LEARN TO FIGHT - LEARN TO TEACH: REQUIREMENTS FOR AIR COMBAT TRAINERS BASED ON FOUR YEARS' EXPERIENCE

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ABSTRACT

The twin dome Air Combat Simulator at British Aerospace, Warton has been in regular use by the Royal Air Force to provide pilot training in Air to Air Combat. The training is given both at TWU (Tactical Weapon Unit) level, and are taught the basic skills and disciplines. OCU pilots are experienced squadron pilots who are taught the optimum deployment of their weapon system, and its capability against likely threats.

The simulator standard is described, with emphasis on the hardware requirements to provide high availability in rugged use. Features have evolved, particularly in he area of the instructor/operator station, to maximise the training benefit. These include rapid access to performance data, immediate selection of new configurations, efficient monitoring of performance, and instant replay.

The organisation of courses also contributes to training effectiveness. An environment is created to produce close instructor/student involvement. Students not participating in the actual combat benefit considerably by monitoring peer performance. The courses are short and intensive, without distraction.

Recommendations emerge relevant to the specification of training devices of this type. In particular, the cost aspects, and the technology trade-offs, are discussed.

INTRODUCTION

It is generally recognised that of all forms of flying, that required for air to air combat calls for the most developed skills. Pilots engaging in combat must have complete confidence in the performance capability of the aircraft they fly, and they must be able to use the performance right up to the limitations imposed by the airframe. They must have a similar understanding of the weapons which they will launch, and just what kind of a threat their opponents can offer. Added to this are the needs for rapid decision making in harsh physical conditions, and an appreciation of a complex three-dimensional scenario viewed from within, and the reasons emerge why top fighter pilots are a select few.

The success of the few does not depend on some mystical quality - all of them operate within a framework of rules of engagement; the tactics they use are open to analysis. Learning these rules and tactics in the air is both difficult and hazardous, and so the transfer of the learning task onto ground based simulators should be invaluable - provided of course that the simulator can be shown to do the task.

Such simulators have existed in both the USA and Europe for 10-15 years. In all cases they were developed in Industry or at a Government Research Centre, to assist in the design of new fighters, and to allow studies to be made of the operational aspects of new designs. In the course of such work, pilots have been quick to appreciate the contribution which such simulators could make to the air Combat Training task.

In view of this background, it is most surprising that Air Combat Training Simulators are not in widespread use by all Air Forces. The purpose of this paper is to relay some of the background experience in the United Kingdom from an Aircraft Industry standpoint. British Aerospace, has made extensive use of Air Combat Simulators for design and development, and emerging from this work has been a parallel activity in responding to the training needs from the Royal Air Force. As a result, we are able to offer views on what technology has to offer, and how it matches up to the customers needs.

AIR COMBAT SIMULATOR EVALUATIONS

Many of our research programmes over the past ten years have needed RAF front line pilots for the evaluations. The interest showed by these pilots led the Ministry of Defence (PE) to prepare a draft Air Staff Requirement for an air combat simulator for comment by Industry in 1979. The requirement called for the features available at Warton (and in other Air Combat Simulators) of projected images of sky, ground and target aircraft, inside a dome. Also included was a mode of operation in which the target aircraft could be computer controlled, and inter-active. Financial constraints on procurement had serious delaying effect on this initiative, although the Falklands crisis in 1982 did re-awake the UK in recognising that air-warfare has a part to play in military operations.

Consequently, the RAF asked for two evaluations to be made on the twin dome air combat simulator at Warton, to help in the preparation for the purchase of an Air Combat Training Simulator. The evaluations covered two aspects - the initial training of pilots in the basic skills of visual air combat, done by the RAF at their Tactical Weapons Units (TWU) - and the next stage of transferring these skills to the front line - done by the RAF at their Operational Conversion Units (OCU).

Each of the trials, designed and conducted by RAF/MOD teams, consisted of using the simulator for a week. Instructors from these units advised the planners on the areas of training where benefits might be derived, and their predictions were tested by bringing half the students from courses about to begin, to get a direct measure of improvements.

Assessment Results

Both assessments came out strongly in favour of the procurement by the RAF of a twin dome ACS for training. In both of these assessments, the course was split, so that direct comparison could be made between students who had received, and those who had not received ACS training. The OCU report concluded:

"The results obtained at the end of the period and in correlation with those achieved on completion of the course, have shown the Twin Dome ACS to be a most valuable training aid, providing realistic ground simulation of air combat training. The OCU staff were able to demonstrate, supervise and monitor student performance in areas such as aircraft handling technique, energy management, air picture and tactical awareness. The results obtained in the ACS and in the air showed a positive correlation. The content of ACS profiles was identical to that of the air combat syllabus and ensured good continuity of training. Significantly, during the air work which followed on from the ACS work, no sorties were lost as a result of student inability and there was a noticeable improvement in their rate of progress."

The TWU report stated:

"Advantages of ACS Training. The advantages noted in student combat after flying the normal syllabus compared with non ACS training students were:

(a) Air Picture Awareness. The major advantage the students had was in air picture awareness. Their target prediction and lookout were better than average, enabling the early sorties to be learnt more effectively.

(b) Basic Combat Manoeuvre (BCM) Comprehension. The ACS gave students a better understanding of BCMs and their effects at an early stage of training. This understanding created a greater enthusiasm and interest in ACM, provoking discussion beyond that usually seen.

(c) Base Height Awareness. The introduction of a base height during the ACS training proved effective. Subsequently only the weakest student had any problem with base height during the flying phase.

(d) Student Predictability. It proved possible to predict fairly accurately student achievement in the flying phase by reference to his ACS performance. Some individual weaknesses were possible to detect, e.g. base height awareness and lack of aggression, so these could be worked upon before the airborne phase.

(e) Flying Hours. It is not felt that the ACS could replace any of the syllabus sorties but should certainly cut down the number of reflys of extra sorties required to bring students up to the required standard. It is noteworthy that no extra sorties were required by even the weakest student benefiting from the ACS training."

RAF SPECIFICATION AND TRAINING MODES

Description

The British Aerospace Air Combat Simulator, as supplied to the Royal Air Force, comprises:

- Two Domes - each contains a cockpit and image projection equipment
- Computing facilities
- Visual generation system
- Instructor's Console - for control and debriefing.

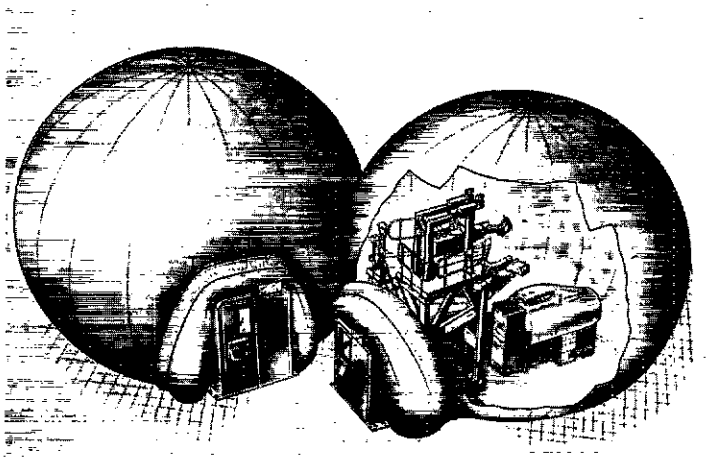

Figure 1 - Air Combat Simulator Domes

The cockpits are representative of the Tornado aircraft and are fitted with the instruments and controls necessary for air combat. The field of view from the cockpit is comparable with modern fighter aircraft. All the gantry/projector structure has been designed to be contained within a small, ±20° segment behind the seat. Cockpit noise, the effects of 'g' and buffet are simulated to a high degree of realism. Images of sky and ground are projected onto the inside of the dome, providing the horizon reference

which moves in relation to the manoeuvres.

The opponent is represented by the image of an aircraft projected onto the inside of the dome. The target image changes as a result of the manoeuvres carried out by the pilot and the opponent (which can be a second student, instructor or computer).

The performance of the simulated aircraft can be altered to match other aircraft types, including Harrier, Phantom, Hawk and threat aircraft. Target images can be changed quickly to give appropriate visual representation. Weapon performances can be also adjusted to simulate a variety of missiles. The host computer is the Gould SEL 32/9780.

Debriefing facilities allow the combat engagement to be viewed in a range of formats in real time and replayed as often as required. Important parameters can be display and recorded for further analysis:

Operating Modes

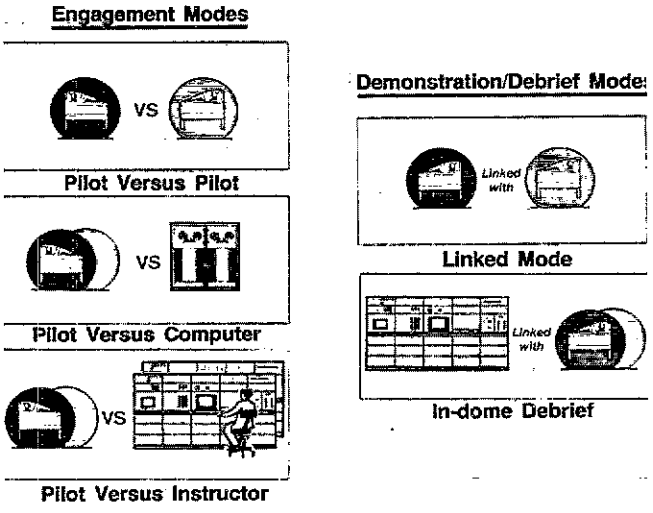

Figure 2 - Operating Modes

Pilot v. Pilot. The primary mode of operation involves a pilot in one dome manoeuvring against a target image which is controlled by a pilot training in the other dome. Thus pilot versus pilot combat is simulated.

Pilot v. Computer. Either pilot can fly against a computer-controlled opponent, which can be flown aggressively or non-aggressively, dependent on the task in hand, and used as a standard against which pilot performance can be readily and accurately assessed.

Pilot v. Instructor. This mode enables an instructor to fly the opponent aircraft using a miniature stick and throttles at the Instructor's Console.

Linked Mode. The domes can be operated in a Linked Mode where the scene in one dome is reproduced in the other. This enables an instructor to take control of the aircraft from one dome and demonstrate the desired manoeuvre to a pilot in the other dome.

In-dome Playback. The domes may be used during briefing or debriefing for playback of a previously recorded mission, providing a more realistic view of the combat engagement than can be displayed on the monitor at the Instructor's Console.

Instructor's Console

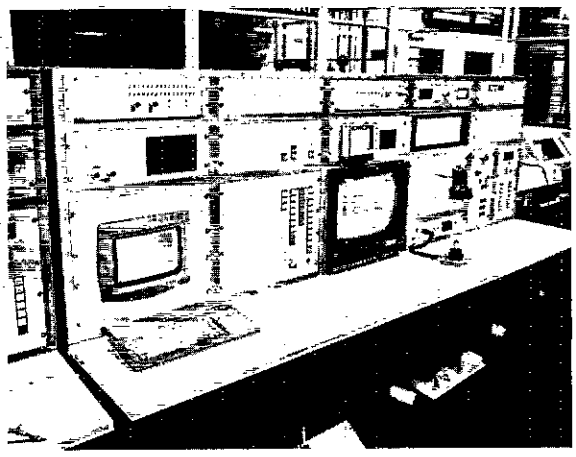

Figure 3 - Instructors Console

The Instructor's Console provides a means of ensuring the instructor has the optimum facilities for training purposes. The console offers the following features:

- o Selection of the sortie parameters:
  - Aircraft types
  - Weapons types
  - Combat starting positions
  - Fuel states
  - Computer pilot skill levels
- o Fully animated pre-briefing,
- o Control and communication,
- o Real-time monitoring of the combat and student performance,
- o Participation by an instructor, against a student in the dome,
- o Recording and playing back engagements, for debrief.

The Instructor's Console incorporates high resolution colour monitors. Engagements can be viewed in real-time or replayed for debriefing. A range of display modes can be selected, including

- o The Air Combat Manoeuvring Display. This display mode provides an external view of the combat. The view can be altered by zooming in or out, and by varying the viewing height and direction. There are two formats:
  - 3-D View. Shows an elevated view of the engagement, viewed from any position
  - Plan View. Presents a view of the combat from directly overhead.

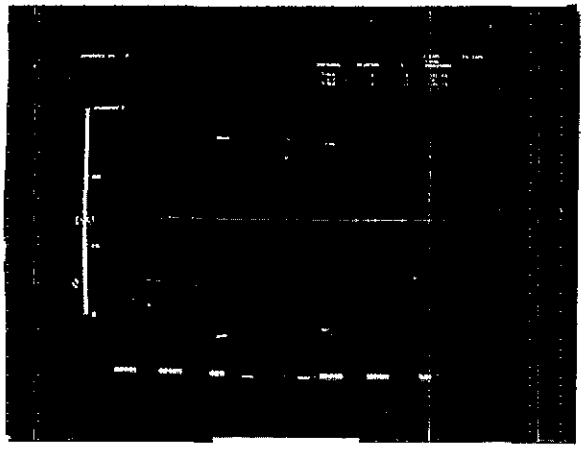

Figure 4 - Air Combat Manoeuvring Display

- o Inside-out Display. The pilot's view from either cockpit, including head-up display and status information. The field of view is variable.
- o Instrument Display. Relevant cockpit instruments can be displayed on demand.

EXPERIENCE

Following the evaluations described in section 2, the RAF saw that every student destined for combat flying could benefit from experience on the Warton ACS. Consequently, the simulator has been leased to the RAF on a regular one-week-in four basis since 1983.

The RAF have been sending 2 courses per week typically consisting of 10 students and 2 Instructors on each course. 86% of courses have been from the Hawk TWU's and the student is exposed to air to air combat in the simulator before the airborne phase of his course. A typical course consists of familiarising the student with the layout of the non-standard R & D cockpit and the cues of the ACS. After this brief period he will execute the basic combat manoeuvres against a pre-programmed and non-aggressive computer controlled target from various start positions. The Instructor will then go into the other dome, take control of the lead aircraft and start to execute mild defensive manoeuvres. The Instructor can immediately assess the students' response to a whole variety of geometrical situations and correct them if necessary.

The student, having watched all the other students' performing those manoeuvres would then progress to the next stage; that of engaging the aggressive inter active computer opponent BACTAC. The use of this opponent gives an immediate ranking of student performance and indicates if any necessary remedial action needs to be taken. They often finish off the course with a student knock-out competition. A small financial stake by each competitor adds to their competitive edge. During the course each student will have participated in about 30 5 min exercises and will have benefited greatly from observing the performance of his peers, viewing either from inside the dome, or at the Console.

The course develops a close Instructor/student relationship: they are off base for a week, with no distractions from the task of learning about Air Combat. Discussion does not stop at the end of the working day. The trepidation some of the students may have felt for the air combat phase of their course disappears, and at the start of the flying phase, Instructors must now watch for over-confidence.

One interesting point is that there has been no evidence of nausea, unlike some US experience, and each course is closely monitored by a questionnaire issued by the Institute of Aviation Medicine.

The other users of the simulator are either OCU's or pilots from operational squadrons, supplementing ACMI work.

The advantages over ACMI is that it is possible to study threat aircraft capabilities, and to prepare for weapon system developments before their introduction to the squadron.

MAN V. MAN COMPARISON WITH BACTAC

BACTAC is a computer programme developed by British Aerospace to replicate the tactics used by a pilot in close combat. It is used extensively, both for research work and in the pilot training courses which we regularly give to the Royal Air Force. The tactical rules it uses have evolved over several years of development in the nineteen seventies.

To engage the pilot, BACTAC continually re-assesses its view of the fight. It examines whether the piloted aircraft is:

ahead or behind,
pointing towards or away,
the range, and the range capability of the weapons.

From these decisions follow the choice of aggressive manoeuvres, defensive manoeuvres, or less extreme manoeuvres which include energy gain or conservation. Ground avoidance is another possible manoeuvre, and has priority over most other demands. The aggressive manoeuvres are sub-divided into regions of increasing threat to the opponent.

It is usual to justify the behaviour of programmes such as BACTAC by reference to pilot testimony. Controlled experiments to compare directly the success of a computer opponent with a pilot are rarely made (or rarely discussed). Four years ago, we conducted such an experiment. Six RAF squadron pilots flew a large number of close-combat engagements, against either BACTAC or each other. The aircraft types were the Northrop F5E and the McDonnell Douglas F4. Both aircraft were armed with rear-hemisphere IR missiles.

Scoring measurements and pilot comments were recorded, together with all parameters needed to reconstruct each fight. Table 1 shows some of the measurements.

Table 1

	Average No. of shots		Average IAS knots		Average g	
F5 man v man	0.11	0.56	256	265	3.0	3.1
F5 man v BACTAC	0.39	0.11	255	244	3.3	3.0

In the case of the F5 v F5 fights, a good validation of BACTAC's logic was obtained. The scatter in the number of shots was less than in the man v man case. The speeds and the g levels are similar. Pilot opinion confirmed that BACTAC was fighting in a similar manner.

COST/EFFECTIVENESS

What does it cost to train for Air Combat in the air? Costs are a sensitive topic, partly because they are useful for comparative purposes, and in such comparisons, the same basis for costs must be used. In a word, however, the answer is 'expensive'. Published information gives an indication of the order of costs. Training an RAF pilot to the point of joining an operational squadron costs around $5 million; only relevant in this discussion if a pilot is lost in a training accident, and a replacement necessary. Similarly, aircraft attrition in combat training is expensive; $10 million per aircraft as a minimum.

Hopefully, accidents are infrequent; the real cost is in the flying hours. Hourly flying costs clearly depend on aircraft type, and whether these costs should include all overheads, including aircraft procurement and spares. A typical range of published figure goes from around $5,000 per hour for an advanced trainer such as the Hawk, to $10,000 for front-line defence aircraft. For a simple one v one engagement, two aircraft are needed, weather and airspace must be suitable, other operational aspects add to the cost. Actual combat engagements in that hour depend on circumstance, like initial separation and control of air space; an average of three is realistic.

The ACMI is a good air combat training arena, with all the benefits of briefing, monitoring, and replay which have been described earlier. The RAF buys about 1000 half hour slots per year on the ACMI in Sardinia; each slot cost $4,500. The crews, aircraft, and ground support have to get to Sardinia. Add it all up, and air combat training is 'expensive'.

What does it cost to train for Air Combat on the ground? This is an easier question to answer. The RAF ACS described earlier today would sell for $7m; technology developments since its specification in the early eighties should allow a simulator with multi-combat, low-level combat capability, including missile fly-out simulation, for less than $15m. How does all this relate to the training cost per hour in the simulator? A week of training as described in section 4, might cost around $25,000, and depending on utilisation, $750 per hour emerges as an all-inclusive leasing cost to the customer.

With the above figures, it is easy to prove that of all ground training aids, Air Combat Simulators are the most cost/effective pilot training simulator on the market, including the well-established Commercial Airline Training Devices.

The unfortunate paradox is that most Air Forces see Air Combat Simulators as luxury items. In broad terms, they cost about the same as a full mission simulator, and they do not do the full mission (neither does the full mission simulator). The full mission simulator is essential - the ACS can be given less priority, because Air Combat Training has to be done in the air. In paraphrasing this customer view, the view sometimes held at air staff level must be added, that simulation of Air Combat still has some way to go. By delaying a procurement decision, a better product which is in the pipeline will emerge, and that is the one to buy. The fallacy of this argument is that the 'expensive' training tap is running right now, dollars are flowing, and some of that flow could be used more effectively, starting today.

CONCLUSION

The technology for Air Combat Simulation was developed for research and development, years ago. This technology has been applied to pilot training for Air Combat with conspicuous success. We have described the experience at British Aerospace in this area. The experience covers both the transfer of the design from a Research Simulator to a Training Simulator, and the operational aspects of using such a simulator to train pilots. The economics of this operation have also been presented.

Air Forces have been slow to recognise the monetary benefits which come from the use of simulators for Air Combat Training, but there is now every sign that the situation is changing. Adding support to this change of policy is the wider choice of training device which industry can offer. The basic ACS trainer has been there for several years. Today's technology not only offers these effective, low cost devices for teaching the basic skills, but also a wide choice of options, all cost-effective, to supplement the specialised training needed for tomorrow's fighter pilots.

ABOUT THE AUTHORS

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