A Training and Cost-Benefit Analysis for the F-111C Mission Simulator

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ABSTRACT: This paper will discuss the application of training task analysis and cost-benefit analysis methodologies and tools to an investigation of potential enhancements for the F-111C Mission Simulator. Key points will include: definition of required training functions, approach to automated assignment of training tasks to modelled training environments, and assessment of key cost-benefit measures. The advantages and pitfalls of employing a training system modeling tool for this type of study will also be discussed.

1.0 Introduction

1.1 General

The recent Avionics Update Program for the RAAF's F-111C aircraft has necessitated a parallel upgrade of the F-111C Mission Simulator. The simulator upgrade path selected by the Project Office involved development, installation and support of a new mission simulator system by Thomson-CSF Pacific Pty Ltd. The new mission simulator has recently undergone Final Acceptance Test and Evaluation onsite at RAAF AMBERLEY and training using the device has begun.

Approaching the end of the acquisition of the new mission simulator, two important issues were faced by the Project Office:

- Were any final enhancements to the mission simulator required due to changes to operations and training practices since the time of initial requirement definition?
- Were some perceived deficiencies in performance of the new mission simulator, possibly outside the scope of the acquisition contract, worthy of the cost of rectification in terms of training benefits?

These issues are common to all projects which seek to acquire complex training simulation systems in parallel with upgrades to operational systems. Recognition of these issues should be viewed as responsible management by the Project Office with the aim of best satisfying the needs of the customer; in this case 82 WING.

The Project Office decided that a study was required to define training requirements relevant to the mission simulator and investigate the utility of various levels of training device capability, ie with and without specific stimuli and instructional support features. Learning Systems Analysis P/L was contracted to undertake this study for the Project Office and commenced work in May 1999. Several stages of the study have now been completed with a final report expected in April 2000.

1.2 The Deficiency/Enhancement Problem

Training studies may be undertaken at any point during capability analysis, acquisition and employment of a simulation system. The context for the study described in this paper is toward the end of acquisition where questions arise regarding perceived deficiencies and possible enhancements.

Deficiencies may be perceived in two ways, either between: specified system performance criteria and actual performance (an engineering discrepancy), or intended training utility and realised utility (a training function discrepancy). The first can be examined through a training study with the result being a statement of cost-benefit implications. The second may be identified through a training study, along with related cost-benefit information.

Enhancements are arguably justified where a training study shows that a training function discrepancy exists. The issue then is to decide whether the enhacement cost is affordable and cost-effective.

While the F-111C Mission Simulator training study provides a context for discussion of this deficiency/enhancement problem, the focus of this paper will be on approaches to gathering and assessing relevant information. The current study has not been completed and specific information on results will not be discussed.

1.3 Related Training Studies

Similar analysis methodologies have been applied to several recent studies: a training analysis for the AP-3C Advanced Flight Simulator (Wallace & Northam, [1]), training requirement definition for the Light Tactical Airlift Capability project (Wallace, [2]) and a training analysis for the Hornet Upgrade Project (Wallace, Walkden & Lintern, [3]).

Each of these earlier studies involved an examination of stimuli and instructional support features necessary for the conduct of defined training tasks, but they did not proceed to the consideration of cost-benefit issues as has been done in the case of the F-111C Mission Simulator. Another more recent study for the RAN's Sea King Flight Simulator has considered cost-benefit issues and a paper discussing the potential use of virtual environments for Sea King training, with reference to the training analysis methodology, is included in these proceedings of SimTecT 2000.

The studies for the F-111C and Sea King have employed a proprietary analysis tool of Learning Systems Analysis P/L. This tool, TANDEM (Training ANalysis and Device EMployment), is a decision support system comprising two main modules: Task Analysis, which provides means for comparing task requirements with the capabilities of potential training environments; and Cost Analysis, which models acquisition and support costs over the life-of-type of the training system.

Each of the projects referred to above has had its own peculiar circumstances and goals. Some are early in the requirement definition process, others, such as the study for the F-111C, are toward completion of the acquisition process. Consequently, it has not been possible to simply apply the same training analysis procedures and tools without modification.

This paper discusses some issues which were especially important for the study of the F-111C Mission Simulator and how they were tackled. Rather than proposing specific solutions to such issues, this paper proposes that any issue should be examined within its own context and an optimal approach to training analysis devised.

1.4 This Paper

Section 2 of this paper presents a description of the process employed to define training functions required for F-111C aircrew and compare these with functions available from potential training environments. This section also describes the modeling of potential future flight simulation training environments that was undertaken.

Section 3 provides a discussion of automated assignment of modeled training environments to defined training tasks.

Section 4 describes the cost-benefit measures employed and discusses their relative merits.

Finally, conclusions and recommendations for future approaches are presented in Section 5.

2.0 Definition of Required Training Functions

2.1 General

The approach used in this study involved the modeling of options for future training so that cost-benefit measures could be compared. The principal difference between options for future training was in the capabilitity of the Mission Simulator. The broad varations in simulator capability under consideration comprised:

- The Mission Simulator with functionality as determined upon the completion of Final Acceptance Test and Evaluation.
- The Mission Simulator with functionality as intended upon completion of the acquisition contract.
- The Mission Simulator with image system enhancements beyond the scope of the current acquisition contract.

The third of the options listed above involved a range of capabilities in vertical and horizontal field-of-view and image resolution. Variations to horizontal field-of-view and both elevation and declination in vertical field-of-view were considered. Variations to resolution were considered both through the use of target generators and through increasing the density of the entire projected image.

Each modelled option for future training combined use of the Mission Simulator with use of actual aircraft to satisfy aircrew training requirements. In order to compare options fairly, a common model of the requirements of F-111C aircrew training was constructed. This encompassed all formal training courses, categorization activities and currency standards. The aircrew training model assumed steady training rates over a ten year period; this was the period also assumed for amortization of costs associated with any further enhancement of the Mission Simulator.

2.2 Identification of Training Tasks

Training tasks are discrete activities undertaken by trainees for the purpose of learning a skill or demonstrating competence. Some training tasks may be derived directly from standards for graduate performance. While others are developed by interpolating back from graduate performance to earlier stages of skill acquisition. For example, performing circuits under all conditions allowed for the aircraft may be preceded by a developmental task of performing day circuits under nil wind conditions and under instructional supervision.

A total of 1470 training tasks relevant to the mission simulator were defined for aircrew. In addition to being organised by course of training, these tasks were structured in terms of a taxonomy for classifying the nature of the activity. For example, the first level of classification involved defining tasks as emergency procedures, normal operations, tactical operations or test events. This system of classification aided systematic identification of training tasks and assisted with later grouping of tasks for analysis purposes.

The potential to train either, or both, crew positions in the simulator at a time meant that consideration also had to be given to the instructional practices employed. At times, training tasks are expected to be 'mutual', ie both crew positions are filled by students. At other times an instructor is expected to fill one crew position. In principle, a single operational event such as perform a take-off could require three types of environment: one providing the stimuli and instructional support features relevant to pilot training, one providing these aspects for navigator training, and one providing aspects for both pilot and navigator training.

In the case of the aircraft all stimuli may normally be expected to be available for both the pilot and navigator and, therefore, the needs of each of the three cases are satisfied. However, the mission simulator is not a perfect imitation of the aircraft and the lack of some aspects of the operational environment may mean that only one of the crew positions can be trained in the event under consideration. We need to be able to identify such cases and this led to some training courses being split into three 'modelled' courses. For example, the initial conversion course exists under a single syllabus, but for the purposes of analysis it was split into a pilot conversion, a navigator conversion, and a crew conversion.

Once a comprehensive set of training tasks had been identified, each had to be studied to determine the stimuli and instructional support features necessary for effective instruction. This step required definition of classes of stimuli and instructional support features to be studied.

2.3 Definition of Critical Stimuli and Instructional Functions

The definition of classes of stimuli is a matter of judgment and must be based on the needs and circumstances of the study at hand. In some previous studies, we have found it necessary to define 20 to 30 groupings of aircraft systems stimuli in order to obtain the detail of information desired and cover all potential areas of interest. However, the present study was relatively narrowly defined with the aim primarily being to investigate pre-defined deficiencies and enhancements.

Consequently, the definition of aircraft systems stimuli was undertaken in two steps. First, systems stimuli related to possible deficiencies in simulator performance were listed. Secondly, broad groupings were defined to encompass all aircraft systems stimuli. As it turned out, six specific systems stimuli were involved in pre-defined deficiencies and six general classes of stimuli were sufficient to cover all aircraft systems.

An examination of the external environments within which F-111C operations are undertaken, in combination with experience from past projects, was used to develop classes of external environmental stimuli. Knowledge of possible simulator deficiencies permitted specific environmental stimuli to be targetted for special attention. For example, concern over the range at which ground targets could be visually detected in the simulator led to this aspect being specifically studied during subsequent analysis.

General groupings of instructional support features which had been used in previous studies were decided to be equally applicable to this study and were adopted. These features generally involved capabilities for instructors to control, monitor, assess and record aircraft and environmental stimuli. In the case of environmental stimuli, the need for entities to exhibit intelligent behaviour was also investigated.

The definitions of stimuli and instructional support features permitted the ramifications of pre-defined deficiencies to be investigated. Additionally, the general classifications of stimuli led to identification of some unanticipated training shortcomings. This latter finding emerged through post-hoc analysis of data and demonstrates the importance of pre-defining potential deficiencies to the greatest extent possible. General 'fishing' for deficiencies is unreliable and, while somewhat successful in this case, can never be certain to identify all issues worthy of consideration.

2.4 Investigation of Training Tasks

Training task statements were developed through a study of training and operational documents and interviews with training and operational staff. The development of training tasks commences with identification of 'events' which require a skilled human response. Events are then matched to skill qualifications and levels of required proficiency assigned. For example, the event of 'instrument approach' may be matched to 'D Category pilot' with competence to be demonstrated at 'Skilled' level.

This 'instrument approach' is an example of a training task based on expected graduate performance. Preceding training tasks which provide opportunities for skill development must also be defined. This can be achieved through application of a skill learning model which provides a basis for defining a succession of training activities. Incremental Transfer Learning (Wallace, [4]) was the skill learning model used in this study.

While syllabuses may seem to provide immediate access to a large number of training tasks, such an approach would challenge the validity of the study. Syllabuses are based on extant training environments, eg the mission simulator with its current capabilities.

Consequently, syllabus objectives, which are at about the same level of detail as training tasks, are likely to be based on compromises between an ideal set of training tasks and those which can be undertaken with current resources. Nonetheless, syllabuses are very useful guides to the types of events which must be addressed.

Survey proforma were developed to record stimuli and instructional support feature requirements for each training task. A standardisation document to guide the process of data collection was also devloped at this time. There is enormous potential for varied interpretation of training task requirements and careful development and subsequent updating of this standardisation document is crucial to the collection of valid data.

Interviews were then conducted with instructional staff to gather data regarding training task requirements. This can be a very lengthy and demanding activity, both for subject matter experts and those conducting the interviews. Fortunately, the experience gained from gathering this sort of data over several projects has enabled efficient practices and tools to be developed and demands on scarce instructional staff were kept to a minimum.

2.5 Identification of Options for Future Training

The information gathered about training requirements was a necessary first step in cost-analysis. The next step was to define options for future training.

Six scenarios for the future conduct of training were defined. Each scenario was effectively a model of how training might be conducted in the future, although the principal difference between each of these scenarios was capability of the mission simulator. The scenarios comprised:

1. Current Capability.
2. Expected Capability.
3. Enhanced Target Detail.
4. Enhanced Field-of-View.
5. Enhanced Target Detail and Field-of-View.
6. Contingency Capabilities.

The Current Capability scenario represented the capability of the mission simulator at the time of data collection. This capability was less than that expecetd upon completion of the simulator acquisition process due to several performance problems that were in the process of being resolved. The Exepected Capability represented the full capability of the mission simulator that was expected by Project Office staff.

The capability of the mission simulator to present visual information was determined to present the most opportunity for cost-effective enhancements. Furthermore, target detail and field-of-view (FoV) were selected as the two aspects of principal concern within the visual system. Consequently, the third, fourth and fifth scenarios present variations in these capabilities.

The Contingency Capability scenario was included to investigate the implications of a failure to resolve current perceived performance deficiencies. In effect, the decrease in capability associated with each deficiency was applied to the other scenarios.

It is important to understand that each scenario for future training represented variations in capability and not alternative technical solutions. As with any capital equipment project, the philosophy was to first determine the level of capability required and then examine technical solutions. The only concession that had to be made on this point was examination of 'representative' technical solutions in order to gauge likely acquisition and support costs.

The examination of representative technical solutions also revealed potential for some variations within each option. For example,the use of a target generator to provide required target visual detail versus increasing the resolution of the entire visual display. The implications of these variations needed to be considered and, so, options within each sccenario for future training were also defined.

Each option within each scenario was then defined in terms of the same stimuli and instructional support features used to examine training tasks. This now provided a basis for assessing the training effectiveness and cost of possible future training systems.

3.0 Automated Assignment of Training Environments

3.1 General

Each option within each scenario needed to be examined as a distinct approach to training. This examination would then reveal cost-benefit measures which could be used to compare the options. The F-111C aircraft and the mission simulator, as modelled within each option, were the two training environments available for the conduct of training tasks. Accordingly, a decision had to be made on which environment to use for each training task. TANDEM provided an automated capability to perform this assignment task and enabled rapid development of a training program for each option.

The version of TANDEM used in this study was tailored to account for the context and imperatives of F-111C aircrew training. Many automated instructional design tools have been developed over the past 20 years, especially to assist the development of computer-based instruction. However, an unavoidable flaw with such tools is that they are based on very general assumptions about the context of training. Tailoring these assumptions to a specific situation would overcome this problem, but then the tool would not be as widely applicable and, therefore, commercially viable.

Contextual analysis is outside the scope of the present paper, but such a process formed the first part of the F-111C training study. The outcome of the contextual analysis was agreed assumptions and principles for subsequent analysis and modelling of the training system. This was then used to develop a version of TANDEM specifically tailored to F-111C aircrew training.

3.2 Assignment Factors

Three parameters were identified as relevant to assignment of training environments:

1. matching of stimuli requirements to capabilities,
2. matching of instructional support feature requirements to capabilities, and
3. preference to use simulation where possible.

A training environment had to provide all required stimuli in order to be assigned to a training task. This approach was consistent with the approach used to collect data. A test used to determine whather a particular stimulus was required was whether training could be successfully underaken if this stimulus was absent. Consequently, absence of any required stimulus was sufficient to discount a training environment from consideration.

The need for instructional support features is less clear cut than that for stimuli. An instructor can generally adjust teaching techniques to compensate for a desired support feature, although at some point the lack of such features may make training ineffective. A threshold of approximately 80% availability of instructional support features was used for the purpose of automatic assignment of training environments.

Where both the aircraft and the mission simulator were capable of supporting a training task, preference was given to the simulator. TANDEM provides a function for prioritising the use of training environments and, while only two such environments were under consideration in this study, this is very useful where several training platforms are invloved.

4.0 Cost-Benefit Measures

4.1 General

A decision to correct deficiencies or undertake enhancements eventually comes down to cost-effectiveness. The processes described above resulted in options for future F-111C aircrew training being modelled within TANDEM and several cost-benefit measures being made available.

Tools such as TANDEM can only present cost-benefit information with actual decisions requiring consultation between stakeholders and funding agencies. The key benefit of the processes undertaken in this study and the data made available through TANDEM is that a systematic and transparent approach has been taken so that assumptions and conclusions are clear to everyone. Moreover, the process is open to audit should the results be challenged.

4.2 Flying Hour:Simulator Hour

This measure presents the annual F-111C flying hours and simulator training hours calculated for each option. Aircraft hours are based on training tasks which are conducted between ‘brakes release’ on the runway and completion of after-landing checks as per current practice for the recording of flying hours. Simulator training hours are based on the time required to conduct all assigned training tasks, including hours which would not be included within ‘flying hours’ if performed on the aircraft. This approach to the calculation of training hours ensures that flying time is not reduced by transferring non-flying training tasks from the aircraft to the OFT.

4.3 Amotized Upgrade Cost per Additional Annual Simulator Hour

Additional simulator hours are those over the calculated annual usage of the ‘Expected Capability’ (Scenario 2). The Amortized Upgrade Cost is based on the capital acquisition cost and associated support costs amortized over a ten year period. For example, an upgrade with an acquisition cost of $1,000,000 and no additional ongoing support costs providing an additional 10 simulator hours per year results in a ratio of (10 simulator hours) / ($1,000,000 / 10 Years) = 10/(1/10) = 100:1. This measure does not, by itself, indicate the total annual simulator hours available through any option and should be considered in conjunction with the Annual Aircraft : Simulator hours measure. This measure makes no assumptions regarding savings in aircraft hours; the same ratios would be obtained whether or not the conduct of additional training on the simulator results in flying hour reductions.

4.4 Prohibitions

Training tasks are considered to be prohibited from whole-task training on the aircraft if they are unsafe or impractical. Consequently, training of such tasks on the aircraft must be in a manner constrained by safety or practicality issues. Training tasks are assigned to the simulator wherever this platform provides the minimum necessary stimuli and instructional support features; in all other cases tasks are assigned to the aircraft, even when prohibited from whole-task performance. In principle, the number of prohibited training tasks which must be performed on the aircraft should be kept to a minimum. However, this provides a very rough guide only as the implications for training effectiveness will vary dependent on the nature of each task. Consequently, this measure is presented for general consideration, but is not used as a prime basis for evaluating options.

5.0 Conclusions

The study of F-111C aricrew training was conducted late in the acquisition phase and primarily aimed at providing information related to perceived simulator deficiencies and possible enhancements. The approach to the study was based on modelling potential future training systems and comparing their cost-effectiveness. A training system modelling tool was used to support the analysis of data and to generate cost-benefit information.

1470 aircrew training tasks were identified and examined in terms of defined classes of stimuli and instructional support features. These tasks encompassed the full scope of aircrew skill development and maintenance, from type conversion through categorization to currency activities.

Six scenarios for the future conduct of training were defined in terms of the same stimuli and instructional support features used to investigate training tasks. These scenarios were designed to represent current simulator capabilities, expected capabilities, possible enhancements and contingencies.

A training system modelling tool (TANDEM) was used to support the analysis of data. Cost-benefit measures related to flying hours, simulator hours, cost of increasing simulator hours and prohibitions on the use of aircraft have been developed. This information is now being used to resolve the 'deficiency/enhancement problem'.

6.0 References

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7.0 Author Biography

Phil Wallace is the principal consultant for Learning Systems Analysis P/L. Phil retired from the RAAF after 21 years service in 1996. He was primarily employed in training requirement definition for major projects in the last eight years of his service with project experience including C-130J and Lead-In Fighter. He held a Defence Force Fellowship in 1991 for a study of instructional design for simulation systems. In recent years, Phil has undertaken training analysis studies for the AP-3C Advanced Flight Simulator, Light Tactical Aircraft project, Hornet Upgrade project, F-111C Mission Simulator and Sea King flight simulator. He holds a B.Sc from the RAAF Academy, post-graduate qualifications in educational technology and a Masters degree in education.