(Student Paper) Educational Benefits of Unmanned Aerial System Design and Interdisciplinary Engineering Opportunities

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Introduction

One requirement for an Engineering program to be accredited by the Accreditation Board for Engineering and Technology, Inc (ABET) is to "Provide both breadth and depth across the range of engineering and computer science topics…". This is often done through paper-based design projects where multiple aspects of a project will be theoretically designed but never implemented in the real world due to time and budget constraints, thereby denying students the actual experience of constructing a complex multidisciplinary project.

With the rise in availability and capability of Unmanned Aircraft Systems (UAS) there is an opportunity to further expand their use for the purpose of education and scientific research. This provides a means to not only introduce and familiarize students with the theoretical engineering design process, but also to provide the opportunity to implement and field-test those designs in a way that is informative and engaging for the student. Not only does the UAS itself provide a platform for in-depth learning about various engineering disciplines (eg, power, computer, and aeronautical engineering), but the ability to integrate various payloads into the UAS provides a way to incorporate systems engineering and other scientific disciplines into the learning process, giving students exposure to broader and more practical perspectives that they might otherwise have missed when working on strictly theoretical designs.

This paper focuses on the educational benefits of UAS design and related aerospace academics, culminating in the design of a UAS system. This system provides the capability for autonomous precision landing on an Unmanned Ground Vehicle (UGV) in the absence of Global Positioning Satellite (GPS) signals for the purpose of automated recharging of onboard batteries and data collection storage. This paper outlines the wide array of engineering disciplines that these platforms touch upon, and highlights some of the tangible benefits accrued by students implementing a project in a real-world environment.

This particular project is just one piece of a much larger, complex endeavor that has had multiple students work on various systems in support of the overall mission design. The primary mission was to design and build a paired UGV/UAS platform capable of autonomous operation in a GPS-denied environment, specifically to support search and rescue operations inside of a building or mine shaft (described in more detail below). However, the design was also implemented in such a way as to not be unnecessarily limited by the initial mission goals, but to also be easily adapted towards other uses, such as static remote data collection stations or long distance operations that would otherwise require human intervention for UAS charging and piloting support.

This paper is not meant to describe the entire UAS/UGV system design in detail, but to highlight how a specific subset of the overall system requirements was satisfied within the context of the larger mission goals. The entire system (UGV autonomous operation, UAS automated charging, UAS automated landing, UAS interior pathing and object avoidance, UAS to UGV data transfer) is much too broad and intricate to be encompassed by one student's work and by necessity must be a collaborative effort between several disciplines and sub-disciplines of engineering.

However, the complexity and multi-student contribution aspects are seen as benefits and not a detraction from the educational value of this project. Not only does it provide an opportunity for interdisciplinary engineering, it also forces each student to incorporate their piece of the project into the larger design and not just look at a single system in an educational vacuum. Learning to work as a part of a larger team in a long term project such as this is invaluable for an engineer's career as projects and designs in industry and laboratories are often multiple year collaborations that a single semester long class cannot adequately replicate.

Aerospace Opportunities in Small Schools (Senior Author Perspective)

Small universities and colleges are often limited in their ability to offer meaningful opportunities in systems engineering or multidisciplinary engineering endeavors. A lack of faculty, material resources, and students can all too often hamper efforts to institutionalize such experiences. However, the existence of even a few meager aerospace-related pieces of a puzzle – a work experience as an undergraduate, an academic course, a graduate research project, a design team, or a user agency with real-world needs – can sometimes combine to provide the perfect set of experiences and opportunities for a motivated student to wildly succeed in following their passions and in making a difference.

The remainder of this paper is dedicated to describing one example of how individual opportunities, even as 'one-off' offerings for the school, can have a dramatic impact on the student, the school, and on users wrestling with real-life problems. From that perspective, this effort is about much more than providing the design of a single engineering project which satisfied a challenging technical requirement. More to the point, this paper is meant to outline how such an opportune experience can provide students with a profound sense of pride and increased confidence resulting from reaching beyond their own pre-existing bubble of technical competence. It is this author's hope that the example described below may serve as motivation to other faculty considering whether to invest their valuable time and efforts into new aerospace/ interdisciplinary courses and experiences.

Educational Benefits of UAS Engineering, One Author's Journey

It is not often that an engineering project of any size and scope pertains to just a single discipline – they often encompass many engineering and scientific disciplines. This was particularly apparent during my education while working on UAS projects. In my own case I was able to start during my sophomore year, working with a mechanical engineering student to design and build a modular UAS to support arctic research operations out of the University of Alaska Fairbanks (UAF) Poker Flat Research Range (PFRR). During the design phase of the project we met with a range of researchers and users, including biologists interested in counting birds and sea life, geologists looking into cataloging soil erosion rates, and state agencies looking to supplement wild fire monitoring and search and rescue operations. We needed to take into consideration the range of capabilities necessary to support such a wide variety of needs in a way that remained economical.

This design process was extremely valuable not only because it gave an idea of the specific uses that such a system would need to supply, but it went beyond a standard engineering lab or classroom project where such considerations would be hard to emulate. Our findings were presented, funding was secured, and we designed and constructed a prototype hexacopter, which would become named the Alaska Center for Unmanned Aircraft Systems Integration (ACUASI) "Ptarmigan" UAS. Over the next several years more aircraft based on this design were constructed and grew into a fleet of 5 aircraft being used as the main operational aircraft for ACUASI.

Later, in my undergraduate program, I had the opportunity to build upon the lessons learned during this project by taking an Aerospace Systems Engineering class. This class focused on the design and construction of two systems, based on DJI's S900 and S1000 UAS airframes. We worked closely with ACUASI to determine how to design systems that would support realistic UAS use and operations. Because of my previous design work, I functioned as a project manager for the class, determining timelines for design and construction that fit within the semester long timeframe for the class, and forming teams of students to tackle the multiple subsystems involved. We designed communication and control systems, integration circuit boards, power consumption and battery health monitoring, designed and 3D printed weatherproof cladding, performed cold weather battery testing, developed data collection and management plans, and studied FAA regulations on small sized UAS use and restrictions.

While the class consisted of multiple disciplines of electrical and mechanical engineering students, specific effort was made to make sure that every student, no matter the discipline, understood and had the opportunity to contribute to every individual component and process involved in the design, construction, and use of the UAS. In addition, every student was able to get hands-on time using the system, being able to operate the finished product themselves in a controlled environment at the end of the class. I was able to contribute to future versions of the same course, which helped not only reinforce the engineering concepts, but also gave me valuable experience in project management.

Project Inspiration and Development

This experience working with and designing UAS gave me the opportunity to work with ACUASI during my undergraduate and graduate degree programs, and eventually as a full-time engineer after graduating from my master’s program. The work with ACUASI during my undergraduate program led to the idea for the focus of my master’s project, a paired UAS/UGV system capable of autonomous landing and remote operation. This was an ongoing mission need of interest to the mining community and it fit well with my previous electrical engineering courses and UAS experience. A simple graphic representing this mission type is shown below (taken from another UAF graduate student project focused on UAS/UGV-to-personnel communications link) [1].

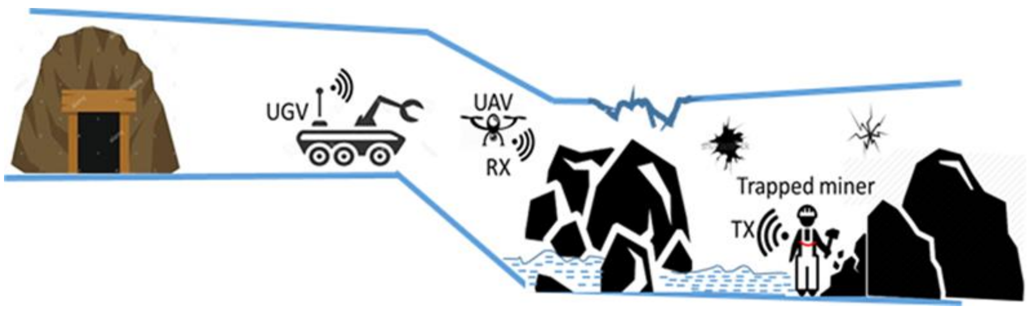

Figure 1: Conceptual diagram depicting UAS/UGV paired operations in mine rescue operations

UAF has been developing a novel capability consisting of UAS/UGV paired operations to support the rescue of trapped miners in an emergency situation. A UGV which is capable of operating for 4-8 hours is used to carry a UAS down into the mine tunnel network to locate trapped miners. If the UGV is unable to make contact due to cave-ins or obstructions, the UAS may be utilized to make contact. The UGV is equipped with a charging base to recharge the UAS for multiple flights, as well as serving as a communications link to the outside world. In addition to this aspect of the project (autonomous landing of the UAS on the UGV), several other technical challenges have had to be tackled for this system to become viable, some of which are still being worked on at this time (eg autonomous navigation and obstacle avoidance for both the UGV and UAS individually, real-time communications with the ground control team).

In addition to the mine rescue application, the capability for autonomous UAS landing operations at a precise location was of broader interest. While working with ACUASI, we were often limited in our operations by the need for a static home base to pilot the aircraft from and have it return to for swapping batteries when they ran low during a mission. Oftentimes we would have to extend operations for several days, operating from a slightly different location each day to cover the necessary area for the data collection. This severely limited the operational range of the aircraft, and as a result, the speed and economy with which we could gather data.

It became apparent that in order to extend the functionality of UAS systems a mobile (or in some cases static emplacement for longer term missions) automated landing and recharging platform was necessary. Without prohibitively expensive precision systems, the GPS network was determined to not have the precision and reliability to support this kind of system. In addition, there were missions being considered, such as inside of a building or mine, where GPS signals are unavailable. I had previously taken a class in image processing which led to the idea for having an optically based tracking system. This would have the added benefit of having as small as possible impact on the weight and power consumption onboard the UAS itself, only needing a pair of lightweight LEDs on the aircraft, with the bulk of the system being on the UGV or ground platform. Work was initially done with a mechanical engineering graduate student to design and construct the charging dock and interface, working out how precise of a landing was necessary and how to secure the UAS to a platform reliably.

Without the entirety of my previous education in working with other engineering disciplines (scoping and designing UAS systems, project management of complete UAS system design, and practical field operations), I don’t see how I would have been able to even envision this project, let alone see it through to a fully realized and functional design. The fundamentals learned through the normal course of an electrical engineering program are of no doubt essential, but no amount of classes in circuit theory or command and control systems would have given me the same breadth of experience that working on and with UAS systems has provided.

Additional Uses of Design

The potential applications of a paired UAS/UGV system such as this one extend beyond the initial intended design. This specific system was designed for use in mine rescue operations, to be sent into an underground environment to assist with search and rescue of personnel and atmospheric assessment of difficult to reach or potentially dangerous environments. It could be expanded to be used in surveillance of pipeline infrastructure, like the Trans-Alaska Pipeline, where the long length prohibits static base station operations and a mobile communications and charging platform would be needed to extend the reach of any UAS based data collection. Paired operations would be useful in rural road grade assessments, such as in Alaska where there are thousands of miles of rural roads that are constantly shifting due to impacts from permafrost.

The concepts and components of this design would also be of use in other operations that don’t need a mobile platform, where a human pilot might not be economic or feasible. Periodic missions such as monitoring of glacial flows, river breakup, shoreline sea ice monitoring, or wildlife monitoring would otherwise require constant visits but with a system that can takeoff, fly a mission, land precisely, and charge autonomously, a person wouldn’t need to be involved nearly as often. With solar cells for power and a microwave or satellite data connection, a system could be left alone for months or years, providing a great boon of scientific data for a much smaller economic impact, making the ability to collect data more widely accessible.

Figure 2 - Husky with UAV Side View

System Overview

The system itself consists of a Clearpath Husky UGV that has been modified to include a landing/charging platform for a UAV that has been adapted to interface with the charging platform. There are 4 conical receptacles in the landing platform which are used to guide the landing legs of the UAV onto the connections that charge the onboard batteries of the UAV after flight operations. The landing docking/recharging systems was created by another graduate student as their thesis project [2]. The onboard batteries for the UAV are then charged from supplemental batteries carried by the UGV, allowing for multiple flight operations in a shorter time period than would be necessary if the UAV had to return to a central location to recharge after flights.

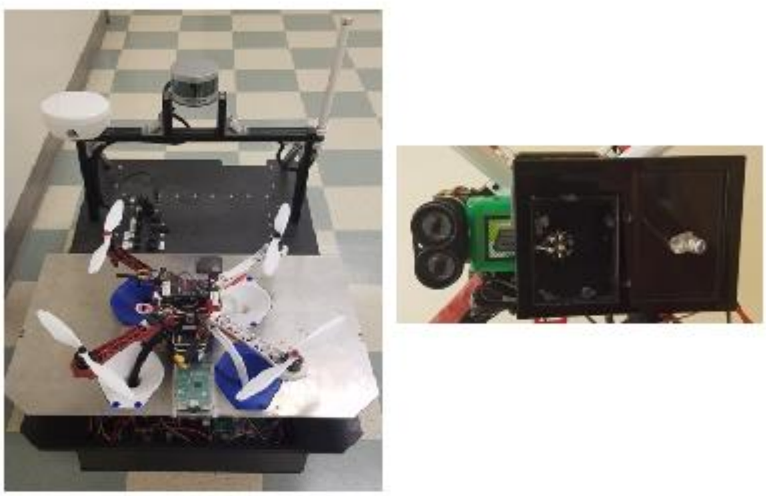

Figure 3 - Husky with UAV Top View, Bottom View of UAV with Tracking LEDs

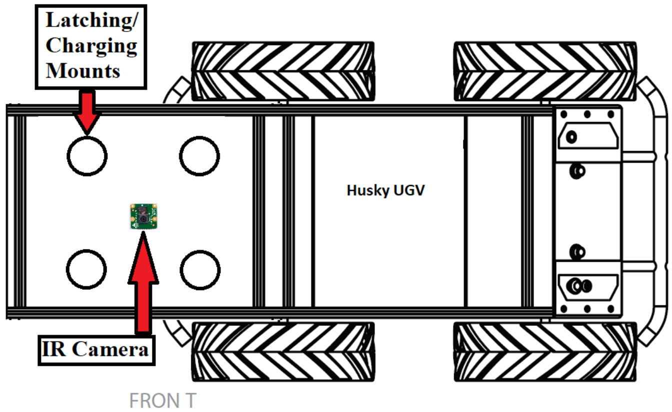

Figure 4 - UGV Functional Diagram

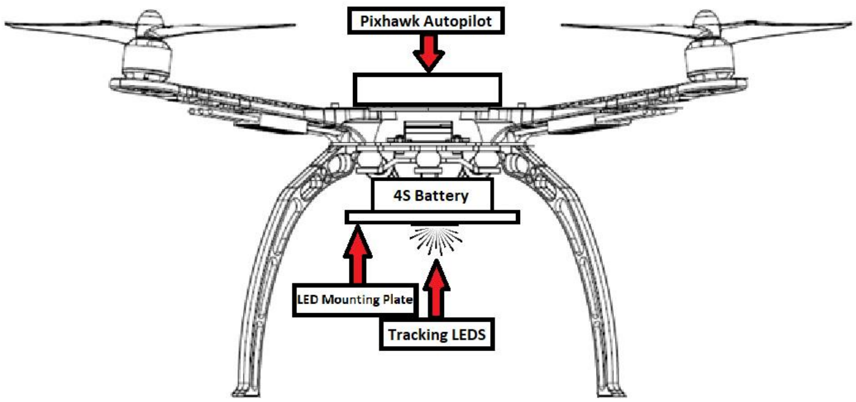

Figure 5 - UAS Functional Diagram

The RaspberryPI is mounted to the landing platform, with the IR camera being mounted centrally between the 4 landing cones. The UGV supplies USB power to the RaspberryPI without the need for modification. The RaspberryPI is connected to an RFD900+, a 1 W, 915 MHz, serial modem, which transmits the flight control commands to the UAV while in flight. The program running on the RaspberryPI is able to send between 5-7 command updates per second to the UAV. The command update rate is limited by how fast the RaspberryPI can capture the image, mask the image, then calculate the position of the LEDs on the (x,y) plane of the image frame.

The UAV is a quadrotor UAV based on the Pixhawk Autopilot system using a DJI 450 ARF frame. It is powered by a 4S, 5200 mAh Li-Po battery. The UAV has been modified with a plastic plate attached underneath on which the tracking LEDs are mounted. The plate extends 15 cm off the front of the aircraft, with the IR LED mounted in the center and the blue LEDs mounted 10 cm further towards the fore of the aircraft. A RFD900+ serial modem is attached to the Pixhawk to receive flight control commands from the RaspberryPI.

This radio is in addition to the standard telemetry radio on the Pixhawk, used for UAV to Ground Control Station (GCS) communication. The same radio could be used for both GCS communication and control commands from the RaspberryPI, but this would require sending the RaspberryPI commands through the GCS computer, as well as the responses to queries of UAV flight mode and altitude. This method was not used because of the increased lag and unnecessary complexity this would introduce to the system.

System Components

Raspberry PI 3 Model B+

Figure 1 - RaspberryPI Model3 B+

The RaspberryPI Model3 B+ is a microcomputer based on the Cortex-A53 (ARMv8-A) 64-bit instruction set [3]. It features the Broadcom BCM2837BO quad-core processor at 1.4 GHz. It is equipped with 1GB of LPDDR2 SDRAM, a 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, a Camera Serial Interface (CSI) port for the RaspberryPI NoIR camera, and a MicroSD port for storage. It is running a modified version of Debian called Raspbian, which has been optimized to run on the RaspberryPI. This operating system also provides functionality specific to the RaspberryPI, in the case of this project support for the RaspberryPI NoIR Camera interface. All programming for this project was done in Python v2.7.13.

The RaspberryPI Model3 B+ was chosen for this project for multiple reasons. It is a very small device, which makes it easy to mount and install in the limited space available in the UGV. It has low-power consumption, with max power consumption being around 5 W, which is negligible when being powered from the 480 Wh batteries on the UGV. It has a dedicated interface for the RaspberryPI NoIR Camera, allowing much faster image acquisition than when using a camera through a separate interface, such as USB. The RaspberryPI is also inexpensive, with a MSRP of $35, making it very desirable for its capabilities when compared to the price for similar functionality from a laptop or other computer system.

RaspberryPI NoIR Camera V2

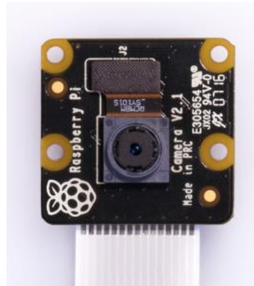

Figure 2 - RaspberryPI NoIR Camera V2

The RaspberryPI NoIR Camera V2 uses a Sony IMX219 8-megapixel sensor and does not employ a physical infrared filter like the majority of cameras [4]. It has a horizontal field of view of 62.2° and a vertical field of view of 48.8°. It was chosen for this project because of its dedicated interface with the RaspberryPI, the availability of the Picamera Python libraries, the V4L2 drivers which allow for unencoded image capture, and the ease of interfacing with OpenCV libraries which will be used for LED tracking.

Pixhawk v1.0 Autopilot

Figure 3 - Pixhawk v1.0

The autopilot controlling the UAV is the Pixhawk v1.0 running on the ARM Cortex M4 at 180 MHz [5]. This autopilot system has been proven to be very reliable and is easy to interface with due to its open source development. Unlike other commercial autopilot systems, such as DJIs Wukong-M system, its design supports easy modification and provides several communication interfaces, as well as extensive documentation on how to use and modify the operation of those interfaces. The available UART communication interface is used to inject flight control commands from the RaspberryPI, as well as provide feedback to the RaspberryPI on flight mode status.

Tracking LEDs

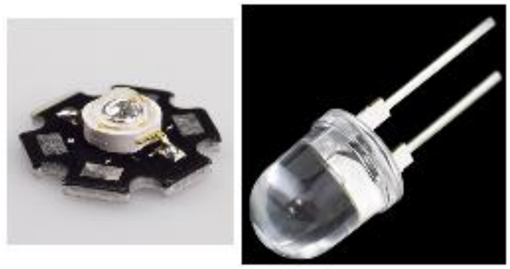

Figure 4 - 1W 850 nm InfraRed LED, 465 nm Blue LED

The central tracking LED on the UAV was chosen to be a 1 W 850 nm InfraRed LED [6]. This LED has a radiant power of 315 mW and a viewing angle of 140°. The LED package, including the pictured heat sink takes up a total area of 14.5 mm x 7.5 mm, making it small enough to easily mount on the UAV. It has a forward voltage of 1.9 V at an operating current of 700 mA, making it easy to integrate into the existing power system on the UAV. An IR LED was chosen for ease of separation from standard indoor light sources and for slightly better penetration of atmospheric disturbances, in this case smoke and dust in a damaged building or mine.

A pair of 465 nm blue LEDs were chosen for the forward LED indicators [7]. Initially a 625 nm LED, similar to the 850 nm, was chosen but it proved to be too close in spectrum to reliably identify, so the 465 nm blue LEDs were selected. The blue LEDs have a viewing angle of 45°, so 2 were mounted angled slightly away from each other to provide a wider detection angle. They have a forward voltage of 3.0 V at an 80 mA operating current, making them easy to integrate into the existing UAV power system. In order to protect the Pixhawk autopilot of the UAV, which runs on a DC-DC switching 5 V regulator attached to the onboard 4S battery, an additional DC-DC switching 5 V regulator was installed to provide power solely for the tracking LEDs. This was done to ensure that any failure or shorting of the LEDs would not also lead to the failure of the Pixhawk autopilot.

The LEDs are hardwired to the 5 V output of the regulator with current limiting resistors in series on the input. When compared to the current drawn by the UAV in flight, the additional current from the LEDs does not amount to a large impact on flight or charging time.

Clearpath Husky UGV

The landing/charging platform for the UAV, as well as the mounting location for the RaspberryPI and NoIR camera is a modified Husky UGV made by Clearpath Robotics [8]. The Husky is 99 cm x 67 cm x 39 cm and weighs 50 kg, with a maximum payload of 75 kg. It is powered by a 24 V 20 Ah Lead Acid battery, with 5 V, 12 V, and 24 V 5

A power supplies available. It has been modified with a landing platform for the UAV and an additional storage space under the landing platform for the charging system and supplemental charging batteries. The landing and charging platform and UGV modifications were designed and built by previous student for their master's project.

RFD900+ Serial Modem

Figure 5 - RFD900+ Serial Modem

The RFD900+ serial modem was chosen to provide flight control communication between the RaspberryPI and the Pixhawk autopilot on the UAV. The RFD900+ is a 915 MHz, 1 W transmit power, serial radio [9]. This radio has been previously used in UAVs built for operations for UAS CENTER, UNIVERSITY's UAV operations department, as well as numerous CEM drone class builds.

Method of Identification

OpenCV

This project uses OpenCV libraries to facilitate identification and tracking of the LEDs on the UAV. OpenCV, originally developed by Intel, is a free for use open source library released under a BSD license [10]. The fact that it is open source and very widely used in a variety of image tracking and object identification projects made it an ideal choice for this project, with many online tutorials and extensive documentation. The specific version used in this project is OpenCV2, built for Python 2.7.X. OpenCV also provides native support for the RaspberryPI and RaspberryPI NoIR camera.

Basic Program Operation

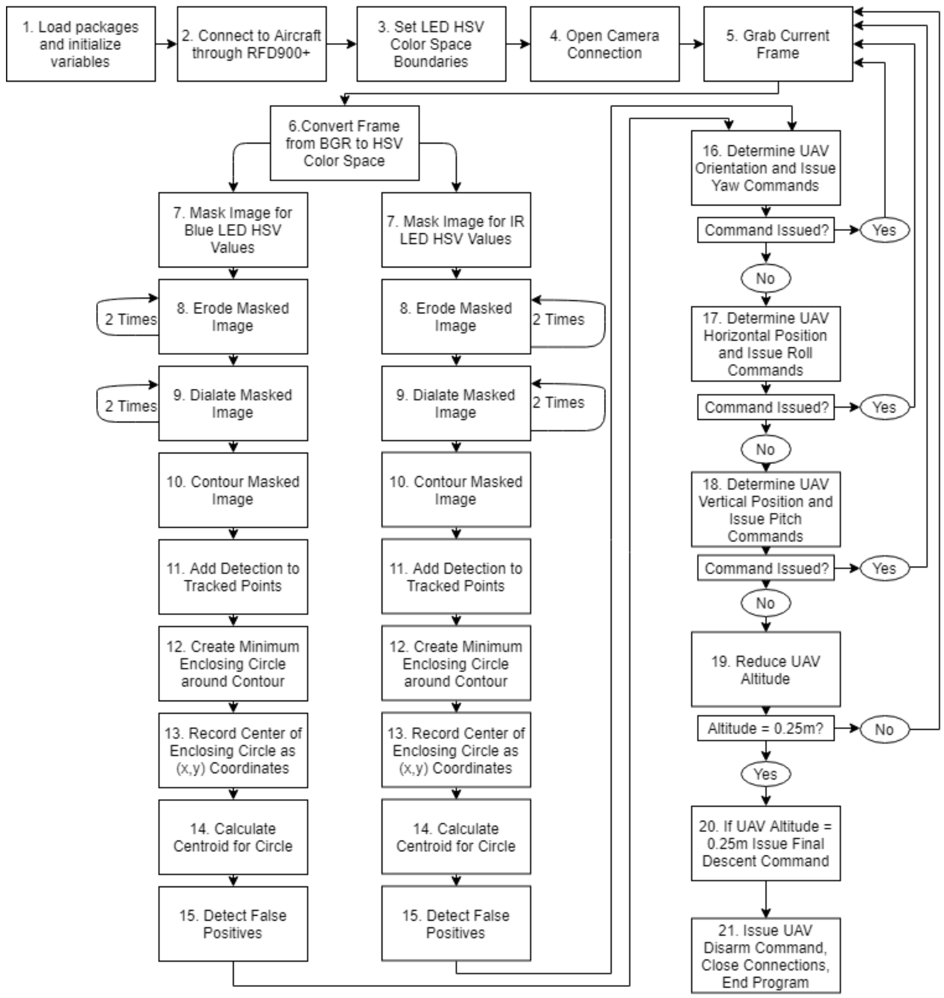

Figure 6 - Program Flowchart

The basic operation of the program is as follows:

1. The required OpenCV and Dronekit [11] packages are loaded and variables are initialized.
2. Connection to UAV is opened through RFD900+.
3. The program sets an upper and lower boundary in HSV color space for the LEDs.
4. A connection to the camera is opened and a 2 second wait is observed to allow the camera sufficient time to start up and self-adjust.
5. A loop is entered where the current frame is grabbed.
6. The grabbed frame is converted from BGR to HSV color space.
7. The image is masked with the cv2.inRange() function using the HSV color values for the LEDs.
8. Two passes of the function cv2.erode() are performed to reduce the noise in the mask as well as to draw in the edges of the detected LED.

9. Two passes of the function cv2.dialate() are performed on the mask to fill in the area of the detected LED.
10. The edges of the LED in the mask are defined using the function cv2.findContours().
11. If a positive detection has been made, then the detection will be added to the list of counted points for that LED.
12. A circular area enclosing the detected contour is created using the function cv2.minEnclosingCircle().
13. The center point of this circle is then calculated and saved as (x,y) coordinates.
14. The centroid of this circle is then calculated using the function cv2.moments() on the created minimum enclosing circle.
15. In order to reduce false positives, the detected circle must span at least 3 pixels, if it does the detected circle is then drawn on the output image to indicate detection.
16. If both the IR and blue LEDs have been detected, then the orientation of the UAV is determined using the relative position of the LEDs and commands to either rotate clockwise or counterclockwise are issued until the blue LED is towards the top of the frame and aligned with the IR LED. The loop is then restarted.
17. If no rotation commands have been issued this loop then the horizontal position relative to the center of the image is calculated based off the IR LED, with commands being issued to bring the UAV into the horizontal center of the image. The loop is then restarted.
18. If no rotation commands and no horizontal movement commands have been issued this loop then the vertical position relative to the center of the image is calculated, with commands being issued to the UAV to bring it into the center of the image. The loop is then restarted.
19. If no rotation, horizontal, or vertical movement commands have been issued this loop the UAV is commanded to reduce altitude. The loop is then restarted.
20. Once the UAV reports its altitude as less than 0.25 meters, the UAV is commanded to drastically cut motor RPM and descend. This aggressive control is necessary because of the large influence that ground effect has when so close to the landing platform.
21. The UAV is then considered to have landed, disarm commands are issued, and the program is finished.

Educational Breadth and Depth

As this paper has demonstrated, there is an extensive breadth to the engineering disciplines involved in a project design such as this one that utilizes a UAV as its main platform. While the main bulk of the implementation is directly associated with computer engineering, the system could not be designed without knowledge of, and learning from, other disciplines.

Aeronautical engineering is necessary for being able to understand the flight behaviors of the UAV in a confined space, such as interior spaces this system is designed to be used in. One problem that came up during the terminal phase of the landing process was that the UAV would exhibit a tendency to float unexpectedly when on close approach to the landing platform. This led to an investigation into the ground effect experienced by rotary wing aircraft when landing.

Research was done into optics and how a camera actually receives and encodes the different spectrums of light it receives, even beyond the visual range it displays. Also into how different wavelengths of light behave in non-ideal environments such as when there are significant levels of gasses and particulates that may diffuse or occlude certain spectrums and would be expected to be present inside of a collapsed building or deep in a mine shaft. The lens of the camera also had to be considered and how it would distort the light and relative position of the image it passed through to the camera's sensor.

Image processing is the backbone of this system and this went beyond simple programming of the code to process the image but expanded to needing knowledge of the physical architecture of the processor running the program. Being able to do the processing quickly was paramount and being able to understand how the image was captured, encoded, buffered, and stored was integral to being able to utilize the relatively small processing power available in the RaspberryPI.

Cost Analysis

Below is a basic breakdown of the cost of this project. As with most broad ranging projects, the cost requires a bit of context to be understood as it pertains to this project. The primary expense involved is the Husky UGV, taking the vast majority of the price involved ($50K). This UGV is heavily modified by a previous student graduate project, adding in a landing platform and the associated charging equipment. This project also is part of a larger, very specific, mission to support search and rescue operations in a mining environment and as such, requires much more complexity and ruggedness than would otherwise be necessary for this project alone. Someone wanting to emulate this project for other purposes, such as setting up a static remote station for data collection or just based from a ground vehicle with less rigorous requirements, would find this cost estimate to be many times their needed expenditure.

The portion of interest for anyone wanting to use this project as a roadmap should be the UAS, its associated hardware, and the RaspberryPI hardware. None of the UAS or RaspberryPI hardware is modified to the extent to render it unusable for other educational projects. This modularity is one of the great educational benefits for UAV related projects, they serve as a platform for multiple educational endeavors while still maintaining their functionality. The UAS in this project will still be used for further design projects, flight training, and educational outreach for several years before it becomes obsolete.

Item	Price ($)
UAV Hardware	589
Pixhawk Autopilot	100
RFD 900+ Serial Modem	198
Tracking LEDS	10
Raspberry PI 3 Model B+	54
NoIR Camera V2	28
Total	**979**

Table 1 – Project Cost Analysis

Lessons Learned

The greatest benefit of a project like this is not necessarily the knowledge gained from designing this specific system, but in how to identify and investigate problems outside of my concentration when studying engineering. My undergraduate electrical engineering degree was in communications and the majority of my graduate studies were in command and control, microprocessor architecture, and image processing. This project effectively utilized all of those studies as well as forcing me to expand my learning outside of a regulated classroom and to learn how to research unfamiliar topics on my own, and utilize resources and faculty available through the university, in a way that I hadn't needed to do in a regular curriculum. Being able to incorporate all of the varying aspects of what I had learned and bring them together into a fully realized system I could see working in front of me, gave me a motivation and satisfaction that I never found present when doing a theoretical paper design or when just going through the steps of a project that is basically laid out for me similar to most lab projects. Identifying an unfamiliar problem and understanding what questions need to be asked to find a solution to that problem is something that this project taught me in a way that I would find difficult in absorbing the same way from a lecture style environment.

This project not only gives the basis for an operational unit for use by ACUASI, but also an opportunity for more projects by future students wishing to continue their own education. Developing UAS and associated systems is a continuing process, with each step building off the last. This may give the basis for another student to build a remote operations platform, something that could be set in place in a remote location to provide long term data collection. It could also allow for a science student to collect data for their future graduate project, or maybe a future electrical engineer will use this as inspiration and build an improved method for accomplishing the same goal. Engineering and sciences are built off of the advancements of what has previously been done and the boom in UAS use and research is just one further step in that path.

New students should seek out projects such as this one for the express reason of it not being limited to an individual discipline. The classroom learning is just a foundation; a way to help teach you how to learn, not just what you need to know. I may never use the exact knowledge from a wide ranging project like this one again, but having the opportunity to learn how to approach new and unknown topics is the greatest benefit that I will take with me from this project for the rest of my career.

Educational Reference and Context

This paper serves two-fold as a reference for future students and educators. The technical aspects are important because they give a firm and detailed context to the subsystem itself and how it fits into the greater system and mission it is designed for. Having an in-depth description and analysis of the technical aspects of this design can serve as a guide on how to complete this or a similar project, as well as opening up this specific project to new ideas and methods from others in the future, an essential part of the growth of engineering. The technical aspects however are lifted up when the context of the student experience is added to it. Trying to divorce the 2 aspects, technical and personal, of an educational experience often removes context which is important to understanding the benefits of a project such as this one.

While there is no replacement for the technical education learned in classrooms, by necessity it is often relegated to extremely specific and short-term instruction. This paper serves to highlight how getting a student involved in interdisciplinary education early on in their undergraduate studies can serve to fill the gaps that are often left by classroom learning.

Educators and students should strive to find ways to implement interdisciplinary engineering as early as possible in a student's degree program. While this particular project highlights UAS system design, the important part is to find something that forces the student outside of their chosen concentration while still incorporating important aspects of that concentration. One roadblock in this method of outside the classroom learning is it needs to be continuous and long term. Having complex, but short, projects doesn't give the same benefit as a long term, consistent, design. This isn't to imply that a large project can't be broken down into manageable parts, it just needs to all relate together to give the full impact to the student.

There are many clubs and extra activities for certain engineering disciplines, such as a bridge building team for civil engineers or a micro-mouse team for computer engineers. The benefit of these kinds of activities is clear, they reinforce the classroom teaching in a longer term and engaging way. The problem however is that these teams are often solely composed of students in a single discipline with little regard for learning outside of their field. In my experience in

UAS design, in this project and in others, the exposure to mechanical and aerospace engineering students, practices, and principles only served to enhance my overall graduate and undergraduate learning. Understanding your own field of study is important, understanding the context of that field within the wider world of engineering is crucial.

Protecting Opportunities (Senior Author Perspective)

The previous project and story described by the primary author of this paper highlights the importance of providing aerospace-related opportunities to our students. As noted, many schools cannot afford the expense or complexity of providing a full aerospace engineering program. However, sometimes offering what we can, when we can, can truly make a huge difference to one or more students…and sometimes a single student can go on to make a huge impact to the school's academics, research, and partnered organizations.

As a result of this student's participation in ad hoc opportunities and his subsequent contributions, the school's academic program has been substantially enriched in terms of:
(1) Academics. The quality of offered aerospace/electrical engineering courses have been improved through mentoring and teaching assistantships performed by this student.
(2) Engineering Projects. As a result of this student's work and collaboration with others, the school's graduate and undergraduate programs have multiple viable research projects to act as springboards for future efforts.
(3) Applied Research. The school's UAS center has received high-quality UAS platforms to both conduct future research and participate in public service operations. In addition, the center has benefitted directly from the student's computer communications expertise as an intern and then as an employee on several important grants and other sponsored work.

Clearly, this (now former) student has also benefitted personally and professionally from participating in the aerospace opportunities afforded him at the school. He has gone on to a promising technical engineering career and I fully expect that his love for learning and teaching will eventually find its way back to some university in the future. Such skillsets can be developed and nurtured through our programs, even when these are catch-as-catch-can.

Appendices

References

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Acronyms

ABET	Accreditation Board for Engineering and Technology, Inc
ACUASI	Alaska Center for Unmanned Aircraft Systems Integration
Ah	Ampere Hour
BGR	Blue Green Red color space
BSD License	Berkeley Software Distribution License
GPS	Global Positioning System
HSV	Hue Saturation Value color space
IR	Infra-Red
LED	Light Emitting Diode
LiPo	Lithium Polymer
MAVLink	Micro Air Vehicle Link
MOSFET	Metal-Oxide Semiconductor Field-Effect Transistor
nm	nanometer
NoIR	No Infra-Red cut filter
PFRR	Poker Flat Research Range
PID	Proportional Integral Derivative
PWM	Pulse Width Modulation
RC	Radio Controlled
UAF	University of Alaska Fairbanks
UART	Universal Asynchronous Receiver Transmitter
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
Wh	Watt Hour