

PREPARING AERONAUTICAL ENGINEERING UNDERGRADUATES FOR WORKING IN GLOBAL TEAMS

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Abstract

Within the last ten years, the strategic partnership between Virginia Tech's Kevin T. Crofton Department of Aerospace and Ocean Engineering and the Faculty of Aeronautical and Automotive Systems of HAW Hamburg has facilitated various forms of international student participation in undergraduate design team projects, some of which were very successful while others were not. This paper examines organizational and interpersonal challenges experienced in these international student team projects and identifies important barriers to successful international teamwork as well as possible interventions by supervisors. Root causes which may lead to team dysfunction are analysed, and proactive and responsive countermeasures are described and discussed. Examples of successful team projects are presented and the beneficial constraints and success factors identified. The lessons learned are summarized and related to problems which may arise in the global work environment of the aviation industry.

Keywords: international teamwork, aircraft design projects

1. General Introduction

With the aviation industry being technology-intensive and inherently global, it needs employees with an excellent engineering education and with personal competencies enabling them to collaborate internationally in projects which span borders and cultures. Aeronautical engineering students need opportunities to gain experience in international teamwork so that they can develop the necessary global mindset and acquire intercultural skills.

Consequently, exposure to international teamwork plays an important role in aeronautical engineering curricula [1]. General teamwork experience was mandated by ABET through the EC2000 criteria to address employers' concerns about the importance of teamwork skill for new hires [2]. Undergraduate teamwork assignments shall prepare students for highly collaborative real-world tasks by teaching them essential soft skills like communication, building trust, leadership, understanding and accepting different perspectives, and how to organize collaboration in a small group of peers. Quite often, collaborative experience is gained in instructional laboratories where students conduct experiments in teams. The predominant learning outcome of such labs is the confrontation with real-world applications of engineering fundamentals [3] and the introduction to experimental methods. Similarly, students are frequently asked to work in teams on undergraduate and capstone design projects to provide them with additional teamwork experience. Again, the predominant learning outcomes of these classes are engineering skills. They are complemented with soft skills like problem-solving, project management, and professional communication and documentation.

Many educators believe that teamwork skills are automatically acquired when students are asked to collaborate. However, many students are overwhelmed by the problems in their team projects because they do not know how to deal with teammates who are domineering, excluding others, slacking or otherwise underperforming. These problems lead to frustration because most instructors do not know how to intervene effectively [4]. When self-managed student teams are international, the challenges are even higher because additional cultural awareness and special communication skills are needed.

2. Undergraduate Opportunities for International Teamwork

The aeronautical engineering curricula offered by HAW Hamburg and Virginia Tech permit different opportunities for getting students involved in international collaboration with peers from the partner institution. Depending on organizational boundary conditions, the experiences made within the last ten years involve in-person participation during a semester abroad, purely remote team membership, and combinations of in-person and virtual collaboration with students who started in-person at the partner institution and continued as remote team members after returning to their home institution.

2.1 Virginia Tech: Air Vehicle Design (AOE-4065)

The Kevin T. Crofton Department of Aerospace and Ocean Engineering (AOE) at VT requires undergraduate students to complete a two-course sequence in air vehicle design for a Bachelor of Science degree. (Space vehicle design and ocean vehicle design are two alternative options.) Students typically take the courses in the fall and spring semesters of their last academic year.

2.1.1 Air Vehicle Design—1st Course (AOE-4065, Fall Semester: Aug - Dec)

The first course starts with design teams of six to nine students, each selecting a Request for Proposal (RFP) from a list of several different ones. Note that every academic year, students choose from a list of new and different RFPs. Although a “self-forming” approach for team formation is preferred, composition of each team is carefully reviewed to ensure that the team has a good balance of members with synthesis as well as analysis aptitudes.

The course is architected to help teams learn the conceptual design (CD) process shown in Fig. 1. In the early part of the semester, individual assignments are given to lay the groundwork, and team assignments are given to stimulate teamwork. In addition, we hold classroom discussions every week, on topics of interest that are common to all teams, and targeted discussions with each team on topics that are specific to their project.

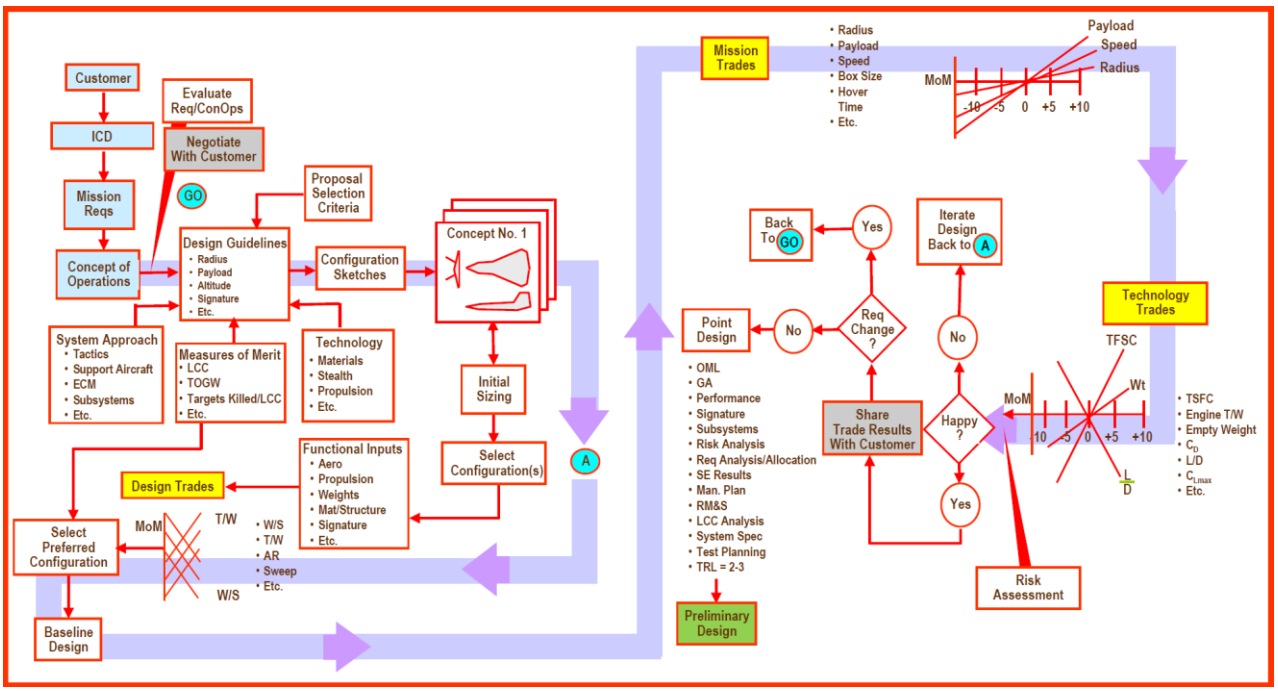


Figure 1 – The Conceptual Design process used by design teams

Student teams ‘learn by doing’ via application of the CD process to define several candidate concepts. The most promising three to four are selected by the midterm oral review. After the midterm review, the teams conduct further trade-off studies to select a single preferred system concept (PSC) or a baseline design by the end of the semester. Each team is required to give an oral presentation of their accomplishments and to submit a “Final Report” in a proposal format to document progress.

2.1.2 Air Vehicle Design--Second Course (AOE-4066, Spring Semester: Jan - May)

In the second course, student teams undertake a preliminary design effort aimed at further refining the preferred concept (selected in the first semester) through analyses and/or tests to validate assumptions and to add more detail. Targeted discussions are scheduled with each team on a weekly basis to assess progress or lack thereof. Each team gives a mid-term presentation and concludes their effort by submitting a final proposal, and giving a final presentation, at the end of the semester.

2.1.3 International Collaboration Imperative

Although there is no explicit requirement for international collaboration in the air vehicle design courses, VT has long recognized the need to provide our students with more opportunities to learn to succeed in the changing aerospace enterprise that has experienced increasing globalization over the past four decades. For example, Airbus is a multinational corporation that is based in France but has 16 sites in four countries, France, Germany, Spain, and the UK; subsidiaries in the United States, Japan and India; and a network of 7,700 suppliers worldwide. Across the Atlantic, the Boeing Corporation, based in the U.S., has substantial international contributions from Japan, Australia, Italy, Korea, France, Sweden, and India for its 777 and 787 production. Even the military aircraft development has become more globalized. For example, development of the F-35 Lightning II fighter is led by the Lockheed Martin Corporation in the U.S. but it involves multiple partners within the U.S. and abroad (Australia, Canada, Denmark, Italy, Netherlands, Norway, Turkey, the UK) with more than 200 suppliers and subcontractors across the globe. Two international final assembly and check-out plants are located in Italy and Japan.

It is imperative that the aerospace engineering graduates entering the globalized aerospace enterprise are more comfortable in working collaboratively with their counterparts throughout the world. This recognition motivated VT to initiate experiments in international collaborative student design projects in the mid-1990s with Kasetsart University in Thailand, with École des Mines de Nantes and ENSICA in France, and with Loughborough University (LU) in the UK. The programs lasted for nearly a dozen years. Interested readers can find more details about the findings and challenges in [5], [6] & [7]. HAW is no stranger either to international, multi-university collaborative student design efforts [8, 9]. In this paper, we highlight our joint experiences over the past 10 years following implementation of ‘Lesson Learned’ from the first two to three years of collaboration starting in 2013 [9].

One of the first changes that VT and HAW have jointly implemented is to facilitate each German student who is spending the fall semester at VT to join one of the teams formed by the VT students. (In many cases, HAW students continue collaboration remotely in the spring semester after they return home at the end of the fall semester.) All students on the joint team are treated exactly alike in terms of class policies, expectations and grading. This change addresses several challenges that were previously identified. It motivates all students to learn to work as a team in overcoming the challenges of language, culture, educational systems, etc., to make sure that everyone contributes to their full potential for the success of the project. It is quite evident to the instructors during the weekly meetings and oral reviews. More importantly, we reproduce a comment by the Chief Engineer of one of the projects about his team members from HAW: *"Working with the HAW students was an experience that prepared our team for the real-world in manners such as communication, deadline buffers, and work ethic/expectations. I cannot speak for other teams, but this partnership worked out extremely well and could benefit teams in the future. Thanks to you, Dr. Abulawi, and Dr. Artis, this partnership is a great success."*

2.2 HAW Hamburg: Aeronautical Engineering Design Team Project (IP)

At HAW Hamburg, the undergraduate curriculum contains a compulsory design class in the fourth semester (IP) which serves as the students’ practical introduction to methodical problem-solving, engineering design, and functional prototyping. The intended learning outcome of this class is:

- students work in small self-organized teams to develop and assess design solutions for real world engineering problems from the aviation industry,
- using approved methods for project and requirements management, creative problem solving, concept assessment, detailed design and functional prototyping, design review, presentation and documentation.

Before the start of each semester, a selection of five to eight new design challenges is defined together with experts from the local aviation industry who are challenge owners. The experts are experienced engineers, mostly from the cabin & cargo department of Airbus Operations in Hamburg or Bremen, but also from other local aviation companies like Lufthansa Technik and Diehl. Some challenges are wicked problems for which even industry experts have not yet found a commercially viable solution, e.g. how to load large cargo containers of type LD3 into aircraft cargo compartments which are not equipped with automatic cargo loading systems. Others are more straight-forward tasks like the design of a moveable class divider or a special-purpose catering trolley. Some tasks put more emphasis on technical and mechanical requirements while others may be more emotional like finding solutions for transporting passengers in their personal wheelchairs. Despite these differences, all challenges match the properties described in [10] which are:

- open ended, requiring multiple solution proposals and their systematic assessment,
- complex with conflicting requirements, requiring out of the box thinking to achieve innovation,
- referring to topics which have not been presented in previous classes, requiring self-directed learning of the students,
- broad enough in scope to require a team approach.

2.2.1 Organization of the Class (IP)

Since 2011, this class has been offered twice a year as an industry-partnered team project, spanning 17 to 18 weeks. Until now, almost a thousand students in 219 teams (76 of them international) have completed the class and worked on one of 139 different design tasks from the aviation industry. Fig. 2 shows a typical timeline of the class.

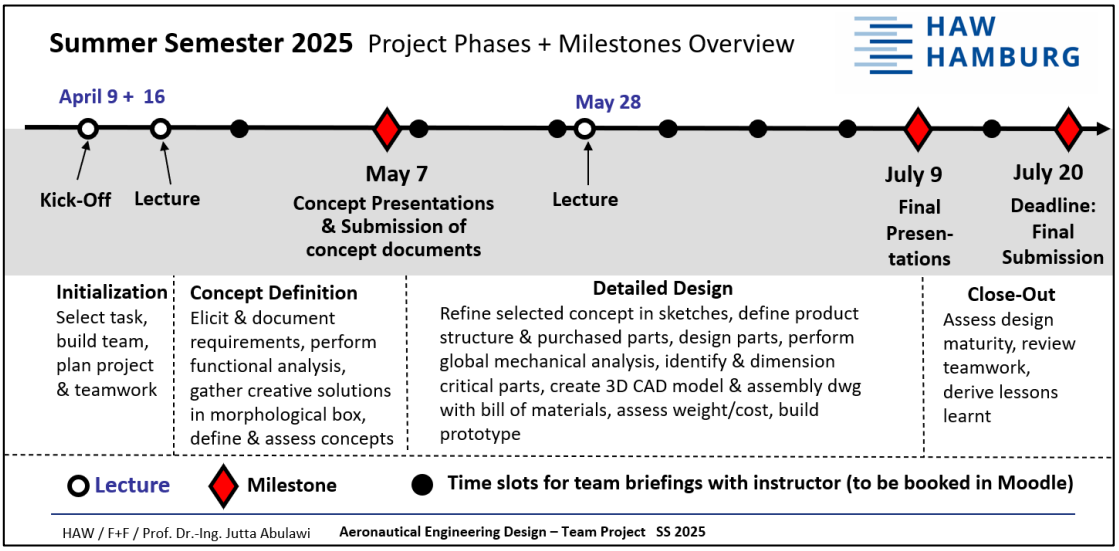


Figure 2 – Overview of typical timeline of the Aeronautical Engineering Design class

Most of the student activities in this class are self-directed learning, and there are only three lectures. The available design tasks are presented in the kick-off lecture, and every student is encouraged to select a preferred task as well as a second and third choice. Then they are asked to identify peers who want to work on the same task so that they can form a team. This procedure naturally requires some students to make compromises regarding the selection of their task and their teammates.

The kick-off lecture also introduces important aspects for the initialization and the concept definition stages like project management, team dynamics, roles in engineering teams, organization of team meetings, team decisions, communication and dealing with diversity. The second lecture explains strategies for engineering problem solving, methodical concept definition and assessment, as well as an introduction to ideation techniques. Students have three weeks to explore and understand the task and systematically define three creative concepts before the concept presentation. For this event, industry experts are invited to participate in person or online to discuss the concepts with the

students. For each team, the most promising concept is selected and refined in the detail design stage. The third lecture explains important activities and considerations for detail design and how they are interrelated, as indicated in Fig. 3.

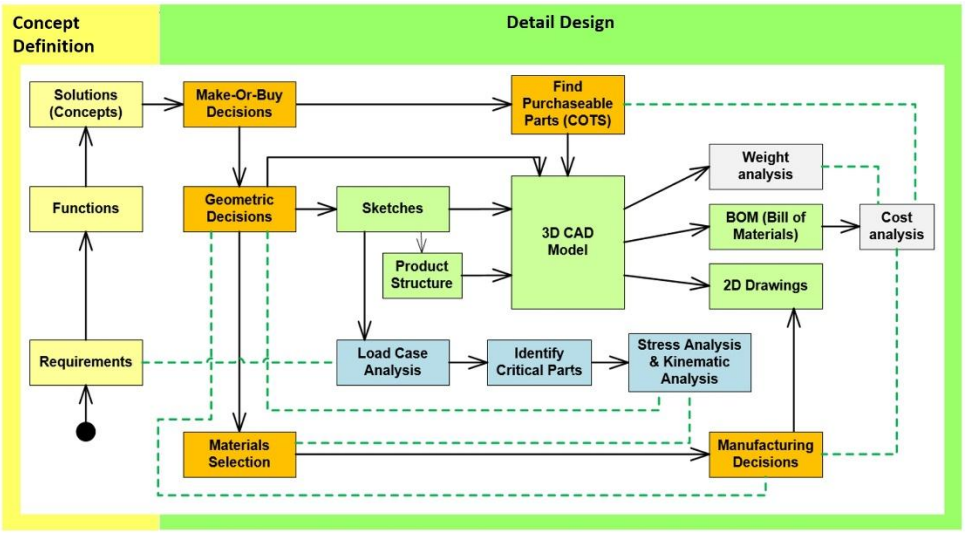


Figure 3 – Overview of typical steps in a mechanical design process

Self-study material is provided on the university's learning platform together with course-specific activities like group enrolment, making appointments for team briefings with the instructor and submitting assignments. Each team has three compulsory team briefings with the instructor: one in the concept stage and two in the detail design stage, to discuss design solutions and prototyping activities. In addition, teams are encouraged to contact and meet their industry experts to learn more about the problem to be solved, applicable design constraints and customer expectations. At the end of the semester, all teams present their final design proposals and functional prototypes which can be printed in the university's 3D space or made from any other mix of available materials and components. To conclude the semester, teams complete and submit their project documentation.

2.2.2 Student Reflections

In engineering design projects, students can be asked to write reflections because this can promote their critical thinking skills and their meta-cognition [11]. For this reason, every student is asked to write a reflection on personal learning achievements and teamwork experience, in addition to the team submission. The reflection is graded and counts 10% towards the grade of the class. To ensure that the reflections are assessable and meaningful, a guideline is provided with a collection of questions on the following aspects:

- Collaboration in the team,
- Individual role in the team/project,
- Improvement of basic engineering skills and project management,
- Methodical design (Concept Definition & Design Elaboration),
- Organization of the class.

In addition to the original motivation for requesting the reflections, they are very helpful to the lecturer when read before grading the team submission. Some reflections contain valuable information on problems students encountered during the project but did not speak about in the team briefings with the instructor. Other students make useful suggestions on how to improve the learning experience in the future. In case of team dysfunction, the reflections usually reveal if one or more team members were underperforming or letting the other team members down. Students are asked not to put blame on other team members in the reflection and not to include any names unless they want to acknowledge special contributions or support from their peers but in between the lines it becomes evident who caused the problems.

2.2.3 International collaboration in the class and team formation

Since 2015, the class is taught in English and open to international guest students in the Hamburg spring semester. In addition to the students from Virginia Tech who come to HAW Hamburg thanks to the strategic partnership, guest students typically come from non-European countries like Mexico, Malaysia, Vietnam, China as well as EU countries like France, Spain and Poland. As the number of guest students always exceeds the number of teams, students are requested to form international teams in the self-formation process. This is supported by several activities in the kick-off lecture to ensure that all students understand the tasks on offer and talk about their favorite task with other students who are also interested in that task. Ideally, students should first choose a task and then form a team with the other students who want to work on the same task. With the ideal team size being four or five students, and a maximum of two teams per task, compromises may be required either regarding the task selection or the team formation.

The reflections show that most teams manage surprisingly well with self-formation. Most students oppose teacher-led team formation because they do not want to be forced to collaborate with students they do not like. Self-formation can therefore increase the initial morale in the team if it allows students to pick friends as teammates. Consequently, the requirement to form international teams can irritate students who had planned to work together with the peers they already know. In most cases however, the combination of task selection and team formation works well, as the following citation from the personal reflection of a guest student from Poland shows: *"I think I was lucky when it came to my team members. It wasn't a complete coincidence though – during the break in the first lecture, I received a small suggestion to choose project number 5. Of course, some team members were people I didn't know before. […] This class was fun. In the end we came up with a very good idea and good further developments. What to do with it next? I don't know and I think nobody from our team knows what to do with this idea next. There is a saying "Fall love with problem not with solution" – I fell in love with both. Thank you for creating this opportunity for us. Now I am waiting for my grade I hope that it will be A+."*

However, team formation does not always work that well. In addition to clashing personalities, communication problems can cause a team to become dysfunctional. This happened once when two HAW Hamburg students with low proficiency in spoken English participated in the class and formed a team with a Polish student who was fluent in English and a Virginia Tech student who did not speak any foreign language. Despite several interventions, the students did not manage to develop a positive team spirit. They were professional enough to develop a design proposal and submit the required documents, but even in the final presentation, the tension among the team members was noticeable. The lack in tolerance and understanding is evident in the personal reflection submitted by the Virginia Tech student: "*It is unfortunate I don't have many positive things to say, but when the foundation of a successful team dynamic is compromised, it is hard to look past. But at the end of the day, I really can't hold anything against anyone though. I think the root cause of all of our problems is the language and culture barrier. Even when asked questions by the experts during our presentation, […] and […] had to talk to themselves in German to understand what was being said. Most of their work and communication was carried out in German which I do not understand*."

A few months after the student had returned to Virginia Tech, the author of this paper met him again and he confessed that it had taken him some time to digest the experience. In the end, he had understood that his attitude towards his teammates had been wrong. At the time of the meeting, he was participating in the first course of AOE-4065 and had again volunteered to lead the team. Having learned from the bad experience with his leadership style in the IP class in Hamburg, he had decided to adopt a more democratic leadership style and to be more patient with his teammates. Meanwhile, he and his teammates have accomplished the capstone design project in a highly functional team and graduated this spring. Fortunately, problems of this kind are very rare in the class, and this team has been an outlier in terms of dysfunctionality. In most cases students make the necessary effort to get into a good working mode with their peers and are prepared to overcome cultural differences and language barriers.

Other Virginia Tech students learned this lesson during their semester at Hamburg, as the following quote from the personal reflection shows: "*However, we sometimes had a bit of a language barrier or a lack of understanding between several people, which can sometimes lead to a lack of communication, but this is quite easily resolved by going back and rephrasing everyone's ideas*

several times and using images of technical objects to understand each other rather than a translation, which sometimes doesn't make much sense. This has taught me that communication is really the most important thing in a project from the moment that several people are working on it."

3. Organisational Challenges

3.1 Grading

Although Hussein found that the grading of project deliverables did not impact his students' motivation, he found a significant increase in the students' perception of their learning achievements when they were graded and concluded that this way the grading improved the students' commitment to their tasks within the project [12]. A qualitative survey of HAW Hamburg undergraduate students in 2009 also showed that students believed that they would learn more in graded projects than in ungraded ones.

International students participating in a graded team project during their semester abroad are not always able to transfer credits back to their home university. Very rarely will they participate in a design project without getting the credits. Some of the students know that they can transfer the credits back to their home institution but will not be able to transfer the grade back into their records. The fact that their assessment in the end just decides between pass or fail can reduce their willingness to work hard in a team project. In addition, whether students aim at high grades and perform accordingly depends on their personal situation and their cultural or social background. Some students are more concerned about their final grade point average (GPA) than others. Some believe that they only need the graduation certificate for job applications while others strive for high grades because they are on a scholarship or want to apply for one or because they want a job with a company which selects future employees based on their grades.

Both at HAW Hamburg and at Virginia Tech, the number of students participating in comparable team projects has been too small to perform a quantitative analysis as in [12]. However, qualitative interviews with undergraduate students from HAW Hamburg and international partner institutions revealed that their motivation does depend on the impact the team project grade has on their GPA. Unresolved differences in the motivation of students who are in the same team can be a potential root cause of conflicts within the team. Students are therefore strongly advised to openly discuss the grade expectations in their first team meeting of the IP class, and that they need to accept that guest students may also want to travel and explore Europe during their semester abroad.

Nevertheless, tensions within a team can arise from different performance levels within the team. High performing students can get frustrated or angry if contributions from other team members are of poor quality and need to be improved or reworked by them to secure the desired high grade. These emotions may get even worse if no improvement or rework occurs and the quality of the team submission is noticeably impaired. Team grades can then be considered very unfair [13].

For this reason, all teams in the IP class at HAW Hamburg are asked to submit a spreadsheet indicating the contribution of individual team members to the different subtasks of the project. However, teams may request a team grade by submitting a corresponding declaration which is signed by all team members. Despite the perceived unfairness of all team members receiving the same grade irrespective of their actual performance in the project, almost all teams request a team grade for the IP class. They do not consider it unfair because their collaboration is so intense that they find it very hard to declare each team member's contribution in a matrix. In rare cases when significantly different personal performance levels are obvious from observations of the team during the semester, individual grading is enforced by the lecturer irrespective of the students' request.

3.2 Academic calendars, curriculum alignment and credit transfer

Spending a whole semester abroad at a partner university or doing an internship in a foreign country are ideal for enriching the educational journey with global experience. Provided that students can participate in classes with team projects at the host university, this is the best way to experience international teamwork. The semester abroad requires a partnership agreement between the home university and the host university which is the case for HAW Hamburg and Virginia Tech. Alternatively, student exchange can be organized by university networks like Global Engineering Education Exchange (Global E3, https://www.iie.org/programs/global-e3/) or International Student

Exchange Program (ISEP, https://www.isepstudyabroad.org/).

In any case, studying a semester abroad requires a minimum alignment of the academic calendars and the curricula of the institutions involved. Fortunately, the mismatch of academic calendars of HAW Hamburg and Virginia Tech does not prevent student exchange: Hamburg students can spend the fall semester (August to December) at Virginia Tech, and Virginia Tech students can come to Hamburg in the spring semester (April to July).

When both institutions started to exchange students, the curriculum mismatch caused Virgina Tech students to lose a whole academic year. This problem was resolved by joint curriculum reforms. Course offerings are now better aligned, and electives were created to allow students to take courses which they would not be able to take at their home institution. As the Virginia Tech spring semester starts already in January, Virginia Tech students can attend crucial courses at their university until they travel to Hamburg at the end of March and continue their participation online until the spring semester ends in Blacksburg. They take proctored exams for these courses at HAW Hamburg. A remaining gap is closed with a special class “intro to thermodynamics” offered by HAW Hamburg to Virginia Tech students to make sure they can stay on track with their degree. All these efforts made it possible for Virgina Tech students to participate in the IP class at HAW Hamburg and transfer their grades and credits back into an elective.

To transfer AOE-4065 back to the Hamburg curriculum as a replacement of the Aircraft Design class, creative solutions are needed. As a whole AOE-4065, is recognized as equivalent to the HAW Hamburg Aircraft Design class. Two participation models are open to HAW Hamburg students:

- associate team membership for students who only participate in the first course of AOE-4065 and quit the team when they return to Germany,
- full team membership for students joining a team for the whole capstone design project until the final submission and presentation (participating in both AOE-4065 courses).

HAW Hamburg students can only participate in presence in the first course if they spend the fall semester at Virginia Tech. With AOE-4065 being a two-semester class, this means that full team membership always requires remote collaboration between Virginia Tech students and their HAW Hamburg team members at least in the spring semester. As remote collaboration has been common practice in the aeronautical industry for more than a decade, the decision was made to offer full team membership to HAW Hamburg students with two options:

- hybrid participation for students who spend the fall semester at Virginia Tech and continue remotely after returning to Germany,
- fully remote participation for students who cannot spend a semester at Virginia Tech but wants to participate in the capstone design project.

Only HAW Hamburg students who participate in person in the first course of AOE-4065 receive grade and credits from Virginia Tech and can transfer them back to HAW Hamburg if they become full team members or continue their work on the preliminary aircraft design in an individual project which is submitted to and graded by a HAW Hamburg professor. HAW Hamburg students who participate remotely as full team members get their grade and credits from HAW Hamburg for the project work.

3.3 Experiences with fully remote and partially-distributed collaboration

International teamwork is challenging, even if the team is fully collocated and face-to-face meetings are possible whenever needed. The challenges can grow when a team is fully distributed and meetings and interactions are only possible online. However, the most difficult setting is that of partially-distributed collaboration because there is a high likelihood of subgroup formation when part of the team is collocated and one or more team members are fully remote [14].

The experiences with joint capstone design teams consisting of Virginia Tech and HAW Hamburg students prove this. The first joint teams were partially-distributed with between two and four HAW Hamburg students being accepted as full team members with fully remote participation to join a team of up to eight Virginia Tech students to work on an RFP. Cultural differences, language barriers, time zone differences and different approaches to problem-solving and project management seemed

unsurmountable for the students who volunteered in these early experiments with virtual collaboration.

The worst experience occurred in the academic year of 2016/17, when ten Virginia Tech students and six Hamburg students were given the task of designing a package delivery drone together. As an additional challenge, two German team members left the project after the fall semester because they started industry internships, and two new team members joined the project. The students were encouraged to split the task into two subtasks with the Virginia Tech students working on the drone subsystems and the HAW Hamburg students designing the cargo hold including the package pick-up and release mechanism. In the initial phase of the project, the fully remote collaboration of the two subgroups seemed to work relatively well until the Thanksgiving break. From that point on transatlantic communication became very difficult because there was always one subgroup that was either on holiday or under exam stress. In the end communication ceased completely, and the Virginia Tech students decided to add a simple hook to their drone design to attach the package. Meanwhile the HAW Hamburg subgroup continued to work in isolation on a very sophisticated solution for safely housing the package during flight and tried to design a universal interface which would permit the attachment of their system to the drone.

The crisis culminated in both teams blaming the other for not communicating and not demonstrating any progress with the subtask. Finally, the situation was resolved by the German subgroup traveling to Blacksburg in April 2017, where both subgroups eventually met in person and all negative emotions were overcome. It was amazing to experience the transformation in the relation between the team members once they had met their fellow students in person and spent an afternoon together in the faculty building. With an enormous last-minute effort, they reunited their design efforts and presented a viable design solution to the jury in the final presentation after a very busy week.

Due to limited travel funds, the experience of a physical encounter could not be repeated in the following academic year. Nevertheless, a new joint team was formed in August 2017, with seven students from Virginia Tech and three students from HAW Hamburg. This time, the students were asked to work on the Undergraduate Team Aircraft Design Task proposed by AIAA and left to organize the distribution of work packages among themselves without interference from the two lecturers in charge of the project. Team collaboration and communication was made more difficult because one of the German students spent the winter semester in Glasgow as a study abroad experience, so the team was distributed in three countries. It was interesting to see that the German students were not at all impaired by their physical separation but found it extremely difficult to collaborate with their American teammates on the other side of the Atlantic.

A third setting was experimented with in the academic year 2018-19. This time, two HAW Hamburg students spent the winter semester at Virginia Tech and formed a team with seven Virginia Tech students and another German guest student from TU Dortmund. All ten students formed a collocated team with regular physical meetings, team briefings with the lecturer from Virginia Tech and regular skype briefings with the lecturer from HAW Hamburg. Again, they worked on an undergraduate design task proposed by AIAA. Despite this perfect start, collaboration came to a grinding halt when the German students returned to their home universities at Christmas. The planned virtual collaboration in the second course of AOE-4066 never reached a productive stage, with the seven Virginia Tech students left on their own trying to cope with the work initially planned for ten students.

Teamwork problems were smallest when HAW Hamburg students joined the Virginia Tech teams as associate team members. Two reasons can be found for this. First, this teamwork never involved remote collaboration, and the face-to-face meetings helped to bridge cultural and other differences. Secondly, the first course is accompanied by weekly lectures and assignments, so that the teamwork is much better guided. The fact that both the HAW Hamburg and the Virginia Tech students participated in presence in the lectures of the first course of AEO-4066 facilitated the formation of a positive team spirit considerably. Although Virginia Tech students knew that HAW Hamburg students would quit the team after the fall semester they never treated the associate team members like second class team members. Consequently, some HAW Hamburg students reversed their initial decision to quit the team after the first course and stayed in touch with their team remotely until the final presentation.

The most successful international team was formed by eight Virginia Tech students and two HAW

Hamburg students in the academic year 2019/20 with one HAW Hamburg student participating in hybrid mode and the other was a fully remote team member. Several factors may be responsible for this positive experience. First of all the two HAW Hamburg students were good friends, and to them it did not matter that only one could spend the fall semester in Blacksburg while the other had to continue his studies in Hamburg. The hybrid team member bridged the gap between the Virginia Tech students and the remote student. By the time the hybrid team member had to return to Germany, friendships were established and communication paths established, and trust and understanding was big enough to enable constructive collaboration of the partially distributed capstone design team. The RFP had requested the students to design a high capacity, short range, transport aircraft with a reference mission of 700nm, a design range of 3,500nm, and a capacity for 400 passengers in a dual class configuration [15]. The team profited considerably from the expertise of the HAW Hamburg students in passenger cabin design. This expertise gave them an important role in the project despite being separated from their peers by the Atlantic and the time zone. In addition, the Pandemic forced all students into remote collaboration, so no hybrid settings had to be juggled with. The team managed to submit an excellent report and was ranked 2nd in the AIAA Aircraft Design Competition [16].

3.4 Motivating students to participate in international team projects

Spending a whole semester abroad at a partner university or doing an internship in a foreign country are ideal for enriching the educational journey with global experience. However, only a very small fraction of the aeronautical engineering undergraduates from HAW Hamburg and Virginia Tech are interested in spending a semester abroad. Despite scholarship offerings and various campaigns to advertise study abroad opportunities, personal, financial and organizational barriers and other constraints seem insurmountable for most undergraduates. Consequently, the numbers of students participating in the bilateral exchange between Virginia Tech's Kevin T. Crofton Department of Aerospace and Ocean Engineering and the Faculty of Aeronautical and Automotive Systems of HAW Hamburg remain small. Since 2015, a total of 48 AOE students has come to Hamburg, and 31 Aeronautical engineering students from HAW Hamburg have studied at Virginia Tech. All students who participated in the exchange stated afterwards that they had profited a lot from the experience and managed to broaden their horizons and develop global engineering skills.

Many of the aspects which keep students from applying for a whole semester abroad do not apply for short-term study abroad programs, which is why they are usually preferred by students when they are offered. Their drawback is that they need much more organizational backup from the faculty. In general, a faculty member is expected to accompany the group which needs to be big enough to justify the program and the engagement of the faculty member. As the destination of the program is usually selected by a faculty member and not by the students, it may be difficult to find enough students who enroll for that program [17]. Only once in the last ten years (in April 2017), a small group of HAW Hamburg students (who were funded) travelled to Blacksburg to visit Virginia Tech for a week. So far, no short-term visits have been organized and offered for Virginia Tech AOE students. There are plans to organize a joint short-term study abroad program for students from both universities but financing it and finding a suitable time in the academic year are still unresolved issues. The future will show whether these plans can be realized.

Although the full remote participation in the AOE-4066 was offered to HAW Hamburg students at no cost and did not require any traveling, it was relatively difficult to find volunteers for these experiments with partially-distributed collaboration. Interviews with the students who participated remotely showed that all students profited from the experience because they improved their English communication skills and they acquired valuable competencies in project management and aircraft design. All HAW Hamburg students received adequate credits and good grades for their project contributions but after the problems with the teamwork in 2017, it was decided that at least one HAW Hamburg student should be a hybrid team member and participate in presence in the first course of AOE-4066. This student would then act as an embassador for remote team members from HAW Hamburg. After the successful experience with the international team in 2020, the effects of the pandemic caused HAW Hamburg undergraduate students who could not study abroad to focus on courses and projects offered at home, and the remote participation was discontinued. This is sad because the skills the students acquired are still highly needed in the aeronautical industry and in

related research because collaboration in these environments is highly international and relies on remote collaboration and digital communication.

4. Conclusion

The lessons to be learned from ten years of transatlantic student exchange and collaboration are that students definitely profit a lot when they participate in international team projects during their undergraduate studies. Aeronautical engineering design projects are ideal for internationalization because students can learn to collaborate in teams while working on their design solutions in similar settings as the associated industry.

At Virginia Tech, the capstone design project which is offered in course one and two of AOE-4066, made it possible to experiment with various forms of participation, ranging from associate team membership for HAW Hamburg students who studied a semester at Virginia Tech to full membership with hybrid or fully remote participation. In the end, the fully remote participation remained limited to several experiments with different tasks and team configurations and was discontinued because it was increasingly difficult to motivate HAW Hamburg students for this offer, and because the effort needed to coach the teams remained extremely high. The associate membership and the full membership in hybrid mode are still available in theory, and the future will show which of the two options are preferred by HAW Hamburg students who decide to spend a semester at Virginia Tech.

At HAW Hamburg, the internationalization@home within the IP class is much easier to achieve because there is a regular number of about 20 international students spending the summer semester in the Faculty of Aeronautical and Automotive Systems and the majority of them selects IP. Remote collaboration was only allowed in the Pandemic, and all students were very eager to switch back to collaborating in presence. The students profit a lot from the challenge-based learning with real-world design tasks being provided by experts from the aeronautical industry. The international team composition feels natural to the students and gives them a good opportunity to acquire global skills in addition to engineering competencies.

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