UNIVERSITY DEVELOPMENT OF A DERIVATIVE AIRCRAFT BASED ON A KIT-GLIDER

G. E. Dorrington[†]
Department of Engineering
Queen Mary and Westfield College
University of London

Keywords: *design, education, aeronautical engineering*

Abstract

The educational advantages of complete aircraft prototype development projects within universities are set out. The use of kit-planes as a starting basis is discussed. Recent progress in the construction of a derivative aircraft based on a kit-glider is outlined.

1. Introduction – the Rationale for Aircraft Projects in Universities

1.1 Current Educational Trends

Queen Mary and Westfield College (QMW) houses one the oldest aeronautical engineering laboratories in the U.K., dating back to experiments carried-out by Sir Hiram Maxim in 1903. Today, experimental facilities include several low speed wind tunnels (all 30+ years old, with working sections of about 1m x 1m) that are still used usefully for undergraduate and postgraduate research work. However, like many leading university engineering departments, great emphasis has recently been placed on the improvement of computing facilities for research as well as the acquisition and/or creation of new software to permit improved simulation, i.e. for computational fluid dynamics (CFD), computer aided design (CAD) and solid modelling. This current strong trend towards simulation is not confined to research, it has led to a necessary shift in undergraduate teaching – which is no doubt required if graduates are to be adequately prepared to join industry in this new century. Hence, in recent years, engineering students have been spending proportionally more and more time at computer workstations - tackling engineering problems in a virtual reality environment. In the context of specific research goals, this shift in the learning environment is probably beneficial; but within the context of traditional aeronautical engineering (stemming from the art/science of flight: aeronautics) it clearly has some drawbacks.

1.2 The Need for Balance: Simulation plus Reality

There is an established body of engineering opinion that maintains young engineers need “hands-on” experience - in order to better appreciate the limitations of engineering models employed in the design process. In other words, the realisation of design concepts is essential to learning. While advances in 3-D CAD (etc.) are advantageous, design solutions derived entirely using software packages are often fraught with practical difficulties that ultimately dominate the real engineering development process. Of course, universities are not necessarily in a good position to reproduce the exact-same real-world problems that appear in (aerospace) industry, in particular there are often significant differences in scale (project time-scale and budget etc.), but by

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[†] Lecturer in Aerospace Design, Ph.D. (*Cantab*), e.mail: g.dorrington@qmw.ac.uk

definition many practical challenges have to be faced in real engineering projects

To reiterate: in engineering design, it clearly is not sufficient to lead a group of students through a development process only as far as a virtual product – possibly a set of preliminary design drawings or CAD solid models (say). In order to give design courses educational depth and real content, it is necessary for the product development process to extend at least as far as the manufacture and testing of real prototypes.

In aircraft design projects this philosophy strongly suggests that parts of aircraft, or aircraft subsystems, or even complete aircraft, should be built and tested.

1.3 The Feasibility of Full-Scale University-Based Aircraft Prototype Development

On hearing the suggestion of university-based development of aircraft, some academics immediately riposte that the goal of building and flight-testing full-scale[†] prototypes can only take place in large industrial establishments. They would say that such developments are outside the scope of university capabilities, are far too costly, and the hazards/risks involved are far too high. (A few external critics have even told the author that the task of aircraft construction lacks educational content.) However, these objections dissolve after a quick survey of some previous aircraft projects around the World is made [1-8], see Table 1.

For example, the achievements of staff and students at the University of Toronto Institute of Aerospace Sciences[1], exemplify the argument presented here. Their recent success in flying a single-seat ornithopter must surely be recorded as one of the most intriguing steps in aeronautical history.

Aircraft Project	**University**	**Source**
Ornithopter (single-seat) C-GPTR	UTIAS	DeLaurier 1999, [1]
A-1 Eagle (twin-seat) Aerobatic Aircraft	Cranfield	Poll 1998, [2]
Icaré (single-seat) Solar Powered Aircraft	Stuttgart	Rehmet 1996, [3]
D-4 (twin-seat) Ultralight Airship	Southampton	Dorrington 1996, [4]
Mitsubachi Human Powered Helicopter	Nihon	Nakamura 1992, [5]
Light Eagle Human Powered Aircraft	MIT	Zerweckh 1988, [6]
Monarch Human Powered Aircraft	MIT	Langford 1984, [7]
SUMPAC Human Powered Aircraft	Southampton	Lassiere et al.1960,[8]

Table. 1 Some previous university-based aircraft projects (an incomplete sample[†]).

As a second example, the achievements of the staff and students in the Faculty of Aerospace in Stuttgart University are equally noteworthy: they recently designed, built and flew a single-seat, solar-powered aircraft, Icaré. Not only was this project a promotional success for Stuttgart University, but more importantly it was also a well-planned educational initiative that was subsequently driven and largely managed by students[3].

Immediately, it should be recognised that both these projects were clearly not primarily intended as commercial enterprises – a financial constraint to which industry is necessarily bound. However, there can be little doubt that the realisation of both these real, full-scale aircraft projects resulted in massive learning outcomes.

With these background thoughts in mind, it should now be obvious why QMW recently made the decision to embark on the

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[†] It should be noted here that the term “full-scale aircraft” does not necessarily preclude the idea of developing scaled aircraft; but it is intended to separate-out the notion of amateur aeromodelling – which does not usually rely on any firm engineering methodology. (And note, it does not separate-out the development of “micro-air vehicles” which must be considered acceptable, along side the development of unmanned aircraft, RPVs etc.) The terms “complete” and “with certification” might be more appropriate.

[†] Note, for example, the sailplanes of the German academic flight (Akaflieg) groups have not been included here, nor have numerous joint industry-university ventures.

development of a full-scale prototype aircraft. The remainder of this paper outlines the rationale and goal of this project – dubbed "Project Orion" - which has recently commenced and is expected to run in QMW from now until about 2003.

2. Selection of a Suitable Aircraft Project for Educational Purposes

2.1 The Need

The benefit and rationale behind full-scale, university-based, aircraft projects has been loosely expressed above, but the specific need and role of such projects within typical engineering programs has not been addressed in any detail. Here, the recent experience of QMW may be relevant and typical.

Students studying aerospace engineering at QMW have to undertake a sequence of module based courses which collectively lead to a program of study that is accredited by the Royal Aeronautical Society and the Institute of Mechanical Engineers. In the fourth year of the Master of Engineering Program, accreditation requirements sensibly call for multidisciplinary group project work (with design and manufacturing content) linking and building upon previous module material - as well as improving student teamwork and group leadership/management skills. Hence, within the framework of accreditation alone, the need for aerospace design-make-and-test projects is currently evident – providing a compelling reason to introduce full-scale aircraft development projects.

Along side this rationale, the other main reasons that QMW decided to embark along the path of a full-scale aircraft development were:

a) It was clear that an ambitious goal of developing an aircraft would help to confirm QMW's reputation in aerospace education, hopefully resulting in the recruitment of creative and enthusiastic students – who have a genuine interest in aeronautical engineering.
b) It was recognised that a large-scale aircraft project would help to provide an identifiable goal for teaching activities – reinforcing teaching material.
c) It was anticipated that the aircraft would also provide a suitable flight test-bed for promising research activities, which would be more difficult to tackle in a wind-tunnel or with simulation methods alone.

Interestingly, these openly stated arguments readily translate into a set of draft project requirements – which can be directly employed in a student project brief (without any veiling or disguise).

2.2 The Constraints

Having established the above (preliminary) project requirements - which probably have some generality to other university-based aeronautical courses, it is important to mention some constraints. These include limitations on facilities, personnel, technical capability, safety, budget and time-scale. At first sight, all of these constraints appear daunting – even prohibitive. But, as has been stated already, other universities have managed to achieve notable goals.[†]

One of the best-defined but most demanding constraints to consider is the timetable of the academic module system. Operating within the timetable constraint means that only 24 weeks are available per year for project work and a fresh set of students have to embark on the project in any given year – breaking project continuity. However, this constraint can be viewed positively in so much as it only demands that the aircraft development has to be broken down into well-defined work-

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[†] In the U.K, it is interesting to note that some previous aircraft projects[4,8] could only progress by bypassing the academic system to some extent. For example, the first human powered aircraft to fly "SUMPAC"[8] was built partly as a 'sideline' by most of the project members, i.e., mainly outside the academic curriculum.

packages – strongly suggesting the need for a rigorous systems engineering approach.

The other project constraints are less well defined and variable. For example, project finance is often dependent on sponsorship - which is difficult to predict. Constraints on facilities, personnel, safety and technical capability tend to be perceived constraints that are often exaggerated. Nevertheless, perceived constraints do tend to add inertia - slowing down new initiatives.

2.3 Selection of an Kit Glider as a Aircraft Project Basis at QMW

After consideration of all the constraints in QMW, it was recognised that one possible way forwards was to purchase an aircraft kit (kit-plane) effectively catapulting an aircraft project into existence by giving it a starting foundation. Interestingly, this idea was met by the immediate objection that a kit-plane would restrict student freedom in the conceptual design phase – one of the most important/creative design phases - and hence negate the overall pedagogic rationale. But, in response, it was argued that most kit-planes are less than 50% complete, and at component or subsystem level substantial *carte-blanche* design work is still required. Furthermore, if a project brief calls for a derivative of a kit-plane (rather than a slight departure from the actual kit plans), then conceptual design at overall system level is retained. Of course, the effect of using a kit-plane will necessarily imply *a priori* constraints on the aircraft's size and primary structure etc., but this can be viewed positively - since it helps to reduce a rather excessive multitude of concept options.

Having accepted this argument, the next controversial problem (at least within the history of this project) was the choice of the kit-plane itself. Here, a major constraint was that the basic kit (alone) had to cost less than £15,000. While there is a plethora of kits within this budget range, many of them are ultra-light flexi-wing aircraft with rather unsatisfactory designs that would have left little scope for derivative options. After a short period, however, the Edgley EA-9 glider kit[9] emerged as a leading contender for possible selection, see Fig.1. Some of the advantages of the EA-9 kit were:

a) The EA-9 had only just been introduced onto the market and it remains unique as a kit-glider.
b) The basic design appeared itself to be well thought through and hence was considered instructive, educationally.
c) The airframe is novel since it makes extensive use of Hexcel Fibrelam™ composite panels, which appeared to be interesting, educationally.
d) There appeared to be plenty of scope for derivative options, in particular a powered derivative (with a relatively small powerplant[†]) was immediately identified as one possibility.
e) Linkage with Edgley Sailplanes also appeared to be promising[*].

In June 1999, therefore, an order for an EA-9 kit (empennage and fuselage) was placed by QMW, and to date many of reasons for selecting the kit have been validated.

[†] The minimum flight power to sustain the EA-9 in straight and level cruise is about 2.2-2.4kW. With modification (e.g., by adding wing tip extensions), it is possible to reduce the power level slightly to permit sustained cruise with an engine/motor with an output of about 4-5hp. The use of active boundary layer control can also be envisaged as a possibility to reduce power levels further.

[*] Note: another kit-plane was rejected since the chief designer stated he had: "no interest in university graduates". The staff at Edgley Sailplanes Ltd., on the other hand, were most constructive in this respect. To date, for example, two summer student placements have taken place and it is hoped future sandwich arrangements might be possible. New and promising ideas for possible joint research are also emerging.

Fig. 1: EA-9 "Optimist" glider in flight, (single-seat, span 15.7m, maximum take-off mass 335kg), courtesy J. Edgley.

3. Project Orion: Phase 1

3.1 Project Progress

In the 1999-2000 academic year at QMW, a group of 8-10 Master of Engineering 4th year students started Project Orion. Their project task involved:

a) Creating a system-architecture (and configuration coding) for an EA-9 derivative.
b) Generating a comprehensive aircraft design specification (around the EA-9 airframe).
c) Investigating and ranking possible (powered) derivatives of the EA-9, that could be used as a flight test-bed – possibly leading to an unmanned long-endurance aircraft capable of auto-soaring for remote-sensing applications.
d) Carrying-out performance studies on the EA-9 derivative aircraft.
e) Producing 3-D CAD models of the fin and tailplane – predicting mass, c.g. and moment of inertia, etc., as well as suggesting possible control surface actuators etc.
f) Commencing the construction of the fin and tailplane of the EA-9 (without structural modification) verifying the mass and c.g. position.

3.2 Studies of the EA-9 Derivative

After carrying-out a Quality Function Deployment on the customer of the aircraft (the author acting on behalf of QMW), the student team converged on an unmanned derivative aircraft that would involve the following basic design changes:

a) Replacing EA-9 mechanical control linkages with a fly-by-wire system.
b) Incorporating an electric propulsion system (at least for preliminary flight-testing).
c) Extending the wings of the EA-9 (using winglets and/or a wing extension) to reduce flight power.
d) Replacing the canopy and with a new nose structure.

One early concept sketch (a simple CAD model generated by the students) is shown in Fig. 2.

3.3 Aircraft Construction Progress

Construction of the EA-9 fin and tailplane was carried-out by the student team earlier this year, and the latter assembly was passed as airworthy in a British Glider Association (BGA) inspection.

In was interesting that this hands-on activity (while appearing to be a relatively modest task) proved to be relatively challenging to the students concerned. This was partly because of the intensive team-working required and also because they had to work within stringent safety constraints (concerned with the use of epoxy resins and the handling of Fibrelam).

The constructed tailplane is shown in Fig. 3, along with the student team.

4. Concluding Remarks

It is too early to arrive at any conclusions concerning the educational benefits of Project Orion. Instead a few emerging challenges regarding project organisation and student motivation spring to mind:

a) One of the drawbacks so far encountered is that some students appear to lose motivation if intermediate project targets are not well defined, since the scale of the overall project goal appears daunting. However, in contradiction with this idea, if intermediate targets are well defined, then the design outcome is effectively predetermined to some extent (which is not educationally desirable). Note also, one undesirable effect of having different student teams tackling the development in each successive academic year, appears to centre on the notion of a lack of product ownership. In particular, the fact that early teams are not able to witness final flight-testing, appears to be a significant factor in reducing motivation.

b) Some students often appear to be driven by assessment criteria, rather than (say) the aircraft's performance criteria or the success of the project itself. Assessment schemes have to be carefully built-in to any such project, since the introduction of interesting aeronautical challenges (alone) do not appear to guarantee uniformly high motivation levels within a student group.

c) When posed with the real problem of aircraft development, with all the (exacting) quality assurance documentation requirements, student team organisation appears to be a critical factor determining satisfactory progress. However, here it should be noted that the subject matter of safety and quality assurance is probably best taught through projects such as this†.

Whatever the outcomes, it is hoped that a future presentation to an ICAS conference will be made after the derivative aircraft has flown successfully, and then the real gains of the project will hopefully be proven.

Acknowledgements

I would like to thank John Edgley and Mike Woollard (BGA) for their assistance. Thanks also go to Prof. John Stark and the staff at QMW - for supporting the vision of Project Orion - although any misconceptions and/or errors herein are entirely my own.

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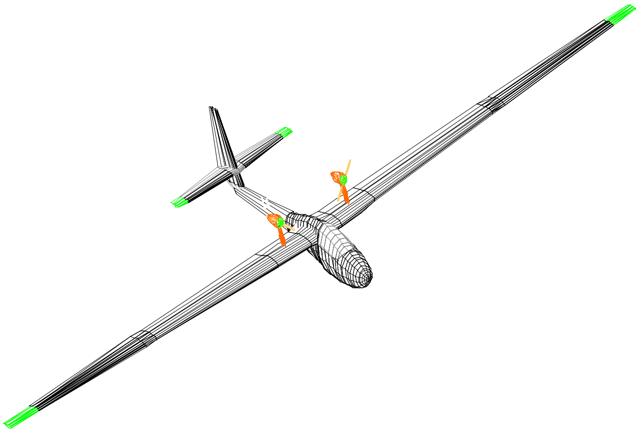

Fig. 2 Concept sketch of possible QMW EA-9 Derivative (with twin over-wing propulsion pods and fly-by-wire control system: all-up-mass: 335kg, span 15.7m increasing to 19.7m, cruise power 2kW at 17m/s).

Fig. 3 1990-2000 M.Eng. Project Orion team with EA-9 tailplane, from left to right: Eniola Thompson, Sam Kim, Anthony Fry, Imtiyaz Hussain, Patrick Yeung, Marc Field, Miles Kijewski, Liaqat Ali.