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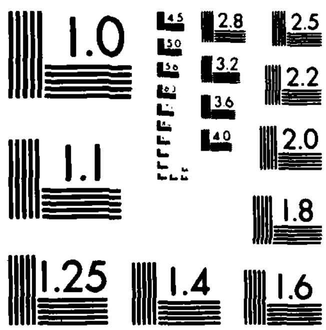

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ANALYSIS OF SIMULATED MAINTENANCE SPECIFICATIONS

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ANALYSIS OF SIMULATED MAINTENANCE SPECIFICATIONS

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FOREWORD

This research and development is being conducted in response to Navy Decision Coordinating Paper (NDCP) W0784-PN, Simulated Avionics Maintenance Trainer (SAMT) Work Unit OWR01029, under the sponsorship of the Naval Air Systems Command (NAVAIR 413). The objectives of the NDCP are (1) to conduct engineering developments for a family of SAMTs, (2) to develop SAMT trial procurement specifications (organizational- and intermediate-maintenance levels), (3) to use the trial procurement specifications to procure the prototype trainers, (4) to evaluate the effectiveness of the trainer, and (5) to refine the procurement specifications based on an evaluation of the procurement process and the trainer effectiveness.

The objective of Work Unit OWR01029 is to develop a generic specification for a mechanical and electromechanical organizational-level SAMT. This report covers the analysis of two existing generic specifications that have been developed for the Naval Air Development Center and the Air Force Human Resources Laboratory (AFHRL) respectively. Results of the analysis, which was performed by Advanced Technology, Inc., San Diego, under contract N00244-79-C-1760, will be used by NAVPERSRANDCEN in developing the SAMT generic specification. Dr. M. Flaningam was the contracting officer's technical representative for this effort.

Appreciation is expressed for the assistance in preparing this report provided by personnel of the Technical Training Division, AFHRL. Particular appreciation is expressed for the support provided by Dr. E. Smith, who is overseeing the Air Force study at AFHRL.

JAMES F. KELLY, JR.
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SUMMARY

Problem

The increasing sophistication of aviation equipment imposes more sophisticated maintenance procedures and increases the difficulty of providing trained maintenance personnel. To facilitate and improve training, the Chief of Naval Operations has selected the Simulated Avionics Maintenance Trainer (SAMT) for procurement and use at training schools. The Navy Personnel Research and Development Center (NAVPERSRANDCEN) has been tasked to develop a mechanical and electromechanical organizational-level SAMT generic specification defining the system evolution from concept, through development, to procurement.

Objective

The objective of this effort was to analyze two existing generic specifications developed for the Naval Air Development Center (NADC) and the Air Force Human Resources Laboratory (AFHRL) respectively. Information obtained will be used in developing the SAMT generic specifications.

Approach

The Navy and Air Force studies were examined as to their format and ease of comprehension, completeness, and interrelation among document sets. The processes described by these studies were then compared as to their assumptions, ability to meet established goals and objectives, applications, scope, and utility. Finally, the two processes were compared in terms of three procedure areas:

1. Determining training requirements.
2. Selecting media to meet training requirements.
3. Producing a procurement specification for training equipment acquisition.

Results and Conclusions

1. The Air Force's procedural requirements document covers the full development cycles of a maintenance-training simulator from course concept to final acceptance.

2. Although the Air Force process was developed for the Air Force environment and was tailored to specific Air Force activities, many of the conceptual problems are common to the Navy and Air Force, and the concepts, procedures, and specifications appear to be applicable to Navy use. The process of developing training and training-equipment requirements for new or existing systems can be used to develop any type of maintenance-trainer simulator.

3. The Navy study provides extensive information on the procurement process, including data on government requirements for simulator design, procurement practices, sample letters, and Request for Proposals.

4. The Navy study provides many aids for use by the government for simulator procurement. These aids are well written and provide much information unknown to some government personnel.

Recommendations

1. The Air Force's training-requirement determination process (with media selection) should be used to assist in the definition of the general functional characteristics of a maintenance-training simulator.

2. The Navy's procurement sample specification, with supporting data, should be used to assist in the development of the procurement section of the generic specification.

The Navy and Air Force study documents cannot be used verbatim and it will be difficult to transfer the information from its original application to the SAMT requirements. Potential difficulties are outlined in this report.

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Problem

The increasing sophistication of aviation equipment requires more sophisticated maintenance procedures, which, in turn, impose more complex training for maintenance personnel. The training problem is exacerbated by the lower level of personnel entering training and by the high turnover of trained personnel. To ensure the state of readiness that must be maintained by our naval forces, it is imperative that more effective training methods for maintenance personnel be developed and at a lower cost per student.

One method of improving maintenance training and reducing training costs that holds promise involves simulation techniques inserted in the instruction curricula. Some of the potential gains from these techniques are:

1. Reduced cost of maintenance training.
2. Increased training-equipment reliability.
3. Increased safety for student and instructor during hazardous activities.
4. More effective instruction from training equipment.
5. Better instruction in troubleshooting by inserting malfunctions under instructor control that would be critical and uncommon during shipboard operating conditions.

While these potential benefits of simulation techniques are fully recognized and are being applied, they have not yet taken effect, and to date little improvement in maintenance training has been realized. To accelerate the simulation program, at the direction of CNO, Navy Decision Coordinating Paper for Simulated Avionics Maintenance Trainer was issued 12 September 1977 to coordinate the development, procurement, and implementation of a simulation trainer concept--the Simulated Avionics Maintenance Trainer (SAMT). The SAMT family of trainers covers maintenance training on mechanical, electromechanical, and electronic systems at both organizational and intermediate repair levels. The Navy Personnel Research and Development Center (NAVPERSRANDCEN) was tasked with the development of a generic specification for a electromechanical and mechanical SAMT at the organizational level (O-level).

Objective

The objective of the effort described here was to analyze the documents supporting two existing generic specifications developed for the Navy and the Air Force and to extract information of use to the NAVPERSRANDCEN task.

APPROACH

The Navy and Air Force studies were examined as to their format and ease of comprehension, completeness, and interrelation among document sets. The processes described by these studies were then compared as to their assumptions, ability to meet established goals and objectives, applications, scope, and utility. Finally, the two processes were compared in terms of three procedure areas:

1. Determining training requirements.
2. Selecting media to meet training requirements.
3. Producing a procurement specification for training equipment acquisition.

THE NAVY STUDY

The Navy study consists of the following three documents, prepared for NADC by Applied Science Associates (ASA), Inc. under contract N62269-77-C-0304:

1. Development Guidelines for Specifying Functional Characteristics of Maintenance Training, February 1978.

2. Procurement of Simulation Systems for Training in Organizational-Level Electronics Maintenance at Naval Aviation Maintenance Training Detachments: Phase I--Task Analysis and Simulator Configuration.

3. Procurement of Simulation Systems for Training in Organizational-Level Electronics Maintenance at Naval Aviation Maintenance Training Detachments: Phase II--Specification for Procurement of a Simulator System.

Hereafter, these documents shall be referred to as Development Guidelines (N), Phase I Document (N), and Phase II Document (N) respectively.

Development Guidelines (N) details a process for the development of maintenance training simulators. Phase I and Phase II Document detail a process that was derived from the Development Guidelines (N) process. The purposes of these documents were to:

1. Produce an actual procurement specification for a simulator to be used with a Naval Aviation Maintenance Training Detachment (NAMTRADET) course in organizational maintenance of the A-6E TRAM/DRS.

2. Note the practical concerns of both the development contractor and the government program manager and improve the development process by specifying for future program managers (a) a generic development process, (b) information requirements, (c) possible information sources, (d) review points, and (e) critical features of program management.

The remainder of this section provides a synopsis of the three Navy documents. Headings are the actual headings from the Tables of Contents (see Appendix A) of the documents; all statements are abridgements of the document text without comment or amplification.

Development Guidelines (N)

Section 1. Introduction

Development Guidelines (N) covers the following areas:

1. A process for functional simulator design.

2. Rules for and responsibilities of both simulator designer and government program manager during simulator design.

3. Pre- and postsimulator design considerations of the government program manager.

To provide information in these areas, discussions are divided between:

1. Tasks assigned the contractor.
2. Actions required of the government program manager.

Discussions of the contractor and government program manager tasks include specified inputs and outputs. Figure 1, from Development Guidelines (N), illustrates the steps in the development of a maintenance-training simulator specification. These steps are described in the following paragraphs.

Section 2. Task Identification

This section discusses the procedure of identifying maintenance activities to be incorporated in the trainer.

Identification of maintenance activities requires a Preliminary Task Identification Matrix (PTIM). The PTIM is developed by the contractor through "brain storming" and by observing actual maintenance training activities. The government and the contractor cooperate in evaluating and validating the PTIM to produce a Task Identification Matrix (TIM). During validation, changes can be made as errors or omissions are identified in the task list. The contractor's task analyst, aided by system hardware experts, also prepares a decision criteria list during validation. Preparation of this list is aided by an analysis of individual tasks to define special behaviors associated with specific equipments. Criteria for this analysis of individual tasks are the human engineering considerations affecting the design of controls, labels, work space, personnel safety, equipment damage, and unique tools and test equipment.

Section 3. Task Analysis

The purpose of the Task Analysis process, as noted by Development Guidelines (N), is to determine the task practice requirements. Task Analysis begins with the development of a Gross Task Analysis, which is performed by entering data from the TIM on Gross Task Data sheets. The sheets produce a document that is complete and that reflects the maintenance mission in terms of the technician's general responsibility for each task listed in the TIM.

The contractor examines the Gross Task Analysis for Normal Repertoire (NR) and Special Behavior (SB) required to perform the listed maintenance tasks. The equipment-related special behaviors are used as an input to the NR/SB decision-criteria development. The NR at the Gross Task Analysis stage of the Task Analysis might be, for example, the aptitude of a maintenance technician to perform simple manipulative tasks that require only finger dexterity and/or hand-eye coordination. SB might be the skill or knowledge requiring review and reinforcement--that is, additional training or practice to achieve the specified level of task performance. Tasks identified as NRs are dropped from the task list (and any further analysis). The decision to drop any task at this stage of the task analysis depends on whether or not task performance involves procedures meeting the NR criteria. Government review provides final approval of the dropped NRs.

The next stage of the Task Analysis is a detailed step-level analysis performed by the contractor. The principal difference between Gross Task Analysis and this step-level analysis is the number of steps into which the tasks are broken.

The last stage of the Task Analysis is a final NR/SB decision-and-division procedure. The criteria for producing the NR/SB decision-and-division procedure are based on prerequisite courses taught at NAMTRADET, Fleet Readiness Aircraft Maintenance Programs (FRAMPS), "A," "B," and "C" schools. The contractor's first action at this stage of

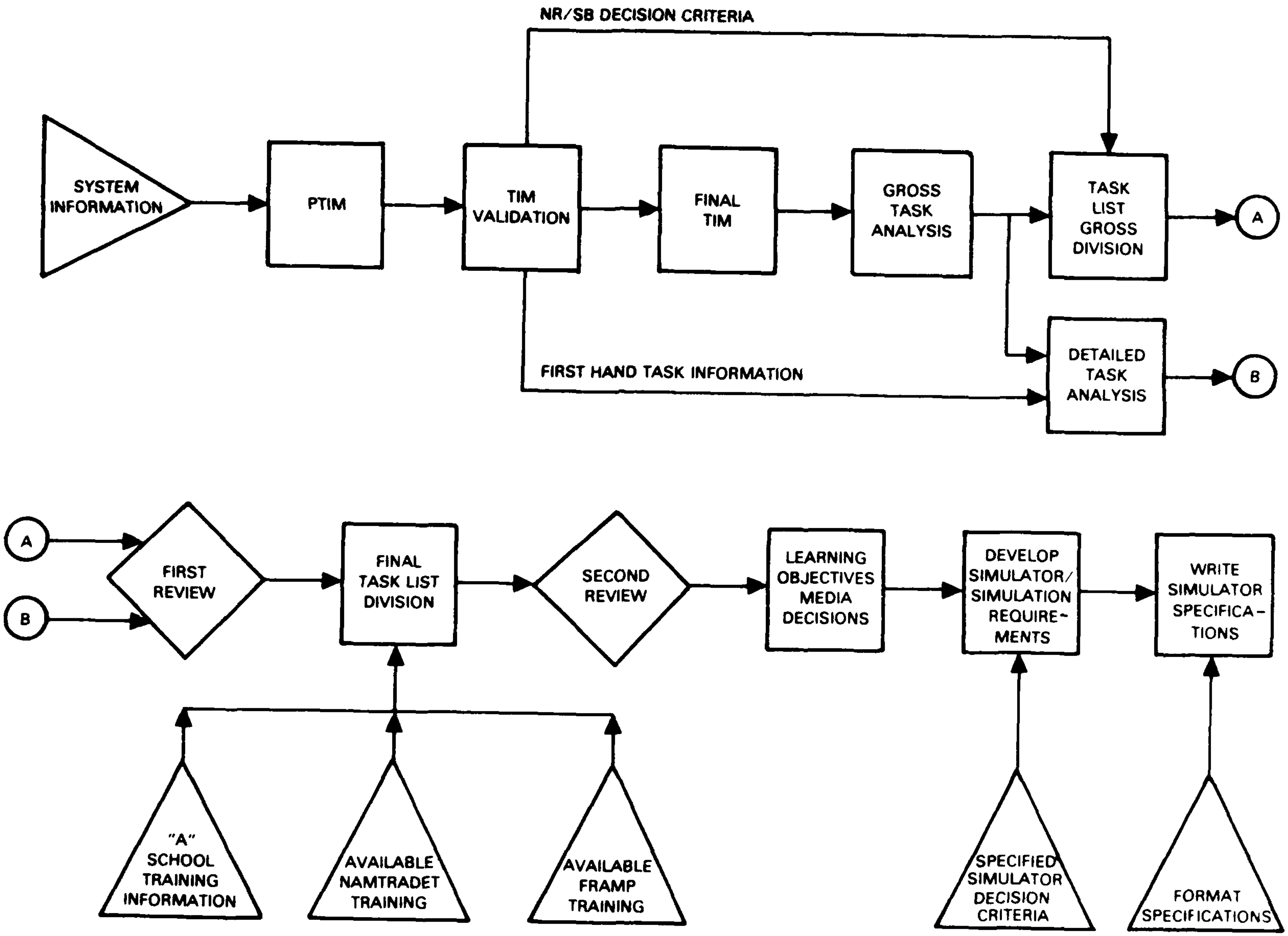

Figure 1. Process flow chart for the Navy study simulator specification development.

Task Analysis is to examine the FRAMP prerequisite training curriculum to determine whether any of the practice requirements associated with the task occur in the prerequisite training. Those that occur are dropped as NRs. Next, the contractor determines the training activity and the level of maintenance for which the simulator is being considered. Tasks not applicable to the activity or level of maintenance are dropped. Finally, the contractor establishes priorities for the remaining tasks, using as criteria (1) difficulty, (2) frequency, (3) importance, and (4) level of proficiency required. The contractor's actions are reviewed by the government.

Section 4. Functional Simulator Design

Of all the steps in the development of a specification for a maintenance-training simulator, Functional Simulator Design is the most difficult. Development Guidelines (N) states that ". . . incorrect or incomplete performance of this step will produce a defective simulator. We have attempted to proceduralize portions of a highly creative process. However, the task . . . cannot be reduced to a square-filling exercise. For these reasons, we recommend that this step be performed by a qualified and experienced Instructional Development technologist."

In Functional Simulator Design, the contractor first compares the skill prerequisites for the job against the skill requirement of each task step in the Task Analysis. If the skill is new or a new application of an old one, it is evaluated in terms of learning difficulty, error likelihood, possible equipment damage, or possible injury to the task performer. Any of these criteria make the skill a candidate for supervised practice in training, and simulation is considered. The candidates for supervised practice are reviewed by the contractor to recommend the media that will best support training. Development Guidelines (N) states that " . . . in all cases, the media decisions shall be within bounds of proven simulation techniques," and continues by directing that the media choices shall always favor the simplest technique to provide the necessary practice. Government review is used to validate the task practice and methods/media decisions.

In the next stage in the Functional Simulator Design step, the contractor determines simulator concepts by looking for commonality in tasks or task steps and in the methods and media decisions. Tasks with common purposes may use the same media and instruction methods. The idea here is to simulate the task environment as accurately as necessary to permit realistic task practice by examining the practice requirements for commonality. From this examination, the contractor determines the number of different task-performance (and therefore practice) environments required. Development Guidelines (N) states that ". . . if there are several practice environments, thought shall be given to individual or part-task simulators. Multiple tasks performed in the same physical environment are logical choices for inclusion in a multi-purpose simulator; however, class size, practice length, and simulator availability, or the number of simulators required, shall be considered. Generally speaking, individual task (part-task) trainers are more flexible from an availability standpoint and are more cost effective to produce." Another consideration to be weighed when deciding simulator type is the suitability of a given simulator for the kind of learning involved.

The final action in determining simulator concepts is that once the number of different simulators and the general purposes of each are established, the contractor establishes what (functionally) is to be simulated. For each simulator, the physical characteristics of the actual hardware and the environment with which the task performer interacts during task performance are listed. Development Guidelines (N) states:

> The contractor shall then prepare a script for task performance (practice). The script shall be written at the individual behavioral

action level. Each script step shall contain three separate format elements: student, simulator, and instructor. The student activity shall be described. The simulator condition or response shall be described completely by noting the condition or state of each previously listed physical characteristic. The instructor's role in task practice shall be specified in terms of monitoring, feedback, or other instructor functions.

The final stage in the Functional Simulator Design step is the drafting and review of the actual specification. The specification includes:

1. The Functional Requirements that entail, in addition to the scripted task practice sequence, a general description of the simulator, and an overview of the simulator, its operation, and its use.

2. The sensory (aural, visual, tactile, etc.) fields of the simulator, on a component-by-component basis.

After the specification has been completed, the government reviews it to ensure that it is correct.

Section 5. Post-Specification Activities

This short section discusses the desired use of specification contractor as a technical advisor to the program manager during the acquisition of the maintenance training simulator hardware.

Section 6. Pre-Simulator Functional Specification Contract Award

This section presents basic information requirements, general organizational principles to follow within the government's maintenance training simulator-development program, and suggested inclusions for a functional specification development contractor's statement of work. The suggested statement of work is composed of the previous text and diagrams contained in Development Guidelines (N).

Phase I Document (N)

The Phase I Document (N) deals with a specific area of simulator development; that is, the development of a NAMTRADET organizational-level electronics maintenance-training simulator.

Section 1. Introduction

The introduction provides a brief background of simulator development responsibilities in the Naval Air System Command (NAVAIRSYSCOM) subordinate organizations.

A section entitled "Plan to Develop Guidelines" describes the steps to be followed by a project director in procuring a maintenance training simulator.

The Phase I Document (N) states that experience with maintenance-training simulators currently in the field suggests the following deficiencies and omissions:

1. Task analyses underlying the requirements for a simulator were sometimes performed inadequately. Consequently, tasks that should have been taught were not being taught, incorrect procedures were being taught, and capabilities of simulators were not being used.

2. Simulator design and development were inadequately integrated with the course curriculum. Often, the simulator was simply an added aid to training.

3. Documentation to assist the instructor and the student in using the simulator was often fragmentary. As a consequence, the simulator was not used to its fullest, and sometimes not at all.

4. Instructor training was sometimes overlooked.

5. Provision for the prompt maintenance of the simulator was insufficient. Consequently, when needed, the simulator was sometimes unavailable. Maintenance manuals were also lacking.

The Phase I Document (N) responds to these deficiencies and omissions by stating that most of them could receive appropriate treatment in a well-written specification for a simulator manufacturer. However, because of the importance of task analysis, as indicated by the deficiencies and omissions, it should receive thorough treatment separate from the simulator specification. Thus, procurement should be a two-part process--part one, the task analysis; part two, the manufacturer's specification. Task analysis might be performed more rigorously and with less bias by other than a simulator manufacturer (a specifications contractor or government agency specializing in training).

Section 2. Phase I Task Analyses and Simulator Configuration

The following actions of the maintenance-training-simulator project director during the task analysis and simulator configuration-development phase are discussed:

1. The initiation of the project by the issue of an AIRTASK from the funding agency to a performing agency.

2. The need for delineation of the constraints on the project and the authority and responsibilities of the performing agency.

3. The general steps to be performed by the project director in coordinating, scheduling, and monitoring "Phase I" work among the various possible military and civilian organizations.

4. The collection of relevant information before letting a "Phase I work" contract. This information is needed by the bidding contractors to estimate precisely the time and cost required to perform that work. Sample forms that might be used for the collection of these data are also given.

5. The possible decisions the project director could be required to make about task analysis data and what the actual "Phase I work" will entail.

6. The actual preparation of a "procurement package" for the "Phase I work."

7. An introduction to the sample statement of work (SOW) included in the third section of the Phase I Document (N).

Section 3. Statement of Work

A sample statement of work (SOW) for the performance of "Phase I work" by a maintenance-training-simulator specifications contractor is presented. Although this sample SOW is conceptually the same as that in Development Guidelines (N), the exact steps and their relative order differ. The steps are presented below, with indications of where they differ from those in Development Guidelines (N).

1. Preliminary Task Identification Matrix (PTIM). The specifications contractor, using documents provided by the government and other documents, prepares a PTIM. The development and format of the PTIM is the same as in Development Guidelines (N).

2. Preliminary Task List for Organizational-Level Maintenance (PTLOLM). The contractor prepares the PTLOLM from the PTIM by identifying only organizational-level maintenance tasks. Each task is listed with the hardware item on which the task is performed and is described briefly in terms familiar to those who will review the PTLOLM. This action is not specifically addressed in Development Guidelines (N).

3. Validation of PTLOLM. The specifications contractor will visit a maintenance performance site to validate the maintenance and to discuss the maintenance tasks with technicians. Discrepancies are noted, along with the names of the maintenance technicians. This validation process might also reveal additional organizational-level maintenance tasks.

4. Government review of the PTLOLM. The government reviews the contractor's efforts at this stage of the specification development, as was done in Development Guidelines (N).

5. Gross Task Analysis (GTA). From the validated and reviewed PTLOLM, the contractor performs a Gross Task Analysis, as was done in Development Guidelines (N).

6. Relative Importance of Tasks. To develop the GTA, the contractor, using Navy and civilian personnel intimately acquainted with the maintenance of the system under study, collects and interprets data on the relative importance of the tasks. The relative importance of tasks is determined by criteria established in the Interservice Procedures for Instructional Systems Development, Phase I, Analysis (NAVEDTRA 106A, 1 August 1975). Development Guidelines (N) establishes task importance in the "Detailed Simulator Concepts" determination process.

7. Commonality of Tasks. The specifications contractor classifies into sets those tasks that require the same, or very similar, behavior with the same class of equipment. From each set of common tasks, the contractor selects sample tasks to represent the whole set. Commonality of Tasks is determined during the "Detailed Simulator Concepts" process in Development Guidelines (N).

8. Selection of Tasks for Training at a NAMTRADET. Results of the GTA, Relative Importance of Tasks, and Commonality of Tasks are examined by the contractor and the tasks are classified as (1) tasks to be taught at a NAMTRADET, (2) tasks to be taught at a FRAMP school, and (3) tasks that need not be taught at all because the student will have already acquired the knowledge and skills at "A" school. Action of this type is not provided by Development Guidelines (N).

9. Government Review. Another government review at this stage covers the GTA, Relative Importance of Tasks, Commonality of Tasks, and Selection of Tasks for Training at a NAMTRADET. A similar review is required by Development Guidelines (N).

10. Final Task List (FTL) for a NAMTRADET. The review previously executed results in a Final Task List (FTL) tasks for NAMTRADET training. Development Guidelines (N) does the same. Both FTLs are used in selecting media.

11. Detailed Task Analysis (DTA). From the FTL, the contractor performs a Detailed Task Analysis (DTA) describing in minute detail, the steps in each task. This step is the same as in Development Guidelines (N).

12. Behavioral Objectives (BO). Based upon the DTA, the contractor will develop behavioral objectives. Each of these behavioral objectives includes (a) an identification and description of the behavior, (b) a description of the relevant conditions under which the behavior is to occur, and (c) a definition of criteria of acceptable performance. Development Guidelines (N) does not provide for the development of Behavioral Objectives, although it does provide for the development of NR/SB criteria to drop tasks that are not required in the DTA.

13. Tasks, Types of Learning, Method/Media Selection. Using the DTAs and BOs for each task or task step, the contractor classifies the tasks into categories representing "types of learning," following some specific scheme in the literature of educational psychology. The contractor provides a reference for the classification scheme, and defines and illustrates each type of learning. The contractor recommends methods/media suitable for training each task, and also classifies the tasks into those to be trained on a simulator and those to be trained by other means. Development Guidelines (N) addresses selection of media but does not address selection of materials to be taught by other means.

14. Preliminary Simulator Designs. Based on the previously performed step, the contractor proposes alternative designs for accomplishing the desired training. Each design will be illustrated, and, for each design, the contractor briefly describes the advantages and disadvantages, the fidelity, and the expectations about the transfer of training. Also, the contractor provides rough estimates of the cost of alternative designs, and an estimate of the cost for 5 years. Development Guidelines (N) provides a step for the determination of simulator design, but requires the contractor to identify only alternative simulator designs, omitting the determination of advantages/disadvantages, the fidelity, expectations about the training transfer, and relative costs.

15. Government Review. A government review is again provided at this stage of specification development. This review will result in the selection of a maintenance training simulator design. Development Guidelines (N) provides for a similar review.

16. Final Simulator Design. The contractor will specify the final simulator design, the physical and preceptual appearance, and the function of the components. In these descriptions, the contractor is required to specify what is to be represented, not how the representation will be accomplished by a maintenance-training-simulator manufacturer.

The contractor is required to include, in the final simulator design, a description of how the student will interact with the maintenance-training simulator and how the student will be provided performance feedback. The instructor's function will be incorporated in the design. If student and instructor panels are required by the design, the specifications contractor is required to provide a functional design for such panels.

Final Simulator Design is detailed in Development Guidelines (N) under "Detailed Simulator Concepts."

17. Script for Task Performance. The specifications contractor prepares a script describing task performance in achieving the behavioral objectives. The script is required to address the roles of the student, the instructor, and the maintenance-training simulator. The contractor is also required to modify the behavioral objectives, as

necessary, and integrate the modified behavioral objectives with the script and with the simulator design. Development Guidelines (N) calls for script development under "Detailed Simulator Concepts."

18. Final Government Review. A final government review of the specifications contractor work concludes the sample SOW. The results of this review are used in the production of an actual procurement specification for a maintenance-training simulator. The final review provided in the process detailed in Development Guidelines (N) occurs after a sample specification has been developed by the specifications contractor.

The sample SOW in the Phase I Document (N) describes the contractor's steps in paragraphs that detail the performance requirements. Data entries making the sample SOW applicable to a specific system under study are set in parentheses. Remarks to orient the administrator (project director) or to justify a suggested course of action are contained in brackets and are preceded by the word ADMINISTRATOR. The sample SOW concludes with sample Contract Data Requirements Lists (CDRLs, DD Form 1423) and Data Item Descriptions (DIDs, DD Form 1664), which relate to specific specification-contractor performance areas.

Section 4. Miscellaneous Advice to the Project Director

Brief comments to the project director are included in this section, covering such areas as funding, schedules, reviews, and simulator manufacturer queries. Of particular note are guidelines and recommendations to assist in determining specification-suggested features or capabilities that are not really needed.

Flow Diagram

The Phase I Document (N) concludes with a flow diagram that relates the order and interrelation of steps in developing a maintenance-training simulator specification. The flow diagram, which is provided in Appendix B, divides the actions of the project director and the specifications contractor.

Phase II Document (N)

The Phase II Document (N) addresses the procurement of a maintenance-training simulator system for organizational-level electronics maintenance training at NAMTRADETs.

Section 1. Introduction

The Introduction of the Phase II Document (N) states that this document, with Phase I Document (N), provides a two-phase approach to the development and procurement of an organizational-level electronics maintenance-training simulator for a NAMTRADET. The two-phase approach is based on the assumption that the most critical aspect of developing a maintenance-training simulator system is the task analysis, and the task analysis would probably be best performed by someone other than a maintenance-training simulator manufacturer. The task analysis of Phase I Document (N) serves as the main input to a procurement specification described in the Phase II Document (N). The following data items from the Phase I Document (N) procedures serve as the input to the Phase II Document (N).

1. A list of tasks to be trained at a NAMTRADET.
2. A detailed task analysis for each task.

3. The methods/media suitable for training each task.
4. Behavioral objectives for the tasks.
5. The simulator configuration.
6. A script for task performance adressing the roles of the student, the instructor, and the maintenance training simulator.

The Phase II Document (N) states that its functions are to provide general discussions and advice to the project director in the actual procurement of a maintenance-training simulator, such as planning and contractor contact, and to provide a sample procurement specification.

Section 2. Procurement Planning

A brief general discussion covers both the formal and informal planning. A format for an Illustrative Procurement Plan is provided to assist the government program manager. A table is also included detailing time required for procurements at NADC.

Section 3. Contact with Contractors

The allowable contact of government employees with contractors is described. Comments on debriefing of unsuccessful offerors and technical direction of award contractor are also included.

Section 4. General Information on Specifications

General definitions of specification types and other procurement specification topics are provided for the project director. Requirements to be included in procurement specifications are briefly covered, and a checklist of specifications requirements from MIL STD 961 is provided.

Section 5. Sample Specification

The bulk of the Phase II Document (N) is devoted to the presentation of this sample specification for the procurement of a maintenance-training simulator. The Phase II Document (N) reports that an attempt is made in the sample specification to include those areas typically covered in a simulator specification--the engineering and integrated logistics support "boilerplate."

In the document, the specification is presented on the left-hand pages; and information, explanations, and instructions for the specification writer, on the right-hand pages. The specification also provides instructions for inclusion of data generated by Phase I Document (N).

Section 6. Parts and Sections of the Request for Proposals (RFP)

The sample specification is only part of the actual RFP needed for procurement of the maintenance-training simulator. This section of the Phase II Document (N) provides the schedule (in the form of Contract Data Requirements Lists, CDRLs, DD Form 1423) that accompanies the specification (actually part of section 6 of a specification). The schedule includes the deliverable items, such as Data Item Descriptions (DIDs, DD Form 1664), as well as information on other RFP requirements.

Section 7. Technical Proposal Requirements, Proposal Evaluation Plan, and Proposal Evaluation Reports

Material on the Technical Proposal Requirements (TPR), the Proposal Evaluation Plan (PEP), and on the Proposal Evaluation Report (PER) is presented.

Computer System for Simulator System

The sample specification (section 5) did not include specifications on a computer system for the simulator. This enclosure to the Phase II Document (N) presents statements on computer systems that might be used in a specification. An outline of functional requirements for microcomputer applications and a document, written in the form of a specification, covering computer software for a fairly complex computer system are included. The computer software specification is written with the assumption that FORTRAN will be used as the major programming language.

THE AIR FORCE STUDY

The Air Force Study at present consists of the following two documents, prepared for the Air Force Human Resources Laboratory (AFHRL), Lowry Air Force Base, CO by Applied Science Associates (ASA), Inc., under contract F33615-78-C-0019.

1. ISD and SPO Procedural Requirements for the Design and Acquisition of Maintenance-Training Simulators.

2. Maintenance Training Simulator Design and Acquisition Model Specifications.

Hereafter, these documents will be referred to as Procedural Requirements (AF) and Model Specifications (AF) respectively.

The two Air Force reports define different program objectives. Procedural Requirements (AF) covers the collection, analysis, and documentation of information for the design, fabrication, and life-cycle maintenance of maintenance simulators. The Model Specifications (AF) covers the acquisition of baseline knowledge on techniques, procedures, and principles necessary for broad applications of simulations in maintenance training. The latter objective appears more in line with the needs of this study.

The documents are preliminary drafts and the final drafts are still in preparation. The following paragraphs provide a synopsis of their contents using the headings of the documents and their organization (see Appendix C). Statements and opinions are those of the authors and are presented without comment.

Procedural Requirements (AF)

Section 1. Introduction

Procedural Requirements (AF) reports that the initial phase of the Air Force effort focused on the information and procedures required by Instructional System Development (ISD) teams and Systems Program Office (SPO) Training Equipment Acquisition Managers in developing cost-effective technical training. Subsequent phases define the maintenance-training simulator from maintenance task data, model training equipment, and model procurement specifications.

The current procedures for ISD training-equipment design and SPO training-equipment acquisition are reviewed. The review, which is a summary of many surveys, includes an interpretation of the project findings in terms of technological gaps and problem areas faced in designing a cost-effective maintenance-training simulator. A training-equipment design-process model is included to serve as the framework for design decisions.

Section 2. Current Training Equipment Procurement Process

An overview of the complete process of acquiring maintenance-training equipment by the Air Force is given.

Present ISD Training Equipment Process. Individual Air Force Command and interservice procedures for the ISD process have been developed. All these ISD processes have a common flow, entailing the following actions:

1. Activities requiring training analyzed.
2. Training requirements determined.
3. Training objectives and their sequence established.
4. Performance measurement techniques developed.
5. Methods and media selected.
6. Instructional materials developed.
7. The instructional program conducted and evaluated.

The document states that the 3306th Test and Evaluation Squadron (T&ES) has been successful in applying the ISD guidelines to the design of maintenance-training equipment. Therefore, the Air Force, in developing standardized ISD procedures, has adopted this *3306th T&ES ISD process for evaluation.*

The ISD processes, as indicated in the AF documents, are not significantly different when designing training equipment for existing systems or for new systems, or for intermediate or organizational-level tasks. To perform effective ISD, comprehensive task information must exist or be generated.

Manning and Training of ISD Teams. Personnel selected as future instructors are assigned as ISD team members in the 3306th T&ES. The Air Force philosophy is that "it is more effective to select and train individuals to be ISD analysts who are already experienced and capable instructors and also experts in the subject matter (Subject Matter Experts) (SMEs) in specific types of subsystems and specialities, than it is to select experienced analysts and attempt to make systems specialists and competent instructors of them."

The various steps of the ISD process are grouped into five general tasks to form a model for ISD. These tasks are seldom performed in sequential order. Figure 2 shows how the 3306th T&ES procedural steps relate to the general ISD model.

The ISD descriptions currently in use by the Air Force were reviewed, and three major shortcomings of the present ISD procedures were identified. These shortcomings, to be corrected by the development of the Training Equipment Design Process Model, are:

1. The present procedures describe an idealistic data availability situation. The depth, accuracy, and reliability of the task data that is usually available to the ISD analyst does not permit clean abstraction into specific categories of the analysis procedure.

GENERAL MODEL		3306th T&ES PROCEDURAL STEPS
I	ANALYZE SYSTEM REQUIREMENTS	1. IDENTIFY MAINTENANCE REQUIREMENTS
		2. IDENTIFY CONDITIONS AND CRITERIA
II	DEFINE TRAINING REQUIREMENTS	3. DETERMINE TARGET POPULATION
		4. IDENTIFY CAPABILITIES OF POPULATION
		5. DETERMINE TRAINING REQUIREMENTS
III	DEVELOP OBJECTIVES AND DETERMINE MEDIA	6. DETERMINE TRAINING OBJECTIVES
		7. DEVELOP TRAINING APPROACH
		8. DETERMINE TECHNICAL TRAINING MATERIALS
IV	PLAN, DEVELOP, AND VALIDATE INSTRUCTION	9. DETERMINE METHOD OF CLASSROOM INSTRUCTION
		10. PREPARE COURSE CONTROL DOCUMENTS
		11. PREPARE INSTRUCTIONAL MATERIALS AND TESTS
		12. VALIDATE INSTRUCTION
V	CONDUCT AND EVALUATE INSTRUCTION	13. CONDUCT TRAINING
		14. EVALUATE TRAINING

Figure 2. Relations between general model and 3306th T&ES procedural steps.

2. The ISD guides and handbooks available are "principle" oriented and provide minimum guidance on the procedural or mechanistic application of these principles in making training and training equipment design situations. There are no real step-by-step "how to" guides.

3. ISD required decision-making necessitates the learning, retention, and integration of a large number of complex concepts/constructs and associated knowledges. The ISD procedures, in total, constitute a set of skills that require extensive practice for mastery.

The SPO Training Equipment Acquisition Process. The current maintenance training equipment procurement processes in the Air Force do not fall into a "typical pattern," and are not consistent throughout the Air Force. The purpose in examining the SPO procedures was to ". . . study, survey, analyze, and determine the requirements of SPO Training Equipment Acquisition Managers who are charged with the analysis and review of simulation requirements, and the synthesis of those requirements into procurement specifications for maintenance simulators." Data sources included document review, Air Force personnel interviews, and Air Force directives review.

SPO Training Equipment Acquisition Manager activities fall into the following categories:

1. Validation of training-device functional requirements resulting from the ISD process.

2. Validation of weapon-system contractors' engineering data.

3. Preparation of procurement specifications that translate previously validated results into hardware design.

4. Management of contract procedures from contractor selection through training-equipment development to ensure timely delivery of an adequate product.

The Air Force requires the SPO acquisition manager to participate in all the analytical and review processes leading to the ISD team specification of functional requirements. When final requirements are presented for procurement, the SPO acquisition manager is knowledgeable about the system, and, specifically, the ISD process that has generated the simulator requirements. The SPO acquisition manager can contribute to both the validation of device functional requirements and the translation of those requirements into procurement specifications.

Major Gaps and Problem Areas. Three major classes of problem areas and technical gaps to be addressed and corrected by the SPO Training Equipment Acquisition Model are defined. This will serve as the basis for developing standardized SPO Training Equipment Acquisition procedures. Problem areas and technical gaps are:

1. Inappropriate specifications.

2. Late acquisition (training equipment delivery too late to support initial operation training).

3. Variable management practices (no single point of procurement management).

Section 3. Training Equipment Design Process Model

This section (1) examines the training equipment (maintenance-training simulator) design process, (2) identifies the underlying decision logic that should structure the process of getting from job information to simulator design characteristics, and (3) identifies at least general classes of information that are really required to support each decision set. The approach used was to adopt a general model with decision sets described at a level that generalizes across most situations in which the ISD process would result in a maintenance-training simulator.

The purpose of this design process is to lay the groundwork for proposing hierarchical and associative relationships between information about tasks and appropriate training-equipment functional characteristics. The model goes beyond existing Air Force ISD procedures and is intended to lead toward:

1. Determination of appropriate ISD procedure modifications that will support cost-effective simulator development.

2. Identification of the procedural steps that can profit by a reference manual (handbook).

3. Description of documents that define ISD maintenance-simulator requirements.

The following decision areas span the evolution of training equipment functional characteristics from determining what must be accomplished on the job to prescribing the best method of documenting the design:

1. Required job-relevant skills and knowledge.

2. Skills and knowledge that must be learned by the trainees.

3. Skills and knowledge that can, at least in part, be learned most effectively through practice on an item of training equipment.

4. Group skills and knowledge by class or type of training equipment.

5. For each type of training equipment, the extent to which skills and knowledge must be learned.

6. The order in which specific classes of training equipment should be employed to facilitate learning.

7. The design concepts that constitute preliminary descriptions of training equipment characteristics to most effectively support specific learning requirements.

8. A preliminary Plan of Instruction (POI) that integrates training equipment and all other appropriate media into an effective training scenario.

9. Equipment design and detail revised and completed for all relevant functional characteristics to be used in the training scenario.

10. Required training equipment functional characteristics documented as the principal inputs to the SPO acquisition process.

Appendix D shows this decision process and summarizes the principal informational inputs necessary for its execution.

Section 4. Implications for Instructional Systems Development

This section pinpoints those aspects of training-equipment selection and design to be dealt with in an ISD handbook and model specifications. These aspects were derived by examining the current 3306th T&ES ISD process for selection and design of maintenance trainers, guided by the Training Equipment Design Process Model.

In cases where ISD is applied in determining training and training equipment by the Air Force, the results are better than other methods previously applied. Four areas that provide the opportunity for improvement of the present ISD procedures used by the 3306th T&ES are:

1. Procedures for training-equipment selection.
2. Procedures for maintenance-simulator design.
3. Specification for maintenance-simulator design documentation.
4. ISD team training.

Procedures for Training Equipment Selection. A maintenance-trainer simulator should be selected as the preferred training equipment only when it provides the most cost-effective training. The Procedural Requirements (AF) deals with the selection of all types of training equipment and course materials, not just maintenance-training simulators. Systematic procedures and formalized guidance for selecting the most cost-effective training system will be developed and included in the ISD handbook. The procedures are intended to replace current use of Rationale Checklists and Media Analograms. Specific procedures will be heavily based on taxonomic relations being identified in the Air Force study. These procedures will meet the following general criteria:

1. They must be as mechanistic as possible. Therefore, SMEs (ISD team analysts) without extensive experience and/or formalized training in human factors and educational psychology will be able to apply them uniformly and reliably.

2. They will be usable within the ISD process currently being used by the Air Force.

3. Documentation (handbooks and procedures) must be acceptable to SMEs.

4. The handbook must be applicable to both organizational- and intermediate-level tasks.

Procedures for Maintenance Simulator Design. Maintenance-training simulator design decisions at the functional level are numerous and complex. Formalized simulator design procedures have been lacking, and there is a tendency by Air Force commands to have simulator characteristics that closely duplicate the actual equipment. Very little attention is paid in the Air Force at present to learning enhancements through specialized instructional features. By building human-factors expertise into job-performance aids available to the ISD team analysis, this difficulty can be corrected.

Specifications for Maintenance Simulator Design Documentation. A section of the ISD handbook, to be prepared, will focus on procedures for developing functional descriptions of maintenance-training simulators. This portion of the ISD handbook will:

1. Present a comprehensive model specification as an output of the ISD process for documenting maintenance-training simulators.

2. Define all data items so that the criteria for necessary information are clear and comprehensive enough to accommodate all conceivable varieties of maintenance-training simulators for Air Force use.

3. Provide instructions for selecting the appropriate data categories to meet description requirements for any particular maintenance-training simulator.

4. Guide the formatting and detailed information content of the complete maintenance-training simulator functional description.

The completed handbook will include (1) step-by-step procedures, at a level of detail compatible with inexperienced ISD analysts, and (2) reference tables and matrices that relate all significant dimensions of the decision process. It will be configured so that it will be useful to ISD team analysts unfamiliar with total ISD procedures as both a procedural guide and reference source. These configurations will also serve as an easy and quick reference source on task-equipment relations for experienced analysts.

ISD Team Training. To facilitate use of the ISD handbook and to integrate the new procedures with those currently employed, indoctrination training will be appropriate for existing and newly assigned ISD team members. Initially, the development contractor for the handbook will conduct the training. The training will be in a form appropriate for in-house conduct necessary to indoctrinate the SMEs. It will be prepared so that it can be integrated into the existing 3306th ISD training program.

Section 5. Training Equipment Acquisition Process Model

This section provides a general decision process for acquiring all Air Force maintenance-training equipment. The starting point for this acquisition process model is the functional equipment-design documents produced by the ISD teams. The model consists of a procedural/decision sequence:

1. Validate the training equipment function and design characteristics documented as a result of ISD.

2. Determine feasibility of the validated equipment requirements in terms of funding estimates, delivery schedules, and engineering state-of-the-art.

3. Justify the concept and cost to the Program Director.

4. Prepare statement of work (SOW) and request for proposal (RFP) to ensure the contractor can produce adequate training equipment.

5. Select contractual source by assessing proposals for technical approach, based on comprehension of goals, timely delivery schedule, experience, facilities, personnel resources, and cost.

6. Reevaluate and complete details of the procurement specification to assure concurrence with every specific requirement, applying special attention in stating to the contractor that rigorous test, acceptance, and checkout procedures contained in the specification will be strictly enforced.

7. Closely monitor, within contractual legal bounds, the development and production process to assure equipment quality and timeliness of delivery.

8. Supervise and participate in the specified test, acceptance, and checkout activities.

Figure 3 shows the procedure/decision sequence.

Section 6. Implications for SPO Acquisition Activities

An outgrowth from Procedural Requirements (AF) will be the development of an SPO Training Equipment Acquisition Manager's Handbook which will provide both guidance and general information. The handbook is intended, primarily, for individual SPO acquisition managers, but will also serve while gearing up for the procurement. The handbook will be useful for training new SPO personnel, and will support (1) procedural guidance, (2) use of available resources, and (3) preparation of procurement specifications.

Procedural Guidance. A major problem for the SPO Training Equipment Acquisition Manager is knowing the steps to accomplish major activities in the acquisition process. While the handbook cannot comprehensively deal with all the acquisition procedures, it will focus on key requirements that impact individual SPO acquisition managers. The following are important handbook subjects:

1. Procedures to establish and maintain continuing coordination with the originators of maintenance-simulator requirements.

2. Procedures and an illustrative model for setting and updating acquisition program milestones.

3. Procedures and principles to guide the acquisition manager's interactions with contracting officers.

4. Standardization of data requirements.

Utilization of Available Resources. Few SPO Training Acquisition Managers are familiar with all of the sources of assistance to the acquisition process that exist outside the SPO itself. The SPO handbook will include reference resources for:

1. Documenting the expertise and experimental study capabilities that can be provided by Air Force laboratory scientists and engineering support organizations.

2. Detailing the procedures necessary to investigate the appropriateness of any particular resource and to arrange for specific assistance.

3. Providing a comprehensive guide to all Air Force documentation relevant to training-equipment acquisition, including Air Force Regulations, Air Force pamphlets, MIL-SPECs, and MIL-STDs.

Preparation of Procurement Specifications. The major responsibility of the Training Equipment Acquisition Manager is to translate a functional description of a maintenance simulator, developed from the ISD process, into a prime item procurement specification that can become contractually binding on a training-equipment manufacturer. The degree of design discretion permitted the contractor is the major factor in structuring such a specification. Therefore, it is required that the ISD team provide the acquisition manager with the essential functional characteristics of the device.

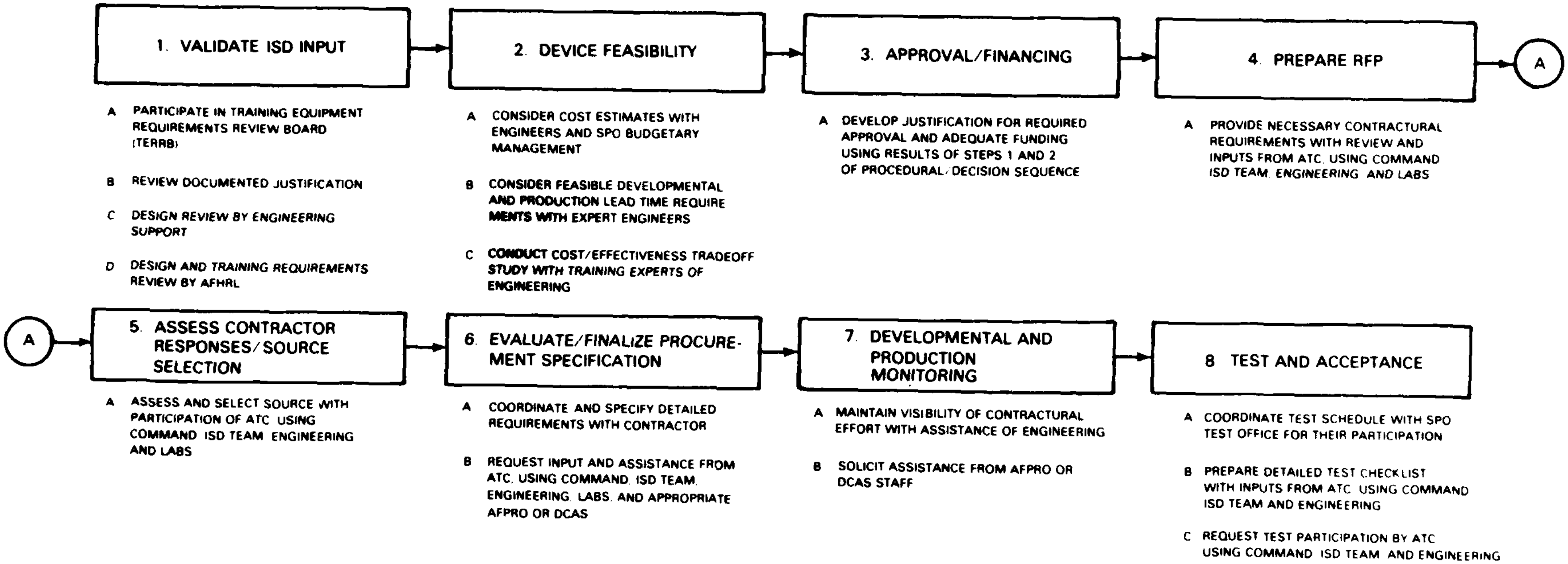

Figure 3. Maintenance-training equipment acquisition procedural/decision sequence for the Air Force study.

Model Specifications (AF)

The Model Specifications (AF) document provides model specifications to the ISD team and SPO Training Equipment Acquisition Manager. These model specifications result from the application of the processes detailed in Procedural Requirements (AF), and will structure and detail the descriptions of training equipments prepared for approval and procurement.

Two model specifications are presented:

1. Training Equipment Design Requirements for (name of trainer to be inserted). The training/trainer descriptions developed by the ISD team and forwarded to the SPO for hardware/software acquisition.

2. Training Equipment Functional Specification for (name of trainer to be inserted). The formal procurement specification that become part of the Request for Proposal (RFP).

An appendix provides a cross-reference for the two Air Force documents.

DISCUSSION AND CONCLUSIONS

The task of developing a generic specification for electromechanical and mechanical, organizational-level Simulated Avionics Maintenance Trainers (SAMTs) is difficult and complex. This is evident from the comparative analysis of alternative approaches provided in the following paragraphs.

Evaluation of the Navy Process

Although it appeared that the Navy study offered two approaches to the development of maintenance-training simulators, the two approaches can be considered as one, since the second is simply a derivative of the first. Various aspects of the process are discussed below.

1. Assumptions. The following assumptions, which were made during the development of the Navy process, define the maintenance environment and functions of maintenance personnel.

a. Task analysis and simulator configuration are the responsibilities of a specifications contractor.

b. The government monitors contractor performance of task analysis and simulator configuration determination through periodic reviews. Reviews will be used to update the contractor's previous work, to evaluate and approve contractor decision criteria, and to provide overall project direction at key decision points.

c. The government project director will ensure liaison between contractor and Navy personnel for data acquisition.

d. The project director will provide an SOW and RFP, will monitor contractor performance, and will accept the final product.

2. Meeting Goals and Objectives. The established goals and objectives of the Navy study and, therefore, the Navy process, were:

a. To produce an actual procurement specification for a maintenance-training simulator to be used at a NAMTRADET in electronics organizational-level maintenance of the A-6E TRAM/DRS.

b. To note the practical concerns of the specifications contractor and the government program manager, and to improve the development process by specifying for future program managers a generic development process, information requirements, possible information sources, review points, and critical features of program management.

No actual procurement specification is included in any documents in the Navy Study. The Phase II Document (N) does, however, contain a sample procurement specification that can be used as the SOW for an RFP.

The primary objective of the Navy Study was to provide an example of a simulator system specification. Practical concerns of the government project director were presented. Information sources and data retrieval procedures were presented and forms for their acquisition were suggested. Guidance to aid the government project director in his review of the specifications contractor performance was presented and review procedures were discussed throughout the Navy study documents. Critical features were explained and possible problems commented on, although more text should have been devoted to this subject.

3. Process Application. There is no indication that the Navy process, as presently described by the Phase I and Phase II Documents (N), has been applied to the actual procurement of a maintenance-training simulator. It is implied that the Navy process has some development experience in performing task analysis and simulator-configuration definition. This is not the case with the procurement discussions and their sample specification forms.

4. Scope. The Navy process addresses aspects from project initiation through acceptance of hardware. It does not, however, address installation, operation, and evaluation of the simulator in the training environment.

The maintenance-training simulator development process defined by the Navy process does not include a feedback function. If problems are met, feedback to upgrade problem areas is not provided. No procedures for upgrading the Navy process are specified in any of the documents.

5. Utility. NAVPERSRANDCEN is tasked with the development of generic specifications for both electromechanical and mechanical, organizational-level maintenance-training simulators. The present Navy process is concerned only with organizational-level electronic maintenance-training simulators. Actual reference to electronics maintenance is minimal, however, electronics is of major importance only during the initial identificiation of tasks to be analyzed. The example forms to be used are designed for electronic devices, and the discussions of government project director actions, and of the sample SOW for the specifications contractor are in terms of electronic maintenance. However, the forms can be easily changed, and appropriate terms included.

The sample SOW in Phase I Document (N) provides the only detailed explanation of the Navy process, although a flow chart (Appendix B) depicts the process in broad terms. It is difficult to comprehend fully the Navy process from these documents. More explanation is needed on the process steps, government project-director functions and responsibilities, the specification contractor's actions, and in particular, justification for the order and action of the individual Navy process steps.

Evaluation of the Air Force Process

1. Assumptions. The following assumptions, which were made by the developers of the Air Force process, either define the environment in which the process is to be performed and/or specify the personnel who are to perform the individual functions required to develop maintenance-training simulators.

a. The approach is a modified Instructional Systems Development (ISD) process.

b. Maintenance training instructors from the Air Force will serve as ISD members (analysts).

c. A separate Air Force office, the Systems Program Office (SPO), will provide all procurement and acceptance functions. This SPO is not part of the ISD team.

d. Information on the system under study will be obtained from (1) contractors who designed and/or built the system, (2) existing maintenance training on that system, and (3) maintenance personnel who currently perform maintenance on that system.

e. The Air Force process will be used to develop all maintenance-training course materials, not just to develop a maintenance-training simulator.

f. Review of the ISD results will be performed by an Air Force organization external to the ISD team and SPO.

2. Meeting Goals and Objectives. The Model Specifications (AF) document specified that the goals of the Air Force study (which resulted in the development of the Air Force process) were to build baseline knowledge about techniques, procedures, and principles necessary for broad applications of simulation in maintenance training.

The stated goal has been met by the Air Force study. The detailed explanation of the 3306th T&ES ISD process, the SPO Training Equipment Acquisition Manager's functions, the problem areas found, and solutions determined all point toward an extensive development of baseline data. The resulting Air Force process itself is broad and appears to cover most, if not all, aspects of maintenance training both in course materials and in simulator functional design and procurement.

3. Process Application. In developing task analysis and determining simulator functions, an existing successful maintenance-training simulator development was selected as the baseline for the Air Force Process. The development of the SPO procedures used existing Air Force procedures for baseline data. In short, the Air Force Process was developed from existing procedures and is the refinement of successful maintenance-training simulator developments.

4. Scope. Procedural Requirements (AF) covers the full development cycle of a maintenance-training simulator from course concept to final acceptance of the simulator.

5. Utility. Although the Air Force process was developed for the Air Force environment and was tailored to specific Air Force activities, many of the conceptual problems are common to the Navy and Air Force, and the concepts, procedures, and specifications appear to be applicable to Navy use. The process of developing training and training-equipment requirements for new or existing systems can be used to develop any type of maintenance-trainer simulator.

Comparative Analysis

The Navy and Air Force processes provide separate approaches that might be useful to NAVPERSRANDCEN as a baseline from which to develop a generic specification for an organizational-level, electromechanical, and mechanical maintenance-training simulator. There are differences, however, in concepts and procedural steps that must be considered. The following discussions compare these differences and assess their impact on the successful development of a maintenance-training simulator.

To provide a foundation for this comparative analysis, three procedure areas, which are common to the Navy and Air Force processes, and, in most cases, to any training-simulator development, will be discussed:

1. Determining training requirements.

2. Selecting media to meet training requirements.

3. Producing a procurement specification for training equipment acquisition.

Figure 4 shows the flow between these procedural areas within the Navy and Air Force Processes. The inherent difference between the processes extends even to the interrelation of common procedural areas.

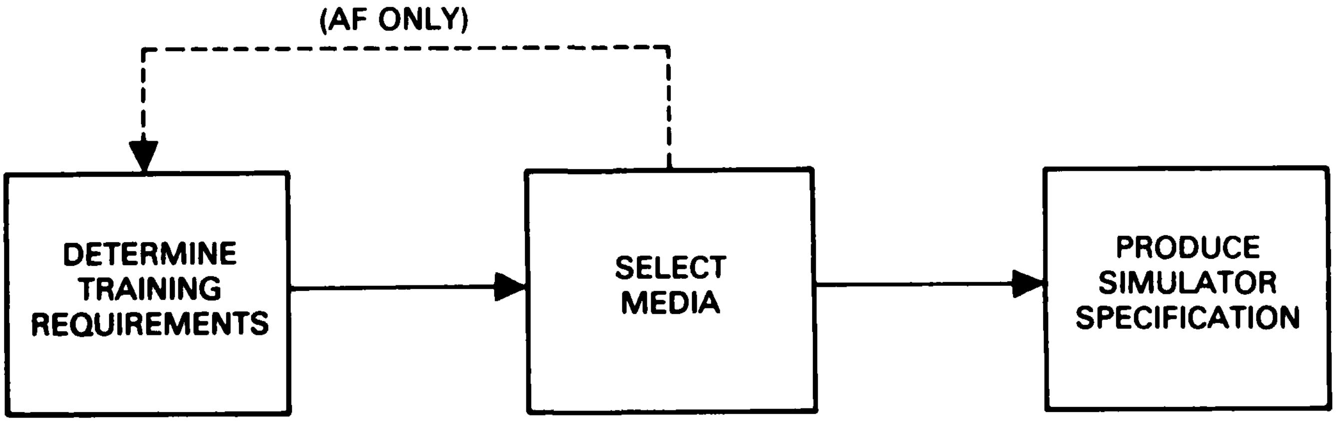

Figure 4. Common procedural areas of Navy and Air Force maintenance-training simulator design processes.

Determining Training Requirements

All of the three areas common to the Navy and Air Force processes are extremely important to the successful design of a maintenance-training simulator. The determination of training requirements, however, is the most influential of the three. Development Guidelines (N) states that a survey performed in 1977 by Federman and Siegel showed that current simulators used by the military contained defects in at least five separate areas: media, fidelity, job orientation, human engineering, and logistics. In each case, the simulator defects were traced back to the use of a faulty task analysis or to no task analysis prior to functional simulator design. The survey results strongly suggest that "a simulator designed and built without a comprehensive task analysis has little chance of being an effective or even relevant learning aid."

The analysis of the training-requirements-determination process of the Navy and Air Force will be confined to the following areas:

1. Personnel assigned to the determination process.
2. Integration of the maintenance course and simulator.
3. Instructor acceptance of the simulator.
4. Task classification weaknesses.

These areas are discussed in the following paragraphs.

Personnel Assigned to the Determination Process. The Air Force ISD process provides that future instructors will be assigned as ISD team members. The operational philosophy is to select individuals to become ISD analysts who are already experienced and capable instructors in specific subsystems specialities. The ISD team analysts, therefore, have complete knowledge of Air Force desires and user needs coupled with instructor experience.

The Navy process requires the government project director to make initial determination of training requirements and the specifications contractor to complete the list. These individuals may or may not understand the user's needs as well as the ISD team analysts do. The contract personnel must also interact through the Contracting Technical Representative and other governmental personnel to perform their tasks. Communication and data access difficulties can arise.

Integration of Maintenance Course and Simulator. The Air Force process provides for the development of not just a maintenance-training simulator but also all maintenance-training course materials. The maintenance-training simulator, if developed, plays a part in the course materials; it becomes an integral part of instruction to be given by the entire maintenance-training course. A Plan of Instruction developed by the Air Force Process is used to ensure integration is achieved.

Development Guidelines (N) states: "With a proper task analysis, there remains a strong risk of training-mission failure without the integrated (parallel) development of instructional materials, including the training devices." A further amplification of this statement is made by Phase I Document (N): "Experience with maintenance-training simulators in the field suggest . . . (that) simulator design and development were inadequately integrated with course curriculum. Often, the simulator was simply an added aid to training."

Even with the above stated requirement by the Navy study for the integration of the maintenance-training simulator into course materials, little is done within the Navy process to ensure this integration. If emphasis were to be placed on this integration, statements to this effect should have been included in the discussion to aid the project director, and also within the sample SOW for the specifications contractor. The sample SOW for the specifications contractor requires the contractor to designate simulated tasks and those left to conventional means. No consideration is given to these other means, however.

Instructor Acceptance of the Simulator. Full acceptance of the simulator by the instructors is mandatory if it is to be successful, regardless of how comprehensive and cost-effective its design. The introduction to the Phase I Document (N) indicates that the instructor has often been overlooked.

The Air Force process assigns maintenance instructors as ISD team analysts, and the instructor's desires, needs, and individual instructional philosophies become an integral part of the development process itself. In the Navy process, on the other hand, little attention is paid to the maintenance instructor either in comments directed toward the project director or in the sample SOW.

Task Classification Weakness. In the Air Force training requirements determination processes, tasks must be classified by some "undetermined" criteria, and a maintenance-task taxonomy is used to link characteristics of maintenance simulators which can effectively support training. Neither the criteria nor the taxonomy are defined. The Air Force study reports that this taxonomy will be developed in later technical documents.

The Navy process provides reference materials (in the sample SOW) to aid the specifications contractor in task classification and in linking simulator functional characteristics.

Selecting Media to Meet Training Requirement

To ensure the development of an effective maintenance-training simulator, extreme care must be taken when selecting media to meet the training requirements. Development Guidelines (N) states: "Incorrect or incomplete performance of this (procedural) step will produce a defective simulator."

In media selection in the Navy and Air Force processes, differences occur in three major areas:

1. Requirements for simulator development.
2. Methods for selecting media.
3. Feedback capabilities.

These areas are discussed in the following paragraphs.

Requirements for Simulator Development. Media selection must ensure cost-effective selection of training materials. Procedural Requirements (AF), when discussing problem areas that exist with the 3306th T&ES ISD process, points out that many times decisions to develop maintenance-training simulators may have been made without investigating more cost-effective alternatives. This idea is further amplified by the statement from Procedural Requirements (AF): "Deciding to use a simulator must occur only after a careful determination that a maintenance simulator represents the most cost-effective approach."

The Air Force process provides for selecting the most cost-effective means of meeting training requirements, and a maintenance-training simulator is not mandatory unless it is the most cost-effective training aid. In the Navy process, when discussing the project director, no statement or implication is made on the selection of cost-effective training materials. With reference to the specifications contractor, at the end of the media selection procedural step, Phase I Document (N) states: "(On the assumption that some tasks will be suitable for training on a simulator), the contractor shall classify the tasks into those to be trained on a simulator and those to be trained by other means (lectures, slides, etc.) at the NAMTRADET." Since more contractual work is designated to be performed by the specifications contractor in the area of functional simulator design, it can be assured that "some tasks" will be selected for training on a maintenance-training simulator.

Methods for Selecting Media. The Air Force process includes procedures for selecting media in the handbooks that will be developed. In the Navy process, the specifications contractor is required to select media using some classification process scheme "already described in the literature of educational psychology . . .," according to Phase I Document (N).

Feedback Capabilities. It is not realistic to consider media selection as a separate entity in the Air Force process, for media selection in the ISD process is part of an iterative procedure of course-materials development. Feedback is available to clarify problem areas that may arise through media integration of training requirements. The Navy process requires that media selection be performed after training requirements have been determined. No specific method of feedback exists.

Producing a Procurement Specification for Training-Equipment Acquisition

An objective of both the Navy and Air Force studies is to document the conversion of maintenance-training simulator characteristics into a specification for a production simulator.

Contract and procurement procedures differ greatly among all government agencies, and, in particular, within Department of Defense activities. Due to the differences between the Navy and Air Force procurement procedures, the comparison of the sample specifications developed in the two studies will be limited to the following issues.

1. Sample specification format.
2. Reference materials for specification development.
3. Aids to government procurement personnel.

These issues are discussed in the following paragraphs.

Sample Specification Format. The Air Force study uses a development process. The ISD team prepares a Training Equipment Design Requirements specification, which is then incorporated into a Training Equipment Functional Specification by the SPO Training Equipment Acquisition Manager. (The Training Equipment Functional Specification is used for RFP development.) This procedure allows for standardization of communications between the ISD team and SPO Training Equipment Acquisition Manager. The procedure appears to be time-consuming but required because the ISD team and SPO Training Equipment Acquisition Manager are separated.

The Navy sample specification is in itself an actual RFP. It excludes some "boilerplate" common to all RFPs. It does not, however, provide the structure for specifying simulator design characteristics that, by the Air Force, is accomplished by Training Equipment Design Requirements and Training Equipment Functional Specifications.

Reference Materials for Specification Development. An implied objective for both the Navy and Air Force studies was identification of applicable military standards, military specifications, Air Force regulations or Navy directives, and Department of Defense directives for simulator design and construction.

The Air Force study provides a table relating the simulator design and construction requirements to the documents defining those requirements. Also included in the table are other (usually personnel) sources of requirements information. The Navy study provides this information within the sample specification, which incorporates paragraphs that fulfill the requirements of various military standards.

A factor that may have affected the Air Force sample specification is the objective of the Air Force study to provide as much design latitude on the part of the hardware/software manufacturer and yet still meet the desired training requirements and characteristics of the simulator. The Air Force study stated that many of the above mentioned documents could place undue limitations upon simulator design and construction, thereby increasing cost and in some cases defeating training effectiveness.

Aids to Government Procurement Personnel. For both studies, assistance to aid the government procurement personnel was defined as an objective of the studies. The Air Force effort is limited in such guidance. Effort was expended in the Navy study to delineate government personnel actions throughout the maintenance-simulator design process. These actions included advanced planning tips, sample cover letter for the RFP, sample CDRLs, sample software specifications, and even a checklist for drafting military specifications. Even though some of the aids from the Navy Study are elementary, the information is useful and desirable.

RECOMMENDATIONS

Recommended Training-Requirements Determination

It is recommended that Procedural Requirements (AF) serve as the reference for the development of training requirements and media selection for the following reasons:

1. The existing ISD process chosen by the Air Force study as a base is a proved and effective process for maintenance-training simulator design specifications. The Navy study, on the other hand, uses a process developed from limited studies and is not based on actual simulator design.

2. Procedural Requirements (AF) appears to be a well developed and easily understood document. Reasons for using the methods chosen are clear and detailed. Criteria to be met by the planned procedures in the handbooks are clear and concise. Sources cited are numerous and provide a wide range of opinion and reference. Definitions of terms are included and their use is consistent. On the other hand, the Phase I Document (N) provides little background information, reasoning behind decisions, discussions of source materials, or justification for the process. Many of the discussions provide limited insight on the development of maintenance-training simulators. Many definitions appear to be "non-government standard," as exemplified by the term project director for an individual who appears to be equivalent to project engineer in standard government terminology. Consistency in terms is lacking.

3. Since Procedural Requirements (AF) provides for the complete development of the maintenance-training materials, a simulator designed by this process will be an

integral part of the training course. Though this problem was addressed in the introduction to Phase I Document (N), little has been done to ensure this integration. The Navy simulator will therefore become an "add-on" to the course and must be integrated after the course has been developed. This external development of the simulator may not exercise the skills and knowledge required by course materials.

4. The development of a maintenance-training simulator is an expensive and time-consuming effort by the government. Procedural Requirements (AF) does not impose a mandatory requirement for a simulator if the skills and knowledge can be taught by other methods. Phase I Document (N) provides little guidance in this area.

5. Instructor acceptance is a key factor in simulator development and design. Even an "add-on" simulator can provide effective training if the instructor recognizes its utility. Procedural Requirements (AF) requires that the instructor become an ISD analyst during development of the training simulator, ensuring instructor acceptance. Phase I Document (N) avoids instructor inputs, and acceptance of the simulator by the instructor is problematical.

6. Feedback is essential in any development process. Feedback provides for correction of problems as they occur. Procedural Requirements (AF) provides for an iterative process that allows feedback during training requirements and media selection. Phase I Document (N) provides only for government review for feedback. This limited feedback is not likely to provide the scope, depth, and/or timeliness required for efficient specification development.

7. It has become increasingly evident in past years that contractors fail to meet government requirements. These failures can usually be traced to poor communication. To avoid this communication problem, Procedural Requirements (AF) calls for Air Force personnel to perform the simulator specification development. Air Force personnel must maintain the level of expertise necessary to do this job. On the other hand, Phase I Document (N) places development responsibility on contractor personnel. Communication between government and contractor personnel is accomplished only through reviews at key points, and because these reviews are limited and time consuming at key points, it is doubtful that they provide the necessary communication.

The following problem areas will arise in using of Procedural Requirements (AF) as a reference when developing the generic specification for a maintenance-training simulator:

1. In translating Procedural Requirements (AF) into the Navy environment, it will be difficult to integrate the contractor into the Air Force process. Because of the limited Navy in-house manpower, a contractor will probably be used to determine the training requirements. To help maintain previously defined advantages of the ISD process, incorporation of instructor inputs and detailed government reviews must be achieved. This is possible if review cycles are provided frequently and existing instructors are utilized as major input data sources. Responsibility for developing the entire course material will also have to be placed on the contractor.

2. Communication with the staff of the Air Force Human Resources Laboratory in February 1980 indicated that, the ISD handbook was near completion. This ISD handbook could provide many of the procedures needed by NAVPERSRANDCEN in their development of generic specifications. Its utility will have to be established.

3. The Air Force Human Resources Laboratory has concluded that the taxonomy criteria needed for task classification is more difficult to develop than was initially

thought. They have therefore excluded this taxonomy for the ISD handbook, and have, instead, implemented a training requirements functional characteristics procedure. This procedure is presented as a form that, when filled in and reviewed by a media selection expert, will provide the same function as the taxonomy criteria. The new training requirements functional characteristics procedure should be evaluated, and its appropriateness to NAVPERSRANDCEN ascertained.

Recommended Sample Specification

It is recommended that Phase II Document (N) be used as a sample specification reference for the following reasons:

1. Information provided by Phase II Document (N) on the entire Navy procurement process is extensive. Detailed information on government requirements for simulator design, procurement practices, sample letters, and Request for Proposal are included. Model Specifications (AF) provides only a format for presenting ISD-developed data for possible SOW inclusion. Some mention of the procurement process executed in the Air Force is contained in Procedural Requirements (AF), but only as a general overview. Also, the Air Force and Navy procurement practices differ so greatly that a detailed discussion of Air Force procurement is of no use to the Navy.

2. The Phase II Document (N) provides many aids for use by the government for simulator procurement. These aids are well written and provide much information unknown to some government personnel. These aids are written in a form understandable by even very inexperienced procurement personnel in the Navy.

3. The results of the specification process in both the Navy and Air Force studies is the development of an RFP for simulator procurement from a hardware/software contractor. The Model Specifications (AF) document (and the discussions provided in Procedural Requirements (AF)) provide little, if any, help to government procurement personnel in writing an RFP. The Phase II Document (N) provides significant information on RFP development, with examples and sample sections for maintenance-training simulator RFPs.

The following difficulties may be met in using Phase II Document (N):

1. The Phase II Document (N) format is not developed for use by the ISD process in Procedural Requirements (AF). Some method for incorporating the ISD process output data into a form usable by the Phase II Document (N) needs development. A possible solution is to incorporate into the Phase II Document (N), those sections of model specifications used for the conversion of ISD process output data into a SOW.

2. An objective in the Air Force study for development of Model Specifications (AF) was to provide the hardware/software contractor as much latitude in simulator hardware/software design as possible, yet provide for the achievement of all simulator design-specification requirements. It is questionable whether all the requirements placed on electronic equipment design from MIL-SPECs, MIL-STDs, DoD directives, and Navy guidelines are applicable to a maintenance-training simulator to be used only in a training and not a combat environment. These requirements usually place many restraints on the hardware/software contractor that add appreciably to the simulator cost.

Qualifications and Special Problems

Although the recommended documents will be very helpful in the development of generic specifications, there are questions that must be answered if the development is to be successful. These questions arise from the complexity of the task. Not all questions can be identified at this time; some will be raised during development. The questions noted below must be addressed if proper development is to proceed.

1. What is a generic specification? The term generic specification has been used repeatedly throughout this analysis, in Navy Coordination Papers, and in communication within and without the Navy. Yet, even with this extensive use of the term, a clear definition is not available. In the context where this term has been used by NAVPERSRANDCEN, a possible definition might be "a device or procedure to provide specific information about a simulator for procurement by the government." This definition does not necessarily correspond to usage by others (such as the Air Force). Standardization of terminology is needed.

2. What form will a generic specification take? The forms that appear to have been taken by both the Navy and Air Force processes are:

a. A procedure or process for determining training requirements and for selecting media to fulfill those requirements. In the Navy process, this was displayed in the sample statement of work in the Phase I Document (N). In the Air Force process, this will be fulfilled by the upcoming ISD handbook.

b. A "form" by which simulator specifics can be identified for manufacturing the simulator. The Phase II Document (N) provided this function in the form of a sample specification that becomes a part of the government RFP. The Air Force process will provide this with a combination of Model Specifications (AF), which documents the desired simulator characteristics, and the to-be-developed SOP handbook.

3. Who will determine training requirements and select media? The use of a specifications contractor could cause the final developed generic specification to be far different than if in-house personnel are used. A specifications contractor will require monitoring and periodic review by the government, and monitoring should be scheduled in the general specification. A SOW detailing the specifications contractor's action should be available or developed from the generic specification. This SOW will be used for contractor selection and to guide the contractor's efforts. Criteria for contractor expertise and experience should be included to ensure correct selection of contractors.

The choice of in-house user personnel for determining training requirements and media selection may require different procedures than if a contractor is used. The level of knowledge and skill of personnel assigned to the specification development must be carefully considered. Training of these individuals also needs to be considered. Some review should be present from sources external to the project staff. The depth and source of this review will need to be determined.

This problem can be extended to consider whether a generic specification could be developed that is independent of the choice of specifications contractor or in-house user personnel.

4. Is a universal generic specification possible? The eventual goal of the Navy appears to be a general maintenance training simulator generic specification. The Air Force appears to have set this goal also, and may very well have achieved it. If it is concluded that this type of generic specification can be developed, the next question would be whether that generic specification could be adopted for all simulator development, and not just for maintenance training.

Concluding Remarks

Although the initial cost of developing a maintenance training simulator "generic specification," in terms of both money and manpower, will be great, the potential benefits also appear to be great. It is important that the generic specification be developed, tested, and then refined. Several iterations may be required. Using this approach, with the recommendations of this report as a starting point, it is likely that the potential benefits will be realized.

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GLOSSARY OF KEY TERMS

Analysis	This report--a comparative analysis of the Navy and Air Force processes or the development of maintenance training simulators.
Environment	Factors that affect the execution of the maintenance training simulator development process.
Generic Specification	A device or procedure that leads from conception of a project, through development of a maintenance training simulator, to the actual procurement of that simulator.
Intermediate-Level (I-Level) Maintenance	Maintenance tasks for a system/subsystem performed by the Intermediate Maintenance Activity (IMA). The IMA is separate from the user organization.
Maintenance Training Simulator	A trainer that provides hands-on practice for aspects of maintenance jobs selected for their criticality and learning difficulty, and reproduced to the necessary degree of fidelity by computer-generated events and/or indications.
Maintenance Task	Action by the maintenance technician to keep equipment in operation (e.g., preventive maintenance to preclude trouble; troubleshooting to detect cause of malfunction; repair or replacement of worn or malfunctioning parts; and calibration, scheduled or as required).
Media	Training aids (e.g., slides, text, lectures) supporting maintenance instruction.
Organizational-level (O-Level) Maintenance	Maintenance tasks performed by the users of a system/subsystem.
Procedural Step	A specific action to be performed within a procedure.
Procedures	Step-by-step instructions on how to perform a task.
Process	A set of procedures.
Procurement Specification	A document that defines a maintenance-training simulator in a form acceptable to the government and a hardware/software manufacturer so that the simulator may be manufactured.
Project Director (Government Project Director)	Synonymous with the term "government project engineer/program manager" used in the Phase I Document (N).

Specification Contractor	A contractor tasked by the government to develop a procurement specification for a maintenance training simulator. The task usually begins with task analysis and results in a procurement specification.
Study	A group of documents developed for either the Navy or Air Force that detail a maintenance training simulator development process.
Task Analysis	An analysis of a process to identify maintenance training tasks and to determine their importance.
Training Requirements	Aspects of maintenance training necessary to train maintenance technicians to the desired level of skill and knowledge.

LIST OF ABBREVIATIONS AND ACRONYMS

AF	Air Force
AFHRL	U.S. Air Force Human Resources Laboratory
ASA	Applied Science Associates, Inc.
BO	Behavioral Objectives
CDRL	Contract Data Requirements List (DD Form 1423)
CNO	Chief of Naval Operations
DID	Data Item Description (DD Form 1664)
DoD	Department of Defense
DTA	Detailed Task Analysis
FRAMP	Fleet Readiness Aircraft Maintenance Program
FTL	Final Task List
GTA	Gross Task Analysis
IMA	Intermediate Maintenance Activity
ISD	Instructional Systems Development
MIL-SPEC	Military Specification
MIL-STD	Military Standard
N	Navy
NAMTRADET	Naval Aviation Maintenance Training Detachments
NAVAIRDEVCEN	Naval Air Development Center
NAVAIRSYSCOM	Naval Air System Command
NAVEDTRA	Naval Education and Training
NAVPERSRANDCEN	Navy Personnel Research and Development Center
NR	Normal Repertoire
PEP	Proposal Evaluation Plan
PER	Proposal Evaluation Report
PTIM	Preliminary Task Identification Matrix
PTLOLM	Preliminary Task List for Organizational-Level Maintenance
RFP	Request for Proposal
SAMT	Simulated Avionics Maintenance Trainer
SB	Special Behavior
SME	Subject Matter Expert
SOW	Statement of Work
SPO	Special Projects Office
T&ES	Test and Evaluation Squadron
TIM	Task Identification Matrix
TPR	Technical Proposal Requirements

APPENDIX A

TABLES OF CONTENTS FROM NAVY STUDY DOCUMENTS

DEVELOPMENT GUIDELINES (N)

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PHASE I DOCUMENT (N)

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PHASE II DOCUMENT (N)

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Enclosures

Guidelines and procedures for the preparation of Technical Proposal Requirements (TPR) and Proposal Evaluation Plans (PEP). Naval Training Equipment Center, ED-PEG-S040A, April 1978.

Guidelines and procedures for the preparation of Proposal Evaluation Reports (PER). Naval Training Equipment Center, ED-PEG-S041A, April 1978.

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Data Item Descriptions.

Computer System for Simulator
- (a) Statements for Specification
- (b) Outline of Functional Requirements for Microcomputer Applications
- (c) Computer Software

APPENDIX B

NAVY STUDY SIMULATOR DEVELOPMENT PROCESS FLOW DIAGRAM

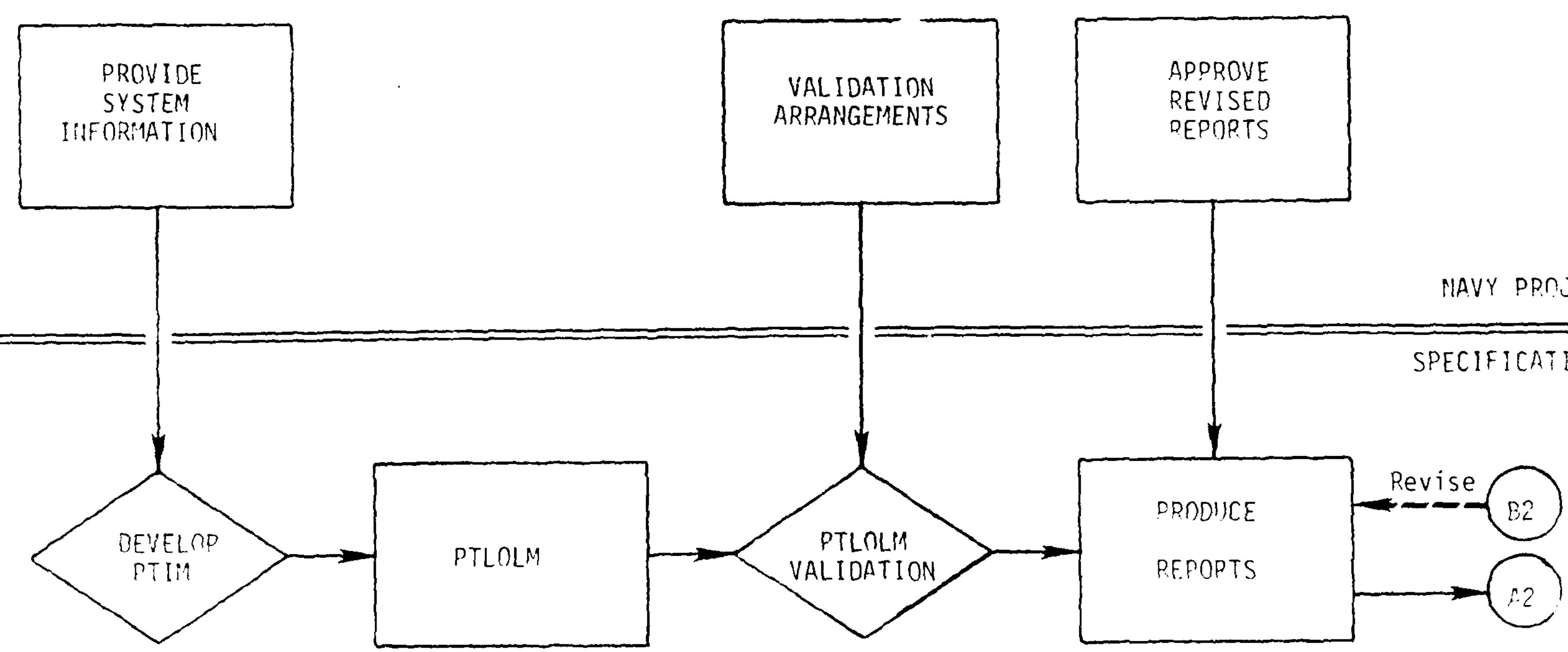

Figure B-1 Navy Study Simulator Development Process

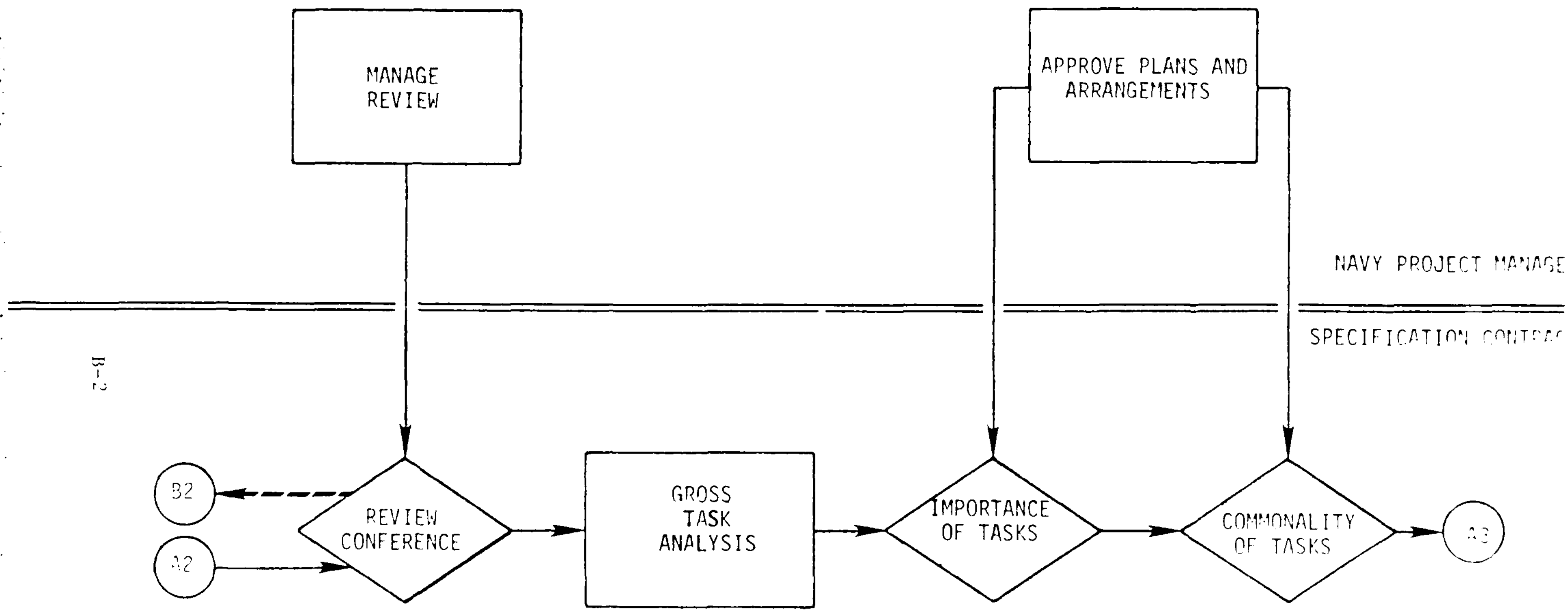

Figure B-1 Navy Study Simulator Development Process (continued)

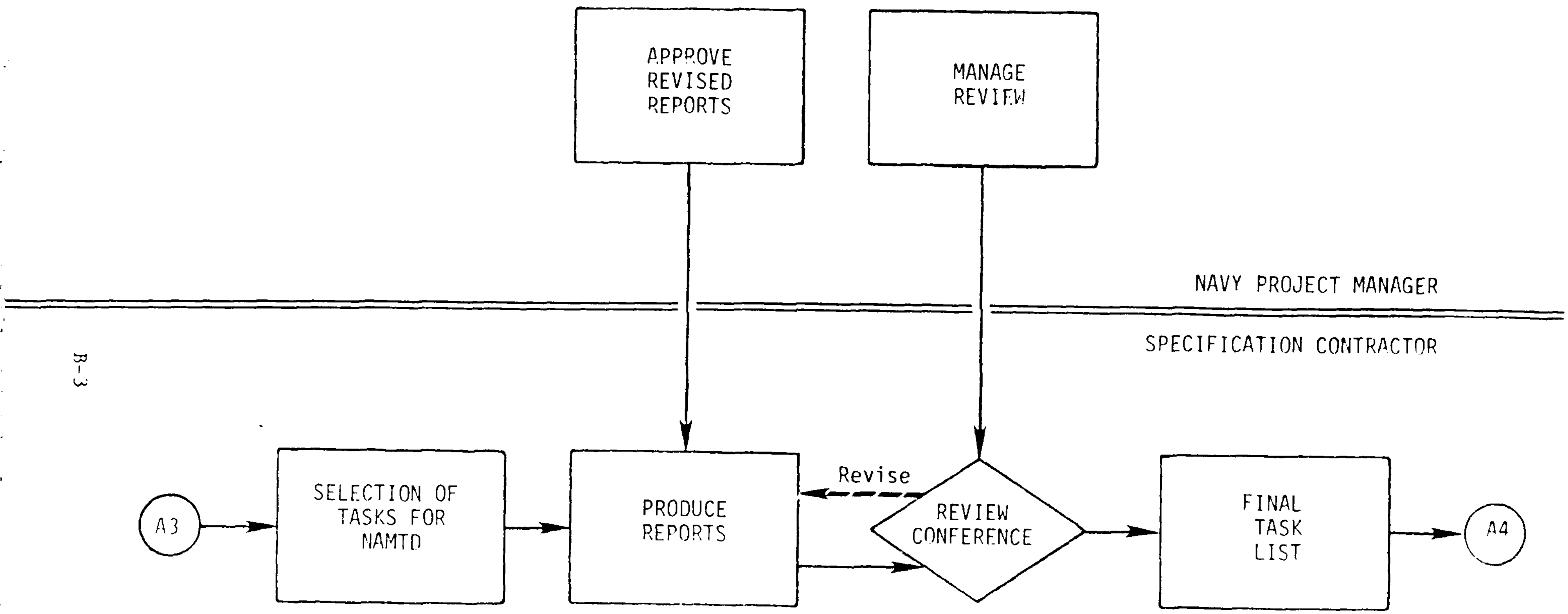

Figure B-1 Navy Study Simulator Development Process (continued)

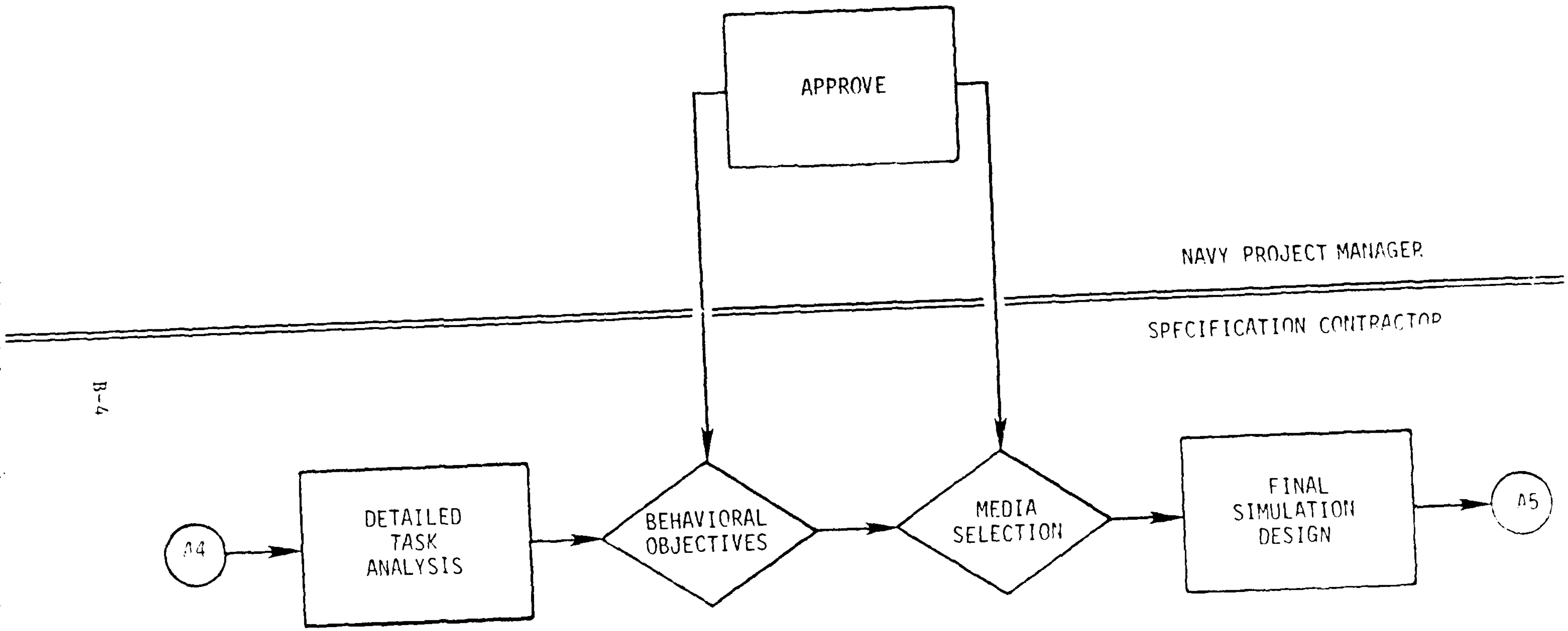

Figure B-1 Navy Study Simulator Development Process (continued)

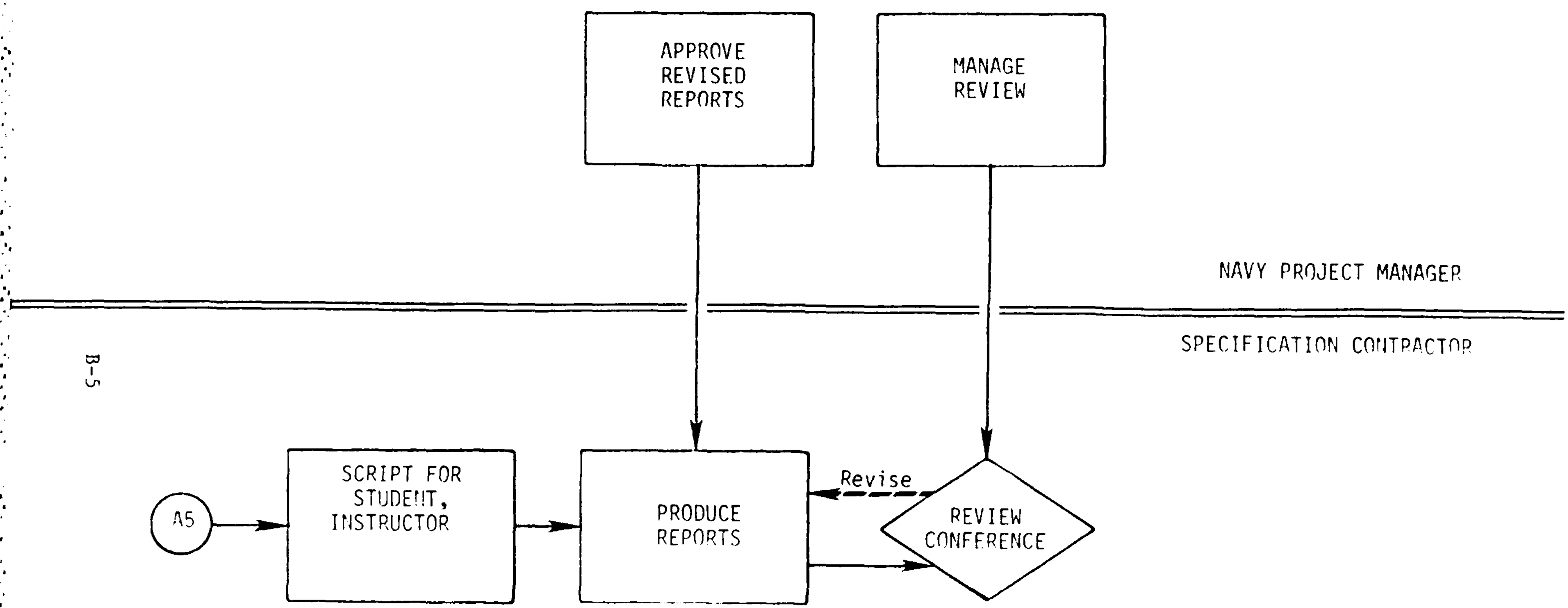

Figure B-1 Navy Study Simulator Development Process (continued)

APPENDIX C

TABLES OF CONTENTS FROM AIR FORCE STUDY DOCUMENTS

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5.6.1 Instructor Station(s), Number and Kind

5.6.2 Instructor Station(s), Displays and Controls

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3.3.1.1 Materials, Processes

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6.1 Notes, General

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APPENDIX CROSS-REFERENCES

APPENDIX D

AIR FORCE STUDY SIMULATOR DEVELOPMENT PROCESS FLOW DIAGRAM

Available Data	

Data Base

Tasks/Steps	Level (0 or I)
Frequency	Interval
Elapsed Time	Conditions
No. Personnel	Criteria
AFSC	Criticality
T.O. No.	

Engineering Drawings
Expert Opinion

1. Derive Skills/Knowledges/ Task-Step
2. Specify relevant performance standards
    a. Use standardized verbs

1. Compare with input capabilities and identify new skills/knowledges
2. Specify skills sets of knowledges requiring practice to meet standards.
3. Classify - Name/Locate/Associate
    Discriminate/Detect/
    Identify/Monitor

    Follow Procedure
    Communicate
    Use Rules/Principles
    Solve Problems/Make Decisions
    Perform Continuous Perceptual-Motor Activity

Figure D-1 Air Force Study Simulator Development Process

3. Identify Skills & Knowledges Best Learned on Equipment

For required practice:

1. Discriminations if
   a. dynamic cues
   b. cues unique to hardware

2. Procedure following or Problem Solving if:

   a. time critical
   b. difficult & high error consequence
   c. task sharing
   d. high psychomotor component
   e. many alternatives
   f. initial confidence (positive attitude) necessary

4. Group Skills & Knowledges by Training Equipment Class

1. Cluster by hardware/S&K commonalities

2. Rank order:

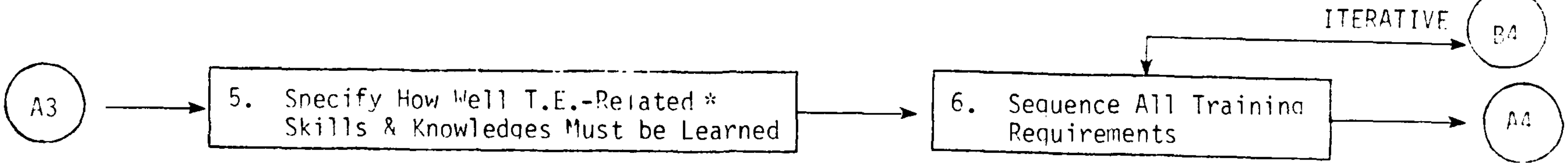
   a. Within clusters by:
      - criticality
      - frequency
      - time to application
      - learning difficulty

   b. Between clusters by:
      - learning dependencies

3. Classify Clusters by:

   a. Learn knowledge & apply
   b. Learn skills/task components
   c. Learn whole task performance
   d. Learn integrated task performance

Figure D-1 Air Force Study Simulator Development Process



5. Specify How Well T.E.-Related * Skills & Knowledges Must be Learned

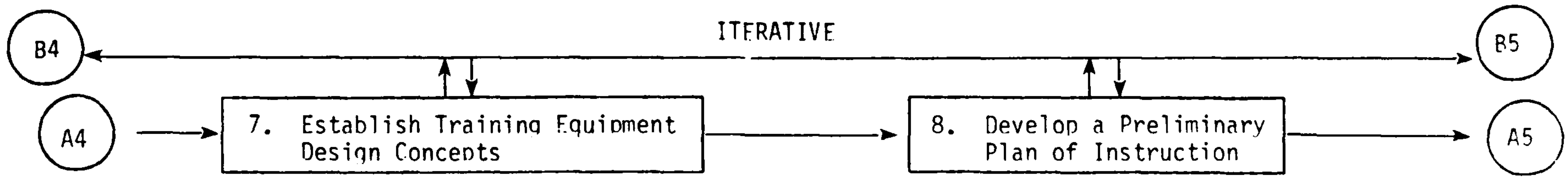
1. Prepare Criterion Training Objectives for T.E. clusters
   a. Conditions of performance
   b. Performance activity (tasks/steps/activities)
   c. Performance standard
2. Prepare Criterion Training Objectives for all other Skills & Knowledges from Step 2.

* T.E. Related refers to Training Equipment-Related Skills and knowledges (S&K) or objectives.

6. Sequence All Training Requirements

1. Classify objectives as:
   a. Common
   b. Task Unique
2. Classify Task Unique Objectives as:
   a. Having a job-related order (contingent)
   b. Prerequisite for learning others
3. Prepare prerequisite sub-objectives on basis of Step 2.3.
4. Order all objectives:
   a. Contingent objectives in job order
   b. Relevant common objectives
   c. Prerequisite objectives & sub-objectives
      - relate to common or contingent objectives
      - by increasing complexity

Figure D-1 Air Force Study Simulator Development Process



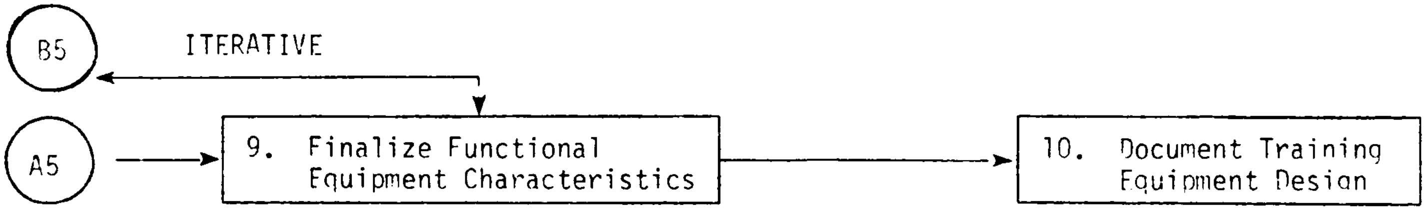
7. Establish Training Equipment Design Concepts

1. Group S&K clusters (Step 4) by ordered objectives.
2. Select Equipment Type of basis of:
   a. Practice implications of S&K
   b. Student flow
   c. Available resources
   d. Use simulation if:
      - personnel or equipment hazards
      - actual equipment in unavailable, inefficient, high cost
3. Determine Equipment Characteristics
   a. Operational fidelity
   b. Instructional capabilities

8. Develop a Preliminary Plan of Instruction

1. Select instructional modules.
2. Flowchart context & presentation
   a. Select strategies (methods)
   b. Determine other appropriate media
   c. Integrate Training Equipment
3. Outline scenario for student and instructor.
4. Assure appropriate practice time/ student on each trainer.
5. Review trade-off; relieve bottlenecks
   - more of same equipment
   - hierarchy of equipment (fidelity)
   - part/whole task division of TE objectives

Figure D-1. (Continued).



9. Finalize Functional Equipment Characteristics

1. Review for:
   a. Learning effectiveness
   b. Course continuity & flow
   c. Equipment feasibility
2. Detail fidelity of:
   a. Functional requirements
   b. Control-display relationships
   c. Instructional features
   d. Unique durability requirements
   e. Programming requirements
3. Hypothesize alternatives.
4. Cost analysis and comparison.

10. Document Training Equipment Design

1. Physical appearance.
2. Behavioral objectives.
3. Functional characteristics
   a. Controls
   b. Displays
   c. Components
   d. Interactions

   (a–d: Fidelity Requirements)
4. Instructional features
   a. Cue/feedback enhancement
   b. Student/Instructor Stations
   c. Time distortion capabilities
   d. Measuring/scoring/recording capabilities
   e. Programming requirements
5. Training applications
   a. Scenarios

Figure D-1. (Continued).

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