Can flight simulators at university level better prepare and motivate tomorrow's aeronautical talent?

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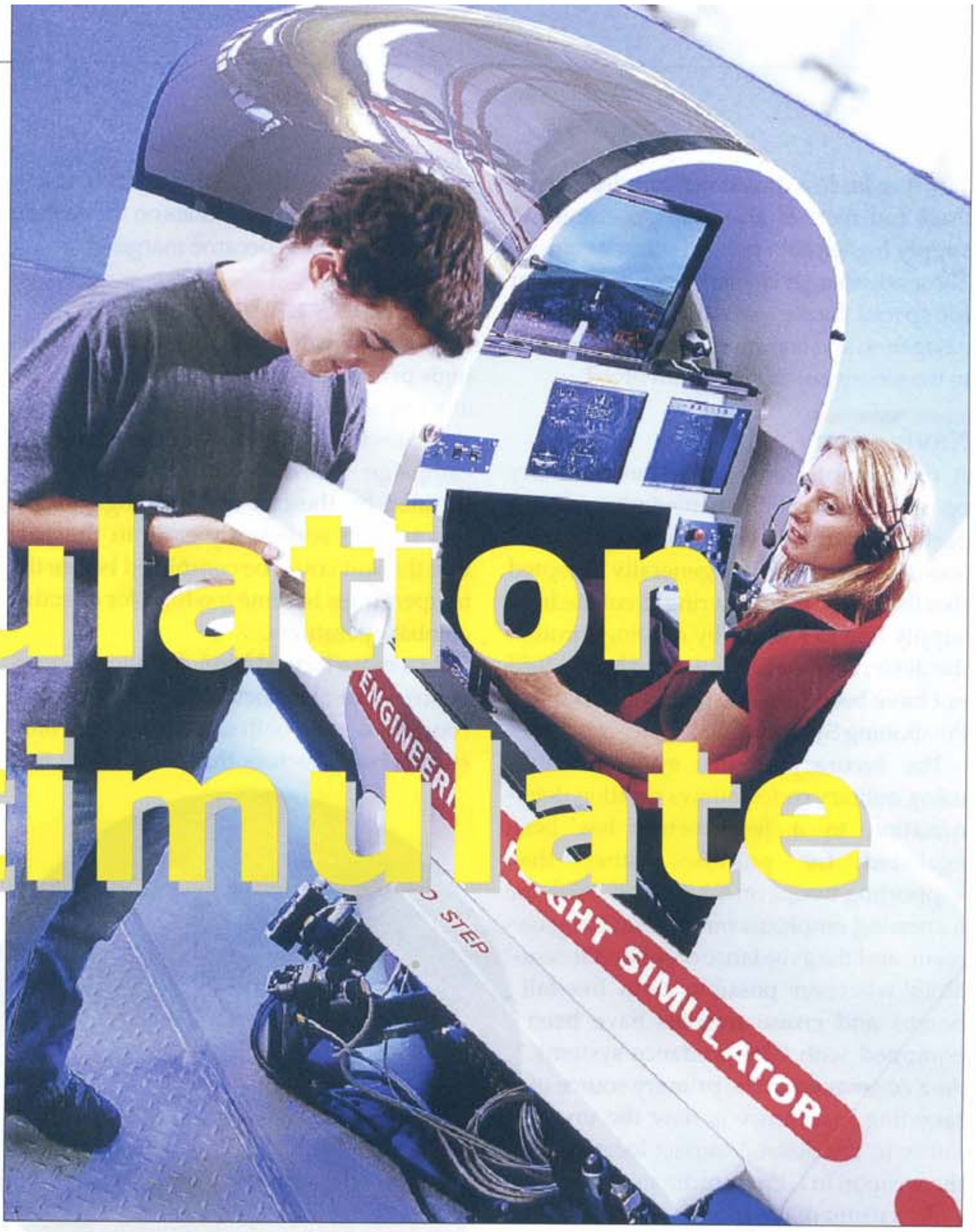
Simulation to stimulate



Simulation is, of course, an important part of any test pilot's and design team's work today — to test and verify that computer predictions match real flying and handling characteristics. However, equally important and now today perhaps neglected, is the role of teaching engineers and students the effect of their design decisions on handling qualities. With fewer aircraft projects to work on and funding tight for even official demonstrators, simulators can step-in to provide that feedback as to good and bad design decisions, allowing the aeronautical trainee to be 'inside' his or her design and thus understand the principles of flight directly.

There is another important point to be made as well. With today's aircraft getting more and more complex, needing larger design teams, the role of the overall designer has been subsumed into larger and larger teams. While most in the aeronautical profession know the names of Sir Sydney Camm, Reginald Mitchell and even Joe Sutter, many would struggle to name the lead designer of the A380, Eurofighter Typhoon or JSF. One of the by-products of these larger teams is that the opportunity for feedback from pilots to engineers may be limited. This is not to say that there is no feedback at all, for nowadays Airbus, Boeing and all the major manufacturers take great lengths in getting pilot and operator input into everything from cockpit trim colours to rest areas as well as the instrument layout and handling qualities — the traditional areas of feedback from pilots.

However, this feedback will usually be disseminated to certain specific teams and because of the amount of people involved, may take the form of written reports rather than face-to-face debriefings — leaving some engineers one step removed from the actual users.

For aeronautical students who then go on to specialise in flaps, landing systems, fly-by-wire etc., this lack of knowledge of the human factor in the cockpit could, in fact, hold them back in later careers. There is a worry among some that, while fly-by-wire computers and modelling may mean there is no such thing as a poorly handling aircraft anymore, there is a gradual loss of basic aerodynamic corporate knowledge that could produce the next Burt Rutan.

In addition, there is also anecdotal evidence that there is, worryingly, a dearth of even basic aeronautical knowledge about how aircraft fly among incoming students that may mean that simple concepts like the joystick, stalls and the four forces may need to be explained to them. As Marion Neal from Merlin Flight Simulation says: "Although there are many really bright students on the aero courses, there are also plenty who are not even *au fait* with the terms rudder and aileron when they start their course. Only a small proportion of aero students have had the chance to fly an aircraft and thus be aware of the responses to pilot inputs."

This may be no drawback in one sense, as that is what the university or college is there to explain and it may make for an easier time for lecturers if everyone starts from the same level. However, using flight simulation, all students can be quickly and easily, brought up to the same level, whatever their background knowledge.

Even for those students attracted to a career in the growing unmanned air vehicles field it may be useful to 'sit in' various UAV configurations at an early part of their career to understand why one configura-

Left: Merlin Flight Simulation Group's MP521 simulator at UWE.
photo credit: Barry Willis

tion may be better for sensor stability, or STOVL operations than another, equally attractive design.

Handling competition

One approach is through the use of university level simulators which allow students to create and adapt designs in a virtual world, fly them (or have them flown) and then get immediate feedback of the design. One company producing these simulators is Merlin, which also organises the annual Merlin Aircraft Design and Handling competition. This year's competition, held at the Royal Aeronautical Society on 5 June, used two distinguished test pilots, Harrier legend John Farley, and David Southwood from the Empire Test Pilots' School (ETPS) at QinetiQ to 'fly' the designs and assess them. A total of 12 teams entered the competition, with entries ranging from a Beluga-type mega transporter to carry A380 wings to a STOL city feeder aircraft, the Smartfish concept, light aircraft and even a successor to the A-10 (see full report in *The Aerospace Professional*, August 2006).

One aspect that emerged from the competition was the high standard of knowledge needed to produce an aircraft with good handling qualities. In spite of computer simulation and for some entrants, what looked like tried and tested designs (including for one team, a virtual 737 — an aircraft that has been in service some time and on which much information is freely available), small defects or changes had large effects from the pilot's point of view that made, one or two designs in fact, almost uncontrollable for the test-pilot and therefore extremely dangerous for the average service or airline pilot. The flight model incorporated into the sim was therefore sophisticated enough to bring out these flaws and provide feedback that an experienced test pilot could diagnose and report on.

As well as the 'in-flight' commentary from the test pilots during the handling assessment phase, the students received a thorough debriefing and tips from these experienced aviators — a priceless interactive learning experience that no textbook could provide.

As Chris Neal, managing director, Merlin, comments: "This may be the only time in their aeronautical careers that they receive direct feedback from a test pilot on their design."

Merlin

The Merlin Flight Simulation Group itself specialises in high-end university simulators, complete with a cockpit, controls and an instructor's station. Even with a fixed base, the enclosed space replicates being in the cockpit of a small aircraft like a fighter or glider. This is enhanced by the ultra-smooth updates which add to the illusion of flight.

The cockpit is equipped with throttle, sidestick controller and pedals plus a microphone and headset for speaking to the instructor's station. For the Merlin handling competition in June, the in-cockpit HUD images were repeated (along with the pilot's commentary) via a projector to a rapt audience of the other entrants in the Society's Bill Boeing Lecture theatre, enabling them to learn from others' mistakes and successes as well as their own.

Merlin offers two types of engineering simulators for the university market — the MP520 and MP521. The flight software, Excalibur, is designed to be extremely user friendly to students to alter, change or incorporate their own designs into the Merlin sim.

Among the universities using Merlin simulators are the University of Manchester, University of Leeds, Kingston University, Queen's University, Coventry University, University of the West of England, University of Salford, University of Hertfordshire and Brunel University.

The latest, the MP521X, not only is a teaching tool but also a FNTP1 (Flight Navigation Procedure Trainer) device. Leeds University was the first to take delivery of this full-motion sim which will help students not only to grasp the basics of flight but learn to fly themselves — an extremely efficient use of resources and major selling point for students considering studying at Leeds.

The simulator, which was delivered to the university in May, will be used for teaching and research for students on BSc (Hons) Aviation Technology with Pilot Studies, BSc (Hons) Aviation Technology and Management and the university has already reported interest from outside organisations such as flying clubs and schools who are interested in hiring the sim when it is not being used by students.

Cuesim

Another company specialising in high-end simulators for university teaching and research is Cuesim, a QinetiQ subsidiary, which also produces simulators for helicopter flight training and military battlelabs. Cuesim incorporates a 6-DoF (degrees of freedom) axis motion system as standard to provide feedback and motion cues.

Cuesim offers two of its Explorer models for the university market, the Explorer RD (for research) and the Explorer TC (for teaching). While the RD model uses an advanced flight model that is compatible with MATLAB/Simulink, the TC version uses a DATCOM (based on a USAF simulation toolset)-driven model — for ease of use.

The HUD view and test pilot's commentary was repeated on a large screen for the audience at the Merlin Aircraft Design and Handling Competition at Hamilton Place.

It has supplied one example to the University of Liverpool for use in a helicopter teaching and research sim — Heliflight (an in-depth look at which was provided in *The Aeronautical Journal* in September 2003). Other universities using Cuesim simulators are: Queen Mary and Westfield College, University of London, and University of Sheffield.

Above: The University of Liverpool's Heliflight simulator, based on a Cuesim design.

An alternative approach

An alternative lower-cost approach to buying custom-made expensive simulators is to use the ever-increasing in sophistication consumer simulations such as Microsoft's *FS* series or Laminar Research's *X-Plane*. Though 'games' as such, the realism which these can now incorporate, coupled with their ease of use and flexibility, means that these, too, can be used as teaching tools.

Dr Kenji Takeda at Southampton University is a keen advocate of this approach and says he first saw the possibility of using sims when he realised the growing power of home computers was being driven by the games industry and that this would have implications for the design and usage of low-cost teaching sims. He adds that, because of these drivers, it is no longer feasible that even the larger simulation and visual display companies can afford to make their own graphics chips or cards — they too, must hitch a ride on the video game juggernaut to take advantage of lower costs, higher volume and ever increasing realism in visuals.

In fact, the latest developments in video games are 'physics' embedded in the game and already a hardware manufacturer (Ageia) is bringing out a separate card (PhysX) to do physics processing. This means that this could be the next gaming revolution which might be harnessed for the professional flight simulation community — in order to calculate airflows, turbulence, centre of gravity shifts or post-stall behaviour etc.

Southampton's set-up

Southampton University has a dedicated simulator set-up in Aerospace Engineering, in the School of Engineering Sciences, using Microsoft's *Flight Simulator 2004* and enhanced with photo scenery and is what should be more correctly termed a 'part task trainer' rather than a full flight simulator. The simulator uses three wall-sized screens and is in the process of being constantly upgraded by students, with the next addition, says Dr Takeda, of professional-level video cards.

In the first year on the course students use the simulator to learn basic flight mechanics such as the functions of the control surfaces and secondary effects from turning etc. They will also experience stalls and by the end of this introductory period will have experienced the difference in speed between a light aircraft and military jet. In this brief introduction the student will therefore have been exposed to the concept of practical aerodynamics and also have performed a take-off and landing in the sim. Some indication of how popular this is, says Dr Takeda, is that, when this activity was added to the first year course, it led to much grumbling from the then second and third year students at being 'left out'. As Dr Takeda says: "The simulator is a highlight of the course."

In the student's second year in the course they are taken up in a real aircraft — a Jetstream for flight engineering tuition. Finally, third/fourth year students, as a large project have to design an aircraft in a team, and it will then be virtually test 'flown' within the simulator and assessed.

Dr Takeda notes how it illustrates the importance of simulation in teambuilding. "In normal paper aircraft design exercises there is an opportunity for students to contribute a chapter on their speciality almost without talking to the rest of their team. However, with a 'real' (if virtual) first flight the flight engineer must gather the correct data from all participants and this acts as a catalyst to bring the team together. If the data isn't right, then the aircraft won't fly. So when the design is first tested in the sim it really is quite nailbiting — almost like the first flight of real aircraft."

"This provides huge motivational benefits, there's a real sense of achievement that tops handing a report in on time. They've built something and that is what engineering is all about." he says.

Among the design projects have been concepts for a Royal Flight replacement,

Southampton University's *FS2004*-based simulator set-up features three large screens and an ejection seat.

and an innovative research handling study which broke new ground by comparing pilot's subjective evaluations of cockpit workload in different situations with objective data taken from joystick movements which was then analysed.

For the next upcoming project for a fourth year course, Dr Takeda plans to set a team of seven students a challenge to produce a '21st Century Spitfire' which will see if a modern team, given the same RAF specifications, engine and armament, but modern materials and design tools, can design an aircraft that will beat R.J. Mitchell's legendary fighter. And in true face-off style, the team's design will face off against a Spitfire in a virtual dogfight to find the winner.

Simulation limitations

However, many still have doubts about using a commercial product like Microsoft's *FS2004*, where its visual model is separate from the flight model (and thus you could make a brick fly with the same performance as Concorde merely by swapping round two files.). Marion Neal from Merlin agrees: "You get what you pay for — for proper evaluation and research of aircraft models you do need a really good aerodynamic model. Difficulties may arise with certain academics — who are not pilots — and therefore cannot see why they should not use a package such as *Microsoft flight sim* or *X-Plane* for serious evaluation."

Dr Takeda admits that there has been 'resistance' to Microsoft's offering but explains that there are advantages and disadvantages to the different methods of calculating flight models. He explains that 'table-based look-up' sims (like *FS2004*) have some advantages — he says with the right data, they can be closer to the published performance. With 'on the fly' algorithm-based simulations (which may be calculated in real-time using aerofoils, wing areas, chords and fuselage shapes) one poor piece of data can throw the entire aircraft model out. He also argues that even the best algorithm-based flight models can monitor only a tiny fraction of the millions of variables you would really need to create a fully representative and realistic simulation. Thus, while *FS2004* (and the soon to be released FSX, coming in October) has its limitations, for some teaching purposes, he argues, it may be equally valid.

Getting them young

Indeed, for some younger students a fully realistic flight model may not be needed. Dr Takeda is also on a mission to demonstrate that flight simulation can be used to stimulate a new generation of engineers from ages as early as 11. In conjunction with Microsoft he has given out 50 copies of *FS2004* last year to schools and has helped design lesson plans to encourage children to study maths and engineering, using flight simulation as an interactive (and fun) teaching aid) as well as taking on the road a portable A380 simulator for children to try.

In addition, with the Future Flight competition, part of the RAeS's Greener by Design initiative, young people are being challenged to think about new solutions for the problem of aviation's dependence on oil, by designing a 'green' airliner that would then be replicated to 'fly' in *FS2004*.

Below: Aero engineer of tomorrow? A youngster gets to grips with a simulated A380.

Conclusion

It is clear, then, that simulation at the university level can be an important teaching tool in bringing to life Reynolds numbers, stall speeds and, in the case of getting feedback from the pilot, understanding the link between aerodynamic or design choices and the human in the cockpit. Whether the student then goes on to specialises in night vision systems, UAVs or even cockpit design, this is a useful primer into the basics of how aircraft fly. As Dr Takeda puts it: "if you get a car designer you would expect them to have a driving licence or at least to have been in a car. Without simulation you could theoretically do an aeronautical degree without experiencing how a aircraft flies."

Surprisingly in this field of using simulators to motivate and teach aero engineering students, the UK may be ahead of other countries. In the US, for example, while sims are used at university level, these are tied into flight training courses designed to produce pilots — rather than as tools to help foster a new generation of engineers.

There also may be little-discussed motivational benefits in exposing students to the simulator and especially test pilots. As well as encouraging them to pick the course from the prospectus in the first place ("hands on stick time at our advanced flight sim — and design your own aircraft") the experience may even help them stay the course and accept being part of a bigger, more faceless team later in life, having 'proved' that they could design a flyable aircraft earlier in their career.

Whether high-end motion simulators or off-the-shelf flight training devices, based on consumer video game technologies are used, it is clear that simulation has a great part to play in teaching and encouraging the next generation of aero-engineers and extended to school children, may even inspire them to study maths and engineering — a growing issue for Western countries. ◆