Support to Hurricane Katrina Disaster Relief Operations

By Margaret Neel

When Category 5 Hurricane Katrina pounded the Southeastern United States in August 2005 (see Figure 1), it caused unbelievable devastation to the region. It also caused tremendous problems for first responders; federal, state, and local departments and agencies; and the Navy, who were all supporting Federal Emergency Management Agency (FEMA) disaster relief operations.

Many people know firsthand the impact of a natural disaster. Something many people may not fully understand, however, is that underlying successful rescue and relief efforts is an invisible force called the electromagnetic spectrum—the medium that transports cellular phone calls, distress signals, and air traffic control commands. The Naval Surface Warfare Center, Dahlgren Division (NSWCDD), through its Electromagnetic and Sensor Systems Department, E3 Force Level Interoperability Branch, Spectrum Engineering Group, supported Hurricane Katrina operations and played a key role in coordinating and controlling the electromagnetic spectrum during those operations.

To do so, it employed the Spectrum Engineering Group's software program called the Afloat Electromagnetic Spectrum Operations Program (AESOP), which sailors routinely use to develop frequency plans for radars, communications, and weapon systems prior to every underway period anywhere in the world. Inherent to the AESOP software is the engineering expertise of the AESOP Team to identify, measure, and quantify electromagnetic interference (EMI) and to develop the AESOP software models that provide actionable results in real-world situations. Without proper AESOP analysis and frequency plans, the U.S. Navy risks system fratricide and the violation of international spectrum law.

In support of the Hurricane Katrina relief efforts, at a time when most normal communications systems and infrastructure had been wiped out by

Figure 1. 050828-O-0000X-001 Gulf of Mexico (August 28, 2005)—GOES-12 Satellite image provided by NASA Goddard, Space Flight Center, Maryland, showing the status of Hurricane Katrina, at 1200Z or 7 a.m., EST. The storm crossed South Florida Thursday and headed back to sea in the Gulf of Mexico. The storm's wind has now increased to 160 mph, a Category 5 storm. Only three Category 5 hurricanes—the highest on the Saffir-Simpson scale—have hit the United States since record keeping began. The last was 1992's Hurricane Andrew, which leveled parts of South Florida, killed 43 people, and caused $31 billion in damage. The other two were the 1935 Labor Day hurricane that hit the Florida Keys and killed 600 people, and Hurricane Camille, which devastated the Mississippi coast in 1969, killing 256. Katrina was over the Gulf of Mexico, about 250 miles south-southeast of the mouth of the Mississippi river at 7 a.m. local time, according to an advisory posted on the U.S. National Hurricane Center's website. The storm was moving toward the west-northwest at 12 mph. NASA photo (RELEASED)

the force of the hurricane and the flooding from Lake Pontchartrain, members of the Spectrum Engineering Group's AESOP team provided both on-site and long-distance support to ensure proper spectrum coordination. AESOP team members were on-site at the Joint Task Force (JTF) Katrina Spectrum Management Element (JSME), which was headquartered in Norfolk, Virginia. They coordinated spectrum use for U.S. Navy ships and U.S. Coast Guard vessels, in conjunction with the National Guard; FEMA; and other federal, state, and local authorities. That was a huge task, involving frequency requirements for several hundred frequency-dependent devices that were very quickly moving in and out of the area. The task was further exacerbated by the fact that there was no estimation of how many of the land-based relay towers or other infrastructure for communications systems were still intact and operational (see Figure 2).

The Navy deployed 19 U.S. Navy ships to the area to provide rescue support. Three of the U.S. Navy ships—USS *Bataan*, USS *Iwo Jima*, and USS *Shreveport*—provided hospital beds to augment the field hospitals established at Louis Armstrong New Orleans International Airport. At least 346 helicopters and 68 airplanes supported the operation and ferried injured civilians to the ships (see Figure 3). None of this could have been accomplished without access to and proper coordination of the electromagnetic spectrum. From communications, to air traffic control, to navigation, hundreds of spectrum-dependent devices were brought into action to support military and civilian operations.

Early in the Hurricane Katrina rescue effort, the on-site AESOP team identified some problems that could have severely curtailed the Navy's ability to provide support to the rescue operation. Two of the more serious problems included a lack of Navy systems' frequency assignments for the Gulf of Mexico area and invalid Defense Department Form 1494 (DD-1494) data for some equipment.

In the same way that you may have seen television public announcements for renewal of a broadcasting license, military equipment also must be

Figure 2. 050903-N-6046R-007 Fort Worth, Texas (September 3, 2005)—U.S. Navy Commander Paul Widish, assigned as Operation Officer of Naval Air Station Joint Reserve Base (JRB) New Orleans, communicates with rescue operation personnel from the base's Emergency Operations Center. The Navy's involvement in the Hurricane Katrina humanitarian assistance operations is led by the FEMA, in conjunction with the Department of Defense. U.S. Navy photo by Photographer's Mate 1st Class Andrew Rutigliano (RELEASED)

granted approval to operate in a given geographic area. In the Gulf of Mexico, at the time of Hurricane Katrina, most of the frequency assignments for Navy equipment had expired. Consequently, from a legal standpoint, the U.S. Navy could not turn on any system that radiated electromagnetic energy that did not have an approved frequency in that area. U.S. Navy ships had a mission to complete, however, and needed a way to solve this problem and save human lives. To address this situation, the AESOP team prepared and submitted to the Area Frequency Coordinator's office, the Navy-Marine Corps Spectrum Office, and the JTF Katrina staff, several requests for special temporary frequency assignments for mission-critical systems. Following this process ensured that the Navy's frequency use was properly logged with the appropriate commands so that those frequencies would be protected and could be legally used to support mission-critical operations.

The second major problem involved outdated DD-1494 forms for some Navy equipment. Some of the requests that the AESOP team submitted for temporary frequencies could not be resolved against the official DD-1494 records for the systems' characteristics, such as emission bandwidth, transmitter power, receiver sensitivity, and antenna gain, to name a few. Consequently, the AESOP team immediately initiated an effort to update the DD-1494 forms for those systems. Updates to several radars have been completed and processed through national databases that track and regulate spectrum use.

Hurricane Katrina represented just one example of how the AESOP team helps to assure Navy missions. Without the AESOP team's support, and without the AESOP program, the Navy might not have been able to fulfill its disaster relief mission and the situation, as bad as it was, could have been exponentially worse.

Figure 3. 050901-N-8047K-158 Mississippi (September 1, 2005)—U.S. Navy air crewmen, assigned to Helicopter Support Unit Pensacola, survey the damage from hurricane Katrina en route to Stennis Space Center, Mississippi, after leaving Naval Air Station Pensacola, Florida, to provide support and relief to victims of the hurricane. The Navy's involvement in the humanitarian assistance operations is led by FEMA, in conjunction with the Department of Defense. U.S. Navy photo by Mr. Larry W. Kachelhofer (RELEASED)

E3 Support of Counter Remote-IED Electronic Warfare

By Kenneth D. Larsen, D. Michael Mearns, and Albert H. Pitts

The Improvised Explosive Device

September 11, 2001, is a day cemented in the minds of Americans. Al Qaeda's attacks on that day initiated what became known as the global war on terror. Seven years later, with U.S. and coalition forces still fighting in Iraq and Afghanistan, thousands of American and coalition forces have died, many as a result of improvised explosive devices (IEDs). Unconventional? Yes. Effective? Unsettlingly so. IEDs clearly took center stage in Iraq, replacing traditional warfare (see Figure 1). They were initially used on a small scale during the Vietnam War and again in Afghanistan years later. However, since the United States' 2003 invasion of Iraq, the popularity of IEDs among Al Qaeda terrorists has greatly increased.

Today, the challenge facing the electromagnetic environmental effects (E3) community centers on remote-controlled improvised explosive devices (RCIED). The question being asked is: How do we maintain the effectiveness of devices designed to counter RCIEDs, while ensuring electromagnetic compatibility (EMC) with other radio frequency (RF) systems that warfighters need? For the U.S. Navy E3 community, this is not unfamiliar territory. Since RF systems were first fielded on ships, the Navy has been confronted with electromagnetic interference (EMI) challenges. To address these challenges, the U.S. Navy stood up programs and assigned them

Figure 1. Result of IED Attack—NSWCDD Reservist in Convoy

the task of improving EMC among ship systems and families of systems. Two such programs are:

1. The Shipboard Electromagnetic Compatibility Improvement Program (SEMCIP), which concerns itself with surface ships and submarines
2. The Air Systems Electromagnetic Interference Correction Action Program (ASEMICAP), which concerns itself with issues related to aircraft

In Iraq and Afghanistan, while the platform focus changed from ships to ground-based vehicles, and while the systems differ from those traditionally observed on Navy platforms, the problem remains essentially the same: large numbers of emitters on limited real estate. To the EMI problem solver, the ground vehicle challenge, therefore, represented nothing more than a ship on wheels.

Over the years, U.S. ground forces witnessed an ever-increasing number of RF transmitters and receivers on ground vehicles. The traditional paradigm of EMC through system separation proved ineffective. Thus, the lingering challenge remained: how do we optimize performance and ensure EMC with the constraint of limited real estate? This is a familiar challenge for the Navy. In accepting this challenge, the Navy E3 community expanded its EMC role to assist the other services and coalition ground forces supporting the global war on terrorism in both the Afghanistan and Iraq theaters.

The Naval Surface Warfare Center (NSWC) (Dahlgren Division (DD) and Crane Division (CD))—in concert with the Naval Explosive Ordnance Disposal Technical Division (NAVEODTECHDIV), U.S. Army Intelligence & Information Warfare Directorate (I2WD), and other agencies—supported the design, development, and fielding of mounted and dismounted counter remote IED electronic warfare (CREW) systems for Program Executive Office, Littoral Mine Warfare (PEO LMW), PMS-408 (PMS-EOD/CREW), and the Joint IED Defeat Organization. Faced with a compressed fielding plan, the tasks were daunting and included such things as system assessments, system effectiveness testing, RF hazard assessments, spectrum management, and EMI problem solving.

Efforts in Support of CREW

System Assessment

The Naval Surface Warfare Centers were assigned the responsibility of conducting system assessments on each CREW systems design and to participate on the source selection boards as subject matter experts. During the source selection process, E3 engineers assessed each competing CREW system's graphical user interface (GUI), functional block diagram, firmware design, RF architecture, and overall system capabilities. Effectiveness, compatibility, and interoperability tests and test results were summarized and explained to the board members. Competition test results, field reports from theater, and inputs from NAVEODTECHDIV, NSWCDD, NSWCCD, Naval Research Laboratory (NRL), Johns Hopkins University Applied Physics Laboratory (JHU/APL), and I2WD were used to shape future system requirements and testing for new systems and for subsystem components. E3 engineers helped shape future system requirements and subsequently performed subsystem component testing during system development, as well as complete systems testing during CREW system competitions or legacy system updates.

System Testing

The Naval Surface Warfare Centers supported system testing in order to quantify each CREW system's ability to defeat an IED. Compatibility tests determined the extent to which non-CREW systems deployed in support of the warfighter could operate simultaneously near a CREW system. These types of tests required detailed electrical knowledge of the IED, how it was employed, CREW system functions, and operational tactics to accurately determine how well a CREW system could defeat an IED. Compatibility tests determined whether two different CREW systems operating simultaneously could suppress an IED without destructive interference. Furthermore, engineers helped determine safe operating procedures to prevent any operationally destructive effects among CREW systems while suppressing an IED. Compatibility testing determined how various non-CREW systems and CREW systems could operate simultaneously on the same vehicle. Knowledge of CREW and non-CREW systems' operational parameters were used to test various scenarios to determine family-of-systems capabilities and limitations. Based on the effectiveness and compatibility test results, tactics were developed to best optimize each type of CREW system's capabilities.

RF Hazards Assessment

NSWCDD's E3 Assessment and Test Branch of NSWCDD conducted hazards of electromagnetic radiation to ordnance, personnel, and fuel (HERO, HERP, and HERF) testing before and after effectiveness. They also conducted compatibility testing to determine if the systems were safe to operate and to determine the safe standoff distances from each CREW systems antenna. The branch conducted a number of HERO tests on a variety of U.S. Marine Corps, U.S. Navy EOD, Army, and Air Force mine resistant ambush protected (MRAP) platforms and other vehicles. As a result, HERO guidance, in the form of safe separation distances, was identified, and this information was promulgated to forces deployed in theater to mitigate the possibility of inadvertent initiation of ordnance in the proximity of vehicular transmitting systems, including CREW. In addition, HERP and HERF testing was accomplished on these vehicles to identify radiation hazard (RADHAZ) concerns, and control measures were subsequently provided to mitigate and manage these concerns. Similar specific absorption rate (SAR) testing was also performed on man-portable CREW systems.

Spectrum Management

NSWCDD's E3 Force Level Interoperability Branch leveraged established infrastructure to provide spectrum management and deconfliction. The Afloat Electromagnetic Spectrum Operations Program (AESOP), originally developed for NAVSEA 62E, is the Navy's afloat spectrum management software tool. It is used throughout the fleet to develop spectrum usage plans and to predict, identify, and mitigate EMI among RF systems. It also predicts intermodulation interference among systems, provides visualization of EMI among units, and ensures that units follow regional and international laws and treaties worldwide.

AESOP was upgraded to include CREW devices (see Figure 2). AESOP helps address the problem of EMI from CREW devices, which could potentially interfere with other U.S. and coalition systems. AESOP's CREW capabilities provide:

- Organic capability with minimal training required
- Visualization of communications quality and EMI severity
- Prediction, identification, and mitigation of interference
- Propagation analyses, based on operational situation, geography, and weather
- Interpretation of engineering analysis results to support tactical decisions
- Interoperability with joint, coalition, host nation, and civilian systems
- CREW parametric data, spectrum emissions, models, and visualization

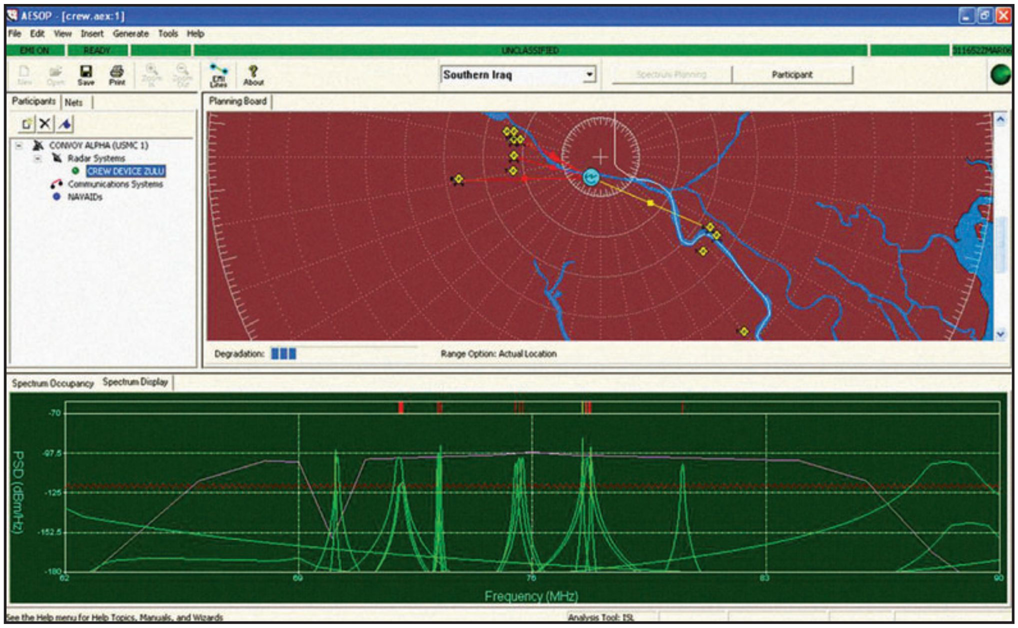

Figure 2. AESOP EW Capability Screenshot

Influence on System Requirements

In addition, the government technical team learned, along with the CREW manufacturers, what was working well with the CREW systems and what needed improvement. This enabled the government team to develop better specifications for next-generation CREW systems, such as baselines 3.1, 3.2, and 3.3. These improvements to specifications have borne fruit, with baselines 3.1 and 3.2 demonstrating increased performance, more flexibility and expandability, and improved EMC. Baseline 3.3 promises even more advances.

EMI Problem Solving

As more systems are added to military ground vehicles, the electromagnetic environment becomes more complex. Many fielded systems today comprise commercial off-the-shelf (COTS) components and, as such, are not designed to operate in a complex electromagnetic environment. Moreover, many systems transmit high levels of energy across a wide band of frequencies, thus saturating the front end of systems. Warfare Center engineers work to design specialized filters, corrugated barriers, and so forth, in order to improve the rejection of in-band energy, thereby allowing simultaneous operation of all systems. Many factors are considered when placing systems on platforms, such as frequency management, in-band and out-of-band emissions, in-band error handling, case cable penetration, antenna location, cable and terminal shielding, and equipment grounding.

Many of the EMI problems encountered have been worked on in multilaboratory, joint environments. A great example of this is the Blue Force Tracker (BFT) Interference Fix (I-Fix). NSWC Dahlgren Division began experimentation with various prototypes filters and had some success, but the effort developed more momentum when the Army's BFT Program Office, Force XXI Battle Command, Brigade-and-Below (FBCB2) and the Communications-Electronics Research, Development, and Engineering Center (CERDEC) Science and Technology (S&T) division joined the fight. FBCB2 tasked the BFT manufacturer to develop a new version of the FFT with a filter inserted to mitigate the CREW EMI. CERDEC S&T provided test facilities and experienced personnel and, within a matter of months, the final solution was fielded (see Figure 3).

Conclusion

Warfighters today are much safer than just a few short years ago, largely due to the E3 community's support to CREW. The success of these efforts enables simultaneous transmissions from CREW and non-CREW systems, thereby assuring warfighter missions. More importantly, they no doubt have saved U.S. and coalition lives.

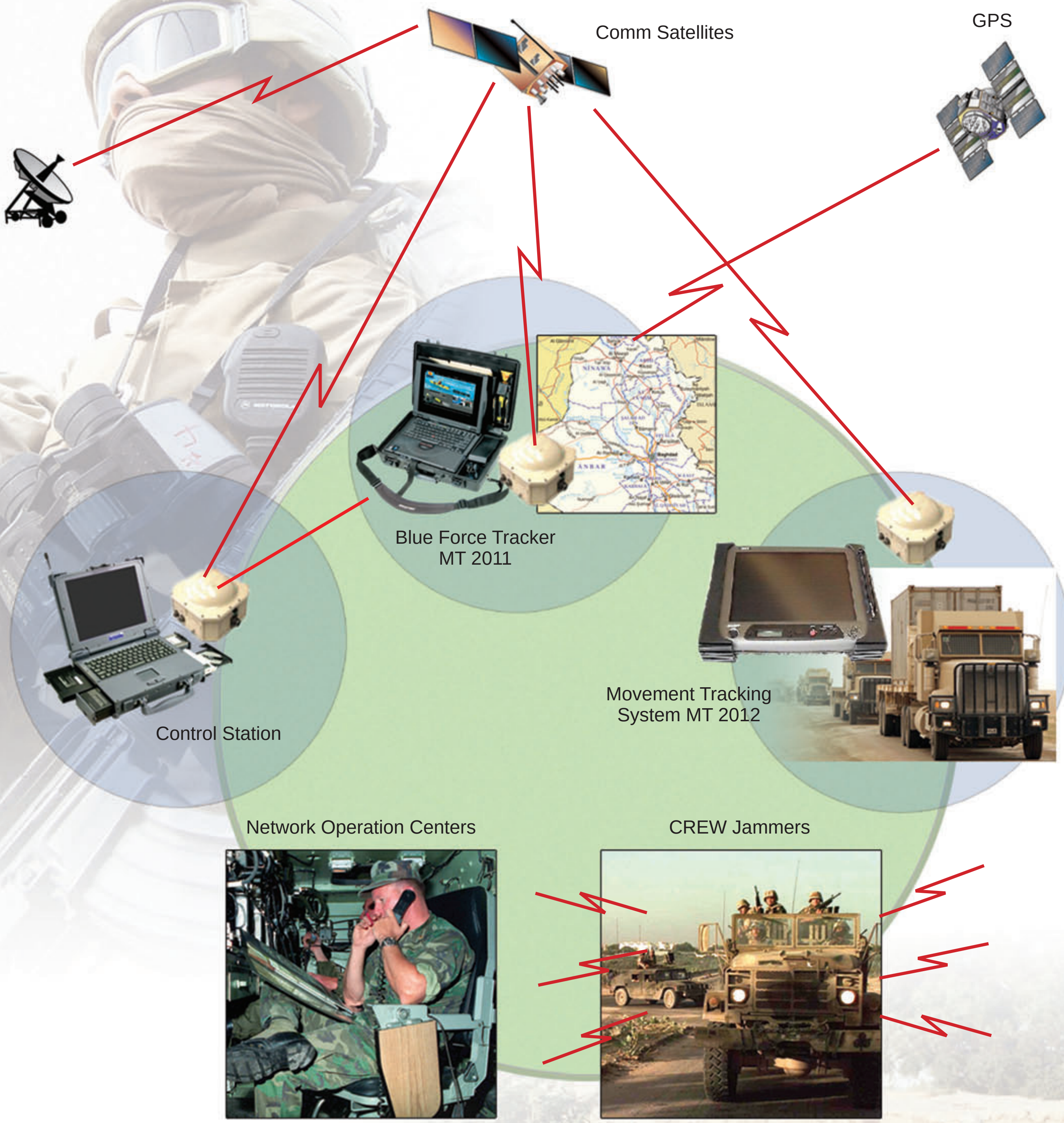

Figure 3. Blue Force Tracker Concept With CREW EMI

Integrated Topside Design Support for the U.S. Coast Guard National Security Cutter

By Richard E. Thompson

The U.S. Coast Guard (USCG) National Security Cutter (NSC) is the flagship of the fleet, capable of meeting all maritime security mission needs. It is the largest and most technically advanced class of cutter in the USCG, with robust capabilities for maritime homeland security, law enforcement, and national defense missions.

At 418 ft, the lead ship in the new *Legend*-class of the NSC is capable of executing the most challenging maritime security missions, including supporting the mission requirements of the joint U.S. combatant commanders. The NSC is the largest and most technically advanced ship class of the Integrated Deepwater System (IDS) program's three major classes of cutters and will replace the aging 378-ft *Hamilton*-class High Endurance Cutters that have been in service since the 1960s. Figure 1 shows the first ship of the class, U.S. Coast Guard Cutter (USCGC) *Bertholf*, Maritime Security Cutter, Large (WMSL 750).

Compared to existing cutters, the NSC's design will provide better seakeeping and higher sustained transit speeds, greater endurance and range, and the ability for launch and recovery of small boats,

Figure 1. USCGC *Bertholf* During Sea Trials

helicopters, and unmanned aerial vehicles (UAVs) in higher sea states—all key attributes enabling the USCG to implement increased security responsibilities. These enhanced capabilities will enable more effective enforcement over foreign-flagged ships transiting U.S. waters. Moreover, Deepwater's more capable maritime security cutters will enable the USCG to screen and target vessels more quickly, safely, and reliably before they arrive in U.S. waters—to include conducting onboard verification through boarding and, if necessary, taking enforcement-control actions. The NSC will serve as an integral part of the USCG's collaborative interagency effort to achieve maritime domain awareness and ensure the safety of the American public and sovereignty of U.S. maritime borders.

The Naval Surface Warfare Center (NSWC) Dahlgren and USCG Teaming Together

The USCG tasked the Naval Surface Warfare Center, Dahlgren Division (NSWCDD), Electromagnetic Environmental Effects (E3) Ship Integration Branch, to serve as topside design agent for the NSC and to address integrated topside design (ITD) and E3) issues in preparation for the ship's post shakedown availability (PSA). The task was not to redesign the NSC, but to integrate new antennas into the existing design, utilizing the available space to maximize performance and minimize impact. Unlike most PSA installations, the planned WMSL 750 PSA effort represented a major integration of electronic equipment and antennas that would provide the NSC with new capabilities to meet the NSC's diverse mission requirements. The principal equipment additions support a Sensitive Compartmented Information Facility (SCIF), navigation, exterior communications (EXCOMM), and electronic support measures (ESM).

NSWCDD's E3 Ship Integration Branch conducted a design, integration, and systems engineering review for the WMSL 750 and USCG *Waesche* (WMSL 751) topside systems. This effort was a subset of engineering activities managed and coordinated as part of the total ship design effort for the *Legend*-class NSC. The task required coordination, teaming, and liaison with the other engineering, management, and production activities, including:

- USCG Deepwater command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) and NSC project officers
- USCG Program Manager Representative Office (PMRO)
- Naval Sea Systems Command (NAVSEA) technical codes
- Space and Naval Warfare Systems Command (SPAWAR)
- Naval Air Systems Command (NAVAIR)
- Program Acquisition Resource Managers (PARMs)
- the shipbuilder, Northrop Grumman Ship Systems (NGSS)
- Supporting contractors

Initial efforts included familiarization with the *Bertholf* topside configuration and the development of a three-dimensional (3-D) computer-aided design (CAD) model. The ITD team identified suitable antenna locations for the new antennas, noting the risks involved by integrating the antennas in particular locations. The Total Ship Electromagnetic and Environmental Effects (TSE3) team provided support to the ITD effort by conducting an E3 assessment of the WMSL 750 and by providing E3 inputs to the ITD team. The Computational Electromagnetic Modeling (CEM) group provided CAD and computational analysis support, producing a new 3-D CAD model in Autodesk Inventor by the end of fiscal year 2008 (FY 08). Additionally, the NSWCDD ITD, TSE3, and CEM design teams:

- Conducted ship visits
- Developed an ITD management plan
- Developed a Source-Victim Matrix
- Conducted Blockage Analysis studies
- Updated the 3-D Topside Model
- Organized a Topside Working Group to support USCGC NSC design studies

Tailored Integrated Topside Design Process

NSWCDD tailored the ITD process to meet the NSC schedule and scope of work based on the current state of NSC construction and the need to review the current NSC configuration. Although most of the system allocation occurred prior to

NSWCDD participation, there was some reallocation of new systems during the overall process. The basic process remained intact; however, the USCG did not seek ITD certification. The tailored process appears in Figure 2.

Modeling Requirements

The USCG provided NSWCDD with a 3-D CAD model of the NSC, previously developed by the ship integrator. This model included the existing antenna configuration planned for the NSC at the time of ship delivery. However, the modeled antennas were generic, in the form of cones and cylinders, and not representative of the actual antennas on board the NSC. Consequently, NSWCDD updated the existing 3-D CAD model to support an immediate need for topside analysis. The updated model would include actual antenna representations required for conducting numerical electromagnetic compatibility (EMC) analysis using the CEM tool set. The updated model would also include the post-PSA antennas. Additionally, NSWCDD determined that a new 3-D CAD model, based on Autodesk Inventor software, would be advantageous to the long-term configuration management requirements of the USCG and future analysis efforts using CEM tools. There were many advantages to using Autodesk Inventor over AutoCAD 3-D, including ease of use, able to convert a 3-D model to a 2-D drawing, and compatibility with CEM tools for numerical analysis. NSWCDD chose to develop the Inventor model in two versions: the existing ship configuration and the post-PSA configuration. The Inventor model would include the level of detail required to conduct numerical analysis and topside configuration management for major topside items, such as antennas, lights, weapons, vents, etc.

Integrated Topside Design (ITC) Analysis

The ITD analysis effort began with a basic learning of the NSC mission and communication requirements, followed by an understanding of the individual system operational requirements. The ITD process served as the conduit to marry these distinct requirements, conduct trade-off studies, and produce a topside design to maximize ship mission effectiveness and minimize system interference. No topside design is without risk, however, and the resultant NSC design was no exception. The ITD process served to identify the significant risk items, which appear later in this article.

Due to the limited available topside real estate (resulting from the presence of other topside equipment, including antennas, weapons, lights, cameras, etc.), the topside team initially looked for available topside space where the systems could operate and meet mission requirements. It was obvious, however, that the larger satellite communications (SATCOM) antennas were going to require relocation of some existing antennas to improve overall antenna coverage and to minimize impact to other systems, especially weapons. The design

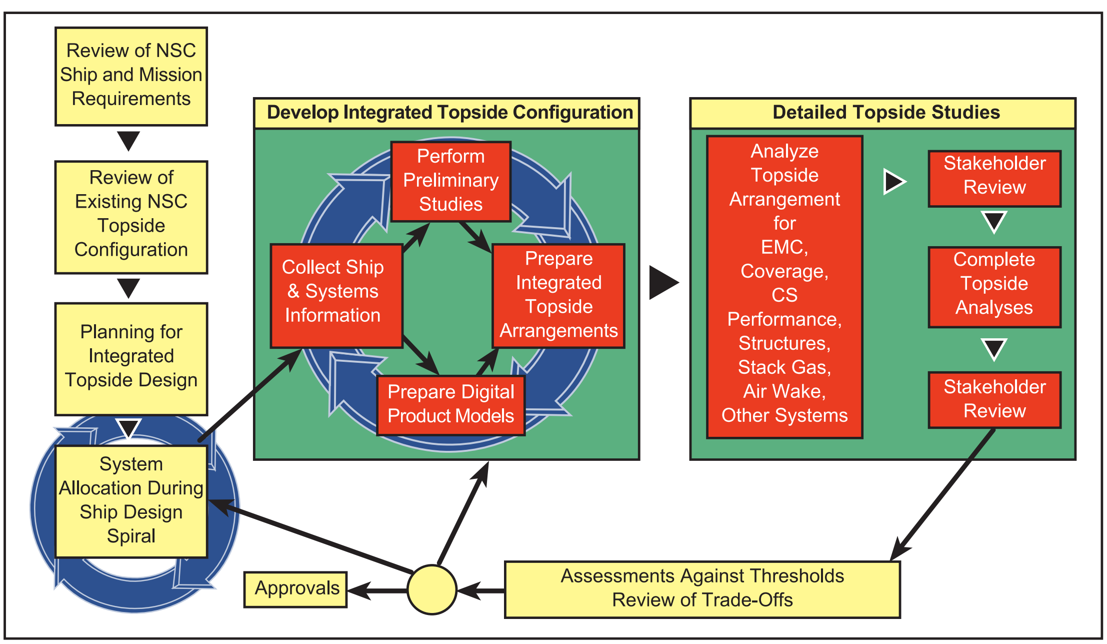

Figure 2. Tailored ITD Process

team identified notional antenna locations utilizing the available topside 2-D drawing provided by the ship builder and the topside model. The design team refined the locations, following ship checks aboard the *Bertholf*, and reviewed analysis results. The SPAWAR System Center conducted the high-frequency (HF) antenna analysis. The following discussion summarizes the analysis followed for the individual topside antennas planned for integration during PSA.

Computational Electromagnetic Analysis (CEM)

NSWCDD conducted CEM analysis to assess the overall NSC electromagnetic (EM) environment, conduct blockage studies, and to analyze the E3 risk due to the integration of PSA antennas. The CEM analysis helped determine the appropriate locations for topside antennas to achieve optimum coverage. The blockage studies utilized Blockage Analysis Model (BAM) and were particularly useful for locating the larger SATCOM antennas. Figure 3 is a sample 3-D CAD model of the topside area above the NSC Pilot House used to evaluate antenna coverage for the numerous topside antennas.

Moving Forward To Mission Success

The additional topside antenna systems planned for the NSC during PSA will provide the NSC with considerable new capabilities in terms of a SCIF, EXCOMM, navigation, and ESM systems. These new capabilities add approximately 30 new antennas to the ship's topside configuration. The NSWCDD ITD team followed a tailored ITD process to develop a topside design configuration to meet the shipboard mission requirements and maximize the performance capability of the individual systems wherever possible. There were many influences on the design, particularly the limited topside real estate to place the new antennas, the E3 consequences resulting from those antenna placements, and the impacts to weapons and personnel. The limited topside real estate forced some antennas to be in close proximity to each other, increasing the risk of electromagnetic interference (EMI) caused by high EM field strengths or inband interference from transmitting antennas. The impact to weapons was a major concern and resulted in the relocation of SATCOM antennas to minimize any loss in coverage. Personnel safety from radiation hazard (RADHAZ) conditions caused by the addition of two HF 35-ft whip antennas will require testing to identify new RADHAZ areas on the ship. Future efforts will involve the Electromagnetic Effects Division to evaluate potential RADHAZ conditions and to conduct EMI discovery and EMC certification tests to understand the ship's true EM environment. All of these efforts help ensure that the USCG's flagship NSC can safely and effectively perform its maritime homeland security, law enforcement, and national security missions.

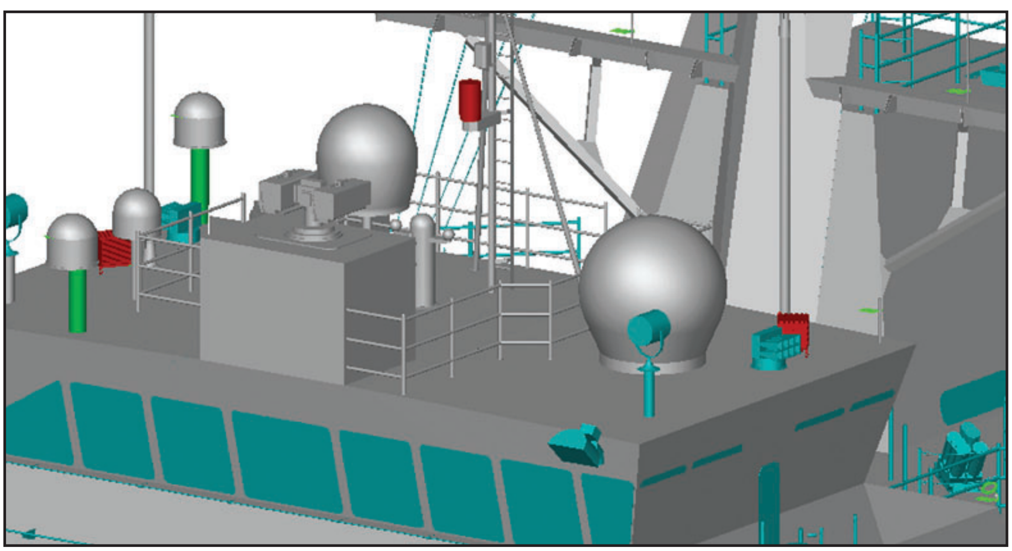

Figure 3. Sample 3-D CAD Model Snapshot