United States Air Force
Scientific Advisory Board

Report on

Air Force Command and Control: The Path Ahead

Volume 1: Summary

SAB-TR-00-01
December 2000

Cleared for Open Publication

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Foreword

This volume summarizes the deliberations and conclusions of the 2000 Air Force Scientific Advisory Board (SAB) Summer Study, "Air Force Command and Control: The Path Ahead." In this study, the Board was asked to assess the command and control system and the supporting communication and information systems; to consider technical and process improvements and to make recommendations on what should be done to "have the Air Force linked by 2005"; and to build toward the Air Force's long-term command and control goals. There are three volumes to the report. This volume, Volume 1, presents a brief summary of the findings and the major recommendations. Volume 2 presents the panel reports, including detailed findings and recommendations. Volume 3 includes the majority of the appendices, a few being included in Volumes 1 and 2.

The study results are the product of a substantial effort by a skilled team, including panels led by experts in their assigned area. The study leadership wishes to thank the many individuals and organizations in Government and industry who contributed to the deliberations and conclusions presented. In addition to SAB members, many ad hoc members devoted their time. Air Force Major Air Command liaison officers were extremely helpful in our research and deliberations, as were the technical writers provided by the Air Force Academy. In addition, both the liaison officers and the technical writers provided outstanding administrative and logistics support. We gratefully acknowledge the contributions and guidance of our General Officer Participant, General John Jumper, Commander, Air Combat Command; and Major General Gerald Perryman, Jr., Commander, Aerospace Command and Control and Intelligence, Surveillance, Reconnaissance Center.

The study leaders would also like to give special recognition to the SAB Secretariat and support staff, in particular to Capt D. Brent Morris, the Study Executive Officer; and to Ms. Kristin Lynch of the ANSER team, who provided invaluable administrative and editing assistance in the preparation of graphics and the publication of the report.

We believe that through the dedication of the current leadership, the Air Force has the greatest opportunity ever in developing an effective and efficient theater command and control system, and we encourage every Air Force member to seize this opportunity.

Finally, this report reflects the collective judgment of the SAB and hence is not to be viewed as the official position of the United States Air Force.

Dr. Peter R. Worch
Study Chair

Gen James P. McCarthy, USAF (Ret)
Study Vice Chair

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Executive Summary

For more than three decades, the Air Force has scrutinized command and control (C^2) modernization planning, programs, training, procedures, and architectures and has identified repetitive C^2 problems in each decade.

The Air Force Chiefs of Staff (CSAFs) have chartered numerous studies and conducted four-star reviews in their attempts to fix the Air Force C^2 problem. These CSAF studies began with the 1986 Air Force Studies Board Summer Study; this was, in turn, followed by the 1992 and 1993 Command, Control, Communications, Computers, and Intelligence Broad Area Reviews, the 1996 Air Force Scientific Advisory Board (SAB) Summer Study, the 1997 C^2 Task Force, the 1997 C^2 Four-Star Summit, and this 2000 Scientific Advisory Board C^2 Summer Study. The Air Force Chiefs of Staff also established a new Air Staff C^2 Directorate, an Air Staff C^2 General Officer Steering Group, and the Aerospace C^2 Intelligence, Surveillance and Reconnaissance Center (AC2ISRC) in their attempts to fix C^2.

The redirection of this year's SAB Summer Study from "limited forward basing" to "command and control" reflects the Chief of Staff's strong desire to improve Air Force C^2 capability. Each study made recommendations for fixing the problems the Air Force was having with C^2. Analysis of the recommendations indicates that the same recommendations were made many times, yet the Service is not achieving the vision of linked Air Force command centers that are able to collaborate globally in support of all commanders in chiefs (CINCs), Services, allies, and the Aerospace Expeditionary Force.

The lessons learned from DESERT STORM and ALLIED FORCE and the results of every SAB and Defense Science Board study have determined that U.S. aerospace power capabilities continue to outperform the associated C^2 capabilities. In theater C^2, this is particularly evident in time-critical targeting, battle damage assessment, and campaign assessments.

The Tasking

The Air Force is not on a path that provides coherence across space, air, and land assets to support the most timely and effective decision making and execution. Thus, the Board was asked in the Terms of Reference (Appendix A) to

- Assess the C^2 system and the supporting communication and information systems
- Consider technical and process improvements and make recommendations on what should be done to "have the Air Force linked by 2005"
- Build toward the Air Force's long-term C^2 goals

The specific tasks are shown below; each task had a panel to address it. Panel membership is in Appendix B. The SAB was to

- **Define the Air Force C^2 system with today's capabilities and identify alternatives to enhance C^2 over time**
- **Define interoperability (joint and coalition) to ensure coordinated efforts on the battlefield**
- **Identify the technologies that can enhance present and future C^2 systems, with near-term emphasis on timely and effective communication**

- **Assess the acquisition, programmatic, and cost-effectiveness issue**
- **Consider the organizational, personnel, training, and support consequences**

And we added a Bridging and Vision Panel.

A Framework for Solution

The Study recognized the many past organizations, directives, studies, and other efforts to develop a Theater Command and Control System for the Air Force. Many dedicated and talented leaders have made great efforts, and even great strides, in the name of C^2. Yet we once again find ourselves on the doorstep with a basketful of comments and ideas to improve the C^2 of Air Force combat operations.

It is our belief that the solution set can, and should, be cast in a framework in order to capture the underlying rationale for the suggestions. Our **framework** includes the following elements:

- A unified, understood, focused approach to C^2
- A process, driven by the concept of operations and based on capabilities, that encourages, not impedes, system operational enhancement
- Acquisition processes that are timely and efficient in capturing emerging technologies
- Taking the lead in becoming more interoperable, including joint/coalition operations
- Horizontal integration of intelligence, surveillance, and reconnaissance (ISR) with C^2
- Focus and follow-through

Recommendations

We recommend the following actions be taken:

Recommendation 1. Emphasize the Role of Command and Control in the Air Force

It is important that *all* levels of the Air Force, as well as Congress and other Government activities, understand the criticality of effective C^2 to the outcome of a crisis.

Recommendation 2. Manage Theater Command and Control as an Integrated Set of Weapon Systems

When an Air Force system (for example, the F-15E) is officially designated a weapons system, a certain formality in the management of that system, including people, hardware, software, training, certification, maintenance, and evolution, is established and implemented. C^2 systems deserve nothing less.

Recommendation 3. Strengthen the Air Operations Center (AOC) Through Restructuring, Staffing, and Training

Though the AOC is at the heart of precision air operations, recent conflicts have been characterized as a “pickup game” of equipment and personnel. Consequently, the efficiency and success of these air operations have suffered. An effective and efficient AOC, ready to deploy or operate from home at any time, is absolutely essential.

Recommendation 4. Field and Evolve the Theater Battle Management Core System (TBMCS)

TBMCS has been a major, albeit painful, step to a new integrated theater C^2 system. Though it cannot be considered a final configuration with all modules in optimum operation, it is a major step forward from the previously fragmented system(s). It is time to accept the system and to accept the fact that continual upgrades will be needed to meet operational requirements and technology advances; the upgrades should be so planned.

Recommendation 5. Institutionalize a C^2 Evolutionary Integration Process

The major difficulty in taking advantage of developments from the military and commercial sectors, including off-the-shelf solutions, as well as those successfully prototyped in laboratory or field exercises, has been the lack of a formal and cyclical means to integrate new capabilities online. The Air Force should create and support a process for the evolutionary integration of developed modules.

Critical to effective integration and management is the creation of a partnership, based on mutual support and trust, of the operators (for example, AC2ISRC); the developers (for example, the Electronic Systems Center [ESC] or Air Force Research Laboratory); the integrators (for example, ESC); and the operational testers (for example, the Air Force Operational Test and Evaluation Center), each of which must accept and carry out its responsibilities.

Recommendation 6. Enable and Encourage Rapid Technology Insertion

The Study determined that there are no technology impediments to substantial improvements in the effectiveness and efficiency of air operations C^2. With some exceptions, in which additional operational focus is needed, the emphasis must be on the timely and effective transition of military and commercial technologies to the Air Force C^2 system needs. The Air Force should follow a focused effort to improve technology exploitation. A C^2 testbed is essential to fostering rapid development of the AOC and other elements of theater C^2.

Recommendation 7. Achieve Information Interoperability for Warfighters Through the Joint Battlespace InfoSphere (JBI)

The opportunity to significantly improve our ability to conduct effective joint and coalition warfare rests on the degree of interoperability of the C^2 processes. The Air Force should seize the initiative to evolve the JBI (see Appendix E) as the basis for true interoperability. Many specific nearer-term problem fixes are also important and possible.

Recommendation 8. Staff and Train to Be Consistent With the Importance of C^2

The Air Force has been a pioneer in recognizing the importance of its people. At the heart of this recognition, and built on the foundational element of "quality people" for the Air Force core competencies, is the establishment of a trained force of C^2 professionals.

Recommendation 9. Strengthen Efforts for Attack of Time-Critical Targets

Recent crises have again highlighted the shortfall in the capability for rapid acquisition, identification, and attack of mobile targets. Clearly, the delays in the process are unacceptable, and progress in the improvement has been marginal. The Air Force should establish a program team to address the rapid-response attack of time-critical targets.

Recommendation 10. Facilitate and Enhance Data Connectivity

Critical to the dynamic management of combat airpower is the data connectivity from C^2 activities to the aircraft. The delays in fielding solutions to the aircraft datalink problem seem to be more political than technical. The Air Force should exercise leadership in achieving the goal of interlinking aircraft based on operational access to message sets (J-series) rather than emphasizing only specific equipage.

Summary

The essence of the recommendation set is to provide focus and follow-through on C^2 issues from a very high level. They key actions are to

- **Establish a single C^2ISR manager at the Air Force level (for example, a three-star operator)—an Air Force Council Member.**
- **Integrate expert information technology professionals (internal and new) into the C^2 staff.**
- **Direct a C^2 program restructuring.**
- **Adopt the Global Command and Control System (GCCS) framework: evolve theater Air Force C^2 applications into GCCS-AF.**
- **Direct a capability-centric evolutionary integration process for $C^{2.}$**
- **Manage theater aerospace C^2 as a system of weapon systems.**
- **Baseline the number, configuration, and location of AOCs. Enhance operation and reduce personnel through daily "wartime" use.**
- **Appoint a "lead dog" for agile combat support software systems (GCSS-AF).**

The Air Force vision of "well-equipped C^2 centers collaborating globally in support of the CINCs" can be rapidly achieved if senior Air Force leadership strongly endorses the need for an enterprise-wide C^2 capability. The Air Force must restructure the way C^2 programs are managed and resourced, and at every opportunity leadership must clearly speak out about their dedication to achieving an enterprise-wide C^2 capability. In this report we have provided a proposal for how the Air Force can achieve an enterprise-wide C^2 capability by 2005. We have provided our views on areas that the Secretary of the Air Force, Air Staff, and major command staffs should focus on in starting down a C^2 modernization journey. The journey of achieving an effective distributed, collaborative, enterprise-wide C^2 capability that allows C^2 centers to collaborate globally in support of the CINCs is one of the most important journeys the Air Force must take in the 21st century.

Table of Contents

List of Figures

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Chapter 1
Introduction

1.1 Introduction

This chapter provides the background and context for the Air Force Scientific Advisory Board's (SAB's) study on improving command and control (C^2). Previous studies and actions to enhance the Air Force's C^2 capability over time are reviewed in an effort to advocate that substantial change in management and resource allocation is required to fix long-term limitations. The history suggests that, as an institution, the Air Force has not found an effective way to change the system. The value of C^2 is discussed to persuade the reader that greater importance must be accorded C^2 as a weapon system. There has been considerable debate about intelligence, reconnaissance, and surveillance (ISR) as a part of C^2. The Study Team considers ISR an essential element of operational and tactical C^2.

Volume 1 is composed of nine chapters. This chapter describes how the Theater Command and Control System fits into the overall C^2 capability. Finally, the chapter advocates the need for the management of combat information to reduce the burden on the warfighter, who is so increasingly overloaded with information that it is difficult to find what is needed. Chapter 2 discusses ways the Air Force should consider organizing for C^2, discusses the C^2 system of today, and offers improvements that form the future Theater Command and Control System. Chapter 3 addresses the issue of interoperability. Chapter 4 assesses technology for future capabilities. Chapter 5 deals with acquisition management, and Chapter 6 discusses the human dimensions of C^2 effectiveness. Chapter 7 addresses the specific actions needed to "link the Air Force by 2005". Chapter 8 covers implementation of the plan, and Chapter 9, the key recommendations of the study.

1.2 History—"Lessons Learned"

The 1996 SAB C^2 study stated, "Systems are stovepiped from the very beginning in terms of how they are defined, funded, advocated and managed by the Air Force…The stove piping problem extends to the very core of how forces are equipped." An additional theme is reflected in Einstein's words: "The world we created today has problems which cannot be solved by thinking the way we thought when we created them." Achieving the Air Force Chief of Staff's (CSAF's) goal of linking together Air Force C^2 requires that we not only look back at what the Air Force has already tried in the past, but also follow Einstein's advice and fundamentally change the way the Air Force thinks about C^2.

Air Force Chiefs of Staff have chartered numerous studies and conducted many four-star reviews in their attempts to fix the Air Force C^2 problem. These CSAF studies began with the 1986 Air Force Studies Board Summer Study; this was, in turn, followed by the 1992 and 1993 Command, Control, Communications, Computers, and Intelligence (C^4I) Broad Area Reviews, the 1996 SAB Summer Study, the 1997 C^2 Task Force, the 1997 C^2 Four-Star Summit, and this 2000 SAB C^2 Summer Study. The Air Force Chiefs of Staff also established a new Air Staff C^2 Directorate, an Air Staff C^2 General Officer Steering Group, and the Aerospace C^2 Intelligence, Surveillance and Reconnaissance Center (AC2ISRC) in their attempts to fix C^2.

The redirection of this year's SAB Summer Study topic from limited forward basing to C^2 reflects the Chief of Staff's continuing concern about improving Air Force C^2 capability. Each of these studies made recommendations for fixing the problems the Air Force was having with C^2. Analysis of study recommendations indicates that the same recommendations were made many times, yet the Service is not achieving the vision of Air Force command centers that are linked and have the ability to collaborate globally in support of all commanders in chief (CINCs), Services, allies, and the Aerospace Expeditionary Force (AEF).

The lessons learned from DESERT STORM and ALLIED FORCE and the results of every Air Force SAB and Defense Science Board study have determined that U.S. aerospace power capabilities continue to outperform the associated C^2 capabilities. This is particularly evident in theater C^2 of time-critical targeting, battle damage assessment, and campaign assessments.

1.3 C^2 and the Theater Aerospace Command and Control System (TACCS)

TACCS is only one part of the overall joint C^2 capability of the Department of Defense (DoD). CINCs of the regional and functional commands each have C^2 systems. TACCS defines the capability to support a Joint Forces Commander and the Joint Forces Air Component Commander (JFACC) in daily, crisis, or combat operations. TACCS must interface with other component commanders and specifically with Space Command, Special Operations Command, and Transportation Command C^2 systems. This study includes assessment and recommendations for improving all Air Force C^2 capability but focuses on theater C^2 as reflected in the terms of reference. Specific components of the TACCS are defined in Chapter 5.

1.4 The Value of Theater Command and Control

Theater C^2 is defined as the processes and systems that the commander uses to develop the strategy, to plan operations, to control execution, and to assess the effects in crisis or combat. While the well-defined principles of C^2 remain valid, the rapid improvements in combat aircraft and sensor capabilities are driving the need for more rapid decision making processes. New concepts of operations (CONOPS), including effects-based warfare, precision strike, and flex targeting to attack moving or movable targets, all require integration and synchronization of larger and diverse forces.

Commanders need to optimize force application to rapidly achieve objectives and end the conflict quickly. Enhancing C^2 means reducing the decision cycle time to significantly shorter timelines than the adversary's. This enables the commander to dynamically gain the initiative and respond to opportunities. The key elements of dynamic C^2 are knowledge of the adversary, real-time knowledge of the battlespace, distributed knowledge of the commander's intent, decentralized execution, dynamic control of sensors and shooters, and real-time assessment of effects. C^2 must be improved in order to improve our force effectiveness today and to be prepared to exploit the capabilities of our future forces such as the F-22, the Joint Strike Fighter (JSF), the airborne laser, and other systems.

1.5 ISR in Command and Control

Commanders need information and knowledge to make effective decisions in all elements of combat or crisis operations. As the speed of operations accelerates, commanders require more responsive processes for decision making. Because of their traditional use of ISR to gather information of strategic value, control of those assets has been retained at the very high levels and priority given to collection for Washington decision makers. There is a growing recognition that those assets need to support the Joint Task Force (JTF) Commander. Significant improvements have been implemented and others planned to make these systems more responsive to the dynamics of combat and crisis operations. U.S. Space Command has implemented a number of support concepts to aid the supported CINC and the JTF Commander. Other assets, such as the Joint Surveillance Target Attack Radar System (JointSTARS), and the Predator and Global Hawk unmanned aerial vehicles (UAVs), have been designed to give the operational commander dedicated assets to support operations.

Integration of this capability is essential to optimize the commander's knowledge of the battlespace. Sensor management is an integral part of C^2. The only way to speed the planning and execution process is to dynamically manage the ISR assets. Combining ISR and combat aircraft to find and destroy moving or movable targets requires the dynamic execution of both capabilities. Therefore the study concluded that ISR is an essential element of C^2.

1.6 Combat Information Management

Dynamic battle management requires the management of information. *Joint Vision 2010* defines the goal of information dominance. But information dominance implies more than just obtaining information: it means converting that information to a complete understanding of the situation and sharing that understanding with decision makers at every echelon at the right time, in the right format, and at the right level of detail. The amount of information available to commanders today has increased dramatically in both quantity and quality. But possession of large amounts of information does not necessarily enhance C^2. Information overload; lack of interoperability; immaturity in fusion; outdated tactics, techniques, and procedures; and the lack of an information operations function all contribute to latency in decision making.

This Study recognizes the need to enhance C^2 by creating an information management capability, including trained staff; tactics, techniques, and procedures; and support tools to control access and ensure dissemination to authorized users. The SAB studies on C^2 in 1996 and on information management in 1998 and 1999 are recommended for further understanding of this issue.

1.7 Summary

The chapter provides the foundation and context for the remainder of the report. The Air Force's documented difficulty in achieving the needed capability of C^2 as well as the value of C^2 in today's and future operations should stimulate the reader to understand the study's conclusions and recommendations. The importance of ISR and combat information management are also included.

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Chapter 2
Theater Command and Control

2.1 Introduction

The Study recognizes the critical importance of theater C^2 of air forces as an element that is fundamental to the success of air operations. In our meetings and briefings, we gained the distinct recognition that while this importance was fully understood throughout the leadership and operating elements, C^2 in general and theater C^2 in particular are not afforded the benefits of an integrated approach to implementation. The organization, management, and process are not in place to carry out the evolution in capabilities corresponding to evolving operational concepts and advancing technological opportunities.

Successfully accomplishing the Air Force mission is critically dependent on how effectively C^2 of the air forces is performed. Consequently, C^2 should be viewed as an essential element of the foundation of the Global Engagement arch and the core competencies, just as "quality people" is a cornerstone of that foundation. It is the enabler for the effective employment of aerospace power. The key to achieving an elevated role for C^2 and the vision of "command centers collaborating globally" is to establish an empowered single manager for C^2 at the Air Force level.

The lessons learned from DESERT STORM and ALLIED FORCE and the results of past SAB and Defense Science Board Studies have determined that U.S. aerospace power capabilities continue to outperform associated C^2 capabilities. This is particularly evident in theater C^2 of time-critical targeting, battle damage assessment, and campaign assessment. This chapter provides a vision for Air Force C^2, assesses where we are today, and recommends ways to fix the recurrent problems and to move toward a vision for Air Force C^2.

2.2 Organizing for C^2

2.2.1 The Air Force C^2 System and Enterprise-wide C^2 Management

The lack of understanding of the Air Force C^2 vision and constancy of purpose is evident at many levels: fundamental is the fragmentation of management as exemplified by

- Too many offices in charge of different parts of the same C^2 system
- An excessive number of Program Elements (PEs) spread across too many panels in the Air Force corporate process
- No central Global Command and Control System (GCCS) management structure aligned with Joint Staff instructions
- Confusing placement of the AC2ISRC under a major command (MAJCOM) while holding Air Force-level responsibilities

This lack of coherent, focused management at the Air Force leadership level has fostered stovepiped C^2 systems, multiple disparate improvement efforts striving for similar outcomes, confused training requirements, inadequate manning, and difficulty in deciding on a baseline C^2 structure.

The Air Force must view its C^2 system as an integrated system of weapon systems composed of many C^2 centers or nodes. Each is managed as a weapon system and has a Designed Operational Capability Statement, operational qualifications, currency requirements, and inspection programs. In addition, the Air Force should manage these C^2 weapon systems with the same job performance and safety standards as it does with other weapon systems that have life-and-death operational consequences. *The goal of a C^2 improvement program should be a distributed and collaborative system of systems that is operated by certified C^2 warriors.* Additionally, an effective C^2 capability requires an effective common operating picture (COP) that not only correlates data, but also fuses information into knowledge for the decision maker. The COP's role in Air Force C^2 is crucial because it will dictate the nature of information management at all theater levels, from the weapons system displays to the CINC or Joint Task Force Commander's operational picture.

2.2.2 Institutionalizing Enterprise-Wide C^2

A clear vision must guide any organizational transformation by motivating and compelling its people. A C^2 vision should be short and simple and should capture C^2 as a core business of the Air Force. It should reinforce the doctrinal value of centralized planning and decentralized execution, provide a theater perspective, and clarify the command relationships to achieve unity of command. Such a vision of Air Force C^2 exists. It was documented in the AC2ISRC's *USAF C^2 CONOPS, Dynamic Aerospace Command—USAF Command Centers Collaborating Globally in Support of all CINCs, Services, Allies and the AEF*. It should be embraced by the Air Force leadership and institutionalized. Such a vision, backed by senior leadership's commitment to transformation, will enable the Air Force to embrace a true understanding of C^2 as the lifeblood to Global Vigilance, Global Reach, and Global Power. The Air Force must also follow the Joint Staff's *Joint Vision 2010* lead and elevate C^2 to a prominent role in its vision.

2.2.3 The Role of Air Force Leadership

Essential to structuring an effective C^2 architecture and process is the dedication of leadership to adopt a formal process for evolving the C^2 system along with the advancement in environment, doctrine, strategy, and tactics. The past practice of handling the C^2 system as a pickup game is an artifact of the lack of emphasis at all levels in recent conflicts. C^2 can no longer be treated in this fashion, and must therefore be viewed and managed by the senior staff as cornerstone for effective airpower. Thus, the Study sees the solution of today's C^2 difficulties as an issue of top-down emphasis.

2.2.4 Joint Interoperability

No single Service has the C^2, sensors, and weapon systems to accomplish all DoD missions. Therefore, the Services must be able to leverage another Service's situational awareness and weapons systems capabilities. Dynamic retasking of aircraft in support of commanders' priorities will require rapid access to appropriate databases to obtain the near–real-time information that is essential for dynamic decision making. Interoperable databases and appropriate datalinks are the foundation of this concept. Joint interoperability also requires Air Force C^2 systems that are interoperable with GCCS and other Service C^2 systems. See Volume 2, Chapter 3, for a detailed review of the TACCS Joint Interoperability Initiatives.

2.3 The Air C^2 System Today

2.3.1 Theater C^2 Elements

Today, the Air Force lacks the C^2 systems and processes to fully harness the capabilities of the weapons systems, munitions and ISR systems it possesses. The Air Force C^2 system includes the Theater Air Control System (TACS), the Mobility C^2 System, the Special Operations C^2 System, the Space C^2 System, and the Information Warfare Center. Key elements are

The Expeditionary Air Force (EAF) C^2 System. The EAF C^2 System includes all the command centers listed in Figure 2-1. These Air Force C^2 centers must be capable of collaborating globally in support of all CINCs, Services, and allies.

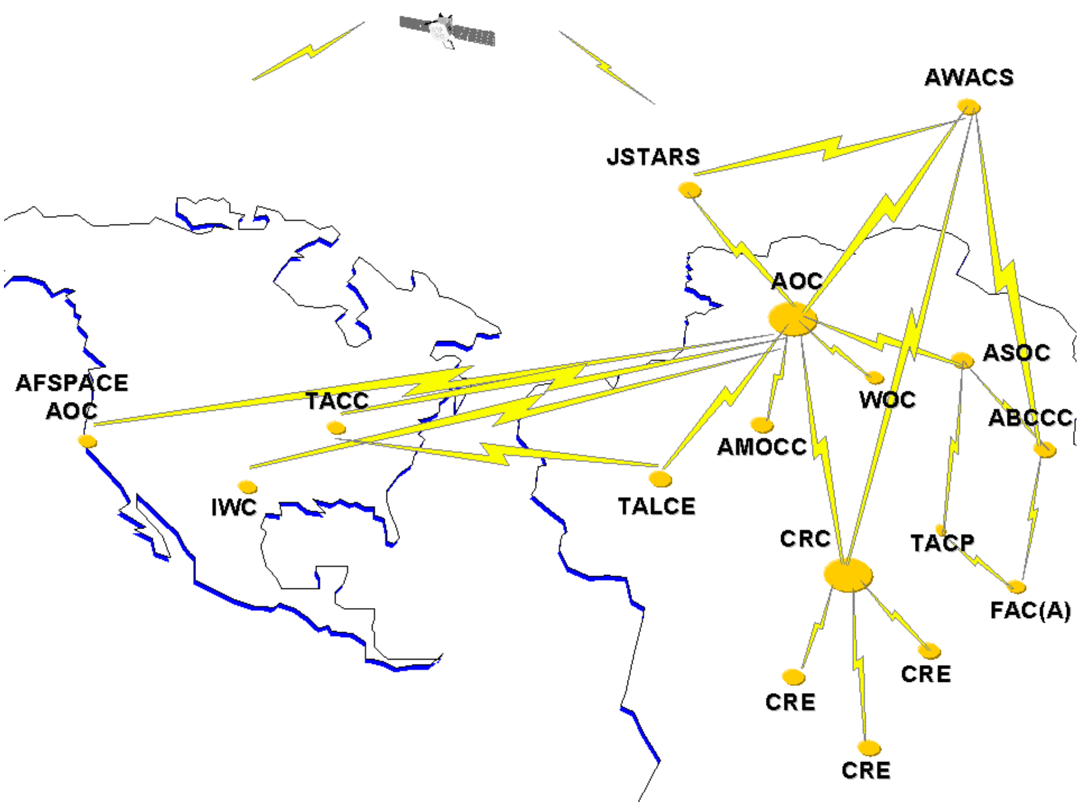

Figure 2-1. *Current EAF C^2 Centers*

The Theater Air Control System. Air Force forces (AFFOR) respond worldwide in support of theater CINC missions by deploying an Air Force C^2 capability for the employment of operational forces. These C^2 centers support the Aerospace Expeditionary Task Force Commander, Air Forces Commander (COMAFFOR), and Joint/Combined Force Air Component Commander (J/CFACC) at the operational level of warfare.

The Air Force Forces Combat Support Center. The AFFOR Combat Support Center provides a capable, mobility-ready, theater-smart aerospace support and sustainment element for the COMAFFOR.

The Air Operations Center (AOC). The AOC commands and controls decisive aerospace power in support of CINCs or JTFs. The AOC performs the functions of planning, direction, and control over deployed air resources. The AOC supports COMAFFOR, C/JFACC, the Airspace Control Authority, and/or the Area Air Defense Commander. The AOC produces, distributes, and executes the integrated air tasking order (ATO).

The Control and Reporting Center (CRC). The CRC is subordinate to the AOC and is a primary control node for the decentralized execution of air operations. The CRC directs region or sector air defense and provides aircraft control and monitoring for offensive and defensive missions. The Control and Reporting Element (CRE), a subordinate unit to the CRC, extends these capabilities.

The Air Support Operations Center (ASOC). The ASOC is subordinate to the AOC and is the primary air support liaison element to the Army Corps headquarters. It is the conduit to exchange close air support combat information between air and ground units. It plans, coordinates, and directs tactical air support of ground forces, normally at corps level or below.

Tactical Air Control Party (TACP). The TACP is subordinate to ASOC and is responsible for controlling close air support and advising and assisting the U.S. Army commander when air support is required.

The Wing Operations Center (WOC). The WOC, both fixed and deployed, includes the following functional areas: operations control, maintenance coordination, and battle management/survival recovery.

The Tanker Airlift Control Element (TALCE). The TALCE coordinates and executes both preplanned and immediate airlift requirements with the Tanker Airlift Control Center and the Air Mobility Division within the AOC. The TALCE provides continuous onsite management of airfield operations.

The Airborne Warning and Control System (AWACS). AWACS provides all-weather, all-terrain target detection, weapons control, and threat warning.

The Airborne Battlefield C^2 Center (ABCCC). The ABCCC is responsible for management of tactical air forces and liaison with ground forces. Its primary employment role is an extension of the AOC combat operations and as an alternate ASOC or Direct Air Support Center.

The A-10 Forward Area Controller (FAC-A). A TACP operating from a suitable aircraft, the FAC-A coordinates air strikes between the TACP and close air support (CAS) aircraft. The FAC-A provides terminal control, relays CAS reports, provides immediate target and threat reconnaissance, and marks targets for the attacking aircraft.

The Joint Surveillance Target Attack Radar System (JointSTARS). JointSTARS is a theater-wide battle management C^2 platform that conducts ground surveillance and provides attack support functions to friendly offensive air and helicopter elements.

2.3.2 Supporting the Continental United States (CONUS) Command Centers

The following CONUS-based Air Force command centers provide critical support for successful EAF operations.

Air Force Space Operations Center (AFSPACE) AOC. The 14th Air Force AFSPACE AOC is an in-place equivalent of the theater AOC and accomplishes parallel planning and operational functions for the Commander, AFSPACE.

The Tanker Airlift Control Center (TACC). The TACC is Air Mobility Command's hub for planning, scheduling, tasking, and executing America's mobility forces around the world. The TACC is dedicated to providing quality service to a wide range of mobility customers.

The Air Force Information Warfare Center (IWC). The Air Force Information Warfare Center develops, maintains, and deploys information warfare/C^2 warfare capabilities in support of operations, campaign planning, acquisition, and testing.

2.4 The Future Theater Command and Control System

2.4.1 Combined Aerospace Operations

While the fundamental mission of every Combined Aerospace Operations Center (CAOC)/AOC is similar, each theater performs CAOC functions differently. Historically, there has been little effort to standardize CAOC operations. The North Atlantic Treaty Organization (NATO) Allied Tactical Air Forces (ATAFs) each planned and executed its air campaigns using different procedures and equipment. For example, CONUS augmentees to the 2nd ATAF CAOC in northern Germany, known as the Allied Tactical Operations Center, would find very different procedures and processes from those found in the CAOCs supporting 4th ATAF (southern Germany), 7th AF (Korea), and the CONUS-based numbered Air Forces (8th AF, 9th AF and 12th AF).

Section 2.4 presents the significant issues that will affect a commander's ability to plan and execute an air campaign.

2.4.2 The CAOC/AOC Organization

The organization of the Theater Air Control System is well defined and documented, with the exception of the CAOC/AOC. Air Force AOCs support a wide variety of CINCs throughout the world. The fact that these Air Force AOCs support a wide variety of commands often results in extensive customization. Other Air Force weapon systems are not customized for each theater of operations. CAOC/AOC should follow the "organize, train, and equip" concept the Air Force uses for other major weapon systems, such as the F-15, the F-16, and AWACS. They are not customized by theater, but provided by the Service to the theater as a combat capability package. See Volume 2, Chapter 7, for a description of the AOC organization.

The CAOC is the operational C^2 center in which the Combined Forces Air Component Commander has centralized the functions of planning, directing, and controlling aerospace resources. The probability that the Air Force will operate a U.S.-only AOC is extremely remote; yet many of our development efforts do not address the underlying coalition security and system engineering issues in the technical design of the AOC systems infrastructure. Coalition operations must be viewed as the operational baseline of the CAOC/AOC weapon system and, as a result, become the driving force behind its organization, technical design, and systems engineering.

2.4.3 CAOC Manning and Training

Air Force CAOC/AOC training programs have lagged in definition and rigor compared to other weapons systems. This results in a pickup team approach for CAOC operations in both exercises and real-world contingencies—a major operational problem.

A brief review of the history of formal CAOC/AOC training may help frame the overall issue as it exists today. The Air Force created the Blue Flag program in the late 1970s with the objective of providing AOC training. The initial goal was to train potential AOC augmentees in theater-specific processes and procedures. Typically, Blue Flag would plan an exercise such as “Korea” by visiting the theater well in advance of the exercise date. The visit focused on identifying current theater procedures, updating the Blue Flag library with the theater documents, and identifying selected theater personnel to come to the exercise and act as advisors. The Blue Flag AOC was configured to replicate the theater-specific facility. This approach provided a reasonably high degree of fidelity with regard to each theater’s AOC processes. This approach, however, was not continued.

In the late 1980s, both the 9th AF and 12th AF began to use Blue Flag as a training vehicle and helped develop the warfighting scenarios. The numbered Air Force (NAF) staffs relocated to Hurlburt Field once a year for Blue Flag training. This training was focused and received very high marks from Gen Horner after his DESERT STORM experience. While Blue Flag continues to provide valuable training, there is no formal mechanism to identify, train, and track people who have been trained in theater-specific AOC operations. A second issue is the manner in which CAOC/AOC training is conducted. The requirements for AOC training are defined in Air Force Instruction 13-1, Volume 3. This document provides a well-recognized training construct of initial qualification training, mission qualification training (MQT), and continuation training; however, continuity of this construct falls apart during implementation. The MQT training program is implemented as a local unit-training program and may not provide the trainee with a realistic picture of the dynamic CAOC environment. Continuation training is also conducted at the unit level, with occasional opportunities to work in a CAOC exercise (such as a Blue Flag or Ulchi Focus Lens) or similar joint-level exercises.

The SAB concluded that current training falls far short of what is needed and is not consistent with the Air Force’s belief that we “train the way we fight.” *The CAOC weapons system is complex and needs to be “flown” regularly—not once or twice a year*. The Theater Battle Management Core System (TBMCS), the primary software system for the CAOC, is extremely capable, but complex. No one individual understands its full capability. Just as Air Force operators must fly complex aircraft frequently and regularly to maintain proficiency, C^2 warriors must operate the complex CAOC weapon system frequently and regularly to maintain proficiency.

Air Force–provided AOCs are not fully manned, and there is no reason to expect this situation to improve. The problem is exacerbated further by the lack of school slots at the C^2 Warrior School and by limited Blue Flag training opportunities. This lack of a quality training program, combined with an inadequate number of training opportunities, keeps AOC operational proficiency low.

2.4.4 CAOC Process Improvement

The AOC processes *have never been standardized* the way other weapon systems have. It seems clear that the Air Force needs to implement a CAOC baseline that provides a significant level of standardization while providing some flexibility for unique theater operational needs. Standardized CAOC processes would allow a far more efficient crossflow of trained people, provide rapid absorption of augmentation personnel, and set the framework for other management actions to further improve overall Air Force C^2. A standardized CAOC would also improve the worldwide applicability of the CAOC training that is provided by the C^2 Training and Innovation Group (C^2TIG) at Hurlburt Field.

The C^2TIG has led the development of a detailed hierarchy of publications for use by fielded CAOCs and training organizations. However, the majority of these documents remain in draft form. See Volume 2, Chapter 7, for a list of these CAOC/AOC–related documents.

2.4.5 The Theater Battle Management Core System

TBMCS provides the basic C^2 hardware and software set for daily aerospace operations, from the development of the ATO to dynamic attack control and battle damage assessment. Newly developed and now being fielded, the TBMCS contains some 55 software modules and replaces the Contingency Theater Air Planning System (CTAPS) and associated elements. It has been developed over 4 years and is considered by the Study to be the basis for future air operations management.

The Study recognized the many difficulties in the development of TBMCS, brought about in large part by the changes in both operational concepts and technologies spanned by the 4-year program. Above all, the message to be remembered is that neither the operational concepts nor the technologies will stand still over such a period, and future systems must evolve so as to fully accommodate change. In fact, C^2 systems should, as a matter of policy, be developed incrementally, rather than in a turnkey, stovepiped process.

2.4.6 Time-Critical Targeting

Time-critical targeting (TCT) will require a change in how the Air Force thinks about C^2. It will impact theater C^2 architecture design, modernization, and training. Although the TCT target set may be small or non-existent during the initial phase of an air campaign and overall is a fraction of total C^2 activity, TCT needs will push operational process improvement, pull technologies, and drive C^2 efficiency.

An effective TCT capability will require superior coordination and C^2 of sensors operating in air, ground, and space and simple intuitive tools for C^2 warriors to effectively find, fix, target, track, engage, and assess any target in the battlespace. Building an effective TCT capability can be the operational imperative that breaks down the organizational, technology, and process stovepipes that constrain C^2 effectiveness today. Aircraft weapon systems and munitions are designed and built to meet the most demanding missions. TCT, the military's most demanding C^2 mission, can and should be the driving force behind Air Force theater C^2ISR modernization and development. *Developing a highly effective TCT capability will address most theater C^2 mission deficiencies that exist today.*

The AC2ISRC's TCT analysis in its Air Force Requirements Oversight Council–approved "Family of Systems Requirements Document," 11 January 2000, and "Strategy and Modernization Plan for Time Critical Targeting and Real Time Information to the Cockpit," 7 February 2000, is extensive and addresses the key end-to-end organization, process, and technology issues for fixing TCT. This analysis offers the Air Force a "silver thread" that can be used as the foundation for the joint and multi-Service theater C^2 system modernization.

2.4.7 Fielding the Battle Control Center (BCC)

The BCC concept will provide a modernized, decentralized C^2 execution node for the Air Component Commander (ACC) and CAOC. It should be organized to direct air battle execution¸ theater air defense, datalink management, combat identification, and surveillance. The BCC should provide the ACC and Joint Force Commander with a near–real time means of managing a single integrated air picture from air-, sea-, land-, and space-based sensors. Not only should the BCC provide the ACC with the personnel, tactics, techniques, and procedures (TTP), and equipment necessary to direct and control theater air operations, but the BCC should be equipped and trained to conduct limited theater planning, coordinate air operations with other joint and combined forces, and directly augment the ACC's airspace control and area air defense commander functions. When equipped and trained as described, the BCC can serve as a backup to the CAOC.

2.4.8 Air Force Forces

Operations from World War II to the present point to a lack of progress in defining, organizing, and institutionalizing a theater-smart highly trained AFFOR capability. More attention is needed for the maturation and development of the AFFOR organizational concept, staffing, C^2 training and exercises, decision support systems, processes, and Unit Type Codes (UTC).

Senior leadership must define and baseline the AFFOR organization and should develop a distributed and collaborative operations concept consistent with the Air Force vision of "C^2 centers collaborating globally in support of the CINCs." AFFOR C^2 centers should have forward elements and effective reachback locations. The AFFOR staff is an operational Air Force wartime capability and must be established, trained, and ready to provide direct support for deployed theater aerospace forces. In the past, the Air Force has relied on existing resources and a pickup team to support AFFOR requirements when an operation commences. *AFFOR staff members must be assigned to an AFFOR UTC* and receive effective training to carry out their mission.

2.5 The Global Information Grid

As a consequence of the Clinger-Cohen Act of 1996, the Office of the Assistant Secretary of Defense: Command, Control, Communications, and Intelligence (OASD/C^3I) issued guidance on several aspects of information management. Included in that guidance was the establishment of the Global Information Grid (GIG) as a mechanism to generally integrate the DoD information system. The GIG is defined as "the globally interconnected, end-to-end set of information capabilities, associated processes and personnel for collecting, processing, storing, disseminating and managing information on demand to warfighters, policy makers, and support personnel."[1] At this point, there remain non-trivial difficulties in the interpretation of the extent of the GIG, particularly as it pertains to the field systems (such as mobile C^2 systems, weapons systems, and aircraft), and it remains to be determined just what the implications are. OASD/C^3I is currently addressing these issues.

The GIG is correct and achievable and offers greatly enhanced integration of the DoD information system for speed, security, robustness, and effectiveness. In spite of the complications at the warfighter end of the GIG, the Air Force must take action to accept and embrace the GIG and to address the integration of the C^2 systems into the GIG structure.

2.6 The Relationship to the Global Command and Control System–Air Force (GCCS-AF)

To date, the Air Force has produced stovepiped legacy C^2 systems across numerous mission areas, such as mobility, space, strategic, ISR planning and weapons control, mission planning, theater battle management, and agile combat support. Separate acquisition and support efforts have led to duplicative information views across mission areas and different computing infrastructures. These stovepiped C^2 systems have limited interoperability. This results in multiple C^2 systems within C^2 centers that provide inconsistent information views and produce complex technology environments for the operator.

The existence of most of the stovepiped C^2 systems can be attributed to multiple C^2 management structures, limited crossflow of requirements, and a lack of a consolidated C^2ISR enterprise-wide view of C^2. An example is the separate processes that manage Air Force joint requirements for GCCS and TBMCS. These separate management processes have resulted in stovepiped system production, duplication across mission areas, questionable use of resources (such as funding and manpower), and fragmented information to the warfighter. See Volume 2, Chapter 7, for a detailed breakout of GCCS–AF issues.

The near-term technical strategy for an integrated GCCS–AF must include migration to the joint GCCS common integration framework—the Defense Information Infrastructure Common Operating Environment (DII COE) Level 6. This should continue for the short near term; however, the mid- to long-term solution is a web-based integration framework, which will, in turn, enable the development of a full Joint Battlespace InfoSphere (JBI) capability as described in the SAB's December 1998 study "Information Management to Support the Warrior" and December 1999 study, "Building the Joint Battlespace InfoSphere."

2.7 Migrating to the JBI

The JBI is a proposed improvement for information support to C^2 that recognizes and exploits the design and development processes that have been sweeping across the commercial information technology markets. It represents a major evolutionary milestone in the concept of information system design and offers operational, system, and technical improvements.

Currently, no Air Force program provides for the development, acquisition, or fielding of the JBI. The Air Force needs to establish a JBI program, and it is our recommendation that it be an

[1] DoD Chief Information Officer (CIO) Guidance and Policy Memorandum No. 8-8001, 31 March 2000, "Global Information Grid."

infrastructure element of the GCCS–AF program. Resolving the technical issues involved in migrating from today's GCCS DII COE design construct to the JBI design construct will require that it be closely linked to the GCCS program. Close cooperation with the Defense Information Services Agency (DISA) and DII COE governing bodies will also be needed. Appendix E describes the fundamental nature of the JBI.

2.8 Summary

The Air Force must focus on the evolution of its theater C^2 capability through effective single-point management and a flexible architecture capable of adaptation to the future environment. This management must include control of the system operational architecture, the integration roadmap, and the funds and people to make it happen. We can no longer depend on interconnecting stovepiped systems developed in isolation or on excessive processes to formalize requirements. This is an era of rapidly changing environments, capability needs, and information technologies, and the Air Force must adapt thoughts, plans, and actions to that reality.

The Air Force vision of "well-equipped C^2 centers collaborating globally in support of the CINCs" can be rapidly achieved if senior Air Force leadership strongly endorses the need for an enterprise-wide C^2 capability. The Air Force must restructure the way C^2 programs are managed and resourced, and leadership must clearly speak out about their dedication to achieving an enterprise-wide C^2 capability at every opportunity. In this chapter, we have provided assessment of the Air C^2 System and general recommendations on how the Air Force can achieve significant improvements in C^2 capability by 2005. We have provided our views on areas that the Secretary of the Air Force (SAF), Air Staff, and MAJCOM staffs should focus on in starting down a C^2 modernization journey. The journey of achieving an effective distributed, collaborative, enterprise-wide C^2 capability that allows C^2 centers to collaborate globally in support of the CINCs is one of the most important journeys the Air Force must take in the 21st century.

The Study believes that the Air Force, and the AC2ISRC in particular, have made significant advances in capturing the operational concepts and plans, and these advancements should be the basis for future C^2 evolution cycles.

Chapter 3
Interoperability in a Joint and Coalition Environment

3.1 Introduction

Information dominance—the ability to employ information to achieve decisive battlespace advantage while denying such use to an adversary—is a central tenet of joint doctrine, strategy, and tactics. Achieving this advantage means that Air Force, joint, and coalition forces must be able to gather, share, process, interpret, and use information with superior speed, reliability, security, and resistance to enemy actions. As all of military history shows, the side with an information advantage will usually prevail, even against superior numbers.[2] This is increasingly the case in modern operations and applies to every level within the spectrum of conflict.

Rapidly advancing technology, from sensors to communications to computers and displays, provides much of the foundation for information dominance. Yet, decades-old problems with incompatible equipment, divergent definitions and uses of data, uncoordinated procedures, and other aspects of information sharing continue to plague U.S. and allied military forces. We have repeatedly found ourselves enjoying an advantage in the sophistication of our technology, only to see that advantage blunted by a lack of interoperability. Recognizing the seriousness and importance of this problem, this SAB study has devoted a specialized panel to the topic and charged it with determining the sources of non-interoperability and the immediate and longer-term steps needed to redress these shortfalls.

Interoperability means the ability to link the right people and systems, at the right times and places, so that they can pass consistent data that convert to shared understanding, ultimately producing cooperative decision making and action. A bit more formally, the authoritative definition is

> 1. 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. 2. The condition achieved among communications-electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users.[3]

The key words are "operate effectively together." As we have learned in this study, passing messages and data is only the beginning of interoperability. Even the ponderous definition just cited only hints at the complexity of the problem of reliably achieving truly synchronized, mutually supportive action among elements of a force. Interoperability has a myriad of facets, not only warrior to warrior and system to system, but command to command, Service to Service, joint to component forces, and joint to coalition partners.

In warfare, the Air Force works in the air superiority, close air support, and ground strike warfare regimes and meets air mobility, airspace management, aerial refueling, and other requirements. In a joint environment, Air Force units are joined by the Navy in both air superiority and ground strike, as well as by the Army and Marine Corps in ground strike. With the burgeoning role of

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[2] As one example, the unauthorized extended absence of Jeb Stuart's cavalry just prior to the battle of Gettysburg deprived Lee of critical intelligence and is considered a major contributor to his defeat.

[3] Joint Publication 1-02, "DoD Dictionary of Military and Associated Terms."

Naval surface and undersea fire support from offshore, the Navy's role in ground strike has now extended beyond the functions of naval aviation, adding yet another variable. When allied forces join the mix, still other disconnects, ranging from equipment peculiarities to differences in policy and doctrine, can arise in the interoperability equation of joint and coalition warfare.

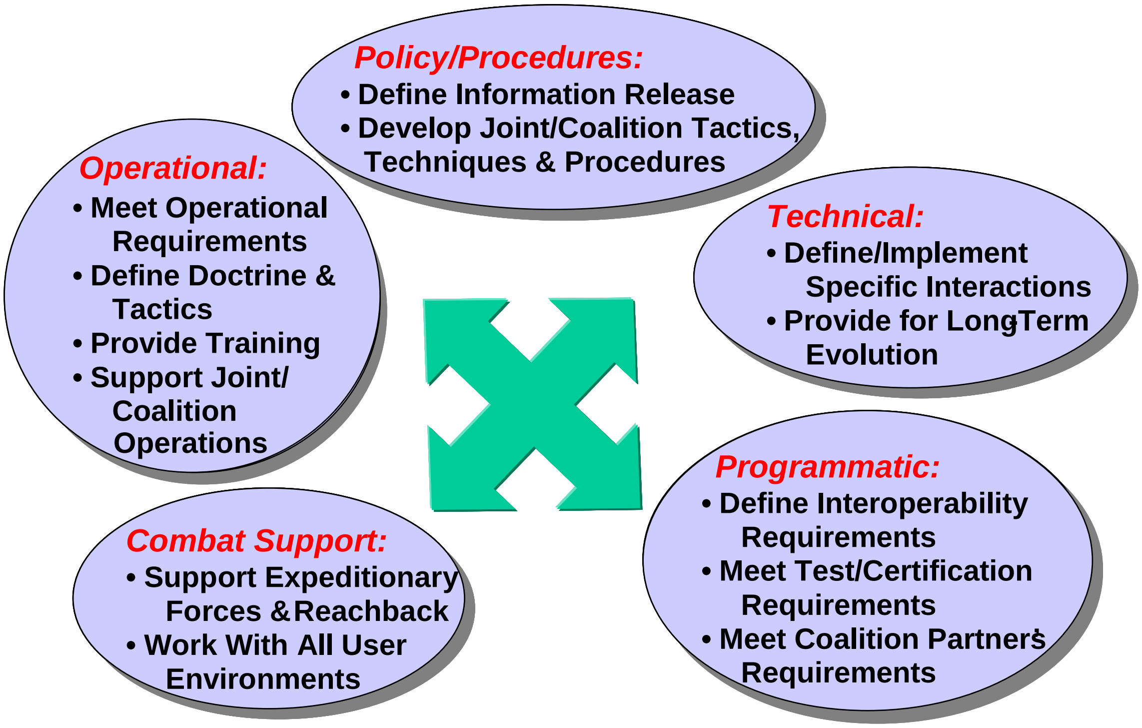

Figure 3-1. *Interoperability Has Many Dimensions*

The diversity of factors that must be harmonized to achieve interoperability is suggested in Figure 3-1. In joint or coalition operations, consistent policies and procedures that enable sharing and use of information across national and Service boundaries are essential. For each organization and system, interoperability raises a wide range of operational and support questions. Finally, in the requirements definition and acquisition processes, interoperability generates both technical and programmatic concerns. This last aspect is especially troublesome, because interoperability is quintessentially a force or system-of-systems proposition, but our approach to acquiring systems focuses on individual programs. Historically, program managers have had great difficulty compromising their narrow individual interests for the sake of the greater good. However, in their defense, they are often encouraged (through funding practices) to produce their system first and consider interoperability second. In recent times, the individual program manager is increasingly seen as responsible for making interoperability happen, but the largest part of the problem lies in the implementation of other systems, and is thus beyond his or her control.

These issues are not new. DoD has pursued endless standardization initiatives in equipment and procedures. NATO has for decades described rationalization, standardization, and interoperability as a high alliance priority. And the impressive record of military successes by the United States and our allies since Vietnam attests that these efforts have not been without effect. Today's joint and coalition forces stand without peer in the global security environment and are superbly capable, especially in large-scale conflicts. However, two things are changing as we enter the 21st century. One is the exponential growth in our reliance on information in operations, creating both a host of new and more complex interoperability challenges and an ever greater urgency in dealing with them. The other is the reality that missions at the low end of the conflict scale, such as humanitarian relief, evacuations, separation of hostile parties, and the like, will see the most frequent tasking of our military forces. The situational ambiguity, lack of clear separation among hostiles and neutrals, limits on use of weapons, and other factors in such situations place extreme demands on enabling information processes and interoperability.

3.2 The Real Meaning of Interoperability

As the first step in dealing with the interoperability dilemma, it is essential that the meaning of the term and its multiple dimensions be clearly understood. Like many other words (*architecture* comes to mind), interoperability means different things to various individuals and organizations. For example:

- To communicators, interoperability usually means the ability to connect nodes and exchange messages. The key to this dimension of interoperability is a set of well-defined interfaces across which interacting information processes can talk to each other.
- To information technologists, it usually means the ability to connect equipment via networks and to have software applications that cohabitate and (ideally) cooperate when loaded on workstations, servers, and nets. The key here is control of the platforms on which applications ride, of the shared services they use, and of the networks through which they exchange data.
- To the warfighter, whose opinion is the one that counts, interoperability means something much closer to the definition given earlier: the ability to exchange information in such a fashion that it enables cooperative activities to accomplish the mission. This requires that *all* aspects of interoperability be accounted for.

We have found that the best approach to shed light on this complexity is to construct a hierarchy of successively higher levels of interoperability. Figure 3-2 summarizes this construct. At the lowest level, interaction requires that the parties involved share channels for communication. These may be landlines, voice radios, datalinks, satellite communications, or, for that matter, couriers on horseback. This layer is labeled "Connectivity" in the figure and is characterized by the physical and electronic parameters of a channel; an example would be the waveform (frequency, modulation, power level, etc.) of a network radio. Connectivity enables the exchange of *signals* via *datalinks or channels*.

Next, we require compatibility in the way these channels are used to exchange messages. For a voice radio, this can be as simple as a common language and a set of defined terms. In current DoD directives,[4] data exchanges are specified by Information Exchange Requirement (IER) matrices, which specify transactions among specific platforms or operational facilities in response to particular events. For a network or datalink, messaging is controlled by a protocol that governs such things as the message structure, how data is encoded, how errors are detected and corrected, and how networks and channels are managed. A typical example is the network

[4] Chairman Joint Chiefs of Staff Instruction 6212.01B, "Interoperability and Supportability of Notional Security Systems, and Information Technology Systems," May 2000.

protocol and J-series messages defined for Link-16. We call this layer "Communication," and it enables the exchange of *messages* to achieve *shared data.*

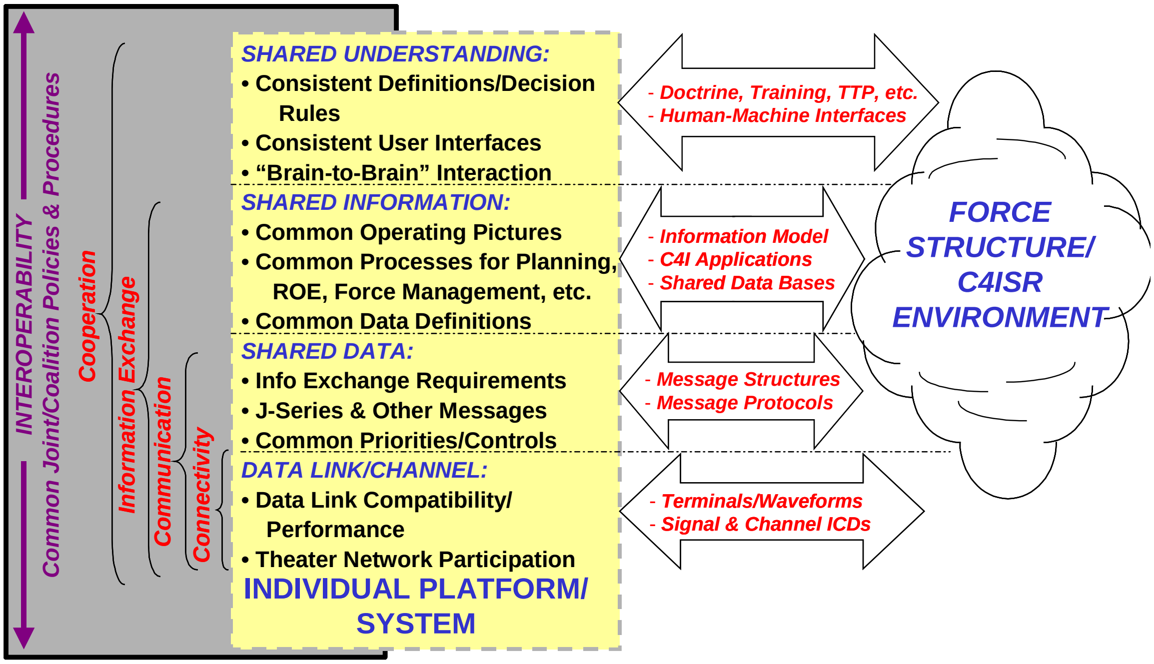

Figure 3-2. *A Hierarchy of Levels of Interoperability Illustrates Its Complexity*

At the next level up, the issue becomes one of compatible information processes, which ensure that shared data are treated and used consistently. At this point, a common information model, discussed in detail later and in Chapter 3 of Volume 2, is absolutely essential. Aspects of this would typically include use of appropriate elements of a common operating picture via shared databases and use of the same or equivalent algorithms for data processing. We call this layer "Information Exchange," and it results in *shared information* among the participating information systems.

Yet another set of interoperability factors enters when we address the top layer, involving the interaction between information systems and human users. This involves both the human-machine interface, especially the need for consistent information presentation, and the underlying cognitive processes involved in decision rules, tactics, and training. When this level is fully achieved, the result is what has been called brain-to-brain interoperability[5] such that commanders and warfighters possess a common understanding that enables cooperative action. Accordingly, we call this layer "Cooperation" and characterize it in terms of *shared understanding*.

Finally, true joint and coalition interoperability demands a foundation of common policies and procedures, drawn in the figure as a background factor spanning the whole interoperability hierarchy. This goes beyond considerations of compatible equipment and equivalent tactics and training. It involves political issues of information release among nations, unity of command for

[5] Julian Ranger, STASYS, Ltd., Through Life Interoperability Program (TULIP) Handbook, 1999.

coalition forces, and shared understanding of legal constraints and rules of engagement. With this, we have the kind of *interoperability* that modern warfare requires.

It should be understood that the implementation of any given layer of the hierarchy can be insulated from the details of the layers below. For example, information sharing may employ a variety of channels and messages, provided the appropriate routers and translators are in place. What's essential is that all these aspects of interoperability be addressed in an effective and consistent strategy.

3.3 The Immediate Problem

A good many of the disconnects in current C^2 environments could be attacked immediately. Correcting them could have huge payoffs in the effectiveness of Air Force units in the kinds of operations that will be our bread and butter in the years ahead. Some of the fixes require significant investment—for example, to equip airplanes with datalinks—while others could be addressed by relatively simple changes to policy or procedures. Some are beyond the ability of the Air Force to address by itself, but may respond to Air Force–led initiatives. The Study urges the Air Force to systematically examine the lessons learned in operations over the past decade or so and to implement a coordinated program of activities to correct as many of the identified interoperability problems as Air Force authority and available resources will allow. Some of the possibilities are as follows:

- **Inadequate secure communications.** U.S., NATO, and potentially other allied defense establishments do not yet possess the level of *secure* communications capacity that operational considerations warrant. The importance of information superiority suggests that this should be a high priority in investment decisions.
- **Separate U.S. or coalition C^2 networks.** The members of a combined force that go in harm's way together should have few secrets from each other that impede mutually supportive operations. Both policy questions of information sharing and technical issues such as network bandwidth were factors in the Kosovo operation and should be addressed through NATO channels. It is important to note that although there should be few secrets, there will probably always be some, and we need to learn how to deal with that interoperability problem as well.
- **Inadequate management of network, bandwidth, and spectrum.** Dependence on networks and the spectrum they use has outstripped the generally available tools for managing these scarce resources. Among other measures, the Air Force could consider adopting UK network management systems that were used to good effect in support of missions over Serbia.
- **Incompatible procedures for the same aircraft or weapons.** There have been instances of TTP for weapon systems that differ in allied and U.S. air forces and hinder cooperative missions. These can be resolved in joint training and exercises.
- **Multiple specific disconnects.** Many individual problems have been documented, and many of these result from inconsistent definitions of data—for example, in defining the time zero reference associated with a track reported over a datalink. The Air Force could and should put someone in charge of systematically rooting out such problems and defining solutions, many of which will involve little or no cost.
- **Inadequate timely, accurate, and trusted combat support information.** Interoperability is as vital in logistics as in flight operations, especially when operating at austere facilities at the end of long supply lines. A comprehensive implementation of expeditionary air power must consider the information processes of combat support and the resources and procedures needed for reachback, materiel management, transportation, and other key combat support processes.

3.4 An Agenda for Interoperability

The other near-term agenda defined by the Study involves actions that need to be started today to enable progress toward the fully competent and interoperable C^2 fabric of the 21st century aerospace force. Many critical details of that future C^2 capability can be worked out only in an evolutionary fashion as enabling technologies mature, as future warfighting concepts are defined and validated, and as systems progress incrementally toward their full realization. Accordingly, the key decisions today involve defining and launching the processes that will yield the required future C^2 environment. Some important aspects of these processes are discussed in the following paragraphs.

3.4.1 Architecture and Information Modeling

The commercial world achieves interoperability to a far greater and more reliable extent through familiar means like the Internet than DoD does in its current system. It is vital that the Air Force and DoD as a whole learn the lessons of commercial practice, adapt them as necessary to the military environment, and apply them appropriately. The Study has looked at this in some detail and concluded that a set of architecture and information modeling actions is essential as the bedrock on which interoperability can be built.

The key to open, interoperable systems and networks is the use of layered architectures, with a carefully chosen and defined set of standards used at each layer. The Internet and file protocols used in the World Wide Web for the network, transport, and application layers are perhaps the best-known examples. It is critical that a minimum set of standards adequately define the architecture employed, that these standards have maximum flexibility and generality, and that they emerge as a consensus within the technical and user communities of interest. Furthermore, the individual system designers should be free to adopt architecture and standards that most effectively and economically meet their needs. Military system designers should be given incentives by means of the cost savings and operational effectiveness delivered by such an approach, not by *a priori* standardization mandates.

A closely related subject is the need for a common, joint information model. This goes far beyond traditional data-modeling efforts, which are doomed to failure because they attempt to span the vast complexity of information needs of all warfighting communities and missions with a single, unstructured list of data elements. The JBI construct[6] includes an object schema and provisions (using fuselets) for transforming and managing the content of the shared information base. This needs to be fleshed out in a complete information model that defines the data structures, the associated processes for such actions as aggregating related data and enforcing security, and the interfaces between the information base, applications, and the cognitive processes of users who employ it. Standards have a role here; for example, use of widely supported standards such as GIF and JPEG helps ensure interoperability of files and databases of graphical information. Properly implemented, the information model will provide the necessary framework to meet the multidimensional interoperability needs of various warfighter communities and of joint and coalition operations.

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[6] In addition to the discussion in Appendix E and in Chapter 8 of Volume 2 of this report, see the following SAB reports for JBI details: *Information Management to Support the Warrior*, SAB-TR-98-02, December 1998, and *Building the Joint Battlespace InfoSphere*, SAB-TR-99-02, December 1999.

Any discussion of C^2 architecture raises the issue of the future of the DII COE. To summarize a very complex subject, the conclusion of this study is that the DII COE should evolve from the present platform and product model to a more Internet-like services model. In the transformation, details of platform implementation that currently bedevil applications programmers and make backward compatibility difficult or impossible to achieve should be buried below interfaces that implement the “publish and subscribe” mechanisms that are a key feature of the JBI. The Air Force should lead the process that achieves this evolution, with the greatest possible involvement of other stakeholders such as DISA, the Army, and the Navy.

Many of the Study’s results in this area look forward to the JBI, which, by its very nature, provides a far more effective approach to interoperability than current architectural concepts that center on transactions between pairs of systems or platforms. With the JBI, the same *physical* events may occur in executing an information exchange as with current concepts, but the *logical* process is completely different. The current DoD approach to specifying and evaluating interoperability involves a large number of IERs between any given platform and the many others in the battlespace with which it interacts. This approach is cumbersome, and such an IER set is rapidly made obsolete by the evolution of the systems involved. In the JBI, the plethora of IERs reduces to a single, admittedly complex, interface between a platform and the InfoSphere. Interactions with the external environment via the JBI are accomplished through publish-and-subscribe mechanisms that are far simpler to deal with than hundreds or thousands of specific IERs. This is discussed in more depth in Chapter 8 of Volume 2 of this report.

3.4.2 Key Processes to Achieve Interoperability

Achieving interoperability is usually a matter of simultaneously evolving policy and doctrine, system requirements and designs, training and tactics, and enabling technologies. It will seldom be the case that a crisp final solution, such as a point design for a system or network, can be specified in advance. This reality means that the key to success is a set of consistent, high-quality *processes* that enforce and implement an interoperability strategy while involving all stakeholders and balancing competing priorities. The idea is to implement processes that keep people focused on the interoperability goal and following the prescribed course while the answers emerge over time from spiral developments, field experience, and system engineering.

Interoperability issues arise at every stage of system acquisition, from requirements definition to testing and evaluation. A particular challenge involves reforming the current multi-year, all-encompassing (sometimes labeled “big bang”) requirements process to be compatible with a spiral development model with a cycle time of 18 months or less. Still other processes with interoperability dimensions involve training (especially joint and coalition), development of doctrine and of TTP, and assessing the interoperability readiness of expeditionary air force packages. In general, processes must move from their present focus on platforms toward a network-centric, and eventually an information-centric, viewpoint. Equally important, interoperability must be treated as a fundamental priority in defining virtually every aspect of the organization, training, equipping, and employment of the Air Force.

A critical role in interoperability rests with the AC2ISRC. The Center is involved in developing CONOPS and operational architectures in which interoperability is a central requirement. The “AOC as a Weapon System” initiative, in providing a central focus for evolving Air Force C^2 capabilities to meet the needs of 21st-century operations, is an especially critical activity in which interoperability must be considered in all its aspects. The study team strongly supports the Center initiative to establish a C^2 testbed (CAOC-X) as the forum for interaction among warfighters, technologists, and developers and the place where the evolving C^2 environment is anchored. Going further, we believe that networking this facility to others, such as the C^2 Unified Battlespace Environment at Hanscom Air Force Base (AFB) and the C^2 Training and Innovation Group at Hurlburt Field, and eventually to similar facilities of the Army and Navy, would establish a powerful tool for working technical and procedural aspects of joint interoperability. This is the logical approach to Air Force involvement in the Joint Distributed Engineering Plant being established across the Services by DoD. In addition, the Center is where the results of operations, experiments, and exercises are brought together with the evolution of the C^2 system of systems to refine requirements and ensure that warfighter needs are addressed. The Center should be strongly supported in accomplishing its broad range of tasks and should be spared the distraction of constant reorganizations.

3.4.3 Joint and Coalition Interoperability

Any future military operation, with a few possible highly specialized exceptions, will be joint, and many will involve coalitions. Thus, while the first priority is to bring Air Force C^2 up to the necessary level of interoperability, these actions need to be part of a larger approach that ensures that a JTF can effectively employ all its resources. Today, more than 400 different mission and functional software applications support JTF Commanders. Among the challenges in joint interoperability are:

- The current platform-centric approach to acquisition, which impedes effective solutions to problems that cut across systems and impact multiple budgets and schedules, especially when inter-Service and inter-ally issues are involved
- The reality of legacy systems that were designed and continue to be used in functional stovepipes, requiring multiple interfaces or gateways to achieve interoperability
- The overall lack of open systems and persistent problems with proprietary designs
- Lack of testing and compliance mechanisms with attendant enforcement (the recently defined Interoperability Key Performance Parameter is intended to address this)
- Shortfalls in connectivity, especially secure voice and data communications; multilevel security is a particular problem in coalition operations, at both operational and political levels
- Technical issues of diverse data models, incompatible data processes, and noninteroperable hardware
- Tactical and procedural disconnects, such as different planning time cycles for Army and Air Force aviation

Besides the inadequate interoperability of networks in the CAOC, other examples of existing problems with coalition interoperability include the fact that our allies tend to lag behind us in technology and system deployment, the fact that security and export control policies may preclude allies from implementing some U.S. capabilities, and the fact that their own security and economic priorities drive allies to purchase products of their own industries, which may not be interoperable with our systems. As a specific example of coalition concerns, the Joint Planning Network is likely to have limited interoperability because it demands expensive satellite communication bandwidth, requires interfacing multiple U.S. and allied networks, and raises multiple information release issues.

DoD and Congress have made interoperability, in the larger context of information systems, a high priority. Both public law (such as the 1996 Clinger-Cohen Act that mandated Chief Information Officers for DoD and the Military Departments) and joint and Air Force directives (such as Chairman of the Joint Chiefs of Staff Instruction 621201B, which defines a detailed interoperability certification process) seek to drive the Services toward interoperable systems and practices. The DoD C^4ISR Architecture Framework, which defines operational, technical, and system architecture views, lays the foundation for an effective, joint process for defining and implementing interoperable systems. The combination of economic and operational payoffs from the envisioned C^2 information infrastructure and these mandatory conditions for acquisition programs to proceed offer a carrot and stick that should help break the mentality of stovepiped development and use of C^2 systems to achieve joint and coalition interoperability.

3.5 Summary

How important is all the foregoing? In an operational context, there are many reasons why the fog of war can dominate the battlespace. The right information, delivered in a timely, consistent, and efficient manner, will often succeed in clearing the fog. Conversely, failure to share and use information effectively could mean disaster to an otherwise dominant force. Lack of adequate interoperability may cause conflicts or fratricide in weapon employment, late delivery of essential information, and asynchronous or faulty command action. There is no alternative to interoperability in the effective prosecution of modern warfare.

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Chapter 4
Technologies for Future Capabilities

4.1 Introduction

The lack of available and relevant technology is not the key problem for development and deployment of a next-generation Air Force C^2 system. For the most part, technologies are available to implement enhanced C^2 capabilities and develop the JBI due to the large-scale investment in information systems technology, fueled mainly by e-commerce expansion. However, problems within the Air Force are preventing transition of this technology into operational systems in a timely manner.

New processing, display, computing, communications, and human-computer interaction technologies are being applied much faster in the world at large than within the Air Force. For the first time since World War II, the Air Force lags behind the civil community in application of new—mostly information—technologies and inventions. The Air Force has no shortage of good ideas on how to apply technology to solving current C^2 problems. However, there is a growing sense of frustration among the operational and development community on how to bring good ideas into operational C^2 systems.

4.2 Harvesting Technologies for C^2 Dominance

A survey was performed on the availability of critical technologies that were considered essential for development of next-generation Air Force C^2 systems and the JBI. These were grouped into the high-level categories shown in Figure 6-1. Both commercial off-the-shelf (COTS) and Government off-the-shelf (GOTS) sources of technology were considered. For each area, an assessment was made; existing technologies suitable for introduction into C^2 systems are labeled green, technologies in development that would be available in the near term are labeled yellow, and where no near-term capabilities were perceived based on current science and technology (S&T) investment levels is labeled red. An assessment was also made on the exploitation of these technologies by ongoing C^2 programs.

It should be noted that for areas where COTS technology is available (green), a lower level of Government technology investment (yellow or red) is not a problem if there is intent to leverage COTS capabilities. Attention is needed where COTS or GOTS technologies can be leveraged immediately (green), yet no exploitation is occurring in current-generation C^2 systems. Figure 4-1 highlights this technology transition problem. For each C^2 exploitation area considered, little progress was perceived in transitioning available technologies into operational capabilities in a timely fashion. A description of the technology areas reviewed and the rationale for this assessment are included in Chapter 4 of Volume 2.

Technologies	COTS Available	GOTS Available	C^2 Exploitation
Dynamic Planning and Execution	Y	G	Y
Connected, Survivable, Reliable Communications	G	Y	Y
Information Fusion	Y	Y	R
Information Assurance	Y	Y	Y
Information Management	G	Y	Y
Human-Machine Interaction	G	Y	R
Enterprise Systems Engineering	G	R	R

Green: Some Ready   Yellow: Future Potential   Red: Not Yet

Figure 4-1. *Critical Technology Status*

4.3 Building Toward the JBI

The consensus of the Study was that many of the technologies needed to build the JBI already exist. The "Way Ahead" TBMCS and the unit-level AOC.mil are both moving towards web-based implementations for C^2, which will facilitate their integration into the JBI overall architecture. The JBI is described further in Appendix E.

Multiple organizations are developing components and capabilities for the JBI—the Electronic Systems Center (ESC), AC2ISRC, the Air Force Research Laboratory (AFRL), DISA, the Defense Advanced Research Projects Agency (DARPA), the Army, the Navy, and coalition partners. The major challenge that we perceive will be to develop a collaborative and cooperative approach for building the JBI and to develop standards that will assure interoperability between components without stifling innovation by attempting to standardize on individual approaches. Although many new web-based technologies are being developed can be leveraged for the JBI, these are not yet mature enough to identify the leading contenders for standardization. A joint committee process is needed, modeled after the World Wide Web Consortium, to allow standards for the JBI to evolve based on user operational needs.

To enable legacy systems to operate within the JBI, the move to web-enable existing C^2 systems should continue. This should include moving to web-based user interfaces and providing access to C^2 data through data transfer standards such as eXtensible Markup Language (XML). If managed appropriately, this transition can also ease the burden of C^2 system training. An analogy to consider is the amount of time needed to train a new customer to use an e-commerce service such as Amazon.com. For operators who are educated in the principles of C^2, transitioning from one web-based C^2 application to another should be no more difficult than learning how to use a new e-commerce service.

4.4 Speeding Technology Deployment

Because of the significant research and development (R&D) investment being made each year by the commercial software industry, commercial advances in information systems are growing at an accelerated rate. As an example, Oracle's internal cycle time from an R&D project to product introduction is less than 12 months. The Air Force's slow acquisition process cannot currently accommodate these fast development cycles. As a result, the current release of TBMCS uses a version of the Oracle database that is more than 100 minor revisions behind the current commercial release.

Technology advances are also significantly speeding development times for new information applications. Web publishing technology is dramatically reducing times for development of customized user interfaces, while scripting languages embedded in software products allow complicated customized applications to be constructed in days or weeks. Previously, they would have required man-years of effort.

The Air Force has elected to adopt a spiral development process to allow evolutionary acquisition of C^2 systems. To accelerate the introduction of new technology, new methods and attitudes are needed to connect the information technology push (mostly coming from commercial products) to the business opportunity pull coming from the operational users. Requirements-based procurement is suited only to a classic waterfall acquisition process. Spiral development is based on the premise of *build a little, test a lot*, where incremental capabilities are added on a rapid cycle (for example, every quarter) and evaluated by operational users as to the capabilities provided. Figure 4-2 depicts the relationship of technology to operational change. These capabilities should be defined through a CONOPS rather than multivolume requirements documents. The CONOPS can also be used as a basis for modeling new functional elements and to produce system characteristics and performance metrics against which new capabilities can be evaluated.

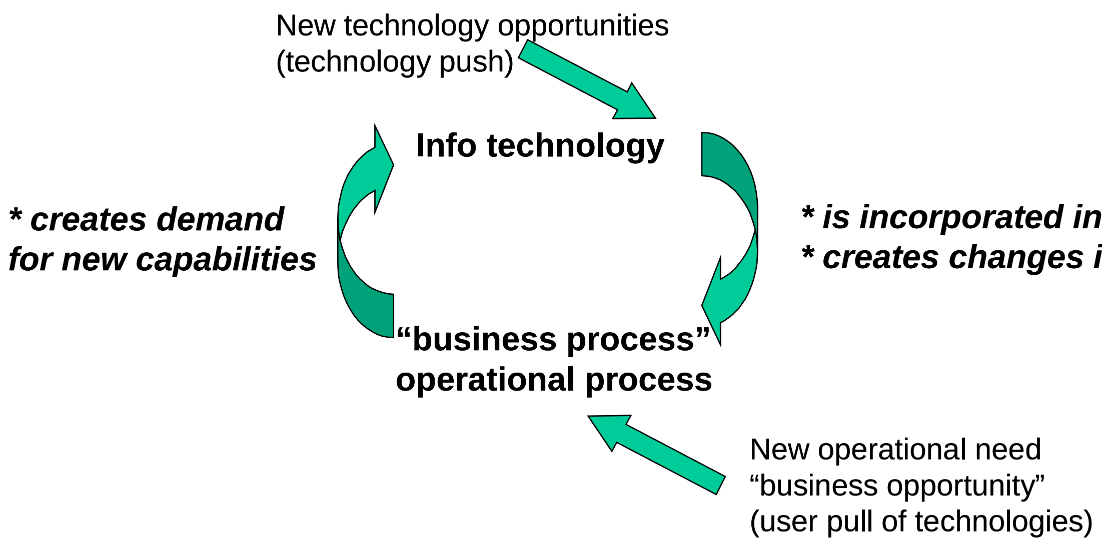

Figure 4-2. *Relationship of Technology to Operational Change*

Another source of delay for some programs, particularly TBMCS, has been the compliance requirements of DII COE. TBMCS was one of the first users of DII COE and as such experienced many of the DII COE growing pains. Two of the major goals of DII COE—to improve the software engineering discipline by providing an operating and development environment and to facilitate interoperability—are still valid; however, the implementation has caused delays and the approach has been to require excessive standardization. DII COE is based largely on COTS technology (for example, Windows, NT, and Unix), and DISA has plans to allow certification of Windows-based systems by adhering to the Microsoft Logo program. This is a good step, and the Air Force should continue to work with DISA to implement this strategy. Associated with that change, DISA should evolve the DII COE from the present platform and product model to a more Internet-like services model. Similar certification processes need to be developed for Unix-based systems. In addition, installation technology influenced by DII COE is expected to be available from industry in Windows 2000 Service Pack 2.

Developing systems that are interoperable has long been a goal for military systems, but one that has been very difficult to achieve. Chapter 3 of this report discusses this topic. The DII COE approach to interoperability is to require greater levels of standardization until at Level 8 there is complete compatibility between systems. This approach is not likely to succeed. Commercial approaches such as those used by the World Wide Web Consortium and research approaches being explored by DARPA and Rome Labs are more promising, since they are developing technologies that specify the semantics of the information being exchanged. This is beyond the current approaches for syntactic interoperability using XML.

4.5 Leveraging Sources of Technology

Historically, the S&T investment in new C^2 capabilities has been poorly leveraged by the Air Force. For example, although much of the technology developed by AFRL has demonstrated significant new capabilities in experiments such as Joint Expeditionary Force Experiment (JEFX), very little has transitioned into operational C^2 programs. The source of this disconnect appears to be mainly due to isolation of the technologists from the end users in developing new C^2 capabilities. Where (in other areas) a good teaming relationship has existed between the laboratory and the end user, technology transition has proved very successful. Without this relationship, the technology transition record through acquisition programs has proved abysmal.

To be successful, spiral development requires concurrent involvement of technology developers, users, and other stakeholders to develop and field a new capability. To leverage the new C^2 capabilities being developed by AFRL (mostly with DARPA funding), AFRL needs to be tied into the spiral development process and connected with AC2ISRC and the end user. Initiatives started by the laboratories and battlelabs should result in delivering a first-generation product to the end user (in, for example, Spiral 1) that can continue to evolve through subsequent spirals without long breaks in the development process. A successful example of this approach was the Broadsword project, which has used spiral development to couple the development team to the end users to deliver a technology product. Broadsword is now fielded and continues to improve with user involvement. Also essential is that transition dollars be allocated to allow the spiral development process for successful projects to continue and bridge the gap in the Program Objective Memorandum (POM) cycle between S&T and program funding.

Most of the Air Force's C^2 systems are being developed by defense prime contractors who have significant history and experience in building the Air Force's legacy C^2 systems. Many of the technology innovations that were identified as being core to development of next-generation C^2 systems and the JBI are being provided by communities that have not been significantly involved in the current C^2 programs. A change in attitude and process is needed to reach out to these communities to allow the Air Force to benefit from their contributions.

Figure 4-3 lists some of the alternative sources of technology that can be leveraged for next-generation C^2 systems. These sources include the Air Force laboratories and battlelabs and DARPA, which contribute the majority of the defense S&T investment, and other sources, such as the Joint Services and coalition partners. The Air Force has the opportunity to take a leadership position in developing the JBI by building a collaborative and cooperative development environment that will allow capabilities developed by other Services and coalition partners to be leveraged. This has the added benefit of facilitating interoperability as well as leveraging other people's money.

The biggest source of new information technologies and products with C^2 capabilities are the commercial "dot.coms". The recommended move to accepting commercial standards and software products in Air Force C^2 operational systems will be a huge step forward enabling timely adoption of new commercial technologies to leverage this investment. In a recent competitive procurement by the National Reconnaissance Office seeking innovative information technology concepts, over 80 percent of the funding was awarded to small businesses. Conversely, within the Air Force a much smaller percentage of contract funding is awarded to small businesses for C^2 systems development.

There already exists a program that the Air Force could elect to use to leverage technology innovations from small "dot.coms" to advance C^2 operational capabilities. By congressional mandate, the Small Business Innovative Research (SBIR) program collects a "tax" from all research and development contract budgets, which is then competitively awarded to small businesses. Although the SBIR program has proved enormously successful in developing and transitioning new technologies into commercial markets, small businesses still face a competitive disadvantage within the Air Force as very few Phase III contracts are let for transition of the new capabilities back into the C^2 core programs. The total SBIR S&T funds are now more than twice the AFRL, Information Directorate (AFRL/IF) S&T 6.2 contract funding, representing a significant investment that could be better leveraged.

The C^2 funding is divided among a large number of different PEs, and there is no funding line item that could be used to work the seams between these different programs. The Air Force has some flexibility, however, in how it chooses to manage the SBIR funds collected from these PEs, consistent with Office of the Secretary of Defense (OSD) management of the funds. Currently SBIR topics are nominated by the individual Program Executive Officers (PEOs), Designated Acquisition Commanders, and AFRL to OSD, where final selections are made, with recognition that SBIR funds must be allocated for both military and commercial applications. If a focused investment strategy were used where the topics selected were influenced by a central operational organization, such as AC2IRSC, and executed through a central agent, such as AFRL/IF, the innovations resulting from the SBIR program could be focused on crosscutting C^2 issues. The SBIR process can also be used to involve "dot.com" pioneers in the development of the JBI. A Phase III transition budget should also be assigned to bridge the POM cycle gap for successful projects between SBIR and program funds to enable rapid deployment of the successful SBIR technologies into operational use.

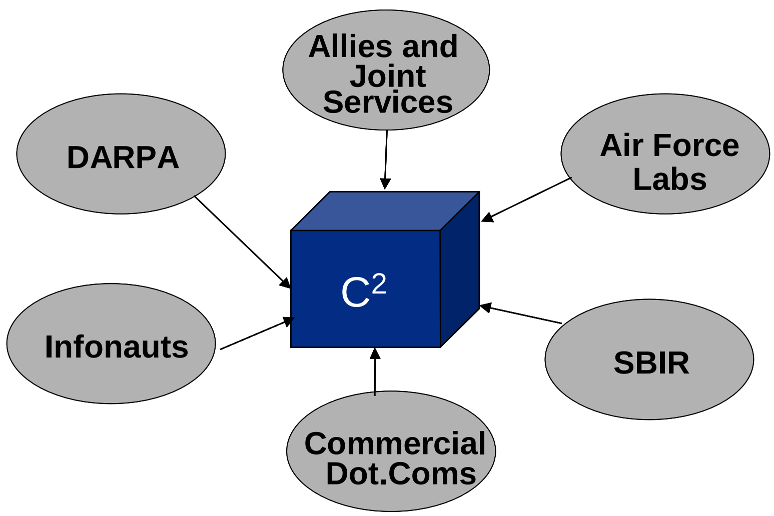

Figure 4-3. *New Sources of Technology*

A major technology source within the Air Force that is poorly leveraged lies in the technical skills of our operational personnel. The information system skill levels of junior officers and enlisted personnel entering the Air Force are continuing to increase. Also, many Air Force Reserve and Guard personnel maintain information technology currency through their professional careers. Because web publishing technology and scripting languages in software applications are simplifying and speeding development times for new information applications, and because tools are being developed for many of the applications in use by the Air Force, such as Oracle, developing a new web-based application could require no more technical knowledge than is needed, for example, to build a PowerPoint presentation.

These Air Force "developers" are experienced in the Air Force's mission and familiar with information technology capabilities; their skills and enthusiasm can be leveraged to accelerate deployment of new operational capabilities. Currently "operational optimization" of C^2 systems by the end users is discouraged, and new capabilities have to be introduced only through the Program Office in order to maintain system integrity and configuration control. The Air Force should institute a formal process to encourage end user innovation and leverage user contributions as part of spiral development. This should also include establishing a mechanism for sustainment of their products in an operational environment.

There is a continuing concern that the blue-suiters experienced with information technology (IT) are, at the peak of their knowledge and experience, leaving the Air Force to work in commercial IT. Recognizing this problem, the Air Force should develop a plan to capture the unique combination of departing operational and technical experience through Air Force Reserve and Air National Guard programs specifically designed to apply IT talent to Air Force C^2 systems and perhaps to other information systems as well.

4.6 Summary

The rapid growth of e-commerce has created a technology rich environment that, if properly leveraged, will allow the Air Force to field significantly enhanced C^2 capabilities before 2005. The major challenge is how to adapt the Air Force's acquisition cycle to allow rapid adoption of new technologies as they are introduced. Commercial advances in information systems are growing at an accelerated rate. Moreover, technology advances are also significantly reducing development times for new applications.

The rapid pace at which information technologies are evolving will require rethinking the processes used to develop and deploy new C^2 capabilities. A process for accepting standards for C^2 data exchange, rather than demanding standardization on specific products or fixed formats needs to be adopted. For example, migrating to XML standards will facilitate interoperability between legacy systems and the next-generation JBI. The process for selecting these standards must be able to respond rapidly as new capabilities are enabled by developed technologies (for example, next-generation XML). The Air Force must be prepared to decide regularly when to introduce new standards—via a quarterly review cycle, for example.

The JBI is seen as a major enabler for facilitating interoperability. By web-enabling existing C^2 systems, such as TBMCS, and providing access to core data through open-data-transfer standards such as XML, JBI capabilities will be able to be rapidly introduced into operation. This will allow the Air Force to rapidly implement new capabilities and also more effectively engage the operational users in implementing innovative C^2 enhancements as JBI applications.

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Chapter 5
Acquisition of Command and Control Capabilities

5.1 Introduction

The Air Force has for some time had considerable difficulty with the acquisition of C^2 systems for the using commands. In general, this has been due to the sometimes rapidly changing nature of operational concepts, but in recent years it has surely also been due to the phenomenally rapid evolution of digital and telecommunications technology.

The acquisition structure, and especially its directives, have been designed to allow orderly and efficient development and production of equipment for the armed forces—the annual Congressional budgeting process notwithstanding. Hence, Air Force policy assumes development of prototypes of new equipment, often in a laboratory environment, then an assessment of the military utility of those prototypes, and, if the utility seems adequate, establishment of an acquisition program office—normally in the acquisition command, Air Force Materiel Command (AFMC)—to develop, procure, and support adequate quantities of the new system. When the system, even though it may have been extensively modified during the support and sustainment period, begins to seem inadequate, a new cycle is started.

That's very nice for systems such as fighters and bombers, but it's totally inadequate for C^2 systems. These are decision-aiding systems, which assist the human military operator to plan and execute military operations. Such systems take advantage of advances in digital and telecommunications technology—and not only do the technologies evolve rapidly, but the approach to and execution of the military operations evolves rapidly as well. And that's the key point: the CONOPS evolve rapidly—and the technology has evolved to where the operators in the field can now build analysis and decision-aiding systems without the help of the development community.

Use of the DoD Directive 5000.1 equipment-oriented acquisition approach by the Assistant Secretary of the Air Force, Acquisition (SAF/AQ), and AFMC makes the command appear to be a major part of the problem of developing C^2 systems rather than part of the solution. Not surprisingly, in many cases the user community has opted to do the C^2 acquisition job itself rather than suffer the pain of having the acquisition community do the job. For some time, US Strategic Command (USSTRATCOM) (and Strategic Air Command before it) have done their own C^2, with *some* help from AFMC (and Air Force Systems Command). The same is true for the U.S. Transportation Command and Air Mobility Command (AMC). More recently, U.S. Space Command (USSPACECOM) and Air Force Space Command (AFSPACECOM) have demanded on-site program offices for their C^2 acquisitions. At this writing, and mainly due to user dissatisfaction with the apparent bureaucracy and inefficiency of the acquisition system, the C^4ISR Architecture Framework (CAF) is taking a much more aggressive role in its own C^2 development.

Our task in this study was to try to identify the problems and to recommend solutions to the tortuous problems of TACCS. The problem was so bad that there was not even a widely recognized term *for* the TACCS. It has been 10 years or so since the Air Force has had to focus more clearly on fighting air wars in theaters other than those dictated by the Cold War. The biggest part of the problem has been identified in prior chapters: there has not been an adequate operational structure, including manning and training, to provide the TACCS capability. If there had been such a structure, the inadequate acquisition approach for providing the structure with the decision-aiding capability it needs would have been addressed some time ago—but better late than never. This chapter is an effort to identify a better way to acquire decision-aiding systems for the TACCS than the inadequate one that has been used in the past.

5.2 Desired Attributes of an Acquisition Process for C^2 Systems

As noted in the introduction, a "big bang"[7] process is totally inappropriate for the design and evolution of a modern C^2 system. The process should, instead, have the following attributes[8]:

- The interest and attention of senior Air Force leadership
- A planning, programming, and budgeting process that fosters cohesion of the components (for example, for the TACCS, JointSTARS, AOC, and TACS) and continuity of development for appropriate components[9]
- A development and evolution or integration process that
  - Allows for recognition of the need for a new capability during system operation
  - Allows for the rapid integration of already developed and tested hardware and software to satisfy emerging new capability requirements
  - Allows for the rapid development, testing, and integration of new capabilities when and where needed
- Fosters continuous communication among the participants in the acquisition—especially including the actual users (as opposed to only surrogates)
- An organizational structure and appropriate resources to execute the Planning, Programming, and Budgeting System and development and evolution processes
- Clear definition of authority and responsibility—for example, who owns the CONOPS, who speaks for the (joint) users in defining the requirements, who directs the contractors involved, and who makes decisions on operational suitability
- Development and integration entities motivated primarily by the success of their efforts

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[7] DoDD 5000.1 still describes a process that may be summarized as "collect and clearly state the system's requirements, develop and test a system implementation that satisfies those requirements, do an independent operational test to insure that the operational requirements are met, field the system and sustain it." It is implied that if a significant increase in capability is required, another acquisition cycle is needed. This is sometimes called the "big bang" approach.

[8] Acquisition is defined as development and procurement. For C^2 systems as well as for major hardware systems, there is a subsequent phase called sustainment, which includes evolution of the system (for example, block changes for airplanes), but for C^2 systems, evolution is a much more significant activity than for major hardware systems.

[9] "Continuity of development" means avoiding the "big bang" approach and instead instituting a continuous development and integration process, much as we define sustainment after a major system's initial development and fielding.

5.3 The Current Air Force Acquisition Process for C^2 Systems Exemplified by a Case Study of TBMCS[10]

The TBMCS is the current Air Force flagship program for automating and integrating the planning and execution of the theater air war. Its five core functions can be defined as

- Intelligence collection and evaluation
- Planning
- Generating and distributing the ATO
- Unit-level scheduling of missions
- Monitoring execution of the ATO

TBMCS is intended to link these intelligence, planning, and operations functions through the integration of several legacy systems (or their equivalent functional capabilities), the most important of which are the Combat Intelligence System, CTAPS, and the Wing Command and Control System (WCCS).[11] In addition, TBMCS migrates these key theater air warfare applications to the DII COE platform. The complexity of this integration and migration was underestimated in the mid-1990s when the program was initiated (as have been most, if not all, similar integrations).[12] The former PEO recently stated, "It's the most difficult program I have ever encountered." Major flaws in this particular "big bang" acquisition include the following[13]:

- **Lack of sufficiently detailed CONOPS, system architecture, and operational requirements.** No formal operational requirements document was ever produced.[14] The problem was compounded by the lack of consensus among the user communities over CONOPS and operational requirements and by continual change and evolution. The constant refrain of the contractor remained: "Will the real user please stand up?"
- **Lack of consistent, strong advocacy leadership in the highest levels of the Air Force and at the System Program Office (SPO) and contractor levels.**
- **Inappropriate application of current acquisition reform doctrines of transferring greater system definition responsibility to the contractor**. The contractor senior management lacked the operational knowledge, technical skills, and initiative to meet this challenge effectively without greater guidance from the Air Force. Clear guidance was not forthcoming.
- **Use of a "big bang" development approach instead of spiral development, delaying fielding and resulting in operator pressure to divert resources to fixing legacy systems.**
- **Insufficient "jointness" in the original program planning.**
- **Underestimation by both the Government and contractor of the technical difficulty of integrating legacy systems.** Multiple contractors had developed the legacy software modules, usually in conjunction with a specific lab and a specific user command. Thus the pieces that

[10] The complete case study is included as Appendix 6C to Volume 2.

[11] The original contract value to the prime contractor was $35 million (excluding fee, zero base fee), with options that were eventually exercised amounting to $109 million, resulting in a total of $144 million. Award fees and miscellaneous changes raised this to $179 million. A category labeled "evolutionary Requirements (Tactical Terrain Databases)" added $161 million, for a total contract value in mid-2000 of $327 million. Mr. Stephen Kent, ESC provided this information.

[12] TBMCS passed its Field Demonstration Test in June 2000. A Multiservice Operational Test and Evaluation was accomplished in late July.

[13] A much more extensive and detailed case history of TBMCS is included in Volume 2 of this report.

[14] CTAPS and WCCS did have formal System Operational Requirements Documents.

would make up TBMCS had no uniformity in architecture, computer language, etc. Little formal documentation existed.

- **Inadequate process for controlling and screening requirements and capabilities development and additions.**
- **Lack of an appropriate strategy for testing and fielding the system.**

5.4 Other Acquisition Approaches for C^2 Systems

In the time allotted for collecting data, the study was not able to exhaustively analyze Government and commercial approaches to acquiring C^2 or C^2-like systems; however, the following four examples are worthy of note for their acquisition process and structure:

- DISA acquisition of the GCCS
- Navy development of Global Command and Control System—Maritime (GCCS-M)
- Air Force Integrated Space Command and Control Program (ISC2)
- DoD Intelligence Information System (DODIIS), managed by the Defense Intelligence Agency and the Air Force

5.4.1 DISA and GCCS Evolution

DISA's process to evolve GCCS is closer to a sustainment than a development process. It recognizes the rapid evolution of software, computer hardware, and communications technologies and seeks to save time and money by integrating capabilities (applications) into the GCCS after those applications have been developed in prototype form and found operationally useful through Advanced Concept Technology Demonstrations (ACTDs), exercises, etc. The process depends on the applications' having been developed, frequently over a period of a few years, to comply with a supporting structure, or platform—in this case the DII COE. While an application may have taken years to develop and operationally test, the process of integration and fielding typically is done within 2 to 3 months. A series of functional working groups overseen by the Joint Staff J3 (recall, the GCCS is the CINCs' C^2 system) ranks those requirements, as the Joint Information Engineering Organization (JIEO) has essentially a level-funded budget each year and hence integration of all requirements cannot be accommodated.

Using primarily a set of facilities (a principal one being the Operational Support Facility) in the Washington, DC, area, the DISA JIEO and its contractors integrate the COE-compliant applications that have been approved into the GCCS and distribute new software to well over a hundred sites worldwide. This integration typically takes a few months for each application, even though the development and operational test of an application may have taken a few years. Applications are fielded continually, usually a few per month. The integration cycle is shown graphically in Appendix 6D of Volume 2, and a recent schedule for applications fielding is in Appendix 6E of Volume 2. A list of all applications and their descriptions is in Appendix 6F of Volume 2.

To execute this GCCS integration process, the JIEO has a budget of approximately $60+ million annually (PE 0303150K), mostly operations and maintenance (O&M) (some procurement), and mostly for contractors and facilities. There are also approximately 200 government personnel (mostly Civil Service) funded in other lines. For DII COE maintenance and evolution, DISA D6 uses approximately $25 million annually, mostly for contractors and facilities, along with 40 to

50 government personnel (mostly Civil Service). Supporting the whole effort are a number of other facilities and organizations, such as the Joint Program Office (DARPA/DISA), which facilitates development and ACTD transition (approximately $25 million annually, including facilities, about 50 contractors, and about 20 government personnel), and the Joint Development and Evaluation Facility (a mini-CINC headquarters), assigned to DISA D8. There are other facilities and participants as well. Procurement and sustainment funding is the responsibility of the individual CINCs.

DISA has been criticized by some (OASD/C^3I-Program Analysis and Evaluation included) for insufficient discipline in managing the GCCS evolution. DISA's lack of a roadmap or objective operational and system architecture certainly leaves it open to that criticism. The fact remains that it has been executing a process, similar in many ways to spiral development (but with very little development done under the aegis of DISA), that has been going on for about as long as TBMCS has—and that has produced a system functionally similar in size to TBMCS (with many more lines of code due to the large inclusion of COTS), in about the same period of time, for a similar budget—but that has released to the operators increases in capability all during the 5-year development process. The applications that have resulted in those increases in capability were mainly developed elsewhere, often by the operational community, and tried in operational contexts before a decision was made to integrate them into the evolving GCCS.

DISA's GCCS evolution process is far from perfect, but the general approach seems the best we have seen. With the addition of an objective CONOPS and operational architecture, and proper maintenance of the existing CONOPS and operational architectures, it offers the best approach to integrating new applications into the operational TACCS in an evolutionary fashion and to staying close to the very rapid evolution of information management and telecommunications.

5.4.2 GCCS-M, DODIIS, and ISC2

GCCS-M is Space and Naval Warfare Systems Command's (SPAWAR's) approach to implementing the Navy's C^2 system, and DODIIS is evolved by AFRL/IF for the intelligence community. They are very similar in process to the DISA/GCCS process. ISC2 is a new approach being used by AFSPACECOM and ESC to evolve the North American Aerospace Defense Command-USSPACECOM Warfighter Support System—which has just gone to contract (with the TBMCS contractor). The basic principles of these are similar to the DISA GCCS approach.

5.5 Oversight, Programming and Budgeting, and Requirements

The AC2ISRC serves as the lead organization to integrate and influence C^2 and ISR for the Air Force. In executing its POM responsibility, the Center functions almost exactly like the Air Staff Panel Structure, in that MAJCOM inputs are received, reviewed, and integrated with other MAJCOM inputs, measured against a funding level, and then submitted as a balanced program, recommending funding levels for O&M and modernization. It is not, however, treated as such by the Air Staff, which receives the input and then refers it to the usual Panel/Board Structure for dissection. These panels have important responsibilities, but an integrated C^2 system is not among them.

While we do not suggest that the AC2ISRC should be immune from review, we do suggest that the AC2ISRC needs a senior champion on the Air Staff to ensure that C^2 receives due consideration in the Air Force priority schema. This individual would be the focal point for C^2 on the Air Staff and would ensure that C^2 has the appropriate priority in the Air Force budget. A further and necessary function of the command, control, and communications "czar" would be to ensure that the command (CAF, USSPACECOM, STRATCOM, AMC) and the functional (logistics, personnel, medical, and finance) C^2 systems do not become (or continue to be) individually and collectively stovepiped but move toward appropriate levels of integration. These are not trivial issues and must be addressed at the Air Staff level. Since solutions to C^2 issues have proved elusive to date, a presence on the Air Force Council seems mandatory.

AC2ISRC is charged with overseeing the entirety of the Air Force C^2 ISR systems. This function encompasses a budget of approximately $9 billion per year and 117 separate PEs. Many of the PEs were created under different, non-integrated management concepts and require realignment so that they fit into a logical management structure. This process has started with the creation of a PE for the tactical Air Forces AOC but needs to be extended to the remaining PE structure.

When AC2ISRC was established, a number of PEs were assigned to its stewardship. Some of these were clearly under the AC2ISRC's purview and were therefore "core." Others were not directly part of AC2ISRC, but it was recognized that the Center had at least a part interest in them. These were "non-core" and were under the Center's cognizance but were not owned by it. In total there were about 130 PEs. Since that time, the number has decreased to 117. The size of individual PEs varies widely from $500 million per year to $100,000 per year. Given that each PE drives an overhead structure—if only in considering funding levels, support at the AC2ISRC and in the Pentagon, and justification to the Office of Management and Budget and Congress—some savings in effort if not in people can be made by consolidation. In addition, consolidation in some logical sequence will provide the much-needed flexibility to quickly react with funding to solve issues or leverage new technology without reprogramming. The structure of the consolidation needs careful attention, as each of the PEs carries a constituency in terms of military, industrial, and congressional proponents.

Two methods of logically cataloging the C^2 PEs were considered: by node (as in AOC, CRC, AWACS, etc.) or by capability (as in ground target attack, air target attack, etc.).

To properly integrate the C^2 system, each PE in the structure must contain funding and direction to provide the tools and system management to ensure that the PE merges within the existing and future operational and system architecture.

The formal Air Force requirements process in use for all systems is formal and sequential and emphasizes broad-based corporate buy-in regarding broad operational capabilities and recommended solutions to mission deficiencies. This process is lengthy and can take from over a year to several years before a final document is prepared that initiates acquisition activity. While this process is appropriate for large, well-defined systems such as aircraft, it is not responsive to the rapidly changing environment of IT acquisition, where several generations of change may be experienced in the time taken to articulate a single generation of requirements.

The concepts of evolutionary acquisition and spiral development (EA/SD) have evolved to enable the acquisition system to cope with the accelerated pace of IT development. Similarly, this accelerated pace demands a revised requirements process that avoids lockstep sequential articulations of required operational capabilities and recommended solutions. As best we can tell, such an approach has not yet been used in a major Air Force C^2 acquisition.

5.6 Development and Integration of New Capabilities

5.6.1 Evolutionary Acquisition and Spiral Development

The Air Force has begun a formal transition to EA/SD for acquisition of C^2 systems. Research, results, and guideline documents have been produced:

- "Reducing Air Force Acquisition Response Times: Developing a Fast and Responsive Development System," 1 March 2000 (SAF/AQ)
- "Air Force Evolutionary Acquisition Guide Draft," March 2000 (SAF/AQ)
- Air Force Instruction 63-123: "Evolutionary Acquisition for C^2 Systems," 1April 2000 (Secretary of the Air Force, Acquisitions, Information Dominance Directorate)
- "Spiral Development Handbook Release 0.1," 1 June 1999 (ESC)

Several ongoing Air Force C^2 development projects are using spiral development. The Global Theater Weather Analysis and Prediction System has completed several successful spirals and four incremental deliveries that are operational. This project is both developed by the contractor and deployed operationally at the user facility (the Air Force Weather Agency), and this perhaps enhanced Integrated Product Team (IPT) effectiveness toward user objectives. At one point a mini-spiral was done in 6 weeks, resulting in an integrated capability to operationally track and predict hurricane paths. The Operational Weather Squadron Production System has also completed several spirals and is being deployed at the weather squadrons. The Attack Options Decision Aid is using spiral development and has successfully taken part in two JEFXs as a component in the time-critical target process. Although successful, the team has had some struggle with requirements management (growth) and developmental testing and evaluation definition tradeoffs as a result of the team's learning the spiral development process along the way.

At this point, the overall Air Force EA/SD experience and results are limited and mixed. It is likely that a major reason for mixed results is that training and experience at the project IPT level has been very limited, and thus the individual teams are feeling their way along.

5.6.2 Standards and a Process to Allow for Rapid Integration

The intelligence and DISA communities have established a process that at least appears to do a better job of accommodating rapid evolution. They rely on an evolving set of standards for integration (the DII COE in the case of DISA) that allow newly developed capabilities (which may have taken years to bring to fruition) to be integrated in months into the evolving baseline C^2 or intelligence analysis systems. The classical development approach in documents such as DoD Directive 5000.1 assumes that such developments are treated as prototypes—and another whole development cycle (again consuming years) is used to integrate the new capability into the baseline system.

It is the Air Force's desire to evolve toward web-enabled systems and minimize dependence on cumbersome client-server architectures as was the norm when TBMCS was started in the early 1990s. This evolution is apparently what DISA is planning for the DII COE. It would seem worthwhile for the Air Force to steer the evolution of this standard toward one supporting the JBI. DII COE should evolve from the present platform and product model to a more Internet-like services model. Support in the Air Force for the COE has been half-hearted at best, and

COE has frequently been treated as a needless and costly encumbrance. We need to adopt an approach for the integration of capabilities into joint systems that serve the CINCs; the approach must allow for integration of appropriate technology as soon as it makes sense to introduce it. The "big bang" development and integration approach will not allow that to happen.

5.6.3 Evolutionary Integration—The Command and Control Testbed

An essential element in the development and integration of new C^2 capabilities is a testbed that can serve a combined and integrated team of operators, developers, integrators, trainers, supporters, and testers to provide a collaborative environment for the evolution of C^2. We heard many pleas for location at the Rome AFRL/IF site and at Hanscom AFB, but we see the need to be close to the operators. We believe that such a testbed should be established at Langley AFB, under the control of a management board including AC2ISRC, ESC, AFRL, and the Air Force Operational Test and Evaluation Center (AFOTEC) (plus the Air Education and Training Command training and AFMC logistics personnel)—with primary lead by AC2ISRC. While the main facility might be at Langley AFB, important satellite development, integration, and simulation work can and should take place at other locations (such as Hanscom AFB, AFRL/IF, and operational AOCs).

Above all, the testbed should be populated by a joint team, a partnership, operating in a harmonious relationship between the activities concerned to the common goal of transitioning C^2 development initiatives and operational concepts to the field. No person is in a liaison role: All are IT operations professionals of high caliber with long-term assignments. Figure 5-1 describes the key responsibilities.

The testbed should have representative fielded equipment as well as the equipment necessary to perform the specific functions of the assigned responsibilities.

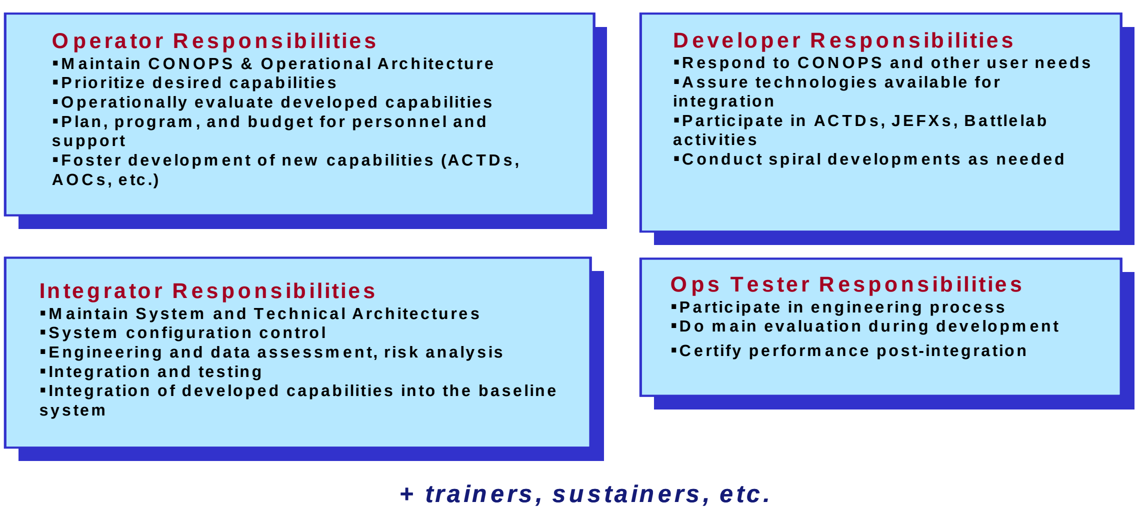

Figure 5-1. *Testbed Team Responsibilities*

The testbed would provide the basis for experimentation with operational and technical concepts as well as provide the final tests of developments and the integration of capability into the operational systems in the field.

Figure 5-2 depicts the cyclical process. Operators develop operational concepts and architectures and identify needed new technology developments. Developers create prototypes, demonstrations, and ACTDs and identify new operational concepts made possible by technology advancements. Integrators develop system and technical architectures and integrate the new capabilities into the testbed and, later, into the operational system. Testers conduct capability testing (on a less formal basis than performance testing), and trainers develop training concepts. Much is done in parallel at the testbed, but the result is a cyclical refreshing of the operational capability in the field. Major physical and functional components of the C^2 testbed may be physically separated from the main facility.

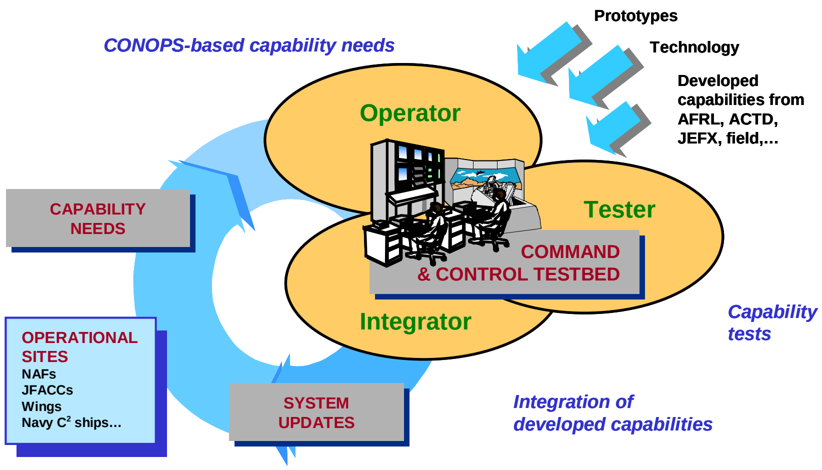

Figure 5-2. *Evolutionary Integration*

5.8.4 Evolution of the Integration Standards

It is the Air Force's desire to evolve toward web-enabled systems, and minimize the necessity to depend on cumbersome client-server architectures such as were the norm when TBMCS was started in the early 90's. This evolution is apparently what DISA is planning for the DII COE. It would seem worthwhile for Air Force to use DII COE as a near-term platform standard to allow rapid integration of capabilities into evolving C^2 systems, and to steer the evolution of this standard toward one supporting the JBI. Support in the Air Force for the COE has been half-hearted at best, and it has frequently been treated as a needless and costly encumbrance. We need to adopt an approach for the integration of capabilities into joint systems which serve the CINCS which allows for integration of appropriate technology as soon as it makes sense to introduce it. The "big bang" development and integration approach will not allow that to happen.

5.7 Testing

Testing and evaluation (T&E) of C^2 systems is an evolving Air Force area of discipline. Beginning in 1995, the Air Force recognized that T&E of C^2 at the developmental test level was seriously flawed. A series of initiatives stimulated by Headquarters AF/TE resulted in a formal, structured, process-oriented T&E team at ESC. A staff element (ESC/TE) is responsible for ensuring that each ESC acquisition program develops and implements an adequate test program, incorporating appropriate contractor, development, and operational testing.

The classic developmental testing (DT) and operational testing (OT) structures were developed in the years before the institutionalization of the significant acquisition reform activities of the 1990s. COTS, cost as an independent variable, component-based design and total system performance responsibility, while meritorious in many respects, all exert downward pressure on program costs with a concomitant pressure to reduce SPO-controlled DT. To the extent that DT is not comprehensive, OT must attempt to fill the gap or risk sending an incompletely characterized system to the user. In essence, the system must demonstrate stabilized performance in a stressing environment before productive dedicated OT can begin.

The Air Force has clearly specified most procedures for EA and SD in Air Force Instruction 63-123. Left unspecified, however, are requirements for operational architectures and CONOPS. These elements are crucial to characterization of the system's effectiveness and suitability. Also unspecified is the specific form of operational testing and evaluation. Unless the operational test agency (OTA) is expected to be continuously involved for the life of an EA system, the architecture or CONOPS must indicate when and where capability improvements are expected. The OTA can then plan episodic events and subsequent realistic assessments of delivered operational effectiveness and suitability.

5.8 Infrastructure for Development and Integration

A major discussion and requirement regarding the actual implementation of our recommendations have been left until this section. Any major enterprise normally capitalizes a set of facilities and operates a set of functions that allow it to pursue its business. In the case of information technology-oriented organizations, these are the testing and integration facilities and the IT-unique evaluation, estimation, planning, architecting, and simulation capabilities necessary to the successful prosecution and integration of systems in this rapidly changing environment. In the early days of acquisition of aircraft, the military invested, and still does, in major simulation and evaluation capabilities—in the Air Force, principally at Wright-Patterson, Eglin, and Edwards AFBs. In addition, with the inception of major new technologies in recent years, very significant new investments were made in signature, electronic warfare, and other lethal and non-lethal evaluation capabilities—often Government owned and operated.

For some reason "the system" in the Air Force has not perceived the need for similar investment in the rapidly evolving and high-leverage field of information technology. Our C^2 systems are therefore developed on a piecemeal, contractor-oriented basis, leading to the very stovepipes we are trying so assiduously to avoid. Facilities such as the Modeling, Analysis, and Simulation Center and C^2 Unified Battlespace Environment at ESC have literally been bought with savings on the base electric and heating bills when winters were unexpectedly mild—hardly the way to run a business! Indeed, the operating commands have in all cases established capabilities that are much superior to anything the C^2 development community has—and it has been done mostly with O&M money.

If we want to continue the stovepiping of Air Force C^2, then that is the way to go about it—to let the operating commands do their own thing. We have done a top-level estimate of the kind of annual budget that should be provided to an organization such as ESC to allow it to operate in a fashion similar to the DISA's JIEO (see Section 5.4.1). A separate PE and budget, starting at approximately $66 million and leveling at $60 million annually, should be instituted, advocated and defended by the Commander, AFMC, to allow ESC to build and maintain a proper infrastructure to accomplish its job. (A complete breakdown and detailed discussion are provided in Volume 2.) This would allow establishment of the following capabilities to support Air Force C^2 evolution:

1. Enterprise and domain architectures: development/sustainment
2. Integration and interoperability (I&I): assurance and certification testing development
3. Collaborative tools in support of infrastructure definition/development
4. Information assurance (IA) support
5. Commercial technology and innovation exploitation

Funding Summary. Initial estimates of the annual costs to implement and sustain the above-listed infrastructure elements are as follows (detailed descriptions and rationale are found in Volume 2):

Table 5-1. *Estimated AFMC C^2 Acquisition Infrastructure Requirements in Millions of Dollars*

Infrastructure Elements	***FY02***	***FY03***	***FY04***	***FY05***	***FY06***	***FY07***	***SYDP***
1. Enterprise and domain architectures: development/sustainment	7.0	7.0	7.0	7.0	7.0	7.0	42.0
2. I&I: assurance and certification testing development	24.2	23.5	22.5	22.0	22.0	22.0	136.2
3. Collaborative tools in support of infrastructure definition/development	4.0	2.7	0.8	0.8	0.8	0.8	9.9
4. IA support	7.8	5.8	5.8	5.8	5.8	5.8	36.8
5. Commercial technology and innovation exploitation	23.0	23.0	23.0	23.0	23.0	23.0	138.0
Totals	**66.0**	**62.0**	**59.1**	**58.6**	**58.6**	**58.6**	**362.9**

5.9 Summary

The Air Force's attention to an appropriate structure to acquire C^2 systems is far from sufficient. The process—from the attention at the Air Staff level through the PE and panel structure and, most important, in the actual approach to executing acquisitions once the overly ponderous requirements and program initiation process is finished—is seriously broken.

By way of example, the process used by the Air Force on the TBMCS program was much more painful and traumatic than it needs to be, and it resulted in a technically obsolescent system, as a "big bang" C^2 development always will. The process used by a number of other programs in the DoD, exemplified by the GCCS evolutionary integration process—where an annual increment of capabilities, already developed in laboratories, ACTDs, etc., in accordance with a set of standards (for example, the DII COE) allowing efficient and rapid integration into an evolving C^2 system (for example, GCCS)—best satisfies the desired attributes for acquisition of a major C^2 system. The Air Force acquisition community has not adopted this sort of approach for reasons unknown—in fact, the requirement to adhere to standards such as the DII COE has been seen as costly and unnecessary. As long as this attitude persists, we will continue to have painful, expensive, and marginally operationally useful C^2 acquisitions.

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Chapter 6
The Human Dimension in C^2 Effectiveness

6.1 Introduction

An essential prerequisite for improving Air Force C^2 is the recognition and accompanying organizational reinforcement of theater C^2 as a warfighting element on equal footing with all other combat functions. At the heart of this recognition, and built on the foundational element of "quality people" for the Air Force core competencies, is the establishment of a trained force of C^2 professionals, dedicated to operational C^2 centers. To realize the vision of C^2 as a highly integrated and effective weapons system, the human dimension in C^2 effectiveness must be addressed. Section 6.2 below presents a vision of the future C^2 warrior, describing the human qualities and characteristics that constitute the foundation for excellence in Air Force C^2. The remaining sections of this chapter provide a discussion of the human-related issues that must be resolved in order to realize this vision. These include the following:

- Institutions
- Organization
- Personnel policies and practices
- Training
- C^2 system design
- Human-system interface (HSI) technologies

6.2 The C^2 Warrior of the Future

The Air Force vision is based on the premise that organizational performance is determined, to a large degree, by the qualities of individual airmen. In the context of this study, the notion of "quality people" implies that C^2 warriors should possess specific attributes that enable them to maximize their contributions to team effectiveness in performance of the C^2 mission. These attributes may be characterized by describing the ideal C^2 warrior of the future:

> The C^2 warrior is an integral part of a dedicated, full-time fighting force. With a solid base of experience as a rated combat warrior, the C^2 warrior feels well qualified to assume the next level of leadership responsibility as a key member of the core theater battle management team in the NAF AOC. The C^2 warriors consider their current C^2 assignments to be essential steps in their career progression as professional warfighters. Their skill and competence are the product of a rigorous, standardized training program built on a solid educational foundation in warfighting principles at the operational and tactical levels of command. The C^2 warrior has gained a working knowledge of all major AOC functions and processes and is capable of transitioning rapidly to another AOC or theater of operations if necessary with minimal spinup time. The C^2 warrior's skills have matured through hands-on experience in a realistic training environment that includes regular participation in peacetime operations and exercises. Proficiency in the C^2 warrior's area of specialization is comparable to that of other combat weapon systems and is maintained through a program of testing and certification that is centrally managed and tracked through a readily accessible database. C^2 warriors take pride in personal knowledge of the AOC weapon system and the combat effectiveness of their team. They are active participants in improving the tools, tactics, and procedures that continually strengthen team performance. The C^2 warrior's career goal is to attain a senior combat leadership position at the 0-6 or general

officer level. As a result of C^2 training and experience, the C^2 warrior's prospects for success are as good as or better than those of contemporaries in staff or aircraft operational assignments.

The present realities of C^2 operations do not conform to this idealized vision. While the Air Force officer corps does include very capable and committed C^2 specialists, some challenges must be overcome in order to bring the concept of the professional C^2 warrior to practical reality. These challenges are discussed in Sections 6.3 through 6.8.

6.3 Institutional Issues

The lack of status and representation for theater C^2 in the Air Force is manifested in a number of ways. With regard to processes, considerable documentation and guidance for the C^2 mission exist, but the documentation is generated through independent channels and is often inconsistent. The absence of professional status for the C^2 warrior contributes to the low priority for staffing, resources, and funding for C^2 warfighting functions. As a consequence, the system defaults to improvised processes and ad hoc staffing solutions in response to crises. Some elements of these problems are being addressed by the AC2ISRC. However, the Center has not been vested with the comprehensive operational, budgetary, and acquisition authority to ensure that standards for C^2 operations are enforced and that acquisition and modernization are accomplished in a prioritized and consistent fashion across the full range of C^2 systems. The paradox is that many previous studies and any number of senior Air Force leaders have recognized and articulated these problems and the changes needed. However, the institutional "will" to fully implement change seems to be lacking.

Without establishing the foundation of strong institutional value for theater C^2, most of the other actions recommended in this Study will enjoy little sustained impact. Theater C^2 must be elevated in status, representation, and resources (both personnel and funding) to the levels appropriate for an essential warfighting function.

6.4 Organization

The primary organizational entity responsible for planning and executing air operations at the theater level is the AOC. There are many AOCs or "AOC-like" organizations worldwide. At present, these AOCs fall far short of operational status comparable to other weapon systems. For example, CONUS AOCs do not have a daily operational mission similar to most weapons systems. Nor do the AOCs routinely interact with those other weapons systems to practice and refine critical coordination processes. Airborne strike support, C^2, and ISR platforms (AWACS, JointSTARS, Rivet Joint, and ABCCC) fly daily with only simulated AOC inputs, and most other operational combat platforms fly with no inputs at all.

Related to the operational shortfalls, staffing is woefully short of needs and is not typically employed on an operational warfighting basis. For example, NAF AOCs are manned by NAF staff who have principal responsibilities elsewhere. U.S. Air Forces in Europe, Pacific Air Forces, and all three CONUS NAF AOCs are understaffed and not ready to deploy. Standing AOCs (Operation Southern Watch, Operation Northern Watch, and the CAOC at Vicenza) operate with only a handful of permanent staff; additional staff rotate every 90 to 120 days. With the onset of a crisis, staffing ramps up rapidly but in an ad hoc fashion, in part because the personnel system does not support ready identification of certified personnel.

In the training area, opportunities for AOC operations are not routinely exploited. For example, the integration of ground-based C^2 into the major Weapons School exercises is lacking, as is the presence of interactive and adaptive AOC functions in Red Flag. Even the dedicated venues of Blue Flag have evolved into qualification events centered around ATO production instead of operational exercises that strengthen C^2 skills, because participants are temporarily assigned on an ad hoc basis from their staff positions without the benefit of adequate preparation or daily C^2 operations. At the higher levels, the JFACC and AOC Director often do not have their first experience in these roles until the advent of a crisis. The result is a lack of sufficient numbers of professional C^2 leaders, at all levels, to staff and execute the warfighting functions of the AOC.

A potential solution to this problem lies in the establishment of a standing AOC capability in CONUS with a daily operational and training mission in peacetime. The existing capabilities at Langley, Hurlbert, Nellis, and the CONUS NAFs (if needed) might be adequate to maintain the proposed capability, but a more robust option is proposed here—specifically the organization of one or more C^2 NAF(s), illustrated in Figure 6-1.

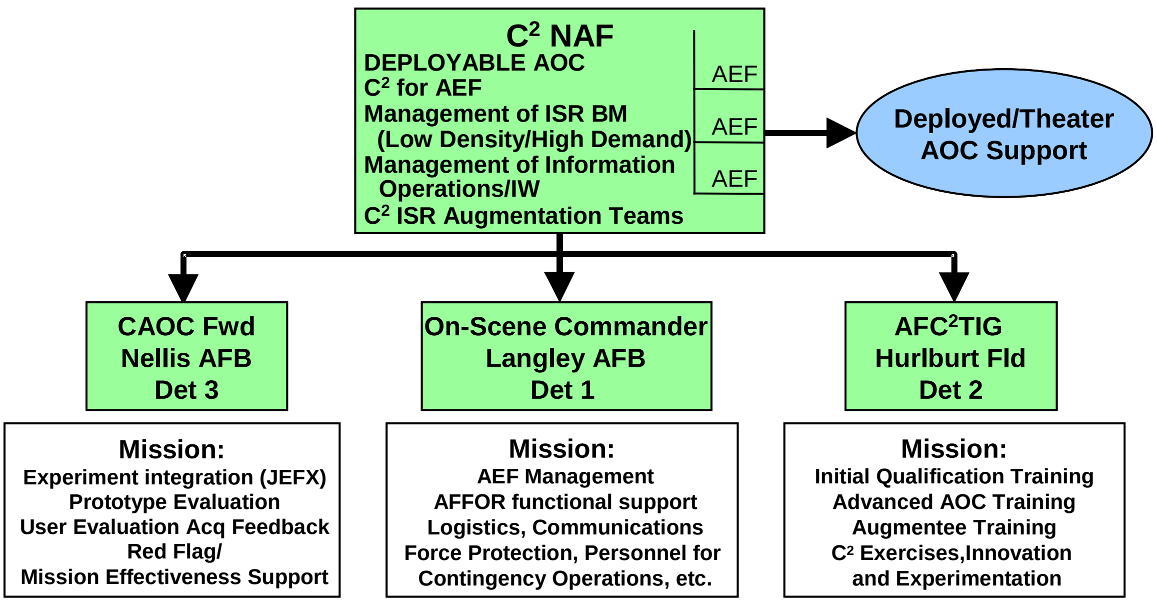

Figure 6-1. *C^2 NAF Concept*

The intent of this organizational concept is to operationalize the CONUS AOC activities and to increase the priority of the C^2 warfighting system by making it the principal responsibility of a CONUS NAF commander. This commander should report directly to the senior ACC operational commander. The CONUS NAF commander would provide not only principal parts of the standing AOC capability, but also manage the low-density/high-demand C^2 and ISR assets and manage the information operations and information warfare resources. The C^2 NAF would be organized to align training and spinup of core AOC personnel in parallel with each AEF for rapid deployment if needed. Staffing and assignments would conform to the functions of the AOC CONOPS, consistent with the personnel manning documents, and would rely on a mix of active-duty, Reserve, Guard, and civilian personnel. The C^2 NAF would also have responsibilities for development of AOC operational standards established for the functions defined in the AOC CONOPS. The standards would provide a baseline capability of common AOC functions while accommodating tailored aspects needed for specific regional deployments.

Supporting the C^2 NAF would be the three key organizations noted above and in Figure 6-1, but in this construct, they would be specifically detailed to the C^2 NAF. Other NAFs and AOCs would maintain the level of C^2 emphasis deemed necessary by their commanders.

6.5 Personnel Policies and Practices

There is a widely held belief among Air Force personnel that C^2 skills and experience are not valued assets for career advancement. Indeed, there is a common perception that assignment to an AOC is a career dead end. This perception is evidently the result of the absence of a defined career ladder, the lack of rewards, and the insufficient recognition and poor promotion rates for C^2 professionals. These factors, in turn, have had a significant negative impact on the skill base and retention of C^2 personnel. The problem is further compounded by the difficulties of tracking skilled professionals in the current personnel system. There are worthy efforts under way at the AC2ISRC to define C^2 career progression requirements through the general officer level and to augment the personnel tracking system, but significant gaps in definition and implementation remain.

A comprehensive effort to strengthen C^2 professional career development should be instituted in the Air Force with principal responsibility assigned to XO/DP. Figure 6-2 identifies the major elements that must be in place to establish and maintain a viable force of professional C^2 warriors.

Figure 6-2. *Elements Enabling the Professional* C^2 *Warrior Force*

The first step is development of the professional warfighter career track. The AC2ISRC efforts in the C^2 warrior focus area for career path development are in line with this step, but we urge the expansion of current thinking to institutionalize the "aerospace warfighter track" illustrated in Figure 6-3 as a distinctive career path within the Air Force.

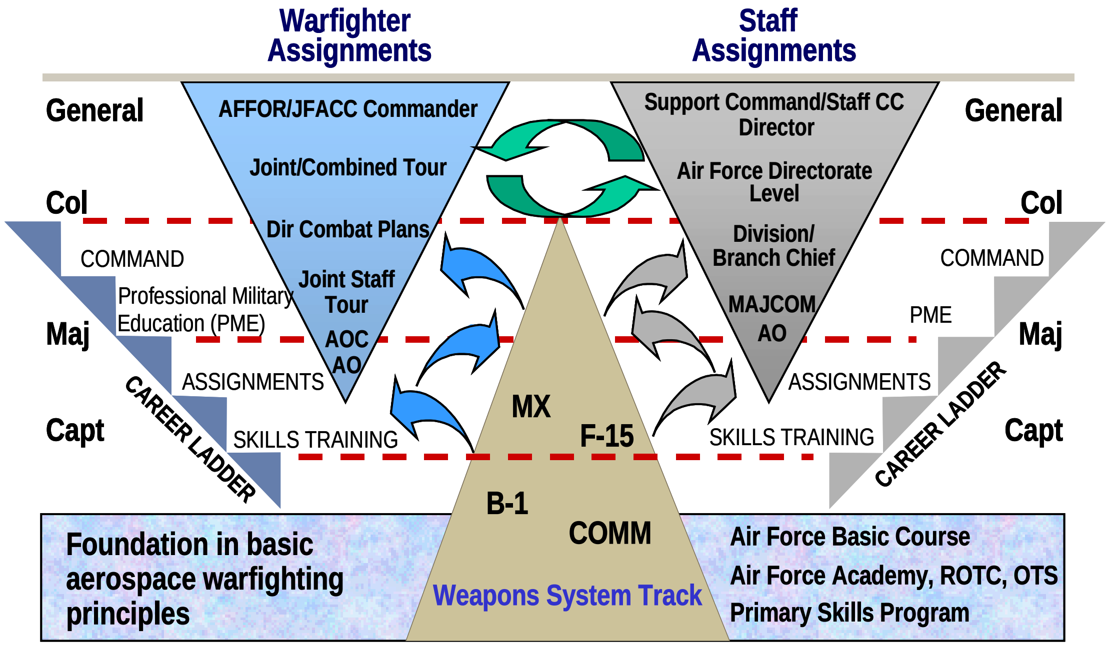

Figure 6-3. *The Professional Aerospace Warfighter Track*

In addition to notionally defining the professional C^2 warfighter career track, Figure 6-3 highlights the fact that advancement opportunities would be clear to all and that visible equivalency with the staff track for advancement would be institutionalized. It is further recommended that all Air Force personnel receive some foundation in fundamental aerospace warfighting principles, including C^2, as part of their basic education at the entry level. A requirement should also be established for formal C^2 training and experience as a prerequisite for promotions above lieutenant colonel. The establishment of fully functional AOCs and the expansion of training opportunities would greatly facilitate the realization of this career path alternative.

A second critical step is the expansion of personnel data management to establish an enterprise-wide qualification tracking system that supports education and training, maintains personnel and training records, and provides the personnel code designations at a level sufficient to rapidly identify the C^2 skill set of individuals. Again, the AC2ISRC has initiated an effort to at least clarify and expand the special experience identifier (SEI) codes. This initiative should be endorsed but extended further to enable complete and efficient access to the personnel management, special skills, training, and other relevant databases.

For the above measures to be effective, they must be supported by an incentive structure that provides tangible evidence of the value and priority assigned to C^2 by the Air Force leadership. Promotion opportunities for C^2 specialists must reflect the importance of jobs they perform and the level of competence with which they are executed. Some possible actions to strengthen the perceived value of C^2 include the following:

- Explore CSAF "contribution-based pay" initiatives such professional warfighter pay for qualified colonels similar to medical pro-pay and the aviation continuation bonus (that is, implementation for all functional domains, including C^2)
- Provide promotional opportunities honoring the premise that "all warriors are created and treated equal" (that is, a parallel to joint assignment and promotion potential initiatives)
- Make career advancement and/or preferred assignments contingent on C^2 training, experience, and qualifications
- Reorient the bonus system to reward qualified volunteers for hard-to-fill, remote, and/or hardship assignments
- Establish a "weapons school" caliber course or program that results in a specialty designation for key aerospace command positions and provides enhanced promotion opportunities for graduates

In combination with the improved training opportunities and daily operations, these measures provide the foundation upon which a professional C^2 warrior force can be built and maintained. It is essential to note, however, that all of the elements identified in Figure 6-2 are interdependent and must be addressed in a balanced, coordinated fashion to realize the desired results.

In addition to the staffing challenges of C^2 operations, there is a continuing concern that active-duty personnel with skills in IT and system administration are leaving the Air Force at the peak of their knowledge and experience. It will probably not be possible to halt that exodus because of the extreme pay differential between IT jobs in the Air Force and in business. Recognizing this problem, the Air Force should develop a plan to capture the unique combination of operational and technical experience through Air Force Reserve and Air National Guard programs specifically designed to apply this talent in a systematic fashion to Air Force C^2 systems (and perhaps other information systems as well).

6.6 Training

The Air Force does not have in place a fully trained force of C^2 professionals in sufficient numbers to respond efficiently to the demands of a major theater crisis. Air Force leaders lack the necessary training and experience to develop the full complement of essential warfighting skills, particularly at the operational level of command. Furthermore, the current approach to C^2 training does not support the "train the way you fight" doctrine and has not been fully integrated with the EAF structure and duty cycle. Resources and priorities for C^2 training are not comparable to those for other weapon systems. Indeed, staff responsibilities often take precedence over scheduled C^2 training opportunities. Performance in these staff positions, rather than warfighting skills, is often seen as the basis for promotion. Given the limited resources allocated to training, the opportunities to gain necessary skills and experience are, in turn, limited. While a relatively complete training curriculum exists, only about 20 percent of AOC personnel have actually completed the "mandatory" training required for certification in their individual specialties. With the compounding effect of the failure to utilize existing training opportunities, a downward spiraling effect is the result: fewer opportunities supported by fewer people.

A critical element in moving toward "C^2 as a weapons system" is the implementation of training programs comparable to those for other weapon systems. Training requirements, curricula, and performance standards should be derived from approved CONOPS and the Mission-Essential Task List for C^2. The "standing AOC" capability described above should be used to generate and execute air tasking orders daily. Consistent with the AOC recommendations above, the C^2 training schedules should be synchronized with AEF spinup and reconstitution training cycles. AOCs should actively engage in force-level training at every opportunity, including continuation training, composite force training, Flag exercises, JEFX, and CINC exercises. The Air Force must allocate the necessary resources to enable compliance with its own training directives and certification requirements for C^2 specialists. In addition, the C^2 community should assume leadership for the further development of Distributed Mission Training (DMT) to integrate AOC training and operations with the wing- and squadron-level operations that are the current focus of DMT. DMT also provides an excellent vehicle for experimentation and validation of enabling technologies and concepts for distributed AOC operations in the future.

6.7 C^2 System Design

Arguably, there is no other warfighting function where the HSI is more important than in C^2 because of the volume, complexity, importance and time-critical nature of C^2 decision making. As shown in Figure 6-4, the effectiveness of the HSI is also a key element in establishing a common operational picture, which, in turn, is essential for collaborative decision making and interoperability across organizations and platforms. The level of attention and resources devoted to the user interface in acquisition of Air Force C^2 systems is not consistent with its potential impact on overall system performance. Involvement of users is often inadequate and/or too late in the development process to ensure effective HSI integration. As a result, performance of some C^2 systems is limited by counterintuitive computer programs, unnecessarily complex or error-prone procedures, excessive operator workload, labor-intensive training, and proliferation of local fixes or workarounds.

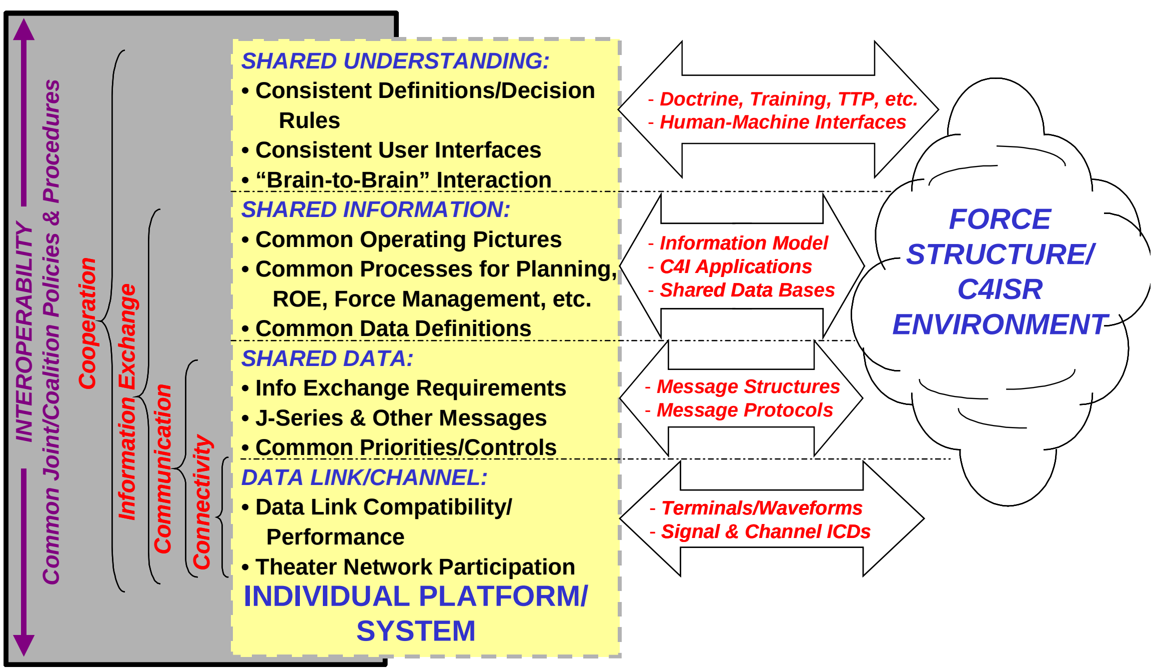

Figure 6-4. *Human-System Interface Contribution to Interoperability*

Effective integration of operational experience and human engineering design principles must be accomplished early in the HSI development process, since they often impact architectural and/or software design decisions that are prohibitively expensive to change at later stages of development. For this reason, a structured, systems engineering approach, comparable to that employed routinely in the development of the HSI for combat aircraft, should be applied in the acquisition and modernization of future C^2 systems. The process shown in Figure 6-5 provides a generic model that can be utilized to improve human-system integration in future C^2 systems.

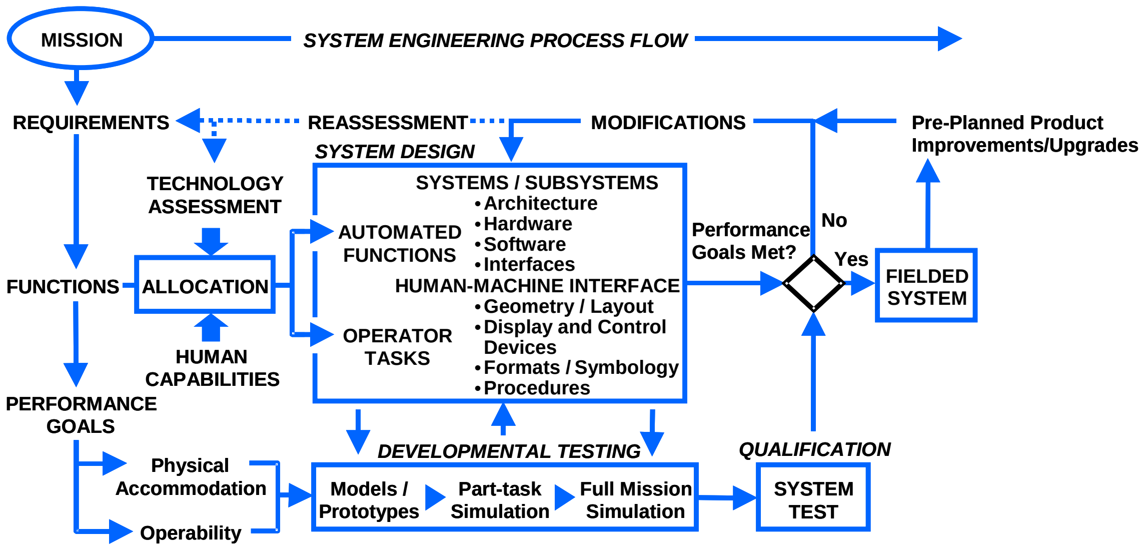

Figure 6-5. *Human–System Integration Development Process*

Several actions should be assigned by USAF/AQ for implementation by AFMC and its product centers to institutionalize this type of systems approach to HSI integration in the acquisition process. These include the following:

- Establish a structured process like that shown in Figure 6-5 to ensure effective HSI integration
- Establish usability goals as Key Performance Parameters
- Include HSI effectiveness criteria within the source selection process
- Tailor and apply Military Standard 1472 and Military Handbook 46855 as appropriate
- Recommend establishment of HSI compliance criteria and processes for DII COE certification
- Require training in HSI for program managers (similar to the U.S. Army Manpower and Personnel Integration program)

An important action for the ACC C^2 operational leadership is to define the reference mission and baseline CONOPS prior to the initial cycle in the spiral development process for new C^2 systems. In addition, a multidisciplinary HSI advisory group, including both HSI professionals and operators, should be established to oversee the implementation of the HSI process.

6.8 Human-System Interface Technologies

Based on its review of human interfaces for present C^2 systems, the Study concluded that the Air Force has not fully exploited HSI technologies, automation and decision support tools that are available or under development for other applications. The Study undertook a review of advanced HSI technologies and concepts for potential applicability to Air Force C^2 systems. For purposes of this Study, the assessment was limited to HSI technologies available in the relatively near term (next 5 years).

The complete results of this technology assessment are described in Volume 2 of this report. Some examples of technologies with potential for near-term C^2 applications are described briefly below. The reader may also find useful a comprehensive review of HSI technologies provided in Volume 2 of the 1999 SAB Study on the JBI.[15]

- Automated speech recognition (ASR) technology is sufficiently mature to provide an intuitive interface for C^2 operators and is under evaluation by AFRL and the C^2 Battlelab for AOC applications. ASR would allow the operator to bypass the menu structure by means of natural-language commands. This would enable significant reductions in time necessary to generate air tasking orders as well as potential reductions in frequency of errors. Benefits in training may also be realized.
- 3-D audio technology is readily available and can be applied to assist operators in discriminating among and selectively attending to multiple sound sources. Introduction of this type of interface would help minimize confusion in C^2 environments with heavy auditory task demands.
- Untethered wearable computers being developed would allow the commander to interact with large-screen displays through multiple means (for example, voice or gesture) as well as interact with databases when moving among different locations.
- Simple combat decision-support systems, based on Bayesian logic and probabilistic estimates of risks that automatically provide a “flag” when specified thresholds are exceeded, can be readily developed. Such a system would be fed and updated at the local AOC level, based on onsite information. Inputs to the system would be provided on different time scales, depending on the source of information and dynamics of the engagement.
- Information capture/recall technologies could enable much more effective utilization of data obtained from C^2 operations and exercises. Operational data could be time- and event-referenced, indexed, retrieved and correlated with screen captures from large-screen tactical situation displays and/or individual operator workstations. This capability could be used in the AOC to exploit this rich data set for de-briefing, training, diagnostics, lessons learned, and improving decision-support tools.

6.9 Summary

The Air Force vision for projecting aerospace power is built upon a foundation of quality people. This vision acknowledges the reality that the skills, experience, and motivation of the fighting force are the fundamental enablers for performance of the Air Force mission. It follows that these key human attributes must be a central focus of any serious effort to improve the effectiveness of C^2 systems and processes. This chapter has described challenges confronting the Air Force leadership in realizing its vision for commanding aerospace power.

These challenges must be confronted directly by the Air Force leadership in the near term to achieve the stated goals for C^2 performance improvement. Unless these human-related issues can be resolved satisfactorily, there is little hope that the other corrective measures cited in this

[15] SAB-TR-99-02, Building the Joint Battlespace InfoSphere, Vol II: Interactive Information Technologies, 17 December 1999.

report will have the desired impact. More specific and detailed recommendations are provided in Volume 2, Section 10.0.

Chapter 7
Linking the Air Force by 2010

7.1 Introduction

The Study was given the assignment to look at the solutions to "link the Air Force by 2005" with specific reference to the difficulty in attacking mobile targets in Kosovo, as well in other recent crises. We established teams to look at the TCT problem generally, as well as the datalink problem in particular, with the goal of reducing TCT timelines from hours to minutes.

7.2 Time-Critical Targeting Timelines

Recent conflicts have highlighted the difficulties in rapidly attacking TCTs. The timeline from recognition of the existence of a targetable object until the "kill" is excessively long. Experience in Operations Desert Shield, Desert Storm, and Operation Noble Anvil (in Kosovo) showed that timelines of 4+ hours were typical. The goal expressed by the leadership is to reduce the time from target detection to target strike to single-digit minutes from the current multiple hours. The SAB has identified and prioritized solutions to bring the timeline down to this goal.

Figure 7-1 portrays the current and future timeline for targeting TCTs as experienced in recent Kosovo operations. Data for the U-2S sensor processing, exploitation, and dissemination process was based on analysis of the image analyst and mensuration logs at the Distributed Common Ground System at Beale AFB and the 20th Intelligence Squadron at Offutt AFB by Adroit Systems, Inc., under contract to the Air Force Studies and Analyses Agency. The times attributed to operational high-level coordination, CAOC nomination, target folder preparation, and attack execution phases were mostly anecdotal information gathered by the SAB from experienced ISR officers present at the CAOC. The best time case indicated is based on strike missions using an F-15E with a JSOW weapon from the combat air patrol position with target folder information relayed by datalink direct to the F-15E pod.

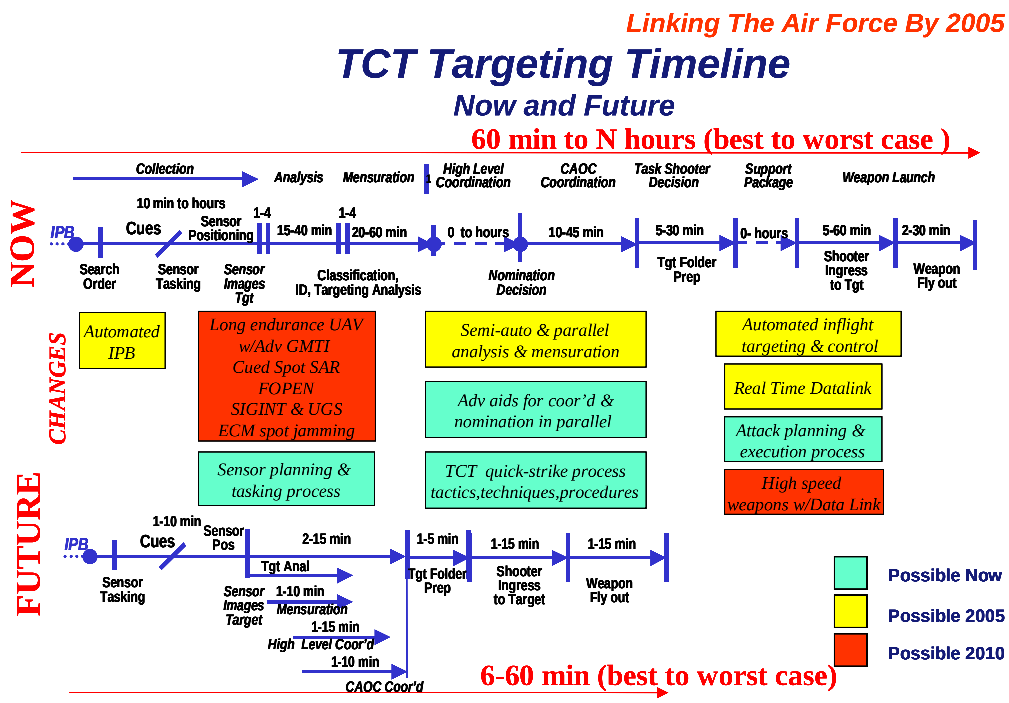

Figure 7-1. *Time-Critical Targeting Timeline—Now and Future*

The analysis of the time-critical targeting experience led the Study to the following findings:

- Enhanced sensor coverage (time, space, and phenomenology) is essential. High-altitude long-endurance UAV systems are sufficiently proven and can provide low Earth satellite–like performance in many regions. They are the only near-term answer for standoff (7 x 24) ISR coverage necessary for defense against TCTs.
- Technology for modular active electronic scan antenna (AESA) ground moving-target indicator (GMTI)/synthetic-aperture radar (SAR) has been developed under the F-22 and JSF programs and is ready for development and production for surveillance platforms.
- The technology of moving-target exploitation (MTE) tools for target recognition and tracking has achieved significant progress but needs maturing and further demonstration using AESA hardware.
- The combination of advanced GMTI, high-range resolution target features, and interleaved, simultaneous spot ultrahigh resolution++ (UHR++) SAR images from the same platform will revolutionize ISR and significantly reduce the tasking, collection, processing, exploitation, and dissemination over that of current wide-area imagery schemes.
- Foliage-penetration (FOPEN) GMTI ultrahigh-frequency (UHF) radar technology is available for use as a complementary system with a microwave AESA GMTI/SAR system. Significant sharing of common hardware is possible. It is the only system that will provide standoff coverage in forested regions. This technology requires more maturation.
- Advances in data exploitation (fusion) are required for robust capability. The technology of fusion processes for timely, geo-registered multisensor inputs from satellite, aircraft, and unattended ground sensors has matured. This includes high-resolution SAR, electro-optical (EO), or infrared (IR) imagery, moving-target indicator/MTE radar, signals intelligence (SIGINT), and hyperspectral signatures. Some capabilities are in the pipeline (MTE, automatic target recognition) but need testing and fielding, and additional capabilities need to be developed for

this focused fusion capability. Currently, fielded sensor control and fusion capabilities are inadequate for future Air Force operations in timeliness, accuracy, and completeness. There are some emerging fusion (GMTI tracking, all-source track fusion) and sensor tasking and management (multi-asset synchronized planning) that offer enhancements.

Although promising, these still fall short of ultimate needs in fusion and control and in their ties to dynamic planning and execution. Presentation and visualization of fused info-products is a neglected area, and there exists no organized effort to codify or quantify what capabilities are available for fusion. This must be done to assess areas for further S&T investment and to determine needs for new or augmented sensing capabilities.

- The technology that enables automated target mensuration of any imagery with features by co-registering it with a precision digital imagery and terrain elevation reference imagery database has matured. Further reference development will provide target geo-registration to Earth coordinates within a meter or so and significantly change and speed the mensuration process.
- Sensor management problems will be magnified in the TCT context. Semiautomatic tools to aid real-time ISR sensor and platform planning and tasking have lagged.
- Semiautomatic aids and processes for target analysis, mensuration, coordination, and nomination in parallel are vitally needed and are key to speeding up time-critical targeting.
- Dedicated TCT cells and processes are required (tools, tactics, techniques, procedures, training, etc.).
- Battle damage assessment is a comparatively underdeveloped capability within the larger (and itself underdeveloped) area of real-time fusion for operations. Combat assessment tools—that is, tools for combined battle damage assessment and responsive tasking—do not exist except as created individually by operators. This represents an area that cuts across standard functional boundaries, namely fusion of information and dynamic planning. Tools and processes to provide coordinated, near–real time combat damage assessment are needed from all imagery, including SAR and EO, strike aircraft video; GMTI motion (or cessation thereof); and pilot reports.
- Use of advanced high-power, high-gain AESA radar systems to provide selective, high-power spot jamming for electronic countermeasures (ECM) support is feasible but requires dynamic sensor tasking, planning, and management.
- Automated in-flight target folder preparation and update tools and secure, real-time datalinks to strike aircraft are required for dynamic targeting of TCTs.
- Continued development of beyond-line-of-sight wideband communications to support remote reachback analysis is needed.
- Intelligence preparation of the battlefield (IPB) is critically important to sensor planning, tasking, exploitation and geo-registration. The role of IPB is changing from operations planning to the more continuous process needed to support agile and dynamic operations: *predictive battlespace analysis* to support missions such as time-critical targeting and precision (and timely) targeting information. Based on a worldwide high-precision, digital foundation data base of imagery, a digital terrain elevation database (DTED), digital feature analysis data (DFAD), and other information, it will produce terrain delimitation (probability of route and location of command posts, forces, etc.) as well as precision geo-registration reference.
- There is a critical need for a complete, dynamically updated, and accurate foundation data environment that maps the battlespace: ortho-rectified and geo-registered data sets and automated, laborless database maintenance.
- High-speed weapons with datalinks for in-flight retargeting are needed for striking critical mobile targets.

- There is no current capability to display how information operations can affect the battlefield and how such operations can offset metal on target.

Figure 7-1 also suggested some areas for improvement of the TCT capability, as well as the resulting reduced TCT timeline. Some of these improvements were demonstrated at JEFX 2000:

- Continuous (7 x 24) ISR using long-endurance, high-altitude UAVs
- Advanced radar with GMTI and spot (UHR++) SAR imagery
  - High-range resolution target features of moving targets
  - Information cues and fusion from satellite, SIGINT, unattended ground sensors, and complementary UHF FOPEN radar
  - Complementary high-power spot jamming ECM mode from the radar that can provide rapid strike protection on call
  - Coordinated near–real time combat assessment—imagery, motion, and identification
  - Rapid semiautomatic analysis of cued (UHR++) spot imagery
- Improved sensor planning and tasking processes with semiautomatic tools
- Automated IPB from a digital foundation reference database consisting of precision satellite imagery, DTED (terrain elevation), and DFAD (terrain and cultural features)
- Automated image mensuration and target geo-registration using a digital foundation reference database
- Advanced tools, techniques, tactics, and processes to allow parallel attack planning, targeting, weaponeering, strike coordination, and target nomination using significantly higher-quality sensor input (better location accuracy, higher resolution, and moving-target recognition) pending a decision based on final target analysis by experts
- Semiautomated tools for target recognition, analysis, and mensuration
- Automated in-flight target folder preparation for targeting and retargeting
- A secure datalink to strike aircraft
- A TCT cell for critical mobile targets using quick-strike processes, tactics, techniques, and procedures
- High-speed weapons with datalinks for in-flight retargeting

The C^2 decision process needs improvement but is not the only problem, because one of the key difficulties is to provide timely, analyzed, geo-registered surveillance and reconnaissance information to the intelligence experts and the operation center commanders for targeting and weaponeering. This includes the information needed for the target nomination decision-making process as well as the weapon system attack execution process.

7.3 Datalinks for Combat Aircraft

In the late 1950s, Air Force air defense fighters depended on semiautomatic ground environment ground control systems and datalinked commands to effect continental air defense. First- and second-generation datalinks were installed in hundreds of aircraft to allow simple messages relaying target data from ground control intercept sites. In some cases, these messages could be linked directly to the aircraft autopilot to essentially steer the aircraft from the ground. Over time, the population of datalink-equipped Air Force aircraft shrank substantially. In the 1991 SAB Summer Study "Offboard Sensors to Support Air Combat Operations," we strongly recommended that the Air Force realize the importance and leverage of airborne datalink systems and develop, fund, and manage a program to facilitate the transfer of data between weapons systems. Yet, during that same year, Air Force senior leadership declared that datalinks were unnecessary "because of doctrine."[16] By 1996, the Air Force had returned to a point where only 3 percent of aircraft were equipped with J-series datalinks—Tactical Digital Information Link J (TADIL-J) and Variable Message Format.

Since that time, the use of the Global Positioning System for navigation and weapons delivery has underlined the importance of digital data transfer directly from computer to computer without the difficult process of voice transfer and computer entry of long number strings—underscoring the need for digital datalinks.

In JEFX 2000, we were able to hear the flight lead air crews debrief the mobile target (TCT) attack missions with nearly universal success using various datalinks on the fighter, bomber, C^2, and surveillance aircraft involved. The variety of datalink systems was a challenge, but the challenge was met with the Talon Gateway system developed and demonstrated by the Space Warfare Center. The key message was that datalinks are important to effective air operations and that the Air Force must establish a serious program to provide data transfer capability to and among aircraft.

The Air Force commitment to datalinks has been strengthening, and current plans and budgets reflect the intent to field 3,372 platforms (aircraft and command nodes) equipped with J-series datalinks by 2015. The installation rate funded by the current (FY00) budget and indicated by the POM submission and reported in the Joint Tactical Data Link Management Plan is shown in Figure 9-2. The challenge presented to this study was to suggest ways to achieve the "linking of the Air Force" by 2005.

The difficulty in attaining a datalink-equipped air combat force can be recognized from the fact that there are 19 PEs and 8 panels involved in the datalink program. It is worse than having no one in charge: everyone is in charge.

The proper approach is to gain single-point management of datalinks and then focus on the operational capability rather than the technical equipage. The management should concentrate first on gaining a J-series message datalink–capable force within each AEF, using a combination of the datalink radios available, the modification schedule they can live with, and the gateways (for example, Talon Gateway) to provide the 80 percent solution in the near term.

It must also be remembered that the datalink problem involves more than the aircraft installations. Plans must be made to provide the infrastructure for a robust network while holding options open for advanced (beyond the Joint Tactical Information Distribution System) capabilities in the future.

[16]"U.S. Air Force Chiefs, C^3I Officials Dispute Need for F-15 Datalinks," Defense News, 8 July 1991.

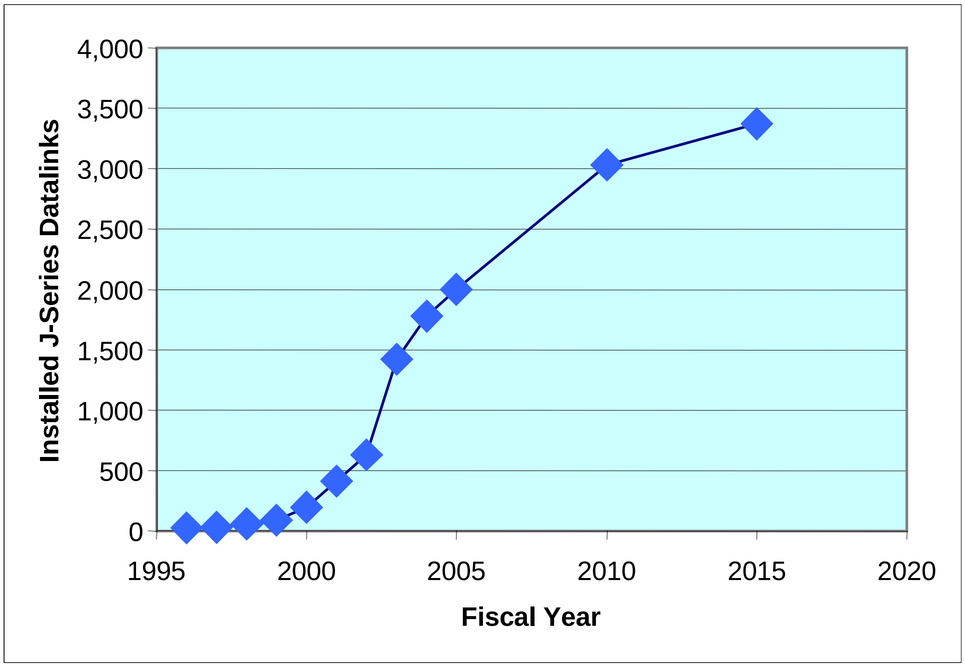

Figure 7-2. *J-Series Datalinks Planned for Installation in Air Force Aircraft*

The only viable alternative that we can suggest (and one that is subject to further investigation and validation) is, starting in 2002, to install J-series message-compatible situational awareness datalink (SADL) terminals in 877 F-16 Block 40 and Block 50 aircraft and develop and field Link-16/SADL gateways in parallel. This option would potentially allow an acceleration of TADIL-J. When Multifunction Information Distribution System (MIDS) terminals are installed in these aircraft, the SADL terminals can be removed (and potentially returned to the Army).

Figure 7-3 illustrates the increase in the number of TADIL-J equipped aircraft if the Link-16/SADL option is implemented.

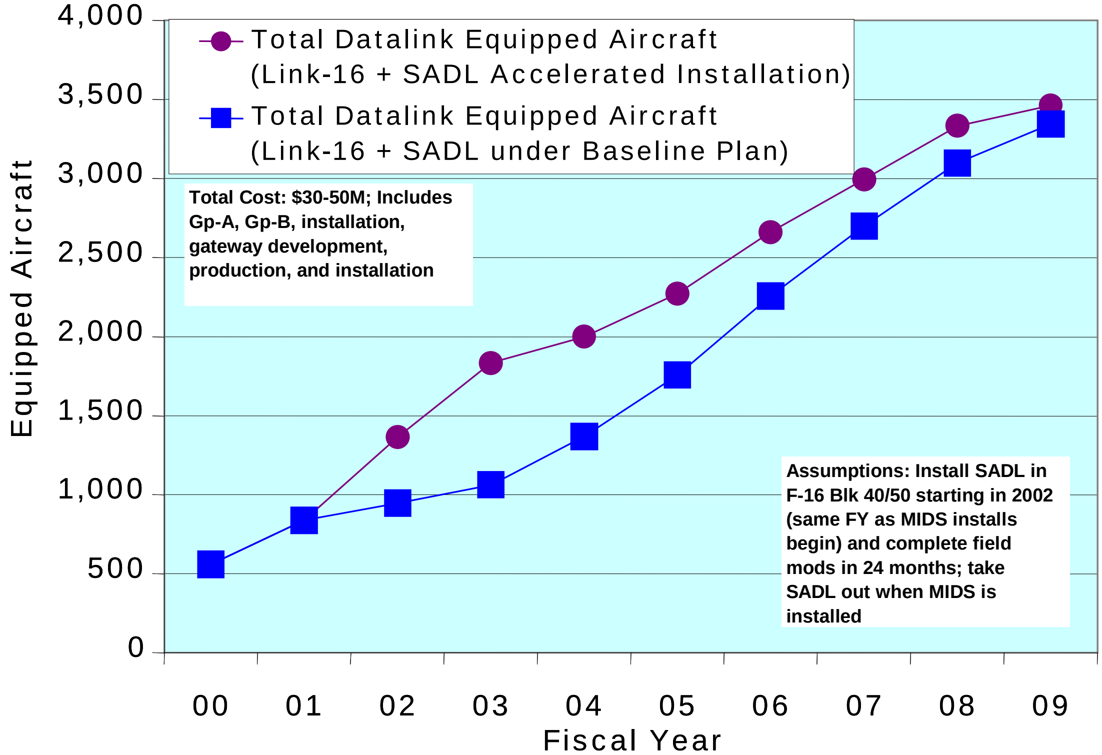

Figure 7-3. *Datalink Implementation Under an Alternative Scheme*

7.4 Summary

For the most part, the TCT solution does not involve major technological breakthroughs, but rather the dedication and focus to concentrate a few resources and some technical and operational thought on the problem. Today's TCT systems rely heavily on imagery because it is the key source to providing the necessary target recognition and identification and geo-registered coordinates. Imagery, especially wide-area imagery, is not rapid in tasking, collection, processing, exploitation, or dissemination—not only because of the very high bandwidth required and the huge data files to be searched, but more because of the very difficult problem involved in machine image recognition and analysis. The work in image target recognition has to continue, but new advanced GMTI/SAR sensors offer significant breakthroughs in real-time detection, accurate location, and target feature information on moving targets; the breakthroughs can provide the real-time cue needed to obtain high-resolution spot imagery needed for the targeting process.

The key ISR improvement is to have continuously available and readily taskable ISR platforms that can stay within rapid access distance of the target. The use of high-altitude, long-endurance UAV would be able to provide 7–day, 24–hour ISR coverage, and an advanced radar could provide all-weather, wide–area GMTI coverage and moving-target recognition as well as simultaneous, interleaved high-resolution SAR spot imagery.

The datalink problem is long-standing. SAB studies going back to 1991 have continually identified the need for concentrated action to gain and integrate effective digital datalink systems. There are solutions that capitalize on achieving an operational capability for transfer of J-series message sets to attack aircraft. The operational approach to achieving a capability within the deploying AEFs in the most rapid, cost-effective way possible should be followed. This will happen only if a single point of management is achieved. Clearly, the datalink solution is both money- and time-consuming, but the tremendous leverage this data-transfer capability provides makes the investment crucial.

Linking the Air Force by 2005 will require decisive action on the part of Air Force leadership to address fundamental human factors issues that impact the performance, readiness, and sustainability of present systems for theater battle management. C^2 must be elevated in status and priority to a level consistent with that of other essential weapons systems and warfighting functions. The establishment of C^2 as a weapons system has important implications for Air Force institutions, organizations, and processes used to select, assign, train, and equip C^2 warfighters.

"Linking the Air Force by 2005" is critical to conducting air operations against TCTs. It is solvable if, and only if, the Air Force staff drops institutional and political barriers and addresses the TCT and associated datalink issues with an integrated, aggressive approach.

Chapter 8
Implementing the Plan

8.1 Introduction

There is no doubt in the minds of the SAB that the Air Force leaders recognize the importance of the effective C^2 of its forces in achieving success in air operations. There is also a profound recognition that leadership is understanding that air forces engaged in past conflicts have not benefited from the awesome power of an effective theater C^2 system with the flexibility and responsiveness necessary in the dynamic battlespace that technology has brought.

Implementing the necessary changes to the current Theater Air Command and Control System involves much more than a technical (hardware and software) change. In fact, it requires a fundamental change in "business practices," to borrow a commercial term. It requires a top-down revision in thinking and in accomplishing before any technical changes are made.

8.2 Leadership Commitment

During the course of the Study, the team reviewed the history of deficiencies and fixes to the theater air C^2 system. There have been numerous studies, including four SAB studies in the past 5 years. There have been organizations and reorganizations, all with little lasting impact on the state of the capabilities.

A fundamental element of the solution must be a commitment on the part of leadership, a commitment not only to initiate actions in supporting the business practice change, but to lay in place a mechanism for high-level review and follow-up to ensure that actions are fully completed and that the resulting C^2 system allows for evolution as the technology advancements, operational concepts, and world environment dictate.

We are encouraged by the dedication of the current leadership—General Michael Ryan (CSAF), General John Jumper (Commander, ACC), and Major General Gerald Perryman (Commander, AC2ISRC)—in recognizing the need for action, as well as both the technical and operational issues associated with C^2 and the information technology field. Continued attention is encouraged.

8.3 Organizational Change

The management of C^2 has historically been spread across combat and support mission areas, boards and panels, and the associated organizational structure without considering the essential need for a C^2 system integrated across the Air Force. Only since the Air Command and Control Agency (now the AC2ISRC) was established in 1997 has there been any serious consideration of the need to concentrate effort in the area. The AC2ISRC has clearly had great impact on the C^2 function, finally getting its arms around the myriad of CONOPS, architectures, programs, PEs, and people.

At the Air Staff level, however, there remains a fragmentation of management of C^3ISR across eight panels, 131 PEs, and four major two-letter directorates. Moreover, as important as the

Center is to the Commander of ACC as well as to the other MAJCOMs, it cannot be effective without a similar consolidation of management at the Air Staff.

Consolidation of the management of C^2 is essential. We cannot expect that the proper management tradeoffs critical to a constrained budget will be made in an organizational structure in which management responsibilities are fragmented.

8.4 Defining Command and Control

The official definition of C^2 is

The exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission.[17]

So, while C^2 is a function, the many hardware and non-hardware elements that enable the function must be considered in the management and modernization process.

8.5 Applying Resources

The Air Force faces a critical shortage of funds for operations and maintenance (3400), for system development (3600), and for acquisition (3080). It is not likely that there will be significant relief in the near future. Thus, the Air Force must assume a level budget and carefully allocate the funding available to get the most from each dollar. We submit that the current process—involving many PEs and no single panel to represent such activities as the AC2ISRC so as to ensure consideration of the alternatives as well as to prioritize the initiatives—is not an appropriate way to manage limited funds.

Thus, we suggest a greatly reduced number of PEs and a C^3 Panel in the Board Structure as the surest way to success in solving the many C^2 problems.

8.6 Summary

The SAB recognizes the substantial pressures on the Air Force to do more with fewer resources. Most certainly, the effective use of C^2 in the management of air operations could improve the efficiency of the combat forces. The recommendations that follow are the collective opinion of the Study team.

[17] Joint Publication 1-02, *DoD Dictionary of Military and Associated Terms*.

Chapter 9
Key Recommendations

9.1 Introduction

The Study recognized the many past organizations, directives, studies, and other efforts to develop a Theater Command and Control System for the Air Force. Many dedicated and talented leaders have made great efforts, and even great strides, in the name of C^2. Yet we once again find ourselves on the doorstep with a basketful of comments and ideas to improve the C^2 of Air Force combat operations.

It is our belief that the solution (recommendation) set can, and should, be cast in a framework in order to capture the underlying rationale for the suggestions. Our **framework** includes the following elements:

- A unified, understood, focused approach to C^2
- A CONOPS-driven, capabilities-based process that encourages, not impedes, system operational enhancement
- Acquisition processes that are timely and efficient in capturing emerging technologies
- Leadership in becoming more interoperable, including joint and coalition interoperability
- Horizontal integration of ISR with C^2
- Focus and follow-through

9.2 Recommendations

We recommend the following actions be taken:

Recommendation 1. Emphasize the Role of C^2 in the Air Force

It is important that all levels of the Air Force, as well as Congress and other Government activities understand the criticality of effective C^2 to the outcome of a crisis. To that end, we believe that the Air Force leadership should

- Endorse and institutionalize a compelling C^2 vision, the first step toward recognizing the essential link between aerospace power and C^2 (AF/CC)
- Establish coherent capability-based management for C^2 and communications—place a single manager (for example, a lieutenant general, operator) at the Air Force level, and include the manager as a member of the Air Force Council (AF/CC)
- Hire expert IT and C^2 professionals (Intergovernmental Personnel Acts [IPAs]?) for key positions in the C^2 structure (AQ, XO, SC)
- Manage and exercise the Air Force C^2 enterprise as an integrated system of weapon systems (AQ, XP, XO, SC)
- Restructure C^2 programs and initiate migration (reduction) to PEs by nodes (weapons systems) and links (AF/XP)
- Establish an Air Staff proponent for AFFOR C^2 processes and systems (AF/CC)

Recommendation 2. Manage Theater C^2 as an Integrated Set of Weapon Systems

When an Air Force system (such as the F-15E) is officially designated a Weapons System, a certain formality in the management of that system, including people, hardware, software, training, certification, maintenance, and evolution is established and implemented. C^2 systems deserve nothing less. The Air Force should

- Designate the C^2 nodes (AOC, ASOC, WOC, AWACS, JointSTARS, etc.) as weapon systems (XO, SAF/AQ). This will ensure standardization of
  - Equipment
  - Software
  - Manning
  - Training
  - Personnel certification
- Create and maintain a capabilities-based Theater C^2 Weapon Systems Integration Roadmap and review it regularly (XO, SC, AQ). The participants would be
  - PEOs
  - Program Managers
  - MAJCOM requirements reps
  - The Air Staff (XP, XO, SC, AQ)
  - AC2ISRC
- Establish and fund a single C^2 integration activity with a testbed for verification of compatibility, performance, and robustness (XO, SC, AQ, AFMC)

Recommendation 3. Strengthen the AOC Through Restructuring, Staffing, and Training

Though the AOC is at the heart of precision air operations, recent conflicts have resulted in a pickup game of equipment and personnel. Consequently, the efficiency and success of these air operations have suffered. An effective and efficient AOC, ready to deploy or operate from home at any time, is absolutely essential. Accordingly, we recommend that the Air Force

- Manage the AOC as a weapon system
- Restructure the operational headquarters (of each NAF) based on requirements to support expeditionary operations (XO)
- Streamline and enhance AOCs based on
  - Baselining their number and locations
  - Standard organization
  - Standard processes and systems
  - Effectively motivated, trained, and certified personnel
  - New technology (TBMCS)
- Conduct daily training for C^2 warriors (that is, 5/12 operations, daily ATO?)
- Conduct joint training (live and virtual)

Recommendation 4. Field and Evolve TBMCS

TBMCS has been a major, albeit painful, step to a new, integrated theater C^2 system. Though it cannot be considered a final configuration with all modules in optimum operation, it is a major step forward from the previously fragmented system(s). It is time to accept the system and to accept the fact that continual upgrades will be needed and should be planned. The Air Force should

- Field and evolve TBMCS (SAF/AQ, AF/XO)
- Web-enable the TBMCS as a step toward the JBI (SAF/AQ)
- Make needed major upgrades as soon as possible (AQ):
  - Incorporate scalability and interoperability
  - Install a simplified and consistent user interface
  - Reduce the system administrator's workload
  - Improve unit-level modules
- Merge and migrate TBMCS to the GCCS-AF (AQ)
- Transition to an evolutionary integration process for yearly upgrades to TBMCS (AC2ISRC, ESC)

Recommendation 5. Institutionalize a C^2 Evolutionary Integration Process

The major difficulty in taking advantage of developments from the military and commercial sectors, including off-the-shelf solutions, as well as those successfully prototyped in laboratory or field exercises, has been the lack of a formal and cyclical means to integrate new capabilities online. The Air Force should create and support a process for the evolutionary integration of developed modules by

- Recognizing the need for continuing C^2 integration and establishing the program and budget for the necessary infrastructure (SAF/AQ, AFMC).
- Adopting an evolutionary integration process for C^2 systems as the normal approach. The DISA approach for evolving the GCCS should be the model (SAF/AQ, AFMC, AC2ISRC). Its major elements would be
  - Frequent periodic identification of capability improvements needed in the TACCS
  - Initiation of developments where they are required
  - Establishment of a configuration control, certification, and integration capability
  - Level funding for integration of mission modules (mostly 3400)
  - Operational testing procedures be adapted to this new process
  - Employment of expert IT professionals (IPA?) to augment the team (AQ, XO, SC)

Critical to effective integration and management is the creation of a partnership, based on mutual support and trust, of the operators (that is, AC2ISRC); the developers (that is, ESC or AFRL); the integrators (that is, ESC); and the operational testers (that is, AFOTEC), each of which must accept and carry out their responsibilities:

- Operator responsibilities
  - Maintain CONOPS and operational architecture
  - Prioritize desired capabilities

- Operationally evaluate developed capabilities
  - Plan, program, and budget for personnel and support
  - Foster development of new capabilities (ACTDs, AOCs, etc.)

- Developer responsibilities
  - Respond to CONOPS and other user needs
  - Ensure that technologies are available for integration
  - Participate in ACTDs, JEFXs, and Battlelab activities
  - Conduct spiral developments as needed

- Integrator responsibilities
  - Maintain system and technical architectures
  - Maintain system configuration control
  - Assess engineering and data, analyze risk
  - Integration and testing
  - Integration of developed capabilities into the baseline system

- Operations tester responsibilities
  - Participate in the engineering process
  - Do the main evaluation during development
  - Certify performance post-integration

Recommendation 6. Enable and Encourage Rapid Technology Insertion

The Study determined that there are no technology impediments to substantial improvements in the effectiveness and efficiency of the C^2 of air operations. With some exceptions, in which additional operational focus is needed, the emphasis must be on the timely and effective transition of military and commercial technologies to the Air Force C^2 system needs. The Air Force should follow a focused effort to improve technology exploitation through the following actions:

- Let CONOPS and desired capabilities, rather than multi-volume requirements documents, drive development
- Link SBIR (6.5) investments to a master C^2 R&D plan
- Fund and facilitate rapid transition of S&T, SBIR, and JEFX developments into weapons systems
- Adopt a formal process to allow operational optimization of C^2 information applications while maintaining configuration control and system integrity
- Streamline the DII COE certification process to accommodate new technology (for example, publish, subscribe, fuselets) in a timely manner
- Provide authority to all C^2 programs to accept industry logo compliance as equivalent to DII COE certification (Level 5)
- Establish a C^2 testbed, which is essential to fostering rapid development of the AOC and other elements of theater C^2

Recommendation 7. Achieve Information Interoperability for Warfighters Through JBI

The opportunity to significantly improve our ability to conduct effective joint and coalition warfare rests on the degree of C^2 interoperability. The Air Force should seize the initiative to evolve the JBI as the basis for true interoperability:

- Start a process to get databases, systems, and people to share information in Services, joint operations, and coalitions
- Migrate TBMCS, the Joint Mission Planning System, the Deliberate and Crisis Action Planning and Execution System, etc., to a common information model; the first step is to web-enable and XML-enable them (AQ, SC)
- Start defining and refining the information model that the JBI needs (AQ, XO, SC)
- Take the lead in moving DII COE to an Internet-like, services-oriented concept (AQ, SC)
- Push the Adaptive Battlespace Awareness ACTD and use it as a vehicle to do all this, and make it the heart of a real C^2 testbed (AQ, XO, SC)
- Establish a process to ensure effective human-system integration
- Involve J-6, OASD/C^3I (DISA), the Army, and the Navy–Communications Electronics Command and SPAWAR are ready to work with us (AQ, SC)

Recommendation 8. Staff and Train to Be Consistent With the Importance of C^2

The Air Force has been a pioneer in recognizing the importance of its people. At the heart of this recognition, and built on the foundational element of “quality people” for the Air Force core competencies, is the establishment of a trained force of C^2 professionals. To realize the vision of C^2 as a highly integrated and effective weapons system, the Air Force should

- Model C^2 training after conventional weapon system training programs
  - Derive training requirements and standards from CONOPS and Mission-Essential Tasks Lists
  - Establish a “standing AOC” with a peacetime operations and training mission
  - Actively engage AOCs in training, exercises, and the AEF spinup cycle
  - Apply DMT to integrate AOC, WOC, and Squadron Operations Center
  - Ensure compliance with existing C^2 training directives
- Elevate the stature and advancement opportunities for C^2 warriors
  - Develop a professional CAF C^2 cadre and career tracks
  - Establish C^2 skill and staffing requirements based on CONOPS
  - Assign Air Force Specialty Code/SEI codes for C^2 specialists and improve the tracking system
  - Recognize and promote to encourage C^2 expertise

Recommendation 9. Strengthen Efforts for Attack of Time-Critical Targets

Recent crises have again highlighted the shortfall in the capability for rapid acquisition, identification, and attack of mobile targets. Clearly, the delays in the process are unacceptable, and progress in the improvement has been marginal. The Air Force should establish a program team to address the rapid response attack of TCTs which should include

- Automated IPB

- Continuous high-altitude, long-endurance UAV with advanced GMTI and spot UHR++ SAR, EO, and IR imagery
- Rapid semiautomatic analysis of cued (UHR++) spot imagery
- Improved sensor planning and tasking processes
- Automated mensuration with a digital reference foundation database
- Parallel processes where possible with approximate location analysis, mensuration, coordination, and nomination
- Automated in-flight targeting and retargeting
- A secure datalink to aircraft
- A TCT cell for critical mobile targets
- High-speed weapons

Recommendation 10. Facilitate and Enhance Data Connectivity

Critical to the dynamic management of combat airpower is the data connectivity from C^2 activities to the aircraft. The delays in fielding solutions to the aircraft datalink problem seem to be more political than technical. The Air Force should exercise leadership in achieving the goal of interlinking aircraft based on operational access to message sets (J-series), rather than emphasizing only specific equipage. Specifically, the Air Force should

- Designate an Air Staff office as the single control point for cross-platform C^2 capability funding and select an execution organization (AFMC) (SAF/AQ, XO, SC)
- Examine interim alternative options in detail for SADL, Improved Data Modem (IDM), and Link-16–SADL–IDM gateways, and other innovative solutions
- Explore operational alternatives capitalizing on partial equipage
- Develop required infrastructure support (network management, message management, testing, training, etc.)
- Prioritize the investments to deploy AEFs with encrypted data-enabled capability
- Address the need for robust, affordable, beyond-line-of-sight links to airborne platforms using low and high data rates (XO, SC)
- Investigate and address other data connectivity issues and solutions (SC)
- Review quarterly at quarterly acquisition program reviews?

9.3 Summary

The essence of the recommendation set is to provide focus and follow-through on C^2 issues from a very high level. They key actions are to

- **Establish a single C^2ISR manager at the Air Force level (for example, a three-star operator)—an Air Force Council Member.**
- **Integrate expert IT professionals (internal and new) into the C^2 staff.**
- **Direct a C^2 program restructuring.**
- **Adopt the GCCS framework: evolve theater Air Force C^2 applications into GCCS-AF.**
- **Direct a capability-centric evolutionary integration process for $C^{2.}$**
- **Manage theater aerospace C^2 as a system of weapon systems.**
- **Baseline the number, configuration, and location of AOCs. Enhance operation and reduce personnel through daily "wartime" use.**

- **Appoint a "lead dog" for agile combat support software systems (GCSS-AF).**

The Air Force vision of "well-equipped C^2 centers collaborating globally in support of the CINCs" can be rapidly achieved if senior Air Force leadership strongly endorses the need for an enterprise-wide C^2 capability. The Air Force must restructure the way C^2 programs are managed and resourced, and at every opportunity leadership must clearly speak out about their dedication to achieving an enterprise-wide C^2 capability. In this Study we have provided a proposal for how the Air Force can achieve an enterprise-wide C^2 capability by 2005. We have provided our views on areas that the SAF, Air Staff, and MAJCOM staffs should focus on in starting down a C^2 modernization journey. The journey of achieving an effective distributed, collaborative, enterprise-wide C^2 capability that allows C^2 centers to collaborate globally in support of the CINCs is *one of the most important journeys the Air Force must take in the 21st century.*

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Appendix A
Terms of Reference

USAF Scientific Advisory Board 2000 Summer Study on
Air Force Command and Control—The Path Ahead

BACKGROUND: The Air Force needs to define its command and control (C^2) system in light of recent points of experience in Operations Desert Shield/Desert Storm and Operation Noble Anvil in Kosovo, taking advantage of technological improvements. The Air Force is not on a path today that provides coherence across space, air, and land assets to support the most timely and effective decision making and execution. The Air Force Scientific Advisory Board (SAB) and other defense advisory boards have conducted a number of studies over the past decade that bear directly on this problem and form a foundation from which to work. The Board is now being asked to assess the C^2 system and the supporting communication and information systems, to consider technical and process improvements, and to make recommendations on what should be done to "have the Air Force linked by 2005" and to build toward the Air Force's long term command and control goals.

Study Products: Briefing to SAF/OS and AF/CC in October 2000. Publish report in December 2000.

Charter:

1. Define the Air Force command and control system with today's capabilities and identify alternatives to enhance it over time:
   - Describe operational C^2 concepts and procedures.
   - Examine functional tasks and consider where these tasks should be accomplished in the organizational construct.
   - Determine connectivity/network requirements for the defined system and improved systems, and identify where today's systems are out of phase or disconnected.
   - Include the integration of intelligence, surveillance and reconnaissance assets.
2. Define interoperability (joint and coalition) to ensure coordinated efforts on the battlefield.
3. Identify the technologies that can enhance present and future command and control systems, with near term emphasis on timely and effective communication.
4. Assess the acquisition, programmatic, and cost effectiveness issues.
5. Consider the organizational, personnel, training, and support consequences.
6. The report should include recommendations on:
   - Defining a specific command and control system with today's assets.
   - Changes in the system possible in the near term with new procedures and technology, with emphasis on "have the Air Force linked by 2005".
   - Longer-term improvements consistent with the Air Force's long-term vision for command and control.

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Appendix B
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Appendix C
Acronyms and Abbreviations

ABCCC	Airborne Battlefield Command and Control Center
AC2ISRC	Aerospace Command, Control, Intelligence, Surveillance, and Reconnaissance Center
ACC	Air Component Commander
ACTD	Advanced Concept Technology Demonstration
AEF	Aerospace Expeditionary Force
AESA	Active Electronic Scan Antenna
AF/CC	Air Force Chief of Staff
AF/SC	Air Force Deputy Chief of Staff, Communications and Information
AF/TE	Air Force Deputy Chief of Staff, Test and Evaluation
AF/XO	Air Force Deputy Chief of Staff, Air and Space Operations
AF/XP	Air Force Deputy Chief of Staff, Plans and Programs
AFB	Air Force Base
AFFOR	Air Force Forces
AFMC	Air Force Materiel Command
AFOTEC	Air Force Operational Test and Evaluation Center
AFRL	Air Force Research Laboratory
AFRL/IF	AFRL, Information Directorate
AFSPACECOM	Air Force Space Command
AMC	Air Mobility Command
AMOCC	Air Mobility Command Center
AO	Area of Operations
AOC	Air Operations Center
ASOC	Air Support Operations Center
ASR	Automated Speech Recognition
ATAF	Allied Tactical Air Force
ATO	Air Tasking Order
AWACS	Airborne Warning and Control System
BCC	Battle Control Center
BM	Battle Management
C^2	Command and Control
C^2ISR	Command, Control, Intelligence, Surveillance, and Reconnaissance
C^2TIG	Command and Control Training and Innovation Group
C^3I	Command, Control, Computers, and Intelligence
C^4I	Command, Control, Communications, Computers, and Intelligence
C^4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
CAF	C^4ISR Architecture Framework
CAOC	Combined Aerospace Operations Center
CAS	Close Air Support
CC	Commander
CINC	Commander in Chief
COMAFFOR	Air Forces Commander
COMM	Communications
CONOPS	Concept of Operations
CONUS	Continental United States
COP	Common Operating Picture
COTS	Commercial Off-the-Shelf

CRC	Control and Reporting Center
CRE	Control and Reporting Element
CSAF	Chief of Staff, United States Air Force
CTAPS	Contingency Theater Air Planning System
DARPA	Defense Advanced Research Projects Agency
DFAD	Digital Feature Analysis Data
DII COE	Defense Information Infrastructure Common Operating Environment
DISA	Defense Information Services Agency
DMT	Distributed Mission Training
DoD	Department of Defense
DODIIS	Department of Defense Intelligence Information System
DT	Developmental Testing
DTED	Digital Terrain Elevation Database
EAF	Expeditionary Air Force
EA	Evolutionary Acquisition
ECM	Electronic Countermeasures
EO	Electro-Optical
ESC	Electronic Systems Center
FAC-A	A-10 Forward Area Controller
FOPEN	Foliage Penetration
FY	Fiscal Year
GCCS	Global Command and Control System
GCCS-M	Global Command and Control System-Maritime
GIG	Global Information Grid
GMTI	Ground Moving-Target Indicator
GOTS	Government Off-the-Shelf
HSI	Human-System Interface
I&I	Integration and Interoperability
IA	Information Assurance
ICD	Interface Control Documents
IDM	Improved Data Modem
IER	Information Exchange Requirement
IPA	Intergovernmental Personnel Act
IPB	Intelligence Preparation of the Battlefield
IPT	Integrated Product Team
IR	Infrared
ISC^2	Integrated Space Command and Control
ISR	Intelligence, Surveillance, and Reconnaissance
IT	Information Technology
IW	Information Warfare
IWC	Information Warfare Center
J/CFACC	Joint/Combined Force Air Component Commander
JBI	Joint Battlespace InfoSphere
JEFX	Joint Expeditionary Force Experiment
JFACC	Joint Forces Air Component Commander
JIEO	Joint Information Engineering Organization
JointSTARS	Joint Surveillance Target Attack Radar System
JSF	Joint Strike Fighter
JSOW	Joint Standoff Weapon
JTF	Joint Task Force
MAJCOM	Major Command
MIDS	Multifunction Information Distribution System
MQT	Mission Qualification Training
MTE	Moving Target Exploitation

MX	Military Experimental
NAF	Numbered Air Force
NATO	North Atlantic Treaty Organization
O&M	Operations and Maintenance
OSD	Office of the Secretary of Defense
OASD/C^3I	Office of the Assistant Secretary of Defense: Command, Control, Communications, and Intelligence
OT	Operational Testing
OTA	Operational Test Agency
OTS	Officer Training School
PE	Program Element
PEO	Program Executive Officer
PME	Professional Military Education
POM	Program Objective Memorandum Program Objective Memorandum
R&D	Research and Development
ROE	Rules of Engagement
ROTC	Reserve Officer Training Corps
S&T	Science and Technology
SAB	Air Force Scientific Advisory Board
SADL	Situational Awareness Datalink
SAF	Secretary of the Air Force
SAF/AQ	Assistant Secretary of the Air Force, Acquisition
SAR	Synthetic Aperture Radar
SBIR	Small Business Innovative Research
SCR	Structured Common Representation
SD	Spiral Development
SEI	Special Experience Identifier
SIGINT	Signals Intelligence
SPAWAR	Space and Naval Warfare Systems Command
SPO	System Program Office
T&E	Test and Evaluation
TACC	Tanker Airlift Control Center
TACCS	Theater Air Command and Control System
TACP	Tactical Air Control Party
TACS	Theater Air Control System
TADIL-J	Tactical Digital Information Link J
TALCE	Tanker Airlift Control Element
TBMCS	Theater Battle Management Core System
TCT	Time-Critical Targeting
TTP	Tactics, Techniques, and Procedures
UAV	Unmanned Aerial Vehicle
UGS	Unattended Ground Sensor
UHF	Ultrahigh Frequency
UHR++	Ultrahigh Resolution
U.S.	United States
USSPACECOM	U.S. Space Command
USSTRATCOM	US Strategic Command
UTC	Unit Type Codes
WCCS	Wing Command and Control Center
WOC	Wing Operations Center
XML	eXtensible Markup Language

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Appendix D
Top-Level Organizations Visited

7–8 March 2000, Colorado Springs, CO: Acquisition Panel

Lockheed Martin

20–21 March 2000, Hurlburt Field, FL: all panels

C^2TIG, AC2ISRC, ESC, JointSTARS, C^2ISR Acquisition, C^2 Battlelab, JEFX 2000, SAF/AQI

22–24 March 2000, Robins AFB, GA: People and Organization Panel

93d Air Control Wing

27–28 March 2000, Orlando, FL: People and Organization Panel

Air Force Agency for Modeling and Simulation

3–5 April 2000, Hanscom AFB, MA: Acquisition Panel

ESC

10–11 April 2000, Langley AFB, VA: all panels

ACC Headquarters, AC2ISRC, ACC Network Operations Security Center

10–12 April 2000, Hampton, VA: Interoperability Panel

Joint Forces Command, Joint Warfare Center, Joint Battle Center

13–14 April 2000, Washington, DC: People and Organization Panel

Lockheed Martin, Boeing Information Systems, U.S. Navy, DARPA

18–20 April 2000, Washington, DC: Acquisition Panel

SAF/AQ, DISA, Department of Energy

25–27 April 2000, Nellis AFB, NV: all panels

Air Warfare Center, Space Warfare Center, Red Flag, ESC Programs, Boeing Independent Research and Development, USAF Fighter Weapons School

28 April 2000, Colorado Springs, CO: Acquisition Panel

Lockheed Martin

3–4 May 2000, Hurlbert Field, FL: Concept and System Definition Panel

C^2TIG

8–12 May 2000, Las Vegas, NV: Concept and System Definition Panel

Agile Combat Support Conference

8–12 May 2000, Washington, DC: Acquisition Panel

Armed Forces Communications and Electronics Association–sponsored GCCS course

16–17 May 2000, Chantilly, VA: Interoperability, Technology, and Concept and System Definition Panels

National Reconnaissance Office, DARPA

16–18 May 2000, Washington, DC: Acquisition Panel

DISA, USAF/XOC, SPAWAR, USAF/XOJ, SAF/AQI, USAF/XOR, USAF/SC, and USAF/XPP

18 May 2000, Washington, DC: Concept and System Definition Panel

DARPA

18 May 2000, Crystal City, VA: Interoperability Panel

Lockheed Martin, OASD/C^3I, JSF Program Office

23–25 May 2000, Langley AFB, VA: Technology Panel

Fusion briefings

30 May–1 June 2000, Wright-Patterson AFB, OH: People and Organization Panel

AFRL Human Effectiveness Directorate

7–9 June 2000, Davis-Monthan AFB, AZ: Concept and System Definition Panel

12 June 2000, Rome, NY: People and Organization, Interoperability, Technology, and Concept and System Definition Panels

AFRL Information Directorate

13–14 June 2000, Hanscom AFB, MA: all panels

ESC

21 June 2000, Washington, DC: Interoperability Panel

Headquarters U.S. Army/DISC4

21–22 June 2000, Langley, AFB, VA: Technology Panel

ISR briefings

26–27 June 2000, Interoperability and Technology Panels

SPAWAR System Center, SPAWAR Acquisition, SWC

26–27 June 2000, Washington, DC: Acquisition Panel

DISA, Ballistic Missile Defense Organization, SPAWAR, and Advanced Information Technology Services Joint Program Office

27–30 June 2000, Seattle, WA: People and Organization and Concept and System Definition Panels

Boeing Phantom Works, Space and Communication

30 June 2000, Ft. Monmouth, NJ: Interoperability Panel

Army Program Executive Office/C3S

10–21 July 2000, San Jose, CA: all panels

SAB Summer Session

10–21 July 2000, San Jose, CA: Technology Panel

Oracle Corporation, Sun Microsystems, JavaSoft, TBMCS briefing

17 July 2000, San Diego, CA: Interoperability, People and Organization, and Concept and System Definition Panels

U.S. Navy Command Ship *Coronado*

7 August 2000, Wright-Patterson AFB, OH: Acquisition Panel

AFMC HQ, ESC, ASC

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Appendix E
The Joint Battlespace InfoSphere (JBI)

E.1 Introduction

Successive Air Force Scientific Advisory Board (SAB) studies have progressively defined the JBI and recommended a program to implement it.[18] The JBI is a powerful *operational* view of information services to the warfighter. The cited studies provide implementation concepts that are carefully grounded in modern information system technology and practice; these concepts establish a basis for moving forward to build a JBI that will provide the foundation for information-enabled warfare.

In the course of the current SAB study, a set of lower-level technical and architectural issues, as well as some exciting emerging technological opportunities, have surfaced from a variety of sources. An extended discussion has taken place among members of the study team and outside experts concerned with information technology (IT) and the JBI. Chapter 8 of Volume 2 of this study gives more details about emerging IT trends and key attributes of the JBI. It also recommends a strategy that will migrate the current command and control (C^2) environment toward the JBI. The results of the recommended steps will, if successful, be largely buried below abstraction layers such that the architects and builders of the JBI can take them for granted and ignore their details, not unlike a pilot who is confident that the avionics will pass messages and compute aim points without worrying about the details of the data bus protocols.

E.2 Summary of the JBI

The following paragraphs provide a very brief summary of the JBI. The reader is urged to consult the SAB reports for more detail. The JBI is a system of systems that collects, integrates, aggregates, and distributes information to users at all echelons. The central premise is that there be a shared virtual information base containing all relevant facts about the battlespace with mechanisms that achieve the often described but seldom seen objective of providing the right information to the right users at the right places and times. The JBI employs four key technologies:

- Information exchange between individual users and the JBI using a publish/subscribe interface in which users send information expected to be relevant to the JBI and receive information based on a set of user criteria
- Transformation of data from multiple sources to a common representation and of data to information to knowledge using elemental processes called fuselets
- Distributed collaboration via shared, updateable knowledge objects
- Templates, associated with assigned units, that describe operational capability, information inputs, and information requirements

[18] U.S. Air Force Scientific Advisory Board Report, *Information Management to Support the Warrior*, SAB-TR-98-02, December 1998; U.S. Air Force Scientific Advisory Board Report, *Building the Joint Battlespace InfoSphere*, SAB-TR-99-02, December 1999.

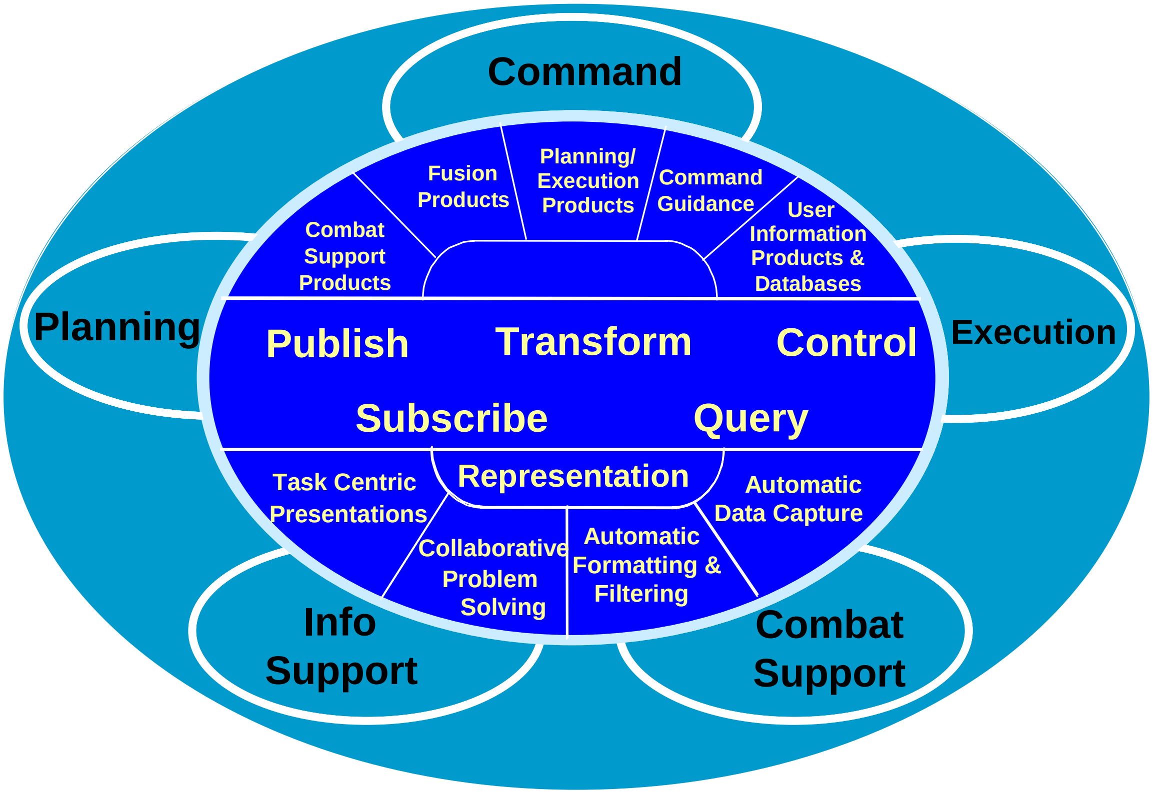

Figure E-1. *The Basic Structure and Functions of the JBI*

Figure E-1 is the JBI "logo," the standard graphical summary of the JBI's functionality. Around the periphery are the warfighting processes that the JBI supports. Within the oval are three layers representing the broad categories of input, manipulation, and interaction, with specific examples of each. At the core, the JBI employs a Structured Common Representation (SCR) in which one or more object schemas are used to define information. A schema provides a way of organizing each piece of information and meta-data (which means "data about data") that allows a common interpretation of the meaning of the data or information objects to be used throughout the infosphere. These information objects, through publish and subscribe actions, are the lifeblood of the JBI. The JBI also includes an information object broker, which automates the collection of information that has been published, the distribution of information objects in response to queries or subscriptions, and the transformation of information objects as needed to support collaboration among users. The full richness of the JBI construct includes fusion of data streams to create first information and then knowledge, sophisticated methods of human-JBI interaction, provisions for security and robustness in the face of hostile actions, and many other dimensions of information support to operational forces. The SCR will necessarily be highly dynamic, growing and changing constantly as new data sources, new user templates, and new information objects enter the JBI. However, by managing the complexities of data exchange among disparate systems, the JBI makes life much simpler for individual users and platforms that employ its services.

As with any complex information system, the JBI requires a variety of views to fully define its structure and functions. For purposes of the present discussion, two top-level views are important.[19] A *logical* view describes the information content of the JBI and the information processes that operate on this content. As discussed in detail later, the essence of this view is an information model. The SCR, the object schemas, the manipulation processes, and the information interfaces are critical elements. A *physical* view has to do with the way the JBI is implemented in the form of applications running on platforms, communicating via networks, and providing a basis for dealing with the rapid evolution of computer and telecommunications technology. Interfaces are still critical, but in this view they take the form of things like applications programming interfaces and network protocols. The physical view involves both hardware and software and defines the geographically distributed platform on which the logical structure of the JBI rides and executes. A specific example is the fact that the shared information base, which is treated in the logical view as a single object repository, will physically reside in a variety of data stores associated with assorted C^2 nodes, platforms, and systems. These views help to decouple the defense information infrastructure common operating environment (DII COE), which is basically part of a platform or physical view, from the JBI, which takes as its point of departure a logical view of information services.[20]

E.3 Information Services for the JBI

The first priority concerns the logical view of the JBI—the way in which an efficient information model is employed to provide information services. For purposes of the present discussion, an information model is defined as

> A schema for the representation of data, together with the processes that (a) aggregate and associate data to create information, (b) fuse and interpret data to create knowledge, and (c) import, transform, access, and export data, information, and knowledge to meet user needs.

Then the JBI presents itself to a user as one or more information service interfaces, defined in terms that are transparent to the technology used to implement the underlying platform and that are intuitively natural for applications programmers to use. Since the essence of the JBI concept is to allow individual users, platforms, and systems to meet their information needs via a publish-and-subscribe interface to a shared infosphere, the top-level services are simply those described in the manipulation layer of Figure E-1:

- **Publish.** Receive and process data or information transmitted to the infosphere by a platform, system, or user upon the occurrence of an event that meets the criteria for the action.
- **Subscribe/Query.** Obtain and present information from the infosphere when the criteria of a subscription or query from a platform, system, or user are met. A subscribe action is defined by a standing set of criteria; a query is generated by an *ad hoc* information need.
- **Transform.** Activate fuselets that perform the necessary operations to produce required information objects and representations.
- **Control.** Monitor and control JBI functions.

[19] Additional important views focus on security, human-machine interfaces, data management, and other key aspects.

[20] However, certain aspects of the DII COE, such as the use of a Shared Data Environment (SHADE), are more closely associated with a logical view.

E.4 The JBI Information Model

The JBI is predicated on a transaction model in which messages—for example, documents, reports, or commands—are exchanged within a force. The basic publish/subscribe mechanisms must deal with information integrity, security, quality (including timeliness), evolution of missions and technologies, and access controls or user privileges. The information model on which these transactions are based must capture the ways diverse data are imported (including from legacy systems), represented, managed, and exported. Current data modeling approaches cannot meet the JBI need but furnish a useful starting point in identifying the types of data involved and their owners and users.

In reality, while it is convenient to speak of "the" JBI information model, there will never be a final, definitive model because the information basis of warfare is constantly changing. Additionally, the very complexity of the JBI information content is likely to demand a number of models, each with its own set of meanings (ontology) and a set of callable service interfaces that are matched to the needs of various user communities. What's needed, therefore, is a *framework* and *process* for the orderly evolution of one or more information models, based on the concepts that have made the Internet so successful and on the most promising technologies for defining and implementing the object schemas and associated processes. Elements of that framework include structure, metadata, and access methods for the JBI information base. For example, standards for metadata definition may be useful in preserving compatibility of information objects across generations of the information systems that use them. The current leading candidate for defining metadata is the eXtensible Markup Language (XML). It is critical that the information model allow users to tailor information access to their specific needs by, for example, presenting information in formats that are native to their legacy systems and to their tactics, techniques, and procedures. This is an important point and it deserves reemphasis: The JBI information model is based on users' conceptual entities, not a designer's data structures, which often take a physical form constrained by the challenges of physically realizing a system.

A number of technology options have emerged that may help in dealing with the problem of the size, complexity, and dynamic nature of the JBI information base. Methods for describing, manipulating, and presenting data that were not available in earlier generations are critical to dealing with the tidal wave of data inundating modern C^2 systems.

The ultimate objective is to present a set of information services to users and applications that are robust, policy-compliant, easy to use, compatible with interoperability across communities and systems, and transparently evolvable with the progress of implementing technology. Key attributes include

- **Domains.** Information stores and associated processes must allow segmentation into domains to make manageable the complexity of the data employed by individual communities and systems. Domains also support the need for individual user communities to collect and structure data to meet their specific needs. XML namespaces offer an initial approach to achieving this.
- **Structure.** Both hierarchy and other structures such as hyperlinks provide tools for dealing with JBI information. The huge, diverse content of a theater database must be embodied in a structured representation if it is to be used with high integrity and in real or near–real time.
- **Compatibility With Heterogeneous, Legacy, and Local Data Stores.** For practical reasons, it is unlikely to be feasible that the vast array of legacy databases be translated into an entirely new JBI object schema, at least not all at once. Moreover, the JBI must be able to access data from

repositories not under its direct control. The information model must provide for wrappers, translators (perhaps using fuselets), or other mechanisms that allow incorporation of such data stores and seamless access to them through the interfaces of the information services set. Figure E-2 suggests the nature of a JBI shared data base that embodies these principles.

- **Abstraction.** The information model must present the information base through one or more abstraction layers that hide the implementation details. Initially, these will be syntactic interfaces, but semantic interfaces should be implemented as the technology matures.
- **Management.** The JBI will become perhaps the most critical resource commanders and warfighters have available in conducting operations. It will sit at the focus of doctrine, operational priorities, and national policy governing the use of military force. Its performance and integrity will largely determine success or failure. At the same time, it will be one of the most complex information systems ever built. For all these reasons, a critical attribute is the structure that is put in place to manage the JBI, both in terms of its real-time operations and in terms of its development, evolution, certification, and integration with supported forces.

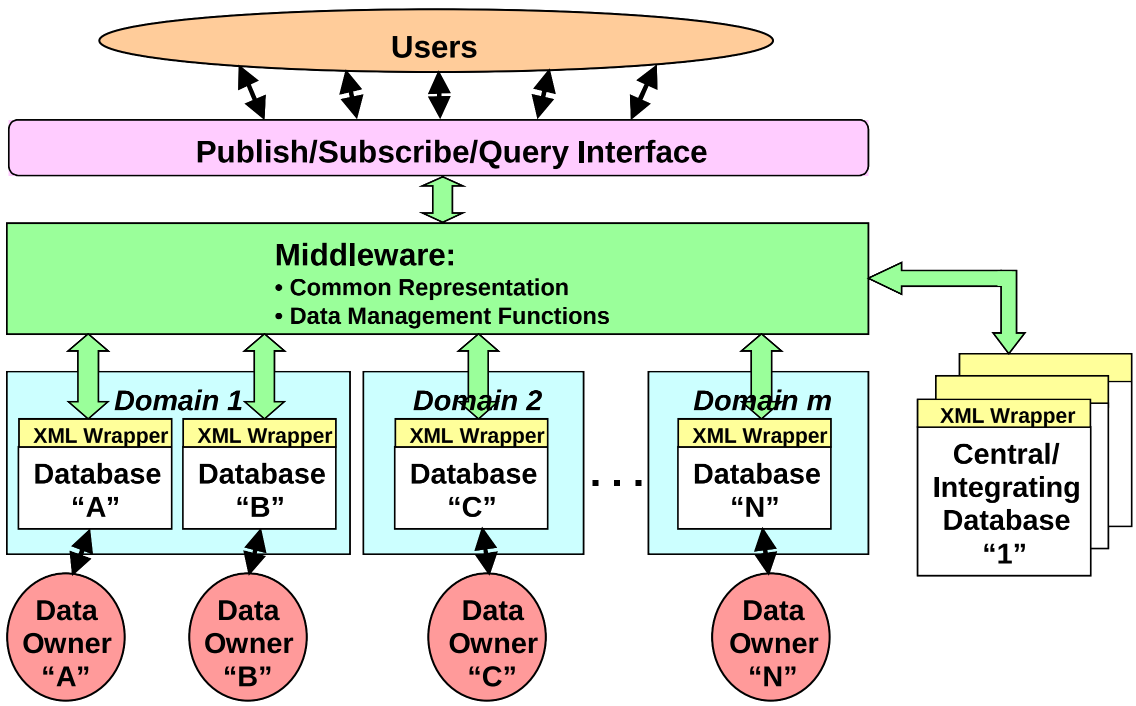

Figure E-2. *Structure and Features of the JBI Shared Information Base*

- **Security.** The JBI interacts with many users and systems, integrates the full panoply of operational and intelligence information, and supports the most critical warfighting decisions. The information model must implement applicable security policies, such as support for virtual private networks, support for multilevel security, and mechanisms for protection against information attacks.
- **Consistency and Replication.** The JBI information base will be geographically distributed and multiply instantiated. It is essential that the information model provide for replication, synchronization, and consistency enforcement across all locations where common data are stored.
- **Quality Assurance.** In the real world, data will be imperfect, whether contaminated by errors, aged beyond allowable latency limits, missing parameters, or otherwise deficient. The

information model must provide for quality checking and allow data to be accessed with appropriate declarations of accuracy, timeliness, trust level of the source, and so forth.

- **Additional Services.** Over and above the five services identified in the manipulation layer of Figure E-1, higher-order services are likely to evolve to make the JBI more efficient and useful. A "discovery" service would take whatever parameters and criteria a user is able to provide about desired information and conduct an intelligent search for content that may be relevant. A "mediation" service would map content from various domains and in various formats to a uniform interface understandable by all users. A variety of "fusion" services can be envisioned, ranging from association and kinematic merging of track updates to combinations of dissimilar or uncorrelated data to produce indications and warnings messages or to discover previously undetected associations.
- **Interfaces.** Last, and most important, the JBI information model(s) must have interfaces that facilitate access to services by each user community. Properly defined and implemented interfaces have far greater impact on the utility of the JBI than the details of information manipulation within the infosphere (as one study participant put it, "Interfaces are more important than algorithms").

E.5 A Physical Implementation of the JBI

The physical structure of the JBI can be represented as an assembly of mission-relevant systems with some enabling information management services all participating in the passing of information among one another. Figure E-3 illustrates a rather primitive example of a JBI. The small dark outlined ovals around the periphery of the communications mechanism called the "global grid" represent the C^2 software. These software-intensive systems might be providing a variety of services for users, and they each have tasks to perform for users who bought or built them. In some cases there is a need for one system to exchange information with another in order to extract information necessary for the functions the first performs. Those message exchanges were traditionally accomplished by exchanging messages between systems over dedicated circuits or via some form of network that could handle the individual point-to-point information transfers.

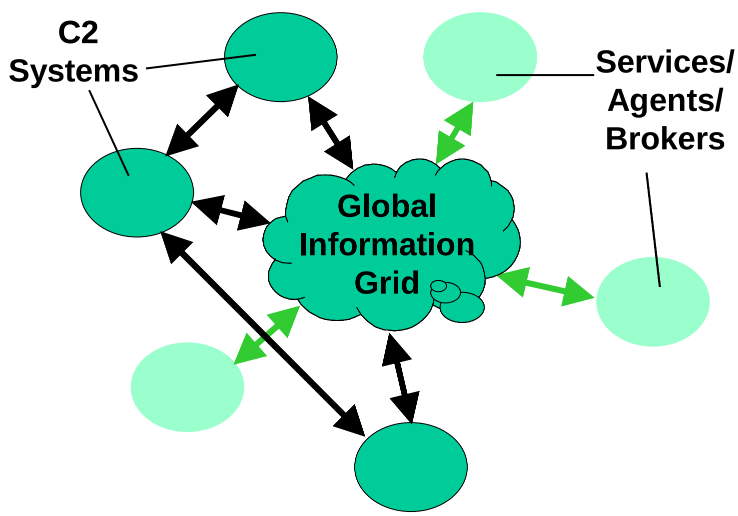

Figure E-3. *Ovals represent legacy or new software/hardware systems which may be connected via the global grid communications*

For the JBI, these information transfers are augmented by having the individual systems expose (publish) their information in a manner that is interpretable by the other JBI participants. If a system conforms to the protocols that enable information to be interpreted in the JBI, then that system is a JBI client.

The light-colored ovals without outlines represent services or "middleware" that enable the JBI to function efficiently and effectively. The individual JBI clients are made aware of one another via one of the JBI enabling facilities that serves as a "broker." An individual JBI client will "publish" information that it anticipates will be useful to other JBI clients. The published information might be raw information, access to an information storage area, or the announcement of a service that the JBI client can offer to other JBI participants. An individual JBI client will also present a "subscription" or "query" for information that it hopes to glean from the JBI. The broker's task is to match the publishments with the subscriptions and to inform both parties of their mutual existence.

Although similar in concept to search engines used on the Internet, the JBI broker is a bit more sophisticated than a traditional search engine because it will make the pairwise associations of publishments and subscriptions with some oversight. The oversight may encompass rules established by the "owner" of the infosphere (for example, a theater commander in chief) for the management of information. These policy rules may prohibit certain publish/subscribe matches and may require others; the rules may also adjudicate preferential connections for yet others. In other words, the broker provides its services according to policy directives and rules that may change from time to time to conform to the commander's intent.

The JBI broker also has some other capabilities. It may prioritize the pairwise matches. These priorities might be established by the commander, but they may also be established with some default conditions. Based on the information content to be exchanged over the JBI, the broker may identify some transactions as higher priority than others, and it may provide that priority hierarchy to the communications systems. In this way, the communications may deliver quality of service that matches the specific information content that is flowing throughout the enterprise.

Lastly, as referred to throughout the logical description of the JBI, other information management services are incorporated in the JBI. These services, also represented by light ovals in the primitive diagram of Figure E-3, may be introduced to the system by merely introducing them into the infosphere as additional JBI clients. Services such as data mediation (implied as a capability to achieve the Structured Common Representation), security policy enabling services, temporary or persistent data storage for mission-relevant capabilities that are "information storage impaired," and portals for preparing special user-relevant information views of the infosphere may all be services that can be added to the JBI as the level of sophistication desired escalates.

An important physical attribute of the JBI is its ability to introduce new capability with minimal impact on existing systems. With current system structure, new capability often requires an invasion by an existing system and disassembly of functions and information such that the new capability can be introduced. With the JBI, as new technology and new communications mechanisms surface, the novel capabilities can subscribe to the legacy information and provide new information objects by merely publishing into the JBI. Acceptance and exploitation of the new information will take place through the natural publish/subscribe mechanisms described earlier. The ability of the JBI to scale is assured by keeping the physical interfaces simple, by decoupling dependencies on critical elements, and by preserving anonymity among participants.

E.6 Summary

We believe that the JBI is the key to achieving the kind of interoperability and robust information support demanded by today's and tomorrow's warfighters. It will be one of the most complex information systems ever built, but it will greatly simplify the development and employment of individual systems and platforms by providing them with an efficient, tailorable interface to the vast information resources of the global and theater C^2 infrastructure. Emerging technologies and system concepts make the JBI much more feasible. We have sketched the essential features of the JBI, stressing the technical attributes that must complement the operational view. The JBI and its information model will grow and evolve indefinitely, but it is essential that an orderly process, supported by adequate resources, be put in place now so that the benefits of this revolutionary view of C^2 can be delivered to operational forces at the earliest possible date.

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BMDO	Ballistic Missile Defense Organization

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AC2ISRC	Aerospace Command, Control, Intelligence, Surveillance, and Reconnaissance Center
ACC	Air Combat Command
– CC	- Commander, Air Combat Command
– 366th Wing	- 366th Wing at Mountain Home Air Force Base
AETC	Air Education and Training Command
– AU	- Air University
AFMC	Air Force Materiel Command
– CC	- Commander, Air Force Materiel Command
– EN	- Directorate of Engineering and Technical Management
– AFRL	- Air Force Research Laboratory
– SMC	- Space and Missile Systems Center
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AFOTEC	Air Force Operational Test and Evaluation Center
AFSAA	Air Force Studies and Analyses Agency
AFSOC	Air Force Special Operations Command
AFSPC	Air Force Space Command
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AMC	Air Mobility Command
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ABSTRACT (Maximum 200 Words)

Air Force Chiefs of Staff have chartered numerous studies and conducted four star reviews in their attempts to “fix” the Air Force C^2 problem. Air Force Chiefs of Staff also established a new Air Staff C^2 Directorate, an Air Staff C^2 General Officer Steering Group, and the Aerospace C^2 Intelligence, Surveillance and Reconnaissance Center in their attempts to “fix” C^2.

The lessons learned from DESERT STORM and ALLIED FORCE and the results of every Air Force SAB and Defense Science Board study have determined that U.S. aerospace power capabilities continue to outperform the associated C^2 capabilities. In theater C^2 this is particularly evident in time critical targeting, battle damage assessment, and campaign assessments.

The Air Force vision of “well-equipped C^2 centers collaborating globally in support of the CINCs” can be rapidly achieved if senior Air Force leadership strongly endorses the need for an enterprise-wide C^2 capability. The Air Force must restructure the way C^2 programs are managed and resourced, and leadership must clearly speak out about their dedication to achieving an enterprise-wide C^2 capability at every opportunity.

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