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FROM VISION TO INTEROPERABILITY: AN ANALYSIS OF DEPARTMENT OF DEFENSE AND SERVICE INITIATIVES

by

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This paper is an assessment of Department of Defense (DoD) and service initiatives to ensure joint interoperability of Command, Control, Communications, Computers, and Intelligence (C4I) systems. Using a consolidated initiative matrix, visions and actions are reviewed to identify intent, and existing documents used by C4I system planners, designers, and developers are assessed against essential system development criteria, required baseline actions, to achieve interoperability. Findings reveal that interoperability development guidance and tools do not address mission-specific parameters of C4I systems. Not all C4I systems are the same. Mission-specific requirements dictate whether a system is interoperable or not. The current interoperability definition is quite vague for mission-specific systems, and existing DoD and service initiatives only address general guidance to focus system development. Common mission-specific cases are provided and demonstrate that achieving interoperability is more than general guidance and more than the ability to pass data or information through seamless interfaces to ensure that systems are functional. Interoperability must be further defined by analyzing a C4I system's unique mission. Finally, to guide C4I system design, a framework to establish quantifiable thresholds is developed and presented using existing joint doctrine.

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FROM VISION TO INTEROPERABILITY: AN ANALYSIS OF DEPARTMENT OF DEFENSE AND SERVICE INITIATIVES

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ABSTRACT

This paper is an assessment of Department of Defense (DoD) and service initiatives to ensure joint interoperability of Command, Control, Communications, Computers, and Intelligence (C4I) systems. Using a consolidated initiative matrix, visions and actions are reviewed to identify intent, and existing documents used by C4I system planners, designers, and developers are assessed against essential system development criteria, required baseline actions, to achieve interoperability. Findings reveal that interoperability development guidance and tools do not address mission-specific parameters of C4I systems. Not all C4I systems are the same. Mission-specific requirements dictate whether a system is interoperable or not. The current interoperability definition is quite vague for mission-specific systems, and existing DoD and service initiatives only address general guidance to focus system development. Common mission-specific cases are provided and demonstrate that achieving interoperability is more than general guidance and more than the ability to pass data or information through seamless interfaces to ensure that systems are functional. Interoperability must be further defined by analyzing a C4I system's unique mission. Finally, to guide C4I system design, a framework to establish quantifiable thresholds is developed and presented using existing joint doctrine.

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LIST OF ACRONYMS

ABL	Airborne Laser
ASB	Army Science Board
ASCIET 95	All Service Combat Identification Evaluation Team
ATA	Army Technical Architecture
BCIXS	Battlecube Information Exchange System
BDA	Battle Damage Assessment
C4ISR ITF	C4I Surveillance, Reconnaissance, and Integration Task Force
CAS	Close Air Support
CCC	CINC Command Complex
CEC	Cooperative Engagement Capability
CID	Combat Identification
CIDC	Combat Identification Coordinator
CJTF	Commander Joint Task Force
COF	Common Operating Environment
CPI	Codes, Permits, and Inspections
CTP	Common Tactical Picture
CWC	Composite Warfare Commanders
DASC	Direct Air Support Center
DCS	Defense Communications System
DDDS	Defense Data Dictionary System
DII	Defense Information Infrastructure
EO	Electro-Optic
FAAD	Forward Area Air Defense
FIPS	Federal Information Processing
FMFM	Fleet Marine Forces Manual
GCCS	Global Command and Control System

GLOBIXS	Global Information Exchange System
GPS	Global Positioning System
HAE UAW	High Altitude Endurance Unmanned Aerial Vehicle
HCI	Human Computer Interface
HF	High Frequency
ICO	Interface Control Officer
IDEF	Integrated Definition
IDEF0	Integration Definition for Function Modeling
IDEF1X	Definition for Information Modeling
IR	Infra Red
IS	Information System
IW	Information Warfare
JADO	Joint Air Defense Operations
JITC	Joint Interoperability Test Center
JTA	Joint Technical Architecture
JTF	Joint Task Force
JWID	Joint Warrior Interoperability Demonstrations
LAAD	Low Altitude Air Defense
LOS	Line-of-sight
LRE	Launch and Recovery Element
M & S	Modeling and Simulation
MCE	Mission Control Element
MCTA	Marine Corps Technical Architecture
NRT	Near Real-time
NWTDB	Naval Warfare Tactical Database
OOTW	Operations Other Than War
RADC	Regional Air Defense Commander
SAR	Synthetic Aperture Radar

TADIXS	Tactical Data Information Exchange System
TAFIM	Technical Architecture for Information Management
TAR	Tactical Air Request
TBC	Tactical Ballistic Missile
TCC	Tactical Command Centers
THAAD	Army Theater High Altitude Air Defense
TTP	Tactics, Techniques and Procedures
UHF	Ultra High Frequency
VHF	Very High Frequency
WWW	World Wide Web

EXECUTIVE SUMMARY

This paper is an assessment of Department of Defense (DoD) and service initiatives to ensure joint interoperability of Command, Control, Communications, Computers, and Intelligence (C4I) systems. Chapter I provides a starting point for readers to understand DoD and service initiatives. This chapter consists of the following sections: purpose of thesis, methodology, scope of thesis, definitions, background, and outline of chapters. This purpose of thesis section introduces and describes this paper's topic and structure for the reader, and the research methodology section gives the reader a reference perspective for the research and analysis conducted. The scope of thesis section develops the boundaries for the thesis and research. The definitions and background sections list Joint Publication 1-02 definitions that directly apply and establish a broad base for the reader to understand both DoD and service initiatives. Within the background section, overviews of the C4I for the Warrior (C4IFTW) concept, DoD Technical Architecture for Information Management (TAFIM), DoD interrelated architectures, Joint Technical Architecture (JTA), and levels of information system (IS) interoperability are provided.

Chapter II addresses the US Air Force perspective. This chapter contains the following sections: vision, architectures, capabilities planning and architecture management, and conclusion. The vision section introduces the Air Force's HORIZON concept. The architectures section is subdivided into operational, technical, and systems sections to identify service applications. The capabilities planning and architecture management section describes processes established to support the development of interoperable systems; lastly, the conclusion section recognizes that Air Force initiatives are evolving.

Chapter III reviews Army initiatives and is divided into the following sections: vision, architectures, and conclusion. The vision section summarizes the Army's Enterprise Strategy, both vision and implementation plan. The architectures section presents the Army's view of interrelated architectures to support the development of

interoperable systems, and the conclusion section acknowledges that Army initiatives have a well-established starting base and are continually evolving.

Chapter IV presents the US Navy, to include the US Marine Corps. This chapter contains vision, architecture, and conclusion sections. The vision section outlines the Navy and Marine Corps' Copernicus strategy, and the architecture section presents the application of recognized DoD architectures used to achieve joint C4I interoperability. Finally, the conclusion section identifies that Navy and Marine Corps interoperability initiatives are progressing.

Chapters I - IV provide a broad knowledge base of both DoD and service actions to achieve joint C4I system interoperability. Chapter V builds on this to conduct a consolidated analysis of the entire action spectrum. Five examples are presented to illustrate that all C4I systems are not the same--each system has its own unique functional characteristics. This chapter contains the following sections: consolidated initiative summary, similarities and differences, positive actions, further definitions, mission-specific examples, and summary. The consolidated initiative summary section presents a vision, action, and baseline action matrix to analyze DoD and service initiatives. The similarities and differences and positive actions sections provide comments based on the consolidated analysis, while the further definition section identifies areas requiring additional development. Within the mission-specific examples section, five C4I systems that require very different functional parameters to support mission objectives are presented. Each example system subsection is divided into scenario, objective, mission analysis, and conclusions, and examples are further compared using a mission-specific area matrix. The summary section highlights the analysis observations.

Finally, Chapter VI contains conclusions, recommendations, and further areas of research. Building on the previous five chapters, this chapter identifies critical issues, provides direction, and recommends research areas requiring analysis. The conclusions section formalizes identified analysis and observations, and the recommendations section presents three initiatives to enhance the development of joint C4I systems. Lastly, the further research section identifies four areas of study for DoD graduate students.

I. INTRODUCTION

The time is ripe to set a course to resolve our C4I interoperability issues.[Ref. 1]

Colin L. Powell
Chairman of the Joint Chiefs of Staff
12 June 1992

A. PURPOSE OF THESIS

To paraphrase General Colin L. Powell (Retired), the time is ripe to quantitatively define interoperability. Not all Command, Control, Communications, Computer, and Intelligence (C4I) systems are the same. Mission-specific requirements dictate whether a system is interoperable or not. The current interoperability definition is quite vague for mission-specific C4I systems, and existing Department of Defense (DoD) and service initiatives only address general guidance to focus system development. Quantifiable parameters must be articulated for all systems to ensure interoperability. This paper reviews current initiatives, provides an assessment of these initiatives, presents five common examples of mission-specific requirements, and outlines a framework to better quantify system parameters for planners, designers, and developers.

Chapter I provides a starting point for readers to understand DoD and service initiatives. This chapter consists of the following sections: purpose of thesis, methodology, scope of thesis, definitions, background, and outline of chapters. This section, purpose of thesis, introduces and describes this paper's topic and structure for the reader. The research methodology section gives the reader a reference perspective for the research and analysis conducted. The scope of thesis section develops the boundaries for the thesis and research. The definitions section lists Joint Publication 1-02 definitions that directly apply, and the background section establishes a broad base for the reader to understand both DoD and service initiatives. Within the background section, overviews of the C4I for the Warrior (C4IFTW) concept, DoD Technical Architecture for Information Management (TAFIM), DoD interrelated architectures, Joint Technical

Architecture (JTA), and levels of information system (IS) interoperability are provided. The last section outlines the five chapters that follow.

Chapter II addresses the US Air Force perspective. Chapter III reviews the US Army, and Chapter IV presents the US Navy, to include the US Marine Corps. Chapter V is a consolidated analysis with examples that identify the need for mission-specific C4I system profiles, and quantifiable interoperability parameters. Finally, Chapter VI contains conclusions, recommendations, and further areas of research.

B. METHODOLOGY

Using a consolidated initiative matrix, both DoD and service visions and actions are reviewed to identify intent. More importantly, existing documents used by C4I system planners, designers, and developers are assessed against essential system development criteria, and required baseline actions, to achieve interoperability. Findings reveal that interoperability development guidance and tools do not address mission-specific parameters of C4I systems. Common mission-specific cases are provided and demonstrate that achieving interoperability is more than general guidance and more than the ability to pass data or information through seamless interfaces to ensure that systems are functional. Therefore, interoperability must be further defined by analyzing a C4I system's unique mission. Finally, to guide C4I system design, a framework to establish quantifiable thresholds is developed and presented using existing joint doctrine.

With the research methodology given, the following questions were proposed:

- Is the current definition of interoperability adequate to ensure the seamless integration of C4I systems?
- What are the DoD and service initiatives to ensure C4I system interoperability?
- Are there differences in initiatives? If so, why and how do these differences compare?
- Are items, such as system interfaces and timing requirements, adequately articulated through existing modeling techniques?

- Should system modeling be more than defining data elements?
- Should there be interoperability profiles based on quantifiable parameters?

C. SCOPE OF THESIS

As previously mentioned, this paper is an assessment of combined DoD and service initiatives to ensure joint interoperability of C4I systems. Directives, guidance, and technical architectures have been developed to conform to service initiatives in a positive direction, but general definition is not enough. The detail of interoperability differs for each mission-specific case. For a C4I system to be functional, certain system parametric requirements must be met. With the vast amount of participants, standards, and systems involved, solid general guidance enhances the development of interoperable systems, but every system is not the same.

D. DEFINITIONS

Joint Publication 1-02 defines the following terms:

1. Architecture

A framework or structure that portrays relationships among all the elements of the subject force, system, or activity. [Ref. 2]

2. Command, Control, Communications, and Computer Systems

Integrated systems of doctrine, procedures, organizational structures, personnel, equipment, facilities, and communications designed to support a commander's exercise of command and control across the range of military operations. Also called C4 systems. [Ref. 2]

3. Interoperability

- The ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces and to use the services so exchanged to enable them to operate effectively together.
- The condition achieved among communications-electronics equipment when information or services can be exchanged directly and satisfactorily between

them and/or their users. The degree of interoperability should be defined when referring to specific cases. [Ref. 2]

4. Tactical Command, Control, Communications, and Computer Systems

The facilities, equipment, communications, procedures, and personnel essential to theater level and below commanders for planning, directing, and controlling operations of assigned and attached forces pursuant to the mission assigned and which provide(s) for the conveyance and/or exchange of data and information from one person or force to another. [Ref. 2]

E. BACKGROUND

It is DoD policy to acquire quality products that satisfy the needs of the operational user with measurable improvements to mission accomplishment. [Ref. 3] The application of this concept is true for the entire acquisition process and is a cornerstone for interoperability. The threat to the United States has drastically changed, and the way the services fight has been altered to meet this challenge. No longer are there single service operations. Today, a multi-service force meets mission objectives in several operational environments--the battlespace. To better support and improve mission accomplishment, the Joint Staff developed the C4I for the Warrior (C4IFTW) concept.

1. C4I for the Warrior (C4IFTW)

The unifying theme of the C4IFTW concept is to achieve global interoperability that will: allow any Warrior to perform any mission at any time, and any place; be responsive, and reliable, secure; and be affordable. [Ref. 1]

This concept addresses joint force C4I interoperability issues in a evolutionary manner. Building upon lessons learned from previous conflicts, rapidly changing technology, and the changing national security strategy, this concept provides a three phase roadmap to achieve total interoperability of C4I systems. Figure 1 illustrates the Joint Task Force (JTF) C4I objective. The phases of the roadmap are: Quick Fix Phase, Mid-Term Phase, and Objective Phase. [Ref. 1]

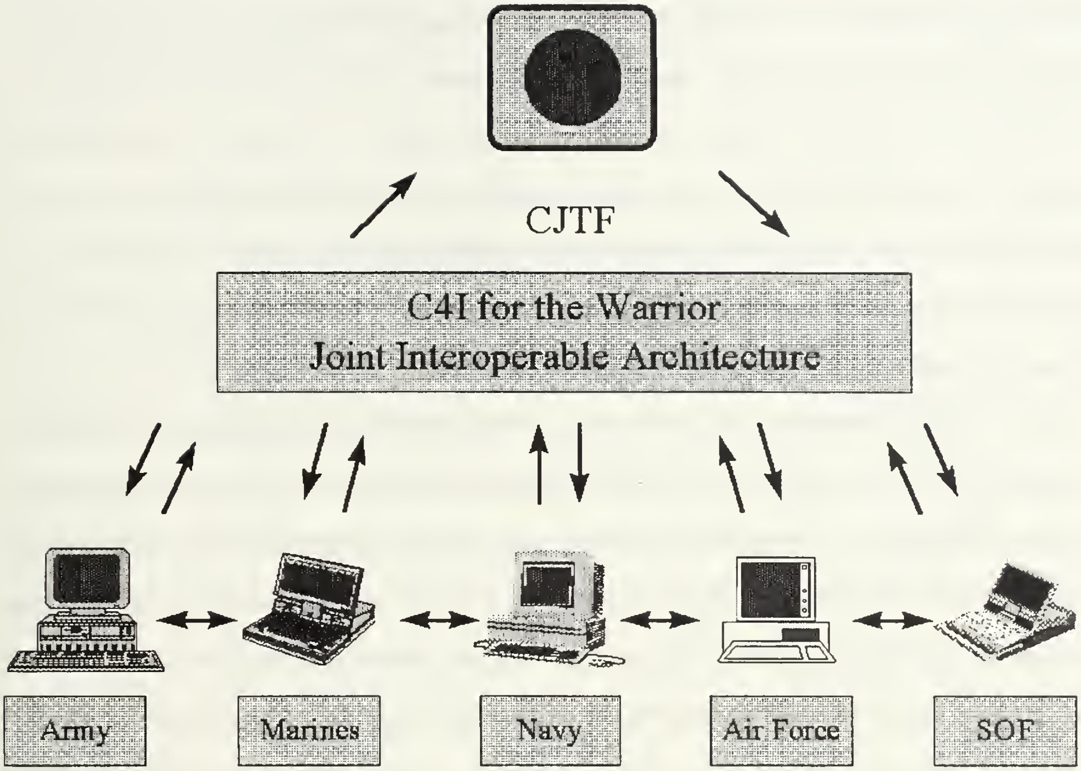

Figure 1. Joint Task Force C4I Objective [From Ref. 1]

The focus of the Quick Fix Phase was to be achieve interoperability of existing systems. [Ref. 1] In 1993, this phase was considered a success based on the following actions: translators and interpreters were developed along with data base interoperability, C4I requirements and architectures were synchronized, and a solid foundation of joint interoperability policy and doctrine was established. [Ref. 4] Items, such as DoD Directive 4630.5, DoD Instruction 4630.8, Joint Publications 6-0 and 6-02, joint training exercises, and the Joint Warrior Interoperability Demonstrations (JWIDs) are products of this phase.

Within the current Mid-Term Phase, total interoperability must be achieved for new C4I systems during development, testing, acquisition, and implementation. Additionally, this includes establishing a joint wide area network based on digital commonality—the Global Command and Control System (GCCS). [Ref. 4] This phase is continually evolving with changing technology, new directives, and updated standards.

Finally, using the experience gained in the first two phases and advancing technologies, the Objective Phase addresses optimizing C4I support for the Warrior. The objectives are to create a multi-functional, multimedia terminal fitted to the Warrior's manprint, a fully integrated tactical picture based on fused information from the battlespace and an integrated global infosphere. [Ref. 4]

2. DOD Technical Architecture for Information Management (TAFIM)

The Technical Architecture for Information Management (TAFIM) is designed to guide the development of the DoD infrastructure. It provides the services, standards, design concepts, components, and configurations to guide the development of technical architectures. The TAFIM promotes interoperability of information systems, but does not address mission-specific applications/systems. Within the DoD, using the TAFIM is mandatory. If everyone follows the DoD directive to use it, more C4I systems will become more interoperable. The proper application of the TAFIM is expected to: [Ref. 5]

- Promote integration, interoperability, modularity, and flexibility
- Guide acquisition and reuse
- Speed the delivery of information technology with lower costs

The TAFIM Version 2.0 is divided into the following volumes: Volume 1, *Overview*; Volume 2, *Technical Reference Model*, a conceptual model for information system services and their interfaces; Volume 3, *Architecture Concepts and Design Guidance*, concepts and guidance to support the development of technical architectures; Volume 4, *DoD Standards-Based Architecture Planning Guide*, a standards-based architecture planning methodology; Volume 5, *Support Plan*, describes how to use TAFIM guidance for acquisition (Draft); Volume 6, *DoD Global Security Architecture*, common DoD security requirements; Volume 7, *Information Technology Standards Guidance*, DoD profile of standards; and Volume 8, *DoD Human Computer Interface*

(HCI) Style Guide, a common framework for HCI design and implementation. [Ref. 5] TAFIM, Version 3.0 *Draft*, is currently posted for review on the world wide web (WWW).

3. DOD Interrelated Architectures

With the rapid growth of architectures in recent years, the DoD defined an interrelated set of architectures to support the development of interoperable systems: Operational, Technical, and Systems. The Operational Architecture describes the tasks, operational elements, and information flows required to accomplish or support a warfighter function. The Technical Architecture is the minimal set of rules that governs the arrangement, interaction, and interdependence of the parts or elements whose purpose is to ensure that a system satisfies a specified set of requirements. The Systems Architecture is the descriptions, including graphics, of systems and interconnections providing for or supporting a warfighting functions. Figure 2 illustrates the relationships of these architectures. [Ref. 6]

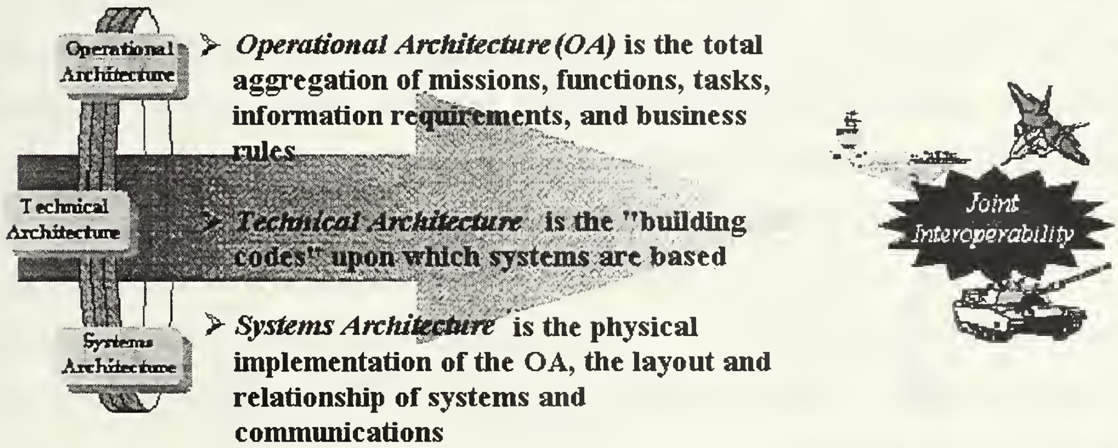

Figure 2. Relationships of Architectures [From Ref. 6]

4. Joint Technical Architecture (JTA)

On 12 March 1996, the Joint Technical Architecture (JTA), Version 0.5 Preliminary Draft, was posted for evaluation on the WWW. This document was developed by a working group using the Army's Technical Architecture (ATA) as a starting point; the ATA will be covered in Chapter III. The JTA has three mutually supporting objectives: [Ref. 6]

- To provide the foundation for a seamless flow of information and interoperability among all tactical, strategic, and sustaining base systems that produce, use, or exchange information electronically.
- To mandate standards and provide guidelines for system development and acquisition which will significantly reduce cost, development time, and fielding time for improved systems.
- To influence the direction of the information industry's technology development by stating the DoD's direction and research and development investment so that it can be more readily leveraged in systems within DoD.

Eventually, the JTA will apply to all systems that produce, use, or exchange information electronically. This initial version is focused on C4I systems and their interfaces with other entities, such as weapon systems, sensors, office automation systems, etc., to support interoperability. Operational requirements developers will use the JTA to guide the development of requirements and functional descriptions. System developers will use the JTA to ensure that new and upgraded systems meet established interoperability requirements, and system integrators will use this document to facilitate the integration of both existing and new systems.

The JTA contains the following seven sections: Overview, Information Processing Standards, Information Transfer Standards, Information Modeling and Data Exchange Standards, Human-Computer Interfaces, Information Systems Security, and Emerging Standards. [Ref. 6]

Section 4, Information Modeling and Data Exchange Standards, identifies the minimum information standards applicable to information modeling and exchange of information for all DoD programs. The Integrated Definition (IDEF) modeling methods have been adopted by the DoD to support the identification of information and information exchange requirements for the development of interoperable systems. Federal

Information Processing (FIPS) Publication 183, Integration Definition for Function Modeling (IDEF0), is used to guide activity modeling, while FIPS Publication 184, Definition for Information Modeling (IDEF1X), is used to govern data modeling. Using a common language, IDEF0 activity models capture an organization's processes at the highest logical levels. Processes are further decomposed into lower logical levels to uncover supporting processes. [Ref. 6]

The DoD created the Defense Data Dictionary System (DDDS) to provide a single authoritative source for data standards. Managed by DISA, the DDDS, a DoD-wide central data base, includes standard data entities and elements and access to data models. Also, the DDDS is used to collect individual data standards and document content and format for data elements. An objective view of how the adopted modeling methods and data standards will support the development of interoperable systems is depicted in Figure 3.

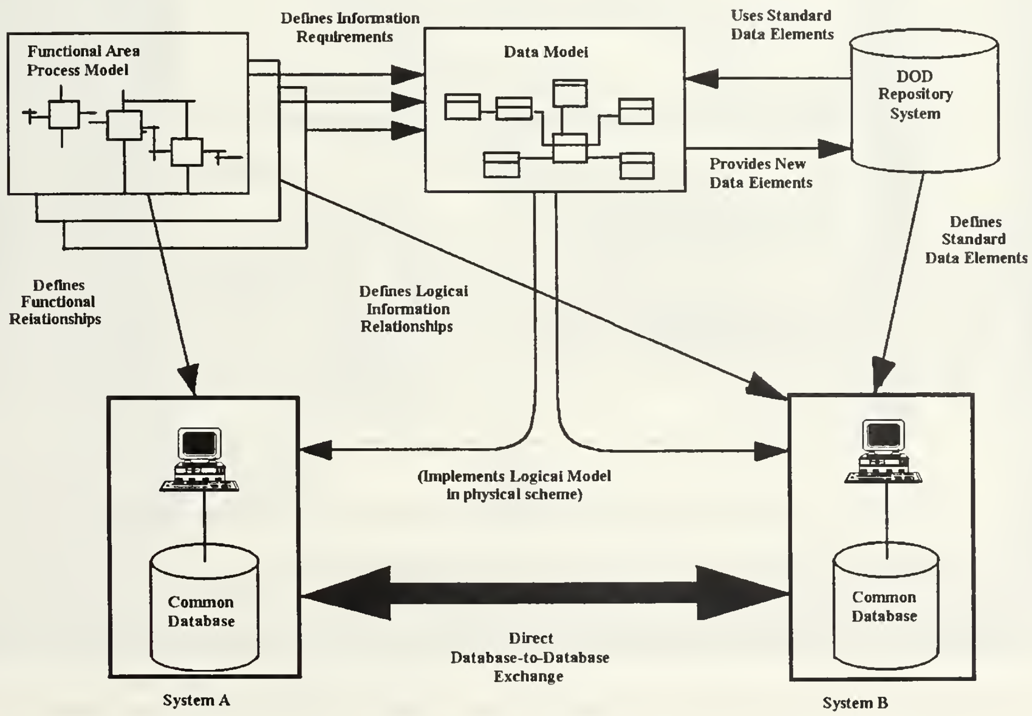

Figure 3. Objective Information Standards Technical Architecture [From Ref. 6]

5. Levels of Information System (IS) Interoperability

In 1993, DoD services and agencies realized that the existing interoperability definition was insufficient. As a result, a simple six-level construct was developed to describe different levels of interoperability. Figure 4 provides a description of these levels along with enabling capabilities for each level. [Ref. 7]

	Levels of Information Exchange and Manipulation	Enabling Capabilities
5	Limited capability for multiple users to build, share and manipulate common picture of the battlespace	DBMS Queries File Exchanges
4	Exchange of complex (multi-media) products	Compound Documents Multimedia Products Annotated Imagery
3	Exchange of simple (single-medium) products	File Transfer e-Mail with Attachments Unformatted Text Formatted Messages Formatted Text Graphics Imagery MC&G
2	Analyst-to-analyst informal dialogue	Basic e-Mail Chatter
1	Single-terminal analyst/windowing of remote products/services (cut-and-paste capability)	VT100/200 IBM 3278/9 NVDET
0	Fundamental link, network, and object-transfer ability	Transport Network Datalink Physical Network Connection

BASIC → COMPLEX

Figure 4. Levels of Interoperability (circa 1993) [From Ref. 7]

In April 1995, the Joint Interoperability Test Center (JITC) expressed an interest in pursuing the levels construct as a basis for joint systems certification, and recently, the C4I Surveillance and Reconnaissance Integration Task Force (C4ISR ITF) endorsed the concept. The MITRE Corporation recently updated the concept to integrate the planned functions of the Defense Information Infrastructure (DII), emerging Internet services, and six NATO interoperability levels. Currently, MITRE is coordinating with key DoD organizations for levels refinement. [Ref. 7] Figure 5 depicts the revised levels construct.

The revised construct contains three interoperability categories: transaction, service, and application. The transaction category addresses the ability to establish a connection between discrete systems and conduct basic exchanges of data. The service category addresses the interoperability effects of: distributed computing services, community leveraging of common solutions, establishing standard system and user interfaces, and exchanging more complex data types. Finally, the application category addresses the establishment of the C4ISR IS objective based on C4IFTW vision. [Ref. 7] The categories are further subdivided into levels as annotated in Figure 5.

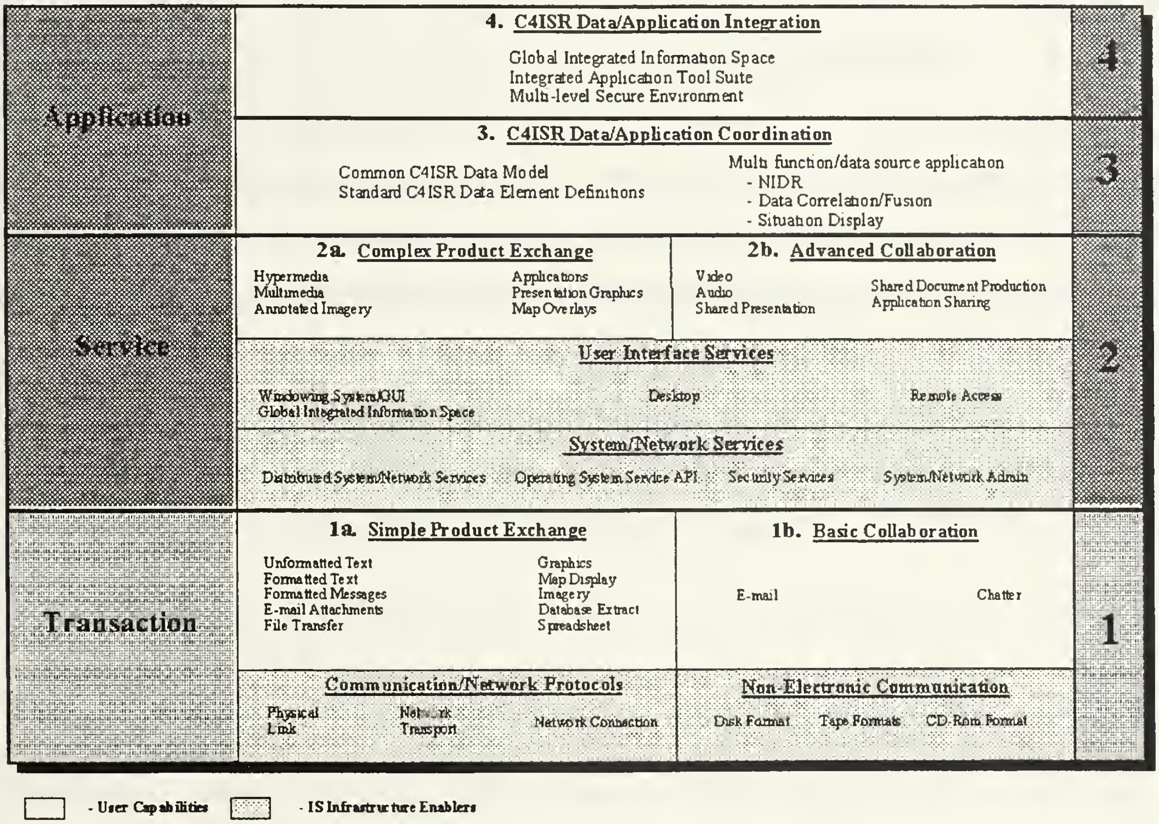

Figure 5. Revised IS Levels Construct [From Ref. 7]

F. OUTLINE OF CHAPTERS

1. Chapter II - United States Air Force

This chapter summarizes the US Air Force's HORIZON vision and supporting actions to achieve interoperability. The service perspective and existing tools in use are described to outline the Air Force's perspective to develop interoperable systems.

2. Chapter III - United States Army

The US Army's Enterprise vision and implementation plan are presented along with the established processes to achieve the development of interoperable systems.

3. Chapter IV - United States Navy and Marine Corps

The Copernicus vision and Marine Corps Technical Architecture are discussed to outline the US Navy and Marine Corps' actions to ensure the development of interoperable C4I systems.

4. Chapter V - Analysis

Chapter V provides a consolidated view of the DoD and service initiatives to address interoperability of C4I systems. Documented actions are compared and consolidated within an analytical matrix format. Mission-specific interoperability profiles are presented to clearly identify that individual system requirements may require different design parameters for systems to function.

5. Chapter VI - Conclusions and Recommendations

This chapter contains conclusions, recommendations, and further research areas based on the Chapter V analysis. A framework to quantify C4I system parameters is outlined.

II. UNITED STATES AIR FORCE

> History has shown that the side that effectively analyzes, decides, and acts the fastest will prevail in any conflict. We can and must make optimum use of information technology to operate inside any opponent's decision cycle. [Ref. 8]
>
> Ronald R. Fogleman
> USAF Chief of Staff
> August 1995

A. INTRODUCTION

With the world changing, information is becoming a new center of gravity—a strategic asset, inviting attack and requiring protection. Before, warfare was only considered in air, land, sea, and space operational environments, but the Air Force has now recognized information as a fifth operational environment. Information dominance is crucial to military success across the spectrum of conflict. [Ref. 8]

Chapter II contains the following sections: vision, architectures, capabilities planning and architecture management, and conclusion. The vision section introduces the Air Force's HORIZON concept. The architecture section is subdivided into operational, technical, and systems sections to identify service applications. The capabilities planning and architecture management section describes processes established to support the development of interoperable systems; lastly, the conclusion section recognizes that Air Force initiatives are evolving.

B. VISION

In 1993, realizing the importance of information technology, the US Air Force developed the HORIZON concept as an extension of the Joint Staff's C4I for the Warrior (C4IFTW) construct for joint interoperability. This concept focused on information architectures to develop an integrated and responsive global infosphere that supports both Global Reach and Global Power objectives. For the first time, the Air Force sought to define a path to a service-wide architecture of C4I systems. This past year, the Air Force updated their vision with C4I HORIZON '95. This document expands the previous HORIZON vision by establishing 21st century information infrastructure objectives and plans for rapid integration of evolving technology within the current and future infrastructure. C4I HORIZON '95 contains the visions for achieving information superiority and leading the US Air Force into the information age. This updated edition defines a planning perspective and evolutionary path for information systems and the application of information technology across the spectrum of Air Force operations. [Ref. 8]

C. ARCHITECTURES

With the vision to seamlessly integrate information systems, the Air Force created a framework to coordinate and integrate related major command (MAJCOM) information architectures. As defined by the Defense Science Board, and previously mentioned in Chapter I, background section, the Air Force adopted the three broad constructs for information requirements and planning: operational, technical, and system architectures. [Ref. 8]

1. Operational

The Air Force models operational architectures that represent a description of the tasks, operational elements, and information flows required to accomplish or support a warfighting function. [Ref. 8]

2. Technical

The Air Force is currently drafting a service technical architecture that will be released for review on the WWW in May or June 1996. The architecture will reflect a minimal set of rules governing the arrangement, interaction, and interdependence of the parts or elements of a system. [Ref. 8] Until the service technical architecture is finalized, C4I system designers are required to use established technical reference codes (TRCs). To assist C4 systems designers during acquisition and modification of C4I systems, the USAF created TRCs. TRCs are a set of reference documents containing policy, directives, transition guidance and standards that designers can easily access using various web browsers on the WWW. They assist planners with standardizing systems to ensure interoperability of future developments. TRCs bring together government and non-government standards and Air Force and DoD policies and guidance for C4I systems and system components of both fixed and deployed systems. TRCs are based on the TAFIM, and they articulate standards to ensure interoperability. Through the process of combining standards and interoperability related documents, a detailed profile is created for almost every conceivable system; therefore, solid guidance for interoperability is provided. [Ref. 9]

There are two types of TRCs: Component and Service. Information for Component TRCs is organized by categories of system components, and information for Service TRCs is organized by user C4I system capability. Usually, Component TRCs are used for smaller acquisitions and piece-part buys, while Service TRCs address larger acquisitions and procurement of a C4I user requirement capability. [Ref. 9] Table 1 outlines the orientations of both TRC types.

***Service TRCs* Tend to Address:**	***Component TRCs* Tend to Address:**
Larger Acquisitions	Smaller Acquisitions
Entire C4I Systems	Individual Components of C4I Systems
Broad-Based Ideas	Commercial-Off-The-Shelf Solutions
Abstract Interoperability Guidance	Interoperability Guidance For Specific Components
Concerns For System Designs	Strategies For Meeting The Specifications of System Design

Table 1. Orientation of Service and Component TRCs [From Ref. 9]

As users access TRCs for information, they start with top level requirements and move down the tree structure depicted in Figure 6. Depending on the level of detail and information required, users may have to reference one or more sub-levels to collect all necessary standards. This may require access to both Component and Service TRCs. [Ref. 9]

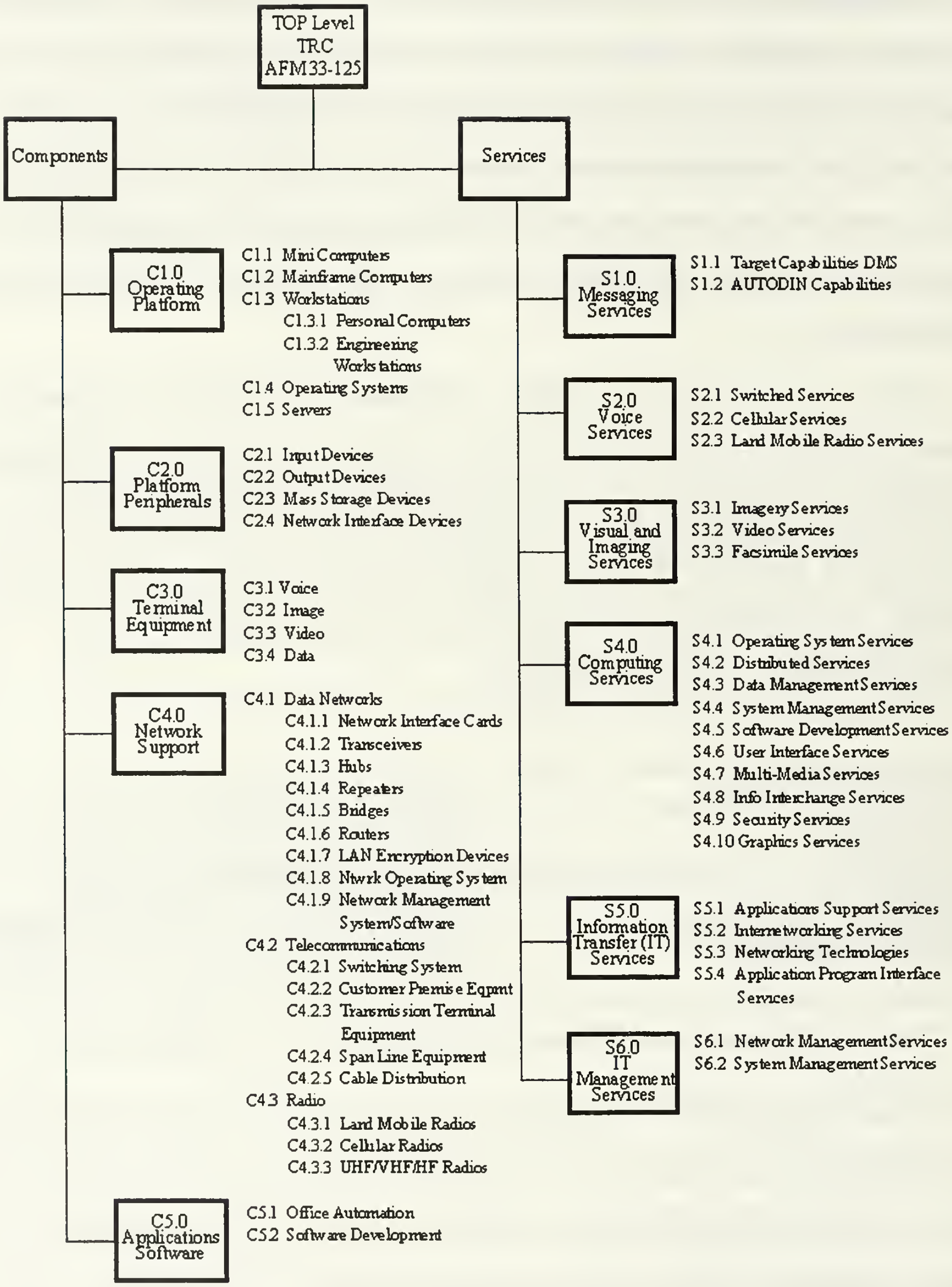

Figure 6. TRC Tree Structure [After Ref. 9]

3. Systems

The Air Force further defines their C4I systems through system architectures. These architectures provide a description, including graphics, of the systems and interconnections providing for or supporting a warfighter function. [Ref. 8]

D. CAPABILITIES PLANNING AND ARCHITECTURE MANAGEMENT

The C4I capabilities planning process, Figure 7, is designed to link operational needs to architectures, and provide a top-level, enterprise-wide view, so systems architects may design fully integrated joint C4I systems. [Ref. 8] Automated tools are used to display, analyze, and manage key architecture elements and interconnections within the service and external entities, such as other DoD organizations and coalition forces. [Ref. 8]

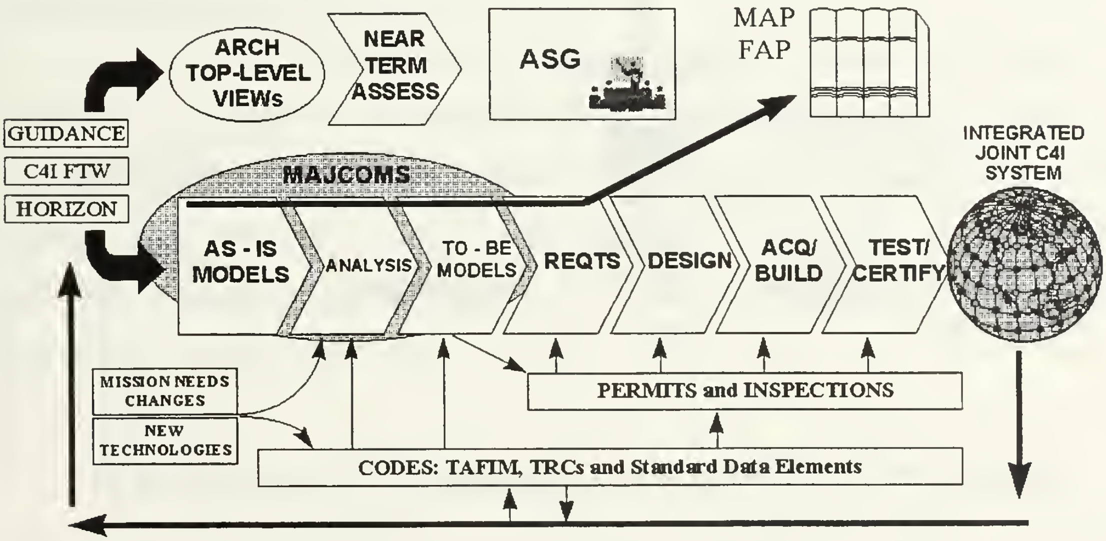

Figure 7. C4I Capabilities Planning Process [From Ref. 10]

The Air Force is institutionalizing C4I Codes, Permits, and Inspections (CPI) to ensure that C4I capabilities and architectures are used throughout the requirements, acquisition, and testing processes. This guides system acquisition to ensure developers follow established building codes. [Ref. 8]

Figure 8 illustrates the HORIZON architecture management process. Within this process, a database is used to develop service-wide architectures. Eventually, the database will be automatically updated from MAJCOM architectural activity databases and tools. Emerging modeling and simulation techniques are used to facilitate architecture development. [Ref. 8]

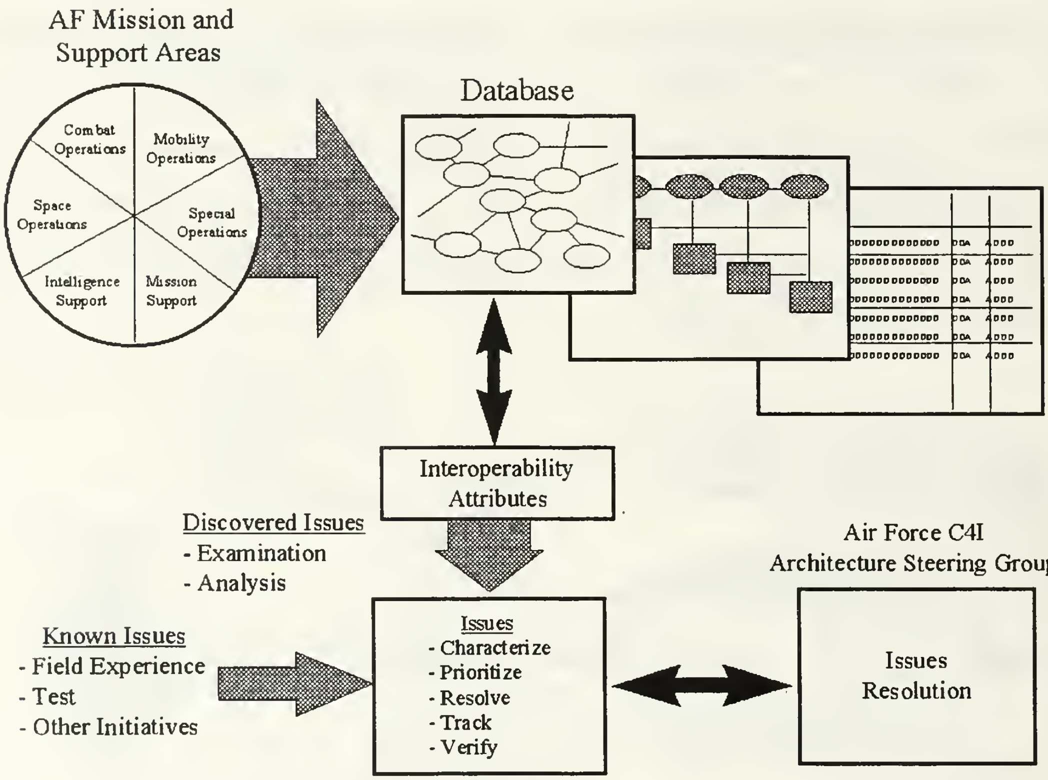

Figure 8. HORIZON Architecture Management Process [From Ref. 8]

E. CONCLUSION

The Air Force's strategy to ensure interoperability is continuously evolving. Many actions outlined within the HORIZON vision have taken place, while others are currently being developed and refined. To better guide Air Force personnel through C4I capability development, paperless information sharing is established via the WWW.

III. UNITED STATES ARMY

> As we know, the challenges of joint interoperability are great. The Enterprise Strategy is the framework by which we will meet and conquer these challenges. It is a vision for present and future information support for our Total Army.[Ref 11]
>
> Gordon R. Sullivan
> General, United States Army
> Chief of Staff
> 20 July 1993

A. INTRODUCTION

Recent history and changes in the world have altered the focus for today's armed forces. Today's threats are less defined and pose unique challenges for warfighters to counter. From the Army's view, countering tomorrow's threats requires "Winning the Battlefield Information War."[Ref. 11]

Chapter III is divided into the following sections: vision, architectures, and conclusion. The vision section summarizes the Army's Enterprise Strategy, both vision and implementation plan. The architectures section presents the Army's view of interrelated architectures to support the development of interoperable systems, and the conclusion section acknowledges that Army initiatives have a well-established starting base and are continually evolving.

B. VISION

As stated in *Army Enterprise Strategy: The Vision*, the purpose of the Army Enterprise Strategy is to support US Army warfighters into the 21st century. The strategy is designed to: unify the C4I community toward a common goal; establish a structure to guide the system development process; develop economic, functional, and technical guidelines and criteria to aid resource managers in making C4I system assessments; and provide a broad systems perspective across DoD. [Ref. 11]

As previously mentioned, for the Army to counter today's threats, warfighters must "Win the Battlefield Information War." Through the exploitation of information technology, this goal is achievable. That is why the Enterprise Strategy focuses on identifying, supplying, and implementing sophisticated information and other C4I technologies in support of the warfighter. [Ref. 11]

The Enterprise Strategy contains both a vision and an implementation plan. The vision introduces and explains ten principles needed to ensure the warfighter has information superiority over any adversary. The following principles are exclusively taken from the Enterprise vision document: [Ref. 11]

- Focus on the Warfighter - Provide the Warfighter C4I systems that meet validated needs.
- Ensure Joint Interoperability - Provide the Warfighter C4I systems that interoperate in Joint and Combined operations.
- Capitalize on Space-Based Assets - Provide the Warfighter assured access to mission essential military and commercial space-based systems that support the Force Projection Army across the entire operational continuum.
- Digitize the Battlefield - Provide the Warfighter an integrated digital information network that supports warfighting systems and assures C2 decision-cycle superiority.
- Modernize Power Projection Platforms - Provide the Warfighter a modern power projection platform to support peacetime operations, mobilization, force projection, split-base operations, and redeployment.
- Optimize the Information Technology Environment - Provide the Warfighter with more efficient information support for combat and peacetime operations.
- Implement Multi-Level Security - Provide the Warfighter the ability to access and exchange information at needed levels of classification using a single C4I system.
- Acquire Integrated Systems Using Commercial Technology - Provide the Warfighter C4I capabilities that leverage commercial technology.
- Ensure Spectrum Supremacy - Provide the Warfighter electromagnetic spectrum supremacy in order to maximize the benefits of maneuver and tempo in conjunction with firepower.

- Exploit Modeling and Simulation - Provide the Warfighter with cost effective training, testing, and rapid prototyping through state-of-the-art modeling and simulation.

As indicated by the principles, the present and future ways the Army intends to conduct military operations is going through a dramatic change. The operational environment is no longer a localized area or geographically contained. The intelligent application of Information Age technology will equip warfighters with the necessary tools to access critical information and enhance coordination for the successful execution of joint or combined operations.

Based on the sound principles established within the vision, the implementation plan provides an assessment of existing systems, an investment strategy or blueprint for the future, and an action plan to implement the strategy. Specific tasks are identified and responsibilities are assigned to focus a unified effort. [Ref. 12]

C. ARCHITECTURES

Due to the rapid growth of architectures within the C4I and information system communities in recent years, the Army Science Board (ASB) conducted a study in the Summer of 1994. As a result, an interrelated set of architectures was defined: Operational, Systems, and Technical. As mentioned in Chapter I, these concepts were adopted by the DoD as well as the Army Enterprise Strategy. [Ref. 13] Figure 9 illustrates the relationship among these architectures. This figure along with the architecture definitions differ slightly from Figure 2, Relationships of Architectures, and definitions presented in Chapter I; the Army Technical Architecture (ATA) was the starting point for the JTA and has been further developed with other service documents by a multi-service committee to support the joint community. [Ref. 6] The following architecture definitions were exclusively taken from the ATA.

1. Operational

The Operational Architecture, often graphical, describes force elements and information exchange requirements between these elements. [Ref. 13] The Army is currently developing these architectures based on the Force XXI initiative, a reconceptualization and redesign of the force at all echelons. The application of advanced technology on today's modern battlefield is altering these architectures.

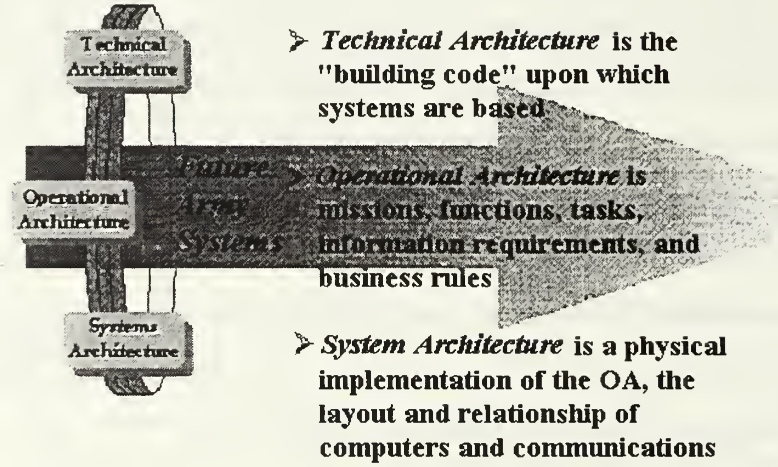

Figure 9. Different Architectures [From Ref. 13]

2. Technical

As defined in the ATA, the Technical Architecture is the minimal set of rules that governs the arrangement, interaction, and interdependence of the parts or elements that together may be used to form an information system. The ATA is recognized as a set of "building codes" and applies to all systems that produce, use, or exchange information electronically. Released 30 January 1996, Version 4.0 is based on the TAFIM, DoD Directive 8320-series governing standardization, and the Army's initiatives to streamline the acquisition process. Articulated in the ATA are three mutually supporting objectives: [Ref. 13]

- To provide the foundation for seamless flow of information and interoperability among all tactical, strategic, and sustaining base systems that produce, use, or exchange information electronically.

- To provide guidelines and standards for system development and acquisition that will dramatically reduce cost, development time, and fielding time for improved systems.

- To influence the direction of the information industry's technology development and research and development investment so that it can be more readily leveraged in Army systems.

The ATA consists of the following six sections: Overview, Information Processing Standards, Information Modeling and Data Exchange Standards, Human-Computer Interfaces, and Information Security.

3. System

The Systems Architecture is the description, including graphics, of the systems solution used to satisfy the warfighter's Operational Architecture requirement.

D. CONCLUSION

The Army Enterprise Strategy starts with sound principles to establish a tightly focused vision for the Army C4I community. By using a process-oriented view for joint C4I systems development, the Army will achieve intended objectives outlined within the Enterprise Strategy. As with all initiatives concerning interoperability within DoD, the process is evolving.

IV. UNITED STATES NAVY AND MARINE CORPS

> We have to be able to adapt quickly to changing technology to fight and win wars in the Information Age. It is clear that information has become a major factor in warfare and will grow in importance in the next century. [Ref. 14]
>
> Admiral J. M. Boorda, USN
> Chief of Naval Operations
> February 1996

A. INTRODUCTION

As the Information Age emerged, the US Navy recognized the potential of using information as a warfighting tool. In response, the Navy developed a strategy to make C4I systems more responsive for the warfighter. For modern warfare in the joint battlespace, the requirement for information dominance has become essential. Information-based warfare allows warfighters to increase the operational tempo of battle by exploiting advanced weapons technology. [Ref. 14]

This chapter contains vision, architecture, and conclusion sections. The vision section outlines the Navy and Marine Corps' Copernicus strategy, and the architecture section presents the application of recognized DoD architectures used to achieve joint C4I interoperability. Finally, the conclusion section identifies that Navy and Marine Corps interoperability initiatives are progressing.

B. VISION

Copernicus provides a focus for the Navy and Marine Corps to make C4I systems more responsive to the warfighter, to field C4I systems more quickly, to capitalize on the advances of technology, and to shape doctrine with these changes. In 1992, the Navy and Marine Corps team published *"...From the Sea,"* and along with Copernicus, these documents reflect the shift from a maritime, open-ocean warfighting environment to joint operations in the littoral. Copernicus is designed as a user-centered C4I information management architecture; this provides a framework for capturing technological change.

[Ref. 14] Warfighters are supported at all levels: watchstander, shore commanders, Composite Warfare Commanders (CWC), and Commander Joint Task Force (CJTF).

Exclusively defined in *Copernicus...Forward*, Copernicus contains the following five essential elements that provide architectural oversight to leverage the C4I infrastructure effectively and enhance the C4I operational perspective. [Ref. 14]

- Seamlessly blend, through common applications in one workstation, critical tactical, operational and administrative data to the warfighter, thus allowing tactical objectives to drive operations.

- Assimilate required information rapidly through standardized data formats, permitting operational commanders and users to "pull" desired information to accomplish tasks. A two-way intelligent "push" capability supplements user-pull when required and prevents information overload.

- Provide information using integrated data formats in a multimedia environment where form fits function (i.e., voice, video, imagery, and tactical data at high speeds).

- Provide a common operating environment (COE) that standardizes workstations for the operator. Workstation and user interface standardization permits greater operator proficiency while reducing training requirements.

- Use common building blocks for modular and standardized hardware design, which permit upgrades and additions to the architecture in an expeditious manner.

Copernicus, a framework of five interactive pillars, links command and control processes at all echelons of command. The pillars include: Global Information Exchange System (GLOBIXS), a system that supports commanders through access to a series of wide area Defense Communications System (DCS) networks; CINC Command Complex (CCC), a primary gateway for communications and information flow from GLOBIXS to deployed forces via Tactical Data Information Exchange System (TADIXS); TADIXS, tactical networks connecting to the CCCs with the Tactical Command Centers (TCCs); TCC, a forward deployed command center, ashore or afloat, that disseminates information to the warfighter; and Battlecube Information Exchange System (BCIXS), a system that supports the battlecube in which tactical forces operate. [Ref. 14] Figure 10 depicts the pillars of Copernicus.

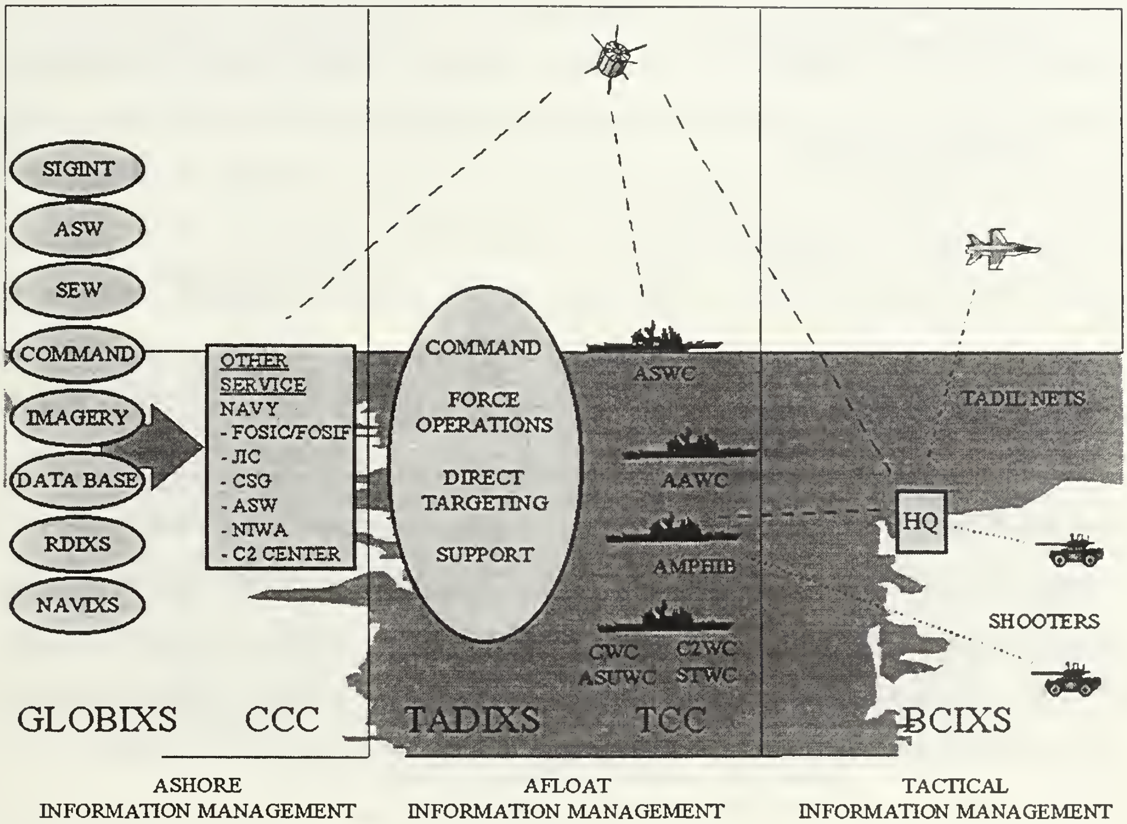

Figure 10. Pillars of Copernicus [From Ref. 14]

Copernicus provides four essential C4I functions: common tactical picture (CTP), connectivity, sensor-to-shooter, and information warfare (IW). The CTP is the information from sensors to the shooter that allows the tactical commander to understand the battlespace, and connectivity links communications nodes to implement the sensor-to-shooter construct. This construct focuses on the process of putting the weapon on target. The migration of the decision-making process from upper echelons down to the tactical commander, or shooter, provides a true sensor-to-shooter environment. As illustrated in Figure 11, the span of control compresses under the sensor-to-shooter construct. Finally, information warfare (IW) is any action to confuse or destroy the enemy's information and/or information systems while leveraging and protecting friendly information and/or information systems to achieve information dominance. [Ref. 14]

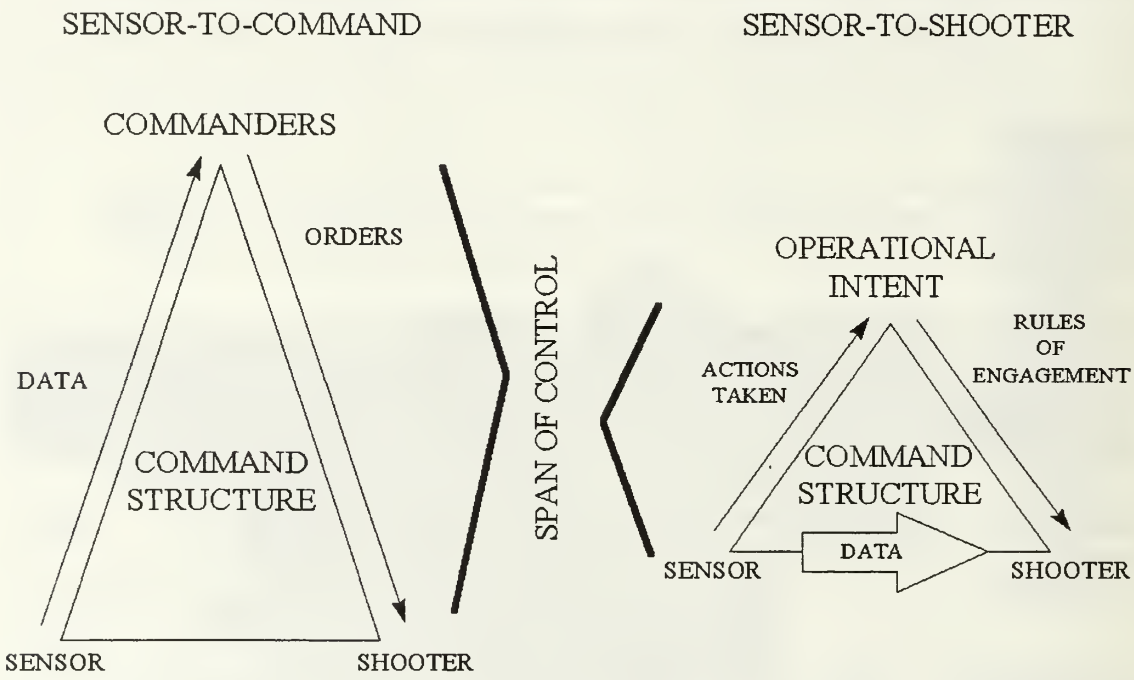

Figure 11. Span of Control [From Ref. 14]

C. ARCHITECTURES

As defined by the Defense Science Board, and previously mentioned in Chapter I, background section, the Navy adopted the three broad constructs for information requirements and planning: operational, technical, and system architectures.

1. Operational

The Navy and Marine model operational architectures that represent a description of the tasks, operational elements, and information flows required to accomplish or support a warfighting function.

2. Technical

The Navy does not have a technical architecture, but expects to fully embrace the JTA as the draft becomes final. Currently, the TAFIM, supplemented with Naval publications, is used to guide system development. For example, the Naval Warfare Tactical Database (NWTDB) Standards Manual provides data element formats and inter-system database exchange structures for system developers, database producers, and operational users. It contains administrative information needed to integrate standards into existing systems, data models, data sets, and data elements that support the evolving DoD standards. [Ref. 15]

Figure 12 is the Navy's objective C4I database architecture. This shows a common interface language or data transfer structure that is required to support common processing in an open systems environment. The database architecture is composed of: standardized data elements, which facilitate the exchange of data by automated systems; normalized logical structure, which provides a standard for human and machine to relate and exchange data; and designated sources, for the production of reference data. [Ref. 15]

In October 1995, the Marine Corps published a technical architecture that applies to all Marine Corps programs for Command and Control (C2) systems. This document provides a minimal set of rules for system development and is designed to ensure interoperability among operating forces, the Marine Corps supporting establishment, and joint C2 systems. The architecture leverages commercial technology and defines Marine Corps specific standards where joint standards do not exist. As with all interoperability documents, this one is continually evolving and future versions will reflect changes in Navy and Marine Corps efforts and interoperability requirements with other DoD agencies. [Ref. 16]

This Marine Corps Technical Architecture (MCTA) is divided into the following sections: Overview, Information Processing Standards, Information Transfer Standards, Information Standards, Marine-Machine Interfaces, and Minimum Desktop Computer Configuration and Software Product Requirements.

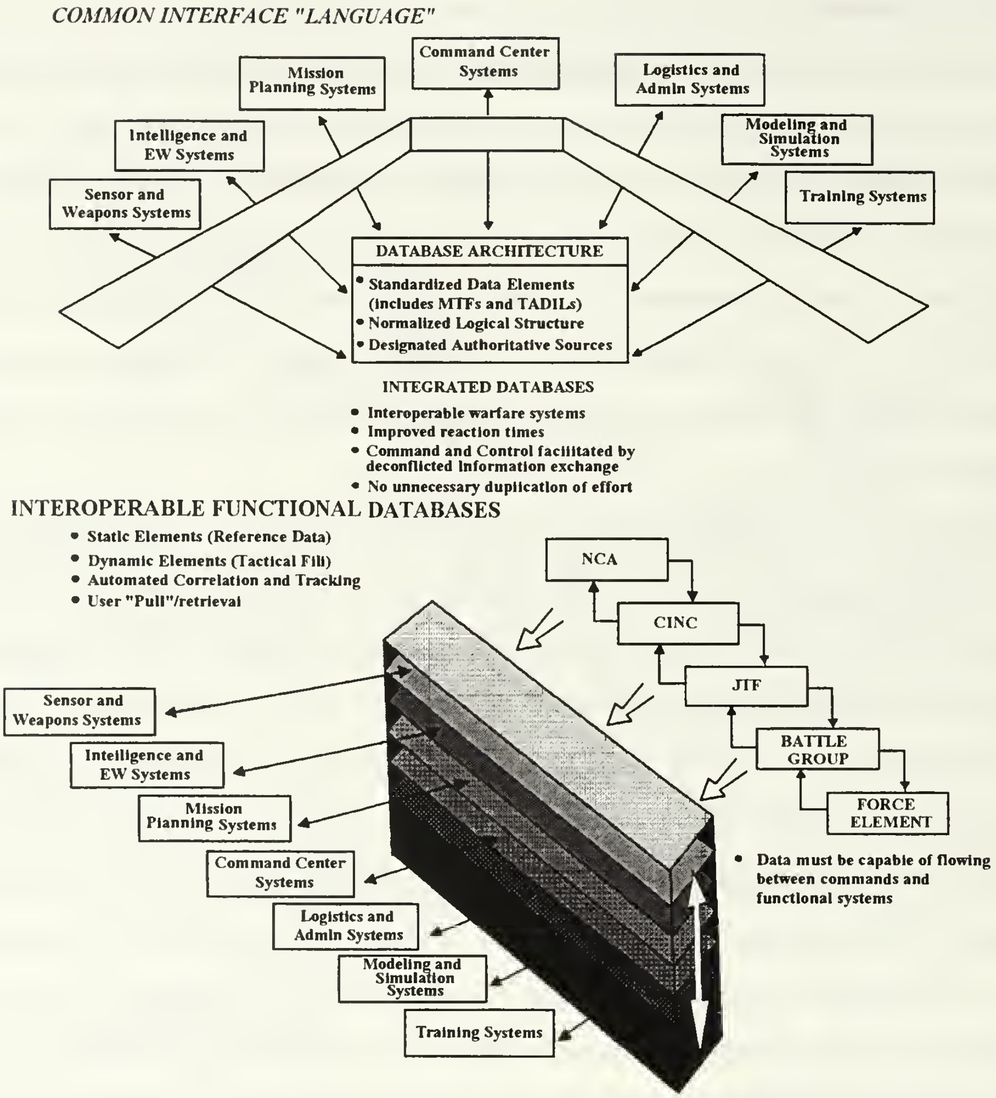

Figure 12. Objective C4I Database Architecture [From Ref. 15]

3. System

The Navy and Marine Corps use systems architectures as descriptions, including graphics, of systems and interconnections providing for or supporting warfighting functions.

D. CONCLUSION

Copernicus, the Navy and Marine Corps strategy to achieve joint C4I interoperability, is fielded and operational, but is continually evolving. Recently, key agencies from the Navy and Marine Corps met to focus Copernicus efforts toward improving support for the Navy and Marine team. By leveraging commercial technology and following simple rules for C4I development, interoperability will be achieved and will lower the cost of information by optimizing a system's ability to reach more users. [Ref. 16]

V. ANALYSIS

A. INTRODUCTION

The previous chapters introduced and provided a broad knowledge base of both DoD and service actions to achieve joint C4I system interoperability. Chapter V builds on this to conduct a consolidated analysis of the entire action spectrum. Five examples are presented to illustrate that all C4I systems are not the same--each system has its own unique functional characteristics, and mission-specific qualities are identified.

This chapter contains the following sections: consolidated initiative summary, similarities and differences, positive actions, further definition, mission-specific examples, and summary. The consolidated initiative summary section presents a vision, action, and baseline action matrix to analyze DoD and service initiatives. The similarities and differences and positive actions sections provide comments based on the consolidated analysis, while the further definition section identifies areas requiring additional development. Within the mission-specific examples section, five C4I systems that require extremely different functional parameters to support mission objectives are presented. Each example system subsection is divided into scenario, objective, mission analysis, and conclusions, and examples are further compared using a mission-specific area matrix. Finally, a summary section highlights the analysis observations.

B. CONSOLIDATED INITIATIVE SUMMARY

After reviewing the Joint Staff's C4IFTW documents, a general list of actions to achieve interoperability was prepared to compare DoD and service initiatives to ensure interoperability. From this, a consolidated initiative matrix, Table 2, was developed to compare service vision and implementation documents. Table 2 is divided into three major sections: vision, actions, and baseline actions (today). The vision identified within the C4IFTW concept is:

- Achieve global C4I joint interoperability,
- That will allow any Warrior to perform any mission--anytime, any place,
- That is responsive, reliable, secure, and
- That is affordable. [Ref. 1]

In Table 2, the vision section denotes the key documents that provide each service's vision to achieve interoperability. The actions section contains explicit tasks outlined in the C4IFTW vision that must occur to attain this goal. Most of these actions are Mid-term Phase actions as outlined by the C4IFTW roadmap. Documents identified are not all-inclusive, but the list provides starting points that formalize system development to pursue interoperability. Finally, the baseline actions section contains publications and tools that are used by C4I system planners, designers, and developers today.

As noted from the publication dates, the efforts to reach interoperability are continually evolving. The actual content from the publications provided may have the same purpose, but there are different objectives to meet individual service needs and expectations.

C. SIMILARITIES AND DIFFERENCES

As identified in Table 2, there are some similarities and differences between DoD and service actions. Even though this table provides differences from service-to-service, readers must address the specific content of these documents to identify the actual similarities and differences for each service.

Every service has a vision, and each vision is tailored to support individual service needs and expectations. For example, the Army is the lead service with respect to the definition and development of technical architectures, while the Air Force has much success with employment of paperless information sharing and TRCs via the WWW.

Consolidated Initiative Matrix	DOD	USAF	USA	USN/USMC

Vision
• Achieve global C4I joint interoperability that
  • will allow any Warrior to perform any mission--anytime, any place,
  • is responsive, reliable, secure and
  • is affordable.
	C4IFTW	Horizon	Enterprise	Copernicus

Actions • Pursue an implementation strategy that finds solutions to interoperability problems and places the solutions in the hands of the Warrior	C4IFTW	Horizon	Enterprise	Copernicus
• adopt and use common information exchange standards to achieve interoperability among existing as well as future systems	DOD TAFIM	DOD TAFIM TRCs	DOD TAFIM ATA	DOD TAFIM MCTA
• fully integrate interoperability into policy, doctrine, and system acquisition processes for all new C4I systems and modernization programs	DODD 4630.5 DODI 4630.8 Joint Pub 6-0/-02 DOD Reg/I 5000.1/.2R	evolving	evolving	evolving
• describe C4I modular building blocks in technical detail	DOD TAFIM JTA DDDS	DOD TAFIM DDDS TRCs	DOD TAFIM DDDS ATA	DOD TAFIM DDDS NWTDB/MCTA
• use a common network operating environment to cement the modular building blocks into a joint network of networks	DOD TAFIM	DOD TAFIM TRCs	DOD TAFIM ATA	DOD TAFIM MCTA
• evolve standardized and interoperable applications to produce fixed, transportable, and tactical communications and information nodes that are interconnected in support of joint or combined operations irrespective of time, place, or Service/Agency sponsorship	DOD TAFIM	DOD TAFIM TRCs	DOD TAFIM ATA	DOD TAFIM MCTA
• evolve joint global infrastructure toward a single common, unified, interoperable system	DOD TAFIM	DOD TAFIM TRCs	DOD TAFIM ATA	DOD TAFIM MCTA
• migrate from unique military standards to commercial national and international standards	DOD TAFIM JTA	DOD TAFIM TRCs	DOD TAFIM ATA	DOD TAFIM MCTA

Table 2. Consolidated Initiative Matrix

Consolidated Initiative Matrix	DOD	USAF	USA	USN/USMC
Baseline Actions (Today) • Adhere to a common set of standards	DOD TAFIM JTA	DOD TAFIM TRCs	DOD TAFIM ATA	DOD TAFIM MCTA
• international	DOD TAFIM JTA	DOD TAFIM TRCs	DOD TAFIM ATA	DOD TAFIM MCTA
• database structures	DOD TAFIM JTA	DOD TAFIM TRCs	DOD TAFIM ATA	DOD TAFIM MCTA
• data elements	DDDS	DDDS	DDDS	DDDS NWTDB
• interface protocols	DOD TAFIM JTA	DOD TAFIM TRCs	DOD TAFIM ATA	DOD TAFIM MCTA
• operating environment	DOD TAFIM JTA DDDS	DOD TAFIM TRCs	DOD TAFIM ATA	NWTDB MCTA
• Conduct rigorous testing for conformance and interoperability	Mod & Sim ACQ LCT Joint Training JWID	same	same	same
• Mission specific	see Table 5.3, Mission Specific Matrix			

Matrix Legend:

ACQ LCT — Acquisition Life-Cycle Testing
Air Force Directive 33-1 — C4 Systems
Air Force Directive 33-108 — Compatibility, Interoperability, and Integration of C4 Systems, 14 Jul 94
Air Force Instruction 33-110 — Air Force Data Administration Program. 1 Nov 95.
Air Force Directive 33-125 — Technical Reference Codes (Draft), 1 Feb 96.
ATA — Army Technical Architecture, Version 4.0, 30 Jan 96
Copernicus — Copernicus... Forward
C4IFTW — C4I for the Warrior, 12 Jun 92 and 12 Jun 94
DDDS — DOD Data System
DOD Directive 4630 5 — Compatibility, Interoperability, and Integration of C3I Systems, 12 Nov 92.
DOD Directive 5000 1 — Defense Acquisition, 15 Mar 96.
DOD Instruction 4630.8 — Procedures for Compatibility, Interoperability, and Integration of C3I Systems, 18 Nov 92.
DOD Reg 5000.2-R — Mandatory Procedures for Major Defense Acquisition Programs and Major Automated System Acquisition Programs, 15 Mar 96.
DOD TAFIM — Technical Architecture for Information Management, Version 2.0, 30 Jun 94.
Enterprise — Army Enterprise Vision and Implementation Plan
Joint Pub 6-0 — Doctrine for C4 Systems Support to Joint Operations, 30 May 95.
Joint Pub 6-02 — Joint Doctrine for Employment of Operational/Tactical C4 Systems (Draft), No Date.
JTA — Joint Technical Architecture (Draft), 12 Mar 96
JWID — Joint Warrior Interoperability Demonstrations
Horizon — C4I Horizon '95: A Vision for the Future
MCTA — Marine Corps Technical Architecture, 5 Oct 95.
Mod & Sim — Modeling and Simulation
NWTDB — Naval Warfare Tactical Database Standards Manual, Version 2.0, Apr 94

Table 2. Continued

D. POSITIVE ACTIONS

Now that all services have a centralized focus and vision for interoperability, C4I system development promotes seamless interfaces that support the warfighter's needs. As the basic building blocks for automated systems, standard data elements are essential for interoperability. Without a centralized starting point, efforts would be useless. Additionally, through modeling and simulation (M & S) techniques, C4I system designers and developers refine system parameters to ensure interoperability, which clearly assist with the definition of C4I systems. Even though the Air Force does not have a technical architecture to guide system development, they provide an exceptional on-line, up-to-date system development information source with TRCs. The ability to access existing standards in near real-time is invaluable to C4I system development.

E. FURTHER DEFINITION

Even with a centralized focus and vision for interoperability, there are several areas that must be further defined to streamline the development process: the definition of interoperability is mission-specific, existing standards (e.g., TAFIM) are too large and lack consistency [Ref. 8], and there is no formal process to develop interoperable systems from the DoD interrelated set of architectures. Depending on the mission purpose of a C4I system, individual functional characteristics may differ. Systems support the Warfighter and command and control functions, but interoperability is not always the same. For example, systems passing imagery in near real-time are not designed to pass information or data that is essential to counter a real-time threat, such as incoming enemy aircraft. The detail of interoperability must be defined from a C4I system's functional mission.

Existing development standards have grown too large for quality management. Using a paperless information sharing environment, as employed by the Air Force with TRCs, will make usable standards more accessible to planners, developers, and designers. The organization and format of TRCs provides clear guidance for system development.

Now that the DoD has defined a set of interrelated architectures, a process must be developed to use these tools to build interoperable systems. Currently, key people, systems engineers, etc., must continually be involved and formally track system design considerations to maintain interoperability. Inter-connectivity is as important as intra-connectivity for all C4I systems.

F. MISSION-SPECIFIC EXAMPLES

After recognizing that interoperability is mission-specific, identifying common parameters with different characteristics or values becomes more apparent. The following examples provide individual mission-specific profiles. From these examples, a mission-specific matrix is developed to demonstrate that there are quantitative differences for each system.

1. Joint Air Defense Mission Profile

a. Scenario

Joint air defense consists of some combination of Army, Navy, Air Force and Marine systems working together to detect, track, identify, engage, and kill hostile air threats. ASCIET 95 (All Service Combat Identification Evaluation Team) tests at Gulfport, Mississippi, during September 1995, serve as an example of a joint air defense mission. The purpose of the ASCIET 95 program was to examine current multi-service combat identification (CID) procedures and capabilities on the battlefield and to identify necessary changes to systems interoperability, doctrine, and tactics, techniques and procedures (TTP). [Ref. 17]

Figure 13 shows a schematic view of the ASCIET 95 scenario. The joint air defense system consisted of Navy Aegis cruisers stationed in the Gulf off of Gulfport; Army PATRIOT batteries stationed near Gulfport; a variety of aircraft overhead including an Air Force AWACS and RC-135, and Navy E-2s and a EP-3; and Marine close-in air defense systems including HAWK, Low Altitude Air Defense

(LAAD)/Forward Area Air Defense (FAAD) at Camp Shelby, approximately 50 miles north of Gulfport. [Ref. 17]

Figure 13. ASCIET95 Scenario [From Ref. 17]

During exercises, red opposition aircraft flew strike routes from Eglin AFB over the Gulf, then into Gulfport and Camp Shelby. Besides the assets mentioned above, the blue forces included intercept aircraft on CAP over the Gulf. The purpose of the exercises was to use the joint assets to detect, track, identify, and successfully engage the opposition force without incurring fratricide. [Ref. 17]

b. Mission Objective

The objective of the joint air defense mission was to maximize the probability of kill of all hostile air targets through the utilization of joint assets, while minimizing the loss of blue force assets due to enemy and friendly fire. [Ref. 17]

c. Mission Analysis

A generic ASCIET95 C3I information flow diagram is shown in Figure 14. The challenges are to provide timely connectivity between all multi-service C3I players and to effectively use ID and track information to support joint air defense operations.

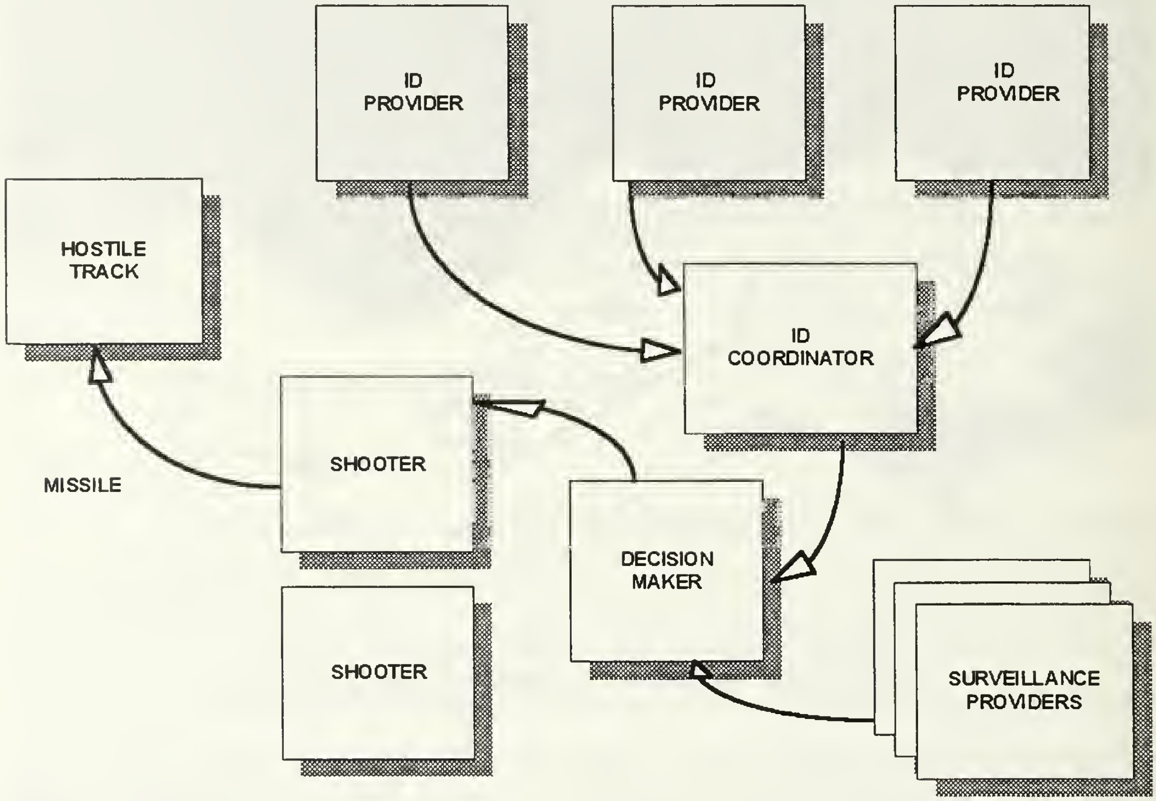

Figure 14. ASCIET95 Information Flow [From Ref. 17]

In ASCIET95, the ID coordinator shown in Figure 14 was the Combat Identification Coordinator (CIDC) and the decision maker was the Regional Air Defense Commander (RADC). In addition an Interface Control Officer (ICO) had a key responsibility for providing a connectivity and data link picture to the RADC. [Ref. 17]

Joint air defense operations (JADO) control responsibilities were decentralized to an assigned regional air defense commander (RADC) who exercised overall command and control of all participating joint air defense forces. The RADC could divide the exercise airspace further into sectors (i.e., overwater/overland) and delegate JADO control responsibilities to a designated sector anti-air warfare commander. The purpose of designating a RADC was to minimize the overall number of independent decision makers within a given theater of operations, provide a centralized focal point for communications connectivity, and reduce the time for target ID-to-allocation-to-destruction process. [Ref. 17]

The Aegis, E-2, TAOC, and E-3 functioned as the RADC at various times during ASCIET95 and provided final ID, allocation and engagement authority. [Ref. 17] The CIDC received ID data from various ID sources/providers and associated it with other track data to determine the correct ID. The CIDC then recommended that ID to the RADC. During ASCIET 95, Aegis, RC-135, EP-3 and the E-2C functioned as the CIDC to resolve probable ID recommendations from the other CID systems. [Ref. 17]

All of the units participating as RADCs, CIDCs, ICOs, and shooters in ASCIET95 had to be linked by a communications network. There are a variety of communications links used by individual units, but no single link is common to all of the units. A communications architecture used in ASCIET95 that interfaces the various links is shown on Figure 15.

During ASCIET95, it was observed that the effectiveness of the air defense system strongly depended on the time latency of data reaching the CIDC and then the RADC. The system began to lose ability to correlate data as information was delayed reaching the CIDC. As a result, multiple tracks of the same air vehicle were displayed and target IDs were miscorrelated with target tracks. In some cases when there were approximately 70 actual air vehicles (both blue and red combatants and background commercial air traffic) in the battle space, there were approximately 200 unique tracks being reported to the CIDC. This caused long differential delays of information coming from separate nodes as well as long overall delays of information coming from single nodes, resulting in track reports of the same target from different reporting nodes falling outside of correlation windows. [Ref. 17]

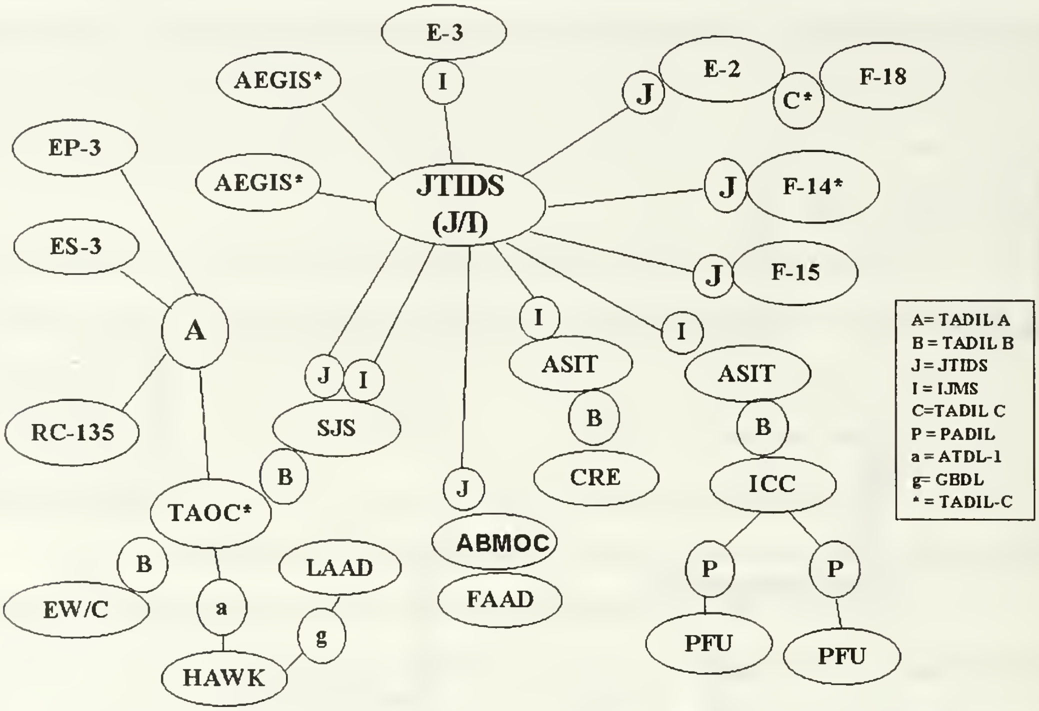

Figure 15. ASCIET95 Communications Architecture [From Ref. 17]

Delays were due to two factors: 1) disparities in communications systems' bandwidths and delays at network translators led to bottlenecks in the flow of information; and 2) multiple nodes reporting the same information led to an overload of the tactical networks and resulted in long network cycle times. Differential delays between JTIDS and TADIL-A sources of information were reduced as message loading was reduced. Similarly, differential delays between sources of information from different nodes within the same JTIDS net and different nodes within the same TADIL-A net were reduced as a function of message loading. Thus, as illustrated in Figure 16, network loading and the control of the amount of information on a joint air defense system network had an important effect on the ability of the system to successfully meet the joint air defense mission objective. [Ref. 17]

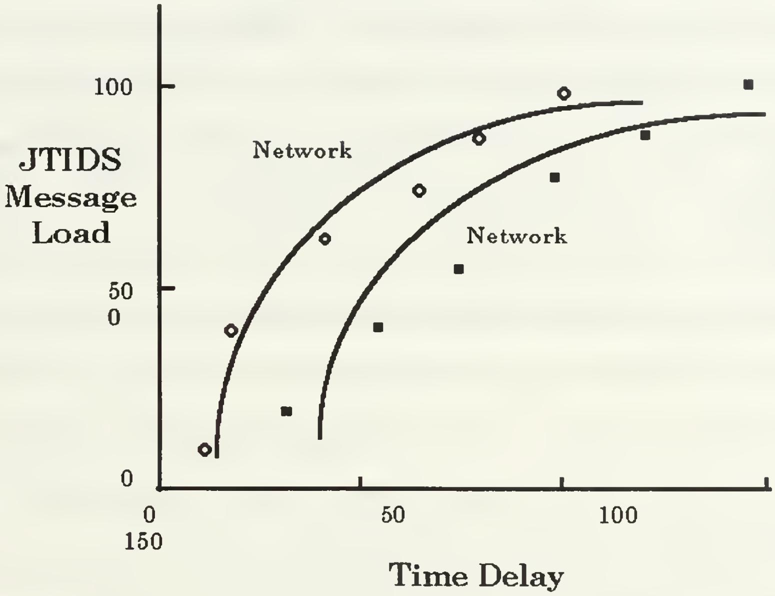

Figure 16. Number of Messages vs. Time Delay [Ref. 17]

d. Conclusions

Analysis of ASCIET95 indicates that all of interoperability requirements specified in the consolidated initiative matrix, Table 2, were met. All systems were linked using interoperable communications links and translators. Common message formats were used. However, there were additional mission-specific requirements that were not identified prior to conducting ASCIET95. These included maximum time delays in information reaching the combat ID coordinator, maximum differential delays in information being reported on the same target by different nodes, and a maximum network loading that depended on the particular network type.

Current interoperability guidelines say that this type of additional mission-specific requirement will be identified during analysis of mission interoperability requirements. However, these types of interoperability requirements can often only be discovered at the joint mission analysis level. Service-specific systems developed for service-specific missions may not be fully interoperable for joint missions if joint mission requirements have not been completely analyzed by the developing service. Therefore, there is a need to look at potential joint mission applications of individual service system developments and derive the necessary additional interoperability requirements arising from joint applications.

Also, in the case of ASCIET95, there was an identified need to provide network control at the system level in order to reduce network delays. The requirement for network control at this level is a joint requirement and leads to the need for new hardware and/or software that is not a service-specific development item but is a joint development item. This identifies the need to have a joint service systems engineering organization responsible for some subset of interoperability issues.

2. Joint Tactical Ballistic Missile Defense Mission Profile

a. Scenario

An example of a joint tactical ballistic missile (TBM) defense scenario is shown in Figure 17. Here we have assumed a littoral environment typical of a Korean theater. Army Theater High Altitude Air Defense (THAAD) and Patriot batteries are stationed on the land area. Future Aegis-based mid-tier missile defense systems are offshore. An Air Force future airborne laser (ABL) is overhead. The ABL will be capable of detecting, tracking, engaging, and killing TBMs during their boost phase at long stand-off ranges, up to 500 miles. THAAD and Aegis systems are mid-tier systems, capable of detecting, tracking, engaging, and killing TBMs during midcourse, after booster burnout and separation. PATRIOT is a lower tier defense system, capable of defending point targets and small areas. [Ref 18]

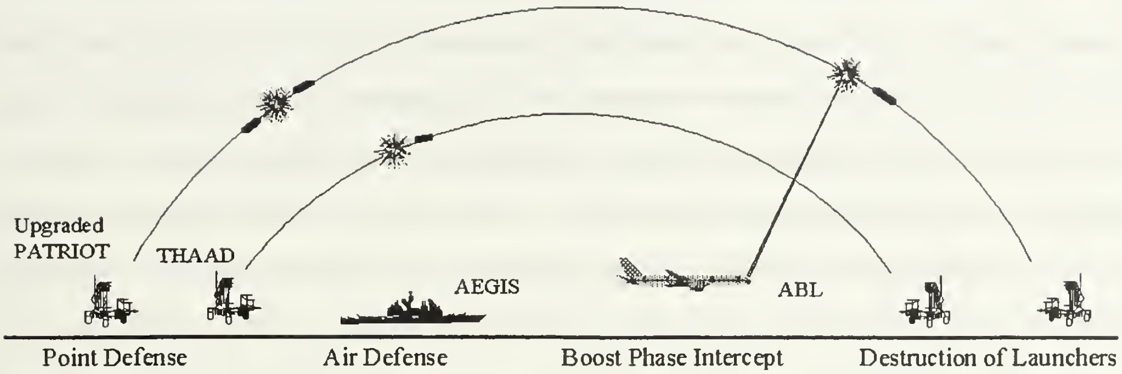

Figure 17. Joint Tactical Ballistic Missile Defense Scenario

b. Mission Objective

The objective of a joint tactical ballistic missile defense mission is to detect, track, engage, and perform complete raid attrition of the missile attack with the most efficient application of joint detection, tracking, and firepower capabilities. [Ref. 18]

c. Mission Analysis

Figure 17 shows a schematic of a tactical ballistic missile flight, from launch to impact, as well as the approximate intercept regions of ABL, THAAD, AEGIS, and PATRIOT.

ABL uses an infrared surveillance system and will detect a missile launch as soon as the missile breaks cloud top, approximately 40 seconds after launch for high cloud cover, or immediately upon launch in clear skies. ABL can rapidly develop a high accuracy track of the missile due to the high resolution and measurement accuracy of the electro-optical surveillance system. ABL can then engage and kill missiles during the boost phase, but since kill times using the directed energy weapon are on the order of 5-10 seconds ABL can only engage a subset of a large missile attack. [Ref. 18]

THAAD and AEGIS both perform exoatmospheric engagements on incoming missiles. Detection and tracking is performed by the THAAD ground-based radars and the AEGIS SPY radars, respectively. These radars detect targets after launch, at the radar horizon if they are looking in the proper area, and detection ranges are typically several hundred miles. The radars can be cued by ABL or by space-based sensors in order to focus their radar energy in a narrow beam that allows earlier detection of targets in some situations. Both systems develop fire control quality data for their own weapons. The AEGIS system might also incorporate the cooperative engagement capability (CEC) system which sends fire-control-quality track data from any CEC platform to all other CEC platforms. All CEC equipped platforms have the same set of radar processing software and hardware, and all CEC radars are gridlocked to high accuracy, resulting in all CEC platforms having identical track pictures. All CEC systems must be linked by a high (2 - 10 MHz) bandwidth system to allow data transfer and sensor gridlocking. PATRIOT detects, tracks, and engages leakers in the lower tier. PATRIOT can be cued by track data from THAAD and AEGIS. [Ref. 18]

There are several interoperability issues that must be addressed in order to coordinate the system and achieve optimal joint performance. These issues are related to three levels of coordinated activity. First, the systems would have to be linked via communications systems in near real-time in order to provide cueing from tier to tier. Second, the systems would have to be linked via communications systems in real time or near real time in order to relay information concerning which targets have been engaged or are planned to be engaged, and which targets have been killed or failed to be killed. Failing to do this will result in multiple shots at the same target, leakers that are not engaged by any system, and extraneous track information due to unidentified interceptor missiles in-flight. Third, the systems could be linked in real time in such a way that would allow the theater battle management to be coordinated jointly, rather than relying on areas of responsibility. The advantage of joint battle management is that it allows optimal joint system performance provided information flow timelines can be met. Joint battle management requires that all systems be linked via a communications system in real time; if CEC is to be used theater-wide then the communications system must be high bandwidth. Each participating system must have a battle management software system that is interoperable with all other system battle management software systems in terms of message formats, data elements, data accuracies and update rates; in terms of modularity of function (each individual system must be able to operate as a node in a distributed battle management system); and in terms of shared system information. The latter refers to the need to know exact details of every system's state, including magazine state, in order to determine optimum distributed firing allocations. The requirements associated with these three levels of coordinated operation are listed in Table 3. [Ref. 18]

d. Conclusions

Analysis of the example joint tactical ballistic missile defense mission indicates that all of the interoperability requirements specified in Table 2 apply. All systems need to be linked using interoperable communications links and translators. Common message formats need to be used. However, there were additional mission-specific requirements that are not identified in Table 2. These include the need for real-time or near-real-time communications links so that maximum time delays in information reaching the various missile defense tiers is short enough to allow the required action by each tier. There is a need to transmit information that is internal to each of the systems to all other systems. This requires that the systems be designed such that there are real time transmittals of the internal information to external systems, and that the information is in a common format. Finally, level 3 of coordinated action requires that the internal functioning of the systems be designed such that battle management can be performed externally to each system as well as internally. Level 3 coordination also requires development of a joint battle management system with all of the interoperability requirements listed in Table 3.

Requirement	Level 1 Cueing	Level 2 Shared Engagement Data	Level 3 Joint Battle Management
Comm Links			
Near real-time	x	x	x
Real-time		or x	x
High bandwidth, real-time			x (with CEC)
Shared Data			
Engagements		x	x
Kill assessment		x	x
Tracks		x	x
Sensor data			x (with CEC, excluding ABL)
System state data			x
Battle Management System			
Common software modularity			x
Common data dictionaries			x

Table 3. Derived Interoperability Requirements for Joint Tactical Ballistic Missile Defense [From Ref. 18].

3. Global Positioning System Profile

a. Scenario

The application of Global Positioning System (GPS) technology has increased the operational effectiveness of the armed forces. Military users in air, on land, and at sea receive accurate navigational information to guide their fighting force within every environment. GPS technology is being incorporated within networked positioning systems to increase the navigational accuracy at all levels. As the services conduct more joint operations and training, the need to share accurate positioning information becomes essential in the joint battlespace environment. Ground troops from one service may receive support from both air and sea units of another. Figure 18 illustrates an operational example where Navy aircraft are in direct support of Army ground troops.

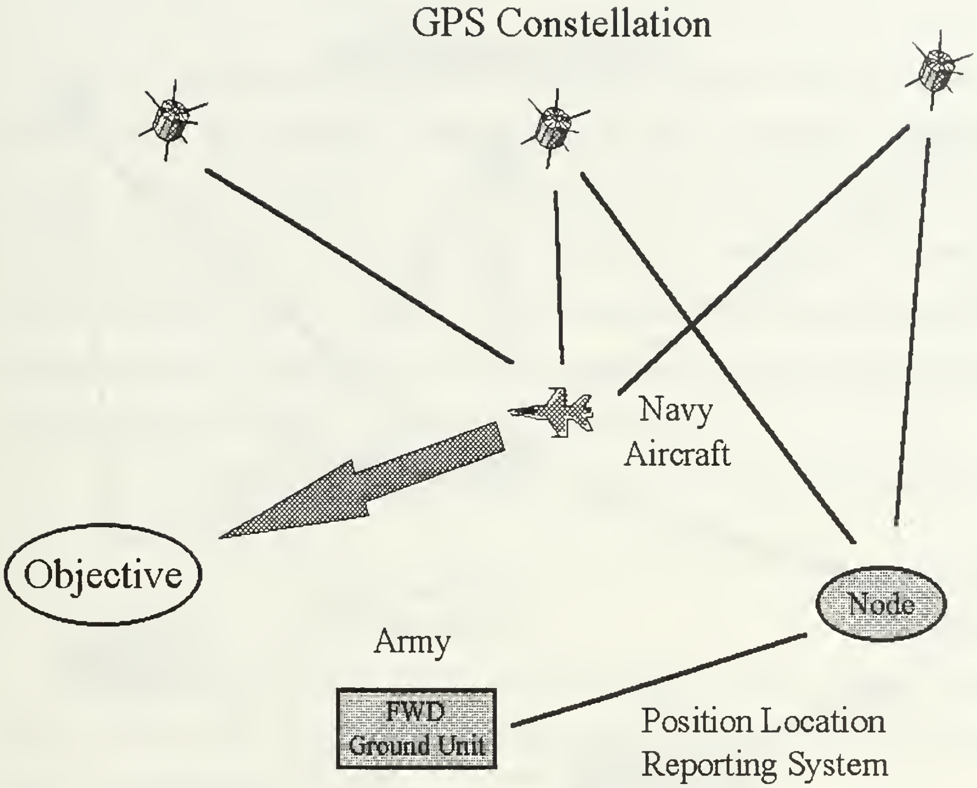

Figure 18. Joint Battlespace Scenario

b. Mission Objective

Within this proposed operational scenario, there is no established means for both air and ground forces to pass navigational and positioning information or coordinate operations. The lack of communications connectivity between air and ground elements is not only limited, but extremely dangerous for all entities involved. Figure 19 represents a proposed operational architecture for the insertion of GPS data and establishment of critical communications links between air and ground units.

Both air and ground units receive accurate positioning information from the GPS satellite constellation. As air and ground forces come within some predetermined range of each other, they begin to exchange positioning information through a temporarily established communications data link.

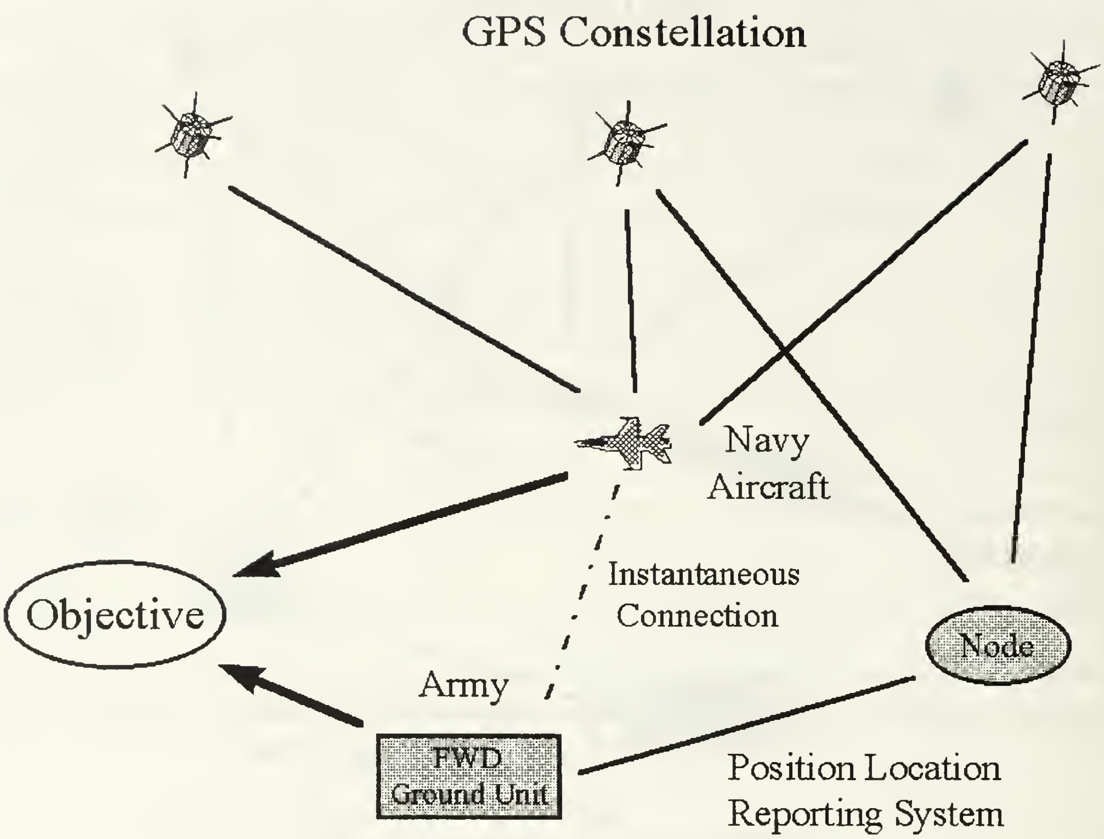

Figure 19. Proposed Communications Architecture

c. *Mission Analysis*

The communications data link must be established early enough to provide positioning and navigational systems the time to process the information received. Also, force elements require ample time to observe, recognize, and react safely in support of real-time operations. If aircraft navigational systems use earth-centered coordinates and ground force positioning systems use flat earth coordinates for operation, systems require design parameters to perform information conversion and maintain functionality to support timely information flow. Predetermined range identification distances may need to be increased to support real-time operations.

d. Conclusions

Both air and ground unit systems must use standard message formats and data elements, as specified in Table 2. The timing and accuracy of navigational data passed over a communications link between air and ground assets is critical for C4I systems of this type. Information must be timely to ensure C4I systems successfully support users and accurate enough to clearly represent the operational environment. The operational field of view greatly differs between aircraft and ground forces; therefore, accurate information is key to operational awareness.

4. High Altitude Endurance Unmanned Aerial Vehicle Imagery Data Link Profile

a. Scenario

With lessons learned from Operation Desert Storm, the DoD found existing deficiencies in military Operations Other Than War (OOTW) which included the following: [Ref. 19]

- Lack of broad area coverage
- Limited Battle Damage Assessment (BDA)
- Limited imagery dissemination to users
- Limited information retrieval and distribution of intelligence data
- Insufficient information to support Warfighter situational awareness
- Insufficient high resolution imagery intelligence to support precision strikes
- Reconnaissance that is not synchronized with the Warfighter

The goal of the High Altitude Endurance Unmanned Aerial Vehicle (HAE UAV) is to provide quality extended reconnaissance that is responsive to the operational Warfighters' needs. [Ref. 19]

b. Mission Objective

The HAE UAV system is designed to provide near real-time (NRT) transmission of sensor imagery. The HAE UAV is a long dwell tactical surveillance and reconnaissance system that is capable of sustained high altitude operations over and into high threat areas. The system can operate at ranges in excess of 500 nautical miles from the launch area and loiter over the target area more than eight hours at an altitude greater than 45,000 feet. The HAE UAV employs both wideband line-of-sight (LOS) and moderate bandwidth satellite communications. [Ref. 19]

The HAE UAV system contains a ground segment (mission control element (MCE)), ground communications element, launch and recovery element (LRE)), and support segment, which can be mission transportable to any theater of operations via three C-141 aircraft or equivalent loads. [Ref. 19] Figure 20 shows an operational view of the HAE UAV system.

The system is designed to provide 24 hour continuous coverage of desired areas of interest using Synthetic Aperture Radar (SAR), Electro-Optic (EO), and Infrared (IR) sensors. The HAE UAV system can collect imagery of pre-planned areas of interest and quickly transmit the messages to combat commanders. [Ref. 19]

c. Mission Analysis

Figure 20 illustrates the program objective for using a satellite link for the transmission of imagery data from the aircraft to the MCE and selected imagery data from the aircraft to exploitation sites and tactical users. Using commercial satellites, data rates up to 50 Mbps are expected, while T-1 rates are anticipated for links to tactical elements. Figure 21 illustrates the second method for imagery transmission from the aircraft to the MCE, exploitation elements, and tactical users. Through LOS systems, aircraft to MCE and exploitation elements data rates will increase to 137 Mbps, and links to tactical users will remain at T-1. [Ref. 19]

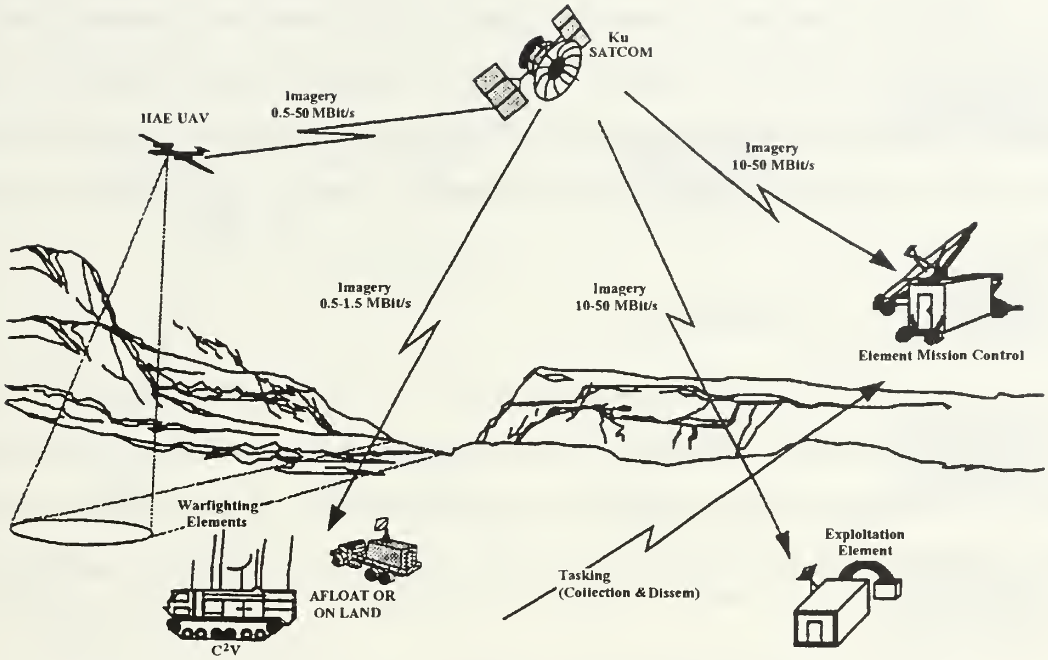

Figure 20. In Theater Operational HAE UAV System using Commercial SATCOM (Ku Band) [From Ref. 19]

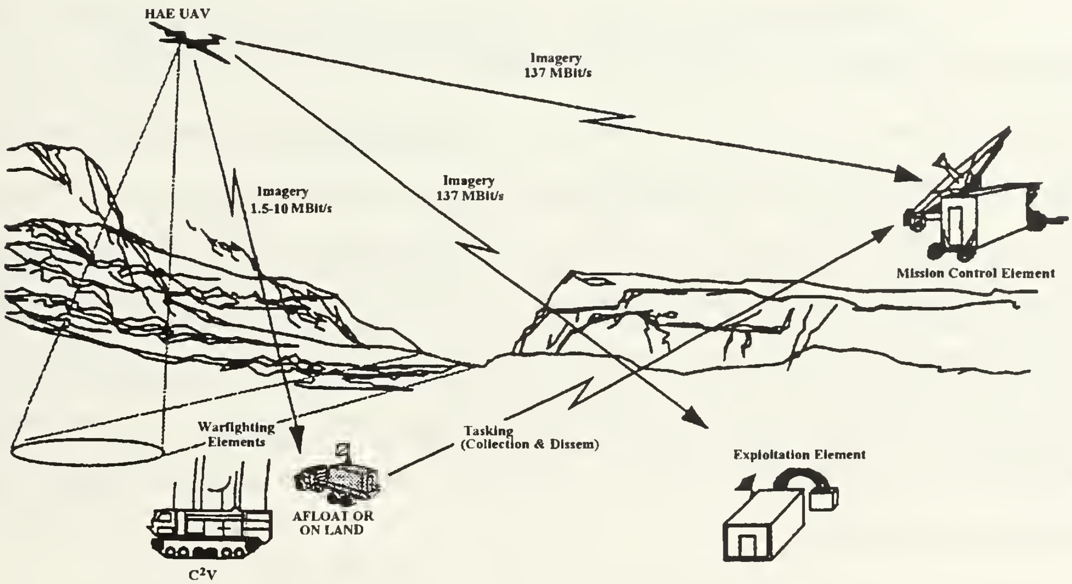

Figure 21. In Theater Operational HAE UAV System using Common LOS Data Links [From Ref. 19]

Different operational parameters change C4I system development. The two communications architecture options, illustrated in Figure 20 and Figure 21, create different requirements for the design and development of C4I systems to support both the MCE and exploitation elements—the interoperable designs have become mission-specific.

d. Conclusions

Since the LOS link from the aircraft to the tactical user remains the same, the development of the tactical users' terminal requires no apparent change. The possible bandwidth limitations may even alter the operational use and employment of the system. New dissemination devices may have to be designed to support the distribution of imagery to the user.

5. Close Air Support Profile

a. Scenario

Commanders use close air support (CAS) to focus firepower at the decisive place and time to achieve local combat superiority. Figure 22 depicts the flow of information from the time that friendly ground forces identify an enemy threat to the delivery of munitions on the target. Requests for CAS are usually on high frequency (HF), ultra high frequency (UHF), and very high frequency (VHF) radio voice nets. Tactical air control parties (TACPs), liaisons to ground forces, request CAS through the direct air support center (DASC); this may be an airborne C2 platform. By monitoring the Tactical Air Request (TAR) Net, battalion, regiment, and division level fire support coordination centers (FSCCs) approve requests by remaining silent and deny or alter requests as needed. [Ref. 20]

b. Mission Objective

CAS execution must be responsive to quickly support forward ground forces. To deter the fast-paced threats of the battlefield and to lower operational risks, offensive actions require immediate support to counter enemy intentions.

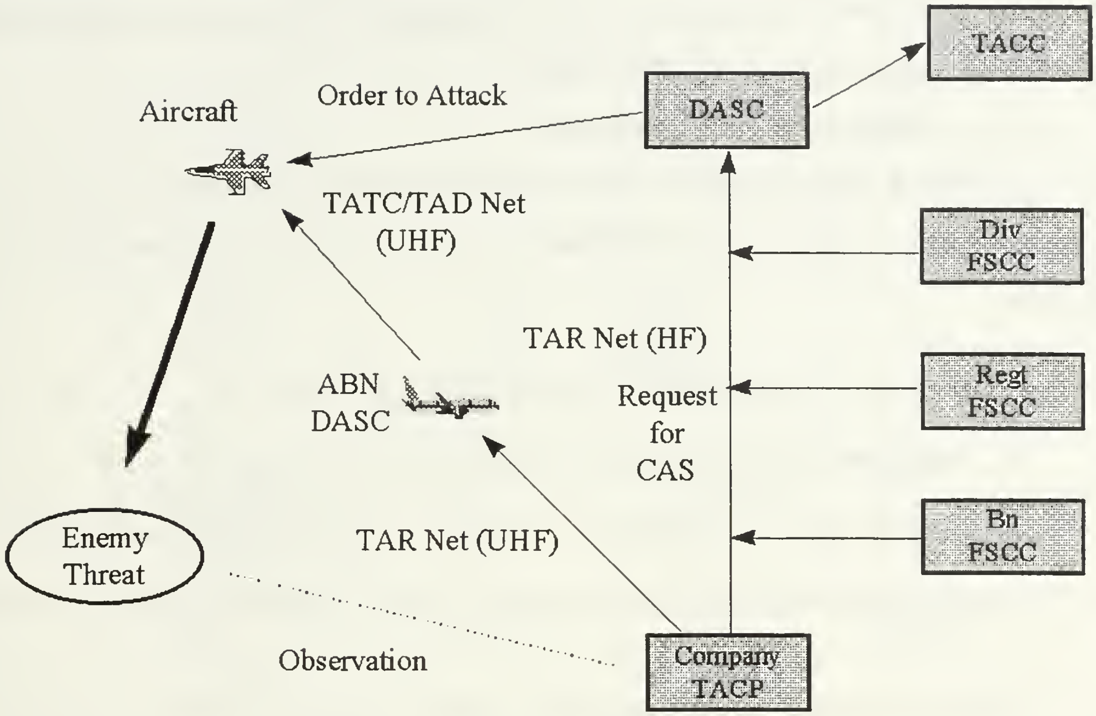

Figure 22. Information Flow for Close Air Support Requests

c. Mission Analysis

C4I systems must be flexible to support tactical users at multiple locations throughout the battlefield. The delay of information may place forces at risk. Even though CAS requests are not automated, there are many operational and design tradeoffs for C4I systems to ensure the request process can support real-time operations. Radio voice quality must be understandable for users to quickly identify essential information without retransmission.

d. Conclusions

As defined in Table 2, C4I system designs with common standards ensure all forces have reliable connectivity to conduct operations for real-time operations. If C4I systems do not facilitate CAS operations, the ability to access powerful lethal assets becomes limited.

High voice quality for systems alleviates the need for retransmission. If the request structure required data links, mission-specific parameters would change the design of the C4I system to achieve adequate interoperability.

6. Mission-Specific Area Matrix

In Table 4, mission profile areas are compared against one another using four of seven information quality criteria identified in Joint Publication 6-0. These criteria are: [Ref. 21]

- **Accuracy.** Information that conveys the true situation.
- **Timeliness.** Information that is available in time to make decisions.
- **Completeness**. All necessary information required by the decision maker.
- **Security.** Information that has been afforded adequate protection where required.

From these criteria, an interoperability profile can be created. Each area is given a rating of high, medium (med), or low. For high, the C4I system attribute is essential or extremely relevant to support warfighter operations in real-time. For a medium rating, the system attribute is critical or relevant to support operations in near real-time (NRT), and low is important, but not as timely as NRT.

Timeliness, accuracy, completeness, and security criteria for a C4I system can be quantified to better define a desired system's requirements. As identified in Table 4, there are significant differences and the depth, level, detail, etc. of interoperability must be defined for each specific case.

	Mission Profile Areas				
Profile Criteria	Air Defense	Theater Missile Defense (TMD)	Global Positioning System (GPS)	UAV Imagery Data Link(s)	Close Air Support (CAS)
Accuracy • Media Type • Operational Environment	High	High	Med/High	Med/Low	Med
Timeliness • Network Design • Network Control • Bandwidth • Transmission Path Length • Processing Capability • Media Type • Applications	High	High	Med	Med Med/Low	Med
Completeness • Media Type	High	High	High	Med Med/Low	Med
Security • Desired Level	Med	Med	Med	High/Med	Med

Relevance Codes:
High
Medium (Med)
Low (important, but less than Medium)

Table 4. Mission-Specific Matrix

G. SUMMARY

The DoD and services have initiated extensive visions to focus service efforts and achieve C4I system interoperability. Service actions are tailored to support individual needs and requirements, and standards are clearly defined and accessible to facilitate joint C4I interoperability development of future systems. Technical architectures and reference codes provide the guidance to design interoperable systems, but every system is not the same. Each system requires systems engineering analysis to ensure mission-specific parameters are met, and interoperability is more than seamless interfaces. In addition to timeliness, data and information may require different accuracy, completeness, and security levels for C4I systems to be functional. As noted within Table 2, a consolidated initiative matrix, every service has defined actions to achieve interoperability, but as the mission-specific examples of this chapter have demonstrated, as shown in Table 4, every case is different. C4I system purposes, missions, operational architectures, etc. affect system parameters that ensure interoperable systems are functional.

VI. CONCLUSIONS AND RECOMMENDATIONS

> The term interoperability has little meaning unless specific parameters are described and specified...[Ref. 1]
>
> C4I for the Warrior
> 12 June 1992

A. INTRODUCTION

Even the original C4IFTW document identified that every system is not the same, and system parameters must be specified in detail. Building on the previous five chapters, this chapter identifies critical issues, provides direction, and recommends research areas requiring analysis. Chapter VI contains the following sections: conclusions, recommendations, and further research. The conclusions section formalizes analysis observations identified, and the recommendations section presents three initiatives to enhance the development of joint C4I systems. Finally, the further research section identifies four areas of study for DoD graduate students.

B. CONCLUSIONS

The definition of interoperability specified in Joint Publication 1-02 is vague regarding mission-specific C4I systems. As written, the definition requires the users, developers, planners, designers, etc. to further define interoperability for each mission-specific case. Alone, the ability to pass data through seamless interfaces does not ensure that systems receive information in a timely manner to render the system functional. Also, incomplete and inaccurate information can not only mislead, but slow down the warfighter's decision making process. C4I systems must be designed to facilitate command and control and provide a well-defined picture of the battlespace without confusion. Interoperability must be defined for the system frame of reference and the use of the C4I system.

C. RECOMMENDATIONS

1. C4I System Mission Interoperability Profiles

As identified in Joint Publication 6-0, information flow must be nearly instantaneous both vertically and horizontally within an organizational structure [Ref. 21]. This publication further describes the information quality criteria listed in Table 5.

Accuracy	Information that conveys the true situation
Relevance	Information that applies to the mission, task, or situation at hand
Timeliness	Information that is available in time to make decisions
Usability	Information that is common, easily understood format and displays
Completeness	All necessary information required by the decision maker
Brevity	Information that has only the level of detail required
Security	Information that has been afforded adequate protection where required

Table 5. Information Quality Criteria [From Ref. 21]

From accuracy, timeliness, completeness, and security information quality criteria, an interoperability profile can be created. These criteria or attributes for a C4I system can be quantified to better define a desired system's requirements. For example, a system that transports essential air defense information must be more accurate, timely, and complete to react to a real-time threat than a system that passes imagery. This is a simplified example, but consider the quantifiable differences for each item of criteria. C4I systems must be interoperable, but to what level? If an air defense system is considered interoperable and accurately passes complete information both vertically and horizontally, but fails to pass this information in a timely manner, then the system is useless.

Establishing profiles for C4I systems will further define and describe user requirements and assist system designers and developers to ensure adequate levels of interoperability. To just identify interoperable levels provides no quantifiable characteristic to follow.

Table 6 contains a proposed framework to establish C4I system profiles.

C4I System Attribute	Proposed Definition	Quantifiable Measure
Accuracy	Data accuracy that conveys the true situation	percentage or Bit Error Rate
Timeliness	Time allocated for data to reach a C4I system so it may be processed in time to render the system effective	measured in seconds or milliseconds
Completeness	Data amount that conveys the true situation	percentage
Security	Security level required for system operation	(e. g., unclass, secret, etc.)

Table 6. Proposed Interoperability Profiles

Profiles must be initially established as C4I system requirements are defined and optimized through modeling and simulation and joint testing processes. The overall purpose of mission-specific profiles is not to create unrealistic requirements and delay the development process for C4I systems, but to establish thresholds to guide designers from requirement definition through initial design, modeling and simulation, and subsequent system upgrades. As DoD guidance and technology advance, profiles should be updated to better support interoperability of like systems--they, too, are continually evolving.

2. Joint Scenario Testing

DoD Directive 4630.5, Compatibility, Interoperability, and Integration of C3I Systems, states that all C4I systems are considered joint unless exemptions are granted. As indicated by the ASCIET95 series of tests, systems must be modeled and simulated and tested in joint scenarios. Interoperability is much more than reliable interfaces. C4I systems may seamlessly interface, but they are not interoperable if the traffic load from joint and service specific systems creates time delays rendering the overall network of systems ineffective. Joint scenario modeling and simulation and testing is essential to ensure interoperability of networked systems.

3. On-line Interoperability Standards

The US Air Force's development of Technical Reference Codes (TRCs) has dramatically enhanced progress to achieve interoperability for all Air Force C4I systems.

Up-to-date standards and system development information can be quickly accessed to guide system planners, developers, and designers within the Air Force. The logical organization of TRC development standards is an effective tool for the commercial industry as well as service personnel. As long as TRCs are adequately maintained, the time from requirements definition to placing the C4I system in the hands of the warfighter will be reduced. All services must adopt this real-time concept of operations.

D. FURTHER RESEARCH

1. Further Develop C4I System Interoperability Profiles

From today's proposed interoperability levels, further develop C4I system profiles to quantify design requirements of military systems.

2. Model a System Development Process

Using commercial industry and theoretical automated information system development techniques, model a system development process that uses the DoD interrelated set of architectures as the starting point.

3. Identify Key Data Repository Elements

Compare commercial industry and military automated information system development techniques to identify similarities and differences and key data repository elements for military application.

4. Further Develop the Copernicus...Forward Vision

Further develop the Copernicus...Forward vision to strengthen the US Navy and Marine Corps team and enhance forward presence operations.

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