Aerospace Partners for the Advancement of Collaborative Engineering (AerosPACE) - Connecting Industry and Academia through a Novel Capstone Course

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***Abstract*— Distributed, virtual collaboration is the way design will be done in the 21st century. However, two new developments can be expected to enhance DVC, social media and Massive Multiplayer Online Role Playing Games. This recognition provided the impetus for the Aerospace Partners for the Advancement of Collaborative Engineering (AerosPACE). This project aims to have students push the boundaries of current Computer Aided Design and Manufacturing (CAD/CAM) tools by collaboratively designing parts driven by a Massive Multiplayer Online Role Playing Games (MMORPG) engine, and coordinated by a social network that pursues continuous improvement through the use of advanced manufacturing processes in a distributed environment.**

The program mimics the geographic and technical dispersion that are commonly seen in the workplace; students, faculty, workplace coaches, and industry sponsors operate in various time zones and come from different engineering backgrounds. This microcosm of capabilities forms a pseudo-global engineering company that gives students the opportunity to work in relatively the same environment, bound by the same constraints that they would experience in industry. The students, under the mentorship of faculty coaches, are designing, building, and flying an agricultural Unmanned Aerial Vehicle (UAV) to increase crop yield, while at the same time learning industry-required skills in a blended learning environment. Research to date has defined a scalable model for industry-academia collaboration in capstone courses intended to contribute to the body of knowledge for engineering education research.

***Index Terms*—Capstone, Coaching, Distributed Collaboration, Multidisciplinary Research**

I. Introduction

Manufacturing in the United States is responsible for 12% of the Gross Domestic Product (GDP) [1], of which the aerospace industry contributes 5.2% [2]. While this contribution is substantial, the entire manufacturing sector is facing an existential threat because of the limited quantity and quality of students in the Science, Technology, Engineering, and Mathematics (STEM) pipeline. While the number of graduates in STEM fields have continuously increased over the last decade, graduates in increasing numbers are reporting that they are unable to gain employment in fields closely related to their highest degree [3, 4]. This trend is having a significant impact on companies like Boeing where the average age is 48 [4], a workforce trait found across the aerospace industry [5]. For example, numerous studies point to a skills gap, both in quantity and quality, between the capabilities of graduates and the workforce requirements of industry being responsible for this disparity [5, 6, 7, 8]. This skills gap is further exacerbated by the fact that less than 2/3 of STEM graduates are eligible for a security clearance [9]. The creation of two new manufacturing innovation hubs by President Obama shows that the federal government is cognizant of these challenges [12].

To successfully counter this skills gap, companies are increasingly reaching out to academia to actively participate and shape the education of students, particularly by supporting capstone programs [10]. In this paper, we describe AerosPACE), a multi-university, multi-disciplinary capstone project co-developed by academia and industry. In addition, lessons learned are abstracted to serve as a guide for other institutions and companies who wish to collaborate in a similar fashion. AerosPACE evolved from lessons learned as part of a technical feasibility study assessing the capabilities of a collaborative CAD tool [11] as well as a year-long pilot study [12]

This paper is organized as follows. Section II presents the governance structure. Section III presents the roles of faculty members at participating universities. Section IV presents the duties of the Advisory Board. Section V presents the role of Boeing coaches and coach-student interaction. Section VI presents the specifics of course and team design. Section VII describes the collaboration tools used on the project. Section VIII summarizes the lessons learned over an eight-month time span. Section IX presents next steps to continue to make progress on the project. Section X provides concluding comments and outlook for the future.

II. Governance Structure

In order to implement cross-organizational governance and manage expectations, it is important to establish the necessary processes and structures. The governance structure was co-developed during weekly meetings between industry and academia, taking into account the cultures of both institutions and outcomes from previous collaborations [16].

A. Particpant Roles

Each party involved in an industry-academia collaboration brings to the table certain expectations and areas of expertise, in addition to their desired outcomes for such a project. Framing these variations in a common agenda that everyone can agree on is vital to successful collaboration. This process takes time – in-person meetings offer unique opportunities to come together around a common goal and often are much faster than could be achieved via electronic-only collaboration. If in-person meetings cannot be arranged due to budget or scheduling constraints, it is important that sufficient time is allowed for this trust building process to take place.

For AerosPACE a work breakdown structure (WBS) was developed to define actions. Specific responsibilities for faculty were as follows:

- Identify, recruit and select students for participation in the program
- Identify lectures, deliverables, and grading rubrics that ensure student success
- Provide faculty and teaching assistants to lecture
- Monitor team progress and assist as necessary
- Provide physical infrastructure for students (e.g. room to attend lectures, lab space to work on project)

Boeing, as the industry sponsor, had responsibility to:

- Provide technical workplace coaches to assist student teams
- Assemble an advisory board including members from various business functions within the company, other industry representatives, and contacts from academia

Figure 1. AerosPACE Governance Structure

- Provide general counsel on the curriculum alignment to industry practice
- Provide learning scientists for curriculum improvement
- Provide select lectures on industry-focused topics
- Provide project management assistance where required

This breakdown of responsibilities enabled successful collaboration and allowed participants to engage in ways most meaningful and familiar to them.

Figure 1 shows the three-pillared governance model for AerosPACE: the industry council, the faculty council, and the advisory board. The advisory board provided general oversight of the program and provided feedback to students. The faculty council met weekly before and throughout the course. Members of the industry council were invited to participate in the faculty council meetings. In addition, the industry council also met with representatives of the lead university (Brigham Young University) on a weekly basis to review program status and funding. Contracts between industry and academia were limited to the lead university which acted as fiduciary agent for all universities involved.

B. University Partner Selection

For an endeavor as complex as AerosPACE it is very important to take great care in selecting partners; there were a broad set of competencies required from each participating university:

- Willingness to participate in a collaborative project
- Declared technical competency aligned to project outcomes
- Faculty members that are early adopters of forward thinking technology to engage learners
- Administrators willing to provide academic capstone credit to an adapted course
- Willingness to engage in a high-risk, high-reward activity

It was determined that university selection should take precedence over selection of particular schools at a university because the intent was to create a multi-disciplinary program based on competency. This should encourage collaboration within individual universities, a process that is well under way at some institutions in the United States [13, 14], but not many.

1) Institution Selection

At the heart of the AerosPACE project is collaboration. But this is a challenging, especially when engineering design and distributed manufacturing occurs across various locations. Brigham Young University (BYU) has an Industry & University Cooperative Research Program (I/UCRC) sponsored by the National Science Foundation (NSF) focused on e-Design. Under this program umbrella collaborative Computer Aided Design (CAD) software is developed [15, 16]. The Center is housed in the Department of Mechanical Engineering alongside the Center for Unmanned Aircraft Systems (C-UAS) where significant research in the area of controls regarding unmanned aerial vehicles [17, 18] and imaging from airborne platforms [19, 20] takes place. Due to its exemplary capstone program [21] and its expertise in the critical area of collaborative design, it was determined that BYU should take the lead role for academia. Students were selected with disciplines from across the capstone program's colleges, including Mechanical Engineering, Manufacturing Engineering Technology, Electrical Engineering, and Industrial Design.

Additional expertise in the design of complex aerospace systems was required; therefore, the Georgia Institute of Technology's Aerospace Systems Design Laboratory (ASDL), a proven center of excellence in this area and on the forefront of current research [22, 23, 24] with state of the art facilities [25], became a partner. ASDL has a long history of supporting Design, Build, Fly (DBF) style projects. Furthermore, the Manufacturing Institute and Rapid Prototyping & Manufacturing Institute (RPMI) provide the Georgia Tech community access to cutting edge research on manufacturing equipment and processes. It was determined that Graduates and Undergraduates alike from the Aerospace Engineering program would be best suited to participate in this project.

As the AerosPACE project took shape, it became apparent that additional expertise in the area of aerospace design was required. With the addition of Purdue University's Aeronautics and Astronautics expertise and facilities, (Boeing Wind Tunnel, 4'x6' test section V_{max} = 200mph) and Embry-Riddle Aeronautical University, with its background in flight testing, the project formed a well-rounded, very capable team.

2) Specific Roles throughout the Lifecycle

In accordance with the governance structure previously described all university partners were given equal voting rights on the faculty council. As such, it was determined the competencies enabled each institution to lead lecture and lab efforts during different phases as the students progressed through the project lifecycle– early phases of the course focused on systems requirements analysis and aerospace sizing, during which Georgia Tech took the lead. For the preliminary design phase Purdue university led lectures and labs. As students began moving into detailed design and manufacturing the strengths of the mechanical engineering program at BYU were drawn upon. Last, but certainly not least, Embry-Riddle provided a majority of the support during the final flight testing.

III. Faculty

Once institutions and schools were identified, it was important to quickly secure support from faculty since they are involved in the day to day activities long after administrators give their approval.

A. Faculty Selection

While ultimate responsibility of faculty selection and approval was left up to each school, recommendations were made by AerosPACE members (industry or academia) where applicable. These recommendations were typically based on previous collaborations with those faculty members by that AerosPACE member.

Faculty selection followed the competency based model described for the identification of partner institutions. At BYU a faculty member with experience in Computer Aided Engineering (CAE) was selected, which enabled a close interface with the NX Connect development team and provided expertise and access to BYU's supercomputers.

At Georgia Tech and Purdue, faculty members with extensive experience in design, build, fly projects were selected. Their expertise was vital in ensuring that students evaluated all possible options as part of the conceptual design phase. Additionally, their experience with various manufacturing processes ensured that students would be able to build what they designed. The faculty team was complemented by an analysis expert from Embry-Riddle with experience in flight testing.

B. Role of the faculty

Throughout the two-semester AerosPACE project faculty members fulfilled various roles. In addition to the traditional role as instructors for lecture and lab sessions, they also acted as coaches for student teams and participated in design reviews as members of the advisory board.

Since lectures and labs were broadcast and recorded via WebEx, faculty did not have to teach every week. Teaching assignments were broken up based on faculty expertise so that each taught at various times throughout the semester. As part of the faculty planning meetings the faculty council determined who would teach what topics.

Each faculty member was assigned to coach at least one team. Coaching style varied among faculty members, but all relied on weekly team meetings, as well as ad-hoc meetings when required. While some faculty acted more in an observing role, providing feedback as necessary, others were more involved, e.g. assisting teams with physical testing. At this moment no verdict can be rendered that one coaching style was better or worse than another, rather all teams are successfully progressing through their design and it appears that teams and coaches have found the means to effectively work together.

As members of the advisory board faculty participated alongside industry and government representatives to provide feedback to all the teams as part of regular design reviews.

IV. Advisory Board

To help guide program direction and student learning, an AerosPACE Advisory Board was assembled. The 41-member panel included Senior Managers, Engineers, and Engineering training professionals from Boeing and other industries, university faculty, and delegates from government agencies. Advisory Board members were recruited based on their expertise in the fields of Product Lifecycle Management (PLM), relational design, CAD/CAM tools, tooling, manufacturing, or systems engineering. Advisory board member responsibilities included:

- Ensuring lectures were tailored to meet specific learning objectives within the project lifecycle
- Reviewing inclusion of fundamental knowledge and practical skills
- Participation in guest lectures
- Promoting the program
- Providing pathways for students to transition into industry

The advisory board's primary role was to guide research on the AerosPACE capstone project. Efforts focused on evaluating the design and process methods required for a simultaneous, multi-user, collaborative work environment, for a computer-aided design, build, fly project. Evaluation criteria included reviewing program objectives and student project goals to ensure high quality and relevance, determining the experience needed by engineers and students within a multi-user environment, and assisting in the promotion of the program.

Board members also participated in project reviews presented by each student team. The intent of these reviews was to assist and mentor students with their designs throughout the product lifecycle. After each review, board members were asked to provide feedback through brief surveys that were aligned to faculty-provided grading rubrics. Prior to the first design review an introductory meeting was held with the full advisory board to introduce the program and set expectations. This practice proved to be very valuable and will be continued next year.

V. Boeing Coaches

A distinctive feature of the AerosPACE project is Boeing's commitment to make technical coaches available to each student team throughout the project. The role of Boeing coaches was to assist students with their project across the design-build-fly phases. This responsibility required coaches to provide help with the CAD/CAM software , FEA, and CFD, in particular modeling techniques for lofting and surfacing, parametric design, analysis, etc. Coaches also attended specific lectures and labs, were available to answer students questions serve as lecturers for topics such as PLM, FEA, and Teamwork in Industry.

To help identify the expertise necessary to support the project, two surveys were distributed to 40 Boeing technical coaches. The first survey prompted coaches for their skills and knowledge of tools used for the project (CAD, CFD, and FEA), and some general time availability questions. The results were used to match each coach's expertise against the overall needs of the project. With approval and assistance from Boeing managers, best-fit matches were selected to support the project across the two semesters. Responses to the second survey helped group specific coaches into skill categories. This data was used to assign coaches to one of the three teams. Assignments were made as follows: Two CAD coaches were assigned to each AerosPACE team to assist with design questions, tool usage, modeling techniques, etc. Additionally, one FEA coach and one CFD coach were assigned to support all three teams with software inquiries and analysis techniques. Once selected, the coaches were introduced to students during a project overview meeting where duties and responsibilities were communicated.

A. Coach-Student Interaction

Collaboration is an essential element of the AerosPACE Capstone project with success being heavily dependent upon the various vehicles used for supporting student-coach interactions. The types of communication ranged anywhere from the typical day-to-day business exchanges to the more complex discussions around design philosophies and processes. Coaches and students were encouraged to communicate on a regular basis, with more casual contacts occurring through the use of telephone calls, emails, and the CorpU learning management system, and formal meetings conducted via Google Hangouts or WebEx. Opportunities for collaborative exchanges between the Boeing coaches and university faculty were also encouraged and occurred primarily during lectures, labs, and team meetings.

An important collaboration goal of the project was to provide overarching, consistent communication across the semester. This was accomplished by having, 1) a coach attend a standing, bi-weekly meeting with their respective student team leads to review status and consult as necessary, 2) coaches hosting post-design review sessions wherein feedback was shared with student teams concerning design philosophies, manufacturing processes, safety, producibility, presentation styles/content, suggested strategies for improvement, etc., and 3) coaches establishing and sustaining mentoring relationships between themselves and the students. The intent of these interactions is to develop and motivate the next generation of advanced design and manufacturing innovators.

VI. Course and Team Design

AerosPACE relied on students from a variety of backgrounds to achieve the objectives stated in the Request for Proposal (RFP) as it required expertise across various disciplines. While these diverse backgrounds are considered a benefit to the program they did present challenges as well.

A. Student Selection

Student selection was left to the respective universities, with no single process used, however there were similar approaches. Following is a generic example:

- Instructor provides information about the program to "regular" Capstone class, or prospective capstone class
- Instructor asks interested students to provide information on relevant qualifications and background (e.g. in form of a resume)
- Instructor evaluates student submissions

- Instructor selects participants and provides contact information to AerosPACE program managers

Some professors have already identified and shared lecture material with potential applicants for the 2014/2015 cohort, based on their experiences with these students in other classes. The effectiveness of this approach will be evaluated as next year's cohort progresses through the course.

B. Team Selection

Three specific criteria drove the team selection process. First, because of the distributed population of students participating in the design-build-fly project, it was determined that larger teams than are typical for capstone courses be formed [10]. Second, each team will have students from each university. Third, due to the significant amount of manufacturing required, each team will have a core group of students from one of the respective universities. The 2013/2014 cohort had 36 students grouped into three 12-member teams, with the final team distributions shown in Table 1.

At the beginning of the first semester, students were asked to complete surveys that asked for information on their background and perceived areas of expertise. Additionally, they were evaluated on their technical competency, communication, motivation and commitment. Survey and evaluation results were used to assign students such that averaged scores in these categories were roughly equal across teams. Skills for some tools were very limited (e.g. experience with Computational Fluid Dynamics), so providing each team with expert users further constrained assignment efforts. Students were assigned to teams by faculty, whereas leadership structures within teams were determined by the students.

Although at the time of this writing the course was still in progress, some preliminary analyses of the teaming process have been provided:

- Having a strong core of students from one university proved to be more of a hindrance than a benefit, it actually slowed collaboration rather than encouraging it.
- Students have been quite successful at splitting manufacturing and testing tasks among the various universities; therefore, it is highly unlikely that the practice of strong cores will be continued for future courses. However, further analysis of the root-cause will continue.
- Having one student from one school on a team should be avoided. While the effects of being the sole member may be deluded once the strong core is eliminated, having more than one person from each university per team is preferred.

C. Course Design

Bringing together multiple universities in an accredited capstone program is a challenge. As identified in various surveys [10, 26] there are many differences among capstone programs that had to be reconciled. For AerosPACE, curriculum and instruction were characterized by:

- Homework, a term design project, assessments, and reflections to evaluate student performance
- Instructional team consisting of subject matter experts from academia and industry
- Rigorous standards in accordance with university standards

All institutions agreed that the capstone course would span two semesters to instill rigor. While all universities are on semesters (as compared to quarters) there were differences in the start, end, and final exam dates. To address this, AerosPACE took place across dates determined by the least common denominator among all universities – AerosPACE did not have a fall or spring break so for each semester instructional periods were 15 weeks in duration.

Overall course objectives were set prior to the beginning of the course, with Wiggins and McTighe's Backwards Design methodology [27] used to determine what lecture and lab topics would be required for students to successfully complete the project. Material taught in the "regular" capstone course was also considered and added where required to maintain ABET accreditation. Once topics were identified, instructors for each lecture were recruited.

The National Aeronautics and Space Administration's (NASA) Systems Engineering approach [28] served as a guide for the students, as well as the course design. Dates for design reviews were set prior to the start of each semester and rubrics for each were created. Design reviews and other assignments were typically graded by multiple faculty members with scores being averaged across instructors. Weightings for the grading were determined by the faculty council, but each faculty member had ultimate responsibility to grade students at their university. Class time was set prior to the start of the semester; however, it was found that an additional hour each week should be set aside for team meetings. These meetings should be scheduled during typical workday hours and must accommodate multiple time zones and the Boeing coaches who are most likely only available during "regular" work hours.

VII. Collaboration Tools

Like most any distributed team, AerosPACE participants require access to collaboration tools that enable them to communicate regardless of their location, the time of day or how often information needs to be shared. Without an overarching, consistent communication plan and the appropriate suite of tools

Table 1. Team Distribution

	Total	Team 1	Team 2	Team 3
Brigham Young University	10	2	6	2
Georgia Institute of Technology	10	6	2	2
Purdue University	11	1	2	8
Embry-Riddle Aeronautical University, Prescott	5	3	2	0

project success will be jeopardized. Though a variety of collaboration tools were used on the AerosPACE project, three were primary: NX Connect, CorpU, and WebEx.

A. *Description of Collaboration Tools*

At the core of the AerosPACE program is a capstone course wherein students design a UAV governed by the tools and processes of a collaborative learning environment. This would not be possible without the help of modern CAD and communication technologies. For instance, BYU, with support from the NSF and industry, has developed a novel, truly collaborative CAD tool called NX Connect [11, 15, 16]. It is based on the Siemens NX platform and enables multiple users to access and manipulate parts simultaneously. Inspiration for this technology came from the gaming industry – the server-client architecture relies on a Massive, Multi-Player, Online, Role-Playing Game (MMORPG) engine.

This technology enables a usage cycle that significantly reduces part design times. These savings are achieved in two ways: First, multiple users can participate in the CAD process simultaneously, and second, representatives from multiple functions (e.g. structures, tooling, production) can access the part in real time to provide feedback. The latter being of critical importance because it helps engineers discover defects early, thus avoiding costly redesigns, and enables tooling to be designed concurrently with the part.

Another asset is that Boeing coaches were able to access NX Connect via virtual machines, allowing them to review part designs with students and provide instant feedback. This proved invaluable given the extensive CAD experience coaches brought to the table.

In addition to the NX Connect CAD tool, students were also required to access a Learning Management System (LMS). In the quest to find an LMS that would satisfy the collaboration needs of AerosPACE, we used Carliner's definition for an LMS, "a one-stop place to go for learning needs" [26] to direct the research. Per this tenant, LMS candidates would have to both, deliver course material to the students, and provide an environment for them to interact within and across the teams. Resulting LMS research determined that a perfect solution did not yet exist, but that AerosPACE could assist with identifying what functionality would be required of such a platform. To this end, CorpU offered most of the desired features, and just as important, the company was willing to work with AerosPACE as partners to further develop the system.

The CorpU platform has two primary features: the course manager and the community manager. The course manager, seen in Figure 2, presents material (e.g. documents, videos, or assignments) each week to notify students what tasks are required to be completed and when. Within the community manager, students have a team space where they can share files or communications with their teammates. It also provides functional communities where students can interact with other teams, faculty, and Boeing coaches to discuss specific problems or concerns. Another feature of CorpU is its robust analytical capability. For example, clickstream data is mined unobtrusively and allows researchers to analyze how students are interacting with each other and/or the course material.

To ensure as many students as possible could attend lectures, the meetings were held via WebEx, which enables access synchronously or asynchronously via recordings – students were able to view the instructor's screen (e.g. for presentations or software) or view a feed from a webcam. Recorded lectures and labs were made available on CorpU shortly after the completion of each meeting.

WebEx was also used for design reviews, meetings with coaches, or team meetings. Students found that WebEx had distinct advantages over alternative free platforms such as Google Hangouts or Skype when more than three to five people were involved in a call. Using WebEx, some of these meetings could be recorded, transcripts of which enabled a better understanding of how knowledge flowed within and across the community of learners.

B. *Feedback on Tools*

The authors agree with the Lean paradigm, that regardless of the state of a product, there is always an improvement in efficiency or capability that can be achieved. This holds true for the collaboration tools used here.

Since its use in the technical feasibility study [11], the NX Connect environment has significantly improved. The platform is much more robust, with few user input errors; however, there are still some limitations regarding surface modeling and parametric assembly modeling. As a matter of process, student feedback was shared with the NX Connect development team to actively address concerns. To date, the count of supported operational features has grown by 367%.

Initially, students found it difficult to locate lecture material on the CorpU website. A refreshed course viewer and added pacing feature, which allowed each student to see what was required of them each week, addressed this concern. Students also expressed uneasiness regarding the social media and data sharing features embedded in the CorpU site causing students to develop workarounds (e.g. for file sharing students relied on Google Drive as a freely available tool) until fixes are incorporated. CorpU is actively working to improve its

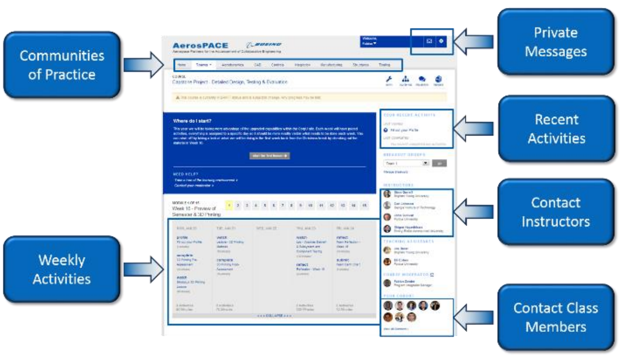

Figure 2. CorpU Interface

capabilities in these area.

VIII. Lessons Learned

Lessons learned from across the 8-month span of the project are many and varied, but already proving valuable for current and future capstone courses. For example, an early dilemma for the project was the realization of misaligned expectations between the students and coaches. Initially, this juxtaposition hindered abilities to construct a collaborative environment for participants and the project's rhythm suffered. However, it could be argued that one of the more positive outcomes of the project is how well the students, faculty, and Boeing coaches adapted to unfamiliar collaboration tools and protocols deployed by the project. Table 2 presents a list of lessons learned, all of which are currently being addressed in preparation for the 2014-2015 capstone course:

Table 2. Lessons Learned During the AerosPACE Project

ID	Description
1	Have Boeing coaches and students meet face-to-face before and after the project
2	Boeing coaches know they can recruit teammates and/or peers from across the company to share their expertise with students and the project
3	Ensure a consistent communication plan between Boeing coaches and students is in place
4	Ensure Boeing coaches schedule work time and off-hours time to support students
5	Set up formal meetings for coaches to share feedback on reviews, etc. with students
6	Students did not realize the benefit of working with coaches until they started interacting with them
7	The collaborative nature of the AerosPACE capstone course benefits both experienced and inexperienced students
8	Many tools can enable students and coaches to collaborate. However, determining which of these technologies serve the project most effectively is challenging.
9	Difficult to get students, faculty, and coaches to exercise unfamiliar collaboration tools such as CorpU and Google Hangouts.
10	Working in geographically dispersed locations makes teamwork more difficult.
11	Student's want open communication within and across teams.
12	Student's desire a high level of trust with their teammates.
13	Set clear expectations with faculty, students, and coaches
14	Feedback from Advisory Board on student reviews has been quite lacking. Must find ways to help the board engage and participate.
15	Encourage Boeing and other industries to construct and deliver more lectures/labs.
16	Universities have successfully completed their own capstone programs, success for a program like AerosPACE requires all to give up some of their traditions in order to form new ones.

IX. Next Steps

The AerosPACE program has been a success on many levels and will continue for the 2014-2015 school year. In preparation for the next session, we plan to execute following steps as the project moves forward:

- Recruiting new universities, including international institutions
- Promoting the capstone project at the 2013-2014 fly-off and recruiting new students
- Organizing & adapting the curriculum for 2014/2015
- Pursuing additional funding opportunities

Certainly, with the success of the AerosPACE program, there is a desire to share the experience with more and more students. For example, it is the authors belief that the program could be further bolstered by adding additional engineering and non-engineering majors. Realignment, supported by data from student success in model completion and knowledge about how people learn in this distributed environment, will serve as the rationale for this action.

X. Conclusion

The AerosPACE project is providing a novel, collaborative approach for bringing industry and academia together in pursuit of innovative aerospace design and manufacturing. The 2013-2014 course presented students a multi-disciplinary, multi-university project to design, build, and fly a UAV for the purposes of monitoring agricultural fields to help improve crop yield for an ever-growing global population.

Across two semesters, three student teams completed conceptual and preliminary design reviews followed by a manufacturing readiness review, and culminating in a fly-off demonstration of their UAV. Each team worked with faculty advisors and Boeing coaches to learn and apply engineering and manufacturing skills across the project lifecycle. Project milestones and student presentations were evaluated by the Boeing Advisory Board whose timely feedback ensured student and project success.

Going forward, the course will introduce key concepts from complex systems engineering with a specific focus on how to model and analyze complex systems, how to manage complexity in complex systems development, and how to exploit social networks in distributed, virtual collaboration. [34, 35, 36, 37, 38]

The capstone course used a state-of-the-art software interface to facilitate a blended learning environment to accommodate the geographic and technical distribution that typify today's workplace – students, coaches, and industry sponsors operate in various time zones and come from different engineering backgrounds. An online learning platform that accommodated the variety of learner types of the participants provided a mechanism for synchronous and asynchronous collaboration.

It is anticipated that results from the capstone course will provide significant contributions to the body of knowledge for engineering education research, with both industry and academia experiencing the benefits a cooperative approach provides to their respective learning goals for employees and students.

Acknowledgment

The authors would like to thank the faculty and workplace coaches supporting this project. In addition the authors would like to thank the other corporate sponsors Stratasys (provided 3D Printing for student teams), CD-Adapco (provided software), and Siemens (provided software) as well as all other instructors that contributed to success of program by providing lecture or labs. A special thank you goes to the chairmen of the advisory board Marcus Nance (Boeing) and Michael Vander Wel (Boeing) and Charles Camarda from NASA who provided valuable feedback to the organizers and students.

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Manuscript received 10 March 2014. This work was supported by the Boeing Company.

Published as submitted by the author(s).