I. ABSTRACT

Drone technology has skyrocketed over the past decade driving costs down and the number of potential applications up, one being agricultural crop monitoring. Normalized Difference Vegetation Index (NDVI) is an imaging technique used to visualize near infrared light, which happens to be a very good indicator of plant health and productivity. This project aims to explore the potential of Unmanned Aerial Vehicles (UAV's) using NDVI imaging for crop monitoring and assess the feasibility of the process by developing a UAV with a NDVI camera to create NDVI maps from the aerial crop images. These maps will be cross referenced with soil samples to check for proof of concept and accuracy. The project will be presented at the 2015 American Society of Agricultural and Biological Engineering conference in New Orleans, Louisiana in the student poster and paper competition and at the Cal Poly BRAE senior project presentation banquet. The final product will illustrate the feasibility, efficiency, and economic benefits of UAV NDVI crop imaging and offer a solution to the dated and tedious process of crop monitoring that is currently physically walking the field.

II. INTRODUCTION

Imagine a farm of the future that is full of robots; aerial robots flying overhead scanning fields in real time and sending signals to ground robots to check areas of concern, fix irrigation issues, and take soil samples for further analysis; this farm of the future is very close to being the farm of today. The purpose of this project is to explore an avenue that will change the way in which big agriculture is conducted forever and bring us one step closer to automated farming. Drone technology has been around for years as a defense

tool, but only recently has it become cheap enough to be utilized by other industries. The Federal Aviation Administration (FAA) first authorized drone use in National Airspace System (NAS) in 1990, however today commercial drone flight is still illegal [1]. Because of this ban drones have yet to be deployed in a variety of industries, one of which is agriculture. Normalized difference vegetation index imaging, or NDVI imaging was developed by NASA scientist Compton Tucker in 1977 outlined in a paper titled "Red and Photographic Infrared Linear Combinations for Monitoring Vegetation". His research concluded that plants reflect varying amounts of near infrared light varying on their health based on the following equation, variation of plant vegetation could be visualized [2].

$$NDVI = \frac{(NIR - red)}{(NIR + red)} \tag{1}$$

This imaging technique has been used over the past 30 years to monitor vegetation from satellites, however it hasn't made economic sense to farmers because of the high cost of airplane and satellite photography. "It's a simple economic equation. The biggest potential for Unmanned Aerial Vehicles is aerial images and data acquisition. You can take a simple UAV and repurpose imagery for a farmer's field for cents on the dollar compared to using traditional aircraft." stated Rory Paul, CEO of Volt Aerial Robotics [3]. Testing will determine if the imaging technique makes sense at lower drone elevations that deal with atmospheric conditions where cloud cover, shadows, and a variety of other issues negated by images taken from satellites must be considered. UAV NDVI imaging combines principles from aerospace, mechanical, electrical, and agricultural engineering to create a final product that could be used for crop monitoring to view irrigation, pest, and fungal problems [4].

III. OBJECTIVE

The goal of this project is to achieve the following while embracing Cal Poly's ideology of learning by doing:

1. Build and develop a UAV with NDVI imaging capabilities.
2. Determine the practicality of using NDVI imaging on drones for crop health assessment based on accuracy and precision.
3. Attend and give a presentation at the ASABE conference for the student paper and poster competition and the BRAE senior project banquet.

IV. METHODOLOGY

Working alongside Dr. Bo Liu of the Cal Poly BRAE department and with the cooperation of the Cal Poly Crop Science Unit the project entails the following:

1. Build upon the functioning prototype by: isolating issues, microcontroller programming, camera integration, ArduPilot installation and programming.

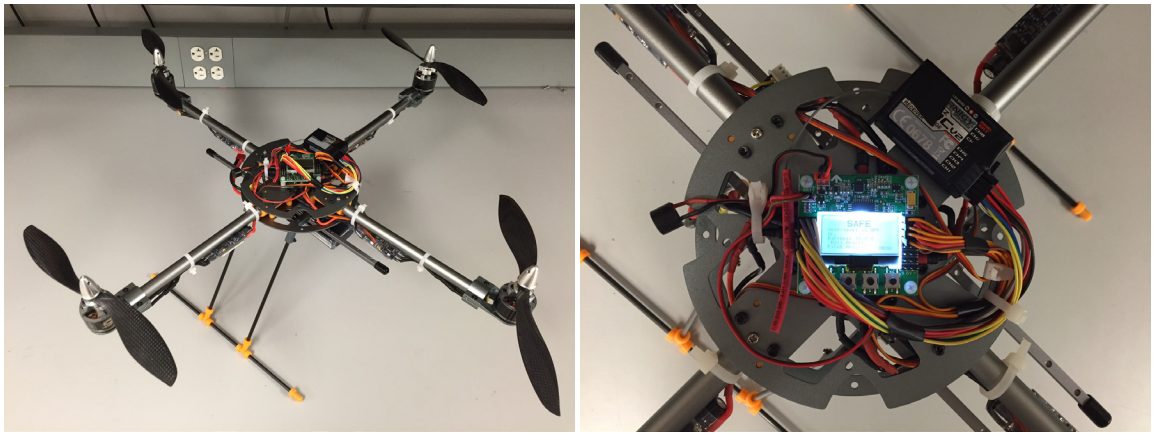

Figure 1 & 2: Drone prototype with onboard electronics.

2. Purchase components and construct larger "heavy duty" drone capable of longer flight times and a larger payload in varying weather conditions based on knowledge gained during prototyping process. Ready UAV for crop monitoring by: installing high precision GPS, autopilot installation and programming, sensor installation, software development used for implementation of live feed, autopilot mission planning, and mapping functions.
3. Purchase and modify NDVI capable camera and devise a method to process the photos for data analysis. Equip drone with NDVI camera while allowing remote user control during flight.
4. Test NDVI equipped drone under varying conditions and test for accuracy of data comparing congruencies and inconsistencies in NDVI images and field samples. Testing will be done at Cal Poly San Luis Obispo in coordination with the Cal Poly Crop Science Unit. Create NDVI maps alongside standard aerial maps to compare benefits of NDVI imaging.
5. Compile data and write formal report analyzing NDVI imaging worth. Present report at Cal Poly and at ASABE conference in New Orleans.

V. TIMELINE

Date Started	Date Completed	Action
10/10/14	11/30/14	Prototype Build
1/5/15	2/5/15	Drone Purchase/Programming
1/5/15	3/5/15	NDVI Camera Purchase/Modification
3/5/15	4/30/15	Testing/Data Compilation
4/30/15	5/31/15	Data Analysis/Final Report
7/26/15	7/29/15	ASABE Conference

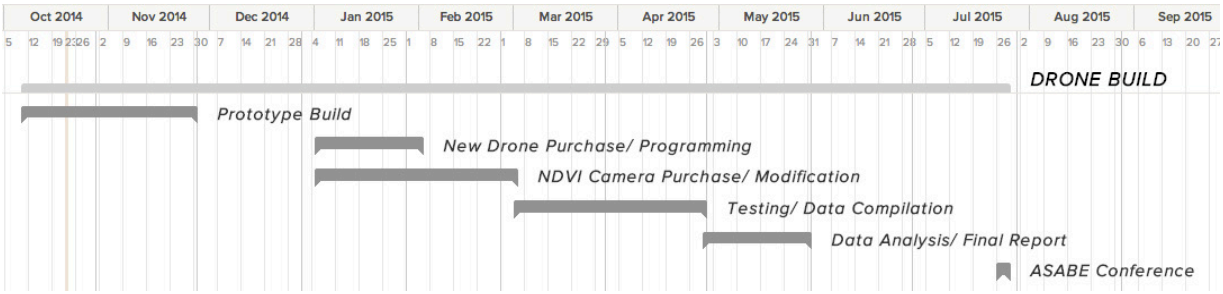

Figure 3: Schedule for completion of drone build.

VI. FINAL PRODUCTS AND DISSEMINATION

1. A UAV will be developed and sent to the 2015 ASABE Robotics Conference for the student paper and poster presentation competition.
2. A presentation will be delivered to the attendees of the ASABE competition and ASABE committee.
3. The final report will be submitted to and judged by ASABE judges.
4. The drone, poster, and senior project will be displayed at the Cal Poly BRAE department senior project banquet.

VII. BUDGET JUSTIFICATION

The non-computer supplies and materials funding covers a large UAV, a high precision GPS, and a NDVI capable camera. This equipment is very expensive and the endowment will likely cover a portion of the project. The detailed budget list is shown on the following page.

PROPOSAL BUDGET

Student Applicant(s): **Derek Myers**	
Faculty Advisor: Bo Liu	
Project Title: Feasibility of UAV Technology to Promote Crop Yield and Health Through Normalized Difference Vegetation Index Imaging	**Requested Baker Endowment Funding**
Travel *subtotal*	**$0.00**
Travel: In-state	**$**
Travel: Out-of-state	**$**
Travel: International	**$**
Operating Expenses *subtotal*	**$ 2,500.00**
Non-computer Supplies & Materials	**$2,500.00**
Computer Supplies & Materials	**$**
Software/Software Licenses	**$**
Printing/Duplication	**$**
Postage/Shipping	**$**
Registration	**$**
Membership Dues & Subscriptions	**$**
Multimedia Services	**$**
Advertising	**$**
Journal Publication Costs	**$**
Contractual Services *subtotal*	**$0.00**
Contracted Services	**$**
Equipment Rental/Lease Agreements	**$**
Service/Maintenance Agreements	**$**
TOTAL	**$2,500.00**

REFERENCES

1. "Unmanned Aircraft Systems." *Faa.gov*. FAA. Web. 8 Oct. 2014.

2. Tucker, Compton J. "Red and Photographic Infrared Linear Combinations for Monitoring Vegetation." *Remote Sensing of Environment* (1977): 127-50. Print.

3. Green, Miranda. "Unmanned Drones May Have Their Greatest Impact on Agriculture ..." *The Daily Beast*. 26 Mar. 2013. Web. 8 Oct. 2014.

4. Johnson, L.F, and S. Herwitz. "Collection of Ultra High Spatial and Spectral Resolution Image Data over California Vineyards with a Small UAV." *Remote Sensing of Environment* (2003). Print.

CAL POLY
SAN LUIS OBISPO
College of Agriculture, Food & Environmental Sciences
BioResource and Ag. Engineering Department

10/20/2014

Baker and Koob Endowments
Office of the Provost & Executive Vice President for Academic Affairs
San Luis Obispo, CA, 93407

Dear Baker and Koob Endowments Selection Committee,

It is my pleasure to write a letter in support of the application of Mr. Derek Myers for financial assistance from Warren J. Baker Endowment.

Mr. Derek Myers is a senior student in the BRAE department and he has been working with me for two months. He has finished most of the required classes for graduation and has been working on his senior project for several months now. He is extremely interested in Unmanned Aerial Vehicle (UAV) applications in an agricultural context, specifically, color Infrared imaging and thermal imaging implementation. This area is very new and promising, but also requires a multidisciplinary background to get involved in. Mr. Myers is one of the most intelligent and hard-working students I have met here at Cal Poly. He also has a strong background in electronics, mechanics, programming, and precision farming, therefore he is capable of doing this project. He has been making important progress during the past two months. A small UAV prototype was finished and some preliminary flight tests were recently carried out. A wirelessly controlled color infrared imaging system also has been developed and is ready to be mounted on the UAV once flights testing is finished.

One of the major barriers he is facing now is that the prototype UAV is not "heavy duty", it cannot carry multiple heavy sensors and equipment with a reasonable flight time. The award is very important for him to purchase necessary sensors, supplies, and materials to develop a bigger and more reliable UAV with higher payload to make this project successful and significant. As I know, he is also planning to present his project (both student paper and poster competition) during the 2015 American Society of Agricultural and Biological Engineers (ASABE) Annual International Conference held July 26-29, 2015 in New Orleans, Louisiana.

The Mechatronics Lab in the BRAE department will provide space, essential electrical equipment, and software for him to complete the project. I am his faculty advisor and will provide technical guidance and support. I will also ensure the project budget is followed and all the purchased supplies are kept in good condition, once this project is funded.

In conclusion, I fully support the efforts of Mr. Myers as he seeks this funding opportunity to support this research project, because the project's fruit will benefit him, our department, and the campus.

Sincerely,

Bo Liu, Ph.D.
Assistant Professor
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