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Final Report

MARINE TACTICAL COMMAND AND CONTROL SYSTEM (MTACCS) FIELD DEVELOPMENT SYSTEM-1 (FDS-1) ASSESSMENT - VOLUME 1

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Executive Summary

Introduction

The United States Marine Corps (USMC) is continuing the development and fielding of the Marine Corps Tactical Command and Control System (MTACCS), a system which exists in varying states of development, fielding, or modernization. MTACCS is currently composed of the following components:

- Tactical Combat Operations System (TCO) for ground command and control (C2),
- Intelligence Analysis System (IAS) with a Genser terminal connected to a TCO workstation for intelligence C2,
- Marine Integrated Personnel System (MIPS) and a TCO workstation using the Marine Combat Personnel System (MCPERS) software for personnel C2,
- Marine Integrated Logistics System (MILOGS) which is composed of the Landing Force Asset Distribution System (LFADS), the Marine Air-Ground Task Force (MAGTF) II, and a TCO terminal using the Marine Combat Logistics System (MCLOG) for logistics C2,
- Marine Corps Fire Support System (MCFSS) for fire support C2, and
- Advanced Tactical Air Command Central (ATACC) and the Improved Direct Air Support Central for aviation C2.

An evolutionary acquisition (EA) approach has been adopted by the Marine Corps System Command (MARCORSYSCOM) for the development of MTACCS. The EA strategy for development, including the Field Development System (FDS) concept, employs the concept of "build a little, test a little, field a little." Utilizing the FDS, MTACCS will be developed through a series of builds, with each build being more mature than the previous. Each build will culminate in an assessment by Fleet Marine Force (FMF) personnel. Each assessment will also include demonstrations of advanced technologies and emerging prototype systems. The first assessment of MTACCS, FDS-1, consisted of an exercise where the FMF utilized MTACCS component systems during a Marine Expeditionary Brigade (MEB) Command Post Exercise (CPX). This assessment occurred at the Marine Corps Air-Ground Combat Center (MCAGCC), Twentynine Palms, California, between 16th and 24th of November 1991. This two volume report provides a summary of the results of FDS-1. It is a compilation of the results of the PNL data collection effort, and the after action reports submitted by the 7th MEB, MCTSSA, and the various MARCORSYSCOM Program Offices.

Objectives

The goal of the FDS-1 assessment was to initiate a partnership between the FMF, Marine Corps Combat Development Command (MCCDC), and MARCORSYSCOM in the development and fielding of an integrated command, control, communications, computers, and intelligence (C4I) system, MTACCS. The overarching objectives supporting this goal were threefold:

- To provide the FMF with an opportunity to assess the acceptability of MTACCS and its component systems during the development and post fielding,
- To provide feedback to MCCDC and MARCORSYSCOM regarding new and changed operational, functional, and technical requirements for C4I systems, and
- To facilitate the integration of MTACCS component systems through incrementally building and testing of MTACCS.

This partnership will allow the FMF to influence the design of tactical USMC systems currently under development as MTACCS through an iterative process of measuring developmental system capability against existing capability, and providing feedback to direct system development and refine tactical requirements.

Specifically, the objectives of the MTACCS FDS-1 assessment were to identify, through FMF and other subject matter expert (SME) feedback, those aspects of system concept and design that: provided improved capability to commanders and their staff, provided little or no benefit to the commanders and their staff, demonstrated potential which should be further developed, refined, or enhanced for future deployments of MTACCS, and were not currently present but which should be incorporated to improve C2.

These objectives were to be met, in part, by focusing on the TCO as a stimulus for comments on command and control capabilities, augmented through information gained from after action reports prepared by other Marine Corps organizations, such as the 7th MEB, Marine Corps Tactical System Support Activity (MCTSSA), and MARCORSYSCOM Program Offices.

In addition, the assessment provided input into the definition of the MTACCS FDS-2 evolution, and helped establish a methodology template for future MTACCS FDS assessments.

Methods Used

The MTACCS FDS-1 assessment was conducted in three stages: training performed primarily at Camp Pendleton, California, from 15 October 1991 through 7 November 1991; the pilot test performed at the MCAGCC from 16 through 19 November 1991; and the field assessment at MCAGCC from 20 through 24 November. Three phases were planned for FDS-1:

phase I - hardware connectivity only; phase II - hardware and limited radio; and phase III - radio and displacement of the Ground Control Element (GCE).

The field assessment was developed around a hypothetical, unclassified MEB operational scenario. Designated representative force list organizations and agencies within and assigned to the 7th MEB were identified as "players" and equipped with the available configurations of the MTACCS hardware and software. Player organizations established their command posts in accordance with their normal standing operating procedures (SOPs), and during the execution of the field assessment, responded to scenario events as though they were engaged in actual tactical operations. Organizations participating as players during FDS-1 included the command elements of the MEB, a Marine Aircraft Group (MAG), a Regimental Combat Team (RCT), a Brigade Service Support Group (BSSG), two infantry battalions, and an artillery battalion.

A Tactical Exercise Control Group (TECG) was established to manage the tactical exercise and simulate subordinate elements, organizations external to the MEB, and the opposing forces (OPFOR). Control cells were used to provide the stimulus to the assessment players. Control cells were staffed with knowledgeable personnel who provided reports and responded to requests for information in consonance with a realistic tactical situation. To perform their respective simulated function(s), control cells were equipped with various types of devices, such as Digital Communications Terminals (DCTs) and TCO terminals, to accommodate digital data input into the systems under assessment. Control of the tactical aspects of the exercise was maintained through maneuver of the OPFOR units. The Tactical Warfare Simulation, Evaluation and Analysis System (TWSEAS) was used to maintain realism in the battlefield simulation and to provide tactical engagement results to the control cell members.

Data were collected by numerous groups during the field assessment. These groups included representatives from MCTSSA, each component system Program Office, and the Pacific Northwest Laboratory (PNL). Data collection was performed by trained data collection teams through observations and the administration of interviews and questionnaires.

Conduct of the Assessment

As would be expected of an untried approach to EA assessment, the MTACCS FDS-1 assessment experienced a number of difficulties in its conduct. These difficulties included a system that was not as robust as hoped, a very challenging assessment environment (e.g., sandy, windy, primitive, etc.), technical difficulties in establishing and maintaining communications, configuration management problems, and a significant learning curve experienced by all participants. Due to the persistent communications difficulties over single channel radio, the field assessment did not transition beyond phase I.

Despite these difficulties, FDS-1 can be considered a success and a validation of the FDS process. The assessment provided a number of opportunities to both the MTACCS development community and the FMF participants. The development community observed the operation of their systems in the end-user environment and gained valuable insights into FMF needs. The FMF gained experience and exposure to the emerging world of MTACCS automated C2, and provided critical direct input into the future design of MTACCS.

Major Lessons Learned

Major lessons learned from FDS-1 are summarized below by programmatic, operational, technical, and FDS process perspectives.

From a programmatic perspective, FDS-1 represented the first opportunity for MARCORSYSCOM to field an integrated suite of systems as a snapshot of MTACCS developmental progress. This fielding resulted in identifying of a number of strengths and weaknesses of MTACCS, and provided a unique opportunity for the FMF to provide input into the design process. The use of FDS assessments should be continued. It was also obvious that development and communication of expectations (i.e., management of expectations) is critical to the success of future FDS assessments. FMF participants reported that they expected much more out of FDS-1 than was demonstrated. The goals and milestones for each FDS must be realistic, with all progress and changes communicated to all participants on a regular basis.

From an operational perspective, a number of major lessons were learned. These included the following:

- The development community needs to ensure that the tasks being automated are appropriate for automation, and that the allocation of automated functions needs to be stratified by echelon.

- Current and future fielding of MTACCS systems could be seriously constrained by mobility considerations and limitations in tactical power and communications system capability. MTACCS development should be an integrated effort that includes considerations for mobility, power, and communications.

- MTACCS development needs to be more responsive to the diverse types of missions performed by the FMF, especially with the changes occurring in the nature of the threat. Current and future systems need be better designed to support missions such as amphibious and noncombatant evacuation operations.

From a technical perspective, it was apparent that during FDS-1, MTACCS provided a number of automated capabilities desired by the FMF. These included the following:

- Electronic tactical graphics, which assisted the FMF user in having a common picture of the battlefield through the graphical overlays and automated position location information. This capability was rudimentary in some systems and well developed in others. All systems needed to improve this capability, especially by implementing electronic terrain maps.

- Automated journal capability, which helped the user to maintain a record of message traffic. Through FMF participants' comments, it was evident that this capability needed to be more fully integrated with their combat operations center (COC) routines.

- Digital message capability, which provided message templates and improved the overall information exchange process. This capability, like that of the automated journal, needs to incorporate the suggestions of the FMF participants to move closer to meeting the users' needs.

From a FDS assessment perspective, the process was shown to be basically sound, but it should be fine tuned in a number of ways. First, representatives of both the user and the component systems need to become involved in the planning process much earlier. FDS-1 was severely hampered in its early planning by the lack of FMF participants because of DESERT SHIELD/DESERT STORM. Second, it was obvious that future FDS evolutions must include more systematic laboratory and integration testing prior to transitioning to the field assessment.

Recommendations

Based on the results of FDS-1, the following recommendations are provided.

- First, the FDS process of development should be continued. FDS-1 succeeded in achieving its major objectives, and this success should be built on.

- Second, future FDS evolutions need to be more closely coordinated, with representatives of all participating agencies involved early on in the planning process. This is especially true of representatives of the user. Implicit in this is the need for a strong central organization for providing the necessary coordination.

- Third, the goals for each evolution need to be realistic. The degree of functionality and the milestones to be achieved by the developmental systems for each FDS evolution should be based on available resources and time.

- Fourth, the FMF feedback resulting from FDS-1 should be closely reviewed by the requirements and development communities and incorporated, as appropriate, in future MTACCS design.

- Finally, the requirements for automation differ by echelon and staff section. The requirements and development communities need to determine how best to implement automation throughout the MAGTF.

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Figures

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Glossary

AAVs - Amphibious Assault Vehicles
ACA - Airspace Coordination Area
AFATDS - Advanced Field Artillery Tactical Data System
AMMO - Ammunition
ARTY - Artillery
ASDS - Air Situation Display System
ATACC - Advanced Tactical Air Command Central
ATO - Air Tasking Order

BDA - Battle Damage Assessment
BN - Battalion
BSSG - Brigade Service Support Group

C2 - Command and Control
C4I - Command, Control, Communications, Computers, and Intelligence
CAEMS - Computer Aided Embarkation Management System
CAP - Combat Air Patrol
CAS - Close Air Support
CASPROJ - Casualty Projection
CASREP - Casualty Report
CE- Command Element
CFL - Coordinated Fire Line
CI - Counter Intelligence
CIFS - Close-in Fire Support
COA - Course of Action
COC - Combat Operations Center
COIC - Combat Operations and Intelligence Center
COMMEX - Communications Exercise
CONOPS - Continuity of Operations
COTS - Commercial-off-the-shelf
CPX - Command Post Exercise
CRT - Cathode Ray Tube
CSS - Combat Service Support
CSSCS - Combat Service Support Control System

DASC - Direct Air Support Central
DCT - Digital Communications Terminal
DISREP - Displacement Report
DLSPC - Data Link Set, Personal Computer
DPM - Deputy Program Manager

DRASH - Deployable Rapid Assembly Shelter
DSMC - Defense Systems Management College
DTG - Date Time Group
DUMPSTATREP - Dump Status Report

EA - Evolutionary Acquisition
EAF - Equipment Allowance File
ELINT - Electronics Intelligence
ENMINEREP - Enemy Minefield Report
EPW - Enemy Prisoner of War
EW - Electronic Warfare

FDS - Field Development System
FEBA - Forward Edge of the Battle Area
FIRECAP - Fire Capabilities Report
FIREPLANREP - Fire Plan Report
FLOT - Forward Line of Own Troops
FragO - Fragmentary Order
FRNDMINEREP - Friendly Minefield Report
FROG - Free Rocket Over Ground
FSCC - Fire Support Coordination Center
FSCL - Fire Support Coordination Line

GCE - Ground Command Element
GPS - Global Positioning System
GUI - Graphical User Interface

HMMWV - High Mobility Multipurpose Wheeled Vehicle

IAS - Intelligence Analysis System
IDASC - Improved Direct Air Support Central
ILS - Integrated Logistics Support
INF - Infantry
INTEL - Intelligence
INTSUM - Intelligence Summary Report
ITUSPOT - Interrogator/Translator Unit Spot Report

JTAR - Joint Tactical Air Request

KIA - Killed in Action

LAN - Local Area Network
LAT/LONG - Latitude/Longitude
LAV - Light Armored Vehicle

LCD - Liquid Crystal Display
LCU - Lightweight Computer Unit
LFADS - Landing Force Asset Distribution System
LOC - Logistics Operations Center
LOGSTAT - Logistics Status Report
LOGSUM - Logistics Summary Report
LSD - Large Screen Display

MACCS - Marine Air Command and Control System
MAFC - Marine All-Source Fusion Center
MAG - Marine Aircraft Group
MAGTF - Marine Air-Ground Task Force
MARCORSYSCOM - Marine Corps Systems Command
MCCDC - Marine Corps Combat Development Command
MCFSS - Marine Corps Fire Support System
MCHS - Marine Common Hardware Suite
MCLOG - Marine Combat Logistics System
MCPERS - Marine Combat Personnel System
MCTSSA - Marine Corps Tactical Systems Support Activity
MDSS - MAGTF Deployment Support System
MEB - Marine Expeditionary Force
MEF - Marine Expeditionary Force
MIJIREP - Meaconing, Interference, Jamming, and Intrusion Report
MILOGS - Marine Integrated Logistics System
MIMMS - Marine Integrated Maintenance Management System
MIPS - Marine Integrated Personnel System
MMI - Marine-Machine Interface
MPF - Maritime Prepositioned Force
MRL - Multiple Rocket Launcher
MSD - Medium Screen Display
MTACCS - Marine Tactical Command and Control System
MTS - Marine Tactical Systems

NBC - Nuclear, Biological, and Chemical
NEO - Noncombatant Evacuation Operation
NFA - No Fire Area
NGF - Naval Gun Fire

OPFOR - Opposing Force(s)

PERINTSUM - Periodic Intelligence Summary Report
PERSTATREP - Personnel Status Report
PERSTRENREP - Personnel Strength Report
PLI - Position Location Information

PLRS - Position Location Reporting System
PNL - Pacific Northwest Laboratory
PhotoRecon - Photographic Reconnaissance
POSREP - Position Report

RCT - Regimental Combat Team
RECON - Reconnaissance

SAAWC - Sector Anti-Air Warfare Coordinator
SALUTEREP - SALUTE Report
SAR - Search and Rescue
SASS - Supporting Arms Special Staff
SCR - Single Channel Radio
SE&I - Systems Engineering and Integration
SENREP - Sensor Report
SHELLREP - Shelling Report
SIGINT - Signal Intelligence
SITREP - Situation Report
SME - Subject Matter Expert
SOPs - Standing Operating Procedures
SPOTREP - Spot Report
SYSCON - Systems Control

T/E - Tables of Equipment
TACC - Tactical Air Command Center
TADIL - Tactical Digital Information Link
TAMCN - Table of Authorized Material Control Number
TAMMIS - Theater Army Medical Management Information System
TARGETREP - Target Report
TCO - Tactical Combat Operations
TECG - Tactical Exercise Control Group
TWSEAS - Tactical Warfare Simulation, Evaluation and Analysis System

UPS - Uninterruptable Power Supply
USMC - United States Marine Corps
USMTF - United States Message Text Format
UTM - Universal Transverse Mercator

WAN - Wide Area Network
WIA - Wounded in Action
WYSIWYG - What You See Is What You Get

1.0 Introduction

1.1 Background

The United States Marine Corps (USMC) is continuing the development and fielding of the Marine Corps Tactical Command and Control System (MTACCS), a system which exists in varying states of development, fielding, or modernization. MTACCS is composed of components from the functional areas of ground and force level command and control (C2), intelligence C2, combat service support C2 (personnel and logistics), fire support C2, and aviation C2. These functional areas were broadly represented at FDS-1, respectively, by the following systems:

- Tactical Combat Operations (TCO)
- Intelligence Analysis System (IAS) with a Genser terminal connected to a TCO workstation
- Marine Integrated Personnel System (MIPS) and a TCO workstation using the Marine Combat Personnel (MCPERS) software
- Marine Integrated Logistics System (MILOGS) composed of the Landing Force Asset Distribution System (LFADS), the Marine Air-Ground Task Force (MAGTF) II system, and a TCO workstation using the Marine Combat Logistics (MCLOG) software
- An interim system represented by the Marine Corps Fire Support System (MCFSS)
- Advanced Tactical Air Command Central (ATACC) and the Improved Direct Air Support Central (IDASC).

These C2 systems will share information and provide decision-making support to their respective functional area commanders and staff. In addition, the TCO will provide an integrated picture of the battlefield to the MAGTF commanders and staffs.

The United States Marine Corps Systems Command (MARCORSYSCOM) has adopted an evolutionary acquisition (EA) approach for MTACCS that employs the concept of "build a little, test a little, field a little." In EA, a system of partial functionality is built, tested, and fielded (wholly or in part) in order to obtain feedback from the user community so that it can be factored into continuing development.

A key element of this EA strategy is the Field Development System (FDS). MTACCS component systems will be evolved over a series of builds with each build more mature than the previous, leading to the deployment of the objective command and control system. Each build will culminate in an assessment, using Fleet Marine Forces (FMF), to determine how well each component system is meeting the FMF's requirements, and what direction the next development cycle should take.

MARCORSYSCOM tasked the Pacific Northwest Laboratory (PNL), as their MTACCS systems engineering and integration (SE&I) contractor, to perform the planning, conduct, and report preparation for the assessment of the first FDS evolution, FDS-1. While this broad charter was focused on evaluating the prototype of the TCO, some data were collected on other component systems. Detailed assessments of other component systems were the responsibility of representatives of those Program Offices.

This report is organized into two volumes. Volume 1 presents the results of the PNL conducted FDS-1 assessment, along with abstractions of data from after action reports prepared by other Program Offices, the Marine Corps Tactical System Support Activity (MCTSSA), and the 7th Marine Expeditionary Brigade (MEB). Volume 2 contains Appendices A through G. Appendix A contains the detailed analyses of the questionnaire data collected during FDS-1. Appendices B through G contain, respectively, the after action reports submitted by the 7th MEB, MCTSSA, DPM Intelligence, DPM Ground Combat Service Support, DPM Fire Support, and DPM Communications/Navigation.

1.2 Objectives

The objectives of the FDS-1 assessment were twofold: first, to provide an opportunity for direct FMF involvement in the design process for MTACCS, in general, and TCO, specifically. The second objective was to use the TCO and other component systems as catalysts to develop more refined design requirements for further MTACCS evolutions. Inputs from the FMF were used to identify how well the systems: met their requirements, needed to be enhanced to meet their requirements, did not meet their requirements, or required additional functionality.

The MTACCS suite of systems deployed during FDS-1 constituted a first step towards the objective system, and was to be used to explore and validate concepts. Participants were briefed that the systems would, in most cases, not meet all user requirements and that the MTACCS acquisition process was evolutionary.

1.3 Limitations

The assessment had two basic limitations. These were as follows:

- This assessment was focused primarily on the TCO system and its interfaces with other component systems.

- A planned technical assessment of the TCO Marine-machine interface (MMI) using human factors design checklists could not be performed due to limited availability of the equipment.

In addition, there were a number of difficulties encountered during FDS-1 that had an impact on the data collection and analysis. These difficulties included the following:

- Because of constant changes to the TCO software during FDS-1 and a general lack of TCO software configuration management, the true nature of the software system being evaluated could not be accurately documented, and the evaluators could never be confident that data collected during the early part of the assessment were still completely valid.

- Considerable technical difficulties were encountered in establishing and maintaining communications, as well as a lack of robust software. As a result, the assessment never transitioned from the first phase where communications were being conducted through wire. Because of this, the FMF personnel who were participants in the assessment may have developed a negative bias in their perceptions of the MTACCS systems deployed for FDS-1. Also the inability to transition beyond phase 1 resulted in not being able to fully address all the assessment issues.

- Confusion regarding the actual capabilities of TCO and other MTACCS systems was considerable. While the contractors' efforts to train the FMF on TCO and the other systems were good, they were hampered by lack of time, space, and equipment. Because of this, the users never seemed to be truly aware of the full potential of each system and how to make it perform to this potential.

- The FMF users had some difficulty distinguishing between TCO and other systems being employed during FDS-1, such as MIPS/MILOGS functionality resident on the terminals used to interface with TCO. This made it difficult, sometimes, for the data analysts to determine when a comment was directed at TCO or at another facet of MTACCS.

2.0 Methods

This section describes the assessment issues, the methodology used to collect data relevant to the issues, and the methods used to analyze the data.

2.1 Issues

During the planning period for FDS-1, specific MTACCS assessment issues were developed, iteratively refined, and published in the Final Draft FDS-1 Evaluation Plan.[a] Since MTACCS is comprised of a number of component systems, each with similar but not identical characteristics, these issues were relevant, for the most part, to all. These issues were loosely grouped as follows:

- Functionality - which determines the capability of MTACCS to perform the functions required to meet MTACCS operational concept and objectives.
- Operational effectiveness - which determines the extent to which the functions provided by MTACCS support the accomplishment of the user mission.
- Usability - which determines how well the design, operation, and procedures of MTACCS meet the expectations and requirements of the users.
- Mobility - which determines the ease with which MTACCS can be transported from one location to another via shore, ship and air lift operations.
- Survivability - which determines the ability of MTACCS to endure anticipated conditions of enemy action, weather, and terrain. Continuity of operations (CONOPS) is subsumed under survivability.
- Vulnerability - which determines MTACCS's susceptibility to electronic warfare (EW) and similar threats.
- Security - which determines MTACCS's provisions for restricting access to controlled information.

(a) Avery, L. W., D. R. Eike, B. A. Fecht, J. G. Heubach, S. T. Hunt, C. W. Holmes, S. F. Savage, and A. P. Shepard. 1991. *Final Draft, MTACCS FDS-1 Evaluation Plan*. Prepared by Pacific Northwest Laboratories for the U.S. Marine Corps Research, Development, and Acquisition Command.

- Trainability - which determines the amount and quality of training required for users to obtain and maintain skills and knowledge needed to operate MTACCS effectively.

- Manpower and personnel - which determine the extent to which MTACCS can be easily set up, operated, and maintained by currently assigned Marine Corps personnel.

- Flexibility and extendibility - which determine the capability of MTACCS to be easily modified to accommodate changing requirements.

- Power and logistics - which determine the impact of logistics elements as defined by the Defense Systems Management College (DSMC) and USMC documents for integrated logistics support (ILS), and the logistic impact of introducing MTACCS to the FMF.

- Reliability, availability, and maintainability - which determine the extent to which the MTACCS is subject to failure, available when needed, and easily restored to working order.

As the assessment neared, these issues were revised to reflect the following:

- A better understanding of the MTACCS functionality that would be present at FDS-1, especially for TCO.

- A change in the focus of the assessment away from doing a detailed assessment of TCO to using TCO as a catalyst for eliciting FMF requirements for a C2 system.

Table 2.1 presents a summary of the issues and associated sub issues used during the FDS-1 assessment.

2.2 Assessment Design

The FDS-1 assessment was conducted to evaluate, through FMF user feedback, the ability of selectively integrated hardware and software to improve both vertical and horizontal command and control within the MAGTF. The systems selected for participation in FDS-1 are identified in Section 1.0. Due to the operational orientation of the assessment, it was decided that the best approach was to provide the FDS-1 integrated system suite to appropriately trained Marine users and evaluate its use during an actual exercise under as close to realistic conditions as equipment limitations allowed. For economic and exercise control reasons, a MEB command post exercise (CPX) was selected as the assessment vehicle.

The exercise structure was developed around a hypothetical, unclassified MEB operational scenario. Designated representative force list organizations and agencies within the MEB were identified as "players" and equipped with the appropriate configurations of the hardware and software undergoing assessment. Player organizations established their command posts in accordance with their normal standing operating procedures and, during the execution of the

Table 2.1. Summary of Assessment Issues and Sub Issues, as Applicable, for FDS-1

Issue	SubIssues
Functionality	Functional Capabilities Hardware Communications Interfaces Operational and Organizational Usability
Operational Effectiveness	Operational Effectiveness System Response
Usability	Ease of Use Information Presentation Data Entry Data Display Screen Design Network Issues Large and Medium Screen Displays Electronic Mapping
Mobility	None
Security	LOG-ON/LOG-OFF Procedures
Trainability	None

CPX, responded to scenario events as though they were engaged in actual tactical operations. Player personnel used the participating systems throughout the CPX where applicable. Organizations participating as players during FDS-1 included the command elements of the MEB, a Marine Aircraft Group (MAG), a Regimental Combat Team (RCT), a Brigade Service Support Group (BSSG), two infantry battalions, and an artillery battalion. This exercise structure is depicted in Figure 2.1.

A Tactical Exercise Control Group (TECG) was established to manage the tactical exercise and simulate subordinate elements, organizations external to the MEB, and the opposing forces (OPFOR). Control cells were used to provide the stimulus to the assessment players. Control cells were staffed with knowledgeable personnel who provided reports and responded to requests for information in consonance with a realistic tactical situation. To perform their

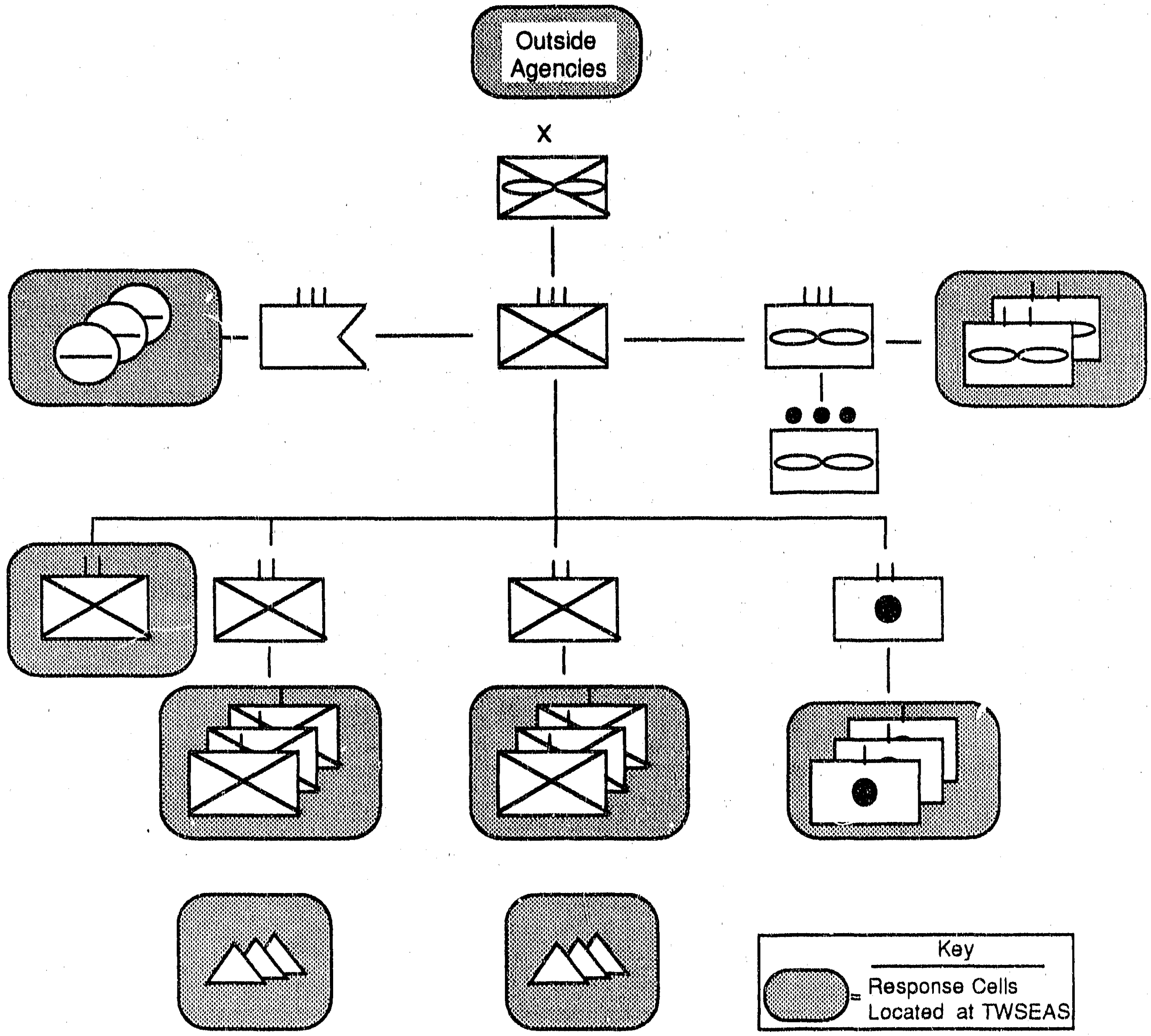

Figure 2.1. Exercise Structure Fielded for FDS-1

respective simulated function(s), control cells were equipped with various types of devices, such as Digital Communications Terminals (DCTs) and TCO terminals, to accommodate digital data input into the systems under assessment. Control of the tactical aspects of the exercise was maintained through maneuver of the OPFOR units. The Tactical Warfare Simulation, Evaluation and Analysis System (TWSEAS) was used to maintain realism in the battlefield simulation and to provide tactical engagement results to the control cell members.

The assessment was to be conducted in three phases. Phase 1 was to consist of communications over wire. Phase 2 was to consist of a gradual migration of communications to radio. Phase 3 was to consist of communications over radio with the RCT being displaced.

Because of the operational nature of the assessment, a fundamental decision was made not to "lead" subjects in their use of the systems under assessment. Subjects were provided the systems as tools and allowed to use them in operational situations as appropriate based on their needs and system functional capabilities. The simulation, therefore, was not structured to facilitate the introduction of detailed, replicable data for capture and later analysis; qualitative, anecdotal information was the focus. Data collectors were present at designated locations during the CPX to observe and record user comments, and interviews and questionnaires were used immediately following the exercise to capture data in a more structured manner.

2.3 Data Collection

Data were collected by numerous agencies during FDS-1. This report discusses only those data collection methods used by PNL data collection teams.

During FDS-1, data were collected on the attitudes of FMF personnel towards the performance of TCO and its interfaces to other component systems, the MTACCS and FDS concepts, and what design considerations an automated C2 system needs to meet user requirements. Four data collection methods were used: observations, questionnaires, interviews, and notes submitted by FMF personnel. Each method, with the exception of FMF personnel notes, was administered by trained data collection teams. The data collection teams, data collection methods, and data analysis techniques employed for FDS-1 are briefly discussed in the following sections.

2.3.1 Data Collection Teams

Ten experienced PNL data collectors gathered information during the FDS-1. To assist in interpreting the events of FDS-1, each data collector was paired with a USMC officer to form a data collection team. All of the data collection teams received training on MTACCS and the use of the data collection methods. During the FDS-1 assessment, each combat operations center (COC) was staffed by a data collection team, with the exception of the MEB, where two teams were used. Following the end of the exercise all of the PNL data collection teams participated in the post-exercise administration of questionnaires and interviews.

2.3.2 Data Collection Methods

Data were collected using observations, questionnaires, interviews, and notes from FMF personnel. Each is described in the following.

2.3.2.1 Observations

While stationed in the COCs each data collection team recorded events, observations, and comments, both positive or negative, resulting from the use of the TCO system and its interfaces to other systems. These observations were recorded in two categories: significant events or general comments. Significant events consisted of those events that had a major impact on some aspect of the COC operations. The general comments category was used to record non-specific effects of TCO and its interfaces, possible methods to improve the system, and non-specific comments or concerns about the TCO system voiced by FMF personnel. Comments about other MTACCS components and FDS-1 concepts were recorded as general comments.

2.3.2.2 Questionnaires

Three types of questionnaires were administered to gather FMF personnel assessments of the TCO implemented during FDS-1, ratings of the importance of MTACCS C2 system functions, and acceptability of the preformatted reports implemented in this version of TCO. Each of these questionnaires is discussed in the following.

1. **Assessment of the TCO** - Three related questionnaires were used to gather information on the opinions of FMF personnel towards TCO. The questions for each questionnaire were drawn from the same general set of questions, but the exact questions varied depending on whether the respondent was an operator, staff officer, or commander. In order to compensate for the limited availability of information on the capabilities of the software prior to the assessment exercise, the questions dealt with very general aspects of a C2 system.

The questionnaires were referred to as the "Commander's Questionnaire", the "Staff Officer's Questionnaire", and the "Operator's Questionnaire". Respondents completed each of these questionnaires during the interview sessions conducted immediately following the FDS-1 CPX. In addition to the numerical ratings respondents were encouraged to write down comments about the performance of TCO. While the questionnaires were being completed, at least one data collection team was present to answer questions pertaining to the questionnaires themselves.

2. **Functional Requirements Ratings** - A questionnaire was developed to assess the opinions of FMF personnel towards the importance of automating certain aspects of MTACCS C2. The C2 capabilities were ranked by officers and non-commissioned officers according to the eight point rating scale illustrated below:

Negative Impact	Inconsequential Impact		Desired Capability		Significant Enhancement		Necessary Requirement	
0	1	2	3	4	5	6	7	8

3. **TCO Reports** - A short questionnaire was designed to gather information about the utility of the report formats provided by TCO for ground C2 and as interfaces to other systems. These questionnaires were administered to enlisted personnel and non-commissioned officers during the interview sessions conducted following the exercise.

2.3.2.3 Interviews

Following the completion of the FDS-1 assessment exercise, a series of interviews were conducted by the data collection team with the FMF personnel who interacted with TCO. The interviews were designed to gather impressions and opinions of FMF personnel about the performance of TCO and its interfaces, the MTACCS concept, and, to a lesser extent, the FDS process.

The data collection teams were instructed to use the moderator's guide only as a resource for starting conversations with the interviewees. Once conversation was begun, the interviewees were allowed to guide the focus of the interviews themselves, as long as the issues discussed related to TCO, the MTACCS concept or the FDS process.

The interviewees were grouped into these categories: operators, staff officers, and commanders. The operators, consisting of enlisted personnel and non-commissioned officers who used TCO during the exercise, were interviewed in groups of about 15 individuals drawn from two or three different COCs. Commissioned officers and non-commissioned officers who interacted with TCO during the exercise comprised the staff officers. They were interviewed in groups of 20-30 individuals drawn from two or three different COCs. The commanders consisted of the commanders of each COC and selected other officers who were involved in the FDS-1 exercise. They were interviewed individually.

2.3.2.4 Notes from FMF Personnel

A substantial number of written comments were submitted by FMF personnel to different data collection team members. These comments were included with the other results obtained during data collection.

2.4 Analysis Methods

This section describes the methods used to categorize and analyze the data gathered by PNL during FDS-1. There were two general types of data: quantitative data (numerical ratings) and qualitative data (text). The methods used to analyze these types of data were different and will be described in separate sections.

2.4.1 Quantitative Data Analysis

Rating data were generated by the Commander, Staff Officer, Operator, Functional Requirements, and TCO Reports questionnaires. The following analyses were performed on the data from each questionnaire: a frequency count of the responses to each question and the overall mean response values for each question with ordinal response values, e.g., a rating from 1 to 6 (For a listing of these values see Appendix A in Volume 2). Due to the nature of the data, inferential statistics were not appropriate.

2.4.2 Qualitative Data Analysis

The vast majority of the data gathered during the assessment was in the form of text. This text consisted of comments written on the different questionnaires, notes about TCO's performance submitted by Marines, observations and comments made by data collectors, and notes collected during the interviews. These data were entered into a text management data base in which they could be searched and sorted, based on the words contained within the text itself. The data collectors also used key words in their notes to facilitate searching the data. Those comments that came from the questionnaires could also be sorted by the specific questions and questionnaires with which they were originally associated.

After the textual data base had been configured, the data base was used to provide information based on a variety of searches, each search being relevant to a particular aspect of the assessment. Inferences were then drawn based on the comments and notes submitted by the Marines and data collectors.

3.0 Findings

The following section presents a summary of the findings from the FDS-1 assessment. These data include that collected by PNL and summaries of information contained in other after action reports. In many cases, recommendations of FMF personnel, PNL data collectors, and MARCORSYSCOM personnel are presented along with the findings.

As discussed in Section 1.3, there were a number of limitations imposed on the data collection. As a result of these limitations, the assessment team focused more on identifying what the FMF personnel believed they needed in an automated command and control system, using the automated systems fielded during FDS-1 as catalyts for comments, rather than on quantifying and evaluating the actual MTACCS systems.

These results, for the most part, represent the distillation of FMF comments and observations from FDS-1 regarding design considerations for automated tactical command and control systems. Given the qualitative nature of much of these data, this distillation represents the data analysts' interpretation of the comments and observations made by FMF and other personnel rather than a quantitative analysis. Specific findings described in these sections may have resulted from one or more reports included in the data base.

This section has been prepared not to provide an assessment of the acceptability of the MTACCS systems used during FDS-1, but rather direction for future MTACCS evolutions. It must be emphasized that these data should be used primarily as an information source to further define design requirements.

The results are reported as design considerations for the following: MTACCS, Ground C2, Intelligence C2, Combat Service Support C2, Fire Support C2, Aviation C2, and the FDS Process.

3.1 MTACCS

The design considerations for MTACCS were defined as those that are more relevant to two or more systems within MTACCS as opposed to a single component system. This does not preclude using the design considerations from those sections that address specific MTACCS component systems. This is especially true for those that address TCO usability.

The MTACCS design considerations were derived from the results of the requirements questionnaire, observations by PNL personnel, comments by FMF personnel, results of the interviews, and review of the after action reports prepared by MCTSSA and the 7th MEB. These considerations are presented in terms of the results of the requirements questionnaire, general capabilities, graphical display, Marine common hardware suite (MCHS), power requirements, communications, and operational and organizational impacts are discussed in the following sections.

3.1.1 Requirements Questionnaire

The Requirements Questionnaire was administered to FMF personnel during the course of the early part of the FDS-1 assessment. Responses were received from 74 individuals. The breakdown of officers and enlisted personnel is presented in Table 3.1.

The results are detailed in Table 3.2. The FMF perceived that 14 (24%) of the 54 listed capabilities were necessary and 40 (76%) were a significant enhancement. No capabilities were rated by the majority of FMF personnel as being less than a significant enhancement. One interesting phenomenon is that the two most important capabilities, voice communications and back-up of data on floppy disks, reflect difficulties experienced during FDS-1. Whether this represents cause and effect is unknown.

3.1.2 General Capabilities

3.1.2.1 Appropriateness of Automation

There were a number of concerns about the appropriateness of the automation.

First, concern was expressed about the extensiveness of the automation of C2 activities. Some users believed that some C2 tasks should be automated and some should not. An example given was the Joint Tactical Air Request (JTAR). This request is usually performed at the Direct Air Support Center (DASC) over manual voice links and was reported to take 5 to 10 minutes longer using TCO.

Table 3.1. Officers and Enlisted Personnel Completing the Requirements Questionnaire, by COC

	COC						
	MEB	RCT	MAG	BSSG	INF BN	ARTY BN	Totals
Officer	12	10	5	4	12	7	50
Enlisted	8	2	3	2	7	2	24
Totals	20	12	8	6	19	9	74

Table 3.2. Perceived Importance of C2 Capabilities, Ranked by Mean Rating

Necessary Requirement	Significant Enhancement
Quickly establish voice communication	Display real time location information from PLRS
Back-up data on floppy disks	Maintain automated journal in COC
Limit access to data for security	Automatically identify mobility corridors
Transmit text	Send messages to everyone in system
Transmit and receive messages	Receive update from GPS
Prepare reports with automated tool	Generate map overlays
Prepare request with automated tool	Transmit graphics
Process classified information with automated tool	Prepare orders
Recreate configuration using floppy disks	Perform automated terrain analysis
Recall messages from journal	Transmit and receive graphics
Reconfigure communication pathways to accommodate computer failures	Automatically perform logistics and time analyses
	Maintain journal at each station
Determine when a message was transmitted	Automatically create INTEL collection plans
Determine when message was received	Import/export to other software programs
	Prepare plans using automated tool
	Transmit/receive information from/to MIPS
	Display real time information from ATACC
	Update situation map automatically, based on incoming messages
	Determine friendly status of supply classes I-X
	Prepare COAs with automated tool
	Transmit/receive LFADS information
	Access instructional information (on-line help)
	Send messages to PLRS unit
	Monitor personnel status
	Monitor current status of requests
	Track WIA
	Display situational maps
	Generate back-up situation maps
	Generate back-up map overlays
	Determine availability of communication assets
	Electronically display situation over paper map on LSD
	Determine when message action complete
	Automatically predict enemy COA
	Plot computer graphics on acetate
	Display color graphics
	Transmit/receive MAGTF II information
	Automatically predict weather information
	Determine when messages were received
	Handle EPW
	Display situation over paper map on MSD
	Overheard function

A second concern related to the way the automation for FDS-1 was designed, especially TCO. All echelons had essentially the same hardware system, with identical software capabilities. In concept this is not necessarily wrong, but findings from FDS-1 suggest that automated capability should possibly be stratified by echelon and even by staff section. For example, each COC would have a minimum core capability, with additional capability included as required by echelon. In addition, each staff section within an echelon would have the system customized to its particular needs. Examples provided by FMF personnel include providing each section with reports organized in an order that expedites the performance of its reporting tasks, and the battalion level intelligence section possibly needing only a data base, not graphics.

A third concern related to having all staff sections on a single local area network (LAN) or net. Ground combat element (GCE) comments indicated that the traffic passed by the S1/S4 sections tended to slow performance of the COC's TCO LAN. The need for these staff sections being on the TCO net at the RCT and lower echelons was questioned, though there would still be a need for some type of connectivity to the operations section's LAN.

These concerns suggest that the requirements and development communities need to conduct a thorough review of how best to integrate automation into the FMF. This review should be directed at more closely defining where automation is best employed in the C2 process, what functionality is truly required at each echelon and staff section, how to best structure communications among staff sections, and what degree of customization capability each staff section needs.

3.1.2.2 Additional Data Base Information

One capability requested was the availability of data bases containing additional reference information. An example given was the Equipment Allowance File (EAF) and the table of equipment (T/E). These could be either on the hard drive or on a floppy disk. On-line or removable disk resident information data bases should be included in MTACCS automation.

3.1.2.3 Design Consistency with USMC Requirements

MTACCS, particularly TCO, Marine Combat Logistics System (MCLOG) and Marine Combat Personnel System (MCPERS), was not totally consistent with the requirements of the USMC. For example, some of the Logistics Report data fields were not flexible enough (maximum of 999 gallons of fuel, maximum of four types of batteries). Also, symbology was not always consistent with USMC naming conventions in that the unit designations (unit number and parent unit) needed to be placed on the left when normally the unit number would be on the left and the parent on the right. In addition, the terminology used in TCO was not always consistent with user expectations. For example, spot report (SPOTREP) was used for position report (POSREP). MTACCS should be designed to be consistent with USMC requirements. More effort is required to bring the user into the design cycle for future versions of MTACCS.

3.1.2.4 Requirement for Multilevel Security

Several sources, including the MCTSSA after action report, identified a requirement for multilevel security procedures to be implemented in MTACCS. While this was not specifically planned for FDS-1, future versions of MTACCS will need to implement include the capability for multilevel security procedures.

3.1.3 Graphical Displays

3.1.3.1 Incorporation of Digitized Terrain Features in the Current Situation Display

While it is understood that this was not a capability planned for FDS-1, the current situation displays would be significantly improved with the use of digitized terrain maps.

3.1.3.2 Graphics for Illustrating LAN Status

One difficulty experienced during FDS-1 was the inability to easily ascertain the status of the LAN. A graphic presentation that provides information for the overall status of the LAN would be helpful. System control (SYSCON), with its larger perspective, needs a broader display that will allow tracking of overall communications and enhance their capability to manage communications resources. This capability should be included in future versions of MTACCS.

3.1.3.3 Color Electronic Map Displays

An extensive amount of information must be displayed on tactical maps, especially those used at MEB and higher echelons. As a result, maps can easily become cluttered and difficult to interpret. The use of color on a map can greatly enhance the ability of USMC personnel to interpret the current map situation, and using color should be explored for future versions of MTACCS, especially TCO.

3.1.4 Marine Common Hardware Suite (MCHS)

3.1.4.1 Large Map Display

The personnel in the artillery battalion primarily use 1:50000 maps. In addition, they need the ability to display the entire range of their weapons. In order for this to be displayed on an electronic map without becoming overly cluttered, a large map display is needed rather than the medium screen display (MSD) used during FDS-1. Similar requirements were indicated by personnel working in the DASC and the Tactical Air Command Center (TACC). The use of large screen displays (LSDs) in the various COCs should be investigated. When implementing LSDs need for mobility and reliability should be considered.

3.1.4.2 Terminal Display Size

The electronic map displays used on the computer terminals by TCO and other systems were too small and quickly became overly cluttered, especially with the way TCO implemented the concept of "trays." A specific example of this problem was the inability of MAG personnel to display an appropriate scale for air direction. The size of map display area needs to be increased. This would entail using a larger display area such as a cathode ray tube (CRT), liquid crystal display (LCD) or plasma screen than is available on the hardware used during FDS-1, in addition to reducing the on-screen, tiled window clutter for TCO.

3.1.4.3 Collateral Materials

In order to effectively use much of the automated equipment deployed during FDS-1, COCs were equipped with additional materials (tables, chairs, wires, etc.) that were not normally part of the unit's tables of equipment (T/E). The design of MTACCS automation needs to consider the interaction of automation and automation support requirements with the operations facilities.

3.1.4.4 Generating Map Overlays

One of the functions of the map graphics capability of an automated system should be to produce acetate overlays for paper maps. During FDS-1 this was not possible, as would be expected given the early stage of design. In the future, the capability to print acetate overlays from the electronic map displays needs to be provided. Where this capability should reside also will need to be determined.

3.1.4.5 Map Printing Capability

At the MEB level, or higher, the capability to print out paper maps was requested. In order to do this, the MEB COC needs to have a color printer large enough to print full size paper maps. The implementation of this capabilities should be explored.

3.1.4.6 Size

The introduction of MTACCS C2 automation could potentially have a significant impact on the mobility of a COC. One of the most obvious ways to lessen that impact is to decrease the size of the computer hardware used to support the C2 system. While this is being anticipated, given the plan to explore the use of the lightweight computer unit (LCU) for FDS-2, the mobility requirements for each of the COCs should be determined. These requirements can then be used to define the maximum acceptable size and weight limits for hardware introduced into each COC.

3.1.4.7 Ruggedness of Support Materials

The additional materials required by MTACCS C2 automation, ranging from power generators to printer paper, may be difficult to maintain in an adverse environment (e.g., the jungle during the rainy season). All supporting materials must be designed to withstand the adverse environmental conditions encountered by the elements of the MAGTF.

3.1.4.8 Hardware Transport

Some of the MTACCS hardware must be specially packed in order to protect it from damage during transport (e.g., the LSD). This reduces the speed with which a COC can displace and increases the probability of system components being damaged as a result of being incorrectly packed for transport. Requirements for stowing MTACCS hardware for transport should be investigated. Ideally, MTACCS hardware should be designed so that it can be safely moved without any special packing, using existing vehicle resources. If special packing is required, it should be designed for quick transport.

3.1.4.9 Multiple COC Configurations

COCs may be configured in a variety of different ways using operational facilities such as high mobility multipurpose wheeled vehicles (HMMWVs), amphibious assault vehicles (AAVs), light armored vehicles (LAVs), and tents. MTACCS hardware, especially TCO, must be designed so that it can be easily integrated into each of the different COC configurations, especially those that will contain more than one component system. In addition, the hardware should not be designed to rely only on a dedicated vehicle. If MTACCS hardware is too dependent on one vehicle, then the system will be rendered useless if that vehicle is disabled. Flexibility must be built into MTACCS to allow the system hardware to be easily transferred to another vehicle.

3.1.4.10 Pointing Device

Several problems with the use of a mouse were noted. Among these were the lack of space in a COC or operational facility for using a mouse, the susceptibility of a mouse to environmental conditions such as dirt or sand, and problems with the mouse cable getting tangled or pulled out of the terminal. Alternative methods for interacting with computers such as a trackball, lightpen or touch-screen, are suggested.

3.1.4.11 Touch-Screen on Map Displays

It was noted that the electronic map displays equipped with touch-screens were susceptible to inadvertent lines being drawn when people accidentally bumped or touched the screens. To avoid this, a means should be provided to either deactivate the touch screen or interact with the electronic map display by some other means (e.g., light pen).

3.1.4.12 System Configuration and Dismantle Time

The time necessary to set-up/tear down of the MTACCS hardware could greatly decrease the speed with which a unit can be emplaced or displaced. This includes the time necessary to establish the necessary communications links. Hardware must be built so that it can be quickly shut down, torn down, configured for transportation, reassembled, and reintialized.

3.1.4.13 Improved Direct Air Support Central (IDASC) S-250 Shelters

FMF personnel indicated, in the 7th MEB after action report, ithat they were impressed with the S-250 shelter deployed with the downsized IDASC. They believed that with some modifications, these shelters could be used by all command elements. It is recommended that their, or similar shelter, use in future development of MTACCS systems be explored.

3.1.5 Power Requirements

3.1.5.1 Power Sources

Each of the COCs involved in the assessment indicated that they would be unable to support the MTACCS equipment with their current power sources. MTACCS equipment must either be able to be supported by the units' current power systems or it must include its own sources of power (generators, batteries etc.).

3.1.5.2 Uninterruptible Power Supply

Several problems (e.g., lost data, interrupted work) resulted from computer failures which were caused by power surges and power outages during the assessment. These problems greatly undermined the FMF personnel's willingness to rely on the system. MTACCS needs either to be equipped with its own steady, reliable source of power, or to be insulated from the effects of an unstable power supply. A suggested solution would be to implement methods that would allow for the temporary use of an alternative power source or automatic orderly shutdown and recovery of the system in the event of a power failure (e.g., an uninterruptible power supply).

3.1.6 Communications

Due to difficulties experienced transitioning to radio, the communications system architecture for FDS-1 relied primarily on wire. As such, this should have represented near optimal quality for most simulated radio nets. However, integration of all of the FDS components with existing FMF tactical support equipment (e.g., communications-electronic, mobile electric power, etc.) resulted in a communications environment that was unable to support the planned demonstration of MTACCS capabilities. While the causes for the difficulties could not be determined, FDS-1 demonstrated that the full potential of automated data processing cannot be realized without robust, digital-quality communications. FMF recognition of that fact was evident in frequent comments by participants. One conclusion was obvious to most observers: the existing communications system is a weak link in MTACCS development. Commanders and staff officers repeatedly cited the belief that improvement of FMF ground element communications was an absolute prerequisite to major improvements in command and control.

3.1.6.1 Digital Communications Concept

FDS-1 provided many of the FMF units with their first exposure to the environment of digital communications and all of its concomitant limitations and benefits. Even accepting the limitations of this exercise, FMF personnel generally recognized the potential benefits of digital communications and automated data processing. During the exercise and the interviews that followed it, participants provided insights into the concept of digital communications as they apply to the FMF.

Voice versus Data Communications. The data indicate that there is a strong consensus within the FMF that some types of communications must be conducted using voice. Messages of particular importance, urgency, or complexity may require a verbal exchange between sender and receiver to ensure successful communication. As a case in point, a commander with a tactically critical message to a subordinate commander will often need to discuss the message directly, over a voice net, to ensure things such as immediate feedback, understanding, and intent/ability to comply. With digital communications, represented by the TCO prototype, the sender did not know if the message had been read or even received by the person to whom it was sent, unless there is a reply. The system should provide an acknowledgement of the message having been read.

Even though there was only one instance of voice/data contention problems cited, conventional wisdom seems to be that the digital and voice nets must be kept separate. Digital communications will therefore require dedication of some of the existing doctrinal nets (voice) to digital traffic. Without careful attention to the design and the inclusion of new technology (e.g., multiplexing, data compression and burst communications) this could reduce net availability for voice communications.

Development of MTACCS should treat the preference for voice in certain cases as a design requirement. While training and experience may decrease the reliance on voice in routine communications, they will not replace voice as the primary means to manage most critical tactical communications in the foreseeable future. Doctrinal nets should be reviewed to minimize voice/data conflict without degrading the ability of the unit to effectively use voice communications when required. Doctrine concerning use of nets should be reviewed with an eye towards exploiting the benefits of digital communications technology. A digital communications server that makes net use decisions without intervention by the operator, or other appropriate technology, should be examined.

Loss of Audible Cues. The loss of the ability to hear the radio voice traffic over speakers in the COC was seen as a mixed blessing. The reduction in noise and confusion was cited as a positive effect but the loss of the audio cues to the current situation was an offsetting negative. Other MTACCS components, such as the map graphics and medium/large screen display, were seen as partially compensating for the lost ability to monitor voice traffic. New procedures for message handling and local announcements of key events could further mitigate this loss. However, reading messages or viewing map graphics are active processes that represent increased effort to acquire information that was obtained passively.

COC procedures should be reviewed to develop methods of handling digital message traffic in a way that keeps key personnel appraised of the current situation. Those methods should make use of new graphics technology (map and screen displays). Prominent posting of critical messages, priority-handling procedures, and vocal announcements can be used to replace the passive monitoring of voice nets. This can have the added effect of reducing COC noise and accentuating critical events.

3.1.6.2 Communications Interface

Data collection on the use of the digital communication capability was focused more on TCO and the COC. Comments pertaining to this interface were generally positive, but with some suggestions on how to improve it from the operators viewpoint. These suggestions, discussed in more detail in other sections, include the following: introduction of a chat mode, inclusion of easy procedures for saving messages and other information, and inclusion of precedence ordering and an ability to scan message headings.

3.1.6.3 FDS-1 Communications Problems

While path quality seemed adequate in most cases, integration of some of the MTACCS software and hardware (e.g., TCO and IAS) with the existing radios and power equipment resulted in a host of problems that were apparently interrelated to the point that no general solution was readily available. As the system deteriorated, problems compounded.

Training of workstation operators appeared adequate for the expected normal operations, but was not necessarily adequate once the system degraded. Operators were generally unable to understand the symptoms or determine the root problem. Therefore, rather than effecting a solution, they may have contributed to the problem by experimenting or generating unnecessary message traffic such as repeated communications checks. Calling and waiting for a vendor technician created a frustrating delay.

Training for FDS-2 operators should include operations under degraded performance conditions. Methods to reduce the deleterious effects of system failures should receive emphasis. Before beginning the next FDS, a successful communications exercise (COMMEX) must be conducted under field conditions that includes full use of the computer terminals and demonstrates the ability of the operators to operate the system.

3.1.6.4 Communications Management

As reported in the MCTSSA after action report, the TCO operator during FDS-1 essentially controlled access to the communications pathways through his terminal. However, with the operator of a C2 terminal controlling the communications pathways, maximum efficiency cannot be achieved. Also, this situation is undesirable from the point of view of doctrine. SYSCON should provide this function, allowing for use of communications resources to their maximum capability. The operator should only have to specify to whom the message is directed, and the system would automatically route it the best way. For future versions of TCO and other MTACCS systems, SYSCON should have control of communications management, and the use of a communications file server should be explored.

3.1.7 Operational and Organizational Impact

This section discusses those findings from FDS-1 that provide indications of the impact of MTACCS automation, especially TCO, on FMF operations and organization, and recommendations where appropriate.

3.1.7.1 Command and Control (C2) Procedures

There was concern that some procedures were modified for the sake of automation and, conversely, there are automation features that were not present in FDS-1 that would have enhanced C2 procedural efficiency. The following paragraphs discuss specific observations regarding automation and C2 procedures.

Standing Operating Procedures (SOPs) and Message Formats. FDS-1 results indicate that Marines are satisfied with existing manual and automated SOPs and message formats. Many comments were recorded that indicate a desire to see a system that automates procedures that lend themselves to automation, but to avoid adding automation to procedures that can be readily performed manually. Further, there is some indication that the automation negatively impacted the ability to make "information flow." For example, Marines reported that too much time was spent in typing short messages for transmission over TCO, rather than using a much quicker voice transmission.

Automatic Updating of Air Tasking Order (ATO). Data indicated that the automatic updating (monitoring) of the ATO was very desirable, and that the COCs be provided with an electronic copy of the ATO.

Duplication of Procedural Capability in a COC. With the number of automated systems being deployed, there exists a risk of duplication of capability within a COC. For example, in the MAG, the functions performed by TCO were similar to those performed by ATACC. The implementation of TCO should not duplicate procedural capabilities between MTACCS systems when those systems reside side-by-side in a single operational facility.

Staff Section Location. During the assessment, the S1 and S4 in the artillery battalion were connected to the other staff sections via a LAN. Sometimes in the Artillery Battalion, the S1 and S4 are located in the rear. In such a configuration it would not be practical for the S1 and S4 to be connected to the other sections via a LAN. TCO must be flexible enough to allow for COC configurations in which different sections are separated by considerable distances.

3.1.7.2 Manpower and Personnel. Implications of MTACCS on FMF manpower and organization were a source of numerous comments and observations. However, little definitive data concerning the need for more Marines to operate TCO, or other MTACCS systems, or of the necessity of a higher education level requirement was gathered. The following observations were gained from the data.

SYSCON Personnel. The proper operation of TCO and other MTACCS component systems will rely heavily on getting maximum performance from the communications system. In order to accomplish that, the communications personnel cited a requirement for greater capability to monitor, troubleshoot, and maintain communications nets and equipment. Several comments suggest that all or part of SYSCON may have to be located within the COC. The potential impact of this suggestion on manpower could be considerable. Other suitable alternatives need to be developed.

MTACCS Automation Operator Skills. MTACCS operators will require a different skill set than the radio operators that they will most likely replace. They will have to possess most of the radio operator skills and will need added skills that are specific to the system (data and computer applications) and the tactical function. In addition, they will need much better typing skills. Some comments suggest a specific position for a system administrator will be required. This needs to be considered in the future design of MTACCS.

3.1.7.3 Training

In general, FMF personnel comments concerning training and training effectiveness varied widely and was inconclusive. The most concrete comment on training related to the generator operators. Because of the nature of automated equipment, increased emphasis must be placed, during generator operator training, on the establishment and maintenance of stable power.

3.1.7.4 Support Requirements

The areas covered here include; mobility, power, maintenance and logistics, and communications.

Mobility. Few other areas raise so many concerns among Marines as mobility. The level of concern varies with the type of unit. For example, the added lift required by TCO for the DASC or the TACC is relatively small, when compared to their current lift. However, the infantry battalion cannot tolerate the additional lift imposed by the current TCO equipment and power generators. Even at the MEB, there may be a requirement for a larger COC. If true, mobility requirements are increased.

Due to the mobility concerns expressed by the infantry and (to a lesser extent) artillery battalions, the MTACCS requirement (size, type equipment, etc.) at these echelons should be revisited. Mobility requirements should be addressed early in system development (part of the logistics process).

Power. The added power requirements imposed by MTACCS can have an impact on many units. The equipment configuration used during FDS-1 almost universally increased the power generation requirements at COCs. Additionally, power stability and grounding requirements must be considered, as well as infrared and noise signatures. The addition of uninterruptible power supplies (UPS) will ameliorate some of the power loss and fluctuation problem but increase the lift (mobility) burden. Future MTACCS development will need to address these issues and trade-offs, with the users, between system support requirements and operational constraints.

Communications. Without question communications are a focal point for MTACCS, especially TCO. MTACCS, as assessed, created a situation where many individuals became de facto communications managers, and communications devices became heavily burdened. The implementation of some features was inadequate. For example, there was no clear way to know that a message recipient received and read/stored a message. The inability of much of today's radios to handle multiplexed voice/data adequately results in duplication of nets. Procedures have not matured to the point where TCO voice and data "nets" can effectively coexist. Within the Marine Air Command and Control System (MACCS) there is a long history of using voice and data nets/circuits in conjunction with one another, there are a number of lessons which can be applied to TCO and other component systems. For example, the Joint Air Defense network is operated using as many as five different digital data link types and is supported with three to five distinct voice nets. Procedures exist to ensure vital traffic is passed, etc. Similar procedures for dealing with voice and data message traffic over MTACCS systems needs to be implemented.

Logistics and Maintenance. There was an insufficient opportunity to collect reliable data on this subject. However, many Marines felt capable of expressing their thoughts into these areas.

There was concern expressed regarding the performance of unit level maintenance on TCO equipment. At the higher echelons, the concern was not voiced as often. The acquisition process for MTACCS component systems must take into consideration how maintenance will be performed. The maintenance concept must encompass all levels of maintenance. The insertion of new equipment also requires careful thought for the provisioning of the required spares, etc. Mobility has already been raised as a concern, which adds to the requirement and constrains solutions. Generally, the performance of the TCO equipment appeared to be adequate from the perspective of true equipment failures.

3.2 Ground C2

As stated in earlier sections of this report, the focus of the PNL data collection was the TCO system deployed for FDS-1. The results of that data collection are presented below in terms of TCO design considerations, usability, TCO interface requirements, and a more formal FMF assessment of TCO.

3.2.1 TCO Design Considerations

The following section discusses design considerations for the Tactical Combat Operations (TCO) system. These considerations, while more germane to TCO, can still be applied to other component systems and are presented in the following topics: general capabilities, message capabilities, journal capabilities, electronic tactical graphics, additional software capabilities, and hardware considerations.

3.2.1.1 General Capabilities

Redundancy of Terminals. In a number of cases, some TCO terminals were utilized as backup or overflow for another terminal. Difficulty was experienced in maintaining an up-to-date data base in the backup terminal, so that it could easily take over the functions of the primary terminal. A capability should be included that will allow a terminal to be configured as a redundant system. In the event of a terminal failure, the backup terminal could immediately assume full functioning as the primary.

Message Flow Control. During FDS-1 the introduction of TCO caused message traffic to flow into and out of the COC without necessarily passing through a central action officer for disposition. FMF personnel, to compensate, set up manual procedures for performing this function. The system should provide some capability for doing this tracking. How this function could be facilitated by automation should be explored and implemented, if feasible, for FDS-2.

Automated Position Location Information. The capability for automatic updates of position location information by PLRS was a very well-received capability. The capability for automatic updates by SPOTREPS, SALUTE reports (SALUTEREPS), and receipt of current situation graphics, while also good, had some inherent weaknesses that need to be addressed in the future design of TCO. These included the reliability of reported friendly and enemy locations, and the procedures by which the user verifies the location. Position Location Reporting System (PLRS) automated update of position location information (PLI) should be continued. For update by other methods, the user should receive the information and make the decision whetheror not to use it.

On-Line Diagnostics. One of the difficulties experienced during FDS-1 was the diagnosis of system problems, where the system consisted of TCO and the attached communications devices. TCO had some internal diagnostics that allowed trouble shooting of the terminal. These did not necessarily help isolate problems associated with the peripheral devices attached to TCO, such as printers and communications gear, or help fault isolate where in the total "system" the problems resided. Capability should be included in TCO that will allow some level of fault isolation to be performed on the total system.

On-line Help Capability. Opinions were mixed on how well the on-line help features assisted the operator. The on-line help capability in TCO should be expanded.

Chat Mode. The capability for a chat mode, as used by FMF forces in Southwest Asia over Banyan Vines, was described as being very useful. The inclusion of this capability in TCO should be explored.

Overheard Function. The overheard function, as implemented in TCO, was a contentious capability. It was reported to be of limited utility and overused by some, while others reported it helpful. This capability should be closely examined to determine if and how it could be best implemented.

Programmable Function Keys. During FDS-1, once a terminal was powered down, the programmable function keys reverted to the system defaults, requiring reprogramming each time the terminal was powered back up. TCO should include the capability for user-programmed function key data to be saved to a default file.

Software Security with Passwords. During FDS-1, the user was not able to specify unit or operator specific passwords. Therefore, access security to the terminal could not be guaranteed. The capability for user-specified passwords should be explored.

Central Communications Server Function. FDS-1 communication was primarily set up using the concept of dedicated communications devices for each terminal. A better concept might involve a dedicated central communications server or a small node configuration having a nondedicated commuicatlons server at one workstation. This possibility should be explored for TCO.

Automatic Save. While the TCO used for FDS-1 had an automatic save, it did not necessarily save enough current information. When a system crashed, the terminal tended to lose the current situation, defaults established by the user, communications configuration, and the message queue. The user had to reinitialize and rebuild these files, and lost potentially critical message traffic. A broader automatic save capability should be included. This capability should save all aspects of the system, including defaults, unserviced messages, and the current situation or other graphics.

Communications Pathway Selection. The selection of the communications pathway for a message is currently performed by the operator (radio or data). This takes time and effort. The communications pathway for a message should be transparent to the operator. TCO should provide a systems communications design that automatically selects the most appropriate pathway for a message.

Keyboard Control of Terminal. TCO was designed to take advantage of a pointing device such as a mouse or trackball. Unfortunately, if the pointing device failed, the user could not adequately use the terminal with the alphanumeric keyboard. Future versions of the TCO should include the capability to perform most, if not all, functions and actions with either an alphanumeric keyboard or pointing device.

Continuous Communications Connectivity Monitoring. As understood by the FMF users, TCO only performed checks for connectivity when a action had been taken by the operator. These actions included clicking on the "Who's There" button or trying to send a message. TCO should include a capability that better accesses and maintains communications status, but does not impose an excessive burden on the communications architecture of TCO or on other MTACCS component systems.

Data Base Access by Adjacent and Higher Headquarters. Given the tempo of typical tactical operations, staff may not be able to respond to information requests and provide reports to adjacent or higher echelon units. The ability for adjacent and higher echelon units to access this information from a COC's terminal could be helpful. The capability for these units to call into another unit's terminal and access required information, using a read-only capability, should be explored.

Operation on the Move. TCO, as fielded in FDS-1, could not be operated while the units were moving. Opinions expressed by the user indicated that this capability is imperative for TCO to be an effective tool. This capability should be a prime design requirement for TCO.

3.2.1.2 Message Capability

Message capability, in the context of this report, refers to the ability to transmit and receive messages, reports, and requests. This capability was one of the stronger capabilities in TCO during FDS-1. The system contained a number of preformatted messages, but the FMF were observed to use the Free Text messages a significant portion of the time. As the comments and the results of the Reports Questionnaire presented in Table 3.3 indicate, the message capability was viewed as a positive design attribute and an improvement over the current manual methods. Two exceptions to this were the target report (TARGETREP) and the displacement report (DISREP), which the FMF participants rated as being about the same as the current methods.

Table 3.3. Mean Ratings of FMF Personnel Perceptions of TCO Preformatted Reports Improvement Over Current Methods

Report Type	Respondents	% Perceived Improvement
AFUBAMOUP	3	68
CASREP	18	78
DISREP	6	50
DUMPSTATREP	9	78
FIRECAP	6	67
FIREPLANREP	6	67
FREE TEXT	37	86
INTSUM	10	80
ITUSPOT	4	75
LOGSUM	11	73
MIJIREP	8	87
ENMINEREP	10	70
FRNDMINEREP	9	67
NBC 1	23	87
NBC 3	21	81
NBC 4	20	80
PERINTSUM	7	86
SALUTEREP	22	77
SENREP	7	71
SHELLREP	12	75
SITREP	26	81
SPOTREP	24	75
TARGETREP	6	50
PERSTATREP	11	91
PERSTRENREP	11	91
CASPROJ	7	100

TCO contained only some of the messages required, and some of those were specific to this implementation of TCO. TCO should implement all USMC-required preformatted messages. The following additional design considerations were identified from FMF comments.

Broadcast Messages and Net Discipline. During FDS-1, terminals constantly received duplicate messages, requiring the operator to service each redundant message. This appeared to be due to a number of factors related to the implementation of this capability in this version of TCO. First, the capability to export the communications assets function allowed duplication of net members as seen on multiple nets. Second, the net structures established a wide are network of system. Third, the broadcast function allowed for wide dissemination of messages to the members of the wide area network with no ability to limit distribution, or inhibit multiple retransmissions of messages.

The USMC needs to explore how best to implement wide area networking. For example, the broadcast capability could be designed to filter out redundant messages at a terminal unless specifically directed not to do so by the recipient.

Preparation of Customized Reports. A difficulty experienced during FDS-1 involved the preparation of specialized reports on friendly or enemy situation. For example, there was no easy method for preparing and printing a report specifying data (e.g., location, status, and other information) on units. TCO should include a capability for querying the system and preparing customized reports, standard in most COTS systems.

FAX Capability. The inclusion of a FAX capability in TCO was suggested. This should be explored for feasibility. If implemented, this capability should include interfaces for both tactical and commercial faxes.

Automated Routing of Messages. While TCO provided some automated routing of messages, TCO needs to implement a much stronger capability for message routing. For example, all tactical messages should be routed to the G3 Operations terminal, while all administrative messages should automatically go to the G3 Plans terminal. While it may be that this structure could have been supported by TCO, the routing scheme needs to be examined to ensure that message routing is optimal.

Message Reply. A feature that would be very helpful in resolving confusing messages and providing a quick response is the use of a message reply capability, which would allow the recipient to send a reply to a message with minimal effort. This capability should be included in TCO.

Message Receipt Acknowledgement. TCO provides an acknowledgement that a message has been received by a terminal, but does not provide any feedback that a message has been read by the recipient. It needs to include the capability for requesting a receipt when a message is read.

Message Sorting. Messages could not be sorted into meaningful groups. TCO should implement the capability to group messages by topic, much like putting related messages into a sub-directory or file folder.

Mailing Lists. One capability that would enhance TCO is to allow the user to specify one or more mailing lists (e.g., all G/S-3 staff sections, etc.). The implementation of this capability should be explored.

Message Queue Capabilities. The message queue buffer for TCO during FDS-1 allowed up to 20 messages. After 20, the oldest message was deleted. The message queue needs to be much larger to ensure that no messages are lost during active phases of the battle. The message queue can also be improved through displaying the messages in chronological order, oldest first, but with priority messages at the very beginning, and allowing the user to randomly select a message for reading (or sending for the outgoing queue), as opposed to reading them in sequential order of time received.

Lack of Marine Tactical Systems (MTS) Format for TCO Reports. According to the MCTSSA after action report, TCO reports were in their own format, wrapped in a Marine Tactical Systems (MTS) plain text shell. This meant that the TCO reports were only readable by TCO, not any other systems using MTS. Future versions of TCO should implement MTS format.

3.2.1.3 Automated Journal

TCO contained an automated journal capability. This capability operated by automatically saving, for each incoming and outgoing message that the user serviced, an entry in the journal that contained date time group (DTG) in and out, a brief summary statement, and action taken. In addition, the user could make manual journal entries. FMF personnel were very enthusiastic about an automated journal, but felt that this capability needed to include the following characteristics. These characteristics should also be considered for the messaging capability.

Common Journal Capability. One method for improving the journal capability would be the use of a common journal for each COC, located on a designated terminal. This would serve as a central source of information. This capability should be explored for implementation in TCO.

Querying of Message Queue and Journal. The capability for querying the journal by subject, originator, or other key word would provide a vastly improved capability. This capability should be implemented in TCO.

Automatic Saving of Messages to the Journal. Apparently, TCO automatically saved messages serviced by the user to the journal. Ideally, the user should make the decision as to what goes in the journal and what does not. The implementation of a user approval capability for saving messages to the journal should be explored.

Management of the Automated Journal. The journal should have the capability to allow the user to selectively read messages, rather than having to read them in order of receipt. This capability should be implemented in future TCO builds.

Automatic Update of Date Time Group (DTG) in Journal. Any additional action taken on a message in the journal did not automatically update the DTG. Therefore, messages were retransmitted without a new field indicating the retransmission DTG. TCO should have the capability for automatic updating of the DTG for any new processing or actions taken, with a message in the journal through, at a minimum, an additional header on the message.

Information Display. The journal capability in TCO did not display enough information on each entry. For each journal entry, TCO should include a display of sender, recipient, subject, DTG, some appropriate key words, and what action was taken.

Journal Autoprint Capability. The journal capability for TCO during FDS-1 included an autoprint feature. This feature was viewed as undesirable. The users should be able to selectively print journal entries.

3.2.1.4 Electronic Tactical Graphics Display

The electronic tactical graphics displays used for FDS-1 provided FMF personnel with the capability for developing, displaying, sending and receiving current situation graphical overlays. The capability to update all or some net member's current situation displays through the LAN and wide area network (WAN) was a very desirable feature of TCO.

Graphics could be displayed on either the TCO terminal screen, a MSD, or a Large Screen Display (LSD). FMF personnel, in general, liked this capability but felt that it needed significant improvement to be truly usable. The following paragraphs describe observations on the graphics display capability. There was some confusion between limitations specific to the MSD and LSD, and those specific to the software used to provide the graphics capability, which may impact the validity of some of the information presented below.

Current Situation Map Graphics Speed. Concern was expressed about the speed of updating a current situation map overlay, especially at lower echelons of the GCE, which would reduce the effectiveness of the graphics. Another concern was the speed of transmission of graphical messages between the G2/S2 and the G3/S3 over the LAN. It was perceived as being too slow during FDS-1. For TCO to be successful, the speed of update and transmission must be faster.

Lack of Layering Capability for Graphic Overlays. The graphic overlays used for the current situation display were designed as a single layer. This precluded the user from decluttering the screen. In addition, when another overlay was transferred to the current situation display, it merged with the current overlay, causing duplicate symbols. The graphical overlays should be designed to provide for multiple layers of information and be much more interactive.

Map Coordinates. TCO map coordinates were in universal transverse mercator (UTM) format, and there was no capability for conversion to Latitude/Longitude (LAT/LONG). TCO should include the capability for the display of location in either UTM or LAT/LONG format.

Symbol Collocation Problems. When symbols were collocated, the user could not highlight one symbol and drop information on it. The symbols had to be off-set. Symbols should be individual objects, regardless of their proximity. The user should be able to highlight one, which brings it to the top of the layer, and perform whatever operation is required on that symbol. This capability should be implemented in future versions of TCO.

Graphic Symbology Correlation. During FDS-1, graphic overlays sent from one terminal to another and included on the current situation frequently caused a duplication of symbols for units contained in both overlays. Operators had to remove redundant symbols, one at a time. A work-around approach employed by operators at one of the infantry battalions was to copy the incoming current situation to a fragmentary order (FragO) or course of action (COA), and use this as a "scratch pad" to select specific symbols to place on the current situation. While this was an effective way to utilize capability in unplanned ways and an illustration of the flexibility within the system, TCO needs to include automatic correlation of symbols.

Future versions of TCO should preclude redundancy of symbology when an overlay is imported from one terminal to another. One method to accomplish this would be to have one terminal that maintains the master copy of the current situation by integrating all relevant data. Other terminals could access this overlay for display.

Concurrent Display of Current Situation. When new information on the enemy or friendly situation was received, there is no easy way for the user to compare the new information with that contained in the terminal's current data base. The capability to simultaneously display the new information (including unit location) with that contained in the terminal's current data base should be explored. This would allow the user to compare and correlate information manually, if necessary.

Symbology Templates. The symbology templates used by TCO, while reported as being very helpful, still had some limitations. In building a current situation display, TCO needs to provide a more comprehensive set of templates for both friendly and enemy units and other symbols. The user should be able to attach textual information in the form of labels and, when a symbol is queried, pop-up windows for information such as enemy killed in action (KIA) or wounded in action (WIA) data, etc Other improvements include the addition of symbols for free rocket over ground (FROG) and multiple rocket launcher (MRL) battalions; helicopter attack points; aircraft coordination areas; joint and foreign symbology; and the ability to plot and display shelling report (SHELLREP) and back azimuths. The inclusion of these symbols should be explored.

Display of Unknowns. TCO was designed so that unique identifiers were required for each symbol placed on the current situation display to link the symbol to the data base. While this is not a bad aspect of design, intelligence personnel felt that they also needed the capability to place temporary symbols for unknown enemy units on the display without naming them. These unknowns would be correlated with known enemy units later. In the current TCO implementation, unknown symbols became part of the data base and had to be individually removed. TCO should implement the capability for easily placing temporary symbols on the current situation display.

Map Scale. The maximum scale available on the current situation map was 1:250000. This was adequate for the MEB. However, a MEF will typically need map scales of 1:500000 through 1:1000000. While TCO for FDS-1 was developed specifically for a MEB, for it to be useful to higher headquarters, it needs the capability to display the appropriate scales.

3-D Display Capability. The 3-D capability in the FDS-1 version of TCO displayed a horizontal grid that provided very little in the way of terrain features. This limited its utility and created uncertainty of its value. The need for this capability needs to be investigated. If it is kept, it needs to be much more sophisticated to be useful. One aspect that would make it useful would be to display artillery range fans and terrain features.

Graphical Representation of NBC Information. This implementation of TCO did not include any graphical representations of nuclear, biological, and chemical (NBC) information. Future versions of TCO need to provide this capability.

Graphical Display of Historical Track. While this implementation of TCO planned on providing a historical track for friendly units, this capability was not demonstrated for enemy units. Intelligence personnel reported the need to have the capability to display a historical track of enemy units. This display should include the actual previous locations of the units and the last time that they were reported at that location (e.g., the update time). A full capability for display of historical tracks for both enemy and friendly units should be implemented.

Engagement Area Information. The Maneuver Control Measures and Air Operations Measures capability did not include the ability to specify engagement areas. This capability should be implemented in future TCO builds.

Graphic Overlay Erasure. To erase an entire graphic overlay, the user had to select each individual item on the overlay for deletion. This was very time-consuming. TCO should incorporate a capability for total overlay deletion with just a few actions, including appropriate protection to prevent inadvertent deletion.

Graphic Overlay Printing. One limitation to the graphical overlay for the current situation display was that all the information had to be manually reproduced on map boards and other hard copy products. The ability to print the graphical overlay information would be a significant improvement over the current manual methods. This is especially true if the user could designate a specific area of the current situation to be printed, rather than the total map. The capability for printing graphic overlays should be explored.

Graphic Overlay Updating. The TCO needs the capability to allow the user to easily identify and select only those symbols from the current situation display that are required to be sent to another terminal, rather than having to send a complete overlay. This capability should be included in the future versions of TCO.

Symbol Movement and Data Base Update from Current Situation Map. The participating FMF personnel requested the ability to move a symbol on the Current Situation Map through the use of a "hook and drag" capability that would automatically update the data base for unit location. There are certain risks associated with this such as inadvertent and incorrect modification of the data base, but the capability should be explored and implemented if feasible.

Drawing Capability for Current Situation Display. The user could draw shapes on the current situation graphical display, but the process was very difficult. The user needs the capability to draw shapes, using the pointing device, much like can be done with existing graphical user interface technologies. TCO should include a "free hand" draw capability.

Symbology Updating. When a user of the FDS-1 implementation of TCO changed the designation in the data base associated with his own ID symbol, the symbol in the net member's tray for other terminals was not necessarily updated automatically. A new symbol was created, with the old symbol marked with an "X", but not deleted. This symbol had to be manually deleted. The system should automatically update symbols displayed in other net members displays without requiring the user to have to make manual changes.

Control of the LSD and MSD Graphical Displays. Control of the LSD and MSD graphical displays was accomplished from the connected TCO terminal but this control was awkward and difficult. For example, users reported that they could not slave the LSD or MSD to the current situation display on the TCO terminal to allow easy panning or change of scale. This reduced the usefulness of the LSD and MSD. TCO should provide the capability to easily control peripheral display devices like the LSD and MSD from the terminal used as a controller.

Overlay Map Displays. The electronic map overlays (the LSD and MSD) did not always line up with certain types of paper maps (e.g., city maps, non-standard maps, etc.). This made the electronic map overlays useless when one of these maps was being employed. A greater range of settings (e.g., 1:25,000 etc.) needs to be provided by the electronic map overlays. Additionally, the electronic map overlays should have the capability for changing settings so that they can be adjusted to line up with non-standard maps.

3.2.1.5 Additional Software Tools

The TCO prototype used during FDS-1 primarily performed message and display of current situation functions. FMF personnel expressed the desire and need for the following additional software tools.

Decision Analysis Software. The TCO implemented for FDS-1 did not include many decision analysis software tools potentially required by FMF personnel. For instance, there was no capability to perform war gaming, terrain analysis, line of sight determination, cover concealment determination, obstacle siting, avenues of approach identification, moon/sun cycles prediction, weather patterns analysis, order of battle predictions, or other analyses. The system was predominantly a communications and current situation device. Additional capability for decision analysis and support should be considered for implementation in TCO.

Capability to Share Files with Additional Software Applications. TCO did not provide the capability to easily share data with other applications software such as COTS word processing or spreadsheet packages. This capability would significantly improve the system. The capability for importing and exporting of files and data to other software applications needs to be explored and implemented.

Tools for Amphibious Assault and NEO Actions. TCO did not seem to meet all the current and future USMC mission needs. FMF personnel suggested that TCO incorporate additional capability to support amphibious assault and noncombatant evacuation operations (NEO) actions. The appropriate analyses need to be performed to define what these capabilities should be.

3.2.1.6 TCO Hardware Considerations

The following design considerations address aspects of hardware design and implementation that are specific to TCO.

Alternative Hardware Solutions. According to comments, many of the functions provided by TCO could have been provided by alternative types of hardware. A specific example compared the utility provided by better radios and digital faxes to those provided by TCO. The possibility of using alternative forms of equipment other than computer related hardware should be investigated.

Commander's Terminal. Most of the message traffic at the infantry battalion COC went through the S3 operations terminal and very little, if any, went directly to or from the commander's terminal. Additionally, very little planning or information access was done on the commander's terminal. The utility of the commander's terminal should be explored.

Transferable Data Storage. The capability to easily save data to a transferable storage medium (e.g., floppy disks) in case a computer goes down is needed. All computers used by TCO must have some form of transferable data storage for the purpose of saving data. These must be rugged enough to survive under adverse conditions.

Printer Access. The data indicated a need for the ability to print messages, reports, and graphics by personnel at each echelon. This means that there must be at least one printer in each COC that contains a terminal.

Hardware Limitations at the Company Echelon. Concern was expressed about the effects of TCO at the company level. The role of a company is one that requires a high level of mobility over terrain that often is impassable to vehicles. Companies also have a very limited maintenance capability. For these reasons, companies can only support a very limited amount of hardware. TCO must take these limitations into account when assigning hardware to companies. Based on comments made during the assessment, it is envisioned that a company could at most support one laptop computer and could not support any additional power requirements.

Hardware Processing Speed. The processing speed of TCO during FDS-1 was reported to be too slow for actual tactical conditions. The operating speed of the system needs to be increased through improved hardware or software performance.

Extraneous Radio Noise. Each time a transmission was sent via TCO the modem produced a loud buzz through the radio speaker. This noise became distracting when there was a high level of message traffic. Audible indications for data transmissions, if required, should allow the user to either defeat them or adjust the volume.

Jump Command Posts. The current implementation of TCO does not lend itself to the concept of jump command posts. A jump command post must provide a commander access to the key capabilities of TCO from a highly mobile platform. During FDS-1, MARCORSYSCOM sponsored a demonstration of a concept for a jump command post that illustrated many of the requirements of this mobile platform including small-sized computers, HMMWV-mounted hardware powered from the vehicles' power supply, and tentage that could be quickly set up. TCO should be designed to be configured for use in a jump command post.

3.2.2 Usability

Usability refers to how easy it is for the typical Marine to perform command and control tasks with the MMI. FMF personnel opinions regarding the usability of the TCO MMI were somewhat mixed. While many liked the use of a graphical user interface (GUI), others felt that the interface was complex and difficult to train for and use. The following usability design considerations were gathered from the FDS-1 data.

3.2.2.1 Tiled Windows Versus Overlapping Windows

TCO utilized a MMI design philosophy that employed tiled windows, as opposed to overlapping windows (used in the IAS). While the reason for using a tiled window approach to the user-interface is understood (i.e., to preclude the user having hidden windows), the interface was reported to be very busy and cumbersome to use. FMF personnel felt that the implementation of an overlapping window interface with pull-down menus, as opposed to the trays used by TCO, would be easier to use. This would provide the ability to work on textual functions, such as messages and reports, as overlays on the current situation, rather than having to scroll up and down between two tiled windows. It would also allow the user to respond to a message without having to leave the current task. The TCO user interface should be migrated to an overlapping window capability, which will also bring it in-line with the USM MMI guidelines.[a] Additional comments on the use of windows include:

Window Sizing. Apparently, windows in TCO could not be easily sized. If the TCO goes to an overlapping style interface, the user should be able to size the windows, as necessary.

Confirmation Windows. To be effective as an automated tool, TCO needs to include feedback to the operator that requests confirmation of some of the more critical actions. For example, FMF personnel reported that when the user closed a message on TCO it was deleted. TCO should have asked the user whether the message should be saved first. One method for confirming actions suggested by the FMF was the use of pop-up confirmation windows. It is recommended that confirmation windows be incorporated into future TCO design.

Menu Structure. TCO utilized some pull-down, button menus. This was viewed as being a very positive feature, which allowed the user to be able to keep a mental model of navigation through the functional hierarchy. Whether or not a tiled or overlapping window approach is utilized in future versions of TCO, the use of pull-down menus and an understandable mental model of navigation are required.

3.2.2.2 Use of Icons

The icons used in TCO provided a positive visual reference for the users and, by having retrievable data associated with them, enhanced usability. The use of icons should be built on for future versions of TCO.

3.2.2.3 Object Oriented Information Handling

The capability to pick up and drop messages, text, symbols, or other information made operations very easy; this was especially true for building plans and orders. The user could take input from different staff sections and drop them on the appropriate button in the document. The users reported that the pick and drop capability would have been significantly improved if they could have picked up multiple objects and been able to drop an object more that once without having to pick it up again.

3.2.2.4 Button Design

Buttons with different functions and behaviors, for the most part, all looked the same. This provided no visual cues to the user as to the function of a particular button. Ideally, shape

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(a) Avery, L. W., R. V. Badalamente, S. E. Bowser, P. A. O'Mara, and S. E. Reynolds. 1991. *Draft Human Factors Design Guidelines for the Marine Tactical Command and Control System (MTACCS) Marine-Machine Interface.* Prepared by the Pacific Northwest Laboratory for the U.S. Marine Corps Reasearch, Development, and Acquisition Command.

coding should be used to differentiate between labels and control buttons, and between buttons with different types of functions. The buttons should be redesigned to include a visual distinction between buttons used as labels and buttons used for control entry, and between different types of control buttons.

3.2.2.5 Prompts

A key design feature for a user-friendly system is the use of prompts to help the user understand what actions or options are required next. TCO did not have enough of these kinds of context sensitive help features. These should be implemented in TCO.

3.2.2.6 Screen Layout

The screen layout was not as well designed as desired by FMF personnel. For example, the columnar data displays were reported to be difficult to read. For future versions of TCO, the designer should work with the user to ensure that the design of the display formats maximizes readability.

3.2.2.7 Order of Messages, Reports, and Plans in Trays

The order of messages, reports, and plans in their respective trays appeared to be random. These should be ordered in a manner that assists the user, either through frequency of use or alphabetically.

3.2.2.8 Corrupted Data

It was reported that when users attempted to call up a file that had been corrupted, the system crashed. To delete the corrupted file required the contractor to place the TCO into a special maintenance mode. The system needs to be capable of identifying a bad file to the user, and allowing the user to delete or fix the file.

3.2.2.9 Preformatted Messages

While the inclusion of preformatted messages (Reports, Requests, Plans, etc.) was viewed as a very positive feature and an improvement over existing reporting methods, FMF personnel reported that the usability of the preformatted messages implemented in TCO for FDS-1 was somewhat cumbersome and confusing. Suggestions for enhancing the capability included the following:

Incorporation of All Necessary Messages. The message set implemented in TCO for FDS-1 did not include all the messages required by the user. Example additional messages include some of those for NBC, photographic reconnaissance (PhotoRecon), ammunition (Ammo), FragO, situation report (SITREP), and a net status report for SYSCON. TCO should implement all messages required by the user.

Improvement of the Message Queue. The message queue design could be improved by providing an indication of whether an action was required by the recipient or the message was for information only, and providing an indication that a message had been sent.

Message Header Design. TCO did not provide a list of all other recipients of a message, which could account for some of the redundant message problems (discussed in 3.2.1.2). Users may have been retransmitting messages to others that had already received the message. The format of a message, once received by a terminal, should include a list of all recipients.

Text Editing Features. The text editing features in TCO were primitive. They can be significantly enhanced by including more features such as "cut and paste."

Cursor Location in Data Fields During Transmittal. It was reported that unless the user moved the cursor from a data field prior to transmitting the message, the data field was deleted. TCO should preclude the requirement of removing the cursor from data fields prior to transmittal.

Positive Indication of Message Received. The current design of TCO provided the user with two indications that a message has been received: an audible alert and a button that provided a visual indication of the number of messages received. The audible alert was reported to be not loud enough to be effectively heard over typical COC ambient noise levels. The visual indication did not require the user to do any acknowledgement, nor did it provide any additional indication other than cumulative count of the number of messages in the queue. In addition, when working in the current situation display or having scrolled down the tools screen, the status line containing the visual indication of message receipt was not always visible.

Methods for improving the indication of a message received include: allowing the user to set the volume of the audible to compensate for the ambient noise environment; and providing a positive indication of a message received, such as a flashing indication, that requires the user to acknowledge receipt to turn off the flashing. In addition, the status line should always be visible.

3.2.2.10 System Status and Warning Buffer

TCO did not save system status and warning messages in a buffer, and a historical record of these could be critically important in diagnostics. This capability should be implemented in TCO.

3.2.2.11 Data Entry Procedures

Data entry procedures were viewed as being, overall, fairly easy due to the ability to pick up and drop information. The following comments and suggestions for data entry procedures were reported:

Data Field Entry. TCO for FDS-1 used a method for filling data fields, such as message addresses, that required the user to make selections from predetermined options by clicking on constantly visible buttons. This tended to clutter the display. A better method may be selecting options from lists contained in pop-up menus.

Error Checking. Users seemed to be somewhat confused about whether TCO provided error checking of data entry. Regardless, future versions of TCO should assist the user by performing some degree of error checking during data entry.

Requirement to Erase Data Fields. When calling up a preformatted message, report or request, the data fields were frequently filled with information from the previous time they had been used. This was especially true for free text messages. This required the user to type over or delete information. TCO should implement the preformatted template capability so that, when called up by the operator, the templates only include specific default information such as unit and DTG.

Data Field Clearing. TCO only allowed the user to clear fields by placing the cursor at the beginning of a field and pressing "Delete." A better method for erasing fields should be incorporated. An example would be a "cut" function that allows the use to highlight areas of text for deletion, much like a standard word processing application package. In addition, the user should be able to easily erase an entire message, rather than field by field.

Requirement for Data Field Completion. TCO would not allow the user to type "not applicable (NA)" or "unknown" in data fields. In addition, a message could not be sent with blank fields, with the exception of the "To" field. Future versions of TCO should allow the user to indicate that a field is not applicable to the message, but ensure that when required fields are left blank, the user is prompted for entry.

3.2.2.12 Display of Journal Messages

According to the FMF, TCO only allowed for the display of a few lines of a journal message. The user should be able to open a window that displays the full message, if desired.

3.2.2.13 Outgoing Message Acknowledgement in Journal

When an outgoing message was placed in the journal, there was no indication in the journal of it being received by the recipient. The journal should have the capability for automatically providing an acknowledgement indication for outgoing messages.

3.2.2.14 Printing

There were a number of difficulties with printing reported by the FMF. These included the following:

Lack of WYSIWYG. TCO was not a true "what you see is what you get (WYSIWYG)" graphical user interface. The format of the hard copy sent to the printer differed from that on the display screen. This caused confusion to the user. TCO should implement WYSIWYG in its design.

Journal Entry Number on Hard Copy. FMF personnel felt that when an entry had been printed from the journal, the journal number should be included on the hard copy for ease of cross-referencing.

Lockout of Multi-tasking. When printing, the system could not perform any other tasks. This appeared to be due to the lack of a printer spool or buffer. While this may be a limitation of the hardware used for FDS-1, future versions of TCO should allow the user to truly multi-task, printing while performing other tasks.

3.2.2.15 Graphical Indication of Net Member Status

TCO provided a very good graphical indication of the status of net members, either a "?" or a "X" across the symbol in the "Who's There" tray. This was reported to be a good feature.

3.2.2.16 Graphic Symbology

The following problems and suggestions regarding the graphic symbols were reported:

Symbol Query. TCO needs to have the capability for user query of symbols on the current situation display. The prototype used during FDS-1 was reported to have this feature, but it only called up messages associated with the symbol. The user could not specify information to be acquired from a data base (as in AFATDS) that would pop up in windows when a symbol was queried (e.g., highlighting a symbol and double clicking). This capability should be implemented in TCO.

Positive Indication of Symbol Movement. When a unit is moved due to automatic update of position by PLRS, the terminal needs to provide a user selectable positive indication through both an audible and visual signal requiring acknowledgement. The user should have the capability to specify which unit movement should be accompanied by this positive indication and which should not.

Availability of Symbols Tray. The symbols tray, during FDS-1, apparently was only available from the current situation display. FMF personnel reported that they would have liked to have it available when preparing reports.

Offsetting of Symbols. When symbols on the current situation display are collocated, the operator had to perform specified procedures for offsetting the symbols. The need for offsetting of symbols is viable, but the procedures were cumbersome and difficult. The capability for the operator to be able to move a symbol by hooking (selecting) the symbol, then dragging it to a new position while maintaining its relationship to its true location should be explored for implementation.

Locating Unit Symbols. One of the difficulties experienced by users during FDS-1 was locating specific units on the situation display. The display itself only provided a small window into the larger situation map. The user found it very difficult to locate a specific unit without having knowledge of approximate grid location. TCO needs to allow the user to specify a unit and have the system identify its location, preferably by highlighting it on the current situation display.

Current Situation Map Improvements. FMF personnel felt that the current situation map capability could be improved by allowing the user to stack multiple symbols, and reducing map symbols so that they did not include any symbols below company level.

Designation of Control Points. TCO did not allow the user to include a visible name or designation of control points such as check points, contact points, or coordination points. TCO should implement this capability.

Symbol Creation. To create multiple symbols, the user must first open the symbol creation function, create one symbol, close out that function, move to the current situation display, and place the symbol. Then, these steps must be repeated for each additional symbol. This becomes very tedious and time consuming. The user should be able to keep both functions open and easily move from one to the other.

3.2.2.17 Lack of Positive Indication of Restored Communications

It was reported that when there was a loss of communications with a net member, a status message appeared in the status message box. When communications were restored with the net member, there was no positive indication. The user had to keep checking the "Who's There" tray. This was a distraction. The possibility of including an indication of restored communications should be investigated.

3.2.2.18 System Initialization Procedures

The initialization procedures, while eliminating the requirement to enter subscribers, tables, and addresses, were described by some of the users as being too complex due to a number of factors. These included the use of terms that were not necessarily part of the normal FMF vocabulary. In addition, the process for initializing the communications links was complex, with operators having to select devices of which they had little knowledge and having to select these devices in a very proscribed manner.

Initialization procedures and terminology should be simplified. One method would be to establish basic mechanisms whereby the user's log-on would automatically configure the system. In addition, the procedures for the establishment of communications pathways needs to be simplified.

3.2.2.19 Undo and Abort Function

TCO needs the capability for undoing or aborting of a control action by the user.

3.2.2.20 Grid Accuracy

Grid information in FDS-1 required an entry of 10 digits. Typically the infantry operations personnel use only six. The users should be able to select the accuracy of grid information according to their needs.

3.2.2.21 Function Keys as Accelerators

TCO used programmable function keys as accelerators for control actions. This was viewed as a positive attribute.

3.2.2.22 Indication of Memory Space

FMF personnel felt that one of the potential causes for some of the failures experienced during FDS-1 was through the over-allocation of memory space. There was no method available to verify this. The internal system diagnostics should include a routine that checks memory allocation and provides an indication to the user when it reaches a predetermined percentage.

3.2.2.23 Save to Drive Procedures

The procedures required for saving information to a drive were very complex and difficult. The user should be able to save to either the hard or floppy drive very easily. One method suggested by the FMF was a "Save" button. If this approach is taken, appropriate checks and confirmation prompts should be included.

3.2.2.24 Scrolling of the "Who's There" Tray

When a terminal's net membership was large, the user had to scroll the "Who's There" tray to see all members. This was reported to be too cumbersome. It was suggested that the symbols in the tray be made smaller to allow for full display of all members. The concept of the "Who's There" tray is good; the best way to implement it needs to be determined.

3.2.2.25 Approve Button

The approve button illustrated a violation of one of the basic tenets of human factors design in that it did not always behave consistently. The resulting action seemed to vary depending on the report or system feature. Control buttons should behave consistently.

3.2.2.26 DTG Update

The operator should have the capability to easily update the DTG, much like on COTS computer systems.

3.2.2.27 Lock Out of Control Action

The TCO appeared to respond like many other systems in that when a message was being received, it locked out current data input capability. While this is not necessarily a problem when the lockout is only milliseconds, for TCO it could be a problem due the length of time required to received some of the large files that contained the current situation overlay. Methods to allow TCO to receive a message without halting all other processing need to be investigated.

3.2.3 TCO Interface Requirements

The TCO interface requirements to other MTACCS systems identified below are based on user-generated functional requirements and do not include technical interface design considerations. During FDS-1, users identified information exchange requirements between TCO and six MTACCS systems. Analysis of the data indicated that there appears to be a direct correlation between the maturity of each system's design and the specificity of users' perceived requirements for its interface with TCO. This is understandable when viewed from the perspective that the more defined the system, the better users understand what it is potentially capable of exchanging. However, the implication of this is that it is likely there are interface requirements which exist but have not been recognized. The global recommendation is made that each system interface identified with TCO be separately examined by teams consisting of appropriate users and persons with detailed knowledge of the interfacing system.

3.2.3.1 TCO to ATACC

A confirmed requirement existed for information exchange between TCO and ATACC.

Air Tasking Order. There is clear consensus that the DASC, MEB, RCT and BSSG headquarters want to electronically receive and monitor the execution of the Air Tasking Order (ATO). Not so clear, however, is the concept of exactly how this should occur. Currently, the TACC sends the ATO to addressees as record traffic; ATACC provides for generation of this in United States Message Text Format (USMTF). At a minimum, this message must be sent to TCO electronically, with no human intervention, to allow its viewing by operators on TCO terminals. It appears that there may be a valid requirement to design a portion of the TCO database to store data on individual ATO missions and to implement the ATO as a databasable message. The additional implementation of messages updating the status of various missions could then allow TCO operators to monitor the ATO execution via database queries or spreadsheet displays.

Exchange of Graphical Information. There is a requirement for the electronic exchange of selected graphical information between the two systems. The definition of the information required for exchange is incomplete. However, it appears that ATACC requires unit locations, some tactical control measures, such as boundaries, objectives, forward edge of the battle area (FEBA), forward line of own troops (FLOT), etc.; some fire support coordination measures, such as fire support control lines (FSCL), no fire areas (NFA), airspace coordination areas (ACA), etc.; and indirect fire weapon fire fans. TCO appears to require some ATACC special points, such as combat air patrol (CAP), corridor, search and rescue (SAR), etc.; missile engagement zones; friendly air defense coverage diagrams; and enemy air defense locations. Further investigation is recommended to identify specific information exchange needs.

Real-Time Air Picture Display. There is an indication that some means of displaying the real-time air picture is desired/required at the MAGTF command element. The cited operational reason for this is to allow the MAGTF to monitor the execution of the ATO in general, and to track air missions to targets in particular. Should this be confirmed as a requirement, the use of an interface between ATACC and TCO to provide this is not recommended, as this information can be better obtained from the Joint Air Command and Control Interface via tactical digital information link (TADIL).

Location Data. There is a consistently identified requirement for locations to be transmitted and received using either LAT/LONG or military grid coordinates. It is a mandatory requirement that both systems implement the identical coordinate conversion algorithm(s).

3.2.3.2 TCO to FIREFLEX

There is a definite requirement for an electronic interface between TCO and the Marine Corps fire support system (MCFSS, AFATDS).

Graphics Information Exchange. Graphics information exchange between the two systems is a confirmed requirement; the requirement for exchange of textual information is less definite. TCO needs to be able to receive and display all fire support graphics which would be present on a fire support overlay (FSCL, Coordinated Fire Lines [CFL], NFA, etc.), as well as locations of fire support assets. Planned targets, groups, series, programs and the like are also desired. The textual information required appears to be oriented toward the transfer of word processing files rather than toward operational messages.

Information Exchange During Planning and Execution. TCO operators envision that the electronic interface would be used during both planning and execution. During planning, fire support appendices and overlays would be prepared by the Fire Support Coordinator on the FIREFLEX system and then transferred to TCO for approval, incorporated into the operations plan/order, and subsequently transmitted to recipients. During the execution of the plan/order, however, the only need would be to display the appropriate fire support coordination measures. It was generally indicated that the display and monitoring of targets and related information would serve little purpose and would unnecessarily clutter the TCO screen. It was noted that this information could be readily obtained from a FIREFLEX system terminal which would be in proximity. During both planning and execution, TCO needs the capability to graphically identify locations and transfer this information electronically to the FIREFLEX system display graphics without human translation.

TCO to FIREFLEX Information Exchange. FIREFLEX system operators indicated a need to receive operational maneuver graphics, NBC graphics and unit locations from TCO. During planning, this information would be used to create the complementary fire support appendices and overlays for subsequent transfer to TCO for approval and publication. During execution, selected graphical information (unit locations, objectives, boundaries, contaminated areas, etc.) would be used to make tactical decisions and to coordinate supporting arms.

3.2.3.3 TCO to IAS

There is a requirement for an electronic interface between IAS and TCO to allow the automated exchange of graphical and textual information.

TCO Intelligence Information Requirements. During planning, TCO requires the capability to receive and display intelligence annexes, appendices, and overlays for incorporation into the operations plan/order, and subsequent transmission to recipients. Based on the description of the requirement, it appears that the exchange of textual information in this case involves the transfer of word processing files rather than databasable messages.

TCO Enemy Situation Informational Needs. During the execution of tactical operations, TCO has the requirement to electronically receive and display current enemy situation information from IAS. Required graphical information includes all enemy symbology currently found on a conventional acetate overlay (confirmed units, suspected units, etc.); amplifying textual information should be linked to each symbol. Additionally, it appears desirable that current meteorological information, astronomical information, and passwords and countersigns be readily available to TCO operators in textual form.

3.2.3.4 TCO to MIPS

The requirement for an electronic interface between MIPS and TCO is unclear. Virtually all the data identifying this as a requirement is traceable to Marine administration personnel who used MIPS during FDS-1. There is no instance where this interface is recorded as a requirement by Marines identified as operations personnel. In nearly every case where the interface is recommended, the supporting reasons include and/or emphasize the use of TCO to transmit and receive personnel-oriented messages and reports between other MIPS terminals. Because of this aspect, it is not unreasonable to speculate that the real requirement identified may be for intra-MIPS communications instead of an automated interface to TCO.

3.2.3.5 TCO to MILOGS

The requirement for an automated interface between MILOGS and TCO is unclear; however, some type of electronic interface appears to be warranted. Almost all the data identifying this interface as a requirement is traceable to Marine logistics personnel who used, or were exposed to Marine Air Ground Task Force (MAGTF) II, Landing Force Asset Distribution System (LFADS), MCLOG and/or Combat Service Support Control System (CSSCS) during FDS-1. It appears that at least some Marines may have confused LFADS with MILOGS and MCLOG with TCO, making the data questionable. As with the MIPS-TCO interface data, many Marine logistics personnel perceive the TCO interface as a communications path between logistics system terminals.

The stated opinion of the commanding officer of the RCT is that commanders require an "executive level" view of MILOGS in TCO. Additionally, he stated that MILOGS can (and presumably should) operate "off-line" at regimental and lower echelons in the GCE. Several logistics officers specifically cite the exchange of SITREP, logistics status report (LOGSTAT) and logistics summary report (LOGSUM) reports/information with TCO as desirable. This needs further definition with G/S-3 and G/S-4 personnel.

3.2.3.6 TCO to PLRS

A confirmed requirement exists for an automated electronic interface between TCO and PLRS. Position location information is critical to commanders and their staffs during the prosecution of combat operations. The capability to have automatically updated unit locations available is desired. The following required improvements to the PLRS automatic tracking implementation observed during FDS-1 were identified.

Visual Identification of PLRS Updated Units. Units which are being automatically updated by PLRS need to be easily identified on TCO displays to reduce confusion. During the assessment, unit positions were updated by a variety of methods. Operators had no quick way of knowing if a changed unit location on the screen was the result of a PLRS update, a received message, or a system error. It is recommended that a symbol modifier be considered to provide quick visual recognition.

Track Quality Indication. Unit locations received from PLRS displayed only the grid location of the unit and did not include the track quality indicator (1-9 or L). The inclusion of the track quality is critical, as it represents the degree of accuracy of the reported location in the PLRS system. For example, a track quality of "L" indicates last known position. If a unit's track is not being reported in PLRS for any reason, the master station maintains its last known location in the database. It is not uncommon for a unit to become temporarily "lost" for reporting due to a variety of reasons. Under these circumstances a unit could move a significant distance and its last known location would continue to be reported to TCO by PLRS. Without the display of the track quality indicator TCO operators would have no indication whatsoever that this might have occurred. It is recommended that future implementations incorporate the PLRS track quality in unit location displays.

Time Stamp Update. As reported in the MCTSSA after action report, when a unit symbol on the TCO screen was queried for information by double clicking on it, part of the information was a time stamp indicating the last update of location. While the PLRS server provided updated information every three to six seconds, this time stamp was only updated when a spot report was received or the PLRS report indicated that the unit had moved at least 200 meters. The time stamp for stationary units needs to be updated more frequently to provide the user with confidence in the location information. It is recommended that future versions of TCO implement a more frequent update of the time stamp.

3.2.4 FMF Personnel Assessment of TCO

This section provides some insights into how the FMF participants perceived the value and usefulness of the TCO system implemented for FDS-1. Data for this section comes from the questionnaires.

Eight commanders, 86 staff officers, and 43 operators responded to questionnaires designed to elicit general and specific information of the effects of TCO on their ability to perform their mission. They were asked to compare the impact TCO had on their ability to perform command and control functions relative to their previous experiences without TCO. Since the commanders, staff officers, and operators perform different functions and have different informational needs, the items for each of the three questionnaires differed somewhat. However, all items were rated using a six-point rating scale. A rating of "1" indicated a negative impact of TCO, and a rating of "6" indicated a positive impact. Respondents could also choose "D" to indicate "don't know" or "NA" to indicate "not applicable."

3.2.4.1 General Information

The items on each questionnaire were organized so that items addressing similar concepts were grouped together. This grouping was derived from the issue categories contained in the Final Draft Evaluation Plan[a] and Section 2.1 of this report. This grouping is used as the

(a) Avery, L. W., D. R. Eike, B. A. Fecht, J. G. Heubach, S. T. Hunt, C. W. Holmes, S. F. Savage, and A. P. Shepard. 1991. *Final Draft, MTACCS FDS-1 Evaluation Plan*. Prepared by Pacific Northwest Laboratoriesfor U.S. Marine Corps Research, Development, and Acquisition Command.

organizational basis for the discussion of responses, but there is not always a one-to-one correspondence with each questionnaire item and a specific issue or criterion from the assessment plan.

Since each group responded to numerous (62 to 90) items, it would be impractical to discuss each item in detail. In addition, the majority of items received a "neutral" rating. Mean ratings between 2.5 and 4.5 were considered to be neutral, indicating neither a positive nor negative impact from the use of TCO. The discussion below will focus only on those items where "extreme" (above 4.5 or below 2.5) mean ratings were given. For those desiring a more detailed examination of the data, each item and its mean response is reported by group in Appendix A.

3.2.4.2 FMF Participants' Background

The commanders indicated that their computer literacy was below average (2.5) relative to other USMC personnel. They also reported that they rarely (2.0) used TCO during FDS-1. This is not surprising since the commanders have both staff officers and operators to interact directly with computers and to provide them with information from them. The staff officers rated themselves slightly above average (3.8) in computer literacy, and as occasional (3.4) users of TCO during FDS-1. The operators rated themselves above average (4.0) on computer literacy and reported that they used TCO frequently (4.7) during FDS-1.

3.2.4.3 Operational Effectiveness Items

Two general categories of items were designed to address issues related to TCO's impact on operational effectiveness. The first was entitled "Operational Effectiveness" on the questionnaires, and refered to TCO's impact on the user's ability to carry out day to day operations. The second category of items was "System Response" and focused on the speed with which TCO was able to perform required operations.

Operational Effectiveness. Of the 21 items in the commander's Operational Effectiveness section, the commanders rated no item above 4.5 and they rated 8 items below 2.5. TCO was rated as having a negative impact on the commanders' ability to detect (2.1), evaluate (2.2), and respond (2.3) to changes in the tactical situation, to plan (2.2), conduct (2.4), and coordinate (2.3) simultaneous employment of forces, and to develop (1.7) and evaluate (1.667) plans and orders. The commanders' comments indicate that they found it easier and more reliable to use the voice communications rather than get the tactical information they needed from TCO. In addition, TCO was considered to be too slow for use in a fast-moving environment. One can conjecture that part of this disaffectation could be due to the difficulties with communications experienced during FDS-1.

The staff officers responded to 22 items in their Operational Effectiveness section. No item was rated below 2.5, and only one item was rated above 4.5. The staff officers reported a slight increase (4.5) in their ability to disseminate logistic and administrative reports and information.

Their comments indicated that when the system was working, it was a great time saver. However, the system was not working a sufficient percentage of the time to see this feature as one that significantly increased their ability to disseminate information.

The operators had 12 Operational Effectiveness items on their questionnaire. Similar to the staff officers, no item was rated below 2.5, and two items were rated above 4.5. They indicated that TCO has a positive impact on their ability to disseminate operational reports and information (4.6), and to distribute plans and orders (4.6). The operators' comments also paralleled those of the staff officers regarding TCO's effect on the speed of transmitting information.

System Response. The staff officers reported that system delays were frequently (2.3) noticed, in terms of response to commands or message transfers. When this occurred, there was little indication of the cause (1.8) and the system rarely (1.8) allowed the process causing the delay to be interrupted. Their comments revealed that system delays (especially in the form of crashes) were more likely when the system was being heavily used. Some conjectured that the crashes might have been due to hardware problems or insufficient memory. However, no cause for delays was ever clearly identified by the system or by the system developer's representatives. In addition to time delays, system crashes resulted in the loss of information. A second type of system delay was caused by the system being required to read incoming messages in the order in which they were received. Several staff officers expressed frustration at not being able to go directly to a high-priority message.

The frequency and duration of system delays was of great concern to the staff officers. In addition, their comments reflected dissatisfaction and impatience with the fact that the cause of the delays was generally unknown and that the crashes were unpredictable. The usual recourse was to reboot the system, which the staff officers felt was an unsatisfactory solution. System reliability was of major importance.

Responses and concerns from the operators were similar to those of the staff officers. They reported that the system rarely (2.3) indicated the cause and estimated duration of processing delays and that the process causing the delay could rarely (1.9) interrupted.

3.2.4.4 Usability Items

The concept of usability has many different aspects. Discussed below are eight aspects of usability that were evaluated for TCO.

Ease of Use. In most cases, the operators were the only personnel to have hands-on experience with TCO. They responded to six items that pertained to the ease of use of TCO. Of these six, four items were rated above 4.5 and none below 2.5. The operators found TCO easy to use (5.2). They rarely (5.0) found the terminology used by TCO to be confusing or misleading, and reported that terms and acronyms were used consistently (4.9) across different screens and functions. Procedures to perform different tasks and functions were also rated as being consistent (4.6). While these ratings for ease of use do not reflect wild enthusiasm for TCO, they do conflict, to a slight degree, with other data collected during FDS-1. Specific causal elements for this are unknown.

Information Presentation. Operators reported that TCO's priority message notification mechanism was moderately (4.6) clear. Their comments indicated that a "beep" signal was not always audible because of the amount of background noise present. Suggestions were made for a blinking signal to indicate a priority message. In addition, operators wanted a mechanism that would allow them to go directly to a priority message, without reading through messages previously arrived.

Data Entry. The operators indicated that data entry procedures were used consistently (4.8) throughout TCO. This was seen as one of TCO's strong points. They rarely (4.6) had to enter data in units that were unusual or out of the ordinary.

Data Display. The operators reported that there were only occasional (4.6) instances when a naturally occurring order in the data was not reflected in the TCO display. One comment suggested that symbols should be listed in unit order.

Screen Design. The staff officers rated the labels used to identify the display screen as easy to understand (4.6), and the operators concurred (5.1). The operators also said that the labels and names used by TCO clearly (4.9) indicated what they were intended to represent. Screen display labels were rated as moderately (4.6) good for indicating where each display screen was relative to other display screens. Comments included suggestions for simpler navigational methods and less cluttered screens.

Network Issues. The staff officers indicated that it was easy (4.7) to locate and enter network addresses for other individual users on the LAN. Some commented that they would like to be able to rearrange addresses as they pleased so that the address tray would not have to be constantly scrolled.

The operators found it easy (4.7) to route appropriate messages and parts of messages to the appropriate organizations and echelons. They also found it easy (5.0) to set up and modify access privileges for individual users and to locate and enter network addresses for other individual users on the LAN (5.2).

Large and Medium Screen Displays. The operators found the text and graphics display characteristics of the large and medium display screens to be acceptable (4.9). They also indicated that it was easy (4.8) to read map legends, labels, and other information through the electronic map overlay.

Electronic Mapping. There were 22 items in the commander's section on Electronic Mapping. Five items received an average rating below 2.5 and two items were rated above 4.5.

The commanders indicated that the map overlay provided by TCO did not meet their requirements (1.3). They also indicated that it was difficult to distribute map overlay information to subordinate units (1.5) and to adjacent units (1.5). The map overlays were not viewed as being an easy way to access friendly force (1.8) or personnel (2.0) information. However, the commanders reported that map symbols were easy to identify (4.6) and that friendly and enemy locations could easily be found on the map (4.6). The commanders' comments indicated that Electronic Mapping was an important capability to have. However, they stated that TCO's implementation was too small, too slow, too cluttered, and lacked terrain features and color coding of symbols, all factors that decreased the Electronic Map's usefulness.

The staff officers gave TCO's mapping capabilities ratings above 4.5 for the display of fire support control/coordination measures (4.7), friendly (but not enemy) unit locations (4.7), tactical control measures (4.6), and man-made obstacles (4.7). Interpretation of fire support control/coordination measures (4.9) and tactical control measures (4.5) were also given ratings above 4.5. Map symbols were rated as easy to identify (4.8) and to be consistent with standard Marine Corps map symbology (4.9). TCO's ability to display current and predicted weather information was rated as poor (1.2), though this was not necessarily a part of the design for FDS-1. The staff officers' comments revealed that the single biggest restriction in using the electronic map was the lack of terrain information. The overlay information was often viewed as useless without the terrain information to provide context for interpretation. In general, the staff officers found the map symbology to be correct (only a few errors were noted) and easy to read. An exception to this occurred when units were close together; then map symbols overlapped each other and became unreadable.

The operators answered 22 items on electronic mapping. Thirteen received a rating above 4.5 and one received a rating below 2.5. Operators report that TCO allowed them to more easily display (5.0) and interpret (5.1) friendly force information, to display (4.6) fire support control/coordination measures, to display (5.2) and interpret (5.0) friendly and enemy unit locations, to display (4.5) friendly force information, to display (4.7) and interpret (4.7) tactical control measures, and to display (5.0) and interpret (4.9) man-made obstacles. Using the map overlays, the operators reported that it was easy (4.9) to access personnel information. Map symbols were rated as easy (4.9) to identify, and generally conformed to Marine Corps map symbology (4.8). TCO's ability to display current and predicted weather information was rated as poor (1.0).

TCO's ability to provide specific unit information by graphically referencing that unit was seen as beneficial. While the comments were generally positive, several suggestions for improvement were made. Operators often found that the map scale was so small that symbols overlapped and created unintelligible clutter on the screen. One operator indicated that NBC symbols would be useful for marking contaminated areas, wind drift, etc. Adding terrain features was also mentioned as highly desirable.

3.2.4.5 Mobility

Commanders rated TCO as having a negative impact on the mobility of their organization (1.9) and their organization's vehicle requirements (1.6). Reasons for these ratings included size, fragility, and power support requirements.

The staff officers also indicated that TCO would have a negative impact on the mobility of their organization (2.1) and their organization's vehicle requirements (1.8). They were emphatic that the current configuration was not mobile. They cited power and communications requirements, system weight, bulk and fragility, and set-up/tear-down times as factors that would inhibit mobility.

3.2.4.6 Training

The thoroughness of the training and the amount of information to be learned were rated as neutral (3.5). The commanders' comments revealed concerns about the length of training required and the depth of computer literacy needed to be an effective operator. The need for simple, easy-to-read user manuals was also stated.

3.2.4.7 Log-On/Log-Off/Security

Staff officers and operators were asked to rate how well TCO prevented data loss resulting from accidentally logging-off and how clearly TCO notified the user when information was updated. Both groups responses were neutral.

3.2.4.8 Jump Command Post

In order to be effective as a Jump Command Post, TCO would have to be smaller, more rugged, less dependent on quality power sources, and be able to work over tactical radios. For these reasons, the commanders rated TCO's suitability for a Jump Command Post as poor (1.8).

3.3 Intelligence

The functional area of Intelligence was represented by a prototype of the IAS. The following observations on the IAS were abstracted from the after action reports of the 7th MEB and Deputy Program Manager (DPM) Intelligence (INTEL).

3.3.1 Number of Stations

FMF personnel believed that the IAS, as fielded in FDS-1, did not provide enough stations at the Marine All-Source Fusion Center (MAFC) or the combat operations and intelligence center

(COIC). They believed that the MAFC should have, for full-time monitoring, the following stations available: watch officer; two ground order of battle analysts; two air order of battle analysts; two collectors personnel; two counter intelligence (CI) personnel; one or two signal intelligence (SIGINT) analysts; two electronics intelligence (ELINT) analysts; and one to two imagery analysts. At the COIC, there should be stations for a journal and workbook, reconnaissance (RECON) liaison, SIGINT liaison, collections liaison, etc. Based on these comments, the required number of stations should be explored for future versions of the IAS.

3.3.2 Single Channel Radio Communications

During FDS-1, the IAS was able to transmit digital data over single channel radio (SCR) sometimes, but the radios had to be tuned to no more than 1 hertz of variance. If a AN\GRA-39 was installed in the communications pathway, communications were lost. In addition, communications using the Protocol Processor Board and the Tactical Communications Interface Module were inconsistent, at best. For future IAS development, the difficulties transmitting data over SCR need to be resolved.

3.3.3 Digital Interface with Other MTACCS Systems

During FDS-1, the IAS could not interface electronically with other MTACCS systems to transmit digital data, the Genser workstation and an air gap was used for data transfer to TCO. This was due primarily to the lack of a current solution to multilevel security. In future versions of the IAS, a solution to the problem presented by multilevel security needs to be implemented.

3.3.4 Message Queue Design

The message queue design for the IAS fielded during FDS-1 required the operator to review messages in the order received. The operator needs to be able to sort and review messages by source, DTG, precedence, etc. This capability should be implemented in future versions of the IAS.

3.3.5 Use of a Windowing Environment for the Marine-Machine Interface

IAS, as fielded in FDS-1, used an overlapping window interface. It appeared that the interface was complicated enough to cause the operator to focus too much on the computer screen. The design of the interface should be simplified in future versions of the IAS to reduce the level of concentration required by the operators.

3.4 Combat Service Support (CSS)

Combat service support during FDS-1 was represented by a number of different systems. On the personnel side the MIPS was the predominant system, along with the MCPERS software designed as the interface between personnel systems and TCO. A number of different systems were used for logistics. These included the Landing Force LFADS, MAGTF II, MCLOG software designed as the interface between logistics and TCO, and demonstrations of the Computer Aided Embarkation Management System (CAEMS), MAGTF Deployment Support System (MDSS) II, and the U.S. Army Combat Service Support Control System (CSSCS). The following sections provide design considerations and observations directed at the MCPERS and MCLOG interface with TCO, LFADS, and MAGTF II.

3.4.1 Personnel Systems

Findings for the personnel systems are discussed in the following.

3.4.1.1 Mass Casualty Reports Capability in MCPERS

Users expressed the desire for a tool in MCPERS that would facilitate the preparation of mass casualty reports. The need for this type of report should be explored.

3.4.1.2 MIPS to MCPERS Interface

MCPERS could read files from MIPS, but MIPS could not read files from MCPERS. For FDS-2, all personnel systems should be able to share information.

3.4.1.3 Casualty Projection (CASPROJ) Information Needs

The CASPROJ requires additional information to ensure a more accurate projection. This additional information should include, but not necessarily be limited to, morale, combat experience, enemy tactics, and fire support and air support superiority. These informational needs should be incorporated into the CASPROJ feature.

3.4.2 Logistics Systems

Findings for the logistices systems are discussed in the following.

3.4.2.1 General Issues

Issues contained in this section relate to capabilities that need to be addressed in the logistics functional area, but do not relate to a specific system utilized in FDS-1. Data for this section was abstracted from the after action reports submitted by the DPM Ground Combat Service Support Command and Control Systems, MCTSSA, and the 7th MEB.

Logistics Tracking System for the MAGTF Command Element. The Logistics systems deployed during FDS-1, such as MCLOG and CSSCS, were focused more on the needs of the

BSSG rather than the MEB command element (CE). The USMC needs to determine what requirements the MAGTF CE has for tracking logistics and personnel information, and develop this capability as part of MTACCS.

Logistics Electronic Overlays. A critical requirement for the functional area of logistics is the development and transmission of logistics specific electronic overlays. During FDS-1, the logistics personnel could develop overlays, but they had difficulty transmitting these to other elements. Future versions of MTACCS need to provide the means to easily develop and transmit logistics overlays.

Automation of the Logistics Operations Center (LOC). The automation deployed during FDS-1 in the LOC at the MEB Headquarters (HQ) was inadequate for the workload. Only one terminal provided the interface between TCO and the logistics area. In addition, FMF personnel believed that the degree of integrated automation for logistics demonstrated during FDS-1 was less than expected. Future development efforts in the logistics area should focus on implementing more integrated and appropriate automation in the LOC.

3.4.2.2 MCLOG

Findings relevant to MCLOG are discussed in the following.

Supply Reports Formats. BSSG personnel reported that the supply reports do not include the capability to determine the difference between the current and previous reports. To make these determinations, the user must recall the previous reports. Supply reports included in the TCO logistics interface should include this capability.

Ammunition and Maintenance Management Capabilities. MCLOG provided little capability for ammunition and maintenance management. The requirements for these capabilities, and a means for providing them, should be explored and implemented as necessary.

Pacing Items and Other Parameters. A capability needed in the logistics area is the ability to set the pacing items and other specific parameters the unit wants to track. This would make it easier for MCLOG or its heir to compute reports.

LOGSTAT Reports. The LOGSTAT reports seemed to be very difficult to prepare and send, especially in the RCT. This may be due to the number of items that were being tracked beyond normal pacing items, causing inordinately large reports; or the use of MCLOG for tracking items that would normally be tracked by LFADS. The RCT reported that the approach for doing LOGSTATs in MCLOG was not totally consistent with their SOPs and it was not flexible enough to make the necessary changes. The requirements for LOGSTAT reporting should be reviewed at all echelons and the necessary flexibility provided in MCLOG to accomplish the task easily.

Message Transmission Delays Due to Report Size. Long reports from the logistics staff, such as LOGSTAT, were seldom transmitted successfully. There were some successful transmissions late in the exercise, so the technical feasibility of sending these reports was demonstrated. Analyses should be performed to determine the maximum length of reports that need to be transmitted over the LAN and WAN. This requirment should be incorporated into the specifications for these systems so that the most effective means for providing the capability can be designed into the logistics systems and other MTACCS systems.

Size of Data Fields. The data field size on the supply report form used in MCLOG for FDS-1 was three characters, which was insufficient. Data fields need to be larger. The required size of all data fields needs to be investigated and appropriate sizes implemented in future logistics systems.

Cumbersome Data Entry Procedures. Some of the reports required complex and cumbersome data entry procedures. For example, when updating the unit LOGSTAT and LOGSUM, the user was required to enter or edit data in a field and then save that field rather than entering all the data and then saving the report as a whole. This lends itself to operator error and takes more time than necessary. Each report should be treated as an entity, allowing for all edits to be performed before saving.

Identification of Equipment. As reported in the MCTSSA after action report, MCLOG identified equipment by nomenclature, rather than by Table of Authorized Material Control Number (TAMCN). This caused items with the same name, such as radio set, to be summarized when each individual type should have been identified. For FDS-2, the logistics systems should identify equipment by TAMCN.

3.4.2.3 LFADS

Data for this section was abstracted from the after action reports submitted by the DPM Ground Combat Service Support Command and Control Systems, MCTSSA, and the 7th MEB.

LFADS Communications. During FDS-1, LFADS was not able to communicate from one terminal to another over the LAN. Future versions need to incorporate the capability to communicate over the LAN and WAN.

LFADS Interfaces. LFADS was not able to electronically interface with either MCLOG or CSSCS, candidate CSS capstone systems. Future versions of LFADS need to incorporate the capability to electronically transmit and receive all required data from the target capstone system.

Marine Integrated Maintenance Management System (MIMMS) Data. FMF personnel believed that MIMMS shared the same basic information as LFADS, and should be an integral part of LFADS. This merging of systems should be explored for future implementation.

3.4.2.4 MAGTF II

Data for this section was abstracted from the after action reports submitted by the DPM Ground Combat Service Support Command and Control Systems, MCTSSA, and the 7th MEB.

Difficulty Changing Force List. At the onset of FDS-1, the MEB staff were disappointed that the force list contained in the MAGTF II did not resemble a maritime prepositioning force (MPF) brigade. The MAGTF II data base was not flexible enough to allow for easy modification of the force list. MAGTF II should implement a design that allows easy modifications to the data base.

Sustainability Algorithms. The most current version of MAGTF II was based on a new data base, and would not perform sustainability calculations. To provide this capability during FDS-1, sustainability calculations were performed with an earlier version of MAGTF II, and the data merged with the new version. This caused the MAGTF II data base to become corrupted, severely limiting its usefulness. Future versions of MAGTF II need to provide the capability for performing sustainability calculations and ensure that there is no corruption of the data base.

3.5 Fire Support

Fire support command and control, during FDS-1, was represented by the Marine Corps Fire Support System (MCFSS). The following observations were abstracted from the after action reports provided by the DPM Fire Support and the 7th MEB.

3.5.1 MCFSS Capabilities

The finding about the MCFSS capabilities are discussed in the following.

3.5.1.1 Supporting Arms Special Staff (SASS) Planning Tool Requirements

The MCFSS fielded during FDS-1 at the SASS was not very well suited for the planning function because it could not be effectively used for deep battle planning because the work-space was limited to a 100 by 100 kilometer grid. In addition, it could not convert between LAT/LONG and UTM and could not use a map zone grid designator. This limited its usefulness in exchanging target information with aviation. In order for the MCFSS (or any fire support system) to be a more complete planning tool for the SASS, these capabilities need to be provided.

3.5.1.2 Target Precedence Lists

MCFSS does not provide the capability to transmit, manage, and store target precedence lists or large, prioritized target files. Fire support systems need this capability.

3.5.1.3 Creation of Mission Schedules

MCFSS did not provide the capability for creating fire, group, or series schedules; the user could only execute them. This capability should be included in future fire support systems.

3.5.1.4 Digital Communications Terminal (DCT) Mission Buffer

The DCT mission buffer was too small for effective communication with the Fire Support Coordination Center (FSCC). The optimum size for the DCT mission buffer should be determined and implemented in the future.

3.5.1.5 Fire Support Coordination Measure Transmission

Marines could only transmit one fire support coordination measure at a time with MCFSS. To be effective, the capability for transmission of multiple coordination measures should be implemented.

3.5.1.6 Additional Tools

To be a more complete fire support system, MCFSS needs to include tools to support naval gun fire (NGF), close air support (CAS), and close-in fire support (CIFS). These should be implemented in future versions.

3.5.1.7 Target Card File System

To be more effective, MCFSS should include the capability for maintaining a target card-type file system to record battle damage assessment (BDA) and target disposition. This capability should be included in future versions of MCFSS or other fire support systems.

3.5.2 Information Exchange with TCO

MCFSS information exchange with TCO is discussed in the following.

3.5.2.1 Autorelay

During FDS-1, MCFSS automatically passed certain types of messages to TCO, quickly overwhelming the TCO terminal recipient. The operator was not able to modify this file transfer function. MCFSS should be designed to provide the operator with flexibility in determining which messages will be automatically transferred to other automation systems.

3.5.2.2 Inability for TCO to Transfer Operational Graphics

TCO was unable to transfer operational graphics to MCFSS. MCFSS operators had to translate free text messages into graphics. The capability for transfer of graphical information from TCO to MCFSS should be implemented.

3.5.2.3 Lack of Capability to Exchange Target Lists

MCFSS could not exchange target lists or blocks with TCO, only single targets. The capability for exchange of multiple targets should be implemented.

3.5.3 MCFSS Hardware Considerations

MCFSS hardware considerations are discussed in the following.

3.5.3.1 Size of Display

FMF personnel at the fire support staff sections felt that the MSD was not large enough. Future versions of MCFSS should provide a LSD.

3.5.3.2 Shelters

The fire support personnel felt that the Deployable Rapid Assembly Shelter (DRASH), used in the DASC, would be ideal for the artillery battalion. In addition, they suggested that it should be covered with an outer lining made of Kevlar or other substance that would provide protection from indirect fire. The implementation of these types of shelters should be explored.

3.6 Aviation C2

The only automated aviation C2 system present during FDS-1 was the Advanced Tactical Air Command Central (ATACC). ATACC equipment was present at the MAG TACC, the Sector Anti-Air Warfare Coordinator (SAAWC), and the DASC. The following observations regarding the aviation automation were abstracted from the 7th MEB after action report.

3.6.1 ATACC

FMF personnel indicated that the ATACC demonstrated great potential. The following suggestions were made.

3.6.1.1 Lack of ATACC Electronic Connectivity to TCO

While not necessarily a planned capability for FDS-1, FMF personnel believed that the ATACC should be able to transmit the ATO or exchange overlays or other information with TCO. Electronic connnectivity between ATACC and TCO should be implemented.

3.6.1.2 ATACC Processing Speed

FMF personnel observed that as the ATACC equipment became more burdened with targets and tasks, the slower the system processing became. In a real tactical situation, the system may not be able to keep up with events. Future versions of the ATACC need to resolve this problem.

3.6.2 IDASC to TCO Interface

During FDS-1, IDASC automation was implemented using a combination of ATACC and TCO equipment. FMF personnel believed that the use of automated and digital burst systems improved operational effectiveness of the DASC. The following observations were made regarding the deployed automation.

3.6.2.1 Interconnection of Agencies

The DASC's connection to various agencies through the TCO interface was not as extensive as it should have been. Future deployments should include digital connection to all agencies requiring communication with the DASC.

3.6.2.2 DCT Lack of Printing Capability

The DCT used in the DASC did not have a print capability, requiring the operator to manually transcribe all incoming reports and requests. Future versions should have either the capability for printing, or provide a digital connection with other systems.

3.6.2.3 DASC to TCO Interface Performance

FMF personnel in the DASC reported that the processing speed of the TCO interface was slow and did not allow multitasking. Future versions should provide a faster processor and allow multitasking.

3.7 FDS Process

The FDS process represents a different approach to Marine Corps acquisition. Because of this it was a learning experience for all participants. Users were generally positive about the concept, and they appeared to appreciate the opportunity to have direct input into the development process. From the perspective of the FMF user, the following are major areas which must be considered during FDS-2 planning.

3.7.1 User Involvement

Success of the FDS process relies heavily on user participation. Early involvement of users in the FDS-2 development cycle is needed to allow users to understand FDS-2 concepts and adequately plan for assessment unit participation. This involvement should begin at the first FDS planning meeting and continue with increasing user presence throughout the FDS-2 development cycle. Additionally, MARCORSYSCOM representatives should establish and maintain FDS-2 visibility at the assessment organization's major headquarters through regular briefings and visits.

3.7.2 Laboratory Testing

The MTACCS systems deployed during FDS-1 were not subjected to rigorous laboratory and integration testing prior to being placed in user hands. Because the FDS-1 assessment was conducted in a field environment, users expected the product to be far more robust and functionally mature than it turned out to be. Instances of system "crashes", data losses, keyboard lockouts, etc. were wide spread and exasperated Marines who were attempting to use TCO and other MTACCS systems under tactical exercise conditions. The lack of system maturity and robustness, coupled with unrealistically high user expectations, influenced users to emphasize negative aspects of the system rather than to identify its potential capabilities. For FDS-2, participating systems must undergo sufficient laboratory and integration testing prior to any field assessment. Additionally, users must be continuously educated on the purpose of the FDS, its objectives, and any known system limitations.

3.7.3 Communications Reliability

The ability of TCO and other MTACCS systems to operate over Marine Corps tactical communications was never confirmed prior to the assessment. Throughout the FDS-1 assessment, MTACCS was unable to consistently establish and reliably maintain communications over field communications equipment. This became a source of continuing frustration for all participants and significantly hindered collecting valid requirements data. Confirmed communications reliability is mandatory to prevent the inefficient use of resources. During FDS-2, equipment should not be taken to field assessment unless it is first clearly demonstrated that it can operate using the anticipated tactical communications equipment.

3.7.4 User Training

Users indicate that overall, TCO system training and MTACCS integrated training did not adequately prepare them for proficient use of equipment during FDS-1. The learning environment (large, crowded, noisy room), inconsistencies between training manuals and actual implementations, system hardware problems, and slow pace of instruction are all cited as contributing factors. It can be inferred from system operator comments that they would have preferred a program of instruction incorporating both traditional classroom instruction to learn system capabilities and characteristics, followed by a period of hands-on experience with practical applications on the actual equipment. Supervisory personnel (officers and staff noncommissioned officers) appear to support this approach as well. For FDS-2 it is recommended that this training philosophy be adopted. It is further recommended that classroom training for supervisors be conducted separately from system operator training, but that a common practical exercise be conducted as a final exercise.

During FDS-1 planning, the training requirements of the TECG did not receive adequate attention. TECG cell assignments were not solidified in time to allow designated system operators and supervisors to form into their representative groups prior to training. As a result, individuals trickled in to training with no concept of why they were there or what their roles were to be. Because they had not been formed into their groups, personnel accountability during training was also affected. In the future when TECG personnel are to be trained, it is recommended that they be assembled one to two days prior to training and provided with administrative instructions and detailed briefings on their roles and assignments.

A final point about training, identified in the MCTSSA after action report, was directed at PLRS training. If the TCO operators, as users of PLI, had received some basic training on PLRS operations, troubleshooting procedures in the field may have been enhanced. For FDS-2, personnel using MTACCS should be provided some training on PLRS prior to the start of the exercise.

3.7.5 Evaluator Observations

While the majority of this report has been a summation of observations, comments, and other data collected from the FMF participants, the evaluators feel compelled to make the following observations regarding the FDS process.

3.7.5.1 Management of Expectations

Participating FMF personnel came into the assessment with a very high set of expectations regarding the sophistication and maturity of the systems involved. These expectations were not met, which created some negative backlash. For future FDS evolutions, the expectations of all participants need to be managed through the presentation of realistic goals for system sophistication and maturity, and the complexities associated with the assessment. As these evolve, the changes need to be communicated to the participants to ensure a common understanding of what can be accomplished. In this way, the participants will not be unpleasantly surprised at the assessment.

3.7.5.2 FDS Schedule

Milestones for the FDS assessment need to reflect a more rigid schedule. Software development should be stopped, and a design freeze implemented well prior to the beginning of the assessment. This will allow for system testing and integration, and debugging of the software. The systems that will be involved in each FDS assessment need to be identified well in advance and controlled to preclude last-minute participants, unless they will be for demonstration only, to ensure proper system testing and integration. This system testing and integration needs to be more formal, with well-defined schedules and test plans. In addition, any COMMEX that precedes the assessment should include utilization of the data systems.

4.0 Final Discussion

FDS-1 was plagued with difficulties, as would be expected for the first evolution of a new design process. These difficulties included systems that were not as robust as hoped, a very hostile assessment environment, technical difficulties in establishing and maintaining communications, configuration management problems, and a significant learning curve required for all participants. Despite these difficulties, FDS-1 generally achieved its goals.

The stated objectives of FDS-1 were to get user involvement in the design process and gain a better understanding of the operational requirements for command and control (C2) systems such as TCO. As Chapter 3.0 of this report indicates, these objectives were met. FMF personnel became very involved in providing insights into their needs for TCO and other C2 systems. An added benefit to this involvement was the insight that FMF personnel gained regarding the future impact of automation on their operational environment.

While it was not possible to quantify exactly what capabilities were provided by the fielded systems, FMF personnel were able to identify a fairly comprehensive list of needed capabilities and design requirements for future TCO and other MTACCS systems. This list will provide a firm basis for the continued requirements definition for each system that is implicit in the FDS process.

In terms of evaluating TCO, as implemented for FDS-1, FMF personnel were ambivalent about how good or bad the system was. With a few exceptions, most of their responses to the questionnaires indicated that the system was perceived as neither an improvement over existing methods nor a hindrance. Possible contributions to this perception include the communications difficulties, high expectations, and the lack of sophistication and robustness of TCO.

A number of points need to be made about the results of FDS-1. First, it is critical that the next phases of development for TCO and other MTACCS systems employ rigorous requirements analyses to determine the exact requirements for automation in the MAGTF. Personnel in all of the COCs could see utility in almost all of the capabilities offered by C2 automation. However, the question they asked was not one of "is this useful?" but "how useful is this?". Before automation is incorporated into a COC, the capabilities it will provide must be shown to justify the burdens inherent with its introduction. One of the primary burdens is the impact the hardware will have on mobility. Other burdens are such things as maintenance and power requirements.

The various capabilities offered by TCO and the other MTACCS systems will have different levels of value at different COCs. What may be extremely useful at the MEB level may have little utility at the infantry battalion level. Similarly, the burdens caused by incorporating additional hardware will vary by COC. For example, FMF personnel in the DASC indicated that an additional terminal would have little effect on DASC mobility while FMF personnel in the infantry battalion COC stressed the difficulty that would be associated with moving a terminal while foot-mobile. The utility and burdens associated for each piece of hardware in an automated C2 system must be examined for each type of COC. These issues must then be weighed against each other to determine what hardware and functional capabilities are appropriate for each echelon.

Second, the successful introduction of TCO or other C2 systems is totally dependent on communications systems. One of the primary, if not the foremost, functions of a C2 system is information transfer. Without the ability to transfer information, an automated C2 system becomes relatively useless. However, development efforts for C2 systems often appear to be focused primarily on the development of information management tools without considering the constraints induced by the communications systems available at the time of fielding. Anyone observing the assessment could easily see the difficulty caused by the inability of TCO to consistently transfer information between COCs.

Third, the development of MTACCS should adopt a systems approach. Each component system must consider not only its own hardware, software, facilities, power and people, but also the other component systems as interrelated parts of the total system. If constraints due to any of the parts put a limit on the performance of the complete system, developers should focus their efforts on designing to that limit.

Finally, the FDS process provides a strong vehicle for both the integration of the user into the design process and the implementation of an evolutionary acquisition approach to system development. But to be fully effective, the FDS process needs to employ a rigorous and integrated methodology. All participants need to be full partners in each evolution, and coordination needs to begin at the start of the cycle and continue throughout. All the participants in FDS-1 have learned a great deal. If this is applied to FDS-2, the USMC will make a strong step towards realizing their goal for implementing automation in the C2 process.

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