Student-Led Aerospace Design Team Experiences

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Introduction.

Design teams offer an inexpensive and effective means to supplement traditional student learning with real-world design experience. Student-led design teams provide one convenient and flexible construct to teach students about popular topics within aerospace and other multidisciplinary engineering fields, while simultaneously providing them with valuable experience and insights gained through the application of the systems engineering design process (SEDP).

The popularity of Unmanned Aircraft Systems (UAS) has skyrocketed, these having become ubiquitous throughout almost every segment of society. Many students are looking for opportunities to work with UAS and to distinguish their resumes with relevant work experience for the future. Unfortunately, it is often difficult for students to fit additional academic courses into their already full schedule. What's more, university programs frequently lack sufficient personnel and resources to support additional academic courses associated with an aerospace program. Club experiences can provide an alternative means to bridge this gap and satisfy student needs.

This paper outlines the motivation for student participation in the University of Alaska's (UAF) American Institute of Aeronautics and Astronautics (AIAA) Design, Build, Fly (DBF) Team. The paper details pertinent skills learned in the UAS design process, team results in recent DBF efforts, and the positive organizational impacts resulting from participation. It also highlights lessons learned and future efforts to be tackled, including insights from the perspective of students leading the team.

Motivation.

The desire for educational programs within the field of aerospace engineering continues to be popular, both due to the increasing availability of technology and stable job opportunities within the aerospace engineering career field. According to the Department of Labor's Bureau of Labor Statistics (April 2018), "*Employment of aerospace engineers is projected to grow 6 percent from 2016 to 2026, about as fast as the average for all occupations."* Rationale for this growth is attributed to several factors, including the increased use of cubesats, aircraft aerodynamic efficiency and noise reduction efforts, as well as the explosion in the field of UAS [1]. In addition to these are the potential for the aerospace workforce to suffer reductions of current personnel as a result of retirements over the next decade [2], [3], [4]. As a result of these factors, aerospace engineering remains a strong area of interest for many students today [6].

Local experience reflects this same desire by students from Alaska and in the Pacific northwest. UAF counselors have provided feedback that new opportunities, including the school's recently instituted aerospace engineering minor, AIAA student chapter, and UAS-related courses are the most sought-after experiences by prospective engineering students. One author, who has spent considerable time participating in high school career day and university recruiting events, has received the same feedback from prospective students. Of particular interest is the opportunity for students to participate in UAS and nanosatellite design projects, with teams being comprised of members from diverse academic majors and year groups. UAF design teams include students from engineering specialties (electrical, computer, mechanical, civil), computer science, physics, and other disciplines. Students are generally able to participate in these experiences throughout the lifetime of their academic programs, depending upon team needs and individual student background, often beginning as early as their freshman year.

Desire to participate in these aerospace design teams stems from many factors. Based upon the authors' experiences over numerous years in both teaching aerospace courses and leading design teams, student motivation tends to fall into one or more broad categories: (1) Students are looking for some means to distinguish themselves academically from their peers. (2) Students are specifically interested in aerospace, either as a means to accomplish research or as an end in itself. (3) Students desire to have an experience with an interdisciplinary project to broaden their skillsets and horizons. (4) Students are seeking a teaming experience to enhance their leadership, followership, and cooperative skills as they move towards an environment more closely resembling the workplace. (5) Students are looking for a professional social environment that nurtures both their professional interests and personal relationships.

While many, if not all, of the above motivating factors may be readily accomplished through more traditional academics and instructor-led design courses, the availability of these are not always sufficient to meet the need of the student population. Schools without an existing aerospace degree granting program may not be able to offer formal aerospace design course opportunities due to a lack of faculty and resources. Funding additional faculty, even as adjunct, can easily prove cost-prohibitive unless sponsored by a long term grant or industry partner. Even in cases where qualified faculty are available, workload or university personnel constraints (eg, contract or union agreement) may prohibit the teaching of additional courses.

Likewise, from a student perspective, formal engineering courses may not always satisfy their needs. Though aerospace courses may exist at a university, these are often available only at those (generally larger) institutions offering a degree program in aerospace engineering. In addition, courses may not effectively be available to the student, either because of restrictive course prerequisites, limited enrollment, course times, and limited offerings. These shortfalls can be further exacerbated for smaller schools where faculty and course offerings are generally even more limited. And beyond the above constraints, students may simply be unable to cope with the higher work load and expense associated with an additional academic course.

The impacts of these same factors can be seen locally. At UAF, the school has recently instituted an aerospace engineering minor in order to serve the desires of the student population. However, while interest in the minor is high, the constraints imposed by a small school environment have hampered the ability of many students to participate. As a result, virtually all of the current students enrolled in the aerospace minor are from the mechanical engineering program, where course overlap and sequencing make it more favorable. Students from other disciplines, such as electrical engineering, traditionally have a much more difficult time in meeting the requirements for the minor due to the inclusion of courses not well suited to their own program sequencing (eg, thermodynamics, fluids…). While a few well-prepared and motivated students from other engineering disciplines have taken this route, it has required a much heavier than normal course load and generally takes an additional year or more to complete. In light of these realities, many students have opted for a more conservative option of taking single aerospace design courses and/or in simply participating in one of our aerospace design teams.

Benefits of Student-Led Design Teams.

Student-led design teams provide a viable means of achieving a valuable hands-on experience in aerospace engineering. These can be used as a supplement to the students' education experience or as an alternative when formal courses are not available. In either, student-led design teams offer a number of benefits to the students and their schools: (1) Design team/SEDP experience. (2) UAS/aerospace project experience. (3) Student organization and ownership. (4) Flexible hours for participation. (5) Early entry and access to subject matter. (6) Collective space for ideation and collaboration. (7) Recognition and networking. Each of these topics are explored further in the following paragraphs.

Design Team/SEDP Experience. Design team activities represent important opportunities to instill valuable career competencies and broad skillsets needed in industry, including structured problem-solving process, leadership, management, communication, program building, and networking. The Systems Engineering Design Process (SEDP) provides a structured framework for students to analyze a problem, postulate possible solutions, and follow the most likely of these through to a successful (or not) conclusion. This process emphasizes numerous valuable concepts such as customer interaction, requirements analysis, functional allocation, interface definitions, product baselining, system integration, testing, product delivery, and the set of written documentation and oral presentations required to successfully deliver a complex product.

Leadership includes the mentoring, training, and development of workers who can work together effectively as a team to accomplish a specific task or set of tasks within the team's charter. Within the informal student-led design team, this function can pose both additional challenges and rewards, as students work through the inevitable issues and conflicts arising as they face the stresses of organizing the team, outlining a plan of attack to address the tasks before them, and dynamically reallocate resources/tasks based upon the schedule and each member's time available, skill levels, and commitment to the overall effort. This function can be particularly challenging (and rewarding) within student groups where most have had little or no experience in organizing and leading peers.

The leadership function also includes the vital task of planning for development of future leaders within the organization. Student-led teams must attempt to anticipate and plan for the turnover associated with individual members transitioning into and out of the group throughout the year, as well as the major disruption caused by the broad exodus of students graduating from school and entering the workforce. The effects of these factors are highly variable in any given year and require the student leadership to be forward-thinking in how to plan for the capture of incumbent member technical and programmatic knowledge and how to best pass this along to incoming members and aspiring leadership.

The management function entails the successful application of planning, tracking, and communications tools needed to coordinate the team's work, meet timelines, de-conflict resources, and secure financial support necessary for success of the program. Again, the nature of the student-led design team presents both additional flexibility and challenges. This includes the scheduling of meetings for a diverse group of students with different class schedules. The size of the team can make it a formidable challenge just to determine what core set of members is essential to satisfy the meeting objectives, and then plan when, where, and how (face-to-face, video chat, telephone…) the meeting is to occur.

Of course, the above leadership and management tasks require the application of various forms of communications. Students participating in student-led design teams gain much practical experience in the application of various communications skillsets which are directly applicable to the workplace. This includes formal/informal, group/interpersonal, written/oral communications, as well as various media and mechanisms for accomplishing this (written reports, briefing slides, photographs, videos, web sites, social media, email).

In addition to these essential day-to-day activities, the student-led design team is also likely to be called upon to participate in various program building activities designed to increased awareness within the university and general public. This often includes supporting STEM outreach events at the university and at local schools within the community, as well as participating in university recruiting efforts. In addition, team members may be asked to speak at professional conferences, community forums, or university fundraising activities which highlight the university's activities in promoting SEDP programs and STEM outreach through aerospace education. In addition to being highly successful in promoting the organization's activities, goals, needs, and interests, these activities also provide student members with a valuable networking opportunity to engage various professionals and local community leaders.

Beyond the skills mentioned above, students also benefit through taking personal ownership of their own educations, career training, and broad life goals. Through these activities, students are better equipped to develop and hone highly-desired traits such as independence, self-reliance, critical thinking, goal-setting, the ability to function effectively in small teams, as well as an awareness of what it takes to support and grow teams/organizations over the long-run.

UAS/Aerospace Project Experience. Beyond the general benefits of participating in a SEDP team experience, specific practical benefits of involvement in a UAS-related design club also include: (1) Experience in developing basic flight skills and proficiency, as well as understanding flight permissions and certifications processes. (2) Test capabilities, with experience in component bench test, 'infinite wind tunnel' (outdoor) tests, and the use of wind tunnels. (3) Rapid prototyping capabilities utilizing 3D printing, foam core with composite skins, and spar/stringer with mylar skin techniques. In addition, UAF is making use of computer numerical control (CNC) milling for student clubs and moving towards advanced 3D printing using metals and composite materials.

Student Organization and Ownership. A huge benefit of student-led design teams is in the power of ownership and commitment by team members. A faculty mentor is typically responsible for providing broad oversight to the team, but not generally from a tactical, day-to-day perspective. The team is responsible, at least principally, for nearly aspect of the organization. This includes outlining its structure, identifying which members hold elected positions, and drafting procedures for holding meetings and sharing communications. The students are also largely responsible for determining intermediate milestones needed to meet the overall team deliverables and deadlines. Finally, the team is vital in identifying and following the practices which will ensure its continued success in future years, such as technical training and leadership development.

Much like in the real estate world where the primary rule for success is “Location, location, location” the real power of student-led organizations for meeting tough deadlines on a low budget and very little sleep is “Buy-in, buy-in, buy-in.” The authors’ personal experience shows that when faced with an intrinsically-motivated challenge where students are free to be creative, they will often go far above the minimum requirements with respect to both system performance and the time commitment required to achieve the goal. As participation in a student-led design team is by its very nature, voluntary, students must be intrinsically motivated to achieve the stated project goal. From this experience, students can learn valuable real world lessons in how to succeed in the business world, and particularly for the intense motivation needed to make startup business ventures work.

Flexible Hours for Participation. As a self-led organization, students have the flexibility to schedule team meetings, group training, and work sessions at times most conducive to its members, versus being tied to the schedule of an instructor. This enables the team to more easily deconflict class schedules amongst members needed for a given activity, and often results in holding meetings on evenings or weekends. This flexibility also allows the effective team to account for surges in academic schedules, where segments of the team may have other course exams or major projects coming due. It can also help support makeup of work for individual members participating in extracurricular activities or having other life commitments.

Early Entry and Access to Subject Matter. A significant advantage of design teams is that students are able to join the activity earlier in their academic career than might otherwise be possible with a traditional course pipeline. Generally, with formal design courses, and particularly so with capstone design courses, students must first work their way through numerous course prerequisites before being able to participate in the design activity. Whereas with student design teams, students may participate in any phase of their academic program.

Student design teams also provide additional flexibility in permitting more diversity in academic backgrounds, depending upon team needs and space available. These factors can provide additional motivation and opportunity for students to join the design team, and often results in them taking additional academic courses aligned with the design experience or in changing academic programs. In some cases, this can even have a large impact in shaping the student’s possible career choices. Multiple authors of this paper have had such experiences with their students, whether these were participating in satellite, rocketry, or UAS design activities.

Collective Space for Ideation and Collaboration. An additional benefit of student-led design teams is realized by them congregating together in their identified work space or meeting area. Beyond providing a location for shared physical resources, this space provides a natural gathering point, and with occasional mentor oversight, readily supports a social atmosphere conducive to both sharing of professional interests and personal interaction. Students tend to congregate together in their workspace beyond the times and purposes of formal meetings or work sessions, either to work on other course efforts, share ideas, or just enjoy one another’s company. And as a university-sponsored team with a recognized organization and workspace, this center acts as a magnet attracting students with shared goals, interests, and friends.

With regard to the design team, the result is a melting pot for current undergraduate students (and former undergraduate students who are now graduate students) sharing technical design ideas, construction techniques, and flight test experiences, as well as strategies for organizing the group towards a successful design competition and enjoyable experience overall. In addition, this collaboration can lead to the establishment of other undergraduate and graduate design projects outside of the original design team effort. With regard to the university programs, over time, this teaming and collaboration provides synergy to feed both the larger undergraduate and graduate engineering programs. And from a personal growth perspective, this provides the basis for long term relationships and professional networking.

Recognition and Networking. Beyond the internal growth generated by collaboration, student-led design teams can be effective in garnering organizational support from both broader university resources and external agencies. Student-led design efforts seem to hold an appeal with both of these groups, generally resulting in a favorable funding environment. One author's local experience with AIAA UAS DBF design teams has been very positive, with funding being approved in each of the team's 4-year history by the university's student organization committee, the engineering college, the Undergraduate Research Studies Association (URSA), and the Alaska Space Grant Program (ASGP).

Student design teams also provide great opportunity for support from external entities, including local companies and agencies, as well as national organizations and industry. This support may come in the form of team sponsorship, mentoring, scholarships, internships, and future jobs. Aerospace companies, in particular, have been very supportive of UAF's design team efforts and have hired several students over the past 3 years from our small program.

UAF Opportunities.

UAS Design Team. Activities such as UAF's student chapter of the American Institute of Aeronautics and Astronautics (AIAA) Student Design, Build, Fly (DBF) Teams offer a low-cost, flexible, and efficient means to achieve the learning objectives mentioned in the *Design Team/SEDP Experience* and *UAS/Aerospace Project Experience* sections above. Now in its 4th year, the AIAA team has experienced remarkable growth and has made increasingly successful runs at the national DBF competition each year.

2015-2016. During the team's 1st year, the IAAA DBF challenge was significant: to build a cargo plane that could carry a full Gatorade bottle around a race track for a certain number of times and at a certain speed. And to build a transport plane that would carry the cargo plane to the competition site. The design challenge favored designs where the cargo plane broke down into the least number of parts and trips required by the transport plane. The UAF's team approach was to build cargo plane that did not break into multiple pieces, instead attempting an ambitious design where the transport plane would form a clamshell around the cargo plane, completely engulfing it from view. The transport was required to fly, both with the cargo plane onboard, and without the cargo plane.

Fabrication of this UAS centered around the use of 3 principal technologies: (1) Some components were fashioned using a foam core with fiberglass or Kevlar skin (eg, most of transport plane, main wing leading edge and empennage of cargo plane). The foam core was either hand-shaped or created by a computer numerical code (CNC) hotwire machine, and then covered with a composite skin (fiberglass or Kevlar) using an epoxy resin and vacuum bagging process. (2) Some components were constructed using balsa wood ribs with mylar skin (eg, cargo plane main wing and tail section). (3) Other components utilized 3D printing technology (eg, landing gear struts).

While the team successfully demonstrated the cargo plane operation, they were ultimately unsuccessful, as they were not able to demonstrate flight of the empty transport plane in time due to challenges with the transport plane stiffness. The overall effort was considered successful, as this was the team's 1st year, and the club had to be chartered by UAF and AIAA before the team could even participate. Even so, the team made it through the design process and was selected to compete in the national DBF flight demonstration, though they elected not to attend as the transport plane could not pass its requirement for empty flight. Members of the team totaled about 10, with 3-6 core members responsible for the main effort.

The 2015-2016 team consisted of about 10 students, from mechanical and electrical engineering. Students formed multidisciplinary groups to tackle the various project challenges. Groups were formed by assigning students possessing core academic strengths and experience appropriate to the specific task, augmented by students of other backgrounds. Both due to the small team size, and because gaining interdisciplinary experience for each student is a primary club goal, all groups were carefully selected to balance learning with maximizing the chances for success.

For example, groups responsible for the design and construction of airframe components (eg, wing, fuselage, empennage) were primarily led by mechanical engineering students with courses and some experience in aeronautics. These were augmented by students having electrical/computer engineering experience to guide the design and manufacturing processes with respect to routing of electrical wiring and use of 3D printed components. Likewise, groups tackling functions such as communications and power were generally led by electrical/computer engineers, augmented by mechanical engineering students to advise in issues such as structural strength, vibrations, and weight and balance. This same approach applied to all subsequent AY design teams.

Primary benefits derived from this first effort were in the areas of: (1) Learning and demonstrating basic skills in the above construction techniques, which required an enormous effort of effort. (2) Application of these to fixed-wing UAS design, with some aspects proving more challenging to master than others. (3) Understanding of current recreational craft (RC) flight rules and demonstration of basic piloting skills. (4) Valuable experience in organizing and administering the team, including leadership positions, management functions, and logistics support.

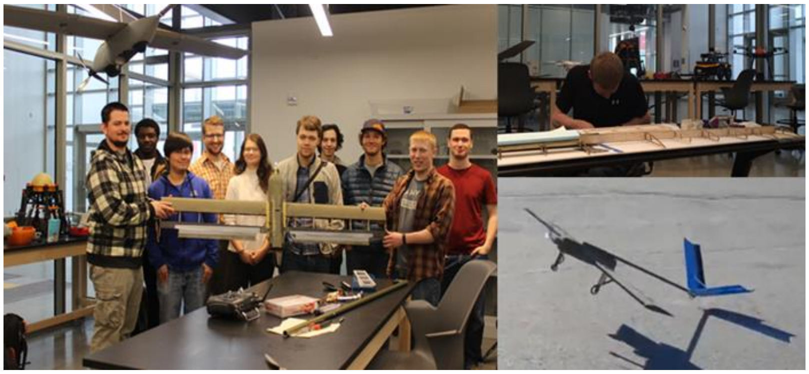

Figure 1: UAF AIAA DBF Team, AY2015-2016

2016-2017. In the 2nd year of the team's existence, the AIAA DBF challenge was again complex: to create a 'switchblade' type UAS with folding front and rear wings which would allow the UAS to be stored in a 10" diameter tube for transport. The UAS was to be transported to the event using the storage tube and undergo a drop test prior to flight. The UAS would then be extracted from the tube and assembled for flight. Rotary joints connecting the wings to the fuselage allowed for rapid assembly and deployment.

Figure 2: UAF AIAA DBF Team, AY2016-2017

Construction of this UAS primarily focused on foam core/composite skin technology. Using the experience gained during the previous year, the team fabricated wing cores using the CNC hotwire mill and incorporated Kevlar skin using the vacuum bagging process. The fuselage section was of a box frame shape, reinforced by Kevlar skin. Landing struts and various other components were fashioned using 3D printing.

The team was again successful in participating throughout the design challenge and was invited to the DBF flight demonstration. This year, the team was able to travel to the event and successfully completed the drop test; unfortunately, the UAS crashed during its initial flight. Cause of the flight crash was attributed to late design changes to the main wing and mounting system, which adversely affected the vehicle center of gravity (CG) location. Team membership this year was about 15-18, with the core team expanding significantly to capture the talents and interest of nearly all members.

Primary benefits seen from this 2nd year were in the areas of: (1) Advancing and mastering skillsets associated with foam core/composite skin construction techniques. (2) Application of new design elements to fixed-wing UAS vehicles (eg, rotary wing-attachment points for rapid UAS deployment). (3) Expanded ability to test UAS stability and flight characteristics using an 'infinite wind tunnel' approach (ie, test appliance on the back of a pickup truck). (4) Consolidated and furthered experience in organizing and administering the team, with numerous improvements to team leadership and management tools and techniques.

2017-2018. In the team's 3rd year of participation, the AIAA DBF challenge returned to a focus on less complex designs, with more emphasis on flight performance characteristics. The goal of the challenge was to optimize weight and cost for a scale model plane that could deliver a combination of simulated cargo and/or passengers, according to passenger and carrier demands.

With the change in mission focus and emphasis on light-weight components, the construction of this UAS shifted to the use of balsa wood and Mylar plastic as its primary elements. Notable design elements selected by the team included a bi-plane wing, as well as differential thrust provided via dual propellers). Balsa wood was used for wing ribs, stiffeners, and the majority of the fuselage and tail section components. Mylar was used for the wings, fuselage and tail section wherever possible on surface areas. Some 3D printed components were incorporated into the design (eg, spaces between bi-wings, motor mounts, and landing struts).

Figure 3: UAF AIAA DBF Team, AY2017-2018

The team was once more successful in participating throughout the design challenge and was invited to the DBF flight demonstration. The team travelled to the event and successfully completed the static tests, however, the UAS crashed during flight. Cause of the flight crash was attributed to stronger than expected winds at the location and season (Wichita, Kansas in April). This was highly disappointing to the team, as they had spent a significant amount of time in optimizing their vehicle design and perfecting their flight techniques over numerous hours of flight test. Team membership this year was about 25, with nearly all members being fully and effectively utilized throughout the design campaign.

Primary benefits seen from this 3rd year were in the areas of: (1) Advancing and mastering skillsets associated with balsa wood/Mylar skin construction techniques. UAF's new laser cutter helped to accelerate the design process significantly. (2) Greatly increased our experience in testing UAS stability and flight characteristics using a refined 'infinite wind tunnel' (ie, much-improved test appliance on the back of a pickup truck). (3) Gained significant amounts of piloting experience with several versions of the UAS. (4) Significantly improved the team's leadership and management functions over previous years. Great strides were made in processes for technical training and development of future leadership. As a result of this team's efforts, they were hand-selected by college leadership for participation in several university functions and outreach briefings and activities.

2018-2019. At the time the original manuscript was being reviewed, the AY2018-2019 team was progressing well in its efforts. The team had successfully passed all intermediate milestones and was selected once again to participate in the final flight competition (11-14 April in Tucson). This year's design challenge was proven quite interesting, incorporating several complex technical elements (eg, automatic expanding/contracting wings, rotating communications dish, kinetic payload delivery system, and takeoff from a 10’ ramp). The size of this year’s team had stabilized at approximately 18-24 members, depending upon the phase of the project and student availability.

Update. The UAF team performed well at the DBF competition, ending the season in 23rd place of 104 teams qualifying internationally. This was the 1st time that UAF successfully completed all phases of the flight demonstration, and beyond the team’s laudable performance, they also made numerous professional contacts with other teams, as well as some potential career contacts.

Figure 4: UAF AIAA DBF Team, AY2018-2019

As in previous years, the team continued to make great strides on both a technical front, and in the organization and maturity of the team itself. UAS design and construction techniques have improved significantly, as have the team’s abilities to plan for all the milestone events and personnel training required of these.

Benefits to UAF Activities.

As a result of its participation in student-led design teams, UAF has experienced significant growth in the size and diversity of students in its the AIAA DBF team (A similar response has been noted in the university’s Alaska Space Grant Program nanosat design team). This growth has positively impacted areas of academics, research, and student interest.

Academics. Student participation in design team activities has had a positive effect on enrollment in aerospace and UAS-related courses. These students have shown strong interest in participating in similar activities, whether a capstone/graduate design course, or in a course exploring these topics. UAS-related courses at UAF have proven popular since their introduction since fall 2014. These include: (1) EE693, *UAS Systems Design*, where students learn about the various subsystems comprising a UAS and how the optimization of these may be accomplished for specific mission requirements. Students also participate in a 2-week intensive UAS workshop, where they build and fly a small/medium size multirotor. (2) EE656, *Aerospace Systems Engineering*, where students form a mock company and step through the systems engineering design process (SEDP) to design, build, and fly a larger multirotor or fixed-wing UAS. Both courses are 1 semester in length, and due to popularity, these have each been extended to undergraduate students, as well as being offered in a blended video-distance format to students from UAA to participate alongside the UAF students.

The above courses have not only benefitted from increased student awareness and interest, but also from the skillsets many of the design team students bring to the course. These skills include knowledge of the general SEDP process, UAS-specific design experience, various construction techniques (eg, foam core/composite skins, balsa wood/Mylar skin, 3D printing), UAS flight experience, and basic awareness of UAS flight rules. These competencies have had a significant positive impact on the overall effectiveness of the classes taking these courses and have generally provided the students additional opportunities to mentor/lead their peers in these activities.

Research. Student participation in student-led design teams has resulted in increased support of research activities by various university affiliated agencies, including: the Undergraduate Research and Scholarly Activity (URSA), Alaska Space Grant Program (SGP), and the College of Engineering and Mines (CEM). These agencies have generously sponsored the AIAA team's activities over the past 4 years of its existence, and beyond this, has led to a number of follow-on aerospace/UAS-related research activities at the undergraduate level. This research has included work in the areas of: Lithium Polymer (LiPo) batteries and the effect of cold weather on their operation; Structural optimization of 3D printed UAS components for decreased weight and increased strength; Design of lightweight, inexpensive fixed-wing UAS for training and mission operations; and Design of a counter-rotating dual propeller multirotor UAS for heavy lift.

Student Interest in Aerospace-Related Opportunities. The increase of aerospace-related opportunities at UAF over the past 4 years has resulted in increased interest in UAF by prospective students, which has (not surprisingly) also been reflected in increased participation in the AIAA student chapter, the aerospace minor, and individual aerospace-related courses. These, in turn, generate more awareness for and interest in the student-led design teams such as the AIAA DBF activity. For a small school such as UAF, this impact has been significant.

The AIAA DBF team has sparked synergies with the university's new aerospace engineering program and UAS operations and research conducted by UAF's Federal Aviation Administration (FAA) Alaska Center for Unmanned Aircraft Systems Integration (ACUASI) test center sponsored by the FAA and by the National Aeronautics and Space Administration (NASA). Due to the close cooperation between these activities, several students participating in activities such as the AIAA DBF team have moved into student intern positions and permanent positions after graduating.

Beyond the university realm, students participating in activities such as UAF's AIAA DBF team or AGSP nanosat program have had good success in transitioning directly into aerospace jobs, whether in space systems or aeronautics. UAF has a strong record of supplying its graduates to NASA, the FAA, and major aerospace companies such as Lockheed-Martin, Northrop Grumman, Boeing, and their subsidiaries. This employment history and UAF's sustained support of student-led design programs has had a synergistic effect, drawing increased interest from the aerospace industry for future collaboration.

Student Feedback.

As evidenced by informal student feedback and strong enrollment, UAF's student-led clubs have proven quite popular with a wide range of students from various engineering, computer science, and other backgrounds. Students have found them to be very exciting, professionally and personally satisfying, and directly beneficial to their education and prospective career paths. What's more, they actively work to improve the quality of the club's training and recruiting programs, website and social media, and participate in community outreach/STEM activities. Specific feedback from a previous student chapter president is provided at Appendix 1.

Recommendations for Future.
The following are the authors' thoughts on additional program activities and mechanisms which may help increase the effectiveness of the program.

1. Increase oversight of team documentation. Beyond the comprehensive DBF design documentation generated by the team, there exists a substantial body of knowledge covering areas such as: (1) the previously mentioned construction techniques; (2) training instruction and completion logs; (3) communications tools; and (4) leadership development training. While much of this is passed along informally and there is a natural resistance to the increased effort required to document these areas, some amount of formal documentation would be helpful in slowing the erosion of hard fought improvements which may not be utilized in a given year, as well as ensuring past lessons learned are not forgotten.

2. Institute a set of incoming and outgoing student surveys designed to capture the motivation for why students joined the student-led design team, and whether their expectations were met and what they've learned from their experience. The questions are similar in nature to feedback provided in the previous section, and are based upon inputs from both the team faculty mentor and from previous student team leaders. It is expected that the questions themselves will evolve as our experience with the program grows.

   Specific questions being asked of students for AY2019-2019 include the following:
   - *How did you first hear about the Aeronautics Club?*
   - *What aspects of the club and/or its activities convinced you to join?*
   - *Do you have any interest in leading a small group?*
   - *Did you have a personal goal coming into the Aero Club? If so, what was it?*
   - *Given your experience at UAF, did the Aero Club reflect the core mission of CEM/UAF?*
   - *What items most appealed to you once you joined the Aero Club?*
   - *What thing do you believe the Aero Club officers could improve upon?*
   - *Do you believe the Aero Club achieved the goals set for the year?*
   - *Do you feel like you had an active role in achieving the Aero Club's goals?*
   - *Will you stay with the club next year?*
   - *If so, what would you like to see happen next year?*

Summary.
This paper has provided examples of how student-led aerospace design teams can provide valuable interdisciplinary/systems engineering experience to young engineers who might not attend a school with an aerospace program or courses, thereby depriving them of this opportunity until later in their careers. While UAF has recently begun to grow its aerospace program, fiscal realities severely limit the ability the school's ability to hire new faculty or grow an organic aerospace degree granting program at this time. Student-led design clubs provide a unique opportunity for students to gain valuable experience in this field, within a flexible and supportive environment. UAF students have already begun to reap benefits of these activities, with several landing jobs in top aerospace industries. It is believed that student-led design experiences such as these will continue to provide a steady stream of qualified engineers for the aerospace industry, and that these opportunities will also continue to attract talented and motivated students to our programs.

Appendix 1:

This section details the personal experiences of a former AIAA DBF team president (and paper author). Feedback was meant to answer the following questions:

- *Why did you join the AIAA team? What drew you to the team? Did its existence affect your decision of academic major or school to attend?*
- *Why did you take on a leadership role within the AIAA team? What were you expecting to learn from this experience?*
- *What did you learn/gain from this experience? What technical, managerial, leadership, or team skills did you strengthen?*
- *Would you have done anything differently if you had it to do over again?*
- *What additional tools or changes do you think would help future years be more successful?*
- *How do you feel this experience will help you in your future career/education?*

Response:
I joined the UAF DBF team in 2016, as a junior. I had not heard of the design team before then, but I had an interest in aerospace engineering that had influenced me to register for the aerospace engineering minor, which UAF had begun offering in 2016. it was exciting to consider exercising the concepts I had learned in my engineering classes in a real-world environment; however, I had no experience in aerospace design or design competitions at that time. The team at that point was very small, with barely ten students in both administrative and technical positions. I volunteered to lead the fuselage design team and was also a member of the landing gear design team due to the personnel shortage. At that time both sections had only one other member. The landing gear team leader, eventually became the vice-president of the DBF team when I became president the following year in 2017. I graduated in 2018, with the team having placed 25th in the international DBF competition, and had doubled the concurrent membership and work space of the UAF team.

The DBF team was still in its infancy in 2016. Much of the design competition occurred simultaneously with explorations of construction and testing methods, organizational and administration techniques, and facility and networking connections. The accumulation of this knowledge and experience was new to most of the team. Near the end of the year, in the spring of 2017, it was realized that much of this knowledge and experience would be lost when the seniors on the team, who were the majority of members, would be graduating. In fact, beyond the incoming president and vice-president, there were only three other returning members. It was clear that a new organizational structure of the club was needed to prevent such a loss of operational knowledge.

A large portion of time during the 2017-2018 academic year was spent by the president of the DBF team to teach the younger members of the team the skills the older members had already accrued, as well as developing a method to transfer knowledge and experience from the graduating members for years to come. This was done by exposing younger members to events and challenges that would improve their knowledge and skill, both in the team and outside. New members were encouraged to travel to the end of year competition, in order to give them a perspective of the scope of the design competition, and exposure to the broader aerospace community. Additionally, they were given latitude to explore their own designs and construction *methods, as a way to allow them ownership of the overall design. The president and vice-president were highly transparent in their methods of applying for funding and networking with university faculty and other organizations. The goal was to provide the incoming leadership the familiarity with the tools and options of the team that the previous administration enjoyed.*

The tools gained by the president from the DBF team are primarily leadership and managerial skills. One important skill in particular is the ability to clearly communicate and present a plan that is understood at all levels of the organization, and tailor a presentation to each listener group. This could be the advisor listening to our progress and goals, the team leaders expecting tasking and guidance, or speaking about the big picture to the team at large. The ability to communicate clearly is an important part of being a leader in the engineering field, and will be a valuable skill to young engineers in their professional development Another important skill is simply coordinating a team of students to commit and execute a complex design plan.

Leading a student team is often an undergraduate's first exposure to peer-to-peer leadership, and the social and technical nuances are many and varied, especially when the focus of the team is a design competition. Allowances and alternatives must be made for schedules, skill levels and previous experience, and the social dynamics of those differences must also be addressed. When the team changes as members come and go, those challenges and difficulties also change, creating a dynamic atmosphere not encountered in classroom situations. The ability to adapt to those changes is perhaps the most important skills that can be learned through a student-led design team.

Going forward, the growth in interest of aerospace engineering and UAS applications at the university means the UAF DBF team is in a unique position to become a flagship program and developmental leader at the school. The dynamic learning environment of the DBF team augments a classroom curriculum and develops both technical skills and leadership potential in future engineers in the aerospace field. The UAF team is still in the first stages of growth, but so far has a firm foundation to build for the needs of the future.

I was very inexperienced when I became president of the DBF team, both as a designer and a leader. Much of the previous year was spent accommodating the senior members' designs, and I had little to show even then. My leadership style was essentially intuition. But I came in at a perfect time. Our team had no money, but no debts. The few existing members were completely on-board with my vision. The new members were highly skilled in their disciplines. And I had support from my vice-president, who whom I could place my trust in completely. This led to a team that exceeded even my expectations. There were little initial dividends; our aircraft did not fly at the competition, our facilities are still small and barely adequate, and the team is still relatively new. But in the strategic scope there is a strong foundation for continual growth and development. As long as there are motivated and interested parties at UAF I believe the DBF team will continue to excel.

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