Drone Construction and Racing for PreCollege Students

Dr. Michael C. Hatfield, University of Alaska Fairbanks

Michael C. Hatfield is an assistant professor in the Department of Electrical and Computer Engineering at the University of Alaska Fairbanks, and Associate Director for Science & Education, Alaska Center for Unmanned Aircraft Systems Integration. He earned a B.S. in electrical engineering from Ohio Northern University; an M.S. in electrical engineering from California State University Fresno, and a Ph.D. in Electrical/Aeronautical Engineering from the University of Alaska Fairbanks.

Dr. Catherine F Cahill, Alaska Center for UAS Research, University of Alaska Fairbanks

Dr. Catherine Cahill is the Director of the Alaska Center for Unmanned Aircraft Systems Integration (ACUASI) at the University of Alaska Fairbanks (UAF). Cathy possesses a B.S. in Applied Physics from the University of California, Davis, and an M.S. and a Ph.D. in Atmospheric Science from the University of Washington and the University of Nevada, Reno, respectively. Cathy's research has focused on atmospheric aerosols and their impacts on visibility, global climate, aircraft safety, and human health. Cathy began working with unmanned aircraft in 2006 as a way to determine the vertical distribution of atmospheric aerosols. In 2015, Cathy became the Director of ACUASI. ACUASI is a world leader in unmanned aircraft operations. ACUASI leads one of the seven FAA UAS Test Sites, heads one of the nine FAA UAS Integration Pilot Program sites, and is a part of the FAA Center of Excellence for UAS Research. During its 18-year history, ACUASI has conducted numerous maritime, subarctic, and arctic unmanned aircraft missions.

Dr. Peter W Webley, University of Alaska Fairbanks

My research interests include volcanic ash cloud modeling, use of unmanned aircraft systems for geoscience applications, connecting emergency managers with real-time remote sensing data, developing decision support tools, real-time monitoring of volcanic activity, and remote sensing of volcanic processes. My aim is to provide tools and products for hazard assessment and risk mitigation.

I have a passion for business development and technology transfer from an academic environment into the private sector. I am a Faculty Ambassador for UAF's Office of Intellectual Property and Commercialization and support and advise UAF's innovators and entrepreneurs along with their Office on providing resources, programs and initiatives to build an innovative culture at UAF.

This led me to become the Vice President of V-ADAPT (Volcanic Ash Detection, Preparedness for Transportation), a start up company out of UAF. We provide real-time decision support tools as well as provide consultancy services to evaluate potential ash impact on day-to-day operations and how to analyze remote sensing data for real-time hazard assessment.

Drone Camp: Construction and Racing for Pre-College Students

Abstract
Engaging precollege students early in their academic development is an important factor in ensuring their continued interest and focus in education. In particular, Science, Technology, Engineering, and Mathematics (STEM) activities involving unmanned aircraft systems (UAS, or 'drones') can provide exciting and valuable outlets for young students who may be considering a technical career path in engineering or a related field.

Advances in technology over the past decade have dramatically decreased drone prices, increased their availability, and made operation easier, making these commonplace in society today. Drones are used for a wide variety of applications including personal entertainment, covering news and sporting events, conducting vital scientific research, monitoring critical infrastructure, and even providing emergency services. In addition, recent relaxations in the regulatory framework governing the rules for UAS operations by the Federal Aviation Administration (FAA) have made it much easier to provide meaningful drone activities to precollege students.

The erosion of these previous barriers has resulted in a much more conducive environment for college and precollege teachers to engage in drone-centric educational activities. As a result, many colleges and precollege schools are beginning to actively partner with various government agencies, industry, and corporate sponsors to bring UAS STEM educational experiences to interested students. One example of this is a program instituted at the University of Alaska Fairbanks (UAF) this past year, in partnership with the FAA and the local school district.

This program, titled *Drone Camp*, provided 5th and 6th grade students from the local community an opportunity to learn how to build and pilot small quadcopters, such as those commonly seen in popular Drone Racing League (DRL) events across the country. Held at UAF and taught by the Alaska Center for Unmanned Aircraft Systems Integration (ACUASI) personnel, the 1-week camp was sponsored by the FAA with the intent of increasing educational opportunities for young students and motivating students to consider STEM-related careers. A secondary goal was to generate foundational materials, plans, and tools so the camp elements could be replicated by others across the USA.

This paper outlines the long-term motivation for UAF's involvement in this Drone Camp and related activities, as well as skills learned by the students participating. It highlights the FAA mechanism to push STEM education, the approaches used, and details the camp structure. It also details lessons learned from this 1st event, including student feedback, and provides a look at future outreach activities to be conducted over the next couple years.

Synopsis
During the period of 11-15 June 2018, UAF's ACUASI and the FAA hosted a STEM summer camp teaching middle school students how to build, program and safely operate a First-Person View (FPV) racing drone. While attending the camp, students were taught about FAA safety programs, applicable UAS regulations, basic flight principals of multi-rotor aircraft, fundamentals of flight, flight controller set-up and flight simulation. Students experienced extensive flight time using their own small UAS with both free flight and competition racing scenarios.

Motivation for the Program
It is important to engage students at an early age to foster the desire later in life to enter STEM related fields. The performance of US K-12 students in math and science in comparison with the Organization

for Economic Co-operation and Development (OECD) countries is below par. More alarmingly, the US has the 5th largest gap between high and low socio-economic status students, and that while white and Asian students perform at about the same levels as students in high performing countries, the performance of African-American students is on par with non-OECD countries such as Serbia and Bulgaria (PISA, 2009 [1]). The data in the latest Programme for International Student Assessment (PISA) report (PISA, 2012 [2]) does not show much change in the standing of the US vis-a-vis the OECD countries. The remark by the Secretary of Education that the educational performance of US students is 'a picture of educational stagnation' (Huffington, 2013 [3]) sums up the status of K-12 education in the US. Several programs have been launched aimed at remedying this situation.

Project-based active learning opportunities have been empirically determined to be effective in student engagement and learning (Prince 2004 [4]; Thomas, 2000 [5]). Project-based learning environments can be designed to enhance teamwork, communication skills, understanding of application of STEM in real life, and self-efficacy. Unfortunately, schools that primarily serve under-represented groups often do not have the resources to provide such learning environments. Simply stated, there is a longer-term need to have more students target STEM related careers, and the best way to do this is via engaging hands-on project-based learning opportunities.

FAA STEM Partnership

As part of the nationwide effort to safely integrate UAS into the National Airspace System (NAS), the FAA has sponsored the Center of Excellence (COE) for UAS Research partnership, entitled the Alliance for Systems Safety of UAS through Research Excellence (ASSURE). The FAA UAS COE is managed by Mississippi State University and includes numerous partners from industry and academia. The main focus of the FAA's UAS COE is to perform UAS-related research to address key technical challenges for safe operation and integration into the NAS. The FAA identified that a necessary element of this overall research was how to prepare the next generation of technologists, scientists, and engineers who can focus on these aviation challenges. Initial funding for STEM outreach was focused on students from groups who are under-represented in STEM fields. This 1st round of STEM efforts was performed by the New Mexico State University (NMSU) and Tuskegee University.

The success of these 2 initial programs energized the FAA to expand to additional universities to reach further regions of the country, maintaining the core focus target of students from groups who are under-represented in STEM fields. This STEM II effort, titled *UAS as a STEM Minority Outreach Learning Platform for K-12 Students II*, included 4 schools: NMSU, UAF, University of California, Davis, and Montana State University. Each school had its own unique approach to this outreach based on staff, resources, and local demographics. NMSU's lead and support to this program forged a relationship with UAF to help plan and conduct the UAF outreach activities. It is this FAA-funded program which sponsored the UAF FAA UAS outreach and Drone Camp efforts.

Rationale and Program Description

Within the framework of ASSURE, there is strong desire to incorporate STEM outreach to students from groups who are under-represented in STEM fields. There is no one single approach that addresses this for students of different ages, backgrounds, or who have different cultural and regional influences. However, there are common technical ideas and instructional approaches that can be used as building blocks which can then be tailored to the various under-represented target groups. These building blocks, using the development approaches and support materials, can then be replicated by other ASSURE members or external groups as well.

The objective of this project was to expand potential STEM outreach approaches that use UAS as the

central learning platform. STEM topics included fundamental concepts and unique UAS-related content. Various approaches for STEM outreach were provided and discussed with the FAA. This project conducted activities which fell into 3 basic categories: 1) UAS Roadshows, 2) UAS Summer Camp, and 3) UAS STEM outreach activities. These events were offered at 3 specific diverse geographical locations where the targeted student communities are not similar and face unique educational conditions. The UAF team interfaced with students who hail from inner cities, rural areas, Native American, Alaska Native, and tribal communities. It was recognized that while their lives and situations may be vastly different, there is a common thirst for knowledge. A goal of this program was to ignite a desire to study STEM-related educational paths. This paper focuses on one of the activity types noted above, specifically the 2nd of these – UAS Summer Camps.

Foundational research was accomplished regarding what relevant materials were available. Materials from the initial NMSU STEM outreach efforts were highly leveraged in the planning stages. These existing materials were adapted as appropriate for each region and new materials developed. As efforts proceeded, the focus shifted to build on previous materials generated as part of this effort or other available efforts for STEM education. The outreach approaches were detailed by school and the geographic areas served. As noted above, the array of activities included on UAS Roadshows, UAS Summer Camps, and other UAS STEM outreach Activities. Many elements developed for each of these activities were used in whole or adapted to the particular events with a particular focus on the areas of valued core content, modularity, and adaptability. Additional elements and approaches were explored as part of the overall process and will be expanded in future years as part of an ongoing process.

A core approach for the program has been student engagement at the appropriate content level to aid in the learning process. This continues to be a challenge and an important aspect to improving student performance. Targeted and flexible educational materials are needed. Institutional infrastructure for student engagement is an essential element to ensure student learning outcomes are achieved. These challenges are exacerbated in school districts that serve students from groups under-represented in STEM fields. Non-availability of funds, materials, trained teachers and technological infrastructure are some of the challenges that are faced by such school districts. The overall environment leads to low self-efficacy in students that impacts learning outcomes.

Previous STEM efforts under the ASSURE umbrella, such as *PMR7 Minority Outreach – UAS as a STEM Minority Outreach Learning Platform for K-12 Students* [6], have been a great success and serve as a model for the efforts described in this paper. This UAS-centered STEM outreach performed 5 UAS Roadshows in 2 states and interfaced with over 700 students. The response was excellent. The FAA asked for an expansion of those activities, so the efforts described here were to craft additional programs targeted toward new demographics in additional geographic areas. The simple idea was to adapt existing/ongoing efforts, develop new targeted curricula and materials, and to expand the FAA's UAS STEM footprint by reaching new and different diverse communities. The educational core material was the same, but the application was tailored to the target community and was therefore new and unique. In the case of UAF, underserved Alaska Native students were targeted for participation in the program. Students from grades 6-8 were recruited for a 1-week long structured summer program to get a hands-on learning experience using UAS as a learning platform.

It is worth noting the focus of the UAS Summer Camps and the other outreach activities were targeted at middle school aged children. Other age demographics and their broader communities of older and younger siblings and parents were also impacted during the UAS Roadshows and community events. The middle school age was targeted because of the increased potential to inspire these young men and women to explore STEM related careers. This age group is figuring out what they want to do later in

life and are more open to explore than some older students. It is difficult to get a student in their junior or senior year of high school to suddenly decide they want to pursue a STEM related career. Middle school age students can be energized to explore STEM opportunities and still take advantage of their time in high school to expand their desired potential career options through technical education.

Drone Camp Structure

UAF's Alaska Center for Unmanned Aircraft Systems Integration (ACUASI) developed and conducted a 1-week long summer camp during the summer of 2017 in which students learned about various topics relating to UAS operations, safety, FAA regulations, airspace, navigation, and aerospace engineering. The students assembled a drone racing league (DRL) style vehicle and learned how to fly it using simulators and through actual flight time. The culmination of the summer camp was to race their UAS around a DRL course at UAF's Patty Center Ice Arena.

The drone camp was designed to create:

- Excitement about unmanned aircraft extracurricular activities, such as drone racing, that encourage students to develop engineering and computer programming skills to participate in the activity.
- A summer camp curriculum for use in future years and in other locations, including at the Pan-Pacific UAS Test Range Complex (PPUTRC) ranges, some of which are run by Native American tribal entities.
- Materials that will be used in additional outreach activities to continue UAF engagement with schools across Alaska, especially focusing on military and Alaska Native schools.
- Enhanced student interest in pursuing STEM studies, especially aerospace engineering and remote sensing, and going to college.
- Preparation of students for new career pathways that can keep place-based students in their communities while conducting high-technology mapping, environmental monitoring, and other UAS-centric operations.
- Realization of the value of unmanned aircraft operations in remote parts of Alaska.
- Awareness of Federal regulations as they pertain to unmanned aircraft activities.
- Understanding the importance of safety in all unmanned aircraft activities.

Selection Process

Participation was open to students from local middle schools (grades 6-8). Due to resource limitations, such as the cost of the drone kits and number of instructors, the camp was limited to 20 slots. The program was advertised through the school district office to the local schools. In the application process, 32 complete packets were returned to UAF from the students. From these UAF selected 20 primary students and 5 alternates in case there were extra seats. After assessing the number of spare parts that were on hand for the camp, UAF was able to accommodate 21 middle school students for the program. During the camp the students were very eager to learn about the drones, what makes them work, how they could potentially have a career in this field…and of course, to fly.

Course Overview

The first 2 days of the camp consisted of PowerPoint classes, parts distribution, aircraft builds, and flight simulator exercises. The students were taught about FAA safety programs, UAS regulations, basic flight principals of multi-rotor aircraft, fundamentals of flight, flight controller set-up, and flight simulation. They were very excited to learn about how the aircraft operated and see them function after they had completed the build. Most of the students were able to easily grasp the concept of flight controls with the aid of the simulator.

The drone model used for the summer camp was the Eachine Firer 110 [7]. The aircraft is made of mostly carbon fiber that measures 110 millimeters crosswise from motor to motor. It is controlled by an Eachine F3 Minicube Flytower compatible with Spektrum, Flysky and Frsky. The aircraft are also outfitted with an Eachine TX05 Mini First-Person View (FPV) Camera. The camera system is capable of providing near real time analog video back to the pilot while also providing some limited aircraft information through an On-Screen Display (OSD) within the Spektrum 4.3" FPV headset/monitor.

Figure 1: Eachine Firer 100 (left), FPV headset (middle), student building drone kit (right).

During the remaining 3 days of the camp, the students were in the classroom setting in the morning finishing any last-minute builds and practicing on the simulator. In the afternoon, after a short walk to the Patty Ice Center on campus, the students were able to fly and race against one another within the ice rink through a short course. It was during this period that the UAF team discovered some issues with the aircraft flight battery's specification and the lack of ability to provide sufficient power to maintain flight above low altitudes within ground effect of the propellers. However, new batteries were purchased from a local hobby store and the students were able to fly their own aircraft through a fun, eclectic course comprised of soccer field markers, tires, hockey goals, and hula-hoops.

Figure 2: Drone camp flights.

Throughout the camp, there were a few lessons learned about ordering parts by mail in a timely fashion as well as communicating details about the parts being ordered. The UAF team also learned that every part needed to be tested to their fullest potential prior to the start of the summer camp. Overall, the team successfully taught 21 students how to build and safely operate a small FPV racing drone that they were then able to take home in order to further their interest in UAS.

Course Content

Elements of instruction included: (1) Basics of flight; (2) Applications of UAS in research and public service; (3) Job opportunities in UAS-related fields; (4) Familiarization with DRL-type small quadcopters; (5) Construction and basic operation of these; and (6) Participation in DRL races on an indoor closed course. The curriculum followed the following structure:

Administration	
	Camp Overview & Schedule
	Introductions
UAS Task Overview	
	Drone Package Contents
	Schedule of Major Build/Fly Events
UAS Background	
	UAS in the News
	UAF Academics & Research Efforts
	UAF Points of Interest
Training & Safety	
	FAA Flight Rules
	UAS Flight Safety
	UAS Pilot Training
	UAS Observer Training
	Drone Equipment Safety
UAS Assembly & Flight	
	Drone Build & Ground Test
	Drone Flights
Student Outcomes	
	Post-Course Survey

Table 1: UAF/FAA Drone Camp Curriculum

In addition to the above skills, students were exposed to basic concepts of teamwork in sharing tools, common equipment, and instructor resources needed for the construction and racing of their drones. They also worked with each other in small groups to provide feedback on construction and preparation of drones, piloting techniques, and race results. Finally, the students were provided a forum to interact directly with experienced educational program coordinators from the FAA for the duration of the camp.

Results

By the end of the camp, the students had learned to build and safely operate their small racing drone and demonstrated those skills in a friendly race at the Patty Ice Center against fellow classmates. When camp came to a close the students were able to return home with the systems that they had assembled and learned about during camp; thus, giving them an opportunity to further practice their new skill set. In the following weeks and months, several students returned to UAF to have ACUASI personnel help them repair their vehicles. The ACUASI team set up a longer-term open-door policy for these students to return with questions and for repairs. This was exciting because it proved the students were using their aircraft regularly. They also learned about FAA rules and regulations, UAS safety, aerodynamics of flight, teamwork, and other important skills needed for careers involving UAS.

Figure 3: Drone camp participants.

Impacts

As a result of its participation in this effort, UAF has experienced significant interest in its educational programs by the students and their families. UAF has recently kicked off a DRL club for the community and plans to increase the number and scope of racing events, including the eventual incorporation of more complex engineering-centric competitions.

Resources Required

Major elements of the camp included the required UAS materials, course instructors and subject matter experts (SMEs), support equipment and space supporting the build process, and an indoor flight area.

1. Materials. An individual UAS kit was provided to each student which they were able to take home at the conclusion of the camp. These kits included a 110mm UAS frame, motors, speeds controller, battery, radio, video link, goggles, screen, and controller (see Figure 1 above).
2. Personnel. The course required the participation of several personnel to successfully complete. The camp lead instructor and 3 other ACUASI pilots provided the main instruction and interaction with the students. These personnel provided essential oversight to the UAS build/fly portions of the camp. In addition, the pilot instructors also taught modules using flight simulators.

Figure 4: Drone camp classroom activities.

3. Support Equipment and Build Space. In order to accomplish all objectives within the limited 1-week period, the course required a dedicated (undisturbed) workspace suitable for learning academic materials and flying the simulator, plus accommodate various pieces of test equipment such as voltmeters, soldering irons, crimp connector kits, and tables.
4. Flight Area. To provide a semi-dedicated and environmentally controlled space, it was necessary to have a protected area such as UAF's Patty Center Ice Arena. Flight preparation and support required worktables for calibration, assembly, battery charging, and repair of vehicles.

Figure 5: Drone camp build/test activities.

Student Outcomes and Feedback

It is important to understand what worked and what did not work well to improve the program and the content. The post-course survey comments provided by the students was universally positive, with their favorite aspects noted as being the hands-on activities of the drone build/fly process, followed closely by the flight simulator. Areas that could be improved were (not surprisingly) "too much PowerPoint" and classroom seat time. The students also remarked on the extraordinary support by UAF staff and instructors, which was further evidenced by the level of follow-up contact several students had with the ACUASI pilots to repair their UAS and tour the ACUASI lab facilities. Students were quick to share their anticipated uses of their drones, ranging from the typical (eg, view house or yard) to fairly ambitious projects involving some actual scientific research possibilities (eg, examine trails, fields, congestion of personnel/vehicles).

Figure 6: Drone camp flight activities.

Feedback/Lessons Learned by ACUASI Mentors

Feedback from UAF staff regarding the camp and structure was also very positive, with a few minor exceptions. Lessons learned from this flagship offering included:

- Support staff. The camp required more mentors and staff than originally anticipated to support the students for the drone build/fly activities, as well as providing oversight during periods outside of major activities (eg, student movements between locations, lunch breaks).
- Pre-course survey. Another recommendation resulting from this 1st offering was to include a statement of student motivation within the application package to determine best-suited students, versus the lottery draw system used this time.
- Advertisement of camp. From this experience, it was determined that advertisement of the camp had been limited, resulting in uneven representation across the district. A recommendation for the next offering would be to work with the district sooner to establish individual POCs in each target school and then ensure those POCs are knowledgeable of the camp content and goals.

Feedback from FAA Program Managers

The FAA programs managers who observed the drone camp came away excited about the future of the students and the potential for STEM activities involving the UAS [8]. They were optimistic and supportive of continuing similar programs in the future. "We're looking to continue this type of education, especially to youth who might not otherwise have an opportunity to be exposed to drones and other STEM-type career opportunities," said Diane Ford, the FAA STEM Program Manager, who had traveled from Washington DC to Alaska to observe the camp. "Taking home their own aircraft fosters further learning in the kids and those they interact with; FAA hopes to bring interested, educated kids into the industry." The continuation of the camp depends on if they get funding from FAA. "It's kind of an investment in the future workforce," says Ford. "If we can influence the kids and enable them to become interested in drones and these kinds of careers, that's a plus for us and our future."

Figure 7: UAF/ACUASI Director, Dr Catherine Cahill (center); FAA PMs Danielle Parker (left) and Diane Ford (right).

Similar Activities and Future Programs

This paper focused on one of the 3 UAS centered STEM activities, the UAS summer camps. The other 2 elements of this FAA sponsored outreach are the UAS Roadshows and targeted UAS STEM outreach activities. These activities have expanded the impact of the program by making students living in outlying schools within the Alaska Interior region more knowledgeable about the use of drones in satisfying research activities and public service missions, as well as opportunities for students to become involved in educational and training programs.

The FAA's UAS COE STEM efforts are continuing with a focus of integrating the cutting-edge research being conducted as a part of ASSURE projects into the curriculum. This inclusion will allow students to understand and communicate the importance of UAS safety to their communities and peers and learn about the exciting research needed to safely integrate UAS into our skies.

As a result of the camp, students have shown interest in pursuing future activities with STEM and the local Drone Racing League events. In addition, UAF has dedicated a space with the Geophysical Institute library to house a small indoor 'Tiny Woop' obstacle course where young budding pilots and scientists can come to learn about mini-drones and hone their piloting skills.

References

1. Pisa, 2009. http://nces.ed.gov/surveys/pisa/pisa2009/
2. Pisa, 2012. http://nces.ed.gov/surveys/pisa/pisa2012/
3. Huffington, 2013. http://www.huffingtonpost.com/2013/12/03/us-test-scores_n_4374075.html
4. Prince, M. (2004) Does Active Learning Work? A Review of the Research. *Journal of Engineering Education*, 93(3), 223-231
5. Thomas, J. (2000). A review of research on project-based learning, http://www.bobpearlman.org/BestPractices/PBL_Research.pdf (accessed 01/27/2014)
6. http://www.assureuas.org/projects/deliverables/sUASSTEMReport.php
7. https://www.eachine.com/
8. https://news.uaf.edu/faa-and-uaf-spark-interest-in-drones-at-camp/
9. https://acuasi.alaska.edu/

Acronyms

ACUASI	Alaska Center for Unmanned Aircraft Systems Integration
ASSURE	Alliance for Systems Safety of UAS through Research Excellence
COE	Center of Excellence
DRL	Drone Racing League
FAA	Federal Aviation Administration
FPV	First-Person View
NAS	National Airspace System
NMSU	New Mexico State University
OECD	Organization for Economic Co-operation and Development
OSD	On-Screen Display
PISA	Programme for International Student Assessment
POC	Point of Contact
PPUTRC	Pan-Pacific UAS Test Range Complex
STEM	Science, Technology, Engineering, and Mathematics
UAF	University of Alaska Fairbanks
UAS	Unmanned Aircraft System