculations, the design of the structure was revised because of the large amount of syntactic foam that is needed. In order to accommodate for the syntactic foam, a larger top enclosure was developed and incorporated into the existing design. The idea of using 2 in (5.08 cm) T bars was considered because of the midbeam buckling. However, when using the 2 in T bar, the critical buckling load was just shy of the weight of the top enclosure with the newly designed size and shape.

4 Winch and Cable System

4.1 Functionality and Requirements

Dr. Geoffrey Wheat and the team have called for the cable system to be comprised of a winch and level wind element to allow for safe operation during multiple lowerings. The winch must employ a custom pressure tolerant optical and power slip ring for communications and in order to supply the necessary energy for the instrument package . The instrument package will utilize both existing and newly developed instruments in order to integrate second generation electro-chemical and optical instruments[13]. The winch will be specialized and built to order and will support cable that will also be ordered to specialized specifications.

How the winch is powered is a primary engineering concern. According to Wheat and Kirkwood, power may be provided by the ROV through the slip ring or mechanically by using a rotational system such as the ‘drill sled’ utilized on the ROVs (Tiberon and Jason). The winch must have a specialized electro-optical slip ring that will function at 16,400 feet (5000 meters depth) and pass 3-phase power or DC. This is to be determined by the specifications of the support vehicle. The specifications set forth for the slip ring call for “a suitable number of multi-mode fiber optic passes for data and video transmission including spares. Multimode is suitable for the 1000 meter deployment down hole from the initial installation depth of the derrick”.[14] The specification sheet for the slip ring can be found in Appendix K.

The following is a list of requirements for the custom winch set forth by Wheat and Kirkwood. All of these items were considered in the selection of the winch and the design of the system.

1. The winch system must be strong enough to raise and lower the approximately 500 lb. instrument package.

[13] Wheat, C. Geoffrey, Kathina Edwards, Bill Kirkwood, Chris Kitts, William Hug, and Everett Salas. “Dark Energy Biosphere Initiative- SubserfacE LifE Characterization (DEBI-SELECT).” Marine Science and Technology Foundation Grant Proposal. 4 May 2012.

[14] Kappell, Ellen. ODP Legacy: ODP’s Greatest Hits. Ocean Drilling Program National Science Foundation, 1 Nov. 1997. Web. http://odplegacy.org/PDF/Outreach/Brochures/ODP_Greatest_Hits.

2. The winch system must have precision control to stop every meter while lowering or raising the instrument package.

3. The winch system must be designed to prevent the tether from slipping out of place.

4. The winch must be securely connected to the base plate.

5. The winch must incorporate a designated slip ring.

6. The winch must incorporate a cable that will transmit power and data to and from the sensor package.

4.2 Considered Designs and Models

This winch shown in Figure 11 is a custom winch that was designed by Sound Ocean Systems Inc. The proposed winch was designed with the following characteristics:

- Drum Size: 16in core x 36in flanges x 36in wide
- Overall Winch Dimensions: 60in wide x 42in long x 38in tall
- Total in-air weight ~ 700 lbs assuming an aluminum construction with some stainless steel components
- Average winch speed = 15 ft/s
- Full drum line pull = 500 lbs
- Bare drum line pull = 980 lbs
- HPU power requirement ~ 0.5HP

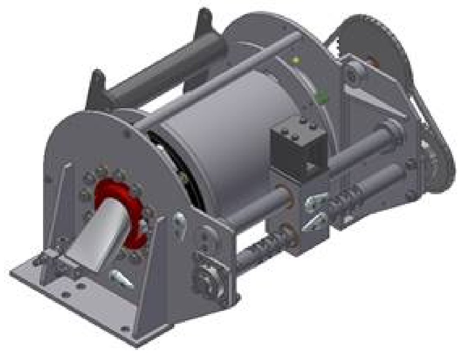

Fig. 11: Custom winch designed by Sound Ocean Systems Inc.

This drum size proposed is large enough to fit a fiber-optic cable with the approximate diameter of 0.5 inches. This winch would cost approximately $90,000. While this winch is large for our application, it is a good approximation of what one might look like and how much it would cost.

5 Base Plate and Alignment

Because it is known that that reentry cones have sustained environmental degradation over time and that some have shifted from their original level positions (Figure 2), the derrick system base plate is designed to accommodate this. The current design of the derrick relies upon a base plate alignment pin system, a set of pins that hang below the base of the structure, as depicted in Figure 12. Pins in this system can be relocated to other holes in the base of the structure to accommodate reentry cones of various diameters, ranging from 10 to 14 feet in diameter. The pin system will prevent the structure from shifting off reentry cones that are not level.

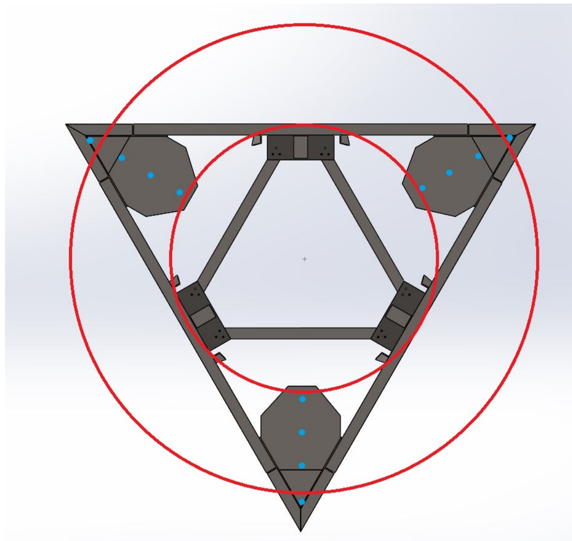

Fig. 12: Base plate alignment pin system with threefold radial symmetry.

6 Testing

6.1 Experimental Reasoning

The experiment that we chose to perform is a tensile test of the strength of a bolt pattern that will be used for the base corner joint of the base plate. This experiment is crucial to understanding the amount of force that can be applied at this joint. Due to the majority of the weight of the structure existing in the top-enclosure and mid-beams, the force must be dispersed throughout the base corner joint correctly in order for the base plate to withstand the whole force of the system. A tensile test was one of the only tests available to be performed with the bolt pattern and material that we chose and is justified to equal the same amount of force seen in compression.

Fig. 13: Bolt test assembly used in this experiment.

6.2 Experimental Procedure

In the design of the structural components of our system, finite element analysis was used to justify the design of this structure. Before the experiment was to be performed, the pieces of the testing material needed to be fabricated to a certain size and length shown below in (Figure 13).

1. Safely fabricate test components from plate 1018 steel.

2. Assemble test joint a. 5 bolt-washer-nut (grade 8 steel hex nut $\frac{1}{4}$" – 20 thread size, 2X grade 8 steel flat washer, steel split lock washer $\frac{1}{4}$" screw size, grad 8 steel hex head cap screw $\frac{1}{4}$" screw) assemblies bind plate steel components together (tighten to 10 ft. lb.)

3. Turn on computer connected to an Instron 1123 electromechanical tensile tester.

4. Insert testing bolt assembly and 1/8" 1018 steel plate spacers into vice gripes of an Instron II23 electromechanical tensile tester.

5. Run test.

6. Interpret the data.

7. Remove desired number of bolts from material and repeat from steps 4-6.

6.3 Results

When interpreting the data for the test it was shown that the machine reached its maximum load limit for this test at the amount of force that it would place on the test piece. The reasoning why is unknown, however it has been theorized that the amount of force was exceeding the machine's limits and that the bolt pattern as well as the material can withstand much more force applied to it. Since the weight of the top enclosure in addition to the mid-beams will be a total of 4000 lbs. the calculated amount of newton force that would be applied for this base corner joint bolt pattern was converted from the weight to equal approximately 3,327 lbf. (14.8 kN). A factor of safety of 2.5 was included in the calculation in order to account for any error. Due to no signs of plastic deformation when the machine maxed out at 15 kN, the observation is that the material and the bolt pattern will withstand the amount of weight required of it.

Shown below in Figure 13 is the curve of the data acquired from the tensile testing of the short specimen and the long specimen.

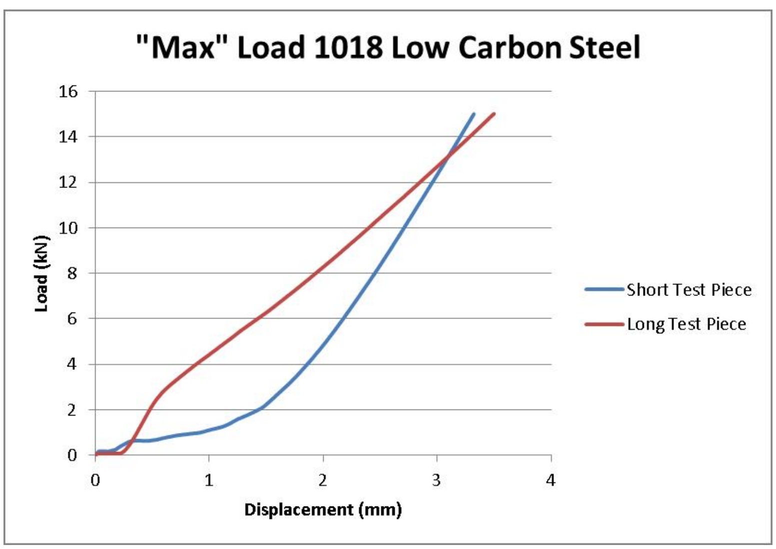

Fig. 14: Load vs. Displacement for the chosen bolt pattern.

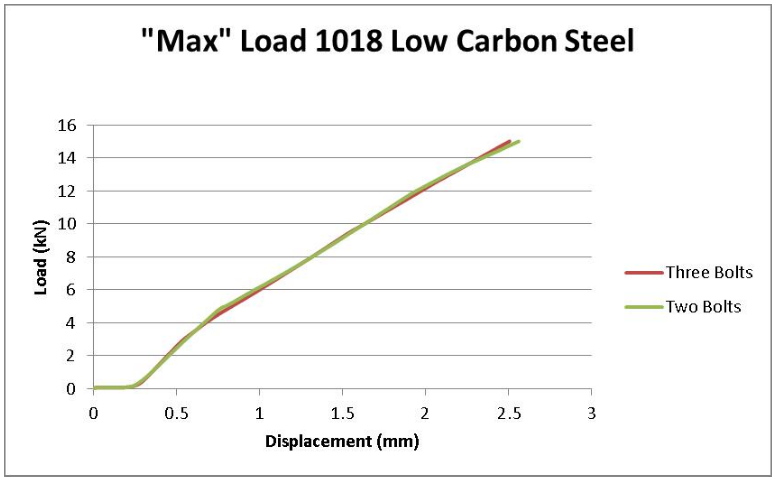

Fig. 15: Displays the curves of the load vs. displacement for a bolt pattern with removed bolts.

Part III. Engineering Analysis and Considerations

7 Team and Project Management

7.1 Project Challenges and Constraints

As the second year of the Legacy Borehole Project comes to a close, there are many successes, and numerous obstacles/delays to overcome. Our team formed effectively and worked together with a sense of mutual respect. Of the many accomplishments this year these stand out as the most prominent: we designed a structure that the customer is satisfied with and have found local companies to manufacture it. However, there were two significant challenges. First, came with significant communication gaps with our customers, who were frequently out of cellphone reach for long periods of time doing research. This absence of a direct and consistent line of communication created gaps in our ability to vet design iterations. Another significant obstacle we encountered included an uncertainty about funding. We learned in the middle of our work that funding was not assured and this caused delays in the manufacture. Resources that were assumed to have been committed to the project became unavailable. As a result of this lack of secure funding, we were unable to build a model. Materials we have secured were either donated or funded by Santa Clara University.

7.2 Budget and Cost Analysis

While the budget for the entire project is still to be determined, the approximated budget can be seen in Appendix N. A quote for a custom winch is approximately $90,000. The slip ring cost is approximately $40,000. The cost of materials for the steel structure is between $10,000 and $12,000. As we understand it, the organization committed to providing the funding has been dissolved, so at this time, there is no funding available to continue with the fabrication of the structure. The proposed budget is shown in section O.3 of Appendix O. In order to fulfill the academic requirements set forth by Santa Clara University, materials for a base corner joint was prepared for testing. There was no cost for the materials for the prototype, as the steel needed was graciously donated by Ken Matzek of PDM Steel in Santa Clara. The cost for welding of the base corner joint was bid at $1,400 with a local machine shop because the machining facilities at MBARI are not available for this project. Because funds were not available to manufacture a half scale corner base joint, we opted to test a bolt pattern, which was funded by Santa Clara University.

7.3 Timeline

The Legacy Borehole project is a three-year project to be completed by three separate teams. Our timeline is set for the current school year (2014-2015). A weekly task list can be seen in Appendix P. This has been our schedule:

- Fall Term - Focus on the design of the derrick structure.
- Winter Term - Work on the derrick structure design and find a company for fabrication.
- Spring Term - Finish the design and move forward with the plans for manufacturing.

A question and response list detailing expectations of the clients was assembled at the outset of the project in 2014 and is included in the Appendix A.

7.4 Design Process

When designing the derrick structure that will sit on the recovery cone at the bottom of the ocean floor, the main objective of our system design must be as simple and efficient as possible. The overall goal is make the most cost-efficient yet longest lasting derrick structure that can survive on the bottom of the ocean for various lengths of time. In order to do this, numerous design specifications were considered when searching for different ways to configure our derrick structure. The first year's design team had already given an example of what the derrick structure could look like, and these ideas were factored into the design process. Many of the initial design drawings can be seen in Appendix D. In order to follow our customer's needs as well as work with our engineering knowledge many trade-offs were evaluated in order to create the most effective and creative design possible.

7.5 Team Dynamics

The team's primary tools to prevent mistakes are communication and organization. The group checked up on each other's progress in our scheduled weekly meetings to confirm that everyone was on the same page. We also stressed promptness in our responses to any communication within the team or with clients. We interacted with companies to get estimates on components and services we required. As issues arose internally or externally in this project, the team maintained a professional tone in our response and resolution. We addressed any and all problems between group members with the appropriate respect and discretion. We have built camaraderie and accountability amongst group members. The assigned areas of responsibility have been as follows:

- Piper Connelly
  - Fabrication logistics
  - Secretary
  - Organization
- Rhys Marks
  - Team Leader

  - Drafting & Structural Analysis
  - Client Communications

- Ronnie Saavedra
  - Treasurer
  - FEA (Finite Element Analysis)
  - Materials

8 Engineering Standards and Realistic Constraints

8.1 Manufacturability and Assembly

This project was designed to be viable and useful for many years per the expectation of the clients and our obligations as ethical engineers. Consideration has been given to the fact that the derrick will be left in storage for many months when not in use at sea. The materials chosen for the derrick structure were at the direction of the client. The design of the derrick took into consideration the need to respect the environment of the subseafloor, specifically that nothing will be left behind to harm marine life. Additionally, the client has directed the team to use steel as a material and to avoid the use of any materials that could degrade and pose a threat to the ecosystem of the ocean floor.

Another facet to the sustainability of the design was a concern by the team that the derrick be easily repairable by the research team and crew while working in the field. For this reason, the team chose to design the derrick using standard components and parts, which are more easily replaced than custom parts. This design consideration was taken for both financial and ethical reasons, to create a product that will be durable and safe and easily repairable for a minimal cost.

The majority of the derrick structure is custom designed and will need to be professionally crafted in a machine shop by those with more advanced skills in manufacturing than are the skills of the undergraduate team. The facilities at MBARI are suitable, however, it was specified by the customer that the team will not be able to utilize this resource due to the amount of time and work that it would take out of the mechanical technicians' schedule. Budget uncertainties unfortunately resulted in an inability to complete the build this year. We have identified and obtained bids from local manufacturers who are prepared to do the work to a high level of quality.

8.2 Health and safety concerns

The health and safety of the testing and deployments teams are the number one priority. It is absolutely essential that no physical harm is caused. It is our responsibility to design a derrick structure that is "user-friendly" and safe during all stages of production and usage. The system has been designed for easy transport and assembly. The most critical period of use in terms of health & safety is when the derrick is being assembled on the deck of a swaying ship. We are confident that given the simplicity of the design, experienced crew and technicians should have no difficulty in the assembly.

8.3 Ethics

In the design and manufacture of the derrick structure, efforts have been made by our team to produce as much work as possible on campus and to adhere to safety codes set forth in IEEE and ASME. In order to accomplish a high level of safety, members of our team have maintained a professional demeanor at all times. Attention has been given to sound ethical judgement and to the responsibilities of engineers that is the foundation of our engineering education as informed by the Mechanical Engineering Codes of Conduct.[15]

We have taken seriously our responsibility to make sure that this project is designed to assure that when it is in use the likelihood of injury will be minimal. The main ethical issue that we have faced is that this project must be made without cutting corners and making sure that the project meets the specific needs of the customer without exceeding the budget. In addition, we have no reason to believe that any harm will come to sea life from the deployment of the system we have designed.

The materials used in this project were explicitly chosen by the client because they can be relied upon to withstand conditions in the ocean and on the ocean floor. No part of this system will be left on the ocean floor. No harm should come to the ocean's ecosystem through the deployment of the Legacy Borehole Project system.

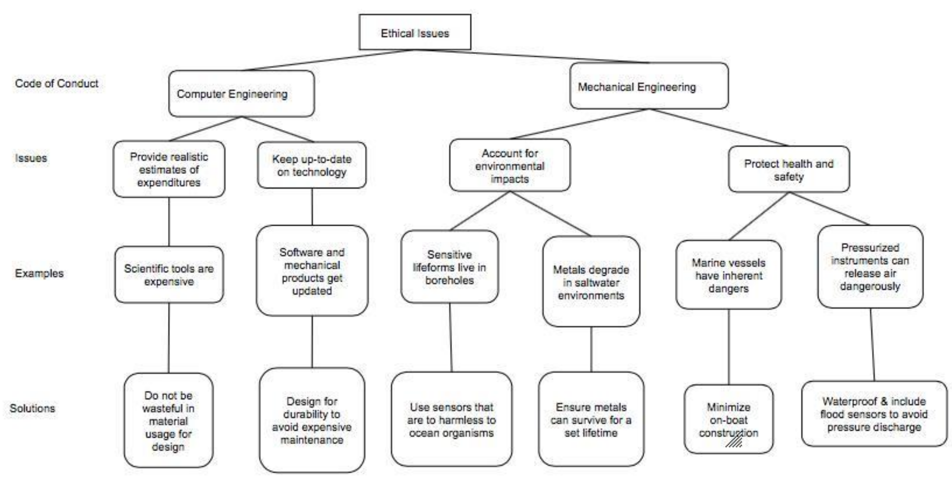

Fig. 16: Ethical Flowchart created by the year 1 team used to determine proper routes of action during the design process. Source: Legacy Borehole Project Thesis 2014.

[15] Santa Clara University School of Engineering: Student Conduct Code: Statement of Responsibilities and Standards of Conduct." http://www.scu.edu/academics/bulletins/engineering/conduct.cfm

8.4 Societal Impacts

This project may profoundly impact society in many ways. The main objective set forth by the project's principal investigator, Dr. Wheat, is to analyze the biosphere beneath the ocean floor, anticipating that what is learned will be shared broadly and have innumerable beneficial impacts on society through its educational mission as well as by sharing data as a means of advancing scientific research in numerous fields such as climate change, carbon cycling, and even our understanding of the origin of the Earth itself. Some examples of the anticipated educational and scientific benefits follow.

8.4.1 Educational

Robotic Exploration Technologies in Astrobiology (RETINA) is a unique educational program teaming engineers and scientists at all educational levels. Students are taught how to develop novel robotic instruments and systems to conduct microbial sampling by means of deep sea submersibles. MBARI scientist Dr. Geoff Wheat oversees the program that "lends itself to the creation of activities for 5th to 8th grade students especially in relationship to ROV operations and the integration of sensors."[16]The college program at SCU, which has both an undergraduate and graduate component, is overseen by Prof. Kitts and Bill Kirkwood.

The stated philosophy of the RETINA program is consistent with the impetus for Legacy Borehole research: "to get all of the information to the community so that they can develop their own scientific justification and sensor payloads to use DEBI-SELECT as a platform to study these valuable legacy boreholes."[17]

[16] Wheat, Geoff, Dr., and Chris Kitts, Dr. "RETINA Vision for Life." RETINA. Santa Clara University. http://retina.engr.scu.edu/

[17] Wheat, C. Geoffrey, Kathina Edwards, Bill Kirkwood, Chris Kitts, William Hug, and Everett Salas. "Dark Energy Biosphere Initiative- SubserfacE LifE Characterization (DEBI-SELECT)." Marine Science and Technology Foundation Grant Proposal. 4 May 2012.

8.4.2 Scientific

Knowledge of the subseafloor by the scientific community is expanding and the Legacy Borehole Project can be expected to contribute to scientific breakthroughs that will arise from this knowledge. It is already established that sediment and rock of this environment are home to microbial life that can exist without sunshine. These organisms in the past have been used to generate new antibiotics and antimalarial drugs. Aerobic microbes can be found as deep as the igneous basement, which is 246 feet (75 meters) below the seafloor.[18] Such discoveries offer potential breakthroughs in our understanding of changes in the environment of the planet in terms of how the ocean absorbs carbon dioxide from the atmosphere partially mitigating climate change.[19] Information that is gathered in Legacy Boreholes is also expected to contribute to understandings of energy production mechanisms of organisms in the darkness of the subseafloor biosphere. Researchers aim to apply this knowledge to the development of "clean" energy sources.

8.4.3 Environmental Impacts

When considering the environment in terms of the design project, the main concern is that the project not fail and become a piece of waste sitting at the bottom of the ocean. However, this is another reason why the borehole project exists: to prevent wasting the opportunity that is presented by the 54 boreholes drilled into the bottom of the ocean's floor. These boreholes should be studied and observed for a greater understanding of the life that exists there. The steel that will be used is going to be safe for the oceanic environment The system itself will also have a transponder and strobe light attached to the top of the derrick structure in order for the crew of the

[18] Schrope, Mark. "DEBI-SELECT: Probing the Subseafloor." DEBI-SELECT: Probing the Subseafloor. Marine Science & Technology Foundation, n.d. Web. 27 Apr. 2015. http://www.mstfoundation.org/story/DEBI-SELECT

[19] NOAA. "Ocean Facts." National Ocean Services. 11 Jan. 2013. Web. 1 Oct 2014. http://oceanservice.noaa.gov/facts/exploration.html

research vessel to be able to communicate and "ping" the derrick, assuring that the system is retrievable.

While participating and being a part of the Legacy Borehole Project, our knowledge of where and how the derrick structure and sensor package will be implemented has come from our client and our research. We know the derrick assembly process as well as how the derrick and sensor package will be lowered into the ocean and brought down to the borehole recovery cone. It is assumed that the assembly process we have created for the derrick structure will be followed by those assembling it on the vessel. It is also assumed that the only use of the derrick structure is for the transportation of the sensor package to the borehole recovery cone.

Regarding the research data that will be acquired through this project, there are assumptions regarding the data. There have been very few research opportunities of the kind anticipated by the Borehole Project to study the subseafloor and acquire microbial and geological data. It is assumed that the data acquired by the sensor package will be used specifically for scientific research and distributed for use by scientists in their respective fields.

The foreseen environmental impacts associated with this project include the discovery of organisms that will lead toward advancements in science and a greater understanding of the significance to global warming of increasing levels of carbon dioxide in the ocean. Research centered on understanding fluid circulation through the oceanic crust and deep sea ecosystems could also yield information that contributes to much needed advancements in the field of clean energy. The importance of research into clean energy cannot be overstated. The National Oceanic & Atmospheric Administration (NOAA) is the federal agency that monitors the level of carbon dioxide in our atmosphere and also measures the level of carbon dioxide in our oceans. In doing so, they track for the public changes in the global atmosphere. It is hoped that a solution can be found to create a downward trend in the curve shown below so that human life can be sustained on earth.[20]

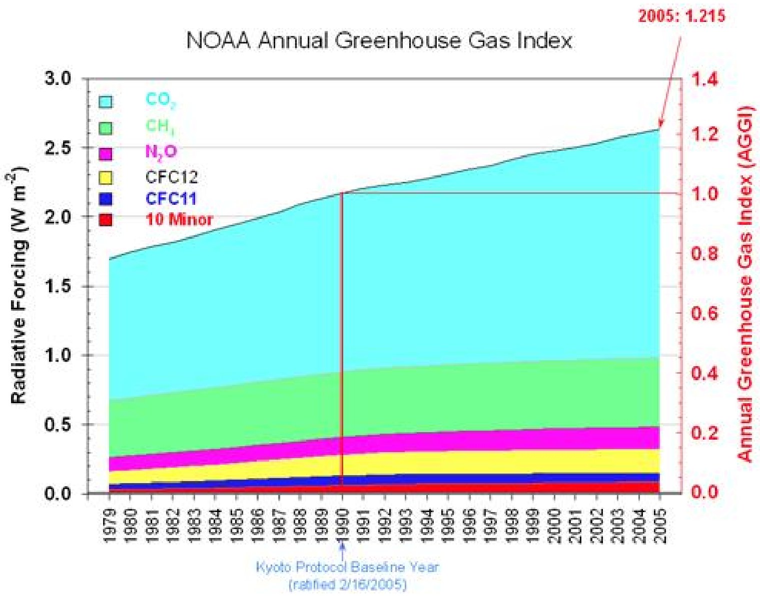

Fig. 17: NOAA annual greenhouse gas index from 2005

[20] NOAA. "Ocean Facts." National Ocean Services. 11 Jan. 2013. Web. 1 Oct 2014.http://oceanservice.noaa.gov/facts/exploration.html

9 Arts Requirement

Team Member	**Description**	**Location**
Piper Connelly	Initial Design Concept	**Figure 5**
Rhys Marks	Detailed Drawings	**Figures in Appendix E**
Ronnie Saavedra	Original Assembly Procedure	**Figure 18**

Tab. 3: Table of the contributions of each team member to the art requirement for Santa Clara University.

Part IV. Conclusion

10 Conclusion

10.1 Summary

Expanded exploration of the basaltic biosphere beneath the ocean floor will be made possible by the Legacy Borehole Project. In this second year of the three-year project our team has designed a derrick structure that is strong and portable and that allows for data recording and sampling from cased boreholes that are part of a longstanding legacy of ocean research. Consulting with the client to define and refine the original derrick design, we have arrived at final plans and have conducted testing.

Prioritizing safety and manufacturability, our design meets both our customer's and our university's requirements. The design and manufacture of this project was not as straightforward as we initially expected. Working for an actual client provided invaluable learning opportunities and profound lessons. There were significant challenges in scheduling, budget, and communications that limited our progress. While we would have liked to have had the funding in time to manufacture the structure, we are confident that what we have developed will position next year's team to complete the project within the three-year time-frame so that the research can proceed.

10.2 Future Work

Now that the design is completed, we hope that next year's team will begin the fabrication process and testing at NASA AMES and MBARI. Once the manufacturing has been completed of the derrick and sensor package system, an assembly test can be done at AMES with Dr. Kitts and his students. MBARI have generously offered their facility for testing

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Part V. Appendices

A Customer Needs and Requirements

1. Derrick Structure

    (a) The construction of the structure must be simple and easily assembled on a boat.

    (b) The structure must be able to be assembled on its side and then lifted on the boat.

    (c) The side of the structure must have a ladder to allow for top construction.

    (d) The structure must be able to be moved with cranes and ropes.

    (e) The structure must have a hole for the passage of the instrument package.

    (f) The top of the derrick structure must have a hook for attaching to Medea (ROV helper)

2. Winch System

    (a) The winch system must be strong enough to raise and lower the approximately 500 lb instrument package.

    (b) The winch system must have precision control to stop every meter while lowering or raising the instrument package.

    (c) The winch system must be designed to prevent the tether from slipping out of place.

    (d) The winch must be securely connected to the base plate.

3. Base Plate and Grips

(a) The base plate and grips must be adjustable for various reentry cone shapes and sizes that are as large as 14 ft. in diameter and as small as 10 ft.

(b) The grips must provide a strong, secure connection to the sides of the reentry cones to prevent the structure from slipping off or falling over.

(c) The base plate must contain a release pad clamp to hold the instrument package in place when not in use.

4. Connections to Jason (remotely operated vehicle) and Medea (ROV assist)

   (a) Medea must have a hook to clasp onto the top of the derrick structure.

   (b) Jason must be able to grip the side of the structure to pilot and center the structure on the reentry cone.

   (c) Wet-mates will be used to connect Jason to the pressure housing of the winch system.

   (d) The connection to Jason will provide both power (coming from Madea) and a real-time data connection from the subseafloor sensors to the surface.

5. General System Requirements

   (a) The system must handle between 1 C and 30 C temperatures.

   (b) The sensor packet must stop every meter at the beginning of the borehole and every 10 meters deeper in the borehole down to 1500 meters for data sampling.

   (c) The system must handle a broad range of geological disturbances in the boreholes.

(d) The system must center the instrument package in the boreholes.

(e) The system must be balanced and outfitted with proper flotation elements so as to stay upright during ascent and descent.

(f) The system must fit within a standard 20' x 8' x 8.5' cargo container.

B Customer Questionaire

Questions for Dr. Kitts (2014-2015)

1. What do you see the derrick structure looking like aesthetically?
2. What type of materials should be used?
3. What additions should be made to the overall structure in order to make the structure easier to use?
4. What is the recommended shape and size of the derrick structure?
5. What does the funding look like and are there an changes?
6. Where should we make the model?

Questions for Geoff Wheat (2014-2015)

1. What do you see the derrick structure looking like aesthetically?
2. What type of materials should be used?
3. What additions should be made to the overall structure in order to make the structure easier to use?
4. What is the recommended shape and size of the derrick structure?
5. Will the structure be made in house, through us, or by using a third party?
6. Where will the testing occur for the structure, in Tahoe or in MBARI?

Mechanical Engineering Questions for Dr. Bill Kirkwood and Dr. Chris Kitts (2013-2014)[21]:

[21] Brady, Maza. Cashman, Luke. Hicks, Erin. Richey, Meghan. Legacy Borehole Project. BS thesis. Santa Clara University, Santa Clara, 2014. Print.

1. How many years, ideally, would this whole system be used?

2. Can you please clarify the baseplate concept?

3. What winches have you used before? What can go wrong with a winch system?

4. Of the different wet-mates out there, what are some of the specs we will need to look for to make a decision?

5. We see fitting the instrument package within the derrick structure (as it will be sitting whenever it isn't traveling down/up the borehole) as fairly loose/close/tight precision. Is this necessarily true? What are the possible repercussions?

6. Is it going to particularly matter if the instrument package spins minorly (5-10 degrees) in the descthoeheothoeheoent of the borehole?

7. The calipers on the sides of the instrument package will be spring-loaded, but should we design them to be retractable as well for the ascent back to the derrick structure? How much control do you foresee being necessary for these?

8. What types of FPGA boards are going to be used?

9. Data transfer: software wise what language/program is being used to transfer data (data turbine) and physically what wires/connectors (copper wires?) are being used?

10. Which sensors do you want real time data and which will be requested on demand?

11. How much data is actually coming in and how fast do you need to sample the data?

12. For displaying do we have to display every data point or can we use an average?

Scientific Questions for Dr. Geoff Wheat (2013-2014):

1. How often do you foresee the need to stop the instrument package? Are you shooting for a certain depth?

2. What safety concerns have arisen in previous employments and do you foresee any safety concerns for our project in terms of the payload and safety of personnel and other facets of safety?

3. Where are you with Bill on the type of reentry cone we will be designing for? We already have three of the design specs supplied to us (funnel vs. hexagonal shape)

4. What Oceans will we exploring? Will the current affect us at all? Has the current affected you in the past?

5. You have been in spots off the coast of WA and SE Asia... are you planning on going back to these? Are there any in particular you are most interested in?

C Raw Customer Responses

Questions for Geoff Wheat (2014-2015)

1. What to see in the Derrick Structure?
   (a) Material
      i. Anodized Aluminum with Zinc coating (currently what is used for elevators)
   (b) Full Size
      i. Rectangular shape with room for flotation device at the top as well as lead weights on the bottom.
      ii. Sensor package will be a maximum of d = 9in, length = 8ft
      iii. Must be able to work with these parameters
   (c) Additional Items
      i. Plenty of taglines (places for hooks to grab onto) at locations where the ROV can easily detach and move away
      ii. Must be forklift accessible
      iii. Must be able to be disassembled and put back together by a crew of four people at most
      iv. Ring at the top in order to lift up by the crane on the boat, along with a quick release for the bale
      v. Room at the top for a transponder, strobe light, and some other sort of communication device
         A. Keep these things to the sides of the top in order to avoid having them interfere with the bale and the crane loop
   (d) Winch Design
   (e) Work backwards from the slip ring as well as the desired cable to be used.

(f) Must be able to lower the sensor package 1km into the borehole

(g) Ocean Process o Could lower into the ocean one of two ways.

  i. Straight drop into the ocean and allow to descend to the ocean floor, which requires 150lbs (-)
  ii. Design in such a way that the Derrick doesn't stray too far from the boat position
  iii. Must have 150lbs (+) when it hits the earth's surface
  iv. Everything that is overhead (transponder, strobe, etc.) must be secured

(h) Cable- undecided o need to confirm with Dr. Bill Kirkwood

(i) Simple deployment

(j) Drop at 150 lb negative buoyancy

(k) On top of cone at 50 lb negative buoyancy

(l) Rising to surface at 150 lb positive buoyancy

(2013-2014) From Geoff Wheat we learned[22]:

1. Logistics

   (a) exploring the holes in the middle of the Pacific Ocean that have been undisturbed for 30 years

   (b) Ocean currents are minimal at the bottom of the ocean and the ROVs can easily handle it

   (c) No big sea creatures (maybe some octopi) to worry about

   (d) Common temperatures range from 1C to 30C (design for 70C max).

[22] Brady, Maza. Cashman, Luke. Hicks, Erin. Richey, Meghan. Legacy Borehole Project. BS thesis. Santa Clara University, Santa Clara, 2014. Print.

(e) Max depth is 1500 m below seafloor (first couple hundred meters are casing and rest is basalt).

(f) In case of storm or emergency, design to be able to abandon the system at bottom of ocean for 1 year

  i. include backup battery pack for cameras to be able to see if recoverable

(g) Geoff will have weekly meetings with Kitts & Kirkwood

2. Data sampling

   (a) All sensors need to be real time (except fluorescent spectrometer & water sampler)

   (b) data will be sampled between 1 time per second to 5 times per second o okay to use a running average for real-time data

   (c) Need to stop every meter (every 10 meters deeper down) for sampling

      i. ROV control van team will decide when to stop

   (d) disturbances due to dropping the sensor package & callipers scraping the wall will help stir up the microbes and is good for the water sampling

3. Interface

   (a) "design for dummies" = simpler the better

   (b) Software needs to have backup mechanical switch just in case

4. Sensor Layout

   (a) wants a modular design that allows different sensors to be added/removed between dives

   (b) cameras positions: one pointing up, one pointing down, one pointing at callipers
      i. looking for cave ins and movement of particles to identify the more porous regions that are ideal of sampling o water sampler must be at bottom o structure needs to be adjustable to various reentry cone sizes
   (c) Sensor package needs to be centered in hole
      i. design a self-centering mechanism(s) to accommodate all cone/hole sizes.

From Bill Kirkwood we learned:

1. How the structure would connect to the borehole reentry cone:
   (a) We will have a baseplate with legs that will extend to grasp the sides on the borehole reentry cone.
2. Where he wanted the origin on the structure:
   (a) The origin will be placed below the base of our structure in the center of the hole that the instrument package will pass through
3. How the ROV would transport the structure down to the borehole:
   (a) Jason's companion robot Medea will have a hook that will clasp onto the top of the derrick structure and lowered down to the bottom of the ocean. Jason will be attached to the side of the structure to act as pilot and center the structure on the reentry cone
4. How the derrick structure will be assembled on the boat

(a) Cranes on the boat will allow us to begin to set up the structure on its side and then lift it up once assembled.

i. The side of the derrick structure will have a ladder that will allow people to climb onto the structure for set up.

From Dr. Kitts we learned:

1. We might want a mini preliminary probe to send down to analyze if the full scale project is worthwhile.

2. Thickness and material of base plate needs to be clarified and its weight taken into account.

3. We need to clarify power sources (will there be batteries in the sensor package) and how to ensure those could last a year underwater.

4. We need to do a tradeoff analysis for our mechanical structure.

5. We need to determine where the ship will be deployed and what the set-up will look like on the ship.

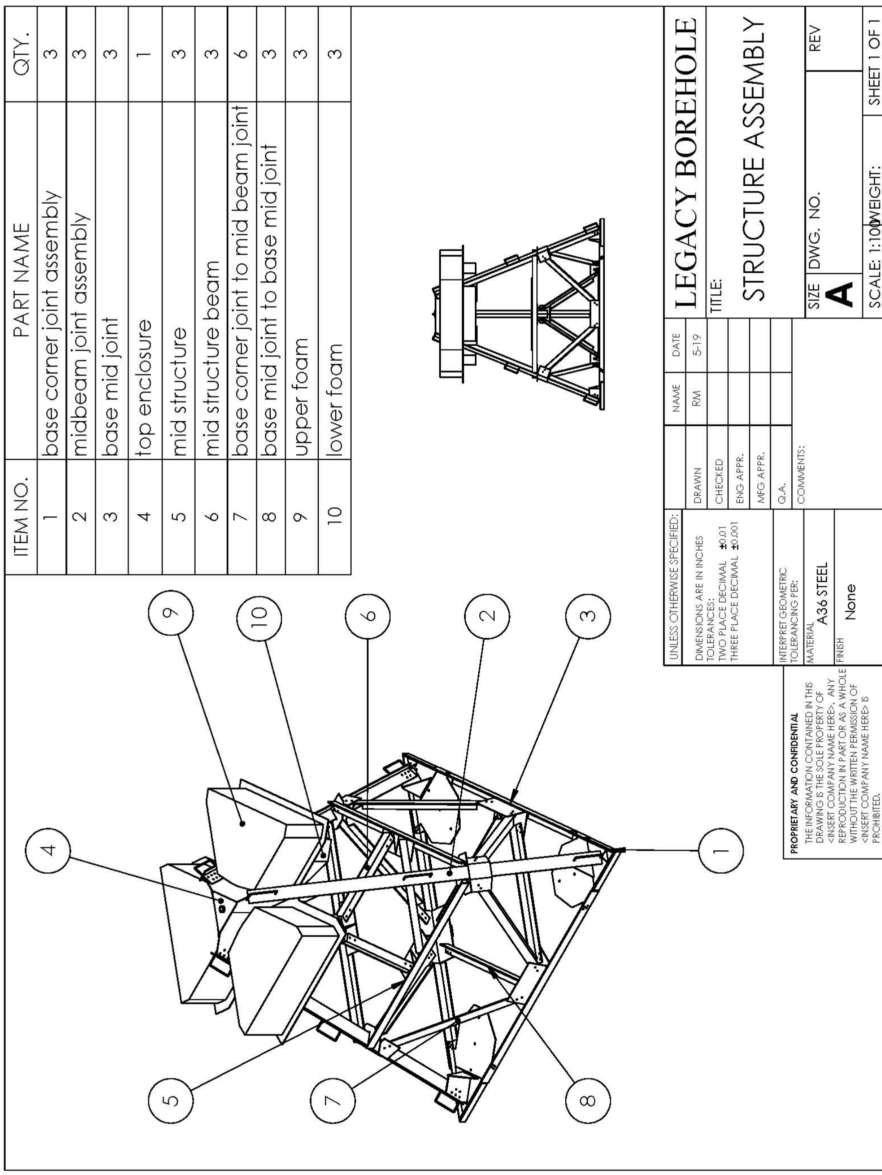
6. We should make multiple versions/solutions of the caliper system that will be used to measure the hole diameter and center the sensor package We need to determine specific requirements for the calipers and why they are needed.

Derrick Structure	Origin Location	➢ Center of the hole, located where baseplate meets the plane of the hole. ➢ Helps us distinguish weight and balance distribution
	Baseplate	➢ Include adjustable grips on each side that hold edges of different size re-entry cones for stability ➢ Release pad to support instrument package at rest
	Winch System	➢ Designed to withstand conditions at the bottom of the sea and still work after 1 year of inactivity
	Transportable	➢ Instrument package will be one piece ➢ Trusses will be removable from baseplate, but easy to reassemble safely onsite with the use of a crane and minimal use of any ladder ➢ Easy to move into position with ROV below water
Data Collecting	Rate	➢ Real-time data with running average to be displayed. ➢ Samples taken every 1-5 sec
	Storage	➢ All data needs to be stored
	Display	➢ Two groups needed: 1 for control van with the operators, 1 for main lab with the scientists. Each has a running average
	Interface	➢ Designed for dummies
	Backup	➢ Mechanical switch on system
	Connection	➢ Wet-mates between ROV and winch cable

Tab. 4: Complation of results from questionaire

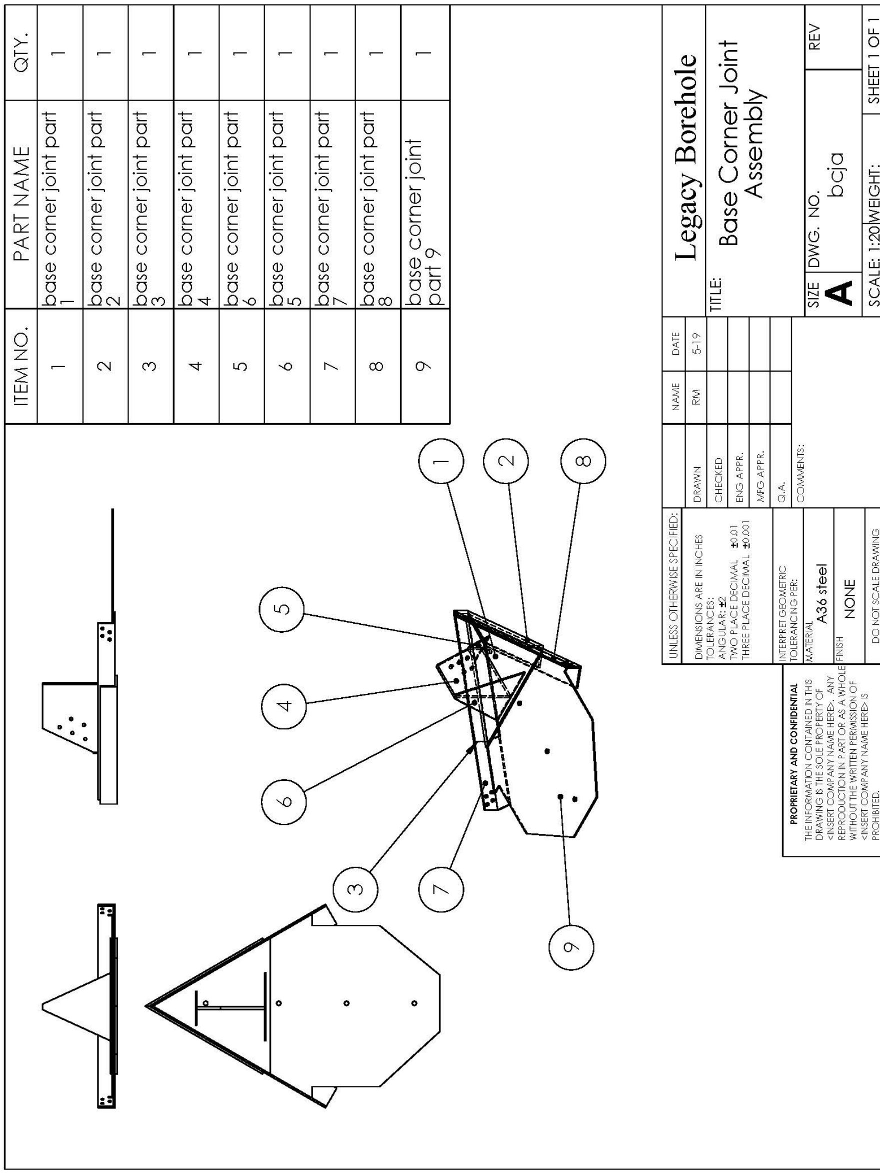
D Detailed Part

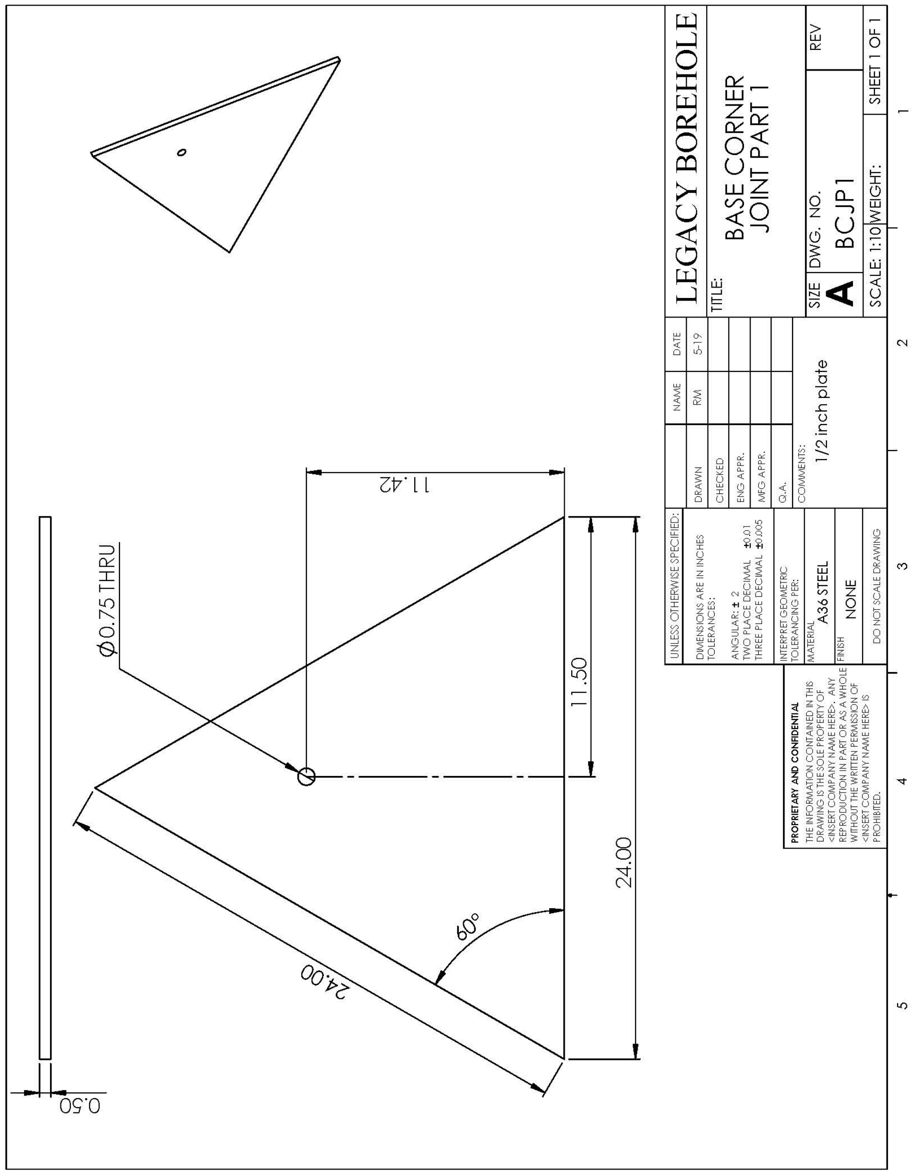
D.1 Full Assembly



D.2 Subsystems

D.2.1 Base Corner Joint





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BASE CORNER
JOINT PART 1
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A
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BCJP1
REV
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WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.005
INTERPRET GEOMETRIC
TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5-19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/2 inch plate
PROPRIETARY AND CONFIDENTIAL
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60°
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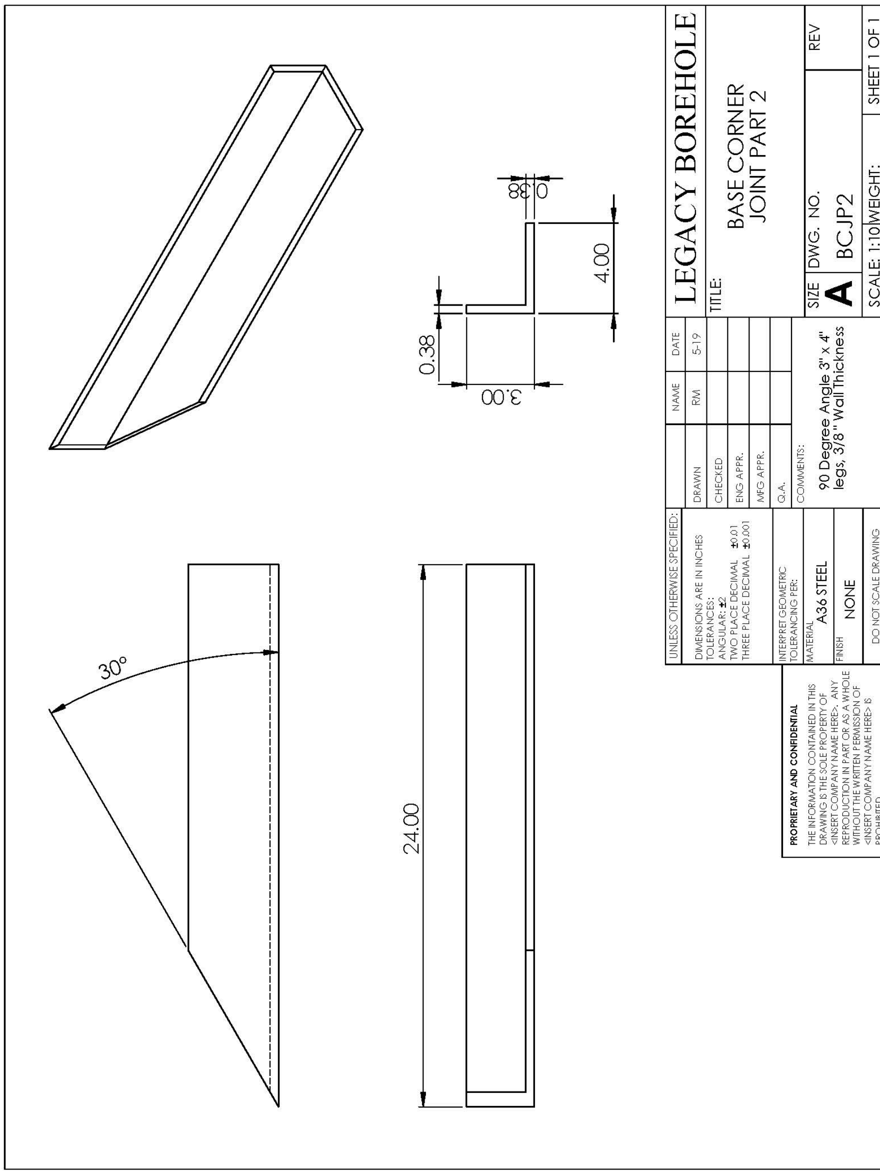
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DWG. NO.
BCJP2
REV
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WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5-19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
90 Degree Angle 3" x 4" legs, 3/8" Wall Thickness
PROPRIETARY AND CONFIDENTIAL
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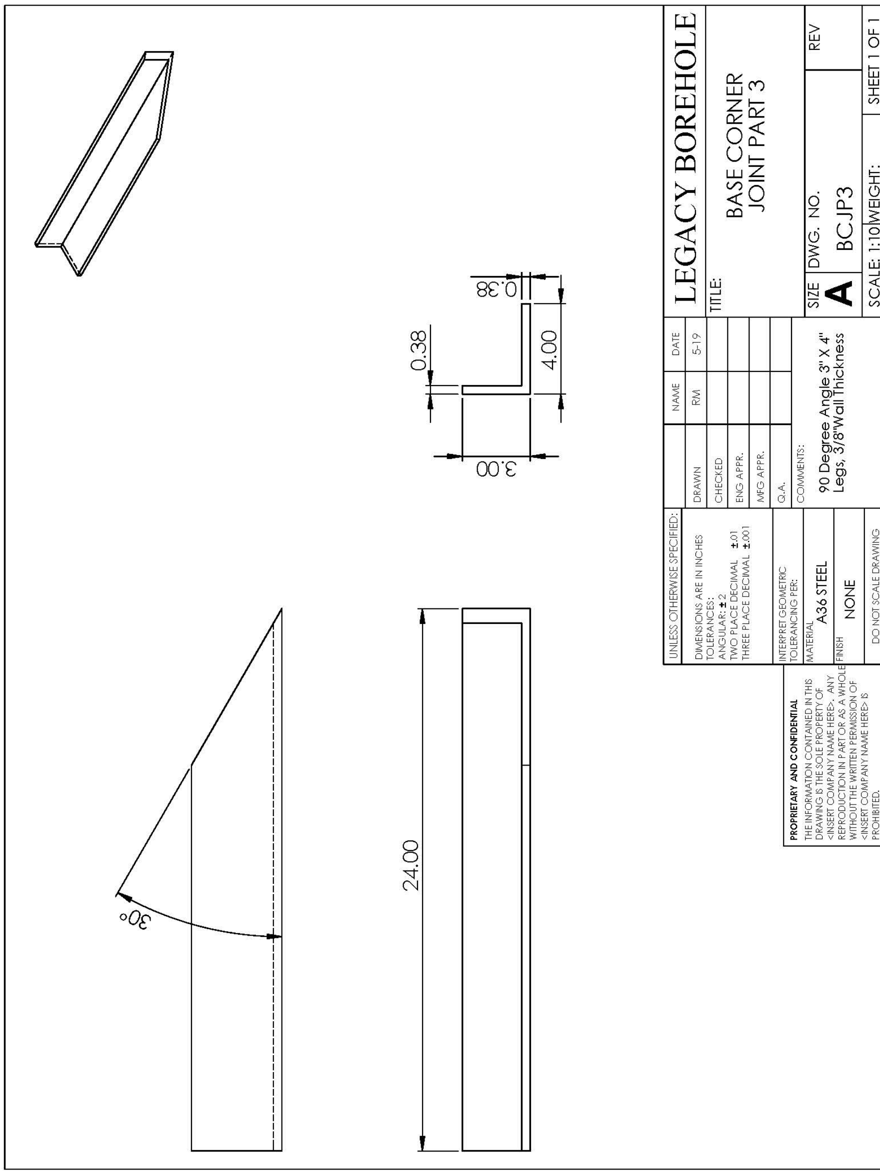
4
5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DWG. NO.
BCJP3
REV
SCALE: 1:10
WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±2
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5-19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
90 Degree Angle 3" X 4" Legs, 3/8"Wall Thickness
PROPRIETARY AND CONFIDENTIAL
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2
3
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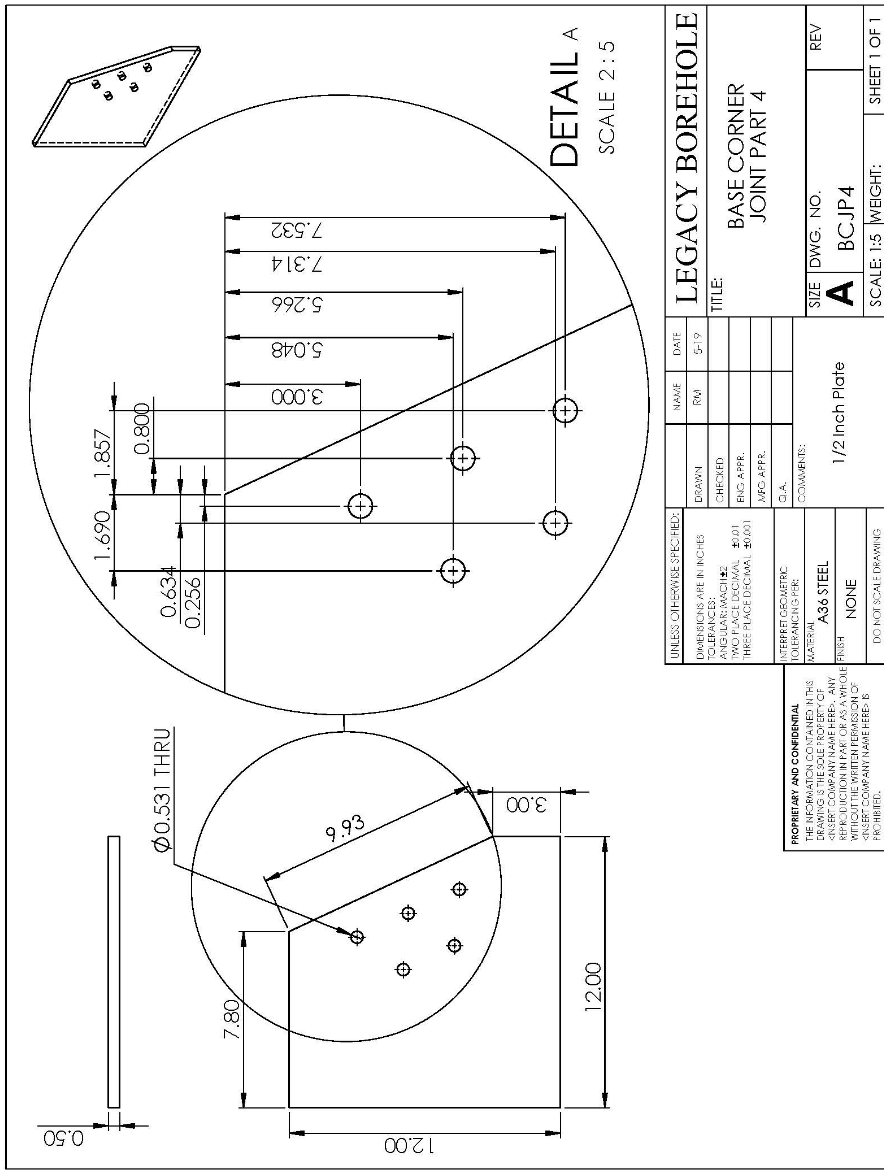
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Ø0.531 THRU
9.93
3.00
7.80
12.00
12.00
0.50
LEGACY BOREHOLE
TITLE:
BASE CORNER JOINT PART 4
SIZE
A
DWG. NO.
BCJP4
REV
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1
NAME
DATE
DRAWN
RM
5-19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/2 Inch Plate
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
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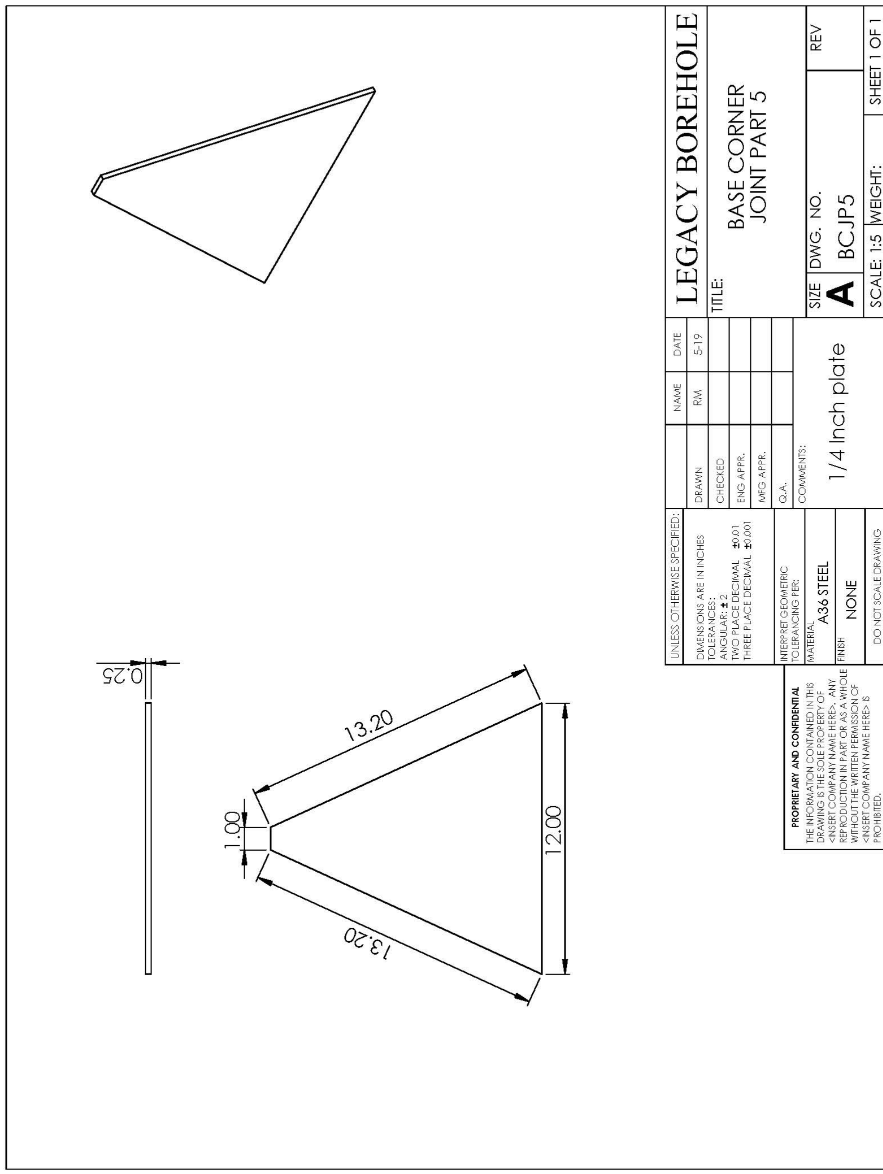

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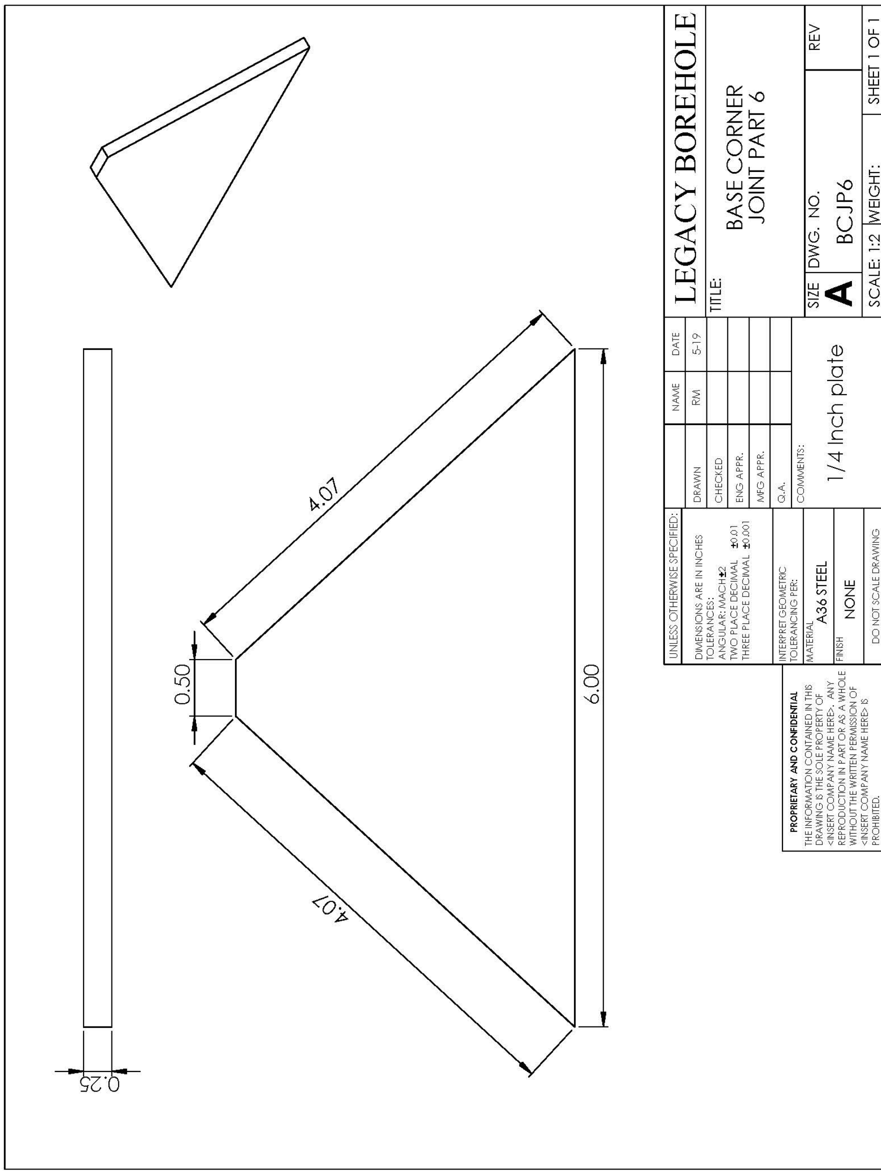
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5-19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/4 Inch plate
LEGACY BOREHOLE
TITLE:
BASE CORNER
JOINT PART 5
SIZE
A
DWG. NO.
BCJP5
REV
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1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DWG. NO.
BCJP6
REV
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WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
NAME
DATE
DRAWN
RM
5-19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/4 Inch plate
MATERIAL
A36 STEEL
FINISH
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DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
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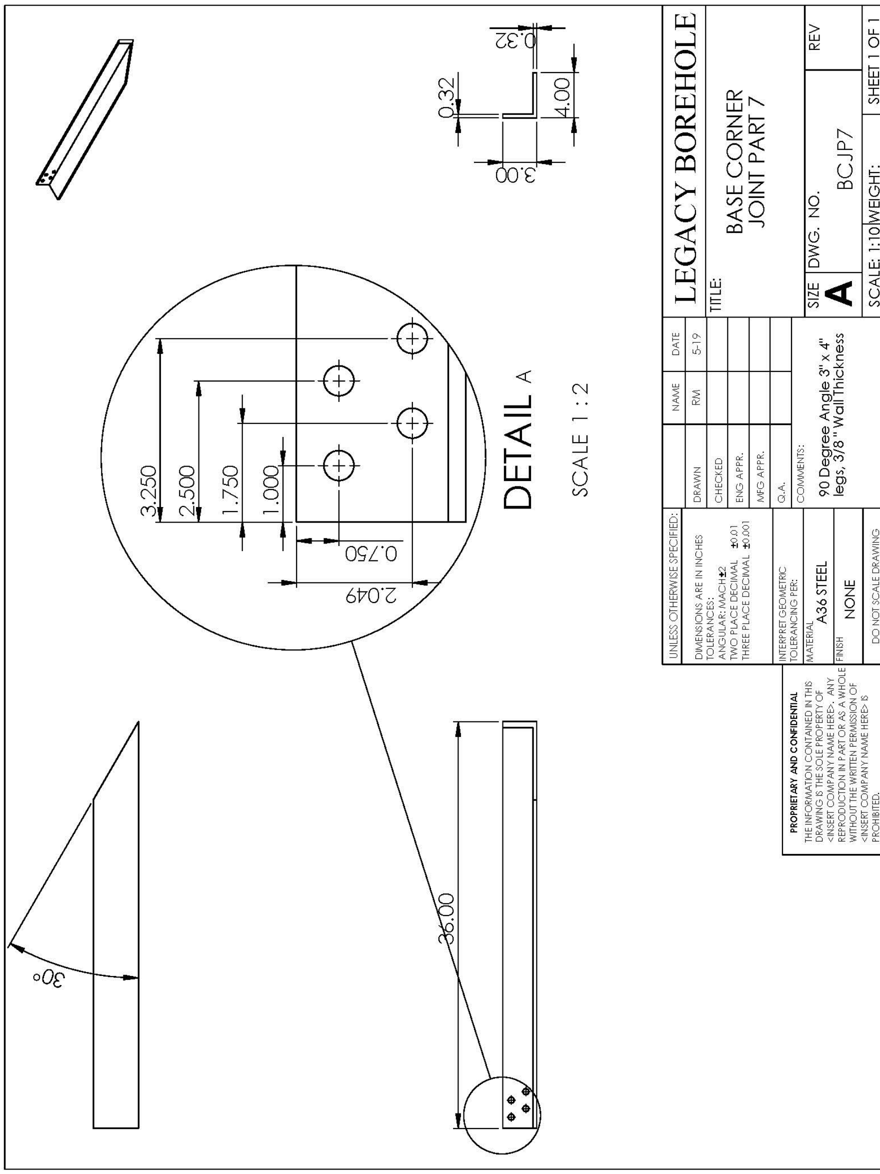
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DWG. NO. BCJP7
REV
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4.00
36.00
30°
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5-19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
90 Degree Angle 3" x 4" legs, 3/8" WallThickness
PROPRIETARY AND CONFIDENTIAL
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2
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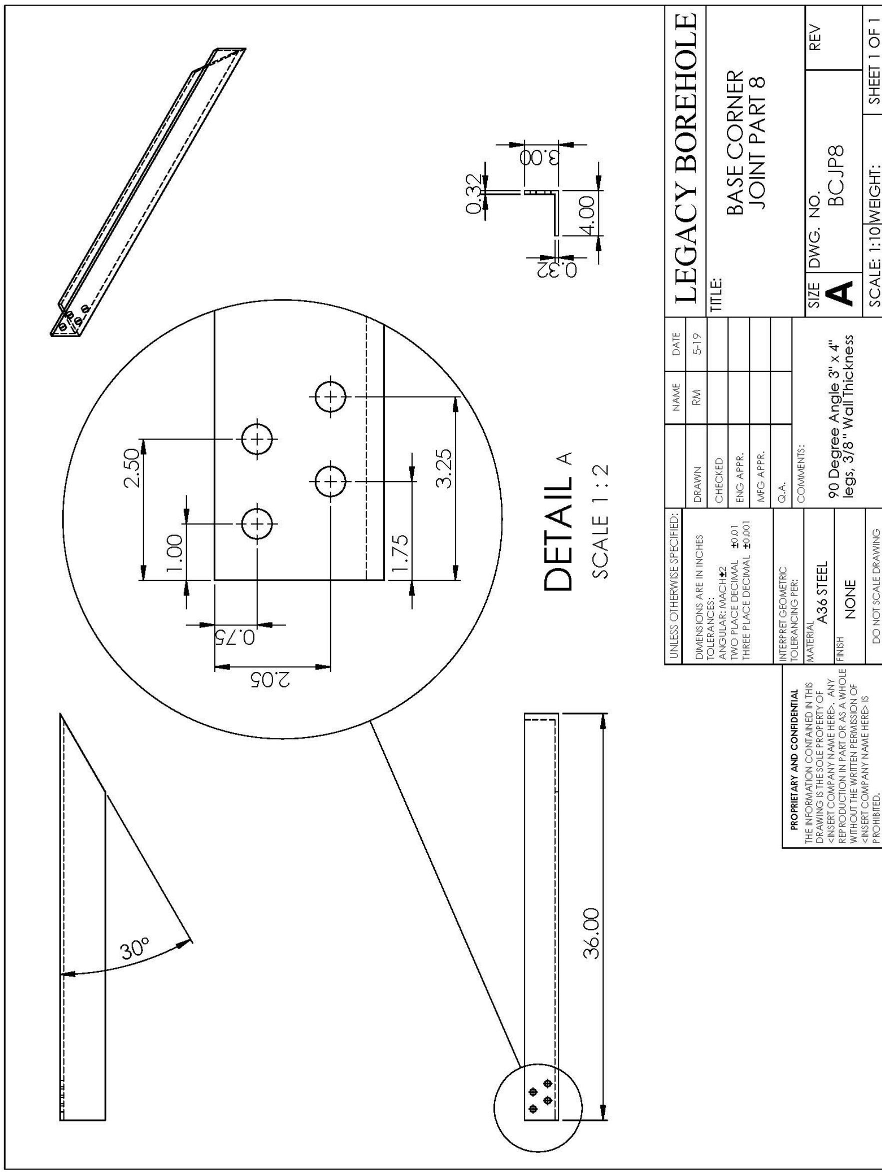
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REV
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WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
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DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
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CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
90 Degree Angle 3" x 4" legs, 3/8" Wall Thickness
PROPRIETARY AND CONFIDENTIAL
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1.00
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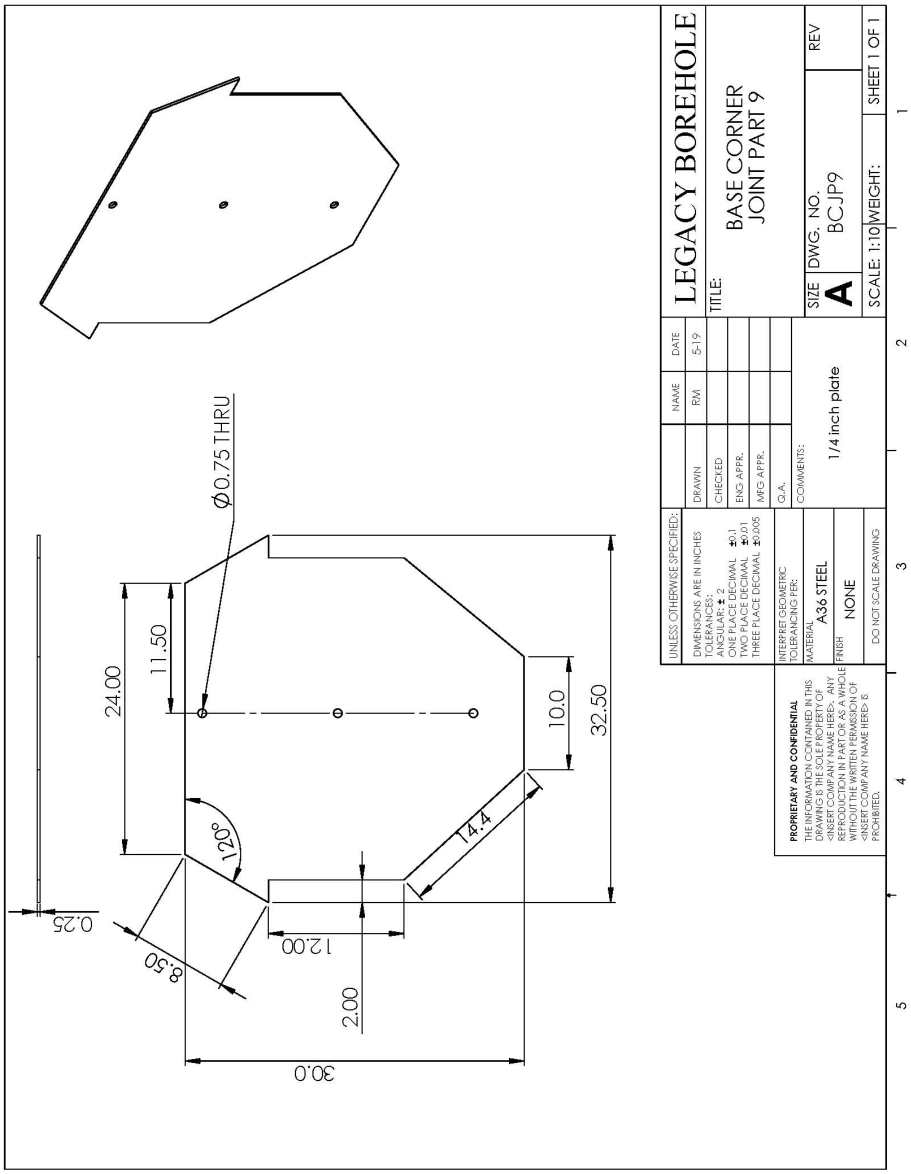
1
2
3
4
5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REV
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WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 2
ONE PLACE DECIMAL ±0.1
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5-19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/4 inch plate
PROPRIETARY AND CONFIDENTIAL
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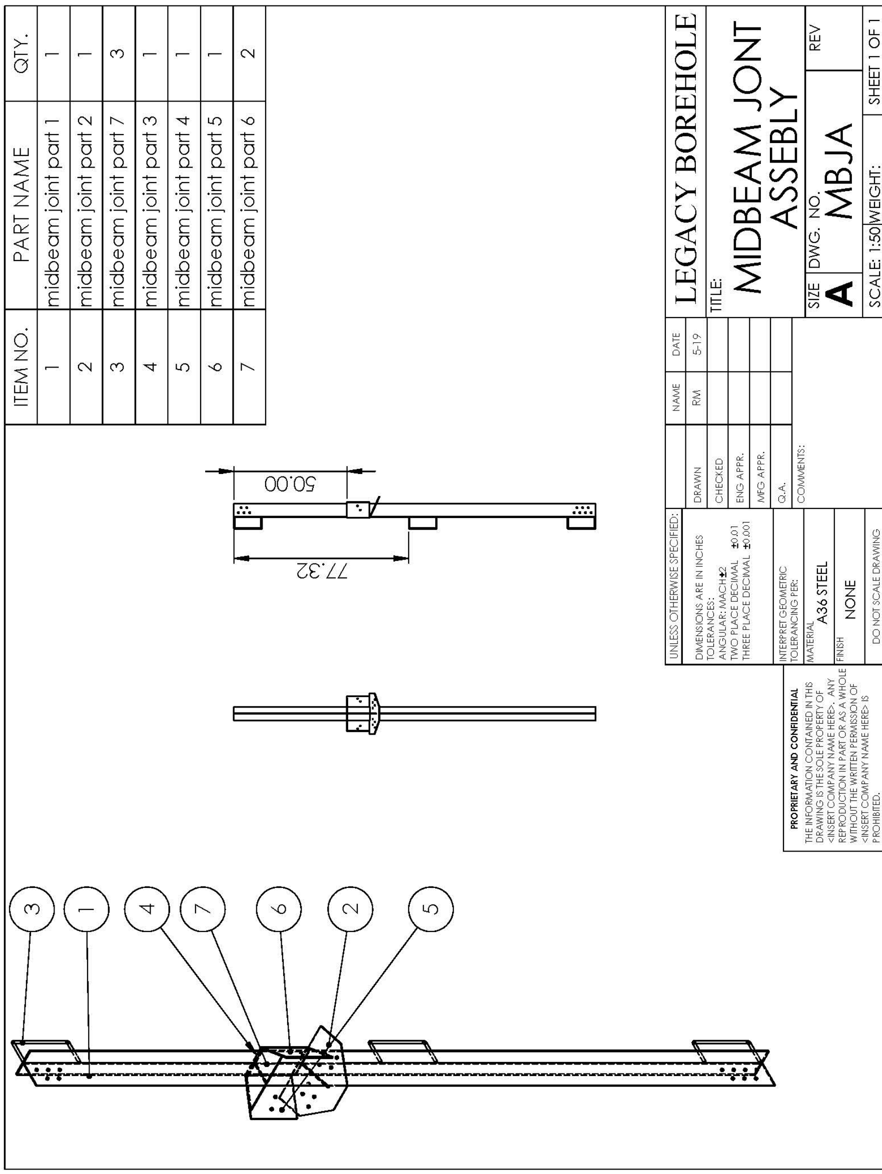
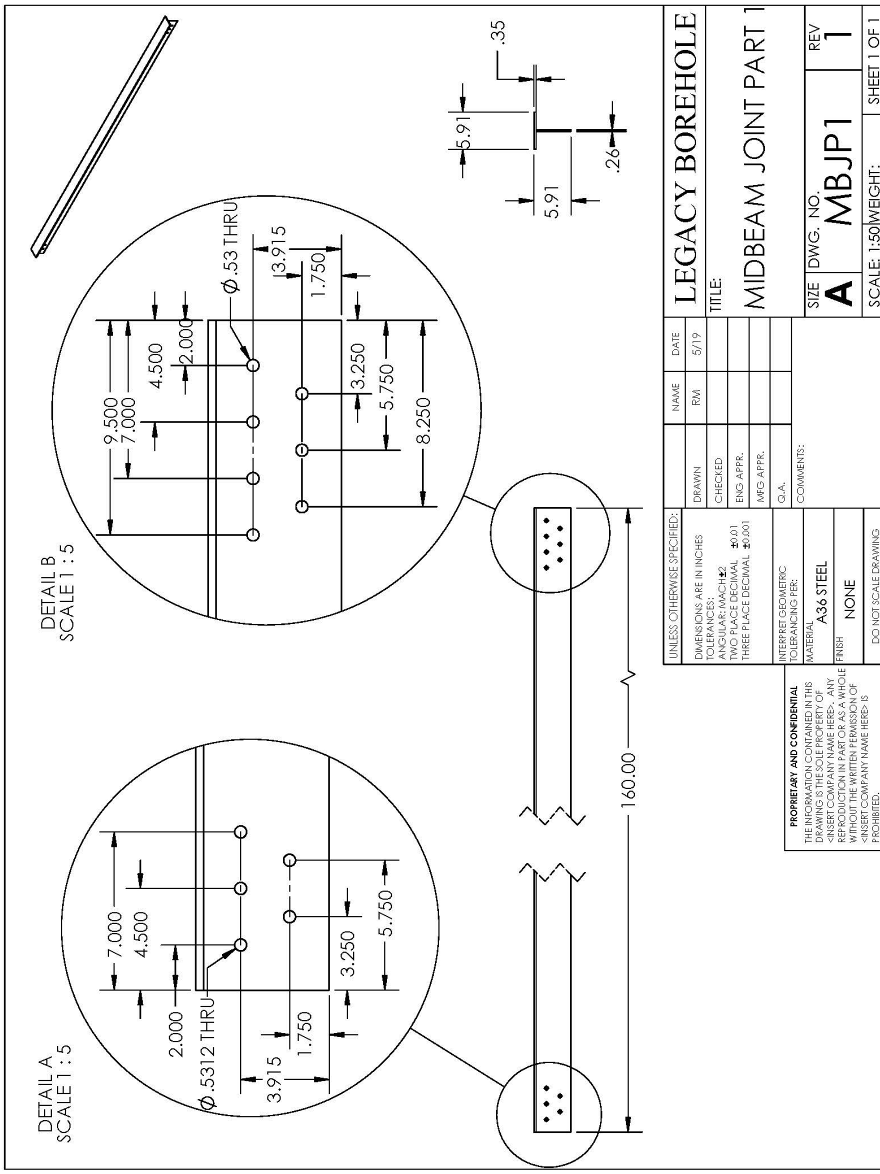
12.00
2.00
30.0

D.2.2 Midbeam Joint





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DETAIL B
SCALE 1 : 5
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Ø.53 THRU
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9.500
8.250
160.00
5.91
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.26
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TITLE:
MIDBEAM JOINT PART 1
SIZE
A
DWG. NO.
MBJP1
REV
1
SCALE: 1:50
WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5/19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
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5
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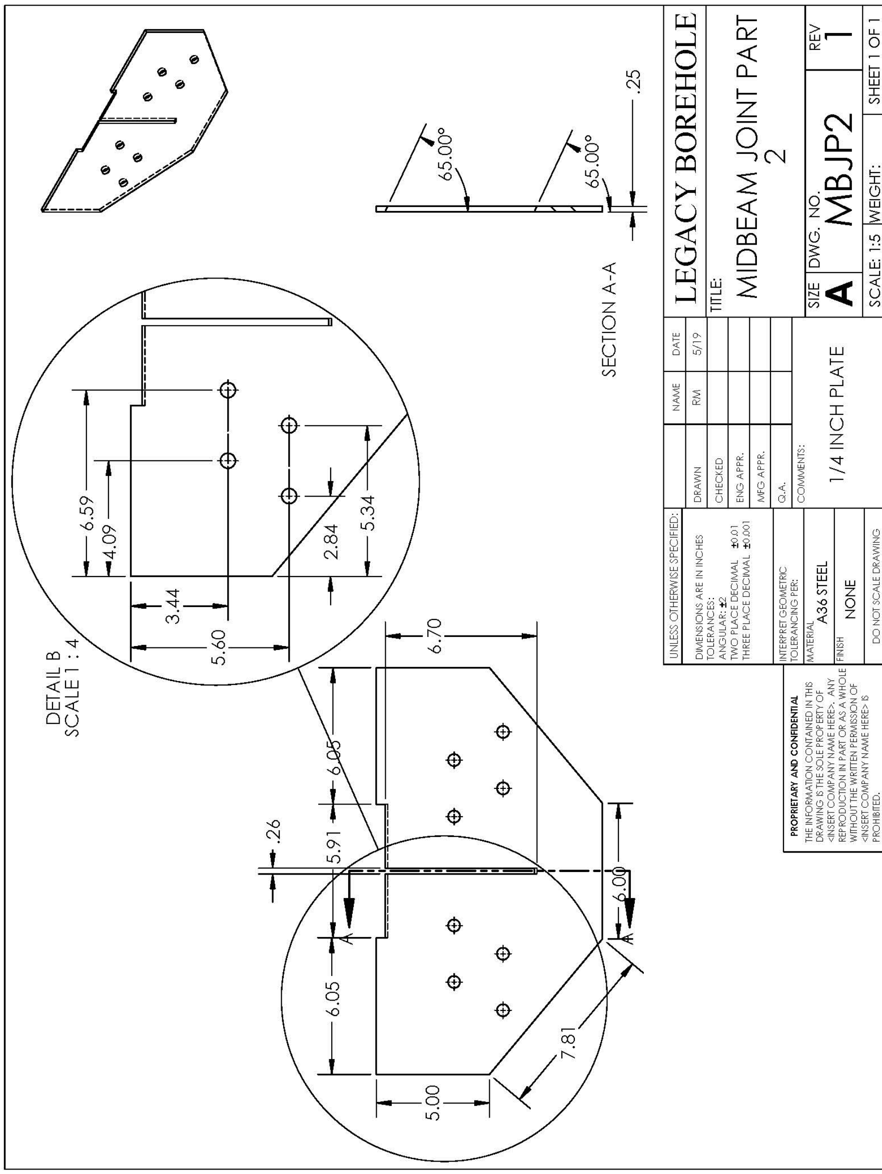
3
2
1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REV 1
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
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ANGULAR: ±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL A36 STEEL
FINISH NONE
DO NOT SCALE DRAWING
NAME DATE
DRAWN RM 5/19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/4 INCH PLATE
PROPRIETARY AND CONFIDENTIAL
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DETAIL B
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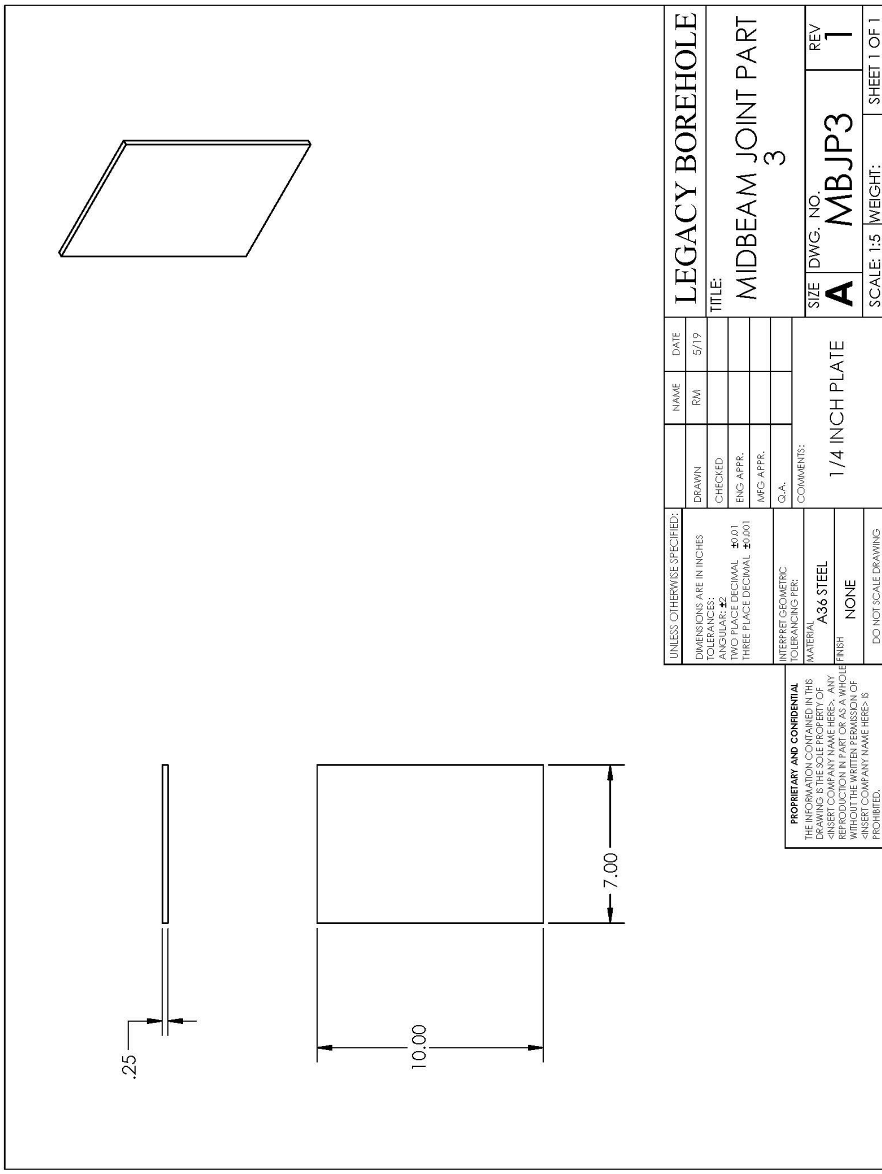

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
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DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5/19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/4 INCH PLATE
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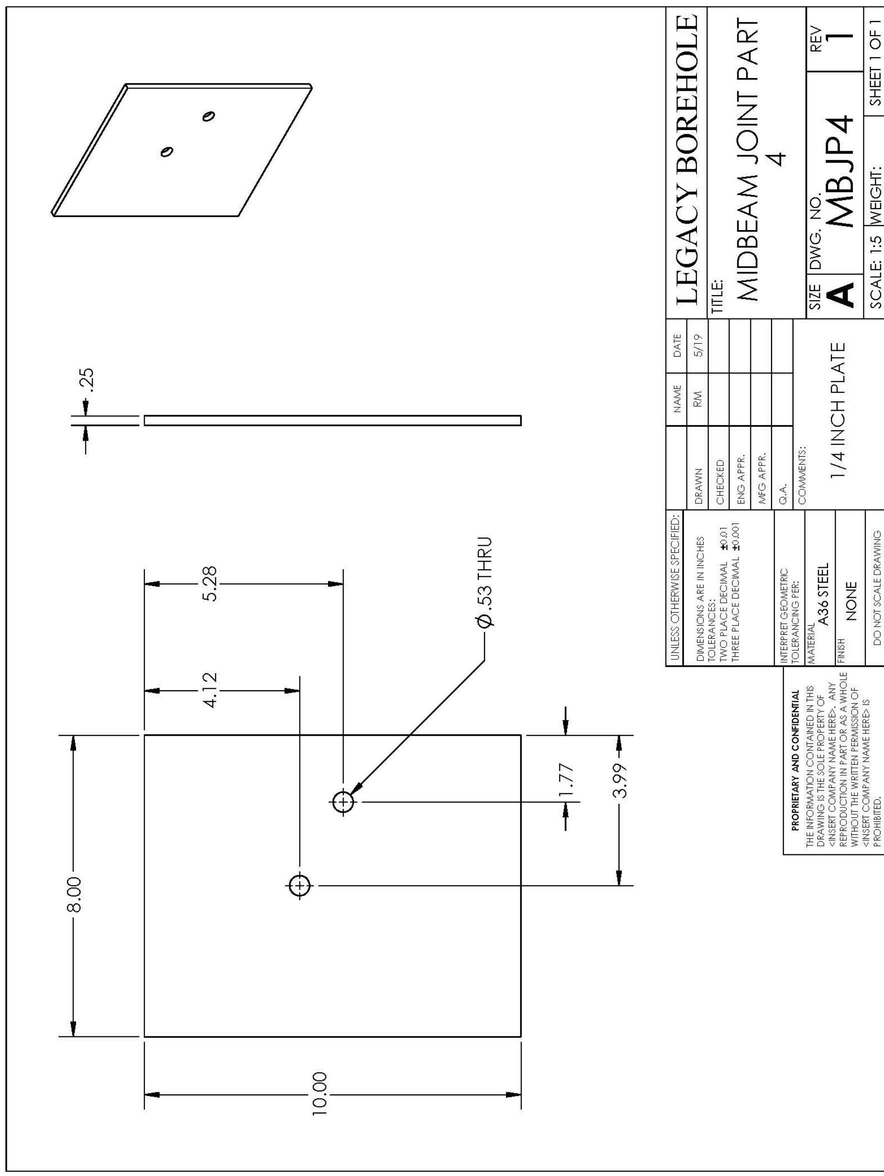
WEIGHT:
SHEET 1 OF 1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SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
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THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5/19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/4 INCH PLATE
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
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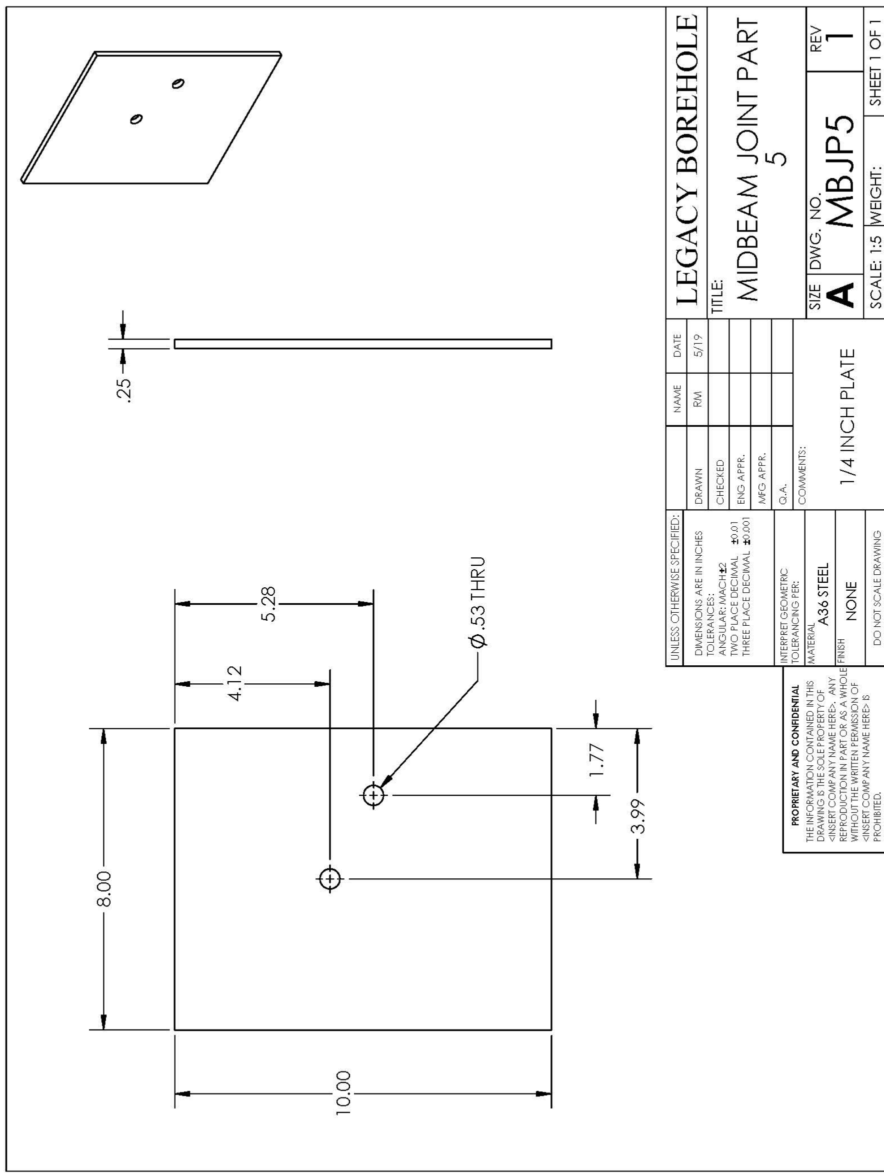
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REV 1
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
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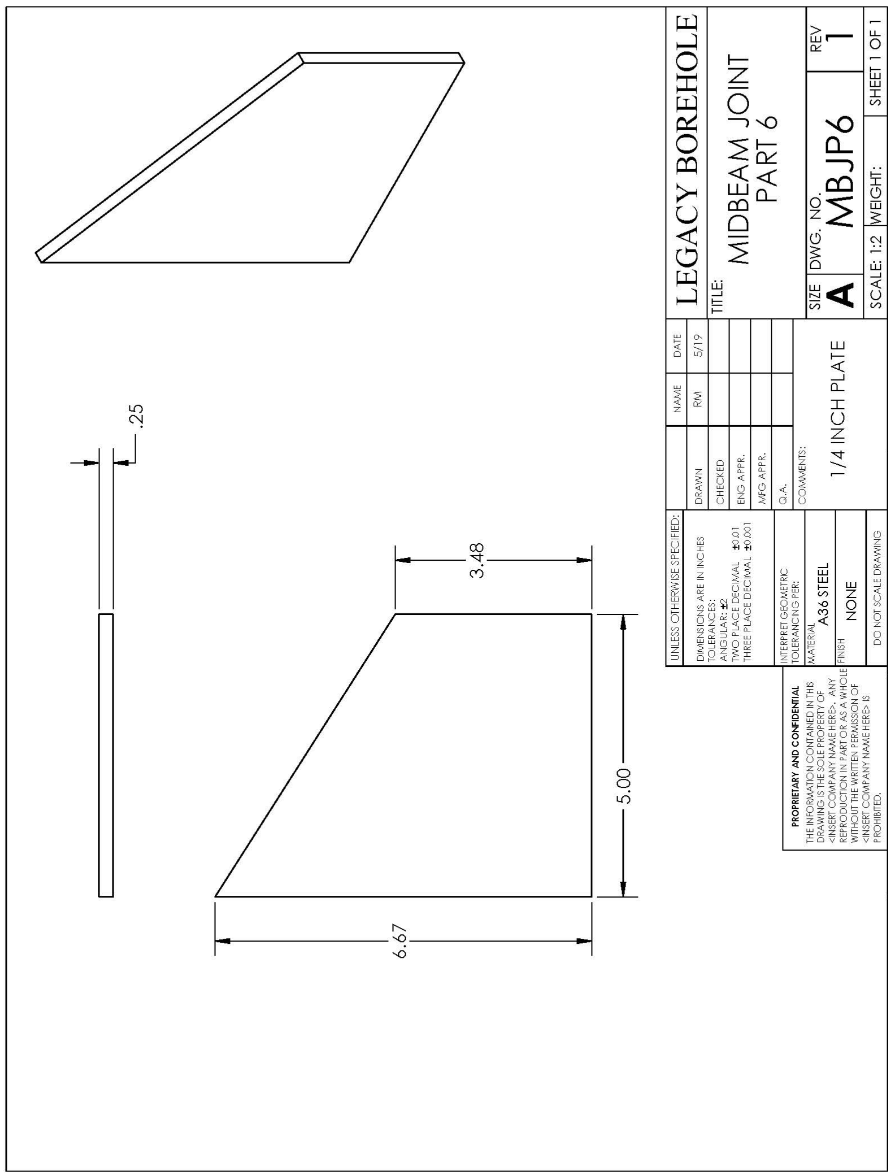
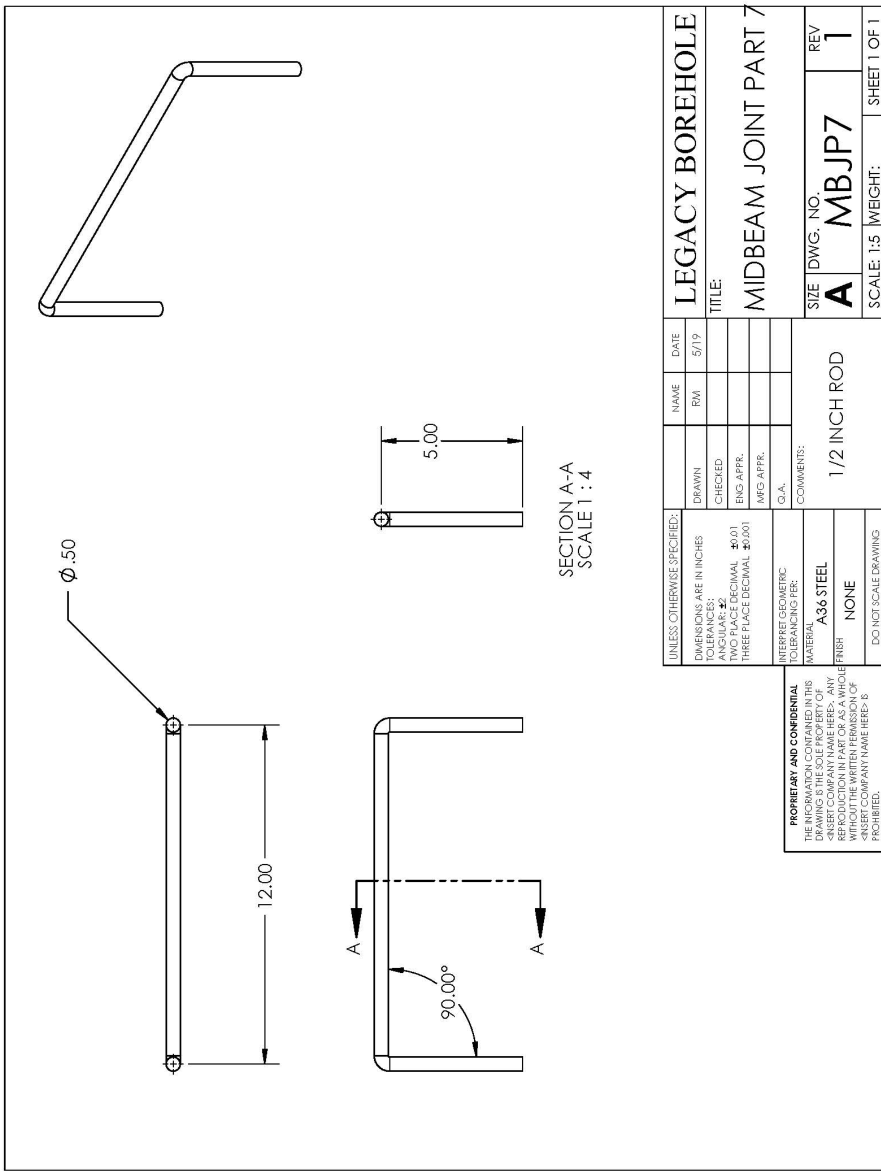
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5/19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/4 INCH PLATE
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
1
2
3
4
5



LEGACY BOREHOLE
TITLE:
MIDBEAM JOINT PART 6
SIZE A
DWG. NO. MBJP6
REV 1
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5/19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/4 INCH PLATE
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
.25
3.48
5.00
6.67
1
2
3
4
5



Ø .50
12.00
5.00
90.00°
A
A
SECTION A-A
SCALE 1 : 4
LEGACY BOREHOLE
TITLE:
MIDBEAM JOINT PART 7
SIZE
A
DWG. NO.
MBJP7
REV
1
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1
NAME
DATE
DRAWN
RM
5/19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/2 INCH ROD
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
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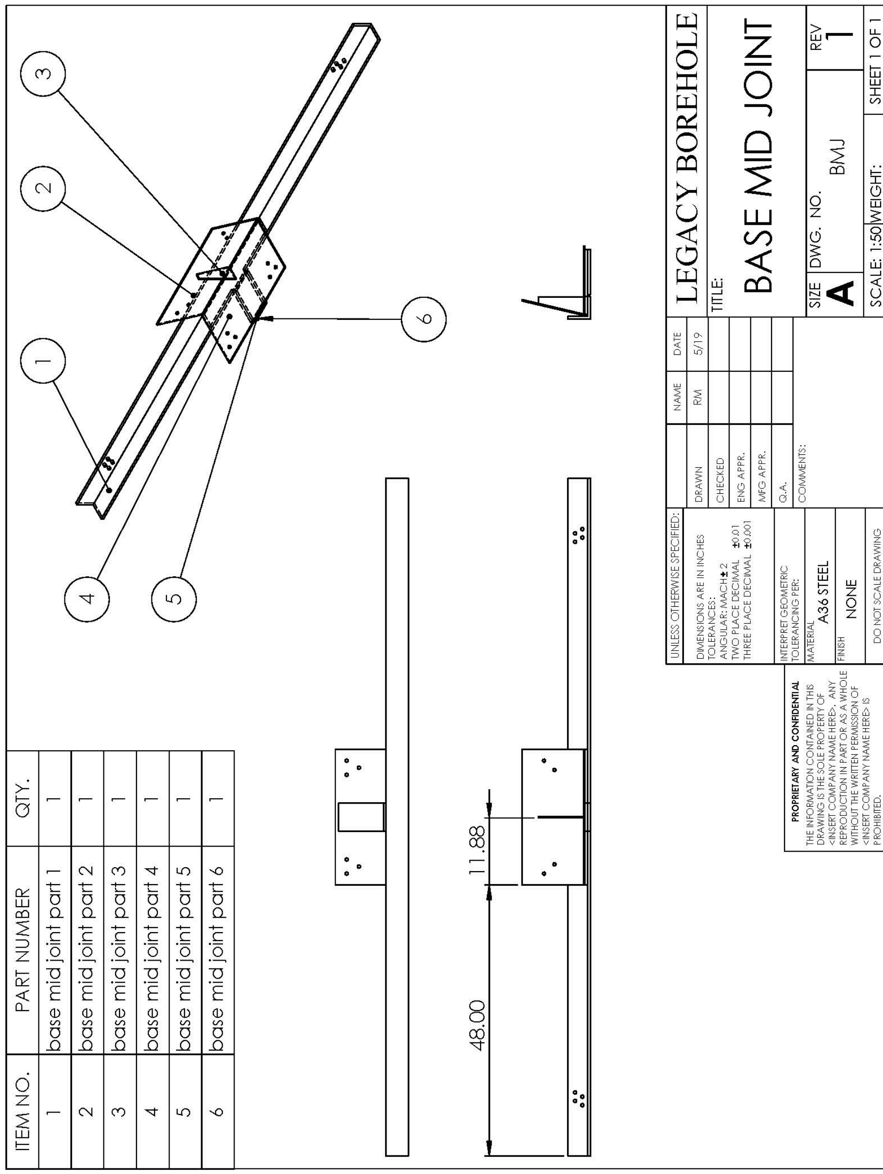
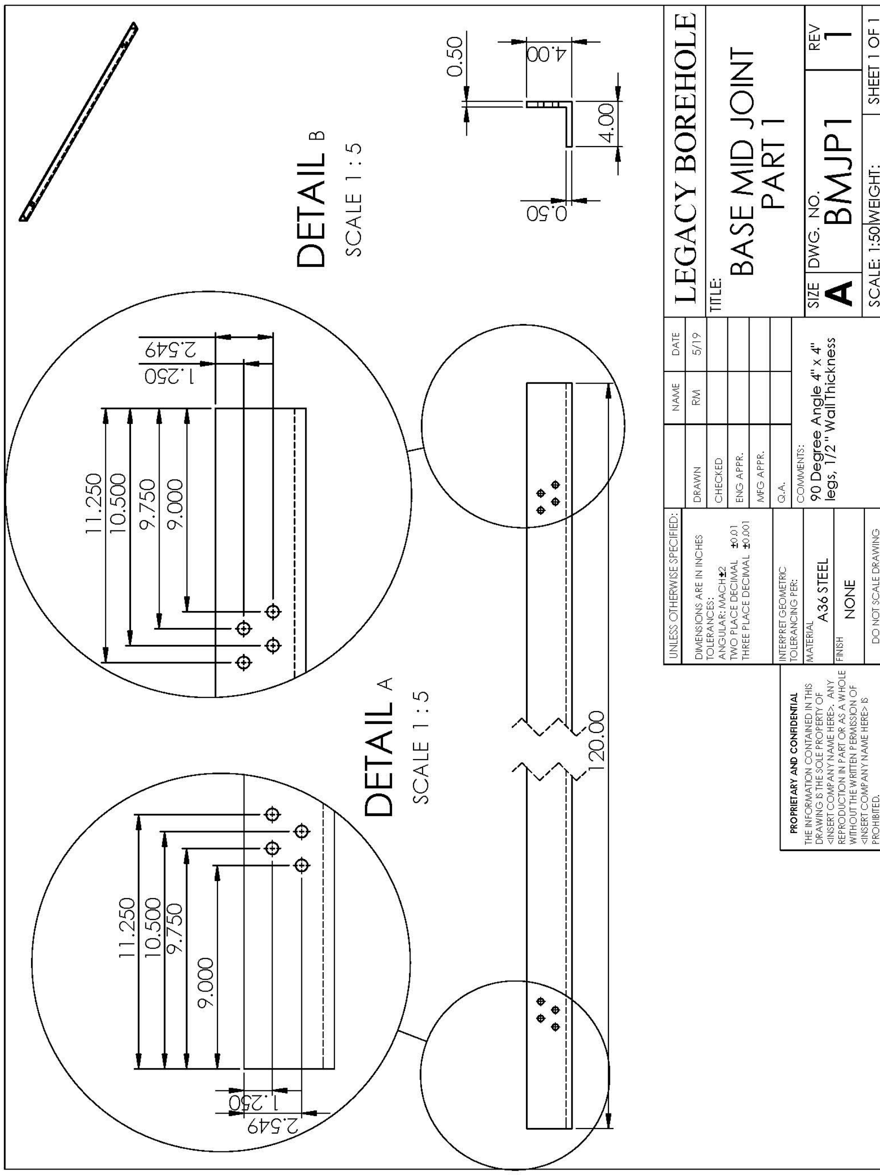
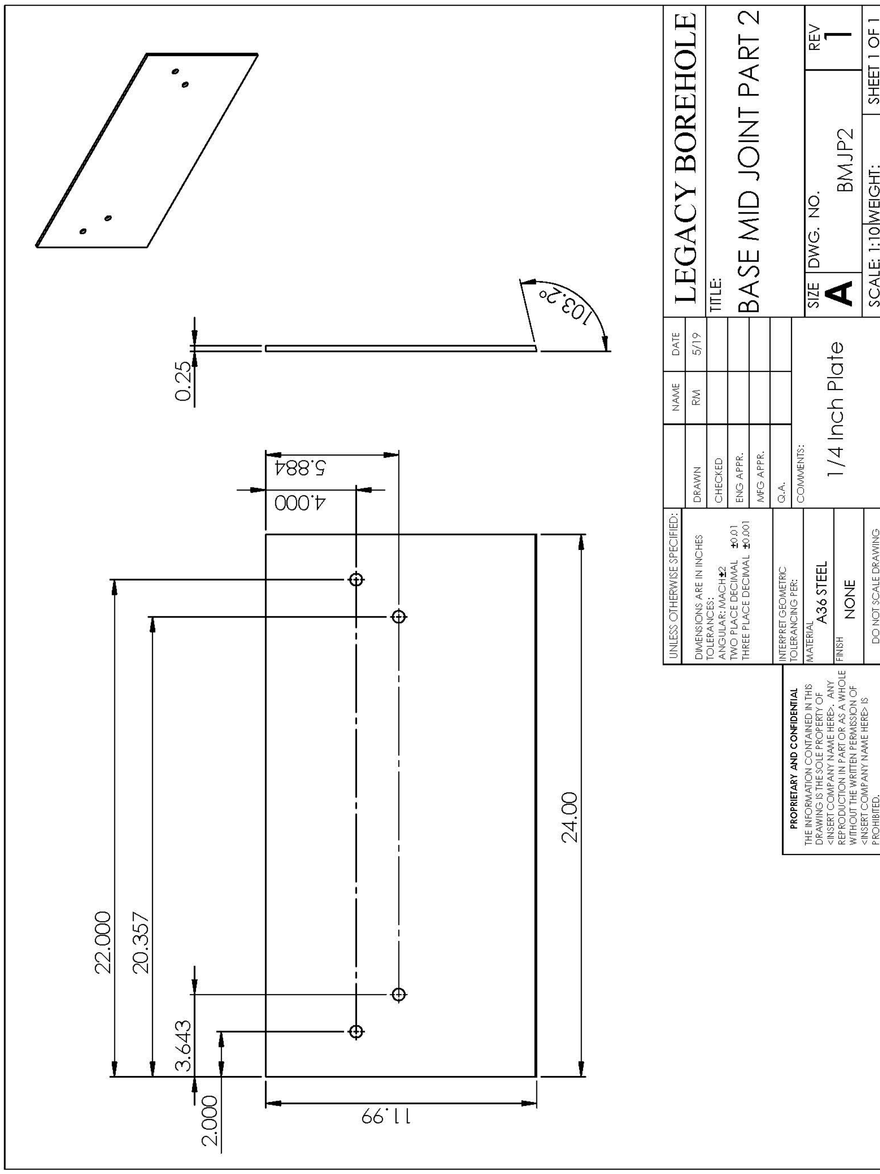
1
2
3
4
5

D.2.3 Base Midjoint




LEGACY BOREHOLE
TITLE:
BASE MID JOINT PART 1
SIZE
A
DWG. NO.
BMJP1
REV
1
SCALE: 1:50
WEIGHT:
SHEET 1 OF 1
DETAIL A
SCALE 1 : 5
DETAIL B
SCALE 1 : 5
11.250
10.500
9.750
9.000
1.250
2.549
120.00
4.00
0.50
UNLESS OTHERWISE SPECIFIED:
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
NAME
DATE
RM
5/19
COMMENTS:
90 Degree Angle 4" x 4" legs, 1/2" Wall Thickness
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL


LEGACY BOREHOLE
TITLE:
BASE MID JOINT PART 2
SIZE A
DWG. NO. BMJP2
REV 1
SCALE: 1:10
WEIGHT:
SHEET 1 OF 1
NAME
DATE
DRAWN
RM
5/19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/4 Inch Plate
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
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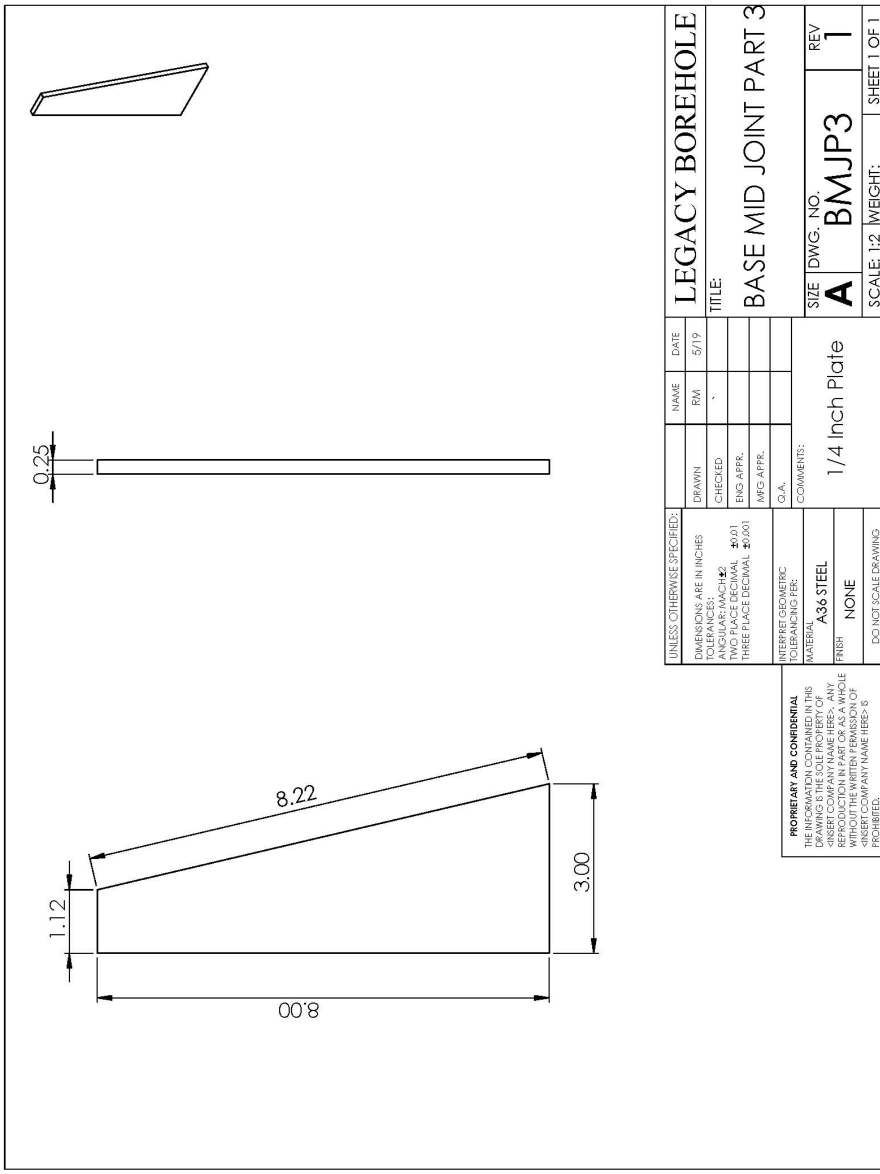
103.2°
0.25
5.884
4.000
24.00
22.000
20.357
3.643
2.000
11.99


0.25
8.22
1.12
3.00
8.00
LEGACY BOREHOLE
TITLE:
BASE MID JOINT PART 3
SIZE
A
DWG. NO.
BMJP3
REV
1
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
NAME
DATE
DRAWN
RM
5/19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/4 Inch Plate
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
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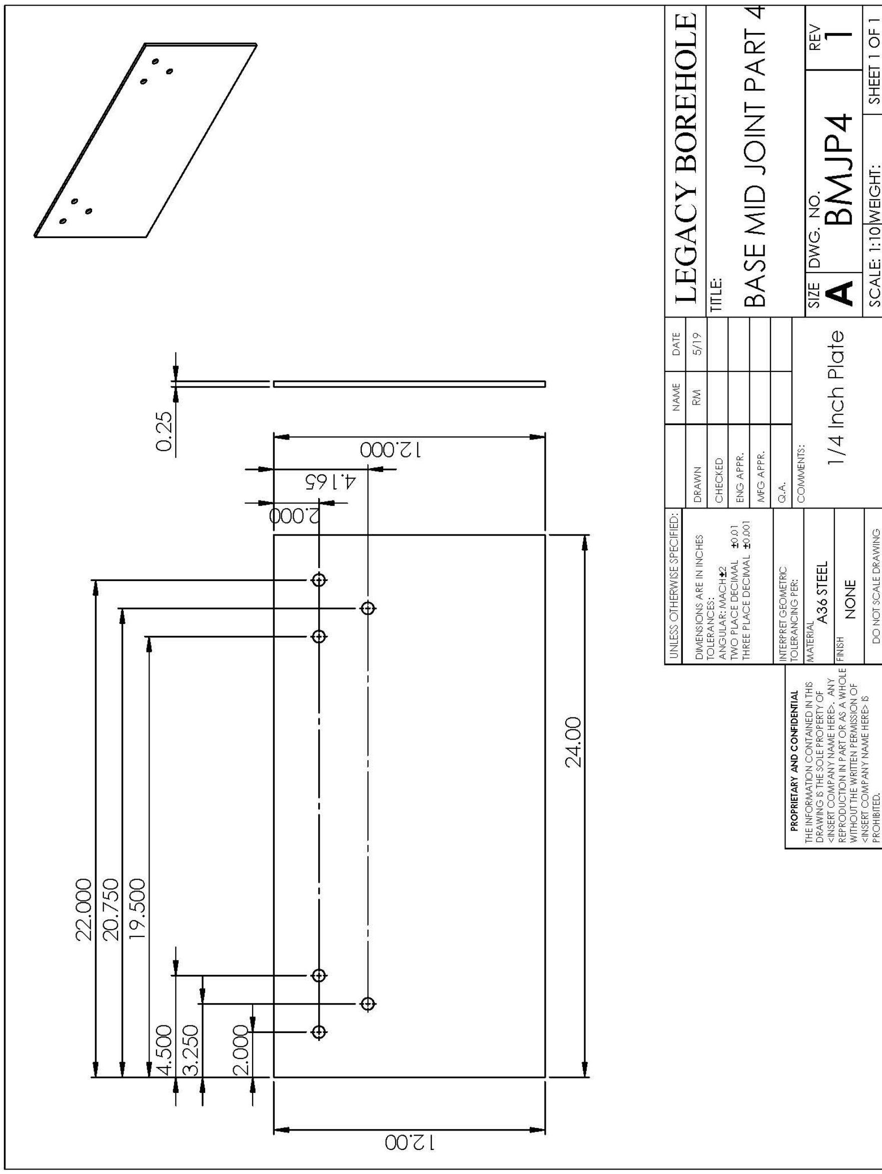
1
2
3
4
5


LEGACY BOREHOLE
TITLE:
BASE MID JOINT PART 4
SIZE
A
DWG. NO.
BMJP4
REV
1
SCALE: 1:10
WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5/19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/4 Inch Plate
PROPRIETARY AND CONFIDENTIAL
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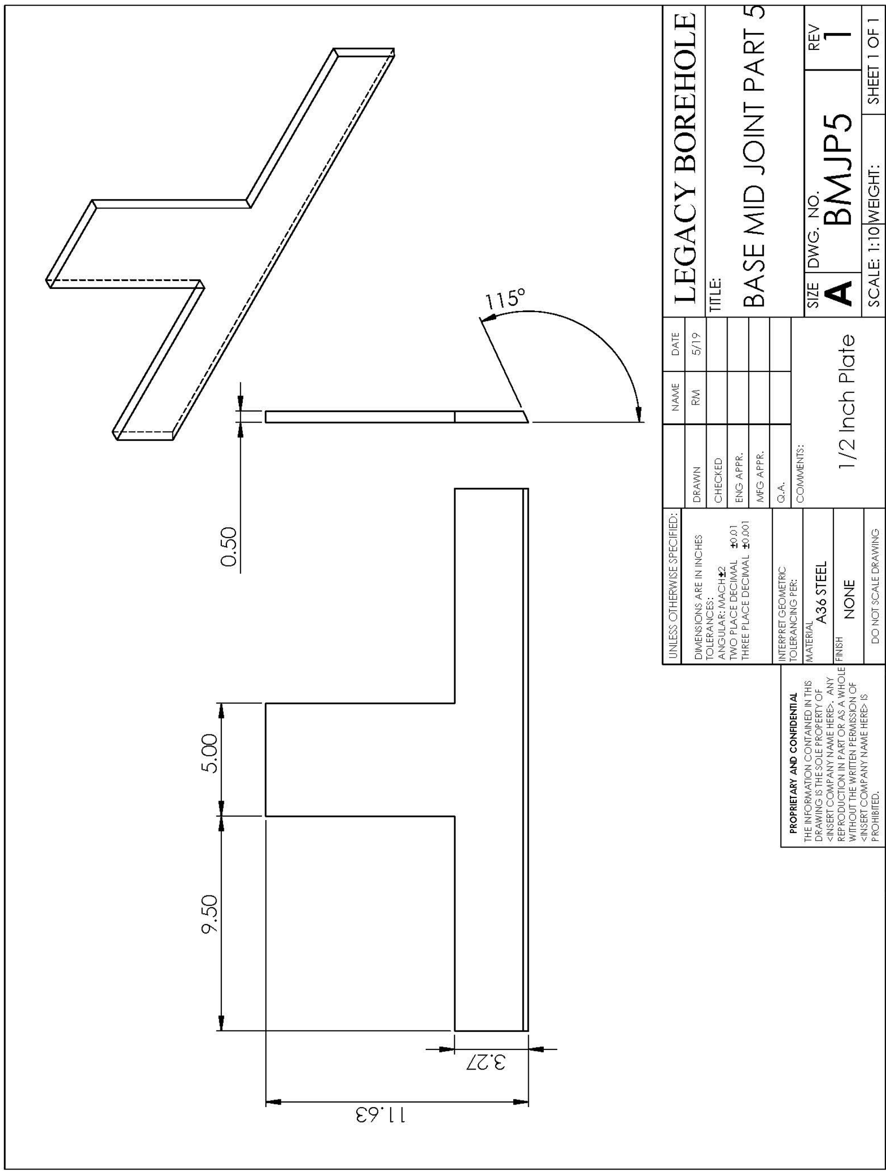
0.25
12.000
4.165
2.000
24.00
22.000
20.750
19.500
4.500
3.250
2.000
12.00
1
2
3
4
5


115°
0.50
5.00
9.50
3.27
11.63
LEGACY BOREHOLE
TITLE:
BASE MID JOINT PART 5
SIZE
A
DWG. NO.
BMJP5
REV
1
SCALE: 1:10
WEIGHT:
SHEET 1 OF 1
NAME
DATE
DRAWN
RM
5/19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/2 Inch Plate
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
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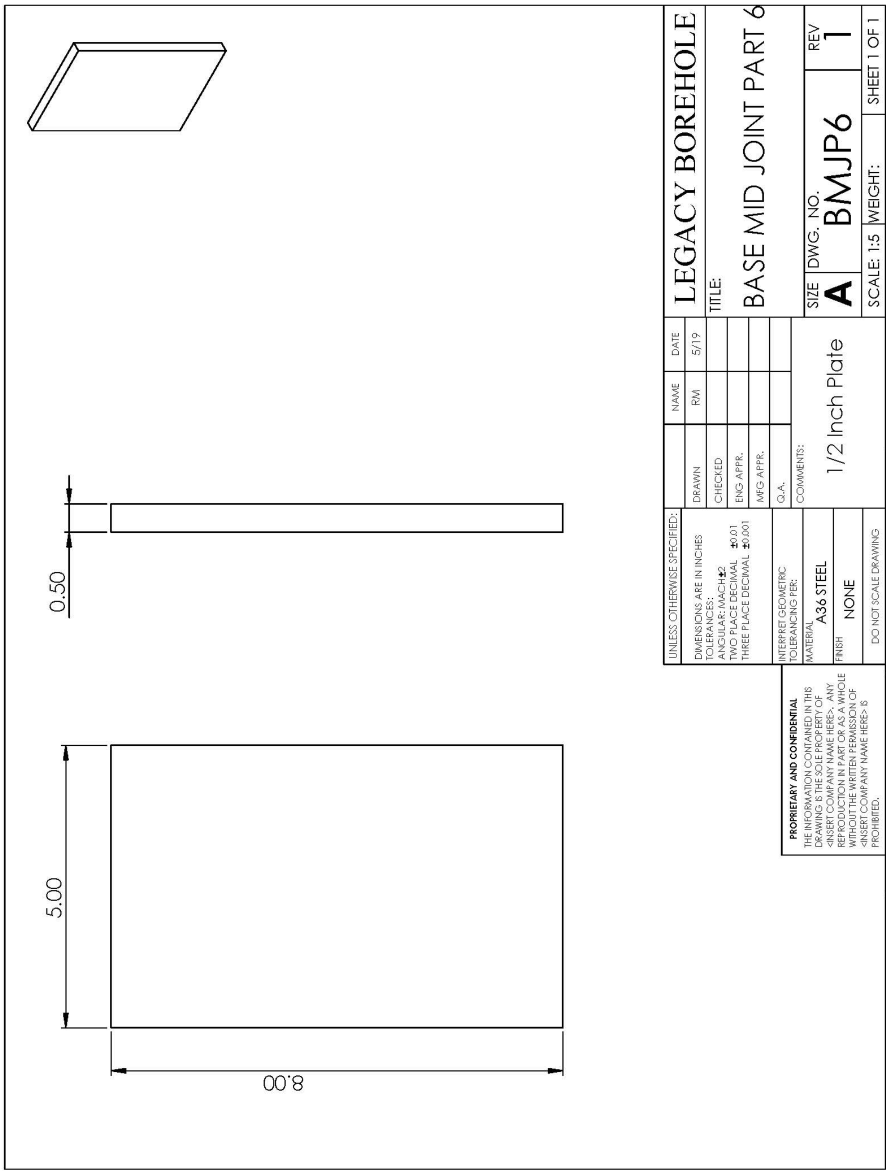
1
2
3
4
5


0.50
5.00
8.00
LEGACY BOREHOLE
TITLE:
BASE MID JOINT PART 6
SIZE A
DWG. NO. BMJP6
REV 1
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5/19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/2 Inch Plate
PROPRIETARY AND CONFIDENTIAL
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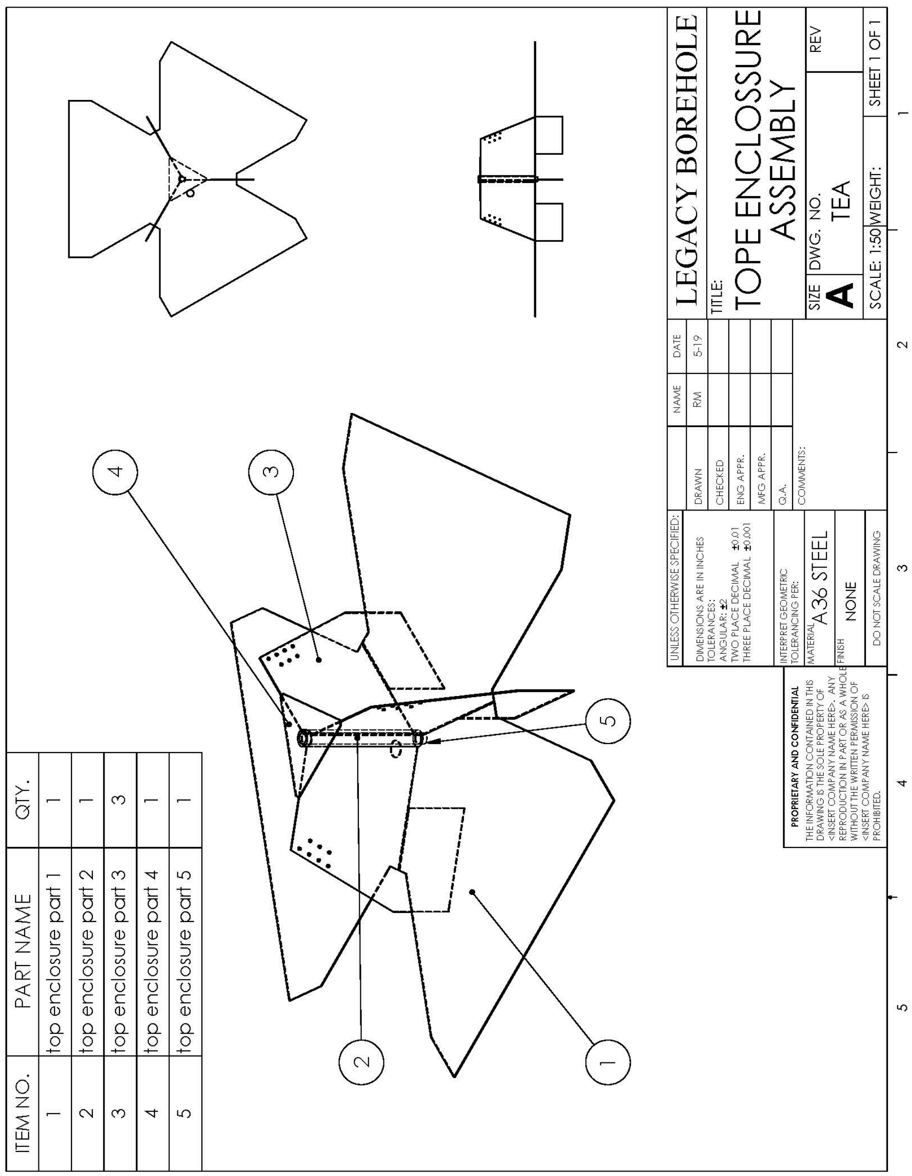
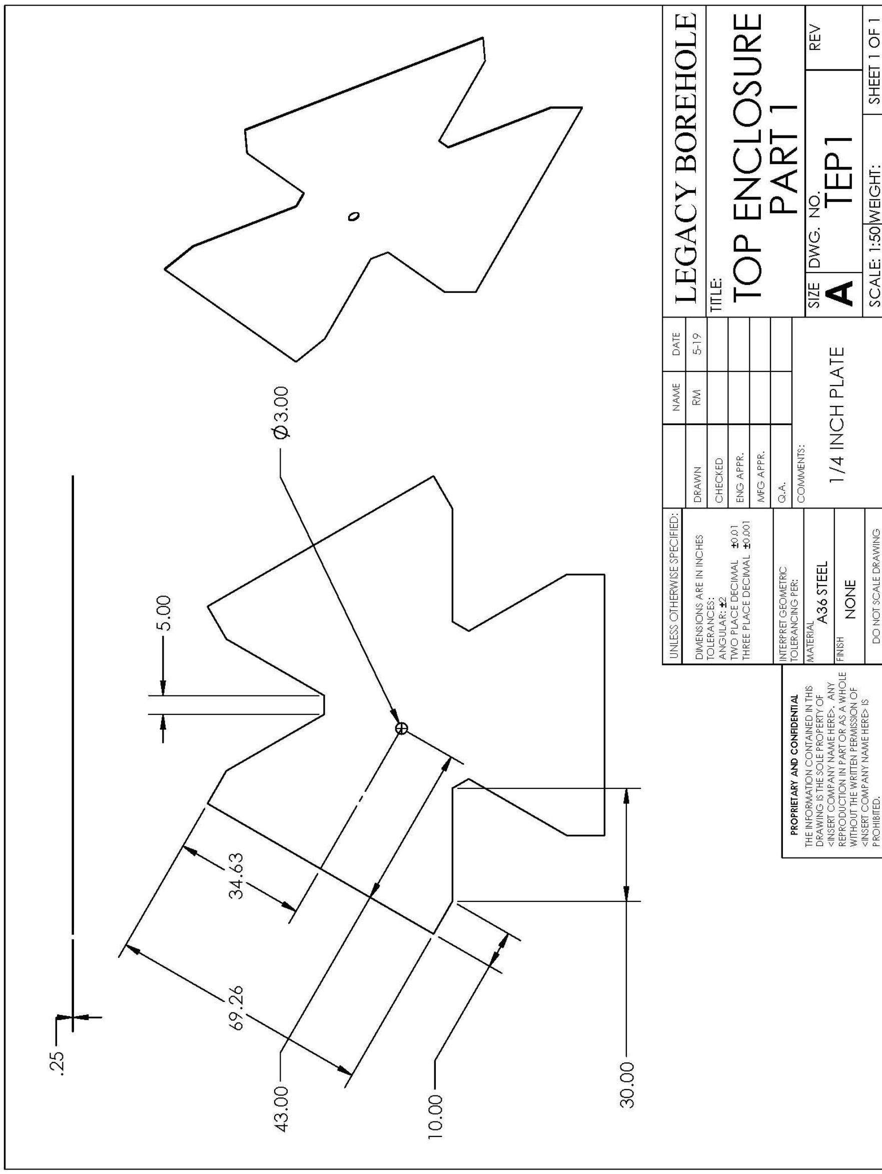
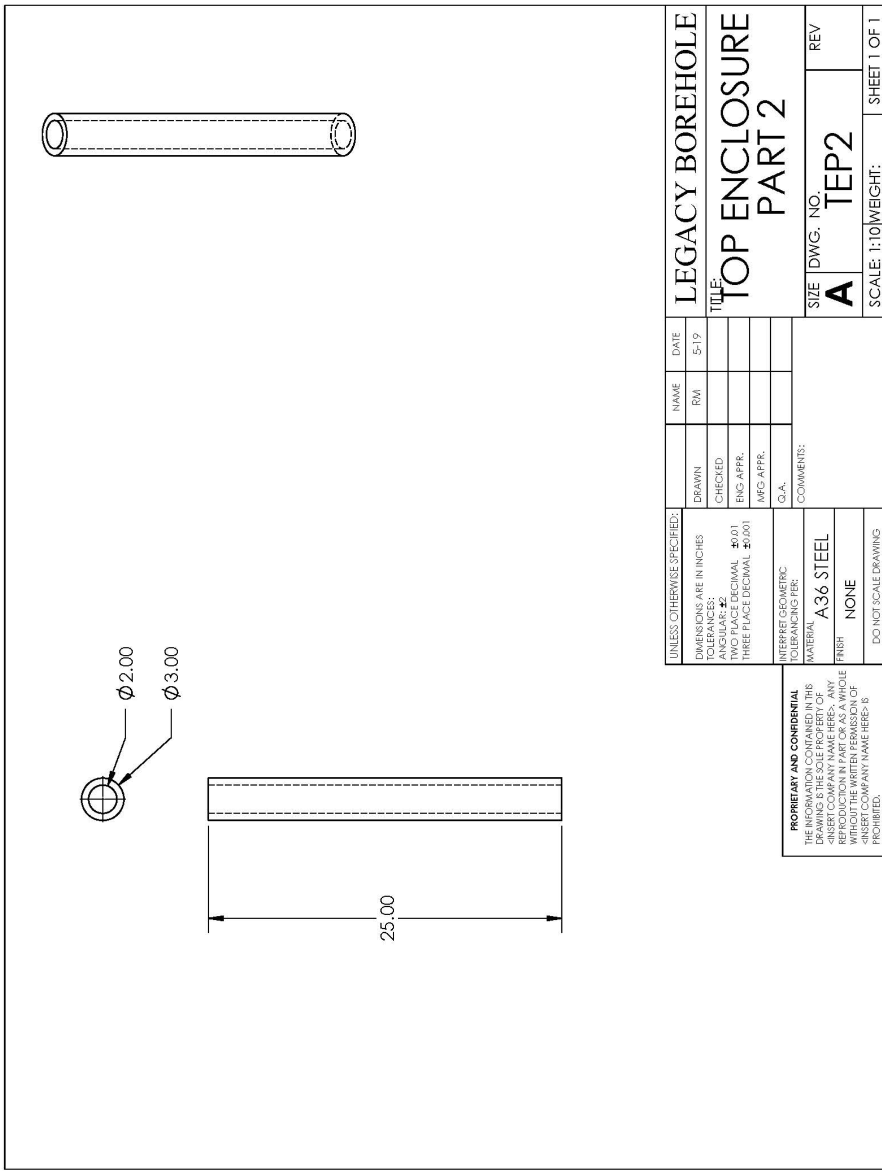
1
2
3
4
5

D.2.4 Top Enclosure




LEGACY BOREHOLE
TITLE:
TOP ENCLOSURE PART 1
SIZE A
DWG. NO. TEP1
REV
SCALE: 1:50
WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5-19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/4 INCH PLATE
PROPRIETARY AND CONFIDENTIAL
Ø3.00
5.00
34.63
69.26
43.00
10.00
30.00
.25



Ø2.00
Ø3.00
25.00
LEGACY BOREHOLE
TITLE:
TOP ENCLOSURE PART 2
SIZE
A
DWG. NO.
TEP2
REV
SCALE: 1:10
WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5-19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
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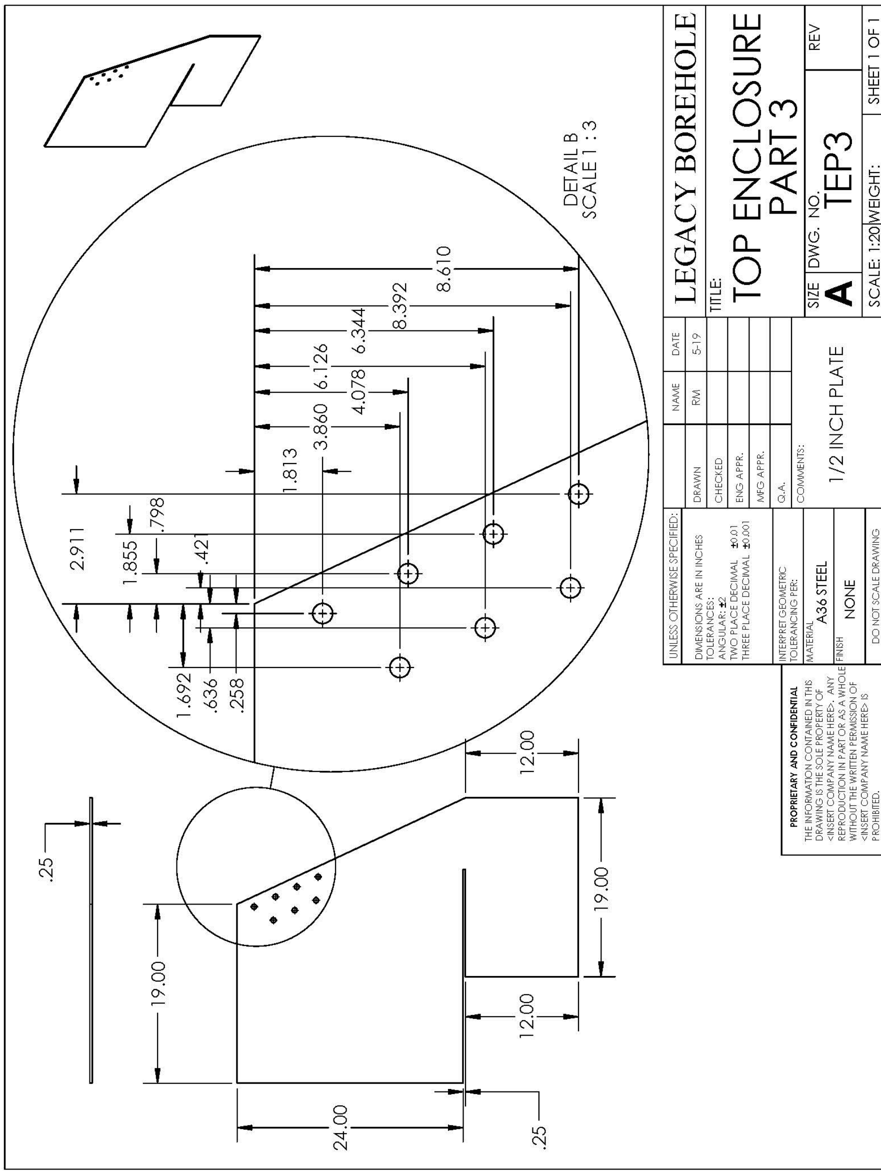
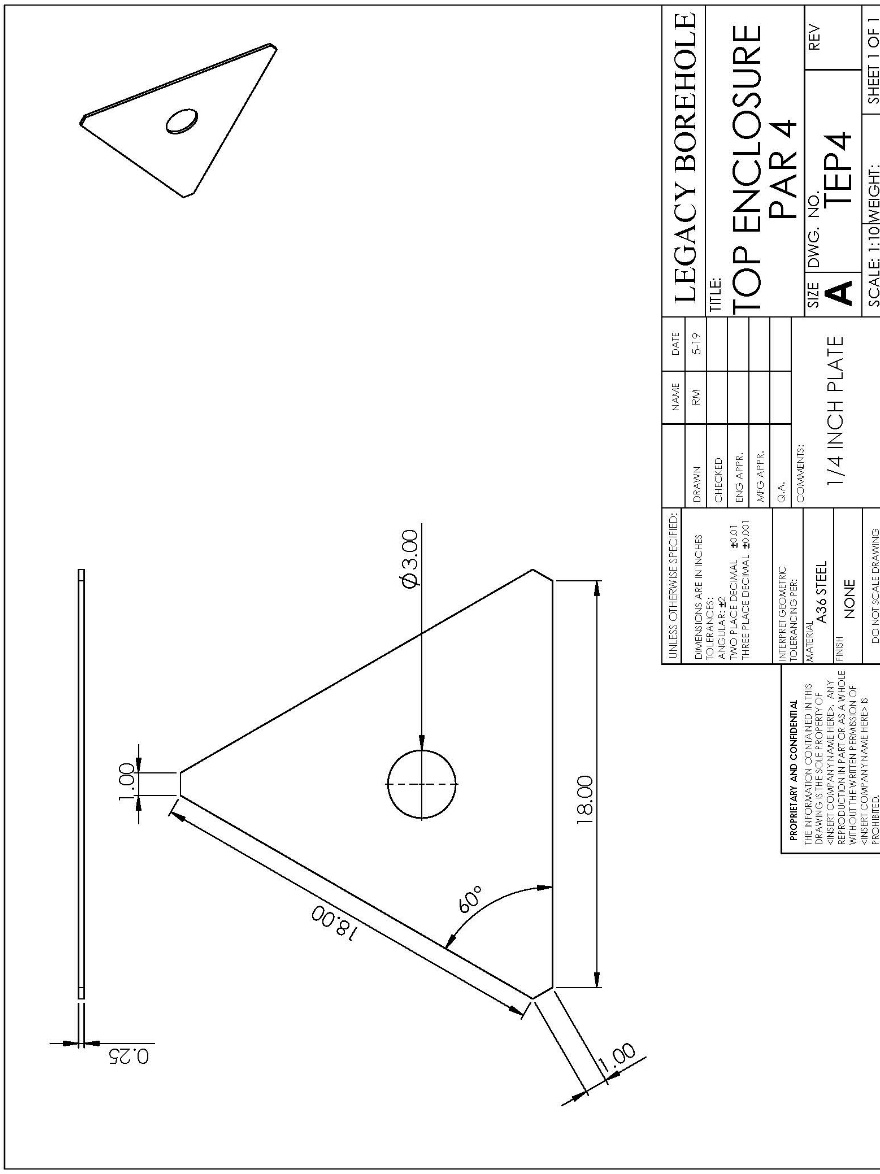
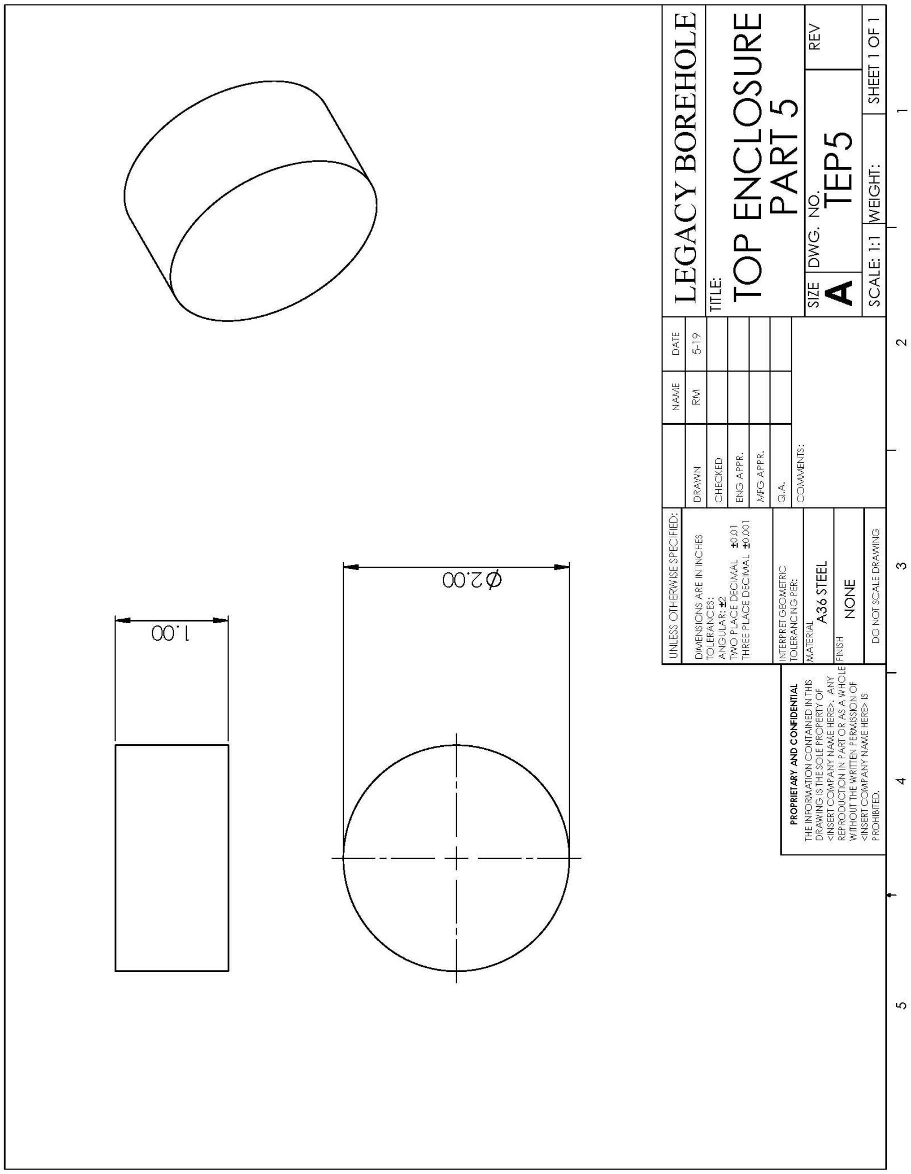

LEGACY BOREHOLE
TITLE:
TOP ENCLOSURE PART 3
SIZE A
DWG. NO. TEP3
REV
SCALE: 1:20
WEIGHT:
SHEET 1 OF 1
DETAIL B
SCALE 1 : 3
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5-19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/2 INCH PLATE
PROPRIETARY AND CONFIDENTIAL
8.610
8.392
6.344
6.126
4.078
3.860
1.813
2.911
1.855
.798
.421
1.692
.636
.258
12.00
19.00
19.00
12.00
24.00
.25
.25
1
2
3
4
5


LEGACY BOREHOLE
TITLE:
TOP ENCLOSURE
PAR 4
SIZE
A
DWG. NO.
TEP4
REV
SCALE: 1:10
WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5-19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/4 INCH PLATE
PROPRIETARY AND CONFIDENTIAL
Ø3.00
18.00
18.00
1.00
1.00
60°
0.25


LEGACY BOREHOLE
TITLE:
TOP ENCLOSURE PART 5
SIZE
A
DWG. NO.
TEP5
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
NAME
DATE
DRAWN
RM
5-19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
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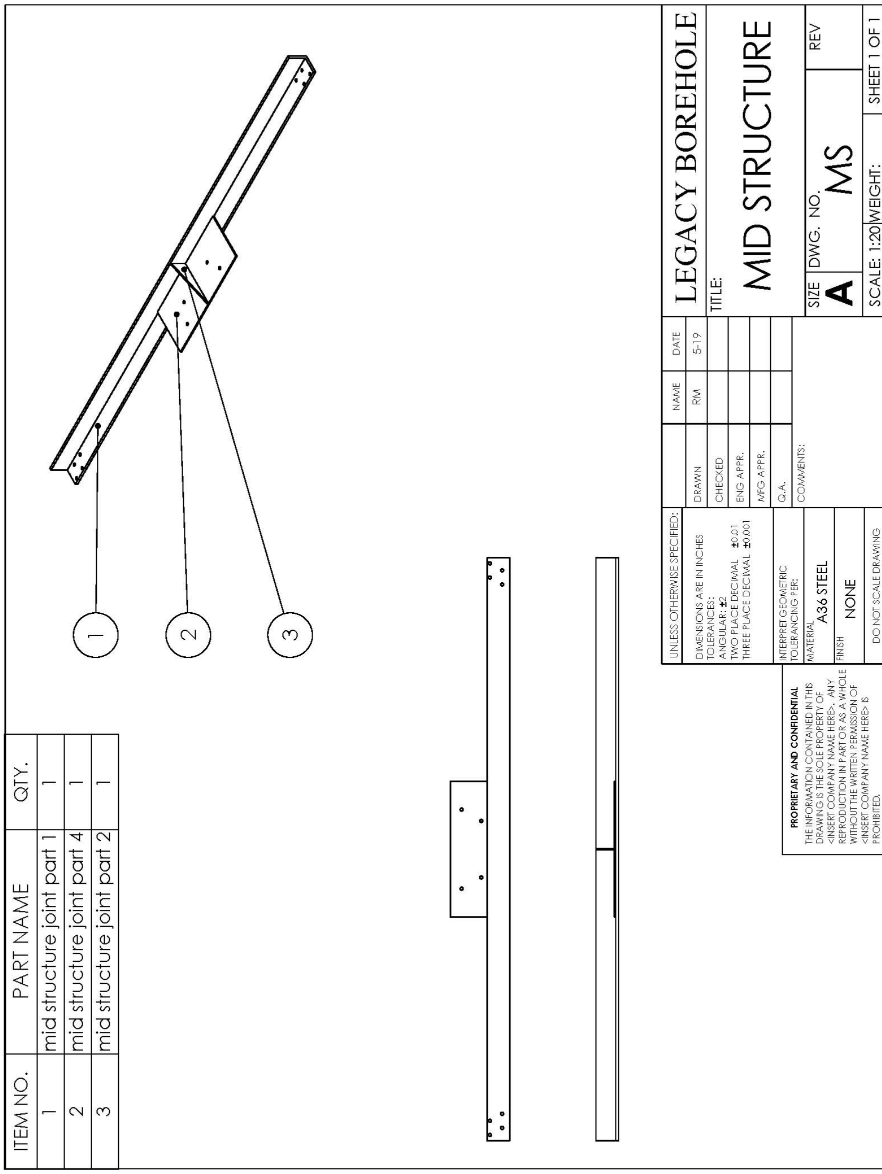
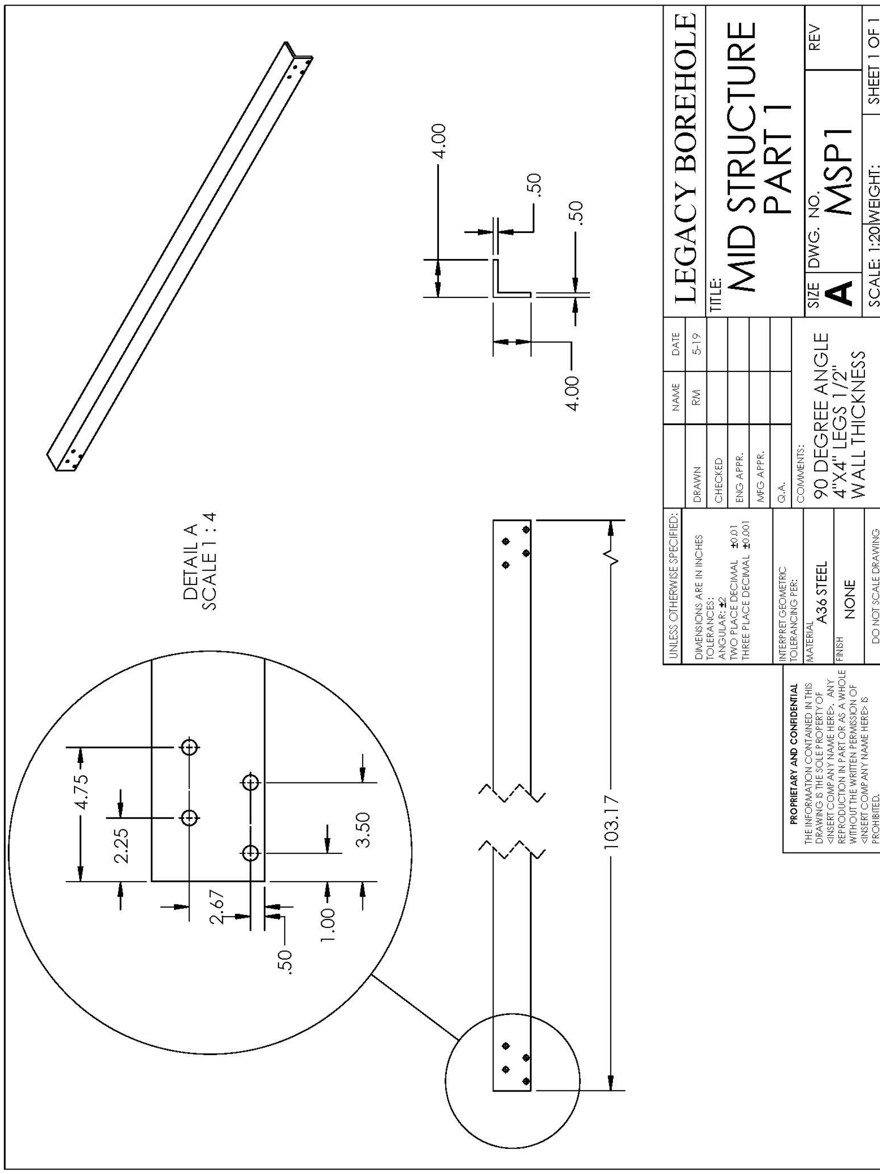
1.00
Ø2.00
1
2
3
4
5

D.2.5 Mid Structure




LEGACY BOREHOLE
TITLE:
MID STRUCTURE PART 1
SIZE
A
DWG. NO.
MSP1
REV
SCALE: 1:20
WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5-19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
90 DEGREE ANGLE
4"X4" LEGS 1/2"
WALL THICKNESS
PROPRIETARY AND CONFIDENTIAL
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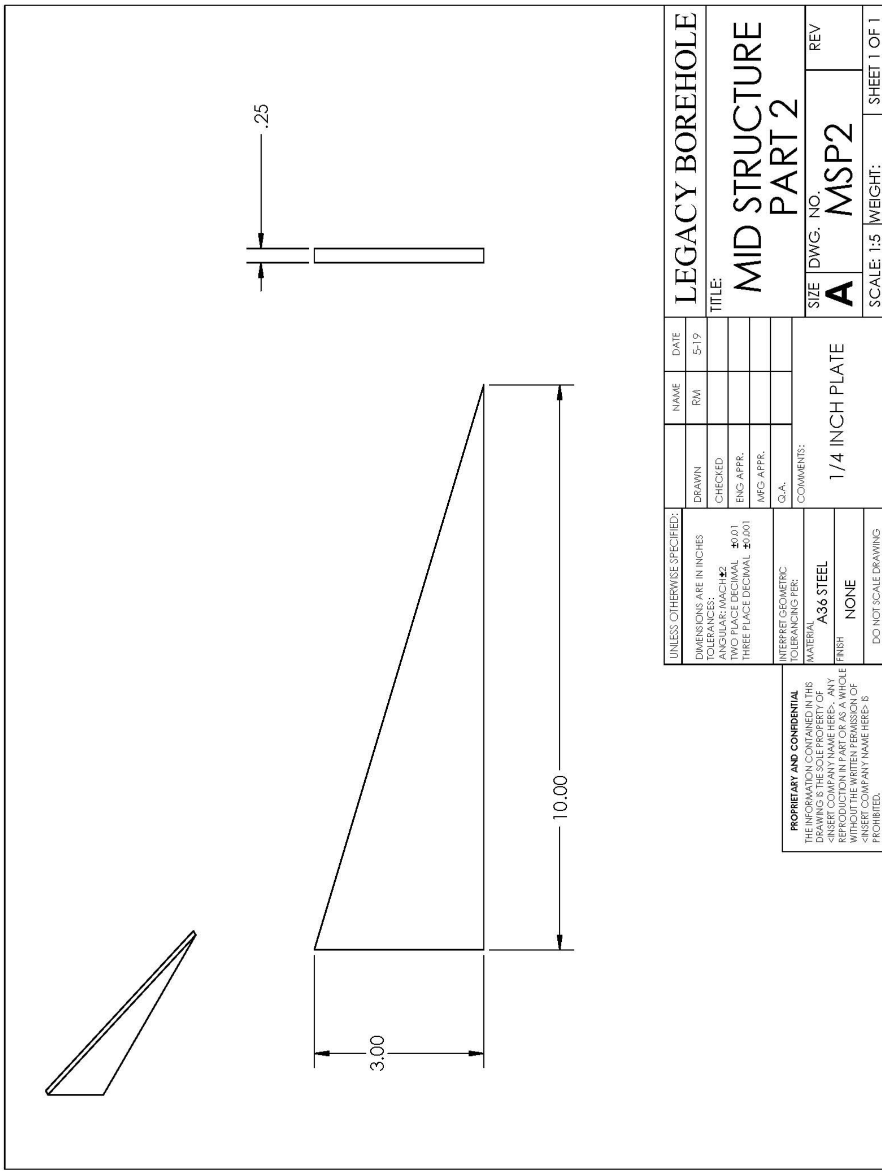
DETAIL A
SCALE 1 : 4
4.75
2.25
2.67
.50
1.00
3.50
103.17
4.00
.50
.50
4.00
1
2
3
4
5



.25
10.00
3.00
LEGACY BOREHOLE
TITLE:
MID STRUCTURE PART 2
SIZE
A
DWG. NO.
MSP2
REV
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1
NAME
DATE
DRAWN
RM
5-19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/4 INCH PLATE
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
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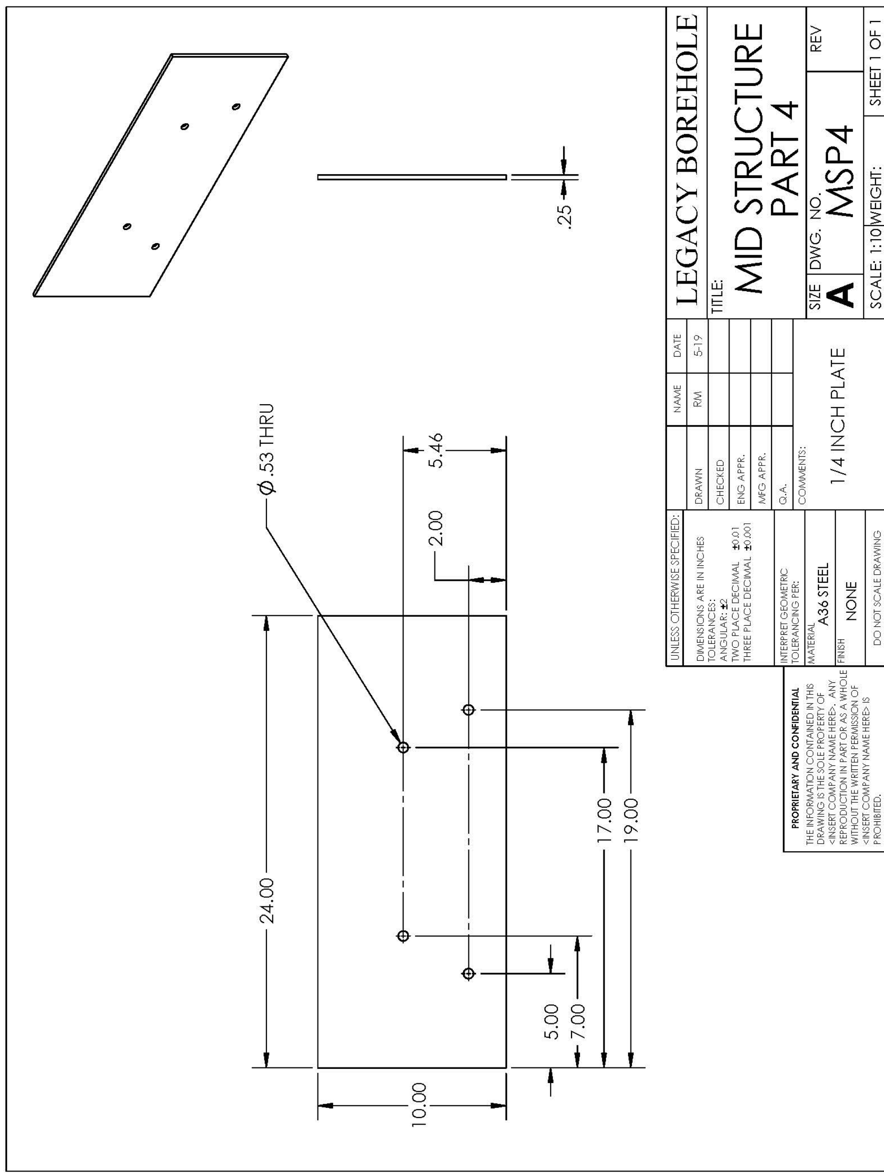
1
2
3
4
5


LEGACY BOREHOLE
TITLE:
MID STRUCTURE PART 4
SIZE A
DWG. NO. MSP4
REV
SCALE: 1:10
WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±2
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 STEEL
FINISH
NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RM
5-19
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1/4 INCH PLATE
PROPRIETARY AND CONFIDENTIAL
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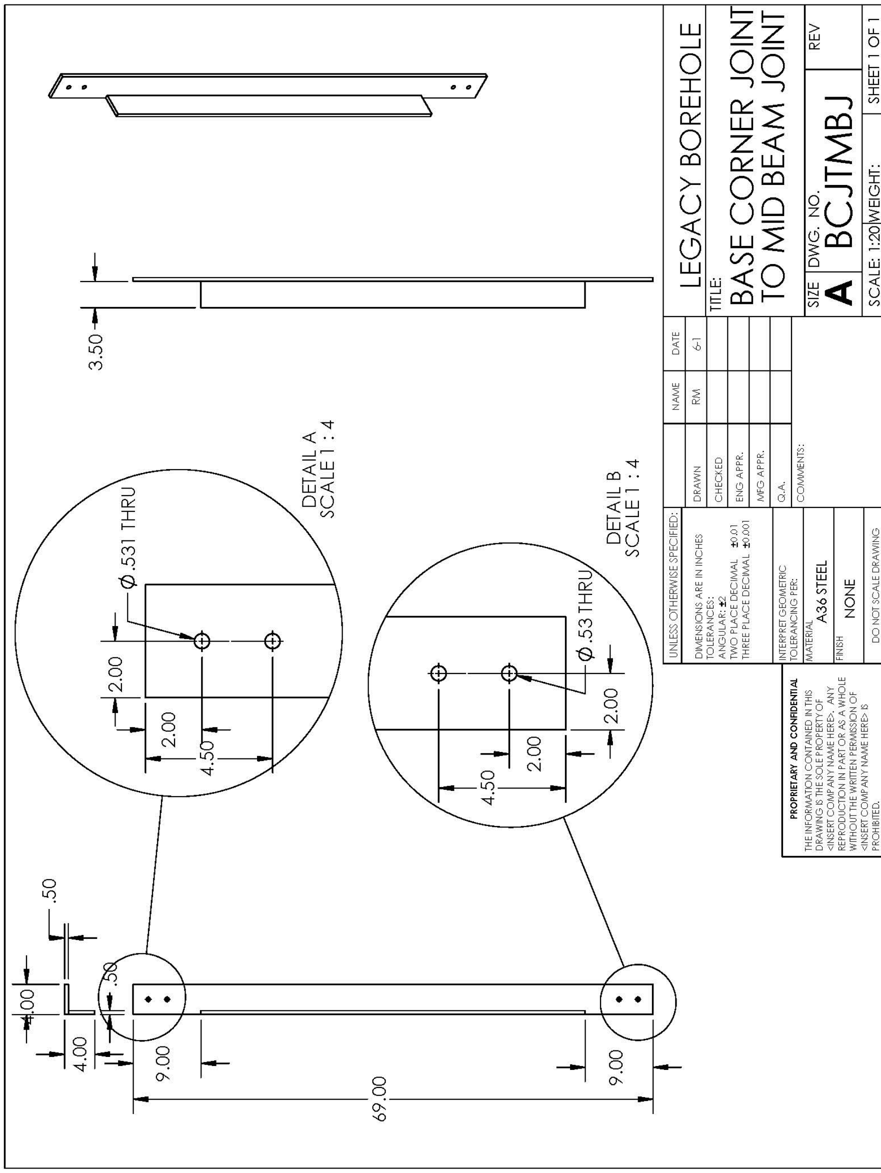
Ø.53 THRU
5.46
2.00
.25
24.00
17.00
19.00
5.00
7.00
10.00
1
2
3
4
5

D.2.6 Base Corner Joint to Midbeam Joint



E Assembly Procedure

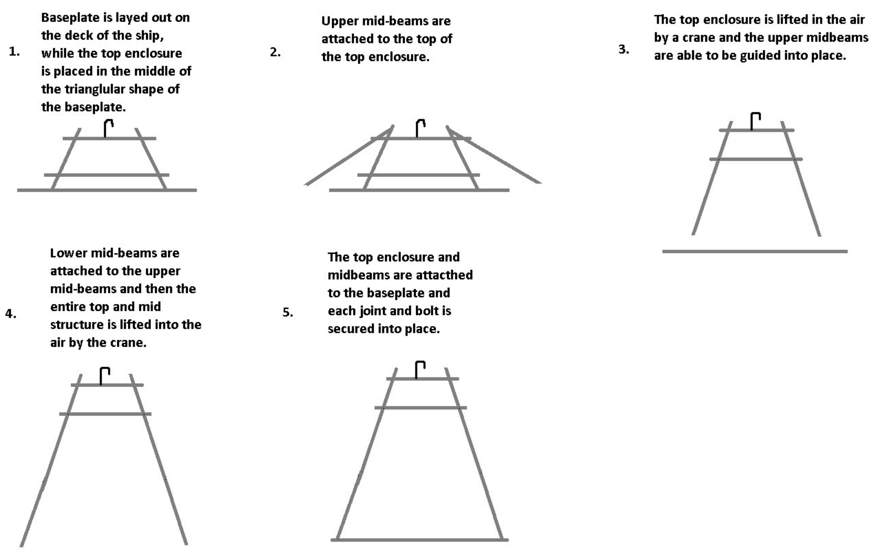


Fig. 18: Original assembly process created to accommodate the second design of the derrick structure.

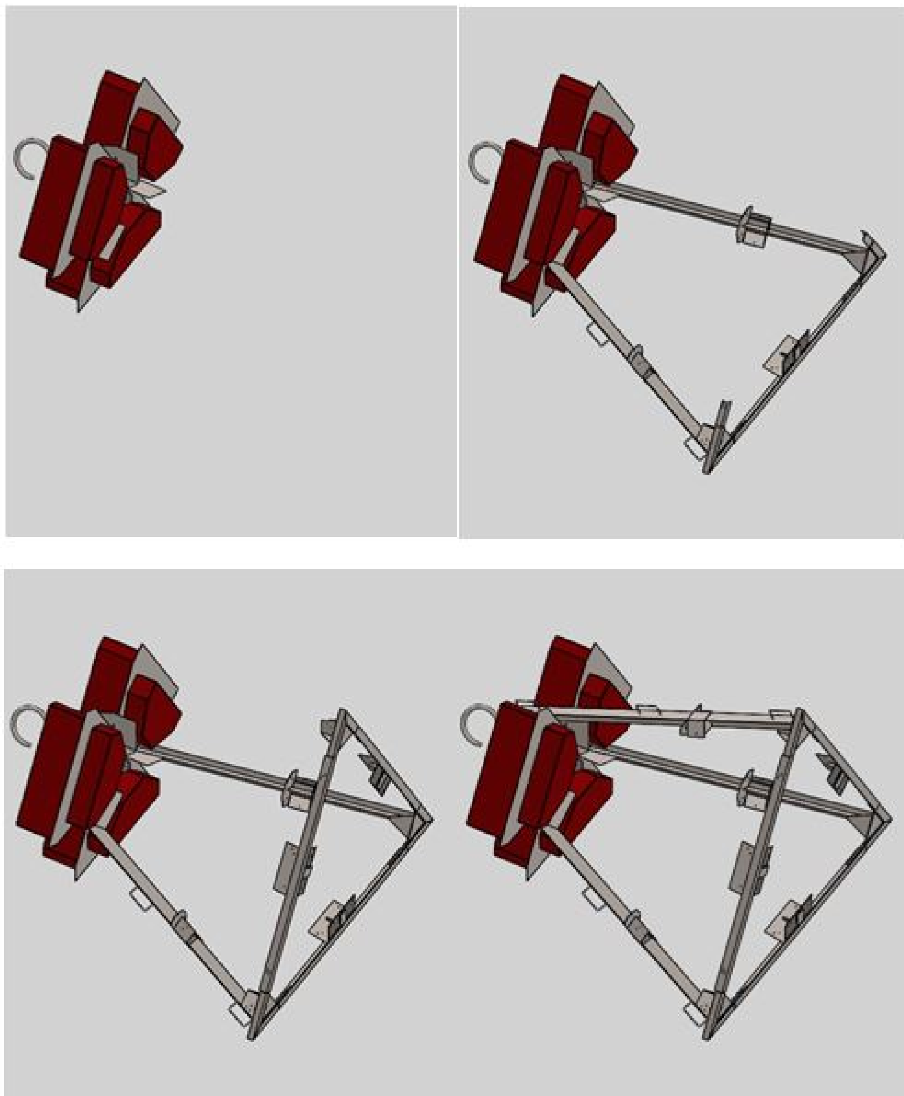


Fig. 19: First four steps in the latest assembly process for the derrick structure, ordering from top left, top right, bottom left, to bottom right.

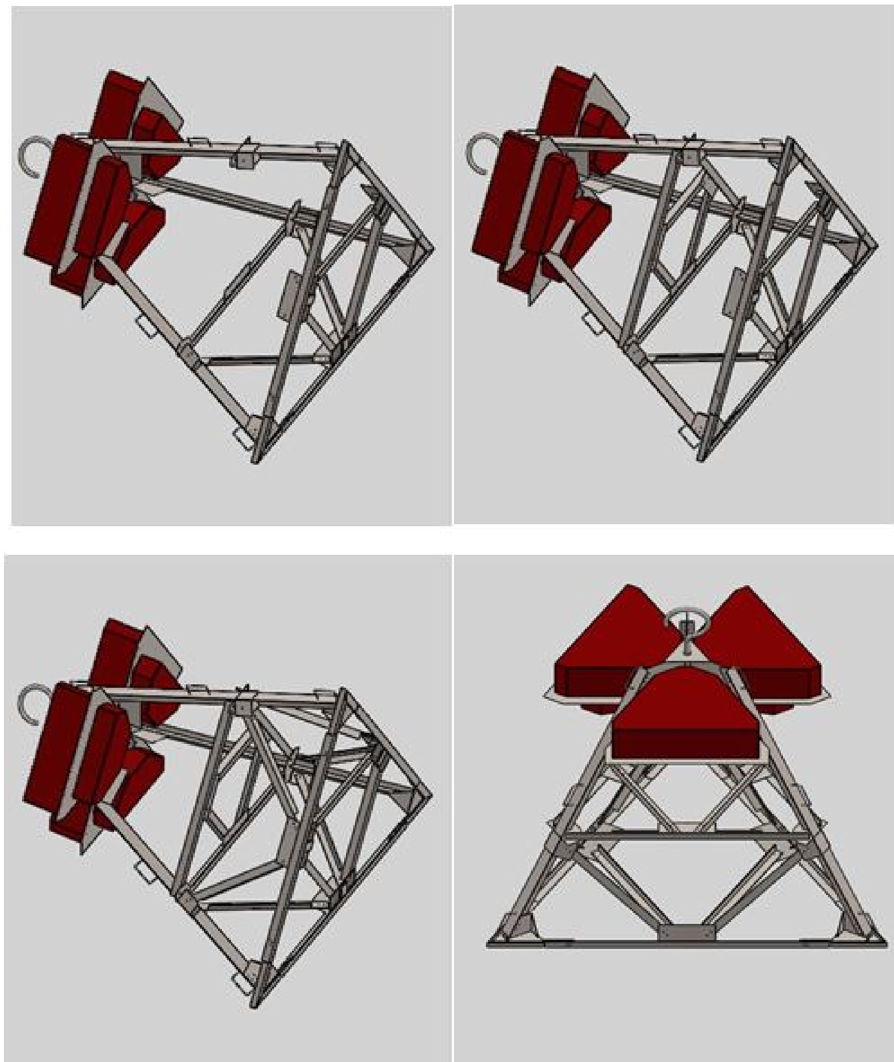


Fig. 20: Last four steps in the latest assembly process for the derrick structure, ordering from top left, top right, bottom left, to bottom right.

F Material Specification Sheet

F.1 1018 Steel

AK Steel ASTM A 1018, Grade 30 Hot Rolled Carbon Steel, Structural Steel (SS)

Categories: Metal; Ferrous Metal; Carbon Steel; Low Carbon Steel

Material Notes: Information provided by AK Steel

Key Words: ASTM A568, A1011, A635, A1018, A659, A749, SAE J1392, SAE J2340

Vendors: No vendors are listed for this material. Please click here if you are a supplier and would like information on how to add your listing to this material.

Printer friendly version Download as PDF Download to Excel (requires Excel and Windows)
Export data to your CAD/FEA program

Physical Properties	Metric	English
Density	7.87 g/cc @Temperature 20.0 °C	0.284 lb/in³ @Temperature 68.0 °F

Mechanical Properties	Metric	English
Tensile Strength, Ultimate	>= 340 MPa	>= 49300 psi
Tensile Strength, Yield	>= 205 MPa	>= 29700 psi
Elongation at Break	>= 22 %	>= 22 %
Modulus of Elasticity	200 GPa @Temperature 20.0 °C	29000 ksi @Temperature 68.0 °F

Electrical Properties	Metric	English
Electrical Resistivity	0.000142 ohm-cm @Temperature 20.0 °C	0.000142 ohm-cm @Temperature 68.0 °F

Thermal Properties	Metric	English
CTE, linear	12.4 µm/m-°C @Temperature 20.0 - 100 °C	6.89 µin/in-°F @Temperature 68.0 - 212 °F
Specific Heat Capacity	0.481 J/g-°C @Temperature 50.0 - 100 °C	0.115 BTU/lb-°F @Temperature 122 - 212 °F
Thermal Conductivity	89.0 W/m-K @Temperature 20.0 °C	618 BTU-in/hr-ft²-°F @Temperature 68.0 °F

Tab. 5: 1018 Steel Property Specifications
Source:
http://www.matweb.com/search/datasheet.aspx?matguid=291ca2e1b3214829ac5bc4ccfc4950a4&ckck=1

F.2 A36 Steel Plate

ASTM A36 Steel, plate

Categories: Metal; Ferrous Metal; ASTM Steel; Carbon Steel; Low Carbon Steel

Material Notes: Steel for general structural purposes including bridges and buildings.

Minimum Cu content when copper steel is specified.

Tests performed in transverse direction for plates wider than 590 mm.

Key Words: UNS K02600

Vendors: No vendors are listed for this material. Please click here if you are a supplier and would like information on how to add your listing to this material.

Printer friendly version Download as PDF Download to Excel (requires Excel and Windows)
Export data to your CAD/FEA program Add to Folder: My Folder 0/0

Physical Properties	Metric	English	Comments
Density	7.85 g/cc	0.284 lb/in³	Typical of ASTM Steel

Mechanical Properties	Metric	English	Comments
Tensile Strength, Ultimate	400 - 550 MPa	58000 - 79800 psi	
Tensile Strength, Yield	250 MPa	36300 psi	
Elongation at Break	20 %	20 %	in 200 mm
	23 %	23 %	In 50 mm.
Modulus of Elasticity	200 GPa	29000 ksi	
Bulk Modulus	160 GPa	23200 ksi	Typical for steel
Poissons Ratio	0.26	0.26	
Shear Modulus	79.3 GPa	11500 ksi	

Component Elements Properties	Metric	English	Comments
Carbon, C	0.25 - 0.29 %	0.25 - 0.29 %	
Copper, Cu	0.20 %	0.20 %	
Iron, Fe	98 %	98 %	
Manganese, Mn	1.03 %	1.03 %	
Phosphorous, P	<= 0.040 %	<= 0.040 %	
Silicon, Si	0.28 %	0.28 %	
Sulfur, S	<= 0.050 %	<= 0.050 %	

Tab. 6: A36 STeel Property Specifications
Source:
http://www.matweb.com/search/datasheet.aspx?matguid=291ca2e1b3214829ac5bc4ccfc4950a4&ckck=1

G Cost of Test Materials

McMASTER-CARR

Order Confirmation

562-692-5911
562-695-2323 (fax)
la.sales@mcmaster.com

Ship to

Rhys Marks
561 Washington St.
Santa Clara CA 95050

Order Date
5/26/15

Ordered By
Rhys Marks

McMaster-Carr Number
3880417

Line		Product	Ordered	Ships	Price	Total
1	90499A029	Grade 8 Steel Hex Nut, 1/4"-20 Thread Size, 7/16" Wide, 7/32" High, packs of 100	1 pack	today	2.97 per pack	2.97
2	91101A229	Steel Split Lock Washer, 1/4" Screw Size, 0.260" ID, 0.487" OD, packs of 100	1 pack	today	2.28 per pack	2.28
3	95362A105	mil. Spec. B1821BH Steel Hex Head Cap Screw, Zinc Plated, 1/4"-20 Thread, 1" Long, Fully Threaded, packs of 10	2 packs	today	7.20 per pack	14.40
4	98023A029	Zinc Yellow-Chromate Plated Steel Flat Washer, Grade 8, 1/4" Screw Size, 0.281" ID, 0.625" OD, packs of 100	1 pack	today	6.36 per pack	6.36
5	8910K571	Low-Carbon Steel Rectangular Bar, 1/4" Thick, 3" Width, 1' Length	3 each	today	13.67 each	41.01
6	8910K557	Low-Carbon Steel Bar, 1/4" Thick, 2" Width, 2' Length	2 each	today	16.88 each	33.76

Merchandise $100.78

Applicable shipping charges and tax will be added.

Notes

Your order is subject only to our terms and conditions, available at www.mcmaster.com or from our Sales Department.

McMaster-Carr Supply Company

Page 1 of 1

Fig. 21: Materials ordered from McMaster-Carr, to run the experimental test

H Finite Element Analysis

H.1 Introduction

This derrick is broken down into three structural subsystems: the top enclosure, the mid-beams, and the baseplate. The major analysis performed for the overall structure was minimal but informative in mid beam analysis. The mid beam analysis discussed earlier addressed maximizing performance of the beam cross sections. This system is going to be exposed to three main environments that are significant in terms of the external loads that will act on the structure when: 1) Fully assembled on the deck of the ship 2) Suspended in the air by the ship's crane and 3) Positioned on the recovery cone on the ocean floor.

H.2 Free-Body Diagram

The structure we designed is not expected to experience significant dynamic loading. For this reason, the structure is analyzed as a static system. While fully assembled, this structure is exposed to multiple environments. Free-body diagrams were developed to better understand the significant loads applied to this structure. A Free Body Diagram is a graphical representation of a system and its significant interface with its surrounding environment. In Figures 23-25 (below), the force labeled Fc is the force applied by the crane on the deck of the ship which keeps the system static and the force labeled FD is the force applied by the deck of the ship which keeps the system in fixed position. These two forces are equivalent, although the area over which these forces are applied is not. It is important to note that the buoyant material (syntactic foam in this case) added to the system and individually to the sensor package changes the values of certain forces when the structure is in the ocean. For this reason, the value of the force of the reentry cone, which is equivalent to the observed weight of the system, is less than the force of

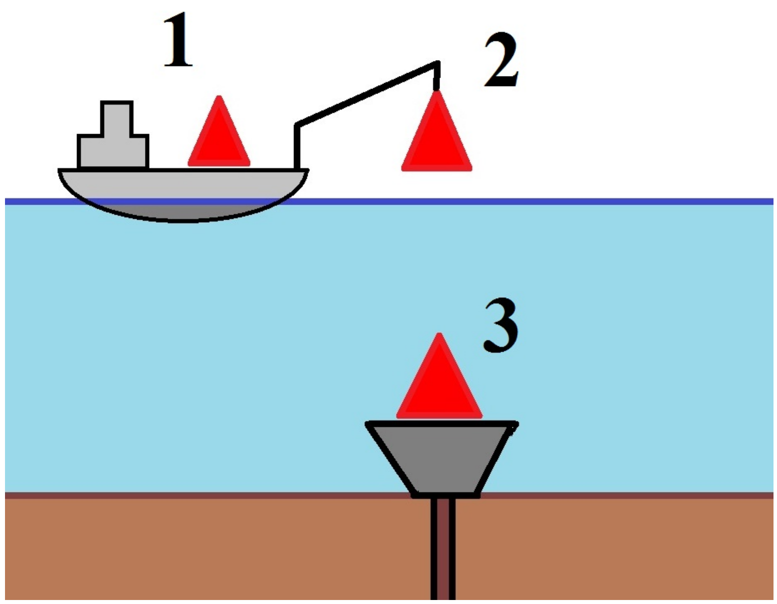


Fig. 22: The significant free-body diagram locations. 1) Fully assembled on the deck of the ship 2) Suspended in the air by the ship's crane and 3) Positioned on the recovery cone on the ocean floor.

the deck of the ship. The system will be positioned on the deck of a ship, suspended over the deck of the ship by a crane onboard, and span the top of a borehole reentry cone. The external forces acting on the structure in these environments are different, thus the free body diagrams must be different.

H.3 Materials

The major materials being used are 1018 structural steel, for the plates of the top enclosure, and A36 structural steel that will be used for the mid-beams. Both specifications can be found in Appendix F. The structure is designed to be made of beams and plates which are welded and bolted together. The beams that make up the base of the structure are $\frac{1}{4}$ " thick 4" x 4" angle irons. The beams making up the mid-beams are 4" x 4" T-bars. The plates making up the top enclosure is made of double angle irons and

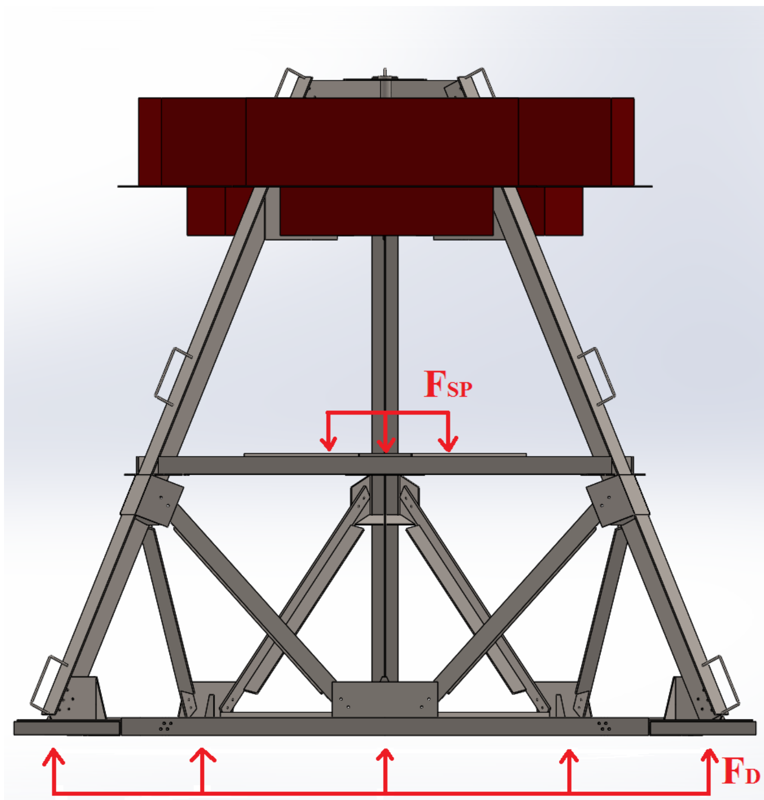


Fig. 23: Free-body diagram demonstrating the forces on the structure when fully assembled on the deck of the ship. Fsp is the force applied by the weight of the sensor package. FD is the force of the deck of the ship acting on the structure.

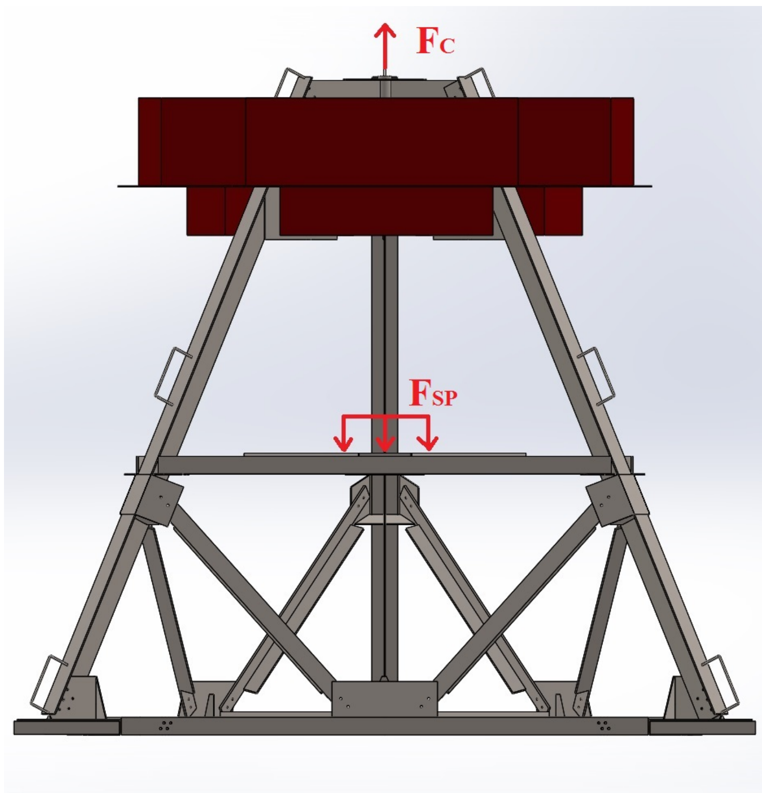


Fig. 24: Free-body diagram demonstrating the forces on the structure when suspended in the air by the ship's crane. Fc is the force of the crane holding the system in the air. Fsp is the force applied by the weight of the sensor package

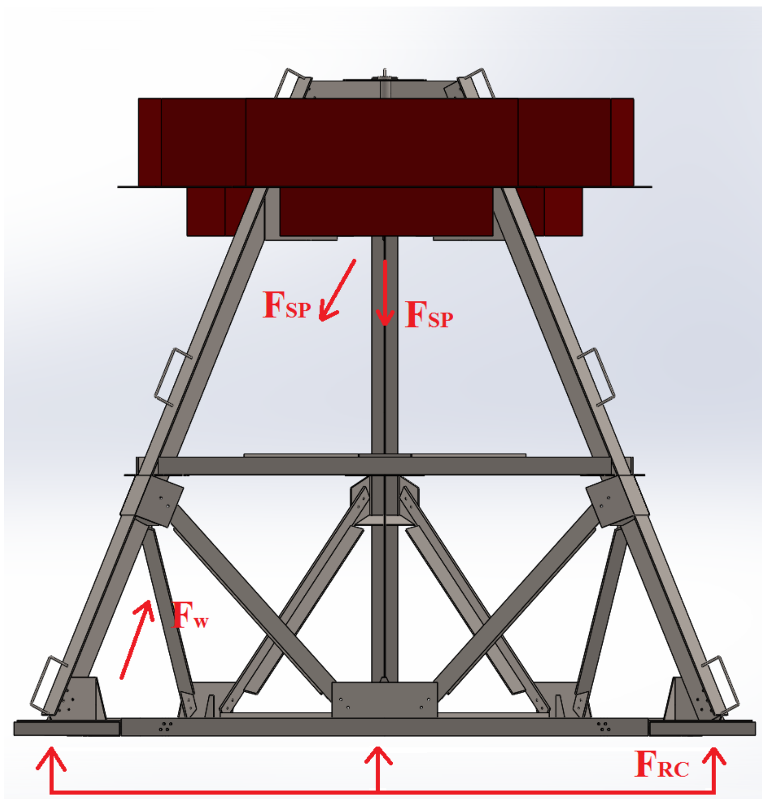


Fig. 25: Free-body diagram demonstrating the forces on the structure when positioned on the recovery cone on the ocean floor. FRC is the force of the recovery cone acting on the structure. Fw is the force acting on the structure by the winch. Fsp is the force applied by the weight of the sensor package.

$\frac{1}{2}$" 1018 steel plates. The angle irons being used as the base plate will help avoid a torsional stress as the heavy sensor package is being supported by the structure. The boreholes that the structure will be sitting on may not be level so it is important for the base to resist torsion in order to remain structurally sound. The mid-beams are T beams in order to resist column buckling as well at torsion. The mid-beams each are broken up into upper and lower components which are connected together due to the fact that this is one way that each piece will be able to fit into the specified sea-containers. This truss system is the best way to keep the weight of each beam down, keep the length of each beam short enough to be carried safely by one person aboard the ship, and strong enough to support the weight of the sensor package. The space between the steel plates at the top of the structure is being used as an enclosure for syntactic foam, for buoyancy. The top enclosure is a location for the connection between the crane and the structure, and the pulley for the cable/winch system and the structure. The components of the structure are assembled and disassembled at joints. In this structure's design, double shear will be utilized at joint locations. In bolted or pinned connections, shear is usually the mode of failure. A good way to minimize shearing stresses acting through connecting components of a joint is to utilize a double shear connection. Double shear occurs when a bolt joins three elements and the inner elements exerts a force normal to the length of the bolt while the outer elements counteract the force. Single shear differs in that there are only two joined elements so there is only one element counteracting the force. Double shear results in an average shearing stress equivalent to half the value of a single shear joint with equivalent force acting through each joint.

For the reason explained above, all joints initially were designed with double shear, however, in the final design the client decided that the joint should utilize single shear in order for the structure to be easier to assemble.

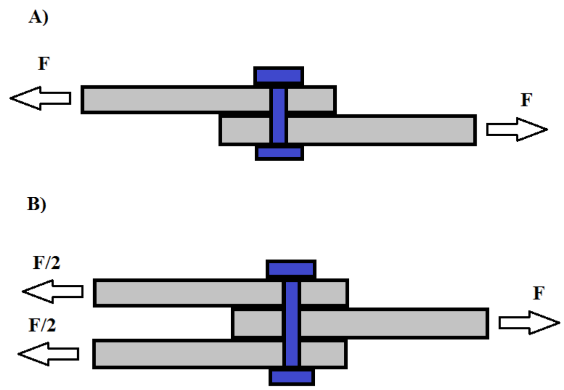


Fig. 26: Cross sections of assemblies experiencing display of shear in a bolted connection. A) is single shear while B) is double shear.

H.4 External Conditions

As described above the structure will be examined in three different loading conditions in which there will be different conditions and loads applied to different parts of the derrick structure. In each environment, there will be two counteracting forces, one which will be the force of the winch on a cable and one from the pulley acting as a mechanism to redirect the weight of the sensor package downward on the overall derrick structure. In the first condition: the derrick is standing fully assembled and erect on the deck of a ship in which it will be experiencing an upward force exerted upwards from the boat on the 3 skids on the bottom of the structure, as well as a load exerting a downward force on the lower metal sheet of the top-enclosure (see Figure 23).

The second condition is when the crane will be lifting the derrick structure with the sensor package locked into place within the derrick structure. During this condition there will be a load of the sensor package exerted downward from the lower metal sheet once again, yet this time there will also be a force exerted upwards from the top sheet of the top enclosure that will be due to the crane lifting up on the overall structure (see Figure 24).

The third condition is when the derrick structure will be sitting at the bottom of the ocean on top of a borehole recovery cone. The derrick will experience nearly the exact same conditions as when it is sitting on the deck of the ship, however the only difference is that there will be a hydrostatic force that he whole derrick will be experiencing. This force is negligible because there will be nothing effected by the force on the derrick structure.

H.5 Expectations

The expected output for the top enclosure in FEA will be that it will fail due to the thickness of the metal plates that were chosen to be $\frac{1}{2}$" thick for both the top and bottom plates. This is because, these plates will be experiencing the majority of the force from the sensor package as well as the overall weight of the structure. The plastic deformation of the top and the bottom metal plate shown in Figure 27 displays that there is too much deformation for the structure to be elastic. Another form of deformation could be failure at the welds between the connecting beams and the metal plates due to the increase in shear force that will be acting on the welds.

H.6 Problems

One problem recently encountered was the weight of the structure and how much syntactic foam would be needed to be neutrally buoyant. This is an issue because space is limited at the top of the enclosure. Due to the large weight of the structure and more importantly, to the winch/cable system and the sensor package, we might have to readjust our design to accommodate for the large amount of foam.

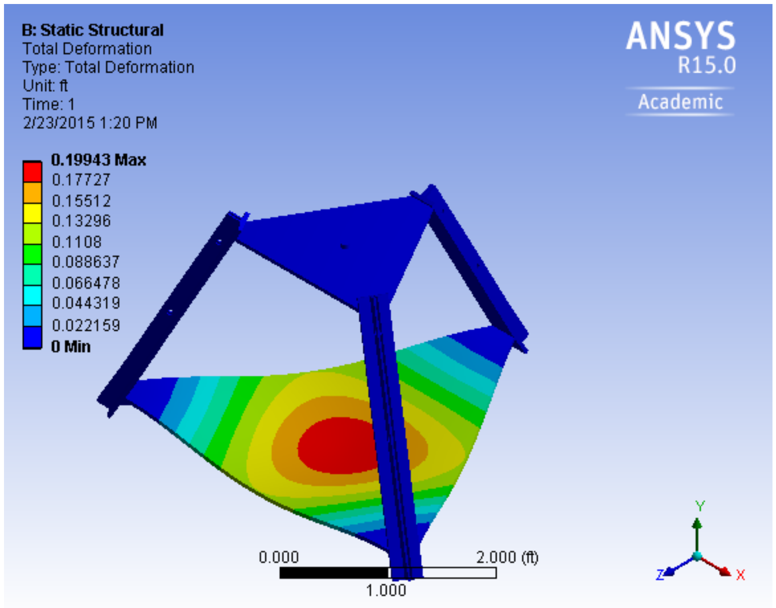


Fig. 27: The total deformation of the first/third condition when the derrick is sitting on the deck of the ship or sitting on the borehole recovery cone.

H.7 Results

It can be seen that the total deformation is very similar on the bottom plate as shown in both Figures 27 & 28 due to the exact same force being exerted for both simulations. Within the top enclosure it can be seen that the amount of deformation taken on is not acceptable enough to just be elastic deformation. This will cause the top enclosure to experience plastic deformation which was predicted earlier within the expectation.

The structure experiences the greatest external forces when it is suspended by the crane over the deck. When the structure is in this state, the top enclosure subsystem experiences the most external force. This subsystem in this environment was chosen for detailed finite element analysis because of its most extreme characteristics. When analyzing the results of the FEA of this subsystem, we learned it found that there is a considerable amount of deformation at the center of both the top and bottom plates of the top enclo-

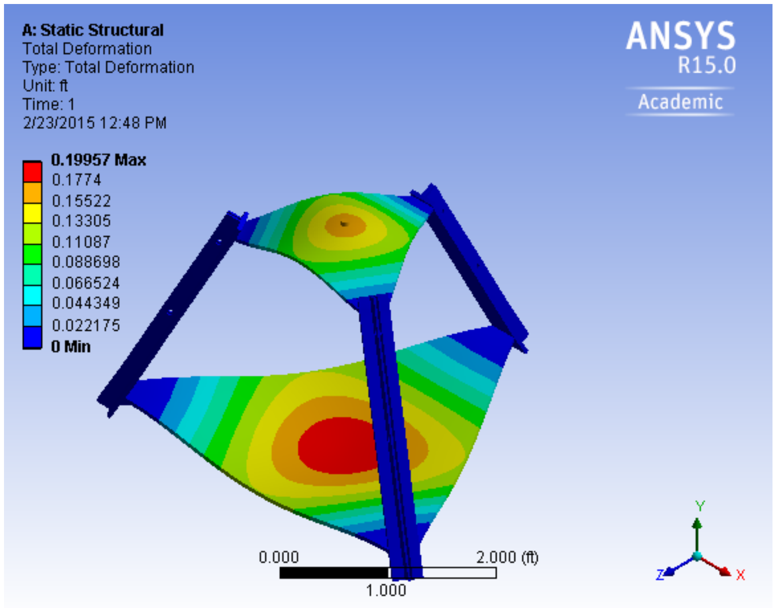


Fig. 28: The total deformation of the second condition when the derrick is being lifted by the crane and the sensor package is hanging within the derrick.

sure. This is due to the external forces being exerted onto these two plates. A solution to the large amount of deformation is to thicken the top and bottom plates. Another structural alteration that could be made is to increase the size of the gussets on the bottom metal plate and possibly to add gussets at the top plate in order to disperse more of the force. The simulations showed that strain energy concentrates at the base plate's gussets.

The first/third condition displays the overall amount of stress, strain, and deformation being exerted nearly entirely on the bottom metal sheet of the top enclosure. This deformation, however, was reduced because of the metal gussets that were placed at the bottom of the sheet and worked to disperse the load onto the connecting angle irons.

The second condition displays demonstrates that the main stress, strain, and deformation being exerted onto both the top and bottom metal plates, yet the bottom metal sheet still receives more force and deformation.

I Sensor Package

Fig. 29: Photo of year one's prototype for the sensor package. [#]

J Slip Ring Specification Sheet

Slip Rings

Electrical	
Voltage	Maximum 5000 VAC
Current	Maximum 20 A per pass [1] Maximum 720 A total current [2]
[1] Higher current ratings possible by wiring passes in parallel	
[2] All current ratings based on a 20°C ambient temperature	

Electrical Power Performance	
Contact Resistance	20 mΩ nominal
Insulation Resistance [1]	Minimum 500 MΩ @ 1 kVDC
Short Circuit Rating	1.5 kA / 1s, 3.7 kA peak
[1] Value dependent on wire type	

Electrical Signal Performance	
Contact Resistance	20 mΩ nominal
Insulation Resistance [1]	Minimum 500 MΩ @ 1 kVDC
Insertion Loss (Nominal) RG59 coax	1.5 dB maximum up to 30 MHz
Crosstalk (Nominal) RG59 coax	-15 dB maximum up to 30 MHz
[1] Value dependent on wire type	

Mechanical	
Rotation Speed	Maximum 50 rpm continuous [1]
Protection Class	IP 66
Operating Temperature	-20°C to +55°C [2]
Housing	Stainless steel (304)
Length "L"	Varies with number of electrical passes
[1] Higher rotational speeds possible. Please consult factory	
[2] -20°C to +40°C for CSA certified Model 176-X	

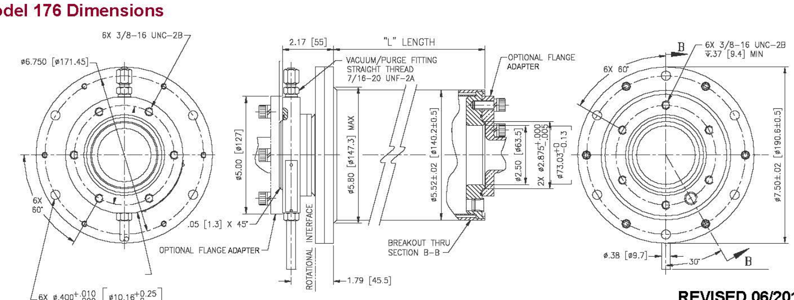
Environment Test	
Temperature	Tested to MIL-STD-810F, methods 501.4 and 502.4
Vibration	Tested to MIL-STD-167-1
Shock	Tested to MIL-STD-810D , method 516.3
Humidity	Tested to MIL-STD-810F, method 507.4

Hazardous Area Option: Model 176-X		
Certification	ETL:	Class I, Division 1, Group C & D, T5 Class I, Zone 1, AEx d IIB T5
	CSA:	Class I, Division 1, Group C & D, T5 Class I, Zone 1, Ex d IIB T5
	ATEX:	CE 0344 Ex II 2 G Ex d IIB T5 Gb
	IECEx:	Ex d IIB T5 Gb
Can be supplied with purge fittings for use with a certified purge system. The maximum total current of Model 176-X is 640 A		

Terminations	
Standard	Wire pigtails, 10 ft [3.0 m] in length
Flange and Cable Covers	Various entry threads and orientations available
Special [1]	Supply and installation of connectors, terminals, conduit, cable, glands, junction boxes
[1] Integration of customer supplied product possible	

Additional Options	
Fiber Optics	Fiber Optic Rotary Joint (FORJ) or optical converter
Covered Pigtails	Tinned copper braid and heat shrink installed over loose wire pigtails
Fluid Classification	Fluid Rotary Union (FRU)
Design Certification	ABS, DNV, BV, LRS
Submersed Applications	Fluid filling fittings or fluid filled / pressure compensated at factory. Internal pressure compensation Model 176 TMS option. Contact factory for details.
Other Devices [1]	RF Rotary Joint, shaft encoder, sensors
Ingress Protection [2]	IP 66, IP 68 to 'x' m
Extended Temperature Range	
[1] Integration of customer supplied product possible	
[2] Contact factory for higher ingress protection	

Model 176 Dimensions



Dimensions in inches [millimeters]

REVISED 06/2014

K Deployment Vessel Details

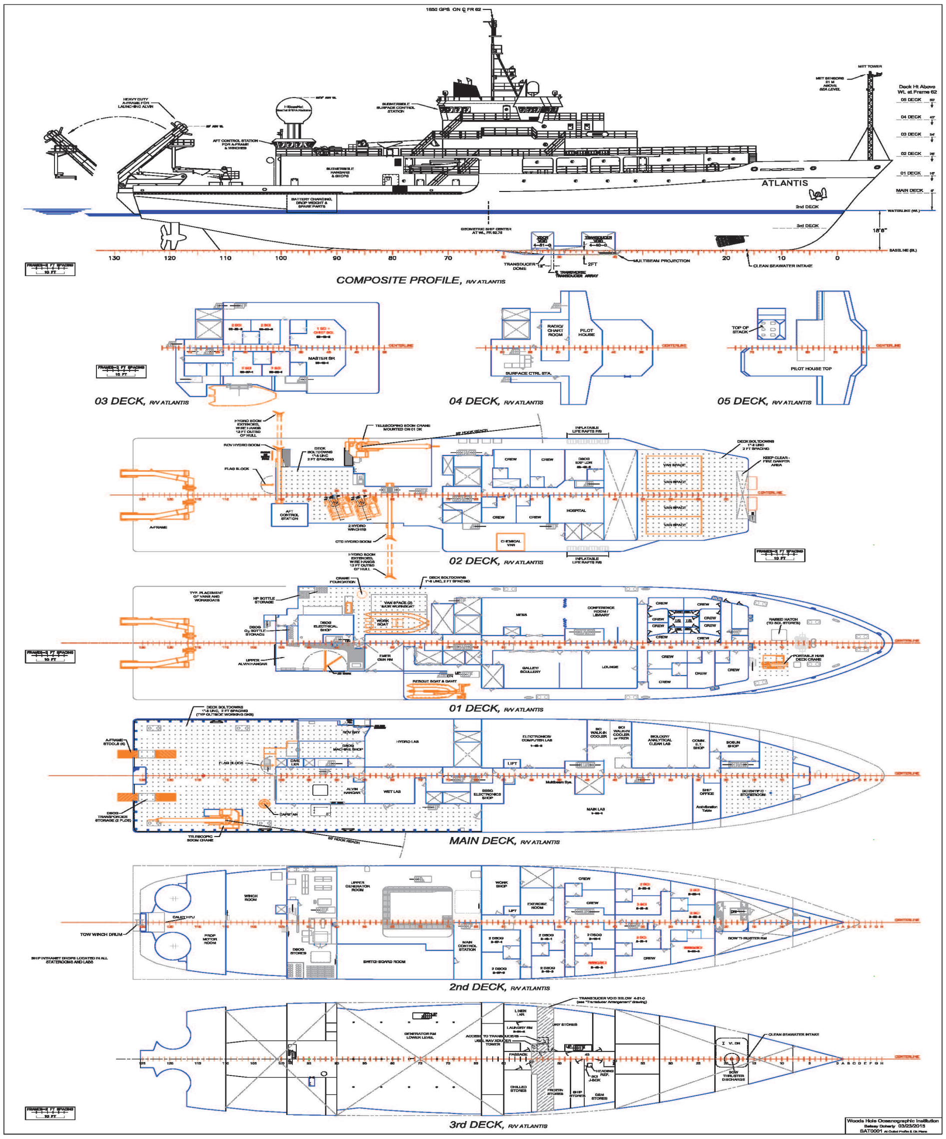


Fig. 30: Overall dimensions of potential deployment vessel provided by the Woods Hole Oceanographic Institution
Source: http://www.whoi.edu/page.do?pid=8222

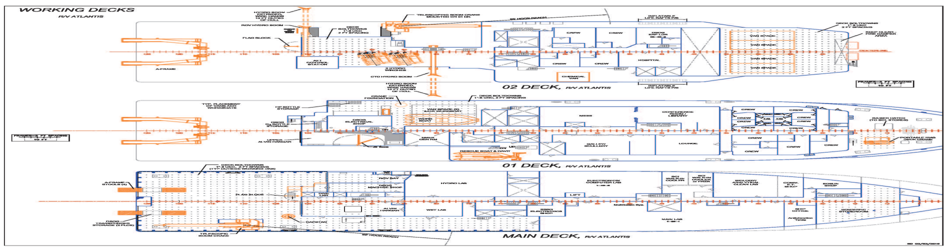


Fig. 31: Deployment Vessel working decks provided by the Woods Hole Oceanographic Institution
Source: http://www.whoi.edu/page.do?pid=8222

L Budget

Components	Raw Materials	COST Purchase	Outside Manufacturing
Derrick Structure			
Frame	$4,000.00	$1,000.00	$10,000.00
Winch Mount	$1,000.00	$500.00	$2,500.00
Winch w/ level wind		$80,000.00	
Optical Slip Ring		**Purchased by C-DEBI**	
Topside Electrical	$1,000.00	$5,500.00	$1,500.00
Optical Connectors		$7,500.00	$7,500.00
Electrical Connectors		$6,000.00	
Pressure Housing	$10,000.00	$2,000.00	$7,500.00
Optical Oil Comp		$7,500.00	
Flotation		$7,500.00	$7,500.00
Assembly Facility		$30,000.00	
ROV/HOV Interface			
Interconnect Housing	$6,500.00	$250.00	$4,500.00
Wet Mate EO Con		$12,000.00	$5,000.00
Penetrators (3)		$2,500.00	
Oil Compensator		$3,000.00	
Cable Whip	$2,500.00	$2,500.00	$1,500.00
Cable			
Custom Spec 6000m Engr. Spec/Manage rated 3 wire 4opt fiber	1500m	$85/m	$127,500.00
Instrument Package			
Bottom Side Electrical	$1,000.00	$5,500.00	
Instrument Cage	$2,500.00	$500.00	$4,500.00
CTD-2x		$80,000.00	
02 Sensor -2x		$34,000.00	
Optical Connectors		$7,500.00	
Electrical Connectors		$6,000.00	
Cable Termination	$2,500.00	$2,500.00	$2,500.00
Pressure Housing	$10,000.00	$250.00	$7,500.00
Caliper		$1,500.00	
2 HD Camera		$10,000.00	
Lights		$7,500.00	
Interconnect Cabling	$3,000.00	$5,000.00	$2,500.00
Sampling System		$10,000.00	$10,000.00
Nitrate Analyzer		$15,000.00	
pH and eh		$10,000.00	$5,000.00
Totals	$44,000.00	$363,000.00	$207,000.00
Grand Total			**$614,000.00**

Tab. 7: Table of the proposed budget by Geoff Wheat in the DEBI-SELECT project proposal. As shown above in the proposed budget for creating one Legacy Borehole System, the approximate cost of creating one fully functioning system with fabrication or manufacturing is approximately $614,000. This allows for a slight bit of overhead with the approximation of the costs being rough.

M Commercialization Plan

M.1 Introduction and Background

Our plan is to provide a product optimized for research of the subseafloor environment. This environment includes, but is not limited to, boreholes, borehole recovery cones, and ocean caverns. The objective of our product is to deploy a set of sensors from an ocean vessel to the sea floor where these sensors will collect data and transmitted to the scientists present on the vessel. Scientists around the world at various universities and organizations have shown interest in launching projects in order to study microorganisms, sediment, and the life at and under the ocean's floor. Industry is likely to pursue research and development on their own as the opportunities for new products becomes evident.

The market in this case is full of untapped potential in many scientific disciplines, yet it is currently limited to universities, non-profit organizations, and or research facilities. The personnel that would be interacting with this device are various disciplines in the scientific community, engineering technicians, and marine technicians transporting the system to and from ports research sites on the oceans of around the world.

There is no direct competition in the commercial market for this type of structure that we are creating. The only "competition" for our product are systems known as elevators. These elevators have been fabricated, in house, by research facilities that have the need to raise and lower certain instruments or goods down to the ocean floor. Due to the high cost of self-fabrication of these mechanisms by the research facilities, it could be more cost-effective to outsource the work to a project such as ours to lease the Legacy Borehole Project system.

M.2 Goals and Objectives

The overall goal of this company is to create a small scale market for deep-sea research that could lead to major revenue streams through governmental contracts, university research partnerships, and scientific collaboration. In doing so, creating business relationships with major organizations and universities could lead to a large increase in profit for the company that will, in turn, allow for greater research & development for even better and more efficient deep-sea/ subseafloor equipment.

Another major objective of commercializing this product is to allow for scientists around the world to gain access to a secure and useful research tool to further their research. Only a limited number of research institutions encourage collaboration among engineers and scientists.

M.3 Key Tech

This product gives the users the ability to lower highly sensitive and expensive equipment in a safe vessel down to the ocean-floor safely and in an innovative way that hasn't been used before for borehole exploration. When using the Legacy Borehole system, it is possible to stabilize whichever load is required by the user for an allotted amount of time. While many competitive products such as an elevator or robotic submarine allow for access to the ocean-floor, the Legacy Borehole System allows for access to both ocean-floor research and subseafloor research This project was conceived for the unique purpose of subseafloor exploration.

Another key piece of technology is the fact that the Legacy Borehole System will be created with an array of sophisticated sensors customized to the customer.

M.4 Potential Markets

We will actively seek out organizations (NOAA and MSTF) and universities that are actively researching the ocean-floor (The University of Southern California, University of Denmark, and University of Tennessee Knoxville). The Legacy Borehole project offers a powerful tool to complement the standard suite of used for scientific exploration. The Legacy Borehole System can be fashioned to work with both ocean-floor research and subseafloor research depending upon which is needed by the customer.

M.5 Competition

As of now there are no systems such as ours available. There exist systems known as "elevators" that are used to lower sensors and instruments for deep sea data collection and sampling, however, they lack the stabilization mechanism, astute assembly process, and quality that the Legacy Borehole system can provide.

Fig. 32: Elevator system used by MBARI.

Another potential competitor in this market is the small-scale robotic that is able to collect samples from of the ocean-floor. These machines are immensely more expensive to use and rent compared to our anticipated pricing of the Legacy Borehole System.

M.6 Sales/Marketing

Team of Salesmen: First we will acquire a list of universities and organizations (preferably governmentally owned) that are involved in ocean research. Cold calls will be made to universities and organizations around the world that are interested in research of the sea-floor. Narrowing the list down to which organizations & universities lack engineering departments would be productive, to a team of well-trained salesmen to reach out to the potential customers . If the potential customers decide to purchase a system, buy then the structure will be shipped in a 20'x8'x8.5' sea-container that will allow for easy storage. Shipping for the container to and from headquarters will be included in the cost.

When advertising for the Legacy Borehole System, a brochure with the details of the project will be sent to each of the potential customers that have shown interest in the use of our product and will continue to stay on our mailing list for up to 5 years.

M.7 Manufacturing

This system will be outsourced to a steel fabrication company for the specific use of creating the derrick structure and sensor package housing alone. Preferably this relationship will be with a local company, near to company headquarters (eg. PDM, SOS). If new sensors need to be acquired, then the project will be customized.

The time for fabrication and full assembly will take about a month. With this plan it will take about 3 weeks for the fabrication company to create the derrick structure and the housing for the sensor package while it will take 2-3 weeks to order the sensors, cables, and additional materials needed for the system. The fabrication and ordering of the sensors can be accomplished at the same time, leaving the last week of the month to fully assemble the system and test it in order to insure quality of use for the customer. On hand we must be able to provide at least 3 full systems at all times to customers whenever needed due to potential use of warranty. This will create a need for at least 3 sea-containers

M.8 Budget/Cost

As shown above in the proposed budget for creating one Legacy Borehole System, the approximate cost of creating one fully functioning system with fabrication or manufacturing is approximately $614,000. This allows for a slight bit of overhead with the approximation of the costs being rough. There are numerous factors that must be considered when addressing the overall cost of the business annually including, office space, storage, outsourcing fabrication, hourly wage, etc. When considering these costs and how much the company would initially need in order to start off successfully, we would need a very sizeable investment to get our company on its feet. The cost of renting or leasing an office in the silicon valley with enough storage room would be approximately $7,900 for one suite per month. This data was aquired from an online source: http://www.loopnet.com/Listing/18636239/530-Lakeside-Drive-1230-Midas-Way-Sunnyvale-CA/.

Once the office has been taken care of, a team of 5-10 employees must be acquired in order to be able to have a fully functioning company. These employees will have a wide range of professions including HR, technical salesmen, manufacturing engineers, and consulting positions (scientific). With this combination of professionals, the annual budget for salary for the entire company will range between $400,000 & $500,000 annually. Office equipment for the respective employees will also need to be considered including utilities, furnishings, office tech., and supplies which will approximate $50,000 for the first year. In order to account for missteps and potential mistakes, a cushion of $100,000 should be secured.

M.9 Service/ Warranties

The Legacy Borehole System is expected to last for at least 10 years before needing to be updated structurally. The sensors may need to be replaced periodically in order upgrade the productivity of the scientific equipment.

If damage does occur to the Legacy Borehole System during the time of the lease, a team will be dispatched to the launching location of the system and where it was shipped to. This is the most efficient way that the warranty can be given due to the fact that this system will be out at sea for weeks, even months at a time. The team will assess the damage that has incurred to the structure and whether or not it can be salvageable. If it is salvageable the team will do their absolute best to fix the problem. If it is not salvageable then the system must be sent back to headquarters where it will be taken apart and a new system will be sent out to the customer at the earliest possible time.

Depending upon the damage that is done to the system the cost could be allocated to the customer if misused or assembled incorrectly outside of the given assembly plan. If the damage is due to a manufacturing error, this will be assessed and potentially charged towards our company or towards the fabricator of the damaged piece.

M.10 Financial Plan

The initial funding required would cover payroll of employees for a year, office space rental and furnishing for a year, and construction of one system. This initial funding would be approximately $1,508,800. Expected investors would be organizations like MSTF or venture capitalists that we would actively seek out as a company in order to acquire the amount of funding plus some overhead. The system will be rented for three month periods for $450,000. After the first year, the number of employees will be reduced to less than five. This would reduce annual payroll to approximately $250,000. By reducing staff in the second year, a smaller office space can be rented. Monthly rent is expected to be $4,000 at this new location. Once this plan has been implemented the revenue of the company will be expected to increase and the numbers will be in the black .

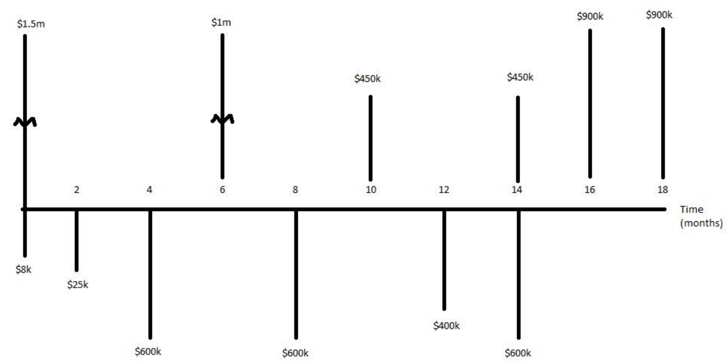
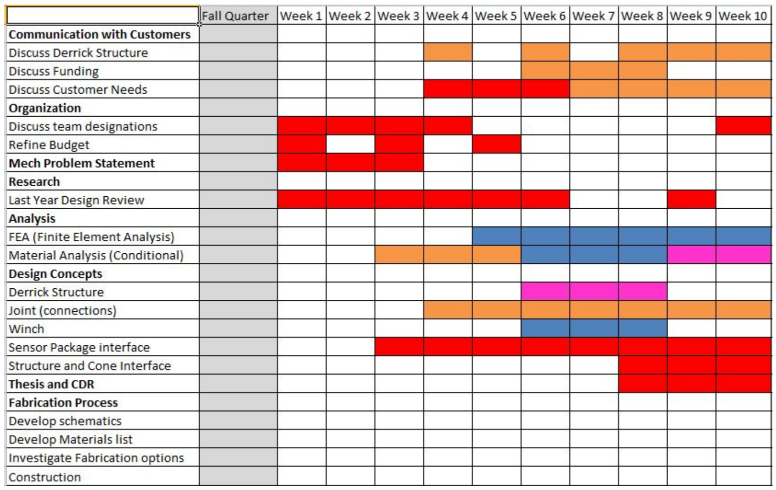


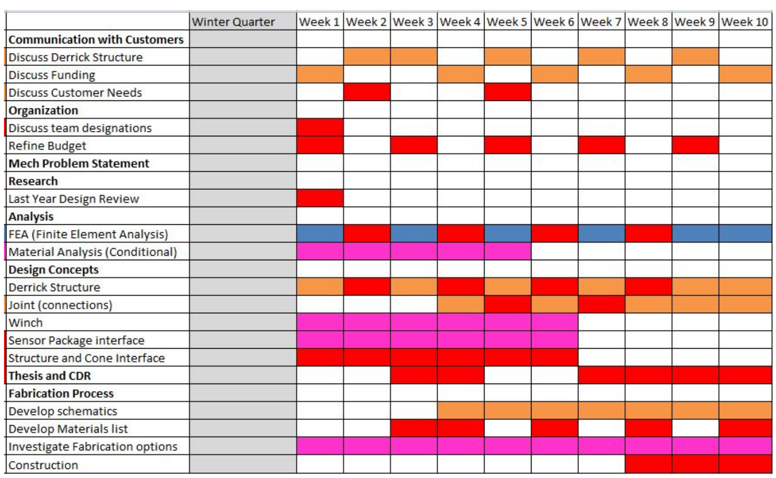
Fig. 33: Cash flow diagram for the first 18 months of business for our company showing a profit by the 18th month, assuming sales.

Assuming that the sales for the product go as planned, there will be a definite profit increase based off of the projections shown above. However, if sales do take longer than expected then the time period for the profit margin to increase will increase as well creating a longer time for the investors to see an ROI. If sales also take longer than expected, then new employees will be added in the sales department allowing for fresh new minds to seek out potential new customers.

N Timeline



Tab. 8: Fall Gantt chart for Legacy Borehole Project



Tab. 9: Winter Gantt chart for Legacy Borehole Project

Spring Quarter	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Man Hours
Assignments											
Resume + Review of Community Service		Due									2
Experimental Protocol			Due								5
PDS Update			Due								3
Societal/Environmental Impact Presentation					Due						3
Final Draft								Due			12
Final Thesis											40
Communication with Customers											
Refine Budget											4
FEA (Finite Element Analysis)											12
Structural Analysis (Conditional)											5
Fabrication Process (Depending on Budget)											
Develop schematics											20
Testing											15
Aquire Parts											5
Fabricate											48
Contact Fabricator											2
Construction (Depending on Budget)											2
Total Man Hours											**178**

Tab. 10: Spring Gantt chart for Legacy Borehole Project

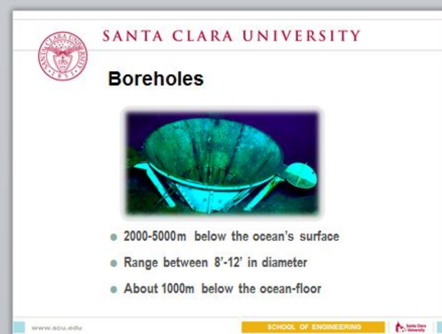
O Ethics Code of Conduct

"The goal of Santa Clara University is to provide students with a general education so that they will acquire knowledge, skill, and wisdom to deal with and contribute to contemporary society in constructive ways. As an institution of higher education rooted in the Jesuit tradition, the University is committed to creating and sustaining an environment that facilitates not only academic development but also the personal and spiritual development of its members. This commitment of the University encourages the greatest possible degree of freedom for individual choice and expression, with the expectation that individual members of the community will:

- Be honest.
- Demonstrate self-respect.
- Demonstrate respect for others.
- Demonstrate respect for the law and University policies, procedures, and standards; their administration; and the process for changing those laws, policies, procedures, and standards."

http://www.scu.edu/academics/bulletins/engineering/conduct.cfm

P Senior Design Conference Slides



SANTA CLARA UNIVERSITY

Mission Statement

Design and build a steel structure, for a sensor package that will operate together as a tool for open ocean research, enabling scientists to collect data from boreholes on the sea-floor.

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7

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Customer Needs

- Assemble on its side on the deck of a ship
- Support weight of sensor package
- An equivalent weight of approximately 50 lbs (when submerged at the bottom)
- Components fit in sea-container (20'x8'x8.5')
- Capable of multiple deployments

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Year 2 Goals

- Design a derrick structure approved by client
- Build derrick structure
- Begin testing on derrick structure
- Acquire specs for a winch & cable

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9

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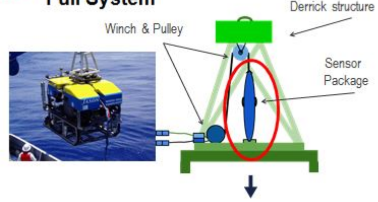
Full System



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10

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Budget

- Total Income: $0
- Expenses:
  - Materials...$254
    - 2" X 2" X ¼" A36 Angle-20' ($60.00)
    - 2" X 2" X ¼" A36 Tee-20' ($96.00)
    - 16" X 48" X ¼" A36 Plate ($98.00)
  - Fabrication..$1400
- Total Cost:..$1,624

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Year 2 Accomplishments

- Designed derrick structure
- Developed assembly and disassembly process
- Acquired winch and cable details
- Identified local manufacturers & fabricators

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Subsystems
Sensor Package
Derrick Structure
Winch & Cable
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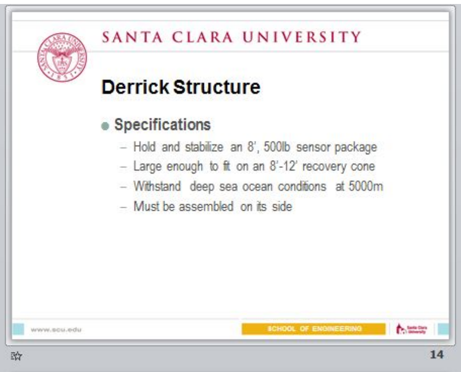
13


SANTA CLARA UNIVERSITY
Derrick Structure
Specifications
– Hold and stabilize an 8', 500lb sensor package
– Large enough to fit on an 8'-12' recovery cone
– Withstand deep sea ocean conditions at 5000m
– Must be assembled on its side
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Design Evolution
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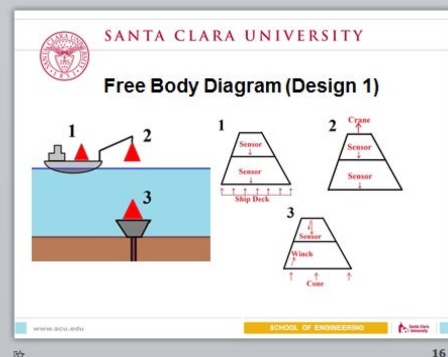
15


SANTA CLARA UNIVERSITY
Free Body Diagram (Design 1)
1
2
3
Sensor
Ship Deck
Crane
Winch
Cone
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FEA (Base Corner Joint)
ANSYS
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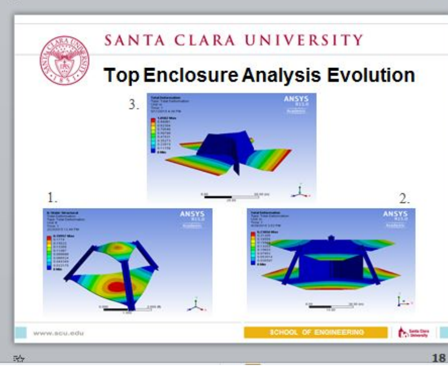
SANTA CLARA UNIVERSITY
Top Enclosure Analysis Evolution
3.
1.
2.
ANSYS
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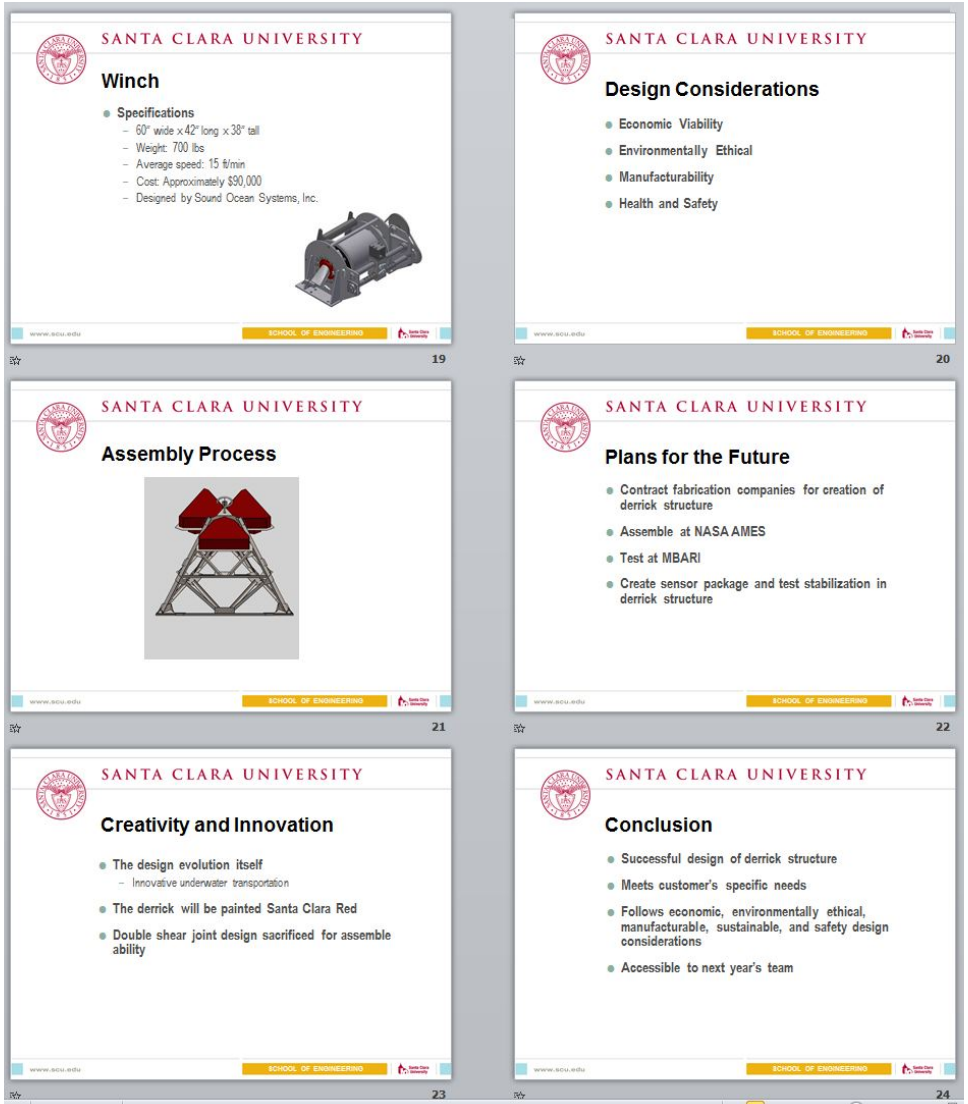
SANTA CLARA UNIVERSITY
Winch
Specifications
60" wide x 42" long x 38" tall
Weight: 700 lbs
Average speed: 15 ft/min
Cost: Approximately $90,000
Designed by Sound Ocean Systems, Inc.
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Design Considerations
Economic Viability
Environmentally Ethical
Manufacturability
Health and Safety
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Assembly Process
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21
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Plans for the Future
Contract fabrication companies for creation of derrick structure
Assemble at NASA AMES
Test at MBARI
Create sensor package and test stabilization in derrick structure
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22
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Creativity and Innovation
The design evolution itself
Innovative underwater transportation
The derrick will be painted Santa Clara Red
Double shear joint design sacrificed for assemble ability
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23
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Conclusion
Successful design of derrick structure
Meets customer's specific needs
Follows economic, environmentally ethical, manufacturable, sustainable, and safety design considerations
Accessible to next year's team
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24

Q Senior Design Conference Evaluation Forms

Santa Clara University
School of Engineering

SANTA CLARA UNIVERSITY
SCHOOL OF ENGINEERING SENIOR DESIGN CONFERENCE
MAY 14, 2015

PROJECT EVALUATION FORM

Session: ***Mechanical Engineering 1***
Room #: ***Benson Center, Parlor B***

Judge's Name: John Quilici

Project Title: **Legacy Borehole Project**
Group Members: Piper Connelly, Rhys Marks, Ronald Saavedra
Advisors: Timothy Hight, Christopher Kitts

Please evaluate senior engineering design projects and presentations using the following point system:

5 = Excellent (at the level of an entry-level engineer you would hire)
4 = Good (at the level of an accomplished college senior)
3 = Average (at the level typical of a college senior)
2 = Below Average (not up to the expectations for a college senior)
1 = Poor (significant errors or omissions)
N/A if no appropriate score applies

DESIGN PROJECT

A. Technical Accuracy	4	E. Addresses Project Complexity Appropriately	4
B. Creativity and Innovation	5	F. Expectation of Completion (by term's end)	3
C. Supporting Analytical Work	4	G. Design & Analysis of tests	3
D. Methodical Design Process Demonstrated	4	H. Quality of Response during Q&A	4

PRESENTATION

A. Organization	4	C. Visual Aids	4
B. Use of Allotted Time	5	D. Confidence and Poise	4

GRAND TOTAL (Sum of Design Project and Presentation Totals): 48

A lot of arm walling; more factual data would have helped.

Please circle each of the following considerations that were addressed by the presentation:

economic, environmental, sustainability, manufacturability, ethical, health and safety, social, political

Comments (Optional): Would have helped to include a table with design requirements in one column and Capability in second Column for example

Parameter	Requirement	Capability
Max Tensile Strength	X	Y
Life Span	X	Y
etc.		

Santa Clara University
School of Engineering

SANTA CLARA UNIVERSITY
SCHOOL OF ENGINEERING SENIOR DESIGN CONFERENCE
MAY 14, 2015

PROJECT EVALUATION FORM

Session: ***Mechanical Engineering 1***
Room #: ***Benson Center, Parlor B***
Judge's Name: Sergei Pushnof

Project Title: **Legacy Borehole Project**
Group Members: Piper Connelly, Rhys Marks, Ronald Saavedra
Advisors: Timothy Hight, Christopher Kitts

Please evaluate senior engineering design projects and presentations using the following point system:

5 = Excellent (at the level of an entry-level engineer you would hire)
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3 = Average (at the level typical of a college senior)
2 = Below Average (not up to the expectations for a college senior)
1 = Poor (significant errors or omissions)
N/A if no appropriate score applies

DESIGN PROJECT

A. Technical Accuracy	5	E. Addresses Project Complexity Appropriately	5
B. Creativity and Innovation	4	F. Expectation of Completion (by term's end)	4
C. Supporting Analytical Work	4	G. Design & Analysis of tests	5
D. Methodical Design Process Demonstrated	4	H. Quality of Response during Q&A	5

PRESENTATION

A. Organization	5	C. Visual Aids	5
B. Use of Allotted Time	5	D. Confidence and Poise	3

GRAND TOTAL (Sum of Design Project and Presentation Totals): 54

Please circle each of the following considerations that were addressed by the presentation:

economic environmental sustainability manufacturability

ethical health and safety social political

Comments (Optional): Very interesting field.
I have not seen finding of corrosion
& How it will work in arctic?
I will it work there?
Marketing is missing!

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SANTA CLARA UNIVERSITY
SCHOOL OF ENGINEERING SENIOR DESIGN CONFERENCE
MAY 14, 2015

PROJECT EVALUATION FORM

Session: ***Mechanical Engineering 1***
Room #: ***Benson Center, Parlor B***
Judge's Name: Doug Aumack

Project Title: **Legacy Borehole Project**
Group Members: Piper Connelly, Rhys Marks, Ronald Saavedra
Advisors: Timothy Hight, Christopher Kitts

Please evaluate senior engineering design projects and presentations using the following point system:

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4 = Good (at the level of an accomplished college senior)
3 = Average (at the level typical of a college senior)
2 = Below Average (not up to the expectations for a college senior)
1 = Poor (significant errors or omissions)
N/A if no appropriate score applies

DESIGN PROJECT

A. Technical Accuracy	3	E. Addresses Project Complexity Appropriately	4
B. Creativity and Innovation	3	F. Expectation of Completion (by term's end)	3
C. Supporting Analytical Work	4	G. Design & Analysis of tests	3
D. Methodical Design Process Demonstrated	3	H. Quality of Response during Q&A	4

PRESENTATION

A. Organization	4	C. Visual Aids	4
B. Use of Allotted Time	4	D. Confidence and Poise	4

GRAND TOTAL (Sum of Design Project and Presentation Totals): ______

Please circle each of the following considerations that were addressed by the presentation:

economic environmental sustainability manufacturability
ethical health and safety social political

NOTES
~~Comments~~ (Optional): CUSTOMER? CORRECT TO OBJECTIVES, MATERIAL SELECTION + REUSE, SPECIAL TOOLING, OCEANOGRAPHY, SCIENCE ORIENTED

Santa Clara University
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SANTA CLARA UNIVERSITY
SCHOOL OF ENGINEERING SENIOR DESIGN CONFERENCE
MAY 14, 2015

PROJECT EVALUATION FORM

Session: ***Mechanical Engineering 1***
Room #: ***Benson Center, Parlor B*** **Judge's Name:** Chris Cupples

Project Title: **Legacy Borehole Project**
Group Members: Piper Connelly, Rhys Marks, Ronald Saavedra
Advisors: Timothy Hight, Christopher Kitts

Please evaluate senior engineering design projects and presentations using the following point system:

5 = Excellent (at the level of an entry-level engineer you would hire)
4 = Good (at the level of an accomplished college senior)
3 = Average (at the level typical of a college senior)
2 = Below Average (not up to the expectations for a college senior)
1 = Poor (significant errors or omissions)
N/A if no appropriate score applies

DESIGN PROJECT

A. Technical Accuracy	3	E. Addresses Project Complexity Appropriately	3
B. Creativity and Innovation	3	F. Expectation of Completion (by term's end)	2
C. Supporting Analytical Work	2	G. Design & Analysis of tests	N/A
D. Methodical Design Process Demonstrated	2	H. Quality of Response during Q&A	4

PRESENTATION

A. Organization	4	C. Visual Aids	4
B. Use of Allotted Time	4	D. Confidence and Poise	3

GRAND TOTAL (Sum of Design Project and Presentation Totals): 34

Please circle each of the following considerations that were addressed by the presentation:

economic environmental sustainability manufacturability
ethical health and safety social political

Comments (Optional): Could have improved on analysis and requirements that guided / informed design. Great Q&A.