DASL UAV Antenna
Preliminary Report

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DISCLAIMER

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1 BACKGROUND

1.1 Introduction

Wildlife is tracked using Very High Frequency (VHF) telemetry tags. Traditionally, humans spend hours in nature triangulating signals coming from the tags on the wildlife. This process can be both time consuming and strenuous. The Dynamic and Active Systems Lab (DASL), led by Dr. Michael Shafer is currently developing an Unmanned Aerial Vehicle (UAV) with a Telonics RA-23K VHF antenna, to make the tracking of wildlife easier and more efficient. Rather than humans tracking through forests, a UAV can fly above tree lines to locate the source of a signal. However, the antenna is not able to properly receive data if a tag is below the UAV. Therefore, the D1 Capstone team is tasked with creating a gimbal system for the user to control the angle and position of the antenna while the quadcopter is in flight. The system must also be able to report the angle and readings of the antenna back to the user to ensure accurate and reliable data. The goal of this project is to make the collection of data faster, therefore allowing the user to be more productive in the tracking of animals. This system is of interest to the DASL because the ability to angle and rotate the antenna will remove the need for the UAV to pitch, ultimately making flight more stable. Creating a system that can pitch the antenna while the UAV remains stable will allow the user to receive more accurate data on the location of tags, even if a tag is directly below the UAV. Overall this will assist in resolving ecological research paradigms as wildlife tracking will be fast and efficient. The next section will further describe the project.

1.2 Project Description

The following is the original project description provided by the sponsor:

> "The Dynamic and Active Systems Lab is currently developing an unmanned aerial vehicle for use in tracking small wildlife using VHF radio beacon tags. The project team would like to be able to move the VHF receiving antenna on the UAV in flight. Students on this project will build a gimbal system that can rotate an antennal about a single axis continually or to a specified angle. Communication will be maintained to a flight computer, which will send commands and receive angle position information from the subsystem. Detailed requirements regarding size, weight, power, communication, etc. will be determined in the early stages of the project. The ideal team would consist of two mechanical and two electrical engineering students." [1].

Since receiving this description, the only thing that has differed is the team composition. The team now consists of four mechanical engineers. Additional, details have been specified by meetings with the client, which will be discussed in the next chapter of the report.

2 REQUIREMENTS

This chapter will discuss the requirements of the project including customer requirements and engineering requirements. These will then be weighted against each other in the house of quality to determine the how crucial each requirement is. The chapter begins with the customer requirements explained in section 2.1.

2.1 Customer Requirements (CRs)

This section will discuss the customer needs and their related importance to the project. After gathering notes from the first meeting with the client, the team formulated five needs they deemed necessary for the project. These needs include a simple and modular design that has multiple modes of movement and can relay the angle to the user. The design should also be maintainable, as it will be exposed to a high potential for damage. Each customer need is ranked on a scale from 1-5 based on what the team believes to be the most important. Each need is described thoroughly in the following subsections.

2.1.1 Simple

Simplicity is one of the main needs stressed by the client. It is important to have a simple device that works well rather than a complicated design that fails when needed. To achieve simplicity, the device shall use as few linkages as possible. On top of this, there shall be as few total components as possible. This will help ensure low cost and success in the field. The team ranked this need as a 4/5 due to the client's insistence on a well-done and simple project rather than an incomplete and complex design.

2.1.2 Modular

The second customer need is that the device must fit on a pre-existing modular housing for the UAV. Each part shall be easily integrated with the pre-existing UAV design, to ensure the success of each flight. The modular design is important, but the team has flexibility in how their device may be mounted and moves, so the modular design is ranked as 3/5 for importance of the customer need.

2.1.3 Multiple modes of movement

Another customer request is that the device shall be able to move in multiple modes. One mode shall be manual, controlled from the ground, in minimum desired intervals. The other mode shall be automatic. The operator shall be able to enable an automatic mode and have the gimbal move the antenna on a predetermined sweep. Although the sweep mode would be beneficial to the client, no emphasis was directly placed on this topic, so it was only ranked as 2/5 for customer needs.

2.1.4 Relay angle to user

The most crucial customer need is that the angle of the antenna may be communicated to the client. This information shall be accurate and easy to read. This requirement is crucial to the customer, because without knowing the exact angle of pitch for the antenna, the data looses accuracy and becomes meaningless. Failing to meet this need would render the project a failure; therefore it is ranked as 5/5 for importance.

2.1.5 Maintainable

The last customer requirement is for the device to be made with easily maintainable parts. When necessary the parts shall be replaceable with off the shelf parts, which are easily obtainable, or with spare parts provided by the team. When possible, 3D printing will enable recreation of parts for lower cost and ease of manufacturability. All part files will be maintained for future production. The maintainability of the device is also crucial to the project, as the device will be mounted on the bottom of a quadcopter and has the most potential for damage if a fall occurs. This means the device should be easy to manage and maintain, even in the field. This led the team to rank the need as 4/5.

Overall, the team's objective is to deliver a simple, maintainable, and modular antenna gimbal that has the capability to move in multiple modes while conveying the exact angle back to the user. Engineering requirements developed based on these customer requirements will be discussed in the next section.

2.2 Engineering Requirements (ERs)

This section will discuss the nine engineer requirements provided by the client, and further developed by the team. Each of the requirements, listed in Table 1, must be met in order for the device to successfully fulfill the project objectives. If one requirement is not met, the device becomes useless to the customer.

Table 1: Engineering Requirements for Antenna Gimbal

Requirement	Units	Target	Tolerance	Range
Weight	lbs	0.5	-0.1	.4-.5
Size	in	5.4x5.4x3	±1	N/A
Serial Communication	Bd	9600	N/A	N/A
Angle of travel	degrees	60	30	0-90
Power Input	V	5	±.5	4.5-5.5
Cost	$	500	500	500-1000
Linkages	#	4	N/A	N/A
Degrees of freedom	#	1	+1	1-2
Part Installation	minutes	60	±10	50-70

Each of the requirements shown in Table 1, are further explained in the following subsections.

2.2.1 Gimbal Weight

Due to the maximum payload the UAV can carry, the gimbal attachment may not exceed 0.5 lbs. Idealistically, the team will be able to create a gimbal even lighter, which will allow for longer sustained flight of the quadcopter.

2.2.2 Size

The external dimensions of the gimbal are defined by the existing modular design of the quadcopter. For the gimbal to be used it must fit within the allotted space of the modular UAV housing. This means, the design must adhere to a space smaller than 5.4 in. x 5.4 in.

2.2.3 Serial communication

The existing quadcopter is controlled through a Raspberry Pi. To be able to integrate the gimbal into the onboard flight controller, the Arduino controlling the gimbal must be able to communicate at a 9600 Baud rate via USB to the Raspberry Pi onboard. Without this communication, the user would not be able to control the gimbal angle, or know the precise angle of the antenna.

2.2.4 Angle of Travel

The gimbal must allow for no less than 60° of travel below the horizontal axis. If possible the client would prefer the gimbal be able to travel to 90° below the horizontal axis, but it is not required. The team will strive to meet desired specifications, after successfully completing necessary qualifications.

2.2.5 Power Input

The gimbal and controller must be able to operate off the quadcopters own power supply. After all necessary flight component power consumptions are accounted for, the team is allotted a remaining 5 V to run the gimbal system.

2.2.6 Cost

For this project, the team is given an ideal budget of less than $500.00. However, if allowable circumstances arise, the client is willing to raise the budget to $1,000.00.

2.2.7 Linkages

In order to maintain a simple design, the system shall contain less than 4 linkages for movement of gimbal. This requirement also helps to keep the design maintainable as there are less components to repair in the case of an accident in the field.

2.2.8 Degrees of Freedom

The gimbal must be able to lower the antenna on a single axis. Furthermore, if weight and cost allows, the client would also like for the gimbal to be able to rotate about a second horizontal axis, if it does not over complicate the simplicity of the design.

2.2.9 Part Installation Time

Given the modular design of the quadcopter, the gimbal should be able to either be installed or removed in no more than 60 min with a ±10 min tolerance. This will ensure the device is maintainable in the field in the case of a crash or other failure.

2.3 House of Quality (HoQ)

This section discusses the house of quality, Table 2, for the antenna gimbal. The team first compared customer needs described in section 2.2 with the engineering requirements in section 2.3, in the center of the house of quality. For needs and requirements having no correlation, the cell is left blank. Little, moderate, and strong relationship is marked as a 1, 3, and 9 respectively. The team repeated this process in the top of the house of quality, this time relating engineering requirements to other engineering requirements to determine the importance of their relationships. Using the weightings of the customer needs and strength of relationship to the engineering requirements, the team was able to formulate an absolute technical importance for each engineering requirement, then rank them in the relative technical requirement row. Through this process, the team found that part installation time, rotational range, and the number of linkages are the highest ranking technical requirements for the project. Since these requirements have such a large relation to the customer needs along with other engineering requirements, they must be strongly considered in the designing of the device. Lastly the house of quality compares customer needs to pre-existing designs, including the MOOG, Octopus, and Marcus UAV gimbal. These pre-existing designs are discussed further in Chapter 3 of this document.

Table 2: House of Quality for Antenna Gimbal

Size <--															
Mass <--		9													
Rotational Range -->		9	3												
Angle Roation Modes -->				3											
Communication BAUD Rate *				1	1						Legend				
Voltage <--				1	1	1					A	MOOG			
Cost <--		1	3	3	3	1					B	Octopus			
Number of Linkages <--		3	3	1	1			3			C	MarcusUAV			
Part Installation Time <--		1	1	3	1			3	9						
		Technical Requirements									**Comparison**				
Customer Needs	**Customer Weights (1-5)**	Size <--	Mass <--	Rotational Range -->	Angle Roation Modes -->	Communication BAUD Rate *	Voltage <--	Cost <--	Number of Linkages <--	Part Installation Time <--	1 Poor	2	3 Acceptable	4	5 Excellent
Simple	4	3	3	9	9			3	9	9		B C	A		
Modular Design	5	9	9	3			1	3	1	3	B	A	C		
Multiple Modes of Movement	2	3	3	9	9	1	1	3	1	1			C		A B
Relay Angle to User	5		1	3	3	9	3	3			C		B		A
Maintainable	4		1					3	9	9	B C		A		
Technical Requirement Units		in^2	oz	°	#	bits/s	V	$	#	min					
Target ER values		15	4	0-60	2	9600	5	500	4	60					
Tolerances		±5	±4	30	±1	±0	±0.5	±500	-2	±10					
Absolute Technical Importance		63	72	84	69	47	22	60	79	89					
Relative Technical Importance		6	4	2	5	8	9	7	3	1					

3 EXISTING DESIGNS

This chapter discusses the approaches to designing the antenna gimbal system. Sources used for research include article databases, and pre-existing design websites. In addition to researching pre-existing designs, this chapter includes the functional decomposition including the black box and functional models. Lastly the team researched the subsystems required for their project and researched existing designs at each subsystem level.

3.1 Design Research

To begin design research, the team first needed a basic understanding in VHF telemetry tracking. They found that "to locate an animal using VHF radio tracking, scientists must be close enough to the animal with the radio antenna so they can pick up the signal from the radio transmitter on the animal" [2]. Once a signal is located, the scientists and researchers are able to follow the direction from which the signal is the strongest in order to locate the animal. This is traditionally done on foot, which can be painstaking and time consuming. Some scientists take to cars to reach the signal faster, and some even use this method while flying in small planes above the forest. With this information, the benefit of being able to track wildlife using a UAV became more apparent. The UAV could cut out the time for tracking on foot, the accessibility cars and trucks might not be able to reach, and the cost of renting an airplane. However, after further research on the reception radiation pattern for VHF, pertaining especially to the RA-23K VHF Antenna used by the DASL lab, the team also saw a need for the need for a rotating antenna. As seen in Figure 1, the RA-23K antenna receives radiation patterns on a horizontal plane, with more information incoming to the front of the antenna compared to the back. Being able to pitch the antenna using a gimbal on the UAV would allow for a larger range of reception and higher data collection and accuracy, especially if the signal is coming from below the UAV.

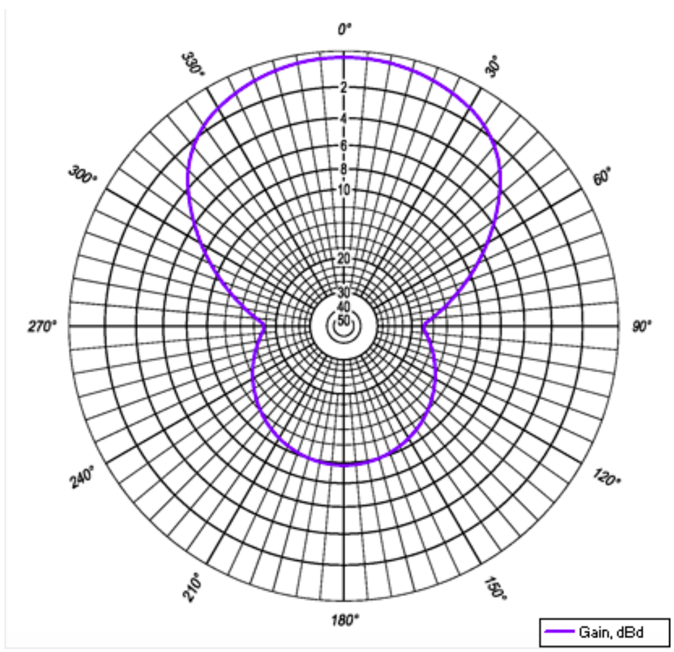

Figure 1: RA-23K Reception Radiation Pattern [3]

After basic research on VHF telemetry tracking, the team began looking into existing designs. Using the engineering database, Compendix, the team found that using UAVs to track wildlife is an ongoing development. Other researchers have also reported "the use of small unmanned aircraft systems (UAS) for wildlife tracking offer many advantages such as cost reduction, human effort reduction and data acquisition efficiency due to the usage flexibility offered by the system in comparison to conventional methods” [4]. This article describes the use of acoustic telemetry to track wildlife using a small UAV. This varies from the team's project as the RA-23K antenna reads VHF and requires a pitch angle. Another team was able to use a commercial radio controlled model aircraft to locate fish tags placed both on land and underwater [5]. While these reports showed the real life applications of using UAVs in tracking wildlife, they did not focus on the rotation of the antenna, so the team began searching the web for antenna pointing mechanisms to help formulate ideas and concepts they might incorporate into their own device. Upon this search, the team found a large range of designs including the MOOG Antenna Pointing Mechanism, Octopus UAV Tracking Antenna, and Marcus UAV Retractable Gimbal. Each of these designs are further described next in the system level section of the report.

3.2 System Level

This section discusses existing designs that address similar requirements relevant to the DASL UAV Antenna project. The three designs found each have desirable qualities for the team’s project, however, they also all have features that would not be compatible with the DASL UAV, which will be explained in each subsection.

3.2.1 Existing Design #1: MOOG Antenna Pointing Mechanism

The MOOG Antenna Pointing Mechanism, Figure 2, is a small device commonly mounted on spacecraft. It meets many of the requirements needed for the DASL UAV gimbal antenna. This mechanism is able to rotate in two directions and in multiple modes to relay information back to the user. However, this product does not meet the low cost need nor is it maintainable, making it impractical for this design. However, this does provide the team with one example of allowing two directional rotation, which is not a requirement, but desired by the client.

Figure 2: MOOG Antenna Pointing Mechanism [6]

3.2.2 Existing Design #2: Octopus UAV Tracking Antenna

The Octopus Tracking Antenna, Figure 3, is used on the ground to track UAVs in the air, but could potentially be used to mount to a UAV and track other signals. The advantage of this tracking antenna is that it can be switched between a directional and omni antenna. It also has an integrated pointed algorithm that automatically points towards the direction of the strongest signal. This could be very useful while tracking wildlife, especially if the team’s system is able to relay the exact angle to the user. Rather than the user inputting multiple angles and trying to find the strongest signal, the antenna would automatically sweep for the strongest signal and point towards it. This angle would then be reported back for quick and accurate data collection. The limiting factor to this existing design is size, which would not be feasible on a UAV.


Figure 3: Octopus UAV Tracking Antenna [7]

3.2.3 Existing Design #3: Marcus UAV Retractable Gimbal

The Marcus UAV Retractable Gimbal, Figure 4, is a 2 direction rotational gimbal mounted to a UAV. However, instead of mounting an antenna to the gimbal, they use it for a camera. This gimbal still meets several requirements such as multiple modes of movement, lightweight, and full range rotation. The full range of movement comes from the fact that the camera is embedded in the system rather than sticking out like an antenna most likely would. However, the team can use this design to further formulate encapsulating designs for the antenna.

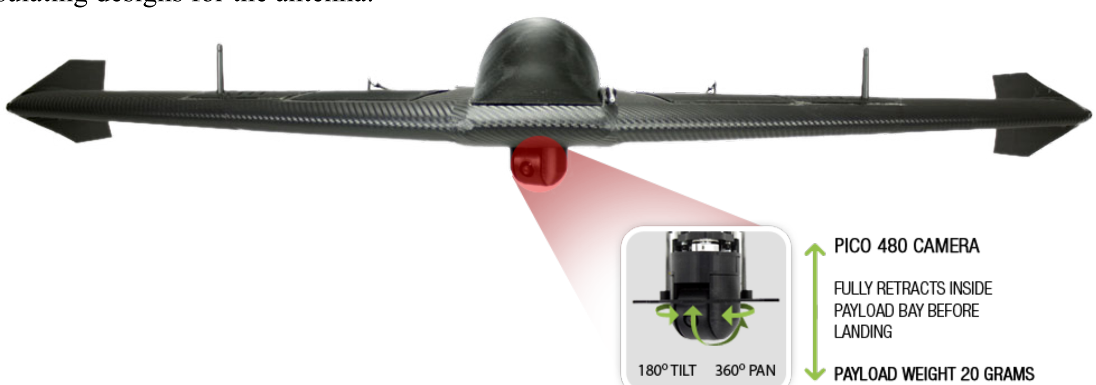

Figure 4: Marcus UAV Retractable Gimbal [8]

3.3 Functional Decomposition

In this section, the functional decomposition is analyzed in two parts. First, the black box will simplify the total function of the gimbal system and categorize the inputs and outputs by material, energy, and signal. The main function of the system is to move the antenna at the request of the user. The action of the system will be further broken down in the functional model by each step that is performed and the individual input and output.

3.3.1 Black Box Model

The black box model allows for an easier understanding of what the device needs to accomplish. This is done by simplifying the design down to the basic inputs and outputs, specifically materials, energy, and signal. This allows the design team to focus on the core elements and make sure that the device successfully addresses the needs of the client.

The black box model, as seen in Figure 5, shows all materials that enter the system also exit, meaning no material stays in the system. Electric energy as well as human energy enters the black box and comes out as heat and sound. Lastly, a signal to move the antenna is sent and out of the box comes a signal indicating the relative position of the antenna to the drone.

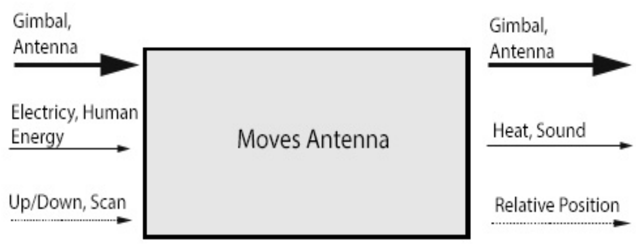

Figure 5: Black Box Model

The next section further analyzes the action of moving the antenna seen in the black box model and fully breaks it down into a functional model.

3.3.2 Functional Model/Work-Process Diagram/Hierarchical Task Analysis

The section describes the functional model for the gimbal antenna. A functional model is a breakdown of how the team theorizes the gimbal system will work. This is derived from the black box model by analyzing the material, energy, and signal imports and exports. The gimbal system takes in electricity from the UAV and human energy from hands controlling the remote and transmits it to rotational movement of the antenna and data back to the user. This process can be visualized in steps in Figure 6. Through this model, the team can visualize that their crucial actions of regulating the angle, receiving VHF signal, and reporting that data back to the user all rely on electricity to run the operations while in the air. From this model, it is apparent that the functionality of the device is crucial on being able to meet requirements for electric usage as described in the engineering requirements, in order for any of the main operations to take place.

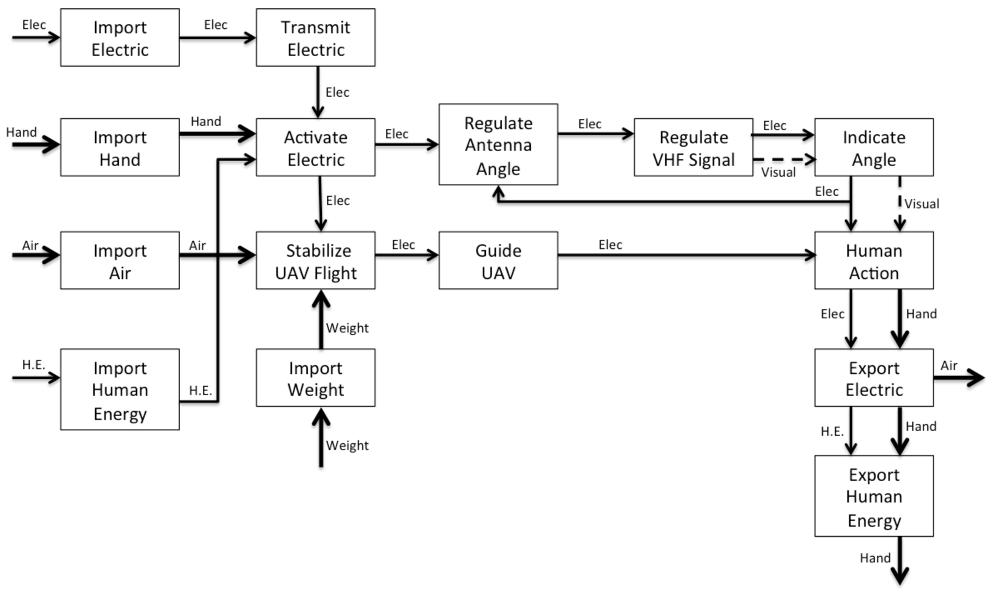

Figure 6: Functional Model for Gimbal Antenna

3.4 Subsystem Level

This section will discuss the different subsystems used to make an antenna gimbal. Currently, gimbals and their controllers are typically applied to stabilize video recording. While incorporating a gimbal to control a VHF antenna is a fairly unique idea, the overall system and controllers can be applied to either situation. The team broke the antenna gimbal system into three subsystems including the control system, motor, and frame/mount. Each of these subsystems are further described in the following subsections along with existing designs for each.

3.4.1 Subsystem #1: Control System

The control subsystem is important in the design of the antenna gimbal because it enables the control of the angle and angle readout. This device will be used to take information from the on board computer and output angles, then relay that information back to the on board computer for communication to the ground.

3.4.1.1 Existing Design #1: Arduino

The Arduino is the industry standard in terms of small microcontrollers. This microcontroller has a large amount of user support due to it being so ubiquitous [8]. An advantage to this control system is there are many forums of existing code the team could use to their advantage in programming.

3.4.1.2 Existing Design #2: MSP430 LaunchPad

The MSP430 LaunchPad is a lightweight microcontroller. Where this device differs from the Arduino is in its lower power consumption, weight, and cost. This device comes in at $4.30 which is about half that of an Arduino unit [9].

3.4.1.3 Existing Design #3: Teensy 2.0

The Teensy 2.0 is by far the smallest microcontroller. It comes in at about the size of a quarter and has the capability of running Arduino programs and sketches. This device is great for projects that are constricted on weight and or space while needing to run Arduino code [9]. The size of this system would be beneficial in fitting to the modular design for the team.

3.4.2 Subsystem #2: Motor

This component of the gimbal is imperative to hit the requirements laid out for the team. These motors need to be able to hold a certain amount of torque at a steady angle under flight power, while maintaining a light weight requirement. This device needs to also be repeatable to maintain accuracy.

3.4.2.1 Existing Design #1: Short Range Servo Motor

This design has the capability to be finely controlled. While it is a stepper motor it has the capability to be put into an orientation and then hold that orientation. They are highly efficient and are great for applications where vibration is an important consideration [10].

3.4.2.2 Existing Design #2: Goteck Metal Gear Micro Servo

This micro servo is designed to be used in lightweight flying machines. It has a high stall torque which would be helpful while maintaining a slim and lightweight design. This servo can run off standard flight batteries and has fairly low power consumption [11].

3.4.2.3 Existing Design #3: DSM 44

This servo motor is designed specifically with RC control in mind. It is both small and lightweight, runs off standard 5 volt supplies and has a surprisingly high torque output for it's size [12].

3.4.3 Subsystem #3: Frame/Mount

This part of the device is important to maintain a rigid platform for the antenna to gimbal from. It needs to be structurally strong, while being lightweight, and being capable of being attached to the UAV via the modular design plates provided.

3.4.3.1 Existing Design #1: Channel Master 3079 Antenna Mount

This antenna mount is a very basic design made from conventional materials. Do to this it is readily available and cheap to purchase. At over half a pound it may not be right for our applications but it is worth consideration [13].

3.4.3.2 Existing Design #2: Panel-Hanging Bracket from McMaster-Carr

This off the shelf bracket is extremely accessible and cheap. Made from stainless steel it is corrosion resistant and easy to maintain. It may be heavy for its weight but overall may be the best choice. This could be modified in house to match our modular design for easy of assembly in the field [14].

3.4.3.3 Existing Design #3: Generic L-bracket

Using this is very similar to the use of the off the shelf bracket from McMaster-Carr but this offers easier obtainability with a lighter weight design. Again it can be made to fit our modular design with some slight modification keeping cost down [15].

4 DESIGNS CONSIDERED

Chapter four will serve the purpose of describing the designs for the DASL UAV Antenna Gimbal as brainstormed by the team. The team formed ten ideas ranging in capability, feasibility and simplicity. Each of the designs are described as follows and displayed in Figures 7-16.

4.1 Design #1: Plate with Motor

In Design 1, Figure 8, the antenna is mounted through a plate, which is controlled by the motor. The plate is supported by two brackets fastened to the octagonal UAV housing. As the motor rotates, the plate and antenna rotate as well. The advantage of this system is simplicity as it only contains four components not including the antenna. It can be made low cost and would be easily maintainable. The disadvantage of this design is the need for a high torque motor that would still be light weight. Another potential downside is a limited range in movement.

Figure 7: Plate with Motor

4.2 Design #2: Motor with Lead Screw

In this design, a lead screw drives the back end of the antenna to control the angle of attack. As seen in Figure 4, the antenna is pinned near its center to the base of the UAV. The lead screw is mounted above one end allowing it to push the antenna down to a desired angle. In this system, the linear movement must be converted into rotational measurements to relay the exact angle to the client. The advantage of this design is simplicity and light weight mechanisms, however, the downfall is that the lead screw would always be sticking out during flight.

Figure 8: Motor with Lead Screw

4.3 Design #3: Pulley System

This system uses a simple cord attached to the antenna. The motor would draw in the cord onto a spool and therefore retracting the antenna upward towards the base of the UAV. This system would also consist of a potentiometer to determine the angle that the antenna is resting at. An advantages of this design is that the sweep mode would be easily incorporated with a constant rpm of the motor. Potential issues could include that the cord is not rigid and could cause the antenna to move with turbulence of the UAV.

Figure 9: Pulley System

4.4 Design #4: Linkage System

This system uses a linkage to drive the angle of attack, Figure 4. The motor is attached to the linkage and that drives the antenna. The linkage cams a boss on the antenna mount to move the angle up or down. The advantage to this design is that all mechanical operation can be seen and problems can be diagnosed quickly. The main disadvantage would be the torque required to power the cam and measuring the angle of attack.

Figure 10: Linkage System

4.5 Design #5: Hydraulic Piston

This is the same as the lead screw but with a self contained hydraulic unit, Figure 5. The system would incorporate a pump, reservoir, and piston system. This unfortunately would both add weight and complexity. However the design has the advantage of being much more self-contained when compared to the lead screw as there are no parts that extend beyond the antenna when retracted.

Figure 11: Hydraulic Piston

4.6 Design #6: Two Motors

Design 6 is similar to Design 1 in the way it rotates the antenna. In this system, rather than the antenna being directly attached to the rotating plate, another motor is first fastened to the plate, then the antenna is connected to the second motor. This allows the system to have to degrees of freedom, which the client showed interest in. Unfortunately the motor rotations could interfere with each other and this would have to be kept in mind during dimensioning and designing of the system.

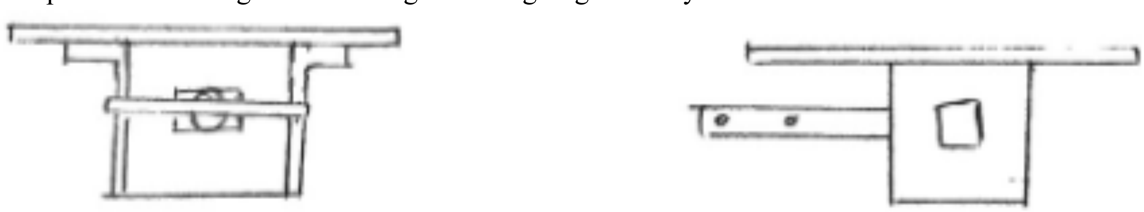

Figure 12: Two Motors

4.7 Design #7: Centered Pulley

This design, as seen in Figure 5, mostly mimics that of design 3, however in an effort to maintain the same center of gravity as the original UAV, the mounting location for the antenna is offset towards of the edge of the UAV with the motor and microcontroller located in a more central position. The disadvantage of this design is again a lack of rigidity as the cable allows for bouncing of the antenna during flight.

Figure 13: Centered Pulley

4.8 Design #8: Single High Torque Motor

Design 8, as seen in Figure 5, works by attaching a high torque motor in a 1:1 ratio, directly to the antenna. This design offers for a more simplistic design, however would require the use of a rotary encoder, or resolver, to track the orientation of the antenna. While the weight of the motor in this design may be high, is the only mass of the component. This design does not account for the length of the antenna and therefore would most likely have interference issues.

Figure 14: Single High Torque Motor

4.9 Design #9: Two Hydraulic Pistons

Similar to design 5, this concept involves hydraulic pistons. There would be one attached closer to the front of the antenna and another towards the back. They would work in unison (one retracts as the other extends), to cause the antenna to pivot. This would allow the pistons to be smaller since compared to the single piston design. A disadvantage of this design would include that the UAV would need to house a pump and water reservoir to allow the pistons to function and therefore adding unnecessary amounts of weight to the system.

Figure 15: Two hydraulic Pistons

4.10 Design #10: Sterling Engine

Design 10 incorporates a sterling engine into the system as seen in Figure 6. This mechanism moves based on a heat gradient. A constant change in winds would allow for continuous movement of the antenna. However, there is not a simple way to control the exact angle of the antenna, leading to inconsistent and inaccurate data.

Figure 16: Sterling Engine

5 DESIGN SELECTED – First Semester

Chapter 5 serves the purpose of explaining the rationale for the design selected by the team. All rationale is described in section 5.1.

5.1 Rationale for Design Selection

To help the team form a rational decision for one of the ten designs described in Chapter 4, they formed a decision matrix, seen in Table 3. The team decided upon five criteria from both customer needs and engineering requirements. The first and most important is the weight of the system. If the device cannot be lifted by the UAV, it is not a viable design. The second most important criterion is the ability to relay an accurate angle of the antenna to the user. Without this piece, the device would not provide accurate data and would be pointless. Third most important is maintainability. Since the UAV is at risk of crashing, and the antenna gimbal is attached to the bottom, it is important that the system be maintainable so that it can continue functioning and collecting data for the user. The team also determined the angle range and position to be important, as the device needs to allow ample rotation to gather quality data, as well as hold the angle in position rather than letting it bounce or hang freely. Lastly the team considered cost. This requirement is not as high of a concern as the budget is loose, however, the team would like to stick to the desired budget of under $500, so cost must be taken into consideration. To evaluate the designs, the team first picked four of what they thought to be the most viable designs. They then scored each design on a scale of 1-10 for each criterion and applied the weight. Through this process, the team found Design 1: Plate with Motor to be the best option. This design meets all customer needs of simple, maintainable, modular, able to relay an angle, and able to have multiple modes. It is also able to meet each of the engineering requirements, which will be ensured through more careful designing of the idea.

Table 3: Decision Matrix

		Design 1 Plate with Motor		Design 2 Motor with Lead		Design 3 Pulley System		Design 4 Linkage System	
Criteria	Weighting	Score	WS	Score	WS	Score	WS	Score	WS
Weight	30%	7	2.1	6	1.8	8	2.4	6	1.8
Relay Angle to User	25%	8	2	9	2.25	2	0.5	7	1.75
Maintainable	20%	8	1.6	6	1.2	9	1.8	6	1.2
Angle Range and Position	15%	6	0.9	6	0.9	3	0.45	7	1.05
Cost	10%	7	0.7	8	0.8	9	0.9	7	0.7
			7.3		6.95		6.05		6.5

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