OFFICE OF AIR FORCE HISTORY
ORAL HISTORY PROGRAM

Flight Simulators in the RAAF

During 2009, the Office of Air Force History conducted an oral history project to capture the experience of the Royal Australian Air Force in acquiring and using flight simulators and procedural trainers over more than 70 years. A total of ten interviews were recorded with individuals who—as uniformed members of the RAAF—were involved with Air Force's attempts to absorb and utilise simulation technology, from its earliest days to the recent past. Subsequently, one of the participants in the project, retired Squadron Leader Bob Weight, undertook to review the transcripts of the interviews and assemble a 'first cut' of the story which unfolded from them. His account is reproduced below. Full transcripts, on which this analysis is based, are held by the Office of Air Force History and can be made available to researchers with a legitimate interest in the subject.

Background Note

The scope and time frame for this study was deliberately restricted to a manageable number of people and to flight simulation specifically. Unfortunately not all people were available at the time of the study and key observations associated with the maritime world (Neptunes, P-3Bs and P-3Cs) were not captured. Further, the more recent OFTs for the C-17s, Wedgetail and the F-35 JSF were not included. The restriction to flight simulation excluded the wider simulations associated with maintenance trainers, air traffic control, loadmaster training and the like. While the study touched on the emerging use of simulation and modelling as a significant tool—in not just capability development but in organisational experimentation, and defining how to bring back the experiential learning in the lessons learnt back into the workforce through simulation—it is clear that to complete the history of simulation in the RAAF a further exercise is necessary to capture these other elements before the record is lost forever. The Office of Air Force History welcomes further contributions to the RAAF's flight simulator story.

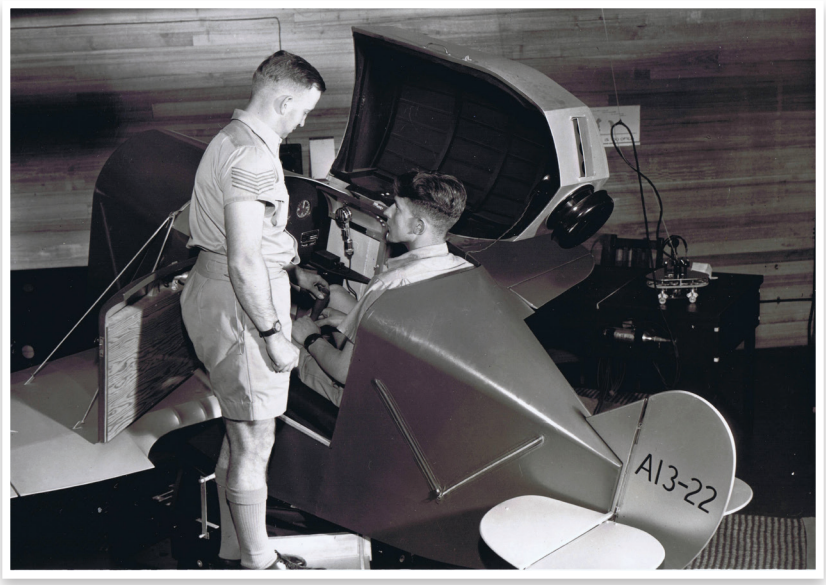
About the author

Squadron Leader Robert (Bob) W. Weight joined the RAAF in 1964 as an engineering apprentice, and on graduating in 1964 was posted to No 2 Aircraft Depot. As a corporal instrument fitter, he was sent to Frognall to study electronic engineering at RMIT, where he graduated in 1974. As a commissioned officer, he remained in avionics engineering until he retired in 1984. In 1977 he was posted from working on Mirages, with No 481 Squadron at Williamtown, to the staff of the Chief of Air Force Technical Services in Canberra, where his job entailed writing the technical specification for the C-130H simulator. He was posted to the US—to Binghamton, New York—as resident engineer/project manager with the H-model simulator. Following promotion to squadron leader in January 1983, he went to Materiel Division in Canberra as deputy project manager for flight simulators in Air Force.

Flight Simulators in the RAAF
A Bold Step Forward or Back to the Future?

There has been a steady stream of new flight simulators and simulation capability into the RAAF over recent years, be it C-17, C-130J, Wedgetail Operational Flight Trainer, Operational Mission Simulator and Mission Support System or F/A-18 Super Hornet Visual Environment Maintenance Trainer. These are often portrayed as 'new bold steps into the future' but are they permutations on a single theme?

The RAAF has a history of the acquisition and use of flight simulators and/or procedural trainers spanning some 70 years from the World War II era 'Blue Box' Link Trainer to the current generation flight simulators with full motion, visual and audio cueing systems coupled with extremely sophisticated instructor stations. An examination of the RAAF's experiences, practical considerations and philosophic underpinnings of these acquisitions and their use highlights lessons learnt that might well inform the future.



Link Trainer

In addition to recent systems, while by no means exhaustive, the Air Force experience with flight simulation includes, Sabre, Mirage, F/A-18 Classic Hornet, Neptune and P3-B/C Orion variants, C-130A/E/H and now the J, F-111C and B-707, as well as various related simulation capabilities including air traffic control, navigator and technical/maintenance systems. Several recurring themes appear throughout the story.

The acquisition of these early flight simulators and procedural trainers, including the Classic Hornet flight simulator, that did not have the luxury of today's total weapon systems and systems engineering approach, appears to have been consistently predicated on a 'sine curve' of reasons bounded by two fundamental themes:

- **Budget and resource considerations.** The use of a simulator will result in lower airframe numbers, particularly in the training environment. So, often this argument led to a prolonged acrimonious debate concerning reduced airframe numbers to the chagrin of aircraft acquisition project proponents!

- **Capability development and experimentation considerations.** For later systems, the use of a simulator will allow the development and rehearsal of operational mission profiles that prudent airmanship and safety protocols would not allow in peacetime. Again, debate

often raged about 'Rolls-Royce' solutions versus simpler (and less costly) alternatives.

The emphasis and mix between the two broad themes, which was more often than not based on the personal experiences and biases of the key project staff, seems to have reflected the chosen orthodoxy of the day.

'**On budget, on time, on spec'.** An inability to achieve these desirable outcomes represented another recurring lesson. That many of the earlier systems might, from the lofty heights of the digital and wireless age, appear little more than procedural trainers, with no or very limited motion and visual cueing systems, might well be true. But that same history shows that, in their day, many of the systems were 'leading edge' in the rather 'Jurassic' world of analogue bells, whistles, sphere resolvers, actuators, valves and pulleys of the earlier 'flight trainers'. That systems could be designed to allow a degree of interactive, problem and emergency fault generation, with a reasonable degree of fidelity to the real world, represented a significant achievement. Indeed, perhaps the 'on budget, on time, on spec' improvement of recent projects might, in truth, owe more to the operational flight simulator being an integral part of the design and development of the weapons system from initial design stages than to a better quality procurement system and procurer!

Aircrew prefer flying real aircraft, fitters prefer to 'fit' real components! No matter the degree of fidelity, it appears simulation is not, self-evidently, 'the real thing'! This historic and apparently enduring phenomenon has been captured within the 'immigrant vs native' analogy. The immigrant, born, bred and raised during the formative years in a foreign culture, will, no matter how well he adapts, always exhibit an accent, idiom and cultural prism, readily evident to the native. To the native, the prevailing culture is not new, it just is! Hence, as the RAAF is increasingly populated by a generation of natives to whom the digital world of gaming, interactive computers and their enhanced visual, aural and sensory cues 'just is', perhaps this phenomenon might decline. Of course, the pace of technological change might also turn the native of today into tomorrow's immigrant—if not, dinosaur!

What of the future? The reality is that flight simulators and simulation are an integral part of the RAAF and its ability to generate air power and associated outcomes. An ability to network flight simulators was dreamed of many years ago but now represents a force multiplier in terms of national and international interoperability, operational capability development, training and experimentation. Accordingly, such capabilities are expected to remain an integral part of the RAAF well into the future.

Further and perhaps a lot more interesting is that already within the mind's eye of appropriate strategic capability development staff is the wider use of simulation and modelling and, in particular, 'simulation at the desktop'. The ability for commanders, supervisors, managers and perhaps all RAAF personnel to have a personal and collective simulation capability is seen by some as the way of the future (if not the 'here and now').

The ability to conduct iterative 'what if' modelling, simulation, gaming and rehearsal in terms of organisational structure, resource allocation, personnel demographics, command and control relationships and task specific process permutations is seen as vital. The technology already exists and is used elsewhere and is emerging within Defence, but what of governance, coordination and communication protocols and guidelines? How well does our previous experience of platform-based simulation prepare us for the transition to decision superiority–based simulation?

F-35 Simulator

And of course the ultimate challenge—are the natives, immigrants and dinosaurs ready for these bold steps forward into the new simulator-enabled RAAF? A backward glance might well inform and provide inspiration and stimulation, for the way ahead.

From the 1950s to the 1990s

One wonders if Ed Link ever realised what he was starting. From the somewhat quaint piano/pianola factory beginnings of the Link Trainer in Binghamton New York, through the only 'real' test of flight (or space) simulation training—when 'Buzz' Aldrin successfully landed the Apollo 11 Eagle lunar module on the moon—through to the modern flight simulators where commercial pilots can go direct from the simulator to flying the actual aircraft, the technologies, capabilities, usage and user acceptance of flight simulators have all undergone massive advances. One might well be excused, nonetheless, for thinking that the ever-improving pilot acceptance of such devices is perhaps not just the result of the significant strides in the technologies but a result of the present-day kids seemingly endless fixation on computer games and the associated 'simulation type' devices?

One wonders that while they were creating history if those of the time were aware of the legacy they were establishing. Certainly it would seem from Squadron Leader Bob Weight's account[1]—the Singer Link project engineer on the RAAF's C-130H Operational Flight Simulator (referred to as an OFT – Operational Flight Trainer) during the early 1980s, who was part of the later stages of Ed Link's time—they did understand the potential of what they had developed at that time. Nonetheless, it was highly unlikely that the initial users of the Link Trainers shared Ed Link's view of the future as, from

1 Squadron Leader Weight joined the RAAF in January 1964 as an apprentice instrument fitter. Commissioned as an ENGINST in 1974, he went on to work in the RAAF's initial simulation project office within the then Air Force Materiel Division. He left the RAAF in 1984.

all accounts, the pilots of the time simply wanted to 'punch holes in the sky' and not be bothered with such earthly devices as trainers and simulations! As Bob Weight also recollected, the very first USAF exchange officer into the Air Force Material Division as the flight simulation project manager (PMA3), Lieutenant Colonel Dick Hackford Jr (a Vietnam veteran—F4 pilot who had been shot down and spent more than 2 years as a POW) when meeting the Australian C-130H simulator contingent in Binghamton stated, 'When the Russians agree to fight the next war in simulators then I will support simulators but until then give me more aircraft, missiles and bullets!' This would seem to be the commonly held view of the time, especially amongst fighter pilots.

The Link Trainer was certainly not a flight simulator but definitely just a trainer as its name implies. However, it was probably most likely that the differentiation between the two terms was not understood or even cared about at that time. It is generally acknowledged that the start of 'flight simulation' in the RAAF was with the F-86 Sabre simulator. Before that, the Link Trainer was it! As Wing Commander Warren Tassell put it:[2]

> *It started off with my first posting after commissioning [circa 1950] when I went to Victoria Barracks and I came to work for, well he was then a Flight Lieutenant, Tom Keck and Tom had been the kingpin of the Link Trainer world; of course, we only had Link Trainers in those days, ANT18s and then later we got D4s. And of course that was instrument simulation, so when they introduced the first simulator, which was the Avon Sabre, well that's where true simulation of an aircraft type started in the mid-50s.*

At that time the Link Trainer was an integral part of the RAAF pilot selection and training. Wing Commander Geoff Schmidt said:[3]

> *There were two models in order, the ANT18 which was a piston version of a trainer plane and a D4 which was a jet engine version. They were used in the late 40s through to the 70s, as a test for selecting candidates for pilot training. They called it 'the Box'. It was a blue box and it had a hood over it and the pilot sat in the Box with the usual aircraft instrumentation on the panel in front of him/her. The 'pull over hood' would shut from the inside and produce instrument flying [IFR] flight conditions.*

He went on to say:

> *But anyway they were the major pilot training machine, certainly at Wagga and Temora and places like that. All had Link Trainers and you did not get in an aeroplane until you passed your Link training course. And anyway they were very important for pilot training but they were certainly the first simulator and they did a very good job too. I mean, banking turn indicators and of course the idea of navigation, particularly flying air speed and for how long; if you had the time you should be able to fly that box pattern and that was very important for the flying instructor. The instructors took their work very seriously. The students were just too keen to line up to go flying. Anyway the Link Trainers were undoubtedly used as an aptitude testing tool for selecting candidates for pilot training as well.*

As Wing Commander Schmidt also said:

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2 Wing Commander Tassell joined the RAAF in 1942 as an instrument maker and served for 34 years, which included a number of postings that involved him in those very early days of using flight training devices.

3 Wing Commander Schmidt joined the RAAF in 1958 as an apprentice instrument fitter. He was subsequently commissioned as an ENGINST having various roles with responsibilities for the maintenance of all RAAF flight simulators at the time.

In the Air Training Corps [ATC], Link Trainers were taken very seriously and maintained with great pride. But more importantly, the 'Links' were a great attraction for the cadets who could be taught basic flying skills. And quite a lot of those cadets did go on to join the Air Force as pilots and quite a lot of them went on to do commercial flight training. So the Link Trainers were a wonderful ATC asset and I think there are still some of them around today.

There was also, or so it would seem, a somewhat different recollection of the way the Link Trainer was viewed by the engineering staff and the pilots—as Air Vice-Marshal Kerry Clarke recalled:[4]

I do recall being involved in Link Trainers. Now I don't believe it was a formal program in any way to teach people how to fly, but it was an exposure opportunity where you could sit down and fly the vehicle such as it was. It was primarily designed, in my recollection, as an instrument flying tool. So you had the usual altimeter, attitude indicator, a turn and bank indicator, a very simple rudimentary broomstick-like pole in the centre, rudders and the thing rotated and tilted within I guess plus or minus—the rotation I think was continuous, but pitch was plus or minus 30 and bank was probably about the same, that sort of scale. I do recall being more interested in the way the map and tracking system worked outside … [and also] … I sort of recalled it as being a whole bunch of fun. That was my first exposure and hence my sense was that it wasn't any rigorous training program.

But without doubt the Link Trainer in its various forms did play an important part in the pilot training during the 1940s and 50s in particular. Significantly, the Link Trainers also provided the basis for the generic simulation technical and engineering capabilities and technical training at that time. While the Link Trainers were around for some time after the 50s, the emergence of the then newer aircraft types—the Sabre, Canberra, Neptune and Caribou in particular—quickly took over the thinking, application and use of the associated procedural trainers and/or flight simulators. Even though these trainers and simulators might have been extremely rudimentary at the time, they were, nonetheless, more often than not on the limit of the technologies of the time.

This leading edge technology approach seems to have been a consistent theme throughout that period and the subsequent years as the flight simulation fidelity and capabilities improved. These improvements where both:

- in step with the technology move from valves, servos and electromechanical devices through solid-state electronics to modern processors with comparatively vast amounts of memory and the associated processing speed that permitted the development of the required functionality and fidelity demanded by the emerging training regimes; and

- the increasing realisation at that time by the aircraft manufacturers of the significance of flight simulators and the need for accurate aircraft-validated flight data and the later move to using flight simulation in the engineering development and prototyping of the aircraft itself.

Nonetheless, during the 1960s and 70s there remained a general reluctance of pilots to accept simulators, as so eloquently put by Wing Commander Geoff Schmidt:

The aircraft simulators in the 50s and in the 70s were generally considered a waste of time by operational aircrew as there was no 'pucker factor'. The pucker factor, by the way, means that

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4 Air Vice-Marshal Clarke joined the RAAF in 1966, went through the RAAF Academy and after graduating flew Caribous, Mirages and F/A-18 Classic Hornets, and had numerous staff positions until his retirement from the RAAF in 2005. His simulation experience covered the whole gamut of the technologies of the time from Link Trainers through to the F/A-18 OFTs.

contraction of the sphincter as you're heading towards the ground and may be going to crash. I'm talking about now from the time of the Sabre and Mirage simulators and mainly the fighter aeroplanes, certainly well after Link Trainers. The QFIs [Qualified Flying Instructors] and also the flight commanders really had to get hold of the young pilots and twist their bloody ears to make them go and fly the simulator. And of course it was always argued that they would at least learn their drills for emergency situations; thus trainees begrudgingly saw their value as a procedural ('switchology') trainer. Now the thing is, as the young bucks would say, 'If there's no pucker factor, it's no bloody good and it doesn't fly like the real aeroplane.'

And this was reinforced by Air Vice-Marshal Kerry Clarke:

My log book reflects that I did the usual six or seven sim rides [in the Mirage simulator]. Sim wasn't very well thought of in those days. People didn't like to go into it. It was just nothing like flying the aeroplane. And of course in the early 70s there was still quite a hangover from postwar and Korea. In other words, the executives in the flying game were much more about—the Air Force was much more about—being gung-ho taking risks, being on the edge of the envelope, much more of what you might call a classic fighter school mentality. Therefore, a simulator didn't fit in any of that cycle at all.

This view seemed to be universal, as stated by Air Commodore Bob Kee:[5]

… but the pilots, once they got to learn how to fly this thing were loath to do any refreshers on it … they wanted to get and fly their own little aeroplane. They had to be forced to get back into the simulator once they'd flown the aeroplane.

The RAAF's Caribou, Neptune and Canberra aircraft had no associated flight simulators, having just basic procedural trainers. The reason for this is not known but is most likely due to the age of the airframes, the existing technologies, the lack of any realistic aircraft performance data and, maybe more importantly, the attitude of aircrew and senior officers at the time on the need for such training systems. Maybe it also had something to do with the fact they were all multi-crew aircraft—–but who knows? However, in the same time frame, the RAAF started to see the emergence of actual flight simulation capabilities and, even though not generally accepted by the aircrew, the integration of such devices into the overall pilot training program. The C-130A, Sabre, the later Mirage and P-3B OFTs, and a bit later still, the F-111C simulators were all generally consistent in regard to the technologies—fixed base (i.e. no motion systems), no visuals and very limited (if any) audio cueing and instructor station capabilities. And, of course, the scope of this history project does not get us into the wider RAAF simulators and trainers that have been used extensively for many decades—things such as the Air Traffic Control Simulator and Synthetic Navigation Trainer (both at East Sale), the Mirage flight controls mock-up and many similar systems. Perhaps this could be the basis for a much wider unit history project?

While the technologies were mostly very consistent with the flight simulation technologies of the time, the changes especially in maintenance trainers are really exciting involving, as explained by Tony Di Pietro:[6]

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5 Air Commodore Kee (deceased since this interview) joined the RAAF in January 1949 as an apprentice instrument fitter on No 3 Course at RAAF Wagga Wagga. In 1954 he spent some time in the UK doing a flight simulation course in preparation for the Sabre simulator. Commissioned in 1953, he went on to serve in many and varied positions with overall flight simulation engineering and technical responsibilities.

6 Tony Di Pietro served 30 years with the Navy, with significant time as an experimental test pilot; as such having a variety of flight simulation experiences. After leaving the RAN, he eventually became involved in the 2030 Air Force study with extensive application of computer modelling and simulation in regard to organisational and personnel development.

This simulation technology, properly employed (and it can actually be right now), allows one to have a model of an engine, a pump, whatever you like built in virtual 3D. You can have a technician go into a room, plug in, and they can actually select tools, read the procedures, they can actually physically manipulate an engine or a pump, they can feel the tension, the torque and all those sort of things. The really beautiful thing about it is they can actually keep their skill up on site. The idea being to not have to take people away to say Wagga for eight or 12 months or eight or 12 weeks, but you can actually do it in the workplace. We could have the supervisor know exactly the potential of the individual in their team and they can monitor where those individuals are up to in terms of skill set. Because of this knowledge they can utilise the skill set as it's achieved. That is, immediately in the workplace and not having to wait until they've come back from a course. The individual would not need to be reassessed and go through the 'supervisor trust loop', which is basically the supervisor getting a good sense that you really did learn something and can apply it.

Compare this to the 'first' RAAF flight simulator. As Air Commodore Bob Kee stated:

The Sabre simulator, based on then available analogue computer design, was basically a procedural trainer for instrument flying and aircraft handling over an extensive range of activities and flight profiles. As there were no dual Sabres, the simulator was an important training tool used to convert pilots to the actual aircraft. One important feature of the service was that an instructor (himself a qualified Sabre pilot) operating from a specially designed control console would act as mission controller, air traffic control officer and emergency faults generator to which simulator pilots had to react. A pilot training schedule was put in place and exercises were repeated until the student got it right. When instructors judged the students were proficient in the simulator they could then fly the aircraft. Bear in mind that this was an important process because we had no dual Sabres.

In regard to the technology of the day, Air Commodore Kee observed:

The analogue technology employed was old hat. Amplifiers were thermionic valve driven, wire wound configured potentiometers representing performance graphs, for example, abounded, relays and uniselectors were used for switching and servo motors controlled signal outputs. Transistors were not used. Today a PC has more computer power than the simulator's analogue computer which filled a large room. Nonetheless, it faithfully represented the aircraft cockpit and handling characteristics. Keeping it modified to stay compatible with the aircraft was always difficult. Furthermore, once pilots got to fly the aircraft they were reluctant to do simulator refresher training, which to my mind was important in terms of emergency procedures.

But even so they were consistent with the technologies of the day and, even with some pilot reluctance, the simulators did provide positive training to the pilots.

Former test pilot, Group Captain Ron Green, used some 'innovative' techniques to provide such positive training:[7]

When Operation Sabre Ferry was finally given approval to take place, I was the Nav Officer of 78 Wing at Williamtown and, as such, a lot of the planning fell on my shoulders. One of the aspects of concern was some level of apprehension about the intertropical convergence zone [ITCZ], which we were going to have to fly through. People kept emphasising to me

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7 Group Captain Green joined the RAAF in 1950, graduating in 1954 going into the fighter stream flying Mustangs and Sabres until completing the Empire Test Pilots' School (ETPS) course in the UK. Thereafter doing a lot of test work with Mirages and F-111s, and gaining significant flight simulation experience throughout that time.

the turbulence, the thunderstorms, the noise, the lightning, the hail, you name it. We only had one Sabre simulator at that time and that was the fixed simulator at Williamtown (the mobile one was not in commission) and I got the job of putting all the pilots that were going to fly on Sabre Ferry through the simulator … we finished up modifying the fluorescent lights in the simulator building, getting a very smooth running electric drill and fitting the drill with a shaft with rubber paddles installed. We could mimic turbulence through the flight controls to a reasonable extent. So every one of those pilots had to go in there, with me sitting up behind with the simulator room lights dimmed, and then the opaque canopy was closed so he couldn't really see what was going on and we then turned the lights down, just gradually dimmed them until they finished and, after probably 10 minutes or so, after reaching cruise altitude, started feeding a bit of turbulence into the system prior to the first of the thunderstorms. Turned the fluorescents on and off and getting them to flicker, flash before entering the simulator hailstorm. This involved using the electric drill spinning up the paddles and allowing them to hit the front bulkhead. We weren't really very advanced. However, there were very few people in 78 Wing that came out of that exercise without perspiration pouring off them. So I guess we were fairly pleased with that, it was good value.

C130 H Simulator

And from Group Captain Bryan Harris in regard to the 'trash haulers' experience:[8]

> *We were probably a bit scared of them [simulators] because it was always seen as an assessment process, but right from the start it was interesting the way the simulator was used in 37 Squadron. Although none of us had ever heard of CRM [Cockpit Resource Management] at that time and I don't think it had formally been named yet, that was always a part of the way the simulator was used to take away the dictatorial 'Captain speaking' sort of role and spread involvement right across the cockpit so that, if you were posed a problem, it was part of the process that you would automatically involve the other crew members in reaching a sensible resolution.*

Bryan went on to say:

> *Well in the mid to late 60s we'd always done it in the aircraft, but it was what later became known as CRM and, although we didn't know it, we were really at the forefront of pushing that as a way to do things to the extent that one of the executives of the squadron reverted to type in his first simulator trip. It was quite interesting, as an example of people riding the thing for the first time. He was given an engine fire and decided the copilot and the engineer were being a bit slow with the checklist so he pulled the condition lever to feather and pulled the fire handle, except he managed to shut down two engines by doing it all himself; so the point was well and truly reinforced and that really brought it home. But it was interesting; one of our instructors having never actually pulled a fire handle in anger was posed in the right-hand seat with a situation where they had an engine fire, he had to shut the engine down and he grabbed the fire handle and pulled it right out of the panel. From that point, I suppose it was worthwhile, knowing how the actual bits of the aeroplane reacted when you used them.*

But interestingly, perhaps Bryan and his peers might still have had something to learn about the capability:

> *I was in the simulator one day, in the left-hand seat and they gave us a simulated smoke and fumes elimination, and I didn't know they could do that. This was around the time those astronauts met a nasty end at Cape Canaveral in a simulator fire, and the engineer commented, 'Lot of smoke in here today'. I looked around over my right shoulder and I could see the thing was full of smoke, so I unstrapped and departed. I was politely told to get back in the seat and handle the emergency.*

The C-130E simulator was the first simulator to introduce a motion system into the RAAF. Although the RAN introduced the first visual system into the ADF for their Sea King helicopter simulator at NAS Nowra (late 1970s/early 1980s), the C-130H and AP-3C Operational Flight Simulators (OFTs), as they had then become known, were the first to introduce a visual system into the RAAF. The C-130E simulator incorporated a basic three degrees of freedom (3 DOF) motion system (roll, pitch and yaw) with no horizontal, lateral or vertical forces that were not introduced until the development of the 6 DOF systems that came along in the RAAF during the 80s.

Nonetheless, the E-model simulator still lacked the fidelity needed to provide the level of training necessary for the aircrew. Bryan Harris again:

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8 Group Captain Harris joined the RAAF in February 1957 as a radio apprentice and soon after completing his training transferred to pilot training. He left the RAAF in 1996 after many years flying a variety of RAAF and USAF aircraft, mostly in the transport world. Through that he had extensive experience, in particular, with the various C-130 simulators.

Yes, it [the C-130E simulator] was always more of an instruction than a test that we were using it for. I don't know whether we were using it more in those days to help kids that were having trouble in the aeroplane or whether, because I was CO, I and was more aware of it (which is probably more to the point), but there were episodes where if a kid was having problems with a particular area we'd just take him down to the simulator and do it over and over again, particularly instrument work and things like that because that old E model wasn't a bad instruments procedural trainer. It didn't quite fly like the aeroplane, but very few of those old simulators did.

But, equally, what was then arguably the most modern aircraft anywhere in the world, the F-111, had a relatively unsophisticated flight simulation capability. The technology limitations played a part in this but perhaps more significant was the lack of any relevant flight test qualified data on the flight performance of the RAAF's F-111C aircraft. It was not until the much later replacement of the F-111 simulator that it became more than a cockpit procedures ('switchology') trainer and became a flight simulator. Also about this time the issues associated with computers and 'software', rather than mechanical or electromechanical devices were starting to emerge, sometimes much to the concern of both the RAAF and the contractors. As Group Captain Ron Green observed:

We [RAAF and the contractor] talked about the simulator and amongst the points that arose with this simulator, was that it was the fifth one that Link had built and the only difference between this simulator and the A-model simulators was a couple of little tweaks in the software to cope with the longer wings. So I was invited that afternoon to use my flying kit and actually get in and fly this thing for the first time. It was essentially a procedures trainer—it looked like the cockpit and even smelt like it as well … We fired it up, we taxied out, lined up on an imaginary runway, looked at all the run-up procedures and they had really done an excellent job. Up to mil power and the engines responded just the way they should then into burner, again the response we recorded was very good. Maximum burner, again the same sort of thing, brakes off and away we went. At around about the 95 to 100 knots a little back pressure on the stick, the nose started coming up and then the nose wouldn't stop coming up. Stick forward until it was hard on the stops and the nose was still going up and up and up until it wheeled over on one wing and crashed. Very embarrassing for everybody. So we went back to the beginning of the runway and started off; three times I tried this and I couldn't stop that damn thing from crashing. And again it was the same thing. Then Link management brought in two tech sergeants, (not qualified aircrew at all), put them in the seats and away they went. They took off just like normal, brought it back and landed, touch-and-go, just as normal and people were laughing quite openly. It was a very interesting situation, very embarrassing. After that we sat down with Link to try and sort out what the problem was and at this stage Link had adopted the posture that they sat back with arms folded because there was nothing wrong as far as they're concerned. If a tech sergeant can fly it, why can't a test pilot? After some time I advised the higher-ups that I don't know what's going on here, but the aeroplane won't fly for me. It'll fly for a couple of tech sergeants, but it's totally unsuitable, it doesn't represent the aeroplane at all, so I'm going to have to reject it. Went back and I saw Link and said, 'In my opinion this does not represent the behaviour of the aeroplane and is not acceptable. Accordingly, I have to reject it.' And that of course really put the cat amongst the pigeons. Not long after I got a telephone call from Link saying we realise you've got problems with this, but we have been able to make a couple of adjustments to the software and we'd like to invite you to try it again. So I agreed to it, of course, and first thing on Monday morning we were out there again and, naturally, with everybody standing around. Got in and fired the thing up. It took off and behaved like a charm. Landing was no problem at all and I was able to complete the test cards and that constituted acceptance. And they wouldn't tell me what they'd done. A bit later on I came across one of the tech sergeants

that had been at Binghamton, running a course at Nellis [Nellis Air Force Base in the US] and took the opportunity to have a few words with him. He was rather guarded, but he said essentially what they'd done that weekend was get together with their software engineers and run through the software section by section with a whole team of people working on it and they discovered that the coefficients used in the ground effect equations had some polarities reversed. When they put the polarities in correctly, then gave it back to me, the aeroplane flew fine. And guess what happened shortly after that? Link went around, and very quickly changed all the software.

Although a number of years later, Squadron Leader Bob Weight, the C-130H OFT RESENG/Project Manager, recalled that the OFT had been dropped into the ship when being readied for shipment to Australia (after the factory acceptance tests had been completed). When it was fixed some 8–9 months later, Bob and the test pilot Flight Lieutenant Bruce Fulton were retesting and each time they did a LAPES (Low Altitude Parachute Extraction System) drop it crashed. After some time it was determined by the contractor; that during the previous factory testing, where we had found that one of the 'malfunctions' we could feed in—the load shift malfunction (to simulate a load shift in flight)—it was this that caused the aircraft to crash. The contractor had modelled the load as a complete unit and when the malfunction was fed in it shifted rearwards to infinity, so as the load went backwards so did the centre of gravity of the aircraft until the obvious happened. To fix it at the time they put in a software switch to stop the load at the ramp. At the time we did not think to go back and retest all related potential impacts (things like software regression testing had not emerged at that time). It was not until the subsequent testing that we determined that by putting the software 'switch' in it stopped the total load at the ramp. But the way the load was modelled was that the switch was at the mid-point, so in 'simulation' half the load was going out when doing a LAPES and half was staying on the ramp. At the low levels of a LAPES drop, the change in the centre of gravity with this on the ramp caused it to crash. It took the contractors best software engineer and best aeronautical engineer some days to work out how to solve the conflict between dropping the load during a normal extraction and also having a load shift malfunction in flight where the load could not go past the ramp. As Bob Weight confirmed with the contractor at the time, it was most unlikely they would have sent such specialist to Australia had this problem not been detected until in the factory.

Back to the story. The C-130H introduced some really great capabilities at the time. Still not perfect but certainly a technology leap over the previous and existing flight simulators at the time. We were still almost a decade away from the application of systems engineering approaches to capability development, so the specification was still very much a 'personal' matter. There was no concept of a Training Needs Analysis to properly define the requirement—it was more like 'we are buying some aircraft, we might need a simulator'. What was also evident at that time was the fear held within the old A-Block in Russell that if they bought a simulator it might mean that the then FDA (Force Development and Analysis—or 'Forces of Darkness and Annihilation' as it was colloquially known) would reduce the number of aircraft they wanted to buy. It was a fight to convince the 'system' that flight simulators were adjuncts to the flying training program, not a replacement, and while simulators might reduce overall flying training time they do not replace aircraft. It was a fun time!

The truth was that, at that time, we simply took what the USAF was doing with its C-130H simulators and adapted their specifications to our unique variant. It was a similar approach for the AP-3C OFT, where we just took the 'spec' for the USN device at Barbers Point in Hawaii. However, while there was really no alternative, it did prove the vital importance of the contractor having access to flight test qualified data or at least quality aircraft performance data. In both cases neither the C-130H nor the AP-3C had such data so the end OFT product certainly had some limitations and differences to the aircraft but, even so, they were a significant step over the previous systems. Certainly, even though the AP-3C came along a couple of years after the C-130H, its technology was almost identical and its lack of qualified data did cause some serious training issues. Once again from Bob Weight's recollections:

The AP-3C OFT pilot—then Squadron Leader (I think) Mal 'Mother' McLean—took me on a flight in the P-3C to show me the acceleration issue. I was in the right-hand seat and Mal had slowed the aircraft down to as slow as he could and two things happened at once; just as he pushed the throttles hard to the wall, the copilot stepped into the cockpit with two cups of coffee. I am not sure what I learnt more, the shear acceleration forces we experienced or just how fast the copilot disappeared backwards at a great rate of knots until he slammed into a rear bulkhead with coffee all over him (there might also have been the odd word mentioned by the copilot about Mal's parental heritage!). Nonetheless, without any aircraft data there was nothing we could do at the fundamental software modelling level—we had to rely on tweaking the software based on pilot inputs over time.

But, as Bryan Harris pointed out:

… for quite a while with the H-model simulator they did have a bit of trouble with acceptance with the senior people around the squadron. New arrivals on conversion course could land it beautifully but line pilots couldn't. It was just the slight disconnect between the visuals and motion, and that is enough to totally throw you and you really get negative training transfer from it.

The problem of not having flight test validated data is that when individual pilots are used to 'tweak' the software to change the performance of the simulator, you end up with as many different simulator performances as you have pilots—they generally feel and see things slightly different and you end up chasing your tail—especially in regard to software changes. But while some might have had some negative views overall, it was Bob Weight's view that the C-130H OFT was generally well accepted and well used:

Generally I think it was quite well accepted given that it had some limitations, but compared to the old E model and the A model it was a significant leap in technology and flight training capability. But equally so I think it also proved to the flight crew what could be done. So they started to think about then of what things could be done better. Certainly the pilot that I was dealing with who was our operational liaison guy and did all the flight testing and the introduction into service, Flight Lieutenant Bruce Fulton, he was very enthusiastic about the whole training and training transfer. Again, not so much to reduce training flying hours of the aeroplane, but to make each one of those training flying hours that much more productive. So yes it was well accepted, but I think as the simulation technology improved so our knowledge of it and what we could do better improved. And the next generation of simulators started to emerge, so then I was heavily involved back here in Canberra on the P-3C flight simulator. At that stage we were looking at upgrading the F-111 and the F/A-18 and buying the 707 simulator back.

The C-130H and AP-3C OFTs introduced visual systems into the RAAF, albeit these visuals were night only, showing patterns of light points only with no associated ground surfaces. Importantly, they also introduced 6 DOF motion systems, high-fidelity audio systems and extremely capable instructor station capabilities. These devices proved to us all the absolute importance of the combination of these capabilities to the overall 'make believe' scenarios.

About the time the C-130H and AP-3C entered service (1982 and 1984 respectively), things started to move at a much faster pace in regard to flight simulators in the RAAF. This was directly related to the acquisition program for the replacement of the various aircraft, including that of the Mirage with the F/A-18 Classic Hornet.

Also around this time, we took a backward step in regard to flight simulation technology when we acquired the B-707 simulator from Aer Lingus—who had bought it from Qantas when they sold

off their 707 fleet. The B-707 simulator at that time had no visual system and a 2 DOF scissor-jack motion system and a very rudimentary instructor station. Interestingly, Qantas had to rehire a senior technician, who had retired but was the most experienced B-707 simulator technician in Australia, to do the acceptance testing in Ireland. Nonetheless, it was the only 707 simulator in the world that represented the RAAF's 707 aircraft—so while not perfect it did provide some degree of flight training.

The Hornet acquisition introduced a number of new technologies but one in particular at the time was not properly appreciated when it came to buying the OFT—improved visual (day/night) and G-suit capabilities to better simulate the forces associated with fast jets. The combination of the visuals and the effects of the associated inflation and deflation of the suit provided a level of capability that was not possible with standard visual/6 DOF motion systems. Such motion systems simply are not able to simulate the associated g-forces. The F/A-18 purchase also introduced part-task capabilities to support the overall pilot training system. The HOTAS (Hands on Throttle and Stick) trainer removed the need for using the OFT for basic cockpit 'switchology' training.

Nonetheless, as Squadron Leader Weight, who was the engineering representative on the OFT evaluation team, observed we still had not necessarily learnt the lessons from the past or the disciplines associated with the systems engineering approach had not emerged:

> *I think we learnt lessons about being able to specify the technology maybe a little bit better and some of the requirements, but we hadn't actually moved to a systems engineering approach, I don't think, in Defence at all in those days. So things like an operational concept document just wasn't part of the whole development cycle. This whole business of defining the operational needs leading to then some sort of an overall capability which will then lead to a functional performance 'spec,' it just wasn't heard of and it wasn't in the lexicon.*

Also at that time there was considerable debate about the level of simulation to be involved with the two OFTs being bought for the Classic Hornets. While visual systems were developing at a considerable rate, in the world of fast jets there were still some significant limitations with the technology being able to provide the fast jet pilots with the essential visual cues across the entire flight regime. Things like the visual system being projected onto the pilot's helmet visor, with sensors detecting where the pilot was looking and the picture being projected accordingly into his/her vision, was one serious development. The one we were very interested in was what was called the 'dome' system, whereby the OFT sat inside a large dome (half sphere) which had a full 360° visual 'picture' projected onto the inside of the dome. It also had the ability to project friendly or enemy aircraft, and the ability to network the simulators was also emerging. We seriously considered at the time the capability and the ability to link the OFTs at RAAF Williamtown and RAAF Tindal, whereby the simulator pilots could be flying together or against each other even though they were some 'x' kilometres apart. At the time, this was seen as a 'Rolls-Royce' solution and was dropped in favour of a more simple and less costly simulator. One might well ask if it was such a 'Rolls-Royce' solution or a simple matter of the lack of an available budget at the time. As an interesting aside, some years later, the Australian Army introduced a dome simulator for its RBS70 Ground-Based Air Defence (GBAD) system, whereby the RBS70 system and the gunner would be in the centre of the dome and attacking aircraft projected into the visual picture and the gunner could track the target and fire the missile with extremely high fidelity. At the time, the contractor and the Army were discussing the potential to link this GBAD simulator with the F/A-18 OFTs.[9]

But had we learnt much or anything from the previous projects? In Bob Weight's view, not all that much:

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9 **Editor's Note:** This was outside the scope of this history but further research needs to be done to determine if this happened or not and the benefits of doing this to the overall training programs.

At that time we made another fundamental mistake (my view) in that during the on-site tender evaluation we were extremely concerned over the ease with which McDonnell Douglas (one of the tenderers) was able to alter the software and the performance characteristics of their OFT—we saw this as a huge risk in terms of software configuration control. We did not realise at that time the significance of McDonnell Douglas having used their OFT for the engineering development of the aircraft itself and the real benefits that brings with it. This did not become evident until much later on when the contractor (Sperry at the time) started to have real problems with simulating certain of the major aircraft systems. While it might not have changed everything, having a systems engineering approach at the time may well have reduced the chances of making the wrong acquisition decision.

To be fair, the combined benefits of formal systems engineering approaches and looking at the acquisition from a complete weapon system (the aircraft and everything that goes with it to make it a weapon system) point of view, rather than each element in isolation, were then starting to quickly become standard practice in Defence and also the RAAF. Accordingly, the updated F-111C and B-707 simulators proved to be hugely more acceptable than the devices they were replacing.

More recent capabilities such as the Wedgetail and C-17 had the simulator capability fully integrated into the fundamental specifications for the total weapon system. Perhaps this huge leap in technology is best described by Wing Commander Jack Foley when he recalled:[10]

Yeah, I think we really have come a long way just in my time in the Air Force. I remember like on CT4s we didn't have a simulator. I don't know what they use today, BFTS [Basic Flying Training School], but you basically just had this bit of a cockpit mock-up, if you like, and go through the checklist and sort of push these sort of buttons and it was all a bit kind of 'Noddy,' but it had its place in trying to learn a checklist, but it really was a bit sort of hopeless. And then even some of the earlier sims that I remember having a go on when I was working at Williamtown on the Mirage simulator; there were no visuals whatsoever and it was a very clunky device; it had its purposes as a procedural device if you like and clearly we've come a long way since then. The last couple of years when I was at 285 [Squadron] and we've got some quite whiz-bang simulators on the H and J, and we did on the 707 at the time, although that simulator has now been retired, these flight sims, they really are tremendous. The standard of the visuals today and the ability to replicate the aircraft really are fantastic. Down to little things like the way a needle on a gauge might move on an aircraft. And after you've flown Hercs for years you just sort of know that the needle might sort of slowly move and then it has a bit of a twitch and then it drops, little subtleties almost like that that they will capture and capture well.

10 Wing Commander Foley joined the RAAF in 1982 at the Academy, going through engineering and also navigator training. He also did the Aerosystems Course in the UK and spent many years with C-130s and at the School of Air Navigation with various flight simulation experiences over that time through to his current position in Russell involving the use of simulation and modelling for looking at future air force capabilities.

C-17 Simulator

To make it even more pertinent:

> *If I go back to sitting in a CT4 mock up or even those early Mirage simulators or the old E-model Herc simulator for example, no-one ever thought they were in an aeroplane. It just didn't provide that level of reality. But now, yes you damn well can and I would argue that simulation has reached a stage now where you really can give people a good sense of reality and to the degree that, whilst I'm certainly not suggesting that you don't need to go flying, there some things you can do in a simulator actually much better now than you can in a real aeroplane. And examples I can give you are: you can give all sorts of technical faults in a flight simulator—you know, things bursting into flames and blowing up—that you just can't do in a real aeroplane when you just pull the throttle back; I mean it's a bit lame really. But now we are more into the operational field where we go flying and well there's all sorts of helicopters coming hither and people firing from the ground over here and missile warnings going off, that sort of thing you can create an operational reality which has only really only been possible in the last 10 years or so.*

During this relatively short period of time, flight simulators have progressed from really basic procedural trainers through to full experiential motion, vision and audio capabilities. Similarly, as we have gone along the story, initially the justification for simulators was economic along the lines of, 'Please let me buy a simulator and I won't have to fly so many hours', and of course the 'bean counters' instantly say, 'Well, we'll do that for you, give me a thousand hours and you can have a simulator', that sort of idea. About the 1990s, as technology had at last caught up with the wish list, the motivation for the acquisition of simulators changed slightly and it changed from a simple one of less flying hours through to the existence of a simulator will allow me to explore areas of the operational capability that I would not or should not explore in a real aircraft.

So where to from here? Ed Link may well be surprised to see what his 'Blue Box' has turned into but one suspects that people such as Ed Link would only be frustrated at the time technology has taken to catch up to his vision. Without doubt, the Gen Y and later kids are far more relaxed and accepting of simulation and simulators, and such capabilities are becoming increasingly a fundamental part of the engineering development and prototyping of many systems—not just aircraft. Simulation and modelling is becoming more and more a standard decision support tool for all commanders.

It is interesting that that progression in the justification a simulator does not apparently seem to have made its way as strongly as you might think into the procurement aspect. We are still acquiring simulators because they are economic to do so!

Nonetheless, the future is being managed well by some. Tony Di Pietro, ex-RAN experimental test pilot, provides an interesting insight into the possible future use of simulators:

> *Simulation is no longer affordable as a crutch or a tool. It's an enabler for expanding the capability of our workforce. In the case of your example about flying hours, the argument I'm getting to here is that one hour in the sim does not mean one hour saved in flight. It is rather enabling us to get more of the 'how to fight in the air' into that one hour of flight. What we want to do is actually have people apply their mental models, their acuity and their intellect to things.*
>
> *Also simulation is actually going to play a big part in removing some of the lesser more functional aspects of our daily workplace. For example, I'm going to have an artificial intelligence or a smart agent in the workplace. We'll have a smart agent which will give you the context and you, the human, are going to apply your intellect to that context; freeing you up from the burden of having the tedium and actually giving you space to be creative about what you've got in front of you.*
>
> *So we're talking about a workforce that not only knows how to handle information and how to handle data, it now knows how to contextualise it. It knows how to take those contexts and build relationships across different contexts and, by doing so, know where to connect in terms of the community that they have to be part of to actually achieve an upper level product whatever that product might be. So if you think about it in terms of network centric warfare, we're talking about and what it really relies on is the human being making the context and the links. We've got to train our people to think like that.*

In regard to flight simulation, systems are increasingly being designed and developed now with built-in simulation capabilities. So operators can be sitting in a Combat Information Centre (CIC) of a warship, or in a control cabin of a ground-based air defence system or the cockpit of a modern helicopter or jet and be running simulation scenarios in any part of the world, including the area you might be about to attack—and at the appropriate time just switch over to the real world radar, ESM or whatever feeds.

Will simulation, and flight simulation in particular, ever be universally accepted? Who can tell but perhaps Jack Foley put it best in his simile about 'digital natives' and 'digital immigrants':

> *Imagine if you grew up in another country. It doesn't matter where you grew up and then at some stage in your life you immigrate to Australia and you learn English and you learn the culture and you learn how our school system works and how our political system works and how our banking system works, all of those things. But you always have that accent in your language and you would always find certain things just downright weird or a bit wrong, but you kind of learn to sort of fit in. And that's the sort of typical immigrant. And I don't mean that in any derogatory sense—in fact, more the opposite. You admire the way that person goes out of their way to fit in with this different world, but it's always kind of a bit of a struggle. [Compare that to] the person who is the native, who is entirely comfortable in it. I mean, it is what it is and the world is good and that's what the world looks like and obviously it fits that way because that's the way we are. Well I think it's a bit the same with digital technology. I think people of my sort of generation are those digital immigrants if we look at flight simulators or simulations that you can put on a computer today. But the point is that I am that digital immigrant, but the people we're recruiting today and the people we should make our training systems fit are not people like me. Our training system should not be made to fit*

people of my generation. It should be made to fit the very capable, the very bright kids that we're recruiting today. And guess what, they're entirely comfortable with seeing something on a computer screen and being able to manipulate it on a computer screen and to understand that.

Air Battle Management Simulator

Of course the pace of technological change might also turn the native of today into tomorrow's immigrant—if not, dinosaur! The challenge for the RAAF leaders of today and the future will be to ensure that are the natives, immigrants and dinosaurs are ready for these bold steps forward into the new simulator-enabled RAAF.