# CITRIS Aviation Prize 2021 Proposal

## University of California, Santa Cruz

**November 19th, 2021**

Ahmed Alazzawi, Duseok Choi, Will Daschbach, Jonathan Hartley,
Danielle Laganiere, Jason May, Richard Owens, Atharva Ranadive

**Abstract:** With many bodies of water in remote and hard to reach locations, sending a hydrologist out to conduct water quality assessments can be difficult and time consuming. A UAV payload can be designed with a multiparameter water quality probe (aka "sonde") to reach these remote bodies of water much easier than a hydrologist on foot can and collect useful data from a wide range of points along the water's surface. However, current UAV technologies lack the ability to hover for long periods of time while also maintaining a long vehicle range, characteristics necessary for this application of hydrology research in remote areas. A lighter than air UAV would eliminate the costly energy consumption of hovering and enable the craft to travel longer distances more efficiently.

## Table of Contents



## I. Environmental Survey

### A. CONOPS

In order to satisfy the environmental survey requirement for this competition, our team worked with Assistant Professor Margaret Zimmer of UCSC's Earth & Planetary Sciences Department to design a survey plan that will utilize a multiparameter water quality sonde to collect water quality data from Lexington Reservoir. This payload will consist of the aforementioned water quality sonde as well as a winch for the delivery method.

### B. Water Quality Sonde

Our team has chosen an In-Situ Aqua Troll 500 Multiparameter Sonde for the payload's sensor package. This Multiparameter Sonde is user configurable allowing for versatility in the area of water quality assessments. With the guidance of Professor Zimmer, The following water quality parameters have been selected: Temperature, Conductivity, Rugged Dissolved Oxygen, Ammonium, and Nitrate. All of these measurements can be taken in less than a minute.

### C. Payload Delivery Method

Delivery of the sensor payload will be facilitated by a winch. This winch will deploy the sensor to a depth of 5 feet for data collection and include a mechanism for retracting the sensor along the length of the drone's hull to minimize drag. A float will be attached to the deployment line so that the weight of the sensor payload can be transferred from the drone to the float while measurements are being taken.

### D. Survey Area

The survey will be conducted on the Lexington Reservoir which is a 450 acre reservoir in Santa Clara County. It is located in the Santa Cruz mountains along a section of State Route 17. While 450 acres is larger than the asked for 200 acres, it should be noted that the reservoir only has a surface area of 450 acres when it is full. The surface area of the reservoir in Figure 1 below is actually closer to 220 acres as the satellite imagery of the reservoir was captured when it was at a reduced capacity. Following the guidance of Professor Zimmer, we plan to probe 20 spots along the reservoir as shown in Figure 1.

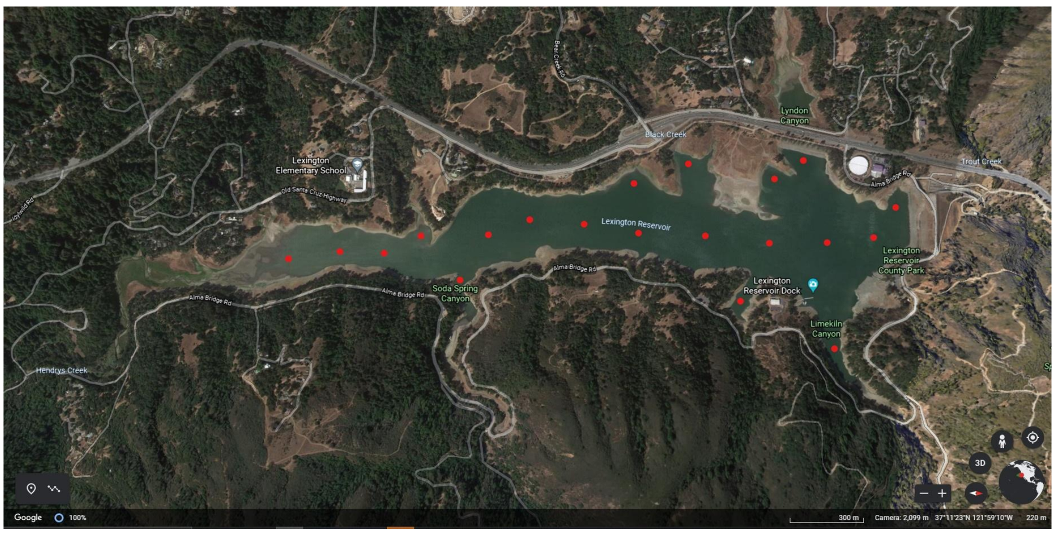


Figure 1

## II. Location & Route Selection

### A. Location

The location settled on by our group is the Lexington Reservoir and its immediate surroundings. As described in the Environmental Survey section, Lexington Reservoir falls into Santa Clara County and is located in the Santa Cruz mountains along a section of State Route 17.

### B. Route Selection

Our selected route will be a 5 mile loop that starts at the James J. Lenihan Dam and will loop to each of our control points. Figure 2 below depicts the route including our three control points.

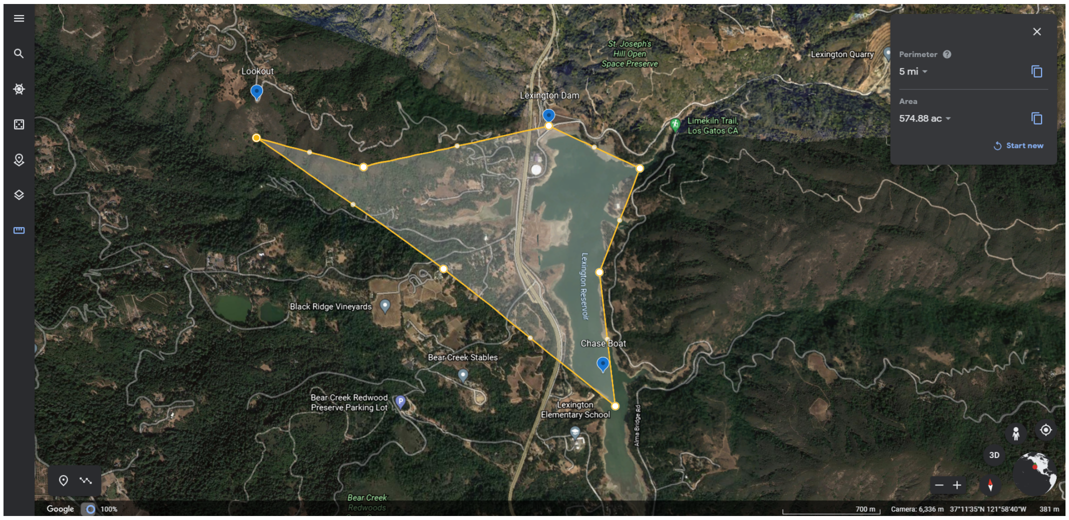


Figure 2

### C. Control Points & VLOS

We intend to use three control points for our flight demonstration. The first will be stationed at the James J. Lenihan Dam, second at Lover's Point which provides a spectacular view of the area, and the third will be a mobile control point in the form of a rented boat on Lexington Reservoir. Between the three control points there are no spots along the route where VLOS with the drone would be in excess of ⅔ of a mile.

In order to facilitate a safe "hand-off" of drone control between our control points, we will utilize the following procedure. First, the next control point will connect to the drone while the previous control point is still connected. Second, once the next control point's connection is secured, that control point will radio with walkie-talkies to the previous control point to disconnect from the drone.

## III. Vehicle

### A. CONOPS

For a vehicle to perform this endurance flight while also having the ability to hover for water quality sampling, our team has chosen a semi-buoyant hybrid airship design. The airship relies on lift generated from lighter-than-air gas envelopes to reduce the effective weight of the vehicle during a hover. With concerns for vehicle size, the weight offset from the gas envelopes will not be equivalent to the weight of the vehicle itself. Our airship design incorporates two mechanisms that allow for this weight gap to be managed without direct VTOL propulsion: Firstly, when the payload package is lowered into the water an attached buoy will hold the payload's weight (and their own) reducing the weight of the vehicle itself, allowing the gas envelopes to render the vehicle buoyant in the air. Secondly, this airship differs from a conventional blimp or zeppelin in its semi-rigid air-foil like shape that allows the vehicle to generate lift in-flight that will more than cover the effective weight of the vehicle.

### B. Airframe

The main structure of our UAV is divided into the tail, gondola, and envelope. An exoskeleton made of carbon fiber will support the airship's semi-rigid PU Nylon envelope and will be shaped to produce aerodynamic lift during forward flight. The tail section will utilize foam core for both the stabilizers and control surfaces.

### C. Power

As calculated in *Ballpark Vehicle Metrics* in the Appendices, the vehicle will require ~3.5 kWh of energy for the 115 mile flight alone. With an additional 45 minutes of flight time in reserves post-flight, this energy requirement increases to ~4 kWh of energy not including the energy expenditure during the ~10-20 minutes of hovering/flight during the environmental survey.

In regards to power storage, battery mechanisms are not feasible to hold this quantity of energy without a significant cost in weight. The higher end of a Lithium Ion's battery's specific energy (energy stored / weight) is 0.250 kWh / kg. To store 5 kWh of energy the vehicle would need ~44 lb of batteries. Gasoline on the other hand has a specific energy of 12.88 kWh / kg. At 20% engine efficiency, the vehicle would only require less than 5 lbs of fuel for the entirety of the trip. Therefore, our team opted to use a hybrid gasoline-electric power system, in which gasoline engines will be used to power all primary propulsion (see *Propulsion & VTOL*) and a battery will be used to power secondary propulsion (see *Propulsion & VTOL*), control surfaces, OBC's and the payload's winch. We believe that the additional weight of the fuel, motors and any structures and safety mechanisms will be less than the minimum of 44 lb required if the system were strictly battery operated.

A battery's power requirements for the vehicle are still to be determined and require further design validation to be safely estimated. However, we have allotted a budget of up to $2000 for batteries if necessary and a weight budget of up to 5 lbs, given the specific energy of Lithium Ion batteries we believe this will be sufficient for control system operations, OBC's, and a ducted fan that will be used only during the environmental survey.

Our team investigated the idea of using a fully electric system and incorporating solar panels to bring down the potential weight of batteries, however the weight of the solar panels would add such a significant amount of weight that the vehicle's size would need to increase to contain enough Helium gas to remain relatively buoyant. Solar panels also significantly limits the operational environment of the vehicle as full sun would be needed to be sustainable. Considering the environmental survey's application is likely flying to remote regions to collect water data, we cannot ensure perfect weather or a recovery mechanism if the weather were to change to a point where the vehicle cannot return home. Lastly, the team would like to experiment with using the engine exhaust to superheat the lift gas in order to increase our max potential buoyancy.

## D. Propulsion & VTOL

As mentioned in *Power*, our vehicle will have two propulsion mechanisms: primary and secondary propulsion. Primary propulsion will be responsible for VTOL capabilities and in-flight thrust whereas the secondary propulsion will be used for maneuvering while buoyant.

The primary propulsion system will consist of two gasoline powered motors with propellers. These will be located on each side of the vehicle oriented in the forward direction, though with variable pitch allowing for VTOL capabilities. These two propellers will be forward on the vehicle but at the same height as the center of buoyancy of the vehicle when the propellers are oriented upwards (for VTOL and hovering) such that the vehicle's buoyancy acts to stabilize the hover of the vehicle.

Each engine chosen will have a maximum power rating of 3 HP, putting our maximum flight speed at 40 mph and our 20 mph cruising speed at ~15-20% throttle. If there is additional space in the weight budget for fuel, our engines will be able to deliver a cruising speed of 30 mph at 50% throttle. The total expected weight for each engine and propeller is 3.3 lbs, we will be assuming a total weight of 8 lbs for the primary propulsion including both engines, propellers, mufflers, starters and for pivoting transmissions. Each engine and transmission system are expected to cost no more than $1000. Lastly, we will be constructing rings or cages around the propellers due to FAA Category Two guidelines.

The secondary propulsion mechanism will be a ducted fan located on the belly of the vehicle, under its center of gravity. This fan will be able to vector 360 degrees by pivoting around its axis, "pulling" the vehicle in the direction that the fan is pointing. Because the vehicle is buoyant during it's payload-lowered hover, the vehicle will not tip from the torque caused by this fan. Our ducted fan will be low power, as it will operate directly from the battery. A 0.5 HP ducted fan will be chosen weighing less than 0.5 lb, totalling to 1.5 lb including the one-axis 360 degree gimbal system.

### E. Control

Onboard control systems on the vehicle will cover all attitude control and trim except for a roll control scheme. Because of the buoyant nature of the vehicle, the stability about the forward facing axis will be created from the helium lift gas. While this makes the roll attitude of the vehicle stable, it also complicates roll ability from ailerons.

The yaw of the vehicle will be controlled through the differential between the two outwing propellers as well as with a rudder control surface attached to a fin on the rear of the vehicle, with the rudder being primarily used during cruise. The pitch of the vehicle will be more challenging to control than on a traditional fixed wing aircraft again due to the buoyancy of the vehicle. We chose to have redundant control via two methods: an elevator in the tail section of the vehicle for cruising speeds and a water ballast system, where one pound of water can be pumped from tanks at the front and rear of the vehicle for trimming the pitch. We anticipate the total weight of this ballast system to be about 2 pounds.

### F. Communication and Command

We will primarily be communicating between the UAV and the Remote Pilot In Control (RPIC) with 433 MHz telemetry and 2.4 GHz control links. 5G communication needs more equipment and will be covered in the following section. The RPIC will have access to a joystick/gamepad (USB) for the purpose of manual control and a Graphical User Interface (GUI) software to display a live video feed and the telemetry information of the UAV. Our Telemetry module will be relaying the necessary telemetry information and will be serial connected to the flight controller. (The **433 MHz PixHawk / Ardupilot telemetry kit** contains all the parts we need for this portion**)**. We will also have a Radio Control Receiver for the purpose of remote piloting in the case the autopilot fails. The radio receiver module(Rx) receives the signals for the flight controller and will be connected to one of its ports and the remote-control transmitter (Tx) will be sending PPM signals in 2.4 GHz and be connected to the RPIC, **(FrSky X-Series receiver)**.

### G. 4/5g Connectivity

The future of unmanned aircraft includes a completely connected traffic management system and our project builds toward it by incorporating 4/5G connectivity into our design. 5G connection is easy enough to set up with purchasing the right hardware, but the real difficulty with a constant 5G connection is the power consumption. This is especially evident in the smartphone industry where battery life is imperative, and with our long flight time, it is also of utmost importance to our design. To accommodate this strain of power on our system, we plan to implement the addition of a **5G mobile handset** to our design. The Mobile phone will be the 5G gateway of the UAV and our flight controller will receive the data from the 5G network through it. The battery life to 5G connectivity ratio in the current generation of phones performs better than anything we could design.

Additionally we need to include a mini-computer for interfacing purposes between the 5G mobile phone and the UAV flight controller. A **Raspberry Pi3 Model B+** would be lightweight and have low power consumption.With 4 USB ports, less than 45 grams and max 2.5 A current draw, it will fit our needs perfectly. The onboard computer will run MAVProxy, a specialized software that will be configured to forward MAVLink messages of the Remote Pilot In Control (RPIC) to the flight controller and vice versa. We will also have an HD Camera connected to the Raspberry to have video streamed to the RPIC and our Emergency Landing and Obstacle Avoidance computer vision software. (It will be connected to the Raspberry's Camera Serial Interface (CSI) using a ribbon cable.) A **Raspberry Pi High Quality Camera - 12MP** with a **6mm 3MP Wide Angle Lens** will suffice.

### H. Autonomous Flight

The team will use a Pixhawk4 board as the main flight controller module in order to manage the trajectory of the airship, utilizing Ardupilot, a free open source autopilot software, to control the path planning aspect of the mission. The software will be fed the desired trajectory as waypoints, which are pre-selected and inputted from a separate machine, either before the flight or incrementally to the flight controller via microcontroller. In order to realize the desired path, the flight controller also receives data from the connected sensors, including GPS, Gyroscope, Accelerometer, Magnetometer, and Altimeter, and runs the readings through the Ardupilot software to generate the necessary path following commands. These commands are eventually converted into control signals that are sent to the control surface drivers. If required, the aircraft's telemetry data can be extracted from the controller's telemetry ports. When the RPIC has to take control of the aircraft in case of emergency, the RC receiver is routed through Pixhawk to the control surfaces.

### I. Emergency Landing and Obstacle Avoidance

Before a problem can be solved, it first must be known. To detect emergency situations, (like hardware, software or external conditions), we will implement a separate software system to check for potential emergency situations at a specified interval. The system will take data from our sensors and commands and determine if they are differing enough to raise an emergency flag to initiate emergency procedures.

In an emergency, the drone uses computer vision to avoid obstacles in its way and to find a suitable location to land. These tasks would be handled by two separately trained models, running on a Nvidia Jetson. First, for obstacle avoidance, the YOLO (You Only Look Once) algorithm, is optimized for real time applications. Although the algorithm originally runs at 45 frames per sec, accuracy can be traded for speed to give 115 frames per sec.

Once the emergency has been detected and our computer vision software has determined a safe landing spot, the next goal is to guide the UAV to the landing zone. If the UAV is nonfunctional in some capacity that normal flight controls (FC) will not be able to fly the aircraft, then we will have the FCs switch to an emergency version. The emergency FCs will account for whatever parts are nonfunctional and attempt to land the UAV safely. The pros of a blimp like UAV is that the descent of it will be slow. Additionally, there may be some cases where it would be best if the RPIC were to manually take control of the UAV.

## IV. Operational Requirements & Safety

### A. FAA Part 107 & Location Specific Regulations

In our team, at least three members are going to take FAA 107 license tests for the fly operation. Duseok Choi and Jonathan Hartley are finalized members who have applied for the UCSC CIDER Undergraduate Drone Pilots in Training and Mentoring program for winter quarter which awards the FAA 107 license. A third team member will go through the process of acquiring the FAA 107 license before our demonstration flight.

Additionally, the weight of the drone should not exceed 55lbs. Since the vehicle weight is estimated to be between 37 lbs and 45 lbs, this limit is not surpassed. One person who has an FAA 107 license must be in charge of registering drones. In order to share the registered drone with members with FAA107 license, we must have a paper or digital copy of drone registration certificate for proof. The chosen survey location requires a permit to fly over and the drone will require registration, both of which cost a small fee.

### B. FAA Part 107 Operations Over People

To satisfy FAA Part 107 Operations Over People, three vehicle design requirements must be met: Firstly, the vehicle "Will not cause injury to a human being that is equivalent to or greater than the severity of injury caused by a transfer of 11 foot-pounds of kinetic energy upon impact from a rigid object."

Our design inherently minimizes any rigid impact due to it's non-rigid design. Assuming the vehicle maintains its lift from Helium, the vehicle must remain under 7 mph upon a rigid component's impact with a person to satisfy the requirement. Even if the lift bag is punctured, the vehicle does not immediately lose all helium inside of it, giving time to descend before too much leakage from the vehicle. The rigid portion of the vehicle, being the hanging gondola, will be the only object without the soft gasbag between it and the direction of a controlled descent, therefore, the vehicle will include a compressed CO2 cartridges and airbags on the bottom half of the gondola to prevent any rigid impact. A parachute was considered, however after rough calculations, to slow the vehicle down to less than 7 mph on impact, the parachute would need to be 40 feet in diameter weighing ~20 lbs, putting the vehicle's weight over the FAA 55 lb limit.

The second requirement, "Does not contain any exposed rotating parts that would lacerate human skin upon impact with a human being," is satisfied through the use of a ducted fan for one propulsion mechanism, and rings or cages around any exposed propellers. Lastly, the team will be free of any safety defects that could cause harm to any person, satisfying the third requirement.

## C. Safety Management Plan

While there are many variable risks associated with the flight, some important risks-to-note and their mitigation plans are below. Probability and severity are on a scale from 1-5, with 5 being very unlikely and very severe.

| Risk | Probability | Severity | Mitigation Plan |
|---|---|---|---|
| Engine Failure | 4 | 5 | Severity mitigated via multiple, separate engine systems. Due to the buoyancy of the vehicle, it could likely operate on one propeller via manual control. |
| Helium Leak | 2 | 3 | Probability mitigated by using double-ply material. Severity can be mitigated through pressure sensors that can sense a leak and give the team time to emergency land. |
| Fuel leak | 3 | 3 | Severity mitigated through independent fuel containers for each engine. |
| Power Systems Failure | 5 | 5 | Probability and severity mitigated through redundant electrical systems including control via RC directly to the control surfaces and propulsion. |
| Low Fuel | 1 | 1 | Severity mitigated through fuel level detection via physical sensors & engine output live simulations based on vehicle dynamics. |
| Low Power | 1 | 1 | Severity mitigated through constant power readings and updates. |
| Structural Failure | 4 | 3 | Severity mitigated through redundant structural support critical areas such as the gondola, propulsion, and control surfaces |
| Obstacle Impact | 5 | 5 | Probability mitigated through obstacle avoidance and VLOS. |
| Payload System Failure | 3 | 1 | Severity mitigated via ability to fly to a safe landing point with payload in any state of operation. |
| Controls Surfaces Failures | 4 | 3 | Severity mitigated through redundant control techniques including hydraulic ballasts for pitch control and differential propulsion for yaw control. |
| Extreme weather condition(etc. wind and rain) | 1 | 4 | Severity mitigated through a double ply envelope. Probability mitigated through preflight weather checks. |
| Catastrophic Envelope Rupture | 5 | 5 | Severity mitigated with propellers' VTOL capability and can reduce falling speed drastically even when bearing full vehicle weight. |

# V. Appendices

## A. Ballpark Vehicle Metrics

### 1. Airframe Weight

To extrapolate some rough metrics of the vehicle's weight, we created a simple model of an airship of similar volume to the vehicle we intend to build. This model is not comprehensive and is only used to verify some very rough numbers for the weight of the vehicle. The model is a traditional tube-like semi-rigid airship filled with Helium for the sake of simplicity. This is effectively a cylinder with semi-spheres on each end.

With a diameter/height of 6ft and a length of 20ft from end to end. This puts the volume of the vehicle at ~537 cubic feet. Given that 1 cubic foot of Helium can lift 0.069lbs, the airship has a total lifting capacity of 37 pounds, of course not including the weight of the airship itself. Estimating a rough weight of the vehicle without any onboard mechanisms (propulsion, control surfaces, etc.) involves two components: a frame or skeleton, and the non-rigid envelope.

Firstly, the frame: Assuming a ribbed frame, with ribs every 4 feet along the length of the vehicle, and an additional two supports each stretching around the vehicle lengthwise, is approximately 200 ft of "rib" necessary. We opted to model these ribs after carbon fiber tent-poles, which weigh ~0.048 lbs/ft, putting the skeleton weight at about 9.6 lbs. From this estimation, we chose to allot up to 10 lbs for the skeleton to account for this ribbed structure on the actual vehicle.

The model material chosen is two ply PU coated nylon[1], very similar to the material used on the largest blimp ever launched, the ZPG-3W though with a nylon base as opposed to polyester. The surface area of our ballpark model, that contains the same volume intended to be used in our airship design, is 509 square feet. With the material weighing 0.016 (for two-ply) lbs per square foot, the total weight of the vehicle envelope is 8.14 lbs. For reference, one ply of this nylon has a bursting strength of 10.82 kg/cm^2.

Thus, the total airframe weight of our vehicle can be expected to be around 18.14 lbs for an airframe without propulsion and control mechanisms that has a volume of Helium capable of lifting 37 lbs. This gives a "weight budget" of ~19 lbs for propulsion, power, and control mechanisms to remain buoyant when the payload is dropped. This weight budget is excluding the payload's weight because the goal is to have the vehicle buoyant after the payload is dropped to minimize the size necessary for the vehicle.

### 2. Total Mission Power Requirement

To calculate the estimated power requirement of the vehicle, two methods to calculate in-flight power consumption were used. The first being through direct calculation and the second by using an FAA airship aerodynamics reference manual. In both cases, the same model used to estimate the actual vehicle's weight is used to estimate the power consumption.

Firstly, by direct calculation: The power required to cruise at a given speed is directly proportional to the drag that needs to be overcome at that speed. The equation for this drag is as follows:

$$D = C_d \cdot \frac{\rho \cdot v^2}{2} \cdot A$$

*Equation 1*

Where *Cd* is the coefficient of drag, *Roh* is the density of air, *v* is the velocity at which the vehicle is flying and *A* is the cross sectional area being swept out by the vehicle. The cross sectional area of the model is a circle of radius 3 ft, which is 2.54 m^2 or 27.3 ft^2. This value is increased to 3 m^2 or 32.3 ft^2 to account for any additional surfaces, such as wings or fins and to account for a hanging gondola much like a conventional airship. Reference airships from history were used for the coefficient of drag, and according to research by NASA, "the coefficients vary from about 0.045 for the small blunt airships

[1] Sonawane, Bushan, et al. "Material Characterization of Envelope Fabrics for Lighter Than Air Systems." 8 Aug. 2014.

to 0.023 for the relatively large slender Los Angeles[2]" For our estimations, we assumed the more inefficient coefficient of drag of 0.045.

To derive the power requirements necessary for a propulsion system to overcome this drag and operate at a specific cruising speed, the following equation was used:

$$H.P. = \frac{Thrust\ \{lbs\} \cdot Velocity\left\{\frac{ft}{sec}\right\}}{550}$$

*Equation 2*

Where *H.P.* is the output power of a propulsion system in horsepower, *Thrust* is the necessary drag force to overcome, and *Velocity* is the cruising speed of the vehicle. Using the drag calculated from *equation 1*, The output horsepower a propulsion system would need to provide can be calculated.

The second estimation of the output horsepower required by the vehicle was through the use of a reference FAA document titled Airship Aerodynamics from 1941 [3]. In this document, a general guideline for estimating power requirements of an airship is given:

$$H.P. = \frac{C_d \cdot \rho \cdot (Volume\ of\ Airship)^{\frac{2}{3}} \cdot (Cruising\ Velocity)^{2.86}}{550 \cdot E \cdot F}$$

*Equation 3*

Where *E* is the efficiency of the propeller and *F* is the percent of drag due to the hull specifically, vs due to control surfaces or a gondola for example. While this percentage is generally measured experimentally, the FAA resource offered various experimental values for this value, and a conservative average the team chose for our vehicle is that the hull itself will only account for 40% of any drag resistances, with the rest coming from other surfaces. The propellor efficiency chosen for the model was a 60% efficient propellor.

To maintain conservative estimates, the larger horsepower requirement from either method at a given speed was chosen, in all cases, this was the power estimate from the FAA guideline in *equation 3* which was larger by a factor of two at low speeds and a factor of 5 at higher speeds. Below are the rough power requirements to maintain various cruising speeds:

| | |
|---|---|
| ***For cruising speed of 20 mph:*** | *0.81 Hp → 604 W* |
| ***For cruising speed of 30 mph:*** | *2.59 Hp → 1931 W* |
| ***For cruising speed of 40 mph:*** | *5.91 Hp → 4407 W* |

Therefore, the power requirements to achieve a 115 mile range, not including VTOL, the environmental survey, and any additional flight time are:

| | |
|---|---|
| ***For cruising speed of 20 mph:*** | *3.47 kWh* |
| ***For cruising speed of 30 mph:*** | *7.39 kWh* |
| ***For cruising speed of 40 mph:*** | *12.69 kWh* |

Due to the nature of the environmental survey and VTOL, our team also expects the vehicle to be able to hover or nearly hover (only its effective weight after the buoyant gas lifts ~37 lbs) for ~10-20 minutes.

[2] Thompson, F L, and H W Kirschbaum. "The Drag Characteristics of Several Airships Determined by Deceleration Tests." NASA Technical Reports Server, 1 Jan. 1932.
[3] "Technical Manual of Airship Aerodynamics," War Department, pp. 1–66, Feb. 1941.

## B. Bill of Costs & Weight Budget

The bill of materials either contains specific items to be purchased or budget allotments for those items if they have not yet been defined.

| Item Name | Use | Qty | Units | Per Unit Cost | Total Cost | Estimated Weight |
|---|---|---|---|---|---|---|
| PU Coated Nylon | Envelope Material | 509 | Sq feet | TBD | $709 | 8 lbs |
| Carbon Fiber | Vehicle Structure | 200 | feet | TBD | $365.46 | 10 lbs |
| Raspberry Pi high quality HQ camera (12MP) | camera | 2 | each | $75 each | $150 | 0.34lbs(depends on the lens) |
| Engine, Prop, Transmission | Vehicle Primary Propulsion | 2 | system | $1000 each | $2000 | 8 lbs |
| Fuel | Vehicle Primary Propulsion | 5 | lbs | $0.56 in California | $3.30 | 5 lbs |
| Ducted Fan and Gimbal | Vehicle Secondary Propulsion | 1 | system | $500 Each | $500 | 1.5 lbs |
| Lithium Ion Batteries | Electronics Power System | TBD | each | $2000 Budgeted for total | $2000 | 5 lbs budgeted for total |
| Water Sonde and payload delivery mechanism | Environmental Survey | 1 | each | $6100 | $6100 | 6 lbs |
| Raspberry Pi3 Model B+ | 4/5G Comms | 1 | each | $35 | $35 | 0.1 lbs |
| LORD MicroStrain 3DM-CV5-25 | Inertial Measurement Unit | 1 | each | $500 | $500 | 0.1lbs |
| Slamtec RPLIDAR A1M8 2D | LIDAR sensor | 1 | each | $100 | $100 | 0.8lbs |
| 5G mobile handset | 4/5G Comms | 1 | each | $279.99 | $279.99 | 0.45lbs |
| 433 MHz PixHawk / Ardupilot telemetry kit | Comms | 1 | each | $56.79 | $56.79 | 0.04lbs |
| FrSky X-Series receiver | Comms | 1 | each | $20.99 | $20.99 | .01lbs |
| Total: | | | | | $12,817 | 45.24 lbs (overestimation) |