Dr. F. Edward Baker, Jr., Mr. James S. Egeland, and Capt. Ed Killinger, USN (Ret)

DISTRIBUTED ENGINEERING PLANT FOR ACHIEVING NAVY & JOINT INTEROPERABILITY

ABSTRACT

On 20 January 1999, under the leadership of the Navy's Battle Force Systems Engineer (SEA05), an Alliance of Naval Sea Systems Command, Space and Warfare Systems Command, and Naval Air Systems Command field activities headed by Naval Surface Warfare Center (NSWC), Dahlgren Division, stood up the Navy Distributed Engineering Plant (DEP). The Navy DEP leveraged the Leading Edge Services (LES-98) and Defense Research and Engineering Network (DREN) Asynchronous Transfer Mode (ATM) Networks to connect geographically dispersed Navy Design and Development Activities, Software Support Activities (SSA), Test and Evaluation (T&E) Facilities, and Training Centers. Integrating, at the laboratory level, actual fleet hardware and tactical computer program loads in a distributed configuration provided the Navy a controlled, repeatable environment in which to, for the first time, fault isolate and verify resolution of Battle Group interoperability problems, and system engineer at the 'system-of-system' and 'family-of-systems' level. A resounding success from 'stand-up', the Navy DEP was quickly recognized by the Department of Defense as an engineering tool to solve Joint interoperability problems.

INTRODUCTION

Warfighting capability being developed and deployed transcends traditional system and ship boundaries. Technology to provide this warfighting capability allowed increasingly complex systems to be developed. However, Navy and Joint combat and BMC4I systems have, generally, been designed and procured as "stand alone" systems or elements. *A disciplined force level systems engineering process has not been required nor employed.* Tactical data Link operational specifications, such as OPSPEC 411 and 516, attempt to ensure that systems are interfaced properly over Link 11 and 16 and are interoperable.

Developmental and operational test and evaluation has been conducted at the system or platform level. For vehicles, such as combatants, carriers, and aircraft, the combat systems and Battle Management/Command and Control, Communications, Computers and Intelligence (BM/C4I) systems have been well integrated and tested "within the lifelines" of the platform at engineering facilities such as the Integrated Combat System Test Facility (ICSTF), San Diego California or Surface Combat System Center (SCSC), Wallops Island Virginia. *The capability to design, engineer, and test for interoperability at a battle group or family of systems level has not existed.*

Additionally, *no overarching force or family of systems level interoperability requirements exist.* Interoperability standards are insufficient to ensure interoperability because of minimum implementation and imprecision in specification of critical functions.

Battle Group/Battle Force (BG/BF) warfare system engineering and design has not been performed on currently fielded systems. The first time system of systems could be tested together was during Fleet exercises, BG work ups, or Fleet Operational Test and Evaluation (FOT&E) events utilizing operational forces.

This caused a crisis when the complexity of systems, the lack of successful integration, and failure of critical systems resulted in an incoherent tactical picture for battle group operators, and the Navy could not deploy two combatants. The two ships did not provided reliable interoperable warfighting capability. Interoperability problems were experienced by operational forces -- Sailors and Marines -- as they performed critical operational training (COMTUEX, JTFEX) and during deployment.

The operational at-sea environment could not provide a disciplined repeatable engineering environment for (1) isolating and root causing problems, and (2) engineering solutions to interoperability problems at the family-of-systems level. Both Navy and Joint combat and BM/C4I systems experienced interoperability problems that degraded the warfighting capability of our deploying or deployed forces. This was evidenced by unit reporting responsibility conflicts, position errors, dual tracks, Identification Friend-or-Foe (IFF) conflicts, and track and track number update errors. The warfighting impact was a confused tactical picture, and weapons and sensors that were not interoperable and that were not being used to effective ranges.

In February 1998, Admiral Reason, Commander in Chief, Atlantic Fleet, opined in a message to the Chief of Naval Operations (CNO) that *"despite admirable efforts ... the acquisition community failed to deliver integrated warfighting capability to our Battle Groups"* (CLF Msg 061415Z Feb 98). In response, the CNO assigned Commander, Naval Sea Systems Command *"central responsibility to address BM/C4I/Combat Systems interoperability problems within the Systems Commands/Program Executive Offices (SYSCOMs/PEOs), and to coordinate resolution with the fleet"*(CNO Msg 021648Z May 1998).

To design, engineer, and test for interoperability at the Battle Group/Battle Force or family-of-system level, the engineering and acquisition communities needed a new and pioneering capability -- a Distributed Engineering Plant (DEP). This DEP capability must (1) move interoperability problem discovery ashore, (2) provide a repeatable controlled environment for evaluation of battle group interoperability problems, (3) contribute to the ability to conduct system level "fault isolation" of problems, and (4) enable validation of operational tactics, techniques, and procedures [work arounds] prior to going to sea. The austere times demand innovation to establish and deliver a DEP capability.

DISTRIBUTED ENGINEERING

Interoperability is the "ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces and to use the services so exchanged to enable them to operate effectively together and achieve the assigned mission"(JCS Pub 1). To engineer or test at the Battle Group/Battle Force level in a shore based environment requires that *real combat system/BMC4I hardware and computer programs* for the systems, units, and forces be connected together and operated as a family-of-systems. Distributed Engineering is the application of engineering functions and activities by connecting "real" hardware, computer programs, and personnel at geographically dispersed locations throughout the country using telecommunication and networking activities (Task Force on Combat Systems

Interoperability Report, Vol. I of II, June 1998). Distributed engineering would permit performing secure engineering functions and activities through the sharing of information, databases, and analytical models by geographically dispersed engineering teams.

Critical elements permitting the design and establishment of a Navy Distributed Engineering Plant were:

a. Crisis level Navy interoperability problems resulting in non-deployable combatants,
b. Navy combat system and BMC4I facilities with real hardware and computer programs,
c. Combat system and C4I community networking via Tactical Data Links using telephone lines,
d. DARPA investment in Asynchronous Transfer Mode (ATM) networking, FASTLANE cryptography technology, and Distributed Interactive Simulation (DIS) protocols,
e. Commercial telecommunication Asynchronous Transfer Mode networks, and
f. FASTLANE very high speed/low latency encryption.

A crisis was created when the Navy could not deploy, as combat ready, the USS VICKSBURG (CG69) and USS HUE CITY (CG66). This created the momentum necessary to move Battle Group/Battle Force family-of-system testing ashore.

The Navy had established a number of In-Service Engineering Activities (ISEAs), Software Support Activities (SSAs), combat system integration and engineering activities, and training activities throughout the United States. These activities contain real hardware and computer programs for combat systems, BM/C4I system, and data links identical to that deployed or being deployed in Battle Group/Battle Force. Some of these activities include: NSWC, Port Hueneme Division (PHD) Integrated Combat System Tests Facility (ICSTF) San Diego, NSWC Dahlgren Division AEGIS Computer Center (ACC), Surface Combat System Center (SCSC) Wallops Island, AEGIS Training and Readiness Center (ATRC), NSWC, PHD Dam Neck, SPAWAR System Center (SSC) San Diego and Charleston System Integration Environment (SIE), and NAWC-AD Pax River

Fundamental distributed networking and

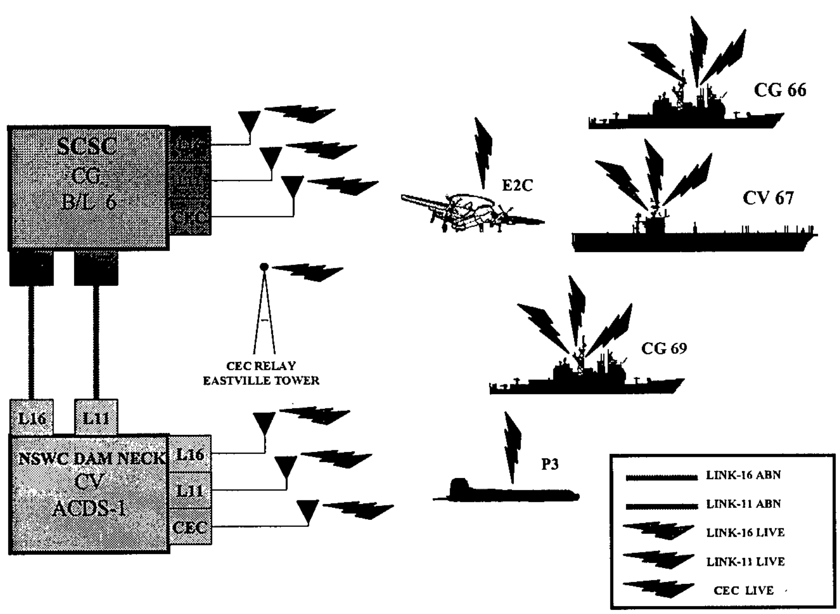

Figure 1. Fundamental Distributed Network Testing circa 1995 - 1998

testing directly applicable to a Navy Distributed Engineering Plant had been conducted by several of these activities. For example, between 1995 and 1998 SCSC, Wallops Island and Dam Neck conducted testing with Link 11 and Link 16 land lines using CEC and fleet assets, see Figure 1.

Additionally, Navy facilities had demonstrated the capability to perform distributed linking of ships, aircraft, land-based test sites, and simulations using the Gateway Terminal Emulator (GTE), AEGIS Broadcast Network (ABN) devices and telephone lines. The testing activity connected ICSTF/SSC-SD, ACC, SCSC, and PHD-DN using Gateway Terminal Emulators and AEGIS Broadcast Network devices, see Figure 2. The C4I community had six years experience using Gateway Terminal Emulator connectivity. Gateway Terminal Emulator devices were in use at 46 Joint/NATO facilities, the Joint Interoperability Test Center (JITC), and in the Ballistic Missile Defense Organization's Theater Missile Defense System Exerciser (TMDSE).

The DARPA Synthetic Theater of War (STOW) program reduced to practice and demonstrated combined use of Asynchronous Transfer Mode Networks, FASTLANE, and Distributed Interactive Simulation communication protocols in a distributed network.

Asynchronous Transfer Mode technology uses small (5.3 byte) fixed length cells to facilitate highly efficient and very fast switching. The small fixed length cells can be easily multiplexed to allow sharing of a common communications infrastructure by different classes of users. The Asynchronous Transfer Mode technology further allows for implementation of Quality of Service (QoS) to ensure the highest priority users get the protection needed, and service on demand as bandwidth and other needs change. Asynchronous Transfer Mode can support very high levels of service (hundreds of megabits) to the end user at the desktop. In a wide area network, Asynchronous Transfer Mode can effectively support shared backbones at gigabit speeds. The KG75 FASTLANE, a high speed Asynchronous Transfer Mode network encryption device,

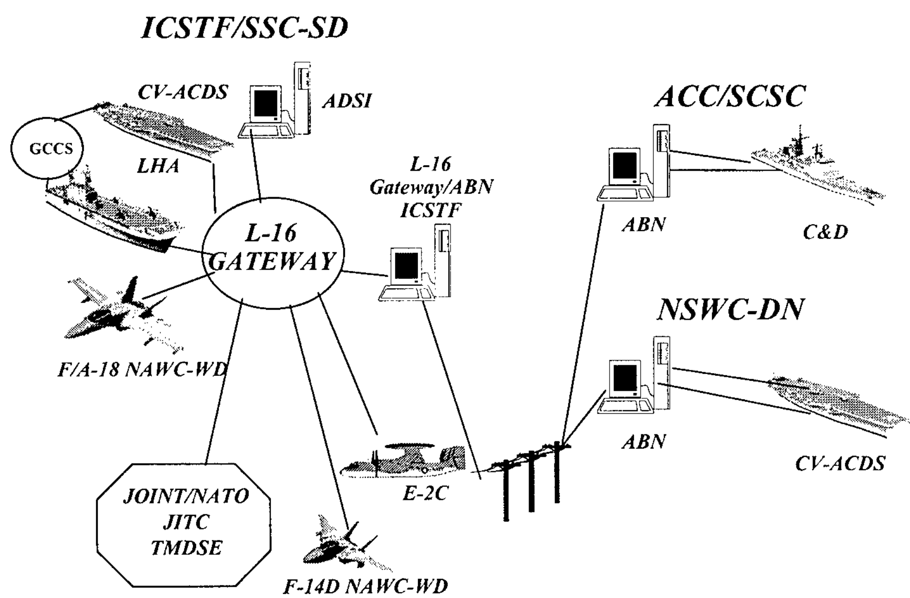

Figure 2. Link 16 Distributed Testing Architecture

introduced in 1997, allowed a transition from static bulk encryption point-to-point links to a dynamic network centric environment. The FASTLANE has a peak throughput of up to 622 Mbps and latency through the encryption device of more than two orders of magnitude less than prior technology.

DISTRIBUTED ENGINEERING PLANT CONCEPT

Conceptually linking together Navy Combat and BMC4I system facilities using a high performance ATM network to establish a Distribute Engineering Plant (DEP) capability involves several main components (Task Force on Combat Systems Interoperability Report, Vol. I and II, June 1998). Figure 3 illustrates the conceptual DEP.

The blue boxes in the middle layer are the actual hardware-in-the-loop (HWIL) systems which represent the actual Fleet combat and C4I systems. These systems include both the hardware and tactical computer programs of the Fleet configuration to the greatest extent possible.

The common environment represented by the upper cloud provides the superset of surface units and friend and foe aircraft [targets] which are visible to all participating combat systems and their sensors. The cloud is essentially the ground truth picture that all combatants interact with from their own perspective and capability. The common environment uses a scenario generator to develop the time dependent location of the targets and Distributed Interactive Simulation (DIS) protocols for distributing entity states to the stimulators.

The stimulators and drivers are existing

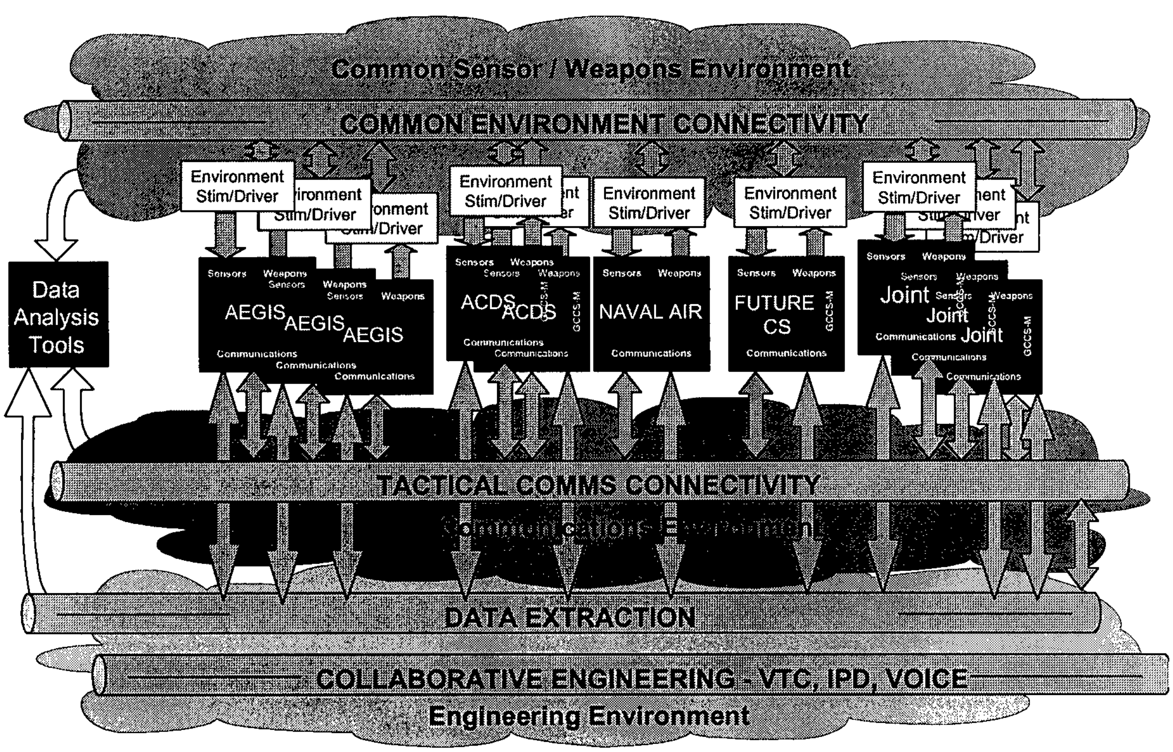

Figure 3. Distributed Engineering Plant Concept

Distributed Interactive Simulation compatible program approved units. They are the conduit by which the HWIL combat systems interact with the common environment. They usually emulate the sensor systems to some extent and are able to interact with the common environment in a manner similar to the real sensor system.

The tactical communications connectivity cloud refers to the requirement to connect the combat systems via the tactical links (Link 11, Link 16, Link 4A) and networks (CEC) that they will deploy with normally. These network connections are the means by which the tactical systems pass their perception of the ground truth.

The data extraction pipeline refers to the requirement to capture and share for analysis the data extracted from the Hardware-in-the-Loop, the ground truth picture of the common environment and the tactical communications nets/links.

A collaborative engineering system is needed for performing engineering, preparing test plans and procedures, and analyzing data over the distributed system.

Finally, data analysis tools and processes are needed to enable analysis of data which is collected across the Distributed Engineering Plant and to compare the combat system perceptions with ground truth of the common environment.

Figure 4a represents the Distributed Engineering Plant with the Asynchronous Transfer Mode network. It illustrates how the ground truth environment and scenario are sent over the ATM network. Distributed Interactive Simulation Protocol Data Units (PDUs) provide the control and sensor tracking information to the remote facilities via the tactical data links. Each platform forwards reports to other platforms via tactical data links [Link 11 & Link 16] over the same Asynchronous Transfer Mode network. Combat system processed results in terms of link messages are compared to the ground truth data and results are analyzed to identify problem areas. The Distributed Engineering Plant provides the

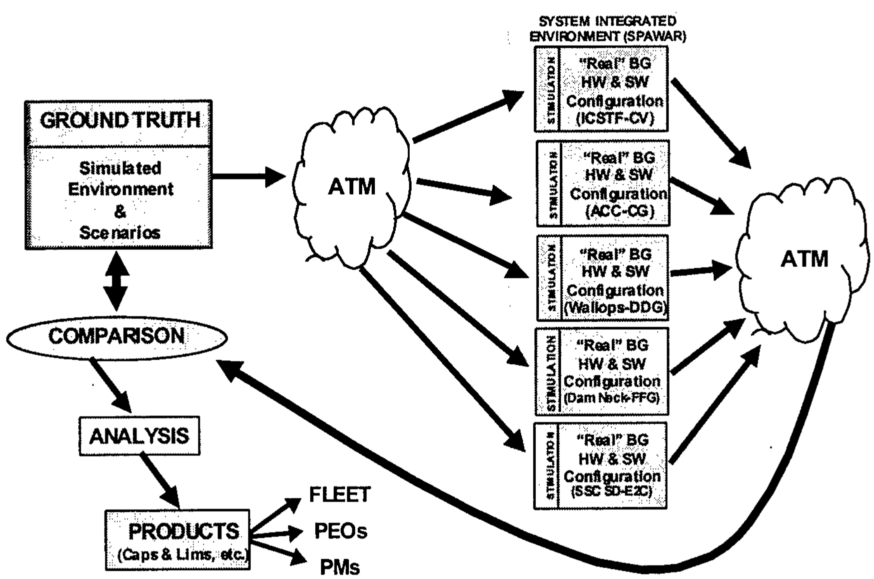

Figure 4a. Distributed Engineering Plant Functional Chart

capability to replicate the Battle Group/Battle Force configurations in a land based repeatable environment that is consistently measurable. Thus, test events are easily repeatable under strictly controlled conditions. Products include (1) engineering quality data, (2) validating the Battle Group Tactical Data Link network setup, (3) developing workarounds for identified interoperability problems, (4) isolation of problems, (5) documentation as Trouble Reports (TRs), and (6) validating Fleet Capability & Limitation documents for training and deployment.

Figure 4b decomposes any one of the brown boxes from Figure 4a and shows the transformation of a typical shipboard configuration to a typical distributed engineering configuration. The radio, Data Terminal Set (TDS) and KG40 have been replaced by the AEGIS broadcast network's Link Data Distribution Device (LDDS) and STU III encryption. The JTIDS terminal has been replaced by the Gateway Terminal Emulator with radio frequency (RF) message path replaced with the Asynchronous Transfer Mode network path. The radar is replaced with the Program Executive Office/Program Manager approved combat system stimulator with its sensor input replaced by Distributed Interactive Simulation entity states over the Asynchronous Transfer Mode Network. The combat system hardware and tactical computer programs [C2P & TDS] are unchanged.

A Distributed Engineering Plant has far more potential than just Battle Group/Battle Force testing. It can be used to: (1) design and develop engineering solutions for TRs for currently fielded systems, (2) verify that the solutions work correctly in a family-of-systems environment, (3) engineer-in interoperability for systems in the design and development phases of the acquisition cycle, and (4) as risk reduction preparing for Battle Group/Battle Force level Fleet Operational Test and Evaluation events.

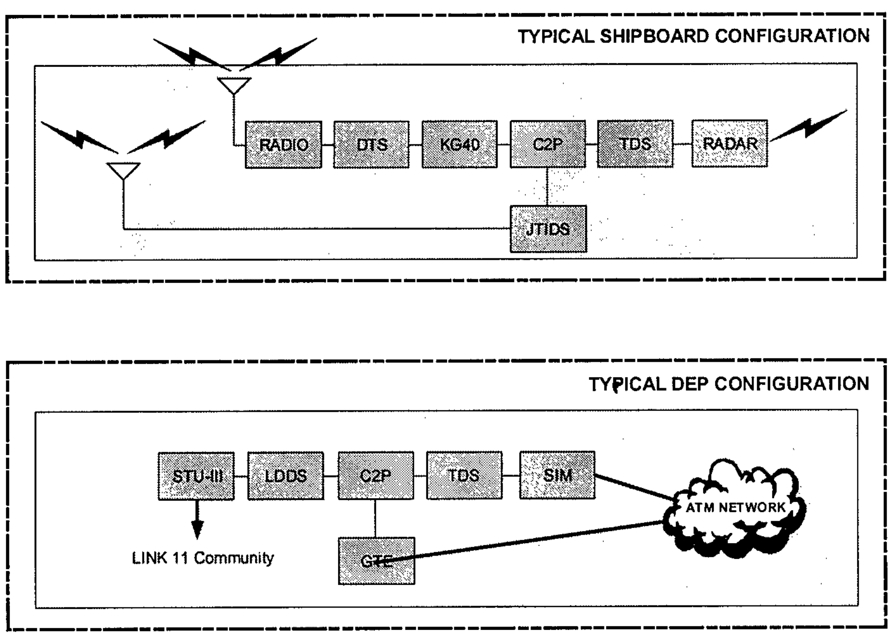

Figure 4b. Example shipboard combat system configuration transformation to distributed engineering configuration

JOHN F. KENNEDY BATTLE GROUP (JFK BG) DISTRIBUTED ENGINEERING PLANT EXAMPLE

Stand-up of the Navy Distributed Engineering Plant started in September 1998 with prototype-Plant multi-site interoperability testing of the KENNEDY Battle Group beginning in January 1999. The initial Distributed Engineering Plant focus has been on the Air Defense mission

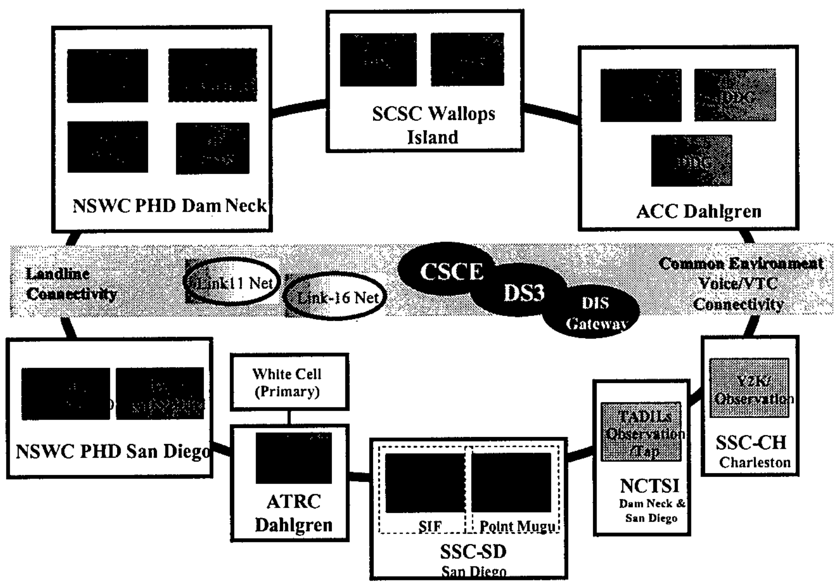

Figure 5a. KENNEDY Battle Group Distributed Engineering Environment

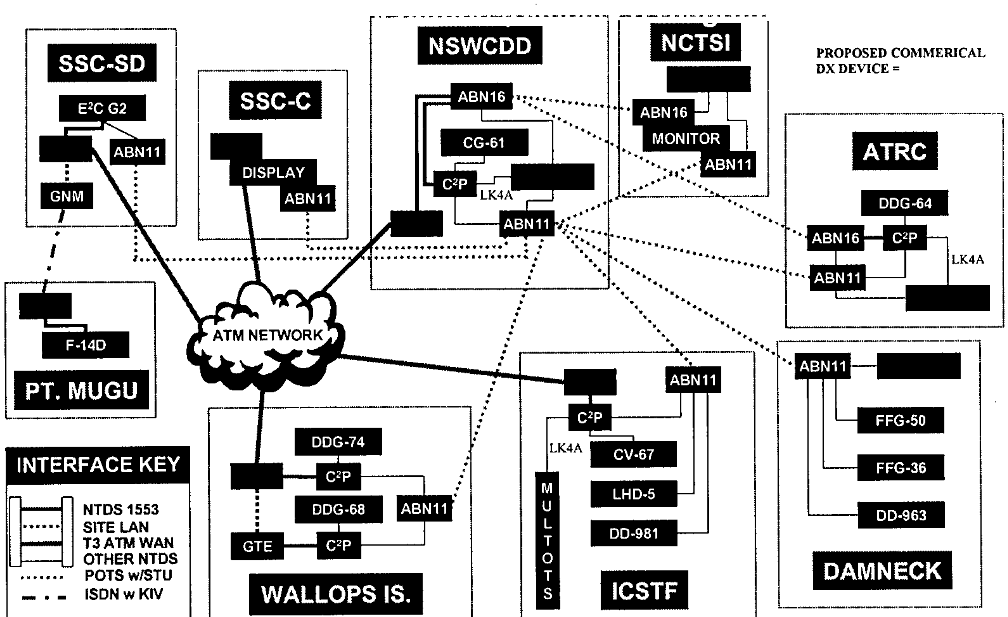

Figure 5b. KENNEDY Battle Group Link Implementation (Simplified Diagram)

As of Dec. 22 98

area. Figures 5a and 5b illustrate the connected sites, combatant combinations at the sites, simulation/ stimulation Common Scenario Control Environment (CSCE), Distributed Sensor Simulation System (DS3), AEGIS Combat System Interface Simulation (ACSIS), and link operating environment. The JFK Distributed Engineering Plant test bed consisted of Naval Surface Warfare Center Dahlgren Division (NSWC-DD), AEGIS Computing Center (ACC), AEGIS Training and Readiness Center (ATRC), Surface Combat System Center (SCSC) Wallops Island, SPAWAR System Center San Diego (SSC-SD) System Integration Facility (SIF), Naval Surface Warfare Center (NSWC) Port Hueneme Division (PHD) ICSTF San Diego, and NSWC PHD Dam Neck test facilities.

To support Battle Group Interoperability Testing an environment was designed that emulates Battle Group operations and composition at ashore facilities. Individual test site configurations replicated the actual KENNEDY Battle Group hardware and tactical computer programs in the loop. A common environment used existing Simulators/Stimulators to provide all sites with a shared realistic sensor picture using Distributed Interactive Simulation protocol. The participating sites were interconnected via an Asynchronous Transfer Mode network that supports the Link 16 tactical data, the common environment, and video teleconferencing communications. Additionally, the Asynchronous Transfer Mode network supports all voice tester-to-tester communications. In the KENNEDY Battle Group prototype-Plant the Link 11 information was passed using conventional telephone lines and STU III cryptography. This was due to the inability of converting AEGIS broadcast network devices to work across the Asynchronous Transfer Mode network and meet scheduled test start dates.

The plant network was validated by conducting "ping" testing through the Asynchronous Transfer Mode network to all Distributed Engineering Plant nodes verifying internet protocol assignments, and conducting end-to-end wide area bandwidth analysis. A typical east coast to west coast round trip Asynchronous Transfer Mode network time (Dahlgren, Virginia to San Diego California) was measured to be 63 milliseconds. Between east coast sites (Dahlgren, Virginia and Pax River, Maryland) that time was measured to be 13 milliseconds. The plant SIM/STIM was validated by verifying that each site individually was Distributed Interactive Simulation capable. Site to site scenarios were passed using Distributed Interactive Simulation Entity State Protocol Data Units until a full up operational scenario verification was conducted with all sites over the Asynchronous Transfer Mode network. The AEGIS Broadcast Network Link 11 sites were validated out using Link 11 message protocols, and the Gateway Terminal Emulator/AEGIS Broadcast Network Link 16 sites were validated using "ping" checks over the Asynchronous Transfer Mode network. Full Link 11/16 open and closed loop tests were conducted. Lastly, a full Distributed Engineering Plant dry run was conducted with scenario execution per test procedures and the data collection process was verified.

Scenarios were developed according to the test procedures that provided:

1. Light to medium target loading with a background of commercial air traffic for tracking, data registration, and identification (ID) testing,
2. Controlled intercept and escort of enemy aircraft with friendly aircraft with variations in IFF and IFF modes,
3. Light to medium target loading in a target rich data link environment for tracking, data registration, identification (ID) testing, multi-Tactical Data Information Link (TADIL) operations, and air control, and
4. Medium target load with commercial air traffic for tracking, identification (ID)

testing, force orders, and weapons coordination.

The scope of the prototype-Plant initial tests and KENNEDY interoperability testing (USS John F Kennedy (CV 67) Battle Force Interoperability Test Plan and Test Procedures; NAVSEASYSCOM, January 1999) was to:

a. Implement, validate, and demonstrate a land based distributed Battle Group capability.
b. Characterize the effectiveness of installed combat systems
c. Assess the impact of baseline upgrades and program problem corrections, and
d. Validate tactics, techniques, and procedures including proposed workarounds for interoperability problems for inclusion in a BG Capability and Limitation document.

The test configuration for KENNEDY was as shown in Table 1.

The seasoned test director for this operation made the following observation: "the Distributed Engineering Plant reproduced, on a daily basis the interoperability issues that plague the Navy – such as track dualing, ID contradictions, track blooming, and inability to reliably control and monitor force engagements. In the long term, the Distributed Engineering Plant will help provide the path to true interoperability as combat systems are drastically redesigned or new ones developed. In the near term, the Distributed Engineering Plant will validate methods of operating with the current limitations and flaws."

The Distributed Engineering Plant provided a controllable repeatable environment enabling fault isolation, facilitating resolution and providing the engineering environment for verification of resolution. This has been conclusively demonstrated in plant operations to date. For example:

(1) Navy's LHD's were reporting a "jumping Participating Unit (PU) and track picture" for over a year prior to Navy Distributed Engineering Plant stand-up. This problem could not be replicated at the Integrated Combat Systems Test Facility (ICSTF) in San Diego or on board ship using the Combat System Test Set (CSTS). However, this anomaly was observed during the KENNEDY Battle Group-Navy Distributed Engineering Plant Battle Group Integration Testing 20 January – 28 February 1999. Both the

Ship Name	Hull Number	Combat System Software	C2P Software	CEP Software
USS John F. Kennedy	CV-67	ACDS BLK1 Lvl 2.1.2	M5R206B03	CEC B/L 2 7.06
USS Monterey	CG-61	AWS 3A.0.8.2	M5R3.07A00	N/A
USS Bataan	LHD-5	ACDS BLK0 Lvl 10	N/A	N/A
USS Carney	DDG-64	AWS 5.0.Z5	M4R4.04B04	N/A
USS The Sullivans	DDG 68	AWS 5.3.6.3	M5R3.07A00	N/A
USS McFaul	DDG-74	AWS 5.3.6.3	M5R3.07A00	N/A
USS Spruance	DD-963	CDS DD963/B6WV8R10/0009A	N/A	N/A
USS Hancock	DD-981	CDS DD963/B6WV8R10/0009A	N/A	N/A
USS Underwood	FFG-36	CDS C4.0/L13/FFG7/003X	N/A	N/A
USS Taylor	FFG-50	CDS C4.0/L13/FFG7/003X	N/A	N/A

Table 1. JFK Test Combat System and Command Communication Processor (C2P) Test

USS UNDERWOOD (FFG 36) and USS TAYLOR (FFG 50) Participating Unit positions jumped over 800 miles from their correct location as observed at USS BATAAN (LHD 5). [Their positions were correct and stable as observed on USS KENNEDY (CV 67) and USS JOHN HANCOCK (DD 981)]. When Ship Gridlock System/Automatic Correlation (SGS/AC) was placed in the "transparent mode", Participating Unit position would remain correct. Logic analyzer data extraction at the Link Data Distribution Device (LDDS 11) – Ship Gridlock System/Automatic Correlation interface indicated a single M1 being transmitted from the USS UNDERWOOD (FFG 36) as the only deviation from OPSPEC 411. Extensive discussions with Ship Gridlock System personnel indicated potential misunderstanding of data values for Advance Combat Direction System (ACDS) enabling "Extended Range". A follow-on meeting at NSWC, Dam Neck, the week of 15 February 1999, with Advance Combat Direction System and Ship Gridlock System personnel did not produce exact problem isolation, but Dam Neck did produce a patch for the singular M1 anomaly. This patch was inserted and the Participating Unit jumping problem ceased. The patch was subsequently inserted and removed to ensure Participating Unit jumping followed the non-patch configuration. Navy Distributed Engineering Plant test personnel recommended further system engineering discussions and investigation by Program Executive Office personnel to ensure a complete understanding of the problem and the "Extended Range" enabling sequence.

(2) The FFG-7 Class Link-16 drop track messages was a classic example of a spurious Battle Group/Battle Force interoperability problem observed by the fleet but not understood sufficiently by the technical community to isolate the root cause. It had not become a high profile issue because standard OPTASK guidance restricted the FFG to report-by-exception. Repeatable, controlled tests in the Navy Distributed Engineering Plant revealed that the FFG software had been coded to an outdated version of MIL-STD-6011/OS411.

NAVY DISTRIBUTED ENGINEERING PLANT ACTIVITIES

Navy's Distributed Engineering Plant has been a resounding success at moving Battle Group/Battle Force testing ashore. In CY99, 'Plant' employment encompassed the spectrum of acquisition activities -- from Test and Evaluation of fielded systems to system and element tests of Baseline Upgrades and new programs in a multi-system environment.

- Battle Group Integration Tests
  - KENNEDY Battle Group
  - EISENHOWER Battle Group
  - WASHINGTON Battle Group
  - LINCOLN-TRUMAN Battle Groups

- Battle Group Y2K Tests
  - KENNEDY Battle Group
  - CONSTELLATION Battle Group
  - EISENHOWER Battle Group
  - STENNIS Battle Group
  - WASHINGTON Battle Group

- System/Element Tests
  - AEGIS Baseline 5.3.7
  - Cooperative Engagement Capability (CEC) IV&V (In progress)
  - CEC Operational Evaluation (OPEVAL)
  - Satellite TADIL J (S TADIL J)

WHAT IS A JOINT DISTRIBUTED ENGINEERING PLANT?

It was envisioned that the Joint Distributed Engineering Plant, like the Navy Distributed Engineering Plant, would be an organized assembly of existing Service/ Joint combat system engineering sites (including Design and Development Activities, Software Support Activities, Test and Evaluation Facilities, and Training Centers) disparately located around the country, interconnected by emulated tactical data links, and stimulated in a prescribed and predictable manner. Some of the important attributes of the sites that would be part of a Joint Distributed Engineering Plant are:

- They have at least an initial focus on Joint Air Defense.
- They contain tactical hardware and computer programs, and are not large-scale simulations of actual systems.
- They contain, in aggregate, at least one of each of the relevant or critical systems to the warfare mission of focus (Joint Integrated Air Defense, in the near term).

Functionally speaking, a fundamental purpose of a Joint Distributed Engineering Plant would be to provide an environment suitable to conduct theater level systems and system-of-systems interoperability tests and experiments. These would be conducted to determine that systems about to be fielded as

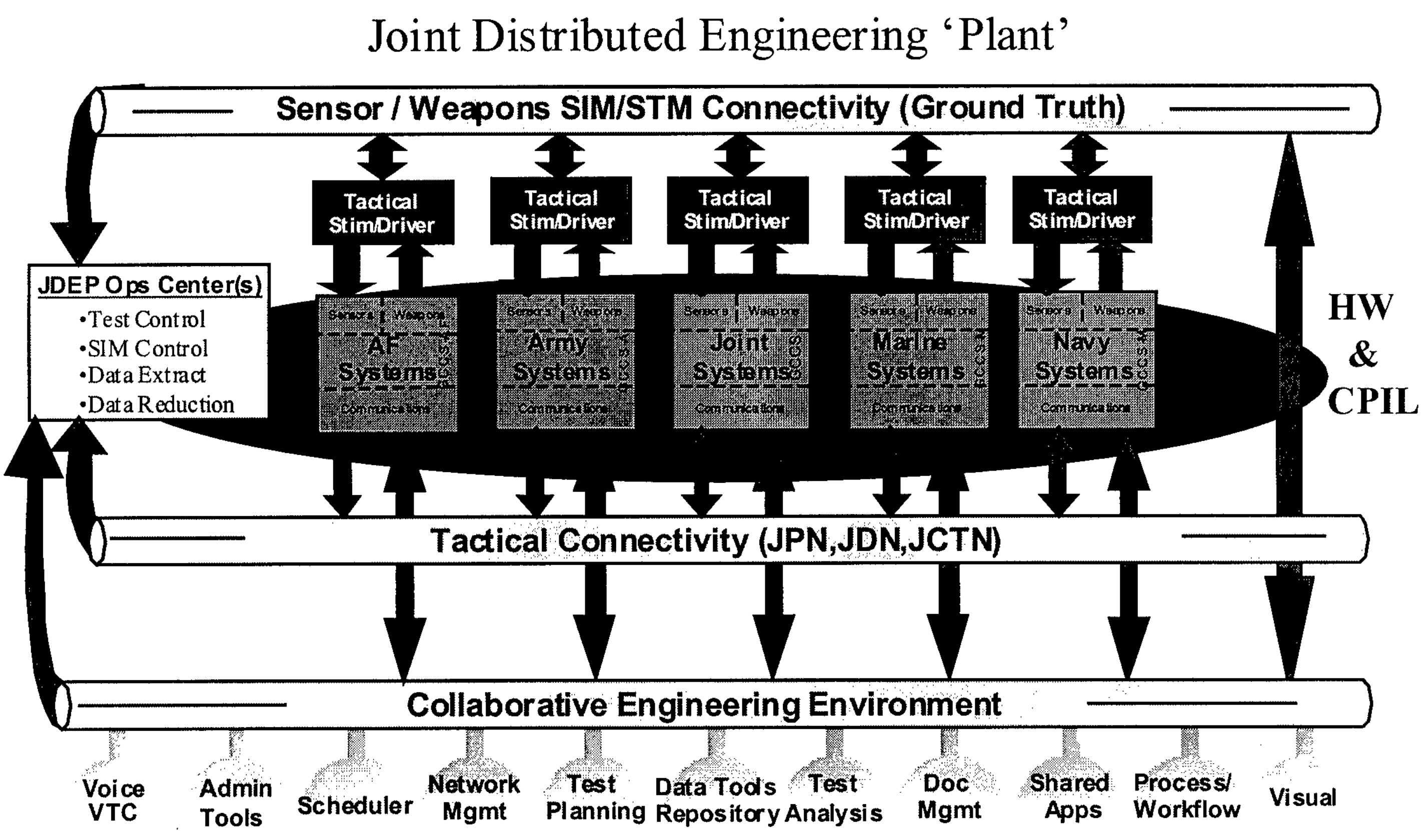

Figure 6. Joint Distributed Engineering Plant

a unit or set of units could function together to provide the operational commander a capability as a system rather than a set of components that do not interact well.

Key attributes of the necessary environment are repeatability and suitable (given that the Distributed Engineering Plant is not in the Battlefield) replication. Even if the time and equipment were available to conduct the necessary tests or experiments in the field, it would not be possible to repeatedly duplicate the conditions in a controlled fashion to fault isolate, determine resolution, and validate the value of design or other changes made to fix problems.

The concept of linking together a Joint Distributed Engineering Plant, similar to the Navy Distributed Engineering Plant shown in Figure 3, would involve the establishment of several components, as shown in Figure 6.

WHY A JOINT DISTRIBUTED ENGINEERING PLANT (JOINT DEP)?

Real-world operations, exercises, and evaluations, e. g., CENTCOM TADIL Improvement Program (1997, 1998), Adriatic Operations (1999), U.S. Forces Korea (1999), Joint Air Defense Organization/Operation (JADO)/Joint Engagement Zone (JEZ), and All Service Combat Identification Evaluation Team (ASCIET) evaluations (1992 -- present), continue to highlight joint warfighting capability shortfalls:

- IFF/SIF conflicts
- Erratic tracking
- Dual/multiple track designations
- Misidentification/Track ID conflicts
- Reporting responsibility (R2) conflicts
- Frequent track number changes and swaps
- Reliance on voice de-confliction
- Operator overload

In the aggregate, these shortfalls make the Joint Theater Air and Missile Defense (JTAMD) family-of-systems 'Not Interoperable'. Some related causes are:

- Stovepipe systems not compliant with technical architecture framework for information management and JTA. (source: USJFCOM Integrated Priority List (IPL))
- Automated identification processing differences
  - IFF/SIF association
  - Multi-Source Integration

  (source: USJFCOM IPL/ JTAMD Master Plan 98B)
- Poor tracking performance and inaccurate assignment of Track Quality (TQ), resulting in improper assumption/retention of Reporting Responsibility (R2) (source: OASD/C3I)
- Correlation/de-correlation algorithm differences (source: OASD C3I & JTAMD MP 98B)
- JTAMD Family of Systems use different correlation algorithms to evaluate identical tracks. (source: ASCIET 97 Results)
- Time latency and poor correlation contributes to multiple tracks on single targets. (source: JTAMD MP 98B)

From this abbreviated listing it is clear that Joint interoperability problems, as with Navy, are not just interface issues resulting from incorrect implementation or interpretation of system interface specifications, although those types of errors do exacerbate the problems. They are more fundamental and complex. Again, there is missing Joint force level system engineering and analysis work associated with identifying and testing the performance characteristics that family-of-systems must

have to support when constructing a Single Integrated Air Picture (SIAP).
To make progress toward significant reduction or elimination of the issues currently plaguing the Joint air picture, experiments and tests must be repeatable and controllable. Effects and interactions that were not anticipated are very likely, leading to the need to rework the data collection and some test procedures to assure an adequate understanding of cause and effect. This repeatable and controllable environment cannot be obtained using live targets and operational forces. Similarity is all that can be expected, and that is not enough to support the required engineering.

Interoperability testing to date for Joint Integrated Air Defense has predominately been focused on message fields and data link Operational Specification (OPSPEC) compliance. These are certainly important, but are not sufficient to give confidence that the combat systems, when operated together, will perform as a whole. In Joint Integrated Air Defense the air picture issues are located in the code of the software in the combat systems, not the data links; for this reason a broader view of interoperability is required.

A Joint Distributed Engineering Plant would provide, for the first time, the environment to enable disciplined systems engineering and testing at the Joint Force-level.
From a systems engineering perspective, future platform and system tradeoffs must be made in the context of the aggregation of platforms in a Joint Force system. From a testing perspective, a Joint Distributed Engineering Plant would provide a *repeatable, controlled environment* for evaluation of Joint Force-level interoperability problems - - enabling the engineer to determine 'why', vice just replicating interoperability problems - - and recommend 'workarounds' and 'fixes'.

Lastly, a Joint Distributed Engineering Plant would enable Joint Forces to validate operational Tactics, Techniques and Procedures prior to deployment. (Joint Engineering Task Force Final Report, Vol. I – III, JTAMD, November 1999)

THE BUILDING BLOCKS

One of the building blocks of the Joint Distributed Engineering Plant would be, of course, the Navy's Distributed Engineering Plant. But there are a number of other Service and Joint initiatives from which to leverage.

The Theater Missile Defense System Exerciser (TMDSE), shown in Figure 7, is a

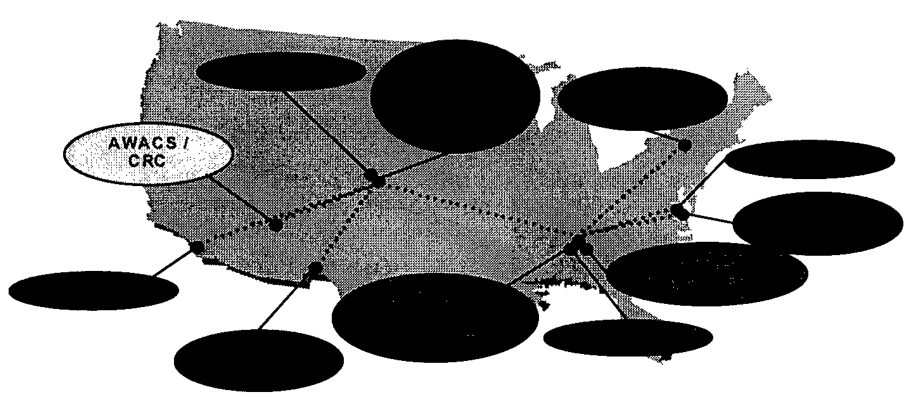

Figure 7. Theater Ballistic Missile Defense System Exerciser (TMDSE)

Ballistic Missile Defense Organization (BMDO)-developed high-fidelity test tool. Theater Missile Defense System Exerciser uses a dedicated T-1 point-to-point communications architecture, in a star topology, to net together existing hardware and simulations. Connectivity is provided at stand-alone Design and Development Activities, Software Support Activities, Test and Evaluation Facilities, and Training Centers to identify Joint Theater Air and Missile Defense interoperability problems at the JTAMD family-of-systems level. The Joint National Test Facility (JNTF), at Schriever AFB, CO, is normally the operational test exerciser controller. The following Joint and Services facilities are netted together:

<u>Army</u>
Huntsville (Redstone Arsenal), AL for PATRIOT and THAAD elements

Azusa, CA (Aerojet) for Joint Tactical Ground Station (JTAGS).

Fort Bliss, TX for operational PATRIOT and THAAD elements.

<u>Navy</u>
NSWC, Dahlgren, VA for AEGIS Weapon System (AWS).

<u>USMC</u>
Syracuse, NY, US Marine Corps TBMD elements including the AN/TPS-59 Radar Environmental Simulator and the Air Defense Communications Platform (ADCP).

<u>Air Force</u>
Schiever AFB, CO Aerospace Fusion Center (AFC)

Kirtland AFB, NM (Theater Air Command and Control Facility) Control and Reporting Center (CRC) and AWACS (E3 SIM).

<u>Joint</u>
Joint National Test Facility, Schiever AFB

Theater Missile Defense System Exerciser is used early in the acquisition cycle for design and development and is of a higher fidelity than Navy Distributed Engineering Plant. Theater Missile Defense System Exerciser provides realistic quantities and types of Theater Ballistic Missiles (TBMs) and Air Breathing Targets (ABTs) threats and man-made and natural environments. Threat stimuli (e.g., Radar Cross Section (RCS), Infra-Red (IR), etc.) is injected into Service tactical sensor's digital data processors in

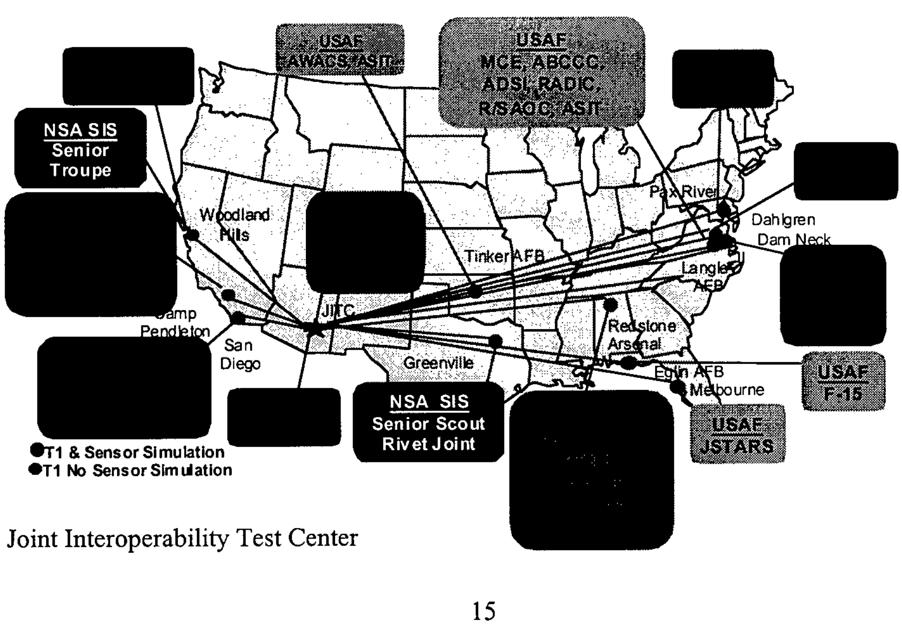

Figure 8. Joint Interoperability Test Center (JITC)

real-time. Update rates and timing match tactical interfaces. Integration and interoperability are assessed when operators and systems respond to the threat environment. Threats and defensive systems interact dynamically through their BM/C4I as they would in a real deployment situation using only an emulated Joint Data Network (Link 16).

The Joint Interoperability Test Center (JITC) at Fort Huachuca, AZ, as shown in Figure 8, uses the Joint Tactical Data Link Laboratory (T1 and Integrated Services Digital Network (ISDN))-based network with sensor simulation and secure tactical/voice communications to conduct interoperability certification testing as shown in Figure 8.

The network is primarily used for Joint Tactical Communications certification. Communications is accomplished via dedicated T1 links. TADIL J is distributed using the Gateway Terminal Emulator (GTE) tool. The Joint Interoperability Test Center operates the Central Test Facility (CTF) at Ft. Huachuca. Remote Test Facilities (RTFs) are located at various support centers, including a new Remote Test Facility in Iceland for the Icelandic Air Defense System and a JSTARS SSF RTF to be located on Robins AFB in Georgia. There are a number of existing Department of Defense network resources with connectivity at several of the potential Joint Distributed Engineering Plant sites that offer the features and characteristics required for implementation of the underlying network support needed for Joint Distributed Engineering Plant tools and functions. The Defense Research and Engineering Network (DREN), the Navy Distributed Engineering Plant, Leading Edge Services (LES), and Federated Battle Labs (FBL) are all Asynchronous Transfer Mode-based Wide Area Networks with Internet Protocol (IP) and Asynchronous Transfer Mode services at the individual sites. Sites in these user communities can be bridged from one network or service to another. Extensions to or shared use of these existing services potentially could meet Joint Distributed Engineering Plant needs. Negotiations for shared use or bridging of any of the networks indicated, though technically feasible, would depend on existing loading, service models and charter. The Navy Distributed Engineering Plant successfully used this sharing model and operates on a combination of Leading Edge Services (primary service), Defense Research and Engineering Network (shared at NSWC, Dahlgren and NAWC, Pax River), and dedicated extensions (Surface Combat Systems Center, Wallops Island). Where it makes sense, and where the Joint Distributed Engineering Plant can get agreement across communities, the Joint Distributed Engineering Plant could employ a combination of Leading Edge Services and Defense Research and Engineering Network or other services using the model that is working for the Navy Distributed Engineering Plant today.

CONCLUSION

Distributed Engineering at the Battle Group/Battle Force and family-of-systems level for certification testing, development, and risk reduction has been demonstrated using advanced Asynchronous Transfer Mode networking technology and FASTLANE encryption devices. The Navy Distributed Engineering Plant, using real hardware and computer programs, is addressing interoperability issues through a disciplined engineering process. The current Distributed Engineering Plant functions with "perfect" connectivity, open ocean without land masking effects, and without weather or environmental effects. A challenge will be to add these effects into the Distributed Engineering Plant as well as developing the capability for the Distributed Engineering Plant to be operated in conjunction with real fleet assets.

Since we fight jointly, we must engineer interoperability jointly. The foundation building blocks are in place and the design for establishing a Joint Distributed Engineering Plant has been developed by the Joint Engineering Task Force. There will be many challenges to putting a Joint Distributed Engineering Plant in place. The greatest challenges are not technical. They are bringing about cultural change, scheduling the engineering sites, and availability of talented engineering people. The warfighting pay-off of a Joint Distributed Engineering Plant will be great.

REFERENCES

CINCANTFLT Msg. 061415Z Feb 98; Subj: Battle Group Interoperability

CNO Msg. 021648Z May 98; Subj: Battle Group Interoperability.

Distributed Engineering Network Task Force Report, Vol. I – II, NAVSEA, 11 June 1998.

USS John F Kennedy (CV 67) Battle Force Interoperability Test Plan and Test Procedures; NAVSEASYSCOM, January 1999

Joint Engineering Task Force Final Report, 30 November 1999; Vol. I – III, JTAMDO, November 1999.

Dr. F. Edward Baker, Jr., PE, is a Distinguished Engineer in the Theater Warfare Systems Department at the Naval Surface Warfare Center Dahlgren Division. He has advance degrees from Virginia Polytechnic Institute & State University and Massachusetts Institute of Technology, and is a graduate of the Naval War College. He has served as: Assistant Director for Science and Technology to the Chief of Naval Operations (CNO), Technical Advisor to the Assistant CNO for Surface Warfare, and as Technology Director for the Program Executive Officer (Theater Air Defense). Dr Baker most recently served as the Executive Secretary of the Joint Engineering Task Force: Joint Distributed Engineering Plant.

Mr. James S. Egeland, is the Director, Warfare Assessments (SEA53D) in the Warfare Systems Directorate (SEA53), Naval Sea Systems Command. He is a graduate of the Defense Systems Management College Program Manager Course and has been at the forefront of Navy's systems engineering and Battle Group Certification initiatives. Mr Egeland is the Program Manager, Navy Distributed Engineering Plant.

Capt. Ed Killinger USN (Ret), a graduate of the U.S. Naval Academy, obtained his Masters in Systems Acquisition Management at the Naval Post Graduate School, Monterey. In his military career he served on a number of Guided Missile Cruisers and Destroyers, commanding the USS PREBLE (DDG-46) and the USS HORNE (CG-30). His last assignment was as Director, Anti-Air Warfare (OP-75) on the Director, Naval Warfare (OP-07) staff. He most recently served as a member of the Navy Task Force on Combat System Interoperability and subsequently supported the Joint Engineering Task Force: Joint Distributed Engineering Plant. He is currently associated with Computer Systems Center, Inc. (CSCI).

The authors would like to recognize the invaluable contributions of Mr. Tom Pendergraft and Mr. Norm Coscia of NSWC, Dahlgren to the development of this paper.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 074-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	21 March 2000	Symposium Paper 21-23 March 2000

4. TITLE AND SUBTITLE

Distributed Engineering Plant for Achieving Navy and Joint Interoperability

5. FUNDING NUMBERS

6. AUTHOR(S)

Dr. F. Edward Baker Jr., James S. Egeland, Edwin E. Killinger, Capt. USN (Ret)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Sea Systems Command (SEA 53)
2531 Jefferson-Davis Hwy
Arlington, VA 22242-5160

Computer Systems Center, Inc.
6225 Brandon Ave., Suite 520
Springfield, VA 22150-2519

8. PERFORMING ORGANIZATION REPORT NUMBER

N/A

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Naval Surface Warfare Center
Dahlgren Division
17320 Dahlgren Road
Code N10
Dahlgren VA 22448-5100

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

N/A

11. SUPPLEMENTARY NOTES

Prepared for the Engineering the Total Ship (ETS) 2000 Symposium held in Gaithersburg, Md. at the National Institute of Standards & Technology and sponsored by the Naval Surface Warfare Center & the American Society of Naval Engineers

12a. DISTRIBUTION / AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
Approved for public release; Distribution is unlimited	A

13. ABSTRACT ***(Maximum 200 Words)***

On 20 January 1999, under the leadership of the Navy's Battle Force Systems Engineer (SEA05), an Alliance of Naval Sea Systems Command, Space and Warfare Systems Command, and Naval Air Systems Command field activities headed by Naval Surface Warfare Center (NSWC), Dahlgren Division, stood up the Navy Distributed Engineering Plant (DEP). The Navy DEP leveraged the Leading Edge Services (LES-98) and Defense Research and Engineering Network (DREN) Asynchronous Transfer Mode (ATM) Networks to connect geographically dispersed Navy Design and Development Activities, Software Support Activities (SSA), Test and Evaluation (T&E) Facilities, and Training Centers. Integrating, at the laboratory level, actual fleet hardware and tactical computer program loads in a distributed configuration provided the Navy a controlled, repeatable environment in which to, for the first time, fault isolate and verify resolution of Battle Group interoperability problems, and system engineer at the 'system-of-system' and 'family-of-systems' level. A resounding success from 'stand-up', the Navy DEP was quickly recognized by the Department of Defense as an engineering tool to solve Joint interoperability problems.

14. SUBJECT TERMS	15. NUMBER OF PAGES
Distributed Engineering; Asynchronous Transfer Mode; ATM; Networks; Combat System/BMC4I; Interoperability; Test & Evaluation	17
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102