1970 FLIGHT SIMULATION SYMPOSIUM IN RETROSPECT

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Historians: failed novelists.
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SUMMARY

The first conference of the newly-formed Flight Simulation Group was held in 1970, with the theme Flight Training Simulators for the '70's. The conference was a success and set the Group's conference programme on its way.

This paper reviews the eleven presentations at that conference, with the benefit of hindsight, to identify the objectives of military and commercial users of flight simulators in 1970. It also examines the technical limitations of simulators at that time, and the regulatory policies being considered by bodies such as the ARB.

The paper considers flight simulation for pilot training and aircraft design, developments in simulation technology, physiological and psychological factors that affect simulator design and studies of the effectiveness of simulation for pilot training.

1. Prehistory

The Society's interest in flight simulation before 1960 appears to have been limited. A few occasional papers were presented at meetings and were published in the Aeronautical Journal. However, the prevailing attitude appeared to be that if it was not worked out on a slide rule, tested in a wind tunnel and subsequently in the air it was not aeronautics.

In the mid 1960’s a group interested in flight simulation began meeting at the Society under the chairmanship of Norman Hill. Norman held a respected position in the Society, having had a distinguished career as an engineer and pioneer rotary wing pilot before coming into flight simulation with GPS Aylesbury.

This paper was presented to the RAeS Flight Simulation Group’s 2010 Spring Conference Flight Simulation Technology: Future Potential in June 2010.
In those days, the Society had an established structure made up of Sections and Groups. These bodies were, to paraphrase George Orwell, equal with some being more equal than others. Whatever their respective positions in the hierarchy they were united in the belief that newcomers such as flight simulation were not equal. Norman was not to be thwarted and was prepared to stand his ground. In the end the Society compromised and flight simulation became an ad hoc group which it remained until the mid 1970’s when it was granted full group status.

In 1970, encouraged by the support it had received from the flight simulator community, the ad hoc Group arranged a two day conference with the theme Flight Training Simulators for the ’70’s. The conference was a success and set the Group’s conference programme on its way. This paper reviews the 1970 conference, with the benefits of hindsight.

The 11 papers (and their authors) in the 1970 Conference were:

1. Captain W J Johnson (BEA) Desirable Improvements in Future Airline Flight Simulators
2. Sqn Ldr J Davis (RAF) & Lt Cdr E J Beadsmore (RN) A Military View of Flight Simulation
5. D Wilson (Link Miles) Advances in Motion Platform Systems.
7. Dr H F Huddleston and Dr J M Rolfe (RAF IAM) Behavioural Factors Influencing Aircrew Response in Training and Research Simulators.

In 1970 the civilian and military users had different objectives for the directions in which they saw their policy advancing.

The commercial users were taking a conservative but progressive view of the future. A main driver was cost. Training in the air was expensive, time consuming and took costly resources away from their revenue earning role of carrying payloads. Captain
Jack Nicholl, then with BOAC, stated the position of the commercial aviation industry with respect to the use of flight simulators when he said:

“If simulators did not save the airlines money they would not exist, and, however valid the other reasons are, we would have no difficulty in convincing ourselves that training in the air was better in every respect!”

Capt Nicholl cited figures to show that, despite the cost of simulators increasing, their contribution to crew training programmes in terms of hours was not significantly greater. Previously, converting onto the Boeing Stratocruiser took 22 hours, of which 16 were spent in the simulator (73%). In 1970, with the Boeing 747, conversion took 26 hours with 18 hours in the simulator (69%).

This situation had to change if the devices were to become cost effective. To bring change about needed improvements in the quality of simulation available and collaborative action between the operators and the legislators.

On top of the economic argument there was recognition that training carried out in the air could be inefficient and dangerous. It was in this context that Captain Johnson from British European Airways put forward the following future policy statement;

"The maximum use of Flight Simulators is advocated in order to reduce the amount of in-flight training required for initial and recurrent training, with the objective of totally removing the need for in-flight training exercises, apart from route training, to be carried out in the aircraft.

All potentially hazardous training manoeuvres should be transferred from aircraft to flight simulators, as and when these can be satisfactorily accomplished in flight simulators."

As well as excluding route training from the syllabus for simulation there was no suggestion that proficiency assessments should be undertaken in flight simulators. The aim was the reduction of in-flight training. The standard of flight simulation at the time was such that it did not play any significant part in recurrent training.

2. Pilot Training.

In 1970 flight simulation was very much a subordinate to training undertaken in the aircraft. The concept of Zero Flight Time Training (ZFTT) was being debated but the BOAC paper argued that the cost of developing a simulator with ZFTT capability would make the training more expensive than if it were undertaken in the air.
However, this was the time when the NASA Apollo Moon Landing Program was in progress and the key role of simulation as the means of providing total mission training was being widely publicised.

The lessons learned from the Apollo simulation programme fed into the FAA's Advanced Simulation Plan and in the mid 1970's promoted the potential for ZFTT by establishing a target, which at that time was technically impossible but was actually achieved within two years of the publication of the Plan.

In 1970 the military users of flight simulation took a similar position. While they embraced a policy for the greater use of simulation they were at the same time adamant that for military aviation there was no substitute for actual “hands-on” training in the air. Again a key reason for this apparently conflicting position was that cost pressures on the military were forcing the pace for the greater use of simulation in training. Consequently, simulation was seen as being imposed upon the military users rather than being accepted as the most effective course of action.

The attitude of pilots in 1970 needs comparison with the wide acceptance that today's pilots give to flight simulation. Airline captains had considerable status at that time. Compared to today, they were under worked, overpaid and their word was law. The technology of simulation was crude, and the potential changes it could bring in pilot certification were not always welcome. Many military pilots with more demanding sorties than airline pilots were suspicious of the value that flight simulation could offer, and had the additional concern that the introduction of simulators would cause a reduction in their flying hours.

Nevertheless, the military were in the process of creating a lash with which they would chastise themselves for at least the next decade - Full Mission Simulation (FMS). FMS would provide the ability to simulate every essential aspect of a complete military operational sortie, from briefing to the debriefing. With this aim in mind, the paper from the MOD to the 1970 conference stated:

"The RAF is introducing a new generation of flight simulators known as ‘Full Mission Simulators’. These simulators employ the latest electronic techniques, and will be more advanced than any military simulator in the western world.”

As the subsequent decade was to show, while FMS continued to be widely espoused, its implementation was to fall short of many users’ expectations. This situation was reflected in the contribution from the RAF to the 1981 RAeS Flight Simulation Conference.

"It is a sad fact that most of our fast-jet simulators have inadequate handling fidelity. Indeed there are many senior Air Force officers, mainly
with a fast-jet background, who, having been weaned on so-called "Mission Simulators", have never forgotten the claims made for these machines nor their actual capabilities."

The anomaly of the military position was that while the concept of FMS was seen as the target, the current technology, particularly with visual systems, left much to be desired. There was no requirement for air-to-air visual simulation (eg combat, formation flying, in-flight refuelling) in current and projected simulators. It was deemed at the time that these activities formed a very small part of the overall flying task and therefore to seek to simulate them would not be cost-effective!

In 1970, it was recognised that improvements in simulator design and performance were necessary. The question was how to go about managing the new technology that was becoming available.

On the civil side it was also appreciated that technological developments alone did not control the pace at which flight simulation could take over training functions undertaken in the air. The added complexity of the flight simulators being offered from by the manufacturers was causing problems in the specification of requirements and the provision of flight data packages. One major source of difficulties was that there were no standardised procedures for airline customers to specify their requirements. A second paper from BOAC argued that this could result in no two airlines producing a comparable specification for a simulator for the same aircraft type. The result was that simulator manufacturers could not standardise on features such as the extent to which aircraft handling characteristics were represented, the number and category of faults required, the instructor station design and even the choice of host computer.

In 1970 this need to reach greater agreement on standardising the specification was being addressed by the airlines themselves and the manufacturers. Reference was made to the initiative being started under the auspices of the Air Transport Association of America, where US airlines and the major simulator manufacturers were working together to produce a guide entitled "Provisioning Aircraft Parts and Data for Commercial Flight Simulator Design, Manufacture, Testing and Acceptance". At the time nothing similar was taking place outside the United States and there was a need to do so.

The BOAC paper also drew attention to issues relating to the reliability of current flight simulators. If they were to play a part in flight proficiency checking and licensing they had to be less susceptible to breakdowns. The situation should not occur where a pilot was barred from operational duties because a requisite flight check had had to be cancelled because the flight simulator was out of action.
Equally important were the attitudes of the legislators. Captain Johnson from BEA observed:

“\textit{A statement of policy is one thing but putting it into practice is much more difficult, especially when Government authorities have to be convinced that the flight simulator can be used to do the training as effectively, and in some areas, more effectively than the aircraft.}”

Perhaps it was not surprising that the authorities needed to be convinced when the subjects of objective measurement of performance and data recording were new and contentious subjects at that time. There was debate as to whether crews would accept their performance being measured in depth by computer-based methods. Derek Ruben from the then Air Registration Board argued that it should be possible to measure the same parameters in the flight simulator as were currently being recorded on the flight data recorders in aircraft. A current programme was exploring the benefits and the acceptability of using flight performance data gathered during normal operating conditions as opposed to accident situations.

At the same conference a paper from the Royal Aircraft Establishment Bedford examined the effect of providing pilot subjects with objective information about their performance, when undertaking low visibility landings in a research flight simulator. These pilots' subsequent performance improved significantly in comparison with a matched group of pilots who were given only subjective feedback about their performance by an experienced instructor.

This work was quoted in the ARB paper in support of the argument that flight crews would accept objective performance recording if they could have access to it as a means of assessing their performance against required standards and not as an examiners’ weapon for determining success and failure.

Apart from the ARB paper, the published proceedings contained little to indicate the thinking and policy upon which regulatory bodies were embarking. However, there was extensive discussion of how flight simulator acceptance procedures should be conducted. One key contributor was Dave Davies, the ARB’s Chief Test Pilot, who became well known for his book \textit{Handling the Big Jets}. My recollection is that in the discussions Davies was adamant that flight simulator acceptance procedures should follow those used when approving the aircraft. They needed to be tighter and more precisely defined. This resulted in Davies being asked to give a paper to the Society outlining his philosophy which was subsequently published in the Journal. Without doubt, Dave Davies had a potent effect on the advancement of realistic simulation. Brian Hampson recalls him saying, in his paper, that he had seen good simulation many times but that, unfortunately, it never all seemed to occur in one simulator. In other words it would be possible to produce good simulation if we all "got our act together".
3. Aircraft Design

No paper at the conference addressed the use of flight simulation in aircraft design - a sad omission. Techniques were well established by 1970, both in industry and research establishments, particularly in the United States. In the UK, research simulators existed at RAE Bedford, RAE Farnborough, Warton, Hatfield, Weybridge and Filton and had materially influenced the design of Concorde, TSR2, Jaguar and other projects.

Emphasis was put on 'flying qualities' because both civil and military designs could present aircrew with unfamiliar behaviour, particularly in the case of flight control system failure. Modern aircraft with digital flight control systems largely suppress airframe behaviour, and the emphasis now lies on operational techniques.

4. Developments in simulation technology with the main themes being computing, visual and motion systems

In 1970 the future for simulation looked towards the development of hybrid analogue/digital computers. At that time few could have anticipated the dramatic changes that digital computing techniques would bring. The digital computer brought change to the hardware and the architecture of simulation. Large computing systems have given way to distributed processing systems. Increased computing capacity has allowed better mathematical models of the aircraft, its subsystems and the environment, giving greater sophistication of the simulations as well as the host simulators. Interactive multi-user battlefield simulations, with the capability for air-to-air combat and similar developments touched upon above are examples of what has been made possible.

The change in simulation capability as a result of increased computing power is exemplified by the capacity to simulate the external visual world and the methods by which it is now achieved. In 1970 the training simulators were fitted with visual systems of the model board variety in which a small television camera moved over a scale model containing significant, but restricted, features of the world, e.g. airports and potential military targets. Research was going on to develop computer generated displays but they were limited to cartoon-like wire frame images with little detail apart from stylised attempts to represent surface texture. The most likely means of advancing the capability of visual systems were seen as combinations of laser scanned photo transparencies, motion picture systems and limited use of computer generated dusk/night images of airfields for takeoff and landing.

A further major area of development has been in the provision of physical motion cues. In 1970 the industry was progressing towards the six degree of freedom motion platforms which are now the normal equipment.
Despite these developments, the value of providing motion cues has continued to be the source of much debate. Critics of providing motion argue that a simulator is constrained by being fixed to the ground and consequently no motion system will be able to fully reproduce the dynamic response of the aircraft. Moreover, motion systems greatly increase the cost of a simulator, add to the maintenance needed and impose requirements for much bigger accommodation (It has to be noted that this is now a spurious claim, as the costs of a modern motion system are quite minor in comparison to other areas). Those in favour of motion argue that, because the flight environment is inherently dynamic, a fixed base simulation is an inadequate representation of flight. Experimental studies have shown that aircrew behaviour in a simulator with motion is much closer to that occurring in actual flight. Both sides have valid points to make and the best course of action may be to seek a definition of how much motion is needed rather than defend a case for an all or none option.

5. **Instructional features, the role of the simulator instructor, instructor work-stations and performance recording and display systems.**

Forty years have seen great changes to the facilities provided for simulator instructors along with their functions. In 1970 the simulator instructor was expected to play a major part in sustaining the simulation in addition to carrying out the functions of instructing. For example, it was the instructor’s task to manually insert the ILS marker signals to the crew in the simulator to indicate their distances from touch down. A paper presented in 1970 reported that when the accuracy of these inputs was measured a wide range of time and distance errors were shown to be present.

Data recording is an accepted part of a flight simulation facility with, in addition, the ability to analyse and present the information obtained in the most appropriate and user-oriented manner. Military simulation has made use of this capacity with the adoption of the idea of debriefing facilities that allow crews to assess and replay their performance outside the simulator.

Along with data recording and presentation there is the increasing capability to interchange data between simulators (i.e. networking) and between the simulator and the aircraft being simulated. The latter is allowing the opportunity to use airborne data as a source from which to generate specific flight situations for both training and evaluation purposes, e.g. aircraft accident investigation.
6. **Physiological and psychological factors affecting simulator design and operation**

Flight simulation attempts to create the illusion that the user is actually in an aircraft in flight. To achieve this end it is necessary to know how the human body senses the cues from flight and to design simulators that can represent these cues to the extent that they are needed to sustain the simulation. One lesson learned, particularly from aeromedical research in support of manned space flight, is that sensed motion cues may be comprised of composite information from more than one sensory modality.

One of the prevailing philosophies of the past years has been that if there is a problem then a more complex simulator is the answer. This may be true when the problem relates to **device realism**, e.g. the representation of the visual world. But it is not necessarily so when the issues relate to **device function**, e.g. the effectiveness of the simulator.

The issue of simulator fidelity (how real should it be?) has been a consistent part of the conference programmes since 1970. It is now recognised that fidelity is a multidimensional concept and that device complexity and training value are not directly related. Physical and dynamic fidelity should match that of the aircraft. Operational and instructional fidelity may be compromised to maximise training opportunities. One issue continues to cause debate, namely should crews be required to wear uniform when training in the simulator?

The change in flight simulator design in terms of engineering fidelity is clearly apparent. In the 1970's it was obvious from the outside which aircraft type was being simulated. Externally, today's simulator may give the impression of being a self-storage facility on stilts but it offers the advantage of permitting easy access for maintenance.

6. **Studies to determine the training effectiveness of flight simulation**

The last 40 years have seen a debate develop over the need to measure the effectiveness of simulator training.

The device acquisition process has grown to be demanding as the more training options from which to chose, the more crucial it is to define the training requirement and the method of selecting the correct solution. Similarly the training validation is critical as the more complex the training device becomes, the more necessary it is to ensure that effective training takes place.
There are those who argue that, despite the increased ability to produce better simulators, there continues to be a requirement to provide objective evidence that flight simulation does actually produce the training results expected of it. In opposition to this is the school of thought that says flight simulation has already proved that it can deliver transferable training and no further proof is necessary. Unfortunately for the latter argument, in the high investment areas of new forms of simulation (e.g. networked simulations and synthetic environments), the issue is not whether transfer will occur. Rather, it is to know how much transfer and in what training dimensions e.g. skill acquisition, maintenance or assessment it can be relied upon to take place. “It’s a long time since I lost a buddy in a training accident” may sound a valid vindication of flight simulation but, as we all must admit, accidents continue to occur in operational conditions and aircrew behaviour continues to be a major contributor.

7. Concluding remarks

With regard to the future, if lessons from the 1970 conference are sought, the following are offered.

- It pays to be optimistic: if the user's training objectives can be stated they are likely to be met.

- It is hazardous to predict the rate and direction of technological development.

- Be wary of conceptual ‘milestones’ that carry innovative labels as they frequently become either millstones that handicap their creators or media buzzwords which lack substance

- If a methodological problem exists relating to the use of simulation, the introduction of more sophisticated simulator technology is not likely to solve it. Rather it may confuse the true nature of the problem even further.

- Progress may be inevitable but successful application is not.

- Never forget that the quality of the simulation is dependent upon the accuracy and extent of the models which represent the elements being simulated.

- No matter how good it is, the flight simulator is not an aeroplane.
References


The author

Dr John Rolfe started his working life as an apprentice in the Royal Dockyard Chatham. He then read Psychology at Hull University and on graduating in 1959 joined the research staff of the Royal Air Force Institute of Aviation Medicine at Farnborough. As head of the Flight Skills Research Group he used the Institute’s flight simulation facility and aircraft to evaluate measures of performance and workload. In 1976 he became scientific adviser to RAF Support Command and in 1984 took up a Defence Fellowship at Wolfson College Cambridge. He returned to MOD as Assistant Director of Science (Air) until 1994. A lifetime career in MOD has lead to the acquisition of sufficient familiarity with disaster management and simulation to continue working as Visiting Professor at Cranfield University.