TECHNICAL REPORT 2002-005

Single Integrated Air Picture (SIAP) Integrated Assessment Plan (IAP)

JULY 2002

SINGLE INTEGRATED AIR PICTURE (SIAP)
System Engineering
Task Force (SE TF)

1931 Jefferson Davis Highway
Crystal Mall 3, Suite 1142
Arlington, VA 22203

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FOREWORD

List of Contributors

The SIAP Integrated Assessment Plan is the result of collective efforts of members of the SIAP SE TF and various working group members. The following individuals, listed in alphabetical order, played a key role in the development and production of the report:

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The Service and Agency review process brought some additional input, revision, and commentary to bear on the report, and through this process the contributions of number of other individuals and organizations are reflected in the final document. In additional to names already noted, contributors to the review process included SIAP SE TF members as well as C/S/A subject matter experts.

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EXECUTIVE SUMMARY

PROBLEM

The Single Integrated Air Picture (SIAP) System Engineering Task Force (SE TF) requires a single, coherent analytic approach that delineates overarching SIAP related analysis objectives. Such an approach will also serve as a roadmap for the integration of selected analysis endeavors. The System Engineer (SE) will use the Integrated Assessment Plan (IAP) to guide and facilitate the comparison of results across different assessment venues and to leverage each venue's strengths. Such an integrated approach requires standardized collaborative teams, tools, and processes that support focused, repeatable, and rigorous analysis of the SIAP. This IAP describes and articulates the multiple analytical venues available to the SIAP and provides a focused implementation plan documenting the strategy for integration of multiple SIAP analysis efforts across multiple SIAP venues. This plan documents a coherent process for the integration of the results from the many different SIAP analytical endeavors.

OBJECTIVES

Define the overarching SIAP related analytical methodologies, and analysis objectives, as applicable for particular SIAP block analytical efforts. Lay out a roadmap for integrating the individual SIAP related analysis results across multiple analytical venues. Doing so will enable the SE to consistently and credibly assess Integrated Air Defense System (IADS) performance and make legitimate and justifiable recommendations to the Joint Requirements Oversight Council (JROC).

APPROACH

Describe the different analyses and analytical venues sponsored, supported, or leveraged by the SIAP SE. Describe standard teams, tools, and processes used by the SIAP SE. Structure the IAP to provide general concepts and guidance that apply to all SIAP analysis in a main document, with the details of each block analysis strategy defined in separate block appendices.

CONCLUSIONS

To ensure proper synergy and leveraging across a host of analytical venues, a single assessment plan must account for options, categorize the strengths and limitations of each venue, and describe a single, coherent plan for conducting thorough and sound block analyses. Enacting and executing the enclosed IAP is the best guarantee of establishing and maintaining a rigorous and disciplined analytical process for the SIAP SE.

RECOMMENDATIONS

The IAP shall be used as the primary planning and execution document for block system engineering analyses for the SIAP SE.

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1. Introduction

This plan documents a coherent analytical approach that delineates the overarching analysis objectives, approach, and processes for Single Integrated Air Picture (SIAP) related analysis. There is no existing, explicit and comprehensive process for assessing the Integrated Air Defense System (IADS) Joint Data Network (JDN) performance. As a result, most of the Department of Defense's (DoD) efforts to date to correct systemic, doctrinal, and process issues contributing to SIAP shortfalls have proven ineffective or incomplete. These shortfalls result in, among other things, reduced system capability and difficulty or inability to anticipate and address emerging SIAP deficiencies. The SIAP System Engineer (SE) developed the Integrated Assessment Plan (IAP) to help mitigate this problem. This IAP provides an overarching strategy and implementation approach for conducting SIAP related analysis and IADS performance assessment.

The SIAP SE is responsible for recommending SIAP improvements to the Joint Requirements Oversight Council (JROC) based on results from a disciplined system engineering process. A rigorous set of analyses, as part of a disciplined system engineering process, is a key enabler to providing said recommendations. This IAP lays out the fundamental steps inherent in applying rigorous system analysis to assessment of IADS performance. It promotes joint collaboration and focus, and allows many types of analysis to be conducted for one central analytical body, the SIAP Analysis Team (SAT). The SAT is a collaborative (among the Services and Agencies under the leadership of the SIAP SE) engineering and analysis team. This method adds focus, order, and value to the many SIAP related analyses being conducted. Effective execution of the IAP will result in timely and meaningful recommendations to the JROC.

The system engineering process will consider the many Service/Agency (S/A) analysis practices already in existence to provide the best answer possible for various aspects of analysis issues and goals. Currently there exist at least four distinct venues that are used by analysis agencies. For the purpose of this document and SIAP related activities, a **venue** is considered to be an assessment structure available to the SIAP SE. The four venues addressed in this IAP are live exercise, hardware-in-the-loop (HWIL), operator-in-the-loop (OITL), and constructive simulations. Within these venues there can literally be hundreds of analysis tools available. For the purposes of this IAP, the SIAP SE defines **tools** as sub-items of venues. Examples include Joint Combat Identification Evaluation Team (JCIET) (a live exercise tool), Joint Distributed Engineering Plant (JDEP) (a HWIL tool), Virtual Warfare Center (VWC) (an OITL tool), and Extended Air Defense Test Bed (EADTB) (a constructive simulation). Additionally, a one-time execution of a particular tool is referred to as an **event**.

To date, there has not been an attempt to coordinate or synergize across the many Joint potential assessment venues and related tools available. The result is that while many venues and related tools characterize some aspect of SIAP related performance in similar ways, none are standardized enough to equitably compare results from one venue with another, or to build a consistent cumulative story of SIAP performance based on their multiple contributions. In short, there is no current systematic and detailed IADS performance assessment implementation plan available to the SIAP SE.

This document describes the different types of analyses to be conducted and leveraged by the SIAP SE in adherence to a disciplined system engineering process. It also describes the standard teams, tools, and processes that support the analyses.

2. Analysis Requirements

The SIAP Systems Engineering Task Force (SE TF) Charter mandated the implementation of a "disciplined system engineering process" to "achieve a SIAP that satisfies the warfighter needs." The SIAP SE's system engineering process will draw upon the IEEE STD 1220-1998 process and be further articulated in the SIAP System Engineering Management Plan (SEMP). This process entails effective root cause analysis (RCA). The results of root cause analysis will support the subsequent development of proposed solutions and recommendations. Performance and cost benefit analyses will address questions "So What?" and "How much?" respectively. The overall SIAP SE analysis plan for achieving the objective SIAP is represented below in Figure 1.

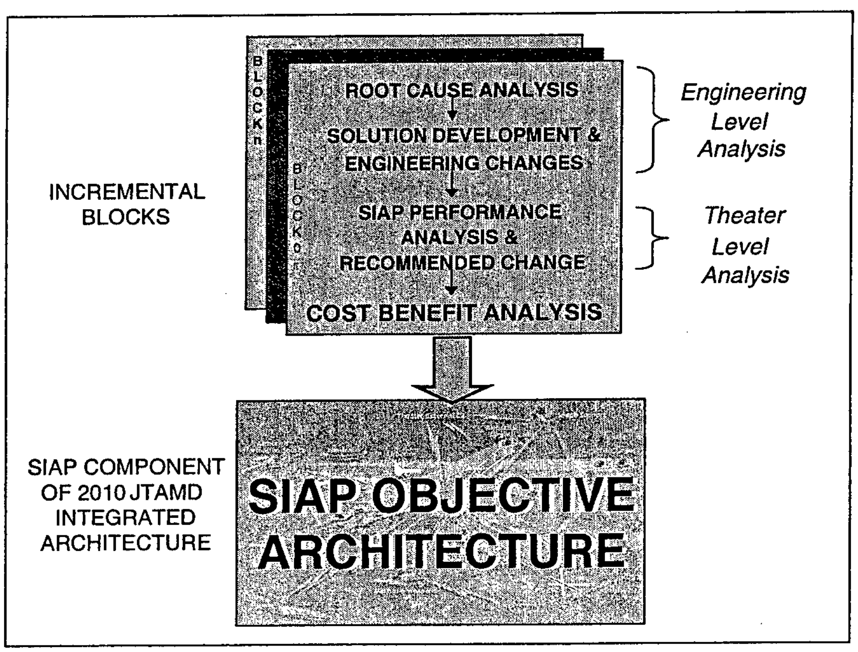

Figure 1. SIAP SE Analysis Plan

The SIAP SE will recommend improvements to the IADS in incremental "block" upgrades. Incremental block upgrades will begin with near term JDN fixes that improve the current air picture and specifically satisfy the requirements defined by capstone requirements documents. By consolidating JDN improvements into logical block upgrades, and by coordinating these upgrades with other planned changes to host systems, the SIAP SE minimizes the number of times that host computer programs must be modified and tested and thereby minimizes cost. The initial block upgrades will target Link 16 deficiencies of the JDN.

For each block, the SIAP SE will establish Block Working Groups to conduct engineering level analysis of issues related to that block. In accordance with the SEMP, Block Working Groups will functionally decompose problems uncovered during root cause analysis and develop solutions to block issues by modifying the relevant functional processes. Before recommending solutions for theater level analysis, working groups will determine that solutions result in improvements of system functions by selecting and/or developing relevant engineering level measures of performance (MOPs) and calculating before/after system performance.

The SIAP SE will then conduct system trade-off analysis of proposed solutions using theater force level models. The SIAP SE employs theater force level models to determine the relative improvement in SIAP performance by calculating SIAP attributes before and after changes are made. Since many force level models also include capabilities which allow investigation of warfighting benefits, those features will also be selectively evaluated to help understand what warfighting benefit may be incurred by implementing a particular solution. To establish the value of a particular proposed engineering level change, or block of changes, on the SIAP, assessment venues and related tools must be employed which reveal the current level of SIAP performance. Then the SIAP engineering improvement(s) can be introduced and the change in the particular measured parameter(s) or metric(s) measured. With sufficient control over the experimental variables, the changes in performance of the introduced engineering improvement(s) can be determined. This type of comparative analysis is essential to the SIAP performance analysis. Trade-off studies will include development of an analysis baseline ("as-is") and assess performance changes in the SIAP as a result of the introduction of alternatives as developed by working groups. Tracking the changes between "as-is" and block upgrade performance will enable the SIAP SE to determine progress in achieving the objective SIAP capability.

Using results from SIAP performance analysis, improvement implementation cost and risk estimates provided by the S/As, and considering the inter-relationships among the alternatives, the SIAP SE then investigates how to achieve the most cost-effective mix of proposed solutions to achieve maximum performance. The cost and risk assessment process is very complex since it could involve multi-systems of multi-Service acquisition efforts. The detail documentation of that process is beyond the scope of this technical report. The SIAP SE also ensures that specific solutions contribute to the objective SIAP architecture as defined by architecture modeling and assessment efforts. These solutions will then be incorporated into a Decision Support Binder (DSB) and recommended to the JROC.

3. Standard Collaborative Teams

The SIAP SE's success can only be achieved through highly motivated collaborative teams adhering to well-understood and disciplined processes. In response to this need, the SIAP SE has established an integrated analysis team to oversee all SIAP related analysis. Additionally, the SIAP SE will establish a Block Working Integrated Product Team (WIPT) for each block and working groups as necessary.

3.1 SIAP Analysis Team (SAT)

The SAT is a SIAP SE led, joint, integrated analysis team composed of various CINC/Service/Agency (C/S/A) analysis experts. The mission of the SAT is to provide cross-Service IADS analysis to support the system engineering decision-making. The SIAP support areas include HWIL, OITL, modeling and simulation (M&S), and other venues. Field exercise and demonstration support includes planning, data collection, evaluation, root-cause analysis, and after-actions activities required to system engineer improvements to the IADS. In the M&S area, it requires support for development and evaluation of M&S tools, operational scenarios, and standard performance metrics and methodologies.

The SAT does not replace existing Service and Agency analysis groups. Rather, it sets standards for generating, utilizing, and comparing results from multiple SIAP related assessment venues and related tools to support the collaborative system engineering decision-making process. Products of the SAT will include planning reports and schedules; documented root-cause analyses of IADS deficiencies, lessons learned, force capabilities and limitations assessments, documented analysis results and engineering recommendations.

The goals of the SAT are:

1. Evaluate IADS performance within a representative architecture
2. Identify performance shortfalls and root cause of these shortfalls
3. Develop methodologies for evaluation of candidate solutions for addressing the shortfalls and improving IADS performance
4. Evaluate performance of IADS with proposed solutions implemented
5. Provide recommendations for improving test venues to better support IADS performance assessment efforts.

The SAT will support the disciplined SIAP system engineering process by encouraging standardization of all aspects of analysis required to support selected exercises/events. The SAT must perform collaborative, overarching planning and scheduling of M&S and live evaluation resources to support SIAP system engineering requirements. Events considered will be included in the SIAP SE analysis schedule if appropriate support can be rendered from SAT membership and virtual task force activities.

3.1.1 SAT Organizational Responsibilities

The SAT shall consist of three levels of organizational responsibility. Figure 2 depicts these organizational levels. These three fundamental levels are:

1. SAT Steering Group (SAT SG)
2. SAT Core Working Group (SAT Core WG)
3. SAT Support Working Groups (SAT Support WG)

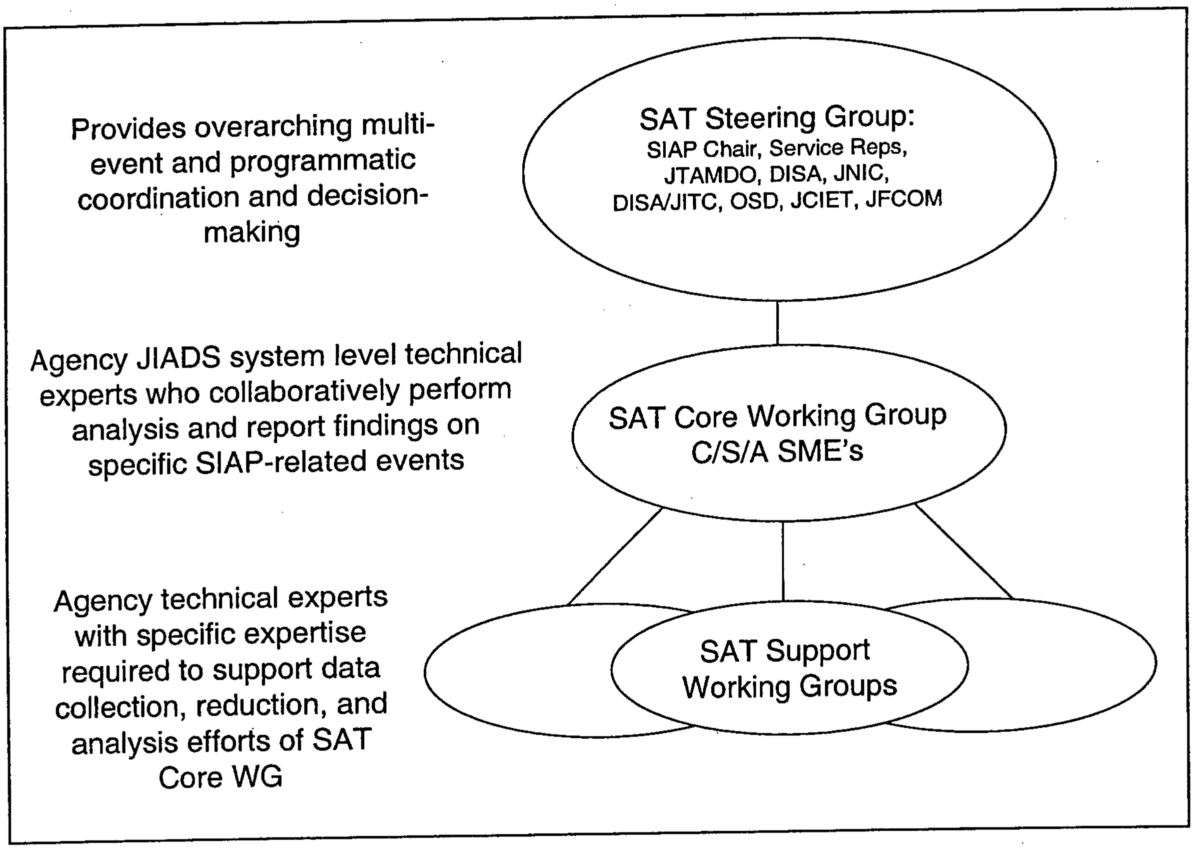

Figure 2. SAT Organizational Structure

The following provides key functions of the three SAT organizational levels:

SAT Steering Group

The following lists specific elements of the SAT SG:

- Formal and long term designated set of cognizant senior representatives from Services and appropriate Agencies
- SAT SG provides overarching analysis objectives and logistics support
- Identifies "critical experiments" for selected exercises and events
- SIAP SE TF Analysis Branch Head leads the team, however Lessons Learned System Engineering Team (SET) and Block "n" leads are members of the SG
- Coordinates the activities to be supported by the SAT Core WG (exercises, HWIL tests, simulation studies) with required C/S/A's
- SAT SG coordinates resource issues
- SAT SG reviews and endorses final reports as prepared by the SAT Core WG.

The SAT SG is a senior level forum chaired by the SIAP SE TF Analysis Branch head and composed of representatives from the Architecture and Block WIPTs, Services, Joint Forces Command (JFCOM), Joint Air and Missile Defense Organization (JTAMDO), Joint Interoperability Test Command (JITC), Office of the Secretary of Defense (OSD) Command, Control, Communications, & Intelligence (C3I), DUSD (Director, Defense Research and Engineering (DDR&E)), Director, Operational Test and Evaluation (DOT&E), and Missile Defense Agency (MDA). The purpose of the SAT Steering Group is to develop and support the overall coordination of exercise and evaluation planning for the SIAP SE IAP process. The SAT SG shall perform the programmatic functions of the SAT effort and provide the vetting forum for all non-technical analysis issues.

SAT Core Working Group

The following lists key elements of the SAT Core WG:

- Formal and long term designated set of joint personnel composed of Subject Matter Experts (SMEs) from each major affected systems are long term members and other system SMEs as required (e.g., Center for Naval Analyses (CNA), JCIET, M&S experts, exercise staff)
- SIAP SE TF member leads the Core WG team and SIAP SE TF provides infrastructural support
- SAT Core WG will expand and contract as needed to support the required analysis tasking.
- SAT Core WG conducts exercise, HWIL and other analysis detail planning

- SAT Core WG provides on-site analysis support in real time and immediate post-mission support
- SAT Core WG convenes to conduct root cause analysis of interoperability problems from exercises, HWIL, OITL, etc.
- SAT Core WG tasks SIAP Support Working Groups for specific analytical tools/products, data collection, and bulk statistics generation.
- SAT Core WG analyzes data from all sources and prepares SAT documentation

Ultimately, detailed SIAP analysis is accomplished at the system level and is inherently the domain of a very small set of SMEs who have significant system understanding, joint interoperability understanding, engineering experience and simulation skills. These SMEs are largely the same personnel who comprise the Joint Integrated Air Defense System (JIADS) Integrated Working Group (IWG). Membership is driven by 'system' level expertise rather than SERVICE/AGENCY expertise. This "Core" team is the heart of the SAT process.

SIAP Support Working Group

The following lists specific elements of the SAT Support WG:

- *Ad Hoc* basis for long or short durations as required by tasks
- Specific analysis scope such as compilation of bulk statistics
- Membership based on expertise in specific tools, etc., as well as task or effort supported
- Working groups are joint endeavors to the maximum possible extent

There are also many SIAP analysis tasks that must be executed requiring significant use of a particular subject matter or tool expertise. These activities (e.g., creating, executing and reducing simulation runs; data collection and data processing at exercises/events; modifying tools and producing the Measures of Effectiveness (MOE) / MOP raw statistics) are accomplished by a different set of personnel with unique capabilities. These tasks will be accomplished by a SAT Support WG and will be overseen by the system SAT Core WG.

Support working groups create data under the oversight of the SAT Core WG, but they do not finalize the analysis or develop the interpreted report. (E.g., an Agency such as Naval Surface Warfare Center (NSWC), Corona Division may execute the programming for metric computations, but the joint group comes together to support them.) SAT Support WGs provide indispensable service, but they do not have the responsibility to make the final technical decision.

3.1.2 General SAT Guidelines

The SAT must lead a challenging mixture of tasking. The primary task of the SAT is to perform collaborative SIAP related analysis through M&S and open-air exercises and events to support recommendations for improvements to IADS warfighting shortfalls. A secondary but mutually supportive task is to coordinate and budget for those same joint and Service-specific evaluations such that results from one venue and related tool can be used to support results from another. This primary task may only be achieved through an apolitical agenda-free environment. The secondary task is froth with organizationally partisan issues. Coordination of these issues creates a potentially confrontational environment that could run counter to collaborative engineering.

While the two tasks must be mutually supportive, vetting the political agendas must occur outside the task of performing joint analysis. Therefore, the programmatic issues must be coordinated at a senior level without squashing the free exchanges between the system SMEs at the Core WG level. High level of corporate trust is essential to accomplish the collaborative analysis tasking. This analysis work cannot be influenced by the program management level interaction, discussion of resources (or lack of resources), academic musings on the "big picture," unique agendas, etc. These programmatic interactions shall occur at the SG level only. As is the case in the JIADS IWG data analyses, the SAT must focus on the data at hand and the way systems currently work and without too much distraction on the future architectural concepts. Therefore, the SAT SG shall be established to control the overall process and provide the required buffer between real work and politics.

SAT Core WG members shall accomplish the analysis and write the report to describe what happened. Socialization and vetting of political issues will occur at the SAT SG level AFTER the results are developed. All stakeholders must jointly develop SAT results with open and robust participation. Interim findings are not elevated to outside agencies or high-level management until there is a technical consensus among the Core WG SMEs. The Core WG is the real-world filter for all reduced data.

SAT Core WG SMEs may be contractors or government personnel. SMEs may work directly for program offices or for Service labs. All personnel must be freely empowered to work across agencies on a technical level.

IADS SMEs have developed their credentials (and maintain them) by performing full-time jobs for their C/S/A sponsors. The SIAP SE TF cannot build new SMEs at this level in anything less than years (and even then, by the nature of the beast, new SMEs would evolve out of the systems rather than joint Agencies). The SAT must be sensitive to the potential of alienating SMEs' sponsors who may ultimately control priorities for their time. The SAT SG must create an environment that the SMEs individually desire to participate in and must minimize time and travel demands to avoid conflicts.

Good infrastructure is important to maintaining the appropriate professional environment and is a serious job for the SAT SG. A smoothly running, well laid out "Fishbowl" with plenty of electrical power, good lighting, security support, etc. makes a tremendous difference, especially when the joint "team" is working nearly around the clock during on-site mission support. This will win hearts and minds of the SME's and provide excellent press for the inevitable crowd of VIPs. It will be the responsibility of the SAT SG to provide resources to support the professional infrastructure required to perform the SAT functions.

3.2 Block Working Integrated Product Team (WIPT)

The Block WIPT is comprised of the Block Manager, SIAP SE engineers and Service SMEs who will be charged with developing the block system engineering recommendations. They will apply an established IEEE STD 1220-1998 disciplined system engineering process (requirements analysis, functional analysis, synthesis of alternatives, system analysis, and cost benefit analysis) to determine the most beneficial way to provide improvements in warfighting capabilities.

The Block WIPT will be a formal body of long term, designated joint personnel and SMEs from each major affected system. The Block WIPT may rely on other Service/Agency SMEs as required in addition to support from the SAT working groups. The Block Manager leads the team and SIAP SE TF provides infrastructure support.

Block WIPT responsibilities that ensure a disciplined approach is taken include:

- Develop the problem statements and tasks for the block issues
- Develop the Statement Of Work (SOW) for the block support tasks
- Develop the block Plan Of Actions and Milestones (POA&M)
- Oversee the block system engineering effort conducted in accordance with the SOW
- Manage the block master schedule and ensure integration of all detailed schedules for the block effort
- Publish and maintain the block status brief to be briefed to the SIAP Integrating Integrated Product Team (IIPT)
- Establish Block Working Groups to engineer/investigate issues
- Work with the SIAP core engineering team and analysis branches to publish the DSB
- Draft the Block Improvement Plan based on the DSB built by the block engineering effort
- Drafting minutes of meetings as well as document follow-up action activities
- Update and maintain block information and data on the SIAP worksite
- Oversee theater level analysis at attribute and MOE level

3.3 Block Working Groups

The SIAP block system engineering approach embraces a number of specific analysis problem areas for each new block of issues. As necessary, working groups will be established when assigned tasks require significant subject matter or tool expertise. Block Working Groups will be composed of SIAP SE TF staff members and SMEs from government and industry that are part of the larger SIAP SE 'virtual' TF. A number of SAT analysis related activities (e.g., creating, executing and reducing simulation runs; data collection and processing at exercises; modifying tools and producing MOE/MOP raw statistics) are the purview of the Block Working Groups.

Overarching responsibilities of Working Group members will include:

- Develop requirements and functional analysis of assigned issue areas
- Work with theater level modelers to develop interface (i.e., 'hooks') to engineering level model inputs
- Develop solution options for performance assessment

4. Standard Tools

The SIAP SE employs multiple test events, evaluation scenarios (Common Reference Scenarios (CRS)), and standard metrics to produce analyses that are comparable, operationally representative, repeatable, and meaningful.

4.1 Venues

Many modeling & simulation, HWIL, and OITL analysis venues exist today. These existing resources are used by the Services and Joint organizations to provide an analytical basis for design, development and evaluation of Theater Air and Missile Defense (TAMD) systems. System specific and joint integrated tools provide a broad range of analysis capabilities at various measurement levels. These separate modeling and simulation tools (i.e. JDN networks tools and IADS modeling tools) currently exist and model different areas of interest for SIAP analysis. No one tool can measure the interoperability of the IADS. Interoperability is reflected in warfighting performance metrics, which provide an indication of how well the Family of Systems (FoS) is supporting the warfighter. By federating several models and analytic constructs to support parametric measurements at the system level (e.g. Air Defense Simulation (ADSIM) with Extended Air Defense Simulation (EADSIM)), variations in system functional performance can be traced to force level capability improvements.

Of the many potential assessment venues available, there has not been an attempt to coordinate or synergize across the multi-Service venues in the past.

The result is that, while many were characterizing SIAP related performance in similar ways, none are common enough to equitably compare results from one venue with another, or to build a consistent cumulative story of the SIAP performance based on their multiple contributions.

To equitably relate results of various venues and related tools with one another, it is necessary to standardize both a set of SIAP metrics and evaluation scenarios to provide as much consistency in the resulting measurements as possible. The SIAP SE took this approach and worked with the appropriate stake holding S/As to develop a standardized set of metrics, which could be used across all of the proposed assessment venues and related tools. In addition, to ensure that assessments (where feasible) are carried out in the same or similar operational contexts, several CRS are proposed and are being jointly developed by the S/As under SIAP SE coordination.

The level of standardization introduced across the many potential assessment venues facilitates utilization of all available data collected by many different DoD activities, and allows the SIAP SE to leverage the considerable efforts of many joint DoD activities for minimal extra effort and expense.

The following paragraphs briefly describe some of the primary venues, which will be utilized for SIAP analysis, citing some of the major strengths and weaknesses of each.

4.1.1 Live Exercises

Live exercises such as JCIET and Roving Sands employ the use of actual system hardware and software and thus provide the best representations of legacy system functionality. We would also expect that live exercises provide the best characterization of warfighting performance of the FoS. However, limited availability of assets may preclude supporting an exercise with the exact platform configurations desired. Conduct of before/after comparative analysis requires having systems that can operate in either legacy or upgrade mode, or the availability of separate systems, some of which are upgraded and some of which are not, in order to compare their performance with each other. Many platforms have multiple baselines, and may be in various stages of upgrade, so that the configurations available may not be entirely representative of the group as a whole.

In addition, live exercises generally are inherently expensive, require long lead times to set up, are subject to many uncontrolled variables, and are not amenable to multiple repetitions of a particular test to assess the effects of a particular change. Additional limitations of live exercises include networking restrictions on Link 16 operation, unrealistic network threat loading, and often restricted airspaces that can impact the participation of friendly and hostile forces when compared to actual wartime employment. Finally the warfighting realism of live exercises is affected by public safety and environment restrictions on live operations.

Live exercises can be extremely useful to baseline real system performance and to provide real-world data in order to validate results from other venues, especially M&S results. Future events support analysis of system performance after changes to the systems are implemented. Each participating system can record data for post-event root cause analysis. The amount and type of data can vary from system to system as well as event to event.

While many factors influence the amount and quality of the data available (e.g. equipment failures, weather, number and type of platforms participating in the events), 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 CNA, e.g., Operational Data Driven for Correlation Algorithm Performance Evaluation (ODDSCAPE) and Naval Surface Warfare Center, Corona Division's Performance Evaluation Tool (PET), support the evaluation of live exercises.

4.1.2 Hardware-in-the-Loop

Tools in the HWIL venue, such as the JDEP, attempt to retain the fidelity of real hardware and software-in-the-loop by linking real or laboratory systems in a controlled environment, typically without radio frequency (RF) transmissions. This permits better control and repetition of experiments, use of specific desired hardware and software configurations, and the ability to do more reliable before/after comparisons. FoS analysis is somewhat limited with most of the tools in this venue due to the limited numbers of platforms participating in an event. In addition, HWIL tools are often extremely limited in their capability to replicate sensor, communications, and environmental issues.

4.1.3 Operator-in-the-Loop

The OITL venue tools, such as the VWC and at the Joint National Integration Command's (JNIC) test facility, are cost-effective ways to evaluate integrated system environments with respect to the man-machine information interface. These tools provide a very important ingredient for FoS evaluation e.g., operator, SIAP related interaction and decision-making effects. This effect is a significant element of evaluating the military utility of information sharing improvements at the system level. JTAMDO has successfully utilized the VWC in assessing warfighting effectiveness given selected SIAP attribute performance levels. JNIC's Wargame 2000 has provided similar results for TAMD missions.

However, OITL tools, like HWIL, generally are limited in their capability to fully replicate family of systems functionality. While HWIL tools permit better control and repetition of experiments, by using specific desired hardware and software configurations, and the ability to do more reliable before/after comparisons, OITL repeatability is somewhat difficult to achieve.

4.1.4 Digital Modeling and Simulation (M&S)

Digital M&S tools serve a wide spectrum of purposes that can range from design to operational effectiveness assessments. Consequently models and simulations exist with differing levels of detail suited to their particular application. Different levels of functional assessments form what may be called a hierarchy of models and simulations as shown below (figure 3).

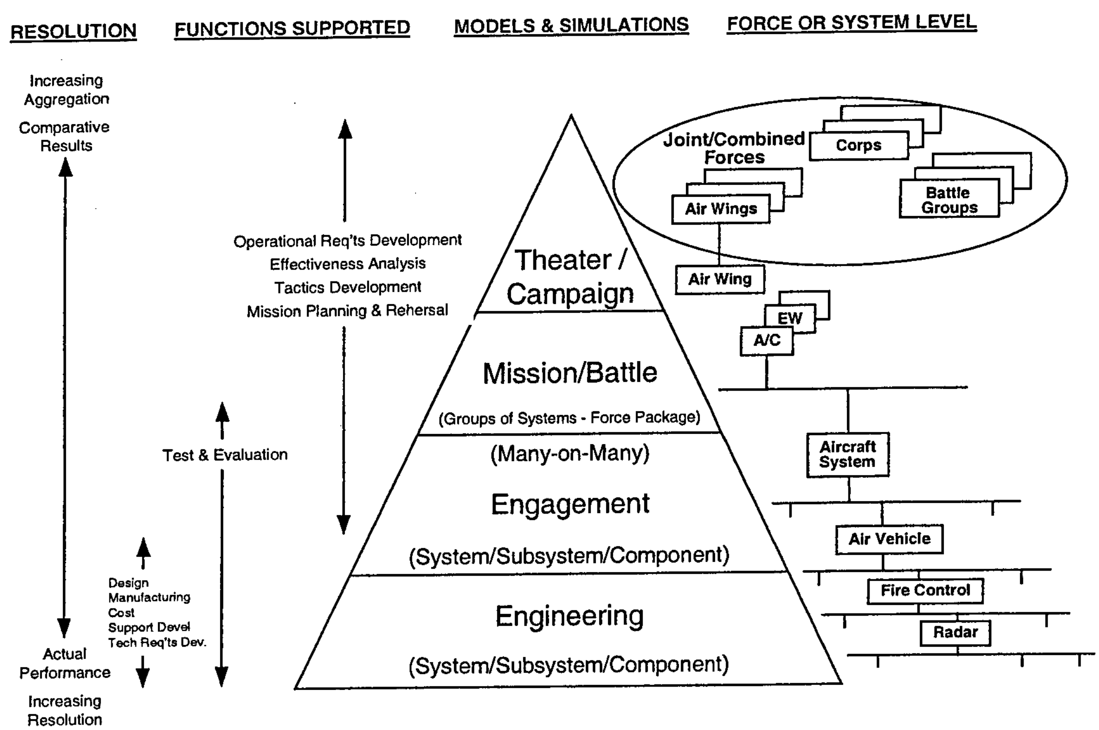

Figure 3. Hierarchy of Models and Simulations

4.1.4.1 Engineering Modeling and Simulation

At the engineering level, models indicate individual system and FoS performance capabilities, or system MOPs and SIAP attributes. For the SIAP SE in Block 0, this meant addressing current system/subsystem performance issues such as formation tracking and identification (ID) taxonomy. For Block 1, this means the reduction of dual tracks, improvement of combat ID, Theater Ballistic Missile Defense (TBMD) performance, and data sharing.

While engineering level modeling may not be required for all analyses (e.g., determining requirements such as force structure assessments/alignments or logistics flows), it is essential for the SIAP SE because it is precisely these engineering level issues that the SIAP SE has been directed to address. Time and time again, it has been shown that engineering level issues issues have impacted the warfighter at the operational level. In addition, since the SIAP SE will conduct modeling at higher levels, it must 1) be able to determine the amount of improvement (MOP) in each block, and 2) be able to aggregate these improvements such that they can be characterized in model runs at the mission/battle and theater/campaign levels.

4.1.4.2 Engagement Modeling and Simulation

At the engagement level, models are used to evaluate system effectiveness against threat systems. Typically expressed as MOEs, the engagement level is generally used in "one versus one" or "few versus few" type of engagements. While this definition works well for a weapon system, the issue is much more obscure when addressing effectiveness within a SIAP context simply because SIAP issues cannot be addressed based upon the effectiveness against the destruction or suppression of a particular threat system, i.e. SIAP is not an element of the kill chain. Rather, it is the enabler for the kill chain sequence. Consequently, while the SIAP attributes and MOEs of block improvements cannot be based intrinsically upon known threat capabilities and raid densities, it's attributes can be measured based upon the block improvements and by corollary, its ability to support tracking and engagement functions where and when required; i.e., clarity, continuity, completeness. The resulting MOE at the engagement level should reflect less fratricide, increased detection ranges, optimized engagement times, and optimized weapons employment opportunities. All of which ultimately allow friendly forces to disrupt enemy decision cycles and preempt hostile action.

4.1.4.3 Mission/Battle Modeling and Simulation

At the mission/battle level, models allow results gained at the engagement level to be aggregated to a force level. This aggregation would encompass a multi platform force package designed to accomplish a specific mission objective such as air superiority, interdiction, or Suppression of Enemy Air Defenses (SEAD). While all levels of modeling are important, it is at this level where the benefits of the block improvements really begin to manifest themselves because the entire objective is to demonstrate warfighter benefit at the force level based upon Cost and Operational Effectivess Analysis (COEA), compatibility, and interoperability.

4.1.4.4 Theater/Campaign Modeling and Simulation

At the theater/campaign level, models represent combined force operations and are used in theater or campaign level conflicts to determine the long term outcome. Theater/campaign level models are also used to determine force structure assessments/alignments or logistics flows. For the SIAP SE, models at this level will be used to determine how the block improvements affect the air picture at the Joint Task Force (JTF) level. Results from engineering level model runs will be aggregated. These aggregate performance parameters will then be characterized in the theater/campaign level model.

The best way to achieve robust parametric evaluations of system of system performance with the potential to dynamically evaluate force on force engagement effects is through digital M&S. The primary strength of available digital simulations is the capability to permit expansion limited engagement vignettes to force-on-force and theater level analysis. This scale up can be done in a controlled, repeatable environment, with the ability to execute multiple runs with many individual parameter variations representing many different potential systems engineering fixes or improvements. However, while digital M&S provides the capability to represent large numbers of systems in repeatable scripted runs, it is limited in the precision with which individual system performance can be replicated. The greatest loss in moving from real hardware and software components in HWIL, OITL, and Live venues, is in the realistic representation of system functionality.

Digital simulations can be used at different analysis levels to characterize and emulate system and subsystem performance in terms of MOPs, to evaluate the effect those changes in system MOPs have on higher level SIAP attributes, and to evaluate the effect that the changes of SIAP attributes have on warfighting MOEs. A combination of specific system functional analysis and parametric analysis must be done. For example, theater level parametric assessments can be made with theater level modeling tools to evaluate the effects of different levels of system performance on SIAP attributes (e.g., assume different levels of navigation accuracy for each participating unit and assess the resulting SIAP). This type of tool is useful in defining ranges of acceptable subsystem performance that needs to be obtained to achieve a certain level of SIAP. Other more detailed M&S might then use high fidelity system functional representations (both legacy and proposed upgrades) to determine the actual values at which the system or subsystem is, or might be, capable of operating. Insertion of actual predicted performance values into higher-level models then allows investigation of the behavior of the SIAP with specific sets of potential change options implemented.

4.1.4.5 Primary/Secondary SIAP Functions

In any modeling environment, the required fidelity of a model's specific system representations depends on the specific purpose of the analysis. For SIAP analysis purposes, system functions fall into two broad categories.

- Primary system functions are those that need to be modeled at relatively high fidelity because they are to be varied in the course of the analysis to show the effects of different implementations. For example, conducting a before/after assessment of different implementations; e.g., modeling of current legacy sensor alignment process or its result when a new sensor alignment process is to be evaluated and compared with the current function. Primary functions need to be represented at a sufficient level of fidelity that changes to those functions reliably represent changed behavior of the system so that credible recommendations for system changes can be made.

- Secondary functions are those whose inputs are required for conduct of a particular analysis, but which need not be varied, so that only a constant representative implementation is needed (e.g., a generic tracker to generate representative inputs to a track file, when a new correlation algorithm is being evaluated, provided the generic tracker generates all data required by the candidate correlation algorithm(s)). The fidelity of secondary system representations will not be considered sufficient to draw conclusions with respect to actual system performance, nor to make engineering change recommendations to those systems or system functions.

When non-network issues are being investigated (e.g., sensor alignment, geodetic registration, system correlation), high network fidelity is not required. In such a case, the network is a secondary function and a model with a generic low or medium fidelity data link representation may be adequate. However, when investigating particular SIAP degrading effects associated with network overload, for example, the network and the data link equipment that create the network are primary systems, and high network fidelity is required to provide an accurate representation of the network effects on SIAP.

The ultimate goal of the SIAP SE digital M&S development is to create a modeling environment in which specific engineering changes can be inserted into specific platform representations, in a theater level operational environment, and to characterize the changes in SIAP and IADS performance that result.

4.2 Common Reference Scenarios (CRS)

Perhaps the most important task in establishing a disciplined analytical process and evaluating IADS performance is the development of scenarios for that analysis. To level the playing field among different analysis venues, a common operational laydown, or frame of reference, must be used as an input. This baseline frame of reference would minimize the number of variables among the venues by ensuring the IADS is measured within the same environment (e.g., same radar angles to threat, communications geometry, force-flows, etc). If necessary, minor excursions can be made upon this baseline in order to examine friendly and threat interactions specific to a block issue area.

Scenario-based design analysis 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[1]]. The SIAP SE is extending the concept of scenario-based design by supporting 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.

The SIAP SE disciplined process is based on standardization of key simulation tools and scenarios, providing common reference frames for "apples-to-apples" comparisons. In addition common reference frames support joint evaluation of the IADS in both the simulated and live environments. The baseline frame of reference must bear some resemblance to the possible IADS operational environments. One of these standardized tools is the establishment of a set of CRS to encompass a broad spectrum of operational environments.

Three CRS representing potential regional conflicts have been defined based on the DoD Defense Planning Guidance process. The first CRS was created for the 2003-05 timeframe and jointly endorsed through the JTAMD process. The CRS is composed of digitally scripted hostile and friendly force dynamic interactions in operationally significant time-phased campaigns. Engineering vignettes, extracted from the CRS, provide particular platform engagements of interest, which can be applied to the M&S, HWIL, OITL, and live exercises to support repeatable engineering level FoS assessments. Within this framework, evaluations of SIAP system enhancements and the resulting impact on warfighter capabilities from the system/unit through the force-on-force level may be quantified. (See SIAP Technical Report 2002- Common Reference Scenarios (CRS) and related appendices for more information.)

4.3 Networks

The SIAP SE has coordinated with the Service Network Design Facilities (NDFs) to provide up to eight Link 16 network designs for SIAP related analyses. The network designs are required to define the technical network interface requirements of the supporting JDN systems. Initially the network designs will be Link 16 (and Link 11 where essential) only, not the whole theater multi-Tactical Digital Information Link (TADIL) networks. They will be used primarily to support the high fidelity Link 16/11 modeling performed by such models as the ADSIM. However, they will be available to all modeling points of contacts (POCs), who can extract the information necessary for their model. If SIAP analysis of a specific block issue requires modifications to a network design, the assigned

[1] John M. Carroll is Virginia Tech Professor and Director of its Center for Human-Computer Interaction. He is a leading expert on scenario-based design, has spoken at various related seminars and written books on the subject.

modeling center may first coordinate with the SIAP SE to create variants, and then submit these derivative network designs to the Service NDFs for review and approval. The Service NDFs will then review for correctness and validate the modeling center developed network design.

4.4 Metrics

A critical part of system engineering the SIAP is identifying a standardized quantification of performance. Metrics are used to objectively evaluate the ability of candidate approaches to meet JROC-validated Capstone requirements. Additionally, they allow us to understand how we are progressing toward the objective end-state.

The concept of a SIAP lends itself to quantifiable warfighting MOEs, mission level attributes, and system level MOPs. Some of these values have been defined, so realistic assessment strategies to evaluate compliance can be developed. SIAP Key Performance Parameters (KPPs) have been defined in the TAMD and Combat Identification (CID) Capstone Requirements Documents (CRDs). These operational requirements must be translated in a traceable way into lower-level technical requirements that can be used by the disciplined system engineering process, and to objectively assess progress in achieving the required SIAP capability. However, as indicated in the SIAP SE TF Charter, one of the SIAP SE's jobs is to help evolve the definition of SIAP.

Quantifiable and testable MOEs, attributes, and MOPs, are the linchpin to the SIAP system engineering efforts. MOEs and MOPs must support various analysis methods including sensitivity analyses to support technical trade-offs, modeling and simulation, experimentation, land-based test and evaluation (such as JDEP), interoperability certification (such as that provided by JITC), and evaluation in an operational context (such as JCIET) of SIAP related changes and other warfighting capability improvements. Several efforts have been undertaken 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)

Quantifying answers to these questions provides an analysis roadmap for system improvement. Ultimately these types of measurements must be evaluated at various levels of aggregation i.e., MOPs at the system/platform level, attributes at mission/effectiveness, theater, and force level and MOEs at the force-on-force/Campaign level. These levels determine a hierarchy of quantifiable characteristics as shown in Figure 4. The flow-down of quantifiable measures from MOEs at the force level to system level MOPs provide 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 used across Services and joint organizations. These attributes provide a common reference to measure a SIAP. In addition, the appropriate MOEs and MOPs must be identified and used by testers, analyzers and evaluators such that common criteria may be used to evaluate, predict, and prescribe performance.

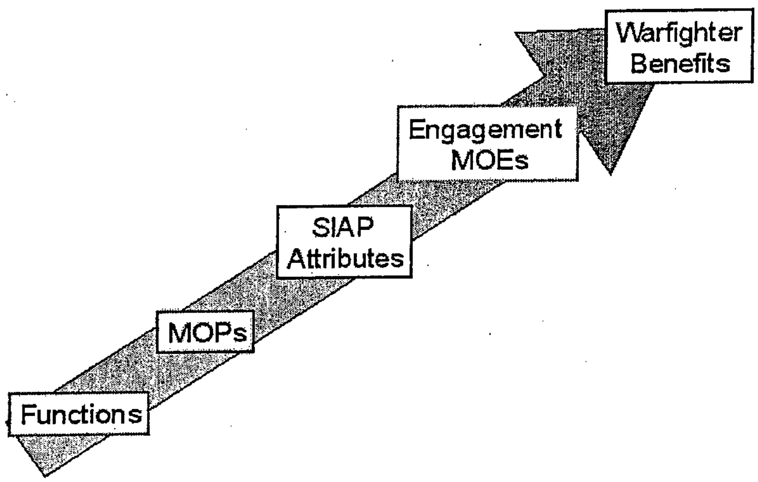

Figure 4. MOP/MOE Mapping

4.4.1 Engineering Level Metrics: Measures Of Performance (MOPs)

At the engineering level, each potential change will have a number of specific engineering level MOPs that can be defined to characterize the relative performance of a specific improvement. Consequently, no attempt has been made to develop a master list of MOPs across all SIAP assessment venues. Working groups are responsible for developing proposed system upgrades associated with their particular block issues. In conjunction with their proposed upgrades, they will need to define the measures by which the anticipated improved performance will be judged at the engineering level. These working groups will also have to help define the relationships between their proposed engineering MOPs and various SIAP attributes so the effects of the engineering level changes can be understood in terms of SIAP impact at the attribute level. Table 1 lists representative MOPs. (See SIAP Technical Report 2001-002 Measures of Effectiveness (MOEs) and Measures of Performance (MOPs) for more information.)

Table 1. Representative IADS 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 in conformance with MIL-STD-6016

4.4.2 SIAP Attributes

Under the leadership of the SIAP SE, Service/Agency SMEs have developed a rigorously defined set of SIAP performance attributes. The effort included specific procedures for implementing and using the attributes. SIAP attributes define and characterize IADS performance in terms that are directly related to the TAMD and CID CRD KPPs. While the CRD KPPs are oriented toward theater-wide performance values, the SIAP attributes also include methods for characterizing IADS performance at the individual unit level. Table 2 lists the defined set of SIAP attributes for air breather aerospace objects. The SIAP SE is currently working to definite SIAP attributes for ballistic missile aerospace objects as part of the Block 1 effort. (See SIAP Technical Report 2001-001 Attributes and SIAP Technical Report 2002-xxx Ballistic Missile Single Integrated Air Picture (SIAP) Metrics for more information.)

Table 2. SIAP Attributes

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 track number assigned to an object does not change.
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 tracks are labeled correctly.
ID Clarity: The ID is ambiguous when a tracked object 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.

4.4.3 Military Utility Metrics: Measures of Effectiveness (MOEs)

The SIAP SE TF is, by design and charter, an engineering organization, but it is also chartered with making recommendations to the JROC with respect to what engineering changes should be implemented across a broad range of Service platforms. Since such recommendations should not be made based on SIAP performance improvement alone, there is a need for the SIAP SE to gain some insight into more operationally oriented MOEs as well. Example MOEs are depicted in Table 3.

Table 3. Representative IADS MOEs

Battlespace: Location/Time of intercept (engagement)
Leakers: Total number of Hostile weapon systems that reached their ordnance release points: by type
Fratricide: Total Number of Friendly targets killed by Friendly forces: by asset type and shooter type
Friendly Attrition: Total number of Friendly targets killed: by asset type

However, 'final' MOE/military utility analysis is the purview of other operationally oriented organizations. Therefore, the SIAP SE TF must coordinate its analysis and recommendations with the appropriate warfighting benefits assessment organizations within the DoD. The primary interfaces for this coordination are JTAMDO and JFCOM. (See SIAP Technical Report 2001-002 Measures of Effectiveness (MOEs) and Measures of Performance (MOPs) for more information.)

The SIAP SE is working closely with the Director of JTAMDO in defining an IADS integrated assessment framework for evaluating the impact on military utility of system level improvement recommendations. Figure 5 depicts the notional roles and responsibilities of the two organizations. Fundamentally, the SIAP SE is chartered with the responsibility of evaluating IADS functional performance and associated system improvements to meet SIAP attribute metrics requirements. JTAMDO is responsible for evaluating the warfighting benefit of that attribute level of performance.

While tools from the OITL venue such as VWC and Wargame 2000 fall under the leadership purview of JTAMDO, other tools span the gamut of IADS analysis. To support the federation of tools required to link system improvements to warfighting benefit, it is clear that the SIAP SE must work closely with JTAMDO to define the appropriate linkages between pure warfighting assessment venues and related tools and other venues/tools. This relationship requires careful coordination.

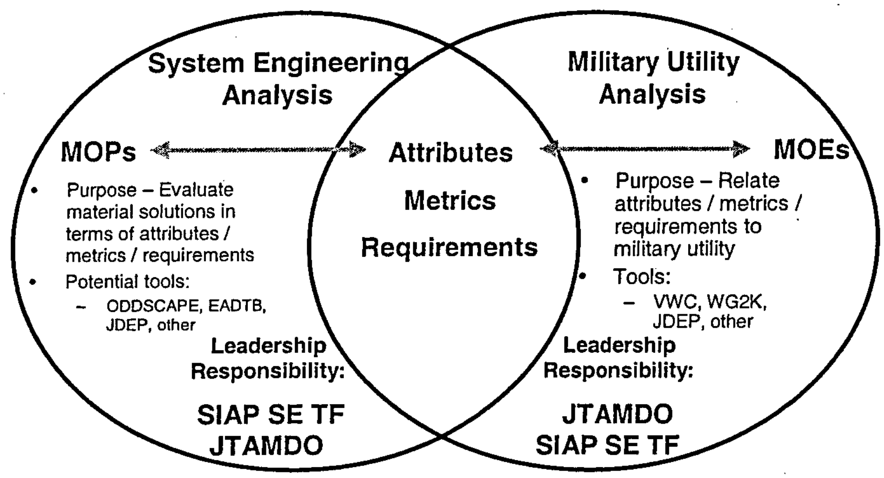

Figure 5. JTAMDO-SIAP Relationships

4.5 Lessons Learned Knowledge Base (LLKB)

Current CINC guidance and memorandum express the need to develop a capability to "track data link implementation and certification across all members of the TAMD FoS." Since there is no current SIAP focused lessons learned repository, there is no efficient way to track and manage MIL STD 6016A compliance. This results in the same SIAP related deficiencies being repeated year after year at various live exercises. A SIAP LLKB could solve these issues by tracking military standard compliance and track data link certification across the entire SIAP FoS architecture, and providing focus for SIAP efforts to evaluate and improve warfighter capability.

The purpose of building a LLKB is to centralize the collection of documented assessments from observed materiel deficiencies. By pooling this information the Services can address the impact, frequency of occurrence, and other trend data to help focus the SIAP SE analysis objectives. The LLKB will enhance warfighter capability evaluation by supporting root cause analysis of events of interest gathered from selected exercises, HWIL, and OITL events of interest. Additionally, the SIAP LLKB will leverage knowledge from previous activities such as: JCIET and the Joint IADS Working Group (JIADS IWG); other tests, exercises and real-world operations; the Joint Composite Tracking Network (JCTN) study and related studies; Joint and individual Service sensor netting studies and analyses; and other sources of lessons learned. The information stored in the knowledge base will provide a basis or point of departure for future analyses and a source for the SIAP Capabilities and Limitations Document.

The LLKB will provide the SIAP SE a categorized listing of TADIL concerns and deficiencies. The SIAP LLKB will be used to support the development of issues to be addressed by the block process.

5. Standard Processes

5.1 Block Assessment Methodology

In general, the following analysis methodologies apply to each Block 0 through n item.

5.1.1 Use All Available Data

One of the hallmarks of the SIAP SE approach is leveraging past and ongoing activities in which SIAP performance assessments may be conducted for minimal add-on cost. One way of ensuring that ongoing activities are able to incorporated into the SIAP SE's overall analysis plan is for the SIAP SE to provide assistance in improving existing data collection effort and verify that sufficient data is captured to calculate the standard SIAP attributes.

Additionally, by documenting data from events as they occur within the LLKB, the SIAP SE provides the option for future SIAP assessments to conduct a "re-analysis" of event data. This analysis might provide insight into a different sector of IADS performance, and is can only be possible by a rigorous documentation of assumptions and limitations of specific event data.

Another valuable source of data that can be leveraged is past studies. Over the last few years, there have been many assessments of SIAP-like metrics in many different venues and related tools. While these did not have the benefit of calculation of the standard metrics (which did not exist at the time), many calculated similar metrics, which can reasonably be expected to show the same trends as new data using the standard calculations. In this way, past, present, and future analyses can all contribute to a growing body of knowledge which, if consistent, can increase the confidence in trends shown, and, if not consistent, help uncover shortcomings in various study and analysis techniques which may need improvement.

5.1.2 Establish a Standardized Performance Baseline

At the highest level, the SIAP performance baseline used to determine when the SIAP is 'good enough' will be determined by joint warfighting requirements as evaluated by JTAMDO. By adding the recommended engineering changes of each SIAP block improvement initiative to the previous block changes, a cumulative record of progress can be mapped out, with the changes shown over the previous block performance. An increasing absolute value of the metrics then culminates in a set of values for the last block upgrades that meet all of the operational requirements.

To establish the value of a particular proposed engineering level change, or block of changes, on the SIAP, assessment tools reveal the current level of SIAP performance. As an improvement(s) is introduced changes in the particular measured parameter(s) or metric(s) are measured. With sufficient control over the experimental variables, the change in performance of the introduced engineering improvement(s) can be determined. This type of comparative analysis is essential to the SIAP analysis.

Quantified Performance Matrices (QPMs) will be used to track changes in metric values as block improvements are made to the baseline systems. Tables 4-7 provide samples of QPMs to be filled out as block analysis is conducted. The first three tables (4, 5, and 6) include placeholders for attribute and MOE values relative to each CRS used for block analysis.

Additionally, the SIAP SE plans to document the functional capability of different systems (as part of a functional decomposition) in a functional performance matrix similar to Table 7.

Table 4. QPM: Air Breather Track Attributes

AIR BREATHER TRACK (J3.2) ATTRIBUTES				
CRS:	NEA III 2003	AGCS 2010	RT-2	NEA III 2010
COMPLETENESS				
CLARITY				
Ambiguous Tracks				
Spurious Tracks				
CONTINUITY				
Characteristic Track Lifetime				
Longest Track Segment				
KINEMATIC ACCURACY				
Position				
Velocity				
ID COMPLETENESS				
ID ACCURACY				
ID CLARITY				
COMMONALITY				

Table 5. QPM: Space Track Attributes

SPACE TRACK (J3.6) ATTRIBUTES				
CRS:	NEA III 2003	AGCS 2010	RT-2	NEA III 2010
COMPLETENESS				
Track Completeness				
LPE Completeness				
IPP Completeness				
CLARITY				
Ambiguous Tracks				
Spurious Tracks				
Ambiguous LPEs				
Ambiguous IPPs				
CONTINUITY				
Characteristic Track Lifetime				
Longest Track Segment				
KINEMATIC ACCURACY				
Track Position				
Track Velocity				
LPE Position				
LPE Time				
IPP Position				
IPP Time				
CORRECTNESS				
Booster Typing				
Post-Boost Classification				
TIMELINESS				
Track Initiation				
LPE Delay				
Booster Burnout Estimate Delay				
IPP Time				
COMMONALITY				
Position/Time/Track Number				
LPE				
IPP/Track Number				

Table 6. QPM: MOEs

MEASURES OF EFFECTIVENESS				
CRS:	NEA III 2003	AGCS 2010	RT-2	NEA III 2010
LEAKERS				
Total # of hostile weapon systems that reach ordnance release point, by type				
HOSTILE ATTRITION				
Total # of hostile targets killed, by target type				
FRIENDLY ATTRITION				
Total # of friendly targets killed, by asset type				
FRATRICIDE				
Total # of friendly targets killed by friendly forces, by asset type & shooter type				
WEAPON EXPENDITURES				
Total # of weapons expended, by type				
C2				
Total # of engagements ordered, by type & target				
Blue sortie rates ordered, by mission, force, and function				
BATTLESPACE				
Location/time of weapon commit				
Time/distance from initial detection to commit				
Location/time of intercept (engagement)				

Table 7. Functional Performance Matrix

QUANTIFIED PERFORMANCE MATRIX			
BLOCK N SYSTEMS:	SYSTEM 1	SYSTEM 2	SYSTEM 3
TIME			
Time Synchronization			
- Difference between own unit's clock time & UTC/USNO			
Element data exchange latency (definition TBD)			
Time to get track report on the air			
- Time a part. obj. meeting reporting crit. has a valid decl. track (track init. time)			
- Reporting responsibility declaration for each track at each evaluation time			
Lost track persistence			
- Total number of drop track messages.			
SENSORS/TRACKERS			
Sensor detection range			
Sensor error			
Residual Biases			
- Sensor aperture range measurement offset bias			
- Sensor aperture range measurement scale factor bias			
- Sensor aperture range-rate measurement offset bias			
- Sensor aperture bearing angle measurement offset bias			
- Sensor aperture bearing angle measurement offset bias			
- Sensor aperture bearing angle measurement scale factor bias			
- Sensor aperture elevation angle measurement offset bias			
- Sensor aperture elevation angle measurement scale factor bias			
- Sensor aperture roll attitude/aperture alignment bias			
- Sensor aperture pitch attitude/aperture alignment offset bias			
- Sensor aperture yaw attitude/aperture alignment offset bias			
TQ correctness			
- TQ as a function of time for each track			
TQ consistency			
DATA CONNECTIVITY			
Time distribution of connectivity failures (radio-to-radio)			
Time distribution of duration of connectivity failures (radio-to-radio)			
Time distribution of connectivity failures (track store-to- track store)			
Time distribution of duration of connectivity failures (track store-to-track store)			
TADIL update rates			
DATA REGISTRATION			
Geodetic Registration			
Navigation error(s)			
- Difference between own unit's navigation measure and WGS-84			
- Difference between inertial navigation measure and WGS-84			
Navigation Qpg correctness			
- Qpg as a function of time for each unit reporting Qpg			
Navigation Qpg consistency			
- Qpg as a function of time for each unit reporting Qpg			
IU Registration			
IU registration error			
IU registration error covariance consistency			
Sensor Registration			
Sensor registration error			
Sensor registration error covariance consistency			
Sensor Gridlock			
Network-wide absolute sensor gridlock error			
Network-wide absolute sensor gridlock error covariance consistency			
Data Processing			
Computational errors			
CORRELATION/DECORRELATION			
Correct correlation rate			
- Number of correct correlations			
Correct non-correlation rate			
- Number of correct non-correlations			
Incorrect non-correlation rate			
- Number of incorrect (false) correlations			
False correlation rate			
- Number of incorrect non-correlations			
REPORTING RESPONSIBILITY			
R2 correctness			
- Reporting responsibility declaration for each track at each evaluation time			
COMBAT ID			
ID program performance			
- System/ID decl. (friend, hostile, unk., etc) on each track at each eval. time			
ID assessment			
Category program performance			
Category assessment			

5.1.3 Employ Verification, Validation, and Accreditation (VV&A) Techniques

Two important questions that must be answered by the SIAP SE are:

1. How much fidelity is required to assess improvements to the SIAP?
2. How much confidence does the SIAP SE have in assessment results?

Before products are officially endorsed, the SIAP SE, the SIAP analysis Accreditation Authority, ensures that M&S analysis has gone through the appropriate level of VV&A. The SIAP SE will follow DoD 5000 guidance for VV&A efforts of all SIAP related assessments.

The purpose of VV&A is to assure development of correct and valid evaluations from M&S analysis efforts. VV&A processes are performed to establish the credibility of the models and simulations used in analysis applications. Credibility depends on model simulation approximations - not in an absolute sense, but relative to the model approximations needed for the specific application. Hence, SIAP needs correct network approximations in network simulation to determine how a particular JDN fix will affect the SIAP, and a good approximation in system effectiveness simulations to determine how a particular improvement in the SIAP will impact a system's performance. The decision on whether or not a simulation provides the necessary degree of accuracy depends not only upon the inherent characteristics of the simulation, but also upon how the simulation will be used, and upon the significance of any decisions that may be reached on the basis of the simulation's outputs.

Technical or resource limitations may place limitations on VV&A activity, requiring related processes to be tailored in a way that is less than ideal from a formal VV&A perspective. The Accreditation Authority, in this case the SIAP SE, must take any such limitations into account when reaching a conclusion for the approval or disapproval of the use of a simulation analysis.

The specifics of VV&A for each of the models and simulations, and V&V methodologies used in each block will be addressed in the associated block appendix.

5.1.4 Standardized Data Management and Analysis Plan (DMAP)

The purpose of the standardized DMAP is to provide a single source for supporting SIAP analysis with regard to live exercises or events. The standardized DMAP conveys the following:

1. Provide a description of the critical experiments to be conducted to evaluate SIAP systems
2. Explain how the SAT will use the data collected at events to assess Joint IADS performance

3. Provide guidelines on what data needs to be collected to support the analysis efforts.
4. Describe how the SAT will evaluate progress in the ability to build and maintain a SIAP.
5. Lay down a schedule that outlines roles and responsibilities of participants (SAT, Services, test staff, etc) before, during, and after the event
6. Explain the importance and utility of a lessons learned knowledge base
7. Provide a streamlined method for event directors and planners to provide event details

The guidelines in the standardized DMAP will evolve as events are conducted and analysis of IADS performance evaluated.

The standardized DMAP also documents critical experiments that the SAT will focus on. In general, a critical experiment is designed to address a specific SIAP issue or concern. Each experiment has associated measurements and a specified analysis method. Ideally, all of these experiments would be carried out in each event, but there may be venue-specific, tool-specific, or event-driven limitations which may require restriction to some subset of the critical experiments provided, or slight modifications of specific experiments. Any such limitations will be specified in the DMAP (if anticipated), or in the data analysis reports (if not), for the particular venue, tool, or event in question.

Critical Experiments:

1. Time Synchronization
2. Sensor Tracking/Reporting Accuracy
3. Data Registration
4. Automatic Local-to-Remote Track Correlation/Decorrelation
5. Identification Processing
6. Formation Tracking and Assessment
7. Model and Simulation/Stimulation Fidelity
8. Commonality
9. Precise Participant Location and Identification (PPLI) Accuracy
10. Multi-Link Translation/Forwarding
11. TBMD Performance
12. Early Warning (EW) Performance

Figure 6 below displays how DMAPs are integrated into the SIAP SE's M&S process.

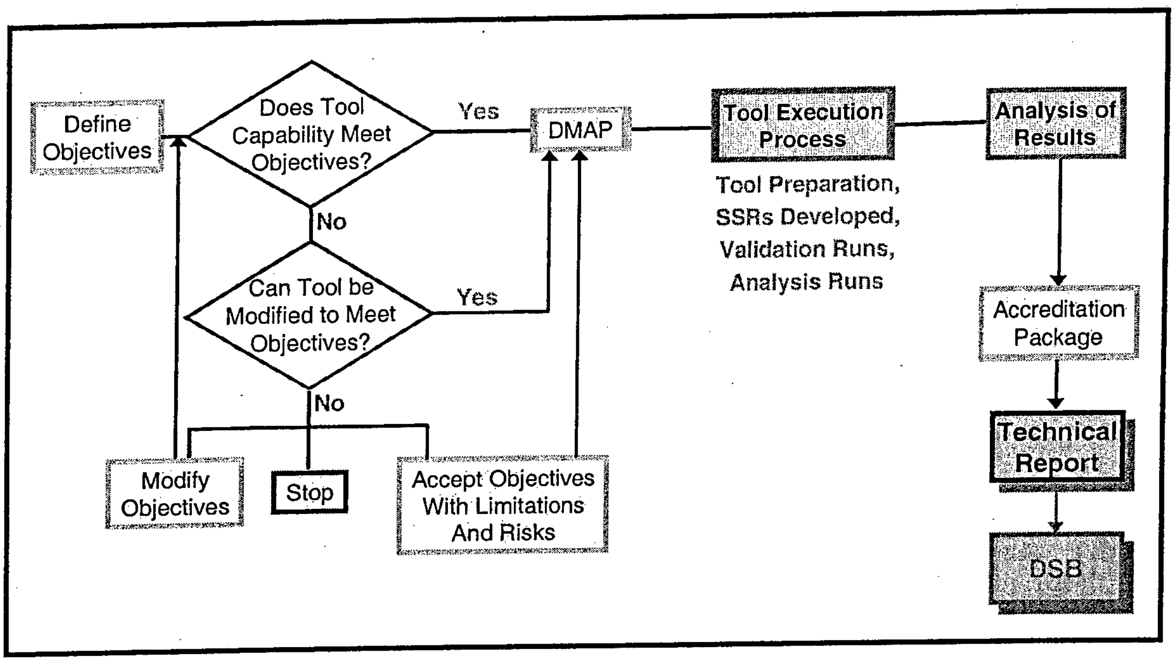

Figure 6. SIAP SE M&S Process

5.1.5 Documentation of Findings: Technical Reports

The SIAP SE will document, in the form of technical reports, all of its analysis results as well as major decisions made in the course of analysis (definitions, goals, assessment guidelines, etc.). Some areas may require several reports, or a report that is frequently updated.

To ensure full Service participation and joint consensus, all SIAP SE technical reports are subjected to an intensive Service/Agency review and editing process prior to final approval and publication. This process must include at least the following stages of input and revision.

- First, the appropriate SIAP working group meets to address the major issues and to note the views and concerns of all members.
- Then a draft document is drawn up within the working group and circulated (usually electronically) among the membership for discussion and revision. The document is revised until consensus is attained within the working group.
- Following (or simultaneous with) this stage of revision, the draft report is reviewed by the SIAP SE TF command chain for consistency with the SE's objectives concerning the problem area under study, possibly resulting in further revision.
- Next, the revised draft is released to a much larger body of POCs in various offices throughout DoD, including OSD, the S/A designated representatives of each Service and joint Agencies, including, but not limited to, those represented on the working group. An attempt is made

to reach every DoD contact with a reasonable claim to having both an interest in the analysis and expertise in the subject area.

- All feedback from these POCs is seriously considered, incorporated to the maximum extent possible, and replied to when not incorporated. The draft is not finalized until consensus is attained at least among the Service and designated Agency representatives.
- The Service/Agency resolved and finalized draft is then sent through the SIAP SE TF command review chain again for a final check, and submitted to the SIAP SE for executive approval.
- Upon SIAP SE approval, the technical report is serialized and, classification permitting, distributed.

It should be noted that the process just described gives the Services and the Agencies represented on the working group two opportunities for input and revision – once during the working group review, and again at the stage of more formal Service/Agency approval prior to submission to the SIAP SE.

To date, the SIAP SE has released five approved technical reports, but several others are in progress as complete drafts in various stages of the review process.

5.2 Integration of Multiple Venues

As stated previously no one analysis venue can completely evaluate end-to-end system to military utility performance. Each potential assessment venue has its own strengths and weaknesses. Therefore, the IAP lays out a strategy that seeks to use the strengths of each venue to compensate for the weaknesses of others. The result of this strategy should be a set of SIAP assessment results, which is better than the individual sum of the parts.

Table 8 below reviews the high-level strengths and weaknesses of each assessment venue available to the SIAP SE. Figure 7 shows how the assessment effort will try to leverage the strengths of each venue to overcome weaknesses in others, and to provide the most robust combination achievable with the tools available for each assessment effort.

5.2.1 Synergy

Table 8 illustrates some of the key features represented to some level of fidelity in the integrated assessment effort, and example assessment tools capable of providing them. In the table, the relative fidelity of the representations or features shown in the left-hand column is subjectively ranked with respect to the various assessment venues shown across the top of the matrix. The ranking scale is 1-4, with 4 being best.

Table 8. Venue Ranking

	Venue			
	Hardware in the loop/ Operator in the loop: (JDEP,VWC,Wargame 2000...)	Live (Data Perturbation Models): (ODDSCAPE...)	Digital Sims: Network Performance (ADSIM...)	Digital Sims: Engineering Change Performance (EADTB...)
Warfighter Benefits	4	3	2	4
# of Participants	1	1	4	4
Event Cost	3	1	4	3
Tool Cost	3	4	3	2
Excursions	1	2	4	4
Control of Variables	3	1	4	4
Network/Link	2	1	4	2
Terminal	3	3	3	3
Host Processing	4	4	2	3
Sensor	4	4	2	3
Human Behavior	4	3	2	2

The ratings against the features in Table 8 show that most of the important assessment characteristics desired are covered quite well in one venue or another. Therefore, if reasonable linkages can be created such that data produced in a venue that is strong in certain characteristics can be used to compensate for weaknesses in other venues, then it is possible to create a more effective combination of capabilities than any one venue by itself. This will create a path from technical MOPs, to SIAP attributes, and on to warfighting MOEs. The number of features requiring theater level analysis also indicates the necessity for tools capable of SIAP performance assessment at that level.

The initial thrust of the SIAP SE's efforts, as directed by the JROC, is towards improving the JDN, with initial emphasis on Link 16. This direction dictates a need for high fidelity data link and network models, and high fidelity modeling of specific host functionality directly associated with block changes to support the required analysis.

5.2.2 Linkages

The frames in Figure 7 illustrate, at a very high level, the process that will lead to the most effective combination of the strengths of the various modeling and assessment venues included in the IAP.

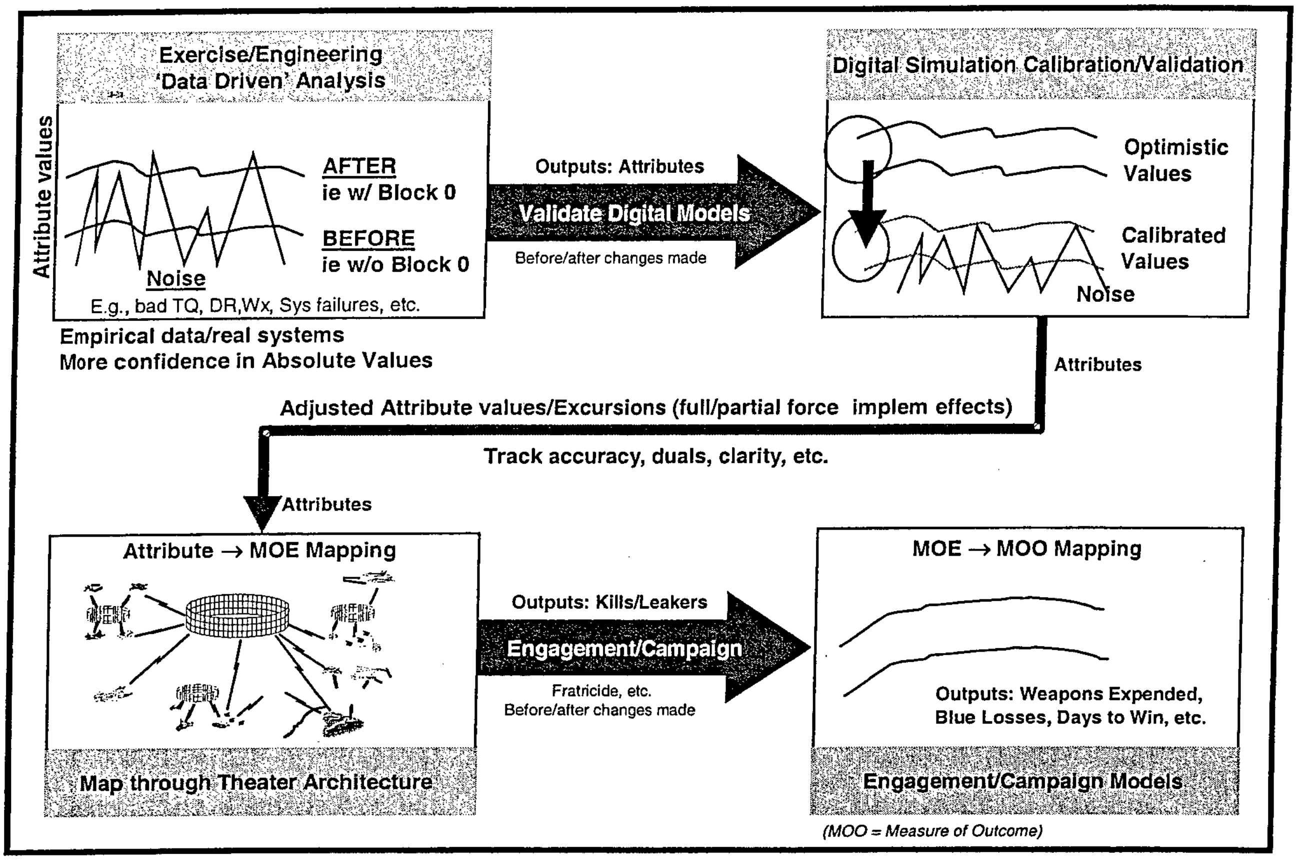

Figure 7. IAP Venue Linkages

Exercise/Engineering 'Data Driven' Analysis

Live and HWIL events (e.g., JDEP, JCIET, and Roving Sands) provide extensive data for quick assessments of SIAP measures. Systems and subsystems that can influence the SIAP do not have to be approximated, because (many of the) real systems are used. The Services and joint analysis communities have developed a number of tools with which to process and analyze real-world data collected at such venues.

Depending on the configuration of platforms participating in these venues, it may be possible to collect and analyze various SIAP metrics before or after SIAP improvements have been implemented in hardware and software. The ideal situation would be to run each test with each participating platform first in the before configuration against some standard scenarios and vignettes, collect data, and then calculate SIAP attributes. Next run the same test over with the same platforms and configurations, except for the addition of changes. In so far as the test conditions, configurations, scenarios, operator actions, hardware and software status, and vignettes can be held constant, the comparison between those data sets should reveal the changes in SIAP metrics due to the system changes introduced.

Unfortunately a variety of constraints and variables prevent the absolute control of open-air analyses, and full theater level analysis is not practical. Weather, hardware failures, system availability, and operator training are a few of the variables that will change from event to event. Consequently, before and after comparisons between different exercises may not be statistically significant. There are too few platforms, too many uncontrollable variables, and essentially no guaranteed repeatability.

In an attempt to overcome some of these limitations, the Services and the joint community are pursuing several initiatives. One of the goals of JDEP is to be able to re-run scenarios with identical hardware in the loop, except for certain specific changes that are made for evaluation purposes. This approach overcomes many of the limitations of the open air exercise venues cited above, but it does not solve the problem of too few platforms, and difficulty in evaluating performance with varying numbers of platforms with and without changes, etc. In addition, to evaluate post-block changes performance, desired changes must be implemented in actual systems. This can be a costly and time-consuming endeavor.

Another approach, data perturbation analysis, has been pursued by CNA as a means for getting more out of the reconstruction of live events. By using live system data directly, this approach accounts for the specific software and hardware configurations actually used by platforms in the exercise. SIAP metrics can then be calculated using recorded data generated from those configurations. These capabilities have come to be called 'data driven' models.

By changing the method by which the actual exercise data is processed (e.g., running the data through the new Block 0 correlation algorithms) at each participating platform, the data driven models can measure the effects of different processing schemes against the recorded data baseline. Except for the new processing logic introduced, this approach has the advantage of still being based on the actual hardware and software configurations of real platforms, and real world recorded data. However, it is still hampered by the limitations of few platforms, sparse data, and an approximation of what actual platform implementations of various SIAP changes might look like.

Digital Simulation Calibration/Validation

Modeling and simulation capabilities in this realm allow scale up to the theater level performance evaluation that is the goal of SIAP analysis. It also eliminates many of the other shortcomings associated with exercise and live-fly events (e.g., weather, hardware failures, operator training, etc.). However, digital simulations must create representations of how all of the primary and contributing systems work (in lieu of having actual HWIL and OITL capability) which provide data to the SIAP functions. The fidelity of system representations will not be as good as with the HWIL or exercise venues. Depending on the specific type and purpose of a particular analysis, many of the subsystems do not have to be of perfect fidelity since their role with respect to the primary analysis is secondary. Figure 8 is a notional example of this concept assuming that network issues are the primary analysis objective.

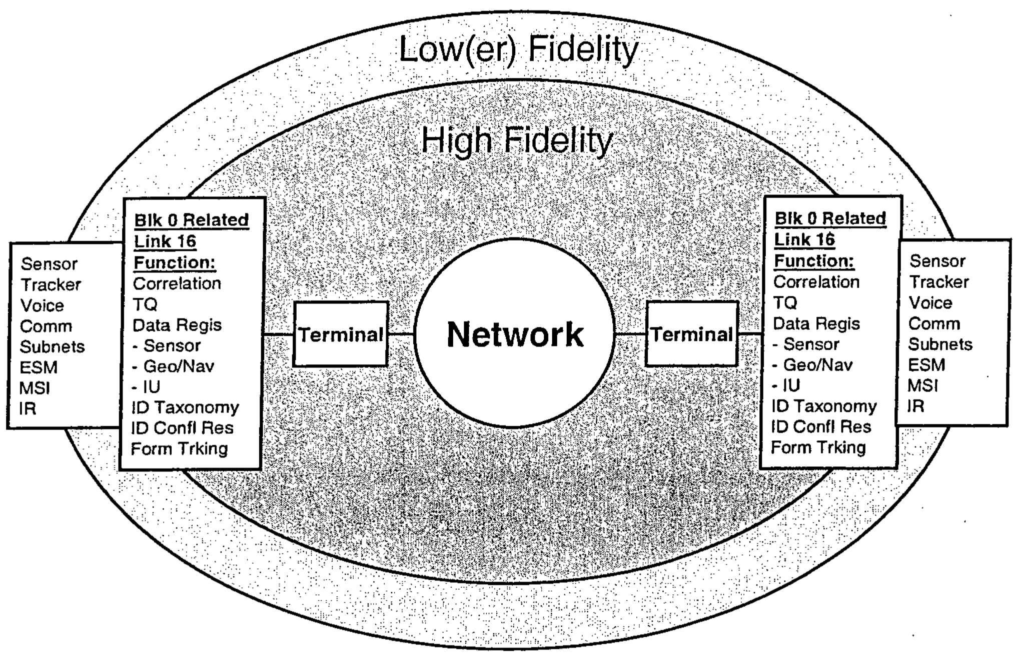

Figure 8. Notional M&S Fidelity Requirements for Network Issues

Due to the complex integration required between host systems and the data link, the problem of deciding which host functions must be modeled in detail and which can be approximated with a lower fidelity implementation is difficult. At a minimum, the system functions that are under evaluation (i.e., the 'primary' functions) have to be modeled at high fidelity to assess both before and after implementation performance within a specific digital simulation environment.

One of the significant differences between tools in the digital simulation venue and those in the live, HWIL, OITL venues is that it is more difficult to model the before case in a digital simulation than it is to model the after case. This fact is primarily driven by difficulties in acquiring the necessary information to model the before case, as opposed to the inability to model the required functionality. When implementing a SIAP change in a digital simulation, it will be clearly delineated which platforms will implement function-changes for particular analysis cases. However, it is not as clear how platforms perform functions in the before case because it is not always known or documented. Additionally, in the after case, the model developer, in consultation with appropriate SMEs, is free to choose the method of integration. As with data-driven tools, this after case is only an approximation of what actual platform implementations of various SIAP changes might look like.

Modeling the before case requires a detailed knowledge of how each platform actually does a specific function, followed by a translation of that scheme into modeling software. Program office review of the implementation is then required for validation of the model representation. This process requires much work and time. It is our experience that this is a very tedious and challenging task. Program Managers are often not very forthcoming with system performance data that might show adverse system performance. Even when completed, the implementations in model software will still only approximate the performance of the real systems. This is why, in Table 8, the digital/constructive simulation baseline functions listed as sensor and host are rated lower than in the live and HWIL venues, though some digital models are better than others.

One of the simplifications usually made in the digital modeling realm is that the lower fidelity modeling of the secondary influences is done assuming that those functions work correctly and consistently across all platforms. With such an idealistic assumption, the after SIAP performance values calculated in the digital simulations may be better or worse than they should be. However, if the absolute values of SIAP attributes derived from the 'data driven' tools are used to help calibrate the output of the digital simulations under similar scenario conditions, there will be more confidence that the absolute metric values produced by the digital simulations are more accurate. At the same time there will be traceability back to the real-world events where no assumptions had to be made. The data driven and digital simulation modelers will be tasked to work with each other to develop the best interfaces between the two venues to support this synergy.

Map through Theater Architecture

To determine the significance of any particular engineering change on warfighting MOEs, it must be placed in the overall operational context in which it will be used. Ideally the changes in attributes caused by engineering changes will flow in an automated way into the mission level model from a higher fidelity model, or a model with end-to-end capability may be used. This process provides a trace from exercise data through calibrated attributes to engagement MOEs. However, today an integrated end-to-end analysis capability does not exist. Therefore, initially, for many specific block changes, separate high fidelity M&S tools will be required for MOP level evaluations. Then the higher theater level, SIAP attribute tools will need to be adapted to reflect the effects of MOP improvements on the SIAP (and selected MOEs).

Engagement/Campaign Models

The lower right quadrant of Figure 7 represents an attempt at an even greater level of roll-up to higher level engagement and campaign MOEs. For example, an MOE model can measure the number of weapons expended in any given scenario, and might show that a strategy of multiple shots at every target results in the highest number of kills. However, if the weapon supply and platform loadouts are considered, such a strategy may prematurely deplete weapons supplies, leaving nothing for later targets resulting in more leakers, loss of Blue Force defended assets, etc. Still other models are designed to assess high-level campaign metrics such as days required to win, etc. These higher level engagement and campaign models will use results from the lower levels as inputs.

The trace from real-world data to campaign level MOEs can be completed following the path shown in Figure 7. While the quadrants display the notional linkages between levels, the many details of the interfaces between levels need to be determined, and may vary from model-to-model, and as models evolve. These details need to be worked out individually for each block. Therefore, they will be addressed in each specific block appendix to this document.

6. Summary

The SIAP SE was chartered to implement a disciplined system engineering process for the purpose of evaluating SIAP IADS shortfalls, and recommending improvements to joint warfighting effectiveness. To accomplish the task at hand, the SIAP SE must establish a standardized analytical infrastructure composed of teams, tools, and processes. This infrastructure is supported by the Services and Joint Agencies and leverages the significant DoD investment in evaluation capabilities. The SIAP SE will use this infrastructure to support a block improvements process aimed at incrementally building an objective SIAP.

The coordination of the various contributors who support the teams, venues and processes is a daunting task. To bring order to the chaos, the SIAP SE has developed this Integrated Assessment Plan, providing an overarching perspective for all SIAP analysis. This IAP leverages and integrates the results of many past and ongoing assessment efforts. It establishes standardized metrics, scenarios, and analysis methods to use across venues for the purpose of comparing and contrasting results and standardizing analysis. It also provides for development and upgrade of tools over time, including VV&A of all tools used in SIAP analysis.

The SIAP assessment approach is designed to leverage and synergize results of multiple analytical methodologies, with the aim of providing the highest quality recommendations to the JROC within the time and budgetary constraints imposed.

7. References

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8. Acronyms

ADSIM	Air Defense Simulation
BMDO	Ballistic Missile Defense Organization
C/S/A	CINC/Service/Agency
CNA	Center for Naval Analyses
CID	Combat Identification
COEA	Cost and Operational Effectiveness Analysis
CRD	Capstone Requirements Document
CRS	Common Reference Scenario
DDR&E	Director, Defense Research and Engineering
DISA	Defense Information Systems Agency

DMAP	Data Management and Analysis Plan
DoD	Department of Defense's
DOT&E	Director, Operational Test and Evaluation
DR	Data Registration
DSB	Decision Support Binder
EADSIM	Extended Air Defense Simulation
EADTB	Extended Air Defense Testbed
ESM	Electronic Support Measures
EW	Early Warning
FoS	Family of Systems
HWIL	Hardware-in-the-Loop
IADS	Integrated Air Defense System
IAP	Integrated Assessment Plan
ID	Identification
IEEE	Institute of Electrical and Electronics Engineers
IIPT	Integrating Integrated Product Team
IR	Infrared
IU	Interface Unit
IWG	Integrated Working Group
JCIET	Joint Combat Identification Evaluation Team
JCTN	Joint Composite Tracking Network
JDEP	Joint Distributed Engineering Plant
JDN	Joint Data Network
JFCOM	Joint Forces Command
JIADS	Joint Integrated Air Defense System
JITC	Joint Interoperability Test Command
JNIC	Joint National Integration Command's
JROC	Joint Requirements Oversight Council
JTAMDO	Joint Air and Missile Defense Organization
JTF	Joint Task Force
JTIDS	Joint Tactical Information Distribution System
KPP	Key Performance Parameter
LLKB	Lessons Learned Knowledge Base
M&S	Modeling and Simulation
MDA	Missile Defense Agency
MIL STD	Military Standard
MOE	Measure of Effectiveness
MOO	Measure of Outcome
MOP	Measure of Performance
MSI	Multispectral Imager
NDF	Network Design Facility
NSWC	Naval Surface Warfare Center
ODDSCAPE	Operational Data Driven for Correlation Algorithm Performance Evaluation
OITL	Operator-in-the-Loop
OPEVAL	Operational Evaluation (Navy)

OSD	Office of the Secretary of Defense
OSD (C3I)	OSD Command, Control, Communications, & Intelligence
PET	Performance Evaluation Tool
POA&M	Plan Of Actions and Milestones
POC	Points of contacts
PPLI	Precise Participant Location and Identification
QPM	Quantified Performance Matrix
RCA	Root Cause Analysis
RF	Radio Frequency
S/A	Services and Agencies
SAT	SIAP Analysis Team
SE	System Engineer
SE TF	System Engineering Task Force
SEAD	Suppression of Enemy Air Defenses
SEMP	System Engineering Management Plan
SET	System Engineering Team
SG	Steering Group
SIAP	Single Integrated Air Picture
SME	Subject Matter Expert
SOW	Statement Of Work
TADIL	Tactical Digital Information Link
TAMD	Theater Air and Missile Defense
TBMD	Tactical Ballistic Missile Defense
TOR	Test Observation Report
TQ	Track Quality
VV&A	Verification, Validation, and Accreditation
VWC	Virtual Warfare Center
WG	Working Group
WIPT	Working Integrated Product Team
Wx	Weather Effects

APPENDIX A: Tool Descriptions

Introduction

The purpose of Appendix A is to give a high level description of known models and tools available for SIAP-related analyses. The information contained in this appendix is a result of/based on inputs from model POCs, users, and official model overview documents.. This appendix is a living document and will be updated to recognize new capabilities and tools as they emerge.

Each description contains the following sections:

1. Overview – What does it do, for what purpose was it created, what platforms does it run on?
2. Design – How does it work?
3. Assumptions and Limitations – What assumptions and generalizations does the user have to consider when interpreting the results?
4. SIAP Contribution – What problems does it solve for the SIAP world?

The descriptions provided in this appendix provide an indication of how the models/tools work and how they might fit into a specific analysis process. For a more detailed description of their precise uses in previous Block n analysis, see the appropriate appendix.

The following is a list of the models/tools described in this document and their location:

Acronym	Tool	POC Name	Organization/(pany	Phone	Email	ȷe Location
ᴉDSIM	Air Defense Simulation	J. Roberts	ESC/MITRE	781-377-2687	jrobert@mitre.org	A-3
ᴉIM	Analysis in Motion	S. Cantey	CSCI	703-866-4000	scantey@csci-va.com	A-4
ᴉRCTIC	Automated Reconstruction and Correlation Tool for Interoperability Characterization	C. Barrett	CNA	703-824-2893	cbarrett@can.org	A-5
:ADSIM	Extended Air Defense Simulation	J. Watkins	Army/SMDC			A-6
		B. Lollie	BMDO/TEM			
:ADTB	Extended Air Defense Test Bed	L. Burger	Army/SMDC	256-955-3070		A-7
		B. Lollie	BMDO/TEM			
ƷCAM_CTS	General Campaign Analysis Model Core Tool Suite	P. Vodola	SPA	703-578-5652	pvodola@spa-inc.net	A-8
ICIET	Joint Combat Identification Evaluation Team					A-9
I8AAT	The Joint Staff J8 Architectural Assessment Tool	J. Cartier	IDA		jcartier@ida.org	A-10
ICTN_Bench nark	JCTN and JDN Algorithm Benchmark tool	R. Rothrock	SPARTA	703-448-1683 x279	Ron_Rothrock@rosslyn.sparta.com	A-11
IDEP_Track2	Joint Distributed Engineering Plant Track 2					A-13
IDNA	Joint Data Network Analysis	J. Barto	SIAP	703-602-6441 x219		
IIMM	Joint Interim Mission Model					A-13
NETWARS	Netwars	LtCol Pat Vye	Army/SMDC	703-693-5332		
NDA	Network Design Analysis					A-14
ODDSCAPE	Operational Data Driven Simulation for Correlation Algorithm Performance Evaluation	C. Barrett	CNA	703-824-2893	cbarrett@can.org	A-15
PET	Performance Evaluation Tool	E. Van Fleet	NWAS	909-273-4155		A-16
RS	Roving Sands		JFCOM			A-17
TMDSE	Theater Missile Defense System Exerciser	L. Burger	Army/SMDC	256-955-3070		A-17
		P. Cash	PEO/AMD/BMDO			
		Ltc. Blue	BMDO/TEM			
TFX	Task Force Exerciser					A-18
VWC	Virtual Warfare Center					A-18
WAM	Warfare Assessment Model	Dr. Lawrence Lewis	JCIET/NWAS/CNA	850-882-9630 x284	lawrence.lewis@eglin.af.mil	A-18
WG2K	Wargame 2000		JNIC			A-19

A.1 Air Defense Simulation (ADSIM)

A.1.1 Overview

ADSIM provides detailed tactical data link modeling, including realistic sensor, tracker and host system function representations. The detailed sensor and tracker models provide the basis for a realistic local track file that is correlated with a realistic network track file. ADSIM then models how host systems turn selected local tracks into Tactical Digital Information Link (TADIL) J messages and transmit them within a theater of operations. ADSIM models host systems properly calculating track quality (TQ), observing reporting responsibility (R2) rules, metering the messages, and buffering the messages, while also modeling JTIDS/MIDS terminals utilizing packing limits, directly importing real (operational) network design constraints, then transmitting the messages through the Link-16 network.

A.1.2 Design

The communications model is capable of simulating the effects of jamming and the impacts of limited time slot availability on track update rates as well as the number of tracks on which R2 can be maintained in a Joint Theater Air and Missile Defense (JTAMD) environment. MITRE has developed complementary, detailed post-processing tools to facilitate analysis and graphically display the results of the simulation. The Link-16 portion of the communications model is the only JTIDS Program Office endorsed model for Link-16 loading studies. BMDO and JTAMDO have funded the MASC's use of ADSIM on numerous occasions to assess a wide variety of Link 16 performance issues.

ADSIM directly utilizes output from the Automated Terminal Initialization (ATI) tool to develop actual Link 16 network designs, based on significant interaction with Service and Joint representatives. The ATI is a compatible prototype of the Joint Link 16 network design tool that is used by all of the Service Network Design Labs. MITRE has developed a complementary tool to automatically import ATI-developed Link 16 network designs directly into ADSIM, which properly uses all of the information provided.

As an analysis provider for the Phase 2 JCTN Study, MITRE also has developed the capability to model composite tracking as defined for JCTN within ADSIM. Composite tracking refers to a process by which sensor measurements from multiple sensor platforms are combined to form a single track (ideally) for each target observed. ADSIM has demonstrated its ability to represent JCTN performance. CEC is not the same as JCTN. Representing all of the accommodations that the CEC program had to make in order to integrate data fusion into the CEC network has necessarily been approximated.

ADSIM is designed to support the simulation of composite tracking through the use of its sensor objects and command center objects. Sensor objects are used to simulate the operation of the various sensor systems deployed. They detect targets and provide sensor measurements to designated command centers where the air and space tracks are established, updated and reported via Link 16. Various combinations of sensor objects and command center objects may be implemented. For instance, to model each sensor as an individual JTIDS Unit (JU) wherein the individual JU prepares and reports tracks using only its own sensor measurements, a separate command center may be established for each sensor. To model composite tracking, a single command center can be established to process the sensor measurements from several contributing sensors.

A.2 Analysis in Motion (AIM)

~~A.1.1~~A.2.1 Overview

CSCI's tool suite accounts for dynamic interactions between platforms, sensors and networks. CSCI's principal theater air and missile defense model is a detection through kill simulation. In this model, measurements created by sensors in a TAMD architecture are subjected to gating and correlation procedures to associate measurements with tracks. Associated measurements are used to update a Kalman tracking filter for real and false tracks. Measurements which fail to associate with any track spawn new tentative tracks. Subsequent measurements can be associated with tentative tracks and the tentative tracks can be promoted to confirmed or network reportable track status. The accuracy of measurements and the track update rate determine the error around a specific track and influence the size of the adaptive gate around this track. Therefore, network performance directly influences the accuracy of tracks which influences whether tracks tend to dual or swap. The AIM™ model can model measurement sharing and reporting responsibility networks either individually or simultaneously in a single run. This modeling approach allows us to identify instances of interest along with the preceding history and conditions leading to the interval of interest. In other words, if a tactical situation involving several sensors and targets leads to a merge, dual or swap situation; we can replicate the events preceding the event, define explicitly why it occurred and what means are available to resolve the undesirable air picture situation.

~~A.1.2~~A.2.2 Design

Automatic local-to-remote track correlation/decorrelation implies a relative performance assessment of techniques for avoiding erroneous network reporting of dual, merged or swapped track reports. As stated earlier, our capability applies directly to the creation of the erroneous reports and our approach towards representing the association/correlation processes gives us the flexibility to evaluate the various approaches towards resolving track ambiguities by explicit representation of measurement, gating, correlation and tracking processes. Our approach lends itself to robustness and sensitivity analyses appropriate to this topic in that we can define the number of participating sensors and corresponding detection measurement properties, the duration of the ambiguous interval and the effectiveness of processes for resolving the ambiguity. This might be best accomplished by first representing various network alternatives in models which assess network delays and capabilities directly and then calibrating one or more networks in an AIMTM analysis from these network specific models. AIM™ would then be used to generalize the network performance model findings to force-on-force level analysis and would report traditional operational metrics. The CSCI team is experienced in the use of detailed sensor and network models to calibrate AIM™ and extend results to force-on-force level analyses.

ID conflict resolution rules implies an assessment of such rules in the presence of an unambiguous tracking situation. Our capability allows for direct implementation and evaluation of these rules and procedures in increasingly more stressing detection and tracking environments. This provides for the assessment of the robustness, frequency and duration of occurrence, precursor conditions, and process intervals. That is, we can measure the frequency of occurrence of ID conflicts and the duration of time during which the conflicts exists - explicitly instead of statistically. We track the precursor conditions leading to the ID conflict and the time it takes to remove the conflict. We need to understand the relationship between this ICP and the ICP related to taxonomy and symbology to clearly define assessment goals.

Formation tracking/correlation implies techniques for distinguishing resolution differences between sensors and how to manage the reporting of tracks on surveillance and sub-nets on Link-16. We explicitly represent multiple networks, the interactions between them with different combinations of participating sensors on each network.

A.3 Automated Reconstruction Correlation Tool for Interoperability Characterization (ARCTIC)

~~A.1.1~~A.3.1 Overview

The ARCTIC tool was developed at CNA to aid in rapid reconstruction of air defense exercises with the purpose of interoperability analysis in mind. ARCTIC automates the process of matching radar track data with ground truth data (usually obtained from GPS pods on participating aircraft) recorded during the event. The track matching process uses simple kinematics rules and hysteresis to choose the "best" match.

~~A.1.2~~A.3.2 Design

ARCTIC users can control rules used to generate matches including kinematics correlation windows as well as how much hysteresis is applied to maintain track matching continuity on objects within a formation. These options allow the user to tailor the reconstruction for suitability with certain kinds of metrics.

ARCTIC is fully compatible with the Performance Evaluation Tool (PET) for generating, viewing, and graphically editing reconstructions. It is also compatible with the standard WAM data format, such as used in ASCIET / JCIET events.
ARCTIC was benchmarked against ASCEIT 99 manual reconstructions and was used extensively for analyses of ASCEIT 00 events. The ARCTIC-PET combination has been employed for reconstruction of Underway Events 10, 11, and 12 (TechEval) for the Cooperative Engagement Capability (CEC) preparation for OPEVAL.

A.4 Extended Air Defense Simulation (EADSIM) *Enhancements*

~~A.1.1~~A.4.1 Overview

The Extended Air Defense Simulation has provided a valuable tool for operational architecture study for many years. As the understanding of possible architectures has evolved, so has the flexibility of EADSIM to represent the possible architectures. A number of enhancements that directly relate to capabilities needed within current concepts have been incorporated into EADSIM via the release of Version 8.00 and most recently Version 9.00. In addition, work is ongoing that directly supports the ability to represent the JTAMD OA and the FoS that will operate within that architecture.

~~A.1.2~~A.4.2 Design

EADSIM Version 8.00 made few modifications directly to the areas identified above; however, there were two major enhancements that are key drivers to analysis in this arena. The first enhancement was the addition of the ISAAC modules for the ABL SPO approved representation of the ABL. These modules handle the slewing and lethality computations for the ABL, while EADSIM internal processing handles the location of the ABL and the threat, as well as the battle management for selecting engagements within a single ABL and between multiple ABLs operating in the same region.

The second related enhancement for Version 8.00 was the incorporation of Reliability/Availability/Maintainability (RAM) specification and modeling to allow detailed reliability statistics at the system and element levels. This capability allows the system and components of the system, such as sensors and communications devices to be disabled based on failure statistics. The disabled system or component would become unavailable until repairs are made. Components that are not modeled for purposes other than RAM can be represented down to any level in the typical work breakdown structure. A generator would be an example of such a component.

EADSIM Version 9.00 introduced some significant enhancements in the area of track processing. The representation within EADSIM without these enhancements provided perfect correlation of tracks for engagement related purposes; thus, making it difficult to show an improvement from the addition of better correlation and tracking techniques that are envisioned with SIAP and CEC. These enhancements also included specific upgrades to IFF and Combat ID techniques to improve the representation of injection of identification information into the air picture. These enhancements allow a truer representation of impacts of current and envisioned tracking systems.

Track processing was enhanced in a number of ways. The primary enhancement is that a single track file may now contain multiple track entries on the same object. Correlation of tracks is now evaluated on a source by source basis. A correlation is not assumed to be valid for the entire scenario. Correlations may now be revisited multiple times during a scenario run, based on a user-defined correlation revisit time. Statistical correlation will now miscorrelate incoming tracks into new track entries. The user may specify to correlate tracks probabilistically and/or based on track error volumes.

Engagement processing is now performed based on track number rather than target ID number. When a platform sends a command message to or receives a command message from another platform, the message contains a track number for the target. If the receiving platform does not recognize the track number, it sends an update request message to the source of the message. Upon receipt of the update request, the sending platform sends a commanded track update, which contains the track data for the target as well as the original command data. The receiving platform processes the track update into its track file and then continues processing the original command message. The number of the target track is also stored in an engager's target record and launch record, and processing of the engagement is performed using this track number. This allows platforms to engage a target multiple times if multiple tracks are held on the same target due to miscorrelation.

A resolution specification has been added to the IFF parameters specified on the system definition. The resolution model allows any platform within the resolution cell of the interrogated platform to influence the outcome of the interrogation. If any platform within the cell responds as friendly, the interrogated platform will be marked as friendly. Individual IFF modes may be defined with different resolution parameters and a mode list may be specified for each instance of performing IFF. The mode list indicates the modes to be used for performing the interrogation, in order of preference.

A.5 Extended Air Defense Testbed (EADTB)

A.5.1 Overview

The Extended Air Defense Testbed (EADTB) is an event-stepped, constructive simulation capable of real-time, interactive, or batch mode operation. It was developed for joint-service, international use, with the primary goal of serving the extended air defense community. Presently hosted on Silicon Graphics Onyx/Challenge, Octane, or Origin 2000 hardware, the EADTB supports modeling from the battery/fire-unit level up to theater-level scope with a high degree of flexibility in choice of levels of detail and aggregation. The EADTB incorporates a capability for detailed, explicit simulation of elements of C4ISR.

A.5.2 Design

Most of the EADTB software, as delivered to the user, consists of object code, precompiled from ADA source code. In addition, the EADTB includes a user-modifiable (or definable) interpreted ruleset language that invokes selected precompiled EADTB algorithms and defines the simulated weapon-system "thinker" behavior. The Thinker ruleset can also be configured to access user-defined, precompiled externals. By placing weapon-system modeling power in the hands of the user, the EADTB serves as a model-development environment as well as a complete simulation.

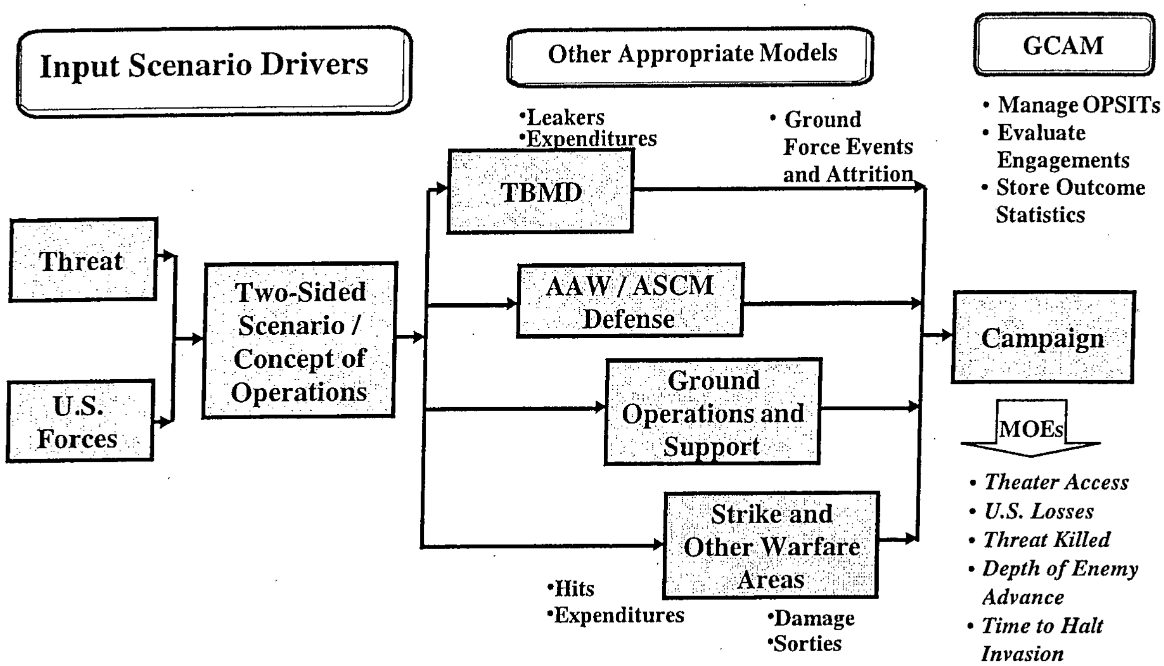
~~A.5~~A.6 General Campaign Analysis Model Core Tool Suite (GCAM-CTS)

~~A.1.1~~A.6.1 Overview

The GCAM-CTS was originally developed in support of the Navy Assessment Division (OPNAV N81), and is a component of the Joint Analytic Model Improvement Program (JAMIP) near-term suite of models. GCAM-CTS is a PC-based set of object-oriented modeling and analysis tools. Using the GCAM-CTS, analysts develop object-oriented stochastic modeling applications, called GCAM cases, tailored to particular issues. The GCAM-CTS was certified as compliant with the guidelines of the Defense Modeling and Simulation Office (DMSO) High Level Architecture (HLA) in September 1999.

~~A.1.2~~A.6.2 Design

Figure 1 shows a typical analysis and modeling process for a notional study employing GCAM. One begins by developing the two-sided scenario and overarching context in which performance is to be assessed. The level of detail and specific tactical features incorporated in a GCAM scenario are tailored to the objectives and issues of the study. GCAM is an integrator, rather than originator, of most mission-level performance analysis. Thus, Figure 1 shows that external models have been employed to create a database of tables or performance curves in four key mission areas . The mission areas and supporting models would depend on the study, desired level of supporting detail, and availability of analysis tools within the analysis team. A variety of mission effectiveness algorithms and campaign features can be implemented directly in GCAM or interfaces using HLA, Visual Basic, Excel, or an external model. The analyst can tailor GCAM and the supporting toolset to the scope and tempo of the study.



~~A.1.3~~A.6.3 Assumptions and Limitations

GCAM is limited only by the level of detail the user can acquire. The analyst decides what level of fidelity to model each system. He also decides how these systems interact with each other and what results to output. Inordinate amounts of information, though, may result in excess run time, thus it is best if methodologies are generalized and assumptions are made. This is why, as previously mentioned, GCAM is best used as an integrator of results.

~~A.1.4~~A.6.4 SIAP Contribution

GCAM will roll up results from other lower level SIAP models described in Appendix A in a similar method as described in Figure 1 above. For instance, it can be used to show the impact mis-correlations have on leakers over the course of an entire campaign. More detailed uses as they pertain to the individual Block n analysis is contained in subsequent appendices.

A.7 Joint Combat Identification Evaluation Team (JCIET)

A.7.1 Overview

JCIET is chartered to employ the equipment and personnel of all Services to evaluate, investigate, and assess Joint integration and interoperability of systems, concepts, capabilities, Tactics, Techniques, and Procedures (TTP), and doctrine which directly affect combat ID within the present and future Joint battlespace.

A.7.2 Design

JCIET evaluates 3 mission areas – surface-to-surface, air-to-surface, and air defense(air-to-air and surface-to-air). The evaluations are done as follows:

- Utilize active, guard, and reserve personnel with currently fielded equipment.
- Coordinate with Services, battle laboratories, doctrine commands, and tactics schools.
- Joint environment/scenario for emerging technology.
- Robust scenarios produce shooter-level "fog of war" yet small enough to be fully instrumented.

~~A.6~~A.8 J8AAT The Joint Staff J8 Architectural Assessment Tool

~~A.1.1~~A.8.1 Overview

The J8 Architectural Assessment Tool (J8AAT) is an analytic, expected value, functional model for estimating the interoperability and effectiveness of an air defense architecture. J8AAT was originally developed under the sponsorship of J8 to assist in the analysis of acquisition alternatives for cruise missile defense (CMD) in a joint environment and was first used in the Joint Land Attack Cruise Missile Defense study (JLACMD) to supplement force-on-force models.

~~A.1.2~~A.8.2 Design

J8AAT is a direct functional model rather than a simulation. It uses a specified laydown of blue force assets but does not follow individual target tracks through the theater based on a detailed scenario (an exception to this is made for CID which requires individual tracks to build up track history). Instead, at each point of the theater, metrics are computed for a target at a specified altitude and current direction of motion. The orientation of the aircraft is primarily used to determine the aspect angle of each radar system with respect to the target for RCS determination. The function model design requires generalizations that are not required of a simulation, however these limitations are offset by the compensating benefits of providing theater-wide maps of metrics and system of systems capability. Whereas simulations have to be run many times to understand expected outcomes, J8AAT rapidly produces global expected values. For this reason, J8AAT can be a valuable augmentation to simulations, since it can quickly build representations of new systems and prioritize major factors that help in the design and execution of large scale simulations or hardware in the loop experiments.

~~A.1.3~~A.8.3 Assumptions and Limitations

~~A.1.4~~A.8.4 SIAP Contribution

The J8AAT model is most effectively used as a rapid turn-around tool for assessing proposed laydowns and scenarios for exercises to see how a collection of systems are going to interact.

- IDA can compute standard CID KPPs (Completeness and Accuracy) for proposed scenarios and relate the impact of SIAP KPPs on the CID KPPs.
- IDA can display selected Warfighter benefits off the SIAP and CID capability.
- The following types of engineering changes can be represented in J8AAT and the effect on SIAP and CID metrics computed:
  - Changes to current Platform specific correlation algorithms
  - Changes affecting gridlock and sensor registration
  - Changes affecting latency of reporting
  - Changes to the TADIL architecture which impact latency or connectivity
  - Introduction of sensor netting and different approaches to correlating fused data with link data.
- While the model does not currently compute information loses due to incompatibilities in CID lexicon across platforms, given that the loses can be estimated by other means, the impact on Warfighter Benefit from these loses can be analyzed.

~~A.7~~A.9 JCTN and JDN Algorithm Benchmark

~~A.1.1~~A.9.1 Overview

The JCTN and JDN Algorithm Benchmark Environment (hereafter shortened to "Benchmark Environment" or just " Benchmark") is an event-stepped computer simulation that provides the functionality and infrastructure to develop and score algorithms against SIAP performance metrics for multi-platform, multi-sensor, multi-target tracking, as well as for single sensor tracking. It was developed by a collaborative team under co-sponsorship of the Office of Naval Research (ONR) and the Ballistic Missile Defense Organization (BMDO). The current version of the Benchmark scores performance within a composite tracking network and for a reporting responsibility (R2) network having features of Link 16 NPG-7. The Benchmark Environment also is adaptable and expandable to deal with other technical issues pertinent to the SIAP SE program, e.g., composite classification and identification. Benchmark is intended to run on desktop computers and is coded in the high level programming language that is provided as part of the MATLAB integrated technical computing environment developed by The Math Works, Inc. (www.mathworks.com).

~~A.1.2~~A.9.2 Design

In its current form, the Benchmark Environment can evaluate the performance of test article algorithms in the face of difficult, real-world tracking and track management issues. These include sensor measurement-to-local track data association, track initiation, local track-to-network track correlation, track promotion to composite track or assumption of reporting responsibility, track merge and track drop logic, balancing performance across competing performance evaluation metrics (e.g., completeness versus redundancy), navigation errors, coordinate frame transformations and their impact on error estimates, gridlock, data latency and dropped messages, and others.

The Benchmark Environment includes high fidelity, operationally realistic scenarios that present difficult tracking situations including merging and crossing air traffic, close formations of maneuvering aircraft, high-g breaks, low-altitude/low-observable targets, terrain masking, etc. It can easily accommodate new and varied scenarios, such as JCIET exercise scenarios.

In terms of tracking, data association, and track correlation, the JCTN and JDN are intended to provide the capability for platforms at different locations to maintain a SIAP. Test article algorithm performance is evaluated, in part, based on the consistency of the track databases maintained at different nodes in the network. The Benchmark Environment simulates the track databases at each node/platform as separate entities.

~~A.1.3~~A.9.3 Assumptions and Limitations

~~A.1.4~~A.9.4 SIAP Contribution

One of the key elements of the Benchmark Environment is the metrics module. The Benchmark metrics are based on evaluating the following SIAP attributes which were originally formulated by the SIAP splinter groups of the 1999 Joint Mission Area Assessment (JMAA) for Countering Theater Air and Missile Threats. The performance metrics currently implemented in the Benchmark include:

- Completeness, specifically (1) object track completeness
- Timeliness, specifically (2) track initiation time
- Track continuity, including (3) mean cumulative switches of tracks and (4) mean cumulative breaks of tracks
- Ambiguity, including (5) redundant track mean ratio and (6) spurious track mean ratio
- Accuracy, including (7) track accuracy and (8) track covariance consistency
- Cross-platform commonality history, including (9) ratio of non-common track numbers and (10) track state estimate differences

The Benchmark also scores (11) the total source message data load presented to the communications network.

A.10 Joint Distributed Engineering Plant Track 2 (JDEP Track 2)

A.10.1 Overview

The JDEP program was established as a DOD-wide effort to link existing service and joint combat system engineering and test sites (including design activities, software support activities, test and evaluation facilities, training commands, and operational units). JDEP is designed to improve the interoperability of weapon systems and platforms through rigorous testing and evaluation in a replicated battlefield environment.

~~A.8~~A.11 Joint Interim Mission Model (JIMM)

~~A.1.1~~A.11.1 Overview

The Joint Interim Mission Model (JIMM) is being developed by the Joint Strike Fighter Program Office (JSF PO) to cover the acknowledged gap in next-generation modeling at the mission level for analysis. JIMM may be used for both constructive (digital only) or virtual (real-time, hardware- or operator-in-the-loop) simulation.

JIMM is the merger of two legacy simulations: SWEG and Suppressor. Each of these two simulations has a rich heritage of virtual and constructive applications, with SWEG better known for its virtual capabilities, while Suppressor is known for constructive analysis. By merging these two simulations into a common, object-oriented simulation written in C++, JIMM will leverage the VV&A history of both legacy tools, while lowering the maintenance costs and increasing the user base.

~~A.1.2~~A.11.2 Design

JIMM models real-world entities via user-defined functional objects. Since no preconceived notions of what constitutes an aircraft, ship, or tank are in the software, JIMM has inherent flexibility to a wide range of applications. The functional objects include:

- Sensors, for the non-cooperative exchange of information [radars, human eye]
- Communicators, for the cooperative exchange of information [radios, land line]
- Weapons, for lethal engagement of others [bombs, guns]
- Disruptors, for non-lethal engagement of others [jammers, chaff]
- Movers, for changing location over time [truck chassis, aircraft engine]
- Thinkers, for processing of data and decision making [targeting cells, computer chip]

Other objects also exist, such as Tactics for rules of behavior, Groups for message definition, Elements for susceptibility and vulnerability modeling, Shapes for physical extent, and Resources for representing expendables and consumables.

JIMM supports real-time operation as an inherent part of its design. A user-definable interface partitions the functional objects within a scenario to JIMM or other assets, depending upon the needs of the analyst. In addition to a robust set of internal protocols and data definitions, JIMM also has interfaces for standard distributed simulation protocols and architectures, including DIS and HLA. These interfaces allow JIMM to be integrated with other simulations or simulators, such as ESAMS or FRED via Shared Memory. These same interfaces are also used to integrate JIMM with hardware systems for more detailed simulation and stimulation applications.

Because of the data-driven nature of JIMM, any discussion would be incomplete without mentioning databases. Legacy SWEG databases from version 6.5.0 and beyond are directly readable by JIMM. Suppressor has a robust set of databases that have been developed and refined over many years. Special effort has been made to ensure these modeled systems are translatable into JIMM. To achieve this, a Database Converter has been developed to automatically convert most of an existing Suppressor database into JIMM format. Those data items not converted are flagged for analyst action or as being not currently implemented in JIMM. Plans are in place to eliminate this latter category.

Finally, standard analyst tools and interface libraries are being developed for JIMM. These include:

- Software for exchanging data through JIMM's Shared Memory structures
- Conversion of standard intelligence community data sets into JIMM format
- Simulation control software and run scripts
- Data extraction, formatting, and display tools
- Graphical displays for real-time monitoring and post-processing
- Extraction and display of detailed JIMM data items
- Pre-processing and run-time Graphical User Interfaces (GUIs)

~~A.9~~A.12 Network Design Analysis

~~A.1.1~~A.12.1 Overview

The systems planned to be used for the distribution of SIAP information are usually also intended to distribute other types of information as well (e.g., commands, etc.). This means that the amount of capacity allocated to the SIAP functions must compete with those other functions. There are many primary SIAP attributes that are affected either directly or indirectly by the amount of capacity allocated, and the degree of connectivity provided, to various SIAP and non-SIAP functions during the network design process. In addition, those other functions also provide warfighting benefits. Therefore, it is necessary to develop a balance between allocation of capacity to the SIAP and non-SIAP functions within the theater network architecture.

Before any SIAP attributes can be assessed, it is necessary to make some top level trades among the various SIAP and non-SIAP functions. A network design analysis is required to ensure that changes to the network architecture or data flows proposed in the name of SIAP do not inadvertently impact some of the critical non-SIAP functions. This is required, since it is possible that any warfighting benefits accrued by using more capacity to improve a specific SIAP attribute may be either partially or totally offset by degradation in another non-SIAP function.

~~A.1.2~~A.12.2 Design

The Services have developed a Joint Link 16 Network Design Aid (JNDA), which provides a mechanism for designing networks to support the full range of SIAP and non-SIAP functionality that needs to be supported by Link 16 in a theater network architecture. Using Service network design guidelines, a baseline theater network architecture will be created, primarily focused on Link 16, though the baseline Link 16 network could also incorporate capacity and features needed to port data from other theater networks (e.g., CEC, JCTN, or other TADILs) into Link 16 as well.

When SIAP related changes are proposed which require changes in the capacity allocations of the baseline network, the impact of the shift in capacity will be determined, and expressed in terms of the appropriate MOEs and MOPs. The network design analysis will attempt to express the gains and losses in SIAP and non-SIAP performance and functionality in terms suitable for inclusion in the Decision Support Binders, which will accompany recommendations to the JROC regarding implementation of various SIAP related changes.

~~A.10~~A.13 Operational Data Driven Simulation for Correlation Algorithm Performance Evaluation (ODDSCAPE)

~~A.1.1~~A.13.1 Overview

The ODDSCAPE modeling and simulation tool was developed at CNA to provide predictive analysis of proposed Link-16 correlation / decorrelation algorithms. ODDSCAPE builds a local air picture for each participating unit from recorded combat system air picture data. Link communications are emulated and rule sets are implemented to produce track reporting over TADIL-J. Then each unit uses a set of proposed correlation / decorrelation rules (such as the Corr / Decorr ICP) to merge the unit's local air picture to the remote reports incoming over the link.

~~A.1.2~~A.13.2 Design

We drive the simulation primarily by the local-sensor-support data recorded on the participating units during ASCIET00. Local sensor updates are delivered to units at the appropriate time step. For remote track updates, a unit in the simulation receives J3.2 track update messages on tracks reported by other units, applies the appropriate logic (including correlation / decorrelation tests), and updates its track database as necessary. Each unit also receives the identical J2.2 PPLI messages it received during ASCIET00. Correspondingly, any local-sensor-supported tracks that are not correlated to incoming remote reports are reported on the link (in accordance with the MIL STD and the ICP) and subsequently received (after some delay) by the other participating units. Finally, we attempt to reproduce the observed operator-initiated messages that may affect correlation / decorrelation decisions by feeding "injection prompts" to a unit. A unit receiving an injection prompt will create and send the specified message in the simulation that, hopefully, replicates the message observed in the ASCIET 00 data.

~~A.11~~A.14 Performance Evaluation Tool (PET)

~~A.1.1~~A.14.1 Overview

PET is a PC-based computer program that reads many data types and compares events automatically to calculate interoperability metrics. PET also displays metrics graphically over time and allows analysts to step through the metrics chronologically to assist in tying metrics to performance issues. PET was developed to load combat system data and calculate metrics within the seven levels that related primarily to tracking and identifying aircraft, beginning with "connectivity" and ending with "Battleforce situational awareness".

~~A.1.2~~A.14.2 Design

Normal PET usage starts with loading data from all combat systems to be analyzed, reconstructing the tracks that represent aircraft and surface units of interest, setting independent variables for how the data is to be interpreted, and producing interoperability measures results and interpretations. This subsequent interpretation of metric results is done by producing graphical displays of metrics over time and tying significant deviations in metric numbers to combat system events, and by detailed combat systems analysis. When the data is reconstructed and calculation rules characterized, the analyst can calculate the metrics and output tabular results and graphical representations of the analysis.

PET is currently programmed to calculate three sets of metrics. The CNO 801 metrics, the ASN RDA CEC metrics and the Timeframe metrics used by JCIET for JCIET evaluations and CNA and NWAS to analyze a variety of other joint events. The ASN RDA metrics will be used throughout the CEC testing and may be further applied to events where the primary focus is characterization of what is in various track files. The

Timeframe metric set has been gaining increasing acceptance since the measures describe what happens over time and are directly related to what an operator sees. A track file metric is generally used to characterize how one track file compares to another (i.e. how does the combat system track file with CEC on compare with the track file with CEC off)? A timeframe metric is generally used to describe what the operator is seeing over time.

A.15 Roving Sands (RS)

A.15.1 Overview

Roving Sands (RS-01) is a one-of-a-kind event that is the world's largest joint theater air and missile defense exercise. RS-01 melds the command, control, communications and computer elements, air defense artillery and aircraft of the Army, Navy, Marines, Air Force and multinational forces into a joint integrated air defense system. Roving Sands 01 is one of a series of training opportunities that provides deployable forces with an enhanced understanding of joint and multinational operations and tasks.

Roving Sands will be conducted at training ranges and sites in Texas and New Mexico. The training objectives for this exercise reflect a wide range of capabilities that may be needed in various geographic areas. This training will enhance the ability of commanders and staffs to plan and conduct joint and combined tactical air operations and theater missile defense operations under realistic conditions.

During this exercise, the forces will refine their inter-operability skills using a joint and combined intergrated air defense network of ground, missile and radar early warning systems. They will face an opposing force of tactical aircraft, ballistic and cruise missiles in a high-threat environment. To do this, Army, Marine and a contingent of multinational air forces will employ air defense systems, such as the Patriot anti-tactical missile system, against realistic front-line attack forces provided by the U.S. Air Force.

A.16 Theatre Missile Defense System Exerciser (TDMSE)

A.16.1 Overview

The TMDSE is a joint services emulation of theater missile defense using Link-16 emulation and hardware-in-the-loop to integrate the theater missile defense family of systems and test interoperability issues between the separately developed systems. Connectivity is accomplished by Data Link Gateway systems at each participating site networked over classified T1 lines, thus enabling a virtual Link-16 network. TMDSE is sponsored by the Ballistic Missile Defense Organization.

~~A.12~~A.17 Task Force Exerciser (TFX)

~~A.1.1~~A.17.1 Overview

The Task Force Exerciser (TFX) provides a capability to realistically stimulate and stress U.S Army Theater Air and Missile Defense (TAMD) systems operating in a task force configuration. It leverages past and current development efforts expended for the Theater Missile Defense System Exerciser (TMDSE) including the Test Exercise Controller (TEC), appropriate tactical drivers, and planned upgrades. This approach minimizes new development and concentrates on incorporating U.S. Army Air and Missile Defense (AMD) elements and uniquely required communications. The TFX provides a cost-effective tool to exercise and test the integration and interoperability of multiple U.S. Army AMD tactical battle management command, control, and communications (BMC3) systems hardware and software. It retains compatibility with TMDSE to leverage past and future Ballistic Missile Defense Organization (BMDO) investments in the use of distributed interactive simulation technology to test-analyze-fix-test AMD systems.

~~A.1.2~~A.17.2 Design

Doctrinally, the TAMD Task Force is an evolving concept that envisions a two-tiered (THAAD and PATRIOT) defense against tactical ballistic missiles (TBMs) and air-breathing threats (ABTs). SHORAD systems have been integrated into the Task Force to provide additional capabilities against ABTs, to include cruise missiles (CMs) and unmanned aerial vehicles (UAVs).

TFX provides a framework for demonstrating interoperability between tactical systems and exploring developmental and operational interoperability issues by stimulating participant systems and measuring their responses.

A.18 Virtual Warfare Center

A.18.1 Overview

A collaborative, immersive development environment for war fighters and commanders (CINC, JFACC, etc). Encompasses over 15,000 square feet for JCMD, computers, networks and visual equipment.

~~A.13~~A.19 Warfare Assessment Model (WAM)

~~A.1.1~~A.19.1 Overview

JCIET, NWAS, AWACS, E-2C and CNA currently use WAM as a display tool to support analysis. Data displayed include ASCII files created from AEGIS, Patriot, TAOM, E-2C, AWACS, ABMOC, AOC, Rivet Joint, Senior Scout, EP-3, TSPI and JTIDS terminal extract (track and link data).

~~A.1.2~~A.19.2 Design

One advantage of WAM is its capability to load track data from the above systems and color-code it by source. Subsequently, tracks can be compared by displaying them "on-top" of each other. Tracking deviations then stand out. WAM also has the capability to display engagements, ESM lines of bearing, and a brief summary of track parameters such as R2, ID parameters, IFF Modes and geographic information.

A.20 Wargame 2000 (WG2K)

A.20.1 Overview

The Wargame 2000 System is the successor to the Advanced Real-time Gaming Universal Simulation (ARGUS), which is a real-time, interactive, discrete event, command and control missile defense simulation. Wargame 2000 is intended to provide a simulated combat environment that will allow war-fighting commanders, their staffs, and the acquisition community to examine missile and air defense concepts of operation (CONOPS). CONOPS includes doctrine, tactics, techniques, and procedures. CONOPS is an integral part of larger combat environment. WG2000 will support CONOPS evaluation through the use of human-in-control experiments and other events. The Wargame 2000 System is intended to provide a robust, flexible, easy-to-use architecture, which incorporates current as well as accommodates evolving weapon characteristics to conduct missile and air defense investigations