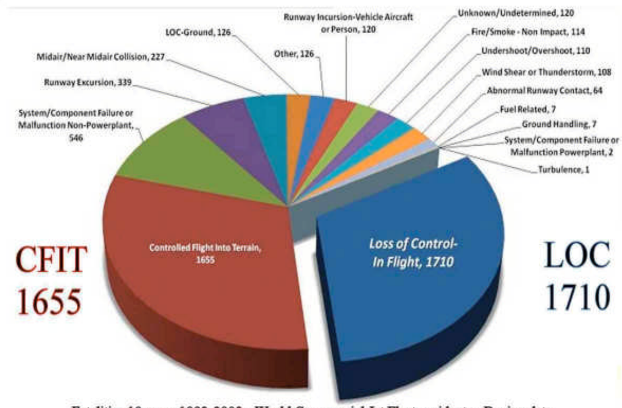
Training on the Edge

The Edge of the Flight Envelope is critical for Upset training

by Ian Strachan MBE AFC FRAeS

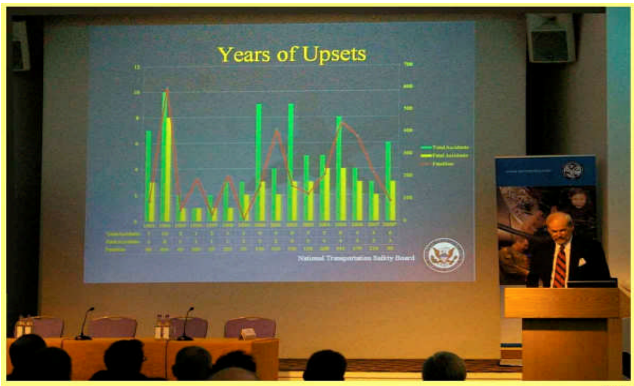
The London-based Royal Aeronautical Society organises several conferences each year with training themes. The Society's Flight Simulation Group organises two-day conferences in June and November, and a conference on more general aviation training is held in September. In June 2009 the theme was "Flight Simulation - Towards the Edge of the Envelope". There was considerable support from the American Institute of Aeronautics and Astronautics (AIAA), from which representatives were present and several made presentations. The reason for this subject was that the main cause of commercial aviation fatalities is now In-flight Loss of Control (ILOC), this having overtaken Controlled Flight Into Terrain (CFIT) in recent years. The conference explored how the edges of flight envelopes can be trained better in simulators and in aircraft, both on type and on others better suited to training for upset manoeuvres. Although military aspects were covered, this article is about commercial air transport.



Fatalities 10 years 1993-2002 - World Commercial Jet Fleet accidents - Boeing data

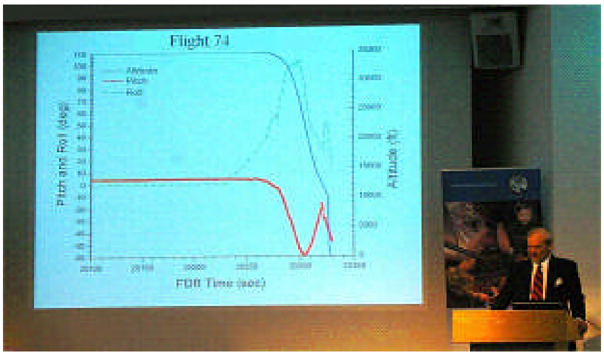
Opening the conference, RAeS President Dr Mike Steeden said that flight simulation makes "a tremendous contribution and society owes the flight simulation industry great gratitude". Conference chairman Dr Sunjoo Advani continued by saying that "the real edge of the envelope is not only the aircraft and simulator, it is the human edge".

First, some statistics. Dennis Cryder of the US National Transportation Safety Board presented NTSB figures of Upset accidents over the last 16 years. These showed an average of 4.9 accidents per year, 2.8 of which involved fatalities. The fatality rate over the same period was 209 per year, a total of 3351 lives lost. Looking at all causes of commercial jet accidents from 1995 to 2007, figures from ICAO and the Commercial Aviation Safety Team (CAST) showed that 38% of fatalities were attributed to ILOC compared to 21% for CFIT, 12% for system failures (non-powerplant), 10% for runway excursions, 4% for collisions/near collisions, then other causes. Significantly, similar ICAO/CAST figures from five years earlier showed ILOC and CFIT being nearly equal. Compared to this, the proportion of CFIT accidents has reduced, whereas fatalities in Loss of Control accidents have increased by 20%.



Dennis Cryder of the U.S. NTSB with slide of upset figures

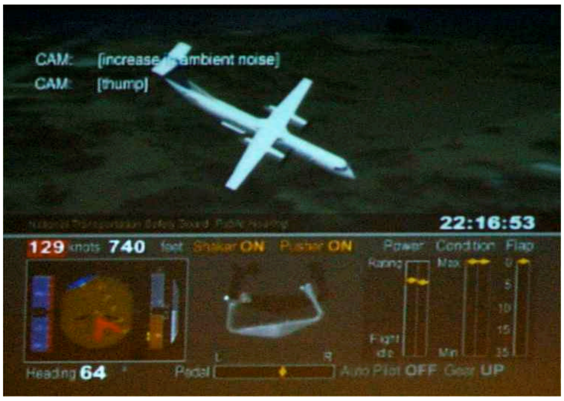
Photo: Ian Strachan



It was therefore no surprise that Captain Bryan Burks of the US Airline Pilots Association (ALPA) called for a higher standard of Upset training. He pointed out that, unlike the past, many commercial pilots had no military flying background, civil ab-initio training did not require either aerobatics or spinning, and stall training was limited. In addition, the increased use of automation in the airliner cockpit has led to a decline in manual flying skills. He called for a different philosophy for Upset training, to include the "precipitating event", followed by the strategies and techniques for recovery. The broader purpose should be "to teach pilots how to evaluate an Upset situation and fly back to a safe and stable condition". He said that many Full Flight Simulators (FFS) did not model Upset events properly and a "Level D Plus" simulator design was needed. Expanded flight simulator aerodynamic models needed to use real aircraft data from Flight Data and Quick Access Recorders (FDR/QAR) and additional data from organisations such as Calspan, the NASA commercial aircraft programme, and the aircraft manufacturer. Improved motion cueing was required and more indication of G was needed. In the end, the goal was "to marry expanded situational awareness, knowledge and judgement, with stick and rudder skills".


Example of presentation of Flight Data Recorder information

Analysing the detail of some Loss-of-Control accidents, John Cox, CEO of Safety Operating Systems of Washington DC, showed graphics of their flight paths. A common thread was a failure to recover from a stick-shaker/stall situation. In one case this started at Flight Level 330 and continued to impact with the ground. These situations were complicated by wing-drop and low roll-damping at altitude, leading to large angles of bank. In turn this sometimes led to a reluctance to push the yoke forward, or to hold it forward for long enough. In one instance where recovery was eventually made, several upset events were generated by a constant desire to pull back the yoke at inappropriate times instead of holding it forward or even just maintaining a neutral position once pitch and roll angles and airspeed had recovered to safe values. I used to be a military Instrument Rating Examiner (IRE) on Canberra and Hunter, and well remember testing Unusual Position recoveries using the Turn needle only with the Artificial Horizon covered over. This was generally no problem, but we were all used to aerobatics and G-forces. The drill was first to roll to reduce the indicated rate-of-turn to within plus-or-minus one, check for adequate airspeed, only then pulling the stick back where necessary. Another rule-of-thumb was that when applying pitch during recovery, a reversal of airspeed change indicated approximately the horizon position. Returning to the present situation, it is fortunate that the incidence of fatal ILOC events is low in scheduled airline service, but Cox's presentation showed an urgent need for better training, particularly in stick-shaker / stall / wing drop situations. His conclusions were that Flight Crew Training should emphasise stall recognition and recovery, and, on simulators, extensive work is needed to improve the accuracy of aerodynamic information at and beyond the stall.



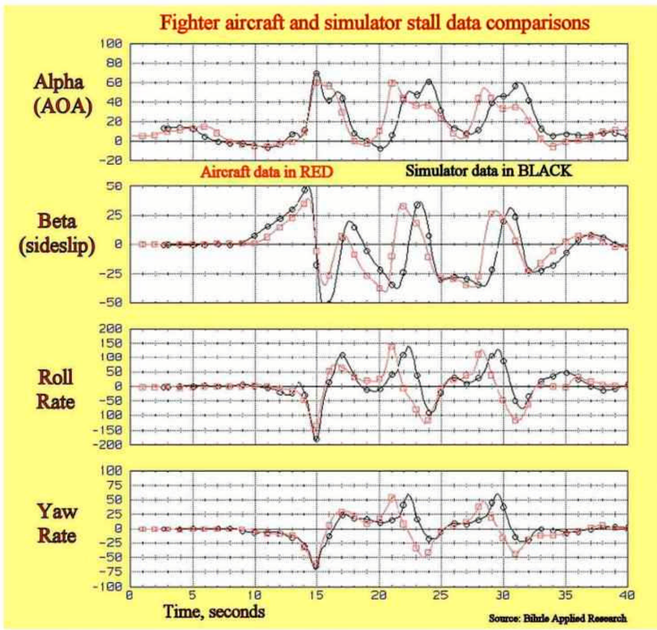
Specific Upset training is available now from companies such as Calspan and APS. Jim Priest of the Calspan Corporation described such a course at Calspan's Flight Research Training Centre at Roswell, New Mexico. This started with academics, covering the aerodynamic background of upsets, followed by the theory behind recovery techniques. Flying first uses a Beech Bonanza certified for aerobatics, followed by a specially-modified Learjet, more typical of an airliner cockpit and handling. The Calspan Learjet has fly-by-wire controls and associated computing to modify control and stability to optimise it for Upset training for specific airline types. A safety pilot / instructor is always carried. The Bonanza is used to show attitudes and manoeuvres that pilots have not experienced recently (or at all, in some cases). A Level D simulator is also used, it's motion platform giving sensations of movement in all six axes said to be required for realistic upset training. However, the G felt in upset situations is not felt and Jim Priest wanted more cues of the forces on "on the pilot's butt".

Drawing on my military background, I suggested that an inflatable seat cushion, as used in simulator G-seats in many military fighter simulators, could be tried in the Calspan simulator for extra "seat of the pants" cueing. In addition, other G-seat functions could be considered such as seat-pan lowering and variable strap tension, as computed G varies. Seat pan lowering makes the pilot stretch to keep normal sight lines (as in a real aircraft due to body compression under G), and strap pressures on the pilot are less under positive G and more under negative as the body moves upward in the seat. Suggestions from others included improved drive algorithms for motion platforms, such as those developed by Dr Advani and Van Biervliet/Sabena Flight Academy, the latter with a system called Lateral Manoeuvring Motion (LM2), as described at the RAeS Conference in June 2008. Other suggestions included adding indications of computed G on the external world visual system either in large numerals or as a colour change, particularly as aircraft limiting G was approached. Clearly more work is required to improve motion cues in Level D simulators, and this and related issues were addressed in other presentations and in the Open Forum at the end of the conference.

Returning to the Calspan course, on testing pilots beforehand it was said that a high probability of recovery from upset manoeuvres was virtually zero. This was said to rise to 76% after the course, the remaining 24% having a "moderate probability" of recovery. Jim Priest concluded by saying that over 500 airline pilots had so far been trained, from 21 airlines from American to United.

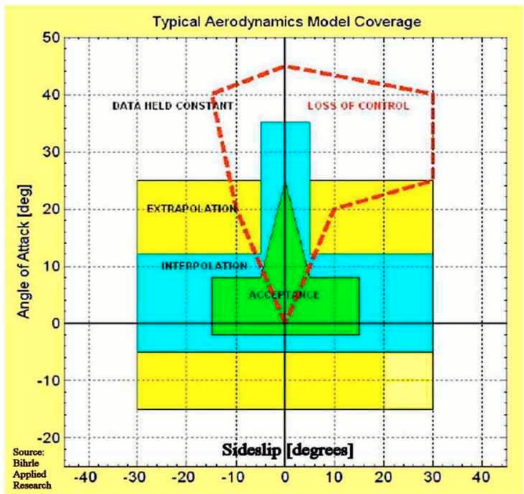
Similar training is offered by APS Emergency Maneuver Training of Mesa, Arizona, also using academics, aircraft and simulators. APS President Paul Ransbury gave Upset recovery success rates of 42% before training and 97% after. The retention figure after 19 months was said to be 76%.

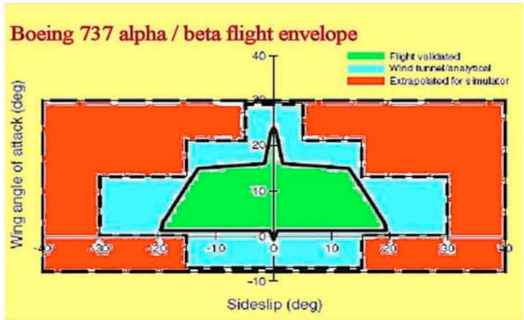
Continuing the theme of improvements in simulator cueing, David Gingras and Jack Ralson of Bihrle Applied Research proposed a Flight Simulator Training Endorsement



Reasonable comparisons shown - why not also with airliner data?

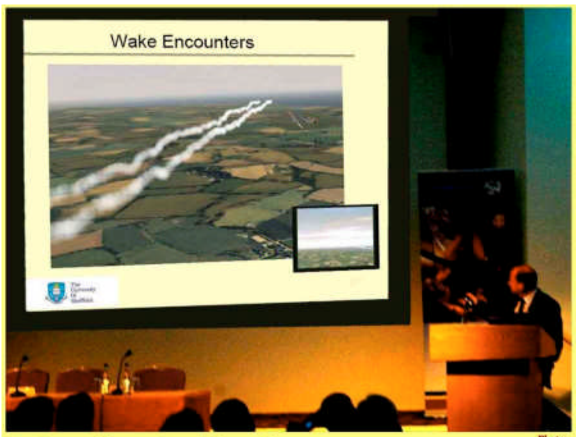
Program (F-STEP). They pointed out that stall/post stall modelling has a proven track-record in military aircraft such as F-16, F-18. F-22 and F-35. There was therefore no reason why something similar could not be done for large commercial aircraft. NASA already had a commercial transport modelling and simulation programme. This used wind tunnel tests and "well established techniques" for data reduction, providing "a better prediction of lateral-directional dynamics in post-stall flight". The F-STEP programme would utilise the latest improvements in modelling techniques and was intended to produce requirements for the expansion of the aerodynamics model for upset training.





For the simulator flight model, extrapolations are made outside the centre of the envelope, but become progressively less reliable unless based on real flight data. As a retired test pilot I pointed out that during certification testing, the flight envelope will have been tested further than the envelope cleared for routine service, at both the low- and high-speed ends. This data should be incorporated in the higher levels of simulators before they are certificated by the Regulators for pilot training. In addition, there are incidents and accidents in service, from which flight data outside the originally-tested envelope will become available through the aircraft flight recorders. There should be a mechanism to incorporate this in the flight simulator aircraft model, the position of Regulatory Authorities being crucial in making this happen.

Peter Jarvis and Captain Lou Nemeth of CAE discussed upsets due to wake turbulence, wind shear, microbursts, icing and aircraft system failures. Wake vortex encounters were also addressed in a presentation by Professor David Allerton of Sheffield University. The CAE team said that for Upset recoveries, "management of G" was important and there was "a propensity to over-react by novice pilots". Simulator modelling of the stall region needed improvement and lack of cues of continuous G was again said to be a problem. A training centrifuge "can simulate continuous G cues but there is a risk of nausea, and it is still a simulator". It was therefore concluded that aircraft platforms are needed to train G awareness and confidence. In current simulators, it was said that dynamic data was often not available for modelling stall conditions, and for some simulators, data was only available up to operation of the stick-pusher, well before the stall itself. However, modelling of the stall region could be improved using wind tunnel tests and Computational Fluid Dynamics (CFD).

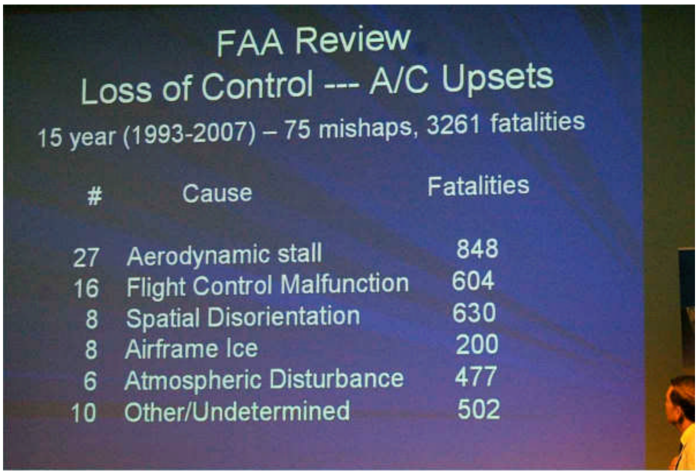


Professor Allerton describing wake vortex encounters Photo: Ian Strachan

The CAE team concluded by proposing the formation of a working group to define standards and techniques for expanding simulation, particularly with more realistic stalls and recoveries.

Other presentations and speakers made similar and valuable points but in a short article, these cannot be reported in detail.

The open discussion forum at the end of the conference expanded on the last two day's presentations and discussions. It concluded by agreeing with CAE's proposal to form a Working Group to carry this work forward. This is to be co-ordinated by the Flight Simulation Group (FSG) of the RAeS. It follows previous FSG-chaired international work that resulted in discussion, consensus and drafting of documents, leading to their publication by ICAO. An example is ICAO 9625, the Manual of Criteria for Qualification of Flight Simulators, now in Edition 3 after an RAeS-led consultation and update process, with a second Volume on helicopters in preparation. The title of the new body is the International Committee for Aviation Training in Extended Envelopes (ICATEE). A meeting between FSG and AIAA personnel was held on the day after the conference, to discuss future co-operation. Conference chairman Dr Advani has produced a draft "Master Plan" that has been circulated to interested parties. ICATEE will involve industry, regulatory, training and academic experts who have been involved in defining, analysing and providing this training. Another task is to review work in research centres, universities and industry, where it involves extended flight regimes. This includes pre-stall conditions, buffet, full stall, deep stall, wing drop and sideslip, incipient and full spin, and so forth. The Working Group will explore the best ways of applying this data to Full Flight Simulators, and suggest areas where other devices such as aircraft, centrifuges or disorientation trainers are appropriate for Upset training. Extending the limits of flight models for simulators has to allow for non-linear and less-predictable behaviour outside the centre of the flight envelope. Also, there is the incorporation of extra flight data that is acquired as a result of envelope excursions in service due to incidents and accidents. An important object will be to devise improved procedures for initial training and recurrency checks, followed by proposing how to translate this into regulatory guidelines.



An inaugural ICATEE meeting was held at the Royal Aeronautical Society in London on 16 November 2009, just before a two-day Flight Simulation Group Conference on "Flight Simulation Training Devices - The Way Ahead". ICATEE attenders included regulators, airframe and simulator manufacturers, training providers, airlines, aeronautical research agencies and universities, and other interested parties. Amongst other things, a series of Work Packages were decided, as well as methodology, timescales and reporting.

There is a lot to do, watch this space!

Pictures: taken by the author at the conference