Flight Testing in Aircraft Design Teaching: Implementation and Impact on Student Experience

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Aero engineering courses at Sheffield Hallam University (SHU) have been offered by the established Department of Engineering and Mathematics for a number of years now.

Seeking ways to improve student experience, the possibility of incorporating flight testing into the course was investigated.

Students were taken to Cranfield University for a two-flight course in a Jetstream Aircraft.

Students were asked to complete a questionnaire on their experience.
Typical Course Structure at SHU

BEng(Hons) Aerospace Engineering
Flight Testing
Why Flight testing?

- Consolidate learning from levels 4, 5 and 6;
- Contextualise learning;
- Develop student self-confidence;
- Meet RAeS accreditation requirements.
"Students on aerospace programmes accredited at CEng level by the RAeS should benefit from a practical flight test. Therefore, the Form ACC2 should include a statement on the School's policy on this matter. The Society recognises that the capability provided by flight simulators is expanding rapidly and that it is possible to make use of such devices in aircraft design courses to ensure satisfactory handling qualities and also to cover a wide range of quite realistic flight simulation that complements practical flight test. **With regard to the latter however, it is the Society’s view that practical flight test and associated flight briefings provide students with experience that is not attainable from simulation alone.** Therefore, the Society believes all students on accredited programmes in aerospace engineering and related topics should experience elements of practical flight test and it accepts that it may be possible to reduce the extent of the practical aspect within a carefully integrated programme involving both practical flight experience and simulation."

• Aircraft design is a level 6 module taken by aero students at SHU.
• Module aim: "Using a systematic design process, students will be involved in applying their previous knowledge in the specification, detail design, analysis, performance improvement, simulation (and where relevant, testing) of aircraft and sub systems."
• Working in groups, students design an aircraft to a given brief, developing and refining their design using flight simulator facilities at SHU.
1) Buy an Aeroplane!
   • Fun experience but...
   • Cost of buying and maintaining plane
   • Vagaries of British weather(!)
   • Need to take students individually or in small groups
   • Issues around feasibility of instrumenting aircraft?

2) Enrol Students on an Established Course
   • The National Flying Laboratory Centre (NFLC) at Cranfield University have an established flight test course
   • Courses can be tailored
   • Course includes a briefing and de-brief by Cranfield staff that complements the flight experience

[2] "G-BUCT (7129006795)" by GerardvdSchaaf - G-BUCT. Licensed under CC BY 2.0 via Wikimedia Commons
The notion of an establishment dedicated to 'aeronautical science' was first mooted in 1943, with courses starting at Cranfield in 1946.

From the outset numerous instrumented aircraft, were used as flying classrooms and for research.

Avro Lancaster
(research aircraft in 1960s, now with BBMF)

DeHavilland Dove
(flying classroom 1949-1975)

Jetstream Mk1
(flying classroom 1972-2004)
Current Flying Classroom

What the aircraft does?

• Flying laboratory courses for undergraduates, postgraduate and other professional courses
  – Flight Dynamics
  – Performance
  – Avionics

• Additional flight test for industry (carrying units for test / evaluation)

Jetstream 31 (flying classroom 2004- )
• There is a rack mount PC at the back and each seat has a 10.4 inch screen
• The information displayed on the screens is controlled by the on-board instructor
Straight and level flight:
• Lift = Weight
• Drag = thrust (estimate from Torque / rpm / Power / Propeller curves)
• Performance – Fuel Flow / TAS, Specific Air Range, best speeds
• Drag Polar – Best Lift to Drag

\[ \text{Lift} = \frac{1}{2} \rho V_e^2 S C_L \]

\[ \text{Drag} = \frac{1}{2} \rho V_e^3 S C_D \]
From initial steady condition demonstrate:

- Short period pitching oscillation
- Phugoid
- Dutch roll (with w/o yaw damper)
- Roll mode
- Spiral mode

**Dynamic Modes**

![Axes and Flight Controls](image)

- Angle of attack
- Pitch rate
- Elevator angle
- Airspeed
- Pitch attitude
- Yaw rate
- Sideslip angle
- Rudder angle
Use initial trimmed condition:

- Elevator angle $\propto$ tail pitching moment
- Record elevator angle / $C_L$ through airspeed range
- Repeat with different CoG's
- Calculate static margin
Students completed a questionnaire covering the following aspects of the Cranfield course:

- Pre-flight Briefing
- Course Handbook and In-flight Tasks
- Flights
- Post-flight De-briefing
- Organisation

Questions were designed to collect quantitative and qualitative data.
The pre-flight briefings sessions were pitched at a level that was:

- entirely appropriate and interesting
- mainly at the right level and helped my understanding
- lacking in clarity which resulted in me experiencing some confusion
- entirely beyond my understanding

A positive response by virtually all students. It may be that the student recording a negative comment had misread the question.
The handbook that included information, tables, graphs etc. was:

- the information is very difficult to understand
- some of the information is too complicated to understand
- has lots of information but some is of limited use
- well presented and full of useful information

The handbook met the approval of two thirds of students and those that were less enthusiastic recognised that there was lots of information but seem doubtful about its use.

There maybe an opportunity to link the content of the handbook to teaching at SHU prior to the flight experience.

There is a possibility that the individual student that had difficulty could be an incorrect entry.
### In-flight Tasks - Comments

<table>
<thead>
<tr>
<th>Example Supportive Comments</th>
<th>Example Issues for Consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;I was able to fill all the results except one during the manoeuvre banking at 60°.&quot;</td>
<td>&quot;The only problem was the fact that we couldn't hear the call out over the tanoy [sic] system.&quot; (plus three similar comments)</td>
</tr>
<tr>
<td>&quot;All tasks were fairly easy to complete and answered during the flights.&quot;</td>
<td>&quot;These tasks were interesting but a little repetitive.&quot;</td>
</tr>
<tr>
<td>&quot;The tasks were relatively easy to complete given that the screen conveyed the information well.&quot;</td>
<td>&quot;It was difficult to write and fly.&quot;</td>
</tr>
<tr>
<td>&quot;It was great and had good experience how the aircraft came back on its own level after disturbance.&quot;</td>
<td></td>
</tr>
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Flight Testing

**Flights**

- Well organised: 17 responses
- Hard work and demanding: 2 responses
- Stimulating learning experience: 15 responses
- Helped me understand aspects of flight theory: 16 responses
- I learned a lot about aircraft performance: 17 responses
- Needed more help from Flight tutor: 4 responses
- Good fun: 21 responses
- Exciting aeroplane to fly in: 17 responses
- Boring: 0 responses
- I learned a lot about flying: 13 responses
- Flight tutor was good at explaining things: 10 responses
- Limited time to complete in-flight tasks: 2 responses

**Question 6**

Students invited to make multiple responses.
Flight Testing
Flights - Observations on Results

- Student responses indicate that this was a beneficial learning experience as it helped develop their understanding in several ways particularly underpinning more theoretical aspects of aeronautical engineering.
- Examples of this are: "I learned a lot about aeroplane performance" (17) and "helped me understand aspects of flight theory" (16).
- A small number recorded it was "hard work and demanding..." (2) and "needed more help from the flight tutor" (4) statements indicating that this very small group would benefit from further help.
- Large numbers of students recorded it was "good fun" (21) and "exciting aeroplane to fly in" (17) indicating this was a worthwhile learning experience.
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<td>&quot;Interesting and relevant enhancing knowledge already learned on the course.&quot;</td>
<td>&quot;Some parts were interesting but long.&quot; (plus four similar comments)</td>
</tr>
<tr>
<td>&quot;Pretty interesting with comparison to the theory.&quot;</td>
<td>&quot;Fairly interesting, needed to be more involving to maintain interest.&quot;</td>
</tr>
<tr>
<td>&quot;Useful information in understanding the results and how it differs from the real world.&quot;</td>
<td>&quot;A little mundane but interesting about the results.&quot;</td>
</tr>
<tr>
<td>&quot;Useful summation of results gathered and reasons for operating the aircraft at various performance levels.&quot;</td>
<td></td>
</tr>
</tbody>
</table>
• **How well was this flight experience organised by SHU?**

![Bar chart for Question 9 with n=24]

- Poor: 0
- Satisfactory: 8
- Very well: 16

• **Was the organisation by Cranfield staff:**

![Bar chart for Question 10 with n=24]

- Disorganised: 0
- Satisfactory: 7
- Very good: 17
<table>
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<tr>
<td>&quot;Earlier in the year because people who aren't pilots can grasp the idea of what a passenger plane feels like to extreme conditions.&quot;</td>
</tr>
<tr>
<td>&quot;Maybe do in year 2.&quot;</td>
</tr>
<tr>
<td>&quot;Do more of this kind of thing to help understand what we learnt in class.&quot;</td>
</tr>
<tr>
<td>&quot;Integrate directly into the module.&quot;</td>
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<tr>
<td>&quot;More to do on breaks between flights.&quot; (plus one other similar comment)</td>
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</tbody>
</table>
Conclusions

- The Cranfield Flight Test course has been successfully incorporated into the aero courses at SHU.
- Feedback shows that the experience has been well-received by students.
- There is a need to build on the positive experience by further integrating into the module.
- Further work with staff at Cranfield University may help to achieve this, for example use of CFD models of the aircraft, flight test data, etc in teaching.