# Looking back: A Student Review and History of AerosPACE – a Multi-University, Multi-Disciplinary, Distributed, Industry-University Capstone Project

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# Looking back: A Student Review and History of AerosPACE – a Multi-University, Multi-Disciplinary, Distributed, Industry-University Capstone Project

Abstract

This paper describes the first three years of a multi-university, multi-discipline, team-based, design-build-test/fly project called AerosPACE. All authors are former students who took the AerosPACE course. The paper does not present a rigorous research approach, but rather, particular focus is placed on the first-hand student experience and consequent translation of learned skills into the workforce. The evolution of the industry-sponsored program is outlined including lessons-learned, student experiences and achievements. A methodology which other industry sponsors could use to replicate and scale similar projects in other fields is discussed. To conclude the paper, the authors (all alumni of the program who are now working in industry) offer their thoughts on how the program has impacted their early careers in industry.

Introduction

Prior to reviewing the project in particular, it is important to evaluate the overall context of engineering education in the United States and its alignment to industry. Roughly half of all college students who begin as engineering students switch to other majors[1-3]. This has contributed, undoubtedly, to many experts predicting an impending shortage of skilled workers, such as engineers, in the near future[4]. Compounding this situation is the fact that the engineering profession is becoming more and more globalized, as explained in a Reuter's special report[5] that cites the example of the new Boeing 787 with its 28 foreign suppliers providing 65 percent of the new airframe[6].

With all these changes and challenges, engineering education has remained, in many instances, nearly unchanged from how it appeared in the late 1950s, as shown by Dym et al[7-8]. The authors of this paper agree that our recent experiences in undergraduate engineering at various institutions across the country confirm that important changes are needed to better engage undergraduate students in preparing for the realities of today's and tomorrow's engineering workplace.

This paper describes and examines one effort to improve the engagement and preparation of engineering undergraduate students via a program called "AerosPACE" (Aerospace Partners for the Advancement of Collaborative Engineering), which is in its fourth year at the time this article is being written. Sponsored by Boeing, AerosPACE now involves senior engineering students from five different universities across the United States from the fields of Aerospace, Manufacturing and Mechanical Engineering in a "Design-Build-Fly" (DBF) style senior design course spanning two semesters each year.

Several distinctions set AerosPACE apart from other senior design programs and from other DBF programs. One is the multi-university aspect. Teams of students are formed to include students from multiple universities on each team with a faculty team coach from one of the universities. Another distinction is the presence of multiple disciplines throughout the life of the project. Various experts have described the importance of and the need for more multi-disciplinary design experiences for students[9-10]. Finally, each team is assigned and interacts with industry mentors who advise each team on technical and professional issues.

These multi-disciplinary, multi-university AerosPACE teams have demonstrated many of the advantages of learning in such an environment. They have also identified some specific challenges and opportunities that academic institutions and industry partners must be aware of. The end of the paper contains a "Looking Back" section where former undergraduate students who have spent 1-3 years in industry provide their feedback on how effective this DBF project was at preparing them to succeed professionally.

Projects Summary

In order to better understand the student experiences and impact, it is important to review the various student activities in the context of their overall projects and their requirements. The AerosPACE project is grounded in active learning[11] and is fundamentally linked to workforce skills gap research[12].

Boeing recognized the need to address this skills gap and identified the interactions with universities as one effective method to directly and quickly mitigate this skills gap[13]. This issue can partly be attributed to the shift toward a global economy. This has been a paradigm shift for industry since work is being distributed globally and carried out in numerous languages within the same functional group; however, a corresponding change in the way engineers are educated cannot be found[14]. An industry partnership with academia can provide the optimal vehicle to translate some of these experiences into the engineering curriculum. While industry has historically been a partner in academic capstone courses at many universities[15], they are not typically very involved in curriculum development. A mitigation of the skills gap requires both the supply of real world problems and guidance on the theory and concepts to be taught.

The Learning, Training and Development group at Boeing has engaged in collaborative research and development and established certificate programs with a variety of leading universities in the United States and abroad. In the fall of 2011, stakeholders from Boeing, Brigham Young University, Georgia Institute of Technology, and the University of Puerto Rico at Mayaguez each took a series of small steps signaling the beginnings of a giant leap for industry and academia relationships; namely, they began the joint development of an active learning keystone course. It was determined that this student project should be multi-faceted and involve the following four concepts:

1. Collaborative computer aided engineering (CAE) tools[16],
2. modern design methodologies[17],
3. a real world design problem,
4. and industry support and feedback.

At the time of this project the Boeing 787—the first commercial aircraft to have a majority of its structure manufactured from advanced composite materials—had been in service for about a year and the official program launch of the Boeing 777X[18] was about a year away. Both the 787 and 777X deviate from a longstanding tradition of aluminum primary structures and instead rely heavily on composites. Any future engineer will have to understand the lifecycle tradeoffs involved in the material choices; therefore, it was decided to have a student project consider these major process steps. Students were asked to redesign the wing for the North American F-86

Sabre, a Korean War fighter jet. The F-86 was selected due to the readily available information about various parts of its design and the instructional staff's familiarity with it.

Ten students participated in the course and, depending on their home institution, received credit or pay for participation in the two semester course sequence. Students were provided with lectures on key subjects like integrated design and manufacturing (IDM), integrated product and process design (IPPD), application of advanced composites, product lifecycle management (PLM), and computer aided design (CAD). Lectures were presented virtually to the entire student cohort with some additional short information sessions on specific topics (e.g. cost modeling) provided as needed. The students worked across geographical boundaries as one team on a common engineering design challenge and reported its findings every two weeks to an advisory board made up of industry and faculty representatives. Students successfully navigated various challenges and were able to produce a viable alternative wing design[19].

Academic interests were satisfied with the technical rigor and application of the design challenge while industry ones were pleased with the distributed work experience and the advances the students made on the collaborative CAE. However, it was quickly determined that in order to be sustainable in the long term, this activity had to part of the "traditional" curriculum track. Most of the students were enrolled in the industry sponsored F-86 activity as well as a "regular" capstone course. This proved to be a significant strain on the students' ability to fulfill their other academic requirements. In addition, student and advisory board surveys showed that the impact of the program could be dramatically increased if students participated in a build activity as part of the course.

For the 2012-2013 academic year, Purdue University was added to the cohort; additionally, graduate students at the University of Washington who were also Boeing employees joined the program. Student participation almost doubled to a total of 16 undergraduate students and 3 graduate students. While a design-build-fly activity was desired, it was determined to be too difficult to achieve in this second project iteration. Instead, a design-build-test framework was chosen as an intermediate step on the way to a collaborative full design-build-fly activity.

In order to avoid repeating the same student project every year, the project's leadership team searched for a test activity template to best fit with the design-build-test challenge. The National Aeronautics and Space Administration (NASA) common research model (CRM)[20] is an internationally acclaimed test standard for computational fluid dynamics (CFD). The CRM is based on a notional high performance twin-aisle aircraft whose geometry was provided to NASA by Boeing. Its wealth of baseline test data, both physical and computational, and its public availability made it a good candidate for use[21]. Thus, the CRM was selected as the project's template.

With the design of the CRM in mind, students were asked to design a new aircraft to replace the notional CRM vehicle. They were provided with a request for proposal (RFP) with performance requirements similar to the notional CRM aircraft. The RFP's deliverables included a new wing design (to again incorporate the aluminum vs. composites tradeoff) and a test plan for verification and validation of their design. Students were divided into four teams and each provided their own conceptual design proposal. The advisory board, acting as the customer, then selected their preferred choice which the entire cohort of students would then develop further and test. In addition to Boeing, Stratasys, an additive manufacturing company, provided engineering and part support as the students designed their test articles. Test articles included a scaled fuselage, two newly-designed wings, and interchangeable wing tips (raked tip and a winglet tip). The scaled aircraft was fully 3D printed and is still used for aerodynamics experiments to this day[22].

After successfully navigating the logistical challenges associated with the distributed design-build-test activity, both faculty and industry stakeholders felt that a design-build-fly activity was now attainable. For the 2013-2014 academic year, Embry Riddle Aeronautical University joined the program. Thirty-four students working in three teams, each with representatives from multiple universities, designed, built, and flew an aircraft. The RFP was based around food availability and supply, which is a global challenge as the world population continues to grow[23].

An after-action review by faculty and industry partners revealed that while there were opportunities for improvement, the general framework for a collaborative DBF activity was successful. A new challenge of assisting first responders was created and Tuskegee University joined the program. Overall, forty-four students from five universities were distributed amongst four teams. While the previous year relied on “cores” (about half of each team was from the same university), it was determined that rather than improving manufacturing ability as intended, cores instead degraded overall team performance and led to friction[24].

After evaluation, it was projected that teams without a “core” would perform much better. At the time of this publication, no evidence to the contrary has been found. The previous cohort also mutually agreed that project progress suffered because students only met face to face at the concluding fly-off of the project and only communicated electronically beforehand. In response to this, a two day kickoff meeting was organized at Boeing to begin this latest project. Students, faculty, and industry partners agree that this approach significantly enhanced the students’ work quality.

Besides altering the overarching theme of the RFP, the structure was also modified. The previous year had a very detailed mission profile and very particular requirements resulting in very similar vehicles from all three teams; so, it was determined that the creativity of the students should be enabled for this next project iteration. They were therefore required to work with the customer (first responders) to develop their own mission profiles and requirements, while only given some high level constraints like budget and size of the final vehicle. This approach has yielded novel design proposals from the students (Figure 1) and is highly encouraged in similar endeavors.

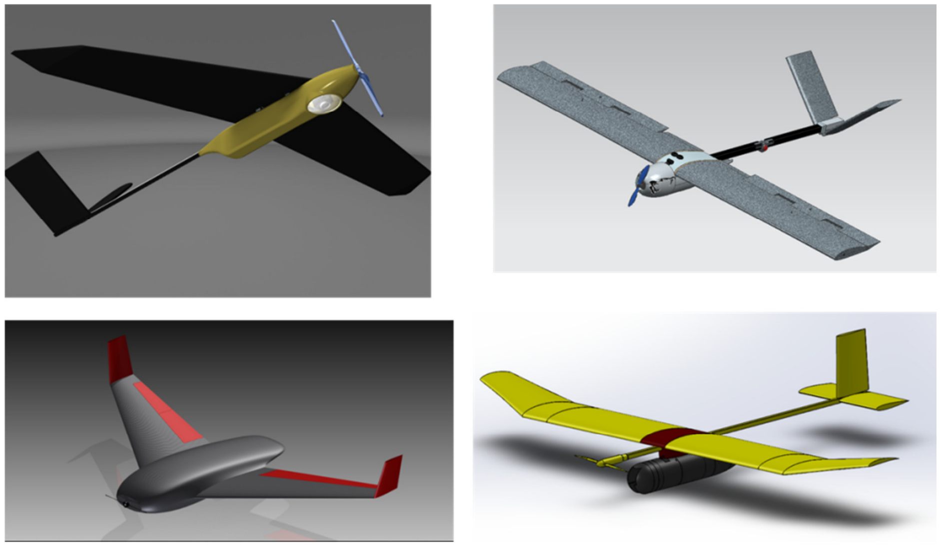


Figure 1: 2014-2015 Student Designs

Included below is a table that summarizes the list of AerosPACE participants throughout each of the four years of the program.

Table 1: Summary of AerosPACE student participants

| **University** | **2011-2012** | **2012-2013** | **2013-2014** | **2014-2015** |
|---|---|---|---|---|
| **Brigham Young University** | 4 | 6 | 10 | 10 |
| **Georgia Institute of Technology** | 3 | 5 | 10 | 10 |
| **University of Puerto Rico at Mayaguez** | 3 | NA | NA | NA |
| **Purdue University** | NA | 5 | 11 | 9 |
| **University of Washington** | NA | 3 | NA | NA |
| **Embry-Riddle Aeronautical University Prescott** | NA | NA | 5 | 9 |
| **Tuskegee University** | NA | NA | NA | 6 |
| **Total** | 10 | 19 | 36 | 44 |

A summary of the lessons learned as discussed in the previous section is included below:

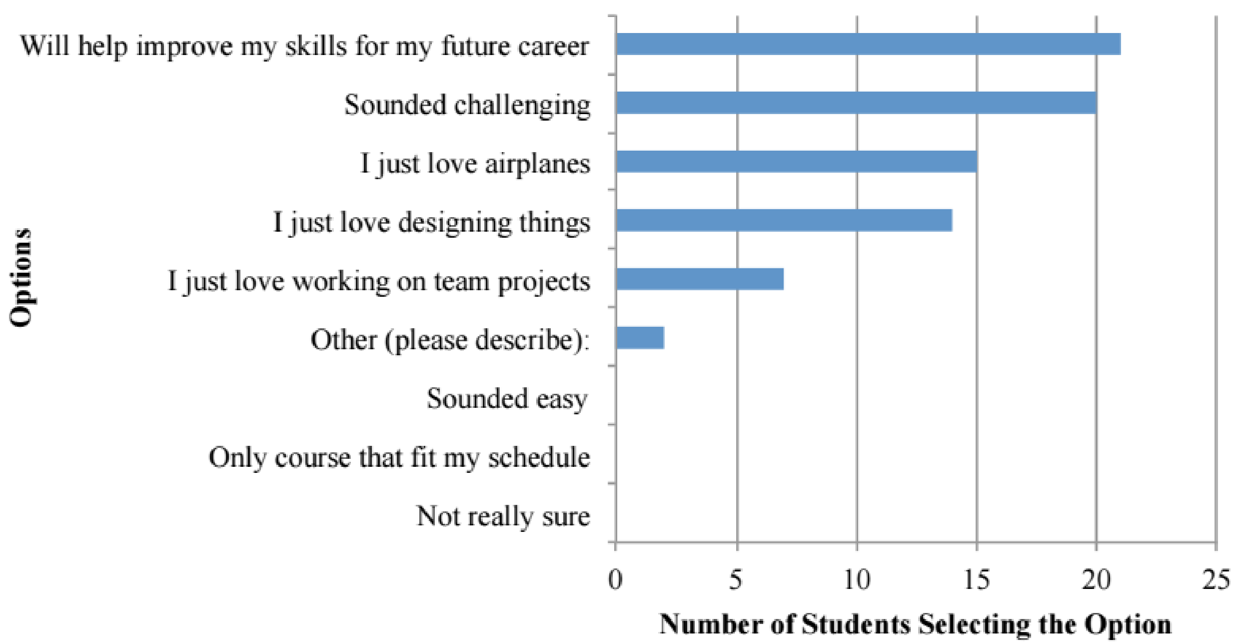
- Involve industry in curriculum development.
- Make the course part of the traditional curriculum track so that students can give proper focus to the course.
- Approximate as closely as possible equal distribution of team members across participating universities instead of having “cores” of students from one university.
- Do not allow a student to be the only member of a team from his/her university
- If budget allows, organize a kickoff meting for students to meet in person at the beginning of the project.
- Give high level constraints like budget and vehicle size, but let the students work with the customer to develop their own list of requirements.
- Have a build/demonstration activity as part of the course.

Student Experiences

While the previous section outlined the overall program architecture and changes made therein, the most important aspect of the AerosPACE program is the people associated with it—especially the students. The following feedback is provided entirely by previous AerosPACE students. The majority of comments come from the authors of this paper who were all AerosPACE students at one time. They describe their experience in the program and provide an evaluation of the impact on their current career. This analysis is not meant to be rigorous nor exhaustive. In compiling this feedback, the authors of the paper responded to two questions: "What did you think of the course?" and "How has AerosPACE impacted your current career?" Comments are organized thematically.

Although the specific student projects changed from year to year, one thing that did not change was the students' motivation. Students are driven by a desire to apply what they learn in the classroom in the real world. This can be seen across the entire group of participating third year students in the results from a question posed to students in the course introductory survey, "Why did you decide to take this course?" as seen in the table below.

**Student Reasons for Taking the AerosPACE '13-'14 Course**




Motivation for taking the course

The diverse mix of third year students all shared a keen interest in the subject matter and a high level of intrinsic desire to do well in the course (taken from the project's introductory survey). When asked to rank how personally motivated they were to do their best in the course on a -5 to +5 scale (-5 being not motivated, 0 being neutral, and +5 being highly personally motivated), the average response was +4.22. Another strong motive was the opportunity to collaborate across multiple regions geographically in a joint effort of solving a complex engineering problem. The following includes some detailed student comments which support the aforementioned motives:

Fabian Zender, a student from the 1st year of AerosPACE who studied Aerospace Engineering at Georgia Tech said: *"When an opportunity presented itself to work an industry sponsored project, there was no hesitation. Working on a real-life engineering problem represented the pinnacle of college studies. It was the single most important objective inspiring me to pursue an engineering career. Having completed three years of my undergraduate studies, I did not yet experience a class that required problem solving across the various disciplines contained within aerospace engineering. Having been motivated to enter into an engineering degree because of the variety of disciplines involved in designing air vehicles, this was quite unnerving."*

Larissa Cannon, a student from the 2nd year of AerosPACE who studied Mechanical Engineering at Brigham Young University said: "*I chose to apply for the COMPACT senior design project* (COMPACT is the former name of the AerosPACE course) *for the opportunity to learn more about aerospace, to develop my collaboration skills and to help beta test NX Connect. My interest in aerospace developed through four internships at aerospace companies. COMPACT offered the opportunity to work with students from other majors and learn from professors and experts outside of the core curriculum I had already taken.*"

Aaron Lau Inouye, a student from the 3rd year of AerosPACE who studied Mechanical Engineering at Brigham Young University said: *"As an undergraduate senior in mechanical engineering, I had already been exposed to the fundamentals of engineering throughout the core mechanical engineering curriculum at a mountain west university. As well as having a core understanding, I also understood the design applications of those core principles (i.e., Computational Fluid Dynamics (CFD), Computer Aided Engineering (CAE), Finite Element Analysis (FEA), and optimization methods) to the level of a novice. The AerosPACE program integrated all of the knowledge that I had obtained throughout my undergraduate career and prior, and allowed me to apply it in a real situation (i.e., the design of a fully 3D printed unmanned aerial vehicle)."*

Team Dynamics

Successfully operating in distributed teams is not easily achieved. Collaboration across multiple time zones is typically unfamiliar to students but is required for individuals to successfully participate in the project. Because of the spread of universities, the participant demographics and educational backgrounds were diverse. The following are some student comments regarding team dynamics:

Fabian (a 1st year AerosPACE student) comments on the uniqueness of the multi-university experience: *"Projects in other classes that were taught across the College of Engineering typically divided any group task strictly along majors. A collaboration with students from another university and another major therefore represented unchartered territory and required careful navigation of this new environment to establish a working rhythm."*

Larissa (a 2nd year AerosPACE student) said that profiling team members based on their technical background proved beneficial. "*There was a lot to digest in that first RFP. I relied heavily on my teammates who had more aerospace engineering experience. I learned a lot of new vocabulary during the conceptual design phase. Our team had good synergy from the beginning even though we had never met each other and were scattered across the country. I attribute it to the fact that everyone was proactive about contributing to the team and we didn't have to pull anybody along."*

Aaron (a 3rd year AerosPACE student) comments that pure virtual collaboration proved difficult at times: *"With the majority of students on our team studying at Georgia Tech, operating as a team was difficult* (Aaron was at Brigham Young University). *A disconnect existed between the three universities, and a decision with regards to the conceptual design was forcefully made due to deadlines."* This feedback inspired AerosPACE administrators to introduce a face-to-face meeting at the beginning of the course as well as at the end.

### Collaboration

Collaboration imposes unique requirements and constraints on the students. New paths to success needed to be discovered by the students in order to complete the challenging task with which they were provided. Utilizing the available social media technology, the students were able to collaborate effectively across multiple regions. The following student comments highlight the importance of communication and workarounds used to enable collaboration.

Fabian (a 1st year AerosPACE student) learned that technical projects require a different collaboration tool suite than that required for simply sharing social experiences: *"Communication is a vital part of collaboration. Communication on engineering projects extends beyond conversations and emails and requires an entirely different collaboration suite to relay the various aspects of a design and its associated engineering data. New software provided unique opportunities and challenges in this regard."*

Fabian also mentioned that collaboration is not always a focus of other engineering courses: *"While the social life in the university settings thrives on interactions and collective experiences with a vast number of people, the same could not be said about the course work. In fact, professors appeared to discourage rather than encourage collaboration among students."*

Teams had to discover what worked for them. Larissa (a 2nd year AerosPACE student) said: *"We found Google Hangouts and Google Drive to be the most effective ways to run the team meetings*. W*e had to ask lots of questions and go to multiple sources to get the answers. It taught us to be versatile and be more robust to uncertainty."*

### Tools for computer-aided engineering

Students were all previously exposed to some Computer Aided Engineering (CAE) tools. However, few of them had to use them in an operational environment. AerosPACE is an opportunity for students to utilize a tool from each step in the product lifecycle. The following are some student comments regarding the computer-aided engineering tools used in the course:

Part of the course was meant to provide a testing ground for NX Connect. Larissa (a 2nd year AerosPACE student) discusses the pros (and cons) of working with a new tool: "*I was the CAD Model team leader and a member of the topology optimization team. NX Connect (a multi-user plugin for NX) allowed the team to solve problems together. At one point, we had three people in the model simultaneously, trying to place a challenging datum plane. It also allowed for the training of students less familiar with NX by allowing student and mentor to be in the model at the same time.*"

Larissa continued to express some of their frustrations in working with a new tool: *"Trying to beta test NX Connect with the pressures of providing deliverables was challenging. Sometimes, the features we needed either weren't supported, or weren't working properly. This was frustrating and left more work for the CAD team because we had to find workarounds and make tradeoffs. Sometimes we had to just put our pencils down, mitigate the risks and move on!"*

Most engineering courses focus on a single type of CAE tool. In AerosPACE, the students had to either use or provide inputs for several CAE tools. This unfortunately limited the number of preliminary design iterations achieved by the students. Larissa expresses her thoughts: "*The preliminary design stage required us to work much more closely with our mentors. We learned about calibrating our analysis with experimental test data, and learned what inputs we needed to provide to the other teams (such as Structures and Aeroelasticity). Due to our unfamiliarity with some of the tools we were using, the team made it through just one design iteration.*"

Moving into the detailed design phase, students were able to validate their virtual analyses using instrumentation, a valuable learning opportunity. Aaron (a 3rd year AerosPACE student) comments: *"In the detailed design stage, the AerosPACE program provided us the opportunity of being able to implement computer aided engineering analysis tools that consisted of the following: computational fluid dynamics (CFD),computer aided drafting (CAD) and finite element analysis (FEA) for the purpose of designing a real UAS. We not only performed complex analyses of the various disciplines in a digital frame, but validated those analyses with state of the art instrumentation (e.g., wind tunnel, STM machines and force gauges), software, and guidance from professionals."*

Manufacturing **M**ethods

Engineering curricula do not typically include many (or any) hands on opportunities. AerosPACE provided such an experience and allowed students to take advantage of advanced additive manufacturing methods through collaboration with an additive manufacturing partner. The following are some student comments regarding the manufacturing methods:

Larissa (a 2nd year AerosPACE student) said: "*We consulted with a 3D-printing company to make sure the 3D-printed model could withstand the lift forces it would see in the wind tunnel. They suggested an innovative approach that leveraged the capabilities offered by 3D printing and showed us some of the models they had printed. It was such a rewarding experience to be able to hold a physical model of something we had designed in CAD all semester!"* See below in Figure 2 for an image of the 3D-printed fuselage interior.

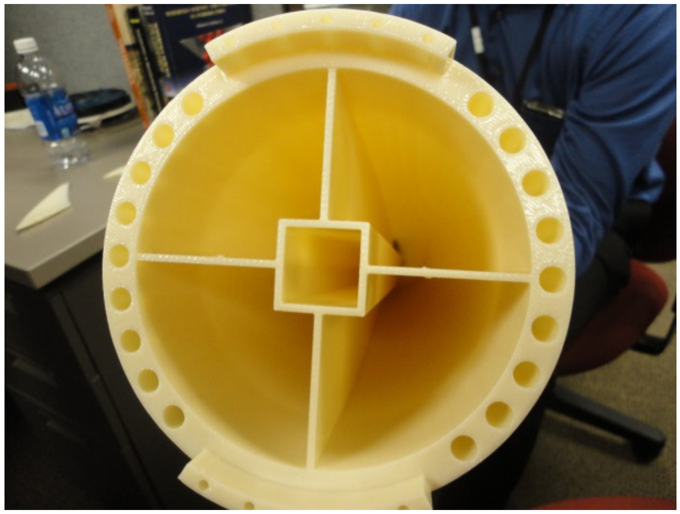


Figure 2: 3D-printed fuselage from Year 2

Students had great success with their 3D printed models. Aaron (a 3rd year AerosPACE student) shares his experience: *"The 2013-2014 Agricultural UAS project gave us the opportunity to push engineering beyond its boundaries in additive manufacturing (AM). Not only did we apply AM to our design, but we implemented it in a fashion that optimized this disruptive manufacturing technology (i.e., AM is optimal for customization and quick turnaround times from prototyping to full on end production) and built a novel UAS. This UAS consisted of an 8' wide, fully 3D printed, 6.26 lb. structure that took 1st place at the first ever ASME-IAM3D Challenge competition."*

Looking Back

Students from the 1st, 2nd, and 3rd years of AerosPACE who have now spent 1-3 years working in industry, share their thoughts on how this project has helped them prepare for their current careers.

Fabian learned how to work on a team with differing skill levels and technical backgrounds. With the current need for mentoring in the workforce, this has proved to be a valuable skill for him. *"Participating in this project required me to understand the knowledge, skills, and abilities of my team members, realizing they each have a unique strength and distinctive skills that can further the teams progress. Every project I have worked on to this day relies on a similar makeup of team members with varying skills."*

Former students from each year of the project were asked to respond to the question: "What was the most valuable lesson you learned from AerosPACE?" Their responses varied. Larissa found dissecting an RFP to be most valuable: *"One of the most valuable lessons that I learned from this senior design project was how to take what the customer wants, turn it into a set of requirements, identify action items, and provide deliverables to the customer. In my current job at a major aerospace company, I employ those skills often and I see it as a key to my ability to satisfy my customers."*

Aaron found that AerosPACE accurately facilitated a real life work scenario that helped him overcome the new-employee learning curve: *"The ability to take a problem, design a complex solution, and implement that solution (all the while collaborating with subject matter experts (SME)) has helped me break down, analyze, design, and implement solutions for processes within a complex operational business unit structure efficiently. The AerosPACE program facilitated an excellent real life work scenario and taught me the value of pulling from the wealth of knowledge and experience that we have surrounding us. These skills that were learned within the program have proved to be universal and have become the foundational building blocks for my career."*

Cory Cunningham, a student from the 2nd year of AerosPACE who studied Manufacturing Engineering at Brigham Young University, found the exposure to many parts of the product lifecycle to be most beneficial: *"Even though I studied in a top notch Manufacturing Engineering program at Brigham Young University, there was still a huge gap between the classroom theory I was taught and the actual work done at the major aerospace company where I work. As a new employee, one of the greatest challenges to me was needing to understand fundamentals of so many other topics and concepts in order to understand how my individual work fit into the big scheme of things. This is how AerosPACE helped me most. By exposing me to an entire design-build project, I learned aircraft fundamentals and considerations that my degree alone did not teach. Since I now had some experience in so many facets of the entire product lifecycle, I was able to hit the ground running when I started full-time. I didn't need to go through as steep of a learning curve as I would have if I had never participated in the project. I strongly believe that I can make better individual decisions for the whole company since I have more context to the things I do. The exposure and awareness I built through AerosPACE has helped me understand how my work fits into the major aerospace company's overall purpose."*

Regarding communication, Larissa also said: *"I have appreciated the experience that this project gave me in communicating with others through a variety of different mediums. In my job today, I talk in person, send and receive emails, talk on the phone, and instant message with my coworkers. Just like this project, my coworkers today are located all over the world. This project helped me develop the skills to communicate effectively."*

Fabian also valued the lessons he learned in how to be a leader and project manager: *"One of the most valuable aspects of this program was the practice it gave me in planning and scheduling tasks. As the team leader I had to ensure that all steps of the design process were accounted for and completed in the proper order. Tasks had to be prioritized against project deadlines. To this day I utilize these skills every day as I am handling multiple projects with varying scopes and deadlines."*

Larissa said that even the challenges of the course proved to be learning opportunities: *"Because NX Connect was still in a beta development stage when we used it in the project, it helped me be robust to tools that may not fit my needs perfectly, or that are still being actively developed. I have encountered similar situations in my current position and this project helped prepare me to be an active participant in the tool-improvement process and recognize that I should leverage a tool's capabilities where possible and find workarounds when necessary."*

## Looking Forward: AerosPACE as an Architecture

This feedback from students has helped identify opportunities for improvement and guided all partners in continuously working to provide an opportunity for this program to thrive and grow. The intent of this paper was not to document one particular year of AerosPACE in any detail. For interested readers, the authors have included several papers of interest in the Bibliography section. A brief discussion of future modifications is included below.

By adding more universities to the program, AerosPACE could increase its positive impact on the number and preparation of new engineers entering the industry workforce. Not only do programs such as AerosPACE directly impact graduates' level of preparedness to work in industry, but the program also increases excitement among underclassmen and produces tangible, easy to promote, visual representations of engineering work that make promoting STEM careers easy. This could help increase the number of students who come into and stay in STEM majors.

Adding more universities from the U.S. would be one way to accomplish this goal. One major advantage of adding more U.S. universities is that the current program coordinators have significant experience in setting up and running AerosPACE at American universities. One potential downside is limiting the students' chance to have a significant international collaborative experience.

AerosPACE currently focuses on professional engineering programs, but in the workplace, interaction with technicians and technologists is commonplace. For Boeing, community colleges are a common means of filling positions that require these technical skills. In addition, the National Science Foundation is currently encouraging community colleges to get involved with STEM research efforts by, "propos[ing]… solutions to perplexing, real-world problems," through its Community College Innovation Challenge. Demographic groups that are currently under-represented in STEM make up a significant portion of community college attendants [24]. By involving community colleges in AerosPACE, the program could increase the quality of the collaborative experience for students by not only increasing the number of students involved, but also the demographic reach of the program, adding to its diversity.

## Conclusion and Recommendations

The student experiences chronicled here demonstrate many of the advantages of learning in an environment that the AerosPACE program offers. The feedback has given a glimpse into the synergies that can be achieved when industry and academia collaborate to close the skills gap.

AerosPACE has been an iterative project. As much as possible, the lessons learned from one year have been applied to the subsequent year. Some of these lessons learned include:

- team formation strategies based on students' technical profiles and location,
- balancing virtual collaboration with face-to-face meetings,
- using a more fully-developed multi-user CAD tool,
- a creative and open design challenge,
- improved curriculum and delivery methods,

– and a more defined role for the faculty and industry partners.

After seeing the positive impact of the program, the administrators of AerosPACE and authors of this paper recommend that universities and engineering companies continue to partner to engage the incoming class of engineering students and ensure their preparation for the workplace of the future. The lessons learned from AerosPACE should be applied in other engineering design courses, capstone or otherwise.

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