The University of Texas at Austin
Aerospace Engineering
and Engineering Mechanics
Cockrell School of Engineering

DECEMBER 2022

USRC – HARDWARE DESIGN REVIEW #2

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MISSION INTRODUCTION

ASE 374K
SPACE SYSTEMS ENGINEERING DESIGN
PROFESSOR NOKES
TEACHING ASSISTANT KAREEM
DEL FOUNDER AND MENTOR MITCH

TEXAS DRONE ESTIMATION LAB
A NASA USRC CHALLENGE MISSION

TEXAS DRONE ESTIMATION LAB - HARDWARE TEAM

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Shayla Patel

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Jordan Burton

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Stefano Bonilla

Trace Larue

Need Statement

The overall need of this project is to develop drones capable of sensing and avoiding obstacles with a minimized risk of collision or damage to property in GPS denied environments.

TABLE OF CONTENTS

- Heritage
- Mission Scoping
- Requirements
- Battery Degradation Study
- Environmental Analysis
- Assembly Modifications
- Safety/Regulations
- Disposal/Outreach
- Future Works/Next Semester Steps

HERITAGE - LUIN

Development of an Autonomous Quadcopter at Murray State University

- Modify a manually flown quadcopter to enable autonomous flight including obstacle detection and avoidance
- Determine performance characteristics such as maximum speed and flight time at different weights
- Examine the considerations and modifications made by the students in this mission to better estimate the considerations and modifications which will need to be made to our own drone

Considerations

- Stopping distance dependent on speed
  - Their study of stopping distance relates to our collision avoidance
- Max speed dependent on weight, thrust, motor output, and sensor range
  - Optimization to ensure momentum will be balanced with maneuverability
- Larger systems can run for longer because sensors take up a lower percentage of weight
  - Our system is larger than this heritage, since their total wingspan was 12”, while just our propellers are 13”

Modifications

- Added a downward-facing ultrasound sensor to measure height, an infrared beam to detect obstacles, and a phototransistor to detect light.
- Accounted for noise using empirical considerations
- Students cut off unnecessary weight
  - We will be doing the same where reasonable: Potentially remove propeller top to reduce weight

MISSION SCOPING - TRACE/VICTOR

GOALS

1. Incrementally modify TAR replica drone to acquire baseline data and inform future designs.
2. Ensure efficient and effective cross-team communication/precise integration of different sub-systems into the drone hardware.
3. Understand drone support equipment and consider open-sourced drones.
4. Create a preliminary design trade study for our in-house drone capable of lifting all required sensors.
5. Develop a flight test plan and test modified drones to simulate real air space.

Incrementally modify TAR replica drone to acquire baseline data and inform future designs

- Work with the sensors/communications team to determine which sensors to implement
- Create mass budget based on sensor requirements in order to track that the flight hardware has enough lift to accommodate the necessary mass
- Select and purchase drone based on the previous TAR design and mass budget so that we will be able to quickly begin modifying the hardware and software

Ensure efficient and effective cross-team communication/precise integration of different sub-systems into the drone hardware.

- Host 30-minute weekly tag-up meetings and maintain a burndown list of hardware related action items.
- Maintain ample documentation through the design process, detailing requirements, design choices, and change notices.
- Complete reiterative testing on hardware designs through prototyping.
- Host internal design reviews in each phase of the process, from criteria to critical, with other USRC teams.

Understand drone support equipment and consider open-sourced drones.

- Determine if open source drones are feasible option for drone control
- What equipment needed for maintaining of drone swarm
- Understand battery charging and storage

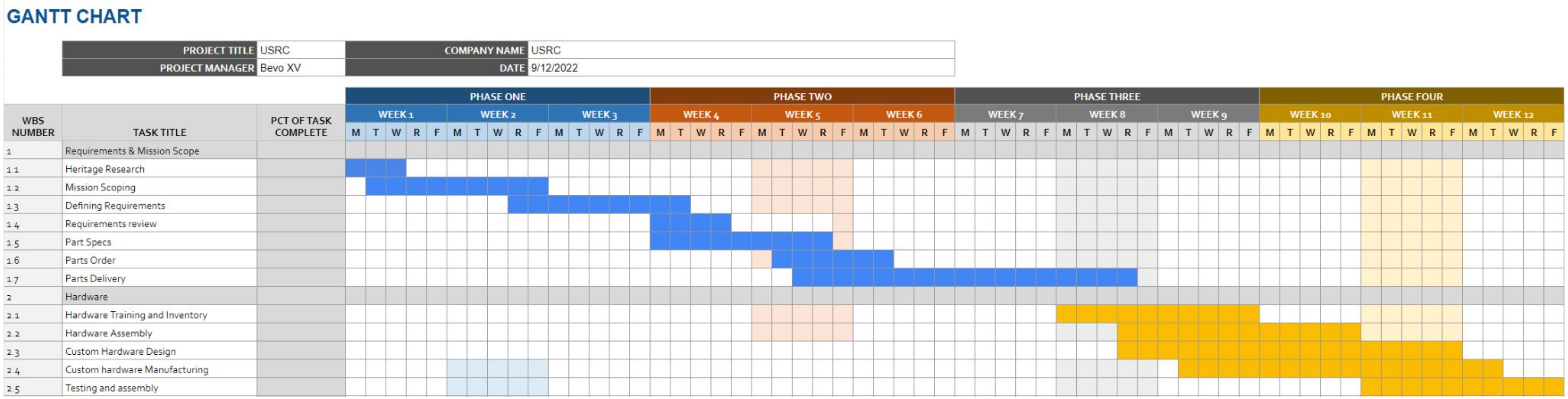
Create a preliminary design for our in-house drone capable of lifting all required sensors.

- Determine the requirements
- Determine weights of the components
- Select frame and motors
- Finalize the components that are needed for the in house drone

Develop a flight test plan and test modified/in house drones to simulate real air space.

- Develop valid testing points for a flight test plan
- Reserve drone cage and complete training
- Conduct pre/post flight check
- Evaluate future test areas and ideas

Semester Gantt Chart



Parts List & Budget

Part Number	Part Name	Quantity	Unit Price	Total Price	Link	Vendor	Ordered	Received
1	Tarot 4006 / 620KV Multiaxial Brushless Motor TL68P02 for RC DIY Quadcopters Multicopters Drone, Tarot FY680 Pro Spare Parts (1 Pcs)	10	$39.98	$399.80	Link	Amazon	Y	Y
2	Lumenier Elite PRO 60A 2-6S BLHeli_32 4-in-1 ESC - 60 Amps	3	$112.19	$336.57	Link	Amazon	Y	Y
3	APD PDB500[X] 12S 52V 500A Power Distribution Board	1	$106.91	$106.91	Link	Amazon	Y	Y
4	4S Lipo Battery 14.8V 5200mAh 120C RC Battery Soft Case for Traxxas/RC Car/Truck/Plane/Quadcopter/Helicopter/Jet/UAV Drone/FPV(2PCS)	1	$91.23	$91.23	Link	Amazon	Y	N
5	Amass AS150 Male and Female Anti Spark Connector Plug Set for Battery, ESC, and Charge Lead	1	$9.95	$9.95	Link	Amazon	Y	Y
6	oGoDeal 155 in 1 Precision Screwdriver Set Professional Electronic Repair Tool Kit for Computer, Eyeglasses, iPhone, Laptop, PC, Tablet,PS3,PS4,Xbox,Macbook,Camera,Watch,Toy,Jewelers,Drone Blue	1	$27.99	$27.99	Link	Amazon	Y	Y
7	Ethix Quad-Builder Cable Set	1	$27.08	$27.08	Link	Amazon	Y	Y
8	Cable Zip Ties,400 Pack Black Zip Ties Assorted Sizes 12+8+6+4 Inch,Multi-Purpose Self-Locking Nylon Cable Ties Cord Management Ties,Plastic Wire Ties for Home,Office,Garden,Workshop. By HAVE ME TD	1	$6.99	$6.99	Link	Amazon	Y	Y
9	Tiger Motors T-Motor Polymer Straight Propellers - MS1302 (Pair) - 13" - Black	1	$14.57	$14.57	Link	Amazon	Y	Y
10	TAROT 650 Carbon Fiber 4-Axis Aircraft Fully Folding FPV Drone UAV Quadcopter Frame Kit for DIY Aircraft Helicopter TL65B01	1	$158.88	$158.88	Link	Amazon	Y	Y
	Total $ Spent			$1,179.97				

REQUIREMENTS - JORDAN

DERIVED REQUIREMENTS

- The project shall not exceed Budget (less than $60,000)
- The project shall follow NASA guidelines
- The project shall follow proposal specifications
- The project shall address safe, efficient growth in global operations and in-time system-wide safety assurance

HIGH LEVEL REQUIREMENTS

- Drone shall operate with a power source of no more than 14.8 V
- Drone shall be capable of being modeled in CAD program
- Drone shall be capable of open sourced collision avoidance programming
- Drone shall be able to function in swarms of 5
- Drone shall be able to avoid static obstacles
- Drone shall be able to avoid dynamic obstacles

INTERFACING REQUIREMENTS

- Drone blades shall be capable of X amount of thrust (further documentation/communication)
- Drone shall be able to land at a downward speed of 5 m/s without breaking
- Drone performance shall not be impeded by foreign object debris (FOD)
- Drone shall be able to operate in any weather conditions with the exception of extremely hazardous conditions (i.e. hail, blizzard, tornado, etc.)
- Drone shall be able to communicate with other drones in flight

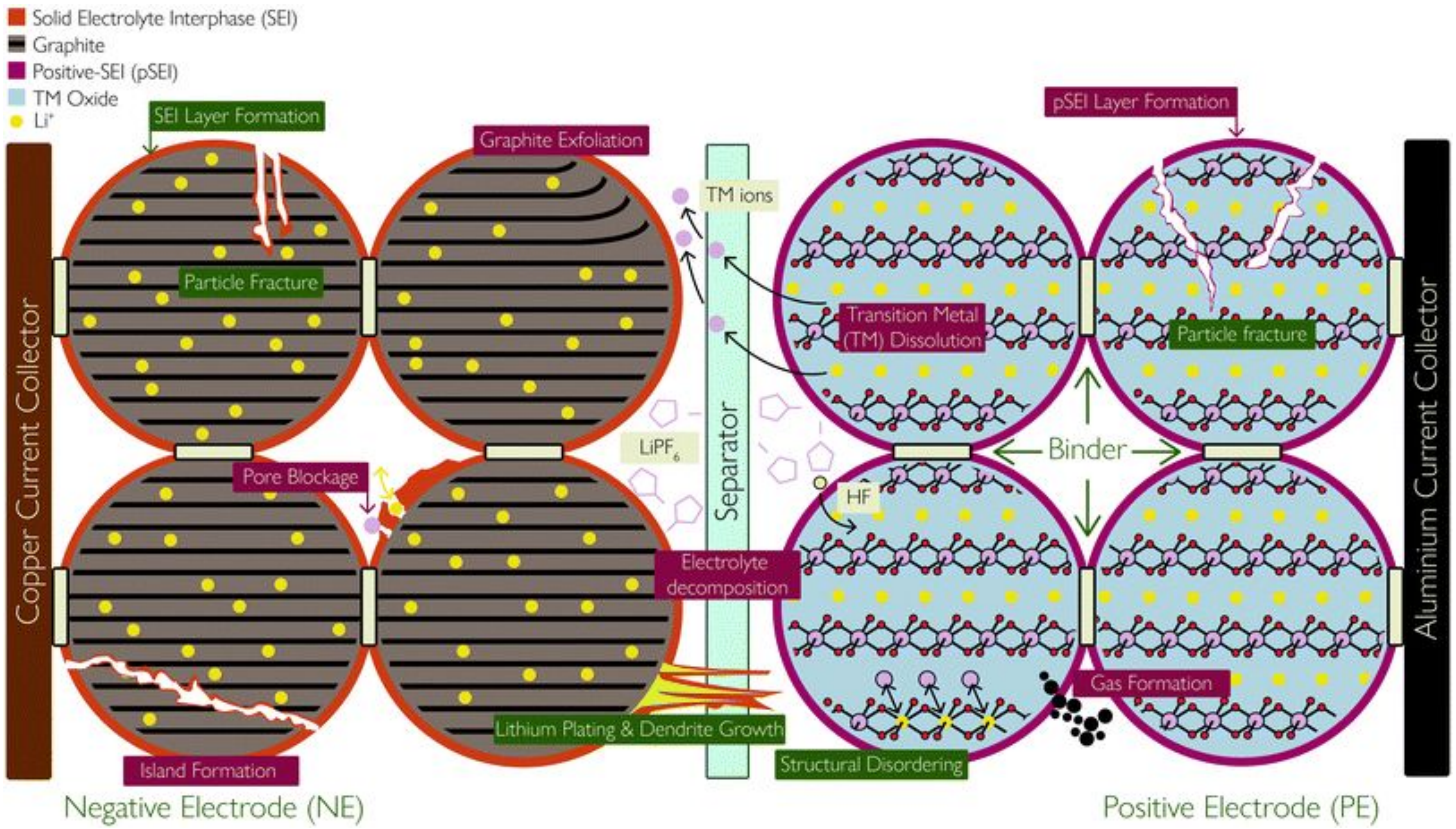
INTERNAL REQUIREMENTS

- Drone shall be capable of moving omnidirectionally
- Drone shall be robust enough to have reused capabilities
- The hardware shall be compatible with FAA standards
- Drone shall have a flight endurance of 20 minutes
- The hardware shall be compatible with FAA standards

BATTERY DEGRADATION STUDY - STEFANO

Understanding Battery Degradation

Li-Po Batteries experience an irreversible drop in capacity with each cycle.



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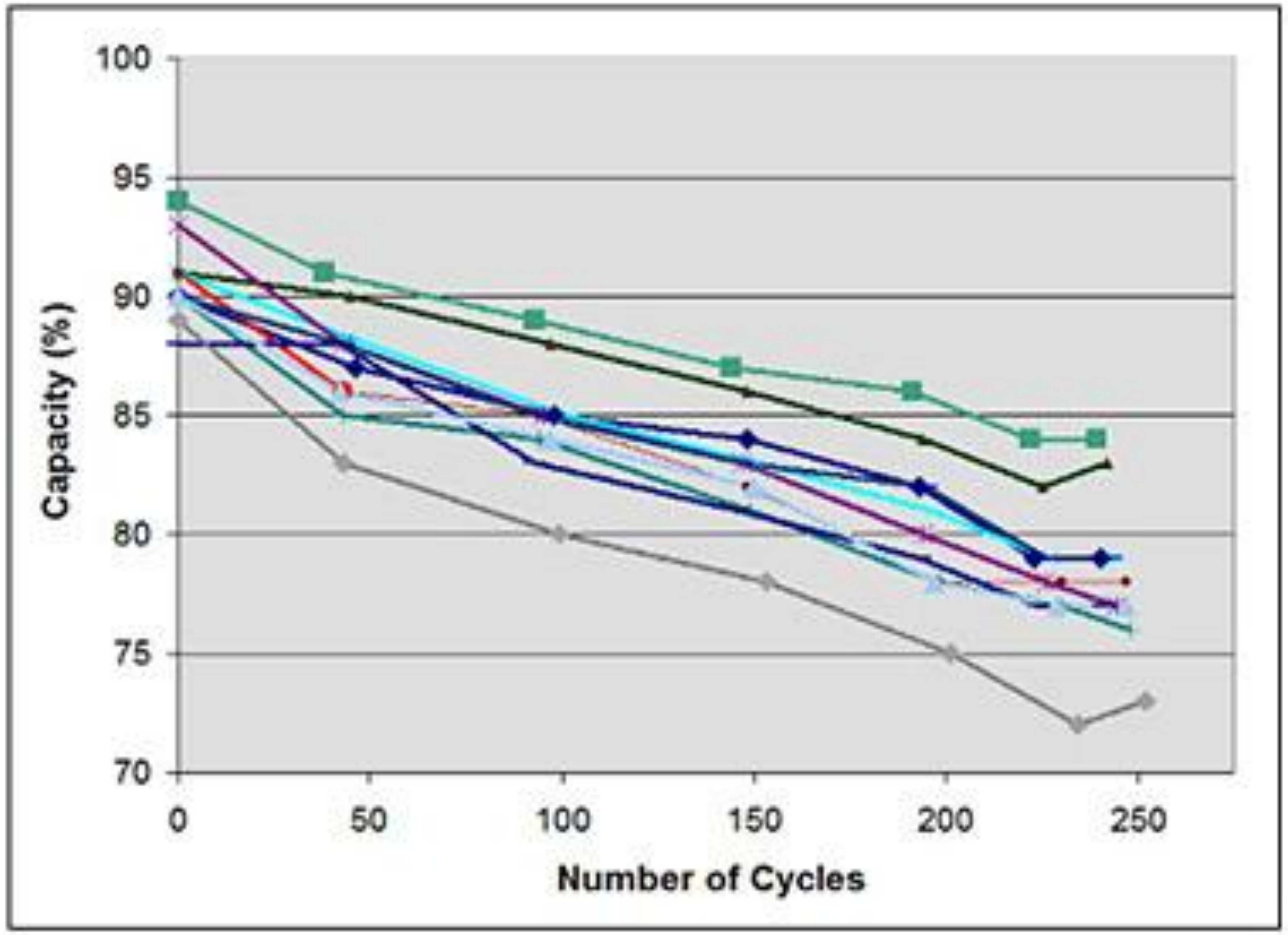
Understanding Battery Degradation

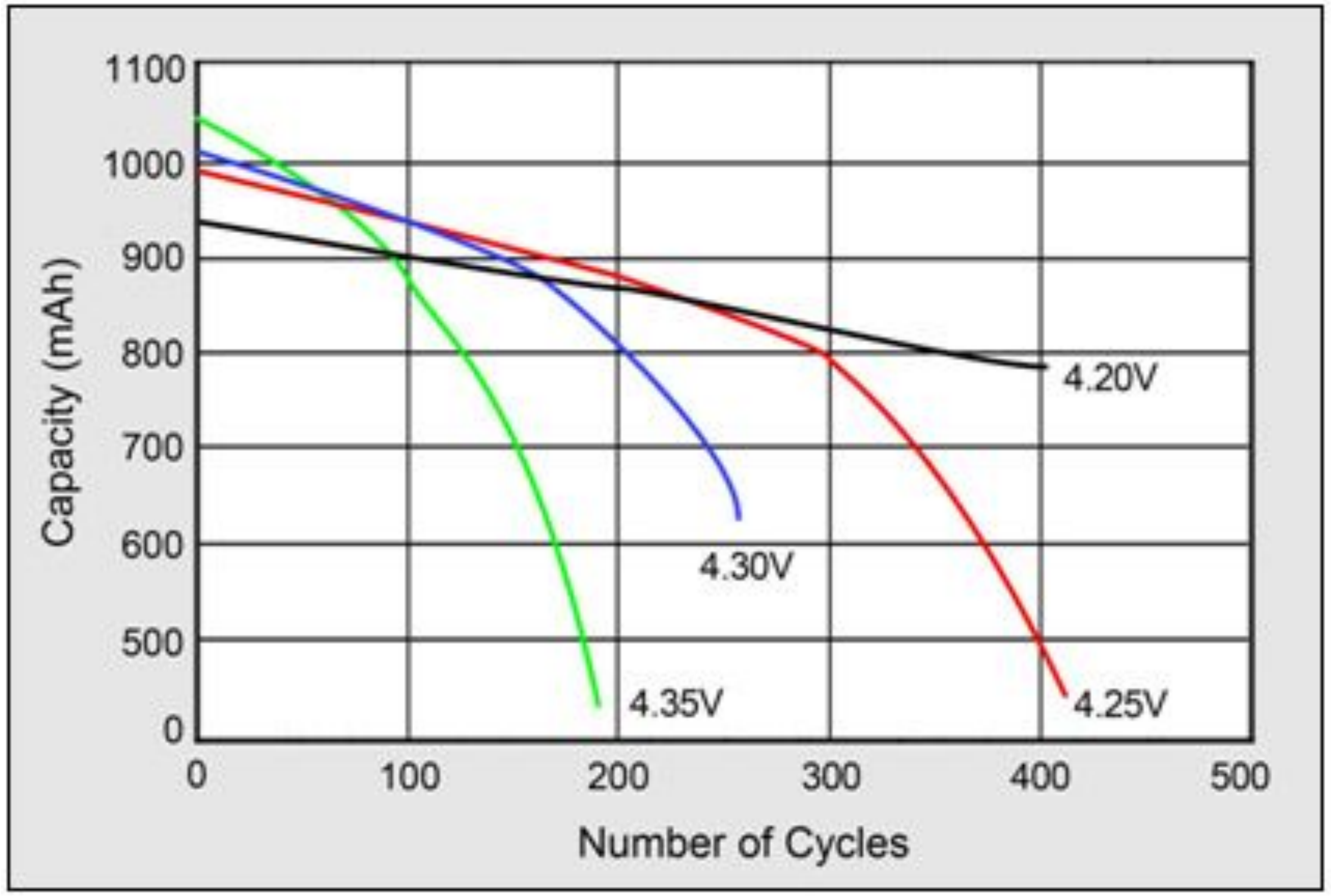
Most consumer-grade lithium based batteries have a life of 300-500 cycles.

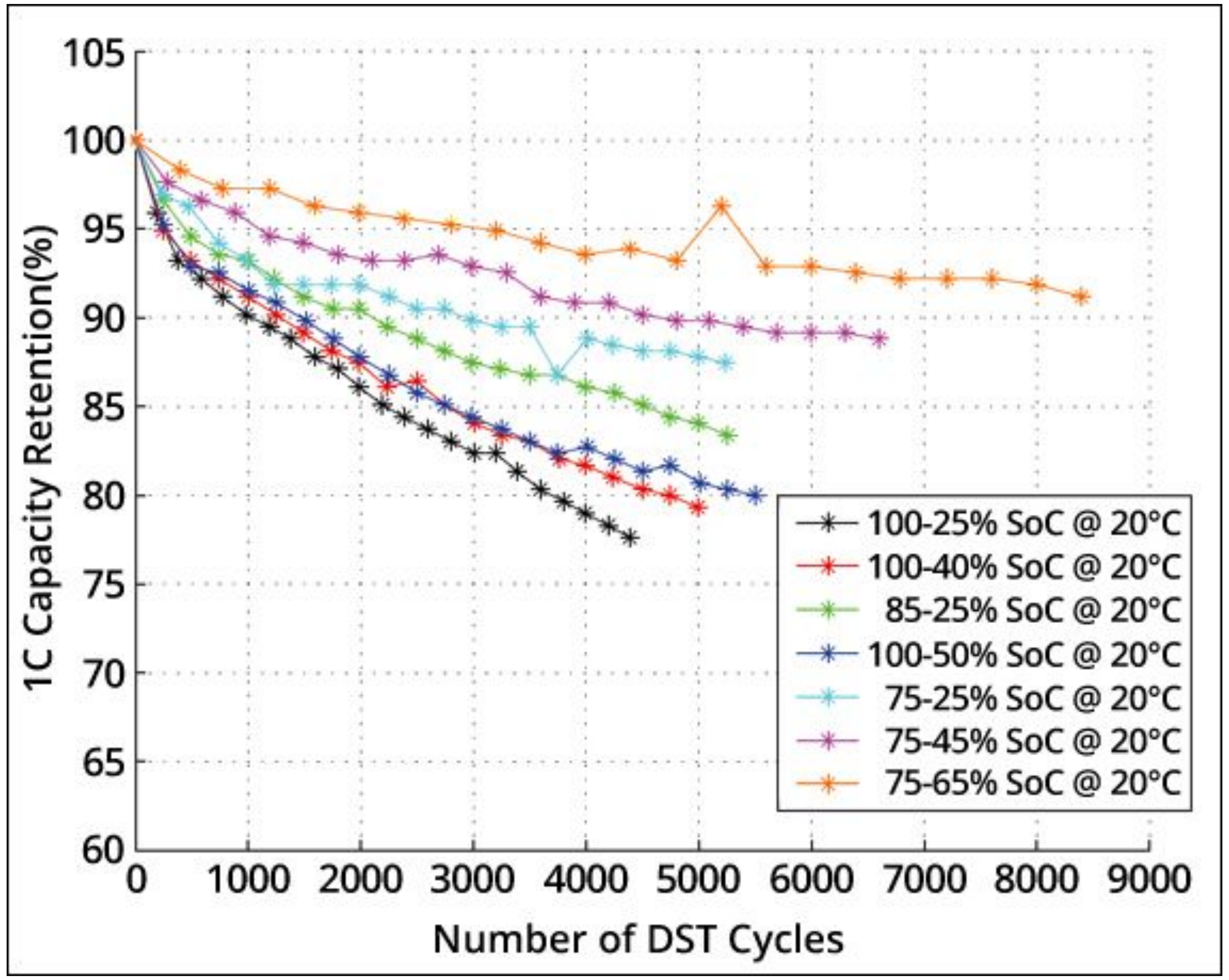


Eleven lithium batteries tested for 250 standard cycles.
Battery University, 3 November 2021.

Understanding Battery Degradation (cont.)

Cell voltage and depth of discharge have an effect on battery capacity.





Effect of cell voltage excess (4.20V is nominal for these cells) and depth of discharge on battery capacity.
Battery University, 3 November 2021.

Combating Battery Degradation

Multiple steps can be taken to delay battery degradation:

- Store the battery at room temperature.
- Use the charger that comes with the battery.
- Avoid discharging the battery completely.
- Avoid storing batteries at full charge.
- Periodically charge and discharge batteries.
- Cycle batteries, use all of them.
- Avoid discharging batteries too quickly.
  - Maximum recommended discharge rate is given in “C”. Maximum discharge current: A = Ah*C.
- Store batteries in fireproof bags.

ENVIRONMENTAL ANALYSIS - SHAYLA

Environments in the Case of USRC Drone

The USRC drone will be operating under several different environmental conditions and risk such as, but not limited to:

- Varying wind conditions
- Varying weather conditions (rain, snow, etc.)
- Varying FOD conditions
- Risk of bird strike
- Risk of landing failure due to environmental factors

This presentation will focus on how varying environmental winds could affect the drone performance and trajectory.

Wind Environments

Varying wind environments pose risk to the structural integrity and performance of the drone.

If wind speed is too high:

- The drone could lose control and fail
- The drone could overwork itself, leading to overheating, and fail
- The structural integrity of the drone could fail and break
- The drone performance could drop, resulting in a lack of capability

So, with this risk and outcomes in mind, it is important to note the value of understanding the wind environments surrounding the drone.

Wind Model Breakdown

To properly model the wind affected drone, this simulation and analysis will utilize the case of a drone bound by a cable.

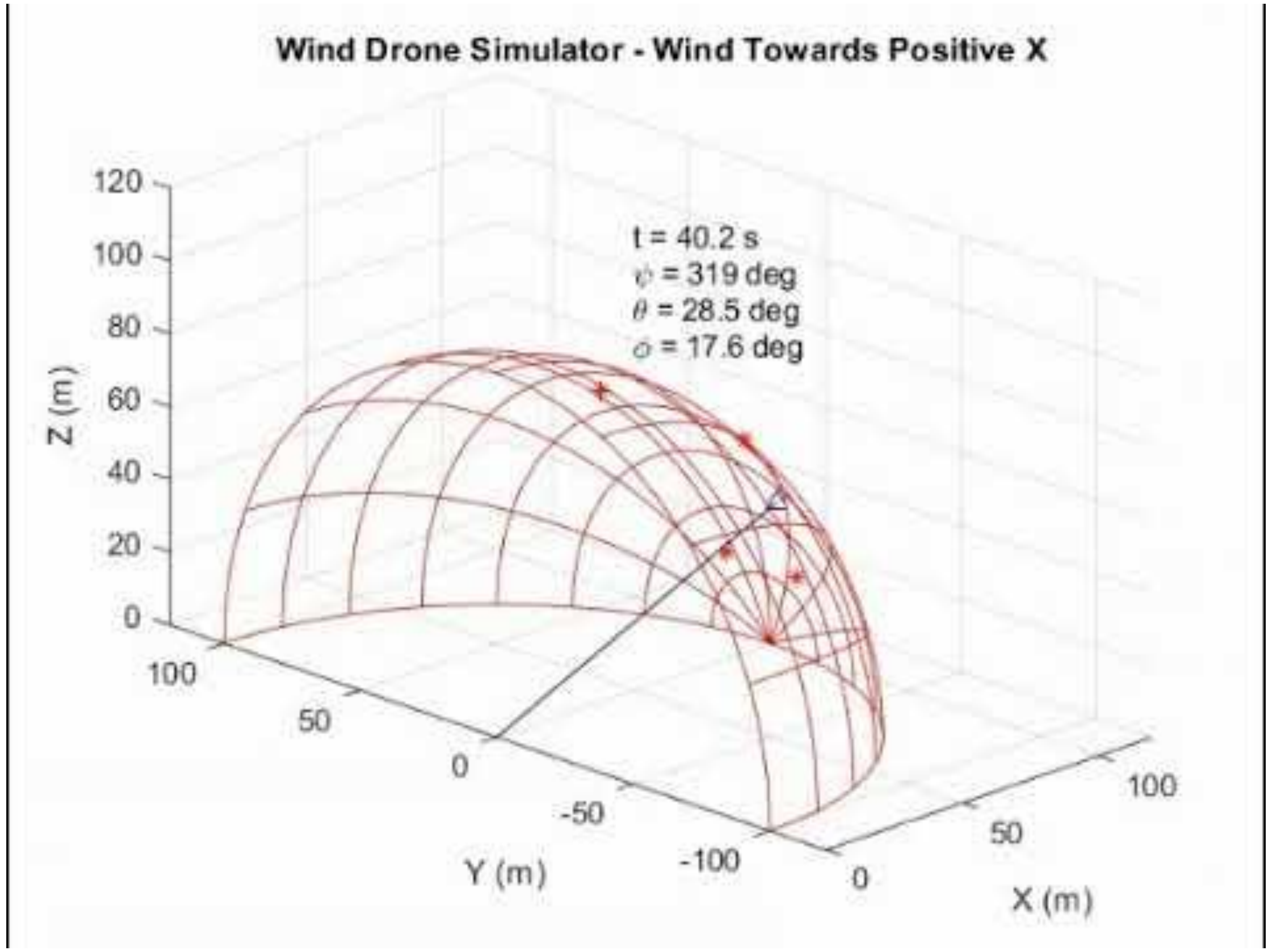
- This allows for angular calculations in order to find changes in amplitude

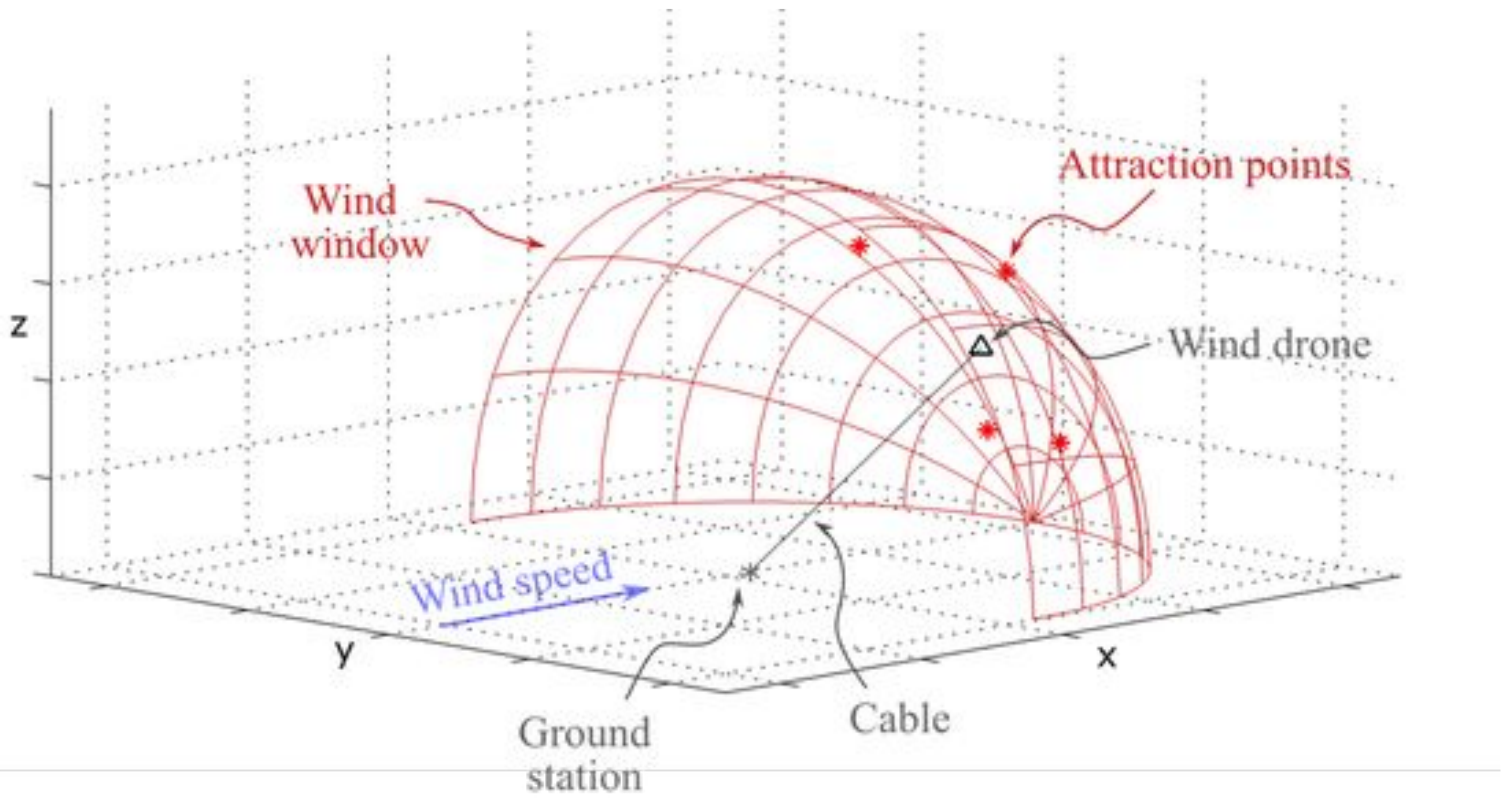
Wind speed will be pushing from the X direction, pushing the drone into the wind window and in the direction of the attraction points.

The wind window is the window in which the wind could potentially push the drone, and the reference system for the drone.

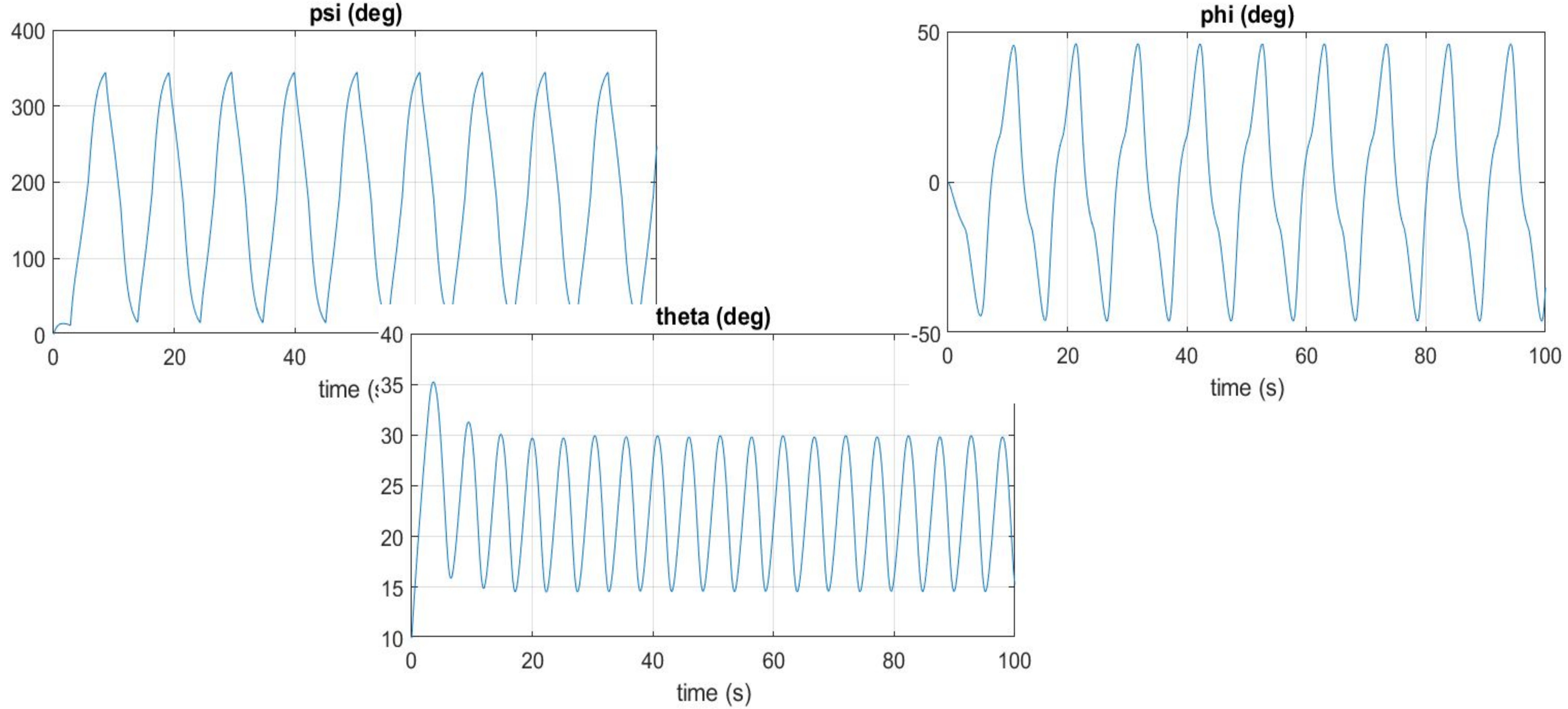
The attraction points are set to determine the wind heading, and are arbitrary.

Simulation Model Video

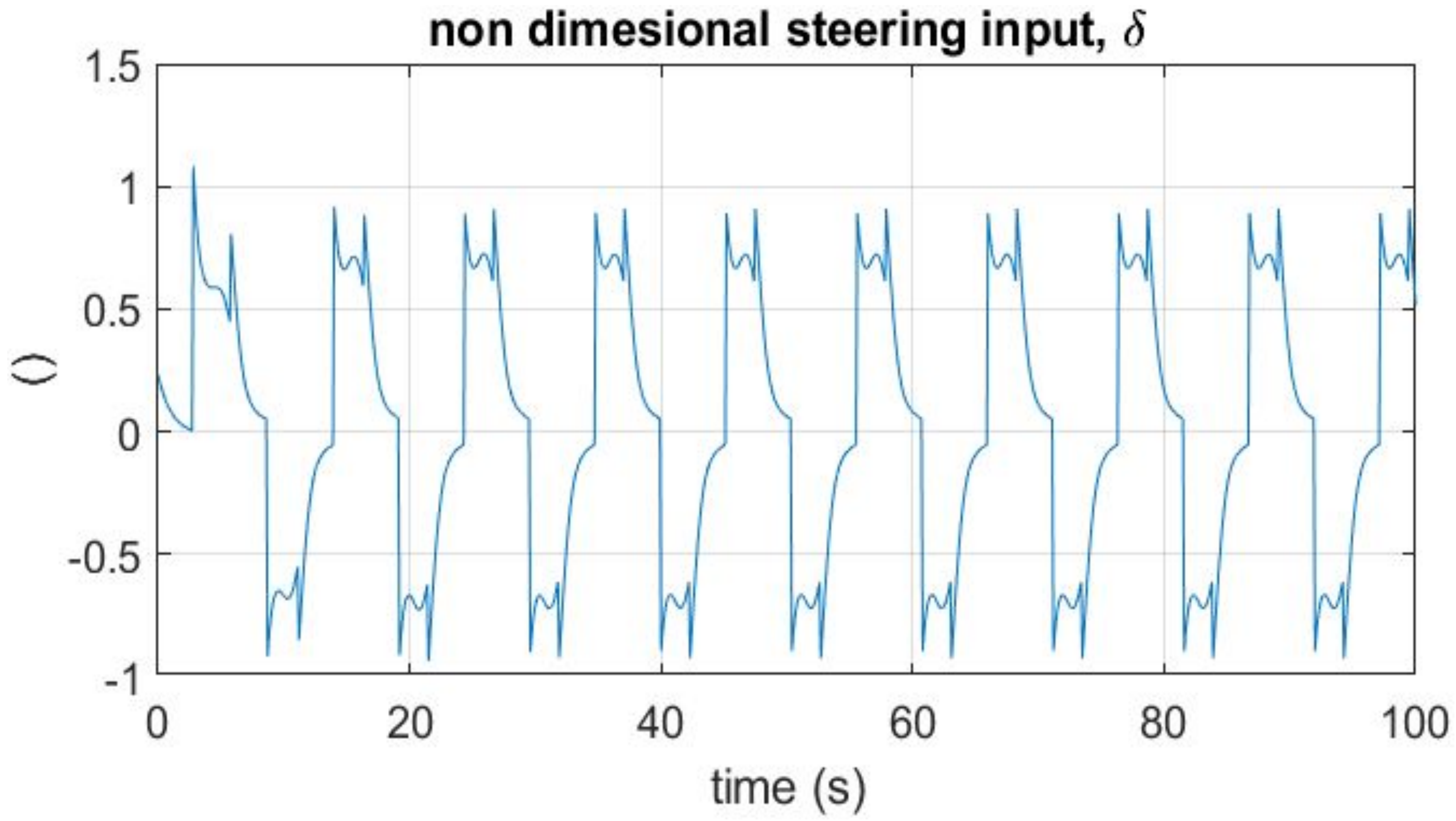


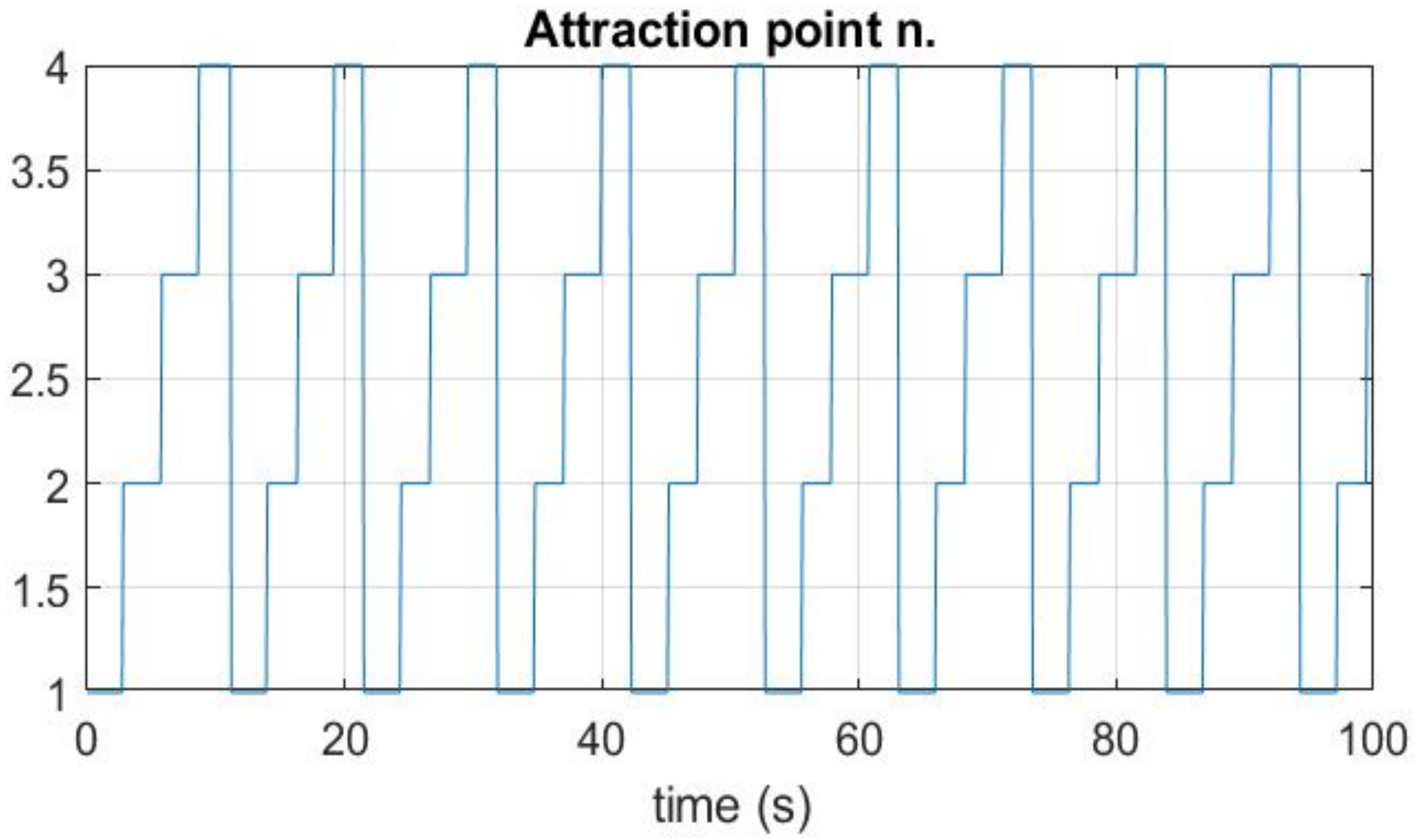


Simulation Results



Simulation Results - 2





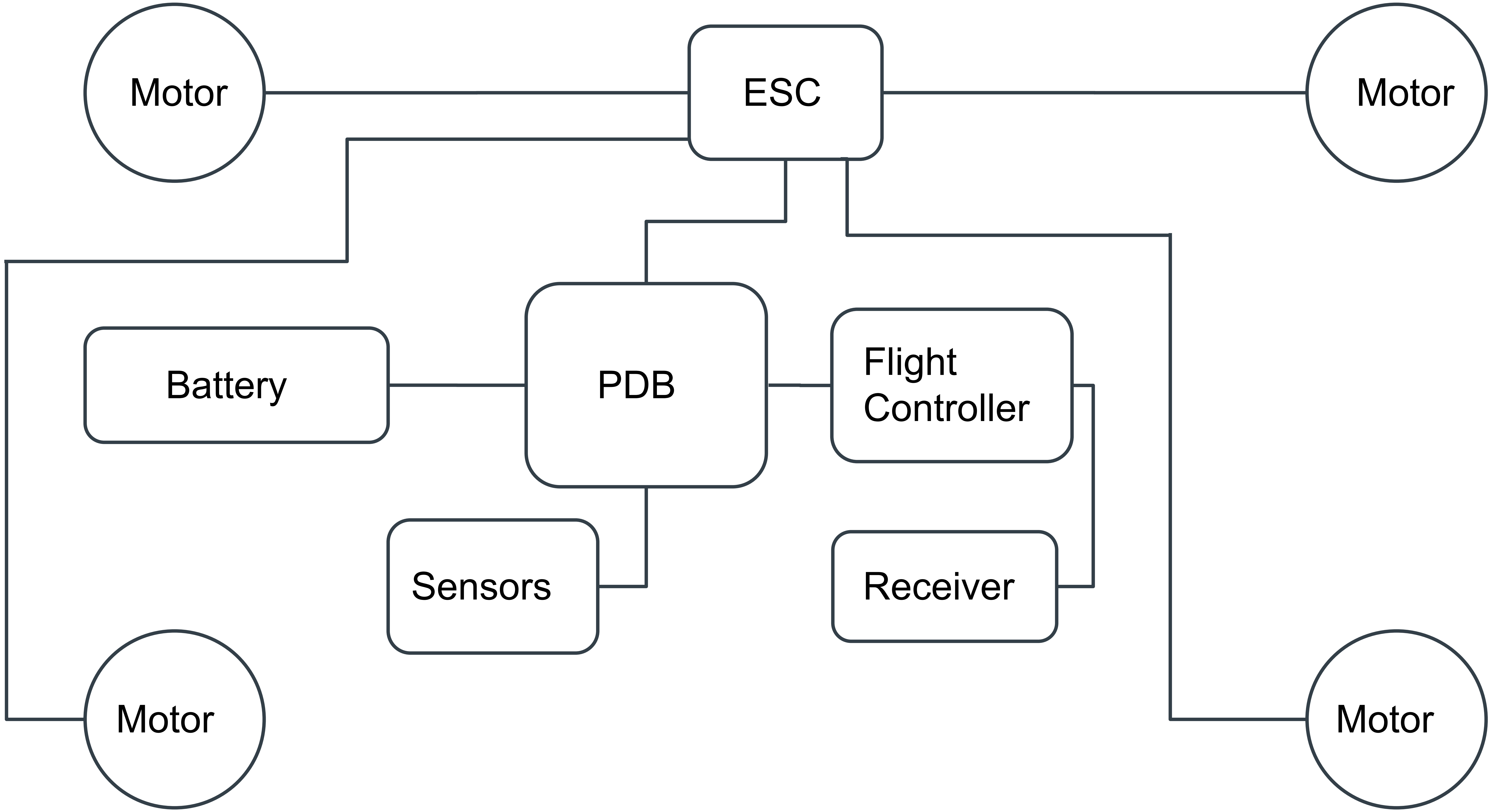
ASSEMBLY - LUIN/VICTOR/SHAYLA

Assembly

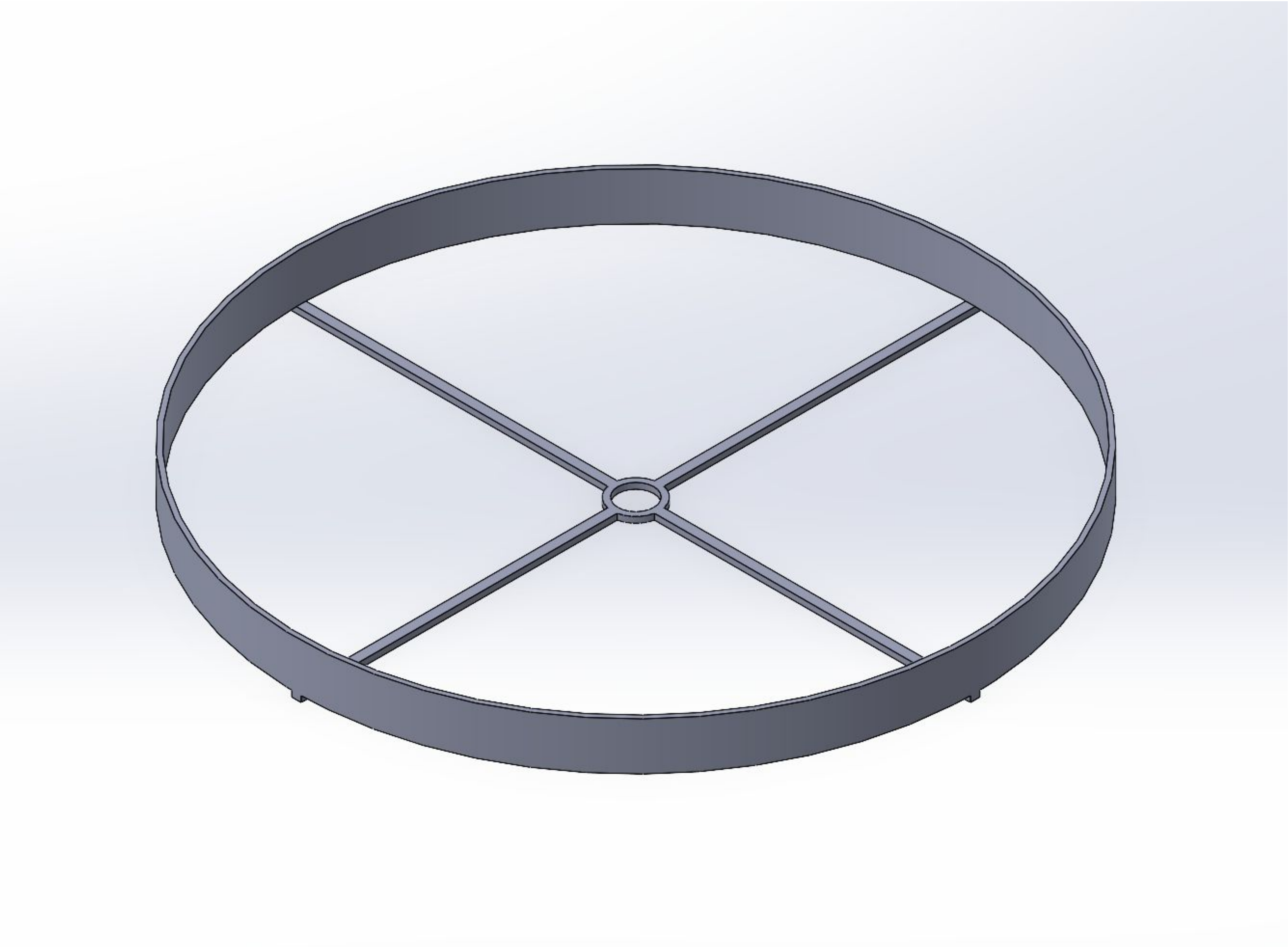
- Switched washer to below plate to provide enough clearance for motor bolts
- Potential unevenness of brackets above and below arm
- Feed wires through hollow arms
- Label the wires to ensure proper connection
- Attach propellers similarly on the diagonal

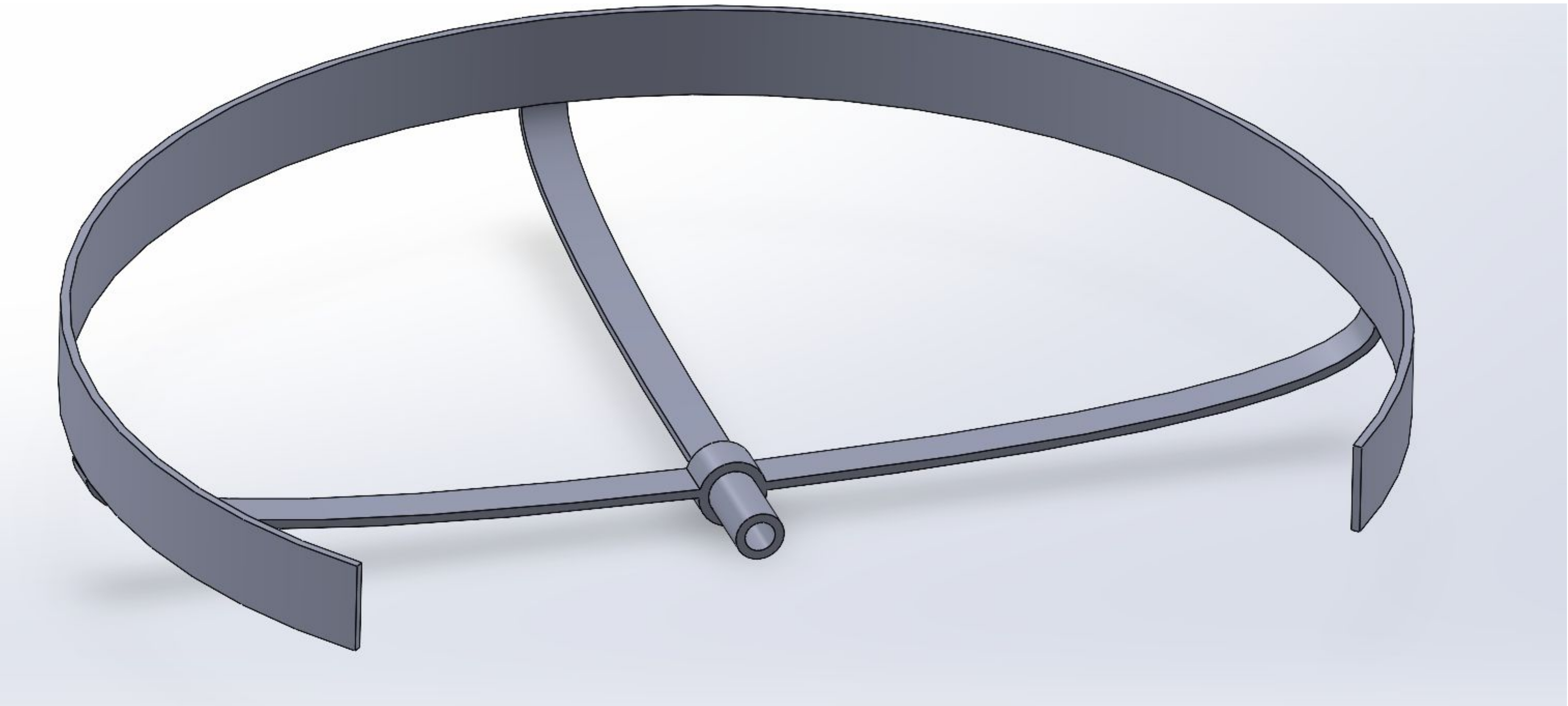
TEXAS AEROSPACE ENGINEERING AND ENGINEERING MECHANICS

System Block Diagram

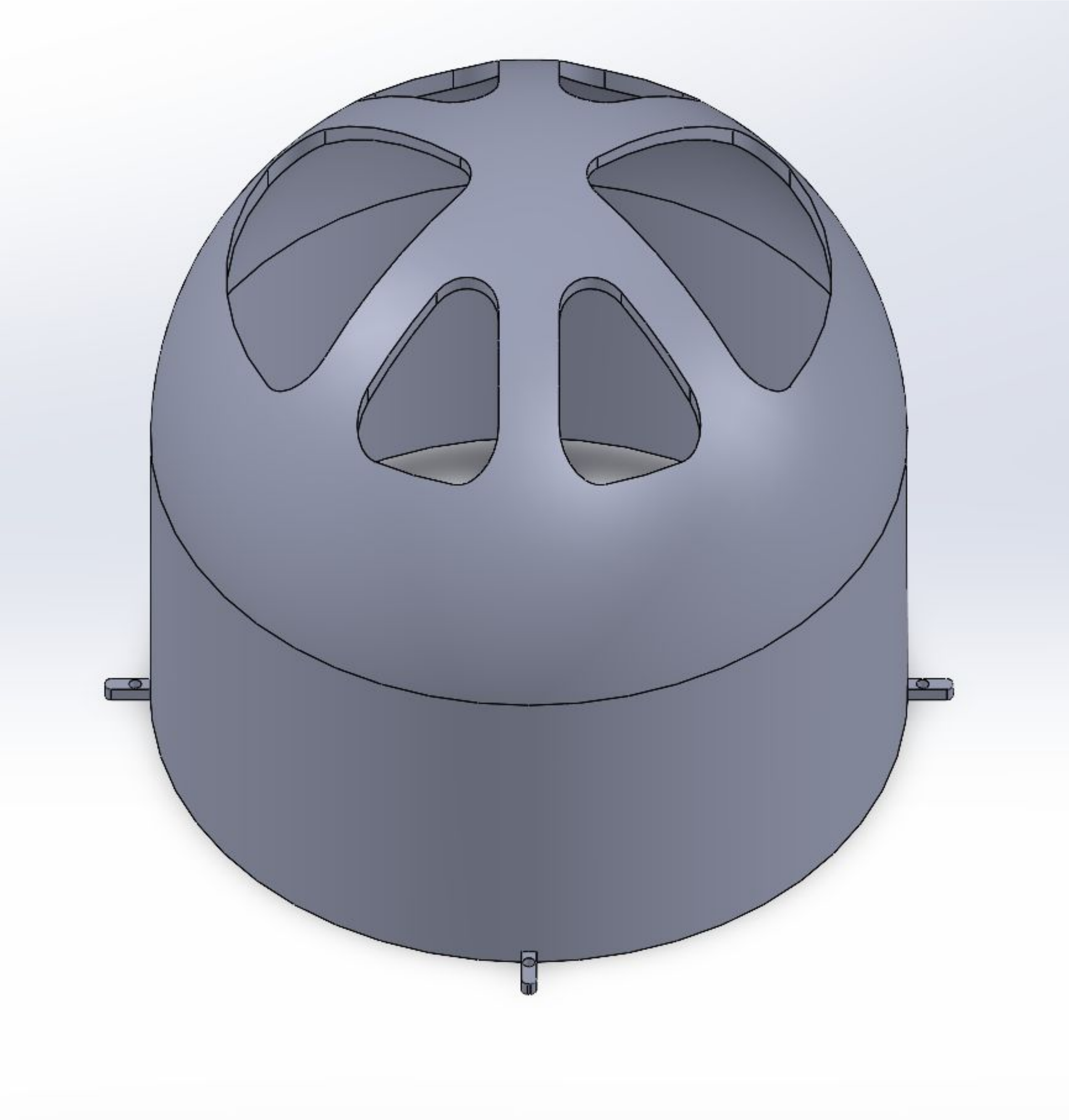


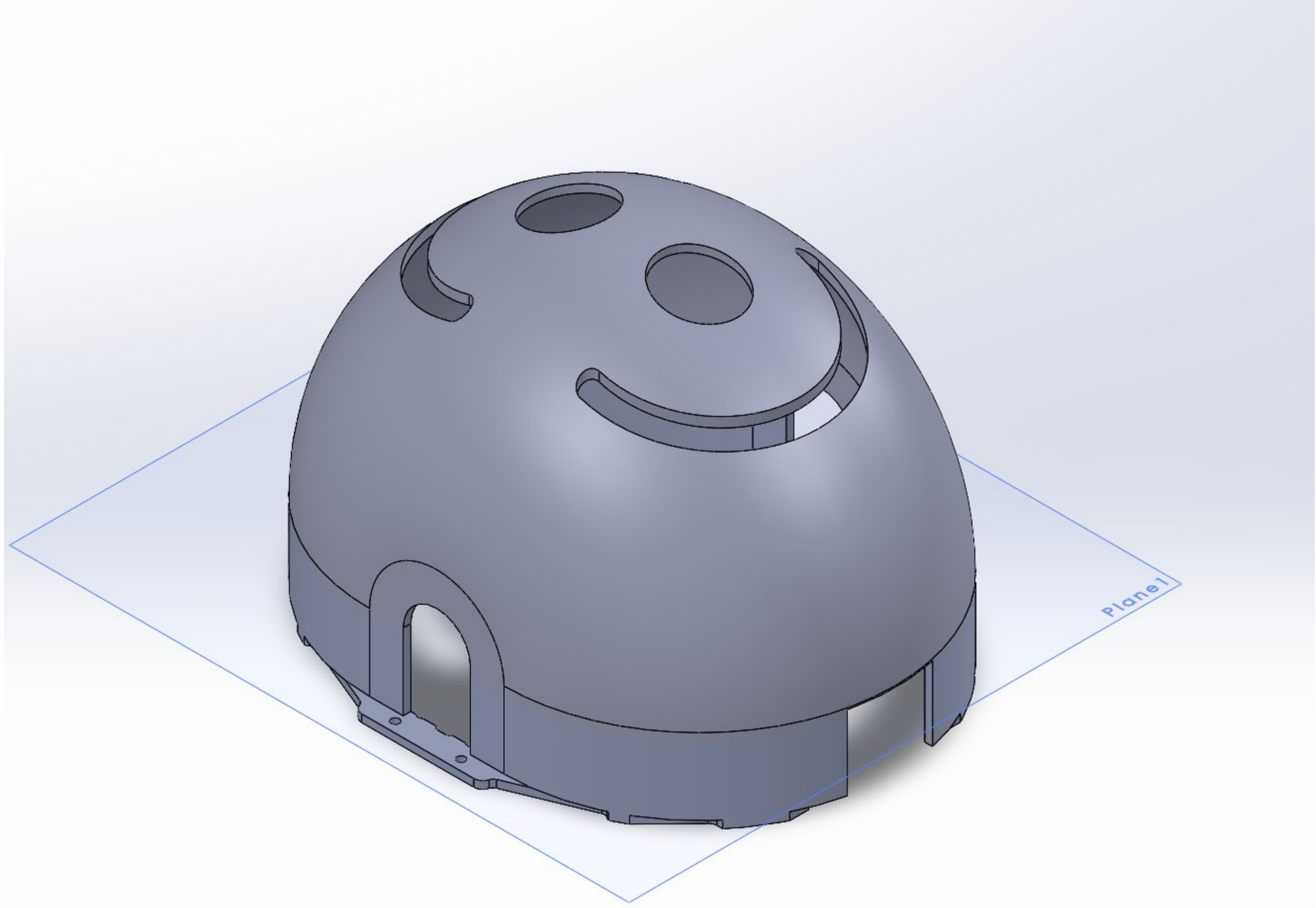
Rotor Guard





Drone Cover





SAFETY/REGULATIONS - AUDREY

Ethical and Legal Implications

Student Outcome #4: An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.

Per FAA Regulations Part 107 Subpart B Operating Requirements [1]:

- Always avoid manned aircraft.
- Never operate in a reckless manner.
- Always keep your drone within unaided sight.
- Do not operate drones from a moving vehicle unless flying over a sparsely populated area.
- Operations in Class G airspace are allowed without air traffic control permission.
- Operations in Class B, C, D and E airspace need authorization.

Ethical and Legal Implications Continued

Per FAA Regulations Part 107 Subpart B Environmental/Physical Constraints [1]:

- Fly during daylight hours (30 minutes before sunrise/after sunset) OR in twilight if the drone has anti-collision lighting.
- Minimum weather visibility is 3 miles from the control station.
- A maximum allowable altitude of 400 feet above ground or a structure.
- Maximum speed allowed is 100 mph.
- Drones can carry cargo as long as they are securely fastened and do not affect the flight characteristics and controllability of the drone.
- Drone must not exceed 55 pounds including payload.

Safety Concerns

- ***Drone Battery Dies While in Flight***
  Add in additional code that warns the pilot when battery life reaches a certain level and automatically descends when at minimal battery life. Professional drone companies such as DJI use this type of preventive software.

- ***Package Dropping***
  This issue is pretty broad and can be hard to combat. The best way to ensure secure package drop-off is to adhere to the FAA guidelines and research how other drone companies secure their packages in flight.

Safety Concerns

- ***Adverse Weather Conditions***

  Flying in rain is not encouraged, especially since it hinders visibility of cameras on board and can damage non-waterproofed equipment.

  To assess whether a drone should be flown in wind, check the handbook of your drone model or use this simple approximation:

  Maximum wind speed = Maximum speed of the drone / 2

  Cold weather can impact battery performance and shorten flight time. Store the battery in a warm place.

Pilot Certification

- ***Drone Cage***

  The FAA does not regulate "indoor airspace," therefore a certification is not needed for beginning testing stages.
- ***Recreational Flying***

  When testing eventually moves to general airspace, most likely Austin Radio Control Association, The Recreational UAS Safety Test (TRUST) is required. It is free and takes 15-30 mins. Additionally, any drone over 250 grams needs to be registered with the FAA and is valid for 3 years.
- ***Commercial Flying***

  In order to fly your drone under the FAA's Small UAS Rule (Part 107), you must obtain a Remote Pilot Certificate from the FAA.

DISPOSAL OF HARDWARE - AUDREY

Disposal of Hardware

Disposal Procedures:

1. Disassemble the drone into the following categories:
    a. Carbon (frame), plastic, metal parts (screws, bolts, etc), wire, electronics (flight controller, ESC, motors, camera, sensors), batteries.
2. Contact your local waste management and recycling centers for proper waste disposal or consider reselling certain parts.

Drone Optix - a company that buys used drones, refurbishes, reuses, and recycles drone parts. You can either donate or make a profit off of reusable parts.

Long Term Planning

When looking ahead there are several plans which will drive actions forward, such as:

- Evaluate the prior design and move forward with redesign if necessary
- Building up a new drone
    - Procure new hardware
    - Rewire sensors in order to optimize the drone
- Develop long lasting hardware plans for optimizing upon developmental testing drones

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THANK YOU.

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