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# Application of 3D Printed and Composites Technology to UAS Development

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# Application of 3D Printed and Composites Technology to UAS Development


## Abstract

Recent advances in the field of rapid prototyping, particularly with regard to unmanned aircraft systems (UAS), offer exciting new opportunities for university research and academics. By leveraging the relative speed and inexpense of 3D printing and other rapid prototyping technologies, UAS represent a powerful emergent capability in satisfying a wide range of vital research needs, while simultaneously empowering students with tools to design platforms and payloads to accomplish these. This represents a significant shift in capability for research and education institutions to make impactful contributions.

This paper provides details of UAS payloads and components fabricated using rapid prototyping technologies at the University of Alaska (UAF)[1] Alaska Center for Unmanned Aircraft Systems Integration (ACUASI)[2] using a teamed approach with heavy participation by undergraduate and graduate engineering students. It discusses exciting new arctic research being supported through these efforts, how students from various academic forums are engaged in the prototyping process, as well as lessons learned and initiatives pushing this technology down to high school (HS) and middle school (MS) students.


## Background

The University of Alaska Fairbanks (UAF) hosts the Alaska Center for Unmanned Aircraft Systems Integration (ACUASI), a collaborative research program linking education in engineering, aviation, and remote sensing with real-world applications for geospatial data products collected by unmanned aircraft systems (UAS). As part of this mission, the center promotes science, technology, engineering, and math (STEM) learning opportunities relevant to the burgeoning UAS field at high schools in Fairbanks and rural communities across Alaska.

As a part of UAF and in partnership with the Federal Aviation Administration's (FAA) Pan-Pacific Unmanned Aircraft Systems Test Range Complex (PPUTRC)[3], ACUASI is tasked with the dual role of exploring the application of UAS to academic and scientific research, as well as evaluating the safety and practicality of operating practices needed to integrate UAS into the National Airspace System (NAS). This construct provides an ideal opportunity for UAF/ACUASI to support the development of multidisciplinary engineering programs.

Leveraging the combined expertise and interests of ACUASI, UAF's College of Engineering and Mines (CEM)[4] faculty and students, and its Geophysical Institute (GI)[5] research faculty and students, the university has developed a coordinated approach for advancing capabilities in all areas. This focus has enabled UAF to simultaneously develop new UAS aerospace assets and sensors, accomplish cutting-edge arctic climate environmental monitoring missions previously not achievable, and provide engineering students with valuable experience in aerospace technology.

**Need**

A rapid prototyping capability is a vital component of the university's research, education, and UAS operations programs. In an environment characterized by short suspenses, limited financial resources and personnel, and a high operations tempo, such a capability is virtually essential for the organization to compete favorably in much of today's market. With the recent explosion of UAS platforms, there is much motivation (and arguably, expectation) to be conversant and efficient in the application of UAS to many fields of research in order to be competitive. This philosophy has guided UAF in adding a new aerospace engineering minor, and infusing rapid prototyping of UAS vehicles and payload suites into our engineering and geosciences curriculum.

For each potential mission and its corresponding UAS/sensor combination, it is important to consider the implications of timing on the research mission to be accomplished, the engineering support needed to create the UAS/sensor package, and the mission operations needed to prove its airworthiness and ultimately fly the mission.

1. Research/Mission. From a research/mission accomplishment perspective, it is important to possess an ability to test a wide variety of sensors and integrate these into UAS platforms quickly in order to respond to short-suspense calls for scientific research proposals. An agile, rapid prototyping capability can also be critical when dealing with scientific phenomena that are quick to emerge or short-lived.

2. Academics/Engineering. From an engineering support perspective, a rapid prototyping capability is important to shorten the design-build-test cycle. This is particularly true when attempting to support student research projects or academic design courses, which typically span the length of semester or two. In order to effectively leverage engineering manpower, it is vital to take full advantage of often fleeting engineering student availability.

3. UAS Operations. From an operations standpoint, an effective rapid prototyping capability is vital in supporting a project with the necessary flight assets and operations personnel. In an organization with a high ops tempo, this is particularly important. Each potential UAS/payload combination requires some finite amount of time, flight resources and manpower for final integration, flight test, and – when all's proven out – to actually accomplish the mission.

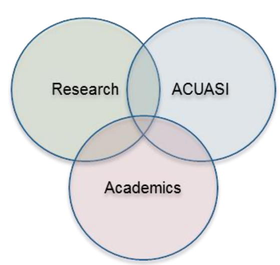



Figure 1: Synergy between UAS, Research & Academic Efforts

Compounding the situation, in a 'lean' university organization with limited resources, the above categories are necessarily tightly integrated for success. Engineering and academics have a symbiotic relationship, where students and faculty provide needed manpower and expertise at a subsystem/sensor level, and the central engineering team serves as technical oversight and final integrators. Missions flown by the UAS center are generally in support of real-world university research programs or other funding agencies, providing much needed external motivation (monetary and pride) to spur success.

In such a system, these three entities are very much dependent upon the ability of the other two for mission success. Similar to that of a circus performer spinning three plates on sticks, it takes a tightly coordinated planning effort and execution to ensure success – timing is everything. A similar case can be made for the need for an inexpensive technology to accomplish the UAS/sensor integration. If any of these requirements (time, money, personnel) in any category cannot be met, the project will likely never commence and a valuable opportunity may be lost. Rapid prototyping provides that possibility, and helps all of the three entities to prosper.

As an example of a such an organization, ACUASI possesses a modest staff with a handful of UAS operators and engineers, yet regularly logs over 150 flying days per year on multiple fixed- and rotary-wing assets. While mission planning would optimally occur somewhere in the range of 12 months or more in advance, often mission requirements might only be known 3-6 months in advance – sometimes even less. The ACUASI team has encountered (extraordinary) cases where it was necessary to integrate a payload and test it in a matter of a day or two. Without the flexibility afforded by a rapid prototyping capability and student augmentation, success would often be out of reach.

**Approach**

Utilizing rapid prototyping techniques such as 3D printing and in-house composite layups, ACUASI is able to create prototypes that can be quickly evaluated and modified, as needed. The ability to design a part, print it, and test it in a day or two allows the dramatic shortening of the engineering design cycle and the ability to rapidly evaluate sensor solutions. While parts can be out-sourced for final design models, it is sometimes the case that in-house 3D printed designs and composite layers using 3D printed molds can be of sufficient quality for the actual field work.

This approach has been applied to the development of aircraft such as the ACUASI Ptarmigan, an electric powered hexacopter which utilizes commercial-off-the-shelf (COTS) components based upon the DJI S800 airframe and 3DR APM autopilot, combined with custom parts (eg, 3D printed covers, battery cases, and sensor mounts) in order to create an open architecture hardware/software system. This capability allows ACUASI to integrate sensors onto a platform without requiring vendor support to overcome proprietary, locked down systems.

Examples of sensors integrated into the Ptarmigan include:

1. Multiple instruments designed to sample particulate matter for volcano and wildfire plumes
2. IR cameras for survey of arctic land/marine wildlife, volcano and wildfire footprints, and monitoring critical oil pipeline/processing infrastructure
3. Single/multiple camera configurations to precisely measure vegetation structure, and create digital elevation models of glacial/sea ice
4. Hyperspectral and near-IR (NIR) cameras to analyze various arctic environmental phenomena, such as vegetation health and regrowth after wildfires, presence of minerals in support of resource discovery, oil spill cleanup, and shoreline soil composition for coastal erosion studies

All of these sensor suites have been developed in large part by engineering and geoscience students, teamed with core engineering personnel providing technical oversight and final vehicle integration. Selected payloads will be described below.

In addition, sensors and payload components for other aircraft types have been developed for fixed-wing and rotary wing aircraft, including gas sensors and gimbal components and protective casings for various camera payloads. Additional UAS vehicles supported by ACUASI include the Insitu ScanEagle, Lockheed-Martin Stalker, ING Responder, and DJI F450/550/S900 families.

This approach of "open" style aircraft combined with the use of cutting edge technology to rapidly prototype and integrate sensors onto UAS has seen numerous successes in projects undertaken by ACUASI. Impacts of these have enabled great advances in our scientific research and academics.

**Prototyping**

ACUASI employs various methods of rapid prototyping in support of its UAS assets and missions. For mechanical components, these include 3D printing, composites (eg, fiberglass and Kevlar), and foam shaping (for fixed-wing aircraft body components). The predominant means has been 3D printing of UAS components/covers and sensor cases/mounts using various plastics. While initial prototypes are generally used to check component form and function and serve as a model for more traditional manufacturing processes, in many instances these 3D components may function adequately to serve as an end item, particularly for short-suspense proof of concept flights where time and money are limited. In addition, 3D printing is useful in producing molds for components requiring composite layup and vacuum molding processes.

**Examples**

The following are examples of UAS components and payloads that ACUASI and students have recently built and integrated for various mission types using typical rapid prototyping technologies. For each, a picture and description of the project is provided, as well as a discussion of the mission it performed, support provided by students, and any lessons learned on its operation or design.

ACUASI Ptarmigan. The Ptarmigan is an ACUASI-developed open architecture hexacopter based on the DJI S800 airframe and motors, integrated with a 3DR APM autopilot. ACUASI has developed several components for the UAS using 3D printed technology, predominantly to provide component protection from weather and handling (eg, battery case, electronics covers/enclosures, sensor mounts). ACUASI has also developed and integrated numerous payloads onto the Ptarmigan using rapid prototyping. The Ptarmigan is capable of carrying a 1.5 kg payload for up to 15 minutes flight time.

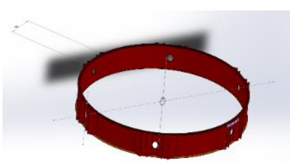
Figure 2: ACUASI Ptarmigan hexacopter

The Ptarmigan has been in service for just over two years and has quickly become one of ACUASI's main workhorses for precision flight missions, supporting numerous payloads and mission types in the extreme arctic climate. It was designed and built by a collaboration of UAF students and ACUASI's core engineering contractor (a spin-off company formed by previous UAF students). The Ptarmigan has served as a valuable tool for both accomplishing vital research missions and simultaneously providing valuable real-world graduate and undergraduate engineering projects.

Following up on the Ptarmigan design, ACUASI has begun work on a new line of hexacopters based upon the DJI S900 airframe and 3DR PixHawk autopilot. Major improvements to the structure include an enhanced weather-proofing system for the autopilot and other electronics in the form of a 3D printed concentric ring between decks of the S900, as well as a lighter weight protective dome constructed from fiberglass or Kevlar. The S900 has a design goal of supporting a 1.5 kg payload for 20 minutes flight time, or a 1 kg payload for 30 minutes.

The S900 was designed and built by UAF students in a one-semester aerospace systems design course. The section was comprised of a mixture of 16 graduate and undergraduate students, tasked with forming a mock company and building out the DJI S900 hexacopter and a Lockheed Martin Stalker airframe. In addition, the students also followed an abbreviated systems engineering design process (SEDP), learning the systems engineering/acquisition process firsthand by doing it.

For the S900 weatherproofing components, a student first drafted vital frame components into popular computer aided design (CAD) software (SolidWorks). With a combination of orthographic analysis and verification, an accurate computer model of the existing hexacopter was developed. From there, dimensions could be referenced for new parts. A successive repetition of prototyping and redesign validated both the computer model and weather cladding.



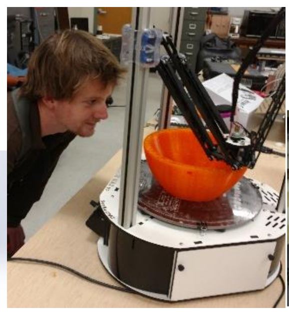



Figure 3: S900 concentric ring between electronics decks
Figure 4: S900 top-ring assembly (bonded to fiberglass/Kevlar top dome)
Figure 5: Printing 3D mold for S900 top dome
Figure 6: Early top dome prototype and concentric ring

For construction of the top dome assembly, students developed a 3D printed mold and employed a vacuum bagging process. Creating a dome with the 3D printing technology on hand posed a challenge due to large overhangs and weight, and it was elected to print a mold for the dome and create the final product out of fiber and epoxy. Dimensions for the dome were extracted from the computer model, and templates for appropriately sized pieces of fabric were developed. Different techniques for fiber binding and layup were tried, and the term “learning experience” was used heavily.

The new top dome assembly is light and strong, yielding approximately 200 g of weight savings compared to the original 3D-printed design, which can be directly applied to additional payload or flight time. Final products proved that in-house designed and produced products were adequate for operations. The finished prototype has been flown on multiple occasions (indoors) and offers much promise for system improvement of the existing ACUASI fleet, and for future assets. Giving students the opportunity to design and fabricate components for real-world applications not only enhanced the learning experience, it saved money and provided improvements in mission performance.

Figure 7: ACUASI S900 vehicle #1

Open Stalker. The Open Stalker is a UAF/ACUASI-developed open architecture fixed-wing UAS prototype based on the Lockheed Martin Stalker airframe and motor, integrated with a 3DR PixHawk autopilot. The Open Stalker is being designed with a goal of carrying a 2 kg payload for up to 2 hours flight time.

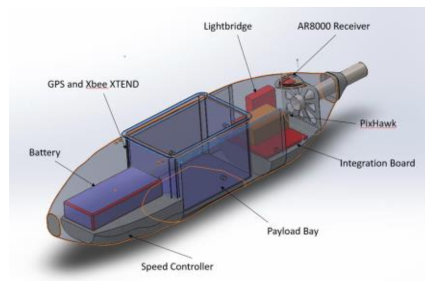



Figure 8: Lockheed Martin Stalker
Figure 9: Open Stalker fuselage design

The Open Stalker and S900 prototypes were designed and built by UAF students in a one-semester aerospace systems design course. ACUASI engineers provided oversight for the design and will support UAF students in accomplishing initial test flights (scheduled for summer 2016). As with other student projects, this airframe was selected to supplement capabilities in the current fleet.

The Open Stalker UAS incorporates several methods of rapid prototyping – 3D printing for internal payload rail connections and other internal components, and a combination of hot-wire shaping of foam core with fiberglass/Kevlar overlay to form control surfaces. Similar to the S900 effort, the Open Stalker UAS incorporates several methods of rapid prototyping. Beginning with drafting the existing airframe into a computer, internal payload rail connections and other internal components can be designed to fit as needed. In addition, a lack of undamaged wings and the desire to support altered payloads and flight characteristics necessitated wing production.

As a first step in creating an organic airframe production capability, a UAF student created a replica horizontal stabilizer as a prototype, employing construction techniques using foam core and composite skin materials. Upon drafting the horizontal elevator, it was learned that the wing employed a complex geometry airfoil and planform. To accurately model the wing section, the university’s anthropology department generously assisted with the use of a 3D scanner. Normally used for reconstructing skeletal artifacts, the scanner was able to pick up the airfoil profile and the smallest of wrinkles. Armed with measurements, wing production consisted of laminating computer numerically controlled (CNC)-cut foam cores with fiberglass, with an additional technique involving 3D printed molds in development.

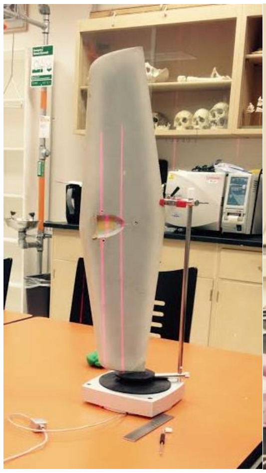
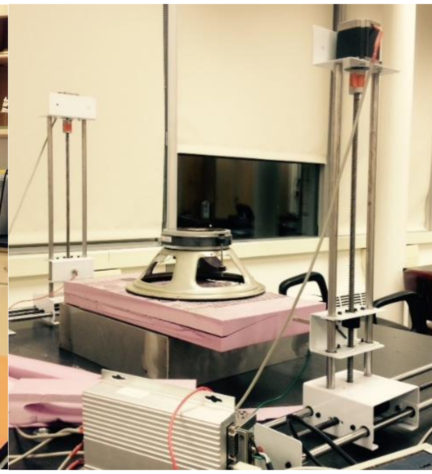





Figure 10: Scanning Stalker horizontal stabilizer in UAF anthropology lab
Figure 11: CNC cutting foam wing cores (shown weighted down to fix position)
Figure 12: ACUASI Open Stalker horizontal stabilizer prototype

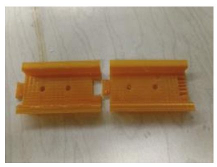
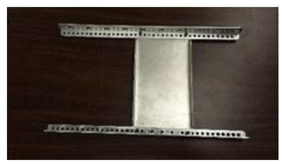



Figure 13: Prototype 3D payload rail connection
Figure 14: Prototype metal payload rail connection

Atmospheric Particulate Matter Samplers. ACUASI has integrated several atmospheric particulate samplers into different aircraft. This includes UAF/ACUASI designs of rotary-drum samplers for integration onto both the Insitu ScanEagle fixed-wing UAS and a smaller version capable of flight on the Ptarmigan hexacopter. ACUASI has also designed and flown a laser-based light optical aerosol counter (LOAC) sensor on the Ptarmigan (shown below).

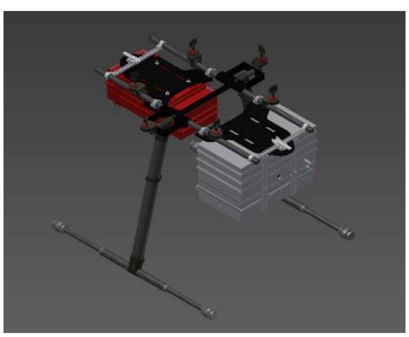


Figure 15: CAD design for LOAC configuration on Ptarmigan
Figure 16: Internal LOAC components packaged
Figure 17: LOAC sensor integrated

The LOAC was designed by UAF graduate students as a summer design project with oversight and integration provided by ACUASI engineering staff. In addition, ACUASI engineers and students have also integrated and flown an atmospheric sensor for the Environmental Protection Agency (EPA) which samples plumes from ordnance explosions, as well as integrating different gas and particulate sensors for use in investigating volcanic calderas and plumes.


Figure 18: EPA particulate sensor (dark box, left)
Figure 19: MicroDOAS (white box, left) and MiniGAS sensor (yellow sensor, right)

Camera Payloads. ACUASI has developed and integrated numerous single and multiple configuration camera/IR payloads supporting a wide variety of arctic research needs, including marine/land animal surveys, law enforcement (LE), search-and-rescue (SAR), vegetation/forestry health, coastal erosion, flooding, wildfires, and infrastructure inspections (pipeline/production facility, communications, bridges, roads). One example of this is the dual-camera payload developed for Bureau of Land Management (BLM) surveys of vegetation health in the Northern Petroleum Reserve-Alaska (NPRA), flown in August 2015.



Figure 20: Dual camera initial design
Figure 21: Sony NEX7 mount prototype
Figure 22: BLM dual NEX7 camera payload

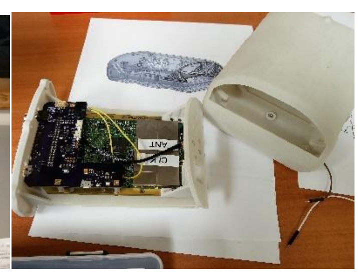



Figure 23: Differential GPS (DGPS) case on ACUASI Ptarmigan frame
Figure 24: DGPS board in 3D case

The ability to quickly and inexpensively integrate components and sensor suites onto UAS represents a vital capability for UAF to support arctic research efforts. This capability enables a rapid design, proof-of-concept, and test of flight potential assets which would otherwise be impossible for UAF/ACUASI to tackle. Continuing to develop and exploit such rapid prototyping capabilities in the future will help the center keep pace with the explosion of arctic-based, UAS-aided research needs being brought to us on a daily basis.

## Impact

Program stability. The impact of 3D printing and other rapid prototyping technologies is difficult to overstate. This singular capability serves as a vital enabler for UAF's UAS program, arctic research, and student academics and research projects. As mentioned previously, because of the shortened timelines and resource constraints involved within the university environment, these efforts all exist in harmony within a relatively fragile ecosystem. Simply put, rapid prototyping technology makes it possible for this ecosystem to exist in its current form.

Student interest. The ability for students to design and build actual hardware to accomplish real-world research and public assistance missions has been a powerful motivator. As a result, we have seen a dramatic increase in student enrollment in courses involving design of UAS and their supporting subsystems. This includes undergraduate and graduate students in electrical, computer, and mechanical engineering, as well as graduate students in geosciences and remote sensing. This pool of eager, motivated students acts as the engine to keep our research development efforts moving forward.

At a programmatic level, this work has resulted in significant increase by students applying to UAF to pursue graduate engineering and geosciences degrees. In addition, interest among undergraduates and local high school students has provided the impetus for UAF to create a new aerospace engineering minor (beginning fall 2015). This degree has been very popular with prospective students who are considering attending UAF.

## STEM Outreach

A vital component of UAF's broad program is that of STEM and community outreach. The university works closely with the state and our local communities to provide relevant opportunities for students wishing to explore aerospace and other STEM-related fields. These initiatives take the form of both focused activities such as summer camps, as well as long-term programs supporting local schools and Alaska's villages.

## Modern Blanket Toss

Modern Blanket Toss (MBT)[6] is a National Science Foundation (NSF) funded effort, led by UAF's Upward Bound (UB)[7] program, designed to provide an immersive, in-depth UAS experience to village HS and MS students. Supported by ACUASI and UAF educational programs, the UB helps low-income, prospective first-generation college students in rural Alaskan schools by promoting interest in STEM career fields. The project is named "Modern Blanket Toss" after the Native tradition of the blanket toss, which enabled people to be lofted into the air and expand their range of observation beyond the immediate surroundings. The program addresses an identified need for STEM initiatives in rural Alaska through the use of an innovative structure and a novel learning tool that is replicable and scalable to other high schools.

The MBT program is currently in the second year of a 3-year effort, serving over 50 students from six different villages. UAS designed by the students are providing valuable service to the communities, supporting roles such as monitoring coastal erosion and flooding, measuring impact of dog teams and snow machine trails on the tundra, monitoring ice break-up, and even providing valuable surveillance of predators such as wolves and polar bears. In addition, the MBF program provides tangible possibilities for students not wanting to choose between a technical career and living their heritage.

Students spend six weeks each summer at UAF's central campus learning about the technical design of UAS and the capabilities of these that can be brought to the villages in order to solve real-world needs. Students not only learn how to fly UAS and understand the FAA's regulatory process, but also build their own UAS from scratch and learn how to perform crucial preventative maintenance and make field repairs, in order to keep these machines flying safely and reliably for long periods of time.

To project fosters students' interest in STEM careers by;

1. Capturing the students interest using cutting-edge STEM technologies, in this case, UAS, and providing them a deep technical knowledge around the technology
2. Developing the leadership skills necessary to lead and work in teams and communicate the science of the project
3. Incorporating all of these skills into the implementation of a meaningful community project.

The MBT project operates year round. During the academic year, each site has a coordinator (typically a math or science teacher) who conducts meetings and works with the students on the "STEM of UAVs". The school sites are provided with the supplies to build beginning and advanced level UAS, as well as GoPro cameras, GPS tracking devices, and smaller and simpler UAS for flight training.

During the summer, students – under the instruction of both local and remote UB personnel – take part in learning activities centered around the science of the UAS, including guest speakers, "virtual field trips," and other instruction delivered via videoconference. The students and staff work through an online *UAS Flight School* curriculum that takes the students from the basic ground school skills of safety, through the levels of acquiring a student pilot license, up to an advanced license. At each level the students take on more responsibility and are capable of doing more with the copters. As they gain experience with the UAS, students will take part in hands-on simulations of sophisticated operations, such as documenting beach erosion, search-and-rescues or charting sea ice.



Figure 25: Students with a simple scale model of a workable UAS quadcopter using K'nex parts
Figure 26: Student explaining design to mentor
Figure 27: Final design using 3D printed components

There are five distinct, but interconnected components of the program:

1. *UAS hardware and build*. Begins with an elegantly simple Knex-build copter that can be flown, crashed, redesigned and rebuilt – they then progress through intermediate level builds and end up with a more advanced build that can carry instruments and fly a prearranged and autonomous route.
2. *Software*. Since not everyone likes to fly the copters, there is an extensive roll in programming the UAS guidance electronics, using Mission Planner, GIS, and 3D modeling software.
3. *UAS Curriculum.* Contains a comprehensive UAS pilots license that takes the students from the basic ground school skills of safety, through the levels of acquiring a student pilot license, up to

an advanced license. At each level the students take on more responsibility and are capable of accomplishing more with the copters.

4. *Communicating science and leadership training*. Individuals discover and explore their own strengths and learn to lead and work as a team member and how it comes together in managing aspects of a larger project.
5. *Drones for Good*. All of the skills come together in a meaningful community project. Teams of students use their newly acquired skill sets to design and implement a project that is beneficial to the community.

In the Summer of 2015, all of these components came together, assisted by two students from UAF's aerospace systems design course, to guide the MBT students through the design process of building an advanced grade hexacopter from scratch, using a PixHawk flight controller, carbon fiber sandwich board and 3D fabricated components (using a Makerbot). The students experienced first-hand the frustration of the design process as they drafted schematics for the electronic component layout and fabricated on a MakerBot suitable landing gear (legs) that would support the multi-rotor.

The MBT project is designed to be scalable and replicable to the 750 other Upward Bound programs across the country, which represent thousands of first-generation college attending youth. Currently, a *Program Users Guide* is being completed, that includes the curriculum of the project in what will be a publicly available, *Creative Commons eBook*. The project is an evaluation based on student academic increases as outlined in the new science standards, by analysis of student transcripts increasingly more advanced academic courses and those results are compared to control sites. Additionally, research is being conducted on student increased awareness of STEM career fields, their shift in developing a "Growth Mindset", and the awareness of what it takes to get into those fields. The eBook and videos from the poster presentation can be found at modernblankettoss.org.

**ASRA Blimps 101**

The Alaska Summer Research Academy (ASRA)[8] provides local HS and MS students an opportunity for an abbreviated, immersive 2-week STEM experience. ASRA provides a variety of technology venues to students, spanning a broad spectrum of subjects, from plant sciences to space technology.

In the summer of 2015, a group of 12 HS and MS students attended the summer workshop to learn about, build, and fly UAS. For reasons of safety and ease of control, blimps were selected to be the UAS of choice for this module. Blimps not only have the advantage of being safe to build and fly, but are also very low cost (even considering cost of helium), and can be effective platforms for teaching the students about the history, technology, and even the FAA regulations governing the operation of UAS.

One of the technologies that assisted in this module was 3D printing. The students were given the drive motors, props, and batteries at the beginning of the module, so the flight power of the aircraft was fixed. They were then given freedom to design and build their blimps around the electronics and motors such that their blimps were both stable and sufficiently maneuverable. They had the use of balsa dowels for the longer structural elements, but were given the freedom to use 3D printing as a means of securing the longer pieces together, as well as to secure the electronics to the balsa, etc.

Student creativity surpassed instructor expectations, with as many different blimp designs flying around as there were students. Some opted to go big, with as many as 4 mylar balloons to carry their craft. Others went minimal, with blimps built onto a single balloon. The performance of these blimps varied as much as the designs: light and nimble, or slow and steady. But in the end, each design had advantages and during the final days' competitions, none completely stood out above the others.

In nearly every case, the students went through multiple iterations of their designs within a few days' time. Some students iterated their designs within a few hours. Once a 3D part was off the printer they would integrate it into their blimp design, then analyze the design to see if it achieves the desired performance, and if not they would go back to the drawing board. Within the span of two days we saw students go from designs that were difficult to control to designs that could weave in and out of the wires of art hanging from the ceiling. Given the ability and the understanding of rapid prototyping, and the tools to achieve it, the students took to it readily and we quickly saw that the student's designs were better off for it.

To the surprise of all 3 instructors (perhaps not so much to the students), all 12 students managed to have operational blimps constructed and flight tested by the $4^{th}$ day of the workshop, allowing them to hold a flight competition by the end of the $1^{st}$ week. Taking stock of the situation and moving on – we congratulated the students, enjoyed the moment, and pushed ahead to the second stage of design experience…a team design for a more complex blimp vehicle.

The final group design incorporated a total of 10 mylar party balloons, stiffened by a combination of ribbon, tape, and balsa wood stringers. The payload consisted of a gondola, which contained a team flag (manually deployed), as well as a first person view (FPV) video stream which was broadcast live to the screens in the auditorium. This flagship event was considered to be an unbridled success, by the students, their parents, and the other ASRA students and instructors. As a result, ASRA plans to offer the course again next summer (2016), this time opening it up to a larger audience.

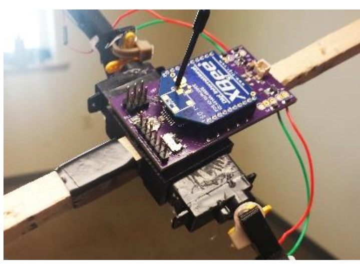


Figure 28: Example individual project control and communications module
Figure 29: Example individual project mini-blimp
Figure 30: Team mini-blimp in final ASRA outbrief

An advantage of introducing HS/MS students to rapid prototyping and additive manufacturing is that they will grow up with that as their baseline, as opposed so some of us "older" individuals who grew up with a different mindset when these techniques weren't yet possible. These students will hopefully learn to approach all their future work with the mentality of "fail early, fail often, fail forward".

**Conclusion**

Integrating the power of rapid prototyping with unmanned aircraft systems (UAS) can serve a powerful role in today's education process, providing increasingly capable technology for creating UAS vehicles and sensor suites to accomplish real-world missions. In addition, by harnessing student interest in this popular technology, and by leveraging UAS focused on solving real-world needs, such activities provide inherent motivation to all parties involved – students, instructors, and the public. By taking full advantage of these educational opportunities, we can help shape our university and HS/MS STEM curriculum and provide students that are better prepared to deal with and apply this new technology.

## References


1. University of Alaska Fairbanks: http://www.uaf.edu/
2. Alaska Center for Unmanned Aircraft Systems Integration: http://acuasi.alaska.edu/
3. Pan-Pacific UAS Test Range Complex: http://acuasi.alaska.edu/pputrc
4. UAF College of Engineering and Mines: http://cem.uaf.edu/
5. UAF Geophysical Institute: http://gi.alaska.edu/
6. UAF Upward Bound Modern Blanket Toss: https://mbt.community.uaf.edu/
7. UAF Upward Bound Program: https://sites.google.com/a/alaska.edu/uaf-upward-bound/
8. UAF Alaska Summer Research Academy: http://www.uaf.edu/asra/