TECHNICAL REPORT 2002-004

SINGLE INTEGRATED AIR PICTURE (SIAP) PROGRESS, PLANS, AND RECOMMENDATIONS

APRIL 2002

SINGLE INTEGRATED AIR PICTURE (SIAP)
SYSTEM ENGINEERING TASK FORCE (SETF)
1931 Jefferson Davis Highway
Crystal Mall 3, Suite 1109
Arlington, VA 22203

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FOREWARD

The Progress, Plans and Recommendations being reported to the Department is with the collective efforts of the SIAP System Engineering Task Force and various government and contractor support personnel. There have been numerous meetings, discussion, updates and refinements as the team attempted to communicate all the activity associated with this product. The following individuals made significant contributions:

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EXECUTIVE SUMMARY

This report responds to USD (AT&L)'s (Under Secretary of Defense (Acquisition, Technology and Logistics) 25 June 2001 tasking to the Single Integrated Air Picture (SIAP) Acquisition Executive. The memorandum requested a report on the Single Integrated Air Picture System Engineering Task Force's:

- Progress,
- Plans to define the SIAP Integrated Architecture, identify and resolve problems with the Joint Data Network (JDN), and define the elements of the Joint Composite Tracking Network (JCTN) and
- Emerging issues and recommendations

A key driver behind this request stemmed from OASD (C3I) and OUSD (AT&L) questions regarding how the DoD would develop a JDN/JCTN roadmap. Our approach is to use DoD's C4ISR architectural discipline to flow requirements to materiel alternatives that will define that roadmap. We began by assuming the proposed JCTN concept represented an accurate, low latency network (Integrated Fire Control (IFC) being one of the key engineering drivers). We expect to have our initial draft of the SIAP architectural framework by December 2002.

This report captures key events, ideas and operational factors that drove DoD decisions to establish the SIAP System Engineering Task Force. It outlines the architectural process the Task Force expects to follow in building the architectural framework for the SIAP component of the Theater Air and Missile Defense (TAMD) Integrated Architecture — the roadmap is a piece of this architecture.

JROC-validated Capstone Requirements Documents (CRDs) define Joint warfighter objectives and identify key performance parameters (KPPs) for Joint operations. The recently approved Theater Air and Missile Defense (TAMD), Combat Identification (CID), Information Dissemination Management (IDM) and Global Information Grid (GIG) CRDs provide the overarching requirements for the SIAP. To put these CRDs in context, the Task Force launched several engineering initiatives that define the operational context and provide measures of progress toward the CRDs objective SIAP. But, to engineer tomorrow we must understand the forces of today.

Many systems contribute to the air picture. Understanding the differences between our current capabilities and those required for future operations identify the gap that DoD must bridge. We have started down this path by looking at our current capabilities and known deficiencies. We have also begun defining some operational scenarios in which our Joint forces will be expected to operate in the future. These scenarios can then be "gamed" through modeling and simulation to determine the capabilities that will be required in the future as approved by the JROC. This analytical framework should then help DoD with insight into the linkage between engineering alternatives and their impact on military utility. The decisions that result from this analysis will be captured in SIAP architectural documents. This architectural repository will provide not only a means to measure improvements from the current baseline, but also provides an audit trail for the functional allocations required to meet Joint warfighting requirements.

The task challenging the SIAP System Engineer is complex, and architecture is central to an orderly and methodical approach to achieving the SIAP. Legislation in the form of the 1996 Clinger-Cohen Act directed DoD to develop and maintain information technology architectures. Through the Secretary of Defense, the Department established the C4ISR Framework as the template. Other DoD regulations and instructions have been issued that help define the documents required to record the engineering of these complex problems.

While the terms Joint Planning Network (JPN), Joint Data Network (JDN), and Joint Composite Tracking Network (JCTN) are used frequently, there is no widely accepted definition for any of these networks. Rather than debate the definitions, the Task Force began an architectural development effort that will define the required functionality. We also expect the architecture to support analysis of functional gaps, overlaps, duplicative efforts and conflicts. This analytical approach to an integrated architecture will translate requirements and define/allocate functionality to weapon systems that can be mapped back to these network concepts.

This SIAP Integrated Architecture (IA) will define the Joint interfaces, functional and allocated baselines, associated information exchange requirements (IERs) and data models. These models serve as the basis for SIAP implementation trade studies and requirements allocation. The architecture will support developers and testers; and is a tool for enforcing integrated implementation of SIAP functional requirements. Architecture products, such as the System Capability Evolution Description will outline this integrated implementation that, with JROC endorsement, will provide the roadmap toward an objective SIAP.

The Task Force initially focused on the description of physical systems and their interfaces. The plan was to start with a small list of systems/functions and then add additional systems and functions in an incremental fashion. The functional descriptions were focused on the breadth of the SIAP capability first, and then followed with additional detail in specific functional areas. As the functional analysis matures, the data and information exchanges will be refined and a behavior analysis will be conducted.

To evaluate the existing air picture, the Task Force developed a set of SIAP attributes, measures of effectiveness (MOEs) and measures of performance (MOPs) that would be quantifiable, testable and measurable. These SIAP attributes established a set of metrics that is derived from KPPs defined in the previously mentioned CRDs. In developing these metrics we encountered, and are endeavoring to resolve, metrics implementation issues that surfaced when we attempted evaluate data from live tests or simulations. By providing guidance on how to use these metrics we plan to further standardize community practices to ensure these metrics retain the proper engineering context. These analytical tools will be our keys to baselining current performance and determining the value of incremental SIAP improvements

However, in evaluating these incremental improvements, these engineering tools will not be sufficient to evaluate tradeoffs unless we reach agreement on a standardized set of warfighting scenarios. These Common Reference Scenarios (CRSs) are being built in cooperation with JTAMDO and JFCOM, and will provide a standardized modeling framework in which to test proposed changes to the equipment and TTP which effect the SIAP. These scenarios are based on approved regional war plans and include details such as friendly and enemy force laydowns, terrain, and timelines for modeling the impact of SIAP system modifications. By evaluating system responses in a common context the Task Force can analytically tie engineering changes to potential warfighter effectiveness improvements.

To augment this modeling and simulation capability we plan to use hardware-in-the-loop, operator-in-the-loop, and live exercises to support our work. By gathering and comparing results from these different venues, we expect to validate the models and testbeds. The validation process will build confidence in these tools and help us toward our goal of providing empirical data to support engineering decisions.

We selected Block 0 as a pilot to help us mature our tool set and frame up an analytical process for making these collaborative engineering decisions. Our Block 0 effort built relationships, refined communication paths and identified administrative, programmatic, financial and technical lessons learned. As a result, in September 2001 the JROC directed Block 0 implementation and recommended Services plan for continued Joint engineering through FY03. These additional funds will allow the Task Force to start and complete Block 1 Joint engineering.

Block 1 engineering will build on our Block 0 experience in helping DoD refine the SIAP System Engineering process. This incremental approach will help us introduce weapon system changes in an orderly, fiscally achievable manner, while retaining engineering flexibility as we flesh out a SIAP Integrated Architecture. Between these two efforts we will build the objective SIAP capability. The Block upgrade process will define work that needs to be done while the architecture is being developed and the architecture will provide the top down descriptions of how systems should work together to meet JROC-validated requirements.

This SIAP IA will be derived from the JTAMD 2010 Operational Architecture (validated by the JROC in November 2001). We anticipate initial product delivery from the SIAP architecture in February 2002 and our first draft of the "objective" SIAP IA in December 2002.

The SIAP IA serves several key functions by defining relationships through a series of structured views—the Operational, System and Technical Views.

Warfighters communicate with engineers through the Operational Views. In these views the architecture shows, in graphical and tabular form, how we intend to fight by:

- Describing interrelationships among warfighting units,
- Describing the functions that warfighting units will perform individually and collectively, and,
- Defining how well those functions must be performed to satisfactorily accomplish the assigned mission in the most effective way.

By decomposing these operational relationships the architect will uncover other critical system and technical relationships, functions and definitions. This work will create a shared repository of system engineering artifacts that will document the results of the system engineering process. By capturing this design we form a contract between the warfighter and acquisition communities; and, we add fidelity to our communications with industry through a series of system and technical views.

The System Views in the SIAP IA will baseline our current interoperability performance and determine what functionality/engineering changes need to be incorporated or developed. To ease into the complexity of these system views we've used an incremental block approach to isolate systems/functions in fleshing out the architecture—the stepping-stones to increased Joint warfighting capability.

Block 0 implementation will reduce dual tracks and decrease operator confusion. The key identification and track correlation issues that made up this initial block laid the foundation for Block 1 engineering options.

Block 1 will improve accuracy and commonality and enhance combat identification capabilities while laying the foundation for Block 2. We've focused on four operational themes:

- Further reduce dual tracks through improved sensor and data registration (time, position, alignment and track management issues).

- Improve identification continuity and accuracy through improved integration of current ID techniques and provide for growth of emerging Mode 5 and Mode S IFF functions.

- Improve theater ballistic missile defense (TBMD) performance through increased accuracy in target/debris reporting and correlation rules.

- Improve data sharing options such as increased Link 16 throughput, multi-link translation and forwarding and options for engage on remote capability (ability of a shooter to engage a target tracked on another system's fire control radar—this capability will provide the basis for integrated fire control)

At this stage in our work we expect Block 2 to build on Block 1 by focusing on improved Link 16 efficiency and throughput, improved gateways with other networks and expanded battle space with improved beyond line of sight options.

In designing the engineering solutions for Block 1 and posturing for subsequent blocks, the SIAP SE will allocate functions and tolerances within the architectural framework. These solutions will be measured against TAMD and CID requirements and will lay the basis for addressing functionality among networks and other platforms. We expect to recommend Block 1 solutions in December 2002 along with an initial draft of the SIAP component of the TAMD Integrated Architecture.

As DoD considers concepts such as a Joint Composite Tracking Network (JCTN), the architectural foundation laid in with Block 1 will help focus issues on the requirements for fleshing out these ideas. For JCTN, the engineering accuracy and communication stressors anticipated with Integrated Fire Control will likely drive the functional allocation and define the elements of the JCTN concept.

To achieve these goals we must stabilize the resources needed to do this work. This will require the Services to work with DoD to plan and program for this activity. Budgets must support three distinct funding categories:

- Joint Engineering—Tier 1—this funding supports the collaborative engineering process. During FY00-03 the SIAP SE Task Force consolidated these funds in a single Navy program element for conducting the engineering analyses underpinning the incremental block development process and architectural design work.
- Service Engineering—Tier 2—these funds remain with each Service and should be designated to resolve the Service specific SIAP related issues. These funds also provide the foundation for Service validation of engineering models and personnel costs for supporting the Joint engineering effort.
- Service Implementation costs—Tier 3—these Service funds should be programmed within Service system program elements to provide for periodic system updates of applicable Service legacy and developmental systems.

By providing resource lines in the Service budgets DoD will create the focus needed to stabilize the Service manpower and industrial/Service support needed to turn engineering designs into improved Joint warfighting. The FY01 funding allocation progress has been slow and, as a result, limited the depth and aggressiveness in building the Task Force's engineering foundation.

It took nearly a year to staff the Task Force and in June 2001 we hit the directed end-strength. Although we still have challenges in maintaining some Service quotas, we must manage the attrition and reduce rotation to promote stability in the workforce. Services typically lack depth in the engineering manpower to do this Joint engineering and the incremental resource strategy to date has not provided the confidence needed to recruit engineers to engage in long term Joint engineering. The Services should lay in out-year programs and create budget options that will promote stability and move interoperability above the cut line.

As the Task Force establishes the engineering foundation for others to build on, other critical elements need to accompany this Joint engineering initiative:

- JTAMDO must complete the Operational Views of the SIAP Integrated Architecture

- DOT&E should institutionalize the SIAP metrics as the assessment measures for characterizing SIAP performance and to endorse the end-to-end analysis process

- And ultimately USD (AT&L) should assign an activity to budget for, update, and manage the configuration of the SIAP component of the TAMD Integrated Architecture.

This SIAP Integrated Architecture should be the basis for how DoD must develop its JDN/JCTN roadmap. The Task Force made progress in building initial segments supporting this architecture and we've mapped out the architectural discipline needed to trace requirements to materiel alternatives that will define that roadmap. It is this disciplined approach that will help DoD clarify requirements, identify deficiencies in the JDN and define the elements of the JCTN concept. And, by assuming integrated fire control will provide a key engineering driver for future capability, we expect the plan we've laid out in this report will provide a highly accurate DoD network linking CRD requirements to specific materiel alternatives.

We have mentioned a few of the areas where we need help. This technical report has drawn other conclusions and recommendations on a number of varying levels. We have organized the report to address:

Background
Progress and General Plans
Specific Plans
    SIAP Integrated Architecture
    Identify and Resolve Problems with the JDN
    Define the Elements of the JCTN
Summary and Conclusions

We discuss objectives, products and milestones, responsibilities, approach and resources. Each section expands on the progress and plans of the efforts described in this summary and their relation to the tasking directed by USD(AT&L). While we offer a number of recommendations, we don't yet have the detail required to execute or suggest what organization should pursue implementing these changes. As the SIAP SE Task Force products mature, we will forward these complete recommendations to the appropriate authority.

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1. BACKGROUND

In this section, we briefly outline the events and efforts that most directly contributed to the establishment of the SIAP SE Task Force. It is necessary to understand these actions and activities, as they provide the context within which decisions to establish this group have been made. Additionally, this outline provides some insight into the scope of the effort that will be described in later sections.

Understanding that significant warfighting capability shortfalls exist, the Department of Defense has given high priority to improving the capability of U.S. forces to operate together, as well as with allied and coalition forces. Toward that end, a broad range of organizations and programs have been instituted by DoD components, including the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)), the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (ASD(C3I)), the Department of Defense Chief Information Officer (DoD CIO), the Joint Staff, Joint Forces Command (JFCOM), the Missile Defense Agency (MDA), the Joint Theater Air and Missile Defense Organization (JTAMDO), the Services, and other defense agencies and organizations.

In 1994, the Defense Science Board (DSB) concluded in its *Summer Study on Cruise Missile Defense* that "motivation exists for regional adversaries to acquire land attack cruise missiles" and that "readily available and emerging technologies make it possible that a threat from such systems could rapidly emerge." The evolving threat of modern aircraft, tactical ballistic missiles and now cruise missiles presented a challenge too tough for any one service to counter effectively on its own, especially given the post-Cold War reduced force structure. The growing proliferation of weapons of mass destruction added to the sense of urgency. The DSB recommended that cruise missile defense measures be pursued within the context of overall theater air defense and found that "integration of the separate service activities into an effective joint theater air defense will require the Department of Defense to establish joint requirements/doctrine in an organization closely coupled to a system engineering/acquisition organization."

The ensemble of systems that provide the capabilities to perform air and missile defense functions in theater is often called the Integrated Air Defense System (IADS). The Integrated Air Defense System is comprised of humans, equipment, and computer programs. The existing IADS is a *de facto* architecture, albeit poorly documented. The lack of an orderly, disciplined approach to engineering and fielding the IADS has resulted in functional gaps, overlaps, conflicts, and interface standards and specifications that define not only the interface, but functionality on either or both sides of the interface. The IADS is supported by multiple tactical data link (TDL) networks, which are often characterized as the Joint Data Network (JDN). Shortfalls within the JDN generally result in limitations in the capability to reduce the potential of fratricide, to operate weapon systems to their full design capabilities, and to improve warfighting capability against emerging threats.

The Joint Integrated Air Defense System Interoperability Working Group (JIADS IWG) formed during the All Service Combat Identification Evaluation Team (ASCIET) 96 evaluation in response to frustration caused by long-standing interoperability problems highlighted during that evaluation. This *ad hoc* group, comprised of operators and engineers from the services plus selected DoD Agencies, adopted a proven, disciplined system engineering process to characterize and address outstanding "interoperability" issues. The JIADS IWG, working across service and program lines, identified and resolved "interoperability" issues, using ASCIET evaluations as their data collection forums. Because the JIADS IWG was *ad hoc*, it drew resources from Service acquisition programs that had systems in the ASCIET evaluations, as well as from JTAMDO and MDA.

A joint working group composed of representatives from the Office of the Secretary of Defense, Joint Staff, and the Services convened in 1996 to develop the concept for the Joint Theater Air and Missile Defense Organization (JTAMDO). On 2 March, 1997, JTAMDO was established to coordinate with the warfighting CINCs and Services to develop the joint operational concepts, capstone requirements, and operational architecture for fielding a joint, integrated theater air and missile defense (TAMD) capability. The joint working group also developed the joint theater air and missile defense (JTAMD) process, designed to integrate the requirements activities with the acquisition activities of the services and the Ballistic Missile Defense Organization. DoD had the organizational structure and process in place to begin to achieve the joint TAMD operational capabilities it needed for the future.

The Deputy Director, Ballistic Missile Defense Organization and CINCUSACOM developed the concept of the TAMD Flag Officer/General Officer (FOGO) Workshop in 1998. The initial workshop was held in August 1998 and annually thereafter for three years. CINCUSJFCOM, Director, MDA, and Director, JTAMDO sponsored the Workshops. The purpose of the workshops was to bring together senior leadership from the TAMD operational and acquisition communities to address issues designed to enhance current and future Joint TAMD operations.

The first workshop (FOGO I) was held in August 1998 at the Joint National Test Facility (JNTF). During that session, the FOGO established that:

- The Theater Missile Defense (TMD) Capstone Requirements Document (CRD) was the approved statement of joint warfighting requirements for TMD.
- Only the interoperable family of TAMD systems required by the TMD CRD would satisfy geographical Commanders' in Chief (CINCs') requirements.
- Continuous leadership attention to the engineering and acquisition process was necessary to achieve the required level of interoperability in a reasonable amount of time.

The second workshop (FOGO II) was held on 31 August and 1 September 1999 at Tactical Training Group Atlantic. During that session, the FOGO established that:

- The CINCs and Services supported by JTAMDO would further refine and reach consensus on an operational concept for JTAMD.

- A balanced Doctrine, Organization, Training, Materiel, Leadership, and Personnel (DOTMLP) approach to TAMD that was properly synchronized with the systems acquisition process was required.
- Interoperability was a key TAMD enabler, yet assessing and reporting interoperability among joint forces continued to be a major challenge.
- Chairman, Joint Chiefs of Staff Instruction (CJCSI) 3170.01A was a timely and credible effort by the Joint Staff (JS) J8 to focus future interoperability efforts.

The third workshop (FOGO III) was held on 2 and 3 August 2000 at Naval Amphibious Base (NAB) Little Creek in Norfolk, Virginia. During that session, the FOGO addressed the progress made since FOGO II and discussed those areas where further focus was required. They reviewed the current status of the TAMD Operational Concept and TAMD CRD and issues related to major TAMD initiatives to include the TAMD Family of Systems (FoS) and the recently established Single Integrated Air Picture (SIAP) System Engineer (SE).

The TAMD FOGO workshop participants agreed to the following:

- Endorsement of all four elements of the TAMD Operational Concept (Single Integrated Air Picture (SIAP); Combat Identification (CID); Integrated Fire Control (IFC) and Automated Battle Management Aids (ABMA)). SIAP and CID are the foundation of this concept.
- Support for the basic tenets of the draft TAMD Capstone Requirements Document (CRD), including the Key Performance Parameters (KPPs).
- Endorsement of the SIAP System Engineer (SIAP SE), Joint Distributed Engineering Plant (JDEP), and MDA Corporate Test and Evaluation (T&E) efforts. We are counting on an effective SIAP System Engineer.
- That there is a growing interdependence of the National Missile Defense and Theater Ballistic Missile Defense mission areas. This potential convergence needs to be explored to determine where related concepts and requirements intersect.

Based on these points of agreement, four key JTAMD actions were identified:

- USJFCOM, JTAMDO, and the SIAP SE would focus on improving and standardizing Link 16 implementation. Included within this activity would be an initiative to address the issue of enforcing standard symbology for TAMD systems. Further, to demonstrate the effectiveness of the SIAP SE Task Force, the SIAP SE would select one USJFCOM endorsed warfighting capability shortfall and pursue resolution/approval through the JTAMD process including endorsement by the JROC.
- USJFCOM, JTAMDO, MDA, and the Services would develop a Plan of Action and Milestones (POA&M) to implement the TAMD Operational Concept. This plan would address all aspects of DOTMLP.
- USJFCOM would continue to staff the TAMD CRD for JROC validation in Dec 2000. JTAMDO would continue analytical efforts to refine the CRD KPP "to be resolved" (TBR) values through a specific warfighting benefit analysis process. The services would assist in this effort.

- USJFCOM would identify joint TAMD tactical level terminology definitions and would coordinate with the Joint Staff to ensure compliance within the Services.

Directed by the Joint Staff, the JIADS IWG conducted a data collection and on-site analysis effort during ASCIET 97, ASCIET 99, and ASCIET 2000 to rapidly answer warfighter questions and to focus the detailed post-ASCIET data analysis in support of building a Single Integrated Air Picture (SIAP). Following each of the evaluations, the JIADS IWG met to conduct in-depth reconstruction and data analysis. Results were summarized in data analysis reports, which were used to justify changes to interface standards (e.g., MIL-STD-6016A) and host system implementations of those standards.

While ASCIET 2000 was being planned and executed, the JROC was discussing options to establish a joint system engineering organization whose task would be to engineer the capability to build a SIAP. One of the features of the selected option was to absorb the functionality and process of the JIADS IWG. The result of that action is discussed later in this report.

ASCIET 2000 observations included a significant number of warfighting capability shortfalls that prevented establishment of a SIAP and, as expected, adversely affected overall mission performance. In most cases, ASCIET 2000 findings were similar (or identical) to those observed during the tests conducted by the Joint Air Defense Operations/Joint Engagement Zone (JADO/JEZ) Joint Test and Evaluation Joint Task Force in 1992 through 1994 and evaluations conducted by ASCIET in 1995 through 1999. The data link architecture that supported the IADS continued to experience known/repeat integration and interoperability anomalies, which resulted in degraded operational effectiveness. Tactical information and displays at command and control (C2) nodes were often inaccurate, confusing, or inoperable as a result of the following problem areas:

- Track dualing
- Track number changes and swapping of track numbers
- Reporting responsibility (R2) conflicts
- IFF/Selective Identification Feature (SIF) conflicts
- Track ID conflicts/ID swapping
- High net loading on legacy links

These deficiencies could be categorized into the following areas to focus corrective action:

- The physics of the operating environment
- Operational availability of individual systems and equipment
- Design or implementation problems within individual units or in the interface between units caused by:
  - Adequate specifications but poor implementation (typically identified as specific computer program "bugs")
  - Ambiguous or overly general specifications that are interpreted differently by system or equipment developers and maintainers

- Specifications that do not provide the intended result either because they are silent on a particular critical performance issue or are improperly stated
- Tactics, techniques, and procedures (TTP) and training.

Within the third major category listed above, there were several fundamental or "structural" root causes that adversely affected warfighting capability. These root causes include:

- Lack of a common time reference across the force;
- Failure to achieve a common geodetic coordinate frame and to properly account for the different coordinate frames used in the various tactical data links;
- Implementation deficiencies in integration of inertial navigation systems (INS), Global Positioning System (GPS), and the navigation functions of the Link-16 network;
- Poor tracking performance and inaccurate assignment of Track Quality (TQ), resulting in inappropriate assumption of reporting responsibility;
- Automatic local-to-remote track correlation/de-correlation processing deficiencies;
- Automatic identification processing deficiencies; and
- Connectivity shortfalls.

To resolve these root causes, design and implementation problems must be addressed as well as the process by which acquisition and engineering decisions are made today. If actions are not taken to improve the process by which warfighting capability is fielded, the Department of Defense is faced with allocating a large portion of its resources to fixing problems into the foreseeable future. With this in mind, the JROC began discussions in 1999 to build a small organization to make specific recommendations for improvement.

The Single Integrated Air Picture (SIAP) System Engineering (SE) Task Force (TF) was established to resolve IADS capability shortfalls. In March 2000, the JROC recommended the designation of a lead system engineering organization to facilitate the translation of the emerging SIAP requirement to a fielded joint capability. In October 2000, under the authority of the Secretary of Defense, the SIAP SE TF was established, chartered by the Vice Chairman of the Joint Chiefs of Staff, the Under Secretary of Defense (Acquisition, Technology and Logistics) (USD (AT&L)), and the Assistant Secretary of Defense for Command, Control Communications, and Intelligence (ASD (C3I))/ Department of Defense Chief Information Office (DoD CIO). The SIAP SE TF is a jointly staffed organization, with proportional representation from the Services.

Figure 1 shows the relationships the SIAP SE has with the CINCs, Services, and Agencies. We are necessarily intimately bound to the Services.

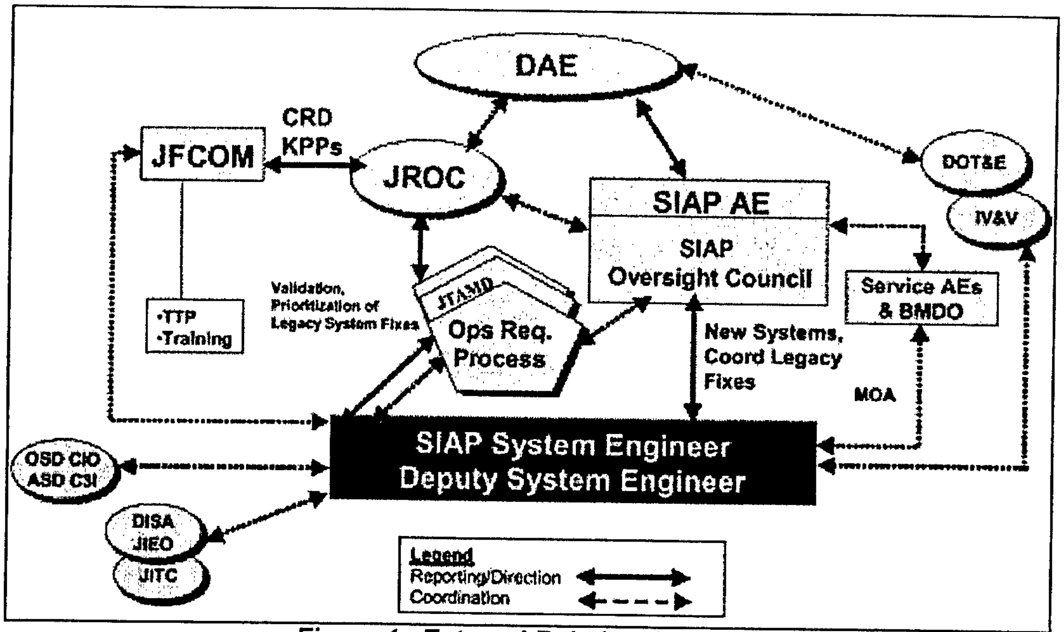

Figure 1. External Relationships

We have strong ties to JFCOM (we work on a routine basis with the J6 and J8, we are collocated with the JI&I (Arlington) contingent, and we work closely with the JCIET staff).

We are tied to the Joint Staff (particularly with JTAMDO, where we are partners in several key efforts (e.g., JTAMD Integrated Architecture, Joint Distributed Engineering Plant (JDEP), JTAMD Process).

We are tied to MDA through shared interests.

We are tied to DISA on JINTACCS Process issues and coordination with allies.

The Services and these agencies recognized they must align the Department's requirements generation and acquisition processes to overcome warfighting shortfalls observed in exercises, evaluations, and real-world operations. In 2001, the JROC validated a series of capstone requirements documents (CRDs) to focus and frame the issues affecting warfighting performance:

- Theater Air and Missile Defense (TAMD)
- Combat Identification (CID)
- Information Dissemination Management (IDM)
- Global Information Grid (GIG)

These documents provided the foundation upon which the SIAP SE Task Force began constructing its collaborative system engineering process for the purpose of detecting tracking, reporting, processing, and engaging aerospace objects in a theater of operations.

By charter, the SIAP SE TF is responsible for the system engineering necessary to develop recommendations for systems and system components that collectively support building and maintaining a SIAP capability.

> "The mission of the Task Force is to identify the most effective and efficient means to achieve a SIAP that satisfies the warfighter needs. The SIAP SE will satisfy this mission by implementing a disciplined systems engineering process. This process will yield recommendations for fielding a SIAP, which will lead to measurable improvements in warfighting capability." [SIAP SE Task Force Charter]

The key focus of SIAP SE TF efforts is the implementation of a disciplined system engineering process. This process yields specific engineering recommendations for the purpose of providing measurable improvements in warfighting capability. The SIAP SE TF is accomplishing this task by building a collaborative work environment, which leverages existing infrastructure and processes. The Task Force will pilot a process leveraging the strengths of the existing JTAMD and JINTACCS processes while expediting system engineering solutions to warfighter shortfalls and the eventual achievement of the objective SIAP capability. The SIAP SE TF is considering the entire spectrum of alternatives (including training and tactics, techniques, and procedures (TTP)) to make recommendations on the most cost-effective means to achieve the SIAP.

Table 1: SIAP SE TF Charter excerpts:

(1) Develop and maintain a disciplined system engineering process and use that process to develop and integrate a SIAP capability. Efforts will be limited to those areas in the following subjects, and only as they relate to the SIAP: (a) TAMD BMC4I systems (b) JDN and systems that express JDN functionality (c) JCTN (pending validation of a JCTN requirement). (d) Other Joint TADILs, networks, advanced concept technology demonstrations (ACTDs), or upgrades as may be assigned by USD(AT&L) or ASD/C3I and approved by the JROC. (4) Focus initial efforts on identifying, prioritizing, and recommending fixes to the existing JDN deficiencies, while ensuring these fixes are on the path to an effective SIAP capability. (5) Submit recommendations for JDN improvements to the JTAMD process, SIAP Acquisition Executive (AE), and JROC for approval. (8) Establish the required collaborative engineering environment (including simulations and hardware-in-the-loop capabilities), for problem investigation and the development, testing, and validation of the equipment and computer programs that build and maintain the SIAP. Provide feedback from the test and evaluation process to USJFCOM so this information can be used to refine TTPs. (10) Supported by the JTAMD process, use a disciplined system engineering process to develop the system and technical views of the SIAP component of the TAMD integrated architecture, to include an overall time-phased development and deployment schedule, ensuring this work is consistent with and supports the operational views of the TAMD integrated architecture. Ensure the work to define the system views is consistent with and supports the common operational picture/common tactical picture "family of interoperable operational pictures" initiative.

The SIAP is both a means and an end. It is an enabler for more effective warfighting and is part of a larger construct that must be carefully engineered so it can easily migrate toward, and support, a coherent tactical picture. As such, it is recognized that the SIAP supports Joint Forces Air Component Commander (JFACC) mission areas involving the tactical employment of airpower. An incremental approach is needed to develop and implement improvements to command and control capabilities of existing systems, and the integrated architectures within which these systems operate, while the objective SIAP capability is being developed.

Figure 3 shows the scope of the problem the task force is chartered to solve. There are several good efforts underway to ensure RF and data "interoperability".

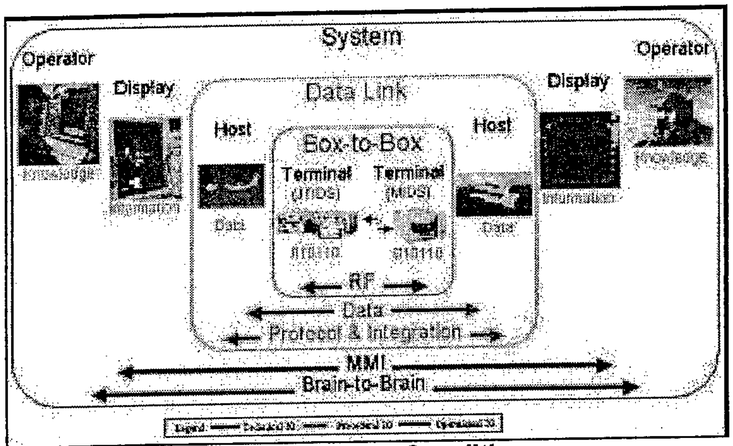

Figure 2. Boundary Conditions

Interoperability is achieved when warfighters can work together to accomplish a mission. "Good interoperability" is the state achieved when equipment and computer programs work together to make the warfighter's task easier. "Poor interoperability" is the description used when the equipment and computer programs do not make the job easier, or, in extreme circumstances, make the job harder.

The job of the SIAP SE TF is to focus on the warfighter - to do the engineering necessary, in the aerospace domain, to achieve the "good interoperability" state.

INTEROPERABILITY

Interoperability requires the successful achievement of three progressively difficult states, as follows:

(1) Achieving information exchange connectivity between participating entities
(2) Applying the information exchanged in a value-added manner in the recipient's information processing systems
(3) Ensuring the end result is better when using the information than when not using it.

The first state is *technical* interoperability. The second state is *operational* interoperability. The final state is *mission* interoperability. The earlier states are necessary (but not sufficient) to achieve the later states. An interoperability effort is not successful unless it achieves the final state. And achieving this state requires substantial *integration* of the participating entities. In other words, interoperability must be *built in*, not added as an afterthought. The fact that many of the participating systems, (as well as the interconnect that provides the interconnect services), are pre-existing *legacy* components of the "want-a-be" integrated system, make integration a highly demanding task with considerable technical risk. Changes to any one component can have far reaching effects as it interacts with the other members of the system-of-systems. Fixing one thing may well introduce several new problems because of these interdependencies unless a well-disciplined engineering process is employed.

Achieving SIAP is often equated to achieving interoperability in the FoS. This association helps highlight the complexity of the challenge. Interoperability is more than radios and RF waveforms. It is more than the standards and specifications. To achieve a SIAP (or interoperability), we must follow a disciplined system engineering process aimed at a specific outcome.

Our approach is to leverage work that is already underway in the Services. Because the Services have often had to out-prioritize Joint engineering specific Service requirements, there wasn't much to leverage. If we attempt to leverage Service system engineering, we often tap into people who are already overextended and who do not have experience conducting joint system engineering. We will not enter into an SE&I contract -- that wouldn't make life easier, anyway, as industry has the same problems that we have with the Services. A major hypothesis under consideration by the Task Force is that improvements to the Joint Data Network (JDN) and the consideration of a Joint Composite Tracking Network (JCTN) within or in addition to the JDN is required to support a SIAP.

The product of the SIAP SE TF recommendations will be combat-ready, operationally certified equipment and computer programs that enable the warfighter to build and maintain a SIAP, and input to TTP necessary to operate the C2 components of an IADS.

As stated in paragraph 5.b of the SIAP SE Charter,

> "The SIAP provides the warfighter the ability to better understand the battlespace and employ weapons to their designed capabilities. The SIAP will support the spectrum of offensive and defensive operations by US, allied, and coalition partners in the airspace within a theater of operations (e.g., attack operations, suppression of enemy air defenses, air and missile defense, intelligence preparation of the battlefield). The SIAP is accomplished through a combination of materiel and non-materiel improvements."

The Task Force will review SIAP related warfighting shortfalls to determine whether there might be non-materiel solutions which can be applied (e.g., solutions that involve changes/improvements to doctrine, organization, training, leadership, personnel, and facilities). Recommendations for non-materiel approaches are turned over to the appropriate organization(s) (i.e., CINCUSJFCOM in the case of tactics, techniques, and procedure modifications) for further action.

The end state of SIAP efforts for the warfighter will be recommended improvements to deployed systems that will (1) correct problems that currently, unnecessarily require operator actions to ensure accurate and effective system operations, (2) augment and/or improve capabilities of fielded systems to help warfighters executing their respective missions, and (3) insert new technologies where appropriate to improve performance, reliability and robustness in the operation of fielded systems to support warfighter capabilities.

WORKING WITH ALLIES

The SIAP SE TF Charter also recognizes the importance of interacting with our allies as the system engineering work proceeds. We have described the SIAP SE Task Force objectives and approach to several NATO allies (United Kingdom, Germany, France, Netherlands), but have not established the formal relationship necessary to describe how we would work together to satisfy mutual interests.

Our primary avenue for allied cooperation and coordination is the present Joint Interoperability of Tactical Command and Control Systems (JINTACCS) process. The JINTACCS process is discussed later, along with a series of actions we are taking in concert with U.S. DoD JINTACCS process stakeholders to improve the performance of this process. These Changes in the JINTACCS process should have a positive effect on allied/coalition operations. We can (and should) do more.

The DoD acquisition system requires *requirements* as the engine that drives development. For the last ten years at least, DoD policy guidance has stated that interoperability is a requirement for all joint systems, and that all C^4I systems are Joint. Most of the system Operational Requirements Documents (ORDs) reiterate this requirement. Yet CINCs continue to complain that the new systems they and their Joint Force Commanders are receiving fall short in delivering interoperability capability. As a result, recent changes have been made in Joint Requirements System guidance that mandate interoperability as a Key Performance Parameter. In addition, information exchange requirements (IER) must be provided to try to be more definitive about exactly what information must be exchanged across-systems. But any effort to design in interoperability must also recognize the need for flexibility to accommodate the many emerging interoperability requirements that are not yet quite official. This area continues to be under estimated, and under planned as architectures are created.

As an example, consider the creation of a single integrated aerospace picture. In the recent past, sensors would not only pass their track information up and down their chain of command, but would additionally broadcast it over networks such as Link-11 or NATO Link-1 to a larger community as relevant information. Simple rules were established to minimize duplicate reports, but by and large the sensors were unaffected as they carried out their primary missions for their chain of command. The "air picture" that resulted was unmanaged and unsupervised. In the future, a management function will be imposed to oversee quality and trustworthiness in the air picture. The rules for contributing will become more complex and more adaptive. Sensors may be asked to move to cover gaps, and are required to correct data registration errors before reporting their tracks. Some sensors may be asked to increase their reporting rates for selected objects or objects about to be engaged. Other sensors may shut down under Emission Control (EMCON) conditions, while still others may be asked to pick up the slack. Several sensors may be asked to report instead of a single sensor having the "best track." Or information from a new airborne intelligence intercept platform may need to be appended to the track file and reported on the broadcast net for everyone to use.

The architecture for information management must anticipate these emerging requirements so that the infrastructure can be modified; i.e. plan for growth, when the requirements firm up.

The success or failure of interoperability ultimately involves highly specific and detailed information about the characteristics of the system-of-systems and its participants and processes. Such detail is not apparent at overarching levels. Thus measuring success in interoperability is basically a confidence building process involving many steps. Each step verifies that the next level of detail is working, and confidence that full interoperability will be achieved progressively grows. But it never reaches absolute certainty because of the complexity of the system-of-systems. There are so many variables that full testing is unlikely to ever be achieved, or even attempted.

Interoperability "defects" not detected early become increasingly expensive to fix later, as seen with the many fixes now required for the Link-16 infrastructure and its participating hosts systems to reposition them as the foundation for the Single Integrated Air Picture (SIAP). Confidence building steps must be applied early in development to catch these defects while they can still be fixed at minimum cost. Building such confidence includes many sequential steps such as architecture development, requirements analysis, system engineering review, code walkthroughs, developmental compatibility testing with other systems, and problem report root cause analysis. In this way the more obvious problems can be discovered early on and fixed, leaving the more subtle problems to be discovered later in more extensive developmental or certification testing.

In summary, interoperability must be designed in from the beginning. In the case binding legacy systems into a new system-of-systems, this option is not available because all the systems have already been designed without sufficient consideration of interdependencies of the system-of-systems.

INTEGRATION

Integration issues and risks are well known and understood for individual platforms. For example, when a Link-16 terminal is added to a Battalion command vehicle, issues of interfacing the terminal with the mission computer in the vehicle must be planned and designed. If the primary function is to extract information being sent over Link-16 and display the information, the integration function is fairly simple. When adding a Link-16 terminal to a helicopter, a fighter aircraft, or a ship the complexity grows, and it is not uncommon for the cost of integration to be several times the cost of the item being integrated. If the information received results in changes in state or performance of the existing weapons system, then these effects must be well understood and carefully tested. For example, if a Link-16 terminal passes the computed location and velocity of its host weapons system platform to the weapon system computer, and this information is integrated with the onboard inertial navigation system, doppler navigation system, or GPS system, then the resulting position will be different than any one alone. If this new position is now reported to others, it will correlate, to some degree, differently than the original position when compared with a locally generated radar track. Thus integrating the Link-16 equipment on one platform has produced an effect on all other platforms. These are interdependencies – when information from participant "A" causes participant "B" to behave differently, no matter how slight. Thus the integration issues associated with the system-of-systems is even more daunting that within a single platform.

When considering the creation of SIAP and the use of SIAP products for sensor and weapons system management, the system engineer must be well versed in all the participating systems. When designing the operating modes for the interconnect infrastructure – JDN and JCTN services – there are further interactions and interdependencies between these two services, over and above the participating weapons systems. Consider the following. The JDN service is providing tracks on two aircraft that are closing. While separation is large, the single reporting responsibility concept is applicable, and the SIAP is generated using tracks from one sensor (JDN services). As the air tracks converge, the risks increase that the two will be confused if JDN services are continued. So at some time before the merge, the JDN service stops tracking and the JCTN services take over – now using the information from all sensors not just one. The increased reporting rate from these multiple sensors, along with their frequency and spatial diversity, and the range-azimuth-elevation measurements, permit each aircraft to be tracked with much higher resolution and confidence. And during the time they are operating in close proximity JCTN services continue to prevail. When one is shot down, or when they diverge again, the accuracy of JCTN is no longer required by the community of users, and the JCTN drops the track and JDN again takes over. This example illustrates the interdependencies between the two providers of track services – JCTN and JDN. It also indicates that the two concepts must be developed in lock step in order for them to be full compliments to each other.

Thus it is clear that the creation of an effective, efficient and responsive system-of-systems to support SIAP is highly complex and requires a rigorous and disciplined system engineering process to guide it to success.

SYNCHRONIZATION

If the above system-of-system attributes were further complicated by participants placing demands on the complex that are time variant, this introduces additional interdependencies, especially with the demands are conflicting. For example, envision a PATRIOT unit committed to engage an approaching threat cruise missile at the same time a nearby naval ship is preparing to engage a high altitude threat. Both weapons systems ask for SIAP support requesting track updates at a one-second rate. What if the available taskable radar resources don't have enough power to do both jobs? How will the available resources be used in the best way to support both customers? This is one example of synchronization where the supporting SIAP resources must be time phased in their support because there isn't enough to do both jobs at the same time. This introduces even more complexity in system-of-systems design and operation.

Another example of synchronization involves the fielding of the system-of-systems. Imagine a future capability to achieve time slot reallocation for Link-16. If all participants join in the process at the same time it works well. But if one of two does not, the benefits quickly evaporate. Thus in many cases it is essential to deploy an attribute simultaneously across the force structure, since if everyone does not participate the benefits are diminished. This requires cross-program synchronization, something that is not at all easy to achieve given the independent development cycles of participating systems. On the other hand, if we wait until the last system is capable to activate a new capability, we cannot capture any of the benefits for the earlier systems. We have wasted any investment in accelerating the fielding if just a few are delayed.

A final form of synchronization is the deployment sequencing of systems delivered to the theater. The design approach must be as insensitive as possible to the reality that not all participating systems will arrive in theater at the same time. The early systems must be able to constitute a significant increment of capability in the absence of all. And the design must permit each new arrival to "plug" into the system-of-systems without upset. The benefits of each new addition must be immediately realized by all participating users.

There is no central focus for S&T activities that relate to the Theater Air and Missile Defense mission. This results in additional gaps, overlaps, and conflicts, as there is no organized way to share information and align efforts. As a result, we miss opportunities for collaborative work, and have a lower probability of transitioning promising technologies into production and fielding. Many good ideas fail to achieve critical mass.

There is a related problem with Advanced Concept Technology Demonstrations. Each ACTD should be focused on helping to shape operational requirements, and should be aimed at specific opportunities for transition to production.

In the next section of this report, we discuss the progress we have made in engineering the SIAP and general plans to complete the actions required by the Charter.

2. PROGRESS AND GENERAL PLANS

Much of our current Task Force activity follows a traditional project management approach. Projects are often characterized by time and cost constrained efforts, involving complex system developments. Our efforts have focused on three major components of the system engineering process: people, processes and products. The job is complex, involving multiple systems, across competing programs, services, joint organizations, and diverse mission areas. In addition, we must coordinate change among existing and new concepts and systems, within tight budget constraints.

Our success can only be achieved through a highly motivated collaborative team adhering to well-understood and disciplined processes which produce well-defined products. The successes of our nation's greatest technological efforts including the Manhattan Project, Polaris, Apollo, and naval nuclear propulsion program can characteristically be traced to people, processes and products. We also believe that today's warfighting shortfalls can ultimately be traced to deficiencies in one or more of these components. "When technical systems fail, ...outside investigators consistently find an engineering world characterized by ambiguity, disagreement, deviation from design specifications and operating standards, and *ad hoc* rule making"[1]

DoD leadership concluded that a joint system engineering approach was required to address this situation. Further, the DoD leadership recognized that a significant investment was required to realize the potential that could be obtained by networking existing systems.

The SIAP SE Task Force is engaged on two broad fronts. First, we are charged with "fixing" existing problems. This involves characterizing the problem, developing and analyzing candidate solutions for those problems, and making recommendations to the Services regarding implementation. This is akin to fire fighting -- putting scarce and valuable resources where they can best arrest a bad situation and minimize damage. The second front is focused on putting the department on a sound, joint system engineering path. As long as there are joint warfighting requirements, the department will need an activity to make recommendations to translate these requirements into equipment and computer programs. Doing this job well will significantly reduce the resources consumed by scrap and rework. This effort is akin to fire prevention -- investing time and energy into avoiding costly problems.

We have been challenged with developing a disciplined system engineering process while providing recommendations for SIAP-related improvements. We are therefore building the bridge as we try to traverse the abyss. What is particularly daunting in both these efforts is the cultural and infrastructural improvements required of both tasks. No standardized process exists today to support joint collaborative system engineering. Our efforts add order to the chaos. Our approach standardizes collaborative teams, products, and processes to support focused, repeatable, and

[1] Vaughan, D. (1996). *The Challenger Launch Decision, Risky Technology, Culture, and Deviance at NASA*. Chicago: University of Chicago Press.

rigorous analysis to effect change. Within budgeted FY01 funding, the task force has made significant, measurable progress in several key areas as we focus on people, products and process.

This section highlights our efforts to establish an infrastructure which effectively uses high-quality people and processes to develop high-quality products. This infrastructure is required to support the "disciplined system engineering process" we were tasked to develop.

2.1. TEAM FORMATION

We are challenged to build a system engineering leadership and management team, composed of professionals with diverse technical and leadership background. There are very few "joint" experts whose experience base supports a broad understanding of the IADS and operational integration issues associated with SIAP deficiencies. In addition, we are required to remain organizationally "lean" leveraging the personnel provided to us from the services "out-of-hide". The diverse nature of each engineering issues requires representation not only from multiple players across joint organizations and Services, but from within a particular Service and organization. We have however, built the initial framework for a joint, collaborative system engineering team. This team recognizes that joint collaboration is as much about trust and confidence as it is about capability. Our efforts have leveraged previous and on-going work done by the CINCs, services, and agencies (C/S/A). We have defined a number of system engineering teams and working groups composed of subject matter experts (SMEs) from the services and joint organizations who are building the various components of our processes.

Table 2: Personnel

As of mid-May 02	Task Force Staff			
	Army	**Navy**	**Marine Corps**	**Air Force**
Civilian	**3***	**6***		
Military		**5**	**3**	**8**
Contractor	**4**			**0**
Total	**7**	**11**	**3**	**8**
Allocation	**9**	**9**	**3**	**9**
Delta	**-2**	**+2**	**0**	**-1**

*Includes borrowed military manpower

The size and structure of the Task Force is designed to ensure that most of the system engineering work is done by the Services in the field. We have learned a great deal about how this arrangement can be made to work. We have been working through the issues that can be expected by coupling a Joint system engineering effort to existing Service system engineering efforts.

We have built our collaboration effort on the concept of achieving "reasonable consensus" among participants. Reasonable consensus ensures each view is fairly represented and considered. The decision reflects what the joint group believes is the most reasonable approach. Most notable, is the consensus reached through the process by which the SIAP attributes were defined. The Services, JTAMDO, MDA, JITC, JCIET, and JFCOM have endorsed these metrics as the assessment measures for characterizing the SIAP.

To offer meaningful joint engineering recommendations, a standardized collaborative analysis process must occur. This joint analysis process includes: analysis planning, data collection, forensic analysis, and reporting. The JIADS IWG provided the first integrated forum by which joint evaluation of IADS performance could be achieved. The JIADS IWG established a collaborative joint environment for the purpose of conducting cross-platform forensic (root-cause) analysis in support of ASCIET exercises. The JIADS IWG has been significantly successful in identifying root-causes of joint warfighting shortfalls and recommending solutions for many of those shortfalls. Following the JIADS IWG model, we have defined a collaborative SIAP analysis process. This process compares results and links critical experiments from multiple T&E events.

SIAP Analysis Team (SAT)

The SAT is a SIAP SE led joint analysis team composed of CINC/Service/ Agency (C/S/A) IADS analysis experts. The mission of the SAT is to provide cross-service IADS analytical expertise to support SIAP-related system engineering decision-making. This mission includes: analysis planning, data collection support, evaluative, predictive and prescriptive analysis, and after-actions required to system engineer improvements to the IADS. The SAT does not replace existing service and agency analysis groups. Rather, its purpose is to act as an standard-setter for comparing results from SIAP-related live exercises/critical experiments, hardware-in-the-loop (HWIL), operator-in-the-loop (OITL), and other modeling and simulation (M&S) events to support the collaborative system engineering decision-making process. Products of the SAT will include planning reports and schedules; documented root-cause analyses, lessons learned, IADS capabilities and limitations, and documented results and engineering recommendations.

The SAT is modeled after collaborative nature of the JIADS IWGs but expands the JIADS IWG's responsibilities to support SIAP-related analysis other events/exercises including: Roving Sands, Foal Eagle, Virtual Warfare Center, Joint Distributed Engineering Plant, Joint National Test Facility, etc. The SAT is also responsible for assessing the utility of Service and Joint M&S, HWIL, and OITL tools in support of SIAP related efforts. Such assessment include: determining the availability of tools, schedule coordination, IV&V pedigree, required upgrade, data formats, potential for federation, etc.

The SAT will support the disciplined SIAP system engineering process by standardizing all aspects of analysis required to support selected exercises/events. The SAT must perform overarching planning, and scheduling of M&S and live evaluation resources to support SIAP system engineering requirements. The SAT will accomplish this overarching planning through collaborative overall objectives for events and exercises. Events considered must be scheduled such that appropriate support may be rendered from SAT membership. Initial consideration must be given to the overall purpose of events, the participants, and most importantly the availability of high fidelity ground-truth data. Once the determination to support an exercise/event is made the SAT will follow a four-phased process consisting of: 1) event planning, 2) conducting the event 3) analysis, and 4) reporting.

Event planning. During this phase, the SAT will emphasize the "What, Who, When, Where" aspects of the evaluation effort. The first step is to determine exactly the end product and the scope of the effort. This will depend largely on the exercise/event and whether or not any SIAP-related improvements have been incorporated into the systems that are expected to participate. Analysis efforts should be focused on assessing the warfighting benefits attributable to improvements to systems using an established set of criteria in addition to determining root-cause for any problems observed. The focus and the products of that focus must be documented. For this purpose the product is a list of potential actions, which support improvements to warfighting capability. The path to defining this product includes measuring existing capability, comparing those measurements with required capability as defined in requirements documents, and understanding deltas between the two by conducting root-cause analysis of the shortfalls. The problem space must be bounded to maximize resources. This bounding includes identification of types of warfighting shortfalls of interest, mission areas, and operational context. In addition, for the M&S environments the SAT must identify the appropriate tools to use to support specific improvement objectives and the potential to federate tools to support evaluation of warfighting benefit.

Event conduct. The type and amount of involvement in an event by the SAT will depend on the overall objectives of the analysis effort. For Block improvement assessments and exercise/event performance evaluations, the SAT will operate both as an oversight body with coordination responsibility for federating tools required to support the SIAP SE decision making process and provide appropriate resources to support event/evaluation conduct. For root-cause or assessment of selected live events and major M&S/HWIL/OITL venues the SAT will not only analyze existing data collection/extraction activities but ensure that the SIAP-related data collection requirements, as detailed in the (Data Management and Analysis Plan) DMAP, are being met. The SAT will also be responsible for supporting on-site analysis for SIAP-related issues. The purpose of this on-site analysis is to isolate issues either for rapid (one/two day) response, (so that immediate changes to tactics, set-up, or procedures can be implemented for the remainder of the event), or for post-event analysis. SAT representatives will also be responsible for the generation and disposition of Test Observation Reports (TORs) that are generated during the selected events. A TOR database will be developed and maintained by the appropriate TOR database manager. SAT representatives will periodically review the state of TORs. Events of Interest (EOI) will be compiled during live exercises and a priority TORs list to guide post-test analysis. Potential issues will be derived from debriefings and/or observer notes.

Analysis. The analysis efforts are highly dependent on the type of event, the purpose of the event, and the analysis requirements. The DMAP shall delineate the responsibilities of the SAT. The analysis phase will be driven by the overall objectives for the test. The SIAP Integrated Assessment Plan (IAP) will delineate overarching SIAP-related analysis objectives. The SAT must identify the candidate M&S/HWIL/OITL and live exercises required to support the engineering decision-making process. The IAP must establish the roadmap for integrating the individual analyses resulting from use of the designated analysis tools. During live exercises and selected HWITL/OITL two important factors must be considered for the analysis efforts. (1) Co-location of the data analysis team and (2) the capability to conduct replay analysis. Co-located, collaborative analysis efforts are key for successful and insightful evaluation of SIAP-related events. The capability to overlay time-space-position-information with weapon system data and C3I data provides a valuable analysis methodology for root-cause analysis. For live events and selected HWIL/OITL events post-event data analysis consists of initial on-site analysis supported by SAT representatives over a period of days, followed by "Team" data analysis meetings scheduled approximately three weeks after the test event. Between "Team" data analysis meetings, the SAT will coordinate the conduct of follow-up analysis at C/S/A sites for evaluating platform-specific TORs and EOIs and assisting in roll-up analysis of the documented performance assessment measures.

Live exercise post event analysis will be performed in accordance with the goals of the DMAP. These goals may include:

1. Isolation of immediate issues

2. Resolution of EOIs

3. Resolution of TORs

4. Recommended corrective action, and

5. Evaluation of capability using documented assessment measures

Root cause analysis is accomplished though categorization of issues as defined by the Lessons Learned Database process. The category bins are:

1. "Bugs"--Specific system related issues usually caused by a failure to properly implement a requirement

2. "Structural" root cause—Issues shared by two or more systems usually caused by improperly derived or omission in a requirement

3. Tactics, Techniques or Procedural (TTP) issues including training

4. Not repeatable issues

Further characterization of "structural" issues, require the decomposition of these issues into lower-level "bins." Such bins include specific system functionality, time synchronization; navigation; detection and tracking; connectivity; data registration; automatic local-to-remote track correlation; reporting responsibility; identification information processing; and display. The SAT will be responsible for ensuring such binning is accomplished through the appropriate C/S/A experts. Issues will be identified as follows:

1. Issue name

2. Issue description

3. Warfighting impact expressed in operational terms

4. Identified work-around

Actions. All identified issues shall be documented in the SIAP Lesson Learned Database. For live events issues will be dispositioned as follows

1. "Bugs" are returned to service-specific program offices for action

2. "Structural" Theater Air Warfare issues are forwarded to the SIAP SETF for prioritization, engineering analysis, and solution recommendations

3. Clearly defined TTP must be returned to the warfighting community i.e., JFCOM for action.

For M&S related events, the SIAP SETF will coordinate and support joint warfighting analysis. Such analysis shall be in accordance with the SIAP SETF Integrated Assessment Plan, and will leverage previous M&S, HWIL, OTIL and Live evaluation data. The SAT will coordinate integrated analysis efforts utilizing joint and service-specific analysis organizations and tools.

All analysis efforts will be documented in formal technical reports, coordinated through the appropriate C/S/A's.

Recommendation: Endorse the SIAP Analysis Team as the oversight body for planning, coordinating, analyzing and reporting SIAP performance at all SIAP related T&E events.

2.2. DISCIPLINED SYSTEM ENGINEERING PROCESS

The SIAP SE Task Force Charter directed the implementation of a "disciplined system engineering process" to "*achieve a SIAP that satisfies the warfighter needs.*" The discipline in the system engineering process flows from standardized policies, procedures, and processes, which support the capability to perform rigorous and repeatable engineering analyses and other activities. Three important elements of rigorous engineering analyses include the capabilities to: (1) evaluate present capability to understand differences between current and the required capability, (2) prescribe improvements to meet requirements, and (3) predict performance based on those improvements. The "discipline" in the analysis is accomplished through clear, consistent, and repeatable standards. These standards include the use of common methods, tools, architectures, operational context, and metrics to perform meaningful, repeatable, and operationally representative analysis.

The block improvement process addresses specific JDN issues, and identifies warfighting capability shortfalls in a prioritized order. The first set of warfighting shortfalls have been characterized as "Block 0." The effort to deal with this first set of issues provides a "pilot" for development of disciplined processes, of ever-expanding complexity to achieve an objective SIAP capability as defined by JROC-validated requirements.

We have used our Block 0 efforts to begin building the disciplined system engineering process needed to realize the level of performance required by the TAMD and CID CRDs. The SIAP SE has identified mutually supporting efforts to address near, mid and far-term improvements to the JDN, while implementing the required process and structural discipline to build an objective SIAP capability.

We recognize the complexity of building a disciplined system engineering process within a complex system of systems (SoS) environment. Integrated development normally starts from the ground up. System reliability traditionally is achieved through rigid architecture definitions and interface standards combined with an uncompromising adherence to technical requirements. Unfortunately, the SIAP SE effort must build reliability into an IADS comprising a mix of legacy and new development systems. This imposes the significant challenge of building infrastructure and discipline after the fact. Dealing with this challenge invariably leads to "interfaced" vice "integrated" systems.

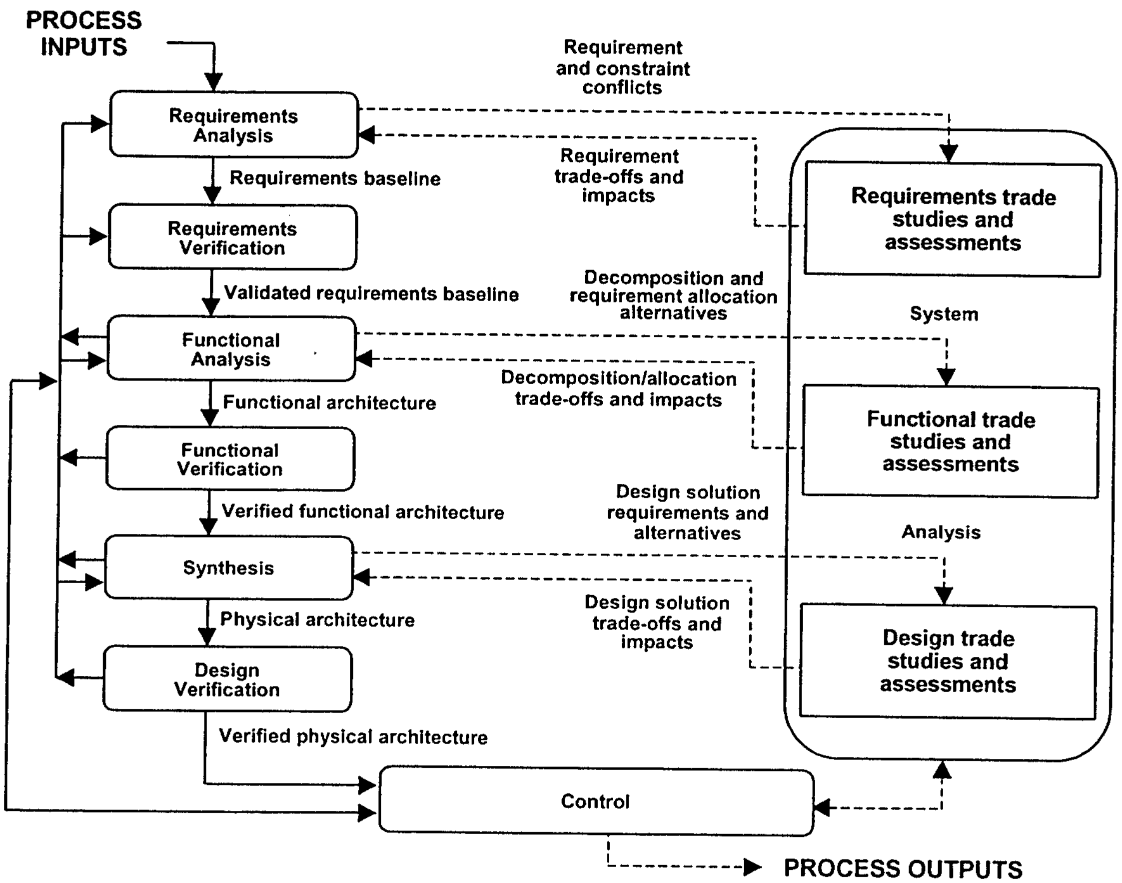

Figure 3. IEEE Std 1220-1998: The System Engineering Process

Recommendation: Reduce Service specific "point" solutions which lead to interfacing vice integration of systems.

Our disciplined approach is based IEEE Std 1220 -1998 System Engineering standard. Our approach is to answer five fundamental questions:

1. What is the technical requirement as manifested in the CRD KPPs?
2. What is the current IADS capabilities-system to warfighter benefit?
3. What is the delta to current capabilities and requirements?
4. What system improvements alternatives will close the gap?
5. What are the cost, schedule and performance trades to make required recommendations?

To answer these questions, the analytic efforts must support the System Analysis portion of figure 3. Our tools, processes and teams support the conduct of: requirements trades studies and assessments to ensure we understand the warfighting requirements we are trying to meet; functional trade studies and assessments to parametrically map IADS functionality from system levels to the warfighting requirements; and design trades and assessments to determine specific system improvement alternatives to meet functional requirements.

Our analytical goals are to institutionalize clear and deterministic assessment measures and assessment processes based on joint requirements. Joint requirements define integrated system architecture. It is the system and technical views of this architecture that support engineering. These standards support the use of common tools, processes and collaborative teams across test and evaluation venues.

The complexity of the SIAP environment necessitates a disciplined system engineering process by which capability assessments of system integration can be made and overall performance can be baselined. Processes such as the Joint Interoperability of Tactical Command and Control Systems (JINTACCS), Service and Joint interoperability certification, and Independent Operational Test and Evaluation, all provide methods by which we can evaluate how well systems operate within service mission areas and in the joint context. Unfortunately, the Joint evaluative processes and systems are compartmentalized. These processes have not been integrated to provide a complete, end-to-end, process that supports multiple layers of interoperability evaluation. It is only through capability improvement process that includes the integration of the various configuration control, management, and certification processes identified above that the DoD can consistently and reliably field warfighting capable systems. Various land-based tools along with live exercises must be analytically linked in a reliable and repeatable process that provide the vehicle by which an end-to-end joint certification effort can be maintained. Joint certification must go beyond message standard compliance. Joint certification must be based on not only how well units send and receive information, but must be based on how well systems process and display the information received. This requires "final exam" or series of "final exams" of the system of systems. We have a number of HWIL, OITL, and live events available to comprise an IADS "final exam." The "final exam" should be based on standardized metrics, scenarios, and grading criteria. The "final exam" must be based on deployable configurations of the systems of systems.

These efforts must include the following key requirements:

- Common warfighting scenarios and mission engagement vignettes used across service and in joint evaluations
- Common MOEs, attributes and MOPs by which to quantify performance and capability
- The SIAP component of the TAMD Integrated Architecture, reflecting deployable systems, equipment and computer programs
- A Joint analysis team for "honest broker" data reduction and analysis
- Linked results, such that outputs of one tool or venue may be analytically linked to inputs of other tools or venues to compare and contrast results
- A single Joint authority that will enforce the above requirements and can direct that improvements to platform and standards be implemented before systems can deploy. In addition, this authority must empower the appropriate organization to enforce configuration control on system computer programs, to ensure that systems are truly certified interoperable before deployment.

Recommendation: Support development of a capability assessment approach, with a single joint authority.

2.2.1. Common Reference Scenarios

Scenario-based design is recognized as a significant tool to support the system engineering process. "Scenarios afford multiple views of an interaction, diverse kinds of and amounts of detailing, helping developers manage the many consequences entailed by any given design..." [Carroll] . In addition, "...scenarios promote work-oriented communication among stakeholders, helping to make design activities more accessible to the great variety of expertise that can contribute to design, and addressing the challenge that external constraints designers and clients often distract attention from the needs and concerns of the people who will use the technology" [Carroll].

We are extending the concept of scenario-based design to support the contextual representation of the SIAP operational concept. A representative operational context supports evaluation of IADS capabilities in real-world replicated settings. The operational context provides a foundation for the development of the Operational View of the TAMD Integrated Architecture.

Our disciplined process is based on standardization of key simulation tools, providing common reference frames for "apples-to-apples" comparisons. In addition, to support the work-oriented communication cited above, common reference frames support joint evaluation of the IADS in both the simulated and live environments. One of these standardized tools is the establishment of a set of Common Reference Scenarios (CRSs).

We have defined three CRSs based on Defense Planning Guidance. These CRSs are composed of digitally scripted red and blue force interactions in operationally relevant time-phased campaigns. These interactions are dependent on operationally detailed engineering vignettes (under development), flowing from the force level scenarios. The engineering vignettes provide stressing limited scope platform engagements which can be applied to the Modeling and Simulation (M&S), HardWare In the Loop (HWIL), Operator In The Loop (OITL) and open air test exercises to support stressing IADS assessments in realistic and repeatable engagements. Within this framework, evaluations of SIAP-system enhancements and the resulting impact on warfighter capabilities from the system/unit through the campaign level may be quantified. The operational framework will contain the definition of requirements and support the development and certification of system functional baselines.

We are gaining joint endorsement of SIAP CRSs through the JTAMD Operational Architecture Roadmapping (OAR) Working-level Integrated Product Team (WIPT). While Red Force interactions receive formal endorsement through the Defense Planning Guidance process, the OAR WIPT process provides the best opportunity for Service collaboration and eventual Joint force endorsement on the collective SOS Blue Force lay-downs associated with each CRS.

Recommendation: Institutionalize SIAP Common Reference Scenarios across DoD as the standardized operational context(s) for characterizing SIAP performance.

We recognize that we cannot script every possible operational employment of our forces against every possible adversary. We do believe that the "joint" community must agree upon a limited number of CRSs. DoD has no centralized capability to standardize both Red and Blue force scripted scenarios. While scripting of Red forces is well organized, Blue force scripting has in the past been left to individual services for very specific and limited evaluation purposes. No joint organization has responsibility for approving combined dynamic interactions of Red and Blue forces in operational representative CRSs. This severely limits DoD in developing, understanding and documenting joint warfighting requirements.

2.2.2. Analytic Tools

Standardized evaluative tools form the basis for repeatable analysis. The Department invests significant resources in test and evaluation tools annually. To optimize this investment, system of system (SoS) analysis must utilize various assessment venues in conjunction with live exercise evaluations to reduce development risk. M&S, HWIL, and OITL venues support evaluation of specific components of the Family of Systems (FoS) from system specific to integration performance perspectives. The objectives of our efforts are to leverage existing tools to the maximum extent practical.

Many M&S/HWIL/OITL tools exist today. These tools are used by the Services and Joint organizations to provide an analytical basis for design, development and evaluation of TAMD systems. System specific and joint integrated tools provide a broad range of analytical capabilities at various measurement levels. By federating models and analytic constructs to support parametric measurements across all levels, variations in system functional performance can be traced to force level capability improvements. Each tool supports analysis for a particular facet of the Family of Systems (FoS). No one tool models all aspects of the IADS functionality from systems performance to warfighting capability. As described earlier, we ultimately desire a "final exam" of integrated system performance at live evaluations and exercises such as JCIET, Roving Sands, and OPEVAL.

No one tool can measure the "interoperability" of the IADS. In fact, measuring "interoperability" is a misnomer. Interoperability in and of itself can only be traced to quantifiable measures, which provide an indication of how well systems have been integrated.

We are building a "tool kit" of required analytic tools to support evaluation of the IADS. Through our Block 0 analysis efforts we have solicited Service input for identifying the required M&S, HWIL, and OITL analytic tools to conduct our analysis. We recognize that each tool brings with it selected capabilities and limitations at each level of evaluating SoS performance. We are using a federation approach, linking an optimized mix of tools, to map system performance to warfighting benefit. The following paragraphs address the capabilities of the various tools under consideration.

2.2.2.1. <u>Modeling and Simulation</u>

Numerous constructive simulations (tools that run faster or slower than real time without human interaction) exist that have varying capabilities to analyze either the performance of SIAP-related systems or the operational effectiveness of missions relying on SIAP information. These simulations exist at several levels of scope, including campaign level, mission level (otherwise referred to as scenario level or theater level), engagement level (otherwise referred to as vignette level) and system/subsystem level. Such environments include purely digital simulations such as the Air Defense Simulation Tool used at Modeling, Analysis and Simulation Center at Electronic Systems Command, Hanscom MA, the widely used Extended Air Defense Simulation environment, and service specific platform models and engineering test-beds.

We are working with Service Subject Matter Experts (SMEs) to identify the appropriate M&S tools to use in our constructive simulation environment. To credibly use these tools, the models must be appropriately validated and the platform/fighting unit representations must be endorsed by the Services. Services agreed to support the verification and validation of SIAP-related M&S tools in the SIAP Charter. To date, not much progress has been made to validate many of the tools used to characterize IADS performance.

Recommendation: DoD lead an extensive effort to validate the appropriate M&S tools to support FoS for SIAP-related analysis.

2.2.2.2. Hardware-in-the-Loop

The HWIL environment moves testing a step closer to evaluating the performance of operational systems. HWIL events can be used to address interoperability issues and unforeseen equipment and computer program conflicts. In the case of the SIAP, HWIL testing is performed with either baseline or engineering load software reflecting the proposed changes. HWIL testing is generally limited to a small number of systems and configurations. These limitations inject uncertainty with respect to how well the tests actually represent the real world. These HWIL environments include: the Joint Distributed Engineering Plant (JDEP), Theater Missile Defense Simulation Environment (TMDSE) and the aviation extension of JDEP, Distributed Network (DNet). These tools are limited by simulation/stimulation inputs. No organized process exists to validate sensor, environmental, and scenario generation tools for joint use.

2.2.2.3. Operator-in-the-Loop

OITL events are cost-effective ways to evaluate integrated system environments with respect to the man-machine interface. However, as with HWIL, virtual OITL events generally are limited in their capability to fully replicate family of systems functionality. As previously noted, no standardized, jointly endorsed process currently exsists. Testers should consider these limitations when evaluating the utility of OITL events alone. Like the HWIL environment, no organized process exists to validated sensor environmental, and scenario inputs to these tools.

Recommendation: Support an orchestrated standardized process for validating SIM/STIM sensor and environmental inputs to HWIL and OITL tools.

2.2.2.4. Empirical Analysis

Live exercises can be used to baseline real system performance and validate M&S results. Future events support analysis of performance deltas after changes to the systems are implemented. Each system can record data for post-event forensic analysis. The amount and type of data can vary from system to system as well as event to event.

Additional factors influence the amount and quality of the data available (e.g. equipment failures, weather, number and type of platforms participating in the events.) However, empirical analysis can provide representative information from real system hardware, operated by real warfighters, in realistic engagements and therefore represents very credible exhibitions of SIAP performance.

So-called data-driven modeling tools such as those used by the Center for Naval Analyses' Operational Data Driven for Correlation Algorithm Performance Evaluation

(ODDSCAPE) and Naval Surface Warfare Center, Corona Division's Performance Evaluation Tool (PET) support replay of live exercise data.

2.2.2.5. Prior Studies

Lessons learned from previous SIAP-related studies support ongoing analysis. While each study typically uses differing methodologies, metrics, and objectives, results from prior efforts when reviewed in the context support ongoing SIAP-related efforts. It is our objective to standardize the methodologies, metrics and objectives to support the capability to compare and contrast results. In addition, these studies become sources for lessons learned. The formal Service review of the 1999 JTAMDO Joint Mission Area Assessment (JMAA) SIAP Technology, Architecture and Roadmap (TAR) study characterized this effort as a viable stepping-stone for further SIAP analysis. The JMAA TAR study is a foundational tool for SIAP analysis efforts.

We are using the combination of M&S, HWIL, OITL, empirical analysis and prior studies to support a comprehensive analysis effort for evaluating IADS performance, predicting capability and prescribing improvement. We have documented this process in the SIAP Integrated Assessment Plan (IAP). The IAP is addressed in more detail later in this report and can be input into our lessons learned database.

2.2.3. Metrics

A critical part of system engineering the SIAP is identifying the degree to which we are meeting JROC-validated warfighting requirements. The definition of SIAP lends itself to quantifiable warfighting Measures of Effectiveness (MOEs), mission level attributes, and system level Measures of Performance (MOPs). Once these values have been defined, we can proceed with developing realistic operational tests to evaluate compliance. As noted earlier operational requirements for the SIAP are found in the TAMD and CID CRD. These operational requirements must be translated (in a traceable way) into lower-level technical requirements that support a disciplined system engineering process, and to objectively assess progress in achieving the required SIAP capability. However, as indicated, one of the SIAP SE's jobs is to help evolve the definition of SIAP. This will be natural fallout of the systems engineering efforts that will be undertaken to create a SIAP that most efficiently and effectively meets warfighting requirements.

Quantifiable and testable MOEs, attributes, and MOPs, are the linchpin to the SIAP system engineering efforts. Quantifiable MOEs and MOPs must support various analysis methods including sensitivity analyses to support technical trade-offs, modeling and simulation, critical experiments, land-based test and evaluation, JDEP and JNTF wargaming, interoperability certification (such as that provided by Joint Interoperability Test Command (JITC)), and evaluation in an operational context (such as JCIET) of SIAP-related changes and other warfighting capability improvements. We have worked very closely with the Services and joint organizations to develop a quantifiable set of SIAP-related measures. Such measures provide answers to three fundamental questions:

- What do we have today? (Evaluative measures)
- What is required? (Predictive measures)
- How do we get what we need? (Prescriptive measures)

Metrics are used to objectively evaluate candidate approaches to meet JROC-validated Capstone requirements. Additionally, they allow us to understand how we are progressing toward the end-state.

Quantifying answers to these questions provide an analysis roadmap for system improvement. Ultimately these types of measurements must be evaluated at various levels of aggregation i.e., measurements at the system/platform level, mission/ effectiveness, theater, and force level. These levels determine a hierarchy of quantifiable characteristics as shown in Figure 4. The roll-up of quantifiable measures from MOPs at the system level to MOEs at the warfighting level provides the capability to determine how systemic problems and improvements affect warfighting capability.

To build a common lexicon, and make progress toward achieving the SIAP, it is critical that the processes and products that result from the various measures and attributes efforts converge to a standardized approved set. At a minimum, a standard set of definitions and derivations of SIAP attributes must be established and universally used across services and joint organizations. These attributes provide a common reference to measure a SIAP. In addition, the appropriate MOEs and MOPs are being identified for use by testers, analyzers and evaluators such that common criteria will eventually be institutionalized to evaluate, predict, and prescribe performance.

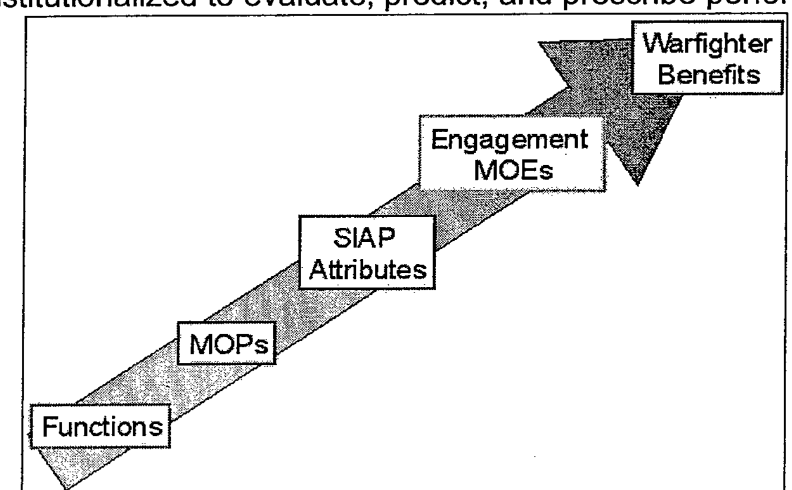

Figure 4. MOE/MOP Mapping

Technical specifications as translated into MOPs can quantify system functionality. MOPs defining system level measures are fundamental characterizations of how IADS equipment and computer programs operate. Table 3 lists representative MOPs.

Table 3: Representative MOPs

- Time difference between system internal time at central track stores and JTIDS terminal
- Latency of messages due to buffering, prioritization, staleness, and time slot allocation
- Translational and rotational error quantities
- Percent of time units correctly report track quality with respect to MIL-STD-6016A

MOEs define IADS performance in terms that matter most to the warfighter. Table 4 lists several MOEs.

Table 4: Representative MOEs

- Distance target penetrated blue air space
- Number of blue losses to red due to air picture or CID
- Number of blue losses to blue due to blue being misidentified as red
- Number of blue defended assets lost; blue casualties

Quantifiable SIAP attributes relate MOPs to MOEs. Through a collaborative working group composed of joint C/S/A representatives, we have derived and defined eight key attributes, which characterize SIAP performance. These attributes flow directly from KPPs defined by the TAMD and CID CRDs. Figure 5 lists the set of SIAP attributes.

The SIAP attributes are easily measured surrogates for the measures of effectiveness.

Completeness: The air picture is complete when all objects are detected, tracked and reported.

Clarity: The air picture is clear when it does not include ambiguous or spurious tracks.

Continuity: The air picture is continuous when the tracks are long lived and stable.

Kinematic Accuracy: The air picture is kinematically accurate when the position and velocity of a track agrees with the position and velocity of the associated target.

ID Completeness: The ID is complete when all tracked objects are labeled in a state other than "unknown".

ID Accuracy: The ID is accurate when all tracked objects are labeled correctly.

ID Clarity: The ID is ambiguous when a tracked objects has two or more conflicting ID states.

Commonality: The air picture is common when the tracks held by each participant have the same track number, position, and ID.

Figure 5. SIAP Attributes

Recommendation: Institutionalize SIAP metrics as the assessment measures of choice for characterizing SIAP performance.

2.2.4. Coordinated Analysis Process

We are leveraging existing test and evaluation assets to provide credible, and complete system engineering analysis to support recommendations to the JROC. Evaluation of mission area performance supports iterative utilization of the previously described analysis venues described. DoD 5000.2R calls for a portfolio management process whereby "investments are grouped by mission related or business process to establish a portfolio. Trade-offs among investments are made to maximize benefit to the mission, and benefits are measured and evaluated in the context of the overall strategy for the mission." Figure 6 depicts an analysis process, which starts from an operational architecture and joint requirements and iterates the evolution of capability through various system-specific and integrated environments. Each venue is supportive. By linking various venues, an end-to-end analysis effort will support forensic investigation of SoS integration deficiencies, prescribe improvements to systems, and predict warfighting performance based on those improvements. At each step, results are evaluated in the context of the IADS portfolio.

One of the key elements in the analysis process is the SIAP IAP designed to support the IADS portfolio at each level and is detailed in section 2.2.5. The end state, however, is to ensure that the tools support development of quality and reliably integrated systems, which perform flawlessly during open-air exercises.

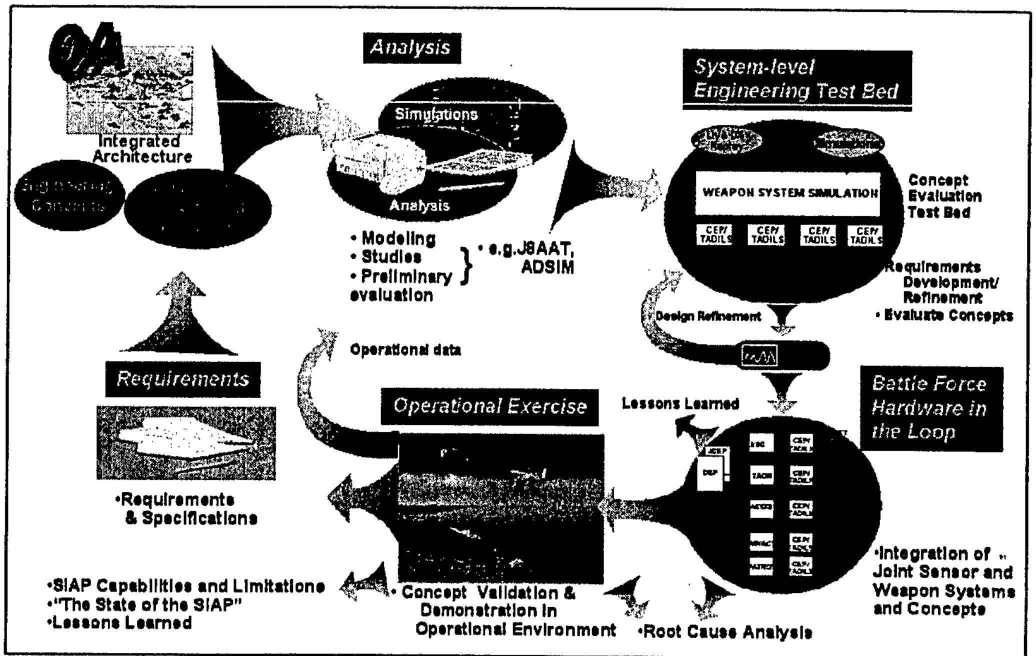

Figure 6. Analysis Process

Live events generally support two purposes; 1) training, and 2) verification and validation. Operators and engineers compete for hardware and time during exercises. This competition limits the effectiveness of both endeavors. We desire an end-state where live event evaluation proves capability rather than deficiency. Our goal is for leadership to be surprised when interoperability fails during joint exercises, rather than expect deficiencies. In addition, by increasing the capability to perform credible land-based integrated system performance evaluation, a large measure of quality assurance testing is moved out of the live environment back into the shore-based test facilities. Our efforts to build an IADS portfolio must be supported by the dedicated IOT&E required by law. Our efforts must be integrated and endorsed by DOT&E to support mission capability assessments.

We have two primary ways of testing at the IADS level. The first method uses the extensive test networks, in place today, to interconnect the systems that comprise an IADS and to challenge this configuration with threat-representative scenarios. This testing shows discontinuities in the interface between individual systems (e.g. implementation of the Tactical Data Link Standards). These discontinuities, in turn, are resolved by the individual implementing systems. Certification of specification compliance by each of the individual systems is necessary (but not sufficient) to meet our IADS requirements.

A joint analysis team such as the JIADS IWG is a means by which we can continue to encourage collaborative IADS assessments. The most important products of the JIADS IWG is the increased communication in the acquisition community, and the training our engineers obtain in developing systems that will support joint operations. Assessing capability and performance by way of either of the above methods is supported by three essential elements: people, products and processes.

Recommendation: DOT&E to support an end-to-end SIAP analysis process, led by the SIAP SE, which leverages tools at all levels of system test and evaluation.

2.2.5. Integrated Assessment Process

As noted above, Department of Defense invests significant resources each year to develop and use Joint and Service-specific T&E tools. However, the various resources are rarely used collaboratively. Unique exercise objectives, requirements, planning, evaluation criteria, metrics, and analysis limit comparison of results from one venue with those of another.

We have integrated the above standardizing products through an Integrated Assessment Plan (IAP). The IAP specifies: M&S, HWIL, OITL, and open air tools for performing analysis; analysis methods; supporting organizations; required CRS engineering vignettes; network designs; and reporting requirements. The IAP also addresses the federation and integration of tools, which supports identification of underlying system deficiencies rolled-up to warfighting effects. The federation of tools approach has been piloted through a SIAP Metrics Proof of Process (MPoP) effort. The MPoP maps system functional deficiencies to warfighting effects i.e., weapons expenditure, and fratricide for a specific engineering vignette. This effort mapped sensor registration, navigation positional, and track quality reporting errors to SIAP attributes of *Clarity* and *Kinematic Accuracy* and respective warfighting MOEs. The MPoP provides an example of the fundamental aspects of the IAP process. Figure 7 depicts the MPoP pilot effort.

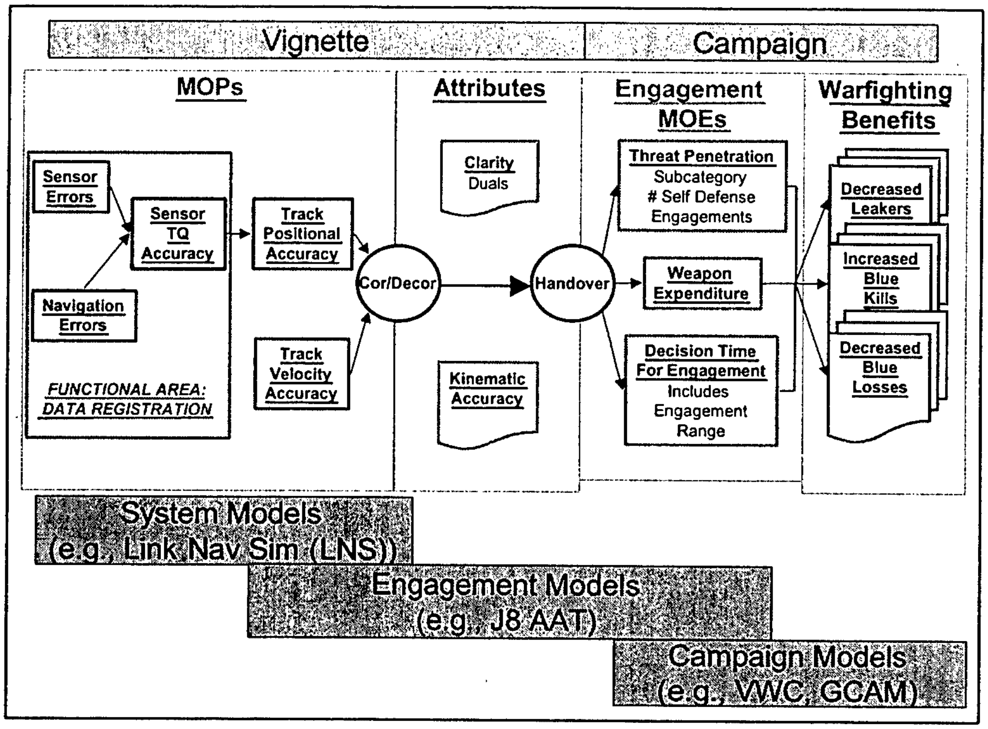

Figure 7. SIAP Metrics Proof of Process: Data Registration Requirement Mapping

The SIAP SE Task Force will leverage existing Test and Evaluation (T&E) capabilities to provide credible, and complete system engineering analysis to support recommendations to the JROC. As noted above, the DoD invests significant resources each year to develop and use Joint and Service-specific M&S, HWIL, OITL and live evaluations for the purpose of assessing IADS performance. However, the various resources are rarely used collaboratively. Unique exercise objectives, requirements, planning, evaluation criteria, metrics, and analysis limit comparison of results from one venue with those of another.

2.2.6. Critical Experiments

Objective and repeatable analysis is supported by well-planned critical experiments. Critical experiments document objectives, rationale, purpose, expected outcome, metrics, requisite conditions, and standardized methodologies for assessing key SIAP-related issues. We have defined an initial list of nine critical experiments for evaluation in various T&E venues. Figure 8 provides the initial list of related SIAP critical experiments. Results from these critical experiments will be documented and catalogued for comparison with M&S/HWIL/OITL analysis and other open-air exercises to support engineering decision-making. The critical experiments allow us to develop and challenge specific SIAP-related hypotheses and to use what we learn to make improvements. As critical experiments are completed, and results are digested, the list will be adjusted.

- Time Synchronization
- Sensor tracking/reporting accuracy
- Commonality
- Data registration
- Automatic Local-to-Remote Track Correlation/Decorrelation
- Identification processing
- PPLI accuracy
- Formation tracking and assessment
- Model validation

Figure 8. Initial SIAP Critical Experiments

These critical experiments are directly linked to the Block improvements and to the SIAP Integrated Architecture.

During Roving Sands FY01 (RS01) the SAT supported by Service Subject Matter Experts used modified critical experiment to support evaluation of AN/TPS-59 and Patriot sensor registration capabilities. These SIAP critical experiments will be used during JCIET 02.

Recommendation: Endorse SIAP critical experiments as primary objectives for SIAP-related analysis across venues.

2.3. CHARACTERIZATION OF THE EXISTING CONDITION

The previous sections address infrastructual improvements to institutionalize discipline in our analysis efforts. These improvements directly support and are directly supported by other SIAP SE products and processes. Our LLDB provides repository for storing observations and warfighting shortfalls identified through our analysis efforts. The proposed concept for this database sees an electronic linkage to already established lessons learned database efforts in the Services and Joint agencies. Data in repositories such as the AFKKLB, Navy LLDB, and JFCOM JCLL must be culled for SIAP-related data, then linked to a centralized SIAP repository, quite possibly associated with one of these existing tools. The SIAP-repository then provides an engineering warehouse for SAT forensic and prescriptive analysis and supports the development of IADS capabilities and limitations document.

In addition, the SIAP SVs and TVs of the TAMD integrated architecture become the technical context for defining SIAP functionality to support mapping system performance to warfighting capability. We cannot define the beginning and end-states evaluative and predictive efforts without defining this architecture. Upon, completion the integrated architecture becomes a repository for all our engineering efforts.

The development of our analytic infrastructure also directly supports our Block improvement recommendation process. Each of the identified tools, processes and associated teams are required to support the disciplined approach we were chartered to build.

The services continue generate substantial evidence of warfighting shortfalls within the IADS. Post-action reports from military operations, training exercises, and joint evaluations such as those conducted by the All Service Combat Identification Evaluation Team (ASCIET), identify specific issues. We have developed a process for collecting and consolidating these SIAP-related issues.

In accordance with the SIAP SE Charter, CINCUSJFCOM will sponsor the resolution of TTP issues on behalf of the joint warfighter to the appropriate operational organization(s).

We expect the Service system program mangers to resolve computer program deficiencies applicable to their systems. CINCUSJFCOM can have a significant influence in the prioritization, scheduling, and ultimate implementation of the fixes to these problems by working with the Services to ensure appropriate direction and resources are in place for the program mangers to take remedial action.

The SIAP SE has collaborated with the respective Services to analyze structural and unresolved issues as part of the SIAP SE's lessons learned efforts Service and MDA "top ten" lists have been generated. The "top ten" lists were categorized as described above. Other amplifying information has been included such as: observation date, time, event origin, systems involved, recorded data information, etc.

We are developing a lessons learned repository, leveraging existing service/joint capabilities such as the Joint Automated Lessons Learned Tool. We believe an automated tool can contribute significantly to collecting, tracking, and documenting the resolution of technical interoperability shortfalls.

Recommendation: Support the development of an automated Lessons Learned Database to provide a repository for collecting and consolidated joint SIAP-related lessons learned.

2.4. INCREMENTAL CAPABILITY IMPROVEMENT

The SIAP SE TF plan focuses first on recommending specific changes in the systems that support the "JDN", while ensuring the fixes are on a path to an effective SIAP capability. Incremental SIAP block upgrades will evolve from near-term "JDN" fixes that improve current capability and build to fielding a SIAP capability that meets the requirements defined by the TAMD and CID CRDs. Implementation of materiel JDN fixes is expected to require modification to affected host-system computer programs and equipment. Computer programs and equipment must be modified to implement the fixes, and then the systems must be tested and certified following implementation of any changes. This process becomes quite complex given that many of the systems have existing upgrade/update plans and schedules, and they may be impacted by constraints such as shipbuilding schedules or Operational Flight Program (OFP) upgrades.

The most cost-effective approach to implementing near-term "JDN" fixes is to consolidate them into logical block upgrades to minimize the number of times that host computer programs must be modified and tested. It is important to understand the definition of "JDN". From the TAMD CRD, *"the backbone of the JDN is Link 16 transmitted via JTIDS and MIDS terminals. The JDN is the collection of near-real-time communications and information systems used primarily at the coordination and execution levels."* Therefore, the SIAP SE Task Force is focusing on specific tactical data link fixes, with an emphasis on Link 16.

The SIAP SE Task Force has established milestones to provide an initial recommendation for a Block 0 upgrade by December 2001, with Block 1 to follow 12 months later, and future Block upgrades to follow on a two year periodic to coincide with the budget cycle. To identify the root cause problems that would be addressed in these blocks, the Joint IADS (JIADS) Interoperability Working Group (IWG) analyzed ASCIET 99 and ASCIET 00 data. Over 30 items were identified as significant issues that needed to be addressed. Four of the items were selected and endorsed by the JROC as the initial demonstration of the SIAP SE process, and these form the basis of the Block 0 upgrade.

The four Block 0 items were selected due to their impact on the "JDN", their applicability across all four services, and the broad set of SIAP system engineering processes that will be developed and used to address them. The Block 0 items are:

a. Correlation/De-correlation (ICP TM98-035 Ch 10). This ICP standardizes the correlation/de-correlation processing for all systems participating on Link 16 by prescribing the method by which the correlation "window" will be computed as well as providing details on the use of kinematic, identification (ID), and Identification Friend or For (IFF)/Selective Identification Feature (SIF) data in the correlation/de-correlation process. This ICP was selected because it has great promise to reduce the incidence of dual tracks and because it was already approved by the Services for Allied coordination through the JINTACCS process. This ICP also allowed us to better understand the present operation of the JINTACCS process and to examine how best to link the interface change process to the requirements generation process and how to tie both of these to the SIAP integrated Architecture.

b. Identification (ID) taxonomy and symbology (ICP TJ00-002). This ICP defines minimum implementation requirements for systems participating on Link 16. The ID section of the minimum implementation requirements stipulates that all systems operating on Link 16 will implement all seven ID values (Pending, Unknown, Suspect, Assumed Friend, Neutral, Friend, Hostile) contained within MIL-STD-6016A. Currently, some systems have only implemented a subset of these seven values. This may lead to operator confusion and the loss of previously derived data following a reporting responsibility shift to these systems that have not implemented all seven values. The TADIL J Minimum Implementation (Taxonomy) ICP was selected because it was the one issue that CINCUSJFCOM wanted resolved due to the impact of symbology mismatch on the operational forces. This change also allowed us to understand the connection between the symbology used on displays, underlying information taxonomy, and adequacy of the present interface standards (e.g., MIL-STD-6016A) for use as a contractual requirements document.

c. ID conflict resolution matrix (ICP TM94-005 Ch 10). This ICP establishes the standardized way to process the resolution of ID differences between units. The ICP stipulates under which conditions a track's ID, that is received from another unit and is different than the locally held ID, will be automatically accepted, automatically rejected, or subject to operator review. It also provides the rules for the transmission and processing of ID Difference report messages. This ICP was selected because it has been approved for implementation and because it, too, has great promise to reduce operator workload and distraction. It was also selected because we wanted to understand the coupling of algorithms such as this to the TAMD and CMD CRD requirements.

d. Formation Tracking/Correlation. This is not an ICP, but a problem statement. The problem arises from a difference in how services handle "formation" tracks, one track that is used to represent more than one object, on Link 16. A unit, usually an airborne surveillance unit, transmits a formation track as a workaround for underlying system limitations. When another unit, such as a shooter with a higher fidelity sensor and tracker, receives the formation track and correlates it to one of the local tracks in the formation, that unit is left with unidentified tracks for the other objects in the formation. The formation assessment methods currently used for identifying the other objects are inconsistent. Also, the Correlation/Decorrelation ICP includes a restriction preventing the correlation of a formation track with a local track; this will increase the number of unidentified tracks at the shooter. In addition, USJFCOM stated that formation tracking is inconsistent with the TAMD CRD requirement for one track/object. SIAP SE TF is leading a joint team that will identify the underlying system limitations for which formation tracking is used as workaround and the limitations of formation tracking and assessment. The team will recommend improvements to the limitations and perform analysis to refine the recommendations. The formation tracking issue was introduced by the U.S. Army as a challenge to the Automatic Local-to-Remote Track Correlation/ Decorrelation ICP. The Correlation ICP specifically prohibited correlation of tracks with differing strength values indicating the sensor/operator belief that two aircraft are associated with a single-track report. The Army challenge to the Appeal Panel was denied. However, the Army and the USAF were directed to form a working group to design rules for the association of formation tracks and the subsequent transfer of identification and other critical information. This group did not operate as a formal part of the JINTACCS process, and is now functioning as part of the SIAP Effort.

The four Block 0 items were selected due to their impact on the JDN, their applicability across all four Services, and the fact that three of the four issues were already approved by the JINTACCS process (2 for implementation and 1 for allied coordination). By picking issues that have been previously approved by the JINTACCS process, we are able to assess the JINTACCS process effectiveness in meeting JROC-validated warfighting requirements and identify process improvements to better support warfighting needs. The Block 0 Items are listed in Table 5 and more details regarding their selection are presented below.

Table 5: Block 0 Items

1. Correlation/De-correlation (ICP TM98-035 Ch 10)
2. Identification (ID) Taxonomy and Symbology (ICP TJ00-002)
3. ID Conflict Resolution Matrix (ICP TM94-005 Ch 10)
4. Formation Tracking / Correlation

The Services were asked to nominate systems to implement these four JDN fixes. At first 12 "core" systems were selected from 92 systems utilizing Link 16 in large part due to their plans to participate in JCIET 2002. This exercise would provide an opportunity for the SIAP SE TF and the joint community to assess the impact of the fixes in an operational environment. Additionally as part of the Block 0 initiative, the Block 0 team and Service representatives recommended other systems consider implementing the Block 0 fixes to improve joint warfighting capability. Of 92 Link 16 systems, the Block 0 team used a down select process to define a manageable set of systems and configurations to perform an optimized acquisition analysis (see table 6). These systems meet several common criteria:

- Support air and/or cruise missile defense.
- Established IOC before or during FY06 through the POM 04 FYDP.
- Produce SIAP tracks.

Table 6: Block 0 Systems

Army	PATRIOT ICC **FAADC2** **AMDPCS** PATRIOT BCP RAH-66 ADAM Cell	**USMC**	TAOM
Navy	**ACDS Blk 0** **ACDS Blk 1** AEGISB/L 5.3/3A.0X **AEGIS B/L 6.1** AEGIS B/L 6.3 AEGIS B/L 7PH1 SSDS MK 2 E-2C Group II E-2C Group IIN, MCU, & CEC FA/18 C/D & E/F	**USAF**	**E-3 (AWACS)** F-16 Blk 40 F-16 Blk 50 B-2 F-22 TACP-M **F-15 Suite 5M/ 5E** **MCE, v.111** **RIVET JOINT**
Note: **Bold** indicates Block 0 "Core" Systems			

The Block 0 team delivered a decision support binder (DSB) in December 2001. The DSB represents the centerpiece of Task Force activity and the focal point for SIAP products. The Task Force will develop a plan for each block to identify the specific changes to be implemented in specific systems to achieve specific improvements to the JTAMD FoS SIAP capability. Block Improvement Plans will include:

- Engineering specifications-ICPs, and other technical specifications that must be implemented in each system to achieve the desired capability,
- Supporting rationale-the test results and analysis that project the warfighter benefits for fielding the engineered fixes,
- Acquisition estimates-total cost/system costs to implement specified upgrades as well as schedule recommendations for synchronizing block upgrades with ongoing programs and aligning key insertion points for SIAP functionality. The Task Force will also recommend which systems should not be upgraded based on cost-benefit analyses.

We envision that the SIAP Block Improvement Plans will be the key decision document for JROC approval to proceed with implementation of each SIAP block upgrade. The Block 0 effort was de-scoped as a result of budget limitations driven by the delayed Congressional approval of the FY01 Above Threshold Reprogramming action. However, significant effort will be completed to provide:

- Current Link-16 architecture incorporating the 12 Block 0 core systems,
- Analysis of the effect of incorporating the Block 0 changes into representative systems up to the campaign level, and an

- Acquisition assessment of the recommended systems including cost estimates for incorporating the Block 0 changes and a roadmap view of when the changes will be incorporated into the individual weapon system.

The acquisition assessment will provide a JDN "system of systems" view of ICP implementation across the targeted systems and facilitate any recommendations required. The cost information will deliver budget estimate data the Services can use to build the POM submissions needed to fund Block 0 implementation in both the core and recommended systems.

Overall, SIAP budget limitations severely impacted the quality of budget and schedule data the Block 0 team was able to acquire. Many services were unable or unwilling to provide data above rough estimates due to the cost to acquire cost estimates from the various prime contractors or from the lack of priority assigned to the SIAP effort by the various Service resource OPRs.

We have already learned many lessons from the Block 0 effort. The Services do not develop cost estimates for engineering and implementation for interface changes. Additionally, the Services do not have sufficient engineering evidence to support the changes that are approved through the JINTACCS process to meet the burden of proof requirement levied on us.

Recommendation: Direct Services to provide appropriate funding and priority to prepare budget level estimates and high level program schedules required to implement FoS JDN fixes.

3. SPECIFIC PLANS

In this section of the report, we address the three specific issues discussed in the tasking memo. After a brief introduction to establish context, we begin by describing the plan to develop and maintain the SIAP Integrated Architecture. We then describe the plan to improve the capability of existing systems to operate together ("fix the JDN"), and end with a brief description of the plan to define the "JCTN".

These three specific issues are tightly coupled – the SIAP Integrated Architecture is the framework for the "JDN" and the "JCTN" issues, and all must be tied back to JROC-validated Capstone Requirements Documents (TAMD, CID, IDM, and GIG).

We are operating under several fundamental premises:

- A quality product obtains from a quality process, so building and maintaining a quality process is critical to providing the required level of capability.
- There is no "silver bullet" to the "interoperability" challenge – only a robust, disciplined system engineering process will provide the required level of performance.
- The Department of Defense (DoD) does not have the resources necessary to have <u>healthy</u> competing programs – some convergence is needed to provide lifecycle cost avoidance.
- We do not have the resources to start from a "clean sheet of paper" – we must leverage, and extend as necessary, work that has been done before.
- An incremental ("spiral") approach to providing warfighting capability is the only viable course of action. We have neither time nor resources to wait for the "better" solution.

Improving joint warfighting capability is a task with several hard constraints:

- The DoD has a significant investment in existing systems, with attendant equipments, computer programs, and infrastructure. The vast majorities of the systems that will be in service in 2010 are either in service today or are in development and will enter service in the foreseeable future.
- Joint warfighting requirements must compete against Service-specific requirements for scarce (Service) resources (e.g., dollars and people).
- The DoD will operate with forces provided by other nations, so system engineering efforts must account for allied and coalition operations.

Making progress depends upon balancing conflicting demands in this constrained environment. Progress is made more difficult because the Department of Defense does not yet have enterprise architecture for joint theater air warfare.

Although interoperability tests and exercises to date have been disparate and focused on objectives not directly related to the SIAP, conventional wisdom suggests that the "JDN" must be significantly improved while a "JCTN" or its equivalent capability is also required to meet JROC-validated capstone requirements for theater air and missile defense and combat identification. It is generally accepted that the approach that makes the most sense fixes problems in the "JDN" while either augmenting it with additional bandwidth (or otherwise increase effective throughput) or adding a new network. The Task Force will follow the technically correct path while ensuring a sound methodology so that alternative approaches can be identified with appropriate acquisition rigor to find a solution acceptable to the Services.

3.1. SIAP INTEGRATED ARCHITECTURE

The 14 November 1996 memorandum that discussed the management of Theater Air and Missile Defense activities (Appendix B) directed that a TAMD Integrated Architecture (IA) be generated. The memo directed JTAMDO to "coordinate with the Warfighting CINCs and Military Services to develop joint mission capstone requirements, a joint mission architecture, and a joint capabilities roadmap." BMDO (now MDA) was directed to "assume the role of integration Systems Architect for Theater Air and Missile Defenses." MDA was also directed to "working with JTAMDO and the Services, . . . translate the JTAMDO developed operational architecture into systems architectures, perform system engineering at the architecture level, plan and ensure integrated testing of defense architectures, and lead program acquisition activities."

The TAMD and CID CRDs were validated by the JROC in March, 2001; these documents constitute the mission capstone requirements for TAMD. JTAMDO will deliver the first iteration of the Operational Views of the TAMD IA in October, 2001. The TAMD IA will include the Joint Capabilities Roadmap.

BMDO began work on the system and technical views during FY 00. BMDO was scheduled to deliver the system and technical views of the TAMD IA in the fourth quarter of FY 02. Because BMDO's role in TAMD changed during FY01, BMDO abandoned the effort for generation of the system and technical views of the TAMD IA.

The SIAP SE Task Force Charter recognizes the importance of the TAMD Integrated Architecture and provides the specific tasking shown in figure 9.

(9) Support the JTAMD process in developing the operational views of the TAMD integrated architecture.

(10) Supported by the JTAMD process, use a disciplined system engineering process to develop the system and technical views of the SIAP component of the TAMD integrated architecture, to include an overall time-phased development and deployment schedule, ensuring this work is consistent with and supports the operational views of the TAMD integrated architecture. Ensure the work to define the system views is consistent with and supports the common operational picture/common tactical picture "family of interoperable operational pictures" initiative.

Figure 9. Interaction with the JTAMD Process

We are working closely with JTAMDO to develop the SIAP component of the TAMD IA. To strengthen this team effort, and to facilitate communication, we have collocated the architecture efforts of JTAMDO and the SIAP SE Task Force. This collocation effort has greatly improved communication and teamwork.

To reduce confusion within this document, and to remain consistent with the tasking memo, the term "SIAP Integrated Architecture" refers to an architecture that extends beyond the TAMD IA to cover the entire aerospace domain, while not covering that portion of the TAMD IA that does not specifically relate to objects in the aerospace volume. Figure 10 graphically represents the relationship between the SIAP and TAMD IAs and shows the activity that has the lead to develop specific architectural views.

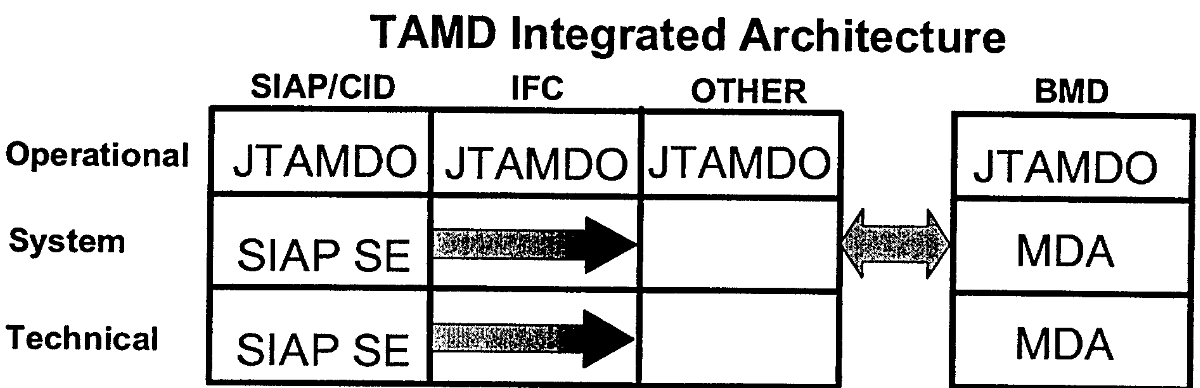

Figure 10. Relationship between SIAP and TAMD Integrated Architecture

The TAMD IA will define an objective capability that is essential to achieve the required levels of TAMD and CID warfighting capability. The IA is a key analysis tool that provides a structured means to document the results of the system engineering process and act as a control mechanism to indicate where analysis is missing or further analysis is needed. The IA is a technical repository for characterizing a SIAP and forms the technical context for performing repeatable analysis. All our analysis and IA development efforts are mutually supportive for building a disciplined system engineering process.

Recommendation: Joint Staff J-8 assign to JTAMDO the responsibility and resources necessary to complete the operational views of the SIAP IA

The SIAP IA specifically includes the processing, management, and dissemination of combat identification information. Additionally, because the SIAP is an enabler of joint warfighting capability, and because it must support the most stringent JROC-validated joint warfighting requirement, it must be engineered to meet the requirements for integrated fire control and advanced battle management aids articulated in the TAMD CRD.

As we have worked with JTAMDO in building both the SIAP IA and the TAMD IA, we realized the need to solicit industry involvement. We recognize that the capability to build and maintain a SIAP will only be achieved through the fielding of safe and effective people, equipment, computer programs, and operating procedures. The equipment and computer programs are developed and maintained by our industrial partners. Having industry involved early and often gives them insight into the direction toward which we are heading and allows us to solicit and understand their suggestions and concerns. We are working with JTAMDO to hold a series of workshops with industry (co-sponsored by the National Defense Industry Association). These workshops will allow, in a carefully controlled environment, for a full and open discussion on the evolving SIAP Integrated Architecture.

The SIAP IA must be maintained (updated and configuration managed) as joint requirements change and as emerging capabilities are engineered and fielded.

Recommendation: USD(AT&L) formally assign an activity to budget for, update and manage the configuration of the SIAP Integrated Architecture.

3.1.1. Objectives

The SIAP IA serves several key functions. First, it allows us (warfighters and engineers) to communicate amongst ourselves. It shows, in graphical and tabular form, how we intend to fight by:

- describing interrelationships among warfighting units,
- describing the functions that warfighting units will perform individually and collectively, and
- defining how well those functions must be performed to satisfactorily accomplish the assigned mission in an acceptable way.

The integrated architecture supports informed decision-making. It helps identify the existence of functional gaps, overlaps, and conflicts, and provides a framework for issue resolution. The IA exposes interrelationships so we can better understand the impact of individual component or system changes on the capability of the larger system.

The IA provides a structured means to document the results of the system engineering process. The IA is also a shared repository of system engineering artifacts. It is a control mechanism, supported by modeling and simulation, to indicate where analysis is missing or further analysis is needed.

Additionally, the architecture forms a contract between the warfighter and acquisition communities, and allows us to communicate with industry.

The SIAP IA defines an objective capability needed to attain JROC-validated TAMD and CID warfighting capabilities. The SIAP IA supports traceability of requirements from CJCS Joint Vision 2010 and 2020, TAMD and CID CRDs, IDM CRD, GIG CRD, and the JTAMD 2010 Operational Views, to system functions, Information Exchange Requirements (IERs), and a system-level physical data model. This requirements traceability provides a coherent audit trail from integrated operational requirements and measures of effectiveness (MOEs) to the specific technical criteria governing the development of a SIAP capability.

The SIAP IA is the product that defines the joint interfaces, functional and allocated baselines, and the associated information exchange requirements (IERs)/data models, and serves as the basis for SIAP implementation trades and requirements allocation. This product supports developers, testers, and is the tool for enforcing integrated implementation of SIAP functional requirements. Architecture products, such as the System Capability Evolution Description, will describe the key elements of the Block Improvement Plans that are a key decision document for JROC endorsement to proceed with implementation of each SIAP block upgrade.

The SIAP IA provides justification for Service and Agency investment in legacy, emerging, and future systems to achieve a SIAP capability. This roadmap will be integrated with the Joint Capabilities Roadmap and the Joint Acquisition Roadmap that is now being generated by JTAMDO and MDA with SIAP SE TF support. The SIAP IA will be used to establish and enforce the integrated fielding of SIAP functional requirements within a TAMD IA context. It will focus on the issues of interconnecting systems and organizations at the Service-to-joint, joint-to-joint, and Joint Task Force (JTF)-to-ally levels of interoperability. The SIAP IA will provide sufficient guidance to system architects and engineers to ensure their systems conform to the information processing and sharing requirements of the JTF.

In the remainder of this section, we briefly discuss some of the terms associated with the SIAP, describe the motivation for the SIAP, outline the concept of operations, and discuss specific SIAP and SIAP-related requirements.

3.1.1.1. Definitions

In this section, we briefly discuss the definitions of some of the terms associated with the SIAP, and some of the problems that arise from the definitions.

While use of the terms Joint Planning Network (JPN), Joint Data Network (JDN), and Joint Composite Tracking Network (JCTN) are used frequently, there is no widely-accepted detailed definition for any of these networks. That deficiency was recognized in the SIAP SE charter:

> "c. This charter recognizes the fluid nature of present concept definitions such as joint planning network (JPN), joint data network (JDN), and joint composite tracking network (JCTN). The SIAP SE will assist the Joint Theater Air and Missile Defense Organization (JTAMDO) in defining these terms and will ensure the system engineering process is responsive to the evolution of concepts such as these. An initial focus of

the organization will be on establishing recommendations for near-term JDN improvements on the path to a SIAP capability."

In general, each of these networks is comprised of operators, computers, computer programs, and communications equipment, and is intended to satisfy specific operator needs and requirements. There are several complicating factors associated with these networks:

- Similar, and in some cases, identical information is exchanged among operators and computers over two or more networks asynchronously. This results in operator confusion and system failure due to data loops and race conditions.
- The computers, computer programs, and communications equipment used in each of these networks are independently resourced and acquired by different services/agencies to meet specific requirements, often unrelated to their performance as part of a network.

The JPN is described in the 1999 TAMD Master Plan:

"The Joint Planning Network (JPN) is the collection of non real time and near real time communications and information systems used to carry out TAMD planning throughout the theater. It provides a distributed collaborative planning capability, automated battle management aids, and a means for distributing plans within the theater. The core of the JPN is the Global Command and Control System (GCCS) operating in the Defense Information Infrastructure Common Operation Environment (DII COE). The Joint Defensive Planner and elements of the Theater Battle Management Core System running on GCCS platforms provide the foundation for TAMD planning tools." [1999 TAMD Master Plan]

The JDN is described in at least two documents:

The Joint Data Network (JDN) is a network of operators, computers, and communication systems that carries tactical command and control information within the theater in support of joint theater air missile defense, and attack operations in the form of counter-air, interdiction, close air support (CAS), suppression of enemy air defense (SEAD), and time-critical targeting (TCT) prosecution. Information is generally exchanged via the JDN in near-real-time. [CJCSM 3115.01, 1 Oct 2000]

The JDN is the collection of near real time communications and information systems used primarily at the coordination and execution levels. It provides information exchange necessary to facilitate the joint-Service battle manager's comprehension of the tactical situation and provides the means to exercise C2 beyond the range of organic sensors. JDN carries near real time tracks, unit status information, engagement status, coordination data, and force orders. JDN can provide information to cue sensors as well. The backbone of JDN is Link 16 transmitted via

> JTIDS and MIDS terminals. However, other data links such as TADIL A, B, or C, Link 22, and Variable Message Format (VMF) will exchange information with JDN through gateways at various platforms to ensure that all participating users are included in the JDN for TAMD. Satellites link geographically dispersed users in near real time without consuming limited tactical bandwidth. [TAMD Master Plan, 1999]

The JCTN is described in CJCSM 3115.01:

> The Joint Composite Tracking Network (JCTN) is a tracking fusion network supporting system-to-system exchange of multi-sensor data in real-time. The JCTN supports systems and firing units in the real-time detection and engagement of tactical threats. The JCTN provides systems and firing units real-time exchange of precision sensor measurement data and weapons engagement signals to conduct engagements in real time. [CJCSM 3115.01, 1 Oct 2000]

There are several differences between the JDN and JCTN that are important to understand. First, the purposes of these two networks are different. The JDN is used to exchange messages that focus on near-real-time elements of situational awareness and mission execution. The JCTN's primary purpose is to exchange measurements and to subsequently "fuse" those measurements to ensure that there is a single track for each aerospace object; composite tracks will be at least as accurate as each of the individual systems contributing to the track of a particular object. In addition, the anticipated JCTN will require significant communications bandwidth to communicate necessary data from each sensor to all destination nodes in the battlefield where data fusion processing must occur; this will create a greater load on communication networks than what JDN imparts today. As a result, it is generally agreed that additional bandwidth will be required to realize the JCTN or to at least implement its functionality within the current JDN concept.

We recognize the technical problems associated with these definitions and will resolve the ambiguity through the system engineering process by which we develop the SIAP Integrated Architecture.

Debate on the definition of these terms is consuming resources that can better be used toward characterizing the functions that must be accomplished to meet JROC-validated requirements. Following a disciplined approach to defining the networks in terms of the functions they perform will clearly show functional gaps, overlaps, and conflicts. We will develop candidate solutions for these problems and will take specific recommendations forward to the JROC for validation.

Recommendation: USD(AT&L) defer the SIAP SE Charter requirement to *define* the terms Joint Planning Network (JPN), Joint Data Network (JDN), and Joint Composite Tracking Network (JCTN) until the functional and allocated baselines have been established in the SIAP Integrated Architecture.

3.1.1.2. Contribution of the Single Integrated Air Picture

The Department of Defense has been connecting individual warfighting units using communication networks for many years. Initial efforts focused on sharing information over relatively low data rate communication channels for the purpose of building shared situational awareness. Operators were able to exploit this information to pair interceptors (aircraft and missiles) to potential targets in an attempt to increasing the effective firepower available by extending the battlespace.

Increases in effective throughput, provided by advances in technology, have allowed the expansion of the number of nodes on these communication networks. Increasing the number of nodes should provide increasing levels of warfighting capability. These increases have not been realized, however, because of the way in which network functionality has been specified, implemented, and verified. The U. S. Department of Defense is on a path to resolve many of these issues and to realize the benefits promised through the interconnection of existing and emerging systems. Many significant warfighting benefits are expected through effective networking of individual warfighting units; these include:

- Better and faster weapon-pairing decisions
- Reduced risk of fratricide
- Improved weapon utilization by minimizing fire control track breaking, enabling more engagement opportunities, and providing more accurate target handover at endgame.
  - Increased weapon effectiveness and battlespace – Negate the threat before weapons are allocated
  - Reduced weapon expenditure – improve weapon-target pairing so multiple units can coordinate fires
  - Reduced collateral damage – understand the location of combatants and non-combatants
- Increased battlespace and depth of fire by providing more engagement decision time, by enabling earlier weapon launch and supporting guidance on remote/composite track/data, and by allowing handover of interceptor missile control among participating weapon units.
- Robust counter-countermeasures and enhanced survivability by exploiting sensor frequency, viewing-angle, and Doppler diversity against low observable targets by using sensor frequency and viewing-angle diversity, triangulation, and/or burnthrough by the most appropriate radar against escort and self-screening jammers; and by enabling engagements by weapon units when their

own fire control sensor is inoperative or employing emission control (EMCON) tactics.

- Increased flexibility. Warfighters, at all levels of the chain of command, have more flexibility. Individual units have increased depth of fire, allowing them to commit assets earlier.
  - Improve ability to choose when/where engagements occur. Fight on our terms, not the enemy's.
  - Lessen restrictions caused by non-interoperability.
- Enhanced operational flexibility by providing robustness against unforeseen threat trajectories and maneuvers, by facilitating deployment of surveillance sensors to optimize theater-level coverage without sacrificing critical defended asset coverage, and by supporting advanced joint concepts using remote weapon launch sites.
- Improved interoperability with Allies/Coalition partners
  - Better coordination of action.
  - Improved sense of inclusion and partnership.
- Improved individual situational awareness
  - Reduced operator workload. With better situational awareness, warfighters can concentrate on exceptions, rather than on every object in the battlespace.
  - Enhanced joint composite identification (ID) data exploitation through improved track identification continuity, through improved local track-to-network track association, and through dissemination and fusion of participant sensor-derived identification information.
  - Better raid count through composite resolution of closely spaced air vehicles with data from more than one sensor.
- Improved collective situational awareness. Sensor information, shared among participants, extends shared situational awareness. Warfighters can understand not only what is in their immediate area, but what is happening in adjacent areas that may soon affect them or units upon whom they depend. Scarce resources, such as sensors and interceptors, can be allocated to regions or threats of greatest need. When shared information is reliable, warfighters can use this information to make more timely decisions, which extends the battlespace available.
  - Less confusion
  - Better discrimination
- Improved sensor resource utilization through sharing of surveillance coverage responsibilities among participating joint sensors, leveraging the special resolution and discrimination capabilities of particular sensor types, and enabling fire control track to be attained and maintained with less expenditure of sensor resources.

3.1.1.3. Concept of Operations

The SIAP must support the spectrum of offensive and defensive operations by U.S., allied, and coalition partners in the aerospace volume within a theater of operations. The SIAP is recognized as being a product used by many elements outside the Joint Theater Air and Missile Defense (JTAMD) community. SIAP will be built both from sources under the control of the Joint Task Force Commander and other relevant information. SIAP will be provided for all joint mission areas where consumers exist, such as airspace management and Joint Forces Air Component Commander (JFACC) mission areas involving the tactical employment of air power. As such, the requirements for SIAP are dominated by the JTAMD community, but also include other task force constituents, requirements, and the architecture must be sufficiently robust to ensure that these external elements have access to the SIAP. The SIAP IA will encompass interfaces with SIAP information sources, the production of SIAP processes, and interfaces with, and applications support to, SIAP consumers.

In its most fundamental form, the SIAP is composed of information on air and space objects of all types, friendly, hostile, and unknown. Much of the information is gathered by individual active and passive sensors. SIAP information on friendly vehicles is often actively broadcast by those platforms, using a variety of means. The basic intent of the SIAP concept is to distribute SIAP-related information from off-board sources to other units in theater to enhance their situational awareness and warfighting effectiveness.

Any tactical unit in a theater, which may have to interact with, or be aware of, air or space objects, has a need for SIAP information. The quantity and quality of SIAP information needed by any specific unit depends on its type, mission, and the mission phase. Many in-theater sensors contribute information to the SIAP from both active and passive sensors. In addition, SIAP information can originate from sensors outside the theater. It can also be self-generated, as in the case of unit position and status reports. All of this information on aerospace objects, when distributed to the right units at the right time can enhance mission effectiveness.

The primary means for distributing SIAP information is by Tactical Data Links (TDLs). Tactical data links provide technology-based implementation to satisfy information exchange requirements. C4I is the framework for situational awareness, decision-making, and execution throughout the battlespace. Efficient execution of information exchange requirements throughout the joint battlespace is key to evolving C4I toward the ultimate goal of seamless information exchange. The primary component of this infrastructure is the C4I TDL comprised of data elements/messages and physical media. No single TDL supports every C4I system or is able to operate in all battlefield environments (JTDLMP). The Joint Tactical Data Link Management Plan has cognizance over 18 separate TDLs. These 18 TDLs include the J-Series Family of TDLs i.e., Link 16, Link 22, and Variable Message Format (VMF) TDLs. CINCs, Services and Agencies developing TDL systems must comply with DoDD 4630.5 as amplified by the 18 October 1994 ASD(C3I) Memorandum, "C3I Tactical Link Policy." This memorandum "designates the U.S. agreed Link 16 data link as the DoD primary tactical data link for all Service and Defense Agency Command and Control (C2), Intelligence (I). . ."

Link 16 uses a single-best-sensor reporting scheme for objects in a broad-brush moderate quality situational awareness (SA) data distribution scheme that typically is widely distributed. This relatively low fidelity wide-area data distribution can be augmented with special high fidelity data distributions to support specific warfighting functions that require higher performance and resolution. These high quality data exchanges are typically confined to a small number of platforms, which have a need for such high quality data. On Link 16, this type of limited distribution is called a subnet. The distribution limitations of the subnets are an integral part of the methodology by which Link 16 attempts to efficiently use its limited bandwidth.

There are other highly capable data distribution systems, which are expected to play an important role in the creation of a SIAP. These are the composite tracking systems such as the Navy's Cooperative Engagement Capability (CEC), and the conceptual extension of CEC into the joint environment under the title of the Joint Composite Tracking Network (JCTN). In the context of the overall theater SIAP architecture, the high quality composite-tracking distributions are similar to the high-speed subnets of Link 16. It is likely that the SIAP architecture of the near future will be some combination of the moderate quality Link 16 wide area distributions, higher quality Link 16 subnet distributions, and still higher quality composite tracking distributions. In the more distant future, it is likely that a continuing migration toward more composite tracking will prevail, provided methods for keeping bandwidth requirements within realizable access limits can be found.

A common question is, "How much SIAP is enough?" The answer is different for different units. Warfighting needs differ from units to units and from one mission and mission phase to another. Therefore, 'enough' SIAP means different data for different units at different times, i.e., a 'tailored' picture. Testing for 'enough' SIAP thus becomes a test of time-varying data requirements versus time-varying data delivery. It means that sometimes, for some units group tracks are fine, and it means that at other times, individual breakouts are required. Success is when the SIAP provides the data in the quantity and quality needed to perform a particular mission. Success with excess (i.e., providing much more data than is needed to perform a mission or function) unnecessarily consumes bandwidth, which could result in a loss of functionality or performance elsewhere, or loss of growth potential for the system, either of which makes 'success with excess' a less desirable than a more efficient result.

3.1.1.4. <u>Single Integrated Air Picture Requirements</u>

The Department of Defense is building a networked joint warfighting capability by inter-connecting a large number of existing systems. Each of these systems is carefully engineered and managed to meet specific operational requirements. Each are comprised of many subsystems that are engineered and built to requirements and specifications that derive from system-level operational requirements. The subsystems interact through carefully managed interfaces. The combination of functions and interfaces express the capability provided by the system.

Exacerbating this situation has been the lack of an outcome-based overarching requirement for the capability needed by the joint warfighter. The Theater Missile Defense Capstone Requirements Document, which was validated by the JROC in July

1999, went a long way toward resolving this shortfall. Considerable effort, involving many people, went into developing, vetting, and validating the TAMD, CID, IDM, and GIG Capstone Requirements Documents.

As previously articulated, SIAP requirements are documented in several sources: TAMD and CID CRDs, the IDM CRD, the GIG CRD, and other relevant operational requirements documentation such as specific program requirements. This set of documents describes the "top-down" requirements that are relevant to the SIAP. Later we will discuss the existing interface standards that comprise the "bottom-up" requirements.

SIAP is a key performance parameter in the TAMD CRD (Table 7):

Table 7: Excerpt from TAMD CRD (U)

(U) Key Performance Parameter: SINGLE INTEGRATED AIR PICTURE (SIAP) a. (U) Criteria: Designated applicable TAMD FoS sensor systems intended to surveil, detect, and track air objects must contribute to a SIAP. The SIAP (the air track portion of the common tactical picture (CTP)) consists of common, continuous, and unambiguous tracks of airborne objects of interest in the surveillance area. SIAP is derived from real time and near real item data and consists of correlated air object tracks and associated information. SIAP requirements are as follows: (1) (U) The SIAP must be scaleable, filterable, and support situation awareness and battle managements. (2) (U) Objectively, each object must have one, and only one, track identifier and associated characteristics. (3) (U) SIAP minimal acceptable attributes and metrics are provided in Table IV-5 (see below)

Table 8: SIAP Requirements

UNCLASSIFIED	
Attribute	***Metric***
Completeness	XX%(T), XX% (O) of ground truth threat objects detected and tracked upon entering area of influence (TBR) XX% (T), XX% (O) of ground truth aircraft detected and tracked upon entering area of influence (TBR) Available and exploitable by XX% of primary/secondary systems available to JFC (TBR)
Ambiguity	Average X.X (T), X.X (O) SIAP tracks per air object (TBR) XX% (T), XX% (O) of tracks represent distinct ground truth objects (TBR)
Continuity	Track: XX minutes (T), XX minutes (O) without any track drops, duals/splits, merges, or swaps (TBR)
Timeliness	See Interoperability KPP
UNCLASSIFIED	
(U) Table IV-5: SIAP Requirements	

CID CRD: Accurate classification and identification

Key Performance Parameter	Threshold	Objective
Identification Probability: Of all detected friendly objects/entities	XX%	XX%
Of all detected enemies objects/entities	XX%	XX%
Of all detected neutral objects.	XX%	XX%

IDM CRD: Part of the Global Information Grid (GIG), IDM establishes requirements for data dissemination pertaining to primary backbone networks, communications pathways, data bases, and computer systems at the tactical level and above. The principal area of applicability to SIAP is data transmission, spanning information access and information delivery, along with consideration of "survival" and "planning" criteria tied to real time and non-real time data.

Table 9: Excerpt from IDM CRD (U)

CAPABILITIES	KPP	REQUIREMENTS
Interoperability	4	Satisfy 100% of critical IERs to the threshold level (**Threshold KPP**). Satisfy 100% of IERs to the objective level of the attributes (**Objective KPP**).

	4	All data, that will be exchanged or has the potential to be exchanged, will be tagged IAW the current JTA standard for tagged data items (XML), COE Level 6 (**Threshold, KPP**) / Level 8 (**Objective, KPP**).
DELIVERY		
Survival Information Dissemination	4	IDM will support and enable dissemination of survival information in "n" sec (TBD) or less, 95% of the time (**Threshold, KPP**) and within "n" sec (TBD) 95% of the time (**Objective, KPP**).
Information Integrity	4	IDM will ensure that information integrity will be maintained at 99.99% (**Threshold, KPP**) and at 99.999% (**Objective, KPP**).
Search Driven Information	4	The information user will be able to acquire needed information by search queries. Successful searches must yield 85% of available needed information, with no more than 20% of the total received being irrelevant/unusable information (waste) or failed searches (**Threshold, KPP**); and successful searches must yield 95% of available needed information, with no more than 10% of the total received being irrelevant/unusable information (waste) or failed searches (**Objective, KPP**).

GIG CRD: Completeness, Continuity, Ambiguity, Timeliness

Table 10: Excerpt from GIG CRD (U)

FUNCTIONAL AREA	CAPABILITY	REQUIREMENT
Interoperability	Satisfy Critical IER Attributes	Systems shall satisfy all critical IER attributes to the threshold level (**Threshold, KPP**) and satisfy all IER attributes to the objective level (**Objective, KPP**).
Store	Data Interoperability	All of a system's data that will be exchanged, or has the potential to be exchanged, shall be tagged in accordance with the JTA standard for tagged data items (e.g., Extensible Markup Language [XML], the current JTA standard), and tags shall be registered in accordance with the DoD XML Registry and Clearinghouse policy and implementation plan (**Threshold, KPP**).

FUNCTIONAL AREA	CAPABILITY	REQUIREMENT
Transport	Quality of Service	Transport systems shall provide QoS capabilities that ensure that information identified as priority is delivered ahead of regular traffic 99% of the time (**Threshold, KPP**) and 99.9% of the time (**Objective, KPP**).
	Information Integrity	Systems shall maintain and guarantee during transport the integrity of all information elements exchanged throughout the GIG to enable user confidence; information integrity shall be 99.99 % (**Threshold, KPP**) and 99.999 % (**Objective, KPP**).
	Transport Element Status	All transport elements (e.g., switches, routers, etc.) shall be capable of providing status changes to network management devices by means of an automated capability in near real time 99% (**Threshold, KPP**) and 99.9% (**Objective, KPP**) of the time.
	Secure Voice Interoperability	Strategic and tactical secure voice systems shall be interoperable, with a 99% (**Threshold, KPP**) and 99.9% (**Objective, KPP**) call throughput success rate.
Network Management	Network Status	Systems shall have an automated NM capability to obtain status of networks and associated assets in near real time 99% (**Threshold, KPP**) and 99.9% (**Objective, KPP**) of the time.
IDM	Search Driven Information	Systems shall have an IDM capability to acquire needed information by search queries, with successful searches yielding 85% of available, needed information based on the user query and with no more than 20% being irrelevant/unusable (waste) or failed searches (**Threshold, KPP**); and yielding 95% of available, needed information and no more than 10% being irrelevant/unusable (waste) or failed searches (**Objective, KPP**).

FUNCTIONAL AREA	CAPABILITY	REQUIREMENT
	Survival Information Dissemination	Systems shall have an IDM capability that, utilizing a standard schema, IAW the commanders' dissemination policies and user profiles, will support the means for prioritization of information flows within a theater, using theater apportioned resources, and enable dissemination of survival information (limiting survival information to less than 12 kb) within the time frames of the matrix portrayed in Figure 5, 95% of the time (**Threshold, KPP**) and 0.5 seconds 95% of the time (**Objective, KPP**).
Information Assurance	Authentication/ Confidentiality/ Non-repudiation	Systems shall meet and maintain minimum IA Defense in Depth standards, including certification and accreditation IAW the DITSCAP process (e.g., *CJCSI 6510.01C, DoDI 5200.40*) (**Threshold, KPP**).

The existence of these CRDs requires several near-term actions. First, we must understand the interaction among these requirements (tables 7-10) and ensure we know the locations of gaps, overlaps, and conflicts. These CRDs are the product of significant intellectual effort – the next step is to ensure they are consistent and complementary, and to show how they interrelate in the integrated architecture.

The SIAP SE TF is assembling relevant requirements into the SIAP Integrated Architecture where a consolidated set of requirements can be maintained along with the traceability necessary to identify the source. Development and maintenance of a single, common set of requirements is needed to identify and document the interpretation of requirement(s) that will be acknowledged where there are ambiguities and/or conflicts among relevant CRDs and/or ORDs. More importantly, this requirements database will serve as a configuration management tool for the requirements set, as TAMD requirements evolve and changes are made in response to geo-political events and technology improvements.

The SIAP SE TF also draws "requirements" from existing service, DoD, and NATO interface standards (e.g., OPSPEC 516.1, MIL-STD-6016A, and STANAG 5516). These "requirements", which predate the JROC-validated CRDs, grew from a system-oriented attempt to characterize a desired level of system performance. These existing interface standards must be incorporated into the SIAP Integrated Architecture so we can better understand how they map to JROC-validated capstone requirements. We discuss specific issue with the interface standards in Section 3.2

Requirements levied upon the Integrated Air Defense System will consist of general requirements and participant requirements. General requirements specify how the IADS perform when multiple participants are interoperating. Participant requirements specify how a system shall perform to be certified as a joint participant and ensure that all participants will contribute as necessary when interoperating to achieve required interoperability as stated in the general requirements.

The general shape of the requirement that seems to be emerging is that the SIAP should provide 'the right data to the right user at the right time'. In other words, the customers for the SIAP have different data and information needs that they want SIAP to provide for them, depending on their unit type, mission, and mission phase.

For example, a fighter has different SIAP data quality needs depending on whether it is on a Combat Air Patrol (CAP) mission, has been assigned a mission against an aerospace object, or is in a highly dynamic many-on-many air combat engagement.

Another key feature of the objective SIAP is that, at the surveillance level, it should provide a *coherent* picture to various platforms viewing the same aerospace objects. That is, if three tactical units are all viewing a particular object via the same or different media, such as Link 11, Link 16, and CEC, they should all perceive the object as the same object, and be able to relate it to a common track number and set of associated characteristics. This is the generally accepted interpretation of the terms 'single' and 'common' as applied to SIAP and its defining references.

On the other hand, one of the often-cited requirements of a SIAP is 'one-and-only one track number per object.' There are times when this implied requirement is unnecessary, inefficient, and perhaps unachievable, and could work to the detriment of the warfighters the SIAP is supposed to serve. For example, Link 16 currently permits tagging a flight of objects moving together as a 'group' track, with a strength field providing information on how many objects that track report represents. If every object required a separate track number in the surveillance portion of Link 16, the efficiency of track grouping would be lost, and fewer objects could be reported in the same amount of capacity.

But Link 16 allows those group tracks to be broken out to individual tracks on more localized subnets. These subnets are intended to be used by 'shooters' for whom a single track per target is a necessity for target sorting and engagement coordination. So it is possible, and more efficient in Link 16 to use group tracks, where the fidelity of individual tracks is not needed, and to break down to individual tracks where such detail is necessary.

Both of these approaches meet the needs of certain users. So the question, for such a system (and for the SIAP SE) is, if the platforms who need the breakout down to the individual target have it (e.g., for target sorting, engagement coordination, or whatever), and others do not, do we say that the specified SIAP requirement is met or not? The answers to such questions will dictate the engineering solutions, which must be fielded to satisfy SIAP requirements.

Earlier it was noted that the SIAP itself is not an end; it is a means to achieve improved warfighting effectiveness. In any finite capacity system which may be used to help build the SIAP, especially a multi-functional system like Link 16, capacity trade issues arise constantly, and the engineering of the best system (i.e., SIAP) to support the customer must consider, and balance, all needs (i.e., what is best for the SIAP may not always be what is best for the warfighter).

Requirements, by their nature, are not concerned with existing system and technology limitations. This creates a challenge, in that specified SIAP requirements may exceed the ability of existing contributing systems to meet them. If such is the case, then the SIAP SE has some choices. First, he can investigate what portion of the SIAP requirements can reasonably be met with the existing systems, including improvements to, and enhancements of them. Then he can estimate what deltas exist between what can be cost-effectively achieved toward satisfaction of a SIAP requirement with improvements to existing systems, and develop an approach for satisfying those deltas with new systems. Another approach might be to define the ultimate system that will meet all of the SIAP requirements. Due to the perceived difficulty, time and lack of resources required to pursue this approach, the SIAP SE has been directed to investigate the application of existing (JDN) systems to the SIAP requirement. In either case, an engineering interpretation of the SIAP requirements is needed.

The flow of requirements from JROC-validated capstone requirements to individual product (equipment and computer program) specifications. For JROC-validated capstone requirements to be realized, it is necessary, but not sufficient, to derive lower-level requirements and to make these requirements a contractual deliverable. Within the aerospace domain, the SIAP SE Task Force is responsible for the translation; the way in which this translation is documented and communicated is the SIAP component of the System and Technical views of the TAMD Integrated Architecture. The impact of this process on a particular system depends on the phase of the system's lifecycle.

3.1.2. Products and Milestones

The objective SIAP Integrated Architecture will be focused within the context of JTAMD, as described in the TAMD 2010 Operational Concept and Joint Vision (JV) 2010 and the integration of the Joint Data Network (JDN) and the Joint Composite Tracking Network (JCTN). The SIAP SV and TV products will include all relevant TAMD primary and secondary systems, but will initially focus on the SIAP SE TF defined Block 0 Core Systems and the 2003 TAMD Architecture (Version 4). The deltas between 2003 and the objective architecture will be reflected in the objective architecture and the roadmap that results in growing from current to future capabilities.

The C4ISR Architecture Framework 2.0 describes a set of products that comprise an integrated architecture. We are starting with that prescribed framework, and tailoring it to meet our specific needs.

Figure 11 shows the interrelationships among the products described in the C4ISR Architecture Framework 2.0. The three main components of the Integrated Architecutre are operational, system, and technical views.

a. The Operational Views define notional resources required to perform the activities envisioned from the operational concept. These notional resources will be described by association operational activities and the needed information exchanges between them. A logical data model will be defined to show the required data needed to perform the required activities. These basic architectural views describe in detail the activities to be performed, the need for information transfer and the data elements required, but these do not define actual systems and system interfaces.

b. The Systems Views establish the relationship of the notional concepts of the operational views with the physical systems and interfaces. First, the notional resources are allocated to real systems and system elements. These systems are then further broken down into the functions that they perform. For continuity, a mapping is done back to the activities defined on the Operational Views to ensure that all required activities are being performed by system functions within system elements. Information exchanges between systems are defined by evaluating the connectivity between notional resources defined in the operation architecture views and the required data for the systems. Actual data need by the systems to accomplish their tasks are further defined in the physical data model which is derived form the logical data model in the Operational Views and the data needs derived from the system function development.

c. The Technical Views are used to define and describe the implementation of the rules and standards that are needed to implement the architecture within the systems defined in the system architecture.

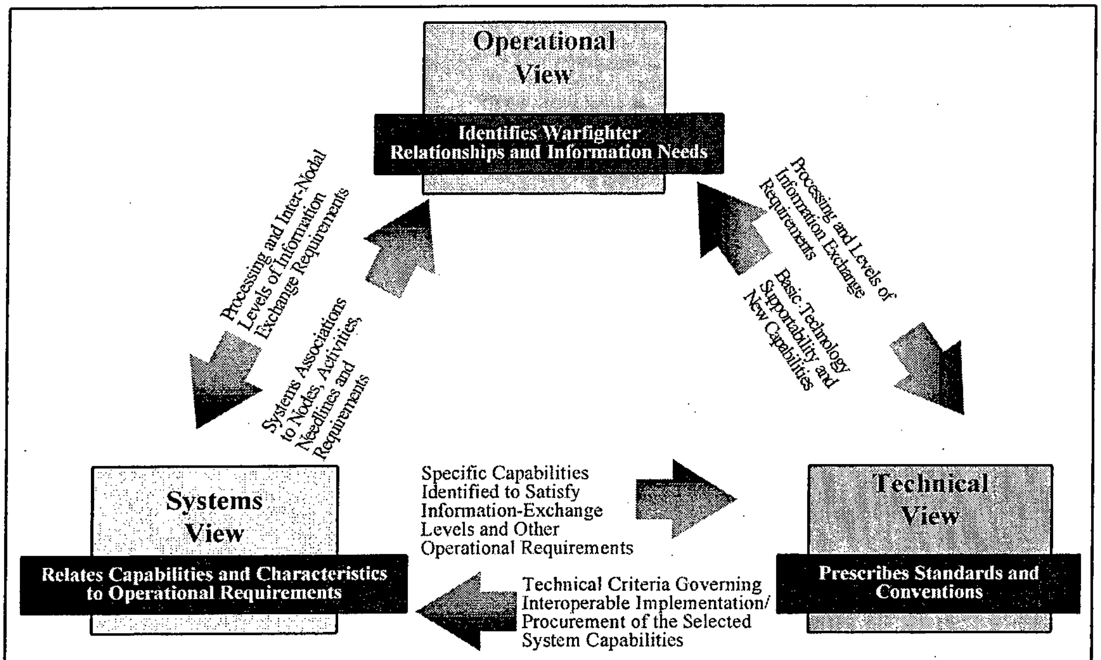

Figure 11. C4ISR Architecture Framework Relationships

The architecture products will be produced from a common ubiquitous database of architectural data and presented in several forms: functional/Unified Modeling Language (UML) executable models, and C4ISR standard information views, as defined in the C4ISR Architecture Framework 2.0.

The primary purpose for the C4ISR Architecture Framework views will be in the area of requirement traceability and to provide an acquisition road map. The primary purpose of the Integrated Architecture Executable Model is to validate behavior, predict performance and update the SIAP Integrated Architecture.

The architecture products can be categorized as descriptions of the physical, functional, data, performance, evolutionary, and behavioral characteristic of the systems and interfaces which contribute to the SIAP capability.

The SIAP SE TF has initially focused on the description of physical systems and their interface, starting with a small list of systems and then expanding to greater numbers. The functional description is focused on the breadth of the SIAP capability first, with expansion focused on detail in specific functional areas. As the functional analysis matures, the data and information exchanges will be defined and a behavior analysis will be conducted. An Executable Model will be developed to initially exercise the data and functional flows for correctness and eventually verify performance. The performance and evolutionary description are

The following existing and pending JTAMD operational views will be reviewed for requirements and SIAP relevancy; if appropriate, comments will be provided:

OV-1 High Level Operation Concept Graphic

OV-2 Notional Resource Connectivity Description
OV-3 Operational Information Exchange Matrix
OV-4 Command Relationship Chart
OV-5 Activity Model
OV-7 Logical Data Model

The following SIAP products will be produced primarily to show requirements traceability and traceability to the JTAMD OA using CASE tools to validate and verify all operational requirements will be met by the SIAP Integrated Architecture:

SV-4 Systems Functionality Description
SV-5 Operational Activity to System Function Traceability Matrix
SV-6 System Information Exchange Matrix
SV-7 Systems Performance Parameter Matrix

The following products will be produced primarily to assist in establishing the acquisition road map and provide guidance for improving interoperability among contributing systems:

SV-1 System Interface Description
SV-2 Systems Communication Description
SV-8 System Evolution Description
SV-9 System Technology Forecast
TV-1 Technical Architecture Profile
TV-2 Standards Technology Forecast

The following JTAMDO-produced Operational Views and SIAP SE-produced System Views will be used to support the development of an Integrated Architecture Executable Model:

OV-6a Operational Rules Model
OV-6b Operational State Transition Description
OV-6c Operational Event/Trace Description
SV-10a Systems Rules Model
SV-10b Systems State Transition Description
SV-10c Systems Event/Trace Description
SV-11 Physical Data Model

Other architecture products will be produced, where required, to provide additional detail for the above architecture products. Figure 12 shows a summary of SIAP Integrated Architecture Milestones and shaded areas depict active development efforts.

Physical	SV-1	System (OpFac) Interface Description
	SV-2	Systems Communications Description
	SV-3	System to System Interface Matrix
Functional	SV-4	SIAP Capability Functional Description
	SV-4a	SIAP Capability Functional Description with Operator Functions
	SV-4b	SIAP Capability Functional Description-System Functions Only
	SV-4c	SIAP Capability Functions to System Function Matrix
	OV-5	SIAP Activity Model
	SV-5	SIAP Activity Model to SIAP Capability Functional Description Matrix
Information Exchange and Data	SV-6	SIAP Information Exchange Matrix
	TV-1	SIAP Standards Profile
	SV-11	Physical Data Model
Performance	SV-7	SIAP Performance Parameters Matrix
Evolution	SV-8	SIAP Capability Evolution Description
	SV-9	Technology Forecast
	TV-2	Standards Evolution Forecast
Behavior and Execution	SV-10a	SIAP Capability Rules Model
	SV-10b	SIAP Capability State Transition Description
	SV-10c	SIAP Capability Event/Trace Description
		SIAP Architecture Executable Model
Shaded areas are where effort has begun		

Figure 12. SIAP Integrated Architecture Products

Figure 13 shows a summary of SIAP Integrated Architecture Milestones.

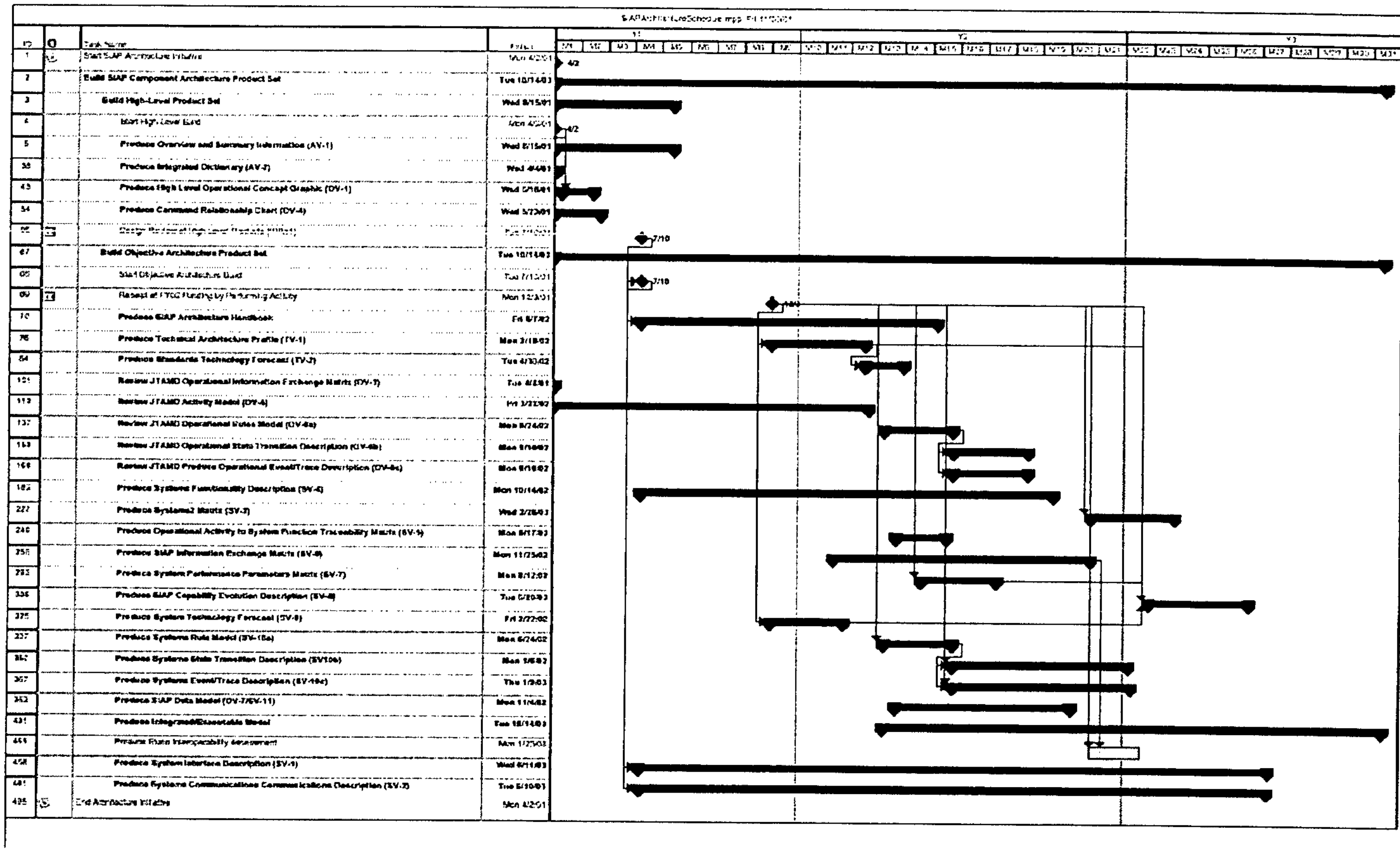

Figure 13. SIAP Integrated Architecture Milestones

> "Supported by the JTAMD process, use a disciplined system engineering process to develop the **system and technical views** of the **SIAP component of the TAMD integrated architecture**, to include an overall time-phased development and deployment schedule, ...". [SIAP SE Charter]

The establishment of the SIAP Integrated Architecture began in July 2001 with the establishment of the purpose, context, scope and strategy of the architecture effort in (AV-1) and the high level operational concept in the OV-1 and OV-4 deliveries. The SIAP Integrated Architecture Strategy is based on the philosophy that to establish a repository of architectural artifacts and data for the 2010, the first step is to determine the functional contributors to the SIAP capability that exist in legacy systems. This was accomplished by the derivation of As-Is SIAP SVs/TVs from TAMD (2003) Architecture for Joint Force Operations (Ver4) Dec 97, with updates from the Services.

Since the complete number of contributing systems to the SIAP capability is over 100, it was also determined to start with systems defined as critical to the Block developments and then expand. The first development of the SIAP SV/TV is based on the 12 "Core" systems as defined by Block 0. The As-Is architecture should be completed by April 2002.

The establishment of the SIAP Integrated Architecture must begin with the operational activities required. The SIAP operational activities and the interrelationships required to satisfy the 2010 will be determined from the SIAP 2010 functional thread of the JTAMD 2010 Operational Architecture. The initial establishment of the SIAP 2010 functional thread should be completed by January 2002. By establishing the SIAP 2010 functional thread and by completing the description of the As-Is SIAP Architecture, the derivation of the Draft Objective SIAP SVs/TVs will be completed by the detailed comparison of the functional requirements between the 2010 and 2003 architectural products. This should be achieved by May 2002.

Part of the functional description of the SIAP Integrated Architecture is the description of the rules and state changes governing its execution. The completion of the architecture must include the validation of the As-Is and Objective SIAP Architecture Views by executing the functions based on these rules and state definitions to determine if the architecture performs correctly. The validation of the As-Is and the Objective architectures should both be completed by July 2002. During the validation process, the architectures will be updated for a final delivery in October 2002 and a final briefing to the JROC on the SIAP Integrated Architecture by December 2002.

Figure 14 shows the original path in the development of a SIAP As-Is Architecture in the context of Block 0 Systems and Block 0 improvements, showing a migration strategy with the Block 0 contribution.

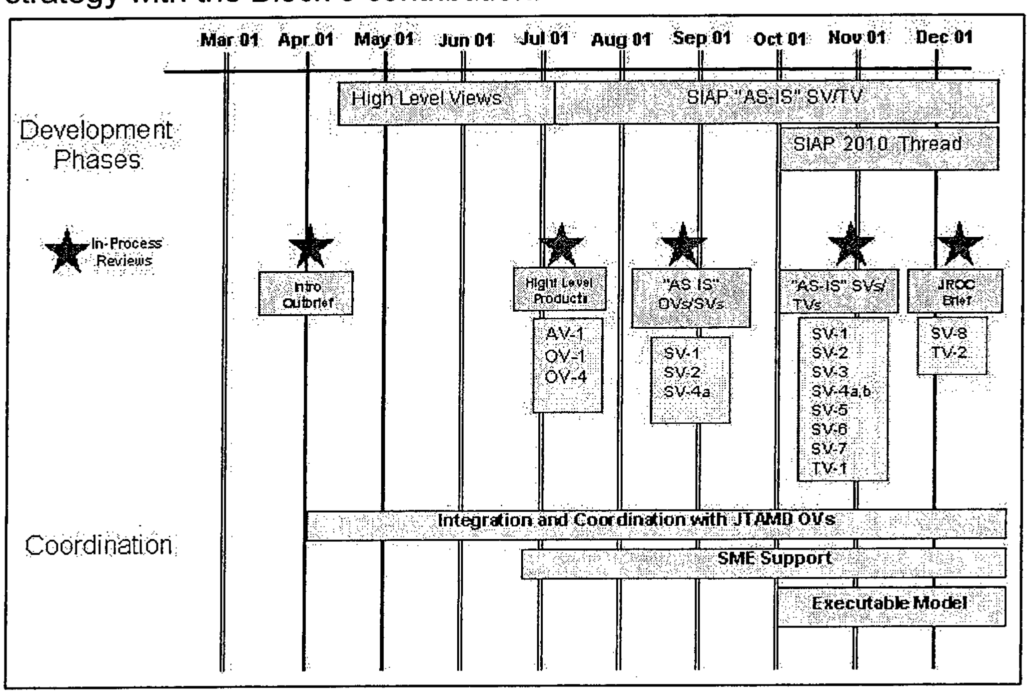

Figure 14. SIAP Integrated Architecture Near Term Block 0 Schedule

This initial tasking for Block 0 established an architecture pilot to refine the SIAP architecture process. The resulting architecture will further be used to support the organized implementation of the Block 0 changes among the Services. The scope of the architectural products was limited to the 12 Block 0 "Core" systems. The intention being to "eat the elephant – one byte at a time." The expansion of the As-Is to encompass the more complete list of SIAP contributing systems will follow in larger and larger steps as defined by the SIAP SE Control Branch.

3.1.2.1. Functional Baseline

The SIAP will facilitate the joint forces' ability to possess adequate awareness of the battlespace and, if required, engage targets at the edges of their weapon engagement envelopes. While this all sounds good in theory, in practice, there must be systems that can perform the myriad of functions required that span the kill chain. These functions include target detection, target identification, cueing, and target engagement. While these systems provide organic capabilities, the real force multiplier in these systems is when they are netted together in a mutually supportive role, and providing a battlespace awareness that is greater than the sum of their individual capabilities. Indeed, these are the very strengths upon which the JTAMD 2010 capabilities are predicated; e.g., Combat ID (CID), Integrated Fire Control (IFC), and Automated Battle Management Aids (ABMA). In addition, capabilities must exist to establish, maintain and manage these networks to ensure that their integrity is maintained.

As already indicated, the capabilities required by the TAMD and CID CRDs, such as IFC and ABMA, are predicated upon the existence of a SIAP. Consequently, in the course of pursuing a SIAP, it is necessary to determine the functions that must be performed, the information required to perform these functions, the capabilities that must exist to provide this information, the systems that can provide these capabilities, and finally, the standards that are associated with the employment of these systems. By definition, the guiding source for each of these requirements is the SIAP Integrated Architecture. It is through the individual views of the integrated architecture that an objective SIAP capability is realized.

While SIAP is an integral part of the JTAMD mission areas and provides a greater understanding of the battlespace, it is nonetheless a state or condition that must be supported by technological means. These means exist in the combination of communication networks and data processing used by the services. It is through these networks that a credible air picture is developed (SIAP), and by corollary, an improved understanding of the battlespace upon which warfighting decisions can be made.

The emerging recommendations regarding the contribution, composition, and functionality of the Integrated Air Defense System are addressed in two aspects; within the context of the SIAP charter, and in the larger context of the JTAMD multi-mission warfighting environment. While they are being addressed in two separate discussions, they are, in fact, inextricably linked since architecturally speaking, the SIAP Integrated Architecture is a part of the larger JTAMD Integrated Architecture. And it is through the architecture of the JTAMD Family of Systems (FoS) that the SIAP component systems are identified.

The TAMD mission area is composed of three elements: TAMD C4I, Offensive Counterair Operations (OCA), and Defensive Counterair Operations (DCA).

- TAMD C4I - The primary functions of TAMD C4I are to provide situational awareness (SA), enable command and control, and facilitate battle management functions, including warning, cueing, and enabling engagements. The TAMD C4I function must also provide applicable command authorities with the capability to plan, monitor, direct, execute, control, and report TAMD operations.

- Offensive Counterair (OCA) - The objective of OCA operations is to destroy, disrupt, or neutralize enemy aircraft, missiles, launch platforms, and supporting infrastructure and systems. Since the preferred method is to neutralize targets as close to the source as possible, preemptive OCA is a viable option and preferable to enemy post-launch OCA.

- Defensive Counterair (DCA) - The objective of DCA is to employ all defensive measures available to detect, identify, intercept, and destroy or negate enemy force actions near friendly forces or defended areas. DCA consists of two elements: passive air defense and active air defense.

  - Active Air Defense is action taken directly to destroy or neutralize the effectiveness of air and missile threats against friendly forces; this includes the use of electronic warfare.

  - Passive Air Defense is action other than active air defense, taken to minimize hostile air and missile threats. These measures include camouflage, concealment, and deception (CCD) as well as protective construction.

To satisfy these TAMD mission areas, a set of fundamental warfighting capabilities is required. These supporting capabilities, identified by the SIAP SE TF, are categorized as Engagement Operations and Non Engagement Operations. Engagement operations are those operations that pertain, among other things, to the passing of time critical information related to engagements, multi-platform weapon employment coordination, identification, and data fusion. Non-engagement operations are those that pertain to mission planning, intelligence preparation of the battlespace, and management and control of the quality of the tactical data links. These two categories of warfighting capabilities provide an air picture that is lucid; and as a corollary not only facilitates timely detection and/or neutralization of air and missile threats, but also prevent fratricide. It should be at least implicitly obvious from the above that the system functionality's required not only entail the ability to transmit and receive information from an array of disparate service systems, but also the capability to establish, maintain and manage these networks to ensure that their integrity is maintained.

As the component of joint theater air and missile defense that has been chartered to provide the "product of composite, common, continuous, unambiguous tracks of airborne objects in the surveillance area", these SIAP capabilities present themselves collectively as the *sine qua non* of the JTAMD mission areas. These capabilities consists of the following:

- Non Engagement Operations
  - Intelligence Preparation of the Battlespace (IPB)
  - Joint sensor and weapon systems planning
  - Mission planning
  - Communication services planning

- Engagement Operations
  - Communication services operations
  - Sensor integration
  - Sensor gridlocking
  - Data fusion
  - Identification
  - JDN and JCTN Integration including tactical data systems and links
  - Engagement coordination
  - Multi-platform weapon system integration

This listing is in order of occurrence as the SIAP is produced. A description of all these capabilities is contained in Appendix A.

Due to historical deficiencies, the SIAP SE TF was established "to identify the most effective and efficient means to achieve a SIAP that satisfies the warfighter needs....and which will lead to measurable improvements in warfighting capability." It is within this context that the JDN and JCTN networks will first be discussed.

As defined in section 3.1, the JDN and JCTN provide time critical information in two time domains: near real-time, and real-time. Information in near real-time is generally used to provide situational awareness (SA); i.e., tracks being reported can be updated every 5-10 seconds and do not need to be updated at a rate comparable to a target that is being engaged. Information in real-time, on the other hand, is used to provide fire control quality information on tracks that pose a threat and must be engaged. If and when required, the update rate of this information must be of sufficient frequency to support a weapon engagement evolution.

In any given battlespace, there are tracks that can be updated in near real-time, and there are tracks that must be updated in real-time. The rate at which they are updated is based upon the threat that they are perceived to pose to friendly forces. This however, is a gross simplification of the network issues and, in order to understand their relationship to providing a SIAP in the context of the Charter, their functionality must be understood.

Regardless of the rate at which track information is passed around in a network, the track information must not only be easily understood but useful. In addition, the networks as well as their information must be managed properly such that the right information is passed to the right individual at the right time. These intrinsic functionalities are the networks' sole reason for being.

Now that the required capabilities are known, the JDN and JCTN functionalities can be addressed not only in the context of the SIAP Charter but also in the context of the TAMD multi-mission warfighting environment.

We recommend that the functions described also be considered for inclusion into the next version of the JTDLMP.

3.1.2.2. Allocated Baseline

The SIAP Acquisition Roadmap provides the overarching migration plan for incrementally integrating the SIAP capability into the JTAMD Integrated Architecture. The Acquisition Roadmap will be derived from the products described above along with Service funding and scheduling inputs. The Acquisition Roadmap will include all systems and capabilities that contribute to the SIAP and will balance life cycle cost and Joint warfighting capability. The Acquisition Roadmap builds on Block 0 implementation activities by further defining mid-term and far-term block upgrades based on cost and schedules to satisfy operational requirements leading to the objective SIAP capability. The Acquisition Roadmap will define the path from current capabilities through the normative baseline to the objective SIAP capability — our piece of the TAMD integrated architecture.

To ensure cohesion with the TAMD Master Plan, the SIAP Acquisition Roadmap is being developed in concert with the Joint Acquisition Roadmap (JAR) and the Joint Capabilities Roadmap (JCR) efforts.

3.1.3. Responsibilities

Figure 15 shows the organizations within the U.S. Department of Defense that are key stakeholders in the development of the SIAP Integrated Architecture. The SIAP Integrated Architecture is a decision-making tool and intellectual framework that documents the results of the collaborative SIAP system engineering process that will be described in the SIAP System Engineering Management Plan (SEMP). Each Service, and elements of the Joint Chiefs of Staff, Office of the Secretary of Defense, and United States Joint Forces Command are participants in the SIAP system engineering and analysis efforts. These efforts develop the information necessary to fuel the process that builds the SIAP Component of the 2010 TAMD Integrated Architecture. The Services, through the "virtual" staff, are creators (not merely reviewers) of the elements of the SIAP Integrated Architecture. Service participation also includes close collaboration with the respective Service POC members of the Task Force Architecture Team. The SIAP SE TF is providing funds through the architecture team to the Services specifically for review of architecture products, but the Services also receive funds for participation in the various System Engineering Teams (SETs) and other SIAP-related Task Force activities.

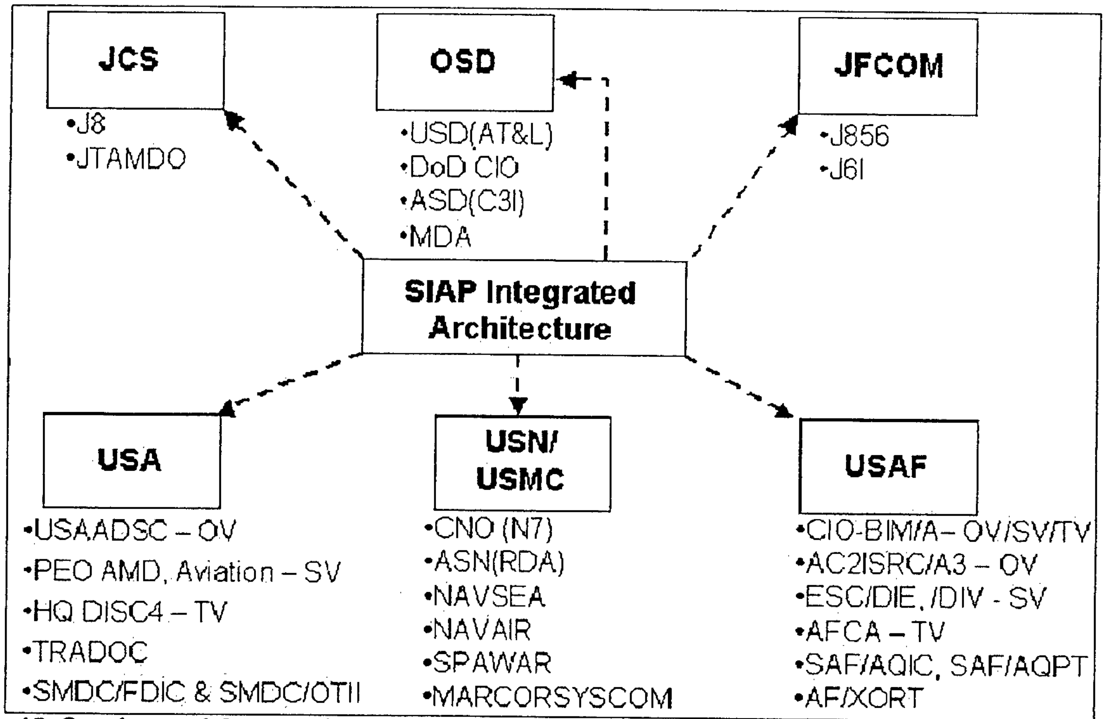

Figure 15. Service and Agency Stakeholders

Figure 16 shows the database or architectural repository which supports the SIAP System and Technical Views (SV/TV) and is established by deriving information from the products of several efforts and sources.

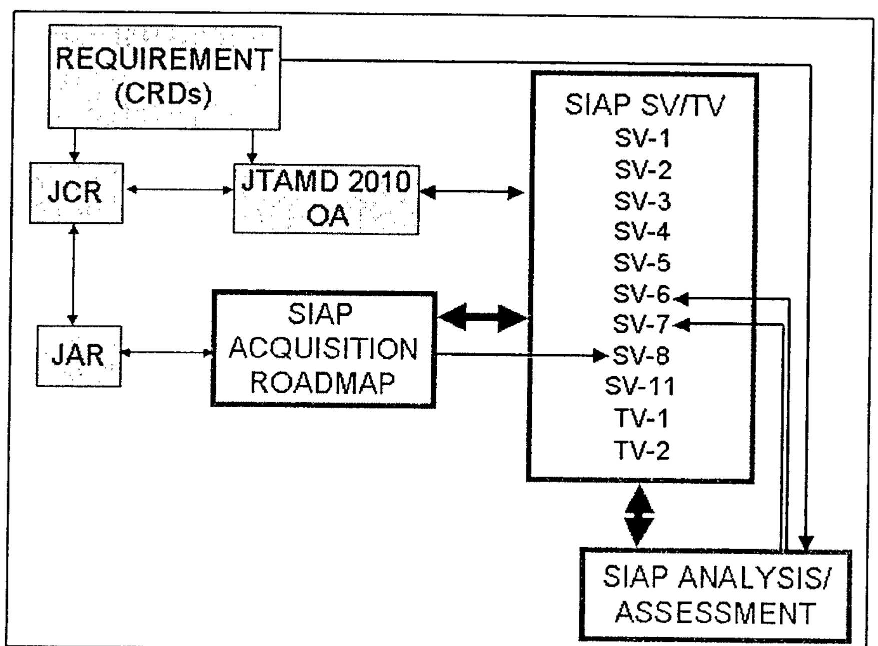

Figure 16. SIAP Architecture Repositories

Data is traceable to the requirements established in the TAMD, CID, IDM, and GIG CRDs. These requirements are interpreted for their operational context by the

JTAMD 2010 OA effort and then placed into a physical context in the SIAP SV/TV development.

The requirements are also derived in the JCR to JTAMD functional capabilities and coordinated for acquisition in the JAR. The input from the JAR is then combined with other SIAP Acquisition data for the development of the SIAP Acquisition Roadmap. The information in the SIAP Acquisition Roadmap is then entered into the SIAP SV/TV and related to specific SIAP system functions in the SIAP Capability Evolution Description (SV-8).

SIAP performance attributes are derived from the CRDs and then input into the SIAP SV/TV in the SIAP Performance Parameter Matrix (SV-7) and the SIAP Information Exchange Matrix (SV-6).

Although the SIAP Acquisition Roadmap and SIAP Analysis and Assessment efforts have primary input in the definition so SIAP Capability Evolution and Performance, respectfully, their impact is also felt in the physical and functional definitions of the systems and all other aspects of the SIAP architecture data base.

It is important that a single team of people (JTAMDO and acquisition personnel), led by a single architect, develop all the views of the integrated architecture to ensure a smooth transition in the translation of operational requirements into performance requirements and implementation.

Recommendation: Resolve responsibility for developing and maintaining the TAMD Integrated Architecture

Recommendation: Establish a Joint system engineering organization to continue the system engineering work necessary to translate JROC – validated joint warfighting requirements into Service systems.

Recommendation: Strengthen the linkage between Advanced Concept Technology Demonstrations (ACTDs) and the requirements process. ACTDs should directly influence requirements.

3.1.4. Approach

The most significant technical issue is the system engineering of an integrated JDN, JCTN, and all the hosts that connect to these networks. This is formidable because of the interdependencies between interacting weapons, surveillance and battle management systems. Such interdependencies demand disciplined system-of-systems engineering approach, including an integrated architecture, analysis, engineering synthesis, design, testing, and certification. It also requires a disciplined acquisition strategy, including synchronization among the interacting components that must all be in place and working together at the same time. Both of these considerations go beyond a *family-of-systems* approach where a less complex *federation* strategy is expected.

Figure 17 shows the SIAP Integrated Architecture is a process which results in architectural products that are iteratively produced, based on dialog between the joint warfighter (represented by JTAMDO) and the architect. The beginning and continual update of the process is focused on the Service system owner. The operational requirements/behaviors are derived from the TAMD 2003 Operational Architecture and the JTAMD 2010 Integrated Architecture. Since almost all of the systems, which will exist in 2003, will also exist in 2010, the system user also provides a description of the Service Systems both functional and physical to establish and iterate the SIAP Component Architecture Repository. The resulting architectural products are reviewed and executed to establish the architecture's behavior. The review and examination of the architecture results in a system user/SIAP Architect interaction and continual update and refinement of the architectural repository.

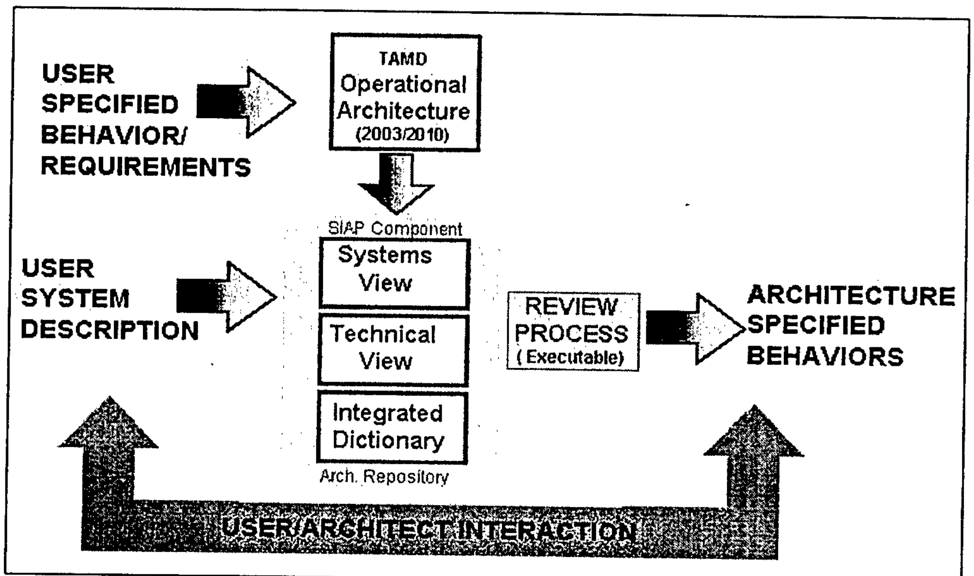

Figure 17. SIAP Integrated Architecture Process

The SIAP Integrated Architecture will be developed to support Block process upgrades and ultimately result in an "Objective" Architecture. The SIAP System View (SV) and Technical View (TV) products will include relevant primary and secondary Theater Air and Missile Defense (TAMD) systems (from the TAMD CRD); be based on an updated 2003 TAMD Architecture (Version 4) (update led by SIAP SE TF); and, focus, initially, on the "Block 0" [1]systems as defined by the SIAP SE process.

The "Objective" SIAP Integrated Architecture will be a 2010 architecture that derives from the JROC validated TAMD and CID CRDs. This architecture will be

[1] Block 0 "core" systems are Patriot ICC, FAAD C2, AMDPCS, ACDS Blk1, AEGIS 6.1, E-2C, FA-18 C/D, TAOM (V)4, E-3 AWACS, MCE, Rivet Joint, F-15 C/E.

derived from the Operational Views (OVs) of the 2010 JTAMD Integrated Architecture and the As-Is SIAP SV and TV products.

The differences between the current and "objective" architectures will be documented in the SIAP Integrated Architecture.

Figure 18 shows a six-stage process based on Structured Analysis for developing C4ISR architectures. This process was developed by Dr. Alexander H. Levis, Professor, System Architectures Laboratory, C3I Center, George Mason University and currently the Air Force Chief Scientist. The output of the process is a description of the architecture represented as Operational, System and Technical Views as defined by the C4ISR Architecture Framework Version 2.0. The SIAP SE TF is using this process as an overarching guide, tailoring it where appropriate, to develop the System and Technical Views of the SIAP Component of the 2010 JTAMD Integrated Architecture.

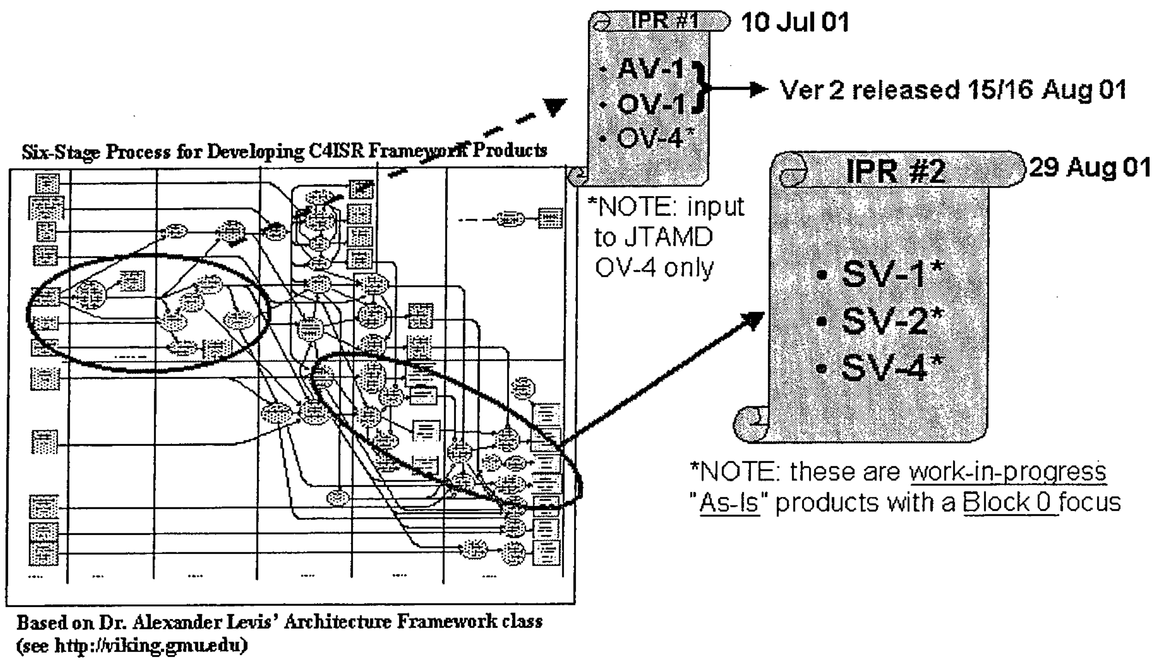

Figure 18. Structured Analysis for developing C4ISR architectures

The initial products of the Six-Stage Process were reviewed at an In-Process Review (IPR) held on 10 Jul 01. These initial products were: 1) the All Views Overview and Summary Information (AV-1), 2) the High-Level Operational Concept Graphic (OV-1), and 3) the Command Relationship Chart (OV-4). AV-1 and OV-1, produced during Phases 0, 1, and 2 of the Process, are "stand-alone" products and provide a baseline to develop the remaining System and Technical Views of the SIAP Component Architecture. AV-1 is "standalone" in the sense that it not only is part of the Joint Theater Air and Missile Defense (JTAMD) AV-1 developed by JTAMDO through the JTAMD Process, but is also a stand-alone document to describe the distinct purpose, scope and context of the SIAP Integrated Architecture. OV-1 is "standalone" in the sense that it not only augments the supporting slides of the JTAMD OV-1, but is also a standalone graphic used as a means of orienting and focusing detailed discussions, at an abstract level, of the operational concept of SIAP.

OV-4 was provided as input only to the JTAMD OV-4. Comments to AV-1 and OV-1 received at the IPR were incorporated and released as Version 2 on 15 Aug 01 and 16 Aug 01, respectively.

At the 29 Aug 01 IPR, the initial draft versions of the following System Views were reviewed: 1) System Interface Description (SV-1), 2) System Communications Description (SV-2), and Systems Functionality Description (SV-4). These System Views are work-in-progress "As-Is" SIAP Integrated Architecture products focused on Block 0.

Architecture Development Process: The Integrated Architecture Views will be developed based on a six stage process (Figure 19) developed by Dr. Alex Levis. The stages and flow of these stages are defined below:

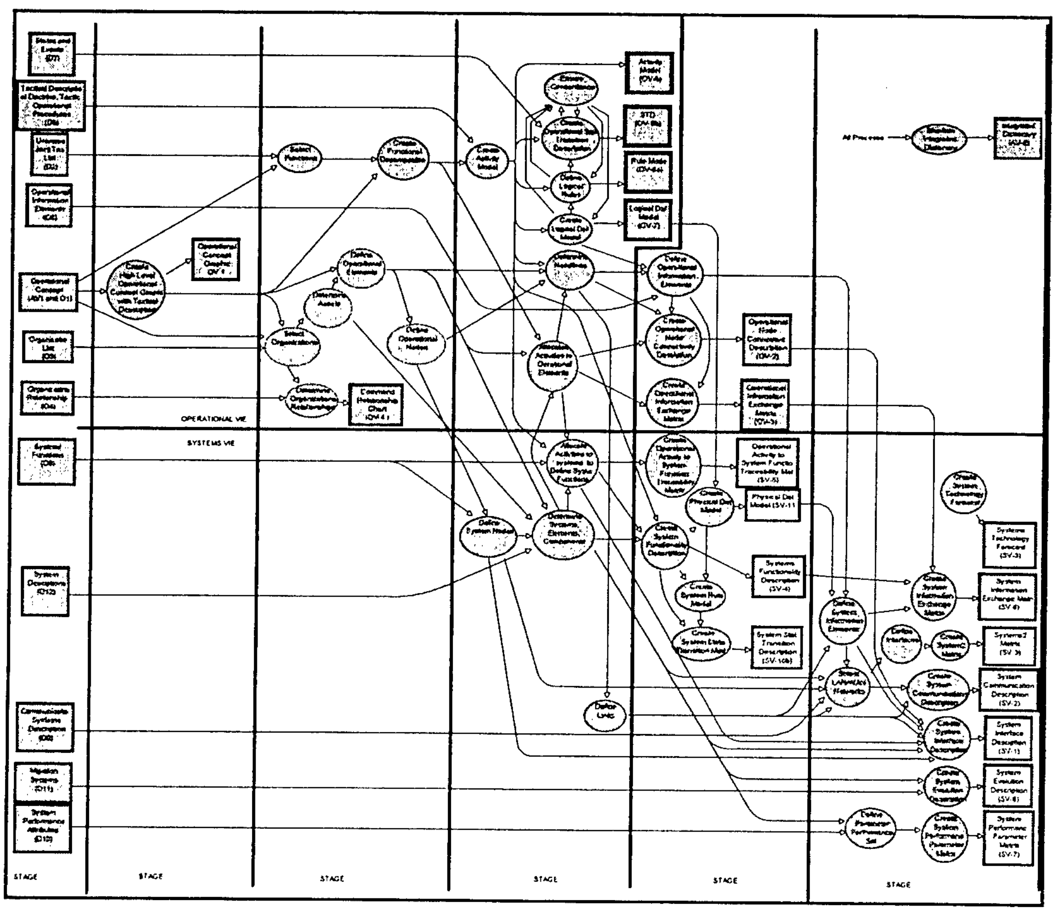

Figure 19. C4ISR Architecture Framework Six Stage Process

- **Stage 0:** Problem Definition and Collection of Domain Information
- **Stage 1:** Operational Concept and Requirements

- **Stage 2:** Functions and Organizations
- **Stage 3:** Activity Model, Logical Data Model, Needlines, System Nodes, System Elements and Functions, and Task Allocation
- **Stage 4:** Operational Information Elements and Exchanges, System Functionality Description, Physical Data Model
- **Stage 5:** System Information Elements and Exchanges, LAN/ WANs, System Interface Description, System Performance

The document the SIAP SE Task Force is going to use to detail the processes and associated products required to support the engineering of a SIAP is the System Engineering Management Plan. The purpose of the SEMP is to support engineering planning and control for systematic engineering and integration of Joint warfighting systems. In addition, it provides an integrating framework in developing the performance, functional, constraint and interface requirements for SIAP, from top-level mission area requirements through system products.

While SIAP-centric, the SEMP is based upon the guidelines of IEEE Std 1220-1998 and documents the plan to conduct the fully integrated technical effort necessary to satisfy the general and detailed requirements for system engineering the SIAP. In essence, the SEMP will provide a standard for managing the development of the SIAP through a disciplined system engineering process by providing a uniform framework for controlling all SIAP products during all phases of development.

3.1.5. Resources

We will allocate resources guiding joint engineering efforts to create the SIAP portion of the Integrated Architecture. The Services will also need to resource their own system engineering efforts for those systems that contribute to or compliment the SIAP IA. Preliminary assessments put the Service requirement at approximately $5M a year, per Service. These resources must be allocated soonest if we are going to meet the December 2002 delivery of the SIAP portion of the TAMD Integrated Architecture.

3.2. IDENTIFY AND RESOLVE PROBLEMS WITH THE JOINT DATA NETWORK (JDN)

As we discussed earlier, the SIAP SE TF Charter directs us to pursue two concurrent efforts to improve warfighting capability and meet the JROC-validated TAMD and CID capstone requirements. The rigorous, disciplined system engineering process that is building the SIAP Integrated Architecture is following a traditional top-down system engineering approach tailored from IEEE Std 1220-1998. We engaged in a companion bottom-up approach, also following a rigorous, disciplined system engineering process. These concurrent efforts will ensure we make time-phased incremental improvements in warfighting capability while working to the objective SIAP capability described in the TAMD Integrated Architecture.

This section addresses, in the context of the TAMD Integrated Architecture, specific materiél and materiél-related deficiencies that degrade joint warfighting capability today, and briefly discusses plans to resolve these deficiencies.

3.2.1. Objectives

In accordance with the SIAP SE TF Charter, the overarching objective of the Task Force is to identify incremental improvements that will lead to improved warfighting capabilities by implementing changes to equipment, computer programs, and interface standards. The SIAP SE TF is initially concentrating efforts on resolving long-standing JDN deficiencies, starting with those related to the implementation of Link-16.

These initial efforts will identify, prioritize, and recommend fixes and enhancements to deficient processes and fielded components of the JDN, applicable across all Services and leading to an effective long-term objective SIAP capability. Related to this objective, the SIAP SE TF will ensure mission success within constraints related to budget, development timelines for new technologies and systems, and the realities of the acquisition process. The principal technical focus will be the identification and correction of computer program-coding incompatibilities that exist in fielded weapon systems. Such errors prevent cohesive, complete and proper JDN operations and do not comply with the guiding specification.

The SIAP SE TF will also coordinate the identification, exploration and crafting of technical enhancements to compliant TDL logic that permits more precise warfighter communications. All current functional requirements documents remain in effect, while the technical interoperability specifications are revised to reflect more concise common results. All of these activities will lead to refinement of the processes and tools that generate less than optimum TDL operations. It will also result in tighter MIL-STDs to meet Joint critical requirements and permit less interpretation of implementations with more predictable and consistent results.

The most timely and cost effective approach to implementing these near-term JDN improvements is to incrementally employ block upgrades consisting of logically related fixes or enhancements across the Services, thereby minimizing the amount of modification, testing of the host computer programs and expenditure of resources. This approach incorporates both participation in the JINTACCS/JTAMD processes and supports the on-going analysis of the Joint Acquisition Roadmap.

Implementation of materiel JDN improvements will require modification to affected host-system equipment and computer programs. In addition, testing and certification will be required following implementation of any modification. Multiple JDN improvements may impact the same computer programs and equipment in many Service host systems. Therefore, the most cost effective approach to implementing near-term JDN improvements is to incrementally employ block upgrades consisting of logically related fixes or enhancements across the Services, thereby minimizing the amount of modification and testing of the host computer programs. The block upgrades will be synchronized with affected Service program development schedules to determine optimal insertion points.

Block upgrades allow early implementation of improved capability while retaining flexibility to insert new capabilities or technologies in the future. The Block approach is an expedient method of improving joint capability by implementing changes to existing TTP and systems, while remaining an integral part of the integrated architecture. For each Block upgrade, the Detailed Block Improvement Plan will identify the specific changes required in specific systems to achieve defined improvements to the SIAP capability. An incremental approach to improving the JDN will balance legacy system enhancements with future SIAP development.

The incremental Block Process is initiated to address SIAP deficiencies noted within the JDN. These deficiencies are identified to the SIAP SE via various means. The SIAP SE TF inputs the data into the Lessons Learned database (LLDB) and organizes and aligns it within the system engineering process. This data, along with other inputs, is used to categorize the JDN fixes into Blocks that can be system engineered as a group and implemented across the Services. The SIAP SE will develop Task Statements for engineering activities to be addressed by a Block Team.

The Block Team will be chaired by a member of the SIAP SE Task Force Core Engineering Team and will have representatives from the Services, MDA, and JTAMDO. The Block Teams will establish a joint, collaborative systems engineering approach to provide oversight of the JDN fix process. The Block Teams will organize and manage Engineering Analyses, Cost Benefit Analyses, and Plan of Action & Milestone (POA&M) recommendations focused on improvements to the JDN. The POA&M document is a means of documenting all of the above and outlining the tasks, schedules, milestones, dependencies, management requirements, and deliverables for the Block initiative. It is the Block Team that provides the orchestration of the entire Block initiative and ensures the POA&M is executable and on track to reaching the deliverables.

The TF will then collect data and conduct the detailed analysis required to perform a cost benefit analysis of the engineering solutions for the deficiencies within the particular Block. The results are then coordinated with the service SYSCOM/PEO/PM, JFCOM, and the JTAMD/JINTACCS processes. The Block Team will prepare the SIAP SE's recommendation to the JROC by presenting the system, product, or process specifications; preparing supporting rationale based on testing and analysis; and providing the acquisition impacts anticipated in fielding these improvements in a Decision Support Binder (DSB) format. In addition, information concerning capability assessments of fielded systems will be provided for use in the SIAP SE TF Capabilities and Limitations documentation.

3.2.2. Products and Milestones

The primary product developed by the incremental Block system engineering teams will be a set of engineering recommendations in the form of Interface Change Proposals (ICPs) and/or Engineering Change Proposals (ECPs) communicated through the DSB and briefings to the JROC, SAEs, and Service Program Offices. The secondary products include lessons learned, prioritized improvement lists, and M&S tools supporting evaluation and prediction of SIAP functionality.

The Block 1 products will include a set of specific engineering recommendations in the form of Interface Change Proposals (ICPs) and Engineering Change Proposals (ECPs) with supporting rationale.

Doctrine, Organization, Training, Materiel, Leadership, Personnel, and Facilities (DOTMLPF) Issues

In the past, resolution of JDN problems and deficiencies has focused primarily on materiel solutions to resolve problems. As a result of recent real world lessons learned and analysis of test and evaluation results, it has become evident that in many cases materiel deficiencies are only a subset of the true problem, not necessarily the primary cause. Doctrinal, organizational, training, and personnel issues/problems have been directly linked to many of the problems that occur during JDN operations. The DOTMLPF approach to issue resolution is a holistic process that keys on addressing issues across a broader spectrum (DOTMLPF) resulting in a improved solution set for the warfighter. To facilitate implementation of DOTMLPF solutions identified by CINCs, Services, and Agencies (C/S/A), CJCSI 3180.01 (draft) has been developed to define a process that allows DOTMLPF change proposals to be addressed and resolved at the Joint level.

We have a detailed Work Breakdown Structure (WBS) that will support the development of these products on the tentative schedule described in Figure 20.

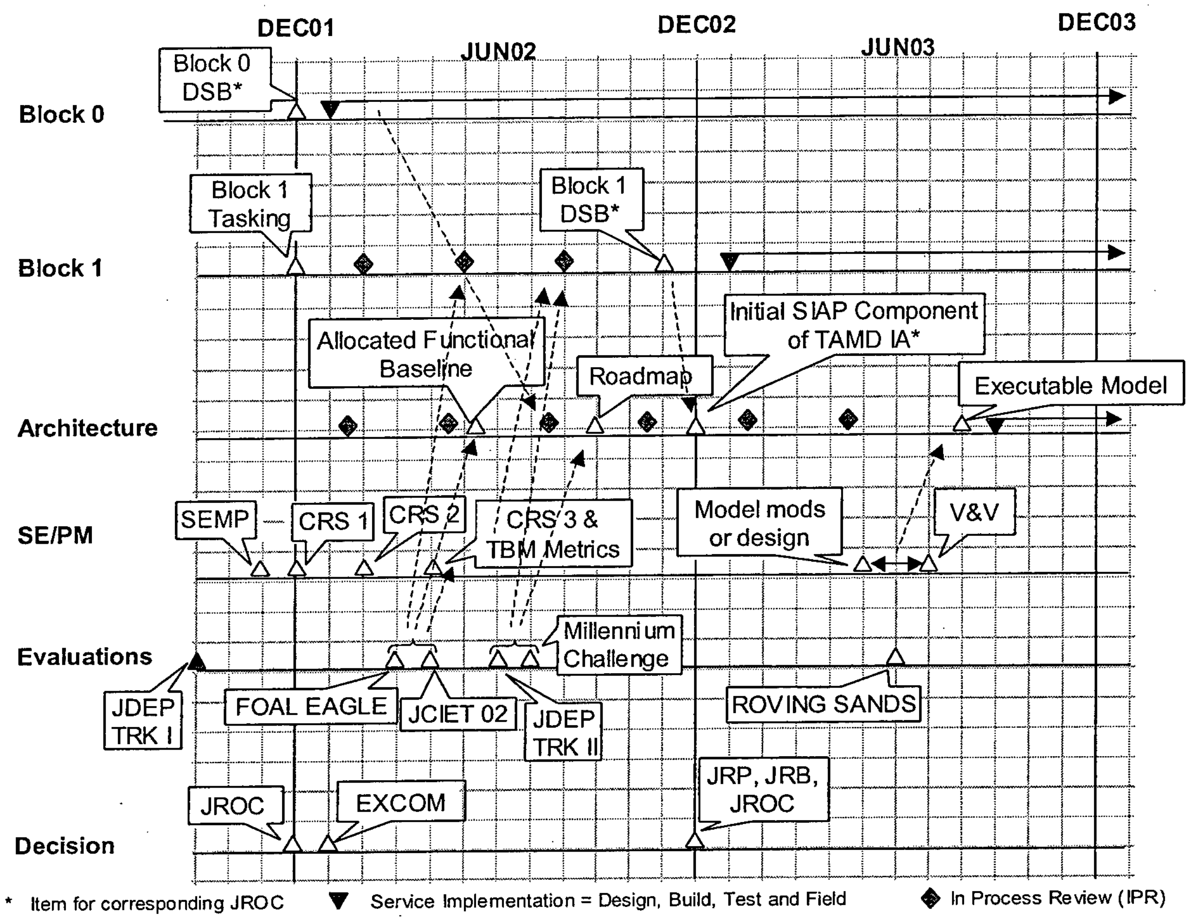

Figure 20. Integrated Plan

3.2.3. <u>Responsibilities</u>

JTAMD Process

From the SIAP perspective, the Joint Theater Air and Missile Defense (JTAMD) process is a formalized process designed to define requirements for improving theater air warfare capability. The JTAMD process impacts potential SIAP customers, by developing the SIAP requirements. As noted earlier, these SIAP requirements may be met using current systems, or by developing new systems. It is the SIAP SE's responsibility to recommend to the JROC the most cost-effective combination of changes to existing systems and fielding of new systems to meet the JTAMD developed requirements.

JINTACCS Process

The Joint Interoperability of Tactical Command and Control Systems (JINTACCS) process is the current process the Services use to introduce, analyze, and approve changes to many of the SIAP contributing systems (i.e., TDLs, which are the main components of the JDN). The formation of the SIAP SE TF by the leaders of the DoD, and current interest in network centric warfare, appear to be, at their core, a recognition that our past processes have been too platform centric (i.e., we have sometimes let the interests of a specific platform take precedence over the interests of the whole group). In this context, it would appear that one of the goals of the creation of the SIAP SE TF is to help elevate the interests of the whole, and to provide the engineering rigor which shows, where true, that properly balancing the individual platform and network interests, the whole can be made more effective than the sum of its parts. The SIAP SE will attempt to define specific warfighting benefits, which can be measured as part of the justification process for SIAP recommended changes.

CINCUSJFCOM: Demand that required TDL communications, data sharing and command messages are executed in an unambiguous fashion. Enforce TDL Certification requirements. Support the JICO Support System training to generate expert authorities in network designs and weapon system limitations. Place TDL interoperability high on the CINC Integrated Priority List to ensure proper funding of these critical theater assets. Be a vocal TDL advocate and learn to articulate the operational benefits of an unambiguous TDL.

Services: Consider Joint TDL interoperability requirements as a Prime Directive when designing new weapon systems or enhancing fielded ones. Include sister Service representatives in the capabilities and design decision phases of TDL changes. Exercise concise Configuration Management of all TDL changes using TULIP or a similar approved construct. Organize and operate Service TDL design activities to directly involve both requirements and resourcing agencies from the earliest stages. Ensure proper attention to Service commitment, implementation and fielding schedules. Plan and POM for appropriate funds so they are available to synchronize the fielding of mutually supporting Joint warfighting capabilities. Ensure TDL operators are provided a strong voice in demonstrating deficiencies, lessons learned and suggested enhancements. Provide Jointly-chartered Service representatives as subject matter experts to the Single Integrated Air Picture System Engineer Task Force to help produce the best possible solution to Joint TDL requirements.

Agencies: Foster a mindset within the DoD which emphasizes and rewards the alignment of Service resources to meet Joint warfighting requirements above that of conflicting Service-specific desires. Generate synchronized and mutually supporting policies to guide the DoD. Set and enforce gateways, thresholds and authorities to monitor and affect progress of new initiatives. Establish a robust multi-level interoperability certification process to document and guarantee interface compliance with Joint Architectures and CRDs to demonstrate expected operational results. Reinforce the high priority of Joint and NATO interoperability relative to requirements refinement, weapon systems enhancements, budgeting and human resources.

SIAP: Identify the most effective and efficient means to achieve a SIAP that satisfies the warfighters needs. The SIAP SE will satisfy this mission by initially implementing an incremental block improvement process supported by a disciplined system engineering process.

JITC: Support thorough independent operational test and evaluation/assessment of C4I acquisitions; identify interoperability deficiencies; conduct rigorous interoperability testing, evaluation and certification; and provide technical assistance as required.

JIEO: Provide engineering and interoperability support.

MDA: Develop and manage programs for overall system integration to achieve interoperability among systems, to include architecture, for TAMD and cruise missile options.

3.2.4. Approach

The Task Force includes a "Lessons Learned" Integrated Product Team (IPT) that is charged with researching the results as well as working with Service System and Interoperability Tests and Exercises to continue to identify lessons learned and document a complete and consistent set of problem reports. The Block upgrades will begin by pulling from this database (refer to section 2.3) and apply the system engineering disciplined approach (IEEE Std 1220) as detailed in the SEMP.

For the purpose of considering possible actions that might be recommended, the Task Force recognizes that some of the possible solutions are simply to fix problems that have been identified in system acceptance testing and/or in interoperability tests and/or exercises. However, to stop at that point would be negligent of the problems forecast to be emerging. For instance, as BM/C3I systems become more advanced and more complex functionality is desired in order to provide commanders with more or better information, additional bandwidth will be needed. In fact, more bandwidth is needed to support the concept of a Joint Composite Tracking Network to communicate sensor data, support the fusion algorithm, and disseminate the resulting information. In addition, the static nature of current tactical digital information links needs to be matured to a dynamic network concept where communications transmissions are not constrained to static time-slots. While current concepts talk of time-slot reallocation (TSR), it is envisioned that dynamic network management would reduce many manpower and personnel resource requirements while also leveraging automation to enable more mature concepts that are also more reliable and robust.

The definition of problems and issues that must be fixed is a continual process addressing all components of DOTMLPF (Doctrine, Organization, Training, Materiel, Logistics, Personnel, and Facilities). Objective solutions to SIAP, and possibly the larger FIOP problem, are needed. The plan to solve these problems is divided into two basic areas: (1) Systems and technical architecture issues including interoperability, integration, synchronization, infrastructure and life cycle components of the JDN and JCTN system solution and (2) Operational issues of Tactics, Techniques, and Procedures (TTPs).

Implementation flaws are the responsibility of the acquisition programs that produce the equipment and computer programs. We do not track these flaws. We are concerned about the warfighting implications of these flaws, particularly because the number of these flaws across the IADS runs into the thousands. While many of these flaws have "work arounds", the sheer number contributes to confusion and operator overload.

The Department of Defense has been struggling with developing insight into the impact of these issues. The Joint Distributed Engineering Plant (JDEP) was developed to help identify these implementation flaws.

Recommendation: Establish an objective priority assignment scheme for implementation of recommended fixes to flaws discovered during JDEP testing

We do not have sufficient resources to permit the kind of robust testing that will be necessary to fully characterize performance. Shortfalls in simulation/stimulation capability and severe shortfalls with site availability limit utility in understanding "structural" issues. Lack of ability to modify computer programs makes JDEP unsuitable as a development tool. JDEP is, however, a useful tool but it must be used in concert with other tools and disciplines.

The "structural" issues are the heart of the system engineering task. We took the "structural" entries from the Lessons-Learned Database. We will use our Block 1 effort to "pilot" the ability to do joint system engineering to work on specific issues. This work will help build the team. As a result of this process, the C/S/A will gain a collaborative SE environment.

3.3. SIAP BLOCK 1

As stated in the SIAP Implementation Plan, the purpose of Block 0 was to exercise the system engineering process and to help the Services adopt the tools and build the foundation for a collaborative engineering environment. The Block 0 process initiated an approach for making system engineering decisions. As a result of this process, we built interpersonal relationships, honed communication skills, and identified areas of work. As a pilot, the Block 0 system engineering process provided the team with many lessons from a variety of aspects including technical, programmatic, financial, and administrative.

Block 1 will incorporate lessons learned as a result of our Block 0 experience to ensure improvements are made as we build the SIAP System Engineering process. The approach outlined below incorporates those lessons as it shapes the content of the next block upgrade.

Block 1 WIPT. The Block 1 WIPT will be comprised of the Block 1 Manager, the SIAP SE Branch Heads, two Service/MDA Points of Contact from each Service/MDA (one person will be responsible for handling acquisition issues and one person will be responsible for handling resource issues), and a representative from JTAMDO and CINCUSJFCOM. The Block 1 WIPT will be charged with developing the system engineering recommendation for each Block 1 candidate issue (which are identified in follow-on paragraphs). These joint collaborative engineering working groups (one for each issue – however, some working groups may be tasked with working several related issues) will be led by a SIAP SE Task Force member and be comprised of subject matter experts from the Services. The working groups will apply an established Institute of Electrical and Electronics Engineers (IEEE) system engineering process (requirements analysis, functional analysis, synthesis alternatives, and cost benefit analysis) to determine the most beneficial way to provide an improvement in warfighting capability.

Services. As defined in the SIAP SE TF charter, the Services will: "Participate in SIAP SE-led engineering efforts to improve the performance of systems, which contribute to developing a SIAP. Assist in characterization of issues, including problem and root cause identification, determination of operational impact, and identification of temporary near-term fixes or changes in tactics, techniques, and procedures that can alleviate symptoms while a longer-term solution is engineered. Conduct engineering and system analysis/system trades for the determination of cost effective SIAP upgrades to legacy systems."

Specifically, provide the subject matter experts that will form the Block 1 WIPT and support the collaborative joint system engineering efforts necessary to develop engineering recommendations for improving warfighting capability.

3.4. DEFINE THE ELEMENTS OF THE JOINT COMPOSITE TRACKING NETWORK (JCTN)

In this section we discuss the plan to provide a joint composite tracking capability in response to JROC-validated warfighting requirements (e.g., TAMD, CID, IDM, and GIG CRDs).

The "JCTN" envisioned by previous studies and other efforts [JCTN Phase I] [JCTN Phase II] [JCTN Technical Requirements Document] [JCTN/JDN Gateway Technical Requirements Document] [Min-Mix Study] embodied a broad list of functions. While the functionality ascribed to the "JCTN" centered on composite tracking, it also included functionality that study/effort participants believed must be implemented in a common way across network participants, if performance goals (these studies and efforts pre-date the TAMD, CID, IDM, and GiG Capstone Requirements Documents) were to be met.

Common implementation of functionality is a necessary condition to achieve consistency across participants, so the intent behind allocating functionality to the "JCTN" is justified and correct. This allocation, however, must be done with great care and must be done in close coordination with the systems with which such a capability must integrate. Moving functionality arbitrarily and without associated action within the "host" will cause conflicts that manifest themselves as problems within individual warfighting units, which will propagate problems across the networks.

3.4.1. Objectives

The objective of this effort is to meet the specific requirements contained in the JROC-validated TAMD, CID, IDM, and GIG CRDs.

Multi-sensor composite tracking of air vehicles among dispersed sensor platforms was motivated initially by needs (1) to avoid gaps in tracks caused by natural phenomena such are obstructed line of sight, Doppler notch, and multi-path fading; (2) to increase effective measurement rate against maneuvering objects with sensors that individually are constrained to low update rates; (3) to overcome countermeasures against radars such as mainlobe jamming to deny range measurements and/or signature reduction; and (4) to resolve closely spaced objects through viewing angle diversity. With development and considerable experience has come appreciation of composite tracking capabilities as an (5) effective counter against low observable (LO) threats and (6) a communications capability common computer program, and associated infrastructure in which participants share a very consistent, kinematically accurate air picture. Air vehicle composite tracking provides significant advantages in all these areas over single-sensor tracking and reporting responsibility (R2) type networks.

Integrated fire control (IFC) against air vehicles has been motivated primarily by the need (7) to perform beyond-line-of-sight engagements, particularly against low flying threats; (8) to overcome characteristics of fire control radars that significantly constrain engagement space, such as azimuth field-of-regard limits; and (9) to enable advanced engagement tactics, such as launching while employing emissions control (EMCOM). All of these increase battle space, depth of fire, and weapons effectiveness.

The JCTN concept combines both multi-sensor, multi-platform composite tracking and IFC to gain the benefits listed above. As a data association, processing, and communications resource for common tactical algorithms, it also can support (10) composite classification and identification of targets, (11) engagement coordination for both single-unit and IFC type engagements, and (12) network-wide dynamic sensor support coordination to exploit fully the detection, non-cooperate target recognition (NCTR), and electronic counter-countermeasures capabilities of participating sensors, as well as to balance and reduce sensor resource loading.

When combined with effective "gateway" functionality to/from Link 16 NPG 7 (and hence to the entire JDN via other gateways), the JCTN can (13) be the primary tracking engine for creation and maintenance of a theater-wide air vehicle SIAP and (14) allow JDN networks to operate more efficiently by concentrating R2, nearly eliminating R2 contention traffic, and providing very accurate tracks with which JDN-only units can correlate their local tracks.

Some of the benefits listed above can be achieved by separate, narrowly focused material solutions, for example, a JTIDS/MIDS-based subnet to perform IFC among a small set of sensor and weapons types. While some of these narrowly focussed solutions can be justified on the basis of immediate need, they are costly to support as long-term solutions. The JCTN concept, including related gateway functionality, subsumes such narrowly focused solutions with a broadly capable, widely used material solution based on common software running in standard processing environments implementing best-of-breed algorithms and exploiting multiple communication technologies.

3.4.2. Products and Milestones

Before the products and milestones can be addressed, there are several characteristics relating to the "Joint Composite Tracking Network" that must be acknowledged. While the term Joint Composite Tracking Network (JCTN) is used frequently, there is no widely accepted definition for this network. Rather than debate the definition, the Task Force began an architectural development effort that will define the required functionality. We also expect the architecture to support analysis of functional gaps, overlaps, duplicative efforts and conflicts.

Technically, JCTN is conceptual. JCTN is not a distinct capability that functions separately from other networks. The SIAP integrated architecture will translate requirements and define/allocate functionality to weapon systems that can be mapped back to network concepts. This allocated functionality, when it exists, will be an integral part of a larger battlespace awareness capability that is greater than the sum of individual capabilities. It is this *integrated* capability that will be required to satisfy the TAMD 2010 Master Plan, e.g., CID, IFC, ABMA. As such, the products and milestones specifically articulated in 3.1.2. refer, *ipso facto* to the integrated capabilities that will be required. In this context, those characteristics considered to be within the JCTN domain are part and parcel of the SIAP "objective" architectural products. Consequently, the Block improvements, in conjunction with the architectural products, provide a time phased and cogent set of recommendations to ultimately achieve those TAMD 2010 capabilities, of which JCTN is a part.

3.4.3. Responsibilities

As we discussed in Section 2, we are working with JTAMDO to develop a series of Common Reference Scenarios that will define the operational environment for SIAP system engineering and assessment efforts. The analytic process, also discussed in section 2, is structured to evaluate candidate approaches to meet JROC-validated CRD requirements. We will use these tools to develop recommended solutions to demonstrated warfighting capability shortfalls.

3.4.4. Approach

As we discussed in Section 3.1, our approach is to derive composite tracking requirements through our work to complete the Block 1 effort and the functional decomposition in the SIAP integrated architecture.

In order to satisfy the fundamental JTAMD 2010 Operational Elements, there is a need for a joint, composite tracking network (*sic*) capability. While some services are progressing to that end, such as the Navy's Cooperative Engagement Capability (CEC), additional analysis and exploration is still required to ensure that the resulting capabilities developed for JTAMD 2010 satisfy the joint force requirements and is not service-centric. We intend to collaborate with the CEC development and exploit those technologies that are relevant to a joint composite tracking capability.

3.4.5. Resources

We cannot yet estimate the resources necessary to engineer a Joint Composite Tracking Network. We do have a significant body of work from previous efforts that will probably reduce the resources required to do the engineering required.

4. SUMMARY AND CONCLUSIONS

The SIAP SE Task Force has made a good start. This is unprecedented work to solve long-standing problems in joint interoperability. Consistent, strong support from leadership is required to make meaningful progress. We cannot continue historically ineffective processes and expect the outcome to be different. Our previous reliance on Service good will has not worked sufficiently to solve our shortfalls. Interoperability KPP's must be a threshold, not an objective. Support from Service SMEs is tantamount to providing thoroughly vetted recommendations.

Block 0 served as an exercise in team building, identified our infrastructure shortfalls, and unearthed various areas where we can make improvements in processes and products.

Block 1 is striving to make systems better now while the architecture is on the path to an objective SIAP. The architectural products will assist in the decision-making process. Sharing information and progress with the variety of stakeholders within the Department will help us meet expectations.

Specific challenges include:

- Building a common definition of joint interoperability and its priority – how does it compete with other requirements?
- Quantifying the benefits of joint system engineering--system engineering doesn't, by itself, win wars (no flame, detonation), so it is very difficult to compete with high visibility programs
- Linking architecture to individual weapon systems.
- This is a legacy world. Whatever we do must account for the large number of existing systems, many of which are difficult to change.
- Maintaining Service accountability for system implementation and certification in accordance with the integrated architecture. SIAP SE can be effective if properly supported. We'll know if success is possible when Block 0 changes are implemented.
- Synchronizing Service-directed acquisition strategies across a complex family of systems -- a key to realizing ensemble performance.
- Translating between system requirements and capabilities of the ensemble. ORDs aren't written for missions – KPPs are typically written too vaguely. Spiral development, performance based specifications and capabilities versus threat-based engineering have also clouded the issues.
- Specifications and standards are insufficient to achieve the required level of performance unless interfaces are well characterized and tightly controlled.
- Leveraging advanced technology. Advanced Concept Technology Demonstrations spur on more appetite than DoD can consume and transition. How do we leverage existing investments in technology and transition these into joint warfighting capabilities?

- Focusing similar Service and Joint experiments and initiatives synergistically instead of each competing over scarce DoD resources.
- Managing external relationships (JTIC, DISA, JIEO, etc.)
- Working with NATO – can't go it alone.
- Accommodating current personnel processes. It's difficult to train people before they rotate to a new assignment. Tough to get something done in a 2 year tour – must have continuity and constancy of purpose. Civilian and contractor decision-makers stick around – the military doesn't.

The SIAP isn't real until it shows up on the battlefield, and it can't show up on the battlefield until the following is done:

- Requirements well articulated
- Engineering changes developed
- IV&V/Testing/Certification determined for joint implementation
- Contracting strategies established.

As the Task Force establishes the engineering foundation for others to build on, other critical elements need to accompany this Joint engineering initiative:

- JTAMDO must complete the Operational Views of the SIAP Integrated Architecture
- DOT&E should institutionalize the SIAP metrics as the assessment measures for characterizing SIAP performance and to endorse the end-to-end analysis process
- And ultimately USD (AT&L) should assign an activity to budget for, update, and manage the configuration of the SIAP component of the TAMD Integrated Architecture.

This SIAP Integrated Architecture should be the basis for how DoD must develop its JDN/JCTN roadmap. The Task Force made progress in building initial segments supporting this architecture and we've mapped out the architectural discipline needed to trace requirements to materiel alternatives that will define that roadmap. It is this disciplined approach that will help DoD clarify requirements, identify deficiencies in the JDN and define the elements of the JCTN concept. And, by using integrated fire control as a key engineering driver for future capability, we expect the plan we've laid out in this report will provide a highly accurate DoD network linking CRD requirements to specific materiel alternatives.

APPENDIX A

THE UNDER SECRETARY OF DEFENSE

3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION AND TECHNOLOGY

25 JUN 2001

MEMORANDUM FOR SINGLE INTEGRATED AIR PICTURE ACQUISITION EXECUTIVE

SUBJECT: Single Integrated Air Picture (SIAP) System Engineering (SE) Task Force – Report on Progress, Plans and Recommendations

The USD (AT&L), VCJCS, and DoD Chief Information Officer chartered the SIAP SE Task Force in October 2000 and put in place the management process that will, among other tasks, define an integrated architecture to provide a Single Integrated Air Picture (SIAP) for joint forces. The Joint Theater Air and Missile Defense (JTAMD) Executive Committee (EXCOM) met in November 2000 and reviewed plans to develop the broader operational and systems architecture views needed to define the SIAP. I request a report to the JTAMD EXCOM on the Task Force's progress and plans to define the SIAP integrated architecture, identify and resolve problems with the Joint Data Network (JDN), and define the elements of the Joint Composite Tracking Network (JCTN). The report should be presented to the JTAMD EXCOM by September 30, 2001, through the JTAMD Overarching Integrated Product Team, and offered to the Joint Requirements Oversight Council before it is presented to the EXCOM. Ensure that the report includes:

- Emerging recommendations regarding the contribution, composition, and functionality of the JDN and JCTN networks within the context of the SIAP SE Task Force Charter, and within the broader context of the multi-mission warfighting environment.

- A plan to develop a JDN and JCTN roadmap, including an implementation strategy that addresses interoperability, integration, and synchronization. As the SIAP SE Task Force develops this plan, they should work closely with the Joint Theater Air and Missile Defense Organization (JTAMDO), Ballistic Missile Defense Organization (BMDO), and Joint Forces Command (JFCOM) to ensure that it properly considers aspects of Doctrine, Organization, Training, Materiel, Leadership, Personnel, and Facilities (DOTMLPF).

- Resources and schedule needed by the SIAP SE Task Force to estimate the costs of engineering solutions for JDN/JCTN across the JTAMD mission area.

- Status of personnel and funding for the SIAP SE Task Force, identifying shortfalls or issues.

- Key issues and concerns of the SIAP System Engineer.

E. C. Aldridge, Jr.

APPENDIX B

THE UNDER SECRETARY OF DEFENSE
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ACQUISITION AND TECHNOLOGY

NOV 1 4 1996

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS
CHIEFS OF MILITARY SERVICES
ASSISTANT SECRETARY OF DEFENSE (C3I)
DIRECTOR, BALLISTIC MISSILE DEFENSE ORGANIZATION

SUBJECT: Management of Theater Air and Missile Defense Activities

This memorandum sets forth the management structure to be used by the Department of Defense in providing the Joint Force Commanders improved capability to defend against air and missile threats. A key objective of this structure is to effectively and efficiently integrate requirements and acquisition activities for Theater Air and Missile Defense (TAMD) efforts.

The management changes described herein will not alter Service or Agency responsibilities for program execution and resource management. Rather, these changes will enhance coordination between the requirements and acquisition communities, focus requirements generation and planning activities, furnish systems-of-systems engineering at the architecture level, and provide for integrated oversight by the Department's senior leaders. A key product of this effort will be a TAMD Master Plan that includes requirements and acquisition road maps. The Director for Force Structure, Resources and Assessment (DJ-8) is responsible for producing the operational concepts and requirements section of the TAMD Master Plan. The Director, Ballistic Missile Defense Organization (BMDO) is responsible for producing the acquisition section of the TAMD Master Plan.

The Secretary of Defense and the Chairman of the Joint Chiefs of Staff are establishing under the Director for Force Structure, Resources, and Assessment (DJ-8), as a Chairman's controlled activity, a Joint Theater Air and Missile Defense Organization (JTAMDO) to define the required system interoperabilities and operational architectures, and to validate the developing joint theater air and missile defense capabilities through both simulation and technology demonstrations. The JTAMDO shall coordinate with the warfighting CINCs and Military Services to develop joint mission capstone requirements, a joint mission architecture, and a joint capabilities roadmap. These efforts will be documented in the requirements section of the TAMD Master Plan for validation by the Joint Requirements Oversight Council (JROC). All responsibilities and functions previously assigned by the Assistant Secretary of Defense (C3I) to the Executive Agent for Theater Air Defense BMC4I will be transferred to the JTAMDO.

BMDO shall assume the role of Integration Systems Architect for theater air and missile defenses. Working jointly with JTAMDO and the Services, BMDO will translate the JTAMDO-developed operational architecture into systems architectures, perform systems engineering at the architecture level, plan and ensure integrated testing of defense architectures, and lead program acquisition activities. BMDO also shall work closely with Service and joint program offices to develop a joint acquisitionroadmap. These efforts will be documented in the acquisition section of the TAMD Master Plan for validation by the Service and Ballistic Missile Defense Acquisition Executives. Any management changes required for BMDO to fulfill this role will not impact Service-unique responsibilities.

To fulfill their responsibilities, JTAMDO and BMDO shall work closely using an Integrated Product Team (IPT) Approach. Only together -- and with the CINCs, Services, OSD, and Joint Staff -- do they have the systems engineering and operational expertise needed to define operational concepts and systems requirements, produce an effective family-of-systems architecture, ensure its proper test and evaluation, and integrate it with the other elements of an effective, wide-area air and missile defense against emerging threats. To this end, the Director JTAMDO and the BMDO director for TAMD shall co-chair an Integration Integrated Product Team (IIPT) to oversee coordination of TAMD requirements and acquisition activity. This IIPT will form working-levelIPTs as needed in such areas as operational concepts, requirements, weapons, BMC4I, integrated testing, modeling and simulation, hardware and software commonality, navigation warfare, combat identification, and red teaming. The Director, Strategic and Tactical Systems and the Director for Force Structure, Resources and Assessment (DJ-8), will co-chair an Overarching IPT (OIPT) for TAMD, on which the Deputy Assistant Secretary of Defense (C3I Acquisition) will play a prominent role. BMDO shall recommend to the OIPT appropriate assignment of acquisition responsibilities for the family-of-systems, element-to-element, and individual element design and engineering duties. This OIPT will support review of CMD activities by an Executive Committeeco-chaired by the undersigned. The Director, JTAMDO will advise the Executive Committee directlyon the degree to which the TAMD Master Plan meets the Department's objectives for Joint Theater Air and Missile Defense.

The Director for Force Structure, Resources and Assessment (DJ-8) shall provide to USD(A&T) and the VCJCS by November 22, 1996, a plan to establish the JTAMDO. The Director, BMDO shall provide to USD(A&T) and VCJCS by November 22, 1996, a plan to integrate TAMD systems engineering and technical activities. These plans will identify needed agreements, describe responsibilities and a detailed management approach, recommend changes to charters, present the start-up schedule, and propose any adjustments in personnel or resources needed to carry out this work.

Maintaining an effective and robust theater defense against the emerging air and missile threat is a challenging problem. With the best efforts of all elements of the Department, working together in this integrated manner, we can meet this challenge.

Joseph W. Ralston
JOSEPH W. RALSTON
Vice Chairman
Joint Chiefs of Staff

Paul G. Kaminski
PAUL G. KAMINSKI
UNDER SECRETARY OF DEFENSE
(ACQUISITION & TECHNOLOGY)

DEFINITIONS

FORCE OPERATIONS

Intelligence Preparation of the Battlespace:
Intelligence preparation of the Battlespace (IPB) integrates data from numerous intelligence systems to provide the warfighter with the best possible situation awareness regarding battlespace environment, terrain and enemy locations, capabilities and plans. This information enables making the best possible use of blue assets by supporting the mission planning functionality. (source: JTAMD CRD Mar 2001)

Joint Sensor & Weapon Systems Planning:
Modeling of Joint TAMD sensors and weapon systems to determine sensor and weapon system coverage/performance against the anticipated Enemy order of Battle (EOB), and Enemy Courses of Action (ECOAs). Automated display of expected sensor performance throughout the theater as a function of blue force laydown and threat characteristics (e.g., RCS, trajectory, and altitude of anticipated threat aerospace vehicles). Automated display of weapon system performance throughout the theater as a function of blue force laydown and aerospace threat characteristics.

Mission Planning:
Utilizing guidance and direction from Joint Task Force and Component Commanders, the Friendly Order of Battle (FOB), products of the IPB process (e.g. the EOB, and ECOA) and products of "Joint Sensor & Weapon System Planning", determine optimal blue force lay-down and alternate courses of action in defense against the TAMD threat.

Communication Services Planning
Communication planning services will consist of decision aids to support development and management of communication architectures/configurations and. real-time capabilities to support the monitoring and control of communication operations. Communication planning capabilities will include, but not be limited to:

- Modeling of communication performance to support sensor and weapon system planning and blue force laydowns
- Tools to develop and assess network architectures and network configurations

Real Time communications planning services will include but not be limited to monitoring and control of:

- Communication system configurations and status
- Connectivity between TAMD units
- Bandwidth utilization and allocations (e.g., TSR,Link-22 SNC)
- Data latencies between units

ENGAGEMENT OPERATIONS

Establish and Maintain Track Files

1. Communication Services

In accordance with guidance provided by JICO, initiate and maintain communication connectivity between TAMD units and distribute data to support SIAP and TAMD operations. Distribution of data will include but not be limited to real-time *and near real-time data necessary to: 1) develop and maintain the SIAP; 2) support C2 and weapons coordination; and 3), support integrated fire control engagements based by local and remote sensors. Joint networking capabilities will include JCTN and JDN for the exchange of real-time and near-real time data, respectively. Specific functions to be performed will include, but not be limited to:*

- *Network initiation and management*
- *JDN & JCTN message generation*
- *Message flow control and routing, (e.g. L11/16/22 protocols)*
- *Message transmission and reception*
- *Joint Range Extension (JRE)*
- Automatic translation and forwarding between components of the JDN (e.g., Link-16 to Link-11, Link-22 to Link-16)

2. *Local and Remote Sensor Integration*

TAMD sensors will provide an interface to the JCTN. Sensor inputs to the JCTN will include local and remote sensor measurement data in support of composite tracking, target characterization, identification, discrimination, sensor coordination, and weapon system control. Outputs to the sensors from JCTN will include information necessary to task the sensor to support sensor and weapon system coordination and control of both local platform and IFC engagements. There will be no interface between the JDN and sensors. Data products derived from local sensors will be interfaced with the JDN by the host tactical data system.

3. Sensor Registration & Gridlock

For all local TAMD sensors contributing to the SIAP and supporting TAMD operations, continuously and automatically calculate sensor bias corrections as pertinent to each particular sensor type (e.g., range measurement offset bias, azimuth biases, elevation biases). Sensor registration should also produce an estimate of residual bias error covariance. Corrections from the sensor registration will be applied to remove biases from sensor measurements.

Considering all TAMD units connected via the Joint Networks continuously and automatically calculate and correct navigational errors with sufficient accuracy to support the spectrum of TAMD operations, including SIAP generation, TBMD target discrimination, and IFC engagements. Sensor gridlock will consider available navigational sources (e.g., GPS, INS) and local and remote sensor data to align local and remote sensor data to a Jointly agreed upon common coordinate reference frame.

4. Common Nav/Time

Maintain navigation solutions, consisting of platform position, velocity, and platform attitude, in a Jointly agreed upon, absolute reference frame that can be translated to the WGS-84 latitude/longitude/altitude and earth-centered earth-fixed Cartesian frames. Also, maintain common time reference to universal coordinated time (UTC) as established by the U.S. Naval Observatory. Inputs from the U.S. Global Position System (GPS), as well as site surveys, gravity measurements, gyro-compassing, and other techniques, will be used.

5. Data Fusion and Tracking

Data fusion and tracking will accept locally derived and remotely provided TAMD sensor measurement and track state data and associate tracks and sensor measurements with locally processed tracks and sensor measurements. When sensor measurement data is available (i.e., JCTN) the associated local and remote sensor data will be fused and integrated to form a single composite track state (e.g. track position and velocity state vectors) and track characterization (e.g. IFF codes, ESM attributes). Fused sensor measurement data will also be used to support cued acquisitions, new track initiation, and guidance control for weapons systems. When local and remote track state data is available (e.g. JDN), integration of track states will be performed, which includes track-to-track correlation.

6. Identification

Track identification will include target classification, identification and discrimination capabilities. Target classification will use fused sensor information to derive and resolve differences in track types (e.g. ASM, TBMD, Aircraft) and platform types (e.g. F16). Target identification will determine each tracks ID in accordance with Link 16 primary ID taxonomy (unknown, assumed friend, friend, neutral, etc) and resolve differences between units. Track discrimination will use fused TAMD sensor information to resolve and identify TBM objects within a TBM cluster. JDN and JCTN will not perform the Combat ID (CID) function; however, will provide the fused target track and track characterizations necessary to support CID and to resolve differences in CID between TAMD platforms.

7. JDN and JCTN Integration Tactical Data System and Links

Both JDN and JCTN will provide an interface with the host tactical data system (to include combat direction system and weapon/fire control systems as appropriate). The interface between the JDN and host combat system will provide for the exchange of system tracks, track attributes, and command and control information (such as ID, force engagement orders, etc.) necessary to maintain a SIAP and to coordinate command and control and weapon systems between multiple platforms. The interface between the JCTN and the host combat system will provide for the exchange of system tracks, track attributes, sensor derived measurement data, and command and control information to support SIAP and integrated fire control between participating JCTN platforms.

Additionally, integration of JCTN and JDN will be performed to support seamless TAMD operations and SIAP across networks. JDN and JCTN integration will provide for the integration of tracks, track attributes, and command and control information between the JDN and the JCTN. Integration functions will include, but are not limited to automatic selection and filtering of data to be transferred from the JCTN to the JDN, gridlock and correlation of JCTN & JDN tracks, management of track and track attributes to ensure that a consistent track picture is maintained between the JDN and JCTN (i.e. single/common system track number on each track), and translation between network coordinate reference frames.

8. Sensor & Engagement Coordination

Sensor coordination will include pre-emptive and reactive planning and management, and real-time dynamic coordination of TAMD sensors in support of collaborative: 1) surveillance and tracking; 2) target characterization, identification and discrimination, and; 3) real-time sensor support for cooperative engagements, including precision cueing and other coordination concepts detailed in "Multi-Platform Weapon System Integration". Sensor coordination will include planning, management, and real-time coordination of sensor waveforms and coverage between multiple platforms to more effectively manage sensor resources and improve detection and engagement performance against all TAMD threats.

Engagement Coordination will include pre-emptive and reactive planning and management, and dynamic coordination of TADM weapon systems in support of collaborative Joint battle force engagement coordination and support for cooperative engagement execution. Specific functions to be performed will include, but not be limited to:

- *Providing weapon and sensor system capabilities & status*
- *Coordinating sensor resource allocation and engagement decisions (e.g. J9.1, J12.0, ABMA-engagement recommendations, Joint-TEWA)*
- *Coordinate/share engagement status (e.g. J10.2)*
- *Coordinate/share kill assessment results*

9. Weapon/Fire Control System Integration

Interface with fire control quality sensors and provide fire control quality sensor measurement and composite track data to Joint TAMD weapon systems in support of IFC engagement execution using locally derived and remotely provided data. Multi-platform weapon system integration functionality will enable execution of Air-Directed SAM (ADSAM), Air Directed AAM (ADAAM), and Surface Directed SAM (SDSAM). Specific functions to be performed will include, but not be limited to:

- *Coordinate sensors, weapons and communication systems to support the execution of IFC engagements*
- *Provide tasking to fire control sensors to support IFC engagements*
- *Provide sensor measurement data to support weapons system guidance*
- *Coordinate and execute hand-over of weapon control to like or unlike remote systems*

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