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TEAM TRAINING FOR COMMAND AND CONTROL SYSTEMS. VOLUME V. EXECUT--ETC(U)
APR 82 D R BAUM, J A MODRICK F33615-79-C-0025
UNCLASSIFIED AFHRL-TP-82-11-VOL-5 NL

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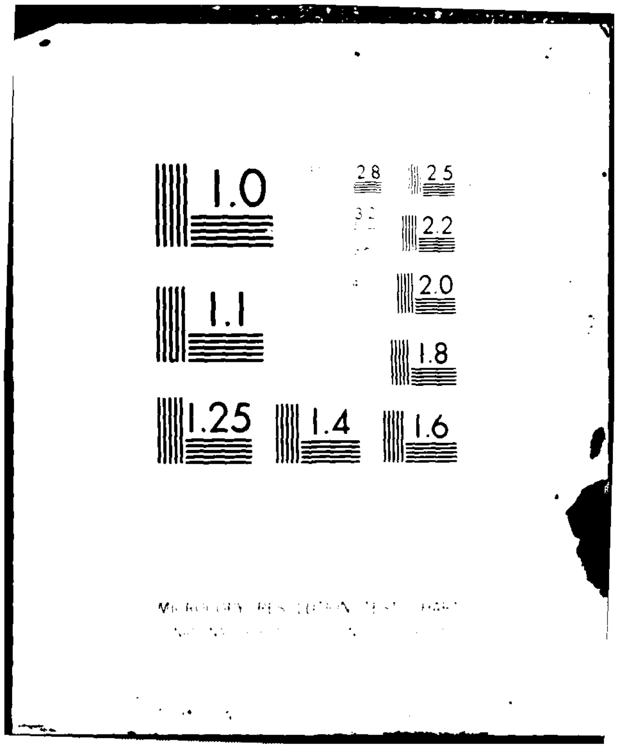
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AFHRL-TP-82-11

AIR FORCE HUMAN RESOURCES LABORATORY

TEAM TRAINING FOR COMMAND AND CONTROL SYSTEMS: EXECUTIVE SUMMARY

By

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April 1982

Final Technical Paper

Approved for public release; distribution unlimited.

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

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Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
AFHRL-TP-82-11	AD-A113 533	

4. TITLE (*and Subtitle*)

TEAM TRAINING FOR COMMAND AND CONTROL SYSTEMS: EXECUTIVE SUMMARY

5. TYPE OF REPORT & PERIOD COVERED

Final

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

David R. Baum
John A. Modrick
Sam R. Hollingsworth

8. CONTRACT OR GRANT NUMBER(s)

F33615-79-C-0025

9. PERFORMING ORGANIZATION NAME AND ADDRESS

Honeywell Systems and Research Center
2600 Ridgeway Parkway, P.O. Box 312
Minneapolis, Minnesota 55440

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

62205F
17100347

11. CONTROLLING OFFICE NAME AND ADDRESS

HQ Air Force Human Resources Laboratory (AFSC)
Brooks Air Force Base, Texas 78235

12. REPORT DATE

April 1982

13. NUMBER OF PAGES

100

14. MONITORING AGENCY NAME & ADDRESS (*if different from Controlling Office*)

Logistics and Technical Training Division
Air Force Human Resources Laboratory
Wright-Patterson Air Force Base, Ohio 45433

15. SECURITY CLASS. (*of this report*)

Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

command and control
Tactical Air Command
team training

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

This paper is an overview and summary of a study to survey and characterize team training (T^2) for operators other than air crew in Air Force command and control (C^2) systems and to make recommendations for programs to improve AFC^2T^2 by addressing weaknesses found during the survey. The recommendations were of three kinds: projects within the current state of technology, projects requiring longer term research and development, and capabilities of a simulation facility to support research in AFC^2T^2. These topics are reported in four other technical papers: AFHRL-TP-82-7, AFHRL-TP-82-8, AFHRL-TP-82-9, and AFHRL-TP-82-10.

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Unclassified

AFHRL Technical Paper 82-11 April 1982

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PREFACE

Throughout the text of this paper, reference is made to volumes I through V. These volumes have been published as separate technical papers identified as follows:

Volume I

Baum, D.R., Modrick, J.A., & Hollingsworth, S.R. *Team training for command and control systems: Status*. AFHRL-TP-82-7. Wright-Patterson AFB, OH: Logistics and Technical Training Division, Air Force Human Resources Laboratory, April 1982.

Volume II

Modrick, J.A., Baum, D.R., & Hollingsworth, S.R. *Team training for command and control systems: Recommendations for research program*. AFHRL-TP-82-8. Wright-Patterson AFB, OH: Logistics and Technical Training Division, Air Force Human Resources Laboratory, April 1982.

Volume III

Baum, D.R., Modrick, J.A., & Hollingsworth, S.R. *Team training for command and control systems: Recommendations for application of current technology*. AFHRL-TP-82-9. Wright-Patterson AFB, OH: Logistics and Technical Training Division, Air Force Human Resources Laboratory, April 1982.

Volume IV

Hollingsworth, S.R., Modrick, J.A., & Baum, D.R. *Team training for command and control systems: Recommendations for simulation facility*. AFHRL-TP-82-10. Wright-Patterson AFB, OH: Logistics and Technical Training Division, Air Force Human Resources Laboratory, April 1982.

Volume V

Baum, D.R., Modrick, J.A., & Hollingsworth, S.R. *Team training for command and control systems: Executive summary*. AFHRL-TP-82-11. Wright-Patterson AFB, OH: Logistics and Technical Training Division, Air Force Human Resources Laboratory, April 1982.

This paper is the fifth of five volumes prepared by Honeywell to document the results of a research program to evaluate the current status of team training (T^2) for operators of complex Air Force command and control (AFC^2) systems, and to make recommendations for enhancing the AFC^2T^2 process. The research was performed for the Air Force Human Resources Laboratory under contract F33615-79-C-0025. This research effort supports a major new Air Force Human Resources Laboratory (AFHRL) research and development program whose primary objective is to improve T^2 technologies in areas particularly relevant to Air Force combat readiness. The program objective requires the establishment of a baseline data base on how T^2 is currently conducted in the Air Force, and how it is developed, implemented, and evaluated. Because Air Force teams vary greatly in size, structure, and functions, it would be impractical to collect data on the training provided to all of them. Rather, the scope of this research effort had to be directed at an area with potential high payoff for increased combat readiness and effectiveness. The area of C^2 was chosen as a point of departure for the research because C^2 teams tend to be well defined structurally, are of a manageable size, and perform functions highly representative of Air Force mission needs. Furthermore, as the research effort unfolded, limited time and resources made it necessary to focus on tactical and air defense C^2 systems to the exclusion of strategic C^2 systems. Thus, the C^2 systems surveyed are, or in the case of planned systems will become, Tactical Air Command (TAC) resources.

The goal of this effort was to develop a picture, through interview and observation, of how AFC^2T^2 is currently developed, implemented, and evaluated, and what C^2 training needs will arise in the future. Based on this picture, strengths and weaknesses of AFC²T² were identified and recommendations were developed in three areas:

- T^2 research and development program
- Resolution of issues using current techniques/technologies
- Simulation technology development for C^2T^2

These recommendations will form the foundation for future research by AFHRL into the performance of C^2 teams and systems. The research will encompass training technology, performance measurement techniques for C^2 teams and systems, human resources issues in the design and operation of C^2 systems, and training of command/decision skills. The ultimate goal of this program is to improve technologies in areas of team and human factors related to the combat effectiveness of Air Force C^2 operations.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (concluded)

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF ACRONYMS

AAR	After-action report
AET	Actual equipment trainer
AF	Air Force
AFHRL	Air Force Human Resources Laboratory
AFOQT	Air Force officer qualifying test
AFSC	Air Force Systems Command
ATC	Air Training Command
AWACS	Airborne warning and control system
AWC	Air weapons controller
CICWO	Combat Information Center Watch Officer
CRC	Control and Reporting Center
C^2	Command and control
ESD	Electronic Systems Division
IPS	Interceptor pilot simulator
ISD	Instructional system development
MCC	Mission crew commander
OJT	On-the-job training
SAGE	Semi-automated ground environment
STEM	System training exercise module
TAC	Tactical Air Command
TACC	Tactical Air Control Center
TACS	Tactical Air Control System
T^2	Team Training

CHAPTER I

OVERVIEW OF THE STUDY

This document is the Executive Summary (Volume V) of a five-volume report on a survey and analysis of the status of team training (T^2) Air Force systems for command and control (C^2) and technical needs to improve training. The content of the other report volumes is:

- Volume I: The Status of Air Force Team Training for Command and Control Systems (AFC^2T^2)
- Volume II: Recommendations for an AFC^2T^2 Research Program
- Volume III: Recommendations for the Application of Current Technology to AFC^2T^2
- Volume IV: Recommendations for an AFC^2T^2 Simulation Facility

Data on Air Force team training for command and control systems (AFC^2T^2) were collected by survey and observation of training. The status of AFC^2T^2 was then characterized in terms of its strengths and weaknesses. This characterization led to the identification of issues and problem areas which could be resolved through: 1) immediate application of available or refineable training technology, and 2) a more extensive research program. Functional requirements were derived for a simulation facility to support training and human factors research. Recommendations were made for the pursuit of solutions in each of these categories.

The study objectives, approach, findings, conclusions, and recommendations are summarized in the following pages.

STATEMENT OF THE PROBLEM

The performance and training of teams and the performance of C^2 systems are being increasingly recognized as critical military problems. The problem for this study is to assess the adequacy of training for C^2 teams in the Air Force. The domain of AFC^2 teams is large, and the focus was narrowed to C^2 teams other than aircrews. The domain was further narrowed during the study to C^2 teams in Tactical Air Command (TAC) as a scope which was feasible to accomplish.

T^2 was identified as a major need for military systems in a recent report by a committee of the Defense Science Board (Reference 1), and a high priority research program was recommended. There is substantial literature on the characteristics and operation of teams and groups as indicated by recent reviews (References 2, 3, 4, 5, and 6 are recommended).

However, the amount and content of the research has not been sufficient to provide a systematic body of knowledge on which to base a technology for team performance and training. The research has often not been focused on the solution of problems in man-machine operating systems. However, when it has been oriented toward these problems, the laboratory tasks and constraints have been seriously unrepresentative of the operational problems and conditions. A review by Denson (Reference 7) revealed few findings or principles which would allow one to confidently develop and implement improved training for Air Force teams. This lack of an explicit and definitive T^2 technology leads to ineffective and inefficient use of time and resources.

The seriousness of C^2 problems have also been given visibility by reports and pronouncements following the Nifty Nugget War Games in 1978 (Reference 8). Performance during the games was characterized as "plagued with computer foul ups, logistical snarls and.... 'great gaps' in understanding among the various players." Nifty Nugget was regarded as the climax of a long history of C^2 breakdowns. The plague affected all levels of command from individual weapon systems to theater combat commanders to the National Military Command Center. The core of the C^2 problem was identified as a "complexity, and for the military, complexity's not-so-distant cousin, chaos."

An interdisciplinary group under Pentagon sponsorship was put to the task of analyzing the C^2 problem. The following quotations are representative of conclusions by that group:

> "There is not much chance for the formulation of a command and control concept so long as the dominant paradigm persists in emphasizing things over relationships and hardware over the concepts needed to use it effectively. This narrow point of view needs to be shifted if the fatal consequences surfaced by Nifty Nugget are to be avoided if and when our forces get in something beyond a war game."

"Much of the expenditure of funds in command and control at present is for the gathering, communicating, processing, storage, and the display of information."

"A better understanding of how the human mind uses information, its power to absorb data could have a major impact on technology requirements."

These conclusions indicate that the people-system interface is a significant contributor to the C^2 problems.

The study reported herein was in support of the AFHRL objective in the area of advancing T^2 technology. The first necessary step in order to ensure relevance to Air Force mission needs was the establishment of a baseline data base on how AFT^2 is currently developed, implemented, and evaluated. Because Air Force teams vary greatly in size, structure, and functions, it would have been impractical to collect data on the training provided to all of them. Rather, the scope of this research effort had to be directed at an area with potential high payoff for increased operational readiness and effectiveness.

The area of C^2 was chosen as a point of departure for the research because C^2 teams tend to be well defined structurally, are of manageable size, and perform functions highly representative of Air Force mission needs. Furthermore, as the research effort unfolded, limited time and resources made it necessary to focus on tactical and air defense C^2 of air resources to the exclusion of strategic C^2. This limitation does not affect the usefulness of the research, because assessing tactical and air defense C^2T^2

necessitated addressing issues of T^2 for performance in emergent (that is, unpredictable), high-stress environments, as well as in established, highly proceduralized environments.

The basis for the decisions to exclude strategic systems was a difference in the performance requirements for strategic and tactical C^2 systems and teams. They differ along three situational dimensions summarized in Table 1. Strategic C^2 is characterized by specifiable environmental conditions, predictable system states, and available solutions and probable consequences. On the other hand, tactical C^2 is characterized by unspecifiable conditions, unpredictable system states, and less available options and probable consequences. This difference suggests that strategic and tactical C^2 teams are different in structure and performance requirements and thus have different training needs. The informal data regarding

TABLE 1. CHARACTERISTICS OF STRATEGIC AND TACTICAL C^2

	Strategic	Tactical
Environmental Conditions	Specifiable	Not specifiable
States of the System	Predictable	Not predictable
Probable Consequences (Solutions)	Available	Potentially available

strategic C^2 collected during this effort suggest that this is an accurate statement. The more emergent or unexpected nature of the tactical situation indicates that tactical T^2 would be more difficult to train. Training must produce some skills that are generalizeable to a large set of possible conditions, states, options, and consequences. The difficulty entails producing those skills in such a way that combat readiness can confidently be assumed.

Improvements in T^2 can be expected to have a higher payoff in tactical C^2 systems owing to this emergent nature of tactical situations and the emphasis on real-time decision making. Therefore, it was decided to concentrate on tactical C^2 systems.

The objectives of this study were to:

- Develop a data base on how AFC^2T^2 is currently defined, developed, implemented, and evaluated (Volume I, Chapters II, III, and IV).
- Identify strengths and weaknesses of AFC^2T^2 and identify high payoff issues and problem areas (Volume I, Chapter VI).
- Determine which problem areas require further research and recommend areas best addressed through a program of research (Volume II).
- Determine which issues or problem areas could be addressed through currently available or refineable technology, and recommend topics for immediate application (Volume III).
- Determine the functional characteristics required in a simulation facility to support C^2T^2 research and development (Volume IV).

STUDY APPROACH

On-site data collection and documentation review were accomplished in order to develop a data base descriptive of the characteristics of AFC^2T^2. Interviews and observations were the primary survey methods, supplemented by reviews of appropriate technical material.

Interviews were conducted with personnel associated with training for the Tactical Air Control System (TACS), Tactical Air Control Center (TACC), Control and Reporting Center (CRC), the Airborne Warning and Control System (AWACS), and the Semi-Automated Ground Environment (SAGE) system. Personnel included program managers, training developers, instructors, students, and evaluators. In addition, personnel in C^2 system design, development, and procurement at the Electronic Systems Division (ESD) and MITRE Corporation of Air Force Systems Command (AFSC) were interviewed.

All interviews were carried out with specially designed guides, each oriented towards the particular type of respondent; for example, different interview guides were created and used for instructors, students, and so on. The questions asked were designed to obtain information about how T^2 was designed, implemented, and evaluated.

Observations of training and training devices/simulators were also carried out according to guides developed especially for this effort. The interview and observation guides can be found in Appendix B of Volume I.

The interviews and observations were supplemented with a review of documents on AFC^2 systems and technical literature on Air Force teams and T^2 when the review by Denson (Reference 7) was done.

Air Force C^2 systems are complex, organized entities composed of many elements. Figure 1 depicts the Air Force system which supports joint force operations. (The acronyms in the figure are decoded in Table 2.) Each center, post, unit, or aircraft depicted in Figure 1 is itself a system, or more properly, a subsystem of the tactical operations structure. Each subsystem consists of personnel equipment organized to allow certain C^2 functions and tasks to be carried out.

The CRC of the TACS, for example, typically consists of approximately 90 people, a hardware/software system known as the TSQ-91 (407L), and other equipment. It is organized into roughly four functional areas. Two areas, surveillance and identification, are devoted to the acquisition of information; command/battle staff does decision making; and the weapons control area directs implementation of tactical action. This type of C^2 team structure is illustrated in Figure 2. Each of these functions is performed by a number of personnel organized in a section supported by equipment or information. The essential components of a TSQ-91 are consoles which display radar imagery and the personnel who observe it to determine the location, heading, and speed of aircraft and missiles.

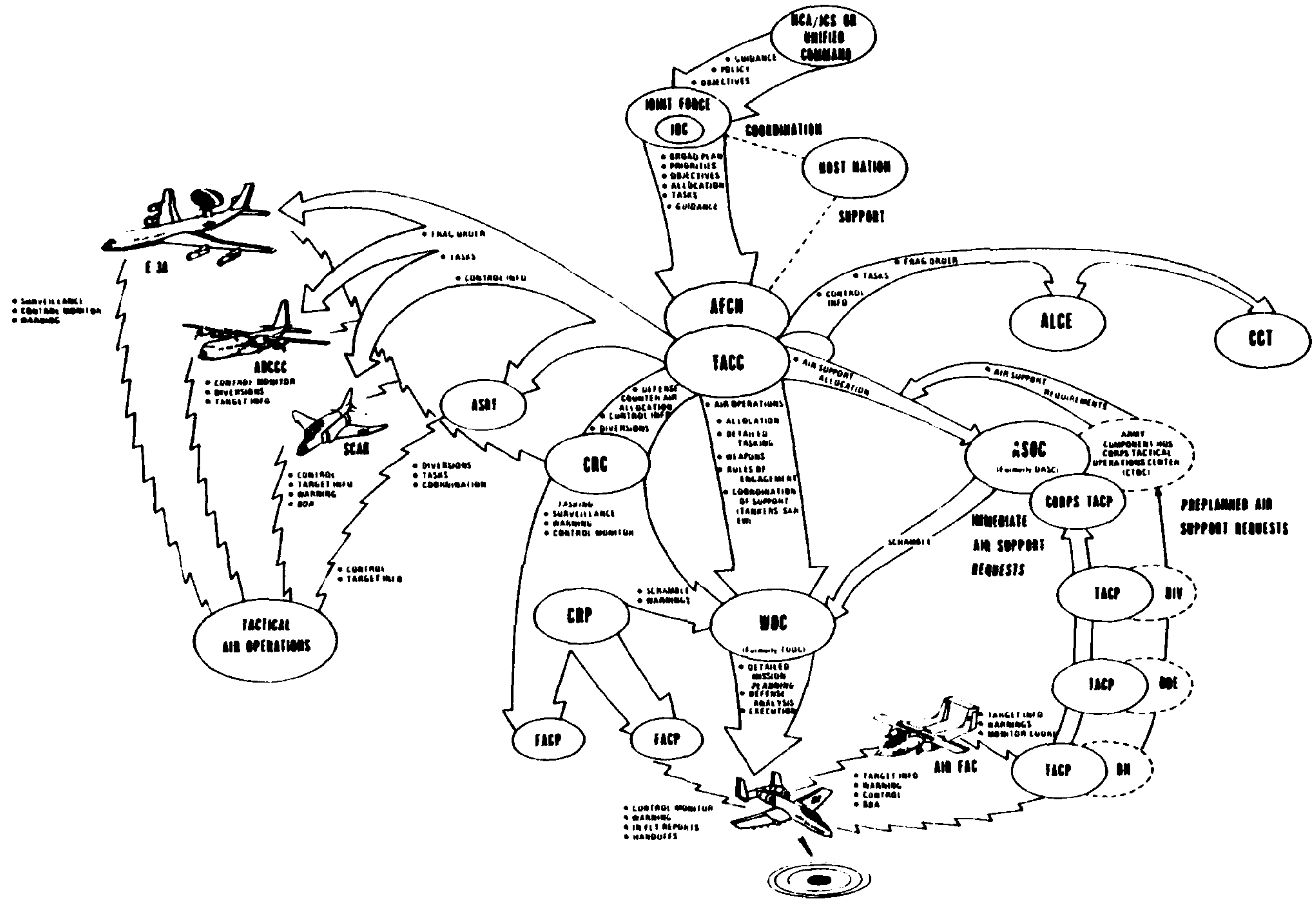

Figure 1. Tactical Air Force Supporting Joint Force Operations

TABLE 2. KEY TO ACRONYMS IN FIGURE 1

ABCCC	Airborne Command and Control Center
AFCH	Air Force Component Headquarters
ALCC	Airlift Command and Control
ALCE	Airlift Control Element
ASOC	Air Support Operations Center (formerly DASC--Direct Air Support Center)
ASRT	Air Support Radar Team
BDE	Brigade
BN	Battalion
CCT	Combat Control Teams
CRC	Control and Reporting Center
CRP	Control and Reporting Post
DIV	Division
FAC	Forward Air Controller
FACP	Forward Air Control Post
JCS	Joint Chiefs of Staff
JOC	Joint Operations Command
NCA	National Command Authority
SCAR	Strike Control and Armed Reconnaissance
TACC	Tactical Air Control Center
TACP	Tactical Air Control Party
WOC	Wing Operations Center (formerly TUOC--Tactical Unit Operations Center)

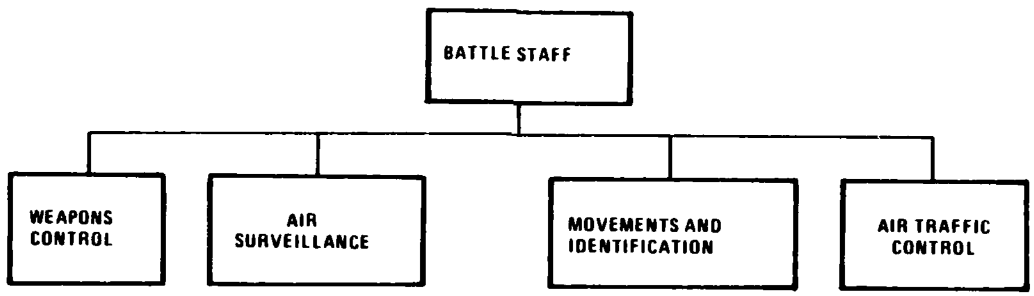

Figure 2. Generic Structure of Air Force Tactical or Air Defense Command and Control System

A team of performance/training models was adopted which consists of three dimensions:

- Performance context
- Personnel category
- Training program type

The model is depicted in Figure 3.

The performance context is elaborated further by application to T^2 for a weapons controller in a CRC/CRP. The results of that analysis are presented in Figure 4. It is based on a concept proposed by Brock (Reference 9).

FINDINGS

The data obtained through the survey were analyzed in terms of training program definition and development (Volume I, Chapter II), implementation (Volume I, Chapter III), and evaluation (Volume I, Chapter IV). Figure 3 shows the three primary dimensions--performance context, personnel category, and training program type--into which AFC^2T^2 can be structured. Each cell of the matrix can in principle be addressed by training development, implementation, and evaluation.

Table 3 summarizes the strengths and Table 4 the weaknesses found by this survey of AFC^2T^2. There are more weaknesses than strengths, but the weaknesses tend to be symptoms of a relatively small number of underlying issues and problem areas which are discussed in the Conclusions section.

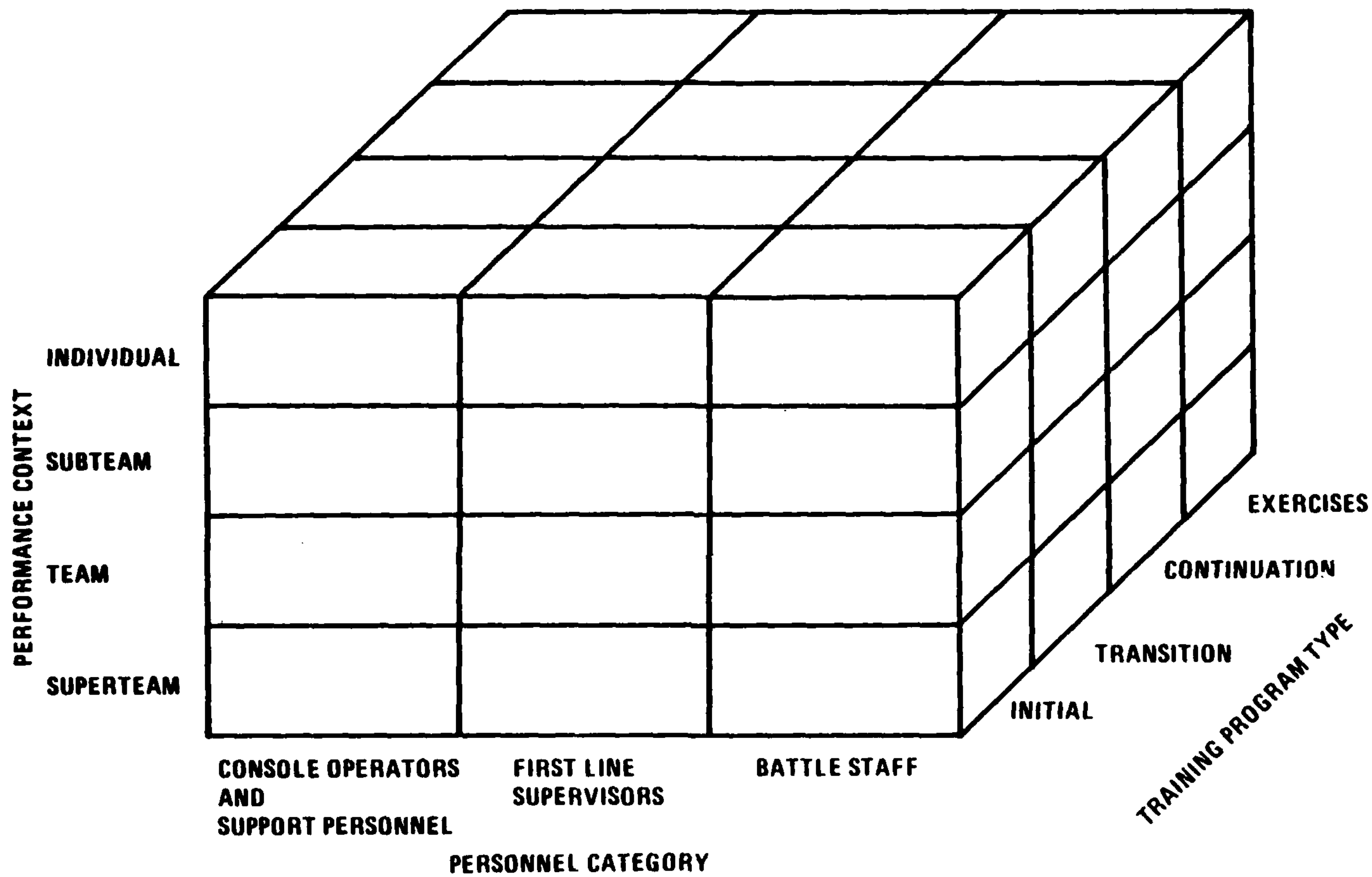

Figure 3. Training Contexts to which Instructional System Development May Be Applied

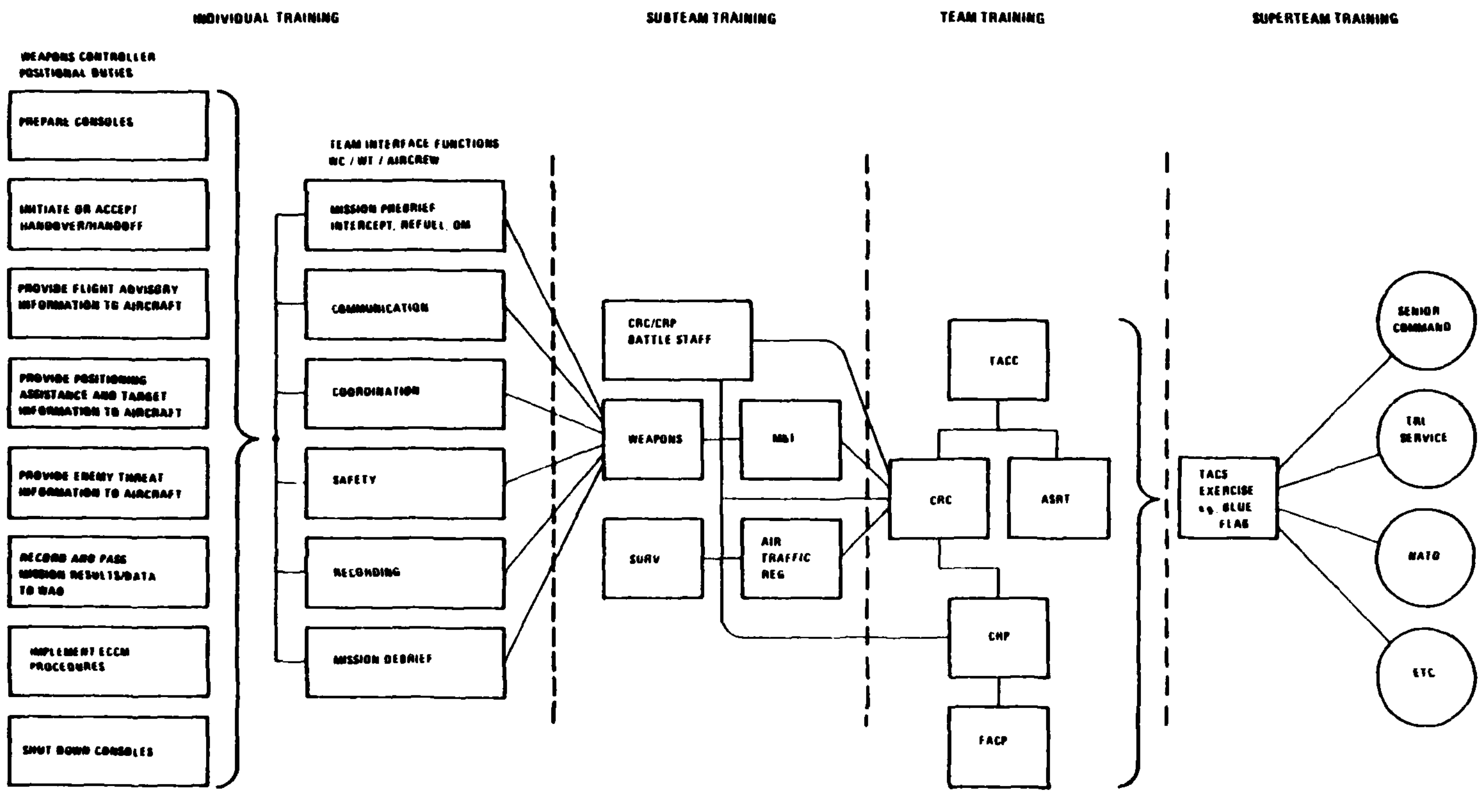

Figure 4. Team Training for CRC/CRP Weapons Controller

TABLE 3. STRENGTHS OF AFC^2T^2

Definition and Development	Evaluation and Modification
C^2 system design documents, for example, data items, provide ample opportunity for incorporating good human factors.	The independent (from a specific training program) status of the Tactical Air Control System Office of Training Development is necessary for meaningful program evaluation.
AFC^2T^2 personnel are dedicated and motivated and perform admirably considering the limited resources they have.	The standardization/evaluation program prevents major discrepancies in T^2 programs.
Recognition of the critical importance of C^2T^2 for joint service operations is increasing.	Questionnaire approaches are positive attempts to query students and operational units regarding the quality of training programs.
Systematic procedures within Instructional System Development (ISD) exist for identifying individual operator job tasks and task elements, especially as related to the equipment console.	Expert judgment is essential to the evaluation of T^2 programs especially large scale exercises like Blue Flag.
The importance of simulation in accomplishing C^2T^2 is well accepted.	
The development of course control documents, for example, course training standards, curriculum lesson plans, etc., provides formal training objectives for individual operator initial and advanced training.	
The System Training Plan developed for new systems is a comprehensive instructional management and production plan.	
Implementation and Management	
Individual operator skills are systematically trained; difficulty is sequenced effectively.	
The limited, predictable nature of static air defense missions makes their training relatively straightforward; system training exercises for SAGE are well defined.	
The standardization/evaluation program is clearly successful in monitoring individual skills readiness.	
Intrateam briefings addressing issues of intra- and inter-section performance are helpful in building team awareness and a shared plan.	

TABLE 4. WEAKNESSES OF AFC^2T^2

Definition and Development

Enforcement of human factors data requirements is incomplete or lax as a result of pressures to develop the system.

Training is often viewed as a panacea for ineffective system design which it is not.

Joint services system acquisition, for example, TRI-TAC, put stress on training developers who might have to contend with different training philosophies and personnel constraints.

In competition for scarce or limited resources the C^2T^2 area has historically had a low priority in the Air Force.

There are no systematic procedures for defining the appropriate team structure for a C^2 system or for allocating tasks to the team as opposed to the individual operator or system software.

Instructional System Development (ISD) techniques do not address team tasks or skills or T^2 objectives, nor do they adequately address non-console tasks and the tasks of non-operators.

There are no systematic procedures for defining C^2 system simulator requirements; nor is there empirical data on the level of fidelity required for C^2T^2.

The procurement of C^2 systems radically different from existing systems, for example, AWACS, puts pressure on training developers because "job" experts find it difficult to relate to unfamiliar operating procedures.

The definition of T^2 requirements is hampered by a lack of articulation of what proficient C^2 team performance consists of.

Training requirements for operations training programs (in-unit) are of dubious validity because they have not been related empirically to C^2 skills achievement and maintenance.

Operations training program requirements for live T^2 are constrained by the availability of flying resources.

Training objectives are developed informally, if at all, for transition and continuation training in the context of simulated combat missions/system exercises.

The selection of instructional methods, media, and sequencing is primarily influenced by factors unrelated to training effectiveness; namely, tradition, resource constraints, etc.

Unified, comprehensive plans dealing with the management and production of operations training do not exist.

Implementation and Management

There are no minimum aptitude requirements for entry into the Air Weapons Controller career field.

Team-oriented skills are not trained systematically; sequencing of training is not optimized.

Implementation and Management (continued)

There is no formal, standardized training for C^2 system supervisors.

The emergent nature of tactical missions makes tactical skill training difficult: simulated combat missions/system exercises for AWACS and TACS are ill defined.

The evaluation of team readiness is hampered by a lack of articulation of the dimensions and attributes of good team performance.

Team readiness assessment is unstandardized in terms of conditions and difficulty.

The importance of feedback to teams is recognized but there are no proven techniques for making feedback effective.

Simulators do not fully support instructor requirements.

Simulation fidelity does not support effective training.

Personnel who simulate interceptor pilots are not formally trained for their duty.

C^2 career fields are characterized by low retention rates and the steady loss of experienced individuals.

C^2 career fields are characterized by low retention rates and the steady loss of experienced individuals.

C^2 training program managers have an incomplete understanding of the C^2T^2 pipeline.

Evaluation and Modification

The successful use of an ISD analysis to evaluate a training program depends on having unbiased subject matter experts; because instructors in the program usually provide the expertise there is inherent bias in the evaluation.

The lack of objective, behavior-referenced criteria for assessing team-oriented skills and team performance limits the stan/eval effort.

Given the unvalidated relationship between operations training program requirements, in terms of, for example, number of intercepts a quarter, and skills maintenance, the achievement of those requirements should not be used as an evaluative measure.

The measurement tools of the expert are unsophisticated, informal, undocumented, and depend on the experience of the particular expert involved.

Incomplete documentation of ISD analyses complicates program modification and makes it inefficient.

Training programs are occasionally modified as a result of resource shortages or changes in management philosophy and such modifications frequently reduce the quality of training.

There are few resources and very low priority for modifying simulators which are known or demonstrated to be deficient in fidelity or capability.

Strengths

Throughout the survey it was evident that AFC^2 training personnel were concerned about improving T^2 effectiveness. The picture that emerged was of competent, dedicated individuals doing the best they could with limited resources and technologies. There is recognition of the weakness of C^2T^2 and a desire to take positive, corrective action.

Training for individual operators is effectively developed and implemented. The assessment of operators' individual skills is comprehensive and well standardized. Good efforts, for example, intrateam briefings, are made at building team identity and spirit.

Weaknesses

The survey found a lack of formal T^2 programs for AFC^2 systems. The system and large-scale exercises that do exist have tended to become ends in themselves rather than being based on and targeted to the job requirements of an operational environment. Exercises are limited by availability of live flying resources and inadequate simulation capabilities to support T^2.

It was also found that current measurement techniques do not support team or training program evaluation. The lack of diagnostic measures of team operational readiness will hamper research and application efforts aimed at increasing it.

A critical problem exists in the C^2 career fields. Respondents to the interview attributed it to low job satisfaction and dissatisfaction with opportunities in the career field. Great pressure is exerted on the training pipeline to provide proficient replacements. Given the importance of subject matter experts throughout the training cycle, the rapid turnover and loss of experienced individuals threatens the foundations of effective Air Force operations.

The low priority given to human factors and training in system acquisition exacerbates the problems that already exist and causes others. Poor system design can sometimes be overcome through training, but this is neither desirable nor does it make effective use of training resources. A limited number of actual equipment trainers are available, and they have limited capabilities to support training, especially in the areas of training functions to support student aid instructors. This deficiency is a result of limited resources for training, unavailability of knowledge to address T^2 requirements to procure simulators and training devices, and inadequate provision for T^2 requirements in the design and procurement phases for C^2 systems.

ISSUES AND PROBLEM AREAS IN AFC^2T^2

The weaknesses identified in the survey of AFC^2T^2 were consolidated into issues and problem areas. Table 5 contains the results of this consolidation organized into the categories of definition and development, implementation and evaluation of training programs, and personnel policy and resource constraints. Personnel policies and resource constraints are not typically matters for research and development, but they have a major impact,

TABLE 5. AFC^{2}T^2 ISSUES AND PROBLEM AREAS

Definition and Development	Implementation (concluded)
Lack of a definitive framework for identifying and analyzing team aspects of operational systems and defining team-oriented task structure.	Lack of training for personnel who simulate interceptor pilots during initial and initial transition training.
Lack of objective criteria and standards for evaluating team-oriented skills, individual and team readiness, and system effectiveness.	Lack of AWACS-oriented block of instruction in Air Weapons Controller Fundamentals or APQ Courses.
Lack of analytic techniques and empirical data for determining institutional and operational T^2 requirements and objectives.	Lack of instruction for supervisors, battle staff personnel, and decision-makers.
Lack of comprehensive, systematic procedures for defining training objectives for simulated combat missions.	Program Evaluation and Modification
Inadequate planning and analytic techniques for defining T^2 simulation/simulator fidelity and functional requirements.	Lack of valid evaluative measures for initial and initial transition training programs.
Failure to define and develop formal training for C^2 system supervisors.	Incomplete use of existing evaluative data for system exercises/simulated combat missions.
Implementation	Personnel Policy and Resource Constraints
Deficient simulator capabilities including a lack of facilities for combined systems training.	Low retention rate of experienced C^2 system personnel.
Mismatch between entry-level requirements and Air Weapons Controller Fundamentals Course syllabus.	Shortage of live flying intercept events and BCM activities for T^2.
Lack of empirical data regarding the optimal instructional methods and sequencing for subteam, team, and superteam skill training.	Inadequate instructor training and evaluation in operations training program.
	Difficulties posed in training and evaluating "soft" as opposed to "hard" teams.
	Inadequate understanding of C^2 training pipeline on the part of C^2 training program managers.

often negative. There may be little that can be done about them through research or technological applications in human factors and training. Studies can be done to generate information on the effect or causes of a shortage of live flying events, loss of experienced personnel, and poor understanding of C^2 training by program managers. But changing those conditions and constraints is difficult because the policies, allocations of resources, and constraints are the responsibility of persons in other areas who must also weigh other priorities. One can develop and recommend alternative man-machine configurations and manpower practices to alleviate the effects of the constraints. One can also use research results to recommend and lobby for changes, but the decision falls under the charter of someone in another chain of command.

A brief discussion of each issue or problem follows. For a detailed *discussion, see Volume I, Chapter V.*

Lack of a Definitive Framework for Analyzing Team Skills and Designing Team Structure and Function

The Research and Development community has failed to deal comprehensively and consensually with this fundamental issue. This failure derives primarily from the lack of a body of universally accepted representative data on teams and a lack of a correponding team performance theory; no science of team performance exists.

A solution to this issue entails the development of a conceptual framework embracing both a taxonomy of team-oriented skills and a methodology for considering team characteristics in C^2 system design. The characteristics which a T^2 conceptual framework should possess are:

1. A classification scheme of types of C^2 teams according to structure functions, missions, etc.

2. An identification of the dimensions of the process of team performance and variables associated with task output

3. A taxonomy of team-oriented skills along with a task analytic procedure which forces attention to cognitive skills necessary in cooperation, coordination, and communication

The characteristics of a C^2 system design framework should include:

1. Guidelines for determining mission/task functions allocatable to machines, individuals, and teams

2. Guidelines which efficiently support the functional allocation of tasks

3. Information predictive of the effects of task or position automation in C^2 systems

<u>Lack of Objective Criteria and Standards for Evaluating Team-Oriented Skills, Individual and Team Readiness, and C^2 System Effectiveness</u>

No measurement tools exist to: 1) assess individual team-oriented skills and relate their level to some standard (of readiness), 2) assess team readiness, or 3) evaluate C^2 system effectiveness.

Resolving the problem of measuring an individual's team-oriented skill proficiency requires development of a valid task taxonomy as discussed above. The standards of task performance can be easily described in established situations where responsibilities and operating procedures are defined. But the absence of standards is part of the definition of emergent situations which characterize tactical engagements; there may be more than one acceptable solution to a problem. This, in fact, is the primary reason for the importance in individual evaluation by observers who are expert in the performance under observation. Better articulation of the standards required of individual team-oriented skills is needed--one taking into account the unpredictable nature of tactical engagements.

Observation of the process of performance should be at the heart of evaluating team readiness and system effectiveness. Readiness cannot be judged solely by concrete measures of number of exercises, activities engaged in per unit time, or percent of targets detected/intercepted. Such information is convenient for obtaining summary statistics for use by higher headquarters. However, it overlooks critical factors such as the quality or difficulty of the experiences or the process of achieving mission objectives. Such process information is captured to some degree in after-action reports, but these are not used to full advantage. Part of the reason they are not used, especially for program evaluation and by higher headquarters, is because of their narrative format.

Any approach to resolving these related problems must focus on improving the tools of the subject matter expert who is still the only valid source of evaluative information in AFC^2T^2. Resolution of these problems is a prerequisite to conducting useful T^2 research; it is difficult without resolution to ensure standards for quality control in training and operational readiness.

Lack of Analytic Techniques and Empirical Data for Determining Institutional and Operational T^2 Requirements and Objectives

The definition of T^2 requirements and objectives is essential in order that training be carried out or improved in a consistent, verifiable manner. This issue underlies a number of weaknesses in the definition and development of training during C^2 system acquisition and for operations training programs.

Joint service acquisitions, the training of experienced individuals for new systems initial deployment, and systems which are a clear departure in design and/or function from existing systems all create especially troublesome problems for Air Force training developers. This is true even for straightforward console operator training. The problems are magnified when non-console, non-procedural tasks are concerned.

Ideally, the instructional system development (ISD) framework should provide procedures and techniques for dealing with these situations. It does not. ISD works well in highly structured, predictable tasks environments, but tends to become ineffective when the process of performance rather than its outcome is of importance. Because process is the critical feature of team performance in emergent situations, ISD in its present form is not a useful tool for developing T^2.

Although it is important to develop systematic procedures for establishing initial C^2T^2 knowledge and skill requirements, it is equally if not more important to develop a data base regarding the forgetting of C^2 skills. Without such data, it is difficult to validly define the requirements for refresher training and operational skills maintenance. The current practice of requiring a certain number of system exercises and events, or hours of activities per month or quarter, is of dubious validity because there are no empirical data establishing the relationship between performance frequency and combat readiness. Such data are needed.

Lack of Comprehensive, Systematic Procedures for Defining Training Objectives for Simulated Combat Missions

Simulated combat missions are utilized for exercising individual positional and team-oriented skills. This technique is necessary for achieving and maintaining operational readiness. Its major function is to expose C^2 teams to the quantity and quality of events which they might face in actual combat. The specification of the quantity and quality of these events is the subject of this issue. There is currently no set of documented, standard guidelines for defining system exercise training objectives, especially when the system mission deals with emergent situations.

The definition of training objectives for system exercises is complicated by a number of factors. It first requires the expertise in military tactics and doctrine and additional knowledge which comes primarily with combat experience. Next it is necessary to create plausible, meaningful scenarios of events for missions which must capture the emergent nature of tactical engagements. This requires a great deal of imagination and must be tied to the variability of mission requirements which characterize a world-wide military potential (TACS and AWACS). Furthermore, the quality and quantity of events must be tied to some index of training value either in terms of team skills or mission task skills or both.

These factors must be accommodated by any procedures or guidelines developed for defining training objectives for simulated combat missions.

Inadequate Planning and Analytic Techniques for Defining T^2 Simulation Fidelity and Functional Requirements

This issue reflects the fact that the fidelity and capabilities of current simulations/simulators are more related to the level of technology available or acquisition resource limitations than to what might be required to support training. Resolution of this issue entails the development of a data base relating simulation characteristics, cost, and performance benefit. Failure to resolve this issue will undermine the critical and expanding role that simulation must play in C^2T^2.

Failure to Define and Develop Formal Training for C^2 System Supervisors

This discussion applies to the implementation issue of lack of instruction for supervisors, battle staff personnel, and decision makers. This issue is to a large degree a matter of policy, not the consequence of a lack of applicable training technology. Strong, competent leaders who thoroughly understand their jobs are a prerequisite for superior team performance. Yet, in the Air Force, system-specific training for supervisors/managers is largely on-the-job training (OJT) during simulated missions; it is informal and unsystematic. These conditions are not usually sufficient for effective training. To make more effective use of supervisor OJT experiences, they must be structured and consistent and designed according to systematically defined training objectives. If this were done, training time to operationally ready status could be reduced substantially.

Deficient Simulation Capabilities

The accepted method of stimulation in AFC^2T^2 is stimulation of actual radar display equipment. Actual equipment trainers (AETs) have historically had three shortcomings: 1) It is costly to develop stimulation materials to generate realistic synthetic imagery; 2) Some display conditions which are desirable if not "musts" for training, are too difficult technically and too costly; and 3) Instructional features and trainer-instruction interface are meager if provided at all. These features are means for controlling stimuli, difficulty of problems, and measurement of performance, for example. In initial training for air weapons controllers, AETs have two major weaknesses. First, they fail to accurately represent aircraft radar tracks in terms of speed, rate of turn, and so on. Second, AETs inadequately support the instructor in such areas as performance recording/management and record keeping.

The problems with AETs are magnified in operations training during simulated combat missions and system exercises. In this context, in addition to the above weaknesses, AETs fail to: 2) eliminate the tracks of targets which have been destroyed, 2) provide the level of target density expected in a (European) theatre operation, 3) simulate fully the effects of electronic warfare, including the use of el ctronic warfare, including the use of electronic countermeasures and counter-countermeasures, and 4) simulate sensor management.

These deficiencies are acknowledged by Air Force training personnel. Solutions to some of the problems for the 407L, the nomenclature for the CRC equipment complex, will be obtained through the deployment of the System Training Exercise Module (STEM). The STEM will replace the current T^2/T^4 system.

There is a lack of hard data concerning the training effectiveness of AETs. Consequently, it is difficult to know in which areas the upgrade of capabilities will be cost effective. Instructor support capabilities could be added confidently with the knowledge that training effectiveness would be improved. Other enhancements, for example, in the area of electronic warfare simulation, would be costly. However, it is most important that development of any of the enhancements is initiated by an analysis of the job and associated tasks in order to derive requirements for simulation which provide sufficient fidelity and are responsive to the performance requirements of the job.

Mismatch Between Entry Level Requirements and Air Weapons Controller Fundamentals Course Syllabus

There are no specific entry level aptitude requirements for the air weapons controller career field (17xx) beyond the requirements for the officer ranks. Some respondents in the survey stated that successful air weapons controllers (AWCs) need skill in mathematics, spatial reasoning, and communication. They further indicated that deficiencies in these skills are characteristic weaknesses of AWC Fundamentals Course students. (We could not determine whether these deficiencies did, in fact, impair operational performance. Our evidence is hearsay at best.) However, this problem places a burden on all subsequent units in the controller training pipeline and has obvious consequences for the quality of personnel in the career field.

This issue must be considered in light of Air Force manpower resources and required manning levels. At the present time the 17xx career field is critically undermanned and projections indicate this situation will get no better. Thus, although psychometric techniques are available for developing selection criteria, it is unclear whether such criteria could be applied to the available officer candidate population. In view of a demand greater than supply, the Air Force will not be able to be selective until the balance shifts. The mismatch between what is taught and what is required given the qualifications of the students will continue to exist until corrective action is taken. Meanwhile, data can be generated to structure remedial training programs or influence management policy if an actual case can be documented.

Lack of Empirical Data Regarding the Optimal Instructional Methods and Sequencing for Subteam, Team, and Superteam Training

A systematic training methodology for T^2 does not exist. Systematic approaches to training presume a building block approach in which components of knowledge and skill are integrated to provide behavioral capabilities needed on the job. The course of training is a progression through intermediate behavioral objectives that increasingly approximate terminal performance objectives. This systematic shaping, however, does not occur in T^2. There are two reasons for this. First, team knowledge and skill objectives are defined only in broad general terms. The objectives are not analytic enough to support sequencing or selecting particular training methods which might be superior to others. Second, existing training methods might not support the needs. In fact, there is a need for data regarding the success of various methods in T^2.

Lack of Training for Support Personnel Who Simulate Interceptor Pilots

This issue is prominent in initial and initial transition training programs, specifically the Air Weapons Controller Fundamentals, Automatic Positionally Qualified, and TACS 407L courses. The individuals who simulate interceptor pilots--interceptor pilot simulators (IPS)--do not receive any training beyond orientation to the equipment and radio vocabulary pertinent to the task they perform. As a result the training situation for AWCs is suboptimal.

A related problem is that during live flying in these same courses, the pilots are usually students themselves. Because their skills are not necessarily sharp, the training experience for both parties can leave much to be desired. For example, the student pilot may not respond correctly or as quickly as an experienced pilot to controller instructions. Student AWCs may learn to compensate for these errors and may thus learn techniques inappropriate to communicating with experienced pilots.

Lack of Valid Measures in Program Evaluation

Currently, questionnaires are typically used for evaluation of institutional training programs. Questionnaires are used for two purposes. First, the students are given an opportunity to critique the course they have just completed. Second, operations training program personnel are surveyed by air training command (ATC) and TAC institutional personnel to determine if student skills and knowledge meet expectations.

Institutional training program managers are as responsive to this information as they can be within the limits of policy and available resources. But several factors work against the utility and validity of the information produced via the questionnaires. The students are not always in a position to judge whether they have been trained effecively or to a sufficient level of proficiency. Also, they tend to be less outspoken and critical for fear of adverse effects on their record. But these factors do not have an especially noticeable, negative impact.

The nature of feedback from the field is more severe in its impact. Each operational location has local operating procedures, some of which represent special cases and therefore deviate from standard procedures taught in the institutional environment. Furthermore, because controlling aircraft is in large part technique, the biases of individual controllers come into play in any criticism that is offered. Different units may come to represent different schools of thought on techniques for controlling, depending on experiences. AWACS, SAGE units, and TACS units are subject to this latter problem, but local operating procedures only impact SAGE and TACS units. The institutional environment emphasizes standardization to an even greater degree than the operational environment. Consequently, institutional training cannot be responsive to these demands regarding procedures and techniques. The net result is that all feedback from the field is taken with a "grain of salt." The danger is that institutional training programs can wind up operating in an open-loop situation and take on a separate existence.

Incomplete Use of Existing Data in Program Evaluation

The after-action report (AAR) is not used to its fullest advantage in program evaluation and modification. The AAR is used by stan/eval personnel in operational units to characterize the system exercise performance of the unit. An individual AAR may have an impact on the design of the subsequent exercise. In any event, the deficiencies noted in the report are the subject of review and corrective action. However, despite their utility, the AARs serve only as a "one-shot" mechanism. Improved compilation of AARs would yield a data base of valuable information regarding team and system performance.

Low Retention of Experienced C^2 System Personnel

Low retention rates are apparently the result of such factors as low pay, poor work conditions or assignments, little job satisfaction, and the lack of clear career paths and attainable objectives. The importance of experienced individuals to successful institutional and operational training and to the achievement and maintenance of combat readiness cannot be overestimated. Definition and development of training requires subject matter expertise in C^2 systems and tasks; the primary method of training is the master-apprentice model; program evaluation depends upon the professional opinion of qualified experts; and so on. Clearly, the loss of experienced personnel represents a threat to the vitality and effectiveness of AFC^2T^2.

Shortage of Live Flying Events/Activities for T^2

It is often claimed, and our survey was no exception, that there is no substitute for the experience of controlling live aircraft. The same level of stress, the so-called "pucker" factor, it is argued, cannot be produced through simulation. An air weapons controller must know that lives are on the line to find out if she/he can indeed control proficiently. The same notion applies to teams, also, in the sense of survival and mission success. Obviously, live flying is necessary for evaluative purposes as well.

Given the necessity of live events for C^2 training and evaluation, some problems have resulted from force and budget reductions in recent years. These would seem to be constraints that must be lived with. Fuel for aircraft will not get cheaper. The prospect of increased live flying to support C^2T^2 is unlikely.

Both simulated and live flying events are needed, given the current state of knowledge. A great deal can be learned from simulated events. All elements of the tasks for the C^2 operators can be represented because their tactical world consists of radar images, graphic plots, and voice/data links. However, the levels of stress and realism (if any) that are associated with "real" events cannot be representated unless the operators cannot tell the difference between live and simulated events and believe or act as if all events are real. Until knowledge is acquired on the contributions of live events to training effectiveness, an informed decision cannot be made to eliminate live flying for C^2T^2.

Ironically, empirical research to determine the relative contributions of live and simulated events to training and proficiency would require live resources in a quantity that is probably unattainable. In addition, the cost of obtaining simulators with high enough fidelity to warrant investigation is prohibitive given present resources and priorities. Both are needed. A strong data-based advocacy is also needed to achieve the appropriate allocation of resources.

Lack of Instructor Training and Evaluation in Operations Training Programs

Our understanding of the comments of our respondents is that instructors in operations training programs typically receive no formal training in how to train, although they might have previous experience as an instructor. They are chosen primarily on the basis of their positional proficiency and are not evaluated on their ability as instructors. This situation places both instructor and student at a disadvantage. The former may feel inadequately prepared to do the job, and the latter could suffer as a consequence. Improvement in this area should be possible if policy decisions establishing instructor training requirements are made.

Difficulties Posed in Evaluating "Soft" as Opposed to "Hard" Teams

A "soft" team is one whose members change from mission to mission; a "hard" team stays together. Little is known about the effect of team stability on skill acquisition or team performance.

The position put forth there is that stability of membership is needed early in training; constant switching of team members would tend to retard skill acquisition. But, in the long term, rotation of membership will produce more adaptable team members with a higher level of team skills.

Although it is possible to evaluate a team's performance given proper criteria and standards, it is unclear what the meaning of such an evaluation is if the team is composed of individuals who work together on a one-time basis. This is especially disconcerting if one is attempting to measure and generalize about readiness. The effect of the soft team policy on the evaluation of readiness should be determined and used to evaluate the position. If the policy must be retained, new techniques of evaluation should be explored.

Answers to these questions are imperative to provide guidance for personnel policy regarding team stability.

Lack of T^2 Guidance for C^2 Training Program Manager

AFC^2T^2 program managers are poorly prepared to do their job. Among other things, C^2 training program managers are inadequately informed about the C^2T^2 training pipeline, about the different performance contexts (individual, subteam, team, and superteam; see Figure 3), and about the importance of developing individual skill proficiency prior to initiating T^2.

Despite the lack of a generally accepted, comprehensive T^2 philosophy, some principles and practices do exist which it would be advantageous to know or follow. That such guidance is unavailable to C^2T^2 program managers in a directly usable form means that they are missing an opportunity to be more effective in their jobs.

RECOMMENDATIONS FOR RESOLVING ISSUES AND PROBLEMS

There are three sets of recommendations for improvement of AFC^2T^2:

1. Near-term solutions attainable through the immediate application of available technology
2. Long-term research topics to address issues and problems which require additional research and development
3. Functional and operational requirements for a simulation facility for AFC^2T^2

The recommended topics for near-term and long-term programs are presented in Table 6, along with the original set of problems and issues from the survey data.

The issues and problem areas identified can be addressed through a research program aimed at specific topics in human factors design, instructional systems development, training methodology, performance measurement, and the like, or in some cases through the immediate application of available technology. Table 6 presents recommendations for AFC^2T^2 regarding long-term research topics and objectives and near-term development needs. The recommendations are indexed to the issues

TABLE 6. RECOMMENDATIONS FOR LONG-TERM RESEARCH AND NEAR-TERM APPLICATION IN AFC^2T^2

Issue or Problem Area	Long-term Research Objectives	Near-Term Applications or Development Needs (See Volume III for Discussion)
Definition and Development	Determination of deficiencies in performance and training for C^2T^2	Taxonomy for identifying and classifying team-oriented tasks and skills. (1)
1. Lack of a definitive framework for analyzing team skills and designing team structure and function.	Develop a conceptual model and framework for the descriptions and analyses of C^2 team functions and behaviors. (1)	Methodology for analyzing team-oriented tasks. (1, 3)
2. Lack of objective criteria and standards for evaluating team-oriented skills, individual and team readiness, and system effectiveness.	Develop comprehensive performance objectives for C^2T^2 at the level of preteam, team, and superteam exercises. (2)	Criteria for evaluating team readiness. (2)
3. Lack of analytic techniques and empirical data for determining institutional and operational T^2 requirements and objectives.	Develop and evaluate a set of performance measures that will assess competence of C^2 teams and battle staffs and relate team competence to system effectiveness and individual proficiency. (2)	Guidelines and aids for defining simulated combat mission training objectives and characteristics. (4)
4. Lack of comprehensive, systematic procedures for defining training objectives for simulated combat missions.	Develop a set of standardized C^2 team exercises which are graded in difficulty and cover the range of C^2T^2 operational activities. (2)	Formal training material for selected C^2 system supervisory personnel. (6)
5. Inadequate planning and analytic techniques for defining T^2 simulation/simulator fidelity and functional requirements.	Develop analytical techniques for deriving T^2 requirements and compile supporting data. (3)	Supplemental training in selected skills for entrants into the Air Weapons Controller career field. (8)
6. Failure to define and develop formal training for C^2 system supervisors.	Develop and evaluate systematic procedures for determining the skill and knowledge requirements for simulated combat missions for C^2 teams and partition them over the categories of individual, preteam, team, and superteam exercises as most appropriate vehicle for training. (4)	Formal training for personnel who simulate interceptor pilots. (10)
Implementation		Improved validity of T^2 program evaluation questionnaires. (12)
7. Deficient simulator capabilities including a lack of facilities for combined systems training.	Develop data for simulation of operational situations for C^2 teams and battle staff which identify the (a) independently controllable features of the simulation, (b) necessary and sufficient conditions of fidelity to reproduce the desired behaviors; (c) cost benefit relationships for inclusion of each feature in a simulation. (5)	Procedure for compiling after action reports into a training exercise data base. (13)
8. Mismatch between entry-level requirements and Air Weapons Controller Fundamental Course syllabus.		Attitude surveys to pinpoint sources of discontent in C^2 career fields and recommend changes. (14)
9. Lack of empirical data regarding the optimal instructional method and sequencing for individual, team, and superteam skill training.	Develop and evaluate techniques for defining the required components, functional capabilities, and level of fidelity for simulation of C^2 teams in a weapons system. (7)	Resource package for operations training program instructors. (16)
10. Lack of training for personnel who simulate interceptor pilots.	Develop and assess feasibility of a psychometric research plan to identify selection criteria for entry into a career field of air weapons controller. (6)	Number refers to number of Issue or Problem Area addressed.
11. Lack of AWC [illegible] related blocks of instruction in the Weapons Controller Fundamental or [illegible] Positionally Qualified (PQ) courses.	Identify and evaluate in a controlled fashion existing instructional strategies. (9)	
12. Lack of instruction for operators [illegible] battle staff [illegible].	Identify new topics and data for research when existing technology does not provide appropriate or adequate instructional strategies. (9)	
Program Evaluation and Modification		
13. Lack of valid evaluation measures.	Develop techniques for interpreting measures of team performance to identify deficiencies in skill and knowledge and to select appropriate remedial action. (13)	
14. Incomplete use of existing evaluative data.		
Personnel Policy and Resource Constraints	Develop techniques for analysis and interpretation of team performance measures in terms of the combat readiness of teams and systems. (13)	
15. Low retention rate of experienced C^2 system personnel.		
16. Shortage of live flying events activities for T^2	Conduct research studies on the comparative cost-cost-effectiveness of live and simulated combat exercises--and mixes of these events. (16)	
17. Inadequate instructor training and evaluation in operations training programs.		
18. Difficulties posed in training and evaluating "soft" as opposed to "hard" teams.	Conduct research to evaluate the comparative strengths and weaknesses of hard and soft C^2 teams on performance of critical C^2T^2 tasks. (18)	
19. Lack of T^2 guidance for C^2 training program managers.	Numbers in parentheses indicate the related issue or problem area.	

and problem areas they address. It is the intent of these recommendations that the long- and near-term research topics and development needs be undertaken in parallel as part of a larger program aimed at developing a model of C^2 team performance as described below.

The third set of recommendations concerns the functional and operational requirements for a general-purpose simulation facility that will be used to explore the applicability of advanced simulation technology to AFC^2T^2 research issues. In addition to its primary function, which is to support empirical research, the simulator will also serve as a prototype AFC^2T^2 training device.

CHAPTER II

RECOMMENDATIONS FOR THE APPLICATION OF CURRENT TECHNOLOGY

The survey data indicated that 11 specific topics could be addressed through the application of current technology. These topics, listed in order of priority are:

1. C^2 team supervisor training
2. Supplemental initial training
3. Compilation procedure for after-action reports
4. Simulated combat mission guidelines/aids for establishing objectives
5. Readiness criteria
6. C^2 personnel attitude survey
7. Training for interceptor pilot simulators
8. Program evaluation questionnaires
9. Operational unit instructor training
10. Task analysis method
11. Team skill taxonomy

Prioritization of these topics was of critical interest to the Air Force. The dimensions of feasibility, utility, usability, probability of success, and practical payoff were evaluated for each topic in the context of a proposed Phase II effort. The criterion of feasibility under these conditions was defined in terms of the time and labor available for Phase II as compared to that judged necessary for accomplishment of the application topic. The criterion of usability was defined in terms of the appropriateness of the topic for inclusion in a source/reference book that would be used by training personnel. The remaining criteria had standard meanings.

The recommended objective, approach, methods, and resources/facilities for addressing each problem are discussed in Volume III and summarized in the present chapter.

C^2 TEAM SUPERVISOR TRAINING

A training program aimed at improving the decision making and team coordination skills of C^2 team supervisors could potentially enhance the operational effectiveness of C^2 teams because knowledgeable, skilled leaders are essential for effective team performance. Unfortunately, however, C^2 team supervisors currently receive little formal training. Therefore, the objective of the first effort would be to demonstrate the feasibility of developing training material for a C^2 team supervisor, the AWACs Mission Crew Commander (MCC), and evaluate that material for appropriateness and training value. A parallel objective is to document the procedures for developing and evaluating the training material. The approach, method, and resources/facilities are summarized below:

- Approach--The approach would follow that used by McCutcheon and Brock (Reference 10) in their highly successful effort to develop training for the Navy Combat Information Center Watch Officer (CICWO). The steps are as follows:

  1. Identify critical job tasks
  2. Identify skill categories
  3. Establish skill acquisition guidelines
  4. Define exercise/experience characteristics
  5. Select training media
  6. Develop set of scripted exercises
  7. Produce training materials
  8. Evaluate materials

  The proposed effort would focus on those job tasks requiring team-oriented decision-making and managerial skills in nonstandard operational situations, or situations for which operating procedures have not yet been developed.

- Method--The identification of these types of job tasks would require on-site data collection and the assistance of an operationally ready MCC who has a background in training.

  The data collection effort would involve observation of live and simulated missions and interviews with operationally ready MCCs.

The specification of training guidelines and media would be reviewed with Air Force subject matter experts.

The evaluation of the training materials produced would require on-site data collection consisting of demonstration and use of the materials. Both student and operationally ready MCCs would participate in the evaluation. The primary evaluative tools would be observation of use and administration of a questionnaire.

- Required Resources/Facilities--Three site visits to Tinker AFB would be required. A subject matter expert would be required for occasional telephone consultation. The production of audio and/or visual materials from approved contractor written scripts would be accomplished by Air Force audio/visual experts.

SUPPLEMENTAL INITIAL TRAINING

Successful AWCs must be skillful in mathematics, spatial reasoning, and communication in English. There are no career field, entry level minimum requirements for these skills. At the present time the Air Force cannot be selective as a result of manpower shortages. The objective of the second research effort would be to supplement initial AWC training with relevant remedial instructional programs. The potential payoff would be to reduce the washback and washout rates for weapon controllers and increase their operational effectiveness.

- Approach--The first step would be to assess deviciencies in mathematical and communication skills. Once deficiencies are pinpointed, the appropriate supplemental training needs could be identified. It is likely that programmed instruction, self-study modules already exist for some skills required; and they could be implemented immediately.

- Method--Existing test records--for example, Air Force officer qualifying test (AFOQT) scores--would provide data on skill levels of past and present students. Trends could be observed. Alternatively, specific achievement tests could be given to samples of the student population, recent course graduates, operationally ready controllers, and standardization/evaluation controllers. Differences among the groups would allow deficiencies to be pinpointed.

- Required Resources/Facilities--Computer support would be required for data retrieval and analysis. Access to personnel records would be required. Standardized tests might need to be procured and administered. Training material would have to be developed if existing material was inadequate.

COMPILATION PROCEDURE FOR AFTER-ACTION REPORTS

The AAR is not used to fullest advantage in T^2 program evaluation, primarily because it serves only as a "one-shot" mechanism. The objective of the third research effort would be to develop a procedure for compiling, analyzing, and synthesizing a series of AARs. The data base so produced could be used in numerous ways including the following:

1. Improve the AAR format so that it more directly addresses feedback to teams about team-oriented skills.

2. Identify issues requiring improved training or modified or new operating procedures.

3. Identify issues of system design which affect team performance.

4. Provide a reference for new team members, especially supervisors.

5. Provide a rich source for specific research issues.

The approach, method, and resources/facilities are summarized below:

- Approach--The approach would be to employ an analytic technique for sorting the AAR data into meaningful categories. The data would then be evaluated in order to pinpoint operational deficiencies and their causes. The consequences of the deficiencies would be addressed in terms of training requirements or corrective action.

- Method--The AAR data would be sorted into task/skill categories within different performance contexts. Figure 5 shows the three performance contexts (preteam, team, and superteam) and the task/skill categories (mission and team) which would be used.

  The mission tasks are operationally defined by the system and the particular scenario. The team-oriented tasks include the following:

		PERFORMANCE CONTEXT		
		PRE-TEAM	TEAM	SUPERTEAM
TASK/ SKILL CATEGORY	MISSION			
	TEAM-ORIENTED			

Figure 5. Analysis Framework for After-Action Reports

--Communications (discipline)

--Adaptability to emergent events

--Anticipation (consequences of own action or information needs of others)

--Adjustment to workload modifications

--Problem solving/decision making

Figure 6 shows the framework that would be used to synthesize the compiled data. There are three different elements which may be characterized in terms of strengths, deficiencies, and the

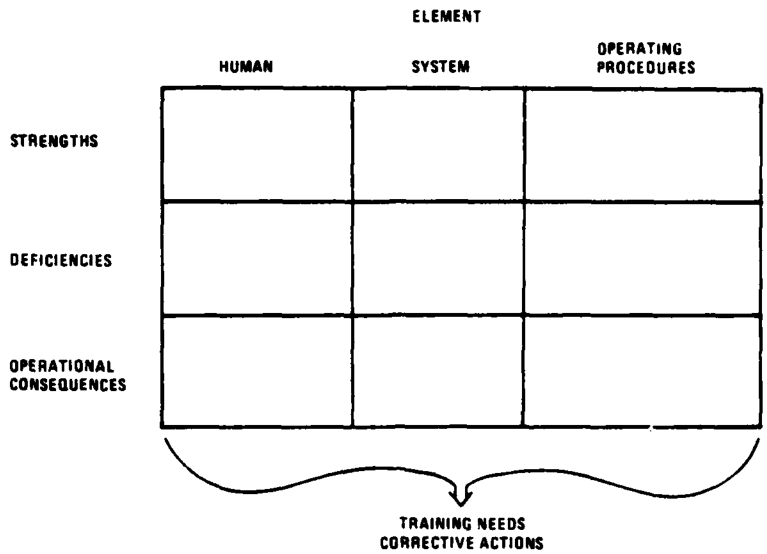

Figure 6. Synthesis Framework for Compiled AAR Data

operational consequences. These elements are human, system (hardware and software), and operating procedures which vary from well defined (established) to ill- or non-defined (emergent). The operational consequences of deficiencies will lead to recommendations regarding training needs or corrective actions involving perhaps system design (future systems, for example) or the development or modification of operating procedures.

- Required Resources/Facilities--Development of the compilation procedure would require the cooperation of a standardization/ evaluation section of the target system (a CRC would be ideal). Access to AAR data would be required, and review with Air Force subject matter experts would be needed.

GUIDELINES/AIDS FOR DEFINING SIMULATED COMBAT MISSION OBJECTIVES

Current methods for defining objectives and characteristics of simulated combat missions are unsystematic. The complexities of the planning task might exceed man's unaided information management abilities. The objective of the fourth research effort would be to develop a set of procedural guidelines, which ultimately might lead to automation, for the definition of features and training objectives for simulated combat missions.

- Approach--The first step would be to understand how planning is currently done and the constraints placed on the definition of the objectives and characteristics of simulated combat missions. The intended users of the guidelines and aids would participate in their development to as great an extent as possible.

- Methods--Observation of current planning conferences would be essential. The structure of existing procedures would be captured as completely as possible. The guidelines and aids would be presented in a procedural format within a source/reference book for exercise planners. The guidelines would be assessed through demonstration and use in a representative planning conference.

- Required Resources/Facilities--Access to at least two planning conferences and at least one demonstration/evaluation would be required.

READINESS CRITERIA DEVELOPMENT

Current evaluative techniques for assessing team readiness are either too objective, with little information value, or too subjective to be of use in training effectiveness assessment. The objectives of the fifth research effort would be to identify the dimensions of team performance to which an expert evaluator attends, and to articulate the criteria the expert applies in judging team readiness. The payoff would be the development of methodological tools for assessing team readiness and training effectiveness.

- Approach--The approach would make use of the techniques of multi-attribute utility theory and apply them to teach evaluation decision making. Expert evaluators would serve as the source for extracting independent dimensions which they consider important and obtaining assessments of the value or utility of particular attributes on the dimensions.

- Method--Extensive observation of and interviews with expert evaluators would be required. Automation of the decision situation structure would be necessary. A representative and general solution could be achieved by using an element of the TACS as the object of the development.

- Required Resources/Facilities--Cooperation and participation of standardization/evaluation personnel would be required. The participation of an operational unit (for example, CRC) would be necessary. A mainframe computer and appropriate software would be required for decision model development.

CONDUCT A C^2 PERSONNEL ATTITUDE SURVEY

Retention of experienced individuals and morale in the C^2 career field are low. The objective of the sixth research effort is to obtain useful data for a review of personnel policies. The payoff would be recommendations for improving personnel policies.

- Approach--The survey would be conducted utilizing state-of-the-art employee attitude survey techniques. A concerted survey effort would provide a necessary data base for policy decisions, plus indicate to the C^2 community that the "employer" cares.
- Method--The survey instrument would have to be designed. The design could be based on existing instruments from industry sources. Data reduction would require automated data processing support. Recommendations would be based on collected data.
- Required Resources/Facilities--A mainframe computer and appropriate software would be required.

TRAINING FOR INTERCEPT PILOT SIMULATORS

Because personnel who simulate interceptor pilots receive no formal training, the training experience for AWCs is suboptimal. The objective of the seventh research effort would be to develop formal training materials for IPS personnel in order to improve the quality of current AFC^2T^2 programs.

- Approach--The tasks of the IPS would have to be specified and training requirements established. Training materials should be of the self-study variety.
- Methods--ISD methodology should provide the proper methods for this application.
- Required Resources/Facilities--Access to "good" IPS personnel would be required.

IMPROVED PROGRAM EVALUATION QUESTIONNAIRES

Current questionnaire approaches to initial and initial transition training program evaluation are of suspect validity. The objective of the eighth research effort would be to produce a questionnaire which would increase the quality and quantity of the evaluative data the schools currently receive from the field. This would in turn potentially improve the quality of school programs.

- Approach--A better articulated purpose and structure of the questionnaire technique would enable field personnel to address issues related to team-oriented skills. More quantitative data regarding student success should be sought.
- Method--A review of current questionnaires should be undertaken. Techniques of the growing area of program evaluation would be applied to the modification/enlargement of the questionnaire. The questionnaire would be utilized to determine if it provides new or usefully formatted evaluative information.

- Required Resources/Facilities--Cooperation and participation of institutional and operational personnel would be required in producing the questionnaire and conducting the survey.

DEVELOP OPERATIONAL UNIT INSTRUCTOR TRAINING PACKAGE

Instructors in operations training programs receive no formal training in how to train. The objective of the ninth research effort would be to develop a training package for instructors in operational units. The payoff would potentially be improved training effectiveness and, ultimately, improved team/system effectiveness.

- Approach--The ATC four-week instructor training course could be used for materials. A mobile training team could teach a condensed course, or a self-study package could be offered as a correspondence course.
- Method--Standard instructional material development techniques would be applied making as much use of existing materials as possible.
- Required Resources/Facilities--Participation of ATC training developers would be desirable.

TEAM TASK ANALYSIS METHODOLOGY

Current task analytic techniques provide for analysis of operators' individual tasks and fail to identify team-oriented skills. The objective of the tenth research effort would be to develop a task analytic methodology for producing detailed descriptions of tasks requiring interpersonal dependencies and interactions. The methodology would be oriented toward improving the team processes of AFC^2 teams.

- Approach--Available task analytic formats (for example, ISD or Data Item-H-6130) would be expanded. Guidelines would be developed permitting the identification of team-oriented tasks.
- Method--Determination of conditions and standards of performance would require subject matter expertise more related to efficient and effective C^2 team performance than to the specific system or mission tasks. The experts should be generalists of supervisory rank rather than technical specialists. The specific details of this effort would depend on successfully developing a team task taxonomy as is described next.
- Required Resources/Facilities--Participation of subject matter experts would be required.

TEAM BEHAVIOR TAXONOMY DEVELOPMENT

Current ISD guidelines and procedures do not address team-oriented tasks and skills. The objective of this effort would be to develop a behavioral taxonomy which forces attention to team-oriented tasks in the initial steps of the ISD procedure. The payoff for this effort would be a procedural framework ensuring the consideration of team performance in institutional system development.

- Approach--The approach would make use of existing behavior taxonomies to as great an extent as possible. A revised taxonomy would include team behavior categories like anticipate, coordinate, initiate/receive (information), etc.
- Method--Observation of actual C^2 teams carrying out simulated combat missions would be undertaken to develop and validate the taxonomy. To achieve representativeness and generality, the TACS CRC should provide the observation environment. Data descriptive of task frequency over mission segments would be collected.
- Facilities--Cooperation of an operational unit would be required. A hand-held data recorder and a mainframe computer for data reduction would be necessary.

CHAPTER III

RECOMMENDATIONS FOR AN AFC^2T^2 RESEARCH PROGRAM

Recommendations for long-term research projects were derived by a three-step process. Long-term research topics were formulated to address the issues and problem areas. These topics were then analyzed to generate research projects. Sixteen projects were recommended as candidates. Table 7 contains a listing of the issues and problems from Volume I and the long term research topics and candidate research projects from Volume II.

The third step was an evaluation of candidate research projects for implementation. These were rated on the criteria of technical feasibility, utility, usability, probability of success, and practical payoff and were ordered in priority on the basis of the ratings. The evaluation process and results are presented in Volume II, Chapter III.

Each of the candidate research projects is described briefly in the following pages. They are taken in the order of the listing in Table 7.

FIELD STUDY FOR PRECISE DEFINITION OF DEFICIENCIES IN C^2 TEAM PERFORMANCE AND TRAINING

The objective is to obtain more precise definition of the deficiencies found during this study by using more objective and more focused evaluation of each issue. Better estimation of the impact on effectiveness and cost-benefit

TABLE 7. RECOMMENDATIONS FOR LONG-TERM RESEARCH

Issue or Problem Area	Long-term Research Objectives	Recommended Research Projects
Definition and Development 1. Lack of a definitive framework for analyzing team skills and designing team structure and function. 2. Lack of objective criteria and standards for evaluating team-oriented skills, individual and team readiness, and system effectiveness. 3. Lack of analytic techniques and empirical data for determining institutional and operational T^2 requirements and objectives. 4. Lack of comprehensive, systematic procedures for defining training objectives for simulated combat missions. 5. Inadequate planning and analytic techniques for defining T^2 simulation/simulator fidelity and functional requirements. 6. Failure to define and develop formal training for C^2 system supervisors. **Implementation** 7. Deficient simulator capabilities including a lack of facilities for combined systems training. 8. Mismatch between entry-level requirements and Air Weapons Controller Fundamentals Course syllabus. 9. Lack of empirical data regarding the optimal instructional methods and sequencing for subteam, team, and superteam skill training. 10. Lack of training for personnel who simulate interceptor pilots. 11. Lack of AWACS-oriented block of instruction in Air Weapons Controller Fundamentals or Automatic Positionally Qualified (APQ) courses. 12. Lack of instruction for supervisors, battle staff, and decision makers. **Program Evaluation and Modification** 13. Lack of valid evaluation measures. 14. Incomplete use of existing evaluative data. **Personnel Policy and Resource Constraints** 15. Low retention rate of experienced C^3 system personnel 16. Shortage of live flying events/activities for T^3. 17. Inadequate instructor training and evaluation in operations training programs. 18. Difficulties posed in training and evaluating "soft" as opposed to "hard" teams. 19. Lack of T^3 guidance for C^3 training program managers.	Determination of deficiencies in performance and training for C^2T^2 Develop a conceptual model and framework for the descriptions and analysis of C^2 team functions and behaviors. (1*) Develop comprehensive performance objectives for C^2T^2 at the level of preteam, team, and superteam exercises. (2) Develop and evaluate a set of performance measures that will assess competence of C^2 teams and battle staffs and relate team competence to system effectiveness and individual proficiency. (2) Develop a set of standardized C^2 team exercises which are graded in difficulty and cover the range of C^2T^2 operational activities. (2) Develop analytical techniques for deriving T^2 requirements and compile supporting data. (3) Develop and evaluate systematic procedures for determining the skill and knowledge requirements for simulated combat missions for C^2 teams and partition them over the categories of indidual, preteam, team, and superteam exercises as most appropriate vehicle for training. (4) Develop data for simulation of operational situations for C^2 teams and battle staffs which identify the a) independently controllable features of the simulation; b) necessary and sufficient conditions of fidelity to reproduce the desired behaviors; c) cost-benefit relationships for inclusion of each fea[illegible] in a simulation. (5) Develop and evaluate techniques for defining the required components, functional capabilities, and level of fidelity for simulation of C^2 teams in a weapons system. (7) Develop and assess feasibility of a psychometric research plan to identify selection criteria for entry into a career field of air weapons controller. (8) Identify and evaluate in a controlled fashion existing instructional strategies. (9) Identify new topics and data for research when existing technology does not provide appropriate or adequate instructional strategies. (9) Develop techniques for interpreting measures of team performance to identify deficiencies in skill and knowledge and to select appropriate remedial action. (13) Develop techniques for analysis and interpretation of team performance measures in terms of the combat readiness of teams and systems. (13) Conduct research studies on the comparative cost-cost-effectiveness of live and simulated combat exercises--and mixes of these events. (16) Conduct research to evaluate the comparative strengths and weaknesses of hard and soft C^3 teams on performance of critical C^3T^3 tasks. (18) *Numbers in parentheses indicate the related issue or problem area.	Field study for further definition of deficiencies in C^2 team performance and training. (all) Construct a model for C^2 team performance in CRC, AWACS, or TACC type of organization. (1) Develop procedures for system and task analysis compatible with MIL-H-468xx and ISD, to be used in design of man machine components for C^2 teams. (3, 4) Develop a performance measurement system for C^2 teams which assesses team competence effect in system effectiveness and needs for remedial training. (2) Compare soft vs hard C^2 teams in performance of representative C^2 tasks. (17) Develop standardized, representative tasks for C^2 teams to be used in experimental studies. (1) Develop a problem space of calibrated exercises for C^2T^2 (9, 4) Develop decision aids for C^2 teams. (1) Assess applicability of existing taxonomies for learning types and instructional strategies to design of C^2T^2. (9) Assess usefulness of available techniques for sequencing instructional content for C^2T^2. (9) Compare C^2 job context vs neutral context for training team skills. (5) Compare cost-effectiveness of live and simulated events for C^2T^2 exercises. (15) Develop simulation and training requirements for ECM in C^2T^2. (7) Develop simulation and training requirements for sensor management in C^2T^2 exercises. (7) Develop Type A System Specification for a C^2T^2 simulation facility. (7) Determine feasibility of developing selection criteria for weapons directors. (8)

data could be obtained. The survey in the present study provided information, but the major accomplishment was to identify problems and needs. The information obtained was not sufficiently detailed to permit analysis of the problems in depth. A subsequent study could build on the survey, using the findings as hypotheses, and develop probes to provide deeper analysis.

Data collection would have to take place in operational units and schools during preteam, team, and superteam exercises. Performance objectives will have to be developed because existing objectives and standards are unlikely to be adequate in terms of coverage, comprehensiveness, metric properties, interpretability, and appropriateness for the research purposes.

The potential impact of these deficiencies on system effectiveness can be assessed, and cost estimates could be made for specific research studies and projects. They can then be evaluated on the basis of cost-benefit comparisons. The results of the study would feed into all other research activities.

CONSTRUCT A MODEL FOR C^2 TEAM PERFORMANCE IN CRC, AWACS, OR TACC TYPE OF ORGANIZATION

The objective is to take the first step in developing C^2 team performance models. The purpose of the model is to provide a conceptual framework and terminology for describing and analyzing the behaviors of C^2 teams. The approach consists of observation of team operations and analysis of the technical literature on teams and C^2 to develop and test a limited model based on a selected system.

Development of a framework for team phenomena is a fundamental need that underlies all research topics. The lack of a systematic, comprehensive framework for describing and analyzing teams and human factors requirements for team operation is a fundamental deficiency underlying all research issues on teams. This deficiency is manifested, for example, in a lack of adequate terminology and taxonomies for describing teams, behavioral phenomena in teams, types of activities done by teams, types of teams that occur in military systems, and differentiation between teams and multi-individual aggregates of people working independently. The model will provide a common reference for research, technology development, and design for C^2T^2.

The objectives of developing a C^2 team performance model would be to establish the nature of teams in four ways:

1. Structure of teams in terms of a set of dimensions or attributes on which teams can vary with a corresponding variation in team performance.
2. Processes by which teams accomplish their functions and work.
3. Internal and external variables that affect the processes and performance of teams.
4. Team behaviors and skills in terms of which activities of teams can be described.

A preliminary C^2 team model was presented consisting of four principal modules: team, tactical situation, command team behavior, and driver scenario. The team module was described in terms of architectural/structural dimensions and functional properties. The former concern team structure, mission tasks, and operating procedures. The latter concern the process by which the team performs. Operational tasks are related to the architectural/structural dimensions while team behaviors are related to the function's properties. Team behaviors are the factors that differentiate teams from non-teams, and they are a function of a shared plan or scheme.

The tactical situation module represents the tactical plan, its objectives, and the changing state of the battlefield as the plan is implemented. The command team behavioral module models the functions and tasks performed by members of the command team (battle staff). The driver scenario module generates the enemy and other events which change the state of the world.

Methodological developments in behavioral analysis and performance measurement would be made possible through and during model development. These, in turn, would be applied to the design and support of C^2 systems.

DEVELOP PROCEDURES FOR SYSTEM AND TASK ANALYSIS, COMPATIBLE WITH MIL-H-46855 and ISD, TO BE USED IN DESIGN OF MAN-MACHINE COMPONENTS FOR C^2 TEAMS

The objective is to develop tools for generating and analyzing behavioral data to design man-machine interfaces, personnel subsystems, and training during system development and maintenance of system readiness. These tools will be adaptations or extensions of existing methods to the less structured situation of command and control systems and team performance.

The approach consists of identifying the sequence of analytical issues and steps necessary to go from an operational need or system concept to completion of development of the man-machine components for C^2 teams, and developing or compiling data bases, algorithms, models, aids, and procedures for implementing the procedures.

Generation of only task-analytic data is not enough. The user must also be provided with techniques and algorithms for processing the task data to provide solutions to the problems of design of team structures, man-machine interfaces, personnel requirements, and training.

This type of approach is the best strategy for communicating the results of the research to the community of designers and developers of systems. Providing techniques, data, and concepts is not sufficient to have an effect on system development except in the very long term. System development is organized principally by formal and informal procedures which have become accepted practices. Changes in system design must be achieved by incorporating new methods, concepts, or data into these practices or replacing part or all of an existing procedure.

MIL-H-46885, related Data Item Descriptions (DIDs), and human engineering specifications (1472B, for example) have acceptance as guidelines for human factors area of design. They have two significant shortcomings for C^2T^2: 1) They do not make explicit provision for the design of teams, and 2) They are oriented toward the knobs and dials approach without adequate consideration of cognitive performance in emergent situations which characterize C^2T^2. Design for C^2T^2 will be inadequate until requirements, methods, and data are incorporated into the standard practices for design, development, and evaluation of systems.

Transferring technology to the community of system developers has been a slow and difficult practice. There appear to be no effective channels for getting information into it from outside sources. There is a straight-forward flow from the developmental to the operational communities. However, feedback from the operational community or information from the technical laboratories and other external agencies flows very poorly.

A possible contributing factor is that engineering development programs usually operate on such "tight" schedules and budgets that changes and innovation in the process are discouraged. Conventional practices are used as tried and proven methods with low risk. Any change decreases the probability of not meeting schedule and cost. The history of system development shows that delays and overruns overturn the program schedule, but the practices persist.

Another possible factor is the turnover in program management personnel. There are several sets of managers, planners, and designers during the period from concept development through engineering development. If there is feedback from the field, it will go to people other than those who made the faulty decisions. It exists as a new problem instead of feedback to the latest set of program managers.

One approach to this problem of influencing the designer process in the area of manpower and training is under development. It is referred to as "front-end analysis." It is a form of human factors/systems analysis of user requirements. It has two objectives: 1) consideration of human factors requirements starting with the concept development stage at the beginning of system development, and 2) iteration and refinement of these requirements at the other stages. Requirements and methods are under development by the Department of Defense (Reference 11), Air Force (Reference 12), Army (Reference 13), and Navy (Reference 14).

DEVELOP A PERFORMANCE MEASUREMENT SYSTEM FOR C^2 TEAMS WHICH ADDRESSES TEAM COMPETENCE, EFFECT ON SYSTEM EFFECTIVENESS, AND NEEDS FOR REMEDIAL TRAINING

The objective is to provide more objective and systematic measures of performance of C^2 teams. These measures are intended to provide an index of team competence, interpretable in terms of impact on system effectiveness, and diagnostic of team and individual training needs.

The availability of these measures will provide appropriate system managers and planners with objective data on unit and individual capability which can in turn be used in planning for operations, training, and support. Programs for the maintenance and improvement in proficiency can be based on more accurate, detailed data than is available today.

COMPARE "SOFT" VS "HARD" C^2 TEAMS IN PERFORMANCE OF REPRESENTATIVE C^2 TASKS

Soft teams do not have a stable membership; team members change between exercises. The objective of this project is to assess the impact of the instability on team performance. The rotation of team members would retard the learning of team skills because some relevant cues and responses would change between training sessions as the team members change. Therefore, it is postulated that stable teams are needed during the early stages of T^2. However, rotation of team membership should yield more stable adaptability team skills for the more experienced person. The skills become independent of the situation-specific cues associated with characteristics of other team members.

Verification of the hypothesis will provide information for management and deployment of team resources that will increase operational effectiveness of C^2 teams and provide a strategy for T^2 that will provide higher levels of competence.

DEVELOP STANDARDIZED, REPRESENTATIVE TASKS FOR C^2 TEAMS TO BE USED IN EXPERIMENTAL STUDIES

The objective is to develop standardized tasks for representative C^2 team functions to be used in experimental studies of team processes. These tasks would be used subsequently in research studies. The software for them would become a library of task modules which can be called up when compiling scenarios and experimental designs for specific research studies. They will also feed information on C^2 tasks into other projects of T^2 research and application.

DEVELOP A PROBLEM SPACE OF CALIBRATED EXERCISES FOR C^2T^2

This project has two objectives: 1) provide link between training content and job tasks by means of a sequence of training objectives that progressively approach job tasks, and 2) provide sequences of training exercises increasing in complexity and difficulty and progressing through higher levels of skill and knowledge.

The assumptions underlying current training technology are that the learning of complex behaviors starts with learning elements of knowledge and skill which are then integrated into more and more complex behaviors. Learning these complex behaviors proceeds by taking the individual through a sequence of simulated performance tasks which progressively approximate job tasks more closely.

Development of the problem space would impose a structure on the problems in terms of the knowledge and skill requirements and establish a sequential relationship among them. It would increase the effectiveness and efficiency of training. Higher levels of proficiency could be obtained at less cost. The resuits would also contribute to the development of objective, diagnostic performance measures.

DEVELOP DECISION AIDS FOR C^2 TEAMS

The objective is to provide improved, interactive decision support systems in man-machine interfaces to facilitate team performance. This project is aimed at effective utilization of the increasing levels of automation in system design. Command and control systems typically are inundating C^2

personnel with quantities of data which they often cannot correlate and reduce into useful tactical information. One observer commented that C^2 systems give data that the users do not use and fail to help them determine what they do need (Reference 8).

Increasing levels of automation are attenuating the usefulness of the dichotomy between man and machine. The complex, difficult performance problems in systems have become tasks of either computer-aided man or man-aided computer. Thus, the design of man-computer transactions and provision of adequate decision aiding are important issues. The TACC in particular is a system that will undergo considerable development in the automation and semi-automation of information processing to assist the operators.

The development of aids will increase the operational effectiveness of C^2 systems and might also reduce the amount of T^2 and numbers of people required.

ASSESS APPLICABILITY OF EXISTING TAXONOMIES FOR LEARNING TYPES AND INSTRUCTIONAL STRATEGIES TO DESIGN OF C^2T^2

The objective is to more fully assess the applicability of current training technologies to C^2T^2. Existing knowledge on the effectiveness of instructional methods for training specific types of knowledge and skill have been developed for individual training. These same methods are undoubtedly applicable to C^2T^2, but the form and extent of their applicability is unknown since the knowledge, skills, and performance objectives for C^2T^2 have not been determined.

This project would result in establishing the relationship between instructional methods and T^2 requirements and make existing technology more available for T^2. More effective and efficient training would then be possible.

ASSESS USEFULNESS OF AVAILABLE TECHNIQUES FOR SEQUENCING INSTRUCTIONAL CONTENT FOR C^2T^2

The overall objective of these projects is to develop an instructional methodology for C^2T^2. Existing methods were developed in the context of individual training and may be applicable to C^2T^2 if the job tasks in C^2 teams can be analyzed to the necessary level. Assessment of the applicability of these methods to T^2 would make this technology available for T^2 as well as individual training. More effective and efficient T^2 could then be provided.

COMPARE C^2 JOB CONTEXT VS NEUTRAL CONTEXT FOR TRAINING TEAM SKILLS

The objective is to compare two approaches to training team skills. One approach consists of training them in the context of the job tasks where they occur; the other approach consists of training them in a context free of job context such as multi-person research games, so that the team skills can be more clearly high-lighted. The approaches may differ in ease of learning and amount of transfer of training. Context-neutral approaches would not require simulation of operational situations. They might then be less costly, applicable to a larger population, and more flexible to use.

If there is a differential in either cost or effectiveness, improved training can be delivered at lesser cost.

COMPARE COST-EFFECTIVENESS OF LIVE AND SIMULATED EVENTS FOR C^2T^2 EXERCISES

The objective is to develop tradeoff data for cost-effectiveness evaluation of simulated events in C^2T^2 exercises. The evaluation can be used to develop a strategy for using simulation to reduce costs and increase the training effectiveness of exercises.

Reduction in live flying would reduce energy costs and conserve operational equipment. Therefore, it is important to determine the comparative training value of live vs simulated events for the purpose of identifying mixes of them that maximize training benefit and reduce costs.

DEVELOP SIMULATION AND TRAINING REQUIREMENTS FOR ECM IN C^2T^2

The objective is to determine the training necessary for job performance in an ECM environment. This area is a critical one for operational effectiveness, but one where performance and training are inadequate. Solving this problem area of T^2 will produce significant improvements in operational effectiveness.

DEVELOP SIMULATION AND TRAINING REQUIREMENTS FOR SENSOR MANAGEMENT IN C^2T^2 EXERCISES

Adding this capability to training exercises will improve the realism, fidelity, and effectiveness of C^2T^2. The area is a significant deficiency in current operational training. It is also a critical area for operational effectiveness since it affects the quality and utility of the information obtained through a sensor system.

DEVELOP TYPE A SYSTEM SPECIFICATION FOR A C^2T^2 SIMULATION FACILITY

The purpose of this project is to develop the functional requirements and system concept for a simulation facility for training and research in C^2T^2. The requirements are derived from an analysis of the intended application and the capabilities needed to operate and support the facility.

This specification becomes the design goal for which more detailed engineering specifications are prepared from which procurement decisions are made.

The responsiveness of the simulation facility to the purposes for which it was procured or built is a direct function of the comprehensiveness and thoroughness of the specification.

DETERMINE FEASIBILITY OF DEVELOPING SELECTION CRITERIA FOR WEAPONS DIRECTORS

There are no selection criteria for weapons directors at the present time beyond those for officer selection. The lack of appropriate aptitudes may be a source of inadequate performance in weapons directors. The objective of this effort is to evaluate the feasibility of identifying and setting entry standards for the career field and thereby improving operational performance. Existing standards of performance and assessment techniques will probably not be adequate for this research, and a suitable one will have to be developed.

If some selection or establishment of minimal entry requirements on basic skills can be set, then a higher level of proficiency can be obtained, and training time and costs can be reduced.

RECOMMENDED RESEARCH TOPICS

The candidate research topics were evaluated against five criteria by two human factors specialists. The criteria were feasibility of accomplishment, utility, usability, probability of success, and practical payoff. The projects were ranked on the basis of the ratings, and the top third are recommended for implementation.

Projects recommended are:

- Develop standardized, representative tasks for C^2 teams to be used in experimental studies.
- Develop Type A System Specification for a C^2T^2 simulation facility.
- Determine feasibility of developing selection criteria for weapons directors.
- Field study for precise definition of deficiencies in C^2 team performance and training.
- Assess applicability of existing taxonomies for learning types and instructional strategies to design of C^2T^2.
- Assess usefulness of available techniques for sequencing instructional content for C^2T^2.

Two additional projects were recommended. They are projects with some technical risk but their pervasiveness in all research areas warrants their pursuit. They are:

- Construct a model for C^2 team performance in CRC, AWACS, or TACC type of organization and develop procedures for system and task analysis.
- Develop a performance measurement system for C^2 teams which assesses team competence effect in system effectiveness and needs for remedial training.

CHAPTER IV

RECOMMENDATIONS FOR AN AFC^2T^2 RESEARCH FACILITY

There is a need for a research facility to be used by the Air Force to support empirical AFC^2T^2 research. Recommendations for a simulation facility to meet this need are presented in Volume IV. The facility should support team research for teams comparable in size and configuration to the principal members of an AWACS, CRC, CRP, or TACC team; and it should be capable of exercising weapons, surveillance, battle staff, and AFC^2 support subteam functions. In addition to consoles and software support for AFC^2 team members, the research facility should also support computer operators, researchers observing team behavior and performing empire functions, role players and script readers, software developers, and maintenance personnel. Finally, the system should include software capable of generating simulated tactical events, providing imagery and tactical information to exercise controllers and AFC^2 team members, and collecting and analyzing team performance data. Figure 7 illustrates the major hardware, software, and personnel components of the recommended AFC^2T^2 research facility.

The functions that are available to an AFC^2 team member should correspond in general to the functions that can be performed in current or anticipated AFC^2 systems. Physical and procedural fidelity should not be required, but functional fidelity would be important. The system should be capable of simulating most current or anticipated operator functions although the displays, controls, and procedures for carrying out a function need not be

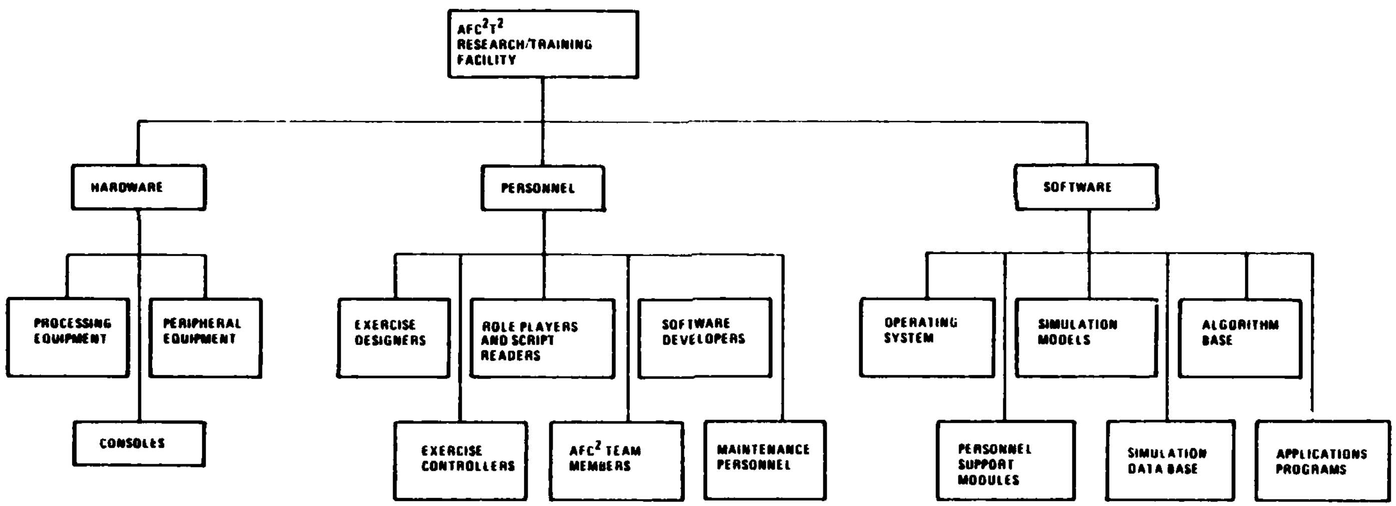

Figure 7. Major Hardware, Software, and Personnel Components of Recommended AFC^2T^2 Research Facility

the same in the simulator as in any actual system. Operator consoles should consist of a display, alphanumeric keyboard, function keyboard, track ball, and voice communication gear. In addition, large-screen displays that can be viewed by more than one operator should also be available.

Consoles for exercise controllers, role players, script readers, and software developers should be identical to consoles for AFC^2 team members, and it should be possible to change the ratio of such consoles to AFC^2 team consoles in order to meet a variety of research requirements.

Exercise controllers would initialize the system prior to a research session, control and monitor simulation events, observe AFC^2 team performance during the session, and analyze performance data following the session. Role players would play the part of superteam members outside the boundaries of the AFC^2 team being evaluated. Script readers would perform functions similar to but more constrained than role players. Their task would be to provide voice stimuli marking predetermined simulation events, and they would do so by reading a prepared script. Software developers would prepare the simulator for use, write applications programs as required, and maintain existing software.

The software driving the system would include interface control modules, simulation models, a simulation data base, applications programs, and an operating system. The hardware comprising the system should include a central processing unit (or several units if a distributed processing architecture is followed), mass storage devices, a map digitizer and map bug, a high-speed printer, a device for the output of hard copies of graphic information, and all required interface equipment.

The recommended facility could be used to support a broad range of research in the following areas:

- Performance measurement of C^2 operators, teams, and systems
- C^2T^2 program objectives and requirements
- C^2T^2 simulation exercise requirements
- Man-machine design for C^2 systems and teams
- Automated C^2T^2 training support functions
- Personnel requirements for C^2 teams

These issues are discussed in more detail in Volumes II and III, and are summarized in Volume IV.

RESEARCH APPLICATIONS FOR THE SIMULATION FACILITY

Most of the recommended hardware and software features of the simulation facility are within the current state of the art in simulation technology. Other features will require modest technological advances. We recommend an incremental development strategy in which low-risk components that are required for a wide range of research problems would be acquired first in order to permit an early payoff in the form of data on key AFC^2T^2 issues. Higher-risk components needed for more complex and specialized research issues would be developed later in the acquisition process.

POTENTIAL IMPACT OF ADVANCED SIMULATION TECHNOLOGY ON AFC^2T^2 PROGRAMS

One of the major functions of the recommended research facility will be to explore techniques for exploiting the potential of advanced simulation technology to improve AFC^2T^2 programs and, ultimately, the effectiveness of operational AFC^2 systems. Advances in the state of the art in simulation technology may increase the cost effectiveness of training programs for AFC^2 teams by:

- Presenting a wider range of training problems
- Achieving greater tactical realism
- Increasing the amount and quality of student practice time
- Improving the efficiency of live exercises
- Making improved use of instructor time and talents
- Permitting the establishment of higher training standards

Wider Range of Training Problems

AFC^2 teams must deal quickly and effectively with a variety of complex tactical problems. Current C^2 simulators do not have the flexibility that is required to generate a broad range of combat conditions. Advances in modeling, modular software architecture, and the design of user-oriented interactive systems make it feasible to design models and data bases that can be accessed and modified by simulation users who are knowledgeable about tactical requirements and training technology but who are not necessarily software or hardware experts. If this is done, the set of C^2

training problems constituting a training program can be expanded or modified to meet changing operational requirements. This capability would enable instructional programs to expose C^2 teams to a wider variety of conditions than is currently possible. The payoff for this flexibility would be C^2 teams which are prepared to react and adapt to unanticipated contingencies in the operational environment.

Greater Tactical Realism

The AFC^2 simulators surveyed do not represent mid- or high-intensity tactical engagements based on realistic numbers, densities, distribution, capabilities, and tactics of own and threat forces. Improved tactical models are required to provide such realism. Moreover, the models and data bases should be conveniently modifiable to allow for the simulation of various levels of intensity, force ratios, and weapons mixes. To the extent that simulation exercises represent realistic combat contingencies, C^2 teams will more likely be able to perform effectively in actual operational settings.

Increased Amount and Quality of Student Practice Time

Students at all sites indicated that more simulation experience is needed than currently provided. Adaptive, individualized, computer-based instruction oriented towards task skills rather than knowledge would provide that experience in an effective manner.

Improved Efficiency of Live Exercises

The cost of live flying is enormous. Live flying exercises are necessary components of AFC^{2}T^2 because they induce stress and they exercise skills that cannot feasibly be practiced under simulated conditions. More effective simulation training can better prepare individuals and teams to take advantage of the limited live flying exercises that are available.

Improved Use of Instructor Time and Talents

A number of instructional support functions should be designed into the AFC^{2}T^2 simulation facility:

- Automated assessment and monitoring of operator and team performance
- Presentation of performance data to instructors
- Automated branching among lesson segments on the basis of student or team performance
- Automated delivery of feedback and prompting to students and teams
- Capability for simulating events in real time and at rates other than real time
- Capability for replaying simulated events
- Part task training capabilities--the ability to exercise a subset of the operator's or team's duties

- Capability for presenting successive approximations to the quality and appearance of imagery on a display scope
- Flexibility, ease of maintenance, and convenient modifiability so that instructors who are not computer professionals can make necessary changes in the data base and models driving exercise scenarios

These features would tend to increase training efficiency by reducing the amount of instructor time required for each hour of student time. The ability of the training device to monitor student performance and maintain performance records would permit instructors to focus their attention on instructional planning and on specialized interaction with students. These benefits would permit a greater training pipeline flow without a corresponding increase in the number of instructors and would tend to improve the quality of instructor-student contact.

Higher Training Standards

Advanced simulation technology may play a direct role in increasing the proportion of students who meet or exceed course criteria. The ability to practice on a wider range of tactically realistic exercise problems than is currently possible can improve the performance capabilities of students and teams. The increased motivation and confidence derived from these exercises in conjunction with advanced computer-based instructional techniques can enhance the benefits of live exercises. Instructional support features of advanced simulators can potentially improve the level and quality of instructor interaction with C^2 students and teams. All of these factors working together can potentially allow training standards to be raised from present levels to meet the actual requirements of the operational environment. If this potential is realized, advanced training simulation technology will have made a substantial contribution to the readiness of AFC^2 teams and systems.

SUMMARY

This report is an overview and summary of a study to survey and characterize team training (T^2) for operators other than air crew in Air Force command and control (C^2) systems and to make recommendations for programs to improve AFC^2T^2 by addressing weaknesses found during the survey. The recommendations were of three kinds: projects within the current state of technology, projects requiring longer term research and development, and capabilities of a simulation facility to support research in AFC^2T^2. These topics are reported in four other volumes.

This report contains a summary of the study approach and the results of the survey in terms of strengths and weaknesses of AFC^2T^2. The survey was limited to selected C^2 systems in Tactical Air Command chosen to represent the domain of semi-structured tasks in emergent situations. The weaknesses were condensed into issues and problem areas which were in turn the objectives addressed by the short-term and long-term recommendations. The issues and problems were organized into four categories: 1) Definition and Development; 2) Implementation; 3) Program Evaluation and Modification for training programs; and 4) Personnel Policy and Resource Constraints.

The lack of a definitive framework for teams is a pervasive problem underlying all issues, and it is addressed in the recommendations of both current technology and research. Lack of adequate performance measures, simulation capabilities for large-scale teams, joint simulated exercises, human factors methods, and lack of formal training for battle staff and supervisors were other major weaknesses.

Eleven current technology projects were proposed, as follows:

- C^2 team supervisor training
- Supplemental initial training
- Compilation procedure for after-action reports
- Simulated combat mission guidelines/aids for establishing objectives
- Readiness criteria
- C^2 personnel attitude survey
- Training for interceptor pilot simulators
- Program evaluation questionnaires
- Operational unit instructor training
- Task analysis method
- Team skill taxonomy

The approach to C^2 team supervisor training is described in detail.

Sixteen candidate research projects were evaluated and the following eight were recommended for implementation:

- Develop standardized, representative tasks for C^2 teams to be used in experimental studies.
- Develop Type A system Specification for a C^2T^2 simulation facility.
- Determine feasibility of developing selection criteria for weapons directors.
- Field study for precise definition of deficiencies in C^2 team performance and training.
- Assess applicability of existing taxonomies for learning types and instructional strategies to design of C^2T^2.
- Assess usefulness of available techniques for sequencing instructional content for C^2T^2.
- Construct a model for C^2 team performance in CRC, AWACS, or TACC type of organization and develop procedures for system and task analysis.
- Develop a performance measurement system for C^2 teams which assesses team competence effect in system effectiveness and needs for remedial training.

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