FAMU-FSU College of Engineering

SAR Imager Redesign

Deliverable #3: Project Plans and Product Specs

Submitted to:
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EML 4551C

Date:
October 9, 2015

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1. Introduction

The sponsor company, Northrop Grumman, is a “leading global security company providing innovative systems, products and solutions in unmanned systems, cyber, C4ISR, and logistics modernization to government and commercial customers worldwide.” [1] The project group has been posed with a problem of developing a system to detect weapons on people who may be a threat. Many systems exist today that meet that goal, but Northrop Grumman wants to create a concealable, low-cost system with low resolution so it does not reveal too intimate of detail.

This project has been continued from last year, with this year bringing challenges of improving the existing design. While last year’s prototype succeeded in providing basic functionality, being a first generation design there is still much to be improved upon. On the Mechanical Engineering side, this includes weight reduction, lowering cost, improving the hardware box design, and a more effective method of mounting the antenna horns.

2. Project Definition

2.1 Background Research

A Synthetic Aperture Radar System (SARS) is a radar system that generates a high resolution remote sensor imagery using multiple antennas and each antenna stores its' data electronically. [2] A SARS normally is used by the military in aircrafts and are used to find targets such as ships by taking Doppler's Effect into account and having the antennas in time multiplex over a certain length. [3] This means that the systems are usually used from the sky, looking downward toward the earth. Signal processing uses magnitude and phases of the received signals over successive pulses from elements of synthetic aperture and it then creates an image.

SARS is used for military use primarily but there are also some non-military uses as well. The "Blackbird's Eye" is where an aircraft pilot uses SARS to establish a location of an object. SARS is used for the 24/7 missions in hostile territories for reconnaissance and counter terrorism, this is specifically called the TRACER and are for unmanned and manned. This system can operate in any type of weather, day or night, wide area-surveillance capabilities, and has a long endurance. For non-military uses SARS is also used for GEO mapping, which is a mapping system to map areas all over the world. These three applications of the Synthetic Aperture Radar System were all created by Lockheed Martin and all are mobile. [4]

Our objective is to make a SARS imager with a purpose of creating a strong security system to protect against threats in public places such as movie theaters and stadiums. [5] People are able to conceal weapons such as handguns or even bombs in public areas without anyone having any knowledge that someone has a weapon and could be a potential perpetrator of mass murder or anything with malicious intent. The difference between a tradition SARS imager is that this device will be on the ground with a target that is horizontal and also that the device will have multiple stationary antennas that is sending data to be stored electronically by taking images of a target that is moving, specifically a human being. Instead of using it in the air, this will be used on the ground and taking images horizontally. The imager should be fully functional, uses materials that are commercially used and low in cost, and also creates a low but useful resolution of an image that can detect concealed weapons.

2.2 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.”

2.3 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 years 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 Electromagnetic 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 Figure 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.

Customer Requiernments	Customer Importance	Engineering Charateristics: Structural Thickness	Material Used	Locking Mechanism	Horn Adjustability	Base size	Height Above Ground	Number of Crossbeams	Mil-Spec Weight
Increased Stability	5	9	3			9	3	6	
Lower Weight	5	3	9			6	3	6	9
Better Horn Mounting	5			9	9				
Cost	4	3	6			3		3	
Hardware Box	2	3							
Portability	2		6			9	6		9
Score		18	24	9	9	27	12	15	18
Relative Weight		78	96	45	45	105	42	72	63
Rank		3	2	6	6	1	8	4	5

Figure 1 – House of Quality Matrix

Our analysis showed that the top three Engineering Characteristics were base size, material used, and structural thickness. The base size, with a ranking of 105, has a direct impact on the cost, weight and stability of the system. This is an important design aspect, because stability and weight are inversely proportional for the base. Specific material of the structure weighting at 96, also attributes to the rigidity of the structure since each has different Modulus of Elasticity and Shear. Depending on the thickness of the structure, with a score of 78 points, the stability of the object and become greater; but like the base, weight is negatively affected. Not too far below this is the number of support cross beams with a score of 72. Their sole purpose is to add stability to the structure which is the common theme of the top Engineering Characteristics.'

2.4 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.

Stability

- Any movement of the structure will result in erroneous phase shift readings by the system
- Maximum allowable error - 5 degrees or less (phase shift)
- Wave length - 1 inch -> 1 inch360°5°=172 inch max error

Weight

- 80lb goal weight

Mobility

- Easy to move: attach wheels

Horns

- Need to be adjustable
- Able to all be focused within 1 ft circle that is 20 ft away
- Can attach laser pointer to horn to make sure alignment is correct "down-range"

Hardware Box

- Improve sleekness
- Consider heat generation from electronic components: ventilation?
- Provide EMI shielding
- Bonus: Protect from environment -- able to endure outdoor conditions
    - Protect components from moisture (add moisture indicator?)
    - Need gasket-type seal?

Cost

- Minimize cost

2.5 Methodology

The methodology describes the general process of how we will complete our deliverables throughout the two semesters. Adjustments will be made over time as the project develops.

1. Project Plans and Product Specs

- ➢ Use project objectives, needs, and constraints to begin planning priorities of what must be completed to satisfy the objective
- ➢ Began to identify viable components to use for the product adjustment and improvement through research
- ➢ Find affordable sources for components, parts, and assembly

2. Initial Web Page Design
    - ➢ Secure website template/base
    - ➢ Collect basic information from teammates, sponsor and put on website
    - ➢ Put list of project objectives on website
3. Midterm Presentation I: Conceptual Design
    - ➢ Concept generation on component adjustments
    - ➢ Concept selection on the generated choices
4. Midterm Report I
    - ➢ Make use off all of the documentation and deliverables to put together a comprehensive and robust report.
5. Peer Evaluation I
    - ➢ To avoid any bad peer evaluations, we will continue to work in unity as we have and remain accountable for our individual responsibilities
6. Midterm Presentation II: Interim Design Review
    - ➢ Make sure to gather information as well as visuals for an effective presentation on the interim design
7. Peer Evaluation II
    - ➢ Once again, we will strive to continue work together and be accountable for our responsibilities
8. Final Web Page Design
    - ➢ Continue to refine the website and add all needed information, visuals etc. to create a seamless and informational story for the website visitor

9. Final Design Poster Presentation

   ➢ Two semester's preparation will go into this preparation and thus we will make sure to deliver our best

10. Final Report

   ➢ Everything that was done will be put into a comprehensive report for final review

3. Deliverables

Figure 2, illustrates the Gantt Chart for all of the deliverables that are due and the time duration that the group has between each deliverable. Figure 3, illustrates the Work Breakdown Structure, this is how we are going about getting everything completed.

	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Project Plans and Product Specs	11 days	Fri 9/25/15	Fri 10/9/15	
2		Initial Web Page Design	15 days	Fri 9/25/15	Thu 10/15/15	
3		Midterm Presentation I: Conceptual Design	12 days	Mon 10/5/15	Tue 10/20/15	
4		Midterm Report I	20 days	Mon 10/5/15	Fri 10/30/15	
5		Peer Evaluation I	28 days	Fri 9/25/15	Tue 11/3/15	
6		Midterm Presentation II: Interim Design Review	21 days	Wed 10/21/15	Wed 11/18/15	3
7		Peer Evaluation II	15 days	Wed 11/4/15	Tue 11/24/15	5
8		Final Web Page Design	28 days	Fri 10/16/15	Tue 11/24/15	2
9		Final Design Poster Presentation	9 days	Thu 11/19/15	Tue 12/1/15	6
10		Final Report	22 days	Mon 11/2/15	Tue 12/1/15	4

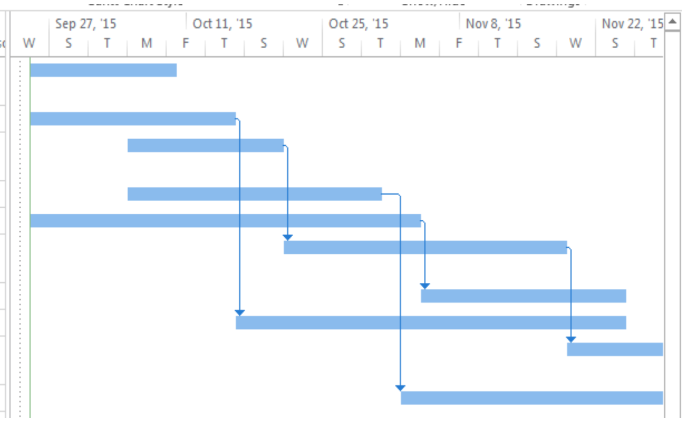

Figure 2 – Preliminary Schedule

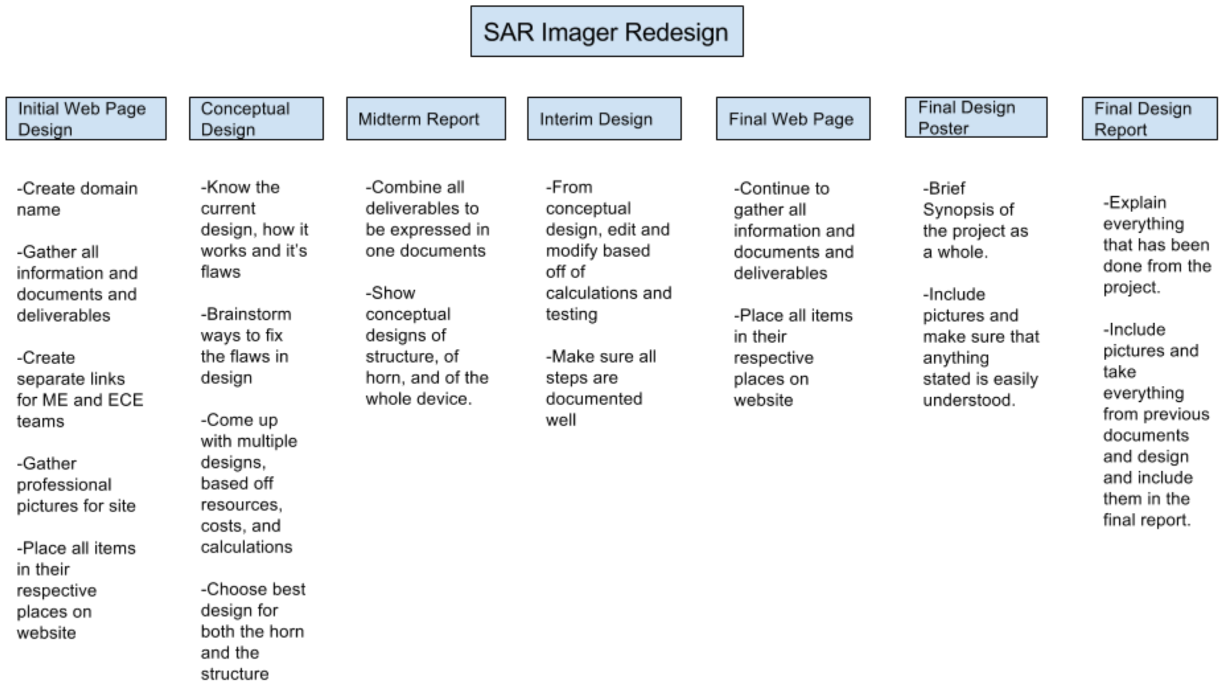

Figure 3– Work Breakdown Structure

4. Assigned Portions

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 the paper trail and ensures that each group member is doing their fair share.

B. Luke Baldin - Overall Structure.

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 Structure.

Dealing with the horns, the mounting of the horns, and making sure there is proper alignment.

D. Desmond Pressey - Web Design.

Has the duty of creating, editing, and translating all relevant information to the web page.

5. Product Specifications

5.1 Design Specifications

A. Structure

Due to the existing requirements of the electrical portion of the design, our team needs to design a structure which can house all the components and antenna array. Selecting the proper material for the structure will determine how we can satisfy many of our design requirements. Weight reduction is one of the main requirements for our project. Last year's design was made of pure steel which gave a total weight of 200 pounds which need to be cut in half for our design. The material also needs to be high strength so that there is little deformation of the structure.

Due to problems with the prototype, increasing the stability of the structure also is required. Last year's project would continue to oscillate after a small perturbation such as a worker accidentally bumping into it. In order to maintain accuracy, the device must not move so that it continuously reads the same point in space. Physical analysis is need to make sure that the natural frequency of the machine is high enough to dampen this force. Another addition to the design is to add portability to the device. This directly correlates to stability, since adding wheels could alter the center of gravity which could add instability. Mobility is not a key requirement of the design but can be combined to the base if our stability analysis is not negatively affected.

B. Horns

SAR radar requires a precise alignment of the transmitters and receivers in order to get an accurate image. The phase calculations for each horn are based off the distance between the target area and each specific receiver. To achieve a precise alignment, it is paramount that there be a vertical and horizontal adjustment of each horn. This allows the operator to fine tune the array for a clear picture. In addition to these adjustments, the horns must have a mount or hole to place a laser which will make alignment easy. However, this piece is flexible and could be built into the product or a separate attachment.

5.2 Performance Specifications

A. **Structure**

Weight reduction is a key feature specified by our client. During our sponsor meetings, they have specified a Military Standard two person carry weight of 80lbs. This weight reduction will help the easy of assembly and portability required by our sponsor. The antenna array also must not vibrate if it is bumped into, resulting in a high natural frequency for the systems.

B. Horns

Our horns need to have azimuth and elevation changes, since errors of 0.1 inch result in a 36 degree phase error for the return radar signal. The electrical requirement is to minimise the error to 5 degree of phase angle so the algorithms can be fairly accurate. This will lead to approximately 0.02 in of error in our horn alignment, however our sponsor has only given us rough estimates and not an exact error which could change our tolerance. Once aligned, the horns must not move in the slightest which requires a locking mechanism. When locking the horns in place, the action must not change the position of the horn.

6. Conclusion

In conclusion, it is understood that the sponsor company, Northrop Grumman, wants to create a concealable, low-cost system with low resolution so it does not reveal too intimate of detail. This project will be a continuation from last year's, with this year bringing challenges of improving the existing design. The focus and objectives of the mechanical engineering team on this project include weight reduction, lowering cost, improving the hardware box design, and a more effective method of mounting the antenna horns. The need statement derived for our project is: "The structure of the current SARS is producing too much of an error and isn't efficient or effective for sensing targets." To quantify a comparison of the sponsor requirements to the engineering characteristics, an HOQ matrix was created. It concludes that our top engineering characteristics will be the base size, the material used, and the structural thickness. The Gantt Chart and the Work Breakdown Structure shows the breakdown of the details of the design such as when things are completely and what exactly is completed.

To satisfy these objectives and requirements while adhering to the constraints, we will have to work diligently as a team to combine our mechanical adjustments with the electrical and programming adjustments of the electrical engineering led team. Going forward, we will have to continue to work with an effective methodology and schedule to produce a quality second generation SAR Imager System.

7. References

[1]"Sandia National Laboratories." : Pathfinder Airborne ISR Systems: What Is Synthetic Aperture Radar? Web. 25 Sept. 2015.

[2]"Radar Basics." - Synthetic Aperture Radar. Web. 25 Sept. 2015.

[3] "Sustainability." Synthetic Aperture Radar: "Round the Clock Reconnaissance" · Lockheed Martin. Web. 25 Sept. 2015.

[4] Cammuse, Matt, Joshua Cushion, Patrick Delallana, Malcolm Harmon, Julia KIm, Benjamin Mock, Mark Poindexter, and Jasmine Vanderhorst. "Synthetic Aperture Radar System." Famu-FSU College of Engineering, 2015. Print.