PERGAMON

Aircraft Design 3 (2000) 239–247

AIRCRAFT DESIGN

www.elsevier.com/locate/airdes

A model for international teaming in aircraft design education

Lloyd R. Jenkinson[a,*], Gary J. Page[a], Jim F. Marchman[b]

[a] *Department of Aeronautical and Automotive Engineering, Loughborough University, Leicestershire, UK*
[b] *Aerospace and Ocean Engineering Department, Virginia Tech, Blacksburg, VA, USA*

Abstract

This paper describes the nature and development of an undergraduate aircraft design course involving students in US and UK universities working in an integrated team that models the international collaboration commonplace in the aerospace industry. The reasoning that led to this collaboration is outlined and details of the organisation and management of the programme described. Observations from the three years of experience with running the programme are made and some overall conclusions given. Some of the design projects are illustrated including the roadable aircraft design which won the 1999/2000 NASA/FAA AGATE National General Aviation Design Competition. The collaboration has been successful from an educational standpoint and would serve as an effective model that could be adopted by other pairs of universities.

1. Introduction

Traditionally, aircraft design courses at universities have attempted to simulate industrial design practices. This has generally involved both the synthesis of students' knowledge in their core subjects (e.g. aerodynamics, structures, propulsion, etc.) and a requirement to work in teams. Team working is now regarded as an essential feature of all aeronautical engineering courses. Evidence of this aspect forms part of the accreditation requirements for approved professional engineering courses. In most universities the preferred way to meet such requirements is to expose groups of students to conceptual and preliminary aircraft design work. In most courses this type of work forms a compulsory part of the curriculum. A typical format will involve a group of third or final year students from the same course meeting at regular intervals throughout the year to process the design from initial specification to a preliminary detailed configuration.

* Corresponding author.
E-mail address: l.r.jenkinson@lboro.ac.uk (L.R. Jenkinson).

1369-8869/00/$ - see front matter
PII: S1369-8869(00)00021-5

The popularity of aeronautical engineering courses means that our students are amongst the brightest in their university. They are mainly well motivated and have high expectations that their chosen degree will adequately prepare them for a successful career as practising professional engineers. Although they regard the design parts of their course demanding, they often report that they found the work interesting, worthwhile and enjoyable. At the end of a final year design course one student recently remarked that when he originally chose to study aeronautics he expected the whole course 'to be like this'.

Aeronautical engineering courses are continually evolving to follow the methods and practices used in industry. Academic advisory boards are often the instigators of course changes to keep material relevant to industrial requirements. Within the limitations of university resources, these course changes now include topics and fundamental methods that only a few years earlier were the topics of research (e.g. FEM, CFD, CAD CAM and systems engineering).

An industrial development that has not yet been fully reflected in most aeronautical engineering courses is the now common internationalisation of our industry. For several years all the major aircraft projects have included multinational co-operation. This diversity spreads across all of the industrial aspects (initial specification, design, manufacturing, testing, marketing and management). The traditional sequential design build test process model has been replaced with concurrent engineering. Rapid development of information technology has provided the operational environment to make international teaming feasible.

In contrast most university aircraft design work is still centred on a single campus and involves tightly knit groups of students who meet face to face in a progressive timetabled schedule. The students generally know each other from previous academic and social contact and can easily arrange to meet outside formal teaching periods. Such arrangements, although capable of covering the technical learning aspects of the course, tend to lack an understanding of formal communication and commercial organisational standards required in industry.

2. Programme description

Recognising the contrast in industrial and academic design processes outlined above, the Department of Aeronautical and Automotive Engineering at Loughborough University (LU) in the UK and the Aerospace and Ocean Engineering Department at Virginia Polytechnic Institute and State University (commonly known as Virginia Tech, VT) in the USA decided to jointly develop an aircraft design programme in which students from both countries join together for international team working.

3. Educational objectives

The educational objectives of this collaboration can be summarised as:

- To model, within university resources, modern international industrial design practices.
- To broaden the perspective of student aircraft design projects.
- To improve student understanding of communication and organisational skills.

- To enhance students' personal development.
- To benefit faculty experience.

It is possible to address these objectives in several different ways:

1. 'Case Studies' — involves the single reporting of the end product of students' design work to their opposite group.
2. 'Show and Tell' — in this method students in the two countries work on separate design projects and come together to progressively explain to their opposite group how their work is developing.
3. 'Parallel Teams' — in this pattern student groups in each country work independently on the same design proposal. Although the teams work separately they are encouraged to share data and methodologies.
4. 'Integrated Teams' — this involves the students in each country working together on a joint design project. The full teams are together on two occasions at the beginning and end of the project and conduct virtual meetings in the intervening period.

During the period of co-operation between universities all the above methods have been tried [1–3]. However, it is the last method that has been the most successful in the LU/VT collaboration. This provides the best simulation of current industrial practice.

4. Requirements for success

Our experience has shown that there are several pre-requisites to be met before international team working can be started:

1. Common educational objectives for the project work. In most cases this will not be difficult as the majority of undergraduate aircraft design projects are carried out in the later parts of courses (final or penultimate years). At this time students have a good understanding of the fundamental core subjects and are familiar with the educational learning environment. However, as we show later in this paper, it is not necessary for all the team members to be from the same type of course. A mixture of different skills and backgrounds, has been shown to enhance group effectiveness.
2. A good professional relationship between the academic staff involved. As with the LU/VT project, this requirement is often met by previous contact between faculty members at conferences and professional meetings where their research, industrial and academic work has been presented.
3. Reasonable alignment of academic calendars in both institutions. The students will need to have regular communication throughout the period of the design work and a commonality of calendars maximises the weeks available for collaboration. A comparison of the two universities teaching calendar is shown in Fig. 1.
4. Course requirements, including the nature, procedures and timescale for student assessment, timetable availability (particularly when there is significant international time dispersion), group size and student mixture, and overall tutoring and monitoring procedures. This finer detail must be considered before the start of collaboration as each element can have a surprisingly large impact on the smooth running of the project.

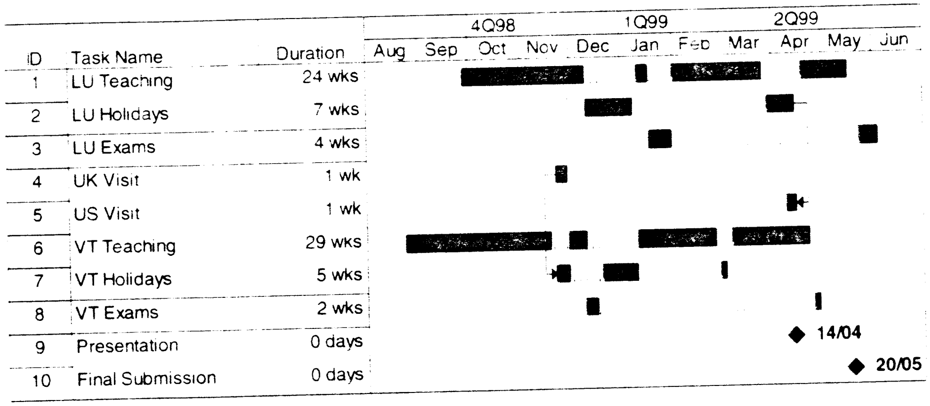

Fig. 1. Academic calendars (1998 1999).

5. Increase in university resource. This includes the provision of academic staff time, provision of appropriate communication and IT equipment and, of course, adequate funding. These aspects are discussed in detail below but without the necessary additional resource the programme will not be possible.

5. Programme structure

Over the past 2 years the co-operative programme structure has settled into an effective working pattern. Obviously, part of this is related to the characteristics of the two institutions and the confidence that has been built up through the years of working together. This structure may not be exactly repeatable with other combinations of institutions, but is presented here as an example.

In both of the last 2 years we have centred our projects on the AIAA annual student team design competition and either a BAE SYSTEMS or a NASA/FAA AGATE aircraft design specification. For the past year (1999/2000) the projects studied were a cruise missile carrier and a general aviation roadable aircraft. Previous year projects involved a STOL transport aircraft, an advanced agile fighter and a general aviation aircraft.

As with conventional aircraft design courses the Request for Proposal (RFP) details were agreed between the academic staff and published before the students started the programme. These details were then given to the students at their first meeting.

The students are given a free choice of project but as the AIAA competition rules restrict the group size to 10 or less some constraints have to be imposed. Other projects are not so limited. Each university has between 15 and 25 students on the programme (this is somewhat limited by the available university resources). Alongside the international teams we have other single nationality groups of students working, in competition, to the same RFP and other design specifications.

At the early stage of the programme both universities are working independently as their academic year start times are not the same. During this time the students are preparing for their first face-to-face meeting in November at Loughborough (i.e. during the American students'

Thanksgiving week). The students in this initial period are expected to work on conceptual design studies. The intention is that at the November meetings all the various aircraft configurational options are tabled and the group decides upon a preferred concept. This will be called their initial baseline design configuration. The layout may not be one of the original options as technical transfusion of design ideas and concepts forms a significant element in their final choice. Just as in real life, compromises between competing ideologies is often found to be necessary.

During the week long visit in November and to some extent privately before this, the students decide on the method and management of the communication that will be essential when the group members return to their own universities and be geographically separated. Progressively, over the past 2 years, and continuing into the coming year the communication methods have developed from initial telephone conversations, to tele-conferencing (later with web-associated graphics and data), to video conferencing. The web and email communication systems represent two significant developments which have undoubtedly contributed to the success of the programme. A dedicated web page is generated for each project forming the repository for documentation, data and decisions. One of the early uses of the web is to post photographs of each group member to facilitate introductions at the start of the project. Email is the normal day-to-day communication means between students. This is used to disseminate draft information during the analysis process, prior to posting onto the web.

The level of enthusiasm for the programme can be gauged by the urgency that the group has in wanting to settle the details of the baseline design at the November meetings. This year they unanimously agreed to cut short a social function to get back to the design meeting!

At the end of the November visit the student groups have to make a presentation on their choice of baseline configuration. The American students take the lead in this work as the Loughborough students are often in other classes during their normal university working day.

Although the formal presentations is the endpoint to the November visit there are several other requirements set for the group during this time. The first of these is to establish a good working relationship between the members of the group and to identify areas of responsibility. It is also necessary to agree on the design standard to be used. This includes the dimensional units (SI or 'British'). The Americans normally work with 'British' (ft.lb) whereas in the UK, SI is used. To avoid difficulties in communication the group has to define the software to be used (this includes word processing, spreadsheet, drawing CAD, and any in-house programs that will be used in the analysis). A further requirement is to establish a management structure and team organisation. It is at this point that team leaders are appointed to act in each university. The method of resolving areas of conflict must be agreed. Often this is required during the week to settle on the group decisions on the baseline aircraft design philosophy and configuration.

After the November visit the team is full of enthusiasm and eager to progress with the design. Unfortunately, the US students have their end of semester exams shortly before Christmas, whilst the UK students have their exams shortly after Christmas. It is not until late January that both halves of the team are again working simultaneously on the project. A similar situation occurs in the Spring when the US students have a week long Spring break and a few weeks later the UK students are in the Easter vacation. Obviously, these interruptions in the working pattern on the project are not ideal but they can be predetermined and therefore can be anticipated and allowances made. In particular, part of the team must be willing to 'hand over' authority for design decisions to the other half during these periods.

The visit to Virginia Tech is in March or April coinciding with the UK Easter vacation and is the conclusion to the main part of the project work. At this time the aircraft design is reasonably well understood and the visit is intended to complete the outstanding analysis, settle any finer detail still not agreed, but mostly to produce a final presentation of the aircraft to invited guests. After the visit the group only have the task of producing the final report for assessment.

An interesting feature of the team structure in both universities is the inclusion of non-aeronautical course students. At Loughborough some Systems Engineering students and at Virginia Tech Mechanical and Industrial course students are involved. Although not intended to be a fundamental aspect of the international teaming programme this multidisciplinary team also reflects current industrial practise. The inclusion of different perspectives to the design problem and the introduction of experience from outside the traditional aeronautical background has been seen to enhance the design process due to the broadening of design decision making.

6. Aircraft projects

The aircraft design projects that have been studied over the last 3 years include:

- A four-place touring aircraft.
- An electric powered light aircraft.
- A 'roadable' general aviation aircraft (shown in Fig. 2 and winner of the 1999/2000 NASA/FAA AGATE National General Aviation Design Competition).
- An agile advanced fighter.
- A cruise missile carrier (shown in Fig. 3).

7. Observations

Over the 3 years that the programme has run several difficulties have had to be overcome. These are recorded here to guide others who might be considering the introduction of international

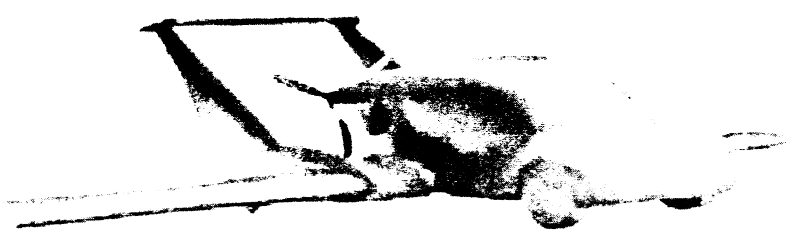

Fig. 2. 'Roadable' Aircraft (NASA/FAA AGATE competition winner).

Fig. 3. Cruise missile carrier with strut braced wing (AIAA competition).

teaming into the courses.

1. The main difference between this type of programme and the traditional single campus course is that difficulties that sometimes arise between student members can be magnified. Delays in responding to requests for information from one group to another can be caused by student lethargy, communication problems, or simply by variations in the academic calendar. Obviously, this can lead to student frustration and confusion. Tighter control of the design process is needed to offset these potential problems.
2. One of the key requirements for this type of programme is the need for good student team leadership. Most educators already have appreciated that this is significant in traditional design projects but it appears that it is even more essential in the international teaming environment. As always identifying a good leader at the start of the project remains a difficulty. The student group is not necessarily the best judge of leadership potential, nevertheless, we have found it is important to involve the group, sometimes discretely, in the process.
3. Good communication is the lubrication that makes the programme run smoothly. This does not occur naturally, therefore, students need to learn how to communicate effectively. The provision of more sophisticated equipment can help but as with all technological innovations it requires time and effort to become proficient and confident in its use.
4. The size of the team is an important parameter in this type of project. There appears to be a critical minimum mass below which the team becomes ineffective. Our experience suggests that this is about four students in each university. On the other hand, we have found that large groups also experience problems. Although it is possible to duplicate tasks in a large group it is also possible for some students to feel isolated. A group size of approximately 15 in each university is the maximum that can be fully effective.
5. One of the most difficult areas to tackle is associated with the requirements for student course assessments. The demand on students, to meet individual and group coursework requirements,

has led to problems between groups in each university. Students tend to be good at analysing the effectiveness of their effort on coursework and this can lead to some of them concentrating their time on individual work at the expense of group activity. We have not yet found a satisfactory answer to this problem as some educators demand individual assessment as opposed to overall group marks. Recognising the potential for disturbance caused by the assessment processes may predetermine the method and scheduling of these assessments.

6. There are several other aspects regarding assessment and the students' perceptions regarding workload, grading and privileges. Most of these issues are amplified in comparison to work on other projects and subjects. The workload issue relates to the demands on project work relative to examined courses. The grading problem relates to the identification of individual effort and ability within a group activity. The perception of privilege is more difficult to deal with as it relates to many non-academic issues. Selection of students to participate in the international teaming projects is likely to become increasingly contentious as knowledge and popularity of the course increases.
7. The effect of the demand on academic staff time and effort to manage and supervise the international teaming work is difficult to quantify. Most academics already have an international perspective to their work. Therefore, the main advantage for them lies in their professional responsibility to their teaching and learning environment. There is extra work involved, but this is partly balanced by the challenging and interesting opportunities that are presented by the programme.

8. Finance

Although we have left this topic towards the end of the paper it is often the first question that is asked. Transporting students to other countries with all the associated subsidence costs is not cheap but if the universities work together it can be kept down. In our model, each university pays for the travelling expenses for their own students and staff. They also meet the accommodation, meal and internal travel costs for the visiting students and staff. The current cost of the LU/VT activity is estimated at about $1000 per student. Both universities have benefited from support from industry (Boeing and BAE SYSTEMS) to partly offset the expenses. At Loughborough we also ask our students to make a small contribution to the costs (partly as an insurance of student intent). In the future, it is conceivable that such programmes could be supported by increased student fees, in the same manner as those charged for 'study abroad' on other current university courses. From a departmental viewpoint, aircraft design projects are relatively low cost as they do not require expensive laboratory and technical support. Taking 20 students on an international team project each year costs a department less than the annual salary of one laboratory technician.

9. Conclusions

From an educational perspective the international teaming projects have been very successful. They have provided an enhanced educational experience for students, simulated modern industrial practices and provided an enjoyable link between academic staff at the two institutions. Although collaborative team work between LU and VT started slowly we have now established an effective model that could be adopted by other pairs of universities.

It is interesting to note that in the final meeting at VT this year, when the team members were preparing for their final presentations, the degree of integration of the US and UK students was such that an outside observer would not be able to determine the nationality of a student except perhaps by their accents. In the 6 months of working alongside each other (albeit at 5000 mile distance for most of the time) the students had built up mutual trust and respect to produce very effective teams. Working with students from different social, cultural and educational backgrounds did not lead to any discernible problems. It became apparent that US and UK students share common aims and have similar educational expectations, professional ambitions and social perspectives. It would be interesting to know if this situation resulted from a 'nominally' shared language. For example would Spanish and Italian integration work in the same way?

When questioned after the course had finished, the students said that they had enjoyed the experience and that it had given them a unique learning opportunity. Keeping students motivated to the learning environment must be regarded as a prime requirement for all academic programmes. We have noticed that this type of programme has a beneficial effect in the earlier year courses as younger students identify the opportunities that are offered to them in their later years on the course.

10. Uncited Reference

[3].

Acknowledgements

We would like to thank all the companies who supported and continue to support this programme, the students who have taken part and responded so positively to their new experiences and to our universities for their foresight in allowing this course development. For those interested in more information on the programme, the authors will be pleased to respond (L.R.Jenkinson@lboro.ac.uk, G.J.Page@lboro.ac.uk, marchman@vt.edu).

References

[1] Marchman JF. Multinational, multidisciplinary, vertically integrated team experience in aircraft design. AIAA Paper 98-0822.

[2] Marchman JF. Multinational, multidisciplinary, vertically integrated team experience in aircraft design. The International Journal of Engineering Education 1889;14(1):328–34.

[3] Jenkinson LR, Page GJ, Marchman JF. International teaming in aircraft design. AIAA Paper 99WAC-25, Oct. 1999