UAV Assisted Energy Delivery

PROJECT PLAN

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List of Definitions

UAV: Acronym for Unmanned Aerial Vehicle, such as a drone

FAA: Acronym for Federal Aviation Administration

LiPo: Acronym for Lithium Polymer, a type of battery

DroneKit: API (see definition of API) used to code drone

API: Acronym for Application Programming Interface

1 Introductory Material

1.1 Acknowledgement

With Gratitude and Enthusiasm, we thank Dr. Geiger, Dr. Chen, and the assistance from the ECpE department for the excellent advice that we were given over the project.

1.2 Problem Statement

At the current pace of technological advancement, more and more devices are requiring more energy to operate. Unfortunately, batteries and other energy supplying technology aren't advancing as rapidly. There's even the issue of a device might not even be connected to the power grid, which can be quite costly to connect. This is where our group comes in.

The goal of our team is to solve this energy problem and UAVs or drones are an excellent solution. The basic idea is for a network of drones to deliver energy to these remote devices. Our plan is to acquire a drone which we can customize and reprogram for automated flight. This drone will need to be able to fly from one location to another, assuming no obstacles, land safely, deliver lasting energy to an electronic device, and return home. This project will also require the design of a charging station for the drone, as well as a method for the drone to dock with a device in order to supply energy.

1.3 Operating Environment

The UAV will be expected to survive and operate weather conditions harsher than our problem statement assumes. Harsh conditions are such: high winds, rain, cold and hot temperatures, etc. However, that is beyond our scope for now. The goal of our group is more proof of concept, than actually implementing weather safety.

1.4 Intended Users and Intended Uses

There are several different users who will have their own specific uses for the UAV. The main users will be individuals in industries who need to deliver energy and data to multiple tethered and untethered nodes. They may want to have more options than a private individual user as to how the drones deliver their energy and data, such as specific ordering of which nodes are delivered first, specifying efficiency of delivery, and delivering to multiple nodes with multiple drones on a large scale.

Additionally, there will also be private, individual users who will be able to call for use of a drone at any time. A drone will then come directly to the user's location, and perform whatever action the user specified. Most often, the action will be to deliver energy to and charge some kind of electronic device.

1.5 Assumptions and Limitations

Assumptions:

- Drones will be able to navigate, dock, and deliver energy or data fully autonomously
- Drones will be able to deliver to multiple nodes before having to return to its base and charge back up
- Power stations for drone recharging can be assumed to be able to gather energy without needing to be recharged themselves, such as connected to the power grid
- System will be low-cost to implement

Limitations:

- Drones must follow regulations already in place, such as avoiding emergency response teams and avoiding no-fly zones
- Drones must avoid obstacles like power lines and buildings
- Due to regulations, we cannot fly the drone within the school zone

1.6 Expected End Product and Other Deliverables

The end product will be a drone that can fly, unassisted, to and from both tethered and untethered nodes. The drone will then attach to the node, transfer either data or energy, and either continue on its delivery path or return to a power station, which will recharge the drone. We will have a drone which can autonomously fly from one point to another at a distance of approximately 100 yards. We will also have a power transfer system, which will be built to allow the delivery of energy to the drone and electronic device. We hope to have completed the autonomous docking feature to allow the drone to shuttle data or energy between multiple tethered and untethered nodes.

Drone Automation: Drone automation is an ongoing process. Our first focus is very basic drone automation, e.g. Takeoff and Landing. The following focus will be directed flight from one location to another. Once the drone arrives at its location it will need to be able to accurately land on the target location. After a reliable connection is made, there needs to be a sleep time frame where the drone charges the device before leaving. When the device is done charging, the drone should take off, and return home.

- Automate takeoff and landing
- Sequential flight path to return home after delivery
- Landing accuracy
- Tests with docking station
- Final Presentation Preparations

- Improvements proposal
- Document Improvements

Docking Station: To allow the drone to land and establish a reliable connection for energy delivery the docking station is a necessary device. First, we will need to create prototypes for establishing a reliable connection. Once connection is capable of being made, it must also be able to break that connection so the drone can take off. Once achieved, the physical docking station can be designed.

- Research Power Methods
- Connections Made/Broken
- Docking Station Designed
- Station built
- Drone Tests
- Final Presentation Preparations
- Improvements proposal
- Document Improvements

2 Proposed Approach and Statement of Work

2.1 Functional Requirements

Requirement 1: The drone will be able to take off and fly to a specified location autonomously.

Requirement 2: Drone will dock with landing pad for power transfer autonomously.

Requirement 3: Drone will be able to deliver power from the payload battery to the landing pad.

This project is made out of three different pieces that work together in order to accomplish the objective of having UAV power delivery. The first piece is to **fly** the drone to a remote location. In order to do this the drone will have to have the ability to fly autonomously to a given GPS coordinate. The drone will fly up to an altitude where it is expected to not have to run into any obstacles. We do not have object avoidance in the scope of this project and will not implement anything to avoid obstacles besides where we are testing and the previously mentioned flying up to a high altitude. This is the first step for the drone to complete its requirements and is needed for anything else to function. The drone will also receive the coordinates of the node before it takes off and will map a route to it. The drone will be able to receive commands as necessary.

The second part is to **attach** the drone to the remote node. In order to do this, there needs to be a secondary flying mode that will allow the drone to precisely land. To complement this there is also image processing to be able to identify where the landing pad is and how close the drone is to it. With the image processing the drone will be able to calculate how centered it is on the landing pad or how far off it is. Once it has calculated how far it is off it will adjust and recalculate to see how close it is. It will be able to repeat this process until it has landed on the node and as it lands makes a connection to the node. Here it will attach to make a valid connection to the node.

The third part is to **deliver** energy to the node. During this process the power in the drone will transfer over to the node. The drone will keep track of how much charge it has so that it knows when it is empty so that I can leave and return to base. During this process the drone will efficiently and quickly transfer power to the node. It is important that this is a quick process because if the drone's battery gets to low it will go back to base before it has transferred all of the payload's energy. The drone will also remember the place it left from in the first step so it can return there in this step.

2.2 Constraints Considerations

For our constraints, the biggest one is that we are restricted on where we can fly the drone. Due to FAA regulations, we cannot fly it within 5 miles of the airport, so anywhere on campus is out, and we all have to find another place to fly. [Ref. 1, 2]

Another big constraint is that there is not a lot of time to fly the drone in good weather, as it is really hard to fly the drone when it is cold and snowy out, which will be most of the year. This means that we need to get as much done as we can before all of that sets in so we can see the big problems we need to work on over the winter. As well as in the spring when it rains it will be unfit for the drone to fly. There is also a point at which the wind could be blowing too hard for flying to be feasible. Overall, with flying the weather will always be important.

Another constraint that we will have to work with for the duration of our time working on the project is the drone's battery life. It will give us our range for as far away we can deliver energy. It also effects how large our payload can be because a heavier payload will take more power to lift.

We also have to worry about safety. When we have a flying drone with four spinning blades moving at high speeds, it is possible that someone could get hurt. We have to keep in mind where we are flying it and when, and to always have a backup plan to turn the drone off or restrain it in some capacity. It is also important to keep the drone in sight at all times. It can be easy to forget about safety when working on other things but it always remains important.

We also need to worry about areas that do not have a strong signal or no signal at all. During our design we need to make sure that the drone can handle times when it gets in a dead zone. Alternatively, we could decide that every location we go to does not have a dead zone, thereby circumventing the possibility of the drone having no signal.

The drone is also prone to breaking, especially the propellers. When flying the drone, it is very possible, even probable, that the drone will get into a few bumps and accidents. During these it is easy for a propeller to snap and need to get replaced. We will keep this in mind and make sure that we have replacement parts when reasonable or order more pieces for any unexpected events.

The drone itself has limitations. The drone is only able to carry so much weight at a time. This demands that we keep our payload under a certain weight. The drone only has so much power in its rotors so it won't be able to handle certain winds. The drone also only has a certain amount of precision in its movements. These are all things that we will keep in mind and work around to complete this project.

We are also limited by our own inexperience. While we are interested in working on this project, we don't have the experience to jump straight into it. We will have to do research at each step and figure things out as we go. This is not a huge problem but we need to factor issues that we will have into our plans and schedules. Since we are so unfamiliar it is only natural that we will have some issues with getting things working when first adjusting to them.

2.3 Technology Considerations

The Intel Aero drone will give us more freedom in with our programming and battery attachment. Intel offers a wide variety of open source code that goes along with it. This will help us program the drone easier and let us manipulate more aspects of the drone rather than if we chose the Phantom drone.

Using a magnetic connection for our power transfer will ensure that there is a secure connection between the battery pack on our drone and the landing station. The landing station will hold one end of the magnetic connection and the drone will hold the other. When the drone comes close to the landing station due to our image processing software it will magnetically connect to the landing station and transfer energy to it.

Our landing station will feature a place for the drone to land and also charge its internal battery. This will ensure the drone will have enough power to take off, transfer energy to the node, and come back on one single battery charge.

2.4 Technical Considerations

We need to consider the LiPo battery we are using and ensure the battery does not overheat in any way. We chose the LiPo battery to act against that fact but there is still a possibility if the drone crashes that the battery could overheat.

2.5 Safety Considerations

The biggest safety consideration is that we need to keep the away from other people, trees, and water. To achieve this, we need to be mindful of where and when we fly the drone, so we can avoid all of these hazards.

2.6 Previous Work and Literature

Currently, there is no official product that can deliver energy through a drone to a specific location as is required for this project. However, there have been previous groups who attempted this method of delivery. The last group to work on this project used the same Intel drone as the one we are using, and focused on the same idea we are working on: to autonomously deliver energy using our drone of choice. They were able to successfully implement image processing and landing station requirements, but were unable to meet all autonomous requirements. As such, we will utilize their project image processing, at least in some capacity, as well as some of their landing station ideas.

Additionally, while there are no official solutions, there are APIs and libraries that already have solutions for specific, smaller parts of the project, such as how to arm and disarm the drone, fly the drone to a specific location, and cause the drone to land. The main API we are working with is DroneKit, which already has the necessary functions that we can implement into our overall code to solve our automation issues. Some of these functions include arming the motors, taking off, and landing. There is also a Git repository that has steps to follow and code for autonomous drone programming in Python, which will be a useful tool for the maneuvering of the drone while in flight. [Ref. 3]

2.7 Possible Risks and Risk Management

Title: Difficulty of drone operations
Risk: Mitigate
Information: The drone is very difficult to operate using the remote controller, so it will likely be even more difficult to operate autonomously using code. There is a possibility the drone can collide with objects, causing the drone to break. Due to the difficulty of operations, the drone is also inaccurate when flying, which is dangerous because during testing, people and surrounding objects could be physically damaged if the drone falls.
Mitigation Action: In order to mitigate this risk, we are going to fly in open fields where there are no objects for the drone to hit, not fly far off the ground so that the drone does not break if it falls due to some failure, and include some object avoidance in the code.

Title: Lack of knowledge about drones
Risk: Mitigate
Information: None of us have worked with drones or DroneKit before, so we are starting from scratch in regards to how we code. This could cause significant delays in our progress because the coding team not only has to learn the API we are using, but also learn how to interface with the drone, as well as learn how to code in Python.

Mitigation Action: In order to mitigate this risk, we have the entire four-person code team researching how to use DroneKit and any additional resources that DroneKit can be integrated with that we may utilize in our project.

2.8 Project Proposed Milestones and Evaluation Criteria

As discussed before, we will break down the project into three main priorities, which shall have their respective milestones. For the drone automation, we hope to have the drone flying autonomously short distances and being near a predetermined destination by the end of the first semester. We hope to have the payload battery, landing pad, payload carriage, and power transfer cord finished by the end of the first semester. The auto-docking will be the most intensive part of the project, as that will use image processing for it to align. The evaluation for all of these milestones will be done using the testing plan outlined in section 2.10.

2.9 Project Tracking Procedures

We are keeping track of where we are in the project by having weekly meetings with our advisors. During these meetings we individually show what we have contributed to the project. We then talk about what will happen in the next week, and how we plan to achieve each goal.

2.10 Test Plan

Requirement 1: The drone will be able to take off and fly to a specified location autonomously.

Test Case: For this requirement we want to test and see if the code we load onto the drone will allow it to take off and fly to a predetermined location without any manual control.

Test Steps:

1. Load code onto drone and activate it from ground control resource.
2. Observe how the drone flies, and measure how far each step in the flying goes, and how off the target is.

Expected Results: The drone will take off and fly to the specified area approximately. It does not have to be exact destination, but there should be some telemetry data for the flight.

Requirement 2: Drone will dock with landing pad for power transfer autonomously.

Test Case: We want to have the drone as it is landing align itself correctly over the landing pad and plug to ensure there will be a connection to deliver energy.

Test Steps:

1. Have drone already in the air over the target destination.
2. Observe how the drone aligns itself over the target as it is landing.
3. Measure how far off the drone is, see if we can get footage of camera used to align itself to make tweaks.

Expected Results: Points where the drone expects itself to land as well as the actual landing points to compare to where we set the landing point to be.

Requirement 3: Drone will be able to deliver power from the payload battery to the landing pad.

Test Case: Have the cord used to connect the payload battery connected to the payload, and connect the plug together to get a voltage reading.

Test Steps:

1. Connect one end of the cord to the payload battery, the other end will go to the landing pad plug.
2. Measure the voltage reading on the landing pad side to see if there is power transfer.

Expected Results: Voltage reading on the landing pad side of the plug.

Testing using the drone will be done with the payload battery and carriage attached to see how the extra weight can impact flying. We will also be testing each “leg” of the flying procedure separately to ensure all directions are functional separately.

3 Project Timeline, Estimated Resources, and Challenges

3.1 Table of Tasks

TASK	MAIN CONTRIBUTORS	SUBTASKS	TIME ALLOTTED
Power Transfer	Kevin, Brendan	Finding how to carry the extra power, how the power will transfer, Testing, creating the dock	Each subtask in this area needs to be perfected since this is the main goal of the project, we would like to spend the rest of fall semester doing research and testing the most efficient power

			transfer that way it will be ready to implement in the spring
Auto Nav.	Allie, Connor, Garth, Kaitlyn	Getting GPS working, follow coordinates/directions, testing, minimal obstacle avoidance	These tasks will be taking up most of both the semesters, since to make the power transfer work we will need to have the drone be able to auto navigate to the docking pad and then land on it's own. We will most likely spend the fall semester giving it GPS coordinates to avoid and making sure it can navigate to a signal or GPS coordinates.
Plug Design	Kevin, Brendan	Making the CAD Files, Making sure the drone can land on the plug correctly, Make the plug, testing	These subtasks will mostly get done this semester. We would like to have the plug design testable/tested by December. That can then be implemented and printed in the spring.
Other Code	Allie, Connor, Garth, Kaitlyn	Testing, Motors spin at appropriate speeds, drone has emergency code (manual override), Learning how to use the API	These subtasks in this group are all important. However, most of these will go on throughout the entire year. These are things that will need to be improved as we progress on our project.

Table 1

There may be more tasks added to this chart, but the main tasks are listed above with the main goals of the project listed in the chart above.

3.2 Resource Requirements

We will need parts for our drone, including:

(1) Propeller A - $19.99

(1) Propeller B - $19.99

(4) Carbon Fiber Landing Gear (Airframe) - $14.00

(1) Carbon Fiber Airframe Top Board + Middle Board + Silicon Rubber Protection for FPC (airframe) - $36.00

(1) Carbon Fiber Airframe Bottom Board (Airframe) - $14.00

(1) Aluminum Posts 4 M3 X10 Screw X 8 (Airframe) - $5.00

(1) Anker 6700 mAh Battery Pack - $23.99

(1) Intel Micro USB to USB for Drone - $16.00

(1) USB Hub - $9.89

(1) Mini HDMI to HDMI - $5.99

[Ref. 4]

We would also like to purchase a new drone so we have two drones for testing purposes.

Intel Aero Ready Drone - ~$1100

[Ref. 5]

Other materials include coding software (DroneKit), and possibly 3D printed parts for the dock or plug.

If all of these parts are used it will be ~$1342 for our project to be completed.

Below is our Agile method that has been working very well for our group thus far:

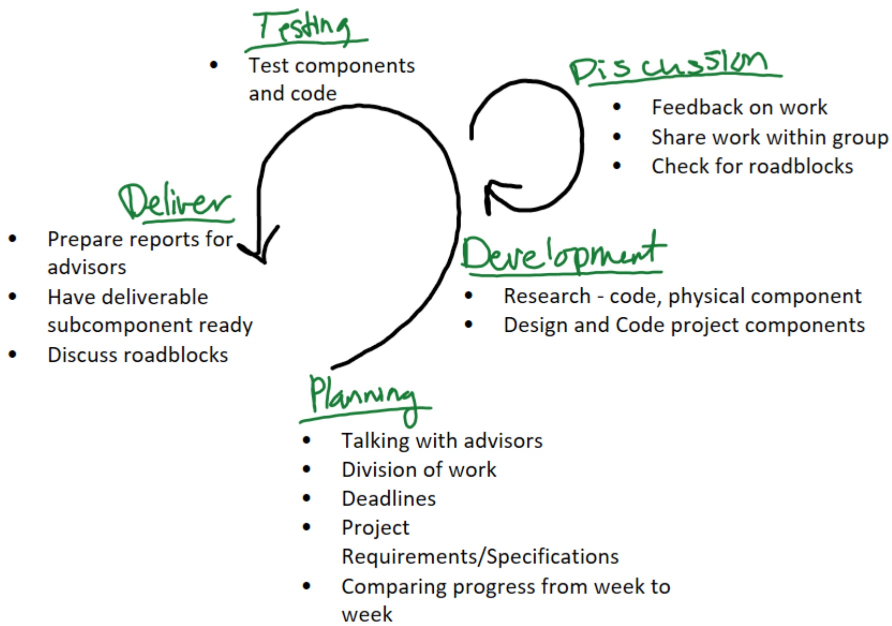

Figure 1

This Agile method requires us to plan our week and tasks. Then start working on the tasks during the beginning of the week. Then midweek, we have a discussion and make sure everyone is doing ok. Then at the end of the week, we test and talk about the results. This allows us to spend a good week on the task and get help from others if needed.

3.3 Project Timeline

Project Planner

Period Highlight: 10

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Project Scope	1	1	1	1	100%
Fly Drones	1	1	1	1	100%
Select Drone	2	1	2	1	100%
Meet with sd18	2	2	3	2	50%
Research	2	3	3	3	80%
Schematics	4	6	4	6	10%
Skeleton Code	4	6	4	6	20%
CAD Files	8	2	9	0	10%
Board Ready	8	2	6	4	60%
Auto Navigation	8	5	0	0	0%
Docking Test	8	1	0	0	0%
Plug Protoype	12	3	0	0	0%
Auto Nav. Proto.	12	6	0	0	0%
Dock	12	3	0	0	0%
Semester Demo	16	4	0	0	0%
Finish Auto Dock	22	5	0	0	0%
Finish Auto Nav	22	5	0	0	0%
Power Transfer	22	5	0	0	0%
Possible Add Multiple Nodes	22	3	0	0	0%
Final Working	25	2	0	0	0%

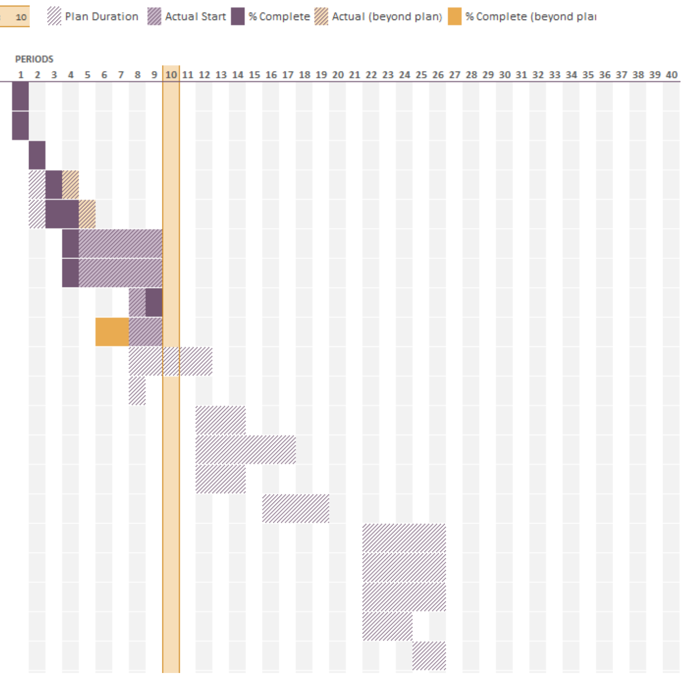

Figure 2

Our Gantt chart covers mainly the fall semester, but lightly touches on the spring semester as well. Since we are unsure exactly how far we will get this semester we have basically left next semester as a tentative schedule. We have a stretch goal we can add if needed.

The three main highlights from our Gantt chart are broken down into smaller goals throughout the semester. The first is Auto Navigation. This will need to get mostly accomplished by the end of the first semester. For this goal, we will need the drone to fly from its home base to a node at given GPS coordinates.

Another main goal is docking. The drone will use image processing to find the node at the given GPS coordinates and auto land onto the dock properly and orient itself for proper transfer of energy.

The last main goal for a successful project is power transfer. We will be using a cord to transfer power from the battery pack on the drone to the node.

If the three main goals above are reached by the end of fall semester or early spring semester we will add a stretch goal. We have determined our stretch goal to be having a queue so the drone can fly to multiple nodes and deliver energy. It will need to be able to auto navigate from one node to the next then back home. We will also then need to make sure there will be enough power to make it to both locations and back.

4 Closure Materials

4.1 Closing Summary

There are many different situations where delivering power to locations is both crucial and difficult. An easy example is after a natural disaster it would be necessary for there to be power at first aid stations or hospitals or just living areas when the power has been knocked out. However, in such situations it can be difficult to transport batteries or generators quickly to places that would need the power. We will make an automated drone system that will autonomously send drones out to locations holding a payload in order to transfer power over to it. There will be multiple drones that can service multiple different nodes and different locations. This will all be able to be done with as little human input as possible. The drones will be able to fly over and hazardous conditions that would impede ground transport and will return to base to refill their payload to continue to service the different locations as quick and as efficiently as possible.

4.2 References

1. https://www.faa.gov/uas/where_to_fly/no_drone_zone/
2. https://www.faa.gov/uas/
3. https://github.com/intel-aero/meta-intel-aero/wiki/04-Autonomous-drone-programming-in-Python
4. http://us.yuneec.com/intelaerodroneparts
5. https://click.intel.com/intel-aero-ready-to-fly-drone-2404.html

4.3 Appendices

Past group's work: http://sdmay18-40.sd.ece.iastate.edu/

DroneKit documentation: http://python.dronekit.io/