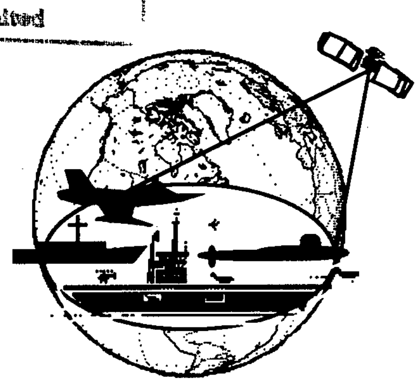
NAVY COOPERATIVE ENGAGEMENT ARCHITECTURE

VOLUME ONE
WORKING GROUP FINAL REPORT

WSA&E

WARFARE SYSTEMS ARCHITECTURE & ENGINEERING

SPAWAR 30



JUNE 1991

SPACE AND NAVAL WARFARE SYSTEMS COMMAND

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1 INTRODUCTION

1.1 GENERAL

In recent years it has become increasingly obvious that no single sensor or weapon, acting alone or even in a coordinated effort with others, will be sufficient to deal effectively with the emerging threat potential of the late Twentieth and early Twenty-first Century. This is true in all Warfare Mission Areas, but particularly when addressing the potential AAW and ASW threats of a major world power. It appears to be equally true for encounters with Third World countries in LIC/CALOW, anti-terrorist and anti-drug operations. During the past ten years a small number of efforts have been initiated to address these issues through a concept loosely termed Cooperative Engagement (CE).

While the genesis of the term Cooperative Engagement is somewhat obscure, it is most likely attributable to the Aegis BGAAWC concept developed in the late 70's. The concept has been expanded upon in the intervening years through various efforts, including that of the A^3ES working group in 1989, continuing initiatives in the BGAAWC program, and the current CE working group.

One might well ask, why cooperative engagement (CE)? The answer to that question is directly related to the estimated threat in the 21st century. The threat in terms of sophistication, diversity, and number of potential adversaries makes it imperative for U.S. Forces to look toward innovative ways to leverage basic capabilities, both now and in the future. The cooperative engagement initiative is an attempt to overcome stand-alone sensor and weapon system limitations, especially when targets employ both flight profile and multi-spectral stealth measures of signature control. Moreover, changing technologies and emerging third-world capabilities present reduced response times, implying the need for a realtime surveillance and response capability available to the force at all times.

1.2 TERMS OF REFERENCE

In November of 1989, the Warfare Systems Architecture Directorate of the Space and Naval Warfare Systems Command was tasked by ASN (R,E, & S) through OP-98 and OP-07 to develop a high level architecture for Cooperative Engagement, to include a detailed functional architecture for AAW. Additional tasking included an identification of technologies, demonstrations, and other initiatives that would be required to meet the Navy's long range goals for CE system engineering, including a review of current and planned cooperative engagement related programs and efforts. This initiative had its genesis in a perceived need for the Navy to develop a conceptual Cooperative Engagement architecture to guide current and future program definition in order to reduce the risk of fielding individual systems which might collectively miss the mark in both function and performance.

To pursue this effort, a multi-laboratory team was established to initially develop a top-down perspective that was unencumbered by programmatics. This initial effort was to include a review of current Navy plans to the 21st century prior to beginning the architectural process. As a part of this top-down look, the focus of the effort was directed toward the development of an overall conceptual CE architecture. Furthermore, we were tasked to take a more detailed look at the AAW problem. The team membership is outlined in section 1.3 below. Following the overall top-down look, a detailed functional AAW architecture would be developed, to include those elements of physical and organizational development necessary to fully flesh out the concept.

Under the guidance of the Director for Warfare Systems Architecture, a Task Force was commissioned. Numerous tasks were identified in the SPAWAR tasking memo, dated 2 Nov 89, including:

- Review future threat and environment.
- Define battle space.
- Review various documents, including top level warfare requirements, master plans, architectures, and other studies.
- Assess adequacy of doctrines, concepts, and tactics.
- Develop a high level concept and understanding of cooperative engagement for all Warfare Mission Areas and Warfare Mission Support Areas, including a force level functional architecture.
- Develop a definitive cooperative engagement functional architecture for Anti-Air Warfare, with excursions into Strike, Anti-Surface Warfare, and Close Air Support.
- Assess the adequacy of the Current Plus (~2003) architecture vis-a-vis the proposed 2020+ architecture for cooperative engagement.
- Recommend research and development and advanced technology transition demonstrators.
- Develop a roadmap for migration to the proposed architecture.

1.3 COMPOSITION OF THE WORKING GROUP

The Task Force was composed of representatives from each of the Navy Laboratories, the Johns Hopkins-Applied Physics Laboratory, the MIT Lincoln Laboratory, and the Space and Naval Warfare Systems Command (SPAWAR).

Laboratory/Organization	Point of Contact	Member(s)
SPAWAR 31A	Director	Capt. David Cowles
SPAWAR 31A1	Chairman	Dr. Robert McWilliams
SPAWAR 312	Capt. Frank Wooldridge	Mr. Todd Repass
SPAWAR 314	Cdr. John Feder	Mr. Steve Brennan
APL	Mr. Sam Brown	Mr. Kent Koehler
DTRC	Mr. C.F Snyder	Mr. Landon Elswick
MIT Lincoln Labs	Lindsey Anderson	Dr. M.J. Vanderhill
NADC	Mr. Tony Mickus	Mr. Carl Van Wyk
NCSC	Mr. John Harris	Mr. Carl Bennett
NOSC	Cdr. Ed Hagee	Mr. Stan Connors
NRL	Dr. Randy Schumacher	Dr. Dave Townsend
NSWC	Mr. Steve Parker	Mr. Mike Buckley
		Mr. John Canning
		Mr. Tim Ryan
NUSC	Mr. Herb Bump	Mr. Mike Pelczarski
NWC	Mr. Larry Lincicum	Mr. David Newport
Consultant		RADM J.R. Batzler, USN (Ret.)

1.4 PURPOSE OF THE STUDY

The purpose of this study is to provide a framework, including a functional architecture, which characterizes and encompasses cooperative engagement capabilities within the context of an increasingly complex and intensive warfighting environment. Within that framework, the capabilities of emerging systems can be evaluated and needed programs identified, should the Navy desire to invest further in Cooperative Engagement.

1.5 SCOPE AND LIMITATIONS

This report will scope and bound the problem through an examination of seven parameters. They are: the time horizon, warfare areas, warfighting media, battle space, size of the fighting force, level of architectural detail, and performance assessment. Each is discussed below.

1.5.1 Time Horizon

The architecture is defined for systems capabilities responsive to the threat spectrum from present to beyond the year 2020.

1.5.2 Warfare Mission Areas (WMAs) and Warfare Mission Support Areas (WMSAs)

The conceptual portion of the study attempted to explore all of the mission and mission support areas. Nonetheless, an emphasis was retained on AAW, with excursions as time permitted into other primary warfare areas. Warfare support areas that received major emphasis were C^3I and EW, particularly as they applied to AAW.

1.5.3 Warfighting Media

There are five warfighting media. They are air, sea surface, undersea, land, and space. Cooperative Engagement potentially can be conducted in any one or combination of these media, and can receive support in the execution of CE from platforms located within any medium. The following priority order for media examination was adopted for purposes of this study:

- Fighting media
  - AIR
  - SEA SURFACE
  - UNDERSEA
  - LAND
  - SPACE
- Supporting media
  - AIR
  - SPACE
  - SEA SURFACE
  - UNDERSEA
  - LAND

Even a limited study of Cooperative Engagement in the air medium would not be adequate unless an examination of support from at least space and surface assets was incorporated. A look at sensor support from undersea assets and correlation/fusion support from land based assets is considered in the conceptual architecture, but no detail of their contributions is pursued in the limited time frame of this study.

While warfighting in the space medium is considered the new frontier, it is hard to foresee how a CE architecture might actually evolve with space-based warfighting systems by the year 2020. Consideration of an architecture for space fighting, particularly in view of the on-going SDI/ADI work, is beyond the scope of this study. However, assets within the space medium for supporting CE initiatives in other warfighting media must be considered as a strength from which to gain support.

Primary emphasis in this study is concentrated in the air arena, with air, sea, surface, and space platforms providing essential support. CE alternatives in offensive and defensive support of surface warfare receives secondary consideration.

1.5.4 Battle Space

Bounding the Battle Space is generally considered in a qualitative way, but with definite quantitative values directly related to the adversary's weapons delivery capability. For purposes of this study:

> Battle Space is defined as that region in which battle action can be expected to be conducted.

A key initiative should be to obtain a capability to engage hostile platforms prior to their reaching a weapons release line. Other appropriate considerations are air superiority, extendable out the threat axis, and air superiority, along own force strike routes. As one example, it may be reasonable to assume that a weapons release range of 1200 miles for air-to-surface launched missiles is probable in the 2020 time frame, if not before. Therefore, a Battle Space for AAW may require an action radius of more than 1200 miles from friendly forces, or at least extendable to that distance along the threat axis, if known.

1.5.5 Size, Capability, and Dimension of the Fighting Force

The size, capability, and dimension of the fighting force required for comprehensively studying CE initiatives must be sufficient to properly consider all aspects of the problem, yet small enough so the effort can be reasonably bounded. The Force to be used in this study will be characterized as a Task Force of sufficient size to demonstrate the conduct of warfare in all the warfare media, and additionally have the wherewithal as well as the appropriate need, from time to time, to call for support from any or all of the spatial media. Under certain excursions, the Task Force may be characterized as a Carrier Battle Group (or Force). For other purposes of the study it could be an ASW Sea Control Force, or an Amphibious Task Force. It may even be as small as a Surface Action Group (SAG), if that is sufficient to fully examine CE principles and initiatives across the required warfare area/warfare support area spectrum. The key issue here is that it should be a tactical fighting entity that can benefit directly, in real time, from the advantages of cooperative engagement in prosecution of hostile detection, tracking, targeting, fire control, and weapons guidance. The task force concept should be adequate to characterize the added value of CE concepts across a minimum of four Warfare Mission Areas (AAW, ASUW, Strike, and ASW) and two Warfare Mission Support Areas (C3I and EW), utilizing all five media for support as necessary.

1.5.6 Level of Architectural Detail

Within WSA&E there are three aspects of an architecture to be described: functional, physical, and organizational. For purposes of this study the emphasis will be as follows:

- Functional component - describes the actions or functions which must be accomplished by the Force. Functional decomposition will be undertaken only to the extent necessary to provide specificity relating to CE, but will include all pertinent decision support and decision functions.

- Physical component - describes the tangible aspects of the Force, i.e. the "hardware." Descriptions will be limited to the platform or unit level, such as type of ship, aircraft, or space-based surveillance platform. Potential "systems" implied by functions needed for CE will be identified.

- Organizational component - describes the Command structure of the Force. While the functional description will include all associated decision support and decision functions without allocation to either man or machine, the implications of CE for organization will be considered.

The conceptual architecture will address the functional aspects of the architecture. The more detailed AAW architecture will include both physical and organizational components.

1.6 ASSUMPTIONS & CAVEATS

With regard to the conceptual architecture, a number of initial conditions, assumptions, and caveats must be specified. First, the architecture reflects a 2020+ time frame. This date was chosen to assure that all current systems will have been replaced and superseded by then. In other words, work done to date is not intended to be a baseline for future efforts. Second, an attempt was made to take a fresh look at the problem, from a warfighting perspective rather than from an engineering perspective. Third, the architecture was developed tabula rasa, i.e. from a blank piece of paper. Fourth, an attempt was made to identify all functions, prior to allocation of function to man or machine. Lastly, at the physical level, specification was limited to the type of platform or unit, although consideration was given to the attributes and characteristics of the various system applications implied.

For the AAW architecture, the SPAWAR Current Plus architecture, with Options 0, 1, and 2, was used as a baseline for development of the CE Option. However, a mapping between the functions of the conceptual architecture, the functional flow, and the AAW architecture was undertaken and the functions reconciled. At this time no one set of functions is accepted as a standard among the various WMAs and WMSAs, precluding direct functional correspondence.

1.7 ORGANIZATION OF THE REPORT

The remainder of the report describes the architectures developed and a preliminary description of the possible benefits derivable from Cooperative Engagement. Chapter 2 focuses on Approach and Methodology. including requirements and drivers, an outline of the methodology, an overview of CE requirements, a functional analysis description, and some examples for application of Cooperative Engagement. Chapter 3 presents a high level CE Conceptual Architecture. Chapter 4 presents the CE Detailed AAW Architecture, otherwise known as the CE option. Chapter 5 discusses Analysis and Evaluation describing insights gained, perceived benefits of Cooperative Engagement, and an Assessment Methodology developed within the working group as well as an Evaluation Matrix for assessment of the status of various on-going programs. Lastly, in Chapter 6, Conclusions and Recommendations and presented.

In addition, supportive material is provided in Appendices as shown here.

- Appendix A: Abbreviations and Acronyms
- Appendix B: A definitive Task Force Level Navy Cooperative Engagement Functional Architecture by Carl M. Bennett, Naval Coastal Systems Center
- Appendix C: CE Conceptual Architecture Implementation by Carl VanWyk, Naval Air Development Center and David Newport, Naval Weapons Center
- Appendix D: Assessment Methodology by Landon Elswick, David Taylor Research Center
- Appendix E: Cooperative Engagement Demonstrations by Dr. David Townsend, Naval Research Laboratory
- Appendix F: Cooperative Engagement Threat Examples
- Appendix G: Cooperative Engagement Cases

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2 APPROACH AND METHODOLOGY

2.1 OVERVIEW

Chapter 2 focuses on the Approach and Methodology. It includes a summary of the requirements and drivers that emerge from The Environment of 2020, an outline of the Methodology for Development of the Architectures, an Overview of the Requirements for Cooperative Engagement, a description of the Functional Analysis, and presentation of some Examples for application of Cooperative Engagement.

2.2 METHODOLOGY FOR DEVELOPMENT OF THE ARCHITECTURES

The architectural development process can be described in five distinct phases, which in actuality are frequently iterative in nature and often occur in parallel, especially while considering different levels of abstraction within the problem domain. These phases are:

- Problem definition
- Value specification
- Synthesis
- Analysis
- Documentation

2.2.1 Problem Definition

The problem definition phase included the isolation, quantification and clarification of the need. It involved the development of a description of environmental factors which define the system and its environment. Specific tasks included describing the geopolitical outlook, the threat outlook, the roles and missions outlook, the technology outlook, and the budget outlook.

2.2.2 Value Specification

Value specification involved selection of the set of objectives and goals which guides the search for alternatives, implies the types of analyses required of alternatives, and provides the multi-dimensional criterion for selecting the most appropriate (or optimum) system. Specific tasks included identification of evaluative criteria in general and various warfighting and system performance criterion specifically.

2.2.3 Synthesis

The synthesis phase included collecting, searching for or inventing a set of ideas, alternatives or options. Each alternative had to be worked through in enough detail to permit its subsequent evaluation with respect to the objectives, and to permit an application of the multi-dimensional decision criterion to decide its relative merits for proceeding into the next phase. The specific tasks included here were development of multiple scenario based functional flows, identification of functions and their relationships, and specification as a functional design.

2.2.4 Analysis

Analysis included deducing those sets of consequences which are specified as relevant by the values determined earlier in the process. These deductions may relate to quality, reliability, cost, effectiveness or capability. Specifically, this phase included analysis of candidate functional descriptions in terms of established criteria and selection of the best alternative functional architecture.

2.2.5 Documentation

Documentation necessarily involved synthesis of the research, organization of the materials in a manner appropriate to the expected audience, and preparation of a report for publication.

2.3 THE ENVIRONMENT FOR 2020

2.3.1 Composite View

Numerous studies have been undertaken in the last year or two to establish the outlook for the next 30 years, to envision key changes, and to speculate on resultant impacts. Major studies reviewed included: Battle Management Architecture (BMA), Carrier Air Wing Study (CAWS), Navy 21, Quo Vadis II, Revolution at Sea 2020, and the Sea Control 2020 Vision.

2.3.2 Operational Outlook

A number of key changes are envisioned by the year 2020 which will affect our military capability to counter the threat. Some that are pertinent to CE include:

- CALOW/LIC
  - Low intensity warfare, but with sophisticated weapons
  - "Police" actions, where extremely minimal losses will be dictated
  - Drug interdiction initiatives, both intensive and pervasive
- Long Range Cruise Missiles/Tactical Ballistic Missiles
  - Expanded range
  - Third world access to weapons

- Low Observable
  - Quieter submarines
  - Reduced signature aircraft
  - Reduced signature ships
- Limited or negative financial growth prospects
  - Peacetime
- Reduced numbers, but more capable Soviet units
  - Improved combat performance
- Soviet Naval Air at sea
  - Integrated air defense
  - Limited sea control initiatives
- Space Assets
  - Improved surveillance capabilities
  - Combat capabilities
- Surface ships detection by Wide Area Surveillance systems
  - Increased vulnerability
- Third World proliferation of high tech weaponry
  - Nuclear, biological, chemical weapons, as well as missiles

The resultant impacts of these changes can be projected, and drivers identified as critical to the Cooperative Engagement architecture. In particular within the AAW arena, properly developed cooperative engagement initiatives can significantly improve our ability to deal with the following areas:

- Discrimination of threat platforms from neutral, particularly during LIC/CALOW.
- Emerging SSGN threat.
- High speed, high altitude anti-ship missiles (ASM)

- High speed (supersonic), low altitude sea skimmer ASM

- High velocity weapons and platforms from upper atmosphere or space, such as TAV, FOB or SRBM/IRBM.

- Low observable fighters and jammers.

- Low speed, low altitude sea skimmer ASM with low RCS

- Low speed, low observable bombers with transition (dash) at high speed.

  - Major offensive strike or raid with high threat density.

- Mixed platform/weapon attack, both regular and stealth.

- SAG on SAG, including range issues and the OTH-T problem.

- Very challenging self-screening jammers for the future.

- Surprise attack during peacetime.

2.3.3 Technological Outlook

Continued developments in a number of technology areas can have a significant impact on our capability to fully exploit the potential of cooperative engagement. Some of these are:

- Advanced Materials

- Automation

- Communications

- Directed Energy

- Information Science

- Kinetic Energy

- Signature Reduction

- Space Technology

2.4 REQUIREMENTS FOR CE

Cooperative Engagement is defined as a warfighting capability designed to defeat threats through the synergistic integration of distributed resources among two or more units. In its implementation as a complete capability, Cooperative Engagement would develop a tactical picture from a wide variety of sensors, with a fire control precision capable of putting a weapon on target. Implied in such a Cooperative Engagement system is sufficient control to task sensors, manage the distributed functionality of the network and its processors, and task weapons.

By implication, each unit within the battle force would be connected to other units within the battle force by means of a covert, jam-proof, high capacity network. In broad terms, a fully developed force-wide battle infrastructure is envisioned, capable of enabling the battle force to be fought under a variety of circumstances with a range of control effected centrally, on the one hand, to autonomous, on the other. Such an infrastructure can be described as an integrated Sensor-C3I-Weapon set of systems, operational at all times.

2.5 FUNCTIONAL ANALYSIS

The development of a function set for Cooperative Engagement was undertaken in a number of ways. First, a priori, candidate sets of functions were available from the various WMAs and WMSAs. Several other previous and ongoing efforts were also investigated as a basis for functional descriptions and allocation. Work is currently in progress to develop a master function set.[1] Secondly, various lists of functions were available, such as the Required Operational Functions or ROFs, which delineate warfighting or operational functions.[2] Thirdly, the Extended Command Process Model provides a framework for the explication of functions from a command and control perspective.[3]

Given the concern that Cooperative Engagement might involve either new functions or different use of existing functions, functional flows were developed for a wide range of problems or scenarios. Required functions were noted as were their relationships. The results of this effort is contained in Chapter 3.

2.6 REPRESENTATIVE EXAMPLES

Figures 2-1 through 2-5 on the following pages portray, in a scenario fashion, those emerging threat examples which have been identified as representative of the most stressing cases. In the aggregate they encompass the perceived limiting cases of threat density, low signature, classification complexity,

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[1] A Phase II SBIR is currently funded by SPAWAR to integrate the various function sets within each Warfare Mission Area or Warfare Mission Support Area and develop a master Force-wide function list. This work is being done by SRS Technologies of Arlington, VA and is scheduled for completion in 1991.

[2] The ROFs are extracted from the Top Level Warfighting Requirements (TLWRs) found in the various Master Plans. The ROFs have been quite controversial during the past few years.

[3] The Extended Command Process Model was developed by Dr. Paul Girard at SAIC under contract to the Naval Ocean Systems Center and reported out on in 1989.

electronic deception/jamming, and high performance at the extremes of the operating envelope. In each case the threat example is characterized.

2.6.1 Example I - Low, RO Cruise Missile

This threat is characterized by long range, subsonic, low flying (sea skimmer) attack profiles with a reduced-observable (RO) signature in both the radar and IR spectrum. This threat may have an autonomous guidance system, with a multi-spectral terminal guidance sensor suite comprising both active radar and IR seekers. Some versions may be anti-radiation (ARM)capable and/or incorporate a Home-On-Jam (HOJ) feature. A target discrimination capability may be resident as well. Figure 2-1 is a graphic characterization of this threat example.

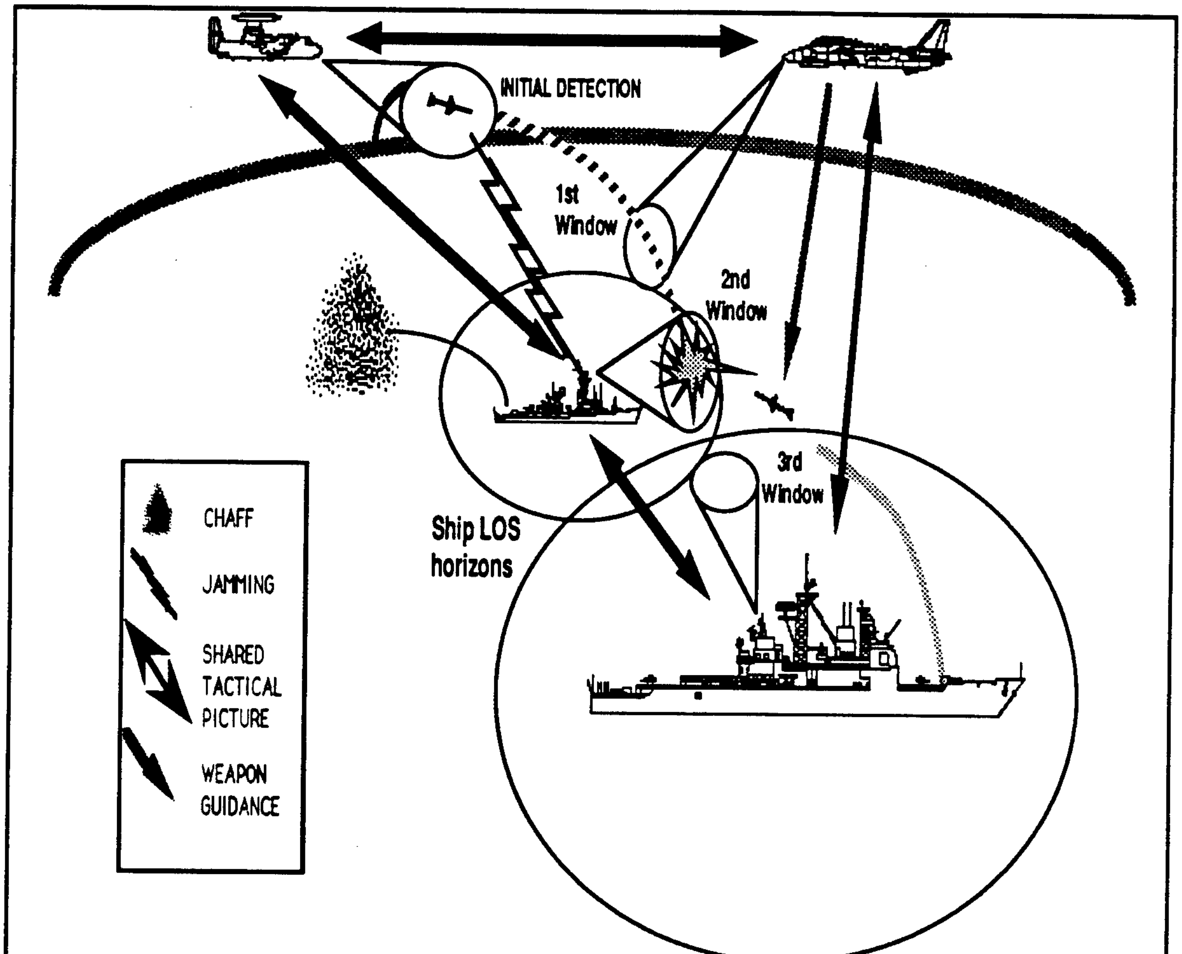

Figure 2-1. Low, RO Cruise Missile

2.6.2 Example 2: Outer Air Battle

This threat is characterized by saturation raids employing multiple launch platforms and weapons. Bombers and fighter escort, both subsonic and supersonic could be employed. Escort EW assets could provide active jamming of surveillance and communication links. Both high and low attack profiles could be present. Stream raids, diversion feints, individual penetrators in multi-axis coordinated attacks could be present with a mix of conventional and RO platforms and weapons. Figure 2-2 is a graphic characterization of this threat.

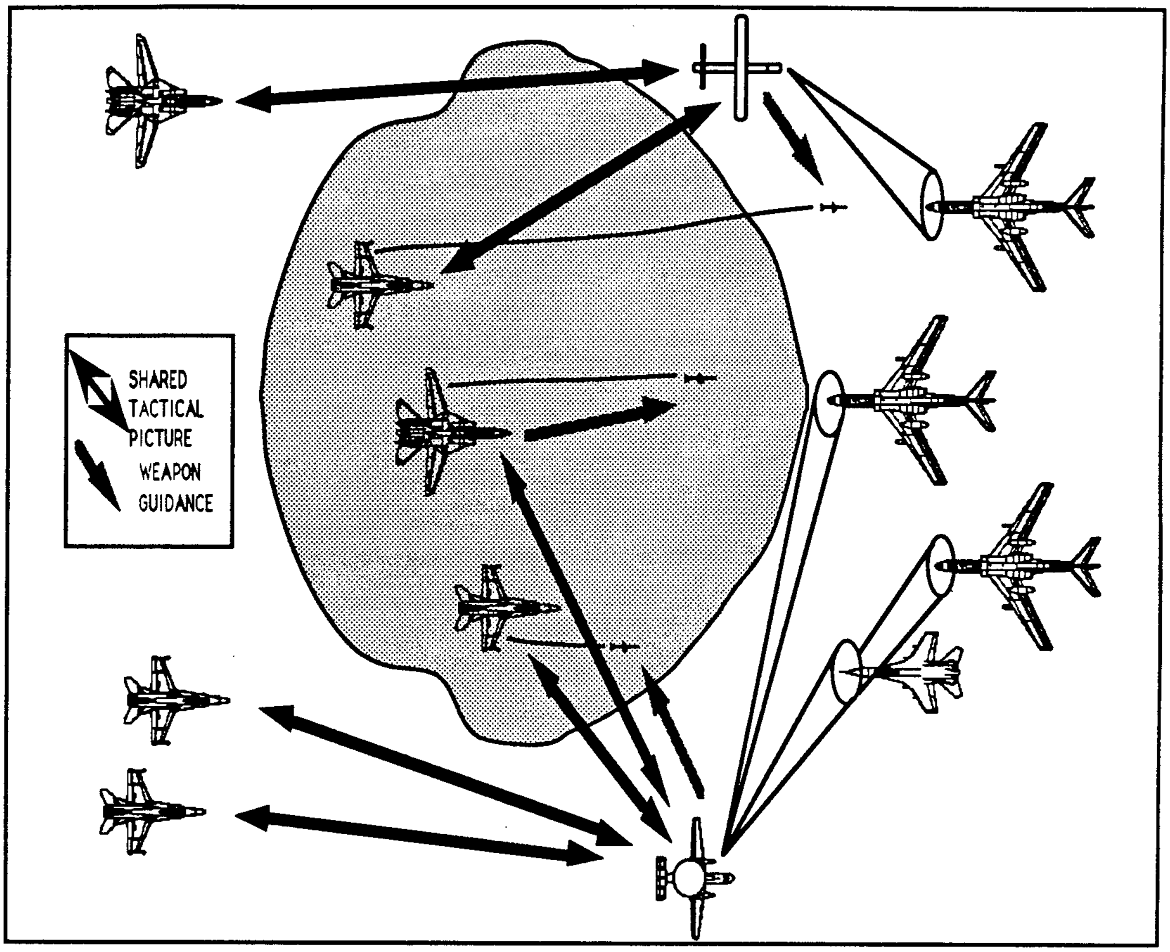

Figure 2-2. Outer Air Battle

2.6.3 Example 3: Fast,High Flyer

This threat is characterized by high altitude, steep dive angle attack profiles against battle force surface units. Delivery could occur from multiple launch platforms including both bombers and fighters in multi-axis coordinated attacks. Ballistic threats may also be employed and could be launched from land sites. Multiple EW resources employing active jamming could be present from escort aircraft. A mix of conventional and RO platforms and weapons could occur. A significant infrared signature could be present. Terminal homing may incorporate multi-spectral guidance modes. Some versions may be ARM capable and/or possess a Home-On-Jam (HOJ) feature. The high attack angles combined with high speed terminal approaches present an extremely time sensitive threat response scenario. Figure 2-3 is a graphic characterization of this threat.

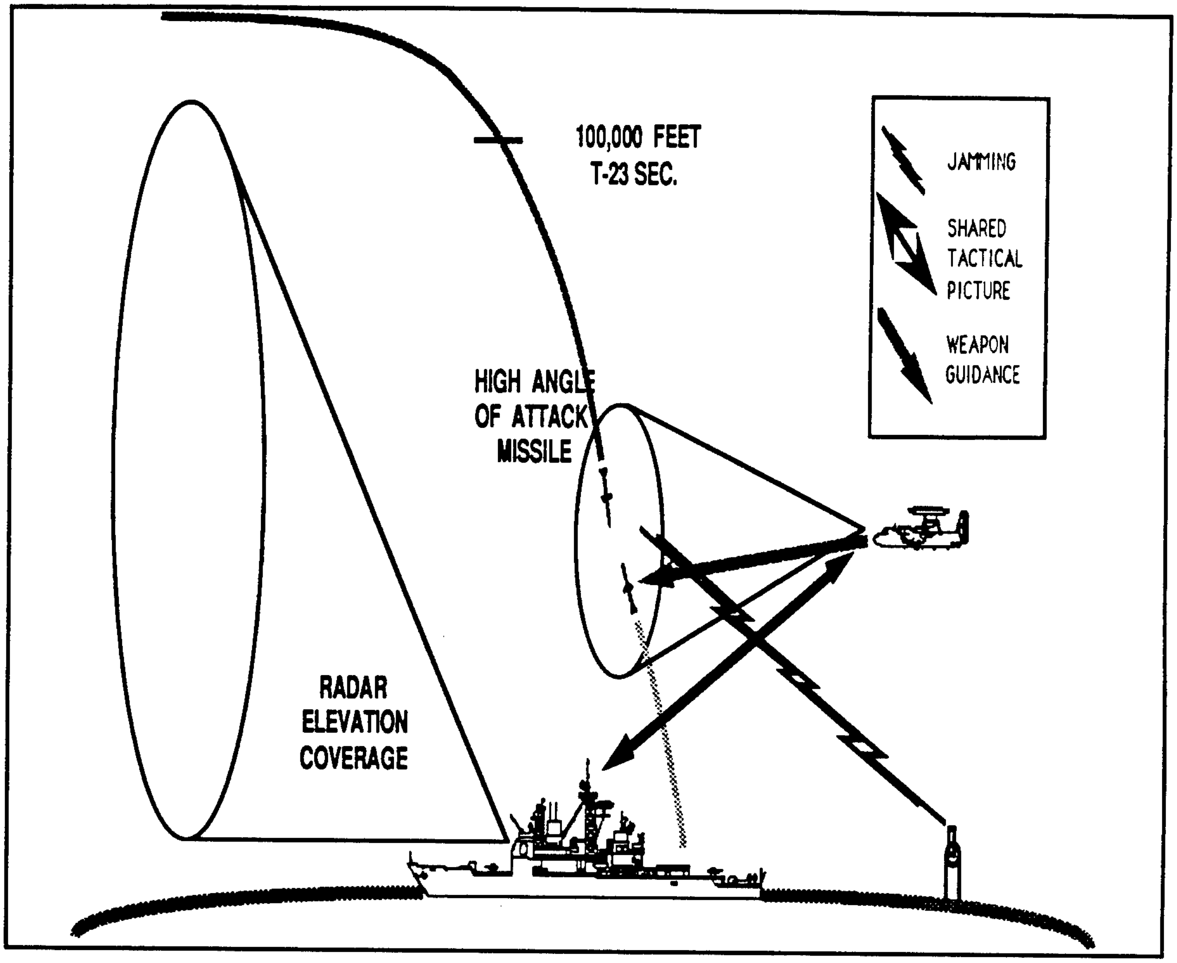

Figure 2-3. Fast High Flyer

2.6.4 Example 4: Fast Sea Skimmer

This threat is characterized by supersonic low altitude attack profiles. Delivery could occur from multiple launch platforms.including bombers, fighters, surface ships and submarines in multi-axis coordinated attacks. Multiple EW resources providing active jamming of communication and sensor links could be present from escort aircraft and surface vessels. A mix of conventional and RO air launch platforms and weapons could be present. A significant infrared signature could be expected. Terminal homing may utilize multi-spectral guidance modes and evasive "dog-leg" maneuvers. Some versions may be anti-radiation (ARM) capable and/or incorporate a Home-On-Jam (HOJ) feature. A target discrimination capability may be resident as well. The low altitude, high speed terminal runs present an extremely time sensitive threat response scenario to the battle force surface units. Figure 2-4 is a graphic characterization of this threat.

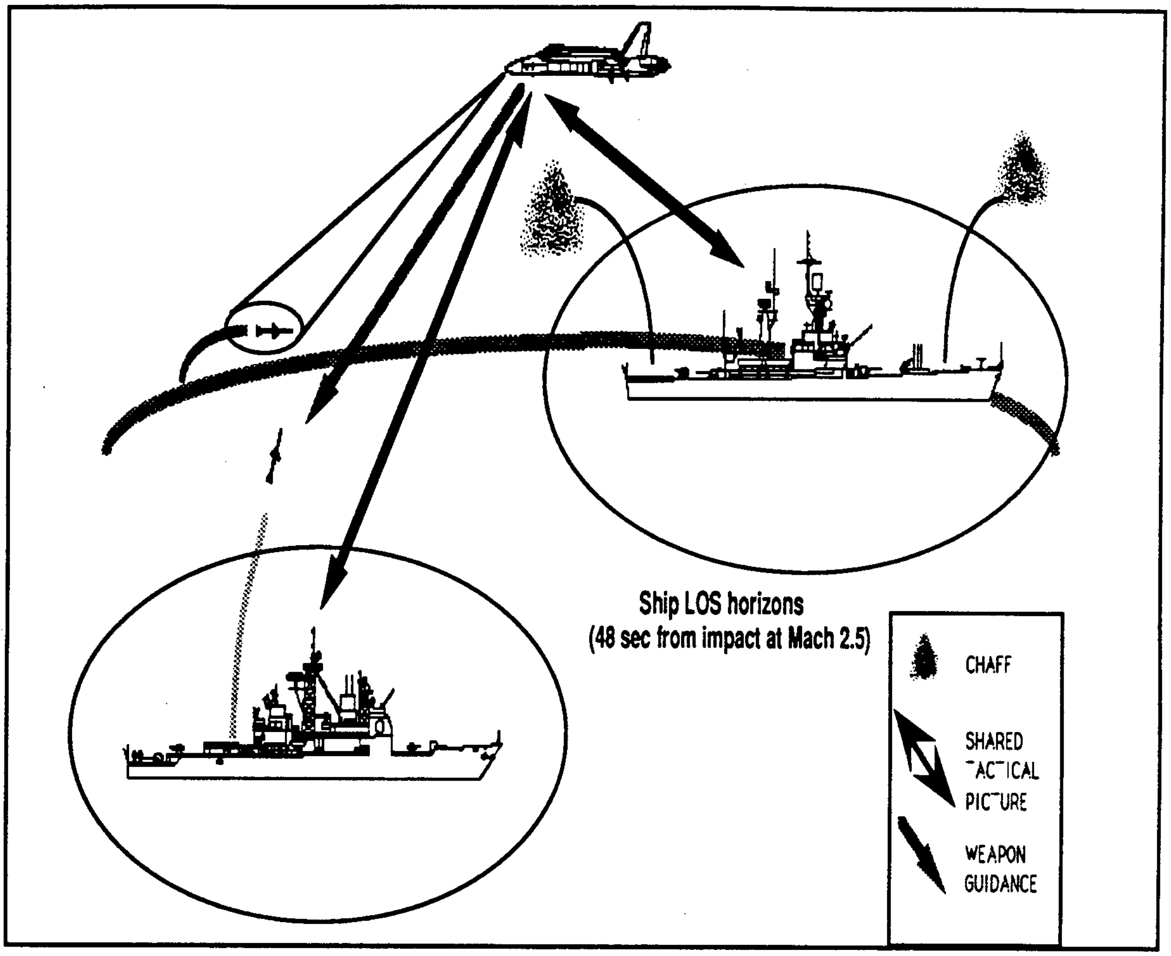

Figure 2-4. Fast Sea Skimmer

2.6.5 Example 5: Drug Interdiction

This threat is characterized by ships and airplanes attempting to deliver drugs to the United States. While unconventional in nature, the problem is not unlike the first four, with a major emphasis on synergistic sensing with engagement up to and including location and intercept. The diverse nature of the contacts and their large numbers present significant problems for tracking and identification.The low Radar Cross Section (RCS) of some aircraft, coupled with low altitude ingress, present additional problems. Differentiation of "threat" aircraft from general and commercial aviation aircraft presents an extremely stressing case.Moreover, great differences exist between equipments currently in use by the various agencies, such as FAA, DEA, Customs, Coast Guard, Air Force, Navy, and National Technical Means. Figure 2-5 is a graphic characterization of this threat.

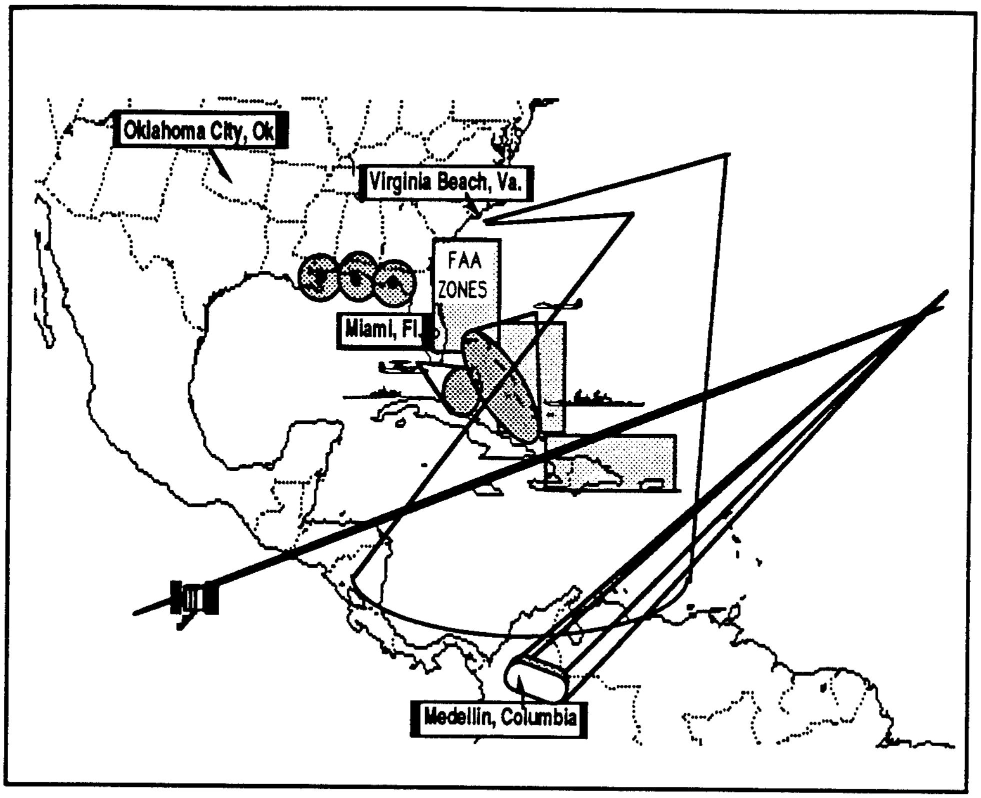

Figure 2-5. Drug Interdiction

3 CE CONCEPTUAL ARCHITECTURE

3.1 OVERVIEW

Chapter 3 presents the high level CE Conceptual Architecture, including a definition, a vision statement, a set of goals and objectives, key concepts, some attributes and characteristics, and emerging issues, in addition to the Functional Architecture.

3.2 DEFINITION

The term "cooperative engagement" does not have a clearly understood, precise, or agreed upon definition. Cooperative Engagement is defined here as:

> A warfighting capability designed to more adequately meet and defeat the threat, through the synergistic integration of distributed resources among two or more units.

The purpose of Cooperative Engagement is to:

> Fight the Force as an entity, just as we now fight individual platforms.

As a concept, Cooperative Engagement seeks to enable real time response capability from the total Force entity, improve the efficiency of operations, and provide resiliency through graceful degradation of capabilities due to attrition. In essence, Cooperative Engagement seeks to enable the Force Commander to better fight his force as a whole.

3.3 VISION

Cooperative Engagement is defined as a warfighting capability designed to defeat threats through the synergistic integration of distributed resources among two or more units. In its implementation as a complete capability, Cooperative Engagement would develop a tactical picture from a wide variety of sensors with sufficient fire control precision to put the weapon on the target. Implied in such a system is sufficient control of the Cooperative Engagement system to task sensors, manage the distributed functionality of the network and its processors, and task weapons.

By implication, each unit within the battle force would be connected to other units within the battle force by means of a covert, jam-proof, high capacity network. In broad terms, a fully developed force-wide battle infrastructure is envisioned, capable of enabling the battle force to be fought under a variety of circumstances with a range of control being effected centrally, on the one hand, to autonomous, on the other. Such an infrastructure can be described as being an integrated Sensor-C3I-Weapon set of systems, operational at all times.

3.4 GOALS AND OBJECTIVES

3.4.1 Goals

The environment described earlier suggested a number of goals for Cooperative Engagement:

- Facilitate passive (covert) sensing
- Control battle force signature
- Identify and classify targets
- Provide force wide Threat Evaluation and Weapon Assignment (TEWA)
- Engage stressing threats
  - long range
  - low altitude
  - high speed
  - low signature
  - high density
  - large numbers
- Increase firepower on target
- Improve platform survivability
- Eliminate blue on blue
- Eliminate redundant engagements

3.4.2 Objectives

3.4.2.1 General. Based upon the projected threat and the above stated goals, a number of objectives may be derived for Cooperative Engagement. The first of these is an increased efficiency in weapon allocation and utilization. The second is leverage of spatial geometric advantages in the Battle Space by providing targeting data to non-emitters, improving sensor detection capability by varying look angles, and enhancing ECCM/ECM/LPD/LPI opportunities. The third objective is to improve survivability and sustainability by architecting a decentralized system. A fourth objective is to enhance Battle Space quality through increased clarity of tactical picture, increased detectability and reliability through multi-sensor opportunities, and expansion (selectively, both omnidirectionally and directionally) of the Battle Space. Lastly, exploitation of Hardkill and Softkill alternatives is a major objective.

3.4.2.2 Specific Capabilities

3.4.2.2.1 Sensor Capabilities. At least four specific sensor capabilities are needed. The first of these is the ability to exploit spatial and spectral sensor synergism (S4) to improve reaction time and to provide for multiple targeting and guidance opportunities. Secondly is to provide for improved detection, tracking, raid count, classification, and cuing functions for Wide-area surveillance systems. Third is to provide for improved detection, tracking, raid count, classification, cuing, targeting and damage assessment functions for Battle Space surveillance systems. Fourth is to provide for seamless integration of the Wide-area and Battle space total sensing functions.

3.4.2.2.2 C^3 Capabilities. Five C^3 capabilities are needed. The first is to handle increased data requirements and throughput which are essential for the sensing and targeting attributes of a CE system. Second is increased netting capability. The third capability is for a distributed, hierarchical, and flexible command structure. Fourth is for an automated and transparent reconfiguration capability. Lastly, is the capability to gracefully degrade from CE to the full functionality of the autonomous platform or unit

3.4.2.2.3 Engagement Capabilities. In order to maximize engagement capabilities, the following specific capabilities are desired. First is for fully leveraged soft kill options through jamming, deception, decoy and evasion. Second is the ability to exploit both offensive and defensive opportunities through engagement of threat beyond their weapons release line. Third is the ability to enhance effectiveness through concentration of firepower. Lastly is the ability to optimize hardkill and softkill tradeoffs.

3.5 KEY CONCEPTS

A number of key concepts have emerged during the development of the high level Cooperative Engagement architecture. These eight concepts are essential parts of a full implementation of CE. First, fight the Force as a "whole." Fight the Force with the same integrity as we now fight each individual unit. Second, implement the full range of functionality available on one platform across multiple platforms, such that sensing might be performed by one set of units, engagement by another set of units, and other associated functions and processes distributed across another set of units. Third, provide Force level management, including signature control, emission control, sensor tasking, engagement resource tasking, authority to remote task, and weapons distribution among units. Fourth, maximize Force efficiency through the optimal pairing of platform, weapon and target, elimination of unintentional redundant engagements, and reduction in blue on blue kills. Fifth, maximize Force effectiveness through improved multi-dimensional and multi-source sensing, in - flight retargeting, optimal pairing of platform, weapon and target, and sensor feedback from the weapon. Sixth, decentralize all processes such that the loss of any unit does not negate the ability of the Force to prosecute its mission (i.e.-

no single point of failure). Seventh, achieve performance through distributed sensors and weapons. And lastly, provide end-to-end data communications from sensor to weapon.

More specific concepts for detection include the fusion of data from multiple sources on a single platform, single sources on multiple platforms, and multiple sources on multiple platforms. Another concept is the management of sensors with a capability to ascertain when additional data is needed and task various sensors or sensor platform combinations to provide additional data.

Command and control concepts include five items. First, provide a coherent tactical picture that is based upon both track and fire control inputs for the entire battle space for all WMAs, established in real-time with zero or near zero latency. Second, transform data to information to knowledge. Provide selective levels of abstraction of information to the Force Commander. Third, generate alternative courses of action and make recommendations through the extensive use of decision support systems. Fourth, automatically decide upon a course of action where response time is minimal or when dealing with massive threats, consistent with the ROEs, doctrines, and directives from the Force Commander. Fifth, automate all decision processes with extensive control by the Force Commander to allow for a wide range of selective implementation, including command by negation, contingency profiles, and parameterized operation. Enable the Force Commander to effect a range of command and control options from autonomous unit operation to multi-unit cooperation.

Specific concepts for engagement include three areas. First, optimize fire control solutions for multiple platforms and weapons within the Force against multiple threats, including allocation, scheduling, and routing (e.g. - forward pass). Second, merge individual fire control systems into the elements of a Force fire control system. Third, determine Force fire control solutions through sensor coordination and data fusion to enable firing assignments on a Force priority basis.

3.6 ATTRIBUTES AND CHARACTERISTICS

3.6.1 General

Given the objectives of improving Force surveillance capability, increasing our capability to engage targets, and providing more reliable and timely exchange of surveillance information and battle management directives/coordination, the following capabilities and their associated attributes and characteristics are needed for Cooperative Engagement.

3.6.1.1 Surveillance. Desired surveillance capabilities include both detection and processing. Specific attributes and characteristics are as follows. Develop and maintain continuous track on intermittent targets by combining data from various types of sensors, combining data from multiple distributed sensor platforms, and combining fleeting detections obtained by various sensors and platforms. Assemble an accurate tactical picture in spite of enemy countermeasures employment also by combining data from various types of sensors, combining data from multiple distributed sensor platforms, and combining fleeting detections obtained by various sensors and platforms.

3.6.1.2 Kill. Desired kill capabilities include the following attributes and characteristics. Engage targets that are not being tracked by the interceptor launching the missiles so that the DLI carrying AAAM type missiles can launch missiles before entering the OAB zone. Also, enable VAW tracking of a low observable target that is still beyond VF detection range. Maintain high effectiveness in a countermeasures environment with reduced vulnerability to AI radar countermeasures due to the availability of remote tracking data. Also facilitate the use of remote data to allow the VF to achieve tactical surprise, reducing the likelihood of effective countermeasures (including enemy launch of arms).

3.6.1.3 Coordination. Desired coordination capabilities suggest the following attributes and characteristics. Allow interceptors to perform target sorting and attack coordination. Prevent blue on blue engagements. Allow aircraft to execute cooperative countermeasures. Improve situational awareness of strike group aircrews by distributing data on potential threats detected by other strike aircraft, VF escorts, or support VAW, VAQ, VQ platforms.

3.7 FUNCTIONAL ARCHITECTURE

3.7.1 Overview

The Force Cooperative Engagement Architecture is a conceptual architecture, that is to say, a design idea or framework stated in future functional terms. It must be emphasized that it is not intended to make the case for Cooperative Engagement. Rather, the emphasis has been on creating a framework, or architecture, within which one can understand the elements that comprise CE and their relationships.

3.7.2 Essential Functions

Initial research suggested a number of functions for consideration as part of cooperative engagement. These included:

- Battle management
- Allocation and scheduling of resources
- Sensing
- Shooting
- Information transfer
- Fusion/correlation
- Tactical picture

- Fire control solutions
- Navigation
- Status collection
- Track generation and updating
- Weapon control
- Communications
- Identification and classification

It quickly became apparent that most, if not all, CE functions were already performed within the Force. What was different was either the level of abstraction reflected in a change in importance within a functional decomposition or, more frequently, the focus of implementation. As a result, the following is a list of the more critical Force functions that are part of Cooperative Engagement, that is to say, functions implemented among multiple platforms and weapons in some very likely automated fashion.

- Control sensors
- Control emissions
- Develop and maintain a consistent tactical picture
- Fuse multi-source, multi-sensor data
- Assess sufficiency and precision of data
- Calculate required sensing geometries
- Task sensors and their platforms for additional data
- Maintain accurate positional information
- Calculate possible engagement opportunities
- Optimize hardkill/softkill solutions for multiple weapons and platforms against multiple threats
- Coordinate hardkill/softkill engagement
- Guide and control weapons
- Provide data communications

3.7.3 Topology

While it would be natural to assume that engagement is the focus of Cooperative Engagement, the central core is in fact command and control oriented. As a result it was appropriate to look to the Extended Command Process Model to provide a structure or topology for the explication of the functions.

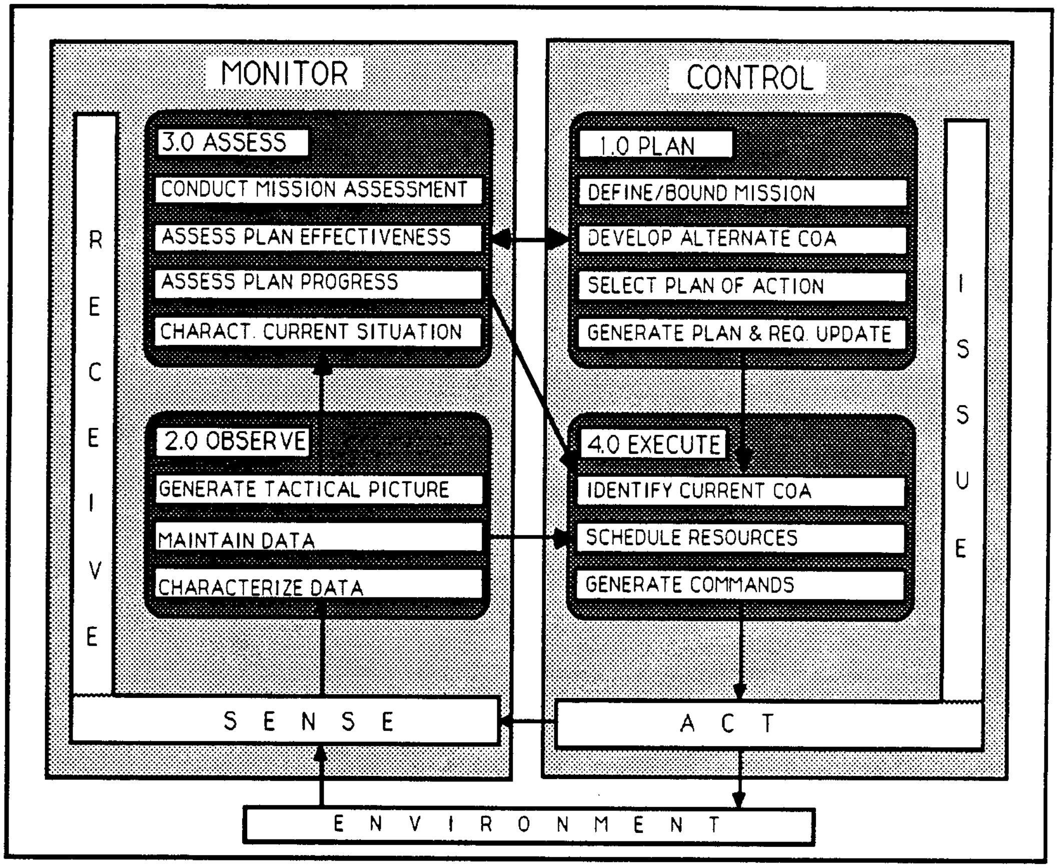

Figure 3-1. Extended Command Process Model

The categories of Sense, Plan, Observe, Assess, Execute, and Act were adopted to provide a framework for the cooperative engagement functions.

3.7.4 Master Function List

As a result of the functional flow analysis, using the Extended Command Process Model as a framework, a preliminary function list for Cooperative Engagement was prepared. Drawing from prior work in other areas, including the various WMA and WMSA function lists and the Required Operational Functions (ROFs) set forth in the Top Level Warfare Requirements (TLWRs), a master function list was prepared.

The following Master Function List has been annotated to indicate those functions considered as part of Cooperative Engagement.

Table 3-1. Master Function List

Ref.No	Functional title	CE
1	**SENSE**	
1.1	**Sense environment**	
1.1.1	Objects	
1.1.2	Weather	
1.1.3	Oceanographic	
1.1.4	Geographic	
1.1.5	EO	
1.1.6	IR	
1.1.7	Electromagnetic	
1.1.8	Acoustic	
1.2	**Process signals**	
1.2.1	Filter	
1.2.2	Enhance signal	
1.3	**Radiate environment**	
1.3.1	EO	
1.3.2	IR	
1.3.3	Electromagnetic	
1.3.4	Acoustic	
1.4	**Control sensors**	CE
1.5	**Control emissions**	CE
1.5.1	EO	CE
1.5.2	IR	CE
1.5.3	Electromagnetic	CE

Table 3-1. Master Function List (Continued)

Ref.No	Functional title	CE
1.5.4	Acoustic	CE
2	**PROCESS (OBSERVE)**	
2.1	**Develop and maintain common, virtual tactical picture (database)**	CE
2.1.1	Store contact reports	CE
2.1.2	Store track files	CE
2.1.3	Store related data	CE
2.1.4	Manage tracks	CE
2.2	**Fusion**	
2.2.1	Single source, single platform integration	
2.2.2	Single source, multiplatform integration	CE
2.2.3	Multi source, single platform integration	
2.2.4	Multi source, multi platform integration	CE
2.2.5	Organic to non-organic correlation	
2.3	**Characterize track information**	
2.3.1	Classify	
2.3.1.1	Friend, foe or neutral	
2.3.1.2	Type of platform/weapon - ship, aircraft, missile	
2.3.2	Identify	
2.3.2.1	Class of platform	
2.3.2.2	Specific identity of platform	
2.3.3	Associate	
2.3.3.1	Associate track with tactical database information	
2.3.3.2	Associate track with other TACPIC information	
2.3.4	Establish threat level	
2.3.4.1	Determine capability of threat	
2.3.4.2	Determine ability to engage	

Table 3-1. Master Function List (Continued)

Ref.No	Functional title	C E
2.3.4.3	Infer intent	
2.3.5	Establish threat status	
2.3.5.1	Determine readiness condition	
2.3.5.2	Determine weapon systems status (engagement posture)	
2.3.6	Establish raid count	
2.3.7	Assess completeness and quality of information	
2.4	**Assess sufficiency for detection (track quality)**	C E
2.4.1	Assess quality of information	
2.4.2	Assess sufficiency for track management	
2.4.3	Request tasking for improved detection data from other platforms	C E
2.5	**Assess adequacy for fire control**	C E
2.5.1	Assess precision of information	
2.5.2	Assess sufficiency for fire control	
2.5.3	Request tasking for improved fire control precision from other platforms	C E
2.6	**Request/task sensors and sensor/platforms for additional data**	C E
2.6.1	Control emissions	C E
2.6.2	Calculate required geometries for improvement in quality/precision	C E
2.6.3	Ascertain availability of sensors and sensor/platforms	C E
2.6.4	Request/task additional sensor data from organic elements	C E
2.6.5	Request/task additional sensor data from non-organic elements	C E
2.7	**Maintain positional information**	C E
2.7.1	Process global positioning data	
2.7.2	Process inertial navigational data	
2.7.3	Process celestial navigation data	
2.7.4	Process relative navigation	
2.7.5	Determine absolute position in geocentroid X,Y,Z	

Table 3-1. Master Function List (Continued)

Ref.No	Functional title	CE
2.7.6	Maintain gridlock among cooperative subnet units and subnets	CE
3	**ASSESS**	
3.1	**Assess situation**	
3.1.1	Define state variables	
3.1.2	Quantify uncertainties	
3.1.3	Hypothesize situation and assess weaknesses	
3.1.4	Generate queries	
3.2	**Infer meaning and discern intent**	
3.2.1	Incorporate I&W	
3.2.2	Analyze laydowns	
3.2.3	Apply tactical doctrine	
3.3	**Analyze alternatives**	CE
3.3.1	Generate alternatives	CE
3.3.2	Quantify values	CE
3.3.3	Conduct analysis	CE
3.3.4	Conduct sensitivity analyses	CE
3.4	**Project potential outcomes**	CE
3.4.1	Determine desired results	CE
3.4.2	Compute probability of kill	CE
3.4.3	Project own losses	CE
3.4.4	Project environmental effects	CE
4	**PLAN**	
4.1	**Establish doctrine, ROEs and parameters**	CE
4.1.1	Establish C3CM policy	CE
4.1.2	Establish emissions control policy for signature management	CE
4.1.3	Establish automatic self-defense parameters	CE

Table 3-1. Master Function List (Continued)

Ref.No	Functional title	CE
4.2	**Calculate possible combat solutions**	CE
4.2.1	Calculate hard kill solutions	CE
4.2.2	Calculate soft kill solutions	CE
4.2.3	Calculate hard kill/ soft kill combined solutions	CE
4.3	**Develop possible allocations of weapons/platforms**	CE
4.3.1	Establish platform and weapon status	CE
4.3.2	Assess current assignments	CE
4.3.3	Establish allocation priorities	CE
4.4	**Generate tentative schedules of resources**	CE
4.4.1	Establish platform and weapon availability	CE
4.4.2	Assess planned schedules	CE
4.4.3	Establish scheduling priorities	CE
4.4.4	Develop multiple options for possible implementation	CE
5	**DECIDE (EXECUTE)**	
5.1	**Select course of action**	CE
5.1.1	Match weapon to threat	CE
5.1.2	Allocate resources and tasks	CE
5.1.2.1	Select platform(s)	CE
5.1.2.2	Select weapon(s)	CE
5.2	**Generate and issue directives**	CE
5.2.1	Issue resource and task orders	CE
5.2.2	Issue signature management directives	CE
5.2.3	Issue sensor/illuminator orders	CE
6	**ACT**	
6.1	**Establish weapon control connectivities**	CE
6.1.1	Assign tracks to weapons platform	CE

Table 3-1. Master Function List (Continued)

Ref.No	Functional title	CE
6.1.2	Assign tracks to guidance platform	CE
6.1.3	Establish weapon/guidance platform coordination	CE
6.2	**Set equipment**	CE
6.2.1	Transfer targeting data to weapon platform	CE
6.2.2	Prepare weapon specific guidance/instructions	CE
6.2.3	Prepare weapon	CE
6.3	**Schedule sensors**	CE
6.3.1	EO	CE
6.3.2	IR	CE
6.3.3	Electromagnetic	CE
6.3.4	Acoustic	CE
6.4	**Schedule illuminators**	CE
6.4.1	Electromagnetic	CE
6.4.2	Acoustic	CE
6.4.3	EO	CE
6.5	**Actuate weapons (launch,enable)**	CE
6.5.1	Actuate hard-kill weapons from other than own platform	CE
6.5.2	Actuate soft-kill weapons from other than own platform	CE
6.6	**Guide/control weapons (as needed)**	CE
6.6.1	Provide launch guidance	
6.6.2	Provide mid-course guidance from other than own platform	CE
6.6.3	Provide terminal guidance from other than own platform or weapon	CE
6.6.4	Transition guidance control to other platforms	CE
6.7	**Engage**	CE
6.7.1	Hardkill engagement	

Table 3-1. Master Function List (Continued)

Ref.No	Functional title	CE
6.7.1.1	Terminal acquisition	
6.7.1.2	Warhead detonation	
6.7.2	Softkill engagement	
6.7.3	Coordinate hardkill/softkill engagement	CE
6.8	**Battle Damage Assessment (assess engagement results)**	
6.8.1	Review BDA reports	
6.8.2	Estimate threat residual	
6.8.3	Issue reengagement/disengagement orders	
7	**COMMUNICATE (virtual connectivity)**	
7.1	**Establish cross-platform subnets**	CE
7.1.1	Identify subnet participants	CE
7.1.2	Establish optimal connectivity, mitigated LPD and AJ requirements	CE
7.1.3	Provide cross-platform connectivity for control of sensors and sensor/platforms	CE
7.1.4	Provide cross-platform connectivity for virtual tactical picture (database) data	CE
7.1.5	Provide cross-platform connectivity for scheduling of sensors and illuminators	CE
7.1.6	Provide cross-platform connectivities for weapon control	CE
7.1.7	Provide cross-platform connectivities for other communications	CE
7.1.8	Provide cross-platform communications for doctrine, ROEs and parameters	CE
7.2	**Provide cross-network gateways**	CE
7.2.1	Establish Force level communications policies	CE
7.2.2	Establish gateways	
7.3	**Provide external communications**	
7.3.1	Establish links to acquire doctrine, ROEs and parameters	
7.3.2	Establish links to acquire I&W, targeting data	
7.3.3	Establish links to other battle forces and shore nodes	

3.7.5 Relationships

The primary functions needed for a complete implementation of cooperative engagement were extracted from the master list and are depicted in Figure 3-2.

Generalization of the functional flow diagrams suggested the high level functional relationships depicted in Figure 3-3.

3.8 ISSUES

During the development of the conceptual, high level functional architecture, a number of issues presented themselves which are included here for the consideration of the reader.

3.8.1 Physical Issues

Tentative preliminary functional allocation and consideration of the desired physical characteristics led to the following attributes of selected elements.[4]

3.8.1.1 Network. A number of observations were made concerning the establishment of Force-wide connectivity. A communications network is envisioned which has the following characteristics: high data rate, high anti-jam margin, and low probability of detection. At the architectural level it is not possible to specify the capacity of the data link since data link capacity is affected strongly by the number of tracks or measurement reports that must be transmitted, the required track update rate, the number of net/subnet members, requirements for directional antennas, network/subnet organization or topology, and fusion organization or approach. It is less strongly affected by other communication and coordination needs. Best order of magnitude is $\sim 10 \times 10^6$ bps.

Low probability of detection networking among aircraft may present significant technical challenges. LPD probably cannot be achieved by waveform design alone. Antenna directionality may be necessary. With a directional antenna or steerable beam, covertness (LPD) will likely be a function of antenna sidelobe level as well as beamwidth. Directional communication, in turn, creates problems for networking, such as signal acquisition and coordination.

Other issues associated with networking include the creation of multiple subnets, participation in multiple subnets, concurrent participation in multiple nets, rapid configuration and reconfiguration of the net, rapid reentry into the net, dynamic allocation, problems of multiple relays over long ranges (including OTH relay), and automatic net control (transparent to crew/operators).

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[4] Adopted from A3ES working group documentation.

3.8.1.2 Network Topology. Network topology and its control appear to be critical to the implementation of Cooperative Engagement. Several alternatives are possible, given antenna directionality. A flat network is one possibility, where everyone gets everything at offered rate. This requires the most capacity. Everyone doesn't need and can't use everything at provided by a flat network at a high data rate. Another alternative is a subnet architecture where platforms participate in one or more subnets, with the subnets organized by information need and utility. This alternative, however, presents scheduling and dynamics problems. Some hybrid is the likely choice based on practical capacity limits.

3.8.1.3 Fusion.

A critical part of the implementation of Cooperative Engagement is Force fusion. Three possible types of implementation present themselves.

a. Centralized Fusion - involves measurements being sent to a central fusion point. In this alternative, only the fusion center implements correlator/tracker algorithms and data base management, broadcasting tracks and track updates to any or all participants on the network. This design results in a single point of failure.

b. Decentralized fusion - involves measurements being broadcast from each participant to all other participants. Each participant then implements correlator/tracker algorithms and data base management on their own platform. In such an alternative, track updates would be retained locally since there would be no need to send them. The volume of data could easily be a limiting factor for this alternative.

c. Distributed fusion involves all participants implementing correlator /tracker algorithms and data base management locally. Measurements are correlated with the local copy of track database and track updates broadcast to all participants. In this case, there is no need to send measurement traffic. This alternative may impose limits on the fusion of unassociated track fragments necessary for multi-source, multi-platform fusion.

3.8.1.4 Tactical Picture

The need for a consistent, shared common tactical picture is clearly evident. This database, containing both track quality and fire control quality data, must be available to any or all participants as needed in realtime. Such requirements will place significant demands on the systems of the future. Realtime fusion, including multi-source, multi-sensor, multi-platform integration, association, and correlation will be needed and will be computationally intensive. Algorithms for determination of track quality and fire control precision also will be required and will need to be developed. Improved display techniques to represent the data will be required, including three dimensional representations of the Battle Space. The overwhelming amount of data

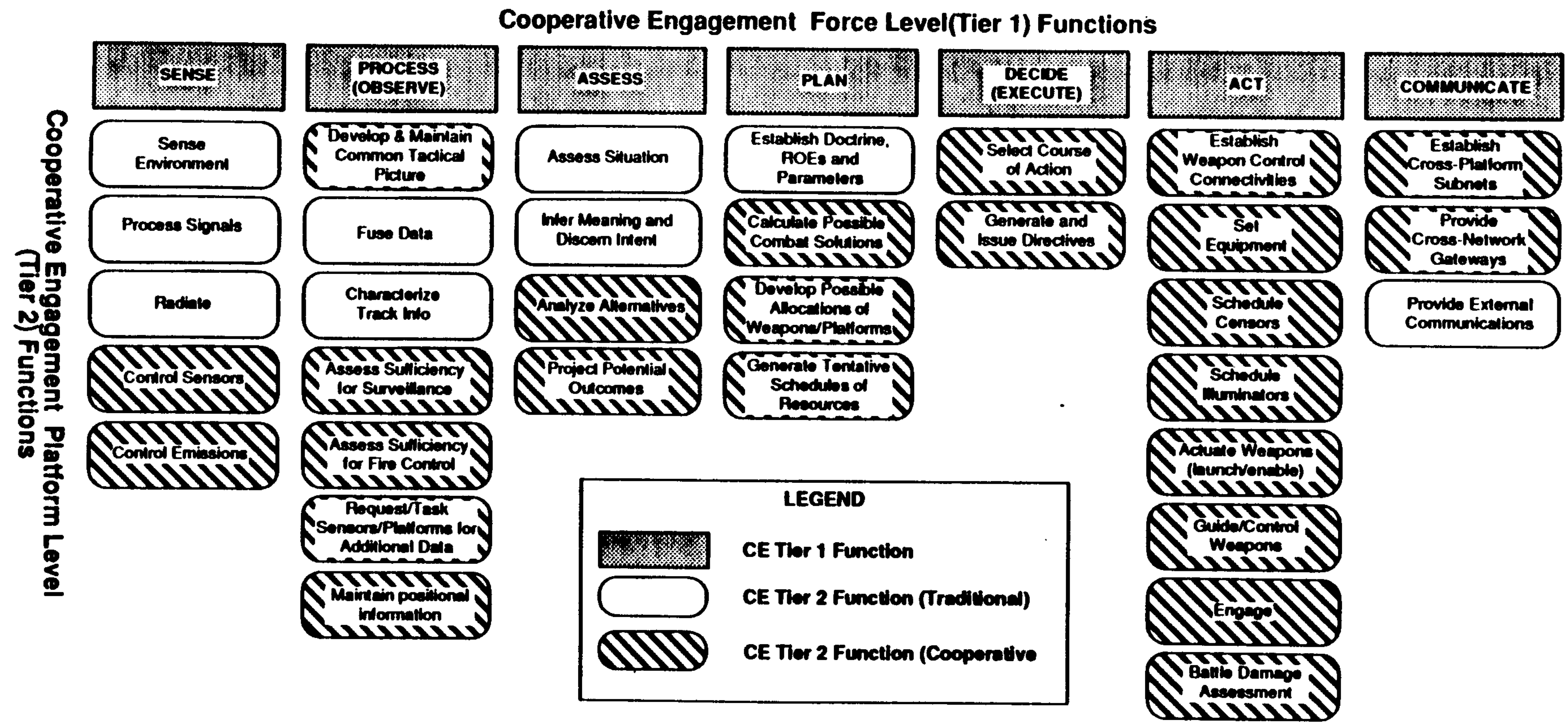

Figure 3-2. Cooperative Engagement Functions

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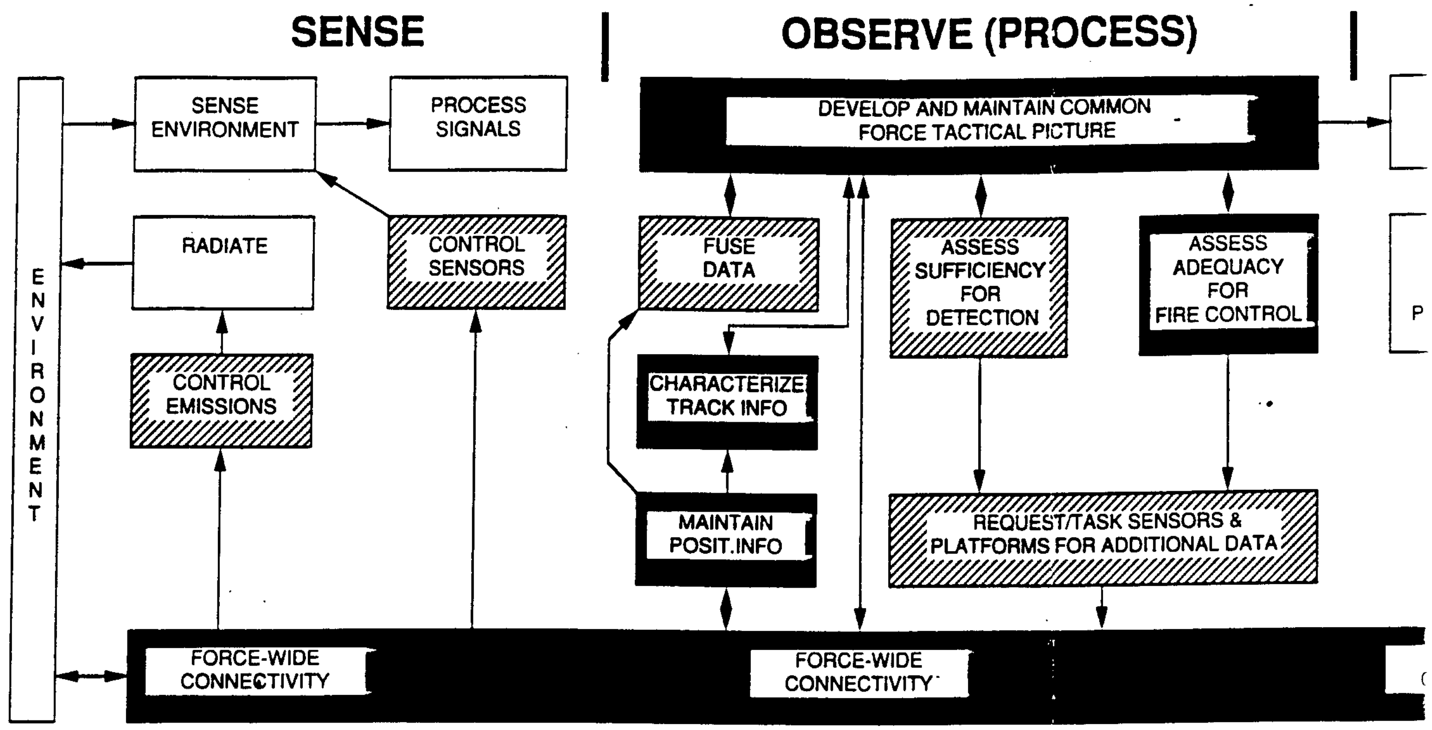
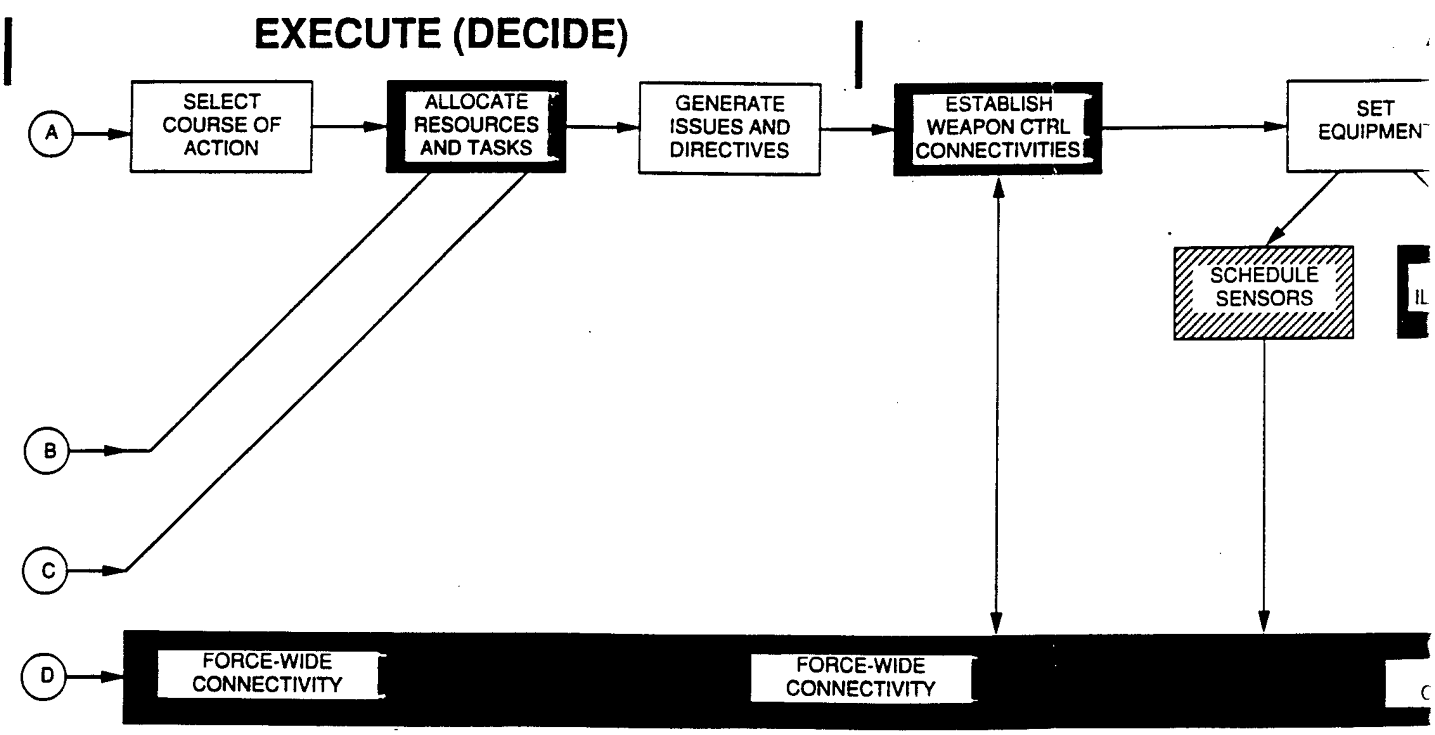
SENSE | OBSERVE (PROCESS)



EXECUTE (DECIDE)



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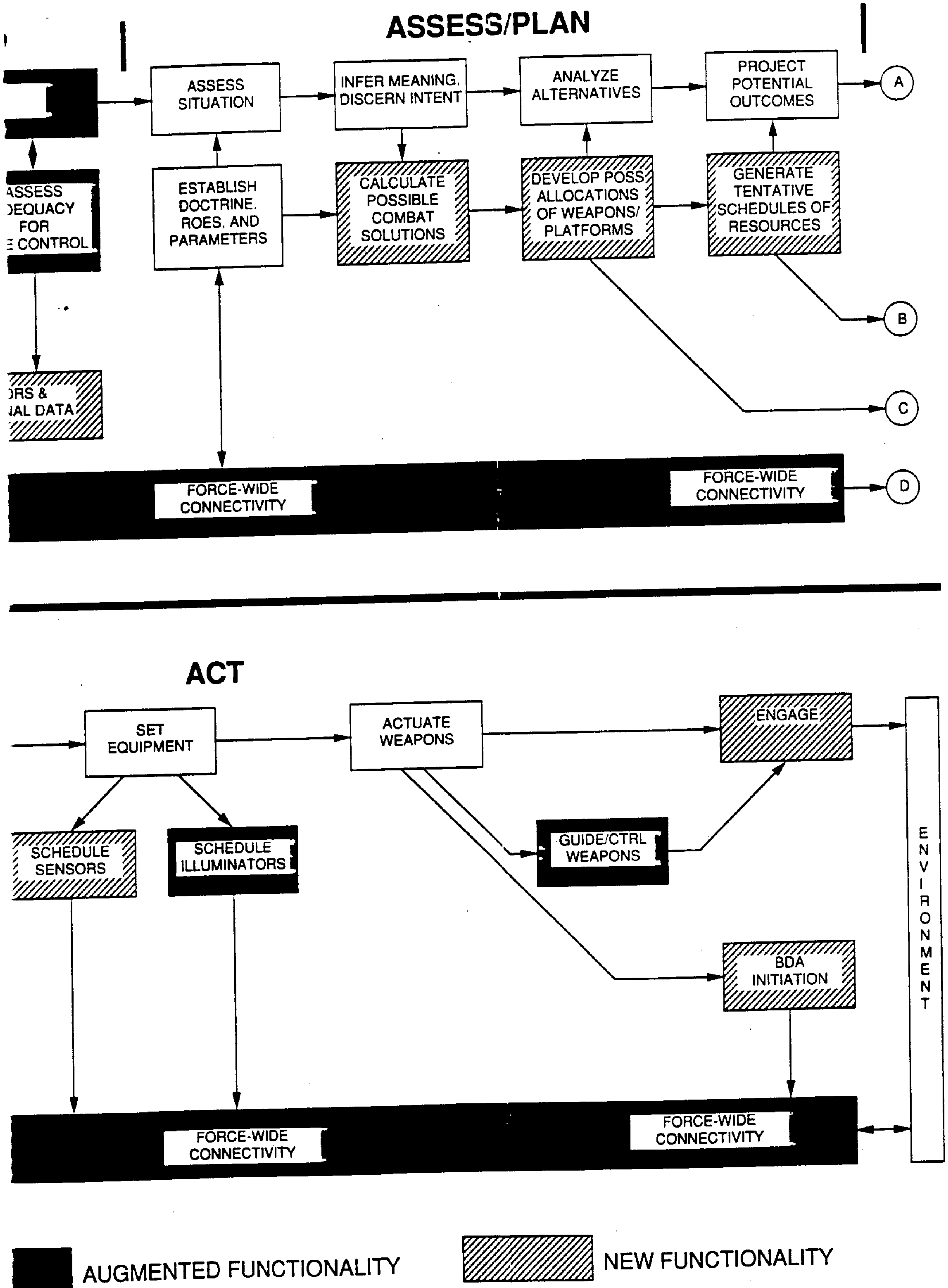

Figure 3-3. Cooperative Engagement Force Functional Relationships

available will necessitate data filtering to present only pertinent data, some type of abstraction to reduce complexity, and decision support to facilitate decision making.

3.8.1.5 Battle Management;

While Battle Management also will be discussed in the section on Organizational Issues, it is presented here as well because Battle Management is increasingly being affected by or actually implemented by automated systems. Two alternatives are presented here.

a. Distributed battle management - requires that each platform determine the engagement state using shared information, common algorithms, and established doctrine. This alternative is most suited for a global, flat network and may be suboptimum for segmented networks.

b. Designated battle management - requires that one platform in a group (subgroup) act as battle manager. In this alternative there is a potential hierarchy of battle managers including the AAWC, a sector controller, and flight leaders, for example. This alternative can be compatible with segmented information networks. However, in order to avoid the single point of failure problem, many platforms must have the capability to serve as battle manager, thus insuring survivability.

A major requirement exists for the development of automated decision making capabilities. Two factors drive this requirement: complexity and speed. The complexity of warfare is constantly increasing. When coupled with reduced time to make decision, some form of automated decision making will be required. More importantly, some new weapons have reduced reaction time to the point where there is a need for nearly instantaneous decisions. Self defense automated decision making is clearly needed.

3.8.2 Organizational Issues

The development of a Cooperative Engagement capability will offer many benefits and undoubtedly some problems as well. Perhaps for the first time since its inception, command by negation will be possible with the availability of a realtime Force-wide tactical picture. Other possibilities include the adoption of a hierarchy of battle manager positions similar to the TRS concept.[5]

With a distributed architecture, so too may come a distribution of authority to commit weapons. In fact, one can easily foresee a time when the Task Force Commander may not be aware of who is committing weapons, or what requirements have been levied on sensor platforms to provide guidance and

[5] TRS refers to the Theatre-Regional-Sector concept being explored for ASW

control capabilities for other platforms designated to launch weapons. Since much of CE will have to be fully automated, organizational changes may be required in order both to monitor a significantly changed automated system and to manage engagements.

One of the questions that must be answered is whether or not a requirement will emerge for a specialist on the Task Force Commander's immediate staff, with primary responsibilities to provide direct support to the OTC in the prosecution of cooperative engagement initiatives. If so, what would his specific duties and responsibilities be? How would he fit in the command hierarchy? Should he have the status of a Warfare Area Commander, a Warfare Coordinator, or simply be assigned as another staff officer reporting directly to the Commander? One alternative is to simply have one of the currently assigned staff members perform the additional duty functions of CE Coordinator. Other alternatives that might be considered are to have the billet assignment directly on the AAWC's staff, with additional CE Coordinators assigned to the other Warfare Area Commanders as appropriate and when exigencies so dictate.

In whatever manner the command structure assimilates the duties and responsibilities of such a Coordinator, the status and positional level in the command hierarchy must take into account how the CE system is envisioned to work, as well. As an example, will the CE system be an overlay of the command and control system, transparent to the user and activated at all times, or is the system intended to function only when required (i.e., when conventional sensor-to-shooter functions cannot achieve the detect, control, engage requirements necessary to kill the target)?

Development of a concept of operations for CE will help clarify some of the organizational issues identified above.

4 CE DETAILED AAW ARCHITECTURE

4.1 INTRODUCTION

This section will document how the conceptual CE architecture described in Section 3 has been extended to the AAW mission area. Paragraph 4.2 discusses the differences between a conventional and a cooperative AAW engagement. Paragraph 4.3 describes the curent AAW architecture from the standpoint of Required Operational Functions (ROFs) and presents operational concepts for cooperative AAW. Paragraph 4.4 presents the detailed AAW CE Architecture.

4.2 CONVENTIONAL VERSUS COOPERATIVE AAW ENGAGEMENT

The following paragraphs present a high level description of the relationship between a conventional and a cooperative AAW engagement (CE). A more detailed discussion is contained in Appendix C of this report.

4.2.1 Top level Description

Figure 4-1 illustrates a stressing AAW conventional engagement threat example.

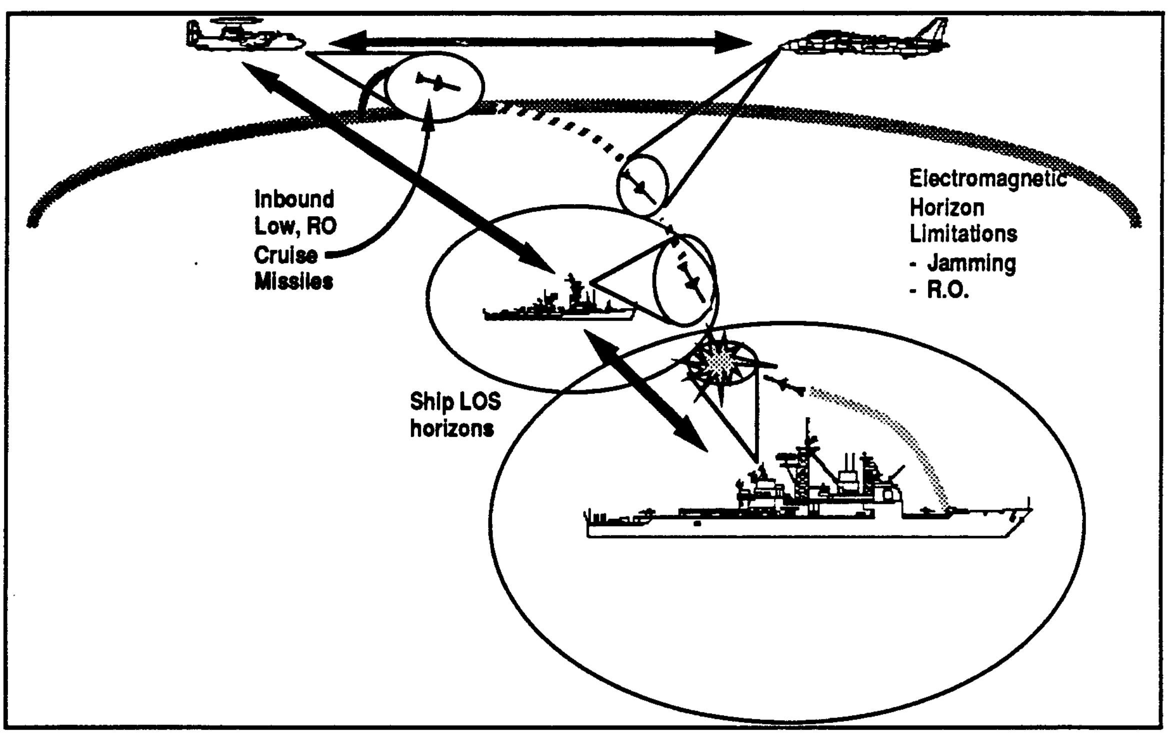

Figure 4-1 Conventional AAW Threat Example

Specifically, inbound low altitude, RO (Reduced Observable) cruise missile(s) launched at great range from the battle force center. They are launched in a series and approach the battle force from over the horizon. In this depiction these cruise missiles are targeted against the high value surface unit. While the missiles are inbound there are several opportunities for detection, but only a very few engagement opportunities. An airborne early warning platform may see them as they go by, but it doesn't have weapons systems available to engage. Similarly fire control radars on Carrier Air Patrol (CAP) aircraft may have a fleeting detection of the missile, but not of sufficient duration to engage. Again the cruise missile(s) may cross through the detection envelope of another ship but the duration is not of sufficient time to engage. The only platform that does have sufficient time for detection, fire control lock-on, and engagement is the targeted vessel but the number of engagements is constrained. This s caused by ship and aircraft horizon limitations, both electromagnetic and LOS horizons, cruise missile closing speed, number of fire control systems or tracks, and weapon minimum employment range. Once inside that minimum range, the inbound cruise missile becomes a point defense challenge.

As illustrated in Figure 4-2, Battle Space, Depth of Fire, and Firepower are all severely constrained in the conventional AAW engagement.

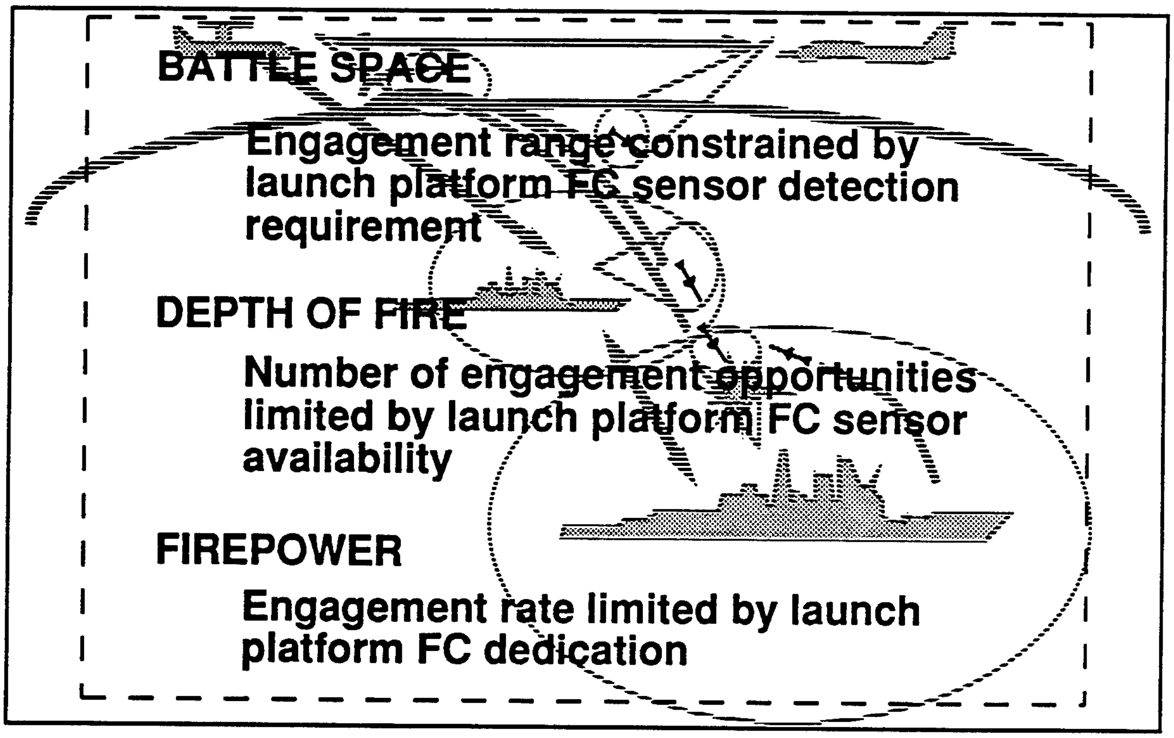

Figure 4-2. Conventional AAW Limits

The range at which it is possible to begin engagement is constrained by the fire control sensor target acquisition range. Since it's co-located with the weapon on the weapon launch platform, engagement range cannot extend out beyond the line of sight. The reduced observable signature implies engagement range could be substantially less than line of sight. For these reasons, the number of engagements is limited by the number of fire control systems and by their acquisition ranges. As the Battle Force is made up of platforms and weapon systems, all of which have similar constraints, the Force Battle Space Depth of Fire, and Fire Power are also limited against threats such as these.

If it were possible to capitalize on the detection opportunities available from the other platforms and convert the detections into engagements then those limitation would be lessened. Doing that, however, would require a change in the way AAW weapons are now designed and employed. If we were able to detect the missile, predict its track, and position a fighter aircraft to provide terminal illumination for a weapon launched from another aircraft, then an engagement would be possible despite the limited duration detection and tracking opportunities. Similarly, if it were possible to use aircraft to predict the time that the cruise missile will enter the fire control range of the targeted platform that platform could then launch a missile to intercept the in-bound cruise missile immediately upon entry into the targeted platform's fire control range. This could provide the time and range for additional engagements. At the very least, a ship with a high precision radar tracking system could provide an accurate fire control quality track to the targeted platform. It could place its fire control system in lock-on mode prior to actual acquisition and be oriented towards the incoming threat to immediately engage upon its entry into the fire control envelope. This also could provide additional engagement opportunities. Together, these improve both battle space and firepower as depicted in Figure 4-3.

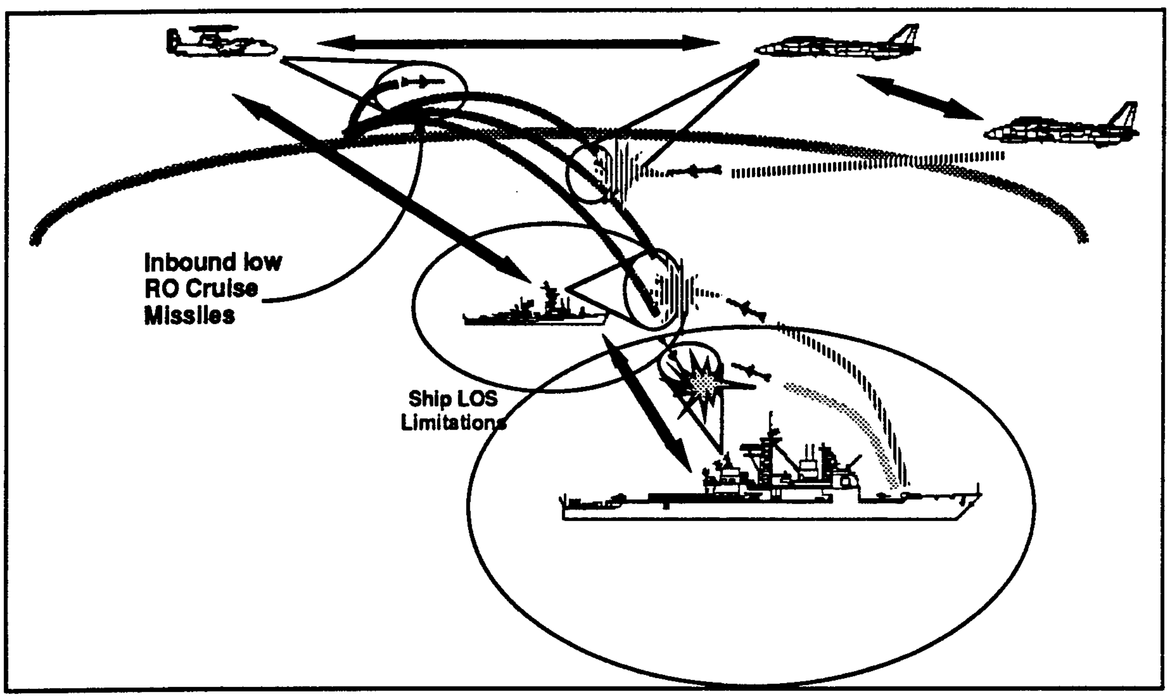

Figure 4-3. Cooperative AAW Engagement Example

4.2.2 Functional Relationships

To illustrate the functional differences between conventional and cooperative engagement, Figure 4-4 depicts the major functions of each.

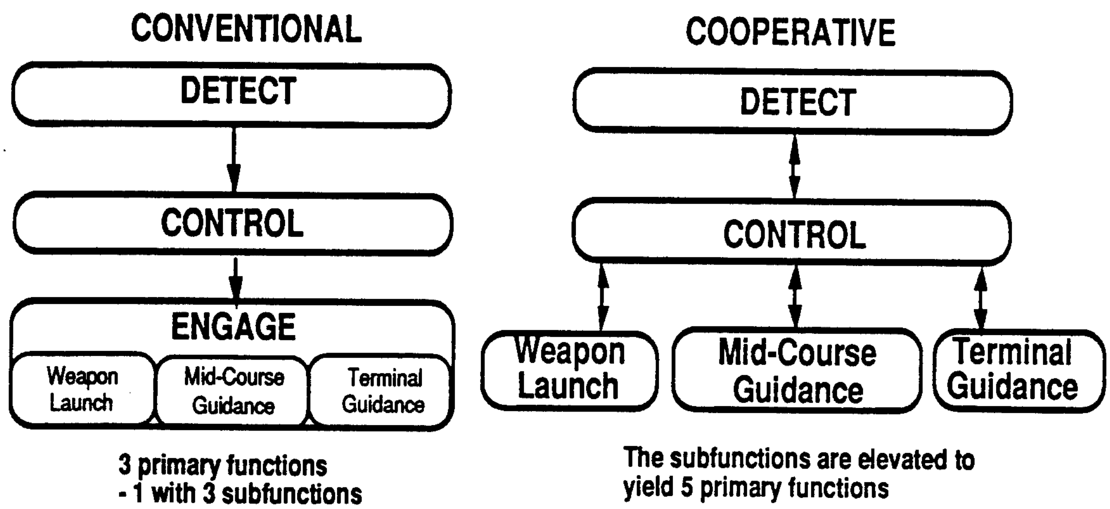

Figure 4-4. Conventional VS Cooperative Engagement Functions

Any AAW engagement begins with the detection of a contact and formation of a track. A control function begins with the assessment of the degree of threat posed by that contact. The threatening contacts and tracks are then prioritized and matched with the available engagement assets. At the appropriate time and position, the hostile track is assigned to a single platform for engagement. In a conventional engagement that platform has all the sensors and data necessary to successfully complete the engagement. For purpose of this discussion, there are three primary functions: Detect, Control, Engage. For a conventional engagement, one or two platforms can be involved in detection and control but only one platform can be involved in the actual engagement.

In general, a cooperative engagement utilizes those resources that are distributed among several platforms and are integrated in order to affect an engagement. For AAW, CE is defined to take place when weapon launch and guidance depends at least in part, upon fire-control data obtained from sensors *not* located onboard the launching platform.

Figure 4-5 shows the CE control function maintaining tracking continuity among several platforms through the duration of a cooperative engagement. The specific type and classes of platforms involved in such a CE configuration might vary depending on the specific tactical situation.

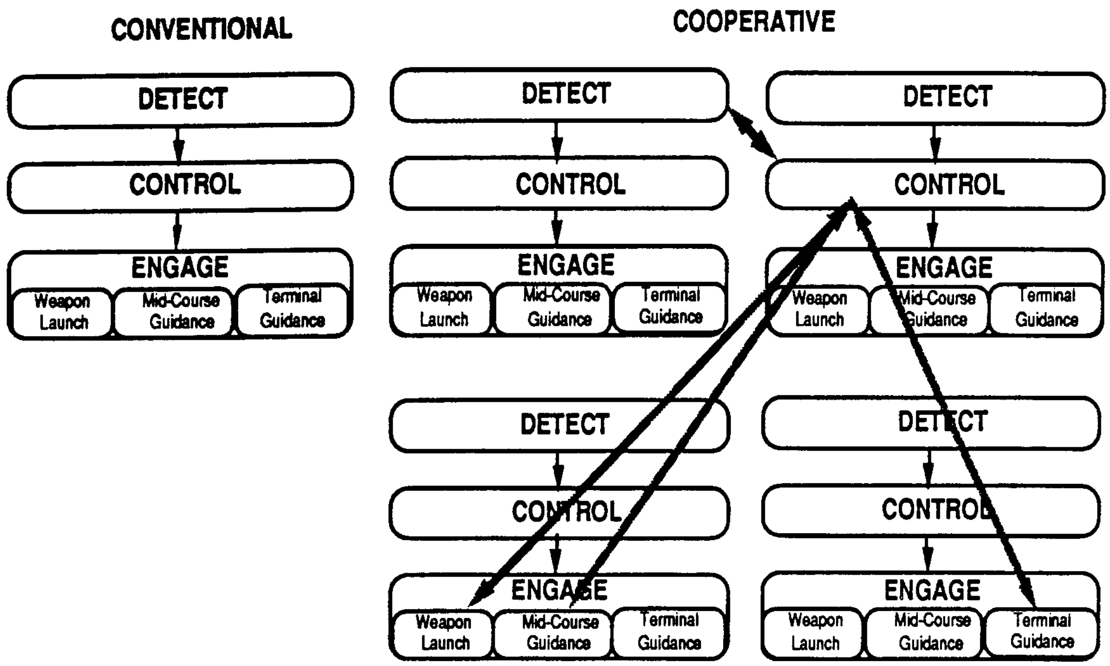

Figure 4-5. Conventional VS CE Functional Relationships

4.2.3 Functional Grouping and Flow

Figure 4-6 illustrates the level of detail required in a set of functions and subfunctions for AAW CE.

These are derived from the conceptual CE functions presented in Section 3 and from the current AAW ROFs. They form the basis for development of the AAW Architecture CE Option functions described later in this Section. These functions, and their relationship, must be considered in the context of the WSA&E AAW Current Plus Architecture.These functions separate naturally into five major divisions: Detect, CE Control, Guide, Weapon Launch, and Terminal (Illumination). For additional information concerning the rational and development of these divisions please see the detailed discussion in Appendix C to the report.

The Detect box includes those subfunctions that are associated for the purpose of detecting and developing contact information. and associating that information into tracks and a tactical picture. This can be for surveillance purposes or, at the direction of a CE controller, for directly supporting a CE.

The unboxed area is where the AAWC functions to provide direction, maintain an adequate tactical picture, and perform threat evaluation and weapon assignment (TEWA). As a part of weapon assignment, the AAWC makes the determination whether or not CE is preferable to conventional engagement. A general set of function for conventional engagement and for coordinating EW with AAW is found in this area as well.

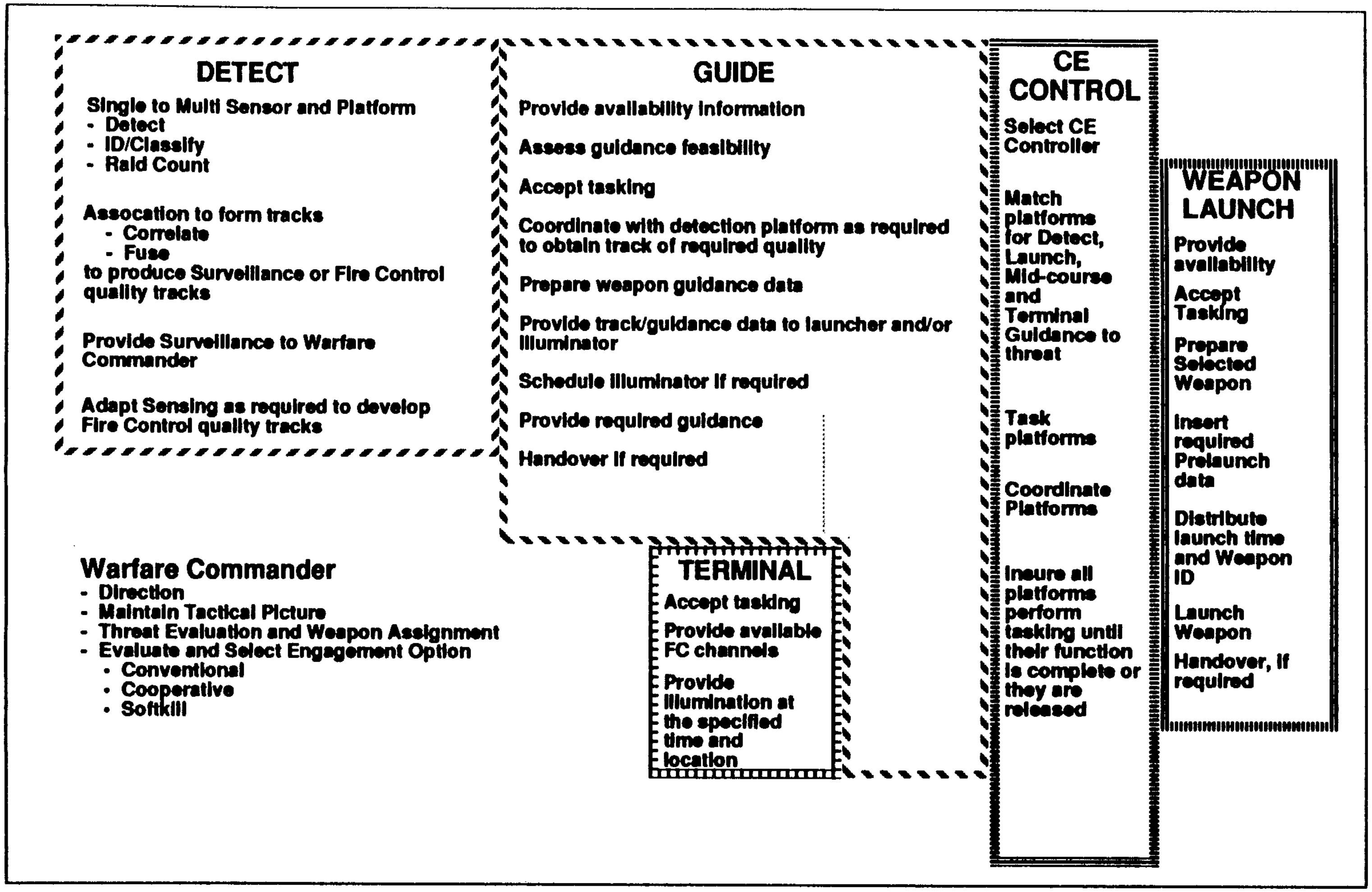

Figure 4-6. Major CE Functional Grouping

Should CE be found preferable, CE control functions must be performed. It is a fundamental precept in developing this CE architecture that an in-flight weapon should never be out of control. The CE controller is responsible for ensuring that overall CE control is maintained. The controller begins be selecting the platforms that will launch the weapon(s) and provide guidance. The controller's involvement continues to ensure that the assets needed maintain their contribution and that the coordination needed to assure an effective launch takes place, and finally that the outcome of the CE is assessed. Should weapons be in-flight to a destroyed target, the controller has the additional responsibility to ensure that those weapons are either directed to alternative targets or are destroyed.

Guidance functions are performed to ensure that the target track data quality is matched to the weapon's requirements for prelaunch, midcourse, and terminal guidance. This involves deciding on where target track quality improvement is needed and working with sensor platform to obtain the needed data. The guidance platform formats and provides the fire-control data to the launch platform and, if required, to the weapon following launch.

The weapon launch functions ensure that the right weapon is selected and prepared for launch, that the weapon prelaunch required fire-control data is available and inserted, and that CE participants are informed of weapon identification and launch time. This platform may also receive weapon guidance data following launch for transfer to the weapon.

Should the weapon require support during the terminal homing phase of flight, the CE controller and guidance platform must ensure that this is provided. If this is in the form of terminal illumination (e.g.; RF or laser), the illuminating platform must be selected and moved to a point where illumination can be provided when required by the in-flight weapon.

Figure 4-7 shows the relationship of the functions just discussed as well as the logic that would govern the sequencing of function performance. CE functions appear in rectangular boxes and logic statements governing paths to follow appear in hexagons, thus depicting the CE functional flow. A detailed description of this functional flow appears in Appendix C.

4.3 EXISTING AAW ARCHITECTURE

The current Anti-Air Warfare Architecture is defined in physical, functional, and organizational terms. The current architecture includes systems currently deployed and those which will be introduced into the battle force by the end of FY 1992.

This section will introduce the functional mapping of the current AAW architecture and then proceed to build into that architecture the modifications and additional capabilities necessary for it to support the Cooperative Engagement concept.

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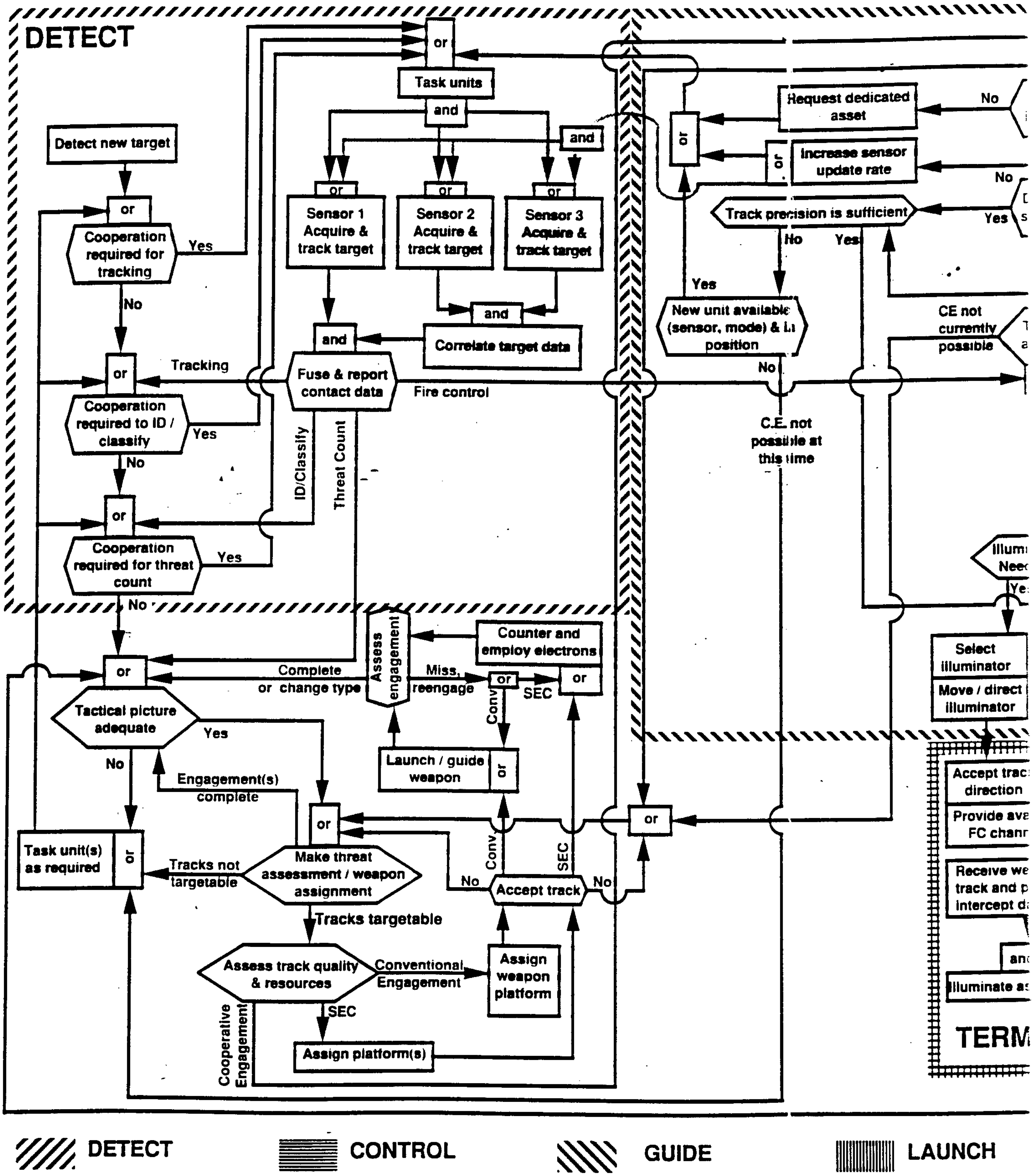
DETECT
Detect new target
or
Cooperation required for tracking
Yes
No
Task units
and
and
or
Sensor 1 Acquire & track target
Sensor 2 Acquire & track target
Sensor 3 Acquire & track target
and
Correlate target data
and
Fuse & report contact data
Tracking
Fire control
Cooperation required to ID / classify
ID/Classify
Threat Count
Cooperation required for threat count
Request dedicated asset
Increase sensor update rate
Track precision is sufficient
New unit available (sensor, mode) & Li position
C.E. not possible at this time
CE not currently possible
Tactical picture adequate
Complete or change type
Assess engagement
Counter and employ electrons
Miss, reengage
Conv
SEC
Launch / guide weapon
Engagement(s) complete
Task unit(s) as required
Tracks not targetable
Make threat assessment / weapon assignment
Accept track
Tracks targetable
Assess track quality & resources
Conventional Engagement
Assign weapon platform
SEC
Assign platform(s)
Cooperative Engagement
Select illuminator
Move / direct illuminator
Accept trac direction
Provide ava FC chann
Receive we track and p intercept d
Illuminate a
TERM
DETECT
CONTROL
GUIDE
LAUNCH

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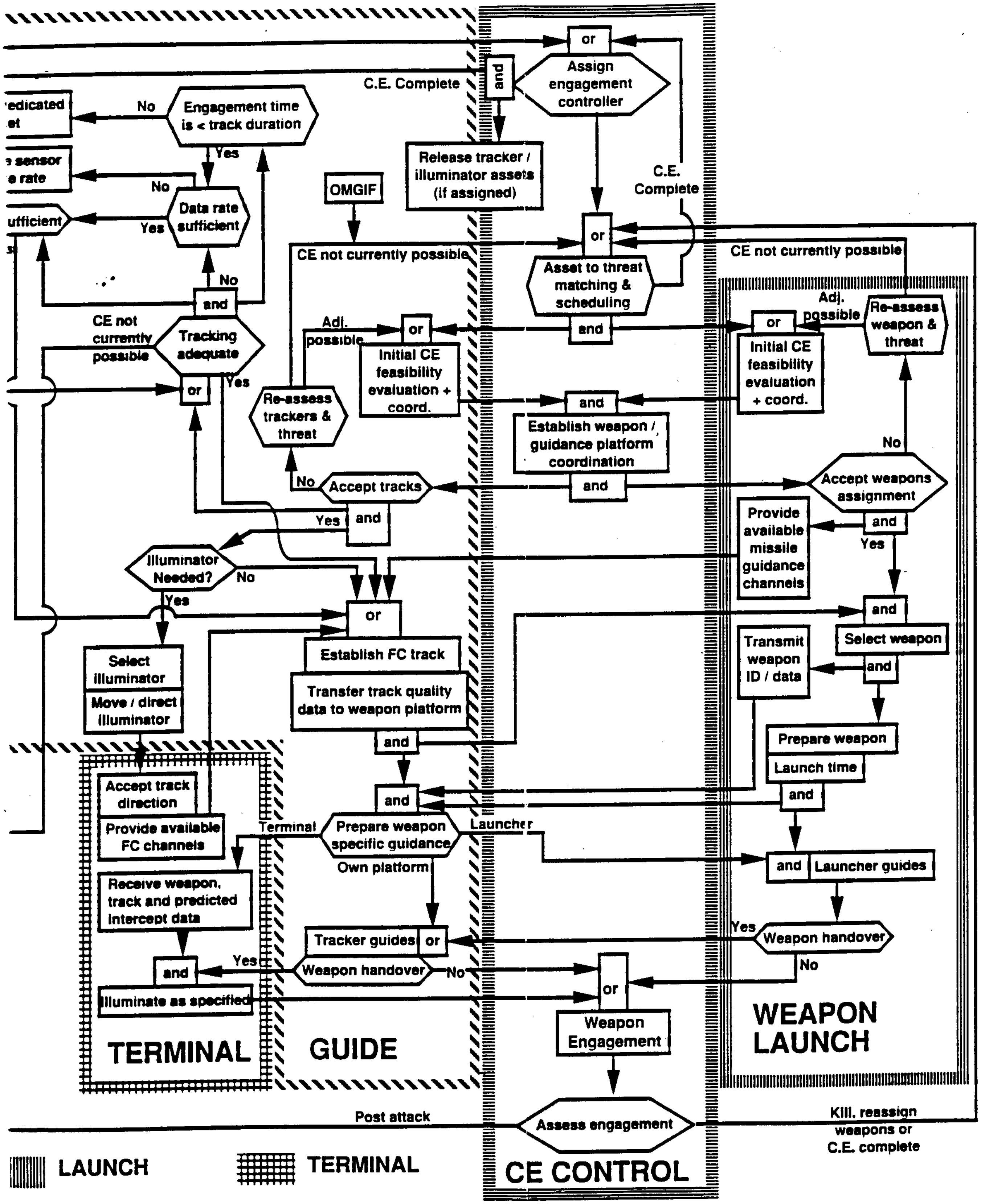

Figure 4-7. CE Function Logic Flow

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4.3.1 Functional mapping

Functionally, the current AAW architecture is defined in terms of 16 Force Level Required Operational Functions (ROFs). These functions allocated to the AAW battle phases (Posture Forces, Counter Platform, Counter Weapon, and Post attack). Within these phases, the 16 ROFs are decomposed into approximately 40 platform-level operational functions. These force and platform-level ROFs and operational functions are the basis for the incorporation of CE into the AAW architecture.

Figures 4-8 through 4-11 illustrate Force and Platform Level Operational Functions for the Current AAW architecture.

4.3.2 Operational Concepts

Greater threat weapon ranges, more sophisticated delivery platforms, expanded weapon varieties and envelopes, and advanced stealth technologies in all media (particularly air and undersea) leads to the conclusion that cooperative engagement concepts must be fully leveraged if we expect to meet the emerging threat , now and in the future. We must develop the capability to expand the battle space, both for tactical picture capability and to obtain full targeting potential to the maximum performance limits of our weapons and weapon systems. In that respect, there are certain key functions that have particular applicability in the successful accomplishment of cooperative engagement.

The first and foremost ubiquitous function essential for employment of cooperative engagement is communications. Any CE communications system must support the necessary data flows, which will likely be a combination of raw, semi-processed and completed track data. Likely additional requirements include LPI, highly jam-resistant communications, especially in the outer air battle and for missile updates. The communications system must be a common system, at least across any net that is in operation at a given time. Complete address commonality among all weapons and weapon platforms is also an essential goal.

The second function critical to CE is accurate position determination and systems status/availability reporting. This function is critical in performing datacorrelation and fusion, in threat evaluation and weapon assignment (TEWA), and in post launch weapon control.

The third critical function is data correlation and fusion. This relates to the capability to take data from numerous sources and determine whether they are observing the same or different objects and assimilate the data to provide a consistent, complete tactical picture. The degree to which this function can be done better and more expeditiously through CE initiatives will be a critical determinant for the operational utility of such a system.

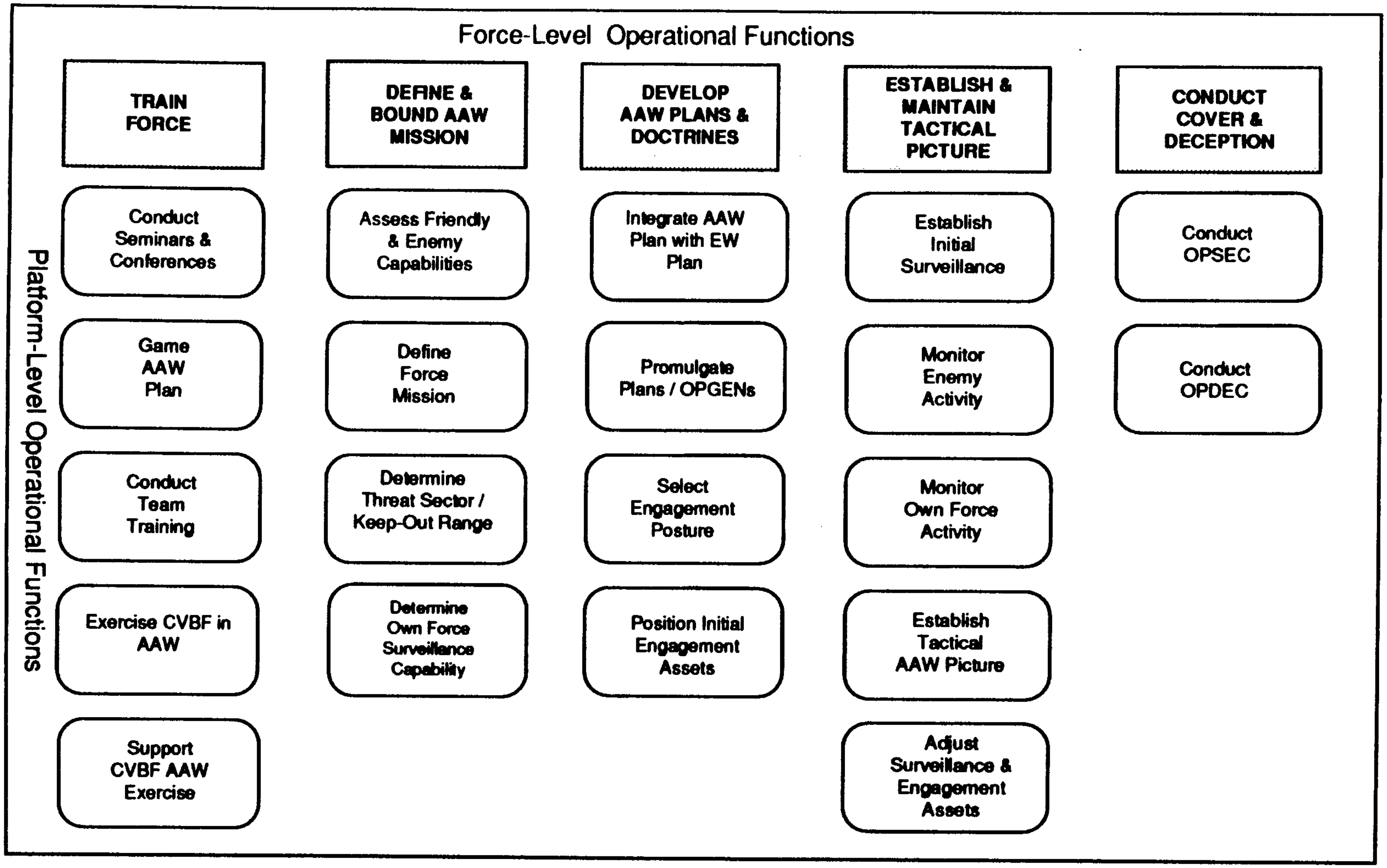


Figure 4-8. Force Level Operational Functions in the Current CVBF Architecture (Posture Forces Phase)

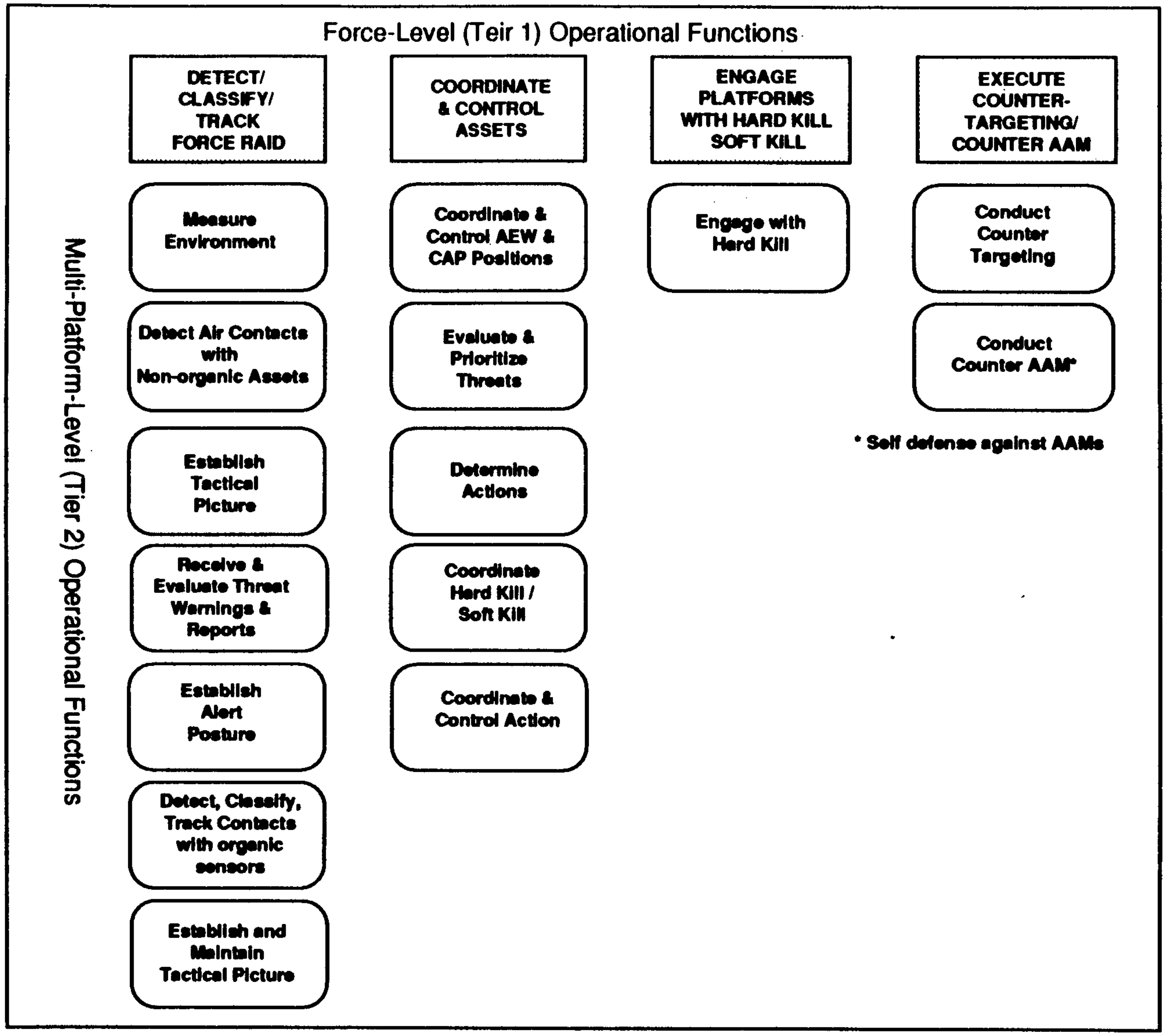


Figure 4-9. Force Level Operational Functions in the Current CVBF Architecture (Counter Platform Phase)

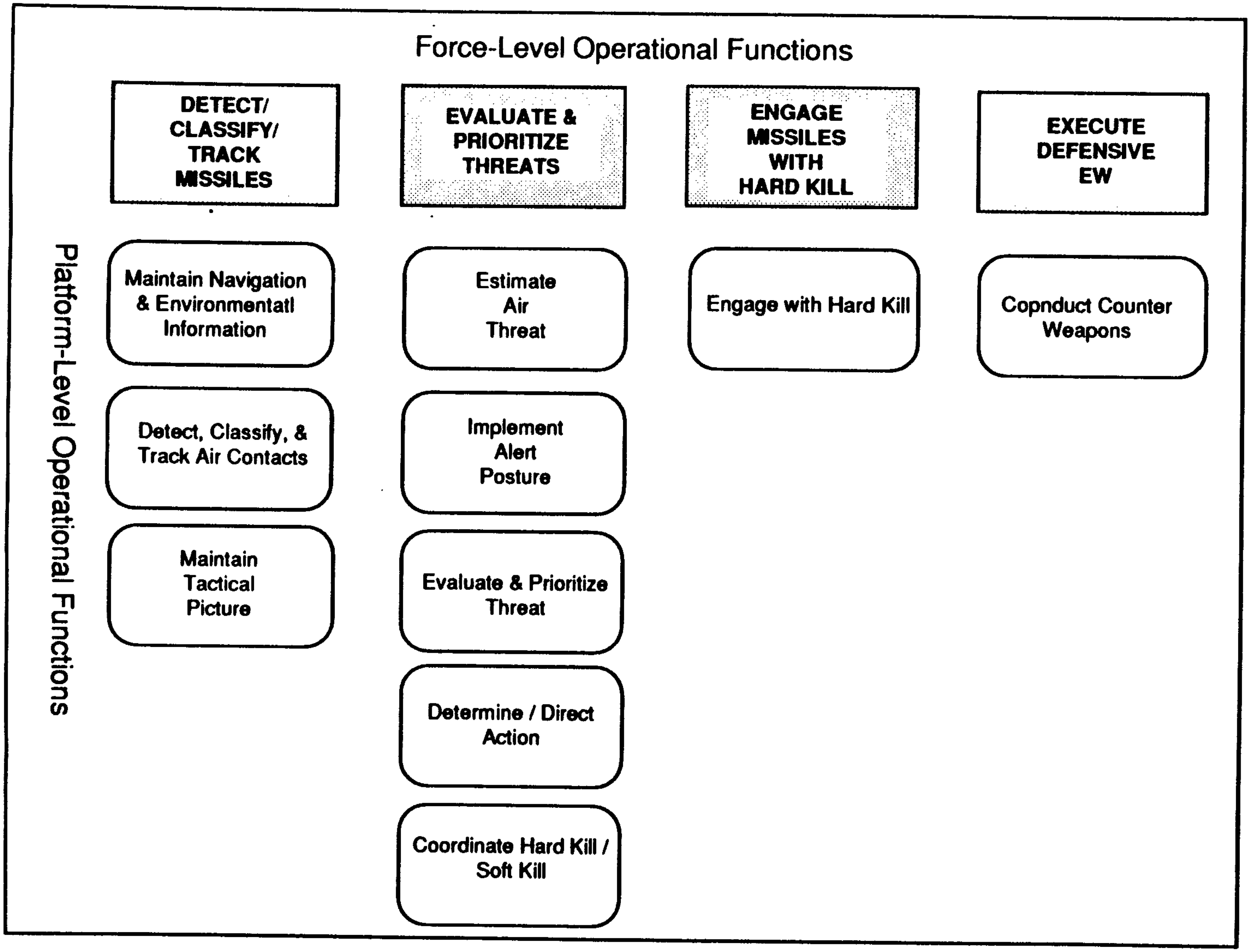


Figure 4-10. Force Level Operational Functions in the Current CVBF Architecture (Counter Weapon Phase)

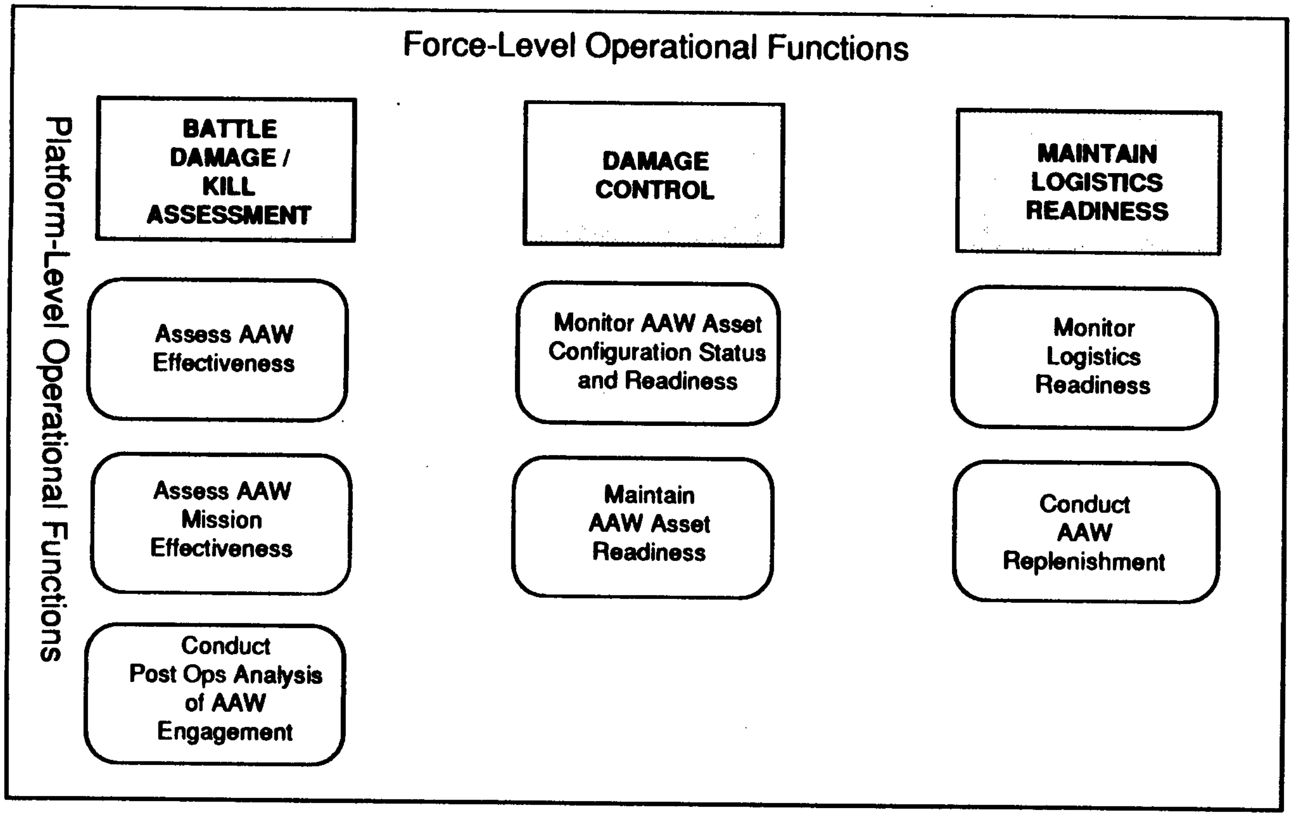


Figure 4-11. Force Level Operational Functions in the Current CVBF Architecture (Post Attack Phase)

To be successful, the sensor-to-shooter concepts must be fully developed in two broad areas. These are implementation of shared data bases across all spatial media and the development of the forward pass concept into operational reality. One way of highlighting the operational advantages that may accrue in a cooperative engagement system embodying the two foregoing technical capabilities is through a critical look at 9 operationally challenging cases. These cases are depicted in the pictorial examples of sub-paragraphs 4.3.1 thru 4.3.9 (below), and include a brief description of the operational advantages that should accrue if the capability were implemented. They are also available in Appendices F and G.

4.3.2.1 Case 1. This Case is representative of a common, shared, data base of correlated/fused tracks and track fragments, obtained from all active and passive sensors resident in the sea surface units of the Force, such that all surface units have a consistent tactical picture of engagement quality. Weapon guidance and control functions would be provided by the launching platform.

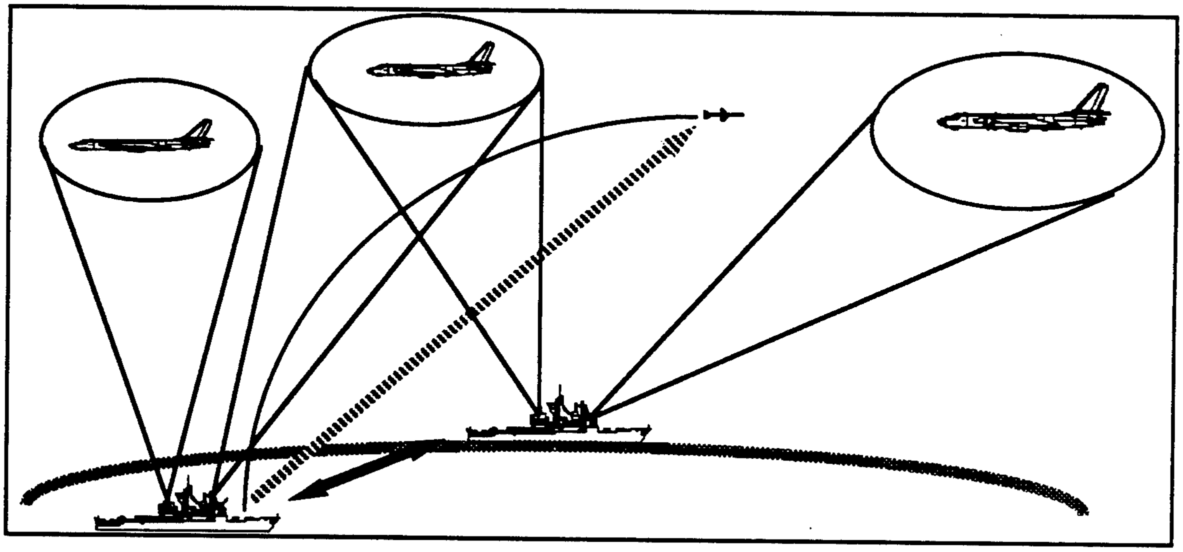


Figure 4-12. Surface Shared Data Base

4.3.2.2 Case 2. This Case is representative of a common, shared, data base of correlated/fused tracks and track fragments, obtained from all active and passive sensors resident in the sea surface units and air surveillance units of the Force, such that all surface units have a consistent tactical picture of engagement quality. Weapon guidance and control functions would be provided by the launching platform. The air-derived sensor information may be either track quality data or raw data only, depending on the ability of the surface net to fuse data or only correlate tracks.

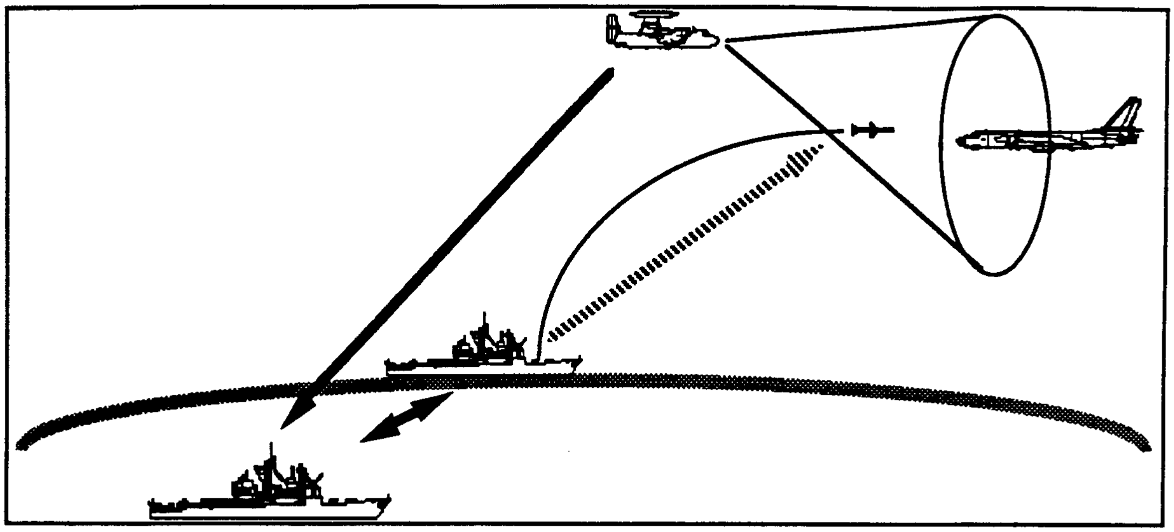


Figure 4-13. Surface Shared Data Base Augmented by Air Surveillance

4.3.2.3 Case 3. This Case is representative of a common, shared, data base of correlated/fused tracks and track fragments, obtained from all active and passive sensors resident in the sea surface units of the Force, such that all surface units have a consistent tactical picture of engagement quality, with the added option to launch missiles from any ship in the Force and provide missile flight and terminal control from any other properly configured ship in the Force.

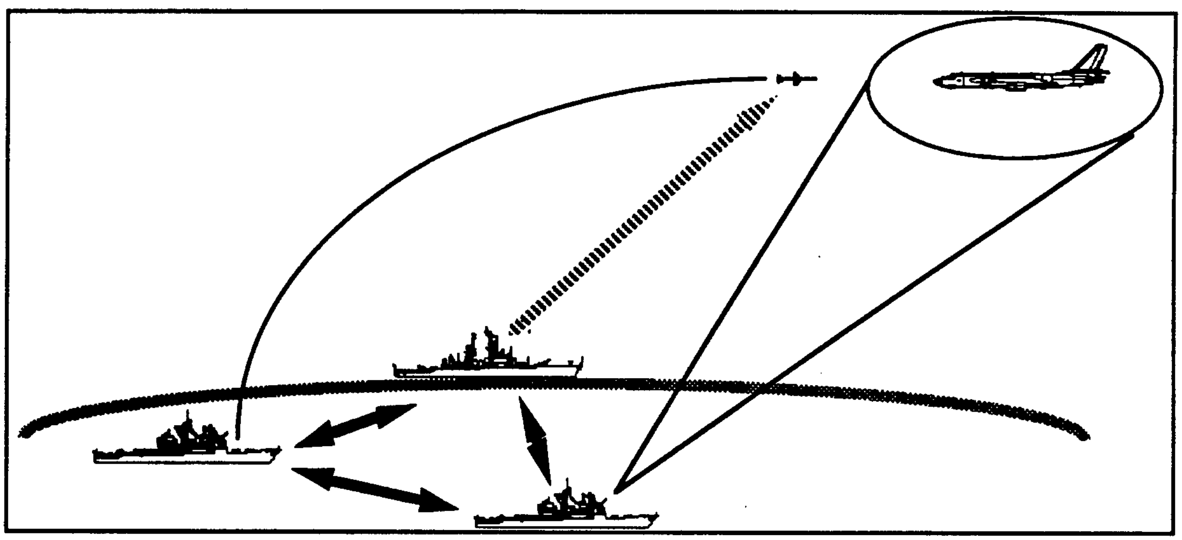


Figure 4-14. Surface Shard Data Base Augmented by Surface Forward Pass

4.3.2.4 Case 4. This Case is representative of a common, shared, data base of correlated/fused tracks and track fragments, obtained from all active and passive sensors resident in the sea surface units, and air surveillance units of the Force, such that all surface units have a consistent tactical picture of engagement quality, with the added option to launch missiles from any ship in the Force and provide missile flight and terminal control from any properly configured air unit in the Force.

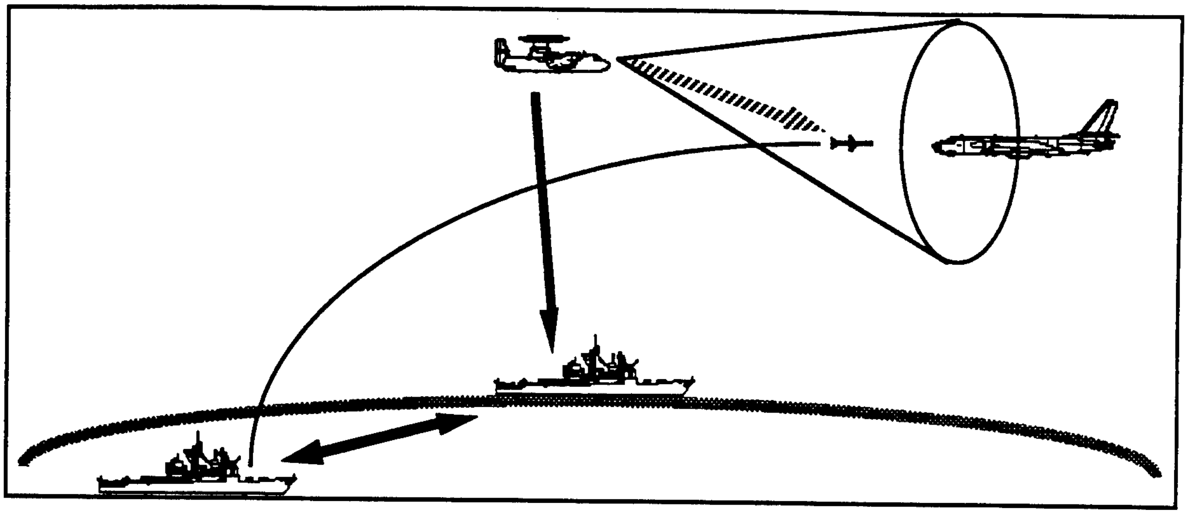


Figure 4-15. Surface Shared Data Base Augmented by Air Surveillance and Air Forward Pass

4.3.2.5 Case 5. This Case is representative of a common, shared, data base of correlated/fused tracks and track fragments, obtained from all active and passive sensors resident in the air units of the Force, such that all air units have a consistent tactical picture of engagement quality. Weapon guidance and control functions would be provided by the launching platform.

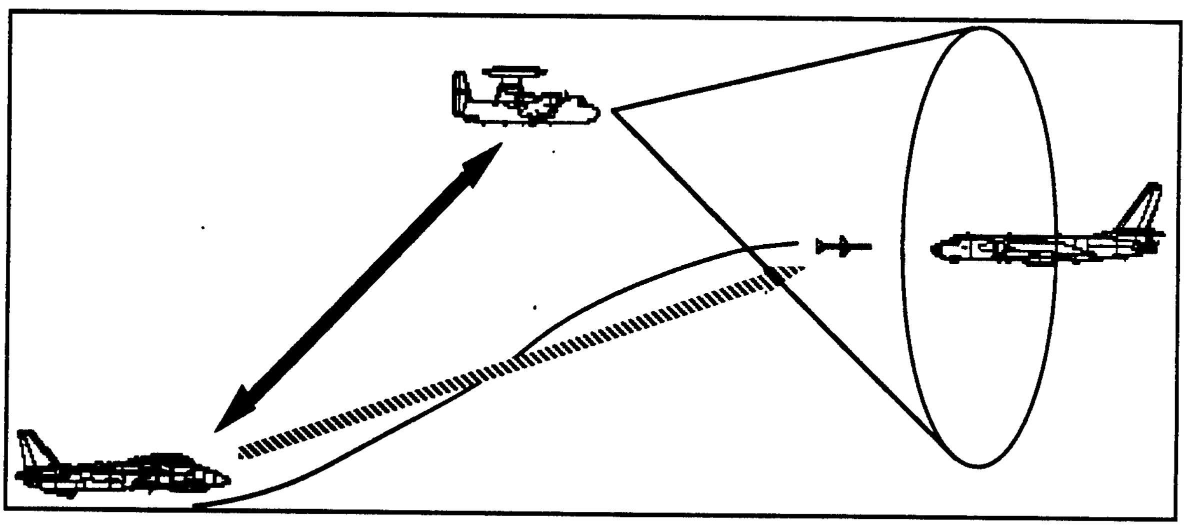


Figure 4-16. Air to Air Shared Data Base

4.3.2.6 Case 6. This Case is representative of a common, shared, air data base of correlated/fused tracks and track fragments, obtained from all active and passive sensors resident in the units of the Force, and augmented by multi-media sensors external to the Force that are accessed through other Service sources, Joint Commands, National sources, or allies. Weapon guidance and control functions would be provided by the launching platform.

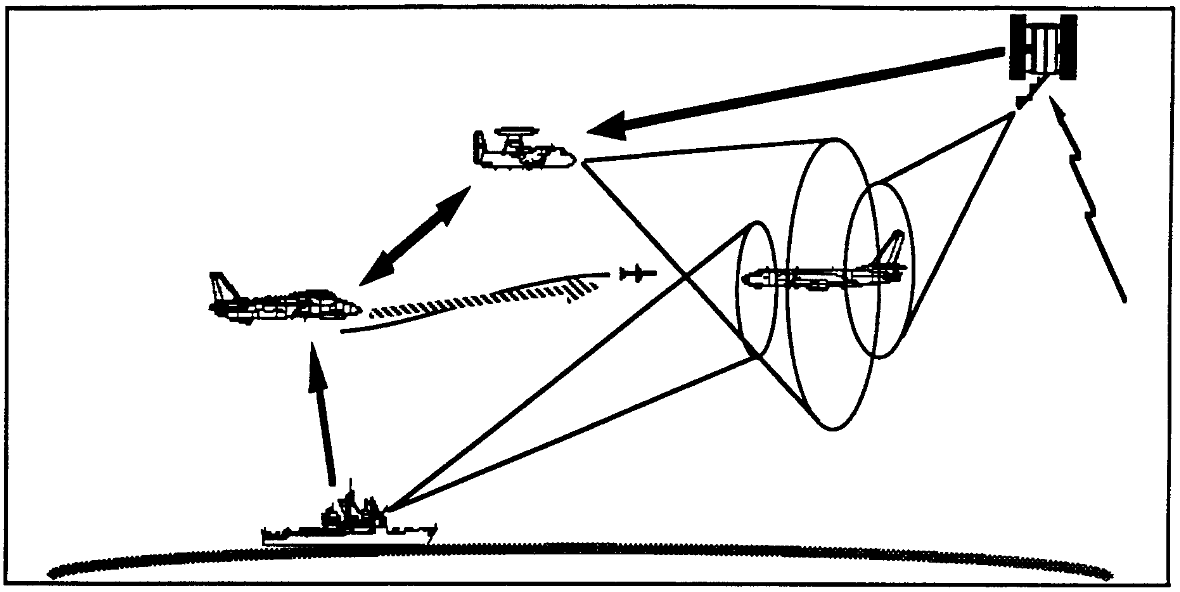


Figure 4-17 Air to Air Shared Data Base augmented by surface, undersea, space or land surveillance

4.3.2.7 Case 7. This Case is representative of a common, shared, data base of correlated/fused tracks and track fragments, obtained from all active and passive sensors resident in the air units of the Force, with the added option to launch missiles from any air unit in the Force and provide missile flight and terminal control from any properly configured air unit in the Force.

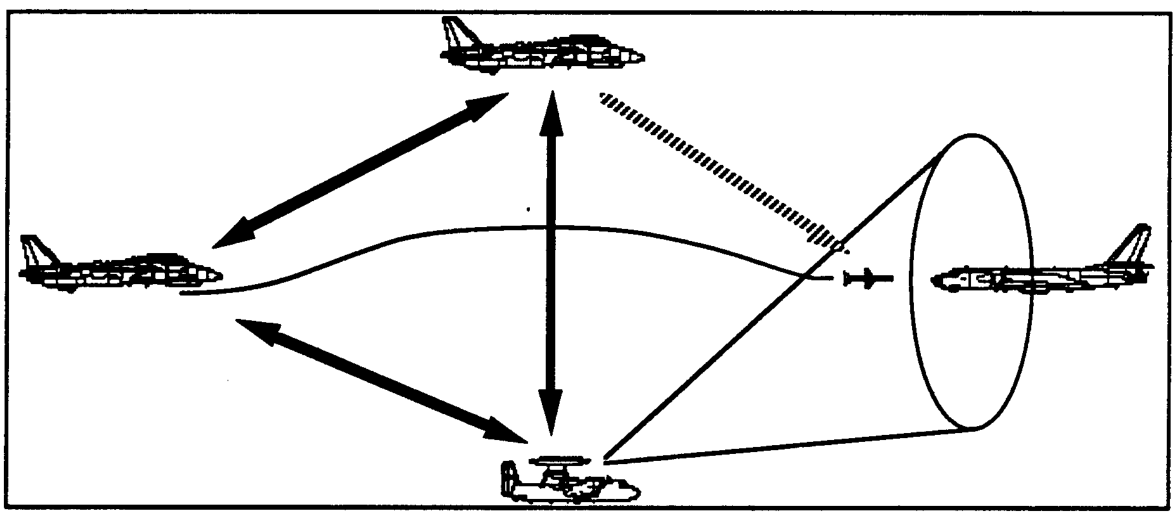


Figure 4-18 Air to Air Shared Data Base, augmented by Air Forward Pass

4.3.2.8 Case 8. This Case is representative of a common, shared, data base of correlated/fused tracks and track fragments, obtained from all active and passive sensors resident in the air and surface units of the Force, such that all participating air and surface units have a consistent tactical picture (appropriate to their area of operations) of engagement quality. Weapon guidance and control functions would be provided by the launching platform.

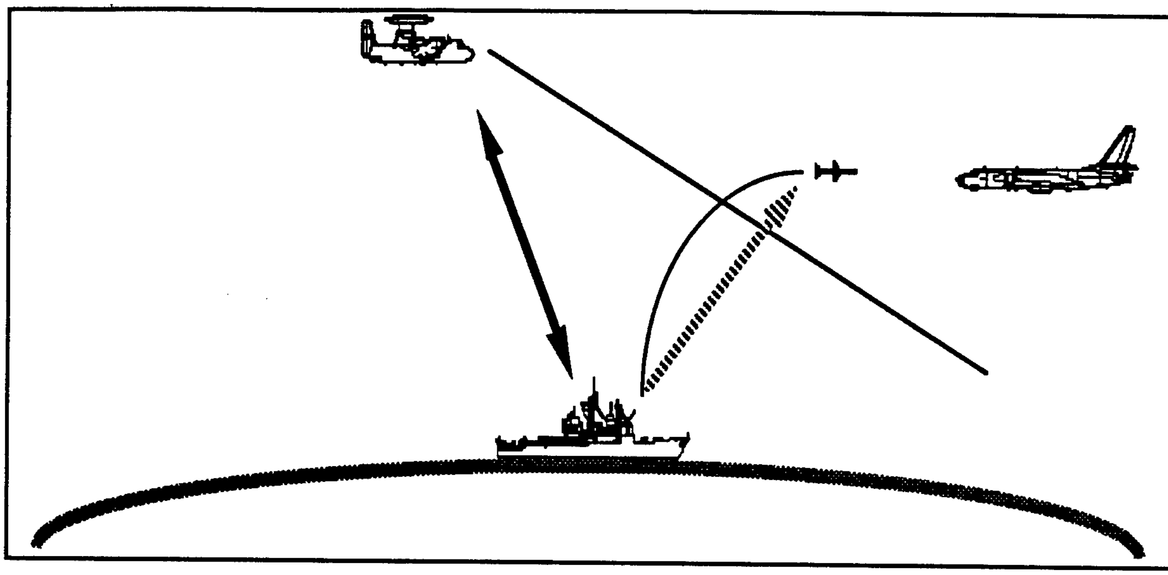


Figure 4-19. Air and Surface Shared DataBase

4.3.2.9 Case 9. This Case is representative of a common, shared, data base of correlated/fused tracks and track fragments, obtained from all active and passive sensors resident in the air and surface units of the Force, such that all participating air and surface units have a consistent tactical picture of engagement quality, with the added option to launch missiles from any air or surface unit in the Force and provide missile flight and terminal control from any properly configured air or surface unit in the Force.

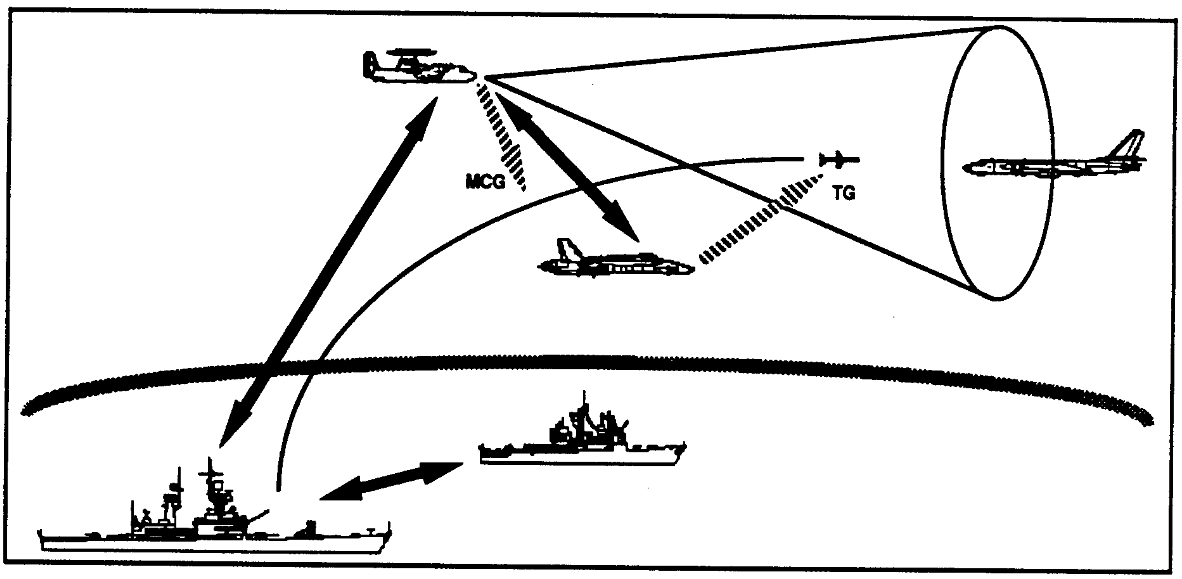


Figure 4-20. Air and Surface Shared Data Base augmented by Forward Pass

4.4 CURRENT PLUS AAW CE OPTION

4.4.1 Introduction

This section focuses on the development of a cooperative engagement architecture focused specifically on AAW applications. This section describes the CE option of the AAW current plus architecture followed by a detailed preliminary design option for AAW cooperative engagement. Its objective is to develop and describe a complete functional, physical, and detailed design option for an AAW CE architecture. The current plus functional architecture defines the AAW CE functions, the hierarchy of functions, and the relationship between AAW functions and AAW CE functions. These functional relationships are described in terms of function diagrams. Functions are mapped to physical objects, in this case platforms, and physical "wiring diagrams" are developed that connect functions and platforms to one another.

Organizational issues are discussed that arise from the feature of a CE system that allows multiple platforms to synergystically collaborate in prosecuting a single engagement.

The detailed preliminary design option for AAW Cooperative Engagement develops a functional flow diagram that can be applied to any of the AAW CE cases considered. Physical and organizational issues are examined using the detailed AAW CE architecture design option.

4.4.2 Warfare Phases

The architectural functions are organized according to the phase of Anti-Air Warfare (AAW) operations architecture (Posture Forces, Counter Platform, Counter Weapon, and Post Attack) as illustrated in Figure 4-14 and defined in the following paragraphs.

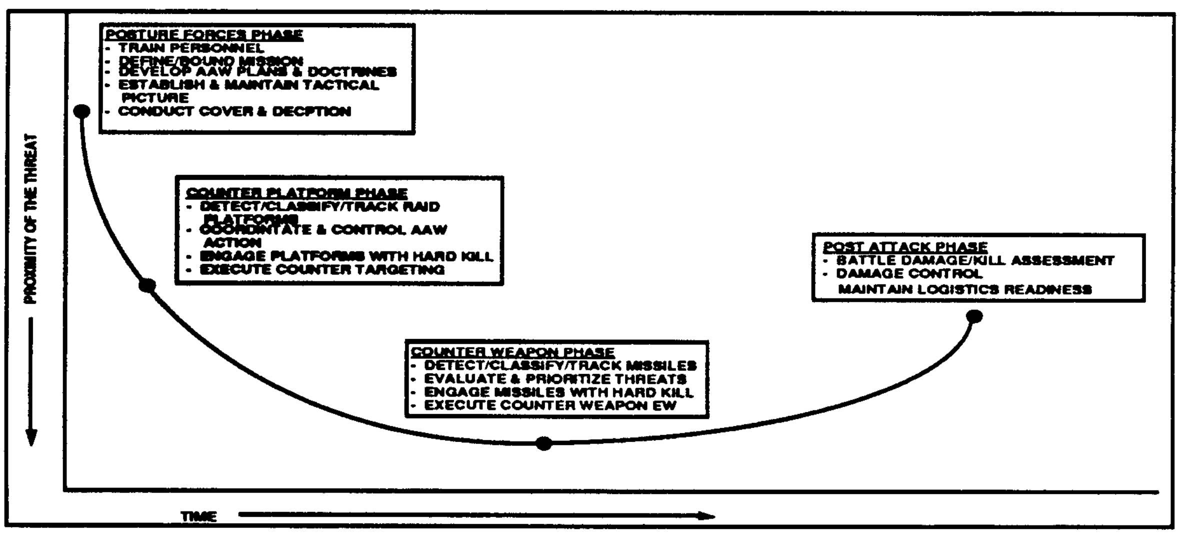


Figure 4-21. Warfare Phases and CE Functions

4.4.3 Functions

4.4.3.1 Posture Forces Phase. Own forces shall be prepared for battle and positioned in accordance with previously developed strategies and task force plans. Non-organic and organic surveillance plans shall be implemented for the cooperative tracking of all contacts within the Force area of interest. Surveillance requires consideration of a force signature management plan to minimize adversary detection and information gathering on the force and to support the OPDEC/OPSEC plans. The functions associated with the Posture Forces phase of AAW operations are Train Personnel, Define & Bound the AAW Mission, Develop AAW Plans and Doctrine, Establish & Maintain Tactical Picture, and Conduct Cover & Deception.

4.4.3.1.1 Train Personnel. The accomplishment of AAW-related training during periods of non-combat activity is essential to the successful accomplishment of the AAW requirements of the mission, including force-level AAW training in shore-based simulators and on at-sea test ranges, as appropriate, prior to deployment. AAW training shall be focused on the employment of CVBF AAW resources over a wide range of operational alternatives, ranging from highly cooperative, centralized AAW to cooperative, decentralized AAW, to coordinated, integrated AAW to widely dispersed, decentralized AAW. AAW training readiness shall be continually assessed at all command echelons and training conducted as required, both afloat and ashore. Among other things, AAW tactics, including cooperative tactics shall be developed and/or refined during the conduct of training. Maintaining strict signature control will fully satisfying the requirements for AAW is also an important task and must be practiced throughout all phases of the training cycle.

4.4.3.1.2 Define/Bound AAW Mission. Based upon tasking directives received from the Theater Commander or other higher authority, the overall force mission shall be defined and planned. The specific AAW requirements associated with the mission shall be defined, along with the critical parameters bounding the accomplishment of the AAW requirements associated with the mission. The latter shall be based upon a comparison of the assessed AAW capabilities of the forces assigned for the accomplishment of the mission with the estimated capabilities of the air threat capable forces expected to be encountered, plus any existing constraints, such as political and geographical intelligence factors beyond the control of the Officer in Tactical Command (OTC) or Force Commander. During the planning of the mission, the requirements for signature management must be evaluated in the context of the mission requirements, the sensor and weapon threat of the adversary and the AAW resources available to the OTC. As required, the OTC/Force Commander shall interact with the Theater Commander to request additional AAW forces for the accomplishment of the mission, and shall assimilate into the planning process any additional AAW forces made available either directly or indirectly (through coordinated support from Collateral Commanders).

4.4.3.1.3 Develop AAW Plans and Doctrine. Early in the mission planning process, AAW plans shall be developed for Force organic and non-organic cooperative air surveillance, AAW engagement including Command, Control and Communication Counter Measures (C3CM) and Electronic Warfare (EW), Signature Management and AAW Command and Control (C2). Embedded in the plans for surveillance and engagement must be the signature management rules along with the tactics and doctrines for changing these rules as the situation dictates. In addition, a detailed AAW command structure shall be specified for the Force and appropriate Rules of Engagement/Standard Operating Procedures (ROEs/SOPs) developed. Specific force, group, sector and Weapons Platform (WP)-level AAW surveillance and engagement doctrine shall be developed in amplification of the plans, to control delegation and automation of action. Modification of the AAW doctrine may continue throughout mission execution, in response to continuing assessment of own force and enemy capabilities and effectiveness.

4.4.3.1.4 Establish & Maintain Tactical Picture. After the AAW cooperative surveillance plan has been developed, it shall be implemented, including the required interactions with non-organic sensors and sources, the assignment of organic air sensor guard duties, and the assignment of air surveillance watch zones, air detection reporting criteria, and the assignment of air contact and track reporting responsibilities. Passive surveillance or power/sector management concepts contribute to the management of observable signals when performing this function. Communications links must be covert as part of the signature plan. A comprehensive and coherent tactical picture shall be maintained. Air contact/track data(reports) received from both organic and non-organic sources shall be correlated, fused, and evaluated. Hostile air tracks/raids shall be identified and situation displays generated, including track-related displays as well as displays of tactically significant non-track related information (e.g., force readiness data). Significant air tactical information shall be exchanged, both within the force and with activities external to the force as appropriate to their areas of responsibility.

4.4.3.1.5 Conduct Cover & Deception. Cover & Deception (C&D) and Operations Security (OPSEC) shall be conducted by the Force. Operational Cover is defined as that element of Operational Deception intended to discourage interest in the units of the force and to conceal the true mission, movement, composition, disposition, and capabilities of the force. Operational Deception (OPDEC) is defined as the employment of deception measures against the enemy with regard to own force systems, doctrines, tactics, techniques, personnel operations, and other activities. Signature management is a critical element in conducting both OPDEC and OPSEC. A successful plan may include selected radiation by AAW assets. OPSEC includes those measures taken to minimize hostile knowledge of ongoing and planned own force operations by controlling and protecting the indicators associated therewith. EMCON is an example of OPSEC. OPSEC shall be employed by weapons platforms, as directed, in the area AAW defense of the force. OPDEC shall be employed by weapons platforms, as directed, in the area AAW defense of the force.

4.4.3.2 Counter Platform Phase. Engage enemy platforms and use measures required to defeat them prior to and after enemy weapon launch. Defeat of the targeting systems and bases are included as well as defeat of the weapons platforms. Force level signature management tactics are an effective means to counter enemy platforms both prior to and after weapon release. The functions allocated to the Counter Platform phase of AAW operations are Detectt/ClassifyTrack Force Raid Platforms, Coordinate & Control AAW Action at Force Level, Engage Platforms with Hard Kill, and Execute Counter Targeting.

4.4.3.2.1 Detect/Classify/Track Force Raid Platforms. Platform positions within the force are determined within the framework of a force signature management plan. Detection, classification, and tracking of hostile launch platforms can be accomplished using a minimum of active sensors while opting for use of cooperating passive sensors. Passive detection and ranging of hostile platforms employing acquisition and search sensors can provide significant information yielding enemy location and intent. After implementing the force AAW unit stationing plans whereby the force units are positioned so as to best cooperate in detection, tracking and countering air threat platforms and after implementing the Force Air Surveillance Plan, Force units shall employ their active and passive sensors in accordance with the force air surveillance plan to detect, classify, and track threat platforms and to report thereon to other units/commanders within the Force. Multi-source, multi-platform data will be correlated, fused, and evaluated. Raid count of threat platforms is considered a part of classification. Initial evaluation to determine high interest tracks/raids shall be conducted at the platform level and used to provide overall force alerts, e.g., AEW aircraft conduct threat evaluation. Force units shall cooperatively control sensors and emissions.

4.4.3.2.2 Coordinate & Control AAW Assets At The Force Level. Once an AAW course has been decided upon, effective cooperation, coordination and control of own AAW force assets is essential to the successful accomplishment of the Force AAW mission. Such cooperation, coordination and control spans all echelons within the Force, including the OTC/CWC, the Force AAW Commander and the Weapons Platform. An integral part of this cooperation, coordination and control shall be the positioning, vectoring and refueling of the AAW assets. Coordination and control of force AAW assets must consider the implications of their action on the signature management plan. Specific tactics to counter the AAW threat can advantageously use signature management of force transmission to confuse or deny targeting information to the hostile platform.

4.4.3.2.3 Engage Platforms With Hard Kill And Soft Kill. Under the direction of the AAW Commander and in accordance with plans and doctrine, air and surface units shall cooperatively engage hostile platforms with hard kill and soft kill AAW weapons systems. These engagements shall include air and surface engagement of air threat platforms prior to and after their weapon release. Hard kill engagements of the hostile launch platforms will require selective use of force sensors if signature management control is to be maintained. Some dispersed force platforms may gain significant advantage in their AAW engagements by maintaining total silence yet receiving fire control quality data via the force tactical data network.

4.4.3.2.4 Execute Counter Targeting/Counter AAM. Cooperative Electronic Countermeasures (CECM) and Cooperative Deceptive Electronic Countermeasures (CDECM) shall be conducted by weapons platforms, as directed, in the area AAW defense of the force (as opposed to jamming in defense of own ship) and self-defense against air-to-air missiles. Deceptive ECM (DECM) employed by select force units can provide effective counter targeting capabilities. Force high value units can maintain emission control "silence" while dispersed units use DECM to deny and confuse information obtained by enemy surveillance, reconnaissance and targeting assets.The intention of these actions is to deny and/or delay threat targeting of own forces by the threat air platforms.

4.4.3.3 Counter Weapon Phase. Cooperatively Engage enemy weapons which threaten the battle group units and use measures required to defeat them with minimum damage to own forces. Tactics to counter enemy weapons shall include the use of force signature management actions. The functions included in the Counter Weapon phase of AAW operations are Detect/Fuse/ Correlate/Classify/Track Missiles, Evaluate & Prioritize Threats, Engage Missiles with Hard Kill, and Execute Defensive EW.

4.4.3.3.1 Detect/Classify/Track Missiles. After implementing the force AAW unit stationing plans whereby the force units are positioned so as to best counter threat missiles and after implementing the Force Air Surveillance Plan, Force units shall employ their active and passive sensors in accordance with the Force Air Surveillance Plan to cooperatively detect, fuse, correlate, classify, and track missiles and to report thereon to other units/commanders within the Force. Force units shall cooperatively control sensors and emissions. Stationed platforms will detect/classify/track missiles by employing a mix of both active and passive sensors. This action shall be taken with the goal of maintaining force signature management plans. The fusion/correlation of data obtained from passive sensors dispersed among cooperating units can minimize individual platform active transmissions.

4.4.3.3.2 Evaluate & Prioritize Threats. Evaluation of the threat level, urgency, and the relative threat ranking of the various air threat tracks shall be conducted so as to develop the information needed to weigh offensive and defensive initiatives and to support decisions on specific AAW weapons actions. Coordination and cooperative use of hard and soft kill AAW assets shall be accomplished throughout the mission. The threat evaluation/prioritization process shall include considerations for maintaining force signature management plans. The offensive and defensive limitations which are developed to counter the threat should weigh the need for employing active sensors. Cooperative use of passive sensing can support the evaluation/prioritization process.

4.4.3.3.3 Coordinate And Control Assets. Once an AAW course has been decided upon, effective cooperation, coordination and control of own AAW force assets is essential to the successful accomplishment of the Force AAW mission. Such cooperation, coordination and control spans all echelons within the Force, including the OTC/CWC, the Force AAW Commander and the Weapons Platform. An integral part of this cooperation, coordination and control shall be the positioning, vectoring and refueling of the AAW assets. Specific tactics to counter the AAW threat can advantageously use signature management of force transmission to confuse or deny targeting information to the hostile platform.

4.4.3.3.4 Engage Missiles With Hard Kill. Under the direction of the AAW Commander, air and surface units shall engage hostile missiles with hard-kill AAW weapons systems. These engagements include both close-in self-defense engagements of own unit as well as inner and outer area engagements in cooperation with other platforms in the overall defense of the Force. Hard kill engagement of missiles will require the use of active emissions for some force platforms. However, force defense can be strengthened by the selective use of active sensors operated under the auspices of a force signature management plan. Anti-radiation missiles (ARM) pose a serious challenge to the battle force, but their effects can be reduced by selectively employing active transmissions. Weapons platforms may engage inbound missiles using fire control data obtained from other platforms.

4.4.3.3.5 Execute Defensive EW. Active Electronic Countermeasures (ECM), Deceptive Electronic Countermeasures (DECM) and Electronic Counter-Countermeasures (ECCM) shall be employed cooperatively by the Force to defend against missiles to own ship or aircraft. Defensive EW signatures shall be executed with the goal of maintaining force signature management plans. Active electronic countermeasures (AECM) shall be employed by cooperating units to the level required to defeat missile homing functions. Deceptive ECM (DECM) can be tactically used to provide force cover and deception capabilities. DECM employed by a few select units of the force can confuse enemy surveillance, reconnaissance, acquisition and targeting activities.

4.4.3.4 Post Attack Phase. Use Cooperative sensing to Monitor and assess battle damage to enemy and own forces and modify weapon platform stationing and logistics force tasks to continue the battle. The functions of this phase are Battle Damage/Kill Assessment, Damage Control, and Maintain Logistics Readiness. As a part of battle damage assessment, cooperative sensing will monitor the level to which own forces have maintained and will continue to maintain force signature management procedures. Repositioning of weapon platforms may be required in order to continue signature management plans.

4.4.3.4.1 Battle Damage / Kill Assessment. The configuration and readiness status of all systems installed in each weapons platform shall be automatically monitored on each individual platform and automatically reported to the Anti-Air Warfare Commander and entered into the engagement scheduler so that required actions can be taken to engage or reengage targets; correct degradations in equipment readiness due to battle casualties, weapon expenditures or other reasons; and to reconfigure systems as required while corrective actions are being taken. Each individual platform shall monitor and report compliance (or ability to comply) with the battle force signature management plan. The inability to adhere to force signature management tactics will require reconfiguration of that platform's role in providing mission critical functions.

4.4.3.4.2 Damage Control. The reconfiguration of AAW mission critical functions, including command structure reconfiguration, shall be performed automatically as necessary. Minimization and containment of battle damage inflicted to own force AAW assets shall be performed throughout the AAW mission. Reconfiguration of battle force units must consider the implications on the force signature management plan. As required, selective "active" assets are activated in order to maintain mission critical functions while the goal of minimizing fleet emissions is maintained.

4.4.3.4.3 Maintain Logistics Readiness. Based upon reported logistics requirements received from individual Weapons Platforms, and upon the availability of underway replenishment forces plus the availability of pre-positioned replenishment sites, the OTC shall control/coordinate the AAW replenishment of the Force. The Composite Warfare Commander/ Force AAWC (CWC/FAAWC) shall be responsible for monitoring equipment readiness/configuration within the force and for coordinating the utilization of force-level maintenance assets (equipment and personnel) to effect AAW equipment repairs. As part of a comprehensive force level logistics plan, individual platforms must report their level of ability to comply with force signature management plans. Maintenance or replenishment of platform assets must be carried out to insure maximum force readiness. Reconfiguration of force disposition may be required when individual platforms can not meet their signature management duties.

4.4.4 Operational Functions Mapping

Paragraph 4.2 of this report presented a mapping or allocation of current AAW architecture ROFs to operational platforms within each of the AAW battle phases (Posture Forces, Counter Platform, Counter Weapon, and Post Attack). Subsequent paragraphs have discussed functions required for AAW cooperative engagement. Figures 4-22, 4-23, 4-24 and 4-25 illustrate these ROFs and platform-level operational functions in the same format as in Figures 4-8 through 4-11.

4.4.5 AAW/Cooperative Engagement Functional Mapping

To provide a departure point for further functional mapping, e.g to individual ship classes, Figures 4-26, 4-27, 4-28, and 4-29 illustrate the allocations of platform-level operational functions to non-organic, organic, and battle force commander echelons.

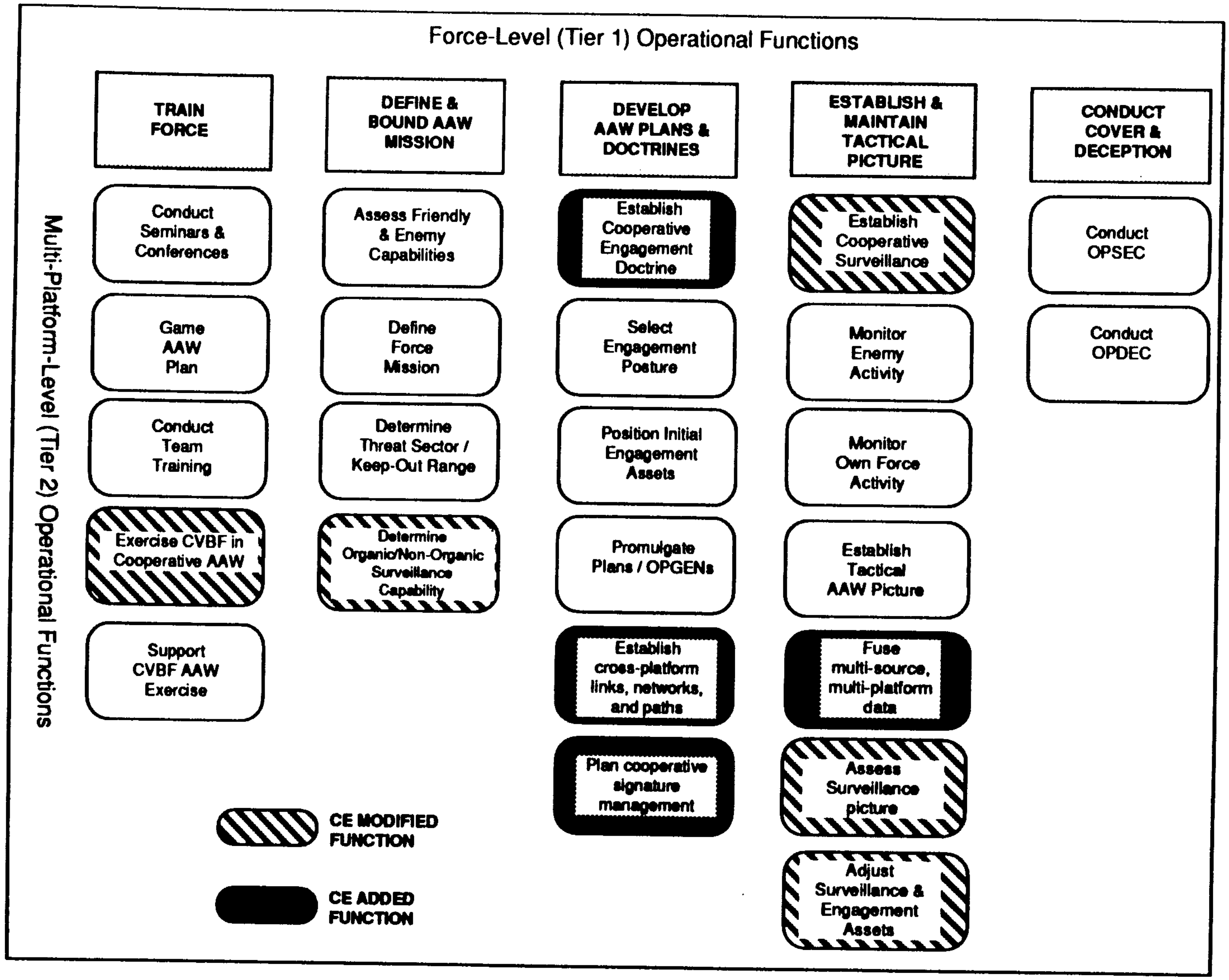


Figure 4-22 Force Level Operational Functions (Posture Forces Phase)

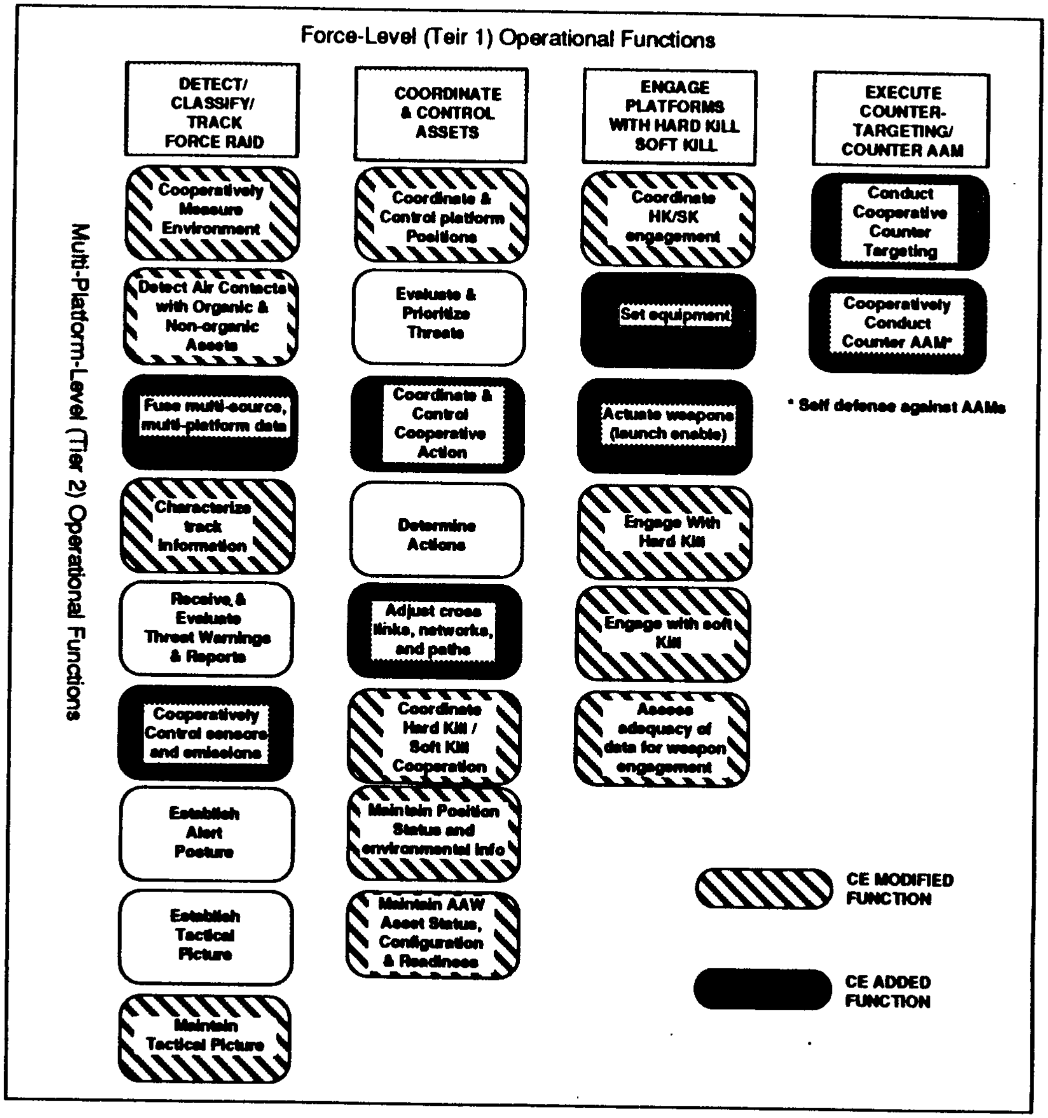


Figure 4-23 Force Level Operational Functions
(Counter Platform Phase)

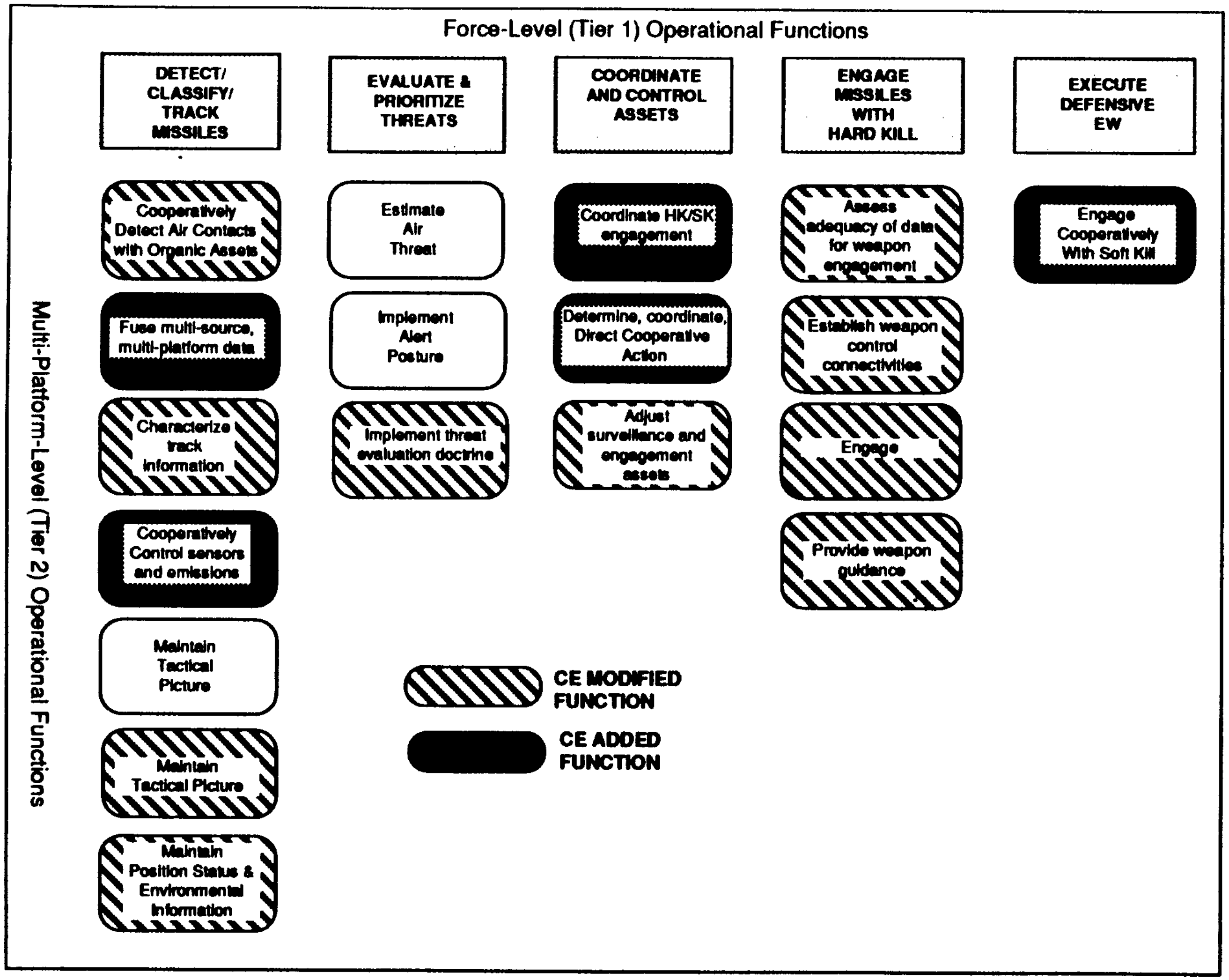


Figure 4-24. Force Level Operational Functions
(Counter Weapon Phase)

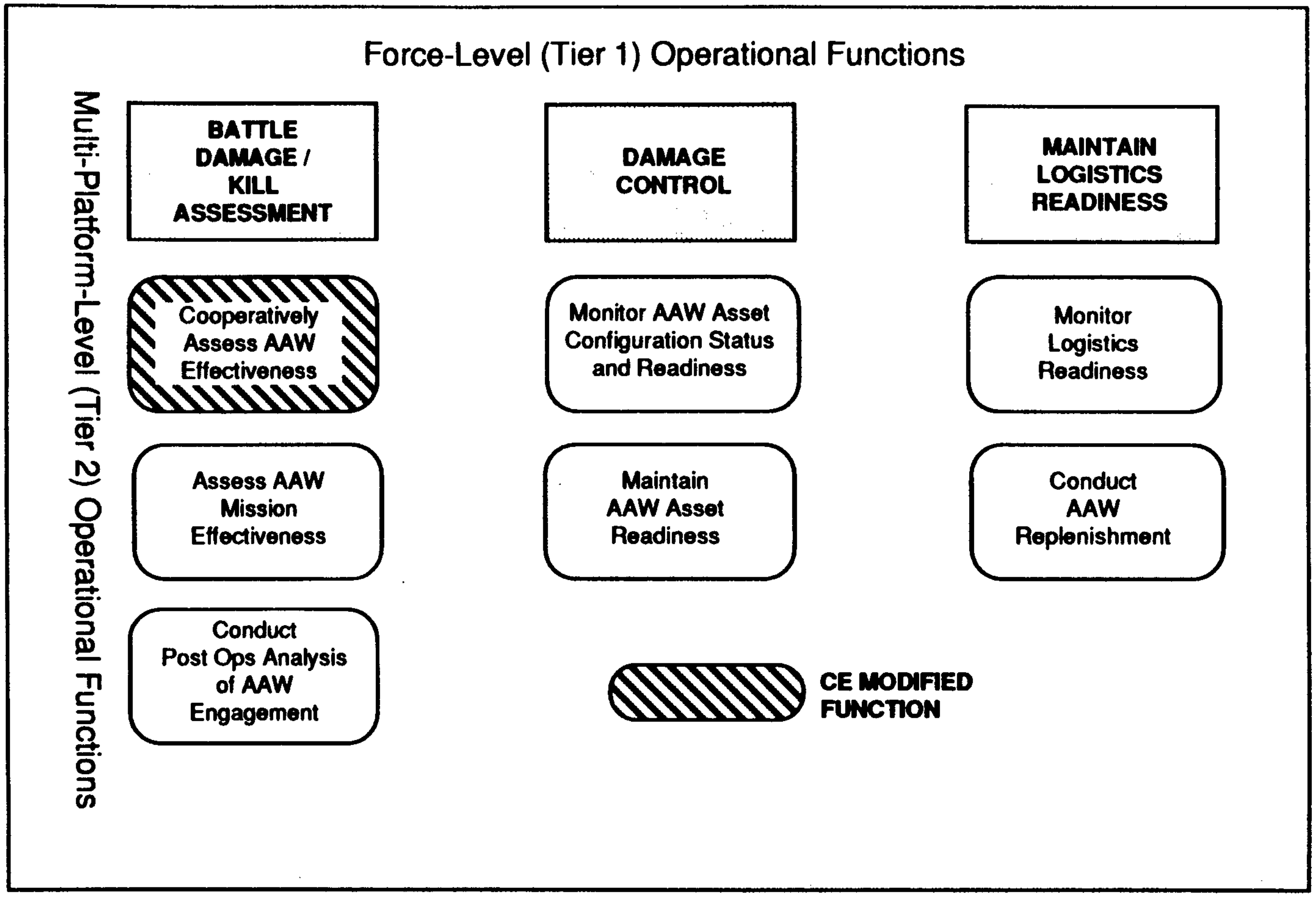


Figure 4-25. Force Level Operational Functions
(Post Attack Phase)

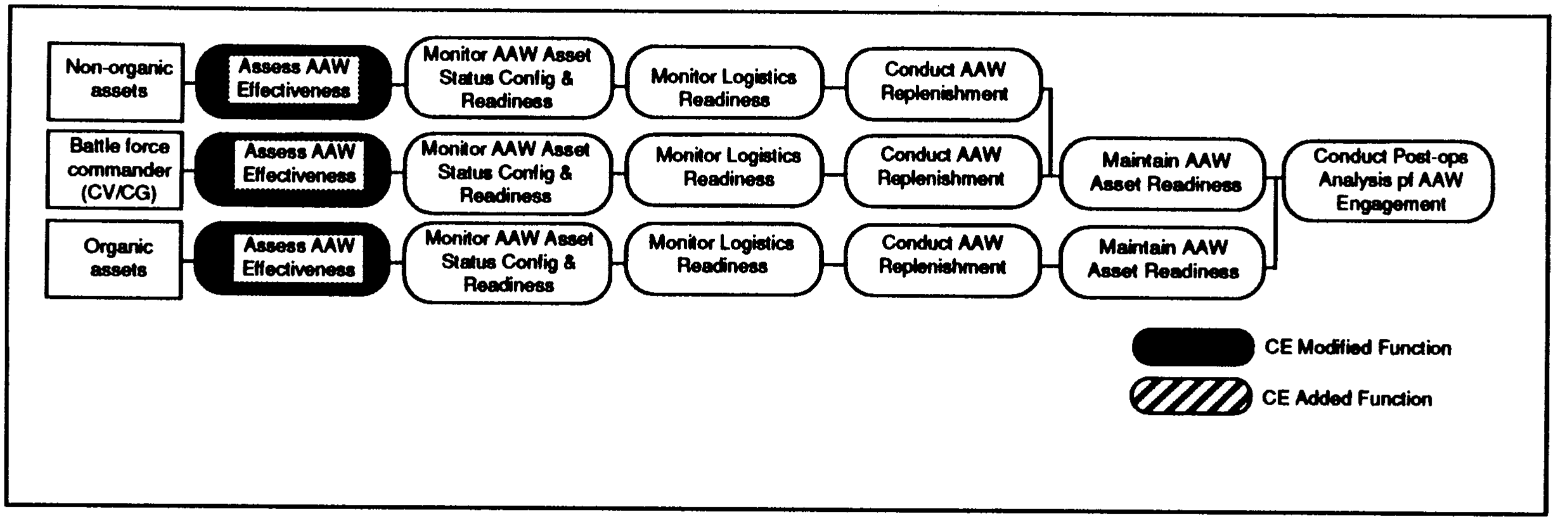


Figure 4-26. Posture Forces Phase Functional Allocation

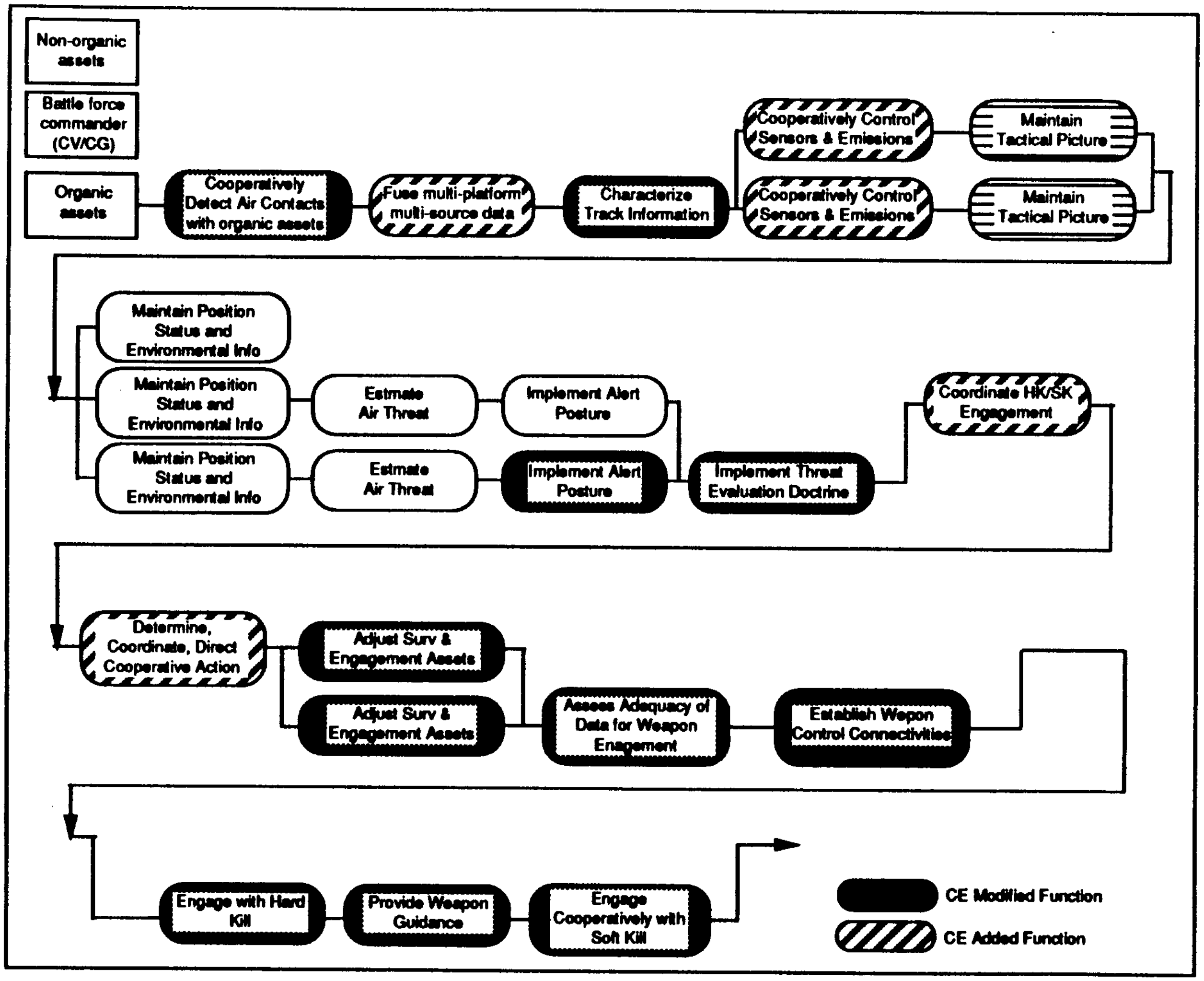


Figure 4-27 Counter Platform Phase Functional Allocation

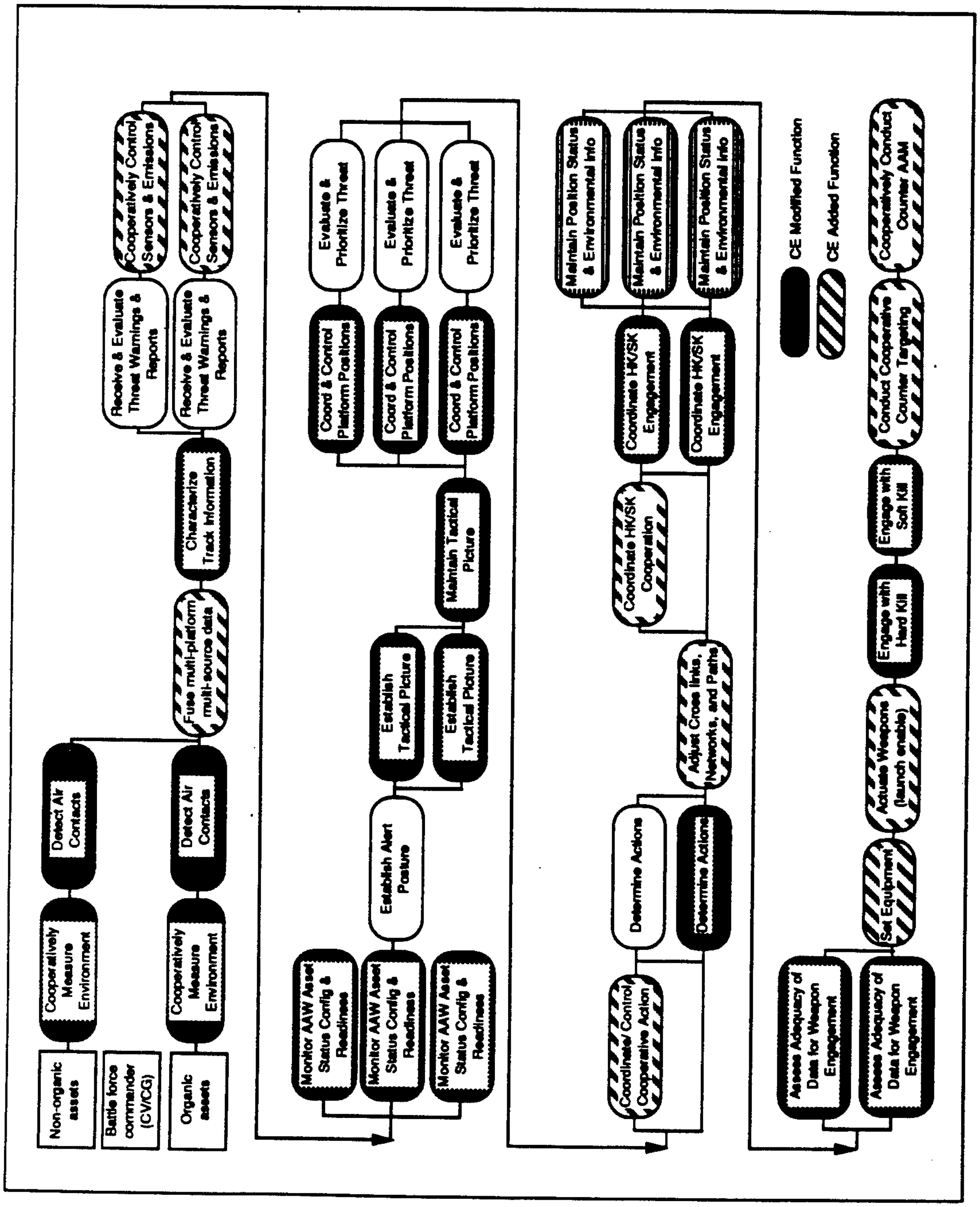


Figure 4-28. Counter Weapon Phase Functional Allocation

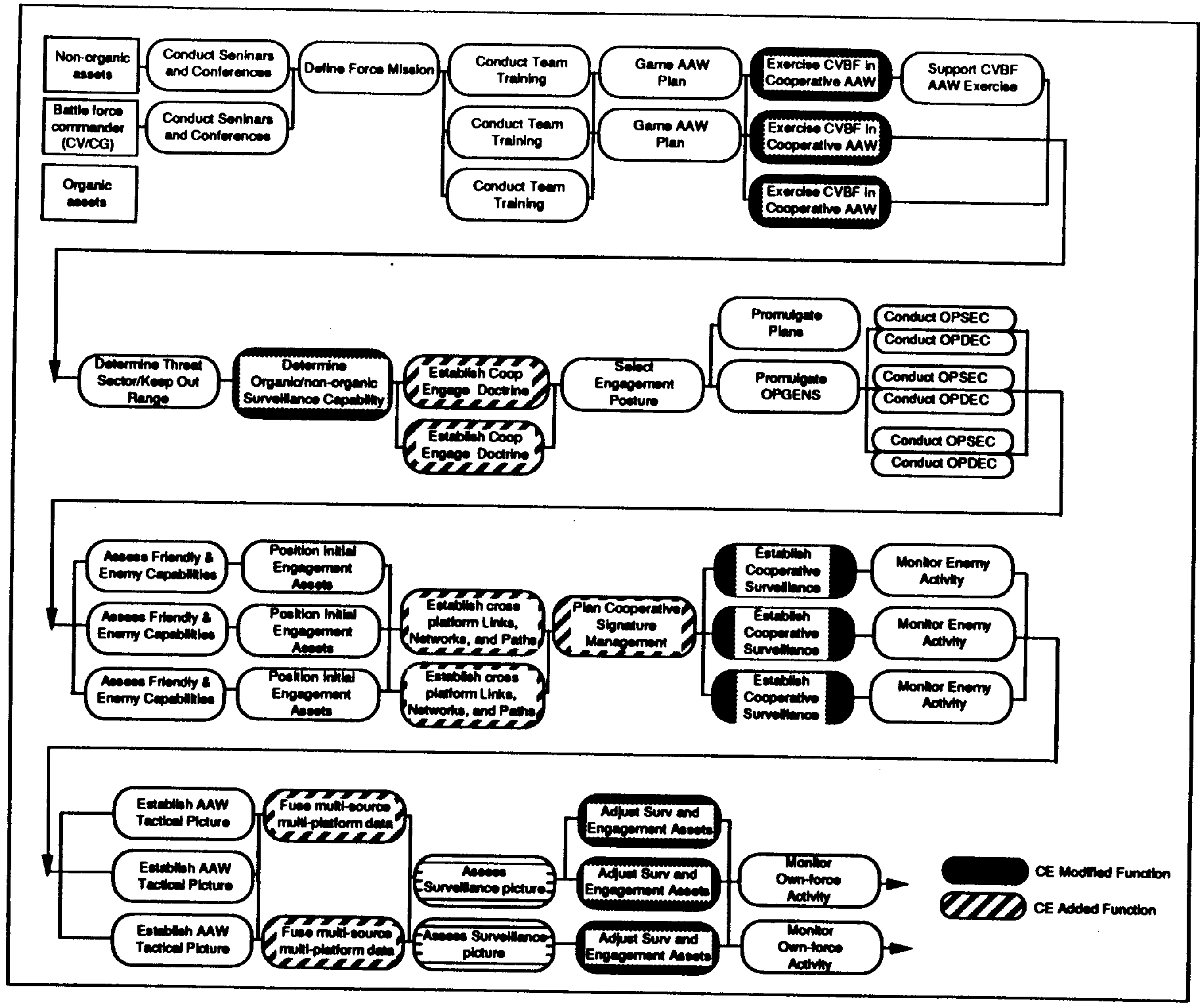


Figure 4-29 Post Attack Phase Functional Allocation

4.4.6 Physical Architecture

4.4.6.1 Physical Components. Notional physical components of the goal (level 9) cooperative engagement physical architecture are discussed in paragraph 4.4.6.2, Attributes of the notional physical architecture components. These are "black box"systems descriptions that may be updates or modifications of existing or planned systems. The notional systems are merely handy ways to depict the physical architecture in an easily interpreted fashion. The selected acronyms are intended to be descriptive of the functions that need to be performed and the manner in which those functions are interconnected, and are not intended to imply whether any existing or planned system does, will do, or could be modified to perform all or part of the required functionality. In several places, especially the surface platforms, the term CE has been added to system names such as Aegis C&D to imply a similar equipment with CE capability is required.

It is obvious from previous discussion that only portions of the goal architecture may be developed at a given time and that the entire level 9 architecture may never be built, however, the physical architecture as depicted is still applicable to any platform incorporating cooperative engagement and to any degree that cooperative engagement is developed.

The concept used in developing the physical architecture assumed that the objective of CE was the efficient use of all available sensors to provide accurate tactical data that would allow timely application of weapons to targets. The physical architecture did not, therefore, assume any changes to sensors currently on platforms. Rather, the assumption inherent in the architecture is that sensor improvements will continue apace with sensor technology and that CE would still be the connecting tissue insuring intelligent use of the available sensor data.

The development of the notional systems was based on the idea that each platform in the fleet has a suite of sensors of various types, some more applicable to AAW than others, but many with at least some capability to support AAW engagements. Many of these platforms currently have no AAW support mission requirements. Should these platforms receive AAW related data from their sensors it is likely that it is filtered out, ie., an ASW aircraft looking for periscopes would likely filter out radar returns from a fast sea skimmer missile, while that data could be critical to fleet AAW defense. A CE system configured to accept such data might allow targeting of a SAM against the sea skimmer based on data from the ASW aircraft.

The notional architecture models the following process.

1. Each platform fuses and correlates data from its onboard sensors.

2. Each platform then passes the processed data to other platforms in the data net hierarchy.

3. Platforms with multi-platform fusion capability fuse and correlate data received from other platforms with data from onboard sensors.

4. Processed data is thus passed up the data net hierarchy with processing at each higher level node until the most capable platform produces a complete tactical display based on fusion and correlation from all participating platforms and sensors,

5. The appropriate sector of the tactical display is transmitted back to the platforms assigned to engage enemy targets along with engagement commands (which may be predetermined doctrine or actual real time commands).

6. Engaging platforms launch weapons and update them based on the fused and correlated data picture. Communications relays may be used to update weapons over-the-horizon.

4.4.6.2 Attributes of the notional physical architecture components. The following paragraphs describe the functional characteristics of the notional components of the goal physical architecture. Table 4-1 lists notional systems used in the Physical Architecture System/Interface for cooperative engagements. Each of these notional systems is further described in the following paragraphs.

- DATA/COMMAND (CE Data and Command Communications Network) - A Cooperative Engagement Communications System must have a sufficient capacity to support the correlation and fusion process; support the position reporting process; redistribute correlated and fused tactical data back to all interested platforms; carry engagement commands; and support weapon update communications. A " split-screen" capability must be developed to distribute correlated and fused data to platforms such that each platform would receive a display of all targets that were within or predicted to enter its weapons kinematic range; a display of all targets that were within or predicted to enter its sensor's range; and, depending on the responsibilities of the platform, all or part of the overall tactical picture. Targets within or predicted to enter weapons kiematic range would be candidates for engagement by that platform based on the composite track independent of the location of the sensors providing data.

- CAPAS (Continuous Automatic Position and Asset Status) - The ability to know the position of all platforms in relation to all other platforms with sufficient accuracy to allow fusion of multi-source data if required. This position accuracy would allow the force to obtain accurate tracks on targets and accurately track and guide weapons to those targets.

Table 4-1. AAW Notional Systems

Notional System	Description
DATA/COMMAND	Cooperative Engagement Data and Command Communications Network
CAPAS	Continuous Automatic Position and Asset Status
MPFP	Multi-Platform Fusion Processor
IADT	Integrated Automatic Detection and Track
CE-ATDS	Cooperative Engagement Compatible Airborne Tactical Data System
CE-CDS/CE C&D	Cooperative Engagement Compatible Combat Direction System/Command and Decision System
ARASTD	Area of Responsibility All Source Track Display
CE AAAM	Cooperative Engagement Compatible Advanced Air to Air Missile
CE SAM	Cooperative Engagement Compatible Surface to Air Missile
CEWS	Cooperative Electronic Warfare System
ICNIA	Integrated Communications, Navigation, Identification, and Avionics

- MPFP (Multi-Platform Fusion Processor)- A Force fusion capability is required to correlate and fuse data as completely as possible on each platform to reduce the volume of data communications as the information funnels to platforms with more processing capability. Subsets of fusion capability may involve correlation/fusion of data from identical platforms such as all F-14s in a sector or all Aegis ships (much like DDS/CEP today) prior to fusion of data from dissimilar platforms at higher levels. The multi-sensor nature of the fusion process would allow very accurate assessment of target behavior immediately after an engagement, so that any need for reengagement could be readily determined. This same process would allow determination of the effects of Electronic Warfare engagements on a target's behavior. A key element of any cooperative engagement architecture will be a concept of operations that locates platforms to provide overlapping zones with multi-sensor coverage. This coverage would be designed to ensure various, simultaneous aspect angles on any target so that data fusion would result in the ability to track and ultimately engage even low observable (LO) targets.

- IADT (Integrated Automatic Detection and Track) - Fusion capability that correlates and fuses data as completely as possible on each platform to reduce the volume of data communications as the information funnels to platforms with more processing capability. Subsets of fusion capability may involve correlation/fusion of data from identical platforms such as all F-14s in a sector or all Aegis ships (much like DDS today) prior to fusion of data from dissimilar platforms at higher levels.

- CE-ATDS (CE Compatible Airborne Tactical Data System) -
  CE-CDS (CE Combat Direction System -
  CE-C&D (CE Command & Decision) - Cooperative Engagement doctrine would be established in much the same fashion as current force doctrine with nets, subnets, sectors, and Rules Of Engagement. The difference would be found in the options for overall Force Management that would be made available by an engagement quality Force-Wide Tactical Picture and by the expanded engagement envelopes for each platform in the force. Individual platforms would always retain the capability to operate autonomously based on the tactical picture generated by own ship sensors or whatever support was available, such as embarked LAMPS or RPV's. Engagements would be assigned according to preestablished doctrine as composite tracks were developed to engagement quality. A platform could engage any target assigned that was within or predicted to enter its weapon's kinematic range. It would not be necessary to schedule other platforms to "Forward Pass," i.e., provide mid-course guidance, or provide terminal illumination. It would be necessary to maintain the surveillance posture and thus maintain the composite

track and relay geometry when the target is beyond the shooter's horizon (physical or electronic).

- ARASTD (Area of Responsibility All Source Track Display) - A "split-screen" capability must be developed to distribute correlated and fused data to platforms such that each platform receives all available information applicable to its area of responsibility, but limited extraneous data. Ultimately each platform would receive a display of all targets that were within or predicted to enter its weapons kinematic range; a display of all targets that were within or predicted to enter its sensor's range; and, depending on the responsibilities of the platform all or part of the overall tactical picture. Targets within or predicted to enter weapons kinematic range would be candidates for engagement by that platform based on the composite track independent of the location of the sensors providing data.

- CE AAAM/CE SAM (CE Compatible Air To Air Missile/CE Compatible Surface To Air Missile) - The goal of Cooperative Engagement is to allow a force to use all its weapons to the limits of their kinematic capabilities in the face of enemy countermeasures or physical and environmental influences that limit an individual platform's ability to support engagements. The way around these physical limitations is to provide offboard information to the engaging platform sufficient for initial targeting and then to continue providing offboard information as the engagement proceeds so that the engaging platform can update the weapon as it proceeds to the target. Weapons updates would continue at appropriate intervals until the weapons was within a terminal acquisition basket at which point the weapon would proceed autonomously after signalling target acquisition. Communications to the weapon in command-all-the-way mode could originate from the engaging platform and proceed via relays by the most advantageous (LPI, JAM RESISTANT) route to the weapon. Platforms providing offboard sensor data to the engaging platform would also be in position to act as relays for weapons updates. The important aspect of multipath weapon updates is the avoidance of communication directly into the path of jamming where the engaging platform is most likely to be. The engaging platform would initiate the weapons based on the composite track data, launch the weapon, and provide all missile updates via relays. This results in a very simple coordination and control system without the contrived line-up of platforms and the physical limitations of "Forward Pass" with terminal illumination. Additionally, a weapon could be assigned a code by the engaging platform so that only updates tagged with that code would be accepted by the weapon. As a backup, any other platform holding the same composite track could be provided with the missile code and provide the weapon updates in case of a casualty on the launching platform.

- CEWS (Cooperative Electronic Warfare System) - Electronic Warfare engagements could be coordinated and controlled based on target characteristics established as a result of the multi-sensor fusion process. The multi-sensor nature of the fusion process would allow very accurate assessment of target behavior immediately after an engagement, so that any need for reengagement could be readily determined. This same process would allow determination of the effects of Electronic Warfare engagements on a target's behavior.

- ICNIA (Integrated Communications, Navigation, Identification, and Avionics) - Aircraft housekeeping functions that feed into IADT, CAPAS and MPFP.

4.4.7 Physical wiring diagram

Figure 4-30 is the physical description of the CE option (Level 9) to the AAW Current Plus Architecture. The architectural philosophy is followed across all platforms in the Battle Force by tying all sensors on each platform to an onboard fusion processor then connecting all platforms to the CE data and command communications net. Thus all AAW data is integrated into the data net no matter whether the source is an AEW aircraft, an ASW aircraft, or any other platform, and all platforms can participate in guiding weapons to targets by serving as communications relays. The concept is flexible in that platforms can be phased into net participation as priorities dictate and as upgrades are developed. It should be noted that the CE-SAM and the CE-AAM are illustrated as net participants. This could mean that missiles are actually using targeting data from the data net to plot own course to target or that course updates are being sent to the missile via the command net. In any case the idea is to break the dedicated launcher to missile link requirement to eliminate horizon restrictions on engagements.

4.4.8 Organizational Issues

4.4.8.1 Command Structures. The command structure with cooperative engagement capability would be essentially the same as it is today. The difference would be found in the options for overall force management that would be made available by an extremely accurate force-wide tactical picture and by the expanded engagement envelopes for each platform in the force. Cooperative engagement doctrine would be established in much the same fashion as current force doctrine with nets, subnets, sectors, and rules of engagement. Individual platforms would always retain the capability to operate autonomously based on the tactical picture generated by own ship sensors or whatever support was available, such as embarked LAMPS or RPVs.

4.4.8.2 Battle Management. Improvements in force management brought about by cooperative engagement enable the following operational options:

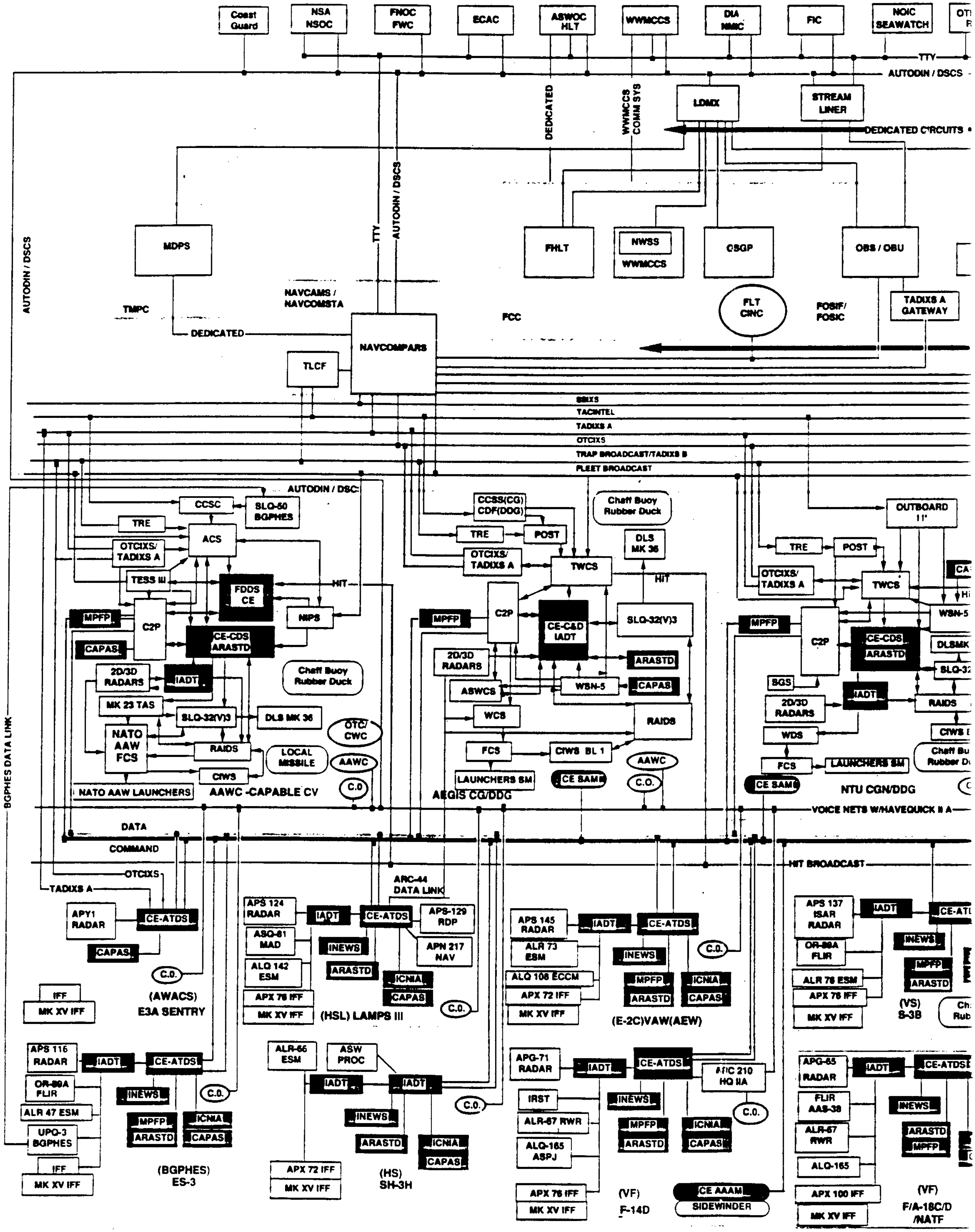
- Platforms could be positioned to exploit aspect angle detections on potential targets. This could allow tracking of low observables threats via overlapping zones, multi-sensor coverage, and data fusion.

- Platforms could be positioned to put layering of sensors (i.e., greater sensor depth) along the expected threat axis. This platform/sensor mix would be tailored to the expected threat type (i.e., Sub-launched Low Fliers, Bombers, Bomber Launched High Flyers).

- Distribution of the tactical picture to platforms could be managed so that platforms could see what they need to see without being overwhelmed with data they don't need. The distribution could be selected via a platform's area of responsibility or alternatively by the engagement envelopes of the platform's weapons.

- Management of EW at the force level improves cooperative soft kill options (e.g., counter targeting as well as allowing force-wide signature management options).

- The ability to reconfigure areas of responsibility as platforms are lost or replaced allows for graceful degradation. The ultimate fallback would allow for autonomous vice cooperative operation.



Coast Guard
NSA NSOC
FNOC FWC
ECAC
ASWOC HLT
WWMCCS
DIA NMIC
FIC
NOIC SEAWATCH
TTY
AUTODIN / DSCS
DEDICATED
WWMCCS COMM SYS
LDMX
STREAM LINER
DEDICATED CIRCUITS
AUTODIN / DSCS
MDPS
TTY
FHLT
NWSS
WWMCCS
CSGP
OBS / OBU
TMPC
NAVCAMS / NAVCOMSTA
FLT CINC
FOSIF/ FOSIC
TADIXS A GATEWAY
FCC
DEDICATED
NAVCOMPARS
TLCF
SSIXS
TACINTEL
TADIXS A
OTCIXS
TRAP BROADCAST/TADIXS B
FLEET BROADCAST
AUTODIN / DSC
CCSC
SLQ-50 BGPHES
TRE
ACS
OTCIXS/ TADIXS A
TESS III
FDDS CE
HIT
NIPS
MPFP
C2P
CE-CDS ARASTD
CAPAS
2D/3D RADARS
IADT
Chaff Buoy Rubber Duck
MK 23 TAS
SLQ-32(V)3
DLS MK 36
NATO AAW FCS
RAIDS
LOCAL MISSILE
OTC/ CWC
AAWC
CIWS
C.O
NATO AAW LAUNCHERS
AAWC -CAPABLE CV
CCSS(CG) CDF(DDG)
Chaff Buoy Rubber Duck
TRE
POST
DLS MK 36
OTCIXS/ TADIXS A
TWCS
HIT
MPFP
C2P
CE-C&D IADT
SLQ-32(V)3
2D/3D RADARS
ARASTD
ASWCS
WSN-5
CAPAS
WCS
RAIDS
FCS
CIWS BL 1
AAWC
LAUNCHERS SM
CE SAM
C.O.
AEGIS CG/DDG
OUTBOARD II
TRE
POST
OTCIXS/ TADIXS A
TWCS
MPFP
C2P
CE-CDS ARASTD
BGS
2D/3D RADARS
IADT
RAIDS
WDS
FCS
LAUNCHERS SM
CE SAM
NTU CGN/DDG
VOICE NETS W/HAVEQUICK II A
DATA
COMMAND
HIT BROADCAST
BGPHES DATA LINK
OTCIXS
TADIXS A
ARC-44 DATA LINK
APY1 RADAR
CE-ATDS
CAPAS
C.O.
IFF
MK XV IFF
(AWACS) E3A SENTRY
APS 124 RADAR
IADT
CE-ATDS
APS-129 RDP
ASQ-81 MAD
INEWS
APN 217 NAV
ALQ 142 ESM
ARASTD
ICNIA
CAPAS
APX 76 IFF
MK XV IFF
(HSL) LAMPS III
C.O.
APS 145 RADAR
IADT
CE-ATDS
ALR 73 ESM
INEWS
C.O.
ALQ 108 ECCM
MPFP
ICNIA
APX 72 IFF
ARASTD
CAPAS
MK XV IFF
(E-2C)VAW(AEW)
APS 137 ISAR RADAR
IADT
OR-89A FLIR
INEWS
ALR 76 ESM
MPFP
APX 76 IFF
ARASTD
(VS) S-3B
MK XV IFF
APS 116 RADAR
IADT
CE-ATDS
OR-89A FLIR
INEWS
C.O.
ALR 47 ESM
MPFP
ICNIA
UPQ-3 BGPHES
ARASTD
CAPAS
IFF
MK XV IFF
(BGPHES) ES-3
ALR-66 ESM
ASW PROC
IADT
IADT
C.O.
INEWS
ARASTD
ICNIA
CAPAS
APX 72 IFF
MK XV IFF
(HS) SH-3H
APG-71 RADAR
IADT
CE-ATDS
MIC 210 HQ IIA
IRST
INEWS
C.O.
ALR-67 RWR
MPFP
ICNIA
ALQ-165 ASPJ
ARASTD
CAPAS
APX 76 IFF
MK XV IFF
(VF) F-14D
CE AAAM
SIDEWINDER
APG-65 RADAR
IADT
CE-ATDS
FLIR AAS-38
INEWS
ALR-67 RWR
ARASTD
MPFP
ALQ-165
APX 100 IFF
MK XV IFF
(VF) F/A-18C/D /NATF

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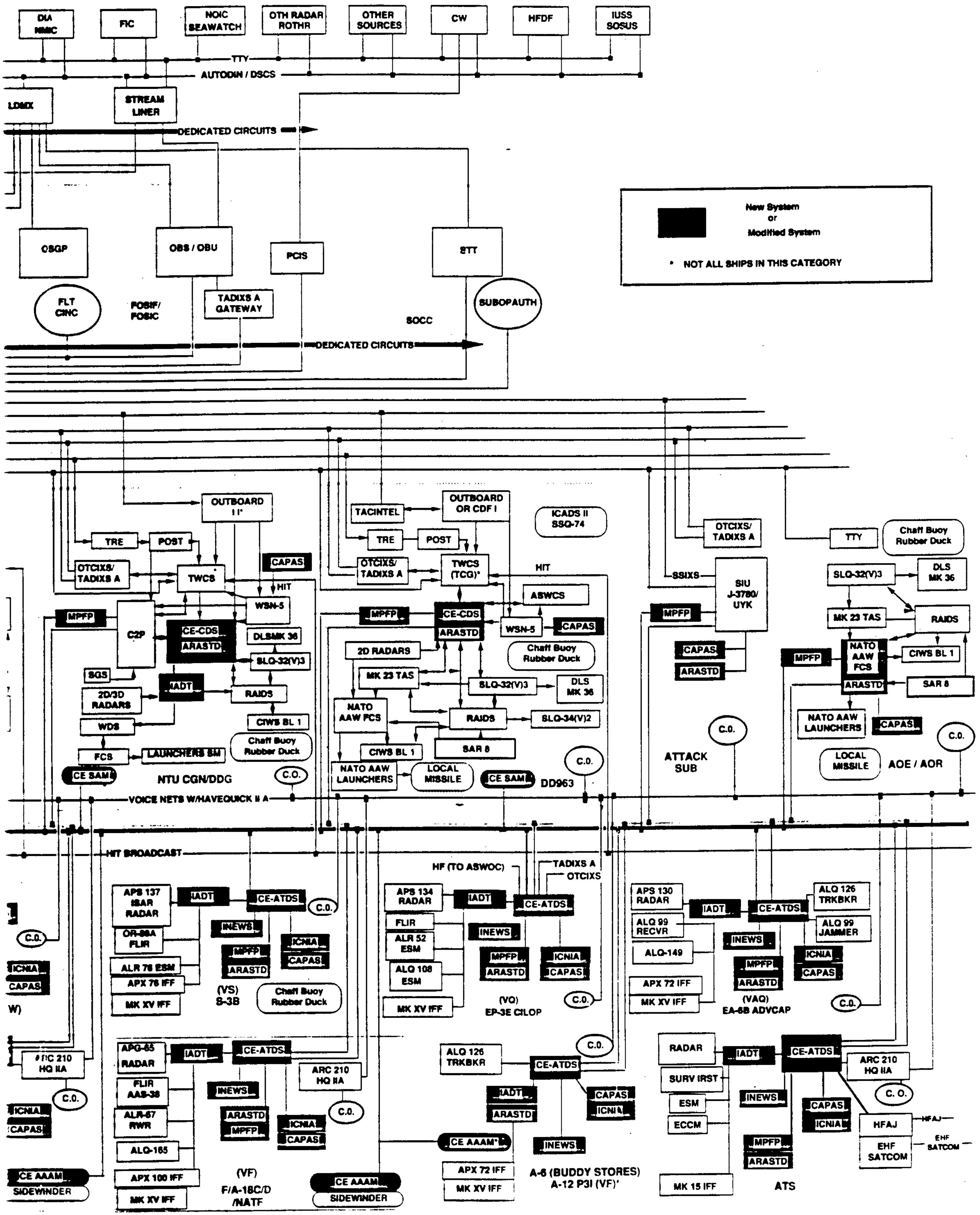

Figure 4-30. AAW Current Plus

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5. ANALYSIS AND EVALUATION

5.1 ASSESSMENT

5.1.1 General

By and large there are no unique measures of effectiveness for CE. Models and simulations containing general measures of effectiveness which include parameterized communications controls can be exercised to reflect that differences between traditional coordinated operations and proposed cooperative operations. Some problems may be encountered in an evaluation of CE. First, most models currently assume perfect communications or provide at best some probabilistic value. Second, new operational concepts and tactics are required in order to maximize the contributions of CE which have not yet been developed, thus limiting the scope of analysis severely. Third, current simulators, especially man-in-the-loop, cannot be configured to accommodate cooperative engagement without imposing additional task loading on the operator.

To be effective CE must:

- Provide sufficiently precise targeting information for the selected weapon(s) to successfully acquire the intended target(s)
- Permit target engagement at times and ranges that preserve tactical advantage
- Enable significantly more engagement opportunities against intermittent targets
- Ensure that the risks in each of the following categories do not exceed acceptable (TLWR) levels:
  - blue losses to red
  - blue and friendly/neutral losses to blue
  - misclassification of red

5.2 PRELIMINARY QUALITATIVE ASSESSMENT

As discussed in Section 2 and 4 of this report, threat examples and sample configurations (Cases) have been used as the basis for both the conceptual and the AAW cooperative engagement architecture. The five threat examples discussed in paragraph 2.6 are further defined here in paragraphs 5.2.2 through 5.2.6 and illustrated in Figures 5-1 through 5-5 and provide the basis for the assessment discussed in this chapter.

5.2.1 Assumptions

During the development of the architecture and evaluation of the examples and cases, a number of characteristics of the architecture were noted which are assumed in most of the analyses.

- Functional system capability
  - standard operating mode
  - covers entire sensor-to-shooter spectrum
- Tactical picture
  - coherent, consistent, and complete within the Force as needed
  - combined surveillance and fire control database
  - all warfare mission areas and spatial media
  - data abstraction techniques
  - sophisticated display capabilities
  - extensive decision support capabilities
- Connectivity
  - high capacity, realtime network
  - responsive, redundant, secure, and covert
  - linking all Force group or sub-group units
- Navigation
  - accurate, standardized positional coordinate system for all warfare mission areas and domains
- Signature (emissions)
  - Force-wide emissions control
- Non-organic data
  - Force-wide realtime access to selected non-organic data
- Scheduling
  - Force-level scheduling and resource control

5.2.2 Low Slow RO Cruise Missile Threat Example

This threat is characterized by long range, subsonic, low flying (sea skimmer) attack profiles with reduced-observability (RO) in both the radar and IR spectrum. It could have an autonomous guidance system, with a multi-spectral terminal guidance sensor suite comprising both active radar and IR seekers. Some versions may be anti-radiation (ARM) capable and/or incorporate a Home-On-Jam (HOJ) feature. A target discrimination capability may be resident as well.

Low altitude flight profiles of this threat make single platform target detection and classification a difficult task. Even the initial implementation of a Cooperative Engagement capability can significantly improve the battle force's ability to counter the threat. Specific CE OPCONS which may be employed to defeat this type of threat include the following:

- Correlation/fusion; of fragmented track information contained in the surface shared data base from similar and/or dissimilar sources leads to an earlier detection.
- Augmentation of the data base with airborne surveillance extends target recognition, identification and engagement.
- Allocation of track responsibilities reduces redundant engagements.
- A battle force level Threat Evaluation and Weapons Assignment (TEWA) function provides enhanced platform/weapons allocation to targets.

EW and Signature Management tactics could also be employed to minimize the threat missile's single shot probability of kill (Pssk). EW tactics could include both active jamming (AECM) and dispensing of distraction and seduction chaff. Signature Management techniques could be combined with EW to minimize the success of ARM threats. EW tactics could also include the deployment of offboard deception devices.

Specific EW and Signature Management Cooperative Engagement OPCONS which may be employed to defeat this threat include:

- Correlation of Electronic Support Measure (ESM) information with other battle force sensors (radar, IRST, etc.) via the shared data base may indicate the presence of ARM threats.
- Force level TEWA assigns appropriate counter-ARM decoy to be deployed from surface or air platform yielding largest geometric advantage in threat engagement.

- Air augmented surveillance picture yields significant indication and warning (I&W) speeding EW response time for chaff deployment and bloom.

- Signature management of targeted surface units reduces ARM Pssk.

- Target position and maneuver information via the shared data base yields assessment of soft kill success.

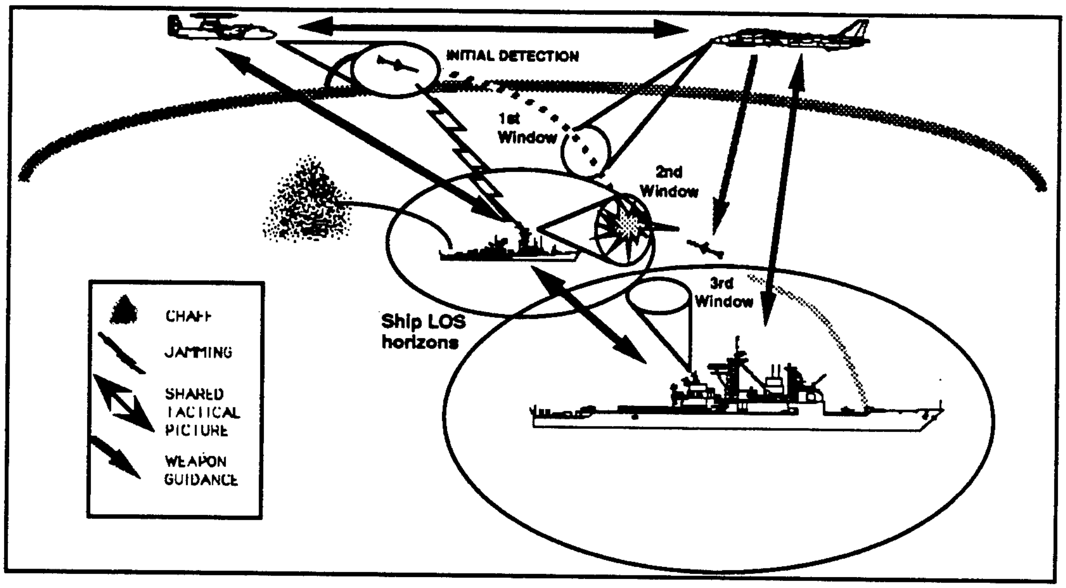

Figure 5-1. Low Slow RO Cruise Missile Threat Example

5.2.3 <u>Outer Air Battle Threat Example</u>

This threat is characterized by saturation raids employing multiple launch platforms and weapons. Bombers and fighter escort, both subsonic and supersonic, are included. Escort EW assets provide active jamming of surveillance and communication links. Both high and low attack profiles could be present. Stream raids, diversion feints, individual penetrators in multi-axis coordinated attacks could be present with a mix of conventional and RO platforms and weapons.

The OAB poses a significant threat to own force air superiority. Coordinated attacks could occur from several approach axis using multiple platforms in order to saturate the defenses. Diversionary tactics could be employed to cause the expenditure of hard kill assets before weapons arrival. Long range detection of the OAB threat may be difficult. Specific CE OPCONS which may be employed to defeat the OAB threat could include the following:

- Shared tactical information between surface units augmented by air surveillance could significantly extend the detection horizon.

- Correlation/fusion of battle force individual sensor data fragments permit earlier formation of target tracks.

- Dispersed battle force sensor capability could provide for maintenance of tactical picture despite adversary's attempt to jam or counter-target.

- Linking of surveillance and intelligence assets from non-organic sources would give improved I&W resource, maximizing battle force reaction time.

- Shared database could allow silent, dispersed shooters to share a common tactical picture of battle force and threat dispositions to engage individual OAB penetrators.

- Forward pass capability between surface units sharing the tactical picture could expand the battle space to exploit over the horizon weapons engagement of the OAB threat.

- Improved data collection and correlation from dispersed multi-sensor units provides for increasingly efficient, effective, and timely kill assessment of OAB threats.

EW and Signature Management tactics could be employed within the arena of the OAB to minimize detection of the Mission Essential or High Value Units of the battle force. The objective of the battle force employing Cooperative Engagement options would be to avoid detection by hostile forces for as long as possible while also engaging hostile launch platforms attempting to deliver anti-ship ordnance. To this end EW could initially serve as a counter-surveillance/counter-reconnaissance asset employed by Blue forces to either deny hostile detection of force disposition or to serve as a cover and deception capability to confuse hostile launch platform operators attempting to target the battle force.

The role of signature management tactics during the initial phases of the OAB could be to deny hostile surveillance and reconnaissance assets the ability to detect battle force position through the detection of telltale electronic emissions. Signature management tactics may cover a range of options from total emission control (EMCON) silence of the high value units to deceptive employment of simulated emissions from a "decoy battle force". Cooperative Engagement options could afford the battle force commander the flexibility of engaging the enemy while also minimizing the detection of his mission essential units using available signature management options.

Specific EW and Signature Management Cooperative Engagement OPCONS which could be employed to defeat the OAB threat include:

- Participation in signature management tactics by all battle force assets could be available through cooperative control of electronic emissions at the platform level.
- The ability to keep high value units (HVU) in total EMCON silence.could minimize detection by hostile forces employing electronic surveillance and reconnaissance.
- Engagement actions within the Outer Air Battle region can be controlled by air units while surface forces maintain the flexibility to selectively participate in signature management tactics
- Integration of individual platform ESM data could provide for a more complete and comprehensive electronically generated intelligence picture, with added targeting advantages from passive ranging techniques.
- Focused EW engagements by both air and surface units could delay threat acquisition of Blue Force disposition.
- Shared tactical picture between surface and air units could significantly increase soft kill options at OAB ranges from the mission essential units.
- Fusion of multi-sensor/multi-platform passive ESM track data fragments could yield high quality tracks on OAB threats while maintaining battle force electronic signature control.

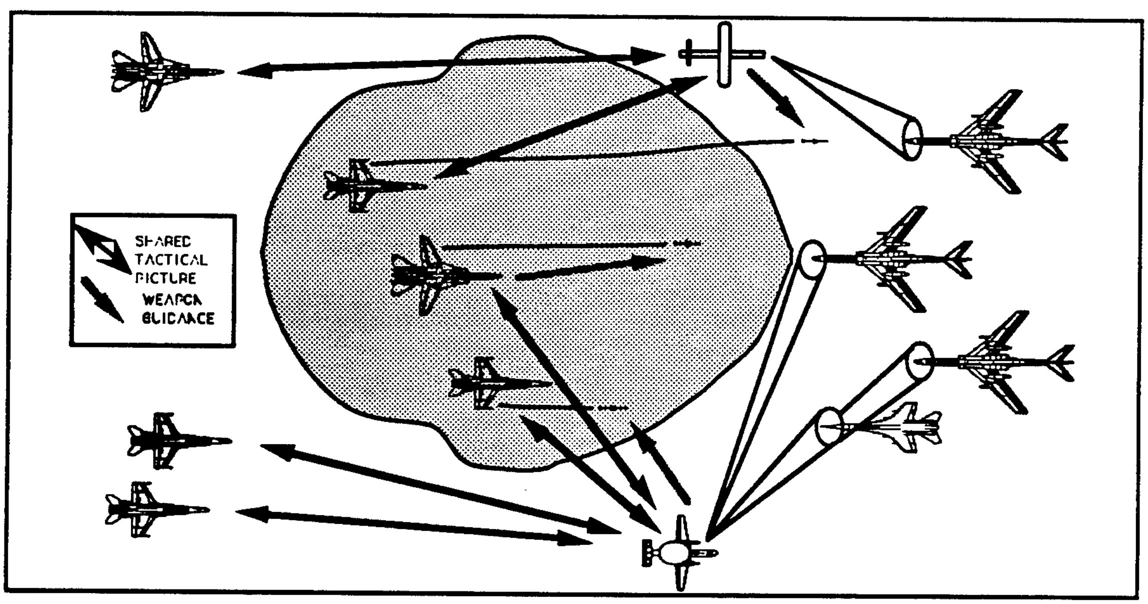

Figure 5-2. Outer Air Battle Threat Example

5.2.4 Fast High Flyer Threat Example

This threat is characterized by high altitude, steep dive angle attack profiles against battle force surface units. Delivery could occur from multiple launch platforms including both bombers and fighters in multi-axis coordinated attacks. Ballistic threats may also be employed and could be launched from land sites. Multiple EW resources employing active jamming could be present from escort aircraft. A mix of conventional and RO platforms and weapons could occur. A significant infrared signature could be present. Terminal homing may incorporate multi-spectral guidance modes. Some versions may be ARM capable and/or possess a Home-On-Jam (HOJ) feature. The high attack angles combined with high speed terminal approaches present an extremely time sensitive threat response scenario.

Advantages of Cooperative Engagement alternatives to defeat the Fast High Flyer threat are:

- Improved reaction time due to air augmented surface shared database could lead directly to earlier fire control solutions and kill assessment.

- Force level TEWA could provide for enhanced platform/weapons allocation to Fast High Flyer targets.

- "Cooperative" allocation of track responsibilities could reduce likelihood of redundant engagements.

- Continuous track could be maintained allowing for scheduling of weapons engagements throughout the attack profile, even when the Fast High Flyer threat drops below the radar horizon of the engaging ship.

- Maximum intercept range could be achieved in threat terminal approach phase since the threat never appears as a "pop-up" targett to the engaging unit.

EW and Signature Management tactics could be employed against the Fast High Flyer threat to minimize threat Pssk. EW tactics could include the use of distraction and seduction decoys and may be used in conjunction with AECM. Offboard deception devices could be employed as well to decoy the threat away from high value surface units.

Specific EW and Signature Management Cooperative Engagement OPCONS which may be employed to defeat the Fast High Flyer threat include:

- Due to the presence of continuous track, EW engagements may be employed during the phase of the attack profile in which there is least likelihood of threat reacquisition and targeting.

- Air augmented surveillance during the dive phase of the attack profile would allow more effective hard kill/soft kill assessment facilitating conservation of engagement assets.
- Fusion of ESM information with other battle force sensors (radar, IRST, etc.) via the shared data base may reveal the presence of ARM threats.

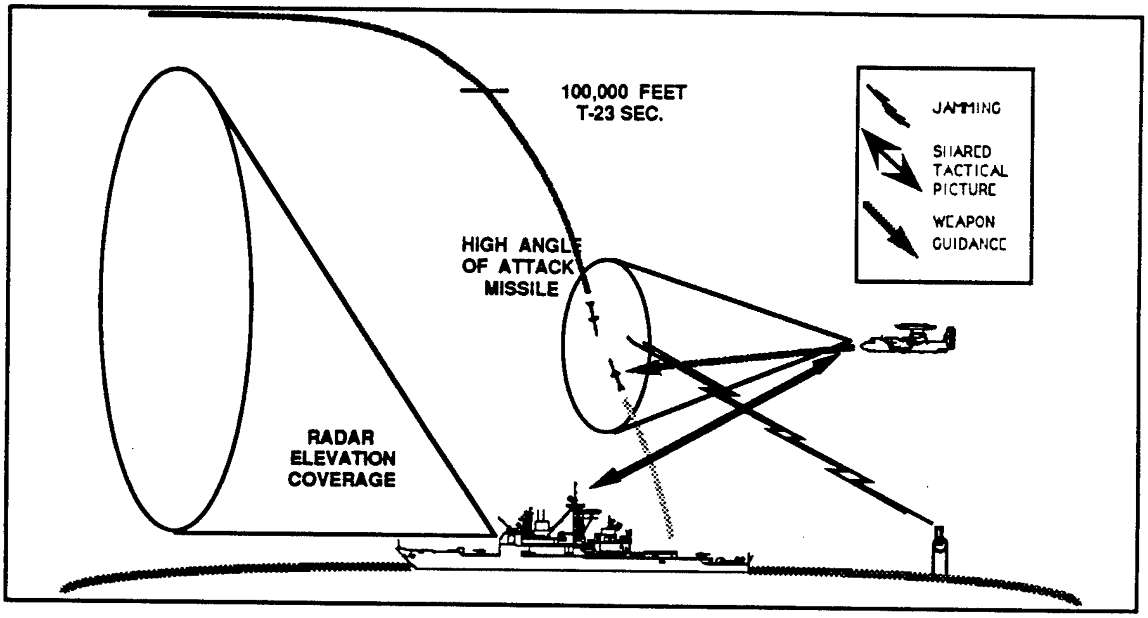

Figure 5-3. Fast High Flyer Threat Example

5.2.5 Fast Sea Skimmer Threat Example

This threat is characterized by supersonic low altitude attack profiles. Delivery could occur from multiple launch platforms including bombers, fighters, surface ships and submarines in multi-axis coordinated attacks. Multiple EW resources providing active jamming of communication and sensor links could be present from escort aircraft and surface vessels. A mix of conventional and RO air launch platforms and weapons could be present. A significant infrared signature could be expected. Terminal homing may utilize multi-spectral guidance modes and evasive "dog-leg" maneuvers. Some versions may be ARM capable and/or incorporate an HOJ feature. A target discrimination capability may be resident as well. The low altitude, high speed terminal runs present an extremely time sensitive threat response scenario to the battle force surface units.

Advantages of Cooperative Engagement alternatives to defeat the Fast Sea Skimmer threat are:

- Linking of surveillance and intelligence assets from non-organic sources gives improved I&W resource, maximizing battle force reaction time.

- Advanced warning due to common tactical picture could provide the potential for engagement prior to Fast Sea Skimmer entry into the surveillance envelope of the engaging asset.
- Surface shared database would yield improved countermeasures resistance through utilization of remotely sensed data.
- Air augmented surveillance picture would improve reaction time leading directly to earlier fire control solutions and kill assessment.
- Surface forward pass capability allows magazine depleted platforms to continue to participate in a detection, guidance and control role.
- Battle force reconfiguration could be available to offset battle damaged assets.
- Remote data engagement provided by shared database could give ARM resistance to forward deployed "Silent Sam"

EW and Signature Management tactics could be employed against the Fast Sea Skimmer threat to minimize threat Pssk. EW tactics could include both AECM and dispensing of distraction and seduction chaff. Signature Management techniques could be combined with EW tactics to minimize the success of ARM threats.

Specific EW and Signature Management Cooperative Engagement OPCONS which may be employed to defeat the Fast Sea Skimmer threat include:

- In the face of complex soft kill engagements, the common tactical picture lends support to determining which threats continue to pose a danger to battle force high value units.
- Air augmented surveillance picture yields significant I&W speeding EW response time for chaff deployment and bloom.
- The threat could be engaged with AECM in order to induce HOJ. The missile would alter course towards the jamming source improving battle force hard kill success by minimizing crossing target threat trajectories.
- Fusion of ESM information with other battle force sensors (radar, IRST, etc.) via the shared data base could indicate the presence of ARM threats.
- Force level TEWA could assign appropriate counter-ARM decoy to be deployed from surface or air platform yielding largest geometric advantage in threat engagement.

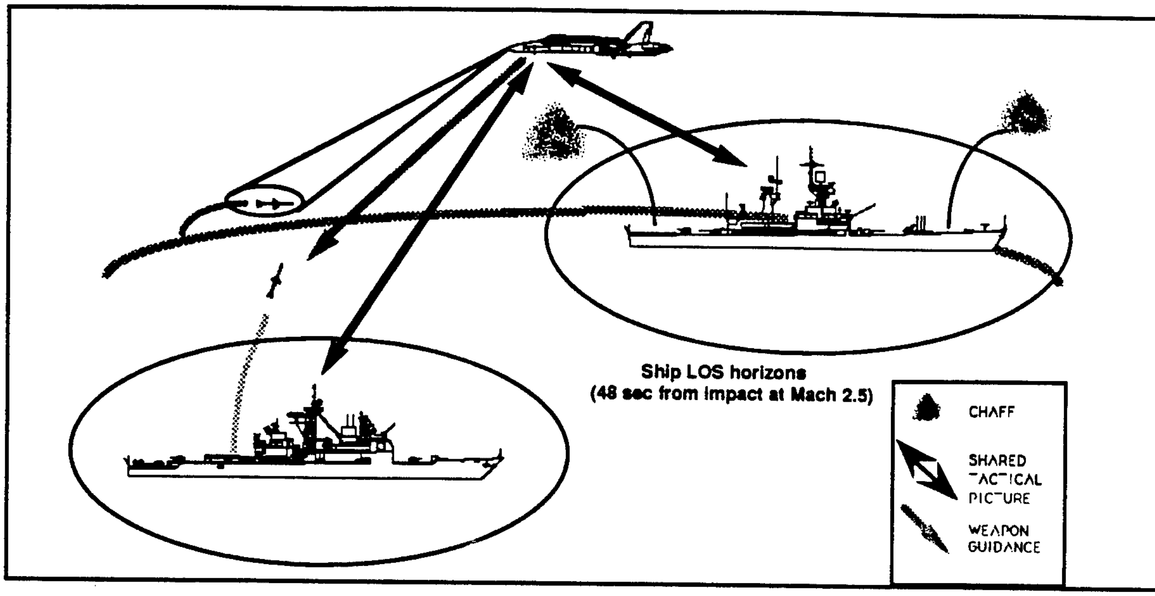

Figure 5-4. Fast Sea Skimmer Threat Example

5.2.6 Drug Interdiction Threat Example

This threat illustrated in Figure 5-5 is characterized by ships and airplanes attempting to deliver drugs to the United States. While unconventional in nature, the problem is not unlike the first four, with a major emphasis on synergistic sensing with engagement up to and including location and interception. The diverse nature of the contacts and their large numbers present significant problems for tracking and identification. Low RCS of some aircraft, coupled with low altitude ingress, present additional problems. Differentiation of "threat" aircraft from general and commercial aviation aircraft present an extremely stressing case. Moreover, great differences exist between equipments currently in use by the various agencies, such as FAA, DEA, Customs, Coast Guard, Air Force, Navy, and National Technical Means.

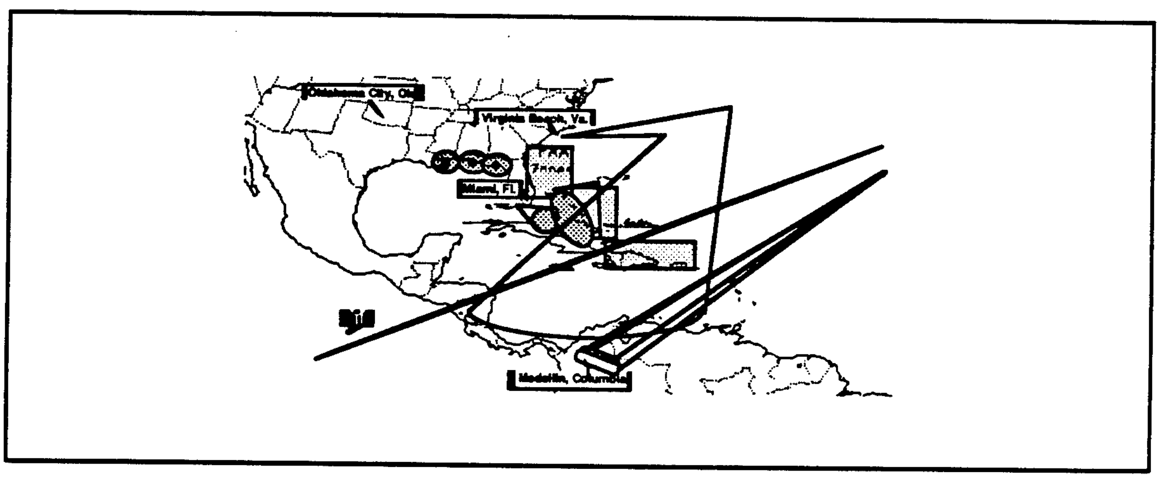

Figure 5-5. Drug Interdiction Threat Example

5.3 SELECTED QUANTITATIVE ANALYSIS

Cases 2 and 5, described in Chapter 4 and in the Appendix, were reviewed by AAW Warfare Mission Area personnel within SPAWAR and the associated Laboratory AAW Working Group. Significant improvements in performance attributable to CE were found in both Case 2 and Case 5.

5.3.1 Case 2 Analysis

Case 2 is described as a Surface Shared Database Augmented by Air Surveillance. See either Chapter 4 or the Appendix for a description.

It was assumed that the adjunct airborne platform included an airborne sensor suite compatible with surface systems. It was also assumed that compatible data link connectivity existed between the air and surface platforms. Lastly, it was assumed that missile modifications were present, providing the weapon with autonomous terminal control beyond the horizon.

The following advantages were found:

- Extends the Battle Force ship horizon
- Allows engagement beyond the launching ship's horizon against sea skimmers and low flying manned aircraft.
- Provides hard kill capability where none currently exists
- Increases depth of fire by at least one in all cases
- Improves crossing fire capability

Quantitative improvements were found as follows:

Change in capability/threat	Improvement
Queing	None
Horizon intercept	
Low fast non-manuevering	1 DOF
Modest horizon extension	
Low fast terminal maneuver	1+DOF
Low manned aircraft (prior to missile release)	1+ DOF
Related benefit	
Redundant engagements	20-35% reduction

Based upon this analysis alone, there is sufficient justification for support of DDS/CEP and its extensions and the implementation of Case 2.

5.3.2 Case 5 Analysis

Case 5 is described as an Air to Air Shared Database See either Chapter 4 or the Appendix for a description.

It was assumed that the adjunct airborne platform, such as ATS, included an airborne sensor suite compatible with surface systems. It was also assumed that compatible data link connectivity existed between air platforms. A AAAM capability with autonomous terminal control was assumed. Lastly, it was assumed that fighter modifications sufficient to allow launch and weapon update on remote track were present.

The following advantages were found:

- Allows engagements beyond launch platform's electromagnetic horizon
- Provides significant increase in warfighting performance
- Enables engagements to kinematic limits of weapon

Quantitative improvements were found as follows:

While the ATS in conjunction with F-14 and AAAM provides a factor of 8 improvement in Bomber Kills over an E-2C with F-14 and AAAM in poor weather, the red/blue fighter exchange ratio remains very low. The addition of CE provides a factor of 12 improvement in Exchange Ratio with slight improvement in Bomber Kills.

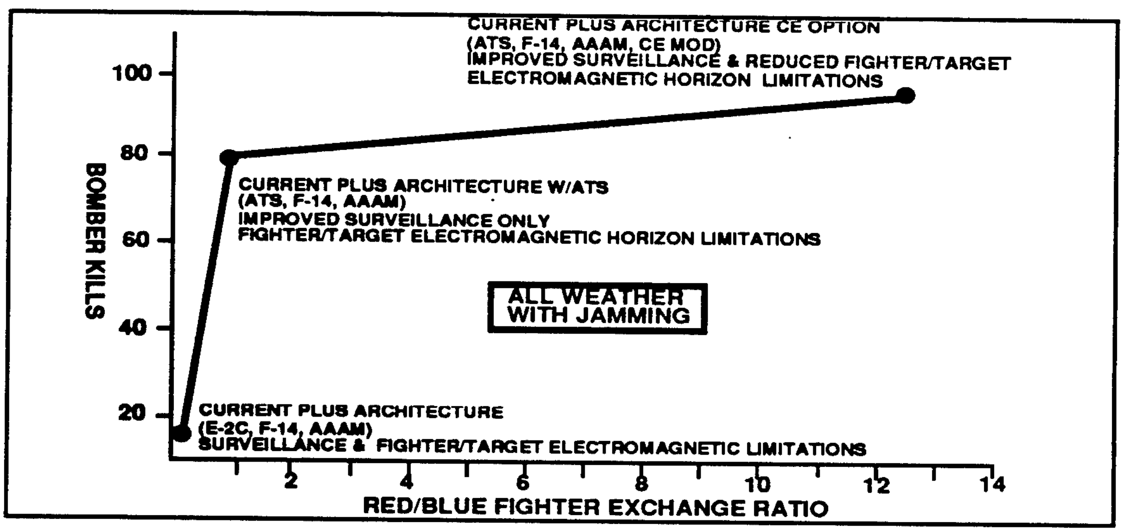

Figure 5-6. Case 5 Performance Evaluation

Based upon this analysis, there is a clear justification for the airborne community to continue its exploration of airborne netting requirements and to undertake its definition of a CE program.

5.4 BENEFITS

The potential benefits of CE observed in the Examples and Cases can be generalized and profiled within the framework of classical evaluative criteria. Expected benefits include:

- Battle space
  - Detection and tracking improvements through synergistic sensing
  - Extended volume through data fusion of a Force-wide consistent tactical picture
- Battle management
  - More complete and timely Force tactical picture
  - Force-wide implementation of complex hard kill/soft kill options
  - Ability to fight the Force as a whole
- Firepower
  - Improved p_k per round through mid-course and terminal weapon guidance from forward deployed units
  - Capability to reallocate weapons in flight due to changes in threat priority
  - Combinations of remote launch, forward pass, and off-board guidance provides greater firepower at extended ranges
  - Increased engagement rate through functional sharing of weapons control among units
  - Optimal matching of platforms, weapons, and targets improves overall p_k in Force level engagements
  - Eliminate undesired redundant engagements
- Countermeasures
  - Extended range for countermeasures action
  - Integration and facilitation of hard kill/soft kill options
  - Electronic warfare coordination within the Force
- Sustainability
  - Inventory conservation through target allocation
- Survivability
  - Improved unit identification with reduction in fratricide
  - Force emission control with selective radiation, reducing detectability
- Mobility

- Weapon hand-off capability enabling forward units to launch and redirect priorities
- Facilitation of the development of a dedicated weapons unit, allowing other units greater mobility

- Readiness

  - Improved Force endurance through graceful degradation
  - Continued platform participation in the battle in degraded mode through flexible partitioning of functions

5.5 ISSUES

5.5.1 General

Many issues presented themselves during the research into the nature of CE. Issues are presented here from a functional, physical, and organizational perspective, paralleling the architectural work.

5.5.2 Functional Issues.

At the conceptual level, functional analysis has produced a subset of critical functions that pervade all warfare areas, and are particularly key to cooperative engagement implementation across multiple platforms and weapons in an automated fashion. In a broad sense, most can be categorized in a sequential way that follows the warfare principles of detect, control, and engage. A few of these top level functions transcend the entire spectrum of battle, from the posturing of Forces through engagement and follow-on damage assessment. If cooperative engagement systems for battle management and execution are to provide a step level increase in warfighting capability, they must provide for at least the following functional capabilities:

General (cross-spectrum)

- Force level management, including signature control, emission control, sensor tasking, engagement resource tasking, authority to remote task, and weapons distribution among units.

- Maximize force efficiency through optimal mating of platform, weapon and target, elimination of unintentional redundant engagements, and reduction in blue on blue kills.

- Maximize force effectiveness through improved multi-dimensional and multi-source sensing, in-flight retargeting, optimal pairing of platform, weapon and target, and sensor feedback from the weapon.

- Decentralize processes to maximize graceful degradation.

- Provide an internetted data connectivity capability that is responsive, robust, secure, and sufficiently covert to meet mission requirements.

- Provide an all-force geopositional reference system with an accuracy sufficient for targeting and engagement.

Detection

- Fuse data from multiple sources on a single platform and/or on multiple platforms.

- Manage sensors with a capability to ascertain when additional data is needed and task various sensors or sensor/platform combinations to provide additional data.

Command and Control

- Provide a coherent tactical picture that is based upon both track and fire control inputs for the entire battle space for all WMAs, established in realtime with zero or near zero latency.

- Transform data to information to knowledge. Provide selective levels of abstraction of information to the force commander.

- Generate alternative courses of action and make recommendations through the extensive use of decision support systems.

- Automate course of action decisions where response time is minimal or when dealing with massive threats, consistent with the ROEs, doctrines, and directives of higher authority.

- Automate a wide range of tactical decision aids for control by the Force Commander to provide a wide range of selective implementation, including command by negation, contingency profiles, and parameterized operation. Provide for a range of high level command and control options from autonomous unit operation to multi-unit cooperation.

Engage

- Optimize fire control solutions for multiple platforms and weapons within the force against multiple threats, including allocation, scheduling, and routing (e.g. - forward pass).

- Merge individual fire control systems into the elements of a force fire control system.

- Determine force fire control solutions through sensor coordination and data fusion to enable priority firing assignments at a force level.

5.5.3 Physical Issues

5.5.3.1 Configurations. Nine cooperative engagement physical configurations (Cases) discussed in Section 4 and Appendix G serve as examples of step-level increases in cooperative engagement capability. Starting at the lowest level of surface only and air only shared data base capability, they extend to interfaces between surface and air units for surveillance inputs, followed by totally shared data base technology between air and surface units. Forward pass concepts for engagement extended the cases to the full capability envisioned for a force level cooperative engagement system. In the development of the more specific and detailed AAW Cooperative Engagement Architecture (Section 4), the configurations were contrasted with what were considered to be the four most stressing threats to a battle force of the future (circa 2020). While all of these configuration provide an increase in warfighting capability, some conclusions can be drawn as regards those configurations that hold the most potential for countering each of the threats. The selection criteria was based on depth of fire, fire power, and robustness (in the sense of graceful degradation). The following conclusions are submitted:

- Configuration 9 (air and surface shared data base, augmented by forward pass) has the greatest potential for handling all four of the stressing threats. It possesses the greatest variety of assets and capabilities, limited only by force disposition planning and trade-offs of complexity versus reliability. This makes sense, however the complexity of the configuration will clearly make it the most costly and technically risky to field.

- Configuration 7 (air to air shared data base augmented by forward pass) possesses an equal potential against three of the listed threats (slow, LO sea skimmer; fast sea skimmer; and outer air battle high threat density), without the complexity of combining air and surface shared data bases. It would appear to have limited capability against the high, fast flyer, as surface launched weapons will probably be the only counter to this threat in the 2020 time frame.

- Configuration 2 (surface to surface shared data base with air surveillance augment) appears to be the least capable configuration that has the requisite operational capability for the cost and risk considerations. In a majority of circumstances it would appear to possess all the depth of fire, fire potential, and robustness necessary to counter the low altitude threat to surface platforms. This configuration is somewhat limited against the high, fast flyer in the sense that there may not be surface platform assets in proper position to provide the necessary horizon extension against certain hostile missile approach corridors.

- Configuration 1 provides significant improvement in Force performance, however, it may be less capable against the most stressing threats.

- Configuration 3, although it adds the key technology of "forward pass", offers little more than Configuration 2 in terms of either defense of the force or offensive capability (in either air or surface warfare), as it requires premature commitment to forward positioning of surface assets to maximize the potential of "forward pass".

5.5.3.2 Characteristics. Preliminary functional allocation and consideration of the desired physical characteristics leads to specifying certain physical attributes, or characteristics, required of selected elements. In other words, operational requirements will often drive the technical approach. Four functional areas are discussed that present engineering alternatives that depend for solution on the operational requirement. The functional areas are those of networking, fusion, battle management, and tactical picture alternatives. In each case the full definition of requirements will drive the engineering solution. The following examples apply:

- In the case of networking, band width is a critical engineering design factor. There exist competing requirements for data rate, anti-jam (AJ) margin, and low probability of detection/intercept (LPD/I), all of which will drive band width or transmission capacity. Whether or not directional antennas are required is also affected by AJ requirements and LPD/I. Directional communication requirements create new problems in networking, signal acquisition, and capacity. Other considerations are level of sub-netting, and automatic net control techniques.

- In solving the fusion problems, one of the major questions is whether to build an engineering design that supports centralized, decentralized, or distributed fusion capability. The decentralized sensor fusion option appears superior at the present time, since it tends to minimize the net loading.

- In the battle management arena the major question to be answered is whether to build a distributed system (each platform determines its own engagement requirements through shared information and doctrine) or a designated/centralized system (one battle manager). Perhaps a combination of systems is appropriate wherein you have a distributed system at some appropriate sub-group level, with a designated system within each sub-group. This alternative would be compatible with segmented information network techniques and also has the greater potential for battle management survival

- Finally, in the tactical picture arena, requirements must be determined for probability of detection, track, classification, and raid count, as well as update rate, consistency, track quality sufficient for engagement, and rule hierarchy for all platform data sharing

5.5.3.3 Components. Notional system components that could be used in the physical architecture system/interface are presented in section 4.4.6.2.

Development of components such as these, in a complete system engineering concept would provide the engineering framework for either a limited or complete cooperative engagement system for force level employment. These are systems that support the functions of weapons, data connectivity and display, spatial positioning requirements, and integrated C^3I/EW Further study must be conducted in regards to these component concepts.

5.5.4 Organizational Issues

With the advent of a cooperative engagement system, possible changes to the current Battle Force organizational structure must be considered. For the first time, cooperative sensing, receiving multiple source inputs to a fused, shared data base of tracks and track fragments, providing third party guidance and control, firing weapons on remotely generated tracks, and employing the forward pass technique may become realities. With a distributive architecture, a distribution of authority to commit weapons may become a reality. Since much of a cooperative engagement system will have to be fully automated, organizational changes must be considered to both monitor a highly automated system, and manage engagements. Above all, the Task Force Commander must be aware of who is committing weapons, and what requirements have been levied on sensor platforms to provide guidance and control capabilities for other platforms designated to launch weapons. With this level of operational complexity, a requirement may emerge for a specialist on the Task Force Commander's staff, with primary responsibilities to provide direct support to the OTC in the prosecution of cooperative engagement initiatives. If so, what will be his specific duties and responsibilities? At what level will he fit in the command hierarchy? Should he have the status of a Warfare Area Commander, a Warfare Coordinator, or simply be assigned as another staff officer reporting directly to the Commander? There are numerous alternative answers, many of which will depend on the OTC/CWC's personal desires and the operational situation at the time. In whatever manner the command structure assimilates the duties and responsibilities of such a Coordinator, the status and positional level in the command hierarchy must take into account how the C.E. system architecture is implemented. There appears at this time to be two basic architectural alternatives:

(1) An overlay of the command and control system, transparent to the user and activated at all times, or

(2) A system that is activated only when required (i.e., when conventional sensor-to-shooter functions cannot achieve the detect, control, engage requirements necessary to kill the target).

At the next level, appropriate rules of engagement (ROE) and standard operating procedures (SOP) must be developed. Specific force, group, sector and weapons platform level surveillance and engagement doctrine must be developed to interpret and build on the battle plans, and control delegation and automation of action. Modification of engagement doctrine must be as flexible as the cooperative engagement system itself, with command authority responding in a dynamic fashion throughout mission execution, in response to changing situation assessments.

Full exploitation of a cooperative engagement capability will require insight into the following operational issues:

- Organization by threat type versus geographic orientation. These alternatives bring problems of contention for assets that are peculiar to cooperative engagement. The organizational choice is dependent on the threat situation, and may require flexibility to adapt during the conflict. Organization by threat type (common signature and profile) has advantages in concentration of netted common sensors and weapons designed to meet a specific threat, hopefully from a particular sector. Organization by geography could involve designated CE coordinators in sector and local command areas. In this structure, asset contention is minimized (each local/sector commander has his own), but with multiple assets committed until an engagement is completed, migration of assets away from locales of responsible commanders may occur, and produce unforeseen stresses on the connectivity of the CE system.

- Determination of weapon control responsibility throughout the engagement sequence from launch through impact. As an example, the launch platform may not have the target track, but the platform commander should have veto authority on launch in order to deconflict any local (terminal) area situations.

- Positioning platforms to exploit aspect angle and layer appropriate sensors capabilities along expected threat axes.

- Layered distribution of tactical data so as not to overwhelm decision makers with unneeded information. Two alternatives are distribution by area of responsibility, or by engagement envelopes of the weapon launching platforms.

- EW management at the force level to improve soft kill options.

- Reconfiguring areas of responsibility to meet the challenge of a changing operational situation. This could imply adding capability to an area where fire power has been lost, or relocating assets from an area where overwhelming tactical advantage has been gained.

5.6 TECHNOLOGY DEVELOPMENT

5.6.1 Technical Issues.

There are certain technical risks in the development of cooperative engagement systems. It is estimated that most of the relevant technological issues are solvable in the near term. The limiting factor on engineering reality is not technology but commitment and funding. Most of the technological requirements are not unique to cooperative engagement initiatives and are well along in development through other programmatic efforts. However, transferring that technology and adapting it to specific CE programmatic initiatives, first in breadboard design and concept demonstrations, and then in prototype development, can be a long term effort, with commensurate expense. Some of the technologies that must be expressly pursued to bring cooperative engagement from concept to engineering reality are as follows:

- Inovative sensor developments in the areas of adaptive arrays, bi-statics, directional antennas, multi-spectral integration, and high gain phased arrays (in several frequency bands) with low side lobes, LPI, and AJ properties.
- High capacity, robust data links and innovative networking techniques, to include data distribution priorities.
- Computer initiatives in artificial intelligence, neural networks, parallel processors, and advanced algorithmic techniques.
- Improved non-cooperative target recognition techniques.
- Decision aid systems for TEWA, signature assessment and management, sensor and connectivity asset allocation, and prioritizing major command decision options.
- Fire control systems with advanced clutter rejection capability, improved wave-form design, multi-sensor options, missile initialization capability between launch and guidance platforms, and remote activation capability.
- Missile guidance technology, including solid state T/R modules, control techniques for forward pass handoff, C^2 antenna technology, communication and wave form interfaces compatible with air and surface units, and autonomous guidance capabilities.
- Missile seeker technology, including compact multi-mode sensor heads, compact phased arrays and signal processors, ultra-low side lobe planar array antennas.
- Real-time resource configuration/assignment for pairing of launch and guidance platforms with weapons, to include alternate guidance and re-targeting techniques for weapons in flight.

5.6.2 <u>Technology Areas</u>

A number of major technology areas requiring further development have been identified:

- Advanced algorithms for correlating and fusing data

- High accuracy position techniques for all platforms
- High throughput, adaptive, self-forming networks with high anti-jam margin and low probability of detection
- Data filtering techniques
- Real time Force level threat evaluation and weapons assignment techniques
- Force level signature management techniques
- Missile interfaces to air and surface platforms
- Missile initialization techniques between launch and guidance platforms
- New missile antenna, seeker, and guidance technologies
- Conformal antenna technology for all platforms

5.6.3 Critical Demonstrations

While it is premature to recommend any particular technology demonstrations at this juncture, a detailed discussion of possible AAW CE-related demonstrations is provided in the Appendix. If a decision to proceed with some level of implementation for CE is made, appropriate demonstrations will be warranted.

5.6.4 Programmatic Evaluation Matrix

At some point in time, it may be appropriate to undertake an evaluation of the various CE-related programs on-going in the Navy. An evaluation matrix is provided for that purpose.

The Evaluation Matrix (Figure 5-6), depicts a set of capabilities or implementations of the Cooperative Engagement concept across the top of the chart. Down the side of the chart, a set of battle force functions that are emphasized in Cooperative Engagement are listed. The first four capabilities are surface ship oriented and the capabilities five through seven are oriented toward air platforms. Capabilities eight and nine are combined air and surface ship implementations. Capability nine is considered the most sophisticated case and is essentially a combination of all of the other cases. The nine Capabilities (cases) have been described in previous sections of this report.

The blocks that are the intersection of a capability with a function simply illustrate that a specific set of functions must be performed to achieve a given capability. The functions that must be performed in order to achieve a given capability will be filled in with a dark circle as illustrated on the chart. By focusing on the blocks with dark circles in them, one can begin to assess our ability to achieve a required capability. If a desired function is required (has a

● APPLICABLE

LEVELS OF CAPABILITY

FUNCTIONAL ATTRIBUTES	1. SURFACE SHARED DATA BASE	2. SURFACE SHARED WITH NON-ORGANIC SURV	3. SURFACE SHARED WITH SHIP FORWARD PASS	4. SURFACE SHARED WITH AIR FORWARD PASS	5. AIR SHARED DATA BASE	6. AIR SHARED WITH NON-ORGANIC SURV	7. AIR SHARED WITH AIR FORWARD PASS	8. SURFACE AND AIR SHARED DATA BASE	9. SHIP AND AIR SHARED WITH FORWARD PASS
1. DATA/CE CONTROL NETWORK	●	●	●	●	●	●	●	●	●
2. MAINTAIN OWN FORCE/THREAT POSITIONS SUFFICIENT TO SUPPORT CE	●	●	●	●	●	●	●	●	●
3. CORRELATION OF MULTI-PLATFORM SIMILAR SOURCE DATA	●	●	●	●	●	●	●	●	●
4. CORRELATION OF MULTI-PLATFORM DISSIMILAR SOURCE DATA	●	●	●	●	●	●	●	●	●
5. COOPERATIVELY MANAGE FORCE SIGNATURE	●	●	●	●	●	●	●	●	●
6. FORCE WIDE COOPERATIVE TEWA	●	●	●	●	●	●	●	●	●
7. ENGAGE WITH COOPERATVE SOFT KILL	●	●	●	●	●	●	●	●	●
8. ENGAGE SOLELY BASED ON FC DATA FROM ANOTHER PLATFORM	●	●	●	●	●	●	●	●	●
9. CONSISTENT TACTICAL PICTURE (SHIP TO SHIP)	●	●	●	●				●	●
10. COOPERATIVE HK/SK BATTLE DAMAGE ASSESSMENT	●	●	●	●	●	●	●	●	●
11. AIR/SURFACE TRACK INTEGRATION		●		●				●	●
12. FUSION OF ORGANIC AND NON-ORGANIC DATA		●				●			●
13. CONSISTENT TACTICAL PICTURE (AIR TO AIR)				●	●	●	●	●	●
14. CONSISTENT TACTICAL PICTURE (ALL PLATFORMS)				●				●	●
15. SHARED COOPERATIVE ENGAGEMENT TASKING			●	●			●		●
16. CONTROL OF SHIP LAUNCHED MISSILES FROM OTHER SHIPS			●	●					●
17. CONTROL OF AIR LAUNCHED MISSILES FROM OTHER AIRCRAFT							●		●
18. CONTROL OF SHIP LAUNCHED MISSILES BY AIRCRAFT				●					●
19. CONTROL OF AIRCRAFTLAUNCHED MISSILES BY SHIPS									●

Figure 5-7. Evaluation Matrix

dark circle in the box) to achieve a certain capability, then one may ask whether we can presently perform that function and if so how well? If all of the functions that have dark circles can't be performed under a given capability column then the capability can't be achieved.

With the insights provided by the Evaluation Matrix, it is possible to see the "holes" that must be filled in to achieve the required capability. After examining the Evaluation Matrix programs can then be started to alleviate the weaknesses that have identified. In some cases, the required functions to achieve a capability are currently being performed but they are not being performed to the level that is necessary. This will force one to think about levels of required individual functional performance and the various means of achieving those levels of individual functional performance.

5.7 FUTURE ASSESSMENT

The extent to which CE will actually improve our warfighting capabilities remains to be determined in quantitative terms at some future date. An assessment methodology has been presented in the Appendix that establishes quantifiable attributes and their properties and develops a system for establishing an objective hierarchy and rating system.

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6 CONCLUSIONS

6.1 PACING THE THREAT

The benefits to be gained from cooperative engagement initiatives and eventual systems that leverage their synergistic capabilities, cannot be fully appreciated until a critical assessment is made of the predicted future threat. The threat outlook for the next 30 years has been the subject of numerous studies, but the proposed solutions generally lack an appreciation of cooperative engagement principles and technical potential that is resident therein. Properly developed cooperative engagement initiatives can significantly improve our ability to deal with the limiting cases of threat density, low signature, classification complexity, electronic deception/jamming, and high performance at the extremes of the operating envelope. Each of these limiting cases seriously reduces the number of engagement opportunities available, and the range at which engagements can take place. As outlined in the following section, the development of cooperative engagement systems at a force level can buy back the firepower and battle space being lost to emerging systems.

6.2 INITIATIVES TO COUNTER THE EMERGING THREAT

Given the threat characterized above, major conclusions can be drawn concerning the advantages that cooperative engagement initiatives may bring to bear on Force level defensive and offensive warfare:

- Correlation/fusion of fragmented track information contained in a shared data base from all sensor sources can lead to earlier detection, identification, and engagement opportunity against threats that are both low observable and possess performance characteristics that required operation at the extremes of the performance envelope.

- More complete and comprehensive allocation of track responsibilities can reduce redundant engagements.

- A Force level TEWA function can provide enhanced platform/weapons allocation to targets.

- Shared tactical information between surface units augmented by air surveillance can significantly extend the detection horizon.

- Correlation/fusion of battle force individual sensor data fragments can permit earlier and clearer definition of stealth target tracks.

- Dispersed battle force sensor capability provides for maintenance of tactical picture despite adversary's attempt to jam or counter-target.

- Real-time linkage of surveillance and intelligence assets from non-organic sources provides improved I&W capability, maximizing battle force reaction time.
- Shared databases can allow silent, dispersed shooters to view a common tactical picture of own force and threat dispositions to engage individual penetrators.
- Forward pass capability between all Force units sharing the tactical picture can expand the battle space to exploit over the horizon weapons engagement at maximum kinematic range.
- Improved data collection and correlation from dispersed multi-sensor units provides for increasingly efficient, effective, and timely kill assessment of all engaged threats.

Special attention needs to be given to EW and Signature Management implications. A totally shared and interactive data base obtained from all sensor information available to the Force can bring immediate tactical advantages in an EW environment. EW and Signature Management tactics of a widely dispersed battle force, cooperatively employed, can inhibit detection while extending soft kill options and hard kill engagement range. Coordinated EW initiatives employed in a counter-surveillance/counter-reconnaissance mode can delay hostile detection of force disposition or serve as a cover and deception capability to confuse targeting efforts of hostile launch platform operators. Signature management tactics may cover the widest range of options while continuing to exploit the full offensive potential of the Force. Added advantages in passive ranging, focused active EW actions, and ESM generated improvements to track quality will accrue.

6.3 AAW SPECIFIC RECOMMENDATIONS

Within the AAW problem, it has been clearly demonstrated that significant improvements can be achieved through partial implementation of the CE goal architecture as described in Case 2, Surface Shared Database Augmented by Air Surveillance, and Case 5, Air-to-Air Shared Database.

6.3.1 Support DDS/CEP

The Data Distribution System/Cooperative Engagement Processor (DDS/CEP), will make significant improvements towards implementation of Case 2. CE can overcome limitations found in the Current Plus architecture based upon platform and electromagnetic horizon, increasing the depth of fire, given weapons improvements.

6.3.2 Define a CE Program for the Air Community

In Case 5, Air-to-Air Shared Database, the A3ES program was prematurely cancelled due to a change in BTI funding requirements. Development of an air netting capability is critical to implementation of Case 5 which will provide significant enhancements in airborne capabilities. The air community needs to define a CE program.

6.3.3 Initiate TOR/DOP Process

In both cases, data exchange and fusion are key required capabilities. Research in these areas needs continued funding. Moreover, sufficient justification now exists to warrant initiation of the TOR/DOP process for Cases 2 and 5.

6.3.4 Leverage Future Opportunities

Develop an approach in the AAW Master Plan to take advantage of windows of opportunity to implement CE capabilities in planned systems.

6.4 Overall Recommendations

6.4.1 Establish CE as a Goal Architecture for the Navy

The Cooperative Engagement concept, while still in its developmental stages, holds significant promise as a Force multiplier that leverages many significant issues for the Naval Battle Force of tomorrow. With decreasing funding and increasing probabilities for real-time threats,the Navy needs innovative solutions, such as Cooperative Engagement, to help solve it's problems.

At this juncture, it is premature to advocate a unilateral investment in Cooperative Engagement as a solution to some of those problems. A great deal of research is still required before a quantitative assessment can be completed that describes CE's total potential contribution to Naval warfighting and evaluates its relative implementation cost-benefits. Nonetheless, the concept clearly has merit.

The full functional implementation of Cooperative Engagement should be established as a goal architecture for the distant future.

6.4.2 Implement CE in Future Navy Programs

Given that Cooperative Engagement involves a fundamental shift in philosophy, CE should be viewed as set of guidelines within which future Navy programs should be implemented. New programs should be compared against the criteria set forth in CE and evaluated for their consistency with the concept and its goals and for its contribution to achieving those goals.

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