NAVAL SEA SYSTEMS COMMAND

Distributed Engineering Plant





HISTORY, OVERVIEW AND ACCOMPLISHMENTS

NAVSEA
NAVAL SEA SYSTEMS COMMAND

INTRODUCTION

In the past decade, the Fleet has seen a significant growth in tactical networking capabilities such as LINK-11, LINK-16 and Cooperative Engagement Capability (CEC). These capabilities are enabling Battle Groups consisting of many platforms including ships, submarines and aircraft to increasingly operate as a single warfighting system. At the same time, this level of integration of previously independent platforms has lead to interoperability problems within the Battle Group. Systems engineering discipline points to the need for a land-based Battle Group testbed as one tool to help address these interoperability issues while engineering and certifying emerging Battle Group capabilities. The Navy Distributed Engineering Plant (DEP) has been assembled to address the need for a shorebased test bed to aid in the development of integrated, interoperable Naval Battle Groups, as well as future Joint battleforces.

BACKGROUND

INTEROPERABILITY. The rapid, accurate exchange and display of tactical and strategic data is the great force multiplier that enables our combat forces to operate as a single integrated fighting force. Interoperability is achieved when each ship and aircraft in the force can exchange tactical and strategic information smoothly, quickly, and reliably with every other platform in the force so that each platform has the same coherent tactical picture.

With the formation of the earliest naval flotillas interoperability took the form of simple communications between ships. These communication methods generally consisted of semaphores, lanterns and other signaling devices in the hands of human operators. They were restricted by environmental factors such as fog, darkness and line-of-sight, procedural problems such as message formats and definitions as well as general training and interpretation issues. The advent of radio in the early 20th century overcame many of the environmental problems of previous methods, introduced several new environmental problems and is still subject to many of the classic procedural and training interoperability issues.

In the mid-20th century computer systems began to appear onboard ships and took on increasingly important functionality in support of shipboard missions. Over time various computer systems were linked to each other within a ship and finally computers on different ships linked to each other as well as to airborne, submarine and shore-based platforms. Today, inter-computer connectivity between ships or any group of platforms has become mission-critical and various interoperability issues that can impact the mission of the platform and the Battle Group have accompanied each expansion in connectivity.

Even early attempts to connect computer systems within a ship experienced interoperability problems. These problems were often caused by procedural and training deficiencies, with interface specification and interpretation as a key contributor. These problems have been overcome or mitigated by implementing systems engineering discipline, accompanied by rigorous intra-platform integration and testing. Today these disciplines are usually supported by several dozen stand-alone land-based combat systems that faithfully replicate the computer hardware, computer program and support equipment configuration of the

ship combat system. These stand-alone facilities enable development, integration and validation of complex systems within a controlled, repeatable environment.

Interoperability between ships and other units of a naval Battle Group has often fallen outside of the scope or budget of any one program or agency. As this Battle Group-level interoperability has become critical to the mission of the Battle Group the need to apply systems engineering and systems development practices to the entire Battle Group has become apparent. The need for a shore-based Battle Group testbed, as a tool for Battle Group systems integration and testing, has become critical.

DEP CONCEPT DEVELOPMENT

In February 1998, the Fleet reported concerns regarding interoperability failures among combat systems recently installed in deploying Fleet units – resulting in two modern combatants tied to the pier during their Battle Group deployment. A great deal of Fleet time during the final six months prior to Battle Group deployment was being consumed with shipboard and Battle Group "debugging" of systems at the expense of valuable Fleet training time.

In March 1998, the Chief of Naval Operations assigned to the Naval Sea Systems Command (NAVSEA) the responsibility to address combat systems interoperability problems across BMC4I/combat systems, and to coordinate resolution with the Fleet.

In April 1998, NAVSEA formed the Task Force on Combat System Interoperability to study the interoperability crisis and provide recommendations for solutions. In May 1998, the Task Force was formally tasked to determine the feasibility and cost of using a land based distributed engineering plant to support design, development, test, and evaluation of interoperability of battle force systems.

In June 1998, the Task Force on Combat System Interoperability reported that the establishment of a Distributed Engineering Plant (DEP) was technically feasible, but organizationally difficult because of the diverse group of organizations and elements involved. The Task Force also emphasized that a Distributed Engineering Plant is only a tool to enable good design decisions earlier in the acquisition process.

Following the Task Force Report the collection of government activities represented in Figure 1 formed a cooperative effort known as the Navy Alliance. The Navy Alliance made up of surface, air, subsurface, and C4ISR components crosses all Navy Systems Commands (SYSCOMS). The initial purpose of the Navy Alliance was to develop a proposal for the establishment and implementation of a Navy DEP. The DEP concept, as drafted by the Task Force and developed and engineered by the Navy Alliance is described in the following sections.

Figure 1 The Navy Alliance

DEP CONCEPT OVERVIEW
- Combat Systems: The DEP Foundation

The DEP is founded on the existence of the shorebased combat system sites mentioned earlier in this text. These combat system sites have been built to replicate the hardware, computer programs, connectivity and environment of the ship and aircraft combat systems to the maximum extent possible. The DEP basically extends this concept to the Battle Group level by interconnecting these combat system sites in order to replicate a Battle Group.

Given that the DEP is founded on shorebased combat systems, understanding the DEP begins with an understanding of a basic Combat System. The combat system consists of many key elements tightly integrated to form a system. As illustrated in Figure 2, for the purposes of this discussion, the core combat system is made up of four main functional groups.

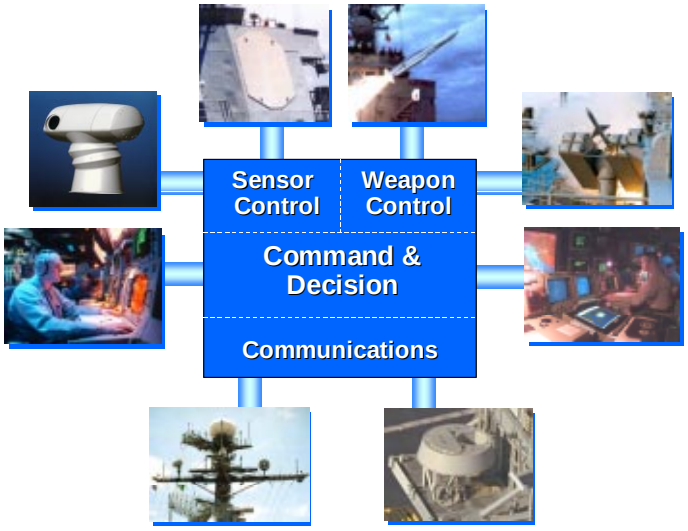

Figure 2 Combat System Functional Groups

In the upper left portion of Figure 2 is a sensor suite consisting of transmit and/or receive devices plus computers to control the sensor and process data. These systems search well beyond the range of human senses in many environments and many spectra using passive and active means to detect friend and foe alike. To the right is a weapons suite consisting of weapons, launchers and weapons control computers to manage scheduling, coordination and launch processing.

Central to the combat system are computer systems to perform Command and Decision (C&D) processing including databases, decision aids and tactical Man-Machine Interfaces (MMI). These systems take the input from various sensors and apply various filters, rules and associations to the data to give the human operators the most complete and accurate information for situational awareness and decision-making.

And finally in the lower portion of Figure 2 are tactical communications systems consisting of processing and control computers plus the associated transmit and/or receive devices. These systems primarily enable the sharing of commands, data and information between the combat system and local and remote systems. At many levels, sensor data as perceived by the combat system elements is shared over these systems.

The four key functional groups of combat systems elements described to this point are for the most part common to all combat systems onboard all combatants in the air, surface and subsurface Navy as well as the combatants of any Service. The mix of systems and subsystems within a functional group varies widely between combatant types depending on the mission of the combatant.

Shorebased combat system development, integration and test facilities generally replicate all of the hardware and computer programs represented by the large blue box in Figure 3. Wide variations in the scope of this replication do exist at the interfaces of the box. For example, some sites do include a live radar that radiates to the atmosphere or that is stimulated by radio frequency horns. Other sites have actual weapon launcher equipment and inert operational missiles.

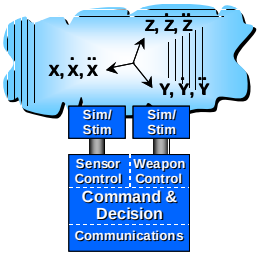

Figure 3 Combat System Sim/Stim

As depicted in Figure 3, any weapon, sensor or system not available to a shorebased combat system is emulated via a simulation or a stimulator (sim/stim). In addition, the sensor and weapon sims/stims generate a common environment representing the real world and entities within it. For Air Warfare this virtual world comprises at least the 3-D atmosphere while entities can include ships, aircraft, missiles, satellites, clouds, etc. Entities possess many of the attributes

of a real world object such as position, velocity, size, radar cross-section, IR emissivity, vulnerability, etc. In this manner, a shorebased combat systems' simulated sensor can detect an entity (such as a threat aircraft), command and decision elements decide to engage the threat, the weapons suite launches a simulated weapon against the threat and the simulated sensor will detect the intercept. The entire sequence is performed within a controlled, repeatable environment under the close scrutiny of engineers and developers.

By assembling real hardware-in-the-loop elements along with their associated computer programs and by emulating the world external to this assembly with appropriate fidelity sim/stim, a majority of a combat systems' functions can be fully exercised ashore. For instance, an operator sitting at a console of a shorebased combat system will see the same tactical display and information as an operator at sea. In many cases, certain functionality can only be fully exercised ashore. For example, subjecting a combat system to a mass raid of hundreds of simultaneous, diverse, inbound threats can only be performed in a shorebased environment. In this manner the ability of the combat system to handle the same type of battle can be fully tested and quantified before the ship is put in harms' way.

DEP CONCEPT OVERVIEW
- Pulling the Pieces Together

The DEP facilitates the federation of many of these shorebased combat systems across country in the following manner: First, candidate shorebased combat systems are identified and cataloged along with their basic capability, configuration and associated sim/stim capability. In Figure 4 these combat systems and their sim/stim are represented by the boxes in the middle layer. Blue boxes such as AEGIS and Advanced Combat Direction System (ACDS) represent systems currently in the DEP. Purple boxes such as Ship Self Defense System (SSDS) and Common Command & Decision (CC&D) represent systems that will join the DEP in the future.

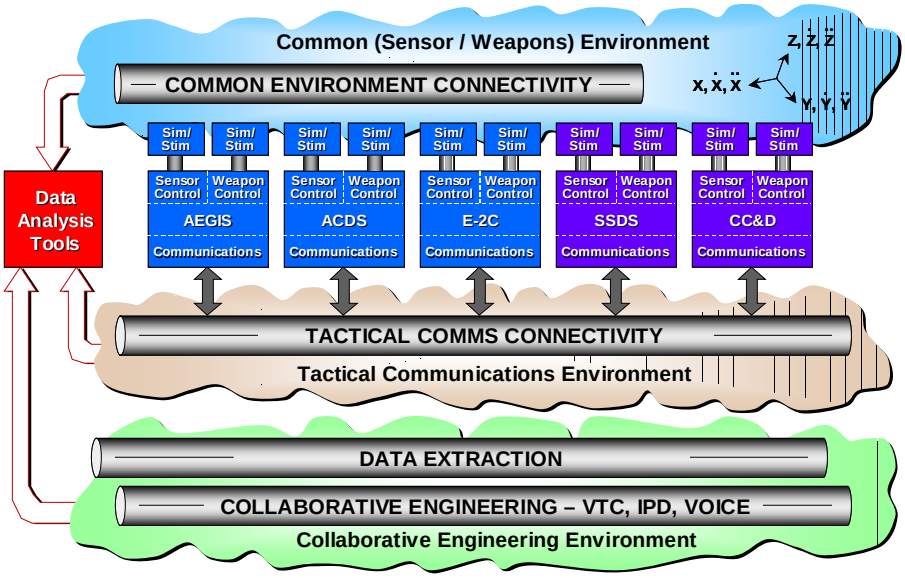

Figure 4 Assembling the DEP Architecture

A Common Environment represented by the blue cloud is created and shared by all combat systems. This environment is created using Distributed Interactive Simulation (DIS) Protocol Data Units (PDUs) that describe all the attributes of an entity. The common environment is shared by passing all PDUs over a high-speed network available to all combat systems. DIS compliant sims/stims at all sites monitor all PDUs and determine how and when the combat system elements will interact with the PDUs.

Standard Tactical Communications (e.g., LINK-11, LINK-16, CEC,…) are shared between combat systems and other systems via a high-speed network represented by the brown cloud. This element is built to emulate many communication types including broadcast, point-to-point, network (Internet Protocol), etc..

As represented by the green cloud, each site is linked via a data extraction network for collection and sharing of extracted tactical and ground truth data as well as a Collaborative Engineering network that provides real-time video, voice and other formats that enable the sharing of engineering and support data.

Finally, data analysis tools represented by the red box allow the rapid comparison of perceived data out of the combat systems to ground truth from the Common Environment. This ability along with bit-by-bit data analysis and GPS time-tagging at all sites enables rapid isolation of faults.

The four networks described in Figure 4 are in reality four layers within one high speed Asynchronous Transfer Mode (ATM) network leased from several commercial telecommunications companies as depicted in Figure 5. In 1999 the DEP ATM network operated at 10 Mbps, but growth to 45 Mbps is easily achieved (at relatively low cost) by leasing more bandwidth in the existing network. As requirements dictate, growth to 155 Mbps and beyond is achievable by upgrading service.

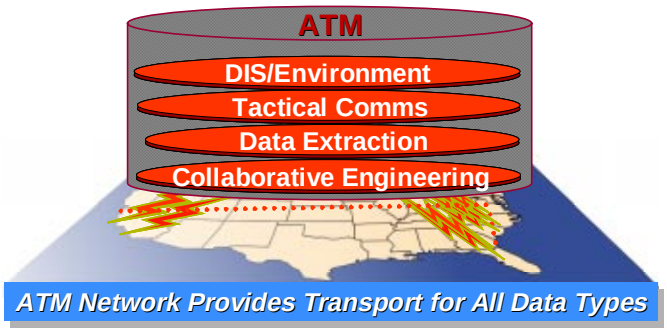

Figure 5 The DEP ATM Network

DEP ESTABLISHMENT

On September 8, 1998 the Navy Alliance proposed the three-phase approach depicted in Figure 6 to the Battle Force Interoperability Flag Steering Group. The Flag Steering Group directed the Navy Alliance to execute Phase Zero of the proposal with an objective to have the DEP ready to test and certify the Kennedy Battle Group in January 1999, six-seven months prior to deployment.

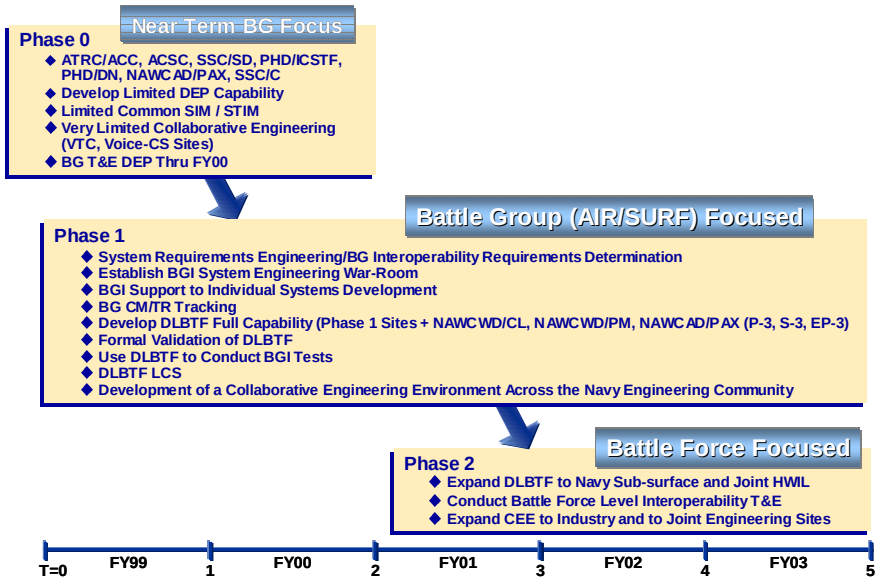

Figure 6 The Navy Alliance Proposal

Over the course of a four-month period the Navy DEP concept was transformed into reality and assembled into the Kennedy Battle Group configuration as depicted in Figure 7. In addition, the Navy Alliance formed an Interoperability Test working group with responsibility for the development and execution of interoperability test plans, scenarios and procedures for the Kennedy testing.

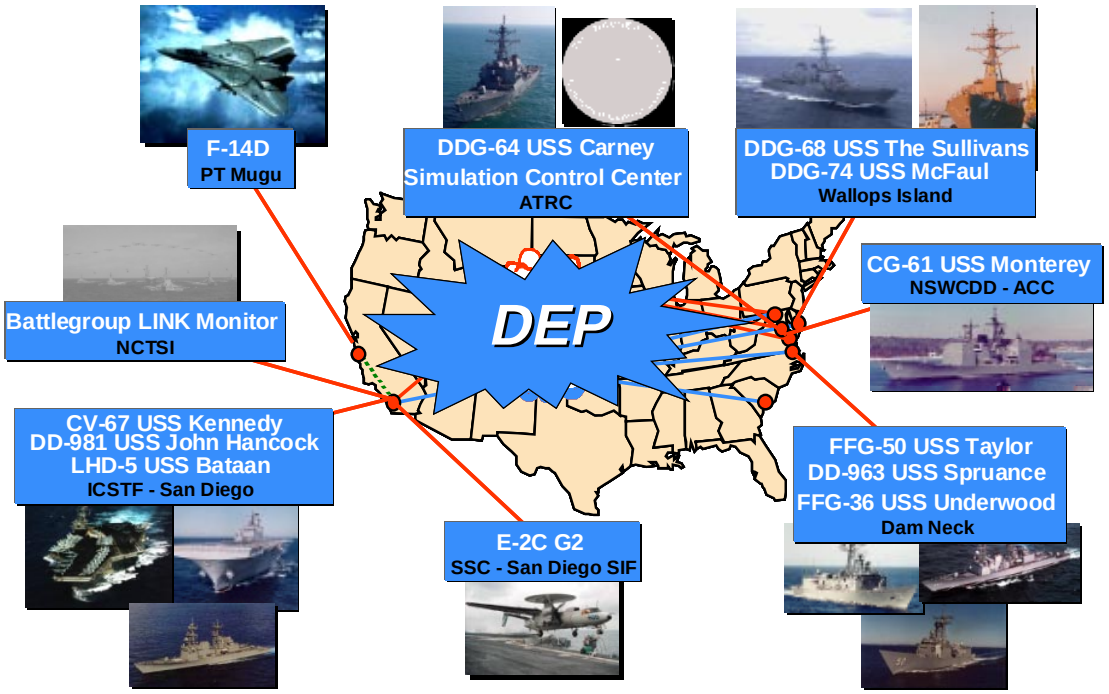

Figure 7 The JFK Battlegroup Assembled Ashore

In January 1999, the Navy's first Battle Group Interoperability Test (BGIT) was executed for the John F. Kennedy Battle Group. Performance of the DEP was as good as or better than expected in all respects including replication of many Fleet problems commonly encountered at sea. The "LINK traffic vs. ground truth" display in Figure 8 is just one example of problems replicated (in this case a dual-track situation with ground-truth in blue and LINK data in orange) during DEP test execution. For the first time, the operators were able to see the truth data and tactical LINK data overlaid on the same display.

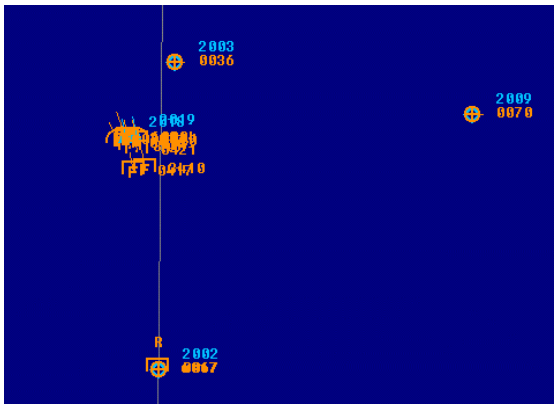

Figure 8 LINK Tracks vs Ground Truth

DEP ACCOMPLISHMENTS

As depicted in Figure 9 the DEP has amassed a significant list of accomplishments from January 1999 to January 2000. In addition to the Kennedy Battle Group BGIT mentioned previously, the DEP has also executed BGITs for the Eisenhower, George Washington, Lincoln and Truman Battle Groups as depicted in the following illustration. A few of the products and general benefits derived from the DEP are described in the remainder of this section.

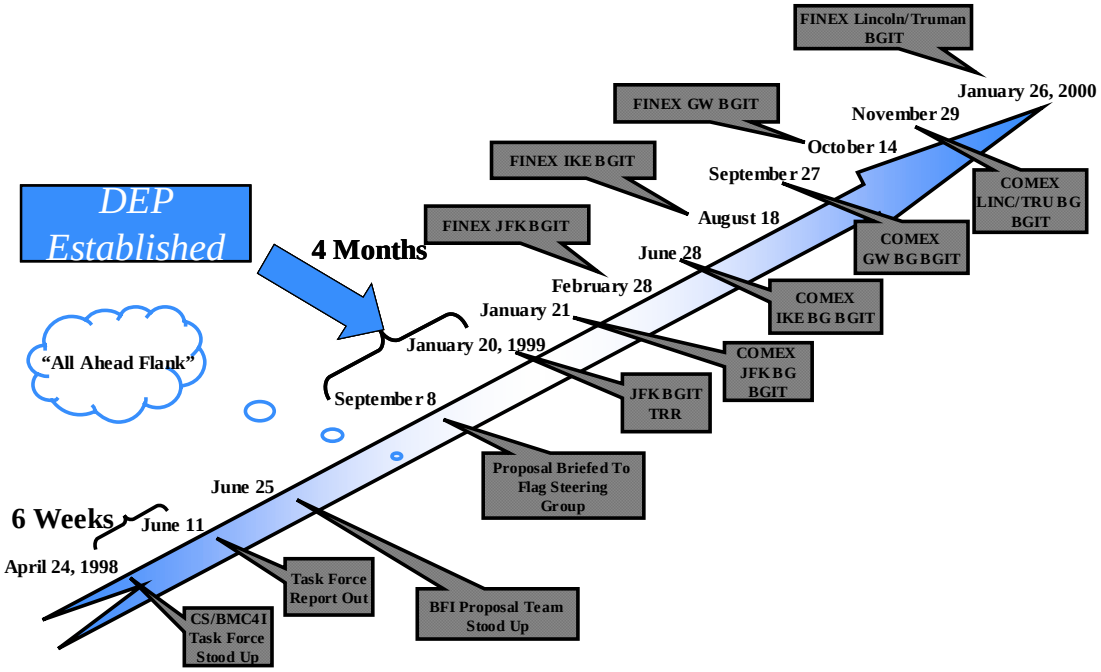

Figure 9 DEP Accomplishments

The primary product of the DEP is a characterization of the interoperability of the subject Battle Group. The first process supporting this characterization is anomaly discovery. For instance, any anomalies discovered during the Kennedy BGIT testing were immediately documented with Trouble Observation Reports (TORs) and forwarded with supporting sets of extracted data to the combat system Software Support Activity (SSA). The problem resolution cycle depicted in Figure 10 was implemented to enable the rapid assignment and resolution of problems discovered. A key feature is the Data Collection and Management Committee (DCMC) consisting of experts from each of the systems under test during a BGIT. The experts within this committee rapidly analyze all TORs and convert valid problems into Trouble Reports (TRs) against the combat system element that had an anomaly. In addition, the BGIT Analysis Review Panel (BARP) depicted within the cycle is made up of platform SSA's, Test Engineers, Program Offices and Fleet representatives from the subject Battle Group. One of the key attributes of this process is the involvement of the actual officers and operators from the deploying Battle Groups. The BARP provides the Fleet with the means to establish the priority at which each problem discovered should be resolved by the responsible combat system program office.

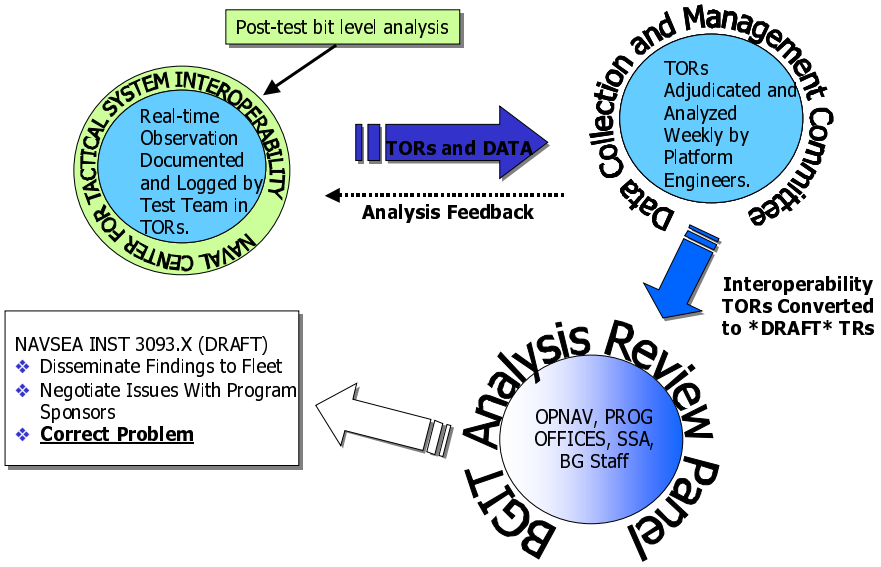

Figure 10 BGIT Problem Discovery and Analysis Process

Over the course of the execution of a BGIT many pieces of evidence are collected that help to quantify the interoperability of a Battle Group. These take the form of the TORs, nightly situation reports, execution log books, and digital data recorded at each combat system, as well as the cumulative findings of the DCMC. Several weeks after BGIT execution and data analysis are completed, a BGIT Data Management and Analysis Report (DMAR) is generated for the Battle Group. This is a comprehensive document that captures the overall test objectives, test configuration, test execution details and test results for each BGIT.

Additional products and information are derived from or along with the DMAR. The first is a Capabilities and Limitations (Caps & Lims) document that is a formal method of reporting the capabilities of the Battle Group as well as limitations arising from known problems that cannot be fixed before deployment. Also, all TRs discovered during a BGIT are entered into appropriate combat system program office databases as well as the NAVSEA-53H master database. This ensures that anomalies will be tracked by cognizant program offices and fixed within the priority structure of the program office. Finally, lessons learned, scenario improvements and enhanced test procedures are utilized as a foundation for upcoming Battle Group BGITs.

THE FUTURE OF THE DEP
- The BGIT Mission

As described in the previous sections, the main mission of the DEP since its inception has been the execution of a BGIT for each Battle Group that is preparing to deploy. This mission is accomplished by performing a shorebased integration of most of the combat system elements that comprise the deploying Battle Group, detecting as many problems as possible and characterizing the capabilities and limitations of the Battle Group as a whole. In order to

increase the scope and fidelity of DEP replication of Battle Groups, the DEP has been continuously improved and expanded in its capability as depicted in Figure 11. The DEP will continue to add systems and subsystems in order to increase the percentage of Battle Group capabilities that can be replicated ashore.

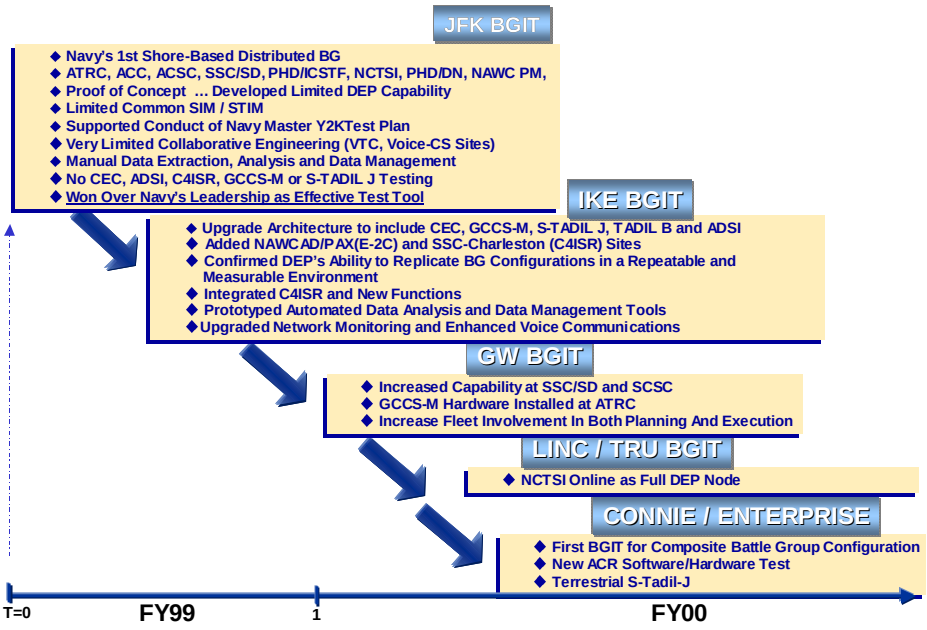

Figure 11 DEP Capability Growth

Since the BGIT is now a required milestone for each deploying Battle Group, an average of five to six BGITs are planned for each year into the foreseeable future. This new requirement is extremely challenging for the Navy personnel and resources resident at these land-based sites which still maintain the platform-level element testing, system testing and training. Of course, experience and efficiency has helped to reduce the total test hours required for each BGIT, but the real savings is believed to be witnessed through functional assessment of interoperability issues by similar systems rather than Battle Group specific compositions. This appears to be feasible if the Battle Groups are fairly similar in configuration and if their deployment dates are also relatively close. This could reduce the number of BGITs to four a year. The Lincoln/Truman BGIT was executed back-to-back, but was assessed as two separate Battle Groups. The first combined BGIT is being planned for the Constellation and Enterprise Battle Groups scheduled for testing later this year.

THE FUTURE OF THE DEP
- New Missions for the DEP

To date, the DEP has been focused on the end of the acquisition life cycle, i.e., T&E and certification. However, many other missions are envisioned. Planned missions are analogous to the various missions performed by individual shorebased combat system sites and includes Battle Group system level development, integration, testing, training and lifecycle maintenance.

The CEC program has already utilized the DEP to perform some aspects of CEC Independent Verification and Validation (IV&V) testing in preparation for CEC operational test and evaluation. A significant number of CEC requirements tests that previously required a live Battle Group as a testbed have recently been validated using the DEP. This in turn has reduced the burden of developmental testing that has previously been levied on the Fleet in lieu of training and other deployment activities.

As the number of Battle Group-level capabilities (i.e. capabilities that require more than one combatant to execute such as CEC engage-on-remote sensor data) increase, the need for a shorebased Battle Group testbed such as the DEP will also increase. Meanwhile, the need to test and characterize Battle Group interoperability will continue into the foreseeable future as engineering solutions to the interoperability problem are developed within upcoming programs such as SSDS and CC&D. The DEP is currently working cooperatively with element and system level engineers to introduce multi-platform integration during the design and development phases of combat system assessment.

The Navy continues to advance the collaborative engineering aspects of the DEP. During the GW and Lincoln/Truman BGIT's the capability to transfer large classified data files was prototyped. Previously, the huge amount of data extracted during testing was captured to various types of magnetic media and then couriered to the analysis facility – often taking days or weeks depending on the location and format. The large bandwidth available through the classified ATM network, established on the DEP, allows the digital data to be directly downloaded to a file server and transferred immediately following the test. This capability will also serve the combat system developers. Similarly, the DEP provides a classified multi-point VTC and communications network for all sites.

CONCLUSION

Over the past few decades the Navy has seen the word "system" applied to collections of larger and larger components. Today, the entire Battle Group is rapidly becoming a system that relies on the interoperability of individual platforms in order to achieve the missions of the Battle Group. In parallel the shorebased development and support community has provided the Fleet with the best systems available by replicating these systems ashore to aid in development, integration and testing of these systems. The Navy DEP is yet another logical step in this long chain of support to the deployed Fleet. Modern networking technology has made the establishment and initial success of the DEP possible for a relatively low investment in time and money. The DEP has made significant contributions toward resolving and quantifying interoperability issues in its relatively short lifetime and will continue to move this new capability back into the acquisition cycle, allowing interoperability to be ***engineered in*** versus testing for it just prior to deployment.