A LOW COST ROUTE TO HIGH COST EFFECTIVENESS

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ABSTRACT

The Royal Air Force policy for microcomputer based training is aimed at solving appropriate and identified training needs in the most cost-effective way. This paper describes three training aids, all developed in-house, which illustrate this policy in practice. The first is an Air Intercept Trainer which is now in use with the air defence training and operational units: it is a small real-time simulation with student replay facility. The second is a part-task trainer for use in navigation training/instrument interpretation on the RAF's new basic flying trainer; this again responds in real-time to students' inputs and provides immediate feedback and replay facilities. The third aid aims to enhance the quality of classroom instruction by the use of computer-generated controlled animated displays of aircraft technical systems. Finally the paper will argue, through the experience gained, the merits of such in-house development.

INTRODUCTION

Background

The use of computers in training, both for the delivery of instructional material and for management, failed to make much impact in the United Kingdom (UK) until the mid-70s. A 5-year National Development Programme for Computer Assisted Learning (NDPCAL), comprising projects in a number of educational/training institutions, was started in January 1973, and included 3 Royal Air Force projects: one on fault finding on a simulated radar equipment and 2 on aspects of training management. The former enjoyed some success, but, as it failed to predict immediate savings, was not sustained when the NDPCAL funding ended. Little further development took place in the RAF until March 1980 when a Working Party (WP) was set up to examine the application and applicability of Computer Based Training (CBT) techniques to the conduct and management of training. The study did not concern itself with computer driven simulators because of a lack (then) of any interaction between the computer and the student. It did however examine what prerequisite skills and knowledge could be separated out from the total simulator task requirements and developed equally well on some form of lower level part-task device. Reporting at the end of that year, the WP therefore pointed to areas of training which were most likely to show both training and cost benefits from the application of computers: small simulation, part-task and procedural training and management of training. It also proposed that aspects of remedial, refresher and on-the-job training might lend themselves to the technique, but cautioned against the large-scale introduction of CBT into basic, ab initio, training because of the high cost of courseware development, doubts as to the benefits of CBT used in the basic tutorial mode and the undesirability of an individualized approach in many areas of basic military training.

Current Situation

Since that time CBT has developed within the RAF very much along the lines suggested and considerable progress has been made in its implementation. There is no doubt that CBT is a very powerful training aid and that it has enormous potential for improving the quality and cost-effectiveness of training. Equally certain, CBT has the potential for wastage of resources on a grand scale, particularly if its introduction is not carefully planned, co-ordinated and controlled.

Definition

For the purposes of this paper, a CBT system is defined as standard, commercially available computer hardware and peripherals running software for training purposes but excludes systems which involve non-standard hardware and software manufactured to RAF specifications such as simulators, emulators and other synthetic trainers.

RAF Policy for CBT

Within the above definition, CBT is regarded as one of a range of teaching methods available for use when new training is being designed or existing training is being revised. In the introduction of a CBT system the over-riding constraint is the availability of appropriate software. Hardware is increasingly cheap and powerful while software development remains expensive as it requires considerable expertise and is both time-consuming and manpower-intensive. Very little ready-made software of direct relevance to RAF training is available commercially. Thus, a decision to implement CBT is only taken when, having taken software development costs into account, CBT provides a more cost-effective solution to a training requirement than other available methods. The following examples illustrate the way in which this policy is being applied in practice to exploit the low cost/high return potential of the microcomputer as it takes its place in the hierarchy of synthetic training devices for both aircrew and maintenance training.

THE MICRO-BASED AIR INTERCEPT TRAINER (MAIT)

Introduction

During the early 1980's it became apparent to Air Defence staffs that the success rate of intercept missions could be improved and an analysis of the training problems was undertaken as a matter of some urgency.

Training Problem

The analysis (simplified for this paper) revealed that:

The 'B' Scope radar system used by the Air Intercept force is of a conical '3-D' type, but when displayed to the aircrew, the presentation is 2-dimensional. This makes interpretation and target tracking a complex operation. At the time of the analysis, navigators were only receiving superficial basic training in these techniques and pilots no training at all until they reached an Operational Conversion Unit.

Until 1986 there were only 2 types of training aid available to students at fighter Operational Conversion Units which allowed them to practise air intercept techniques on the ground. These were the multi-million pound, full simulators and the Air Intercept Trainer, a 20 year old analogue system which was no longer sufficiently accurate in terms of target motion and track analysis. Both systems were expensive, required full engineering support and neither was in any way portable. Consequently there was very little opportunity for students to carry out 'private study' in air intercept techniques. Additionally there were no facilities for the pilot and navigator to practise their intercept skills as a team.

A variety of different aircraft (eg the Phantom, Lightning and the projected ADV Tornado) are, or until relatively recently were, used as interceptors and each has differing display facilities and operating characteristics.

Development

The development commenced using the Phantom system as a model and comprised:

Hardware. The chosen hardware configuration was a BBC Microcomputer with a colour monitor, double 5¼" disc drives, twin joysticks and an 80 column dot matrix printer. The BBC Microcomputer is based on a 6502 - 8 Bit microprocessor and is widely used in education and training establishments throughout the UK. The cost of one complete configuration was approximately £1,000 (including maintenance and consumables).

Software. The software was written primarily in BBC BASIC (which is supplied integrally with the hardware) whilst some sections were written in 6502 Assembler when BASIC was unable to provide adequate facilities. The software team acquired subject matter expertise as and when required from a qualified weapons instructor and designed and developed the software 'in-house' at the Department of Computer Based Learning at the RAF School of Education and Training Support. The software team consisted of a Squadron Leader and two undergraduate Computer Science students undertaking the industrial experience year of their college courses. Approximately 250 man-days were expended in the initial development over a 2 year period. The cost to the Service of this development is difficult to estimate; however, less than £10,000 is probably realistic. At equivalent commercial rates this would have cost £75,000.

Attributes. The package is essentially simple to operate with menu driven options to select and fly a range of standard intercept patterns and a replay facility to view the results of each individual sortie. The software contains a simplified flying model of the Phantom aircraft which responds to joystick and certain keyboard inputs in real time, driving the appropriate radar display simulation on the colour monitor and recording the model's calculated position at regular intervals to provide the replay data for the subsequent debrief.

Implementation

The MAIT package was initially delivered to the Phantom conversion units for incorporation into their training syllabuses. It was then issued to the Tactical Weapons Units and finally to all Phantom Air Defence Squadrons throughout the UK and RAF Germany. The impact of these training aids was immediate and widespread generating demands for both a Lightning version and a Tornado version. The development of these variants took a further 180 man-days over a 2-year period. Again, all software production was done 'in-house' utilizing the appropriate subject matter experts when required. The Tornado version has some significant enhancements over the other variants, requiring an additional computer and monitor to cope with its more complex display. This variant accounted for ¾ of the additional development time. The success of the Tornado MAIT was recognized by the Royal Saudi Air Force who, via British Aerospace, commissioned a further variant for their Tornado F3 training which took a further 60 man-days to complete. To date, a total of 18 RAF MAIT systems have been installed in the UK and RAF Germany and are frequently taken on squadron detachments.

Results/Implications

An evaluation report of the Phantom MAIT after one year in service reported the package as an 'unqualified success'. The hardware has been extremely reliable with no significant down-times. The package has been utilized for between 20 and 80 hours per month (depending on unit type) and is widely accepted as a valuable training aid. The purchase of the package by the Royal Saudi

Air Force has realised the full (Service) development costs of MAIT, whilst they have obtained a product far cheaper than would have been possible by commissioning a comparable commercial venture. The design philosophy of the project has allowed other variants (Lightning, Tornado) to be produced relatively easily and provided a basis for other software projects (see NAVIT below) with flying simulation elements. The use of 'in house' development has limited the capital cost of MAIT to approximately £25,000. The improved training which has resulted is evidence of an extremely low cost/high return investment.

THE TUCANO NAVIGATION INSTRUMENT TRAINER (NAVIT)

Introduction

The MAIT systems were developed to meet a deficiency in our existing training methods. There is, however, an increasing requirement to identify and solve training problems before major equipments enter service. For each major new aircraft or equipment a Course Design Team is established to design and implement the training necessary for a successful introduction into RAF service. The Tucano Course Design Team identified a potentially serious training problem with the navigation training/instrument interpretation for the new Tucano aircraft.

Training Problem

The Tucano is a high performance turbo-prop training aircraft due to enter RAF service between (late) 1988 and 1991, replacing the Jet Provost Mks 3A and 5A for Basic Flying Training. The aircraft will be used to train approximately 250 pilots per year for at least 20 years. Unlike the Jet Provost, the Tucano is fitted with relatively sophisticated avionics, including a Horizontal Situation Indicator (HSI) and a Radio Magnetic Indicator (RMI). These instruments provide the primary sources of navigational and airfield approach data that a student uses to fix his position and navigate throughout a sortie. An external validation of Advanced Flying Training has shown that interpreting them gives students difficulty on the Hawk and Jetstream aircraft, both of which use these instruments. If students on these courses, having already completed their basic training, have problems, the potential difficulty for a novice pilot flying the Tucano in basic flying training is even greater.

Possible Solutions

The optimum solution must allow the student the facility to 'fly' a sortie. This really permits only 2 options:

Flying additional navigation exercises in both the flight simulator and the aircraft. Such a high cost option, although feasible, was quickly discounted as not cost effective.

Flying a part-task trainer which responds in real time to the student's inputs and concentrates primarily on the navigational aspects of the sortie. This alternative was perceived to be extremely cost effective and capable of providing a number of spin-off facilities.

Development

The development commenced in April 1987 and consisted of:

Hardware. The selected hardware configuration was a Research Machines (RM) Nimbus AX20 computer with 1 Mbyte RAM, 20 Mbyte hard disc, 3½ inch floppy disc, colour monitor and joystick. This computer is IBM AT compatible, running the MSDOS operating system. It is a 16 Bit 80286-based microprocessor running at 12 MHz and the version selected incorporated a 80287 maths co-processor. The cost of this configuration was approximately £2,600.

Software. As with the MAIT the software was again written totally 'in-house', this time using the 'C' programming language because of its speed of execution and real-time capabilities. The same software team structure was used as for the MAIT project but with a complete change of personnel. Subject matter expertise was provided by the Tucano Course Design team and a visit to see the aircraft in its acceptance phase at the Royal Aircraft Experimental unit Boscombe Down. The development strategy was to modify the flying model produced for MAIT into a Tucano version and rewrite it in 'C'. This would then be linked to animated colour graphic displays of the HSI and RMI with sufficient other instrumentation to 'fly' the trainer. The development and documentation has taken approximately 220 man-days over 13 months at a cost to the service of about £8,000. At commercial rates, an equivalent package designed from scratch is likely to be in excess of £100,000 (including developing the flying model).

Attributes. The package allows a student to enter all the navigational data required for a sortie in the UK. He can fly from any airfield or designated start point, dial up the appropriate TACAN, VOR and ILS beacon, insert way-points, wind data, etc. He then flies the NAVIT trainer which responds to navigation data as would the real aircraft. A separate 'final approach' mode allows the student to practise landing procedures down to 200 feet, thus obtaining familiarity with ILS marker beacons and selecting flaps, airbrakes and undercarriage. A number of other facilities (eg help, pause, etc) are provided together with a replay which shows the planned route and the actual flight path at the end of each sortie. A normal NAVIT sortie can take between 30 and 90 minutes to complete.

Implementation

The development of the NAVIT has proceeded far more effectively than the real aircraft. A pre-release version of the package has been issued to the Central Flying School and other test versions are undergoing trials at all the basic flying training units by their specialist instructors. The initial feedback has been extremely encouraging with general praise for NAVIT's performance. Already, its potential for modification in support of Hawk, Buccaneer and helicopter training is being considered. There is unanimous agreement amongst specialist aircrew staff that the NAVIT will significantly enhance the cost-effectiveness of flying training in the RAF.

Implications

The NAVIT seems to have secured its success before the real aircraft is introduced into service. A second identified requirement for Tucano BFT is to provide dynamic technical system diagrams to aid the student in understanding complex systems such as hydraulics, electrics or fuel. Standard CBT authoring systems coupled with the modern PC's graphic capabilities give the investment in NAVIT hardware the potential for further exploitation at low cost by non-computer specialist personnel. We are currently developing such systems with the Tucano CDT. The use of 'standard' computers also provides a host of commercial software for word-processing, spread-sheet and database applications, thus allowing BFT units to become more efficient in course administration and support. The potential use of the PC for animated graphics has far reaching implications for the teaching of complex technical subjects; the next project considers this further.

MULTI-ENGINED TRAINING SQUADRON (METS) CLASSROOM AID

Introduction

The requirement to improve the teaching of complex technical systems has continually presented a challenge to trainers. Chalkboards, overhead projectors, slides, films, models, mock-ups, etc have been used with varying degrees of success. The continued growth of the PC's graphics capability now promises a breakthrough in this area. The second phase of CBT production in support of the Tucano training addresses the need. However, many other training agencies are requesting computer generated, dynamic technical system diagrams. This section describes one typical requirement.

Training Problem

The Multi-Engined Training Squadron is responsible for training, converting and refreshing pilots who are to take up appointments flying multi-engined aircraft. All students complete an intensive ground school phase before commencing to fly the Jetstream T Mk 1 aircraft. The Jetstream is fitted with an extensive variety of technical systems with which the pilot must become familiar. It has been described by one pilot as "a multitude of microswitches flying in formation". Current lesson presentations are poorly supported by the existing classroom aids, making it difficult for the student fully to grasp the systems he has to manage. The ground school instructor loading allows little opportunity for supervised extra technical training. The result is that students who need this additional training must gain it in the air, thus taking longer to become proficient multi-engine pilots.

Proposed Solutions

Improved training aids are essential to solving this training problem. The possible options were:

To lengthen the courses, provide a full fixed base trainer which would expand the cockpit procedures trainer into an interactive work station and to increase the instructor establishment.

To produce a PC based graphics system which will dynamically represent the operation of the numerous different systems.

The costs and logistical problems quickly discounted the first option leaving the PC solution as preferred.

Development

The development of this project is still at a very early stage, however, certain important decisions have already been taken:

Hardware. The courses will follow basic flying training during which the student will have used the NAVIT described above. Hence, it was decided to standardize on the same hardware configuration as NAVIT without the joysticks. An additional graphics card was found necessary to enhance the dynamic presentation and large screen display units were needed to provide for classroom presentation. The cost of a classroom station will be approximately £12,000.

Software. The current methods used to produce technical system diagrams for the Tucano project is to 'draw' the system statically using a proprietary 'paint brush' package, then take this image into an authoring system where the animation effects are produced. This method is much simpler to use than writing high level code programs to draw and animate directly. Even using the former method, to draw a system accurately is a skilled, time-consuming exercise with one system taking 2 to 3 man weeks to produce, without the animation. The large number of systems required for the Jetstream package would have tied up valuable manpower indefinitely. We decided therefore to speed up the drawing process by taking in the technical diagram, selector panels and indicators through a video camera; frame-grabbing the images into a professional graphics package and then colouring and animating the system within the package. Tests have shown that the capture and colouring of system diagrams is perfectly viable, achieving in minutes what previously took days. Animation within the graphics package is still being investigated with a view to non-specialist user development. The use of an authoring system has not been discounted. As the project is still in its infancy no manpower costings can be provided. The project estimate was 200 man days using 'in-house' developed software with a technical instructor acting as the subject matter expert. The costs are expected to be less than £10,000 with an additional expense being £7,500 for the graphics package.

Attributes. The package will display a selected system on a multi-windowed screen. One segment will display the selector panel, a second segment the relevant indicator panel and the main area will show the system. The instructor will simulate the selection of the appropriate switches which will activate the appropriate indicators and show the effects on the system dynamically. The effects of faults and incorrect selections can also be shown. Finally, a refresher pack will be provided for each system so that a student can access further stand alone computers out of normal training time to consolidate his understanding.

Implications

This project is very much a development exercise. If it succeeds (as currently seems likely), the software tools we are developing and the capabilities of the graphics package will provide a mass production facility which any user unit will be able to use to quickly produce its own technical systems without the need for significant software expertise. Already a number of specialist aircraft ground schools have identified similar training problems and a great deal of interest is being shown by maintenance training schools. The modern PC has the capabilities to supersede the overhead projector in the technical classroom of the future.

THE WAY AHEAD

The preceding examples serve to illustrate the route being constructed to achieve a high training return from a relatively low financial investment. The three examples however are not stepping stones chosen at random, rather they form a natural progression. The development of the MAIT not only satisfied a training need, but also demonstrated what was possible in real-time simulation. The model developed in this project was capable of being adapted for the NAVIT, but then the choice of hardware, giving entry into the world of the PC and the availability of powerful authoring systems and software packages, led to an ability to satisfy other training needs. Typical among these was the requirement for a dynamic animated display for use by instructors. The computer is thus being used not to replace the instructor but to support him. Once this capability is validated and fully demonstrated then we see a huge market in RAF terms, being developed.

A key pointer to the way ahead is found in the common features of these examples: training needs analysis; in-house software development; user involvement.

Training Needs Analysis. A decision to use the computer as a training aid must be made with a full knowledge of the total training system of which it is a part and after a full training needs analysis has been conducted. This involves a thorough analysis of the work to be undertaken by trained personnel and the specification of the necessary skills, knowledge and attitudes, from which training objectives are derived. A comparative examination is then made of all the training media and devices available to permit an assessment of whether CBT is appropriate. It will also permit the development of a hierarchy of training devices necessary to meet the training objectives. By following the rigour of this process we can be reasonably sure that the training solution is problem driven.

In-house Development. The question of whether to use mainly in-house development is not easily nor readily answered and many factors were considered before we decided to follow this route. Without doubt, commercial organizations, whether large multi-national concerns or small software houses, have all the computer expertise and the resources necessary. However, perhaps until recently, they have not been sufficiently aware of the training needs of the service user or have possessed sufficient training experience and expertise to chart their way. The need for a training solution to be problem driven has been stressed earlier and as no two training problems are the same, then the solutions are generally unique and tailor-made. Commercial packages do not necessarily suit such individual requirements. In-house development permits the closest possible co-operation between the software engineer, the trainers and the subject matter expert, particularly if and when they are all service personnel. This close co-operation is essential to ensure total flexibility in development and if the end product is to be acceptable to the user. Fixed price contracts tend not to encourage such flexibility. Once a CBT solution has been agreed, developed, validated and introduced there is a need for its maintainability and full life-cycle support. There would appear to be a better chance of full support being available for in-house projects, provided of course, the project has been fully documented (software engineers are well known for their lack of enthusiasm in this area). However, the success of in-house development depends upon being able to recruit internally the necessary qualified manpower and fund essential research and development activities. In times of financial stringency and limited budgets, particularly for training activities, this success could be jeopardized by an inability to match requirements. To overcome or avoid this disadvantage it is necessary to define the boundaries of in-house activities.

User Involvement. We have already referred to the involvement of the user and subject matter expert; this close involvement is essential if the project is to meet exactly his training requirements. Further, it leads the way to successful innovation in the training area. The training world can cite many failed initiatives mainly because of the NIH (Not Invented Here) syndrome; total user involvement is paramount to ensure commitment in full to the new training aid or vehicle.

Having been encouraged by the success, both actual and predicted, of the three examples described to the extent that we are firmly convinced of the merits of in-house development, we are realistic enough to realize there are limitations to the size and scope of the work which should be undertaken. The overriding criterion is one of cost justification, coupled with the software complexity of a project which may be totally beyond the capacity of in-house development. However, as long as there is a trend away from major CBT investments towards more small scale applications which can be enhanced over a period of time, the in-house low cost route is the one to follow. Not only should this have a controlling effect on the cost spiral but also it will have a retaining effect on vital user support and involvement.

CONCLUSION

The use of the stand alone microcomputer to solve identified training problems and meet perceived training needs is serving to convince the authors of the merits of in-house software development in carefully selected areas. Close user involvement from the outset not only provides expert assistance ensuring that solutions are problem driven, but also is good innovation practice leading to a ready acceptance of the training aid by the trainers themselves. Within defined boundaries this is a low cost way of providing highly effective training, opening up what we believe is the route to high cost-effectiveness in an ever widening area of application.

ABOUT THE AUTHORS

Group Captain David Priestley joined the RAF in 1956 and has spent most of his career in the education and training field, including a tour as exchange professor at the USAF Institute of Technology, Wright Patterson AFB. He has a Masters degree in Electronics and has been involved in CBT as a policy maker and practitioner for 10 years. Currently he is the Commanding Officer of the RAF School of Education and Training Support, which provides a training and consultancy service for all the RAF's trainers. Squadron Leader Peter Jaques joined the RAF as an airframe technician in 1961 and developed an expertise in computing through being involved in computer aided aircraft servicing. He holds a degree in Computing and Technology and a post-graduate certificate in technical education. On commissioning he instructed on various technical courses before combining his training and computing expertise to become the RAF's CBT consultant.