SPIDRONE

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***Abstract* — This project involves the use of technology to develop a flying drone and charging dock that supports wireless charging using solar power. We want the drone to be operating autonomously as much as possible. Throughout this paper we are going to show how SPIDRONE uses the combination of technologies such as Global Pointing Systems (GPS), Infrared cameras, microcontroller, and other technologies to create an autonomously device as well as a mission for SPIDRONE to complete based on the users path.**

***Index Terms* — Flight Controller, GPS Communication, RF Communication, Wireless Camera, Wireless Transmitter and Receiver, Solar Panels.**

I. INTRODUCTION

SPIDRONE is an environmentally friendly Unmanned Aerial Vehicle (UAV) that provides a tracking mission, uses inductive charging, and solar charging. The name SPIDRONE is an acronym to Solar(S) Power (P) inductive (I) DRONE. The SPIDRONE's mission will be to track its user by utilizing GPS to follow its user's path, based on the waypoints created by the user's movement. The SPIDRONE will not be operated manually, instead its flight patterns will be managed autonomously. Solar energy was the preferred energy source for our charging substation because it is environmentally friendly. This component of our design makes our SPIDRONE very cost effective since the solar radiation are harnessed at no cost. SPIDRONE will incorporate a magnetic resonance charging technology. Our charging substation will have a wireless power transmitter pad that will deliver power to a receiver via multi coils. The motivation behind SPIDRONE, stemmed from a mutual interest in drones, and advances in technology that is becoming available in everyday life. The technological advances that have interested us were the advances in wireless charging in cell phones and televisions and the convenience it provides by not having to plug the phone in. With the advances in solar panels providing an increased efficiency and lower costs, we realized that it would be feasible to apply solar energy to our project, which will ultimately cut down on operating costs of SPIDRONE, and cut down on the emissions that our project may create indirectly from using power provided by utility companies. We also decided to create SPIDRONE to be fully autonomous in order to reduce human interaction. With our project motivation and objectives, we determined the following goals for SPIDRONE:

- Low operating and maintenance costs.
- Environmentally friendly.
- Autonomous user tracking and flight planning.
- Autonomous landing and charging.
- Wireless charging.
- Failsafe for low battery.

II. SYSTEM COMPONENTS

In order to represent our system, we divided each of the technologies into components. The combination of these different technologies results in the SPIDRONE**.**

A. Flight Controller

The flight controller being used is the HKPilot32 offered by HobbyKing, which is based off of the open source Pixhawk flight controller. The flight controller provides stable flight to the drone.

B. GPS Communication

The Global Positioning System (GPS) provides global positioning by using the latitude and longitude that will be use for the tracking mission. An android device will save these coordinates as a text file, and then that file will be able to be launch from the computer, to the drone via Mission Planner software. The drone will have a GPS receiver as well as a Radio Frequency antenna that it's always in communication with the computer.

C. RF Communication

The Radio Frequency Communication module is sending and receiving data from the computer to the drone. The Radio Frequency will always be activated while using SPIDRONE.

D. Wireless Camera

The wireless camera on the drone is going to be mounted facing downward, in order for it to be used during the auto-landing sequence. The camera feed will be broadcast wirelessly to the base station.

E. Wireless Transmitter & Receiver

Wireless transmitters and receivers are used as a charging station for the SPIDRONE to safely land on top of the station and for the station to charge the SPIDRONE wireless.

F. DC/DC Converters

Due to the presence of several sub-circuits within such portable devices with each sub-circuit having its own voltage level requirement different from that supplied by an external supply or the battery, which may be sometimes higher or lower, a DC-DC converter is needed to implement the conversion to the desired voltage level .

III. DESIGN OVERVIEW & CONSTRAINTS

As the objective of our project is to essentially add new functions to a quadcopter, there are constraints that come internally from the development team such as scheduling, and external constraints from social and political sources, especially since unmanned aircraft is considered by some to be a controversial topic.

A. Economic and Time Constraints

The economic constraints imposed on our project stem from the type of project we are creating. Custom built drones or quadcopters have a wide price range for just where the flight controller itself can cause anywhere from $20 to $300 at the time of this project.

The time constraints on this project are imposed by the University of Central Florida. This project is to be developed over 2 semesters for the Senior Design 1 and 2 courses offered by the university. The first semester is senior design 1 where the course is designed for us to create and research the project that we want to do. Senior design 2 during the second semester places emphasis on developing our project based on our prior research. As such physical development of the project is technically slated for approximately 4 months, although extra time can be had by starting the project earlier during senior design 1. As all members of the group are active students, other courses from the university will impede on development time, along with our occupational responsibilities.

B. Environmental, Social, and Political Constraints

The environmental constraints imposed on this project are mostly based on our location. As we are constructing a quadcopter, an ideal environment for testing this project would be a dry spacious outdoor area with good lighting. However, the development of this project will take place in Orlando Florida, which tends to have rainfall on a daily basis. Thus charging would always be at the mercy of the weather since the solar panel cannot produce the necessary power needed to charge the battery on low sunlight conditions. If the project were not utilizing a GPS system we could be able to test the project indoors, such as an empty auditorium or warehouse.

Social constraints imposed on our project can stem from the current controversy regarding the use of drones for unethical reasons. Hobbyists operating drones have reported being confronted by individuals for various reasons such as filming without consent, safety, and noise.

The political constraints imposed on this project come from the FAA regulations established regarding the operation of drones for hobby purposes. The FAA regulations were developed to provide safe operating guidelines for drones such as not to operate near airports, people, or stadiums.

C. Ethical, Health, and Safety Constraints

While the FAA legislation exists that prevents the operation of drones near people, stadiums, and airports for safety reasons, our group is under an ethical and safety constraint to obey the legislation during the development of the SPIDRONE. To circumvent this constraint, alternative testing locations were sought such that we could test without endangering the public. Another safety concern is the chance for injuries while handling the SPIDRONE. During arming and disarming, there may be a chance for the propellers of the drone to spin at high speeds, which are capable of cutting through skin. With this constraint in mind, we have decided that the person directly handing the drone is required to wear proper

There are a lot of health concern when it comes to delivering power over mid-range distance. The real risk arise when the body is exposed to too much of the electromagnetic waves, hence the need to control the exposure to the body. There are standards which set minimum frequency range the body can be exposed to.

The Institute of Electrical and Electronic Engineers (IEEE) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) are the international bodies which have guidelines to protect humans against any known adverse effect of exposure to electromagnetic waves. The frequency set is in the range of 3 KHz and 300 GHz.

The battery that is used for the SPIDRONE project is a lithium polymer battery, which contain health and safety concerns. Energizer's product safety datasheet contains information about their own lithium polymer batteries, but the data can be applied to lithium polymer batteries in general. Lithium polymer batteries carry health risks which can be caused by ingestion, inhalation, skin contact, and eye contact from the chemicals that makeup the battery. To circumvent this, the batteries chosen for this project must be a sealed type which prevents users from maintaining the batteries. Another concern for lithium polymer batteries is the risk of a fire or explosion. During charging, or rapid discharging, the battery may overheat which can potentially cause a fire. Lithium polymer batteries are also capable of discharging a large amount of energy in a short amount of time, and as such a short circuit is also capable of causing a fire. To circumvent this, cool down times will be implemented between charging and flight times, to prevent the battery from overheating.

D. Manufacturability and Sustainability Constraints

Due to time constraints, we opted to modify an already made drone system provided by the vendor rather than building our own mechanical parts from scratch. We choose that process due to the simplicity to assemble and to accommodate software configurations. Since we custom built SPIDRONE with different electronics than the pre-built shields, a variety of modification were made to both the software and hardware:

- Radio Integration & Controller Remote PID Tuning
- Motor Control
- GPS integration
- Camera Integration

The design of this project is approached by the team with sustainability and optimization in mind noted in the environmental and ethical considerations section. Code was commented and written in a way for easy modifiability in future applications. The hardware is easily modified and replaced. This makes for easy repairs.

IV. HARDWARE DETAIL

In section II, we have listed all of the components that we are using for the SPIDRONE in order to achieve its full functionality. In this section, we will go over the hardware details.

A. Flight Controller

The flight controller used for the SPIDRONE is the HKPilot32 flight controller. The HKPilot32 flight controller includes a power module for monitoring the battery consumption. It can operate off of a 2s – 10s lithium polymer battery, and weighs 33.1g. The processor operates at 168 MHz with a failsafe co-processor.

B. GPS Communications

The Global Positioning System (GPS) is an important aspect to the tracking mission. This will give the position by latitude and longitude of the user. The user will record this coordinates using an Android device and save these coordinates into a server. The server then will send the text file to the computer and from the computer we will be able to launch the tracking mission for the SPIDRONE to complete. Using GPS gives a distance advantage, SPIDRONE should be able to complete its mission. Once the mission is completed, the SPIDRONE will go back to its launch coordinates. Since we are using a Pixhawk controller, we want to use a GPS module that that will work alongside the Pixhawk controller and be able to support waypoints concept to record the coordinates. The GPS module used is the Ublox Neo-7M GPS with compass. This GPS is capable of a 10 Hz update rate and comes equipped with a 25 x 25 x 2 ceramic patch antenna. [2]

C. RF Communication

The Radio Frequency Communication is going to be used to have constant communication with the SPIDRONE and the computer. This allows for a full control of the SPIDRONE not only for mission purposes, but also for safety reasons. The HKPilot transceiver telemetry radios set was chosen for communications between the drone and the ground station. It transmits data at 915 MHz.

D. Wireless Camera

The wireless camera being utilized is the Eachines FPV200 kit. This kit includes a 700 TVL camera attached to a 5.8 GHz video transmitter. The camera and transmitter are capable of operating off of a 12v power system and requires 200 mA.

E. Wireless transmitter and Receiver

One wireless transmitter is an LTC4125 from linear technology. It is a high performance monolithic full bridge resonant driver capable of delivering over 5W of power. It is a safe and simple transmitter because it controls the current flow in a series connected transmit coil LC network. It automatically adjusts its driving frequency to match the LC network resonant frequency. Its AutoResonant switching allows it to deliver maximum power from a low voltage input supply (3V to 5.5V) to a tuned receiver. The efficiency in the LTC4125 is optimized because it employs a periodic transmit power search and adjusts the transmission power based on receiver load requirements. The only time the device stops delivering power is when there is a fault condition, or if a foreign object is detected. The LTC4125 also includes an NTC input as additional for foreign object detection. It also has a programmable maximum average input current limit. It performs at temperatures between –40°C to 125°C. Figure 1 show the Transmitter Schematic.

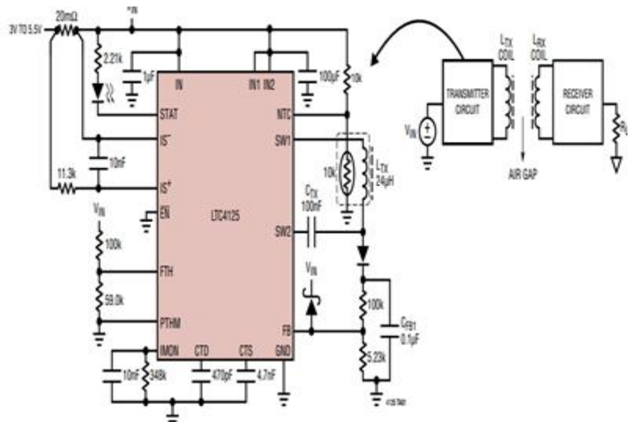


Figure. 1 Schematic of Transmitter LTC4125 [3]

Features:

- **Monolithic** 5W Wireless Power Transmitter
- Input Voltage Range: 3V to 5.5V
- AutoResonant^{TM} Switching Frequency Adjusts to Resonant Capacitance and Transmit Coil Inductance
- Wide Operating Switching Frequency Range: 50kHz to 250kHz
- Transmit Power Automatically Adjusts to Receiver Load*
- Integrated 100Mω Full Bridge Switches
- Multiple Foreign Object Detection Methods
- Programmable Average Input Current Limit and Monitor
- NTC Input for System/Component Temperature Qualified Power Transfer
- Thermally Enhanced 4mm × 5mm QFN 20-Lead Package

The LTC4120 accepts a rectified 4.2V to 40V input from the receive coil to power a full-featured constant-current/constant-voltage 400mA battery charger. The receiver coil will be attached to the drone. The receiver coil is placed directly beneath our drone so it can effectively couple our transmitter coils in our charging station.

The LTC4120 is a constant-current or voltage wireless receiver and battery charger. It has a charge current of 400mA. This LTC4120 is ideal for charging Li-Ion / Polymer batteries. This receiver is capable of charging in harsh environmental conditions and can even charge moving or rotating equipment. It can charge while sealed within an enclosure. The LTC4120 and supporting circuitry has an area of 460 mm2 (single-sided) in addition to a 25mm diameter receive coil. [3]

F. DC/DC Converters

DC to DC converters are very important in portable electronic devices which are primarily powered with batteries. Due to the presence of several sub-circuits within such portable devices with each sub-circuit having its own voltage level requirement different from that supplied by an external supply or the battery, which may be sometimes higher or lower, a DC-DC converter is needed to implement the conversion to the desired voltage level . In applications where space and weight are critical, switched DC to DC converters offer a method to increase voltage from a partially lowered battery voltage thereby saving space instead of using multiple batteries to accomplish the same thing. For this project the various types and topologies of DC-DC converters were explored so as to determine the appropriate ones to be used in the implementation. After careful consideration we decided to use a buck converter that would convert the voltage from the solar panel which goes as high as 18 to 5V so that it can be used to power the wireless transmitter.

LT1376 - 1.5A, 500kStep-Down Switching Regulator was chosen for this design because of the following features which made it useful for our project.

- Constant 500kHz Switching Frequency
- Saturating Switch Design: 0.4Ω

- Effective Supply Current: 2.5mA
- Shutdown Current: 20µA
- Easily Synchronizable
- Uses All Surface Mount Components
- Inductor Size Reduced to 5µH
- Cycle-by-Cycle Current Limiting
- Distributed Power

G. Solar Panels

To eradicate the ethical concerns of this project related to power, solar cells would be used to generate the energy needed to power the device and its components. The benefits of solar energy both economically and environmentally are great

There are many different types of monocrystalline solar panels produced by many vendors. A careful consideration after research of similar products by different manufacturers led to the selection of the 12V, 5W battery by Allpower. The product comes in the following specifications:

- Solar Panel: Mono-crystalline silicon 18V,5W
- The voltage rating is ideal for this project it would provide
- No-load voltage: 18-23VDC
- Load voltage: 18V
- Output current: 250-280mAh (0.2A-0.28A)
- Size: 320x120x5mm/12.6*4.7*0.19inch
- Weight: 0.323kg/ 11.4oz. The weight is one of the best specification features. This makes it portable and also possible to meet the design specification of the charging station.

V. SOFTWARE DETAIL

This section explains the different aspects of the software that we will implement in the SPIDRONE project. Software is often divided into two different categories, application software and System Software.

A. Auto Landing Coding Plan

A Python script will be utilized for auto-landing, in order to handle object recognition. The decision to use a laptop with Mission Planner was made due to the processing resources that object recognition requires. To handle the image processing, OpenCV will be used on the video feed transmitted from the drone. This script will handle determining where the charging dock is in relation to the drone, and control the drone via the API to center it over the charging dock as it descends.

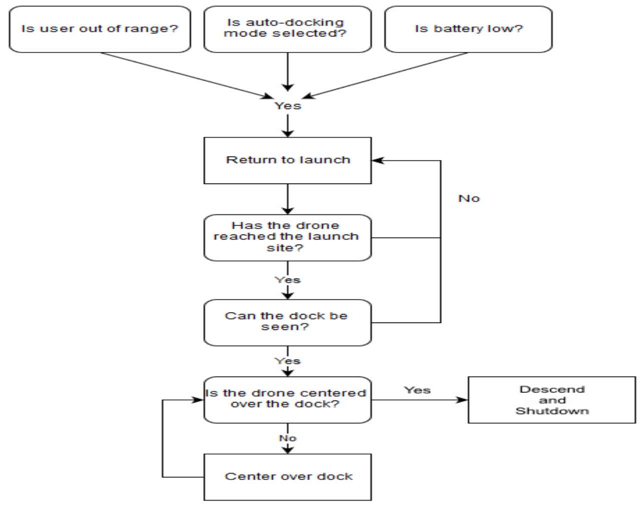


Figure 2. Auto Landing Coding Plan

B. Tracking Coding Plan

The Tracking Coding plan is based on python scripts that are supported by Mission Planner. The user will launch the app from an Android device, press the “start mission” button, and start walking around in the path that the user would like the SPIDRONE to follow. Once the user is done, the user will press the “finish Mission” button, and those coordinates will be sent to the computer as a text file. Using Mission Planner, we will be able to launch the Python script to read in the text file and send those coordinates to the SPIDRONE. When the SPIDRONE receives these coordinates, it will start following the user’s path. Figure 3 shows the tracking plan.

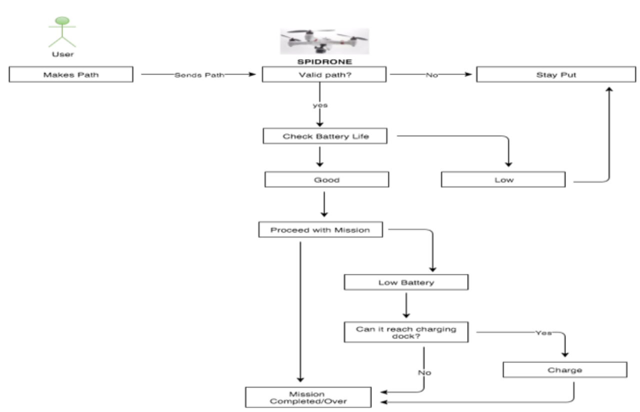


Figure 3. Tracking Plan

VI. PROTOTYPING

The environment for testing the hardware aspects of the SPIDRONE project is crucial to determine how the performance of the different parts. The prototyping and testing of the DC-DC converters was done in the senior design Lab at the University of Central Florida. Since the senior design lab is an indoor lab the power output from the solar panels had to be tested outside.

A. *DC-DC converter prototyping and testing*

Using the LT1376[1] switching regulator and a reference design, we designed, tested and prototyped a simple but versatile and efficient switching regulator and DC converter capable of taking an input between 7V-25V and outputting a 5V low ripple needed to power the wireless transmitter. The schematic of the design is shown in Fig. 4

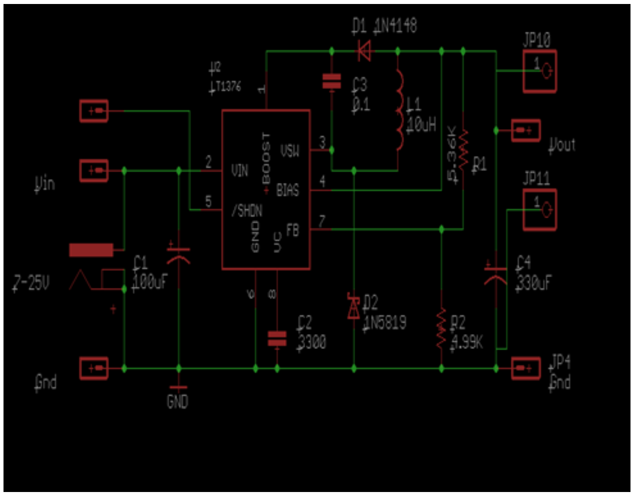


Figure 4. Schematics

B. *Wireless Charging Test*

It is very necessary to test our chosen receiver and transmitter to see if it will meet our specification that we started off with. Samples of the LTC 4125 demo board were used to test LTC4120 to ensure our design executes the charging effectively. The following steps were followed to test the wireless charging system

- The first step is to connect a power source to the transmitter.
- Once the power has been plugged in, the transmitter needs t+o be placed on the LTC receiver and charger. A green LED light on the transmitter turns on. Once the LED turns blinking red we removed the DC2181B and placed it back on the transmitter when the LED turn green again.
- The green bar LEDs on the demo-board should turn green. There is a 10mA which flows from BAT into the LEDs.
- For the basic transmitter. PS1 to 5V, and turned on. PS2 is set to 3.6V, and power supply is turned on. PS2 is the battery emulator battery voltage. The 3.6Ω is to make PS2 into a bipolar supply.
- By placing a 3.6Ω resistor in parallel with a normal supply, the supply can absorb up to 1A at 3.6V.

C. *Software Testing*

Testing the auto-landing function of the SPIDRONE will be handled in different phases. Initial testing will be to establish that the camera, transmitter, and receiver are functioning properly by connecting it the receiver to a television. Then a short Python script will be developed to test that the drivers for the video capture device and OpenCV were installed properly, and that the video feed can be fed into a Python program. The Python script will then be built upon to first recognize the charging dock, and finally determining where the drone needs to fly to center the drone over the charging dock. The code will not be executed with the camera mounted to the drone. Instead the camera will be powered by a power supply and moved by hand. This will allow the code to be tested in a debug mode without the risk of the drone flying off. This also allows us to test indoors instead of outside, which can only be done when it is not raining.

VII. PRINTED CIRCUIT BOARDS

Most reference designs PCB are 4 layer PCB's. Since we decided to use the free version of eagle we could not use exported board from manufacturer but instead create a schematic from reference designs. Using developmental boards helped us understand and guide the connections to pins that shared the similar properties as the ones it was set to be connected too. Some of the pins were not interfering, so they did not have to be rerouting had to be done for the pins so that they would not interfere. The layout was checked to meet all design rules and that there were no air wires still remaining. Once this was done we moved on with the manufacturing process. Figure 5. shows the PCB Design.

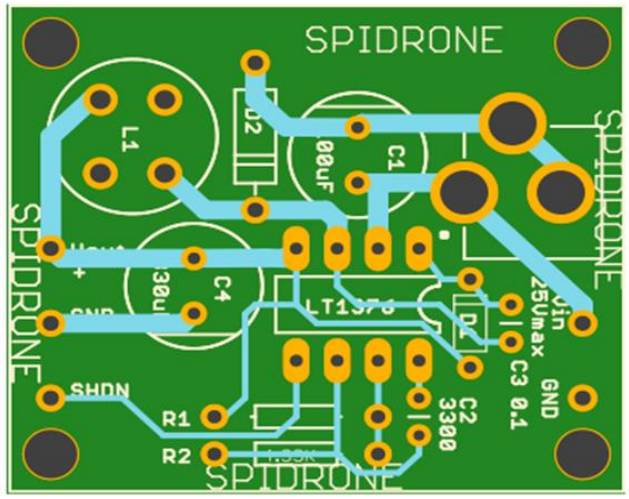


Figure 5. PCB Design.

A. Components Selection

The components used in prototyping though difficult to find were not very bad to handle. Designs in school labs are done on breadboards which makes it quite simpler to handle. For this reason, we decided to use bigger discrete components through every time we could. We thus chose the components that would enable us to have some flexibility mounting and soldering them.

B. Board Design

To create the PCB we used a free software called Eagle CAD. We first had to find the footprint otherwise called the libraries of each component used on our project. The research into the component libraries and footprints was quite time consuming. Though the main component of this design was the linear technology LT1376, other passive components were from different vendors that needed to be sourced by us. Common libraries where downloaded in order to get the passive components such as resistors, capacitors and inductors and the schematics were done after that. When the libraries were found we made a schematic in eagle and from there exported it to make a board. The board wires were then routed to the desired locations and components were conveniently placed for the task.

C. Assembly

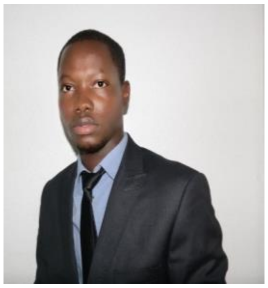
As can be seen in Figure 5., most of the components of the PCB board of the DC to DC converter that steps down the voltage from the solar panel to the wireless transmitter are all through whole mount. The components are carefully soldered onto the board using soldering iron.

VII. CONCLUSION

Our goal for SPIDRONE is to provide a user & environment friendly drone that will support inductive charging, solar panels, and a tracking mission for the user to explore with. The main idea for this project is to provide the user with an entertainment drone that they can fly and also be able to make a path and for the SPIDRONE to follow it using GPS waypoints. SPIDRONE will evaluate the path sent from the user and make its way to the destination or end of the mission. The drone will have available a charging dock, so in case of low battery the drone will look for its charging dock and charge. In the case that SPIDRONE cannot complete its mission and cannot reach its charging dock, the drone will land safety. We as a team wanted to challenge ourselves in designing a drone that was able to use various types of technology currently used. This allowed all our team members to add something to the project that they each wanted to work with, learn from and essentially be able to put it on our resumes. Some of these technologies that are being integrated in our project are wireless communications, microcontrollers, GPS and Infrared sensors, radio frequency communications, Wireless Power transfer, DC/DC Convertors, solar panels, and circuit boards. During the span of this project we were faced with numerous challenges beyond our control but we came out learning new things as we tested our limits to figure out our strengths and weaknesses.

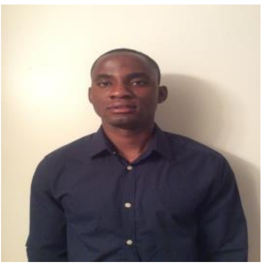
The Engineers

Daniel Camargo- is a graduating senior in May 2016 with a Bachelor’s in Computer Engineering. Daniel is currently looking for a career in engineering. He would like to travel the world.



Jonathan Obah- is graduating in May 2016 with a Bachelor’s degree in Electrical Engineering. Jonathan’s Interests include Power and energy systems, Communication and Control. Upon graduation, Jonathan would pursue a working career in engineering.

Kyle Ferris- is a senior graduating in May 2016 with a Bachelor’s degree in Computer Engineering. He plans to pursue his career in the engineering field while maintaining his job in the event management industry to travel the world. His interests include software development, systems automation, and embedded systems.



Benjamin Atsu - is graduating in May 2016 with a Bachelor’s degree in Electrical Engineering. Benjamin’s Interests include Power and energy systems. Benjamin is currently looking for an opportunity with his interests.

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