TEAMWORK AND DATA DELIVERABLES: A MAP TO SOFTWARE AND TRAINING DESIGN INTEGRATION*

Cathrine E. Snyder, Ned E. Clapp, Jr.,
David E. Smith, Michele Terranova
Martin Marietta Energy Systems, Inc.
Oak Ridge, Tennessee

and

Julie Davis, Joyce L. Finney, Pamela G. Guthrie,
Gail B. Payne, Sheila Webster
The University of Tennessee
Knoxville, Tennessee

ABSTRACT

A team of training technologists has developed an acquisition structure to help the Navy Airborne Weapons Training Program in managing the development of desk-top training systems by the private sector. The goal of the structure is to meet the special requirements of the users: NAVAIR managers, Navy trainers, and the fleet. Developing interactive training systems requires the application of three engineering disciplines: software engineering, instructional design, and human factors engineering. Each discipline has an associated set of military standards and Data Item Descriptions (DIDs), but these usually have not been applied together in the acquisition of training systems. The cost involved in using three sets of standards and DIDs becomes prohibitive, especially for procuring desk-top computer-based systems. The alignment of the three development processes is not specified by existing guidelines. This paper offers a way to specify the objectives of training and to ensure that they are met during the software development process; it also suggests how to integrate human factors engineering up-front at an affordable level that includes the recognition of cognitive and affective factors in the training process. Ultimately, it specifies software documentation and development that should lead to generic programs that can be maintained and supported by the procuring organization. The acquisition structure is summarized in a matrix that aligns the review of documentation supporting each engineering process in an integrated development cycle. The matrix is a map of the planning, analysis, design, and development phases that coordinates the data deliverables for training, human factors, and software development. Only through the successful integration of the three disciplines—software engineering, instructional design, and human factors engineering—can future training goals be reached.

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INTRODUCTION

Teamwork is essential to the development of training programs. This theme has been the basis for the formation of a training network by the Naval Air Systems Command's (NAVAIR's) program for ordnance training, PMA205-11. As part of the large network supporting that program, the federally funded research center in Oak Ridge, Tennessee, has formed a research team dedicated to innovation in the pursuit of specific problems and challenges that affect Naval ordnance training. NAVAIR has utilized the multi-disciplinary resources available at Oak Ridge and encouraged the formation of a team with varied back-grounds and expertise. As a research arm of the public sector, the Oak Ridge team can apply high-risk modern technology to provide prototype applications and profes-sional third-party reviews of private sector developments. The result is an interdisciplinary approach that coordinates the expertise of software developers, instructional systems designers, and human factors engineers to develop new methods for applying technology to interactive training programs.[1]

The mission of the Oak Ridge team has been focused on the development of interactive, microprocessor-based training systems that could be implemented on "fleet-available" computers.[2] As tasks assigned to fleet personnel become more sophisticated, the difficulty of updating training systems in response to partial changes in the operational system has increased. Smaller systems that can be quickly and economically built to train for selected parts of the complete task "system" are becoming recognized as a solution to this problem in the military as well as in the private sector. Teamwork provides the methodology to integrate the "systems" approach and the "part-task" approach in a training concept that is responsive to user needs.

TWO USERS—THREE DISCIPLINES

In our work with interactive training systems development, we found that a training system must always be developed with two users in mind: the trainee and the trainer/training manager. Our teamwork methodology seeks to meet the requirements of both Navy users. For the fleet, it dictates high quality and appropriate realism, even in part-task trainers that are designed to be partial and economical.[2] For the training manager, it specifies modularity and documentation that enables adaptation of the system to changes in the operational environment.

The critical disciplines for the methodology used in the development of part-task training systems are human factors engineering, instructional design, and software engineering.[3] Hardware engineering plays a lesser role because the systems are intended to be developed using commercial off-the-shelf hardware, typically constrained by fleet availability and shipboard space.[2] Although training technology should be the real focus of any instructional system development, computer-based or not, we found that some vendors approached the development of desk-top training systems as a software problem. Human factors engineering, critical both to the development of successful computer applications and to the design of effective training, was usually ignored. This could be attributed to a misconception that human factors guidelines are only essential to operational systems. The fact is that no single standard and accompanying procurement deliverables exist to support interactive trainer development.[3] Vendors have found it difficult to integrate existing standards in software engineering, instructional design, and human factors technology without guidance from the government while remaining within agreed upon cost estimates.

Integration of the three disciplines is necessary if the requirements of both users are to be met. Trainees must be able to use and accept systems in order to learn, requiring that human factors guidelines be taken into consideration early on and throughout the building process.[4] Training managers require cost-effective development, attainable only through early review of data that describe the instructional intent and design. Training managers also need a maintainable product that can be adapted to evolving requirements, which necessitates modular software and structured software documentation.

APPLICABLE STANDARDS

When more than one discipline is involved, the conscientious application of all relevant Department of Defense (DoD) standards can be prohibitively costly. It is even more likely that the application of some standards will be diluted in the development of part-task trainers, where a relatively low cost is part of the justification. The experience in part-task trainer development within NAVAIR has shown that such dilution is a false economy. The Oak Ridge team has set out to identify the critical guidelines that must be used in order to meet the goals of interactive part-task trainers. Military Standard DOD-STD-2167A is applicable and appropriate because it lends itself to the development of modular software necessary for future life cycle support. The extent of documentation of the design and development process described in the standard is necessary to ensure that the modularity can be understood by programmers who must upgrade the software. We therefore believe that each of the Data Item Descriptions (DIDs) listed in Table I is necessary. A special consideration must be given in the procurement of computer-based training systems to the use of authoring systems and other automated development tools. The government buyer must ensure that all development resources, as well as source code, are delivered with the product. No proprietary software that is unavailable to the government should be used in the development process. The government must approve the use of proprietary software after assessing the future cost for life cycle support programming.

ORNL WS 10720

TABLE I
SOFTWARE ENGINEERING DATA ITEM DESCRIPTION (DID) LIST

DOCUMENT	DID
SOFTWARE DEVELOPMENT PLAN	DI-MCCR-80030A
SYSTEMS/SEGMENT SPECIFICATION	DI-CMAN-80008A
SYSTEMS/SEGMENT DESIGN DOCUMENT	DI-CMAN-80534
SOFTWARE DESIGN DOCUMENT	DI-MCCR-80012A
SOFTWARE REQUIREMENTS SPECIFICATION	DI-MCCR-80025A
INTERFACE REQUIREMENTS SPECIFICATION	DI-MCCR-80026A
SOFTWARE PRODUCT SPECIFICATION	DI-MCCR-80029A
SOFTWARE TEST PLAN	DI-MCCR-80014A
SOFTWARE TEST DESCRIPTION	DI-MCCR-80015A
SOFTWARE TEST REPORT	DI-MCCR-80017A
VERSION DESCRIPTION DOCUMENTS	DI-MCCR-80013A
SOFTWARE PROGRAMMER'S MANUAL	DI-MCCR-80021A

At this time a single DoD standard for computer-based instruction does not exist. Yet, instructional technology is the driving force for any training development. The Oak Ridge team reviewed the training standard, MIL-STD-1379C, and found no description of deliverables that meets the needs for interactive computer systems development. The Instructional Systems Development (ISD) standard, MIL-T-29053B, does contain elements for interactive system design. The objective of the ISD methodology is to provide a systems approach to training, which by definition may not be appropriate for a procurement that calls for isolated development of a small part of the training program. A set of new DIDs specifying documentation for Interactive Courseware (ICW) development has been written by the Joint Service Action Group.[5] Table II lists selected DIDs from both the ISD standard and the ICW work for the development of part-task trainers.

Human factors engineering is a discipline that is often ignored by the developers of low-cost training systems, but it is a key ingredient in any system that seeks to guide human performance. Human factors guidelines are especially helpful when coordinating computer-based training development, because they can support the coding of the user interface and also enhance the psychological effectiveness of the instructional design. Military human factors standards and guidelines are written for operational systems and may constitute overkill when applied in entirety toward the development of computer-based trainers. After selecting MIL-H-46855B and MIL-STD-1472C, our human

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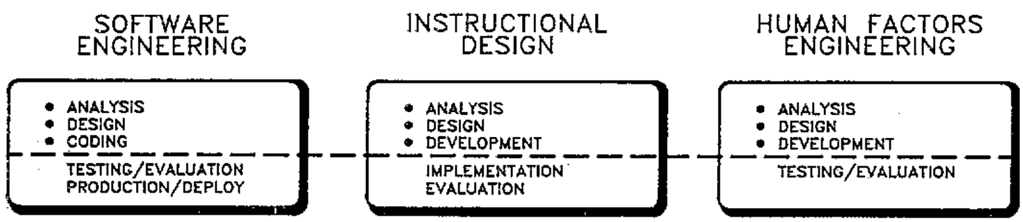

Fig. 1. LIFE CYCLE PHASES OF THREE ENGINEERING PROCESSES

ORNL WS 10721

TABLE II
INSTRUCTIONAL TECHNOLOGY
DATA ITEM DESCRIPTION
(DID) LIST

DOCUMENT	DID
TRAINING DEVELOPMENT AND SUPPORT PLAN REPORT	DI-H-25711B
TASK LISTINGS REPORT	DI-H-25713B
OBJECTIVES HIERARCHIES REPORT	DI-H-25715B
ICW FLOW DIAGRAMS	DI-ILSS-80548
INTERACTIVE COURSEWARE (ICW) SCRIPT-STORYBOARDS	DI-ILSS-80546
TRAINER FUNCTIONAL DESCRIPTION REPORT	DI-H-25718B
STUDENT ORIENTATION MANUAL	DI-H-25730B

factors engineers limited the DIDs (Table III) that should accompany interactive systems development. This streamlined list of DIDs ensures that all human factors data delivered are relevant to the training product.

PLANNING IN THE LIFE CYCLE

The Oak Ridge team realized the need to establish a framework that could coordinate the delivery and review of the relevant data items produced in the development process. We found that reference to specific phases of life cycle development is common to all three sets of standards and DIDs (Figure 1). The life cycle phases could be used to coordinate and prevent overlap of engineering work during the development of interactive systems. Descriptions of the life cycle contained in the three standards are not identical; specific integration of activities and data deliverables was necessary.

ORNL WS 10722

TABLE III
HUMAN FACTORS ENGINEERING
DATA ITEM DESCRIPTION
(DID) LIST

DOCUMENT	DID
HUMAN ENGINEERING PROGRAM PLAN	DI-H-7051
CRITICAL TASK ANALYSIS REPORT	DI-H-7055
HUMAN ENGINEERING SYSTEMS ANALYSIS REPORT	DI-H-7054
HUMAN ENGINEERING DESIGN APPROACH DOCUMENT-OPERATOR	DI-H-7056
HUMAN ENGINEERING DESIGN APPROACH DOCUMENT-MAINTAINER	DI-H-7057
HUMAN ENGINEERING TEST PLAN	DI-H-7053
HUMAN ENGINEERING TEST REPORT	DI-H-7058

When integrating disciplines, an additional emphasis on planning is needed in order to eliminate duplication and to support coordination among the team members working on the project. Because each of the disciplines has a planning DID, we recommended creating a Phase 0 in the life cycle of interactive training development. During this Planning Phase, planning data is exchanged among the three sets of experts and formally reviewed with the client. This establishes up front where a close integration of work effort will be necessary.

The Analysis Phase (Phase I) includes all critical elements of the training program; the more time spent here, the less time will be spent modifying design and coding. Design elements are coordinated in Phase II. The Development Phase (Phase III) includes iterative development by the vendor and periodical review by the government. The iterative development/review process is intended to facilitate the introduction of new ideas and design features that will strengthen the final product. The Test and Evaluation Phase (Phase IV) is needed to provide an end point to this iterative process,[6] although formative tests and evaluation should also be a part of the Development Phase.[7]

DATA DELIVERABLES

The DIDs listed in Tables I through III describe data deliverables that support development and later life cycle management. The software engineering DIDs represent the minimum set required by DOD-STD-2167A. They should be tailored according to the individual training application.

Choosing DIDs for instructional technology was more difficult. Fortunately, the Training Development and Support Plan of MIL-T-29053B can be tailored for part-task trainer development.[8] Documentation of Task Listings and Objectives Hierarchies is required for any training development. The Objectives Hierarchies should be tailored to include cognitive and affective objectives[6] in addition to procedural objectives. Cognitive factors affect performance and accuracy in today's complex weapons systems. Affective objectives should be documented in order to acknowledge trainee emotional responses.[6] The ISD Functional

Description of the trainer is also worth obtaining. The Evaluation Plan called for in the Functional Description is one way to establish a review process of the vendor's intended method for formative evaluation of the system's training components. The Flow Diagrams and the Script-Storyboards of the ICW series of DIDs are specialized and appropriate documents that support the formative evaluation of the training[7] and provide a means to integrate training with software modules. The DID for a Student Orientation Manual can be tailored to describe the Quick Reference Guide, all that should be needed for operation of a training system. Training is interrupted if the trainee must consult a manual while using the system. A Quick Reference Guide is essential for getting started, for providing simple operating instructions, and for explaining any printouts that might be available with the system.

Human factors DIDs should be limited and described in the vendor's contract as part of an integrated life cycle that can be understood and costed with little effort. The human factors engineering effort focuses on the development or improvement of the operator-hardware/software interface of the training system as well as on the content and delivery of the instruction. The objectives are to optimize the training effectiveness and to ensure that the demands placed upon the trainee are within the limits of the user's skills and resources. Our research has indicated that in addition to the Human Engineering Plan, both the Critical Task Analysis and the Human Engineering Systems Analysis should be documented and reviewed by the government. The Human Engineering Design Approach should also be documented. Screen design should produce a consistent interface for users and should be included as a data deliverable. The Human Engineering Test Plan and a resulting Report are essential for evaluating the product.

THE COGNITIVE CONNECTION

Neither ISD nor human factors standards have DIDs that are appropriate for obtaining information concerning the cognitive content of users' tasks. However, the demand placed upon users of today's military systems is generally cognitive in nature.[2] Training systems do not need to focus on physical fidelity to be effective. It is the psychological fidelity of the system that promotes training. Cognitive psychology studies the knowledge processes by which operators assimilate information: how and why skills develop. ISD analyzes the behavioral objectives of the operator tasks. Traditional instructional development falls short in meeting today's training needs because increasingly complex technology places a greater demand on the cognitive workload of operators.[2] ISD focuses on the observable behaviors; cognitive psychology focuses on unobservable skills and knowledge.[9]

The cognitive demands placed upon operators point to the need for a combined strategy to analyze tasks. The ISD Task Listings must be tailored to include cognitive task analysis that identifies the mental models and knowledge structures of expert and novice operators. Traditional task analysis identifies those behaviors that are observable. Cognitive Task analysis is an elaboration of the traditional task analysis but with a new focus: the processing of information. It documents the changes in knowledge structures and mental models during the progression from novice to expert. The Human Factors Critical Task Analysis Report should be tailored to continue the emphasis on combined ISD and human factors strategy in cognitive task analysis.

COORDINATION OF DATA IN TECHNICAL REVIEWS

The Review process is the key to keeping the DIDs coordinated. Figure 2 shows the recommended DIDs embedded in a matrix of engineering disciplines and Technical Reviews. The Review names have been chosen from the Software standard, but the intent is applicable across disciplines.

The System Requirements Review lets the buyer review the development plans from the perspective of each of the disciplines shown in Figure 2. This review also provides a lead-in for the draft system design by listing software segments and instructional tasks.

The System Design Review covers the System/Segment Design Document, the Critical Analysis Report (based on Task Listings), and the Human Engineering Systems Analysis. In the Software Specification Review, the Software Design is presented along with the ICW Flow Diagrams and Script-Storyboards. Objective Hierarchies have been developed based on the Critical Task Analysis and are also presented. The Trainer Functional Description, including plans for formative evaluation, is presented for government input.

Comments on these documents are incorporated during the Design Phase, which will produce the Software and Interface Requirements Specification and the Human Engineering Design Approach for the Preliminary Design Review. Formative Evaluation results are reported at this point and also at the Critical Design Review. The Test Plan for Human Engineering and Software will be presented at the Critical Design Review.

The Software Product Specification, Test Descriptions, Programmer's Manual, and Student Orientation Manual will be reviewed at the Functional Configuration Audit. These documents will be finalized, and a Version Description Document and the Source Code will be reviewed at the Physical Configuration Audit. The plan for Summative Evaluation of the training and the Human Engineering Test Report will be presented. The Test and Acceptance will be backed up by the Software Test Report and the Summative Evaluation.

The review process we recommend is one that guides the project manager through the development process in a systematic and controlled manner. It is not necessarily restricted to new procurements but could be applied to existing contracts where the vendor and the government both want to produce the best possible product for the user through the teaming of engineering disciplines and the coordination of data deliverables.

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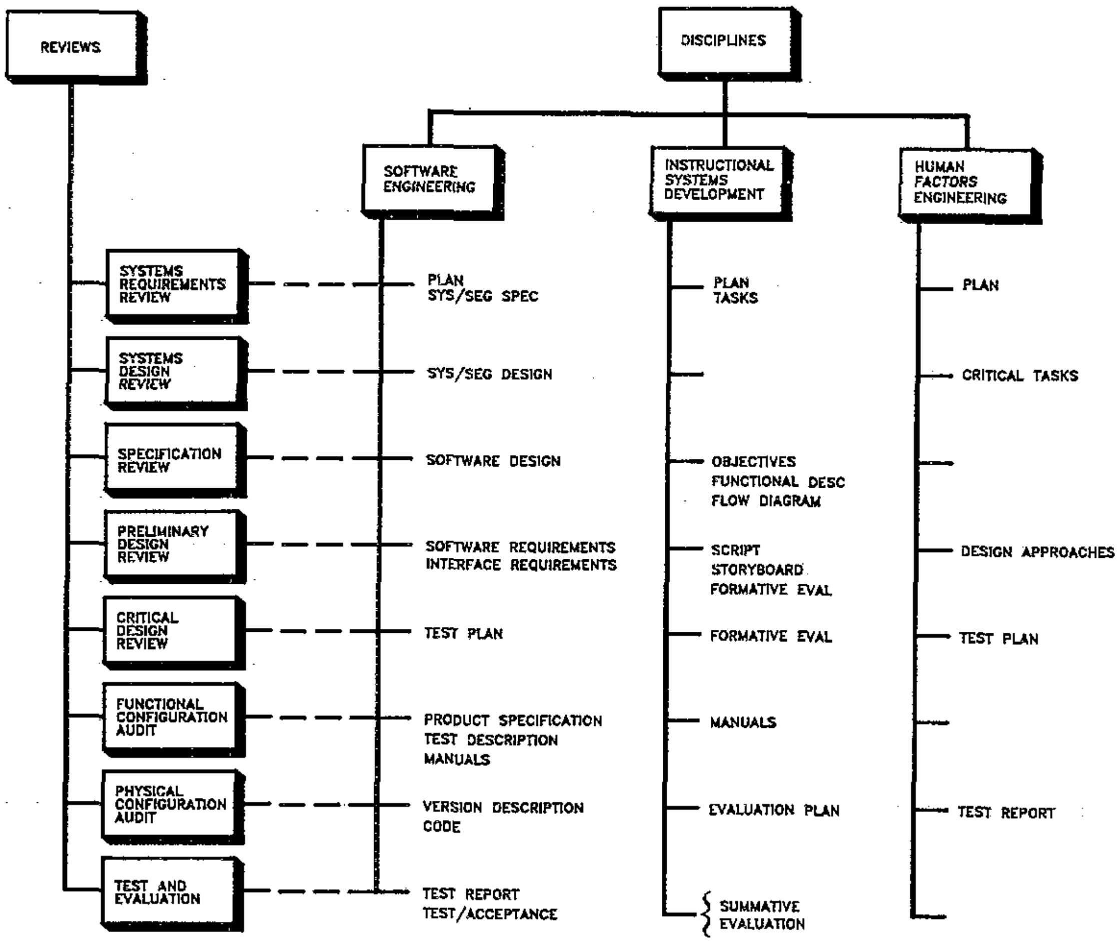

Fig. 2. DATA DELIVERABLES IN A MATRIX OF ENGINEERING DISCIPLINES AND TECHNICAL REVIEWS

Data deliverables become especially important if the product is going to be maintained and modified by the government after delivery.

The integration of software modules with training design data by cross-referencing techniques is essential for ensuring product maintainability.

CONCLUSION

When the Oak Ridge team reviewed available ICW DIDs we concluded that these documents did not obviate the need for the coordination and teaming of disciplines. The use of ICW DIDs does emphasize the role of instructional technology as the central discipline during interactive training system development. It can also lead to the development of a new type of instructional design professional: one specializing in interactive systems. However, in-depth expertise in human factors engineering and software engineering will be needed to assist this ICW specialist. Complex tasking will require cognitive analysis and the use of motivational and mental model research integrated with the ISD process. Because of increased requirements for adaptable systems, software engineers will continue to be needed for their knowledge of new developments that aid in the structured approach to programming. Attention must be paid to the training development process to ensure fleet readiness and preparedness. Only through the successful integration of the three disciplines—software engineering, instructional systems design, and human factors technology—can future training goals be reached.

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ABOUT THE AUTHORS

This paper is a joint research effort between Martin Marietta Energy Systems, Inc., Oak Ridge, and The University of Tennessee, Knoxville. The authors are involved in cognitive science and human factors engineering, hardware and software engineering, instructional systems design, and user system interfaces. They are members of the Oak Ridge research team, led by Cathrine E. Snyder, that supports the Naval Air Systems Command's program for ordnance training.

At Martin Marietta Energy Systems, Inc., **Cathrine E. Snyder** is a Research Associate in the Data Systems Research and Development Program who manages projects designed to modernize information systems and to improve training technology for the Department of Defense. She is recognized in the area of User System Interfaces and serves as chair of the International Standards Organization U.S. Technical Advisory Group X3V1.9. **Ned E. Clapp, Jr.**, M.S.E.E., is Group Leader of Surveillance and Diagnostic Methods with the Instrumentation and Controls Division at Oak Ridge National Laboratory. **David E. Smith**, B.S. Physics, M.S.E.E., is a Development Engineer in the Instrumentation and Controls Division at Oak Ridge National Laboratory. **Michele Terranova** holds a Ph.D. in Industrial Psychology and works in the area of human factors engineering with the Engineering Physics and Mathematics Division at Oak Ridge National Laboratory.

At The University of Tennessee, **Julie Davis** is working towards an M.S. in Industrial Organizational Psychology at the University. Her recent work in Oak Ridge has been in human factors research. **Joyce L. Finney**, M.S.L.S., is an Information Scientist. She provides project management direction and is involved in the establishment of a Training Technology Center for Applied Learning. **Pamela Guthrie**, M.S.L.S., is a Research Associate experienced in curriculum development and financial management with interest in interactive video training technology. **Gail Payne**, B.S. Journalism, is a technical writer and editor. Experienced in the sciences, her focus as a Research Associate is in the areas of SGML and CALS compliancy. **Sheila Webster**, Ed.D., is Associate Director for Manpower, Development, and Retraining for the University's Energy, Environment, and Resources Center.