NAVSEA Headquarters' Perspective – Enabling Future Naval Capabilities

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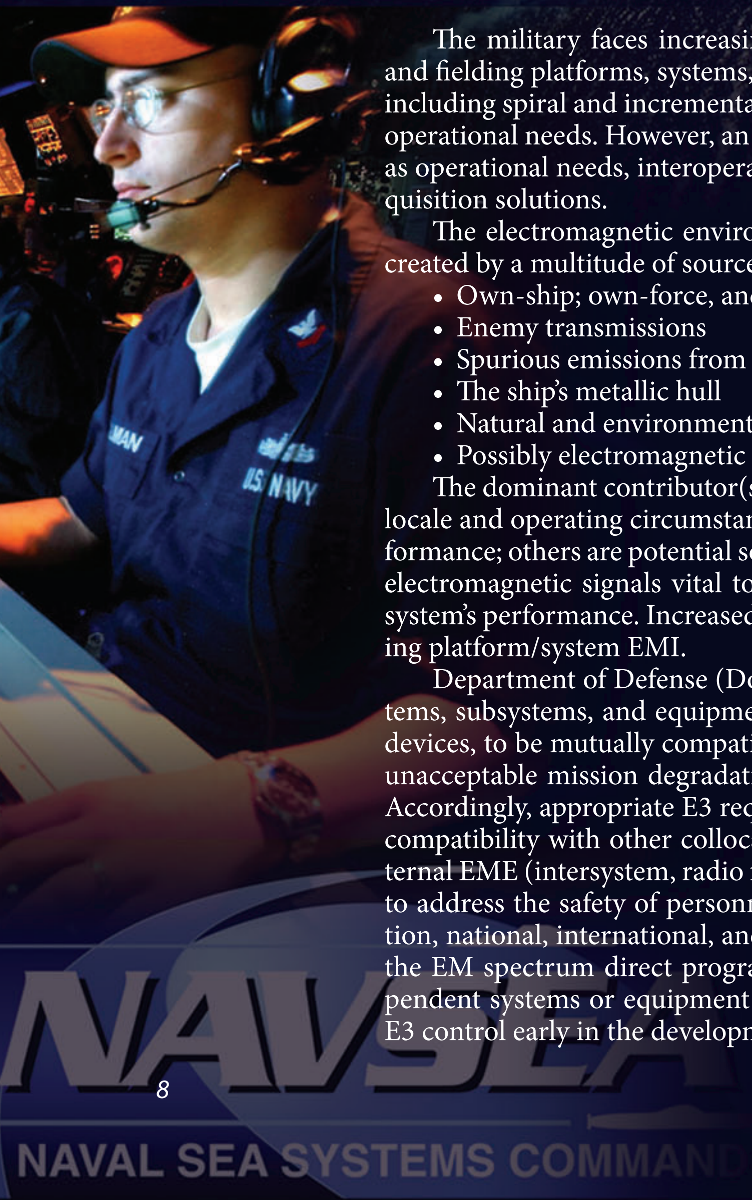

The military faces increasingly complex and challenging problems in developing and fielding platforms, systems, subsystems, and equipment. Evolutionary acquisitions, including spiral and incremental developments, are the preferred approach to satisfying operational needs. However, an appropriate balance is required among key factors, such as operational needs, interoperability, supportability, and affordability of alternative acquisition solutions.

The electromagnetic environment (EME) in which naval systems must operate is created by a multitude of sources. Primary contributors are:

- Own-ship; own-force, and other friendly transmissions
- Enemy transmissions
- Spurious emissions from equipment
- The ship's metallic hull
- Natural and environmental noise
- Possibly electromagnetic pulse (EMP) resulting from a nuclear burst

The dominant contributor(s) to the EME will depend on the platform's (or system's) locale and operating circumstances. Many elements of the EME are vital to system performance; others are potential sources of electromagnetic interference (EMI). Moreover, electromagnetic signals vital to one system's performance may prove fatal to another system's performance. Increased awareness of the EME enhances identifying and reducing platform/system EMI.

Department of Defense (DoD) policy requires that all electrical and electronic systems, subsystems, and equipment, including ordnance containing electrically initiated devices, to be mutually compatible in their intended EME without causing or suffering unacceptable mission degradation due to electromagnetic environmental effects (E3). Accordingly, appropriate E3 requirements must be imposed to ensure a desired level of compatibility with other collocated equipment (intrasystem) within the applicable external EME (intersystem, radio frequency (RF), lightning, EMP, and precipitation static) to address the safety of personnel, ordnance, and fuel in these environments. In addition, national, international, and DoD policies and procedures for managing and using the EM spectrum direct program managers (PMs) who are developing spectrum-dependent systems or equipment to consider spectrum supportability requirements and E3 control early in the development process and throughout the acquisition life cycle.

Naval Sea Systems Command (NAVSEA)

NAVSEA comprises command staff, headquarters directorates, affiliated program executive offices (PEOs), and numerous field activities. NAVSEA is accountable to the Chief of Naval Operations (CNO) to deliver, modernize, and maintain a 313-ship Navy that meets the requirements of our national security plans. NAVSEA engineers, builds, buys, and maintains ships, submarines, and combat systems that meet the fleet's current and future operational requirements. NAVSEA is the largest of the Navy's five system commands. With a fiscal year 2008 budget of $24.8 billion, NAVSEA accounts for nearly one quarter of the Navy's entire budget. It includes a force of 53,000 civilian, military, and contract support personnel.

NAVSEA manages acquisition programs (150) and foreign military sales cases that include billions of dollars in annual military sales to partner nations. NAVSEA strives to be an efficient provider of defense resources for the nation and plays an important role in the Navy Enterprise. As a Provider Command, it has the responsibility of directing resources from resource sponsors into the proper mix of manpower and resources to properly equip the fleet. NAVSEA has the further responsibility of establishing and enforcing technical authority in combat system design and operation. These technical standards use the organization's technical expertise to ensure that systems are engineered effectively, and that they operate safely and reliably.

Technical Authority Warrant

NAVSEA's Force E3/SM Engineering Branch (05W43) has been assigned as the Technical Authority Warrant for EMI Control/Electromagnetic Compatibility (EMC)/EMP/and Radiation Hazards (RADHAZ) for Ships and Submarines. As a Technical Warrant Holder (TWH), NAVSEA 05W43 controls EMI/Spectrum and EMP impacts on warfare systems effectiveness to maintain warfighting readiness for all ships, submarines, and systems.

Virtual Systems Command (SYSCOM) Engineering and Technical Authority Policy, VS-JI-22A, defines the engineering and technical authority policy and actions needed to support PMs and the fleet in providing best-value engineering and technical products. The TWH must demonstrate sufficient proven ability in the following competencies in order to hold the warrant:

- Setting Technical Standards—Establish technical policy, standards, tools, requirements, and processes, including certification requirements.
- Technical Area Expertise—Provide technical advice to the fleet, depot chief engineers, and other DoD customers. Maintain technical expertise, and interface with the science and technology (S&T) community in technical areas related to EMI Control/EMC/EMP/RADHAZ for ships and submarines.
- Ensuring Safe and Reliable Operations—Ensure that safety and reliability is properly addressed in technical documentation. Ensure

that products are in conformance with technical policy, standards and requirements. Where they are not, identify options and risks; minimize risks so they are technically acceptable.

- Ensuring Effective and Efficient Systems Engineering—Ensure that engineering and technical products meet Navy needs and requirements, including interoperability. Support programmatic authorities and the fleet by providing best-value engineering and technical products.
- Judgment in Making Unbiased Technical Decisions—Provide leadership and accountability for all engineering and technical decision-making. Promote and facilitate communications to ensure that appropriate personnel and organizations are aware of, and are involved in, technical issues and technical decisions.
- Stewardship of Engineering and Technical Capabilities—Ensure that an appropriate engineering and technical authority support network is established for the warranted technical area and provide leadership for the support network.
- Accountability and Technical Integrity—Exercise integrity and discipline to ensure the soundness of technical decisions. Keep organizational chain of command informed of issues and decisions.

To move forward and execute the required TWH competencies, NAVSEA 05W43's goal is to partner with each system, ship, or submarine program to provide the best products to the warfighter. This is accomplished by getting "plugged-in" at the earliest stages of program development. NAVSEA subject-matter experts (SMEs) help guide individual programs through the E3/spectrum certification (SC) process, through requirements identification and controls implementation, and in exercising the Technical Warrant Pyramid (see Figure 1). In this manner, NAVSEA 05W43 works with the PEOs to implement upfront E3/

Figure 1. Technical Warrant Pyramid

SM engineering. These processes and procedures are executed by the Force Level EMC Program. The Shipboard Electromagnetic Compatibility Improvement Program (SEMCIP) is a subelement of this overarching program.

Shipboard Electromagnetic Compatibility Program (SEMCIP)

SEMCIP was established by NAVSEA under the sponsorship of CNO N6. SEMCIP provides "cradle-to-grave" systems engineering for mission assurance and EMC/spectrum management (SM) engineering to ensure that equipment, systems, ships, and submarines meet mission requirements/goals in their intended operational environment. The Force-Level EMC Team:

- Provides a central engineering capability to prevent, identify, and correct EMI problems
- Ensures that EMC is adequately addressed during all phases of the design and overhaul/modernization of ships, submarines, and ship systems
- Provides EMI control policy, processes, and documentation (i.e., instructions, tools, processes, and standards)
- Provides technical support to PMs to obtain frequency allocation/certification for shipboard equipment/systems
- Provides EMI fixes to correct mission-degrading EMI problems on deploying ships and submarines, thereby restoring combat capability and fleet readiness.

The successful execution of these E3 and SM initiatives require effective working relationships with appropriate outside agencies and entities that affect Navy EMC and spectrum supportability.

Tri-SYSCOM EM Leadership

NAVSEA Headquarters leads the Tri-SYSCOM organization among the Space and Naval Warfare Systems Command (SPAWAR), NAVSEA, and the Naval Air Systems Command (NAVAIR) for EMI control, EMP, and SC matters. Figure 2 shows the top-down organization of the Force-Level EMC Program. NAVSEA has upfront systems engineers within its headquarters organization to interface with the various PEOs; e.g., PEO-Ships, PEO-Carriers. At the field activity level, NAVSEA designates engineering agents (EAs) for specific functional areas. These EAs form teams of SMEs to assist in the investigation and resolution of EMI problems ashore and afloat. These activities champion and execute E3/SM in the design, development, procurement, and integration of equipment and platforms, as well as naval shore sites. NAVAIR and the Naval Research Laboratory (NRL) have been designated as support activities to NAVSEA.

The field activity technical teams (as illustrated in Figure 2) are:

- Naval Surface Warfare Center, Dahlgren Division (NSWCDD) Code Q50: Serving as the EA for Surface Ships. NSWCDD Q50 is assigned as the life-cycle engineering manager (LCEM), in-service engineering agent (ISEA), and design agent (DA) to the ships as a whole entity, encompassing the ship itself and all systems, subsystems, and equipment. They manage efforts in the following areas:
  - E3 EA for Surface Ships
  - EMI Reduction
  - EMI Control
  - Platform Certification
  - Fleet Response Plan (FRP)
  - Strike Force SM
  - Specification/Standards & Policies/Process
  - Warrant Holders
- Naval Undersea Warfare Center (NUWC) Code 3431: Serving as the EA for Submarines. NUWC Code 431 is assigned as LCEM, ISEA, DA, and Technical Support Activity (TSA) to the submarines as a whole entity, encompassing the submarine itself and all systems, subsystems, and equipment. They perform engineering and problem investigation to resolve high-priority fleet EMI problems, support submarine predeployment EMI surveys, and provide quick-response capability (QRC) to deployed submarines and support systems.
- Naval Surface Warfare Center, Carderock Division (NSWCCD), Code 953: Serving as the EA for E3 Engineering and SME for Hull, Mechanical, and Electrical (HM&E) Systems. NSWCCD Code 953 is assigned as LCEM and ISEA for EMI, EMC, and SM of HM&E. They provide engineering, analytical, and technical support to achieve EMC among and between HM&E systems and/or

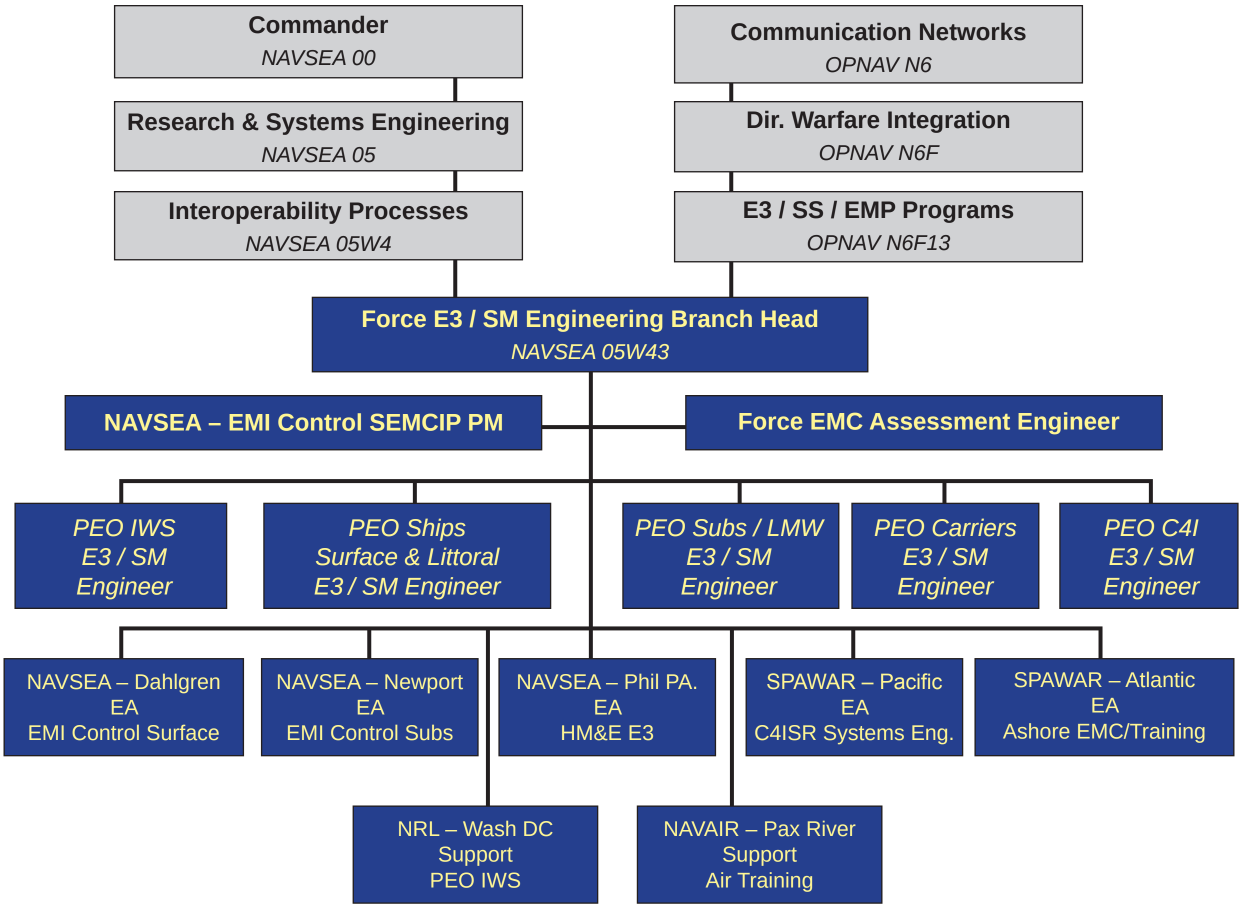

Figure 2. NAVSEA 05W43 Organization

equipment and assist in testing and resolution of shipboard HM&E EMI problems.

- SPAWAR System Center (SSC), Pacific: Serving as the EA for command, control, communications, computers, and intelligence (C4I) systems. SSC Pacific provides life-cycle upfront engineering support for operational Navy ships, with emphasis on system acquisition to eliminate significant degradation from EMI to the warfighting capability of the fleet. They provide assistance to various PEO C4I & Space/SPAWAR/SSC program offices with E3 and SM issues affecting command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) development and installation efforts. Additionally, they provide participation in national standardization groups, such as American National Standards Institute (ANSI) C63 and North Atlantic Treaty Organization (NATO) working groups on naval E3 standardization issues affecting international coalition efforts.
- SPAWAR System Center (SSC), Atlantic Code 725: Serving as LCEM and TSA for EMC and SM training. SSC Atlantic Code 725 is also the EA for Navy shore site E3/SM. They provide engineering, analytical, and technical support to achieve EMC among and between ashore electronic/electric systems and/or equipment. They provide establishment of E3/SM training requirements for fleet management, engineering, operations, and maintenance personnel associated with cognizant systems, platforms, and facilities.

They provide E3/SM related engineering evaluations and support for Navy shore facilities.

- Naval Research Laboratory (NRL), Washington, DC: Serving as a support activity to NAVSEA for research and development related to E3 engineering and SM ships and systems.
- Naval Air Systems Command (NAVAIR), Patuxent River, Maryland: Serving as a support activity to NAVSEA through development and presentation of air-specific multimedia E3 and SM training. NAVAIR provides development, presentation, training specialists, fleet trainers, and E3/SM SMEs to review, revise, update, develop, and present multimedia operator, maintenance, officer, and Department of the Navy (DON) civilian air-specific E3/SM curricula. They also administrate their SEMCIP counterpart program for Air systems called the "Air Systems Electromagnetic Interference Corrective Action Program (ASEMICAP)."

Upfront Engineering

The Technical Warrant Pyramid describes the depth of knowledge and expertise that exists within the Force-Level EMC Program. The technical warrant, although assigned to an individual within NAVSEA 05W43, is actually executed by the entire Force-Level EMC Program. This team maximizes the operational performance and safety with respect to E3 and SM in ships and submarines, their combat systems, and shore installations. The key to ***enable future naval capabilities*** is with well-engineered warfare systems. This is accomplished through a disciplined, upfront systems-engineering effort. Upfront engineering embodies the review of acquisition documents (initial capabilities documents (ICDs), capability development documents (CDDs), capability production documents (CPDs), or capstone requirements documents (CRDs)). To ensure EMC for new systems introduced into the fleet, NAVSEA executes its review of ship change documents (SCDs) and ensures that systems attain SC. NAVSEA ensures the performance and readiness of current naval systems, and that platforms are "ready to fight" by executing shipboard EMC and RADHAZ certification and the submarine predeployment EMC survey, and by providing direct fleet and PM support.

Historically, a large number of programs encounter issues without E3/SC upfront systems engineering support. E3/SC input can contribute to

saving lives, capability, money, readiness ,and performance. A disciplined systems engineering approach helps address potential issues at the earliest possible stage. This process includes assisting the PEOs/PMs with establishing the proper E3/SM requirements, integrating these requirements into their acquisition and design documentation, and ensuring adequate E3 testing for the resulting shipboard systems, platforms, and shore-site equipment installations.

The NAVSEA team supports the PMs with EMC acquisition engineering and analysis in the review of a wide variety of documentation to ensure E3 and SC have been properly addressed. Documents reviewed include:

- Equipment Specifications
- Equipment Change Proposals
- Ship Alterations
- Test Specifications
- Test Reports
- ICDs
- CDDs
- CPDs
- CRDs
- E3 specifications and standards

Test and evaluation master plans (TEMPs) are also reviewed to ensure that E3/SC requirements from the CDDs and CPDs are properly translated into test and evaluation requirements. E3/SC personnel perform EMC validation of system specifications required for the deployment of new systems and the continued operability of existing systems. In order to ensure good radio-frequency SM, frequency certification documents are reviewed.

The NAVSEA team exercises technical authority by holding formal TWH reviews, thereby enforcing E3/SC acquisition policies and providing E3/SC technical SME/guidance. The team initiates discussions with the PEOs, by pursuing E3/SC involvement with individual programs to implement process improvements. The team also communicates to PEOs for endorsement of SEA 05W43 upfront E3/SC efforts.

Ship Change Documents (SCDs)

SCDs are reviewed for possible EMI/EMC and Frequency Allocation concerns. SCDs that pose an EMC and/or a spectrum concern are reviewed in detail with various SMEs to conduct risk assessments. Based on this assessment, a recommendation to move forward or reject the SCD is made by NAVSEA 05W43 to the SHIPMAIN Technical Assessment Team (TAT). In order to accomplish these efforts, the NAVSEA team actively coordinates with the program offices submitting the SCD in order to obtain additional information and clarification and, when applicable, provide EMC guidance.

The SCDs were born under the SHIPMAIN, or Ship Maintenance Process. It is said that the shortest distance between two points is a straight line. In the world of ship maintenance, many sailors would tell you that the distance between identifying that something that needs to be fixed, and something actually getting fixed, is anything but. However, a new set of maintenance practices was introduced (2002) on the waterfront that shortens the distance between those two points and gives sailors more say in what and when things get fixed. These practices are part of SHIPMAIN, a Navy-wide maintenance

initiative that builds a more effective and efficient maintenance system as the CNO lays out the FRP, the Navy's roadmap to a surge-capable force.

SHIPMAIN specifically examines the planning processes for surface ship maintenance, from the point where ship's force first identifies the work, through the point when sailors begin turning the wrenches.

Vice Admiral Phillip Balisle, former Commander, Naval Sea Systems Command, said, "As we look ahead to the Navy of the 21st century, a fleet of ships ready to surge and respond at a moment's notice, operated by optimally manned crews of highly skilled and trained sailors, we need an improved maintenance system to support that fleet," He went on to say, "SHIPMAIN is the kind of process change we need that addresses today's problems and lays the foundation for tomorrow's Navy."

Spectrum Certification

The availability of an adequate spectrum to support military electronic systems and equipment is critical to maximizing mission effectiveness. Spectrum planning and management must be given appropriate and timely consideration during the development, procurement, and deployment of military assets that utilize the EM spectrum. To ensure maximum EMC among the various worldwide users of the spectrum, it is essential that spectrum-dependent equipment and other intentional radiators, including identification devices and stock control micro strips, comply with spectrum usage and management requirements.

Use of the EM spectrum by DoD is expanding based on emerging, advanced technologies and joint warfighting strategies. DoD employs a large number of weapon systems in executing military missions, and most, if not all, depend upon the EM spectrum. Loss of spectrum access, however, has the potential to derail efforts to exploit available technology. DoD is provided access to the spectrum by the federal government and shares the spectrum with other federal agencies, local governments, and private industry. Consequently, DoD must demonstrate critical needs in order to maintain specific portions of the spectrum for exclusive use. This is truer now more than ever before, considering the wide use of wireless technologies in the marketplace.

Spectrum use is governed by international agreements and national laws since DoD operations are conducted worldwide, bringing new challenges to efforts involved in planning and coordinating joint missions. Relocation of systems to new bands is difficult and costly because equipment may interact with other equipment. In addition to the increased likelihood of operational EMI because of overcrowding in the remaining spectrum, equipment redesign, additional testing, recertification for spectrum use, and training all may be necessary. Further domino effects are also likely, forcing changes to other parts of the integrated military system. Many frequencies used by DoD are those that work best for the intended purpose, dictated by the laws of physics. DoD efforts to safeguard needed spectrum access depend on the capability to demonstrate the criticality of targeted frequencies. The acquisition community plays a key role since the data generated during the SC process provides much of the information needed to substantiate DoD positions.

The NAVSEA Team helps the PM to attain SC, which is obtained by completing the required documentation, Application for Equipment Frequency Allocation (DD Form 1494). The form must be completed and submitted for each acquisition development stage, which coincides with the DD-1494 Stage Levels (1–4), for all RF spectrum-dependent systems, active and/or passive, including commercial off-the-shelf (COTS) equipment. The NAVSEA team has established safeguards to ensure that SC is obtained before assuming contractual obligations for system development and demonstration, production, and deployment and/or procurement of any communications-electronic (C-E) equipment, including COTS.

As stated previously, "the key to ***enable future naval capabilities*** is with well-engineered warfare systems." The NAVSEA team executes the upfront system engineering process with a focus on acquisition documents, SCDs, and SC. In the past year, the NAVSEA team has provided technical support to a large number of systems and next-generation platforms, including (but not limited to):

- Participated in USS *Virginia* (SSN 774), USS *Gerald R. Ford* (CVN 78), DDG-1000, and Aegis Modernization (AMOD) COTS Refresh Three (CR3) TWH reviews.
- Participated in Joint High Speed Vessel (JHSV), Littoral Combat Ship (LCS), P-8A Multimission Maritime Aircraft (MMA) Electronic Support Measures (ESM), Electromagnetic Aircraft Launching System (E-ALS), AN/SPS-74 Periscope Detection Radar (PDR), and Sea RAM program reviews.
- Reviewed 21 (subs) and 35 (surface) specifications, technical documentation, or waivers and provided feedback to PM/PEO/PMS codes.
- Supported the Commander, Operational Test and Evaluation Force (COMOPTEVFOR) by providing E3 subject-matter expertise in the C4ISR design evaluation phase of the DDG 1000 Operational Assessment (OA).

Team Deliverables included:

- Published technical pyramid identifying key competencies and technical knowledge of assigned EA and technical leads.
- Provided presentations discussing E3 issues and risks associated with bringing new technologies to ships/subs to 12 key S&T meetings.
- Successfully EMC-certified 24 ships and RADHAZ-certified 45 ships.
- Published biweekly (SCDs) and monthly Joint Capabilities Integration and Development System (JCIDS) status reports of technical reviews completed.
- Published (14) biweekly reports discussing significant TWH issues and Technical E3/SS/EMP issue resolutions.
- Reviewed and provided concurrence to PMS 450 on USS *Virginia* (SSN 774)-class EMC Control Plan.
- Reviewed and provided nonconcurrence to SEA 05V on the Northrop Grumman Newport News request to eliminate the EMP test requirement from the CVN 78 Ship Specification Section 400.
- Combined NAVSEA INST 2450.1/2450.2 and issued NAVSEA INST 2400.20 E3/Spectrum Supportability Policy for Review (September 2007 and April 2008).

Ongoing team activities include:

- Investigating development of EMC and RADHAZ certifications for submarines.
- Utilizing SCD/JCIDS reviews as a means to train PMs/PEOs on the proper development and adherence to E3/SS policy requirements.
- Providing E3/spectrum leadership to USS *irginia*-class and USS *Gerald R. Ford* (CVN 78) Electromagnetic Advisory Board (EMCAB).
- Providing E3/Spectrum support to the AMOD COTS Refresh.
- Providing research and analysis of SC for a number of systems planned for DDG 1000.
- Providing technical support to PMS 450, PMS 415, PMS 401, PMS 399, PMS 394, PMS 392, SEA 05U1, SEA 07TC, and PMW 160. [ex. Submarine Local Area Network (SubLAN), Advanced Seal Delivery System (ASDS), T1 Acoustic Media, NextGen Countermeasures, and High-Frequency Transmitter]
- Providing technical support to PEO C4I, PMS 312, SEA 05D, SEA 21/PMS 470, SEA 05V, SEA 05Z, and PEO ships. [ex. Automated Digital Network System (ADNS), HM&E Systems, Commercial Broadband Satellite Program (CBSP), and Joint Biological Point Detection System]

Recently, the Chief of Naval Operations (Admiral Gary Roughead) issued the CNO Guidance (CNOG) for 2009. The CNOG reviews the Navy's major 2008 accomplishments and reaffirms the vision, mission, guiding principles, and focus areas articulated in last year's guidance. The Navy's primary focus areas remain:

- Build the future force—We are building a Navy with the right force structure to deliver capacity and capability to combatant commanders on time and at the right cost.
- Maintain our warfighting readiness—We are the world's dominant naval force, working with our joint and global partners to prevent and win wars.
- Develop and support our sailors and Navy civilians—Our diverse and competent military and civilian force is focused on readiness and underpinned by a Navy ethos.

The CNOG forms the basis for the goals of NAVSEA 05W43 to ensure that we will build the future force (through an upfront engineering process), maintain our warfighting readiness (through SHIPMAIN), and develop our sailors and Navy civilians.

Harsh EM operating environments and the increasing power of shipboard emitters, coupled with increasingly more sensitive electronics, significantly increases the potential that EMI problems will increase even though we have a significant front-end engineering process. Like other areas of expertise, E3/SM must evaluate emerging technologies in test equipment, test processes, modeling and simulation, components, and systems. It must also transition viable merging technologies to better identify and correct E3/SM issues, ultimately improving fleet EMC, thereby delivering warfighting capability and mission assurance to the U.S. Navy.

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The Importance of E3 Science and Technology in Preparation for Future Warfare

By Lucas Hale and June Drake

Warfare differs significantly today from warfare only a decade ago. A decade from now, it will likely differ even more. Our fighting forces need to be prepared for future conflicts so they can continue to fight, win, and come home safely. That means Naval Sea Systems Command Warfare Centers' scientists and engineers need to actively research, develop, test, and evaluate new technologies, systems, and capabilities today to ensure that tomorrow's warfighters will always have the edge and will never find themselves in a "fair fight" with adversaries.

Science and technology (S&T), as it applies to the military, is the generation and application of new knowledge based on scientific study for the purpose of extending or enhancing U.S. military superiority. This knowledge generation and application function represents a major aspect of the Warfare Centers' identities. S&T not only allows today's naval workforce to develop and deliver technologies to solve warfighter challenges in the field, it strengthens and supports the Warfare Centers' technical capabilities. It also maintains the Warfare Centers' role as the Navy's "smart buyer" in providing an intelligent bridge between technological possibilities and national needs.

The U.S. security environment has changed dramatically since the terrorist attacks of 2001. Consequently, the defense community must continually adjust and adapt. Moreover, a never-ending need exists to rapidly insert innovative and emerging technologies to meet the immediate and evolving needs of national security. This can be accomplished only through aggressive teaming across the Warfare Centers and with other services, industry, and academia. As new opportunities and challenges continue to emerge, it is critical that the Warfare Centers become highly skilled at rapidly locating, developing, and integrating technologies to not only improve existing capabilities, but to also create new capabilities. S&T is at the core of such flexibility.

Current Electromagnetic Environmental Effects (E3) S&T Challenges

S&T efforts pursued at the Warfare Centers are aimed at fulfilling the needs of operational forces. Over the last 100 years, naval forces have grown increasingly reliant on electromagnetic (EM) systems to ensure mission success. The force relies on EM effects to communicate and share information, search for and engage targets, land aircraft, handle cargo, and perform many other functions. The operational EM environment mission environments. The utility of EM systems has proven so great that current operations would cease without their functionality.

Shipboard Complexity

U.S. Navy ships field the most powerful mobile EM systems in the world. These ships are also self-contained "floating cities" that carry the myriad provisions, sailors, equipment, and military assets required for mission completion. Because of the physical limitations of each platform, the shipboard environment quickly becomes congested, especially as related to the EM environment. Consider the example of *Nimitz*-class aircraft carriers (see Figure 1), which field roughly 150 EM systems topside. Due to the aircraft launch, retrieval, and handling requirements of such a ship, most of these EM systems are relegated to compressed spaces on the island, aft tower, mast, or along the flight-deck edge. Other ships have similar restrictions on topside real estate allocated to EM systems. As new systems are developed, they are added to the already congested topside spaces. One role of topside design is to ensure that these EM emitters and receivers functionally coexist as much as possible. This task is not easy; the fixed real estate and increasing EM system load means that U.S. Navy platforms are *the* most complex EM assets in the world.

This complex EM environment requires that a great deal of effort be paid to exploring the interactions among emitters, receivers, and other devices. EM systems can impact personnel safety, fuel, and ordnance by coupling to devices or structures, causing inadvertent initiation or burns. The

Figure 1. *Nimitz*-Class Nuclear Aircraft Carrier

pervasive nature of EM systems on ships, coupled with the inability to gain relief through physical separation, requires that the Navy exercise expert judgment in EM system safety and compatibility. Every system onboard ship must be certified for safety to include a series of Electromagnetic Interference (EMI)/Electromagnetic Compatibility (EMC) tests, such as Hazards of Electromagnetic Radiation to Ordnance (HERO). Below decks spaces, such as ammunition storage lockers and helicopter bays, are also areas of concern as they are becoming filled with wireless communications and inventory systems such as WiFi and Radio Frequency Identification (RFID), respectively. The increased RF emissions in these spaces can generate potentially hazardous conditions as ordnance is staged and moved through the spaces. Advanced testing methods for characterizing below decks spaces, such as mode stirred chamber testing, are essential to ensuring ship safety now and in the future.

Mission Requirements

As outlined in *A Cooperative Strategy for 21st Century Seapower*, U.S. maritime forces must conduct operations across missions spanning major combat operations (MCO); asymmetric warfare; and stability, security, transition, and reconstruction (SSTR).[1] Success in these missions requires heavy reliance on collaborative engagement between U.S. and allied forces, often in close proximity (see Figure 2). Bringing these units together, each with their own complex EM environment, results in an even more stressing EM environment. Not only do the platforms need to ensure operability of their own systems, but the group must deconflict within itself to ensure that the group as a whole is compatible.

The evolving nature of warfare and the mission set described above have expanded the operational domain of U.S. maritime forces. In order to effectively prosecute present and future naval missions, U.S. maritime forces must move beyond

Figure 2. A Collection of Platforms Increases E3 Environment Complexity

blue-water operations into the littorals, land, and cyberspace. As platforms and collections of platforms move closer to land, the EM environment increases in complexity due to terrestrial emitters interfering with naval systems, and vice versa. These terrestrial systems are often part of the civilian infrastructure, but they can also consist of enemy and allied systems. Figure 3 provides a notional illustration of these challenges.

Government policy also plays a role in the EM environment. Since the 1993 Omnibus Budget Reconciliation Act gave the Federal Communications Commission the authority to auction segments of the U.S. EM spectrum, 85 such auctions have taken place. Coupled with the negative political ramifications of unintended EM interference, these spectrum auctions have resulted in the military bands being squeezed on all sides by commercial allocations, resulting in degraded capabilities, more system risk, and increased need for frequency deconfliction. Operating effectively in this constrained environment is an additional challenge facing our warfighters that requires the E3 community to pursue innovative S&T solutions.

Future E3 S&T Challenges

The future poses unprecedented challenges for the E3 community. Next-generation naval platforms are fielding novel systems that rely on EM effects in unprecedented ways. Proper S&T is essential to ensure these systems operate as expected.

Advanced radars currently under development, such as AN/SPY-3, are expected to bring order of magnitude increases in power to the shipboard environment within a decade. The E3 community is presently focusing S&T efforts on developing methods for analyzing and testing these new systems to ensure ship safety and EMC. Additional understanding of next-generation systems is required in order to accurately model apertures, propagation, signal processing, and interferences. Testing must be completed in conjunction with the research and analysis to gather the data and insight required to validate the models developed. New instrumentation and methodologies must be pursued to collect, store, and analyze the data. Unless S&T is conducted concerning the analysis and testing for next-generation EM systems, future fleet operations, weapons, flight, and combat system safety could be impacted across all major programs.

Directed energy (DE) and high-power microwave (HPM) weapons use EM energy to achieve effects on target. Their employment will fundamentally change the landscape of naval engagement, as effects will be delivered at the speed of light and with tunability. These weapons will come in many shapes and sizes, such as the Laser Weapons System (LaWS) and the Active Denial System (ADS). To field such systems, the Warfare Centers must conduct S&T to ensure understanding of effects on target, shipboard integration, atmospheric propagation, and other factors. Once operational, these weapons will provide naval forces with flexible engagement options necessary for effective operations across future SSTR, asymmetric, and MCO missions.

Along with new directed-energy weapons, integrated power supplies (IPS) capable of running them will be needed. The design of IPS requires S&T expertise in power generation, storage, conditioning, and control. The IPS will generate its own EM effects that will need to be assessed for interference with other below- and above-deck systems. Additionally, DE weapons will create additional EM fields that will need to be minimized or controlled to acceptable levels for ordnance and personnel. Again, this will require advanced techniques in testing and analysis.

All design, development, and mitigation techniques and tools for the shipboard environment are also being applied to support the joint and coalition forces operating in complex EM environments. The war in Iraq has demonstrated the need for agility in fielding technologies to defeat the improvised explosive device (IED) threat. Novel EM-based solutions have been identified and fielded throughout the war, saving the lives of the U.S. and allied forces, Iraqi civilians, and police. S&T efforts must continue to identify and exploit EM means for achieving desired effects. Without a strong S&T backbone, the viability of future U.S. military forces will be in jeopardy.

Preventing Technical Surprise

Technological surprise occurs when an adversary develops a technology that provides a revolutionary capability. Instances of technological surprise often destabilize existing balances of power and change the competitive landscape among nations. Historical examples of technological surprise include the development of the atomic bomb, submarines, aircraft carriers, amphibious warfare, strategic bombers, intercontinental cruise missiles, and satellites. S&T was critical in the development of each of these destabilizing developments, and it continues to be the first step in developing any new capability.

The above technologies are taken for granted today due to their history of employment. For example, aircraft carriers have been employed for

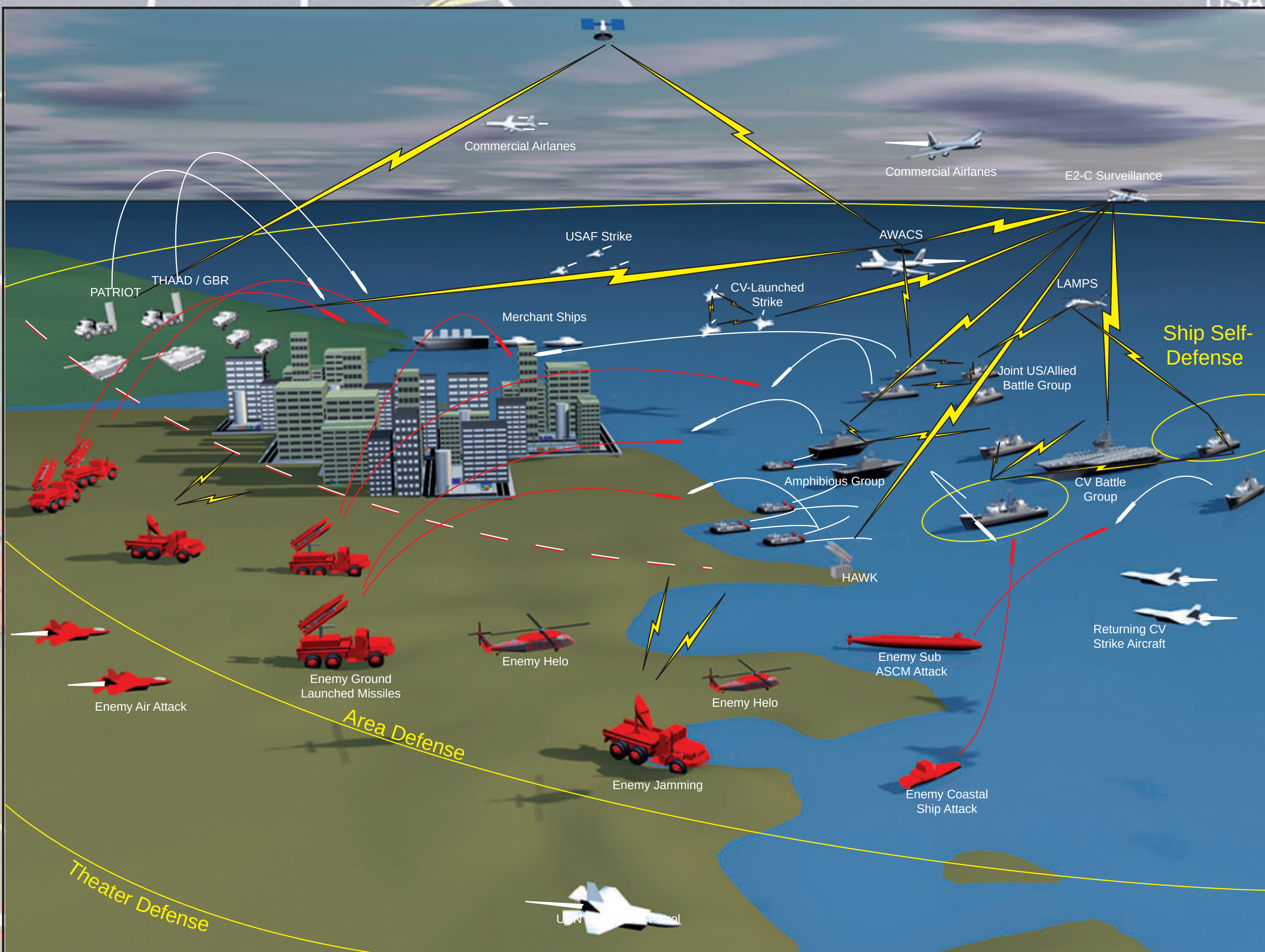

Figure 3. The Present Electromagnetic Environment

over 90 years and submarines for 233 years. But when they were first developed, each allowed its creator to exercise control over competitors in new ways. If atomic bombs and satellites are the technological surprises of the past, what are the surprises of the future?

The pursuit of S&T by the Warfare Centers reduces the probability of technological surprise. If a new technology is developed by a foreign power, our strength in S&T allows us to rapidly study and understand the mechanisms being used, and to develop our own defenses and countermeasures. Further, we must always strive to be the ones introducing the element of technological surprise to the fight. For these reasons, it is essential that the Warfare Centers invest in S&T, not only in E3, but in all areas of military importance. To neglect S&T for short-term goals is nothing short of mortgaging the military future of the United States. This is a risk we must not accept.

Reference

1. Conway, J.; Roughead, G.; and Allen, T., *A Cooperative Strategy for 21st Century Seapower*, October 2007.