30th Congress of the International Council of the Aeronautical Sciences
DCC, Daejeon, Korea ; September 25-30, 2016

USING INTERNATIONAL COLLABORATIVE AIRCRAFT DESIGN PROJECTS TO ENHANCE UNDERGRADUATE EDUCATION: LESSONS LEARNED

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KEYWORDS: ***Aircraft Design, International Collaboration, Undergraduate Education***

Abstract

Virginia Tech in USA and HAW in Germany jointly embarked on a journey in the fall of 2013 with the goal of better preparing our students to succeed in the emerging marketplace created by the increasing globalization of the aerospace enterprise. To accomplish this goal, we needed to enhance the undergraduate educational environment by providing the students, on both sides of the Atlantic, an opportunity to learn about the associated challenges first hand while immersing themselves in the design discipline. The expectation was that the participating students would learn to (a) effectively communicate with people separated by time zones, languages, cultures and educational backgrounds, (b) leverage strengths of a diverse set of teammates, and (c) successfully complete the project by identifying and managing key risks. In this paper, the authors share lessons learned and insights gained based on three years of experience.

1 Introduction

Design education has been a constant part of the Virginia Tech (VT) curriculum since 1941 when the Aeronautical Engineering department was formed 75 years ago [1]. Aircraft design has been a required course for earning a bachelor's degree in aerospace engineering at VT ever since. At the Hochschule für Angewandte Wissenschaften (HAW), Hamburg, known as Hamburg University of Applied Sciences in the English-speaking world, the Aeronautical Engineering degree programmes also have a strong focus on aircraft design along with lightweight structures, cabin architecture and cabin systems [2]. Close cooperation with local industry and the immediate vicinity of the Airbus assembly site guarantee practice-oriented degree programmes with excellent career possibilities.

This emphasis on design at both VT and HAW is a direct reflection of our strong agreement with Prof. Theodore von Kármán's simple yet insightful observation [3]:

> *An engineer is not a scientist. In addition to basic technical knowledge he must have the creative capacity to design new hardware.*

When students earn an engineering degree, they must have a thorough understanding and appreciation of the discipline of design. Therefore, both institutions are committed to providing an educational environment that is best suited for students to learn the fundamentals of design, innovation, and collaboration, so that they can be successful in their engineering careers.

In the remainder of this paper, the authors first highlight the nature and scope of undergraduate design education at Virginia Tech and HAW, and the rationale for undertaking international collaborative design projects in Section 2. Experiences to date are summarized in Section 3, and lessons learned from this worthwhile undertaking are presented in Section 4. A few concluding remarks in Section 5 complete the paper.

2 Undergraduate Design Curriculum

The design curricula of the two universities are not identical for undergraduate (Bachelor of Science or Bachelor of Engineering) degrees. However, there are many common aspects.

Both offer students opportunities to work as a team on a project to apply what they have learned in earlier classes, and to go beyond what they had in class to find additional information pertinent to their project. Students thereby acquire and demonstrate the ability to focus on an identified need; create solution concepts; analyze and evaluate those concepts; choose from among them; develop the chosen design to a level appropriate for the resources available; and then deliver a system that meets the need, is ethical, and is affordable. Students move from *"one problem–one answer"* to *"one need–many answers"* paradigm.

A brief summary of the courses offered by each university is presented in the next two sections.

2.1 HAW Aircraft Design

The Department of Automotive and Aeronautical Engineering at HAW Hamburg, Germany, offers two courses relevant for the present discussion. Key objectives of each course are highlighted in the following subsections. Further information about the content of the classes can be found in the *module handbook* in Ref. 2.

2.1.1 Aircraft Design Course

The key objectives of this course are to help students

(i) learn about aircraft design parameters and their fundamental relationships,
(ii) develop an ability to design an aircraft,
(iii) work in specialized areas in aircraft design using various sources of information, and
(iv) develop ability to structure design activities systematically and efficiently.

Students must actively participate in group work and laboratory.

2.1.2 Aeronautical Engineering Design – Team Project

In this course, teams of 3 to 5 students are formed and tasked to conceive and elaborate a mechanical design solution for an aeronautical engineering design task. They learn to use a methodical approach to identify requirements, and define and evaluate creative concepts. Students apply knowledge of engineering mechanics, materials science, and computer-aided design (CAD) to develop a detailed design solution. Their performance is evaluated based on presentations and discussions of the final solution, and documentation of the whole project in a team portfolio.

This course offers opportunities for students to work in international teams. In the summer terms, it is taught in English, so that exchange students from other countries can participate. In the last two summer terms, all teams had mixed nationalities.

Additionally, students can choose to accomplish their capstone project in aninternational team project. For example, in 2012, three HAW students chose to work on two collaborative aircraft design projects with the University of Sydney.

2.2 Virginia Tech Aircraft Design

The Department of Aerospace and Ocean Engineering (AOE) at VT requires students to take a two-semester aircraft design course sequence in the last academic year of the undergraduate curriculum for a B.S. degree in aerospace engineering. (Students may opt for spacecraft design or ship design instead to suit their preference for a degree in aerospace or ocean engineering.)

2.2.1 Aircraft Design—1st Course (Fall Semester: Aug - Dec)

The course starts with teams of six to nine students, each selecting a Request for Proposal (RFP) for their design project from a list of five to six different ones. Although a "self-forming" approach is the preferred mode of team formation, each team is scrutinized to ensure that the team has a good balance of students with aptitude in synthesis and analysis.

The teams are expected to use a conceptual design process shown in Fig. 1. The first author obtained this figure from Dr. L.M. Nicolai, the well-known author of Reference 4 which VT uses as a text book. The teams use this process

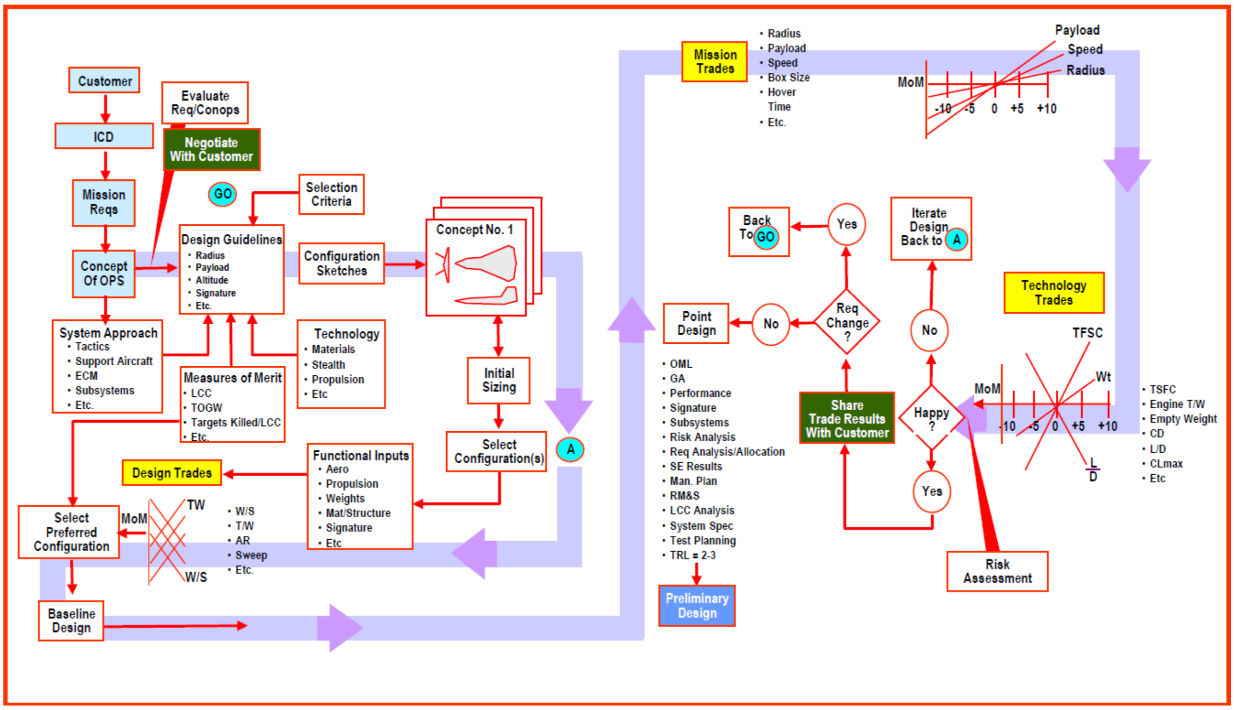

Fig. 1. The Conceptual Design process used by design teams (courtesy of Dr. L.M. Nicolai)

to define several candidate concepts, down-select at least three concepts by the midterm oral review.

After the midterm review, the teams conduct further trade-off studies to select one preferred concept by the end-of-semester oral review. Each team is also required to submit a "Final Report" in a proposal format to document progress.

In the early part of the semester, individual assignments are given to lay the groundwork, and team assignments are given to stimulate teamwork. We also hold classroom discussions common to all teams, and targeted discussions with each team on a weekly basis.

2.2.2 Aircraft Design--Second Course (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.

Note that every academic year, new student teams work on new and different set of RFPs. Also, there is no explicit requirement for international collaboration.

2.3 Need for International Collaboration

With increasing globalization of the aerospace enterprise, future belongs to those who can succeed in an increasingly globalized world. To prepare the next generation of aerospace engineers to succeed in this environment, we need to provide our students more opportunities to learn a great deal about the associated challenges first hand.

Over the past three decades, the world has seen a phenomenal increase in globalization in all human endeavours, and the pace is likely to accelerate in the years to come. In the area of world economics, a tremendous growth in the number and size of multinational corporations doing business in multiple countries is a direct consequence of globalization.

The aircraft industry is not immune from the globalization trend. For example, Airbus is a multinational corporation based in France with 16 sites in four countries: France, Germany, Spain, and the UK. It has subsidiaries in the United States, Japan and India, and a network of

7,700 suppliers worldwide. Airbus employs nearly 74,000 people worldwide, and is recognized for building world's largest passenger aircraft, the A380. Across the Atlantic, the Boeing Corporation in the U.S. has substantial international contributions from Japan (Mitsubishi, Kawasaki, Fuji) and Australia (Hawker de Havilland and Aerospace Technologies) for the 777 production program [5]. Boeing significantly expanded international participation for the 787 development [6,7]. Subcontractors include Japan (Mitsubishi, Kawasaski), Italy (Alenia); Korea (KAI, Korean Air), France (Latécoère, Labinal); Sweden (Saab AB); India (HCL Enterprise, TAL), and UK/France (Messier-Bugatti-Dowty), each with substantial design and development responsibilities.

Even the military aircraft development has become more globalized. For example, Korea (KAI) is developing the T-50 Golden Eagle family of supersonic trainers in partnership with the United States (LM) and an international supplier network [8]. The design and development of the F-35 Lightning II fighter being led by the Lockheed Martin Corporation in the U.S. employs a new paradigm for developing future military air vehicles [9]. It involves multiple industry partners, namely, Northrop Grumman, BAE Systems, Pratt & Whitney, and Rolls Royce. More importantly, there are eight international partners (Australia, Canada, Denmark, Italy, Netherlands, Norway, Turkey, the UK) and more than 200 suppliers and subcontractors across the globe. Two international final assembly and check out plants are located in Italy and Japan.

3 International Collaborative Student Design Projects

The discussion in Section 2.3 makes it an 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. For reasons outlined in Reference 9, experiments were terminated with Thailand and France after about two years, but collaboration with LU continued for nearly 10 years ending after academic year 2007-08 with the change of personnel at both VT and LU. Interested readers can learn more about the findings and challenges in References 10-12. The VT-LU collaboration was revived in 2014 after a long hiatus, but is not covered in this paper.

HAW, Germany, also has recent experience with international, multi-university collaboration. As described in Reference 13, the HAW students collaborated with those in the University of Sydney in Australia, and Université Libre de Bruxelles in Belgium. At the conclusion of that collaboration, HAW proposed collaboration with VT in April 2013. VT offered an enthusiastically positive response

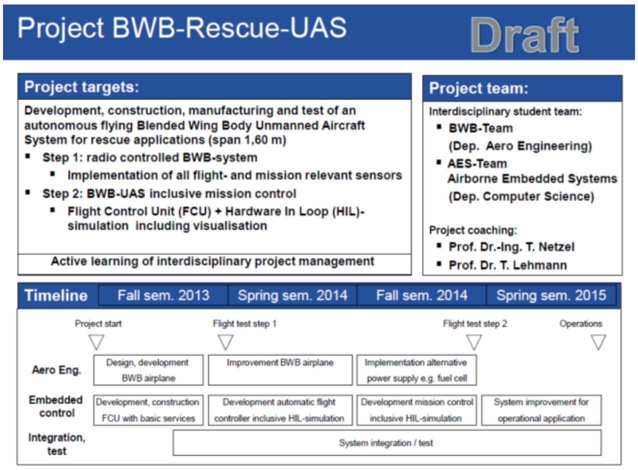

Fig. 2. Initial draft of a student project proposed by HAW

to initiate an experiment for the academic year 2013-14. Figure 2 shows the initial draft of the project entitled: BWB-Rescue-UAS with fixed span of 1.6 meters.

At VT's request, HAW graciously dropped the specification that the configuration be a blended wing body (BWB) even though HAW had a long-standing history of designing, building and flight testing BWB configurations. VT wanted the student teams to create the "best" configuration rather than specifying a configuration up front.

3.1 Academic Year 2013-14

Two teams of students selected the final revised RFP for a search and rescue UAV released by HAW that is shown in Figure 3. The first team had a total of nine students, five from VT and four from HAW. The second team had six students, four from VT and two from HAW.

System Specifications	Search and Rescue UAV
General	• Radio Controlled (RC) Remotely Piloted Vehicle • Transition from/to autonomous flight based on pilot decision and automatic safety analysis • Autonomous flight using GPS (including waypoint navigation based on mission control) • Implementation of all necessary sensors for autonomous flight • Integration of Emergency Landing Unit (ELU) • Transportable as modules in passenger cars
Take-off and Landing	• ≤ 100 m ground roll (at sea level standard day conditions)
Payload	• Total ≤ 3 kg • Camera system for rescue situation detection and evaluation
Speed, altitude, endurance	• Cruise speed ≤ 40 m/s • Max. altitude 1000 m • Flying time 15 min (60 min with fuel cells) in cruise
Other	• "Design to cost" for rapid manufacturing • Flight Control System (FCS) with basic services (RC flight, sensor data acquisition) in step 1 and full services (basic + automatic flight and mission control) in step 2 • Hardware-in-the-Loop (HIL) simulation to validate FCS and for system integration

Fig. 3. System specifications of a search and rescue UAV as proposed by HAW

The participating students and their responsibilities are shown in Table 1 for Team 1. The students in Team 2 and their roles & responsibilities are shown in Table 2. Both teams attempted to leverage the strengths of all participants in assigning individual responsibilities. Note also that two HAW students supported both teams. Their primary responsibility was CATIA support for Team 2, and they lent their knowledge of system integration and subsystems to Team 1.

Table 1. 2013-14 VT-HAW Team 1 participants and their responsibilities

Team Member	University	Responsibilities
James Bizjak	VT	Structures, Materials
Ingo Goldstein	HAW	System Integration, Camera System, External Lights
Bryan Jackson	VT	Aerodynamics, Stability Analysis
Robert Keller	HAW	Systems Integration, ELS, Power Supply, Air Data
Benjamin Krützberg	HAW	Manufacturing, Flight Controls
Sean Lynch	VT	Propulsion, Vehicle Performance
Sebastian Mellert	HAW	System Integration, Fuselage
Chris van Oss	VT	Stability analysis, Weight, Cost
Stephen Young	VT	Component Implementation, Logistics

Table 2. 2013-14 VT-HAW Team 2 participants and their responsibilities

Team Member	University	Responsibilities
Eric Santure	VT	Team Lead, Structures, Materials
Ingo Goldstein	HAW	CATIA support
Andrew Dean	VT	Propulsion
Robert Keller	HAW	CATIA support
Peter Gunderson	VT	Aerodynamics, Stability
Dylan Shean	VT	Performance, Controls

Fig. 4. 2013-14 Team 1 final design of a search and rescue UAV to meet RFP needs

The final designs of both teams are shown in Figures 4 and 5. Details of the design decisions are documented in their final reports. (Interested readers can contact the first author for a copy of the reports.) However, three observations are worthy of note. First, there was no better way for the students to learn the "*one need-many answers*" paradigm than to see it first hand in the products of the two teams. Second, the two designs were quite different in terms of propeller location, tail configuration, landing-gear configuration, etc. Third, neither of the teams selected BWB as their preferred concept.

Fig. 5. 2013-14 Team 2 final design of a search and rescue UAV to meet RFP needs

Based on an assessment of the maturity of the two designs, HAW decided that the designs were not mature enough to warrant proceeding with fabrication and flight testing which was their initial intent. VT and HAW jointly agreed to give another group of students a chance to tackle the same design challenge the following year.

3.2 Academic Year 2014-15

As mentioned in Section 3.1, the 2013-14 project was repeated in the 2014-15 academic year. Based on the feedback of the previous year's teams, a more formal RFP was created for an "*Affordable, Rapid Response UAV for Situational Assessment*." Although the performance specifications remained unchanged, the RFP provided some more details on background, project objectives, proposal requirements, basis of judging, and a list of deliverables. Figure A.1 in Appendix A shows the general layout of this RFP.

Once again, two teams of students selected the RFP. The first team, Team 1, had a total of nine students, all nine from VT and none from HAW. This undesirable situation was certainly not by intent but a result of less than effective team leadership. The team organization with individual responsibilities is shown in Figure 6.

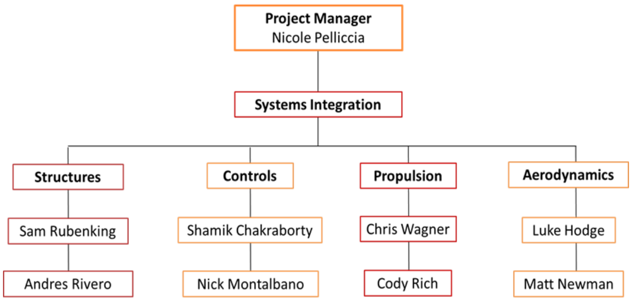

Fig. 6. 2014-15 VT-HAW Team 1 organization chart

The second team, Team 2, had 11 students, seven from VT and four from HAW. The team organization with individual roles & responsibilities is shown in Figure 7. The increased number of VT students offered a clear evidence of the importance they attached to the experience of international collaboration.

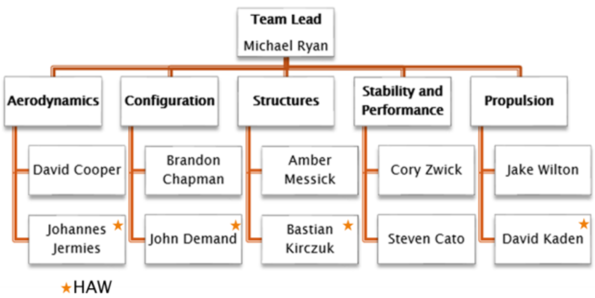

Fig. 7. 2014-15 VT-HAW Team 2 organization chart

The final design of Team 1 is shown in Figure 8, and that of Team 2 in Figure 9. Details of the design decisions are documented in each team's final report and not discussed here. (Interested readers can contact the first author

Fig. 8. 2014-15 Team 1 final design of an affordable, rapid response UAV to meet RFP requirements

for a copy of the reports.) However, a couple of observations are worthy of note. First, the experience clearly reinforced the crucial importance of leadership in successful execution of an international collaborative design project. Second, the decisions made by the two design teams led to configurations that appear to be quite similar except in the type of landing gear. However, many differences are found when the reports are closely examined. The most important one being the choice of electric propulsion by Team 1 and standard internal combustion engine by Team 2.

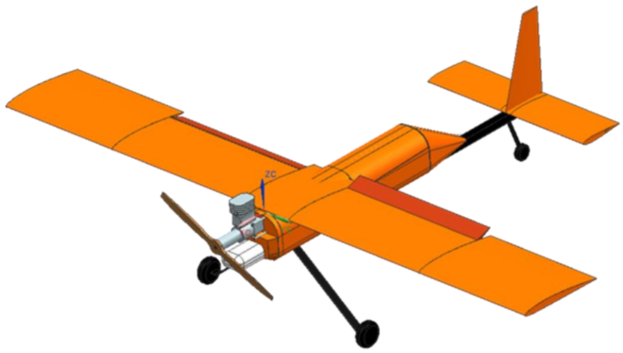

Fig. 9. 2014-15 Team 2 final design of an affordable, rapid response UAV to meet RFP requirements

Once again, the maturity levels of the designs were not much better than what the previous year's teams achieved. The most likely cause is the course construct which did not allow sufficient time for more comprehensive risk reduction through extensive analyses and tests.

During the 2014-15 academic year, there were personnel changes at HAW. Also, the organizational construct of the collaborative projects was not best suited for creating mature designs in one academic year that could be transitioned to manufacturing and flight testing.

After extensive discussions when the second author visited VT in May 2015, it was jointly decided to continue the collaborative experiment but the objective should not include transition to manufacturing and flight testing.

3.3 Academic Year 2015-16

The approach to the 2015-16 collaborative design project was different from the preceding two years as mentioned in Section 3.2. A new project was defined based on the 2007-2008 AIAA Undergraduate Team Aircraft Design Competition, and a RFP was released at the start of the academic year for *Agricultural Unmanned Aerial System (AUAS)*. The RFP included details on background, project objectives, proposal requirements, basis of judging, and a list of deliverables as shown in Figure A.2 in Appendix A.

Only one team selected the AUAS RFP for its design project. The team had a total of eight students in the first semester, seven of them from VT and one from HAW who spent the fall semester at VT as an exchange student. The team organization at the end of the second semester, along with individual responsibilities, is shown in Figure 10.

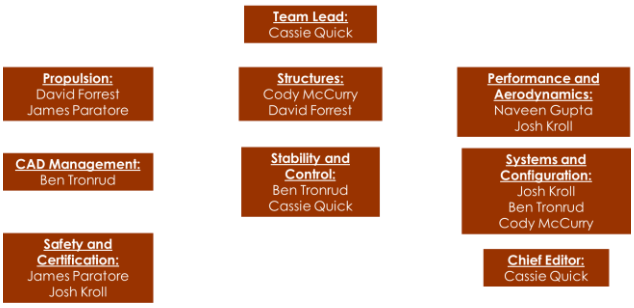

Fig. 10. 2015-16 VT-HAW Team organization chart

Initially there were four HAW students who were interested in participating. But three of them left the project at an early stage. The main reasons for this disappointing outcome are presented by Sibbert [14] based on a study performed under the advisement of the second author. There were many contributing factors but the problems were not due to cultural differences but rather organizational, i.e., different curricula, different start and end dates of terms and associated projects, and a new initiative at HAW for participation in a flying competition in partnership with European companies like Airbus which attracted quite a large number of students.

The final design of the team is shown in Figure 11. Details of the design decisions and technical approach are documented in the team's final report. (Interested readers can contact the first author for a copy of the reports.)

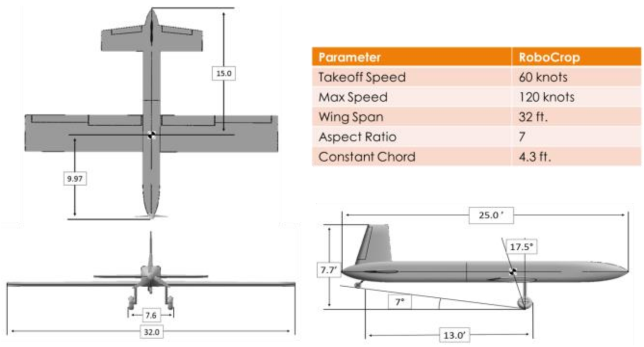

Fig. 11. 2015-16 design team final design of an AUAS to meet RFP requirements

4 Lessons Learned

Many lessons have been learned over the three years that HAW and VT have experimented with international collaborative design projects for student teams. Four key lessons are highlighted in this section.

1) *International collaborative projects are valuable in educating future engineers for globalized marketplace*. In general, all participants, students and faculty alike, agree that such projects are conducive to learning to adapt to differences in time zones, culture, language, personalities, and educational experiences of the team members. But diversity of the participants is an asset.

2) *Curriculum differences present a unique set of challenges*. A team aircraft design project is a mandatory requirement for VT students, and they are encouraged to consider the HAW-VT collaborative design project. However, participation is voluntary for the HAW students. Since the start and end dates of the academic years are different for VT and HAW, students on both sides need to make adjustments to synchronize their work

plans. This has contributed to a perception on the part of the HAW students that work load of the HAW-VT collaborative project is too high compared with other capstone project tasks. Therefore, it has become increasingly difficult to recruit and retain an adequate number of HAW students for the team. The challenge for faculty advisors is to develop a value proposition for the students that convinces them to pursue participation in international collaborative projects.

3) *Leadership of a diverse international team can be quite challenging if done correctly.* In a design class, the faculty are typically faced with the task of guiding teams in selecting a leader when little is known about the leadership abilities of the individuals. The biggest risk is that the selected leaders might not have the requisite soft skills to persuade the team members, both at VT and in Germany (or some other foreign land), to align their personal goals with those of the project, and remain focused on the success of the project. This requires effective skills in communication, conflict resolution, and persuasion. The team leaders need to be able to anticipate possible conflicts. They must have excellent organizational abilities, and be able to motivate the team members.

What makes it particularly challenging is that most young student team leaders do not have a great deal of personal or professional experience to develop an "intuitive feel" to address and effectively resolve issues common to all team environments. Faculty members can help the leaders develop such skills but the student leaders need to realize that they need help and should ask for it. It can be quite time consuming but the time is well worth the reward of helping students realize their hidden potential. A lack of leadership abilities isn't always apparent to the faculty advisors unless brought to their attention early by the team. Some of the early slips in leadership are attributed to the fact the leader is not experienced and still learning. Sometimes it's much too late to take appropriate corrective actions.

4) *Communication is the **most critical** element for success.* Effective communication, both verbal and in writing, is absolutely essential. Effective implies that all recipients understand the meaning of a message in exactly the same way as the sender intended. Delays and misunderstandings typically degrade the effectiveness of inter-personal communications, and the challenge is further exacerbated by differences of culture and language. Students located in the US and Germany are unable to have informal meetings for building trusting relationships since all meetings are formally scheduled. However, modern videoteleconferencing (VTC) tools, such as Skype or WebEx, provide a much better environment for "virtual" interaction that is conducive to collaboration than e-mails or file sharing or telephones of the past.

Table 3 summarizes the recommendations for future collaborative projects based on the analysis and findings of Reference 13. These are equally applicable for all projects whether or not there is any international participation.

Table 3. Design project do's and don'ts

- ***Clearly define the level of technical effort and allocated time for each task***
  - Don't get bogged down in too much detail
- ***Prepare well for team VTCs***
  - Intense focus is required on addressing the right technical issues to make good team decisions
  - Don't waste valuable time in less-than-important aspects
- ***Speak the same "language"***
  - Even though English is used as a common language of interaction, it is important for the team members to use the same technical language to minimize the chances of misunderstandings.
- ***Accurately define deliverables***
  - Clearly define up front what each team member is expected to deliver. Accurate definition of the objective and scope of a task goes a long way towards improving productivity.

5 Concluding Remarks

For three academic years starting in the fall of 2013, Virginia Tech in the US and HAW in Germany have undertaken collaborative aircraft design projects for undergraduate students. This experiment has provided an excellent opportunity for all participating students, on both sides of the Atlantic, to learn a great deal about the challenges associated with functioning in a globalized aerospace enterprise. The challenges include learning to (a) effectively communicate with people separated by time zones, languages, cultures and educational backgrounds, (b) leverage strengths of a diverse set of teammates, and (c) successfully complete the project by identifying and managing key risks.

In this paper, the authors shared (i) the rationale of incorporating international collaborative design projects into the aircraft design course in the undergraduate curriculum, and (ii) the lessons learned from this worthwhile undertaking. Due to the tremendous potential benefits for the students, both institutions will continue to explore options for successfully tackling the challenges that were faced in the last three years.

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Acknowledgment

The authors would like to acknowledge all students involved in the HAW-VT international collaborative design projects for three academic years starting in August 2013. Special thanks go to Prof. Thomas Netzel of HAW, Germany, for taking the initiative to start this effort, and to Ms. Ingrid Weatherall there for facilitating it. The authors would also like to thank their current employers for their support of this worthwhile exercise.

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Appendix A

Figure A.1 shows the 2014-2015 design project RFP, and Figure A.2 the 2015-2016 RFP.

2014-2015 HAW-VT Undergraduate Team Aircraft Design

Affordable, Rapid Response UAV for Situational Assessment

REQUEST FOR PROPOSAL

I. Opportunity Description

Unmanned Aerial Systems are particularly well suited for (i) assessing the nature of damage in areas struck by natural disasters such as the earthquakes, floods, fires, etc., (ii) evaluating the scope of automobile accidents on roads and highways, or (iii) assisting in the search of missing persons in isolated areas that are difficult to access by normal means. There is a need for an affordable, rapid response aircraft system that can be used by law-enforcement authorities, non-governmental organizations, and others in both developed and under-developed countries worldwide.

II. Project Objective

This Request for Proposal (RFP) provides the requirements for an ur is practical, affordable, and easy to operate. The aircraft and the sup be easy to reconfigure to be transported anywhere. Figure 1 sl capabilities.

III. Proposal Requirements

The quality and responsiveness of the technical proposal are the winning a contract. The proposal should be comprehensive, concise and

1. Demonstrate a thorough understanding of the RFP requirements.
2. Describe the proposed technical approaches that satisfy each of th complete description of the technical approach are critically impor
3. Particular emphasis should be placed on descriptions, sketches, d and discussions of novel techniques to permit engineering evaluati
4. Must include tradeoff studies performed to arrive at the final desig
5. Provide a brief description of design tools used to develop the desig

IV. Basis for Judging

1. *Technical Content (35 points)*
   This concerns the correctness of theory, validity of reasoning use and grasp of the subject, etc. Are all major factors considered evaluation of these factors presented?
2. *Organization and Presentation (20 points)*
   The description of the design as an instrument of communicat judging. Organization of written design, clarity, and inclusion o major factors.
3. *Originality (20 points)*
   The design proposal should avoid standard textbook information, and should show the independence of thinking or a fresh approach to the project. Does the method and treatment of the problem show imagination? Does the method show an adaptation or creation of automated design tools?
4. *Practical Application and Feasibility (25 points)*
   The proposal should present conclusions or recommendations that are feasible and practical, and not merely lead the evaluators into further difficult or insolvable problems.

V. Deliverables

The technical proposal must convincingly demonstrate that the design team can provide a superior and cost effective solution to the need identified by this RFP. The proposal should satisfy the following tasks to show how the team would develop the design of a new aircraft.

1. Describe the initial set of vehicle concepts your team evaluated
2. Explain the process used for evaluating each concept's effectiveness in delivering the required capabilities and justify your team's selection of the preferred concept.

mize the final selected design nd takeoff & landing distance, s.

nent.
ig airframe structure and state

uise configuration, the takeoff

id center of gravity travel.
ility for all flight conditions.
its to the design. Address risk ig potential cost increases or

ying configuration, launched

esign features that allow for how the undercarriage meets of gravity.
describe the cargo handling

with zero payload and with

a control system.
e proposed system.
on runs of 50, 100, and 500 air

Figure 1. Required System Capabilities

Able to operate on short landing areas	• Takeoff and Land in ≤ 100 m ground roll (at sea level standard day conditions) • Must include an Emergency Landing Unit
Autonomous Flight during day or night	• Capable of autonomous flight using GPS (including waypoint navigation and in flight waypoint, speed and altitude changes) • Terminal area operations (taxi, warm-up, takeoff, landing, climb & descent) can be autonomous but the option for pilot-in-the-loop control via a ground station must be available • Ground station equipment necessary for autonomous control, handoff and manual control must weigh ≤ 25 kg and be backpack transportable by a person • You are not required to design a mission control system (air vehicle avionics, ground station, antennas, computer equipment) for the vehicle. All equipment should be acquired—off the shelf. The air vehicle must allocate weight and volume for the selected on-board avionics.
Payload Carriage	• Appropriate camera system for video surveillance with images suitable for situation assessment; at least 3 kg payload
Speed and Altitude	• Cruise Speed ≥ 40 m/s, true airspeed • Max. altitude ≤ 1000 m
Mission Performance	• Endurance: Min 15 minutes, Max 60 minutes.
Affordable & Supportable	• Off the shelf components, especially engines and mission control system, can be used to reduce overall development and acquisition cost • The air vehicle must allow for ease of assembly, operation, repair, maintenance, and support in the field
Transportable	• In a shipping configuration, the entire vehicle must fit completely within the cargo compartment of compact automobiles, and be easy to assemble to a flying configuration

Fig. A.1. 2014-15 HAW-VT collaborative aircraft design RFP—more formal and detailed

2015-2016 HAW-VT Undergraduate Team Aircraft Design

Agricultural Unmanned Aerial System (AUAS)

REQUEST FOR PROPOSAL

I. Opportunity Description

There is a need for an affordable agricultural aircraft that can serve the needs of under-developed nations worldwide. Most existing agricultural aircraft r expensive initial investments that many times are out of reach from the community in many parts of the world. The specific needs of the agricultural both liquid and solid particles must be periodically applied to many crops and fi cane for the production of biofuels that can be used to power internal combusti

II. Project Objective

This Request for Proposal (RFP) provides the requirements for an agricultu system (AUAS) that is practical, affordable, and easy to operate. The AUAS a ground station that can be easily reconfigured to be transported anywhere. Th crop duster, but a truly rugged, low cost, easy to fly aircraft that will serve t around the world, operating as a complete, yet simple system that reaches all areas, greatly contributing to the needs of societies everywhere.

III. Proposal Requirements

The quality and responsiveness of the technical proposal are the most importa a contract. The proposal should be comprehensive, concise and clear.

1. Demonstrate a thorough understanding of the RFP requirements.
2. Describe the proposed technical approaches that satisfy each of the requ complete description of the technical approach are critically important.
3. Particular emphasis should be placed on descriptions, sketches, drawing and discussions of novel techniques to permit engineering evaluation of
4. Must include tradeoff studies performed to arrive at the final design.
5. Provide a brief description of design tools used to develop the design.

III.1 Design Requirements and Constraints

- The vehicle must be a fixed wing, unmanned aircraft.
- The expendable payload consists of 100 liters of liquid chemical (weight 2 or 300 lbs. of solid particles (for example seeds or fertilizer with 70 lbs./ft^3
- There should be provisions for the most expeditious loading of the hopper in the field.
- Fuel reserves for 20 minutes of flight.
- Operating altitude: 20 feet above the ground.
- Determine the best operating speed for the mission. The payload may be to assure complete coverage of the field of interest.
- Clean stall speed: operating speed/1.3.
- Maximum landing and takeoff distance: 750 feet within a 50 f improvised airstrip.
- Cruise altitude for short ferry flights of 1 to 2 miles with no payloa level.
- No range credit should be allotted for the climbs and descents.
- The aircraft, the ground station, and all other necessary supporting eq in and/or towed by a standard pick-up truck.
- Easy operation, repair, maintenance, and support in the field.
- Based on technology available today, you must choose the best propu the vehicle.
- The equipment used on board for agricultural applications (pumps, h solid can be considered to be contained within a sphere of 1 ft. radius booms on each side of the aircraft will be used for spraying.
- Low acquisition cost, low operating and maintenance cost, low initia
- The aircraft must be safe enough to protect people and property on th harm in case of failure of any of its systems during flight.
- The design must account for future growth for more capable version longer and deliver more payload.
- The baseline design will be used at sea level (standard day conditions versions, will be used at higher altitudes.
- The vehicle should use as many commercially available, "off th standard parts as possible including a powerplant that is in produc today.
- You are not required to design a mission control system for the veh acquired "off the shelf". The vehicle will be controlled by a qualif who should be aware of the extent of the spray area and any obstacle

III.2 Required Mission Performance

1. Warm-up and taxi at idle power for 5 minutes.
2. Takeoff.
3. Climb to 50 feet above ground level (AGL).
4. Align with the chosen field and descend to 20 feet AGL.
5. Spray a rectangular area of 0.5 miles x 1000 feet with the available c as many passes and turns over the field as necessary to cover the enti the cruise portion of the mission, although it also includes many turn
6. Climb back to 50 feet.
7. Align with landing area and descend.
8. Land, taxi and shutdown.

The landing site can be either on the other side of the field for later retr same location where the aircraft took off from, in that case the mission wi fly at 50 ft. AGL back to the original takeoff location. You have the choi

IV. Basis for Judging

See evaluation criteria posted on the course site on Scholar.

V. Deliverables

The technical proposal must convincingly demonstrate that the design team can provide a superior and cost effective solution to the need identified by this RFP. The proposal should satisfy the *applicable* tasks listed below (in a random fashion) to show how the team developed the design of a new aircraft.

1. Describe the initial set of vehicle concepts your team evaluated
2. Explain the process used for evaluating each concept's effectiveness in delivering the required capabilities and justify your team's selection of the preferred concept.
3. Perform trade studies and provide carpet plots used to optimize the final selected design (including but not limited to cruise speed, wing parameters and takeoff & landing distance, etc.). Use these trade studies to justify the team's design choices.
4. Include a dimensioned 3-view drawing.
5. Include an inboard profile showing the general internal arrangement.
6. Include an illustrated description of the primary load bearing airframe structure and state rationale for material selection.
7. Include a V-n diagram.
8. Show an estimated drag build up and drag polar for the cruise configuration, the takeoff configuration and the landing configuration.
9. Show a weight breakdown of major components and systems, and center of gravity travel.
10. Provide performance estimates and demonstrate air vehicle stability for all flight conditions.
11. Describe any advanced technologies and their relative benefits to the design. Address risk mitigation if these technologies fail to materialize including potential cost increases or decrement to performance.
12. Describe how the air vehicle is transported, configured to a flying configuration, launched and recovered.
13. Describe the undercarriage of the air vehicle, explaining design features that allow for operations on improvised gravel or grass landing strips. Show how the undercarriage meets appropriate tip over and turnover criteria with respect to the aircraft's center of gravity.
14. Describe how the vehicle carries the required payload. Also describe the cargo handling system including the loading and unloading scheme.
15. Describe the range and endurance capability of the air vehicle with zero payload and with specified payload.
16. Describe the capabilities, weight and cost of the selected mission control system.
17. Describe the concept of operations (CONOPS) envisioned for the proposed system.
18. Provide flyaway cost and life cycle cost estimates for production runs of 50, 100, and 500 air vehicles.
19. Any other tasks the team performs to gain a competitive advantage!

Fig. A.2. 2015-16 HAW-VT collaborative aircraft design RFP on AUAS