Int. J. Appl. Engng Ed. Vol. 7, No. 2, pp. 106–110, 1991
Printed in Great Britain.
0742–0269/91 $3.00+0.00

An Integrated Aerospace Engineering Degree*

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A description is given of a new Aerospace Engineering degree containing a number of novel features. The course, though conforming to a modular structure, emphasizes the integrated nature of the discipline of engineering. The methods by which integration is achieved are detailed, together with other salient features. The integrating role of the design process is described, and engineering applications aspects are highlighted.

INTRODUCTION

IN SEPTEMBER 1988, Hatfield Polytechnic replaced its previous Aeronautical Engineering degree with a new Aerospace Engineering degree based on an integrated approach. In the new scheme, we have attempted not only to reduce traditional subject divisions, but more importantly, to show how the various aspects of the discipline are linked together as a coherent whole. The scheme is composed of modules, the linkage being provided primarily by integrating activities such as design, computer-aided engineering, and other means described later. The change of title reflects the development of a broader aerospace industry no longer concerned solely with aircraft.

Figure 1 shows the basic structure of this degree. It will be seen that subject divisions still exist, particularly in the first year where we concentrate on basic engineering principles. However, the number of separate subject modules is relatively small, and in many cases large double modules are used. Thermodynamics and Fluid Mechanics are for example, treated as a single entity.

Integration is achieved by various means including modules of integrating activities such as design, the programmes of 'Engineering Studies', Experimental Engineering, and individual and group projects. Design is firmly embedded within the subject modules in addition to appearing in specific design modules.

In the interests of efficiency and flexibility, the first year is common with our B.Eng in Mechanical Engineering, except for the specialized integrating activities which come under the heading of Engineering Studies. There are also common elements in the second year.

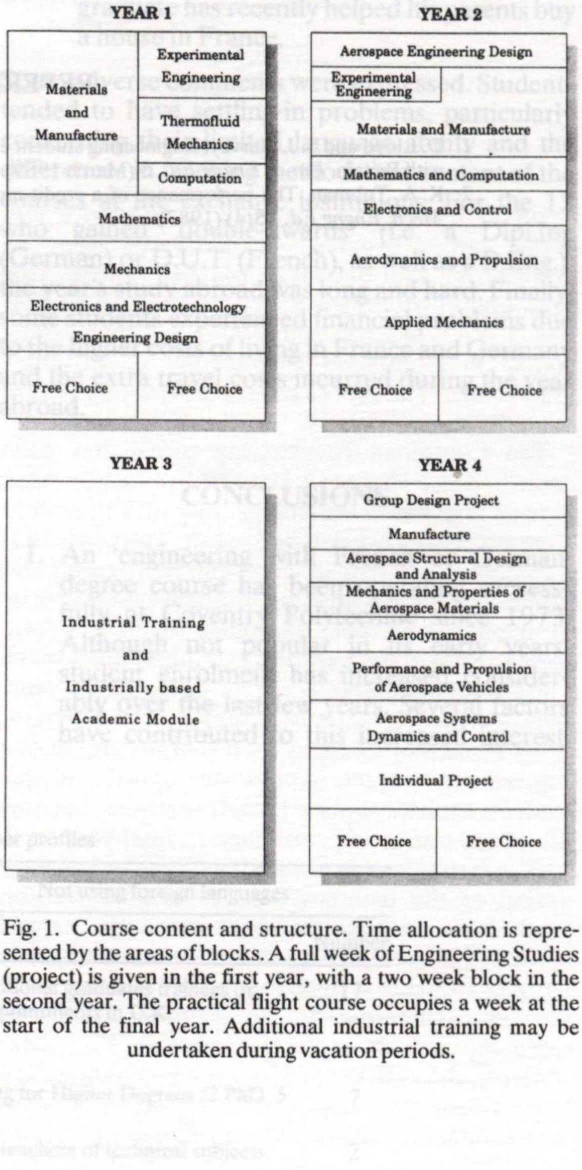

Fig. 1. Course content and structure. Time allocation is represented by the areas of blocks. A full week of Engineering Studies (project) is given in the first year, with a two week block in the second year. The practical flight course occupies a week at the start of the final year. Additional industrial training may be undertaken during vacation periods.

* Paper accepted 13 November 1990.

MOTIVATION FOR THE INTRODUCTION OF THE SCHEME

The new scheme was developed in response to experience in running the previous B. Eng in Aeronautical Engineering. The older scheme was considered to show a number of defects.

- The number of modules was too large, resulting in an excessive number of examinations.
- The use of a two-semester year with consecutive butt-jointed modules produced an undesirable inter-semester gap.
- The short-duration of the modules led to problems due to lack of assimilation time.
- Material was often duplicated in closely related modules.
- Design tended to be seen as a separate subject, mostly involving the production of detailed drawings.
- Student motivation was seen to be poor in the earlier years, as they had difficulty in relating the foundation material to their interest in aviation and space technology.
- The thin sandwich pattern of industrial training with several training periods was found to be labour-intensive in organization, and inconvenient both for the students and for industry. It was also difficult to provide a full-time option.
- Students were being over-taught.

In the new scheme, in addition to remedying these effects, we have included a number of other features.

- clearer objectives for each module, including an assessment of the balance between knowledge, skills and applications.
- the creation of teaching teams for each year of the course with the objective of ensuring that the teaching is properly integrated and interrelated.
- More emphasis in the assessment process on overall performance.
- A group design project
- A larger engineering applications content.
- Earlier introduction of specifically aerospace topics.

DESIGN AS AN INTEGRATING PROCESS

Design is here used in a broad sense to include system and parametric design, and not simply mechanical and structural component design. A typical example in the first year involves the initial stages of the design of a simplified cabin pressurization system. A general arrangement of an aircraft is provided. Requirements of the system are specified, and essential data such as the compressor bleed pressure are given. The students have to produce a suitable scheme including pipe sizes and configuration. Calculations primarily involve simple pipe friction loss estimates with a little heat transfer. Most importantly, this and similar exercises require the student to make intelligent engineering assumptions. Students were rather taken aback when it was explained that there was no unique 'right answer'.

Another first-year integrating activity has been a highly successful group project to simulate the development of an aircraft. This project represents the work under the heading of engineering studies 1 in Fig. 1. It is perhaps worth describing this activity briefly.

FIRST YEAR ENGINEERING STUDIES PROJECT

The majority of the students were divided into a number of aircraft companies, and were asked to submit proposals for a new transatlantic airliner to a specification drawn up by an airline, represented by another group of students. In order to prevent the project from being a mere paper exercise, the Atlantic was represented by the floor of the sports hall, and the airliners were to be small models which were to be tested and demonstrated to the customer. The role of the CAA was taken by a staff member who checked proposals, and issued permits to fly etc. Materials had to be bought from approved suppliers (other staff members), and the whole project had to be costed to produce an economic sale price. Labour costs etc had to be included.

Staff and students entered into the spirit of the exercise with great enthusiasm, and the whole enterprise produced a sometimes frightening mirror of the real world with reported cases of industrial espionage, and rumours of impropriety, and insider dealings. Consternation was created when it was announced that the pound had just been devalued, and materials not yet ordered would increase in price. Advice from staff was readily available but incurred a financial penalty in terms of the development costs.

It was noticeable that in subsequent laboratory periods, the students automatically grouped themselves into the companies of this project, and tackled the lab work with the same kind of competitive urge.

Figure 2 shows part of the flight test programme.

INTEGRATION OF LABORATORY WORK

In traditional laboratory work, a number of different objectives are often simultaneously addressed.

- The demonstration of physical principles
- The learning of specific experimental skills
- The learning of principles of experimentation
- Data reduction and processing
- The development of specific communication skills.

Fig. 2. Students prepare to test-fly models in the final stage of the first-year Engineering Studies project. The payload consisted of a prescribed number of ping-pong balls. The motors (a twin motor configuration was specified) were rubber-band units supplied by an 'external contractor'. The model shown had a number of unconventional features such as push-pull motors and a canard layout. It performed well.

To mix so many aspects is confusing, and in the early stages of our scheme we have attempted to isolate some of them.

The demonstration of physical principles and the learning of subject-specific experimental skills properly belongs within the subject teaching. Provision for access to laboratory facilities is therefore made within the timetable for subject modules, but no specific amount of laboratory time is prescribed. It is left to the lecturer concerned to decide how and when to use the laboratories for teaching.

Although direct hands-on work by the students is generally desirable, there are cases where the demonstration of physical principles is best undertaken by, or closely supervised by a staff member. We can all remember instances from our student days when ill-conducted and badly set-up experiments appeared to prove the opposite to what was intended.

The other objectives listed above are dealt with in the first two years by a programme of experimental engineering, which involves both lectures and hands-on experimental work in a range of laboratories. The communications aspects cover a much wider variety than traditional laboratory reports, and include verbal presentations as well as various forms of written and graphical exercises.

Experimental engineering as an identified activity does not appear in the final year, as by that stage, the students should have enough experience to be able to cope with a more complex set of interacting objectives.

DEVELOPMENT OF INTEGRATION DURING THE COURSE

The first year of any Engineering degree course must of necessity centre on the introduction of basic principles. Over-zealous attempts to fuse the teaching into a single integrated entity at this stage would simply result in confusion. The amount of integration is therefore increased progressively through the course, until in the final year, a large proportion of the time is allocated to individual and group project work.

THE FINAL YEAR GROUP PROJECT

The final year group project represents the culmination of the integration process. In this exercise, the students will work in groups looking at the design of an aircraft. The range of possibilities here is enormous and can extend from the largely conceptual design of say a semi-orbital craft, to the more detailed design, and possibly even design-and-build of a microlight, with industrial support.

The idea that anything approaching a serious overall aircraft design study could be attempted in an undergraduate course was viewed with some initial scepticism, yet experience in America, and more recently in this country, indicates that such exercises are both meaningful and rewarding. In reality, the initial design stages of an aircraft are not particularly complex. It is in the final detail design and development work that the major complexities and difficulties arise. Up until the early postwar period, much of the conceptual design work on a new aircraft was conducted largely by a single individual within each company.

STUDENT MOTIVATION

Students of Aeronautical and Aerospace engineering often arrive with an almost passionate interest in aircraft and flying, and their initial experiences on a traditional course can be very disappointing. To start with, the course will, for reasons of economy, often be common with other forms of engineering. The aerospace degree student finds it hard to accept that steam plant should feature as strongly as the gas-turbine. The structure of our previous scheme was particularly unsatisfactory in this respect, since the students did not meet their specialist aeronautical topics until the third year. In the new course, specialist subjects appear in the second year. In addition, in the first year, the aerospace students are grouped together for tutorial and laboratory work, and have tutorial questions and assignments that are slanted towards their specialism. The Engineering Studies aircraft project described earlier was found to be particularly helpful in maintaining motivation.

EMPHASIS ON ENGINEERING REALITY

A weakness of many engineering courses is their tendency to concentrate on mathematical skills at the expense of a physical understanding or a proper appreciation of the industrial context. I remember in my final year of an aero. degree, being asked in all seriousness by a fellow student 'what's a flap?' The trouble is, that it is much easier to teach the mathematics than the physics, and a board-full of algebra always looks impressive. Mathematics is a most important weapon in the engineer's armoury, particularly in the form of numerical techniques, but the student must understand what it is all for. We attempt to address this problem by emphasizing the indirect or design problem rather than just concentrating on the direct or analytical approach. We also attempt to simulate the industrial environment in the group project work, as described earlier. Wherever possible, the individual major projects are originated in industry. Figure 3 shows a model of a STOL aircraft produced by British Aerospace that has been used for a series of projects initiated by that company. There will also be industrial involvement in the final year group project.

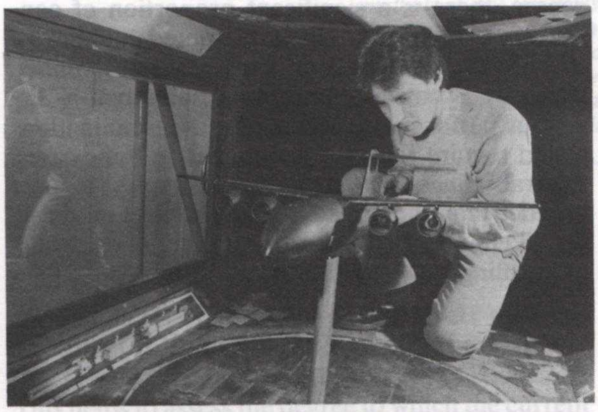

Fig. 3. Most individual final year projects originate in industry. This STOL project model shown in one of our low-speed tunnels was supplied by British Aerospace. It has been used for a series of projects by students associated with that company.

A PRACTICAL FLIGHT COURSE

In any Aerospace degree course there should be some opportunity for exposure to the practical realities of flight. Rather than simply place the students in a flying laboratory, we decided that it would be possible to let them have direct experience of flying an aircraft. We have therefore included a short practical flight course, in conjunction with the London School of Flying (LSF) at Elstree. The course includes practical hands-on flying of light aircraft by each student, together with demonstrations of the flight characteristics of the aircraft and some basic flying skills and airmanship. Some 20% of our students already have some previous flying experience, and a number even have pilot's licences. This advanced group are able to broaden their experience by flying twin-engined aircraft or helicopters, as seen in Fig. 4.

Fig. 4. During the practical flight course, students discovered just how unstable and difficult to control a light helicopter can be.

Both LSF and Hatfield Polytechnic have flight-simulator facilities which are also used. This is being expanded at Hatfield by the introduction of some extremely realistic computer simulation packages on specifically adapted micro-computers. In addition to the practical flying and simulation, lectures by pilots, flight engineers, airline staff etc are included. The flight course has, as expected, been found to be very popular, and helps with motivation. It is also surprisingly cost-effective.

INTEGRATED INDUSTRIAL TRAINING AND THE INDUSTRIALLY-BASED ACADEMIC MODULE

The merits of integrating industrial training within an engineering degree course are by now well established. The sandwich course approach does not however necessarily and spontaneously produce a more relevant programme of study. On early sandwich courses, there was often little real connection between the industrial periods and the academic work. To be successful, the industrial placement must be carefully monitored, and wherever possible, the firms should be encouraged to continue their involvement by supporting student project work.

The industrially-based academic module

A further link between the academic and industrial experience is provided in our scheme by a module of academic work undertaken by means of distance learning whilst the student is in industry. It comprises a series of seven tasks, each taking 4–6 weeks, which cause the student to examine his/her company in detail, and provide a level of understanding of major aspects of company business.

Sandwich patterns

In our previous scheme we adopted a 'thin' sandwich approach with two or more periods of training. Although this had much to recommend it from an educational point of view, the staff effort involved in finding and supporting so many placements became excessive under the pressure of enforced increases in student:staff ratios. Furthermore, many company training officers found our irregular pattern administratively inconvenient, preferring to deal with whole year or short vacation placements as adopted by most Universities. In the new scheme, we have adopted a 2-1-1 pattern, with industrial training forming the third year. Students may additionally find vacation placements on their own initiative. This pattern also allows students the option of following a thick sandwich, or even a full-time non-sandwich programme. The latter option is discouraged, but can be useful in exceptional circumstances.

THE EUROPEAN DIMENSION

Nowadays, the aerospace industry in Europe works primarily on inter-European collaborative projects. It is therefore considered to be important that students should be exposed to the problems of international co-operation and communication at the earliest opportunity. We are therefore collaborating with a number of European educational institutions to arrange a progamme exchanges and credit transfers. This is one reason why we have maintained a basically modular structure despite the emphasis on integration. Thus far a number of German students from the Fachhoschule in Hamburg has successfully completed the final year of our outgoing degree scheme, either in addition to their final year, or more recently, as a substitute. This arrangement will be able to continue in our new scheme.

The problems of sending our students abroad on exchange programmes are considerable because of language difficulties. English is the lingua franca of Europe, and the advantages of learning other European languages are not of obvious pressing importance. In addition, some overseas students, may still be grappling with English. We are, however, intending that our Vehicle Engineering degree students should be taught partly in German during a three-month stay in Hamburg next year, and that commencing in 1991, our M.Eng students should be taught partly in French during a stay in Paris. Depending on the outcome of these experiments, we will be trying to send some if not all of our Aerospace degree students abroad in the near future.

In terms of mass migration, the Aerospace degree presents particular problems due to the very large numbers involved (currently sixty and likely to rise). In the short term we intend to invite a small number of students with some evidence of linguistic ability to undertake their major project work and/or industrial training abroad.

ASSESSMENT

One of the objections to the previous modular degree was the large number of formal assessments that it generated, and their frequency. Students felt overassessed, and staff efforts in generating, moderating and marking the examinations was excessive. It was found that the amount of staff time associated with the primarily summative assessment process often exceeded that actually spent on teaching.

Frequent crises occurred when students failed subjects that were defined as a prerequisite for further studies. This necessitated the running of endless referred examinations, with further and deeper crises if students failed them. In the new degree, there is a significant proportion of continuous assessment, and a restricted number of end-of-year examinations. Progress is determined primarily by overall assessment, although a disastrous performance in one or more examinations would require remedial action, and in some cases, referral. Since the grouping of topics is now broader than the previous single-subject modules, the likelihood of failing one examination whilst performing well overall is significantly reduced.

THE END RESULT

Although there are administrative and economic advantages, the primary motivation for introducing the integrated Aerospace Engineering degree comes from a desire to produce graduates who are able to treat engineering as a creative process as well as acquiring analytical skills, and who appreciate the essential interactions between arbitrarily divided areas. This is particularly important in the Aerospace Industry which is still largely structured on a strictly departmental basis. Unless integration has been taught, it is not easy to appreciate some of the interactions. For example, it is not necessarily obvious that the efficiency of the propulsion system is influenced by the characteristics of the aircraft and by its external flows.

Finally, the scheme is founded on the premise that although engineering studies may always be hard work, they can be both enjoyable and industrially relevant.