FAMU-FSU College of Engineering

Restated Project Definition, Plan, and Scope

Team #18

SAR Imager

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ABSTRACT

Synthetic Aperture Radar is an advance technique of measuring a high resolution radar signature with a smaller antenna. The purpose of this project is to use SAR technology to create a low-resolution image for homeland security applications. Our product will be able to scan individuals for metal objects in order to designate people who need additional security screening. From contact with our sponsor, Northrop Grumman, our team has developed a concise problem statement: "Design an improved housing structure for the SAR Radar array." This project is a continuation from last year's senior design group. New objectives for this year include lowering the weight, making the structure more stable, fixing the antenna horn mounting and alignment, and reducing cost. At this point in the project, the team is nearing completion of the design phase, and is looking to finalize designs based on sponsor feedback.

1. Introduction

In partnership with the FAMU/FSU College of Engineering and Northrop Grumman, the objective of the Synthetic Aperture Radar (SAR) Imager Project is to develop a low-cost weapon detection system that provides suitable imagery resolution for physical security and military force protection applications.

Current detection technologies commonly employed in the security industry such as metal detectors, Advanced Imaging Technology (AIT) scanners, and x-ray scanners can be expensive, obtrusive, and require the subject to be inside the apparatus. An imager based on SAR technology, composed primarily of commercial-off-the-shelf (COTS) components, can be implemented at a lower cost than many industry-standard scanners; it may be placed behind a barrier, out of view from subjects; and most importantly, it can identify concealed metal objects from a distance.

In environments with multi-layered physical security protocols, the SAR imager's superior range can alert security professionals to potential threats before they reach an access control point, or before they progress further into a secure area, depending in which security layer the SAR is deployed. Some environments may be vulnerable to physical attack, but conventional AIT body scanners are too obtrusive or inefficient. An amusement park, for instance, might have high-level security needs, but their customers would not tolerate stepping into a full-body scanner.

Furthermore, random screening protocols have been widely criticized for being culturally or racially biased in practice. With SAR capability, guests can be discreetly imaged while queuing, and persons of interest can be identified for additional screening based on the presence of metal signatures rather than the caprice of a human screener.

This project is a continuation from last year. The first team to work on the project made major progress in pathfinding for this very unique, challenging project. While the work done by last year's team was an impressive feat for a first generation product, there are many things that can be improved upon this year. Two engineering teams are assigned to this project: one Electrical, and one Mechanical team. While the two groups work in tandem, this report will primarily consider the scope of the mechanical engineering team.

2. Project Definition

Compared to other senior design projects, the SAR Imager is a project with open ended goals. It was difficult to initially get a clear idea of the direction of the project. The open nature is partially because it is difficult to assess what is achievable in nine months' time. Information regarding project definition has been outlined, but it is important to note that the scope can be changed as needed throughout the life of the project.

2.1 Need Statement

This is a second generation project; the sponsor being Northrop Grumman and the Mechanical Engineering team from the previous year has demanded some key changes in the aspects of the previous design. These include, improving the rigidity of the frame, changing the method of aligning the antenna horns, increasing mobility, reducing weight to under 150 lbs., changing the material of the structure, and increasing the pointing accuracy of the laser of the horn antenna. These changes are needed because, the horn alignment caused errors in the collection of data and target sensing. The changes are also needed because the current design was extremely too heavy and difficult to transport.

Need Statement:

"The structure of the current SARS is producing too much of an error and isn't efficient or effective for sensing targets."

2.2 Goal Statement & Objectives

From our sponsor meeting, our team was able to create the following goal statement:

"Design an improved housing structure for the SAR Radar array."

During our meeting, our sponsor stated very clearly what his concerns with last year's prototype and what we could do to make it better. The first requirement was improved stability, the 1st-Gen prototype would wobble upon the application of a small force. Operationally this is not acceptable because the SAR takes radar images of a fixed region in space and a small adjustment would mess up the accuracy of what is being read. Another element to help improve the accuracy is improved horn alignment and mounting. The first generation of the imager had a problem with precisely mounting the horn holder to the frame and in some cases JB Weld was used hastily used. It is important to finely adjust the angle of each antenna and lock it into place since errors of even 1/10" can propagate to major errors in the phase angle of the radar signal.

Reducing the total weight is another major concern for Gen1 was made of solid steel and weigh roughly 300lbs. However, this was to save cost as lightweight Aluminum would have been more expensive. A goal of making it a Mil-Spec standard two person carry weight of 80lbs was given. Lowering the weight would also make the device more portable another of our client desires. However, portability can also include easy of breakdown and assembly which is not a main focus of our 2nd Gen design. Design of the hardware box to protect the circuitry from the elements and Electromagnet Interference was given to the two ME students on the EE team, however, we still need to make a way to attach their box to our structure.

From the design requirements, our team produced and House of Quality (HOQ) matrix as shown in Table 1. We took the design requirements provided by our client and ranked them in terms of importance. By brainstorming, our team created the engineering characteristics of structural thickness, specific material used, horn locking mechanism and adjustment, physical size of the base, height of the structure above ground, number of cross support beams and a Mil-Spec weight standard.

Table 1: House of Quality

Customer Requirements	Customer Importance	Engineering Characteristics								
		Structural Thickness	Material Used	Locking Mechanism	Axis Adjustability	Mounting Mechanism	Base size	Height Above Ground	Number of Crossbeams	Weight
Increased Stability	5	9	3	6		3	9	6	6	
Lower Weight	5	3	9				6	3	6	9
Good Images	5			6	9	9		3		
Better Horn Mounting	5			9	9	9				
Cost	4	3	6	3		3	3		3	
Hardware Box	2	3	6							3
Portability	2		6				9	6		9
Score		18	30	24	18	24	27	18	15	21
Relative Weight		78	108	117	90	117	105	72	72	69
Rank		6	3	1	5	1	4	7	7	9

Based on the HOQ, the most important engineering characteristics are the locking mechanism and mounting mechanism for the horns, followed by the material used in construction of the structure and the base size.

2.3 Constraints

Some engineering constraints have been proposed by Northrop Grumman. These are preliminary goals to aim for, but may need to be revised throughout the project since it is still a young, evolving product.

2.3.1 Stability

A main drawback of the first generation of the design was stability. A slight bump of the structure could cause significant wobbling, affecting the accuracy of the SAR. The stability is required because the radar being sent out and received by the antenna has a wavelength of 1 inch. Any movement of the structure will cause the received phase to be artificially shifted to the left or the right. It was determined that the maximum allowable phase shift is 5 degrees. In terms of horizontal movement, this corresponds to 1/72 of an inch in maximum deformation.

2.3.2 Weight and Mobility

The first generation product weighed over 220 pounds. Although this system is designed to be stationary, it is desirable that it can be both lifted and moved by two people, as well as having wheels so it is easy to move. Per military specifications, two people are generally considered to being able to lift an object of 80 pounds easily, so that will be the goal weight of the project. This weight goal may be revised as the project comes closer to actualization if needed.

2.3.3 Horns

The entire purpose of the structure is to facilitate the collection of data by the antenna horns. This will be the most critical design feature, so it will be given priority in design. The sponsor clearly outlined all requirements of the horn: the horns need to be adjustable through rotation in the left to right direction and through rotation in the up and down direction, all horns must be focused within a 1 feet circle that is 20 feet away, and there must be some method of alignment. Last year, the method of alignment was by using a mounted laser pointer to determine the alignment direction. A similar method will be considered this year.

2.3.4 Cost

Although the budget for the mechanical engineering aspects of the project is $5000, the team's goal will be to find a satisfactory price to performance balance that will be below this amount. The methods to reduce cost will be to use commercial-off-the-shelf (COTS) hardware, and to keep design as simple as possible while still meeting engineering requirements.

3. Design Updates

3.1 Structure, S-1

3.1.1S-1, Version 2

While there were no issues with the stress analysis of the structure, additional components were added for convenience. The main horizontal and vertical bars were increased in thickness to accommodate the new horn holder design. There were additional horizontal bars added in the middle of the structure in order to act as something to grab in order to move the structure. The bottom of the structure was framed as well so that castors can be mounted.

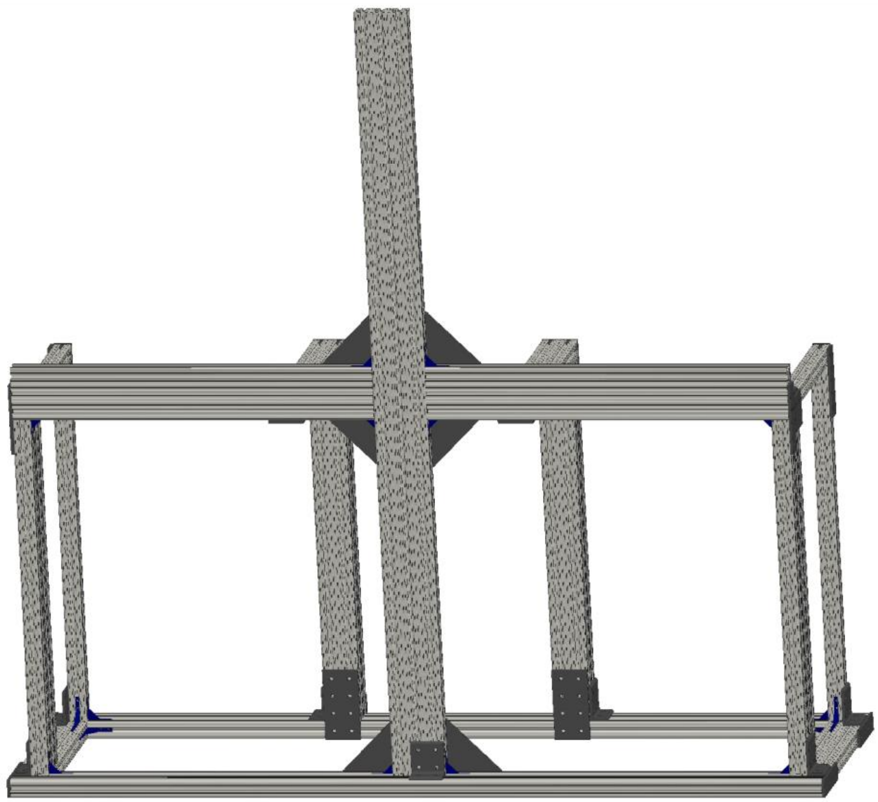


Figure 1: Design S-1 V2

3.1.2 S-1, Version 3

A slight modification was added to Version 2 was to extend the bottom forward bar out from the structure. This addressed a few areas of concern:

- Sponsor requested a laser pointer based testing system that could be mounted to the structure. The bottom platform could be used to mount this to.
- Although tipping would not be a problem when stationary, the extended bar would ensure that if any unexpected forces were applied (i.e., in transit being rolled on wheels), there would be no risk of tipping
- More structure if design were to change

To account for this potential issue, the front of the base was extended 9” forward, while the cross remain in the same position with respect to the rack of the base. This also increase the wheel base depth to 30” which would increase stability of the structure rolling over a tilled floor. A piece of 1545-8020 was added in the middle of the rectangular base to give the bottom of the vertical horn beam support. Due to the restructuring, different attachment plates T-slotted nuts can be used to secure the parts together. This results in a cost difference of $233.17. Going forward, this will be our design choice.

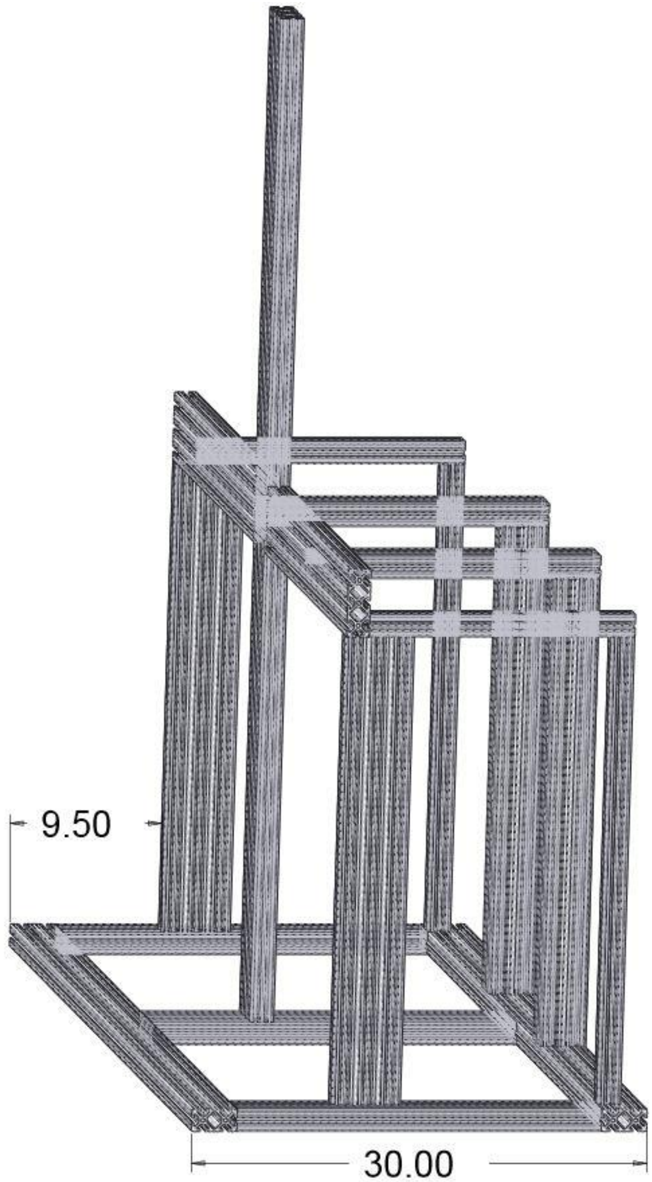


Figure 2: S-1, V3

3.1.3 S-1, Version 4 and 5

After consulting with our sponsor contacts, there have been some changes to the structure design. Notably,

- Switched from 15 series (1.5” cross section) to 10 series (1.0” cross section) 8020 in order to reduce weight
- Removed the horizontal bar that was in front of horns to reduce interference

- Added small diagonal braces on some corners to increase stability

In addition to cutting weight from 170 pounds to around 100 pounds, the structure cost will also be reduced from to $900.

Figure 3: S-1, V5

3.2 Horn Holders

3.2.1 H-1, Version 2

Design H-1 has been modified slightly to be fully compatible with the updated structure iteration. The two ‘L’ brackets have been replaced by one solid bracket to provide more assurance to the holder's strength. To secure the azimuth and elevation positions, four combinations of a wing bolt, star washer, and lock washer will be used. Recently, the ideal distances between the horns for optimal performance were received from the electrical team. To satisfy those distances, the width of the outer bracket piece was reduced so that there will not be any clearance issues. The shortest distance between horns will be between the transmitter and adjacent receiving horns. To be sure that there will be no clearance issues between these horns, smaller thumb bolts will be used instead of the wing bolts.

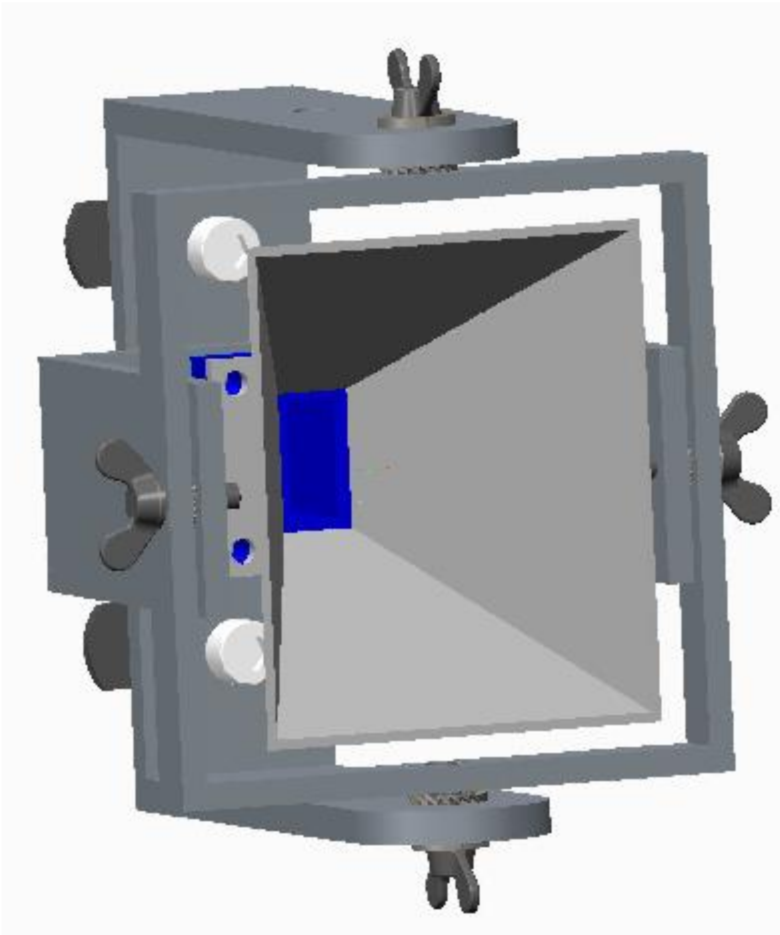


Figure 4: Design H-1, V2

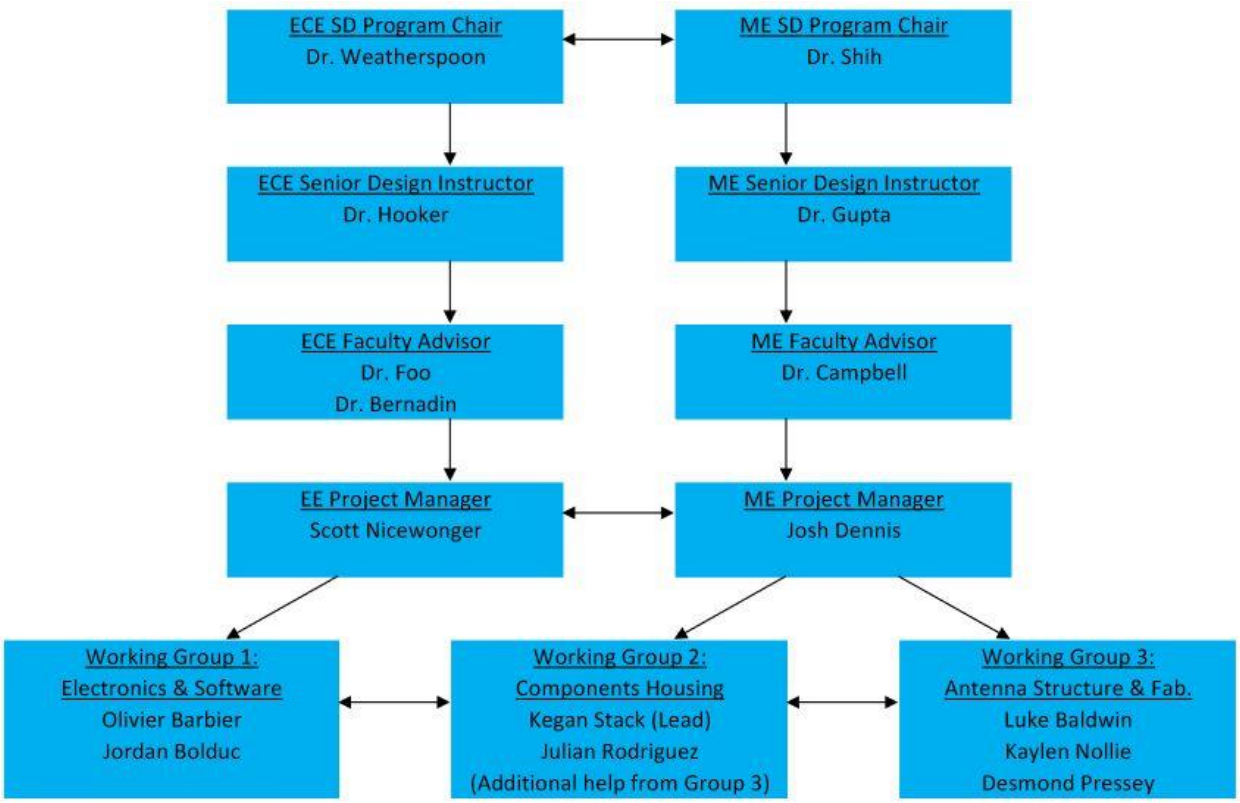
4. Methodology

In order to ensure all parties are up to date and involved in the project process, we will have weekly team meetings, weekly sponsor meetings, and bi-weekly meetings with faculty. The project manager has been tasked with keeping documentation on the process so it can be referred to by the team later in the process, or by another interested party. To apply structure to the project, the following methods have been employed.

4.1 Organization

In an effort to break down the project into more manageable parts, it has been partitioned in the following sections:

Table 2: Organizational Chart



4.2 Schedule

The main considerations when planning the schedule are

1. Anything that can go wrong, will go wrong,
2. There will be lag time between purchasing materials from vendors and receiving them, and
3. The EE Team will need to use the structure to perform testing on.

Because of these reasons, the deadline for having the structure assembled is about a month earlier than the end of the allotted time. This will give the group some flexibility if new circumstances arise that call for extra time.

Table 3: Schedule for Spring 2016

Procurement	**6 days**	**Mon 1/11/16**	**Mon 1/18/16**
Prepare Drawings for Manufacturing	2 days	Mon 1/11/16	Tue 1/12/16
Bill of Materials	2 days	Wed 1/13/16	Thu 1/14/16
Submit for Quotation	1 day	Fri 1/15/16	Fri 1/15/16
Submit Purchase Order	1 day	Sun 1/17/16	Sun 1/17/16
Fabrication	**31 days**	**Fri 1/22/16**	**Fri 3/4/16**
Prepare Schematics	5 days	Fri 1/22/16	Thu 1/28/16
Prepare Drawings for machining	5 days	Fri 1/22/16	Thu 1/28/16
Fabricate 2 horn holders for testing	7 days	Mon 2/1/16	Tue 2/9/16
Submit remaining HH for fabrication	2 days	Mon 2/8/16	Tue 2/9/16
Submit 8020 Parts to COE Shop	2 days	Mon 2/8/16	Tue 2/9/16
Begin Assembly of Structure	11 days	Thu 2/11/16	Thu 2/25/16
Attach Horn Holders to Structure	8 days	Sun 2/14/16	Tue 2/23/16
Complete Assembly, Propose Plans for Im	7 days	Mon 2/22/16	Tue 3/1/16
Implement any improvements	5 days	Mon 2/29/16	Fri 3/4/16
Deliverables	**67 days**	**Thu 1/14/16**	**Fri 4/15/16**
Restated Project Definition and Scope/Pla	5 days	Mon 1/11/16	Fri 1/15/16
Presentation I	3 days	Fri 1/15/16	Tue 1/19/16
Team Evaluation Report I	4 days	Tue 1/19/16	Fri 1/22/16
Web Page Update	11 days	Fri 1/22/16	Fri 2/5/16
Midterm Presentation I	10 days	Fri 2/5/16	Thu 2/18/16
Team Evaluation Report II	2 days	Wed 2/17/16	Thu 2/18/16
Midterm Presentation II	20 days	Fri 2/19/16	Thu 3/17/16
Team Evaluaion Report III	3 days	Wed 3/16/16	Fri 3/18/16
Operational Manual, Design Report	11 days	Fri 3/18/16	Fri 4/1/16
Walk Through Presentation	5 days	Fri 4/1/16	Thu 4/7/16
Final Report	6 days	Fri 4/1/16	Fri 4/8/16
Final Web Page	6 days	Fri 4/1/16	Fri 4/8/16
Final Presentation	5 days	Fri 4/8/16	Thu 4/14/16
Team Evaluation Report IV	6 days	Fri 4/8/16	Fri 4/15/16

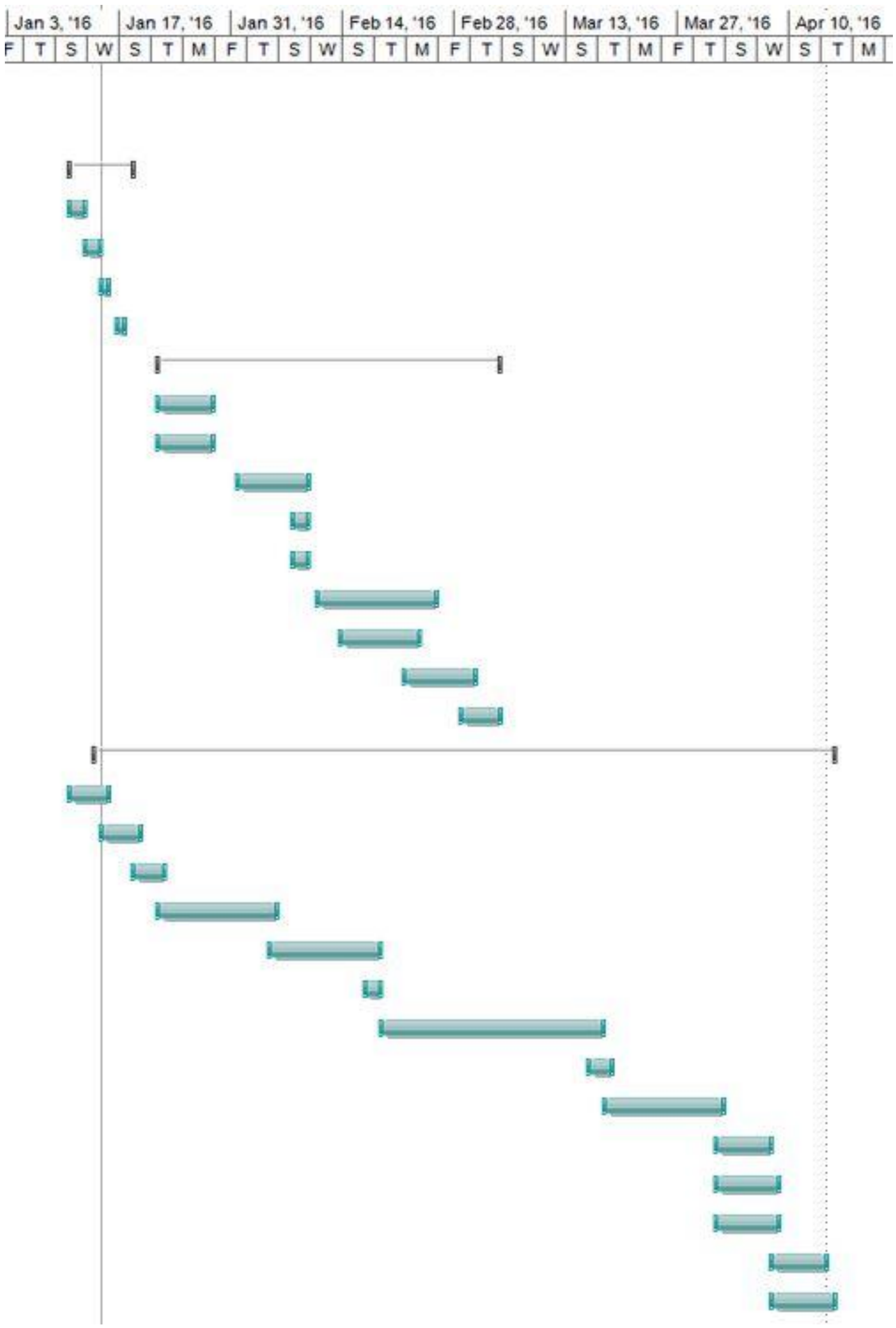


Figure 5: Gantt Chart for Spring 2016

4.3 Resource Allocation

In order to have a successful project, roles must be assigned and clearly defined for each member. While the group will strive to work cooperatively on all parts of the project, a member has been assigned leadership of specific aspects of each part of the project:

A. Josh Dennis - Team Leader

He is the person responsible for setting all meetings with sponsors, advisors, teachers, and ensures that the group is completing the project based off of what the sponsors are requesting and in an efficient manner. He also keeps track of all documents and ensures that each group member is doing their fair share.

B. Luke Baldwin – Structure Design

It is his responsibility to modify the existing structure by redesigning based off of the needs of sponsors, errors from the previous group, and constraints that are set.

C. Kaylen Nollie - Horn Holder Design

Kaylen has been placed in charge of designing a method to hold the antenna assemblies in a manner that meets all requirements of the operation of the SAR.

D. Desmond Pressey - Web Design, Budget

Has the duty of creating, editing, and translating all relevant information to the web page. Additionally, all purchasing will be handled by Desmond, including obtaining quotes from vendors and submitting purchase orders.

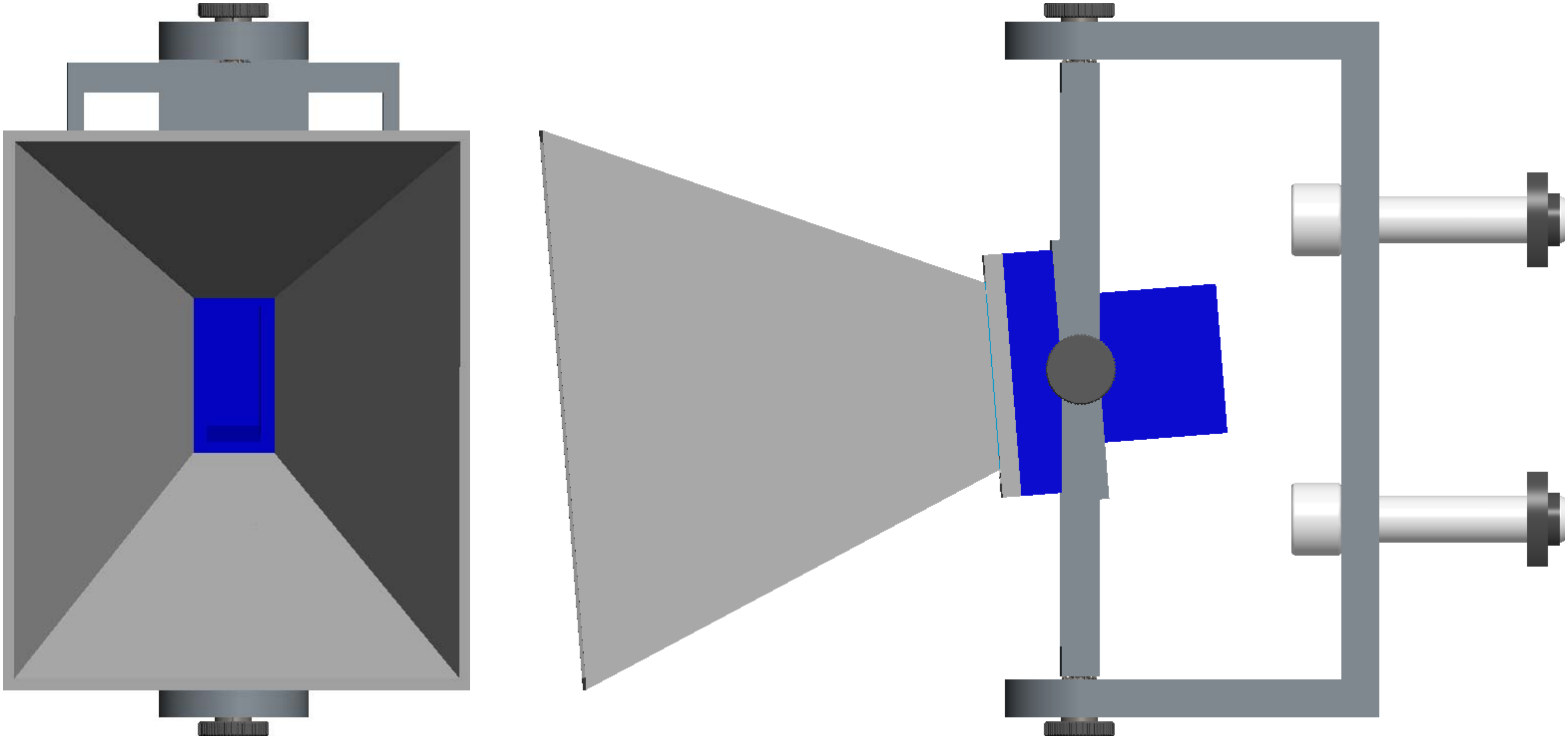
4.4 Procurement

In order to procure the 8020 for our structure, our team is debating two options. Option 1 will involve getting 8020inc. to cut and assemble the structure themselves. They will then ship the assemble product to us. This is a plus since they would already be experienced in fabricating 8020 products and has specialized equipment. We will also avoid the machine shop rush due to other groups manufacturing their pieces. However, this could potentially add more cost to the design which is capped at $2000. The other option is that we contact the local distributor of 8020 and buy set lengths of material which we would machine ourselves. The majority of the horn holder pieces will be bought through McMaster-Carr and be machined in house.

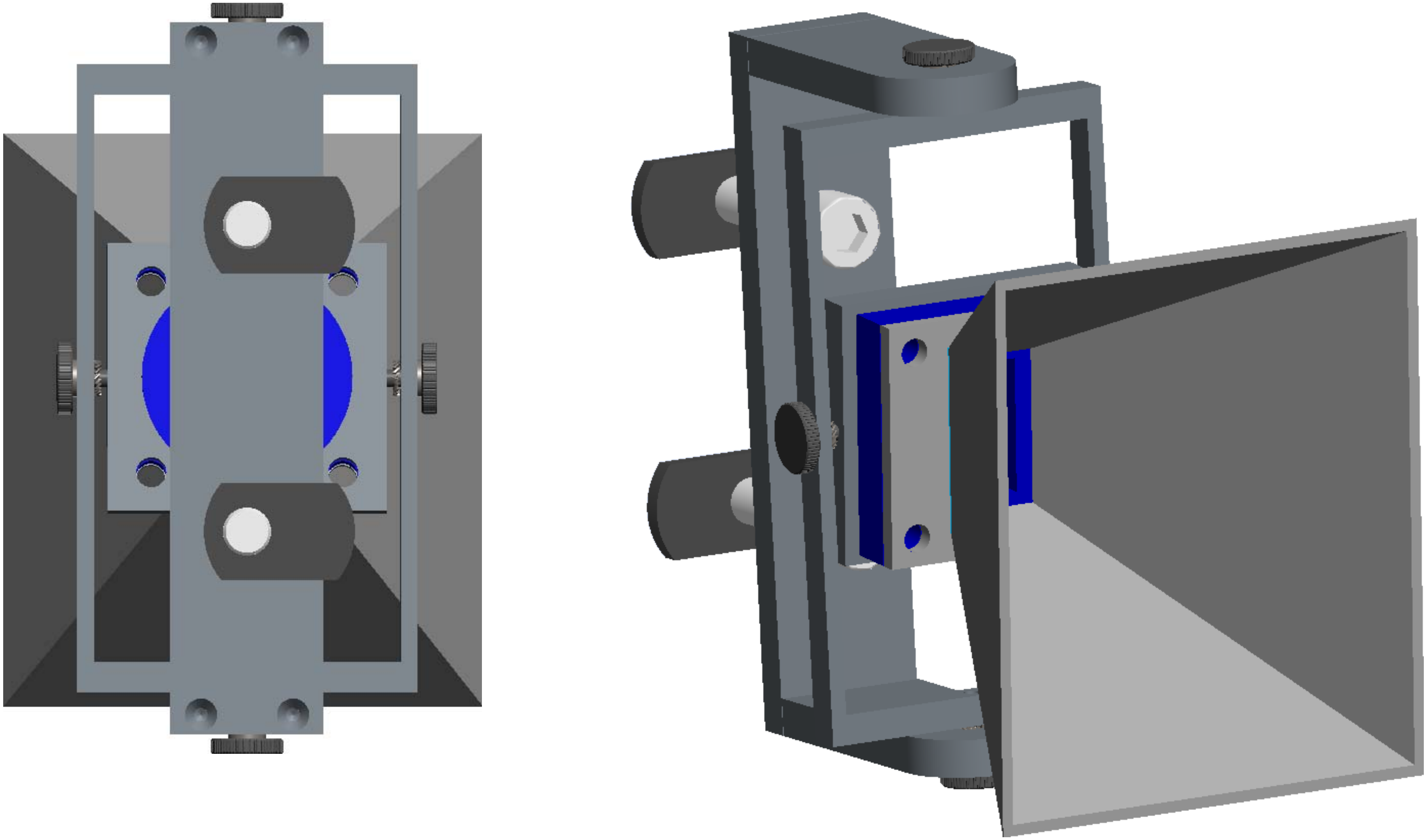
There will be one prototype of the most recent horn holder design produced. This will allow the design to be analyzed on “real world” terms. If there are any unforeseen issues with the design, they can be addressed before an order for 20 of the design is placed. The fabrication will be done by the college’s machine shop, so the only cost will be in material.

Appendix

Attached are the manufacturing drawings for the latest horn holder design.



DIMENSIONS IN INCHES	PART NAME: Front & Side View		PROJECT NAME: Horn Holder	
TOLERANCES: X.X± 0.1 X.XX± 0.01 X.XXX± 0.003 ANGLES± 0.5°	DRAWN BY: SD Team 18		DATE: 1/15/16	MATERIAL: Various
	SCALE: 1.000	REV: 0	SHEET #: 1 OF 1	PART #: P1



DIMENSIONS IN INCHES	PART NAME: Back & Angled View		PROJECT NAME: Horn Holder	
TOLERANCES: X.X± 0.1 X.XX± 0.01 X.XXX± 0.003 ANGLES± 0.5°	DRAWN BY: SD Team 18		DATE: 1/15/16	MATERIAL: Various
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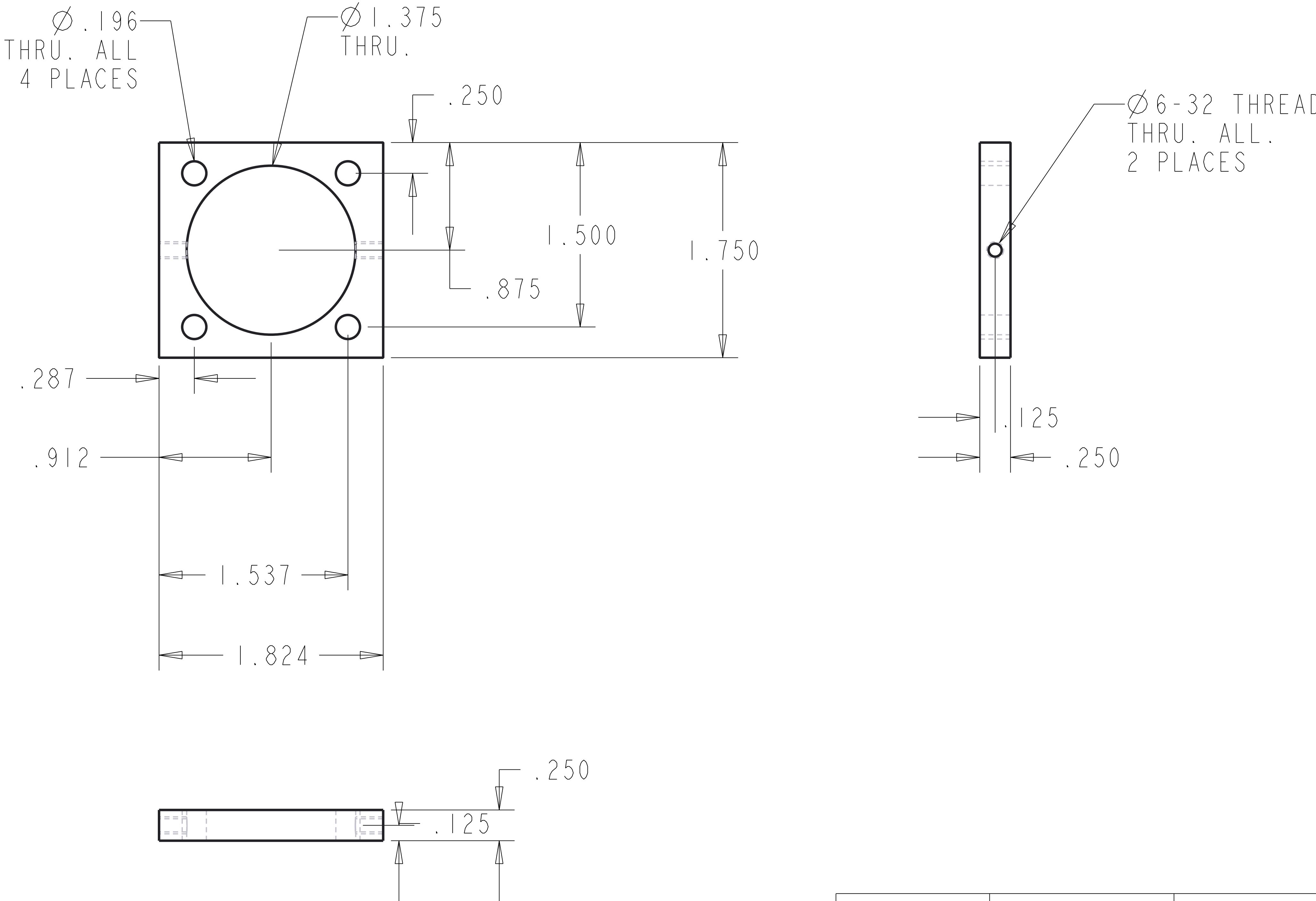

DIMENSIONS IN MILLIMETERS	PART NAME: Flange		PROJECT NAME: Horn Holder
TOLERANCES: X.X± 0.1 X.XX± 0.01 X.XXX± 0.003 ANGLES± 0.5°	DRAWN BY: SD Team 18	DATE: 1/10/16	MATERIAL: Aluminum
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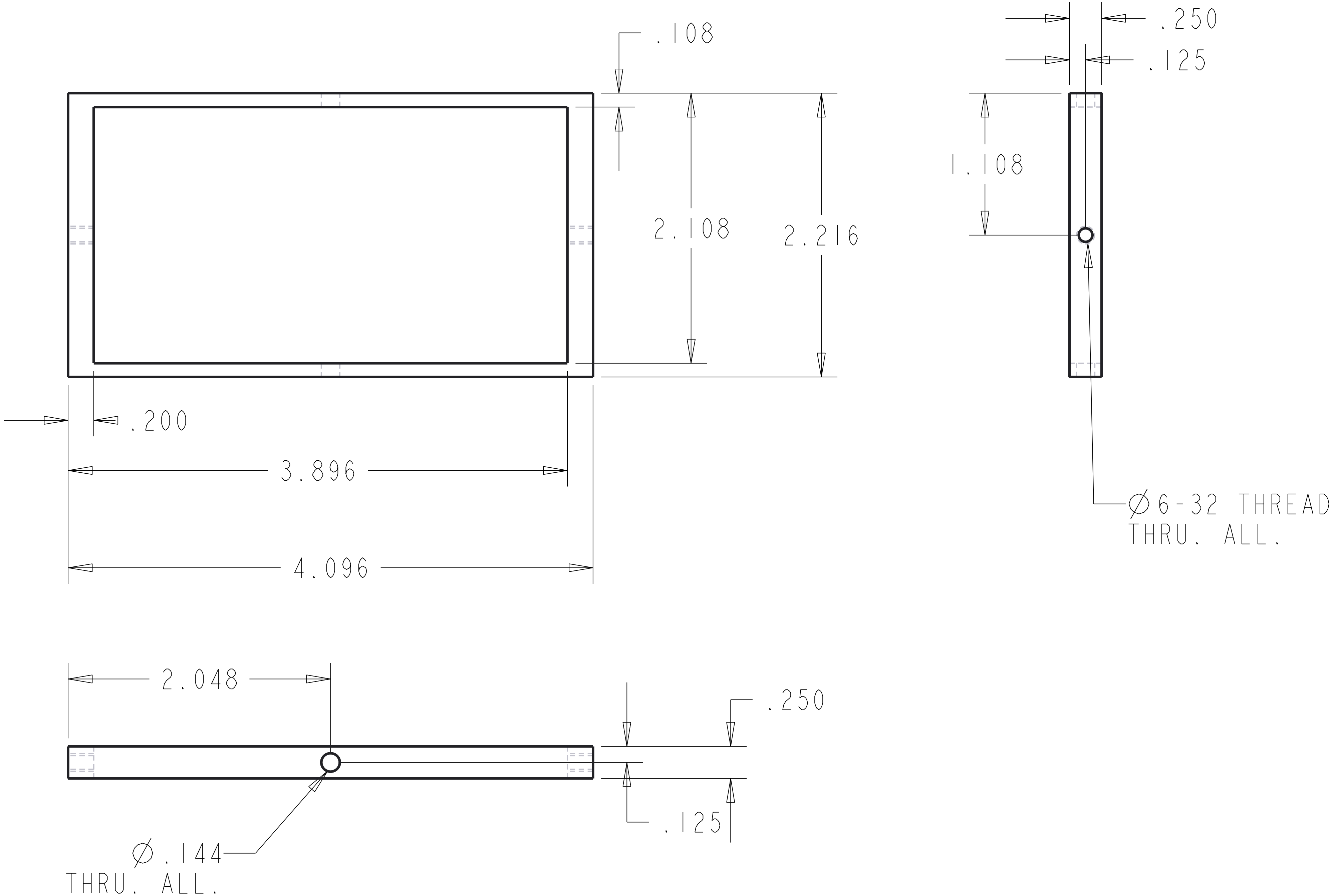

DIMENSIONS IN INCHES	PART NAME: Outer Bracket			PROJECT NAME: Horn Holder	
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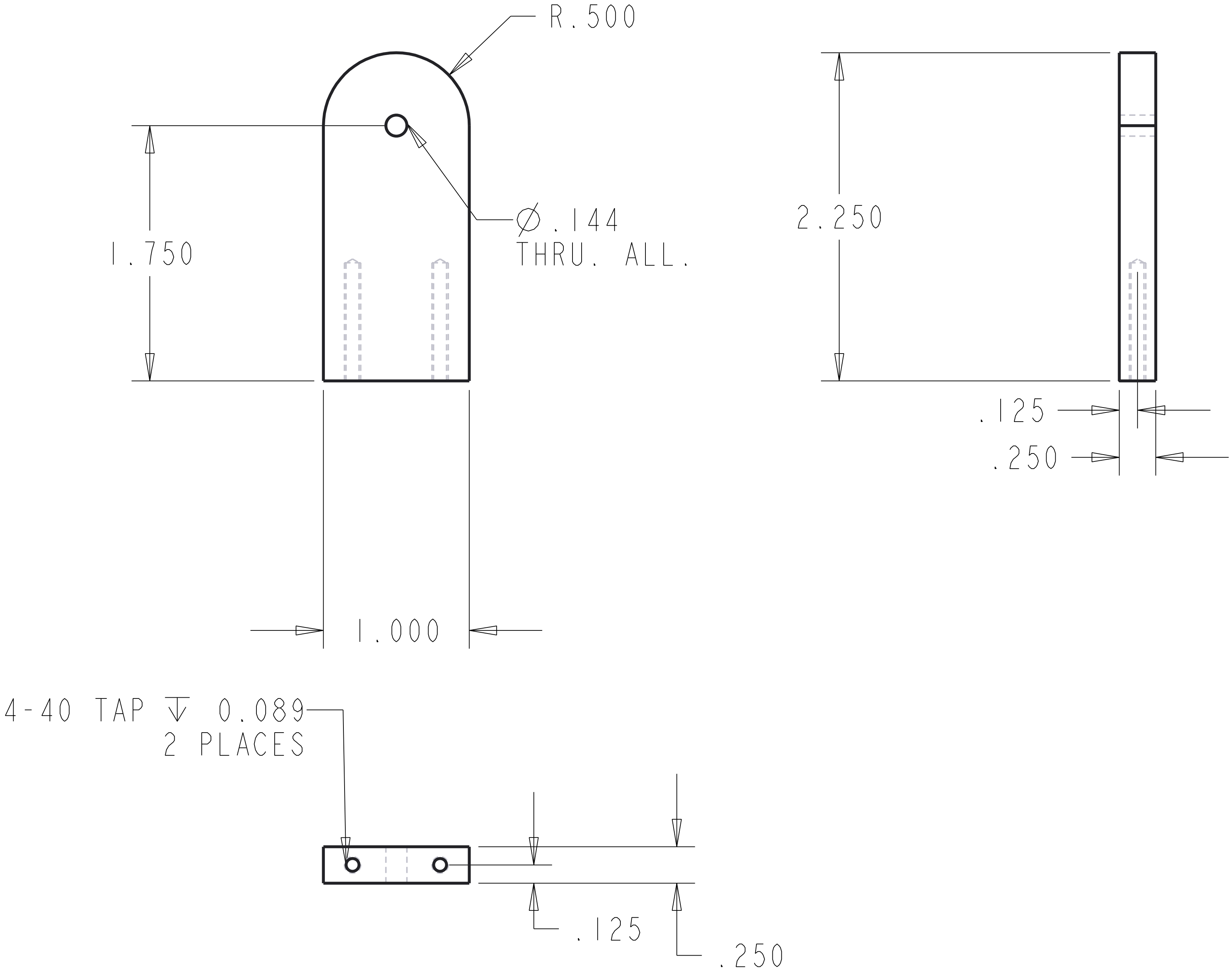

DIMENSIONS IN INCHES	PART NAME: Brace		PROJECT NAME: Horn Holder	
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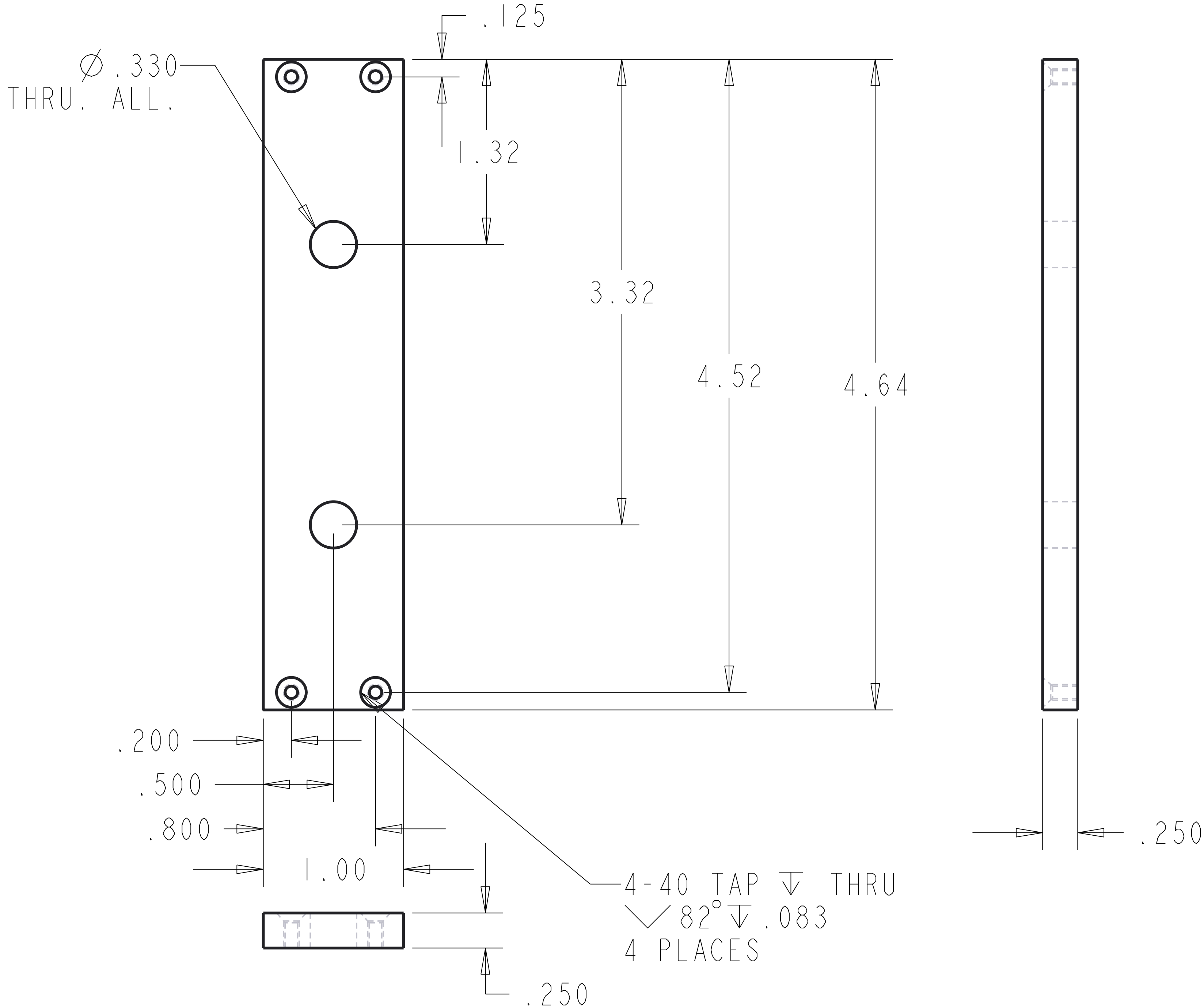

DIMENSIONS IN INCHES	PART NAME: Brace Back		PROJECT NAME: Horn Holder	
TOLERANCES: X.X± 0.1 X.XX± 0.01 X.XXX± 0.003 ANGLES± 0.5°	DRAWN BY: SD Team 18	DATE: 1/14/16	MATERIAL: Aluminum	
	SCALE: 1.000	REV: 0	SHEET #: 1 OF 1	PART #: P1