

APPLICATION OF TRAINING ANALYSIS AND DESIGN TOOLS

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ABSTRACT

This paper describes the application of a software tool in the training analysis and curriculum design of a large multi-national helicopter project. Requirements for the tool are outlined, and the selection process is described. Commercially-available tools are reviewed, and the application of such a tool at Westland Helicopter's Customer Training School is described.

When a new helicopter is developed, airframe manufacturers consider training requirements as part of the overall logistics plan. A training curriculum and an integrated suite of training media (typically ranging from Computer-Based Training to Simulators) are specified and procured. A systematic approach to the training analysis, design, development, implementation and evaluation is required to provide an objective, auditable record of the decision making process, and to allow project controls to be applied. The analysis of maintenance and operator tasks, selection of tasks for training, development and sequencing of learning objectives, and the specification of appropriate training media, are some of the key steps in creating a successful and cost-effective training system.

Software tools are very effective in supporting training analysis and design by guiding analysts through the required decision making processes, allowing them to make quicker and more consistent training decisions. The tools automatically create auditable and traceable records of the decision processes. Logistics Support Analysis Records can be imported as the starting point for the maintenance analysis, helping to integrate the training system with the evolving aircraft design. Training data can be easily and quickly stored, retrieved, shared and exchanged, resulting in a reduction in duplicated data. Configuration control facilities allow changes to be tracked as the aircraft design evolves. Use of a common software tool, data dictionary and database structure allows interchange of computer-readable training data amongst geographically distant organisations.

ABOUT THE AUTHORS

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INTRODUCTION

When a new aircraft is developed (the EH101 helicopter, for example) airframe manufacturers such as Westland Helicopters consider training requirements as part of the overall logistics plan. A training curriculum and an integrated suite of training media are specified, procured, and used to support training courses for helicopter operation and maintenance. The

training media and courses must be in place before the delivery of the first helicopter. A typical suite of training media for helicopter maintenance and operator training is depicted in Figure 1, and ranges from Computer-Based Training, through Part-Task Trainers to Simulators.

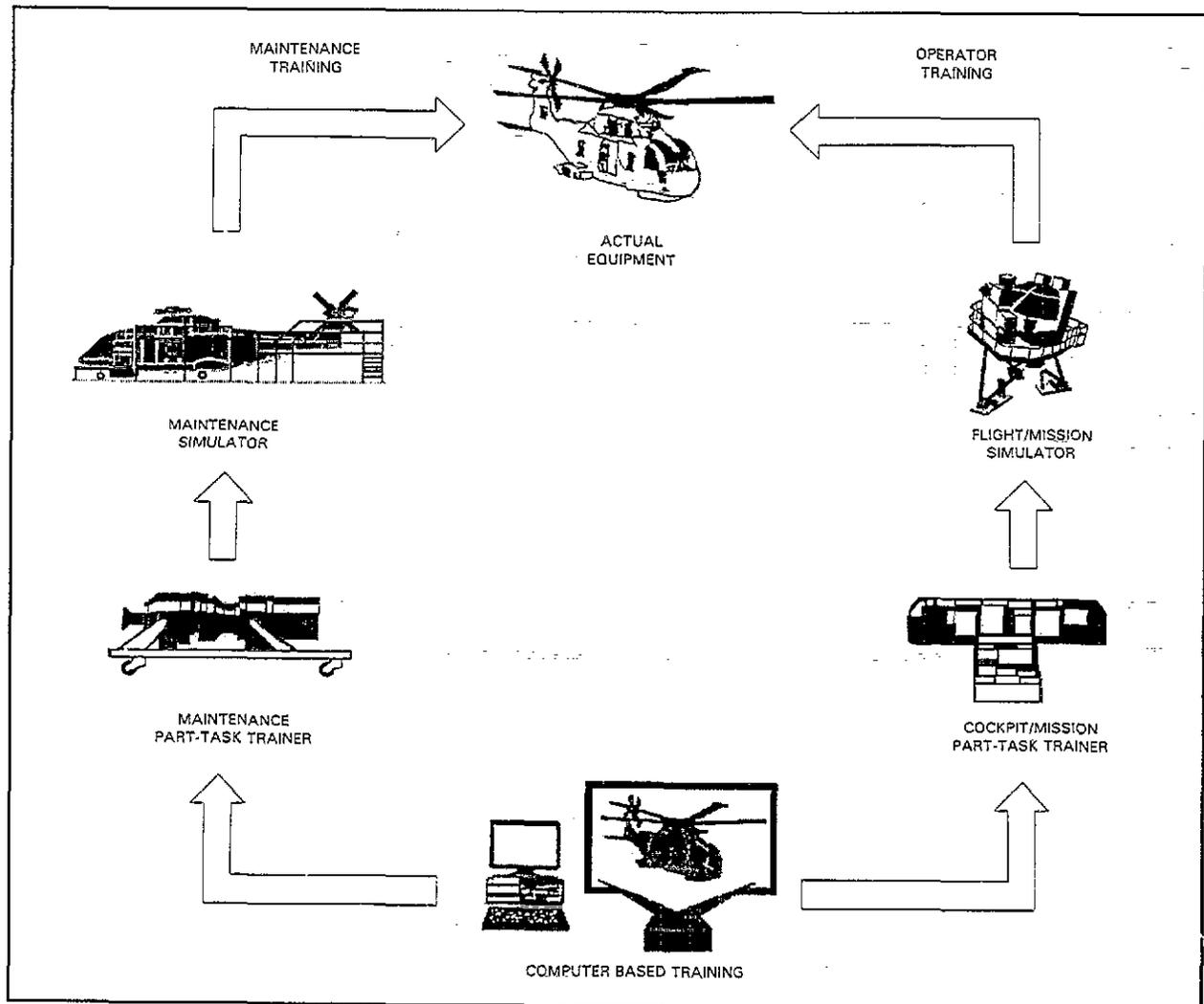


Figure 1 - Typical Training Media for a New Helicopter

Such a suite of training devices is a major expense, and it is essential that the specifications and learning objectives for each training device are systematically established and justified, so that the resulting training is cost-effective.

THE ISD PROCESS

The Instructional Systems Development (ISD) process [1][2] provides a closed-loop iterative approach to the Analysis, Design, Development, Implementation, and Control of large instructional systems (Figure 2).

ISD is a flexible step-by-step process for planning and developing instructional systems which ensures personnel are taught the knowledge, skills, and attitudes essential for successful job performance in a cost-effective way. ISD is also known as the Systems Approach to Training [3][4].

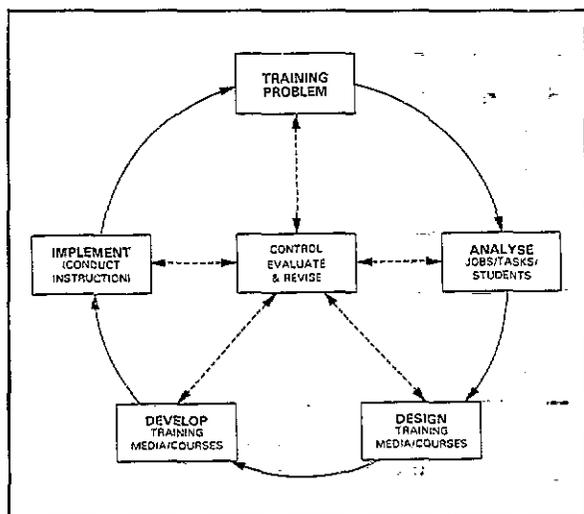


Figure 2 - Overview of the ISD Process

The following key steps from the Analysis, Design and Development stages of the ISD process are employed when developing helicopter training system for aircrew and maintainers [5]:

- Define Aircraft Systems
- Analyze Job Categories
- Analyze Tasks & Performance Measures
- Define Target Trainee Population

- Select Tasks for Training
- Select Instructional Setting
- Develop Learning Objectives & Performance Measures
- Select Training Media
- Develop Training Device Specifications
- Develop Courses

THE NEED FOR A COMPUTERISED TOOL

The ISD process is led by a Project Manager who oversees a team of Training Analysts and Subject Matter Experts (SMEs). In the past, the task selection process, media selection process, and other key ISD steps, were implemented manually, by following a set of written guidelines. The results were documented on paper. The process worked, but tended to suffer from the following disadvantages:

Labour Intensive - The detailed implementation of each of the key steps was a very labour intensive process.

Rework - Considerable effort was involved each time the training analysis data was evaluated and revised as part of the ISD process. Additionally, considerable rework effort was necessary each time the aircraft system design changed.

Inconsistencies - Training decisions tended to be inconsistent from analyst to analyst, and from project to project. Each analyst tended to have a slightly different interpretation of the written guidelines.

Duplication - Paper documents could not easily be shared while they were being developed. This led to duplication and redundant effort amongst the team of analysts.

Use of LSARs - Logistic Support Analysis is the iterative process that regularly updates the new weapon system's design and supportability information through all phases of development. LSARs contain design and logistics information for the aircraft or weapons system. The detailed steps involved in maintenance procedures for aircraft systems are often contained within pre-existing Logistic Support Analysis Records (LSARs) [6], and form the basis for maintenance Tasks and Subtasks.

With a manual process, LSA data was available to the analysts only as printed reports, and records were re-entered. This was inefficient, subject to error, and created rework when the LSAR records were updated.

Audit Trail - It was difficult to search and find information quickly amongst paper records to check why any given decision was made.

Process Training - When a new project started, and when a new analyst joined the team, considerable effort was necessary to train the analysts in how to apply the written guidelines.

Geographically Separate Analysis Teams - The EH101 helicopter is a cooperative venture between Westland in the UK and Agusta in Italy. Training analysis and design is conducted separately in the two countries, and merged to form a whole. A mechanism was needed to allow the two geographically-separate analysis teams to follow consistent procedures, and to merge the results into a single training design database.

Variants - There was a need to take the "core" training analysis for the basic aircraft, and merge it with extra training analysis for each new variant (e.g. mission systems such as sonar and radar). This was time consuming with the manual process.

Supply Machine Readable Data - Increasingly, customers are demanding the results of the training analysis to be supplied to them in a structured machine readable form, as part of the contract for the helicopter. This was the case with the variants of the EH101 proposed for Canada. The training analysis for the basic vehicle was to be handed over in machine readable format to the Canadian Prime Contractor, who would add the training analysis for the mission systems.

REQUIREMENTS SPECIFICATION

For these reasons, the authors set up a project to specify and select a computerised training analysis tool for use on the EH101 project, and future similar projects. To form the basis of the selection process we prepared a Requirements

Specification. The following is a synopsis of the requirements:

Training Analysis Methodologies - The tool must be able to implement the custom methodology and terminology selected for use on the project [5]; this included both maintenance and aircrew training analysis. The tool must also be capable of meeting the standard ISD processes (such as MIL-STD-1379D [2], and A-P9-000 [3]) used by potential customers throughout the world. The ability of the tool to comply with the analysis process and terminology outlined in Canadian Forces Publication A-P9-000 [3] was an important requirement.

Aircraft System Definition - The tool must allow the training analyst to define the aircraft Systems and Subsystems using an agreed coding system such as AECMA 1000D [7].

Job/Task Analysis - The tool must be capable of performing job and task analyses for operating and maintaining a modern aircraft. The tool must assist training analysts by providing facilities for verifying the completeness of data by, for example, searching for inconsistencies or incomplete data.

Job Analysis - The tool must allow the definition of job categories. For aircrew, job categories may include the Pilot, Copilot, Flight Engineer, and Mission Specialists (e.g. Sonar Operators). For maintenance personnel, jobs are defined by civilian and military trade specialities and levels, such as Electrical/Avionics, Mechanical, and Weapons.

Task Analysis - The tool must allow the definition of Tasks and Subtasks for each job category. For flight operations, this is normally done by phase of flight (Preflight, Engine Start, Taxi, etc). For maintenance, the breakdown is for the Conduct and Management of Flight Servicing, Scheduled Maintenance, and Unscheduled Maintenance (i.e. diagnosis & repair). Further breakdown is by aircraft system and subsystem. The tool must support the breakdown of Tasks and Subtasks in terms of the supporting Knowledge, Skills and Attitudes.

Input of LSA Data - The tool must quickly and easily be able to import and utilise LSA data [6] for potential use in a maintenance task analysis.

Iteration - The task analysis is conducted at various levels, depending upon the availability of detailed task data. Early analysis will use conceptual tasks, which will be gradually replaced with the specific details from LSA data as the analysis and design progresses. This enables a progressive definition of the training system, which allows early definition of long-lead training media requirements, such as maintenance or flight simulators. The tool must facilitate this iterative process.

Define Target Trainee Population - The tool should allow the analyst to define the characteristics of the target trainee population. The definition is normally in terms of the Knowledge, Skills and Attitudes displayed by the average prospective trainee prior to the commencement of the training.

Select Tasks for Training - This step in the ISD process ensures that instruction is provided for all important tasks, but that resources are not wasted on unimportant tasks, or tasks which the target trainee population has already mastered.

With information about the target trainee population in mind, those job tasks and subtasks which should be included for training are determined using the 6-factor selection model. This is used to assess the Difficulty, Importance and Frequency of each Task, as well as the impact of New Technologies, Safety aspects, and potential Learning Difficulties. The responses, from one or more Subject Matter Experts guide the training analysts as to whether the task should be selected or excluded from training.

The tool must be capable of implementing, at minimum, the Difficulty, Importance & Frequency algorithm (DIF). Ideally, the tool must be capable of implementing the project's custom-designed 6-factor task selection model.

Instructional Setting - This step in the ISD process considers whether job aids (such as

checklists, placards, and performance support systems) or On-Job Training (OJT), might be more effective than formal training packages in meeting selected objectives. The tool should prompt the analyst for these considerations.

Develop Learning Objectives - The differences between the skills, knowledge and attitudes possessed by the target trainee population prior to training, and those desired after training (often during their productive service), form the basis of a statement of Learning Objectives. Learning Objectives are arranged in a hierarchy of Terminal and Enabling Learning Objectives. Terminal Learning Objectives can be related to a Task which must be performed in the job. Enabling Learning Objectives can be related to Subtasks.

Learning Objectives are written in terms of the Conditions, Cues and Standards which must be achieved at the completion of the course. Supporting Knowledge, Skills and Attitudes may be referenced.

The tool must allow the Training Analyst to copy the Job/Task Performance Objectives which have been selected for training, and to create from them Learning Objectives, incorporating Conditions, Cues and Standards.

Training Media Analysis - The most important key to an effective training system is to match the nature and characteristics of each Learning Objective with the inherent attributes of an appropriate training medium.

For each Learning Objective, primary consideration goes to the types of cues which need to be presented, the types of responses which need to be made, and how these responses are evaluated.

Visual cues required for helicopter maintenance and operator training includes text, static diagrams, animated diagrams, still images, moving images, colour, and three-dimensional views. Sound cues, tactile cues, kinaesthetic cues, and even olfactory cues may also be needed. For example, innocuous smoke is sometimes introduced into the cockpit of flight simulators to provide the first cue of a serious electrical fault in the cockpit!

Trainee responses can include making a decision, speaking to another crew member, activating a switch, or manipulating a control or lever with psychomotor movements.

Evaluation requirements usually include feedback for the trainee's correct and incorrect responses. Task evaluation can be accomplished inherently by the trainee, automatically by the training device, or with the guidance of an instructor. For mission training, post-training briefings are useful, utilising printouts of the track followed, and decisions made.

Other considerations when selecting a training medium include the potential need to create a safer environment to practice critical tasks (e.g. when responding to an engine fire), the need to reproduce the conditions under which the tasks are to be performed (e.g. restrictive clothing, on board a ship at sea), and the need to create an environment which matches the appropriate stage of learning, from initial familiarity with the aircraft system, through learning the steps in a procedure, to practising the entire task.

Each training medium and device has different inherent capabilities for presenting cues, providing feedback, and evaluating responses. Our manual system uses a matrix to correlate the capability of each training medium to achieve each of the required attributes of the Learning Objective. Examination of this correlation can eliminate mismatched training media, and prioritize the remainder. The most cost-effective media mix which achieves all the requirements is preferred.

The training analysis and design tool must be capable of performing a media analysis to select the most appropriate training media from an instructional point of view. The tool must prompt the training analyst for the set of attributes which might apply to the Learning Objective, and present a resulting ranked list from a generic and comprehensive list of modern training media (such as those shown in Figure 1). The analyst must be free to select any one of the applicable media (not necessarily that with the highest score), since cost-effectiveness and course sequencing may be programme constraints. The tool must allow

the user to create comments to supplement the audit trail of why a particular selection was made.

Training Device Specification - The ISD process is iterative. Initially, experience may suggest a suite of generic training media as a starting hypothesis. As a result of performing the key steps in the ISD process, outlined above, the appropriate Learning Objectives will be allocated to each training medium, and the detailed specifications of each training device will begin to develop.

The tool must be capable of being used to consolidate the requirements of a hypothetical training device, and to create a specification for the device. This specification must include a list of the physical and functional requirements for each aircraft system and subsystem to be represented on the training device. The tool should prompt the analyst to establish whether each aircraft system and subsystem requires low, medium or high *physical fidelity*, and low, medium, or high *functional fidelity*. Physical fidelity considers appearance, weight, centre-of-gravity, etc. Functional fidelity considers whether the system needs to work. It must be possible to trace each requirement back to Learning Objectives and Job/Task Performance.

Course Development - The tool must assist the analyst in consolidating and sequencing Learning Objectives into Lessons. Each lesson should build on the previous in a logical progression, with a balanced mix of media and instructional settings (classroom, part-task trainer, simulator, and actual equipment). The tool must assist in assembling the Lessons into Modules, and the Modules into Courses. Each Course is targeted for the needs of a particular target trainee population (e.g. Copilot to Captain Upgrade Course).

Test Items - It is essential to assess the required learning via tests of knowledge and performance. Test items must be properly linked to the Learning Objectives, and must use appropriate media. The tool must be capable of developing and storing test items, and showing the audit trail to the related Learning Objectives.

Cost-Effectiveness Studies - The tool should help perform iterative "what if?" studies in which the scenarios and training media are modified to meet external constraints, such as a limited budget.

The tool should be able to compute the cost effectiveness of any given application of the media analysis algorithm. That is, to assess which of a variety of potential alternative training scenarios (each containing different quantities and mixes of training media) achieves the best training effectiveness and trainee throughput for the lowest cost.

Cost-effectiveness measures require a computation of the total amount and cost of each training medium which has been allocated to the lessons, modules, and courses. For example, the tool should be capable of totalling the run-time hours CBT allocated. If the analyst has defined within the tool the estimated unit cost price of each training medium, the tool should present the estimated project costs for each scenario.

Reports - The tool must be capable of generating a variety of standard and custom reports. Standard reports must include: Job/Task Performance Lists, Tasks Selected for Training, Learning Objectives, Media Allocation, plus reports for Courses, Modules and Lessons.

Security - The tool must implement security controls via user identifications and user passwords. User categories should be implemented which match the requirements of a typical ISD project: e.g. Project Manager, Training Analyst, Course Designer. The tool's security system must restrict the functions permitted for each user category.

Revision & Configuration Control - The tool must be capable of being operated in a multi-user networked environment, with a common shared database, and being used simultaneously by a team of training analysts. The tool must be capable of controlling, and tracking all modifications to the training database. The tool must contain configuration control capabilities so as to mark each record with the date, time, and user who last modified it.

Data Extract & Merge - Facilities within the tool should be provided to allow geographically-separate analysis teams to exchange and merge their separate analyses into one database. The tool should provide facilities to mark selected portions of the database as "locked" or "read only".

Computer Platform & Database - The tool must be capable of running on a Personal Computer, under DOS, and Windows. The tool should use a commonly-available relational database to organise and store the data. The tool must be capable of searching, sequencing, retrieving and cross-referencing data within the database, using Standard Query Language (SQL) or SQL-like statements.

Human Interface - The tool must be easy to use, so that users can focus on the training analysis and design tasks instead of spending time learning new software. The tool should have a user friendly interface, and should require only a minimum amount of training. Functions should utilise the minimum number of input actions (key strokes or mouse actions) to perform data manipulation. The training analysis tool must be easy to customize. The tool must incorporate a comprehensive on-line help facility.

Support & Training - The tool must be adequately supported in terms of documentation and training. The tool must be supplied with easy-to-use operating manuals. Initial training must be available. Technical support must be available for the tool by telephone and fax. The tool should be supplied with a warranty lasting one year or more. New and improved versions of the tool should be available at least once per year, together with add-on modules with enhanced functionality.

Market Share - the selected tool should have been used satisfactorily on several similar projects.

CANDIDATE SYSTEMS

We reviewed the following three training analysis & design tools:

MYSTRO Training Analysis and Design Software, from McAboy Yates Corporation in Garden Grove, CA, USA - Mystro is described [8] as "an automated tool for analysis, design and management of instructional programs". Mystro includes the following software modules (Figure 3): Training Analysis & Design; Survey Module (necessary for selecting tasks for training); Media Selection; Revision Control; Import and Export. Training and support are separate packages.

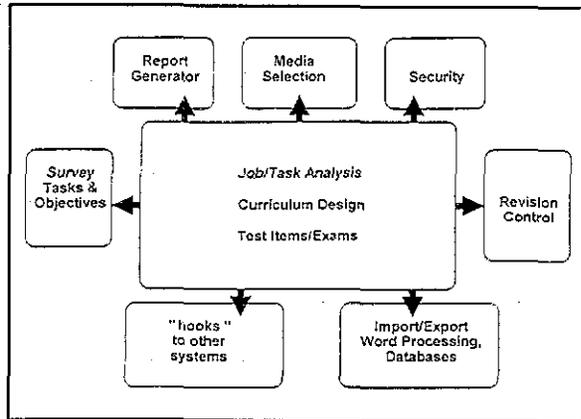


Figure 3 - MYSTRO Functional Overview

Mystro has been used by commercial airlines and airframe manufacturers to manage the Federal Aviation Authority's Advanced Qualification Program (AQP) [11]. Mystro has also been used by a nuclear power company, a telecommunications company, and for a US military application.

JS ISD/LSAR DSS, the Joint Service Instructional Systems Development, Logistic Support Analysis Record, Decision Support System (DSS) - DSS is sponsored and managed by the US Department of Defence (DoD) at Armstrong Laboratories in San Antonio, TX, USA. The tool was developed for the DoD by Dynamics Research Corporation in Andover, MA, USA.

DSS is described [9] as a "major Department of Defence (DoD) effort to better support ISD decision making and to integrate training system development with other weapon system design activities. The PC-based multi-user system consists of data input, ISD analysis, and training system design procedures that

reflect and accommodate service-specific ISD methodologies" (Figure 4). A key feature of DSS is the automated LSAR to ISD data interface. DSS includes a variety of algorithms to select tasks for training, and to select appropriate training media.

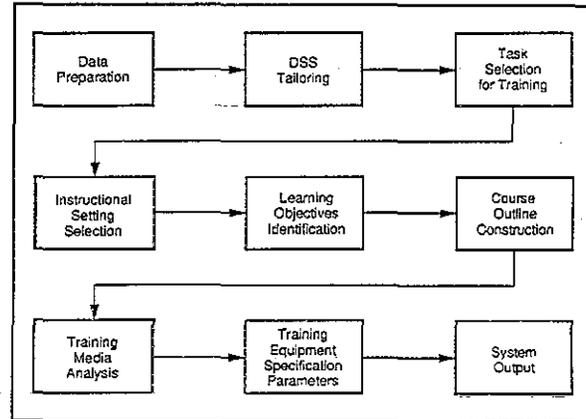


Figure 4 - DSS Methodology Overview

The JS ISD/LSAR DSS has been used by several large aerospace companies to manage the training analysis and design of weapons systems for the US DoD.

The **TRACE™ CASE tool for ISD** [10] by Trace Technologies Incorporated, in Fayetteville, NY, USA - TRACE was developed as an implementation of MIL-STD-1379D [2] for the FAA's AQP Program [11].

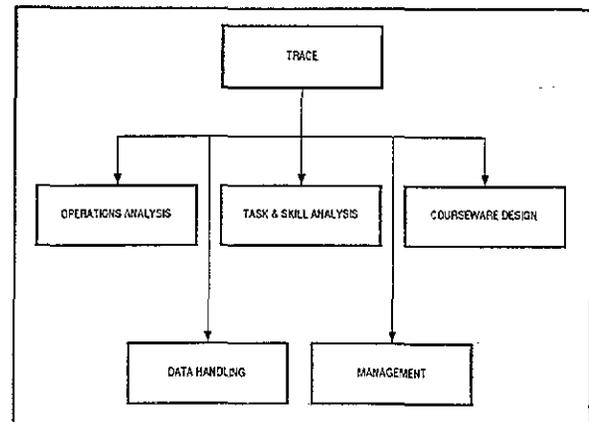


Figure 5 - TRACE Functional Overview

TRACE incorporates comprehensive facilities for Operations Analysis, Task & Skill Analysis, Courseware Design, Data Handling and

Management, including Configuration Management, Database Utilities, Information Management Utilities, System Support and Project Management Tools. TRACE incorporates ISD procedures using the Oracle™ relational database engine and screen utilities.

TRACE has been used in Canada for the training analysis and design for a naval frigate, and is being used by a commercial airline in the USA.

THE EVALUATION PROCESS

The project team used the following mechanisms in its evaluation process for the EH101 Project:

Collate Specifications - We contacted the vendors and asked them to supply technical specifications of their training analysis & design tool, to define version numbers, optional extras, and prices. Vendors were given an opportunity to make presentations on their products.

Compliance Questionnaire - We devised a questionnaire, based on the requirements outlined above, incorporating 66 statements. Vendors were asked if their package fully met, partially met, or did not meet each requirement. We asked for a description of how each requirement was met. We asked if, and how, any non-compliances would be overcome by proposed enhancements to the tool, or by additional packages or services.

We asked for estimates of the amount of effort an experienced training organisation would expend on initial user training, and in configuring the package for use on a project with a custom implementation of the ISD process [5][3].

In-House Evaluation - We arranged a loan of each package, and performed an in-house evaluation, which included a pilot project. The pilot project aimed at testing the most important features of the tool, including:

- Implementing a custom training analysis methodology [5][3].

- Importing a sample of LSA data as a starting point for a maintenance training analysis.
- Constructing a simple hierarchy of Job Performance Tasks.
- Printing a report of the Job Performance Tasks.
- Selecting tasks for training using a simple DIF model.
- Copying the tasks selected for training and converting them into learning objectives.
- Performing a media analysis and allocating media to the learning objectives.
- Printing a report of the Learning Objectives, and media allocated.

References - We contacted references for each tool, and discussed their experiences. We asked their opinion of each tool's strengths and weaknesses.

Spreadsheet - A spreadsheet was used to compile points against each requirement, using the following scale: 0 - Non compliant; 1 - Poorly compliant; 2 - Partially compliant; 3 - Mostly compliant; 4 - Fully compliant.

In addition to points for the requirements outlined, points were also allocated to assess the relative cost of the license, training, and support, together with the in-house setup costs, customisation costs, and operating costs.

A team of evaluators from Westland and the Canadian Prime Contractor allocated the points by mutual agreement. Points were substantiated by reference to source data, such as the compliance matrix responses, specifications on each tool provided by the vendors, and experience during the in-house evaluations and pilot projects.

The points for each individual requirement were weighted depending upon the relative importance, as judged and agreed by the evaluation team. The total weighted score revealed the best match of requirements for a training analysis and design tool for the EH101 project.

RESULT

All three systems are very capable, and no criticism is intended of any of the candidates. It is not appropriate in this paper to publish the detailed scoring. MYSTRO received the highest weighted score, and was considered the best match between the requirements of a training analysis and design tool for the EH101 project amongst the systems examined.

COMMENTS

One of the main driving factors behind the selection of MYSTRO by the Customer Training School was the need to implement the terminology and requirements of their custom ISD process. MYSTRO does not impose a detailed methodology; system administrators can choose and set up their own terminology, definitions and hierarchies for analysis and design. The methodology and terminology can also be changed from project to project, without programming. MYSTRO scored well for user friendliness.

For projects where a standardised, validated and pre-structured approach is necessary, DSS scores well. DSS is well suited to maintenance training analysis which starts with a MIL-STD-1388-2A or -2B LSAR records. The built-in methodology and terminology are fixed, but the Training Development Manager can tailor the setup for each project, and choose from 6 algorithms to select tasks for training, and 4 algorithms for media selection. Users of DSS do not need to import LSAR records as a starting point, but can input job tasks directly for both aircraft maintenance and operations.

The TRACE tool utilises an industry standard database, Oracle[™], which makes it a very good choice where other existing database applications need to be inter-linked with the training analysis and design data.

We considered, but rejected, the option of designing and building a relational database and screens to implement our custom ISD processes. We considered that the costs and risks of such a project would be greater than the use a commercial tool, and considered that it was an advantage to use a well-established

and commercially-available tool to set the standard for transferring data amongst organisations and Governments, rather than to develop an isolated non-standard tool, where proprietary considerations might apply.

APPLICATION

At the time of writing this paper (June 1994) the Customer Training School has supplemented its manual ISD process with a computerised process using MYSTRO. The tool is being used in the ongoing analysis and design work for the EH101 Production Investment Phase.

Task and Subtask data from the Logistic Database have been imported and selected records have been used within the maintenance task analysis.

Our custom 6-factor model for the selection of tasks for training has been implemented using MYSTRO, and we have gained considerable productivity over the manual implementation. A custom media selection model has also been implemented with similar savings.

We have tested the exchange of a machine-readable training database containing Task and Learning Objectives. Both sender and recipient used an identically-configured training analysis tool with a common data dictionary. This opened the door to the exchange of data between geographically-remote training analysis and design teams, and provides Westland with the ability to supply the "core" training analysis for the basic aircraft to a Prime Contractor, who could add the additional analysis of the mission systems.

As the project advances, we expect to gain considerable advantage by the introduction of a computerised training analysis and design tool:

- Consistent and semi-automated implementation of the ISD process.
- Detailed guidance for the analysts and designers through the decision making process - less inconsistencies.
- Increased productivity.
- Automatic creation of an auditable record.

- Quicker and easier rework of the training database as part of the ISD process, and as the aircraft system changes.
- The Import of LSAR data without retyping.
- Rapid feedback to update LSA records.
- Quick, easy storage and retrieval of data.
- Shared use of on-line database.
- Reduction in duplicated data and redundant effort.

CONCLUSIONS

The key steps in the ISD process are very labour intensive and rely on a great deal of detailed information from many sources. Commercially available software tools are very effective in supporting training analysis and design by guiding experienced analysts through the required decision making processes: analysts become more productive and make quicker and more consistent training decisions. The tools automatically create auditable and traceable records of the decision processes. Logistic Support Analysis Records (LSARs) can be imported as the basis for a maintenance analysis. Use of (and feedback to) the LSAR helps to integrate the training system development with the evolving aircraft system design. Use of such tools in a networked environment means that training data can be easily and quickly stored, retrieved, shared and exchanged. This sharing of data inevitably results in a reduction in duplicated data, with the associated savings. Provision of configuration control within the software tools allows all modifications to the data to be tracked, and allows the management of changes as the aircraft design evolves. Use of a common software tool, a common data dictionary and database structure allows electronic data interchange of training data amongst organisations in different countries.

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