Surface Warfare

November/December 1997

Concept to Reality

Concept to *Reality*

In this issue we take a detailed look at concepts being examined by our warfighters, laboratories and industry to bring to *today's* waterfront prototypes of systems and combat capabilities the Surface Navy will require *tomorrow*. From an overview of Network-Centric Warfare to a detailed look at modeling and simulation, we examine the broad spectrum of effort and intellectual capital being invested in the future of the Navy and Marine Corps.

A carefully "gamed" operational concept, ably supported by construction of meticulous models and simulations, will no more guarantee victory in the 21st century than it did in the 19th. Napoleon, one of history's most skilled practitioners in the Art of Warfare, always had a sand table accompany his personal retinue, where battlefield dispositions and field maneuvers would be gamed in great detail by aides and the Emperor before an engagement. Still, for every Austerlitz there was a Borodino: no amount of modeling and anticipated enemy maneuver could accurately predict the steadfast Russian infantry and artillery willing to perish by the thousands resisting the French invasion.

But the value of modeling and simulation in the 20th century cannot be denied. In 1940, the concept of a rapid armored thrust into France through the Ardennes was only accepted by the German General Staff when gaming showed that such a route to victory was feasible without a return to the static trench warfare of 1914-18. Both Admirals Nimitz and Spruance in post-World War II reminiscences, commented on the value of gaming the "Orange Plan" for war with Japan. Between Pearl Harbor and Tokyo Bay, only the advent of Japanese kamikaze suicide planes took U.S. Navy leadership by surprise, not having been anticipated in countless modeling, simulation and gaming efforts at the Naval War College in the 1930s.

Given the rapid technological changes in the offing for our Navy in the first decade of the new century, the fidelity of our models and the veracity of our simulations will become all the more important, particularly given our expectations of a flat-line fiscal climate. To reduce risks attendant in introducing such dramatically increased capabilities and technologies, our Fleet Battle Experiment process is providing an important function, serving as the essential link between laboratories, industry, military skunk works — the "conceptualists" — and those who go down to the sea in ships. The real success of Fleet Battle Experiments Alpha and Bravo indicates we are off to a good start, and I anticipate we will continue to improve the process with each successive experiment.

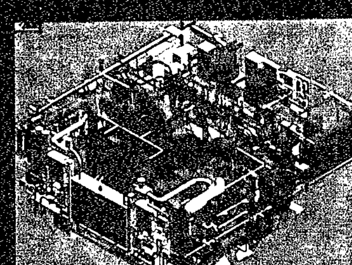
Daniel J. Murphy Jr.
Rear Admiral, U.S. Navy

SEA CHANGE

…peed of command" — the ability t… rn a superior information position i… competitive advantage

by Vice Adm. Arthur K. Cebrowski

There is a "sea change" on the Navy's horizon, a profound transformation in how we fight and prepare to fight. This Revolution in Military Affairs is driven by the seismic upheaval in information technology that is causing a tidal wave of change throughout society. Just as information technology is the new engine of economic growth, so too is it the new linchpin of military effectiveness. The Navy-Marine Corps team is moving out smartly to "catch" this wave and take advantage of its myriad new possibilities.


(Computervision Corp.)

The rapid advancement of information systems and related technologies — distributive communications, 3-D visualization, virtual reality, sensors and precision weapons — are allowing us to explore doing things in fundamentally different ways. We are just beginning to re-examine our operational concepts, doctrine, organization, force structure and training in light of the new possibilities afforded by these to develop a whole new way of doing business. In our efforts to leverage these new technologies, modeling and simulation will be one of the enablers.

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Cover: Modeling and simulation affords the Navy the opportunity to conceptualize the battlespace before experiencing it in the real-world. In this illustration, an external view of a Tomahawk in flight allows a trainee to go "beyond the console" to visualize the battlespace. *(NRL)*

Back cover: The Marine Corps is benefiting enormously from M&S as evidenced by technologies used in the Hunter Warrior warfighting experiment. One of those technologies, the Virtual Reality Responsive Workbench, acts as an electronic sand table for operational commanders. *(NRL)*

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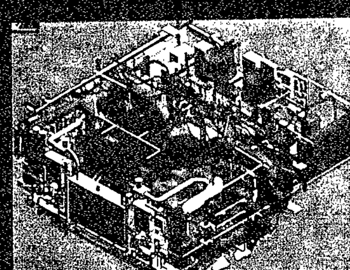
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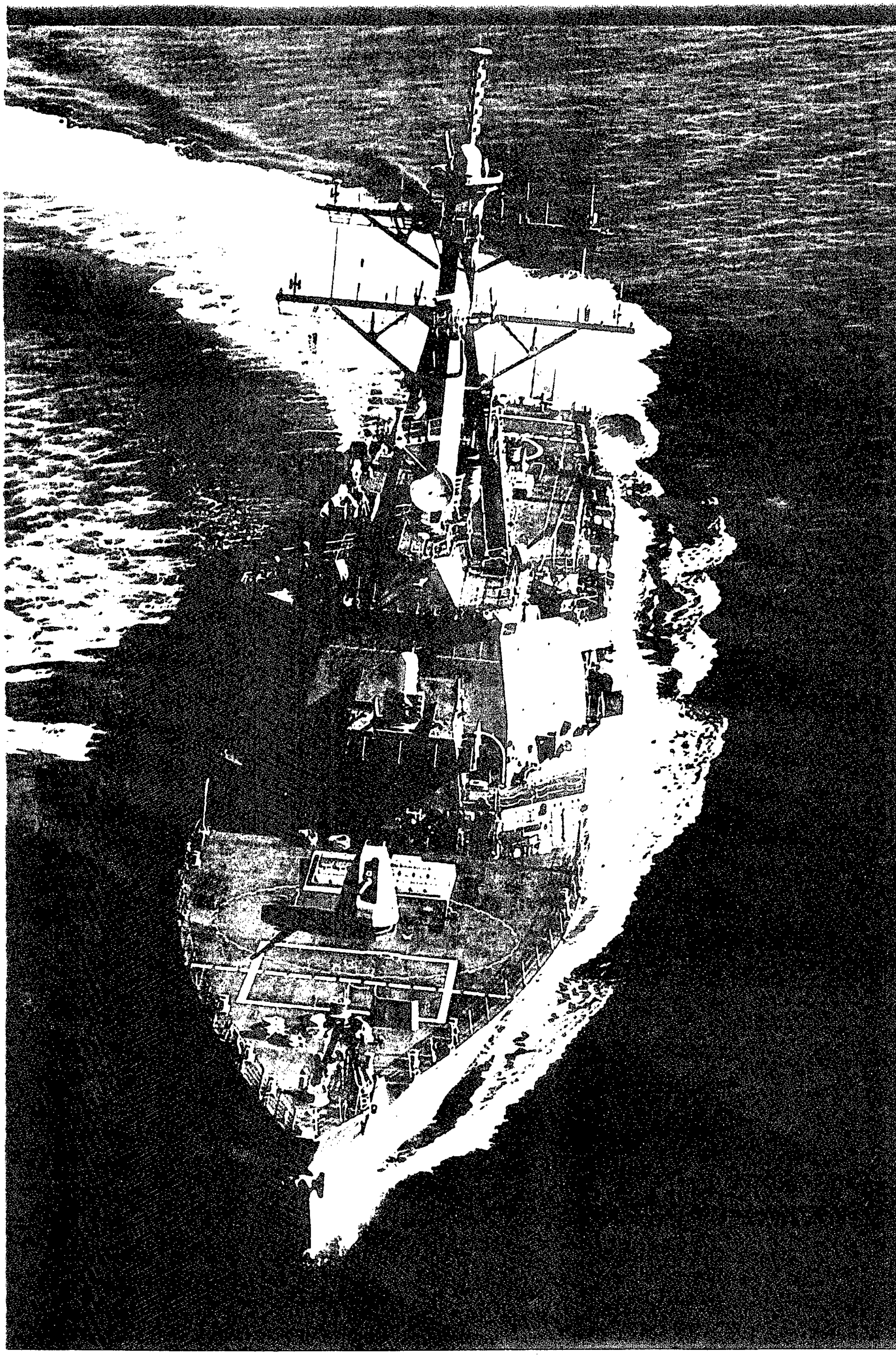


USS *Carney*
(DDG 64)
(*Debbie*
Houston/BIW)

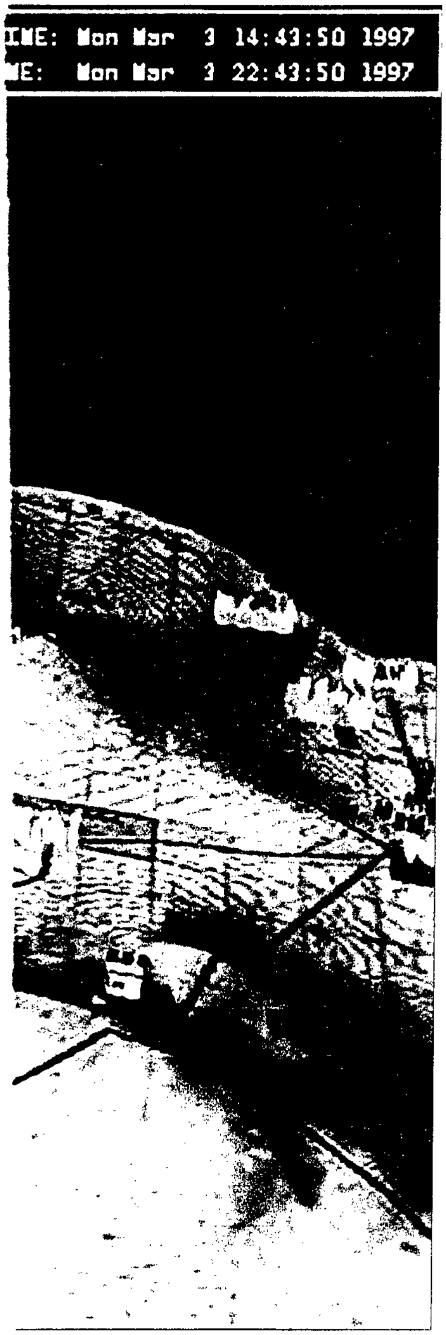
Our dominance of information processes — acquiring it, processing it, distributing it and acting on it — will enable us to focus highly effective combat power fr

Network-Centric Warfare
The *Wave* of the Future

America is the world leader in information technology and integration. Our challenge is to capitalize on that lead to gain and maintain *information superiority* over any adversary. Our dominance of information processes — acquiring it, processing it, distributing it and acting on it — will enable us to focus highly effective combat power from widely dispersed, but well-netted forces.

The principal utility of information superiority is time — the immense advantage of being able to develop very high rates of change. A critical advantage for the Navy-Marine Corps team is our traditional forward-presence role. Being forward allows us to close timelines, change critical initial conditions, foreclose enemy options and stop something before it starts. This is "speed of command" — the ability to turn a superior information position into competitive advantage. It is why information superiority is at the heart of the Navy's concept of warfare in the 21st century.

The Navy's approach to exploiting information superiority is called Network-Centric Warfare. To help understand this, let me start with an analogy to the larger realm of information in general. Just a few years ago, the stand-alone computer or workstation was the high-end of computer use, and computer users sought to have the greatest possible capability in their platform.



ly dispersed, well-netted forces. *(NRL)*

Today, the focus of information systems has shifted away from this "platform-centric computing" to "network-centric computing," in which the greatest possible capability is resident in the network to which the workstation is connected. The network provides vastly increased capability to the end users by increasing the amount of information available to them, accelerating the rate of information transfer and decreasing decision delay.

This foundational shift from *platform* to *network* as the locus of power is the core concept of the new approach to warfighting. In the past, the yardstick of comparison for military forces was platforms — numbers of ships, submarines and aircraft. The focus of this "platform-centric warfare" is *mass*; combat power is generated through the *massing of platforms*, and victory is determined by relative attrition.

On the battlefield of tomorrow, the key to victory will be achieving an information edge and converting that edge into a decisive competitive advantage. We will still need highly-capable platforms, but we'll be able to dramatically increase their aggregate combat power by massing *effects* through the synergy of networking.

Network-Centric Warfare uses high-capacity, multimedia networks of sensors, shooters and commanders to achieve the power of a truly integrated force. These networks form a seamless information grid which provides high-speed information transfer. Additionally, the information grid provides a graphics-rich environment, speeding decision processes and enabling self-synchronization of military operations. Sensor information will fuse with command information to provide a hitherto unrealized capability for dynamic prioritization and allocation of sensors and weapons. This information enables our "speed of command."

By maintaining a higher degree of battlespace awareness, we'll reduce the operational pause associated with decision-making and limit an enemy's opportunity to regain the initiative, transforming warfare from a step function to a continuous process. This rapid, continuous decision-making process will allow us to move from sequential to simultaneous operations.

To make Network-Centric Warfare a reality requires us to develop a compatible methodology for command and control. The network-centric battlespace could easily provide enough information to overwhelm decision-makers. It will do us no good to accelerate bad decisions. To meet this need, we're working on a new concept of command and control — *Command 21* — to help decision-makers cope with the flood tide of information.

The Command 21 concept is based on a new way of looking at the decision-making process — Naturalistic Decision-Making (NDM) — and a new way to design decision-support systems — Decision-Centered Design Process (DCDP). The premise for NDM is that decisions made under stress are not normally made using a rational choice process. Without stress, a decision-maker will often construct several alternatives, evaluate the current situation and select the alternative most appropriate to the situation.

Under stress, however, what information is recognized is then mentally "fitted" into learned situations in which the decisions to be made are known to the decision-maker. This often results in either the decision-maker basing the decision on his "gut" feeling (forcing the situation into a learned one) or on an incomplete understanding of the situation (because information was not recognized, understood or remembered).

DCDP involves a careful evaluation of the information actually used by a decision-maker under stress to reach decisions and then using this to design a more efficient decision-making environment by changing such things as information access, processing or presentation, command center staffing or procedures, and decision-maker training. Here "more efficient" is defined as the decision-maker being able to recognize the useful decisions more quickly and accurately than before the DCDP improvements were implemented.

This fundamental shift from *platform* to *network* as the locus of power is the core concept of the new approach to warfighting. *(USN)*

In seeking to attain faster and more accurate command control, our principal obstacle is the fact that humans have natural information shortcomings when working under stress. One way to overcome this handicap is to shift from an environment where humans operate computers to one in which the computers provide direct support to humans.

First, the information the decision-makers need must be displayed in easily recognizable formats; and second, decision-makers' recognition skills must be honed by training with the display formats on their own support systems. This effort will define a new, higher level of man-machine interface.

These are exciting things on our horizon, but there is much to do to realize all the potential. A "business as usual" approach will not get us there. We need new processes and new tools to help us make better force structure decisions, prepare and evaluate operational plans more effectively, acquire higher quality systems in less time, and train our forces in a new-style warfare. In each of these realms, modeling and simulation holds the promise of meeting our goals.

Modeling and Simulation

The challenge of adapting to Network-Centric Warfare is daunting — this is a fundamental shift in our *modus operandi*. In today's fiscally-restrained environment, we must be concerned about the most efficient use of resources. Modeling and simulation will be one of the keys to adapting to a new warfare paradigm both expeditiously and efficiently. Modeling and simulation — together with other new technologies — will help us to meet the challenges by providing better insights, more realistic training, validation of concepts and doctrine, better assessments of operational plans and force mixes, and a more streamlined acquisition process.

Under the broad umbrella of assessment there are three distinct areas in which M&S supports analytical efforts: budget and force-structure planning; operational mission planning; and doctrine development and validation. Through M&S tools, headquarters analysts will provide decision-makers with more robust estimates of force structure requirements, sizing, costs, effectiveness and alternatives, assuring the best allocation of scarce resources. Navy decisions affecting acquisition, roles and missions, and budget will be strengthened by simulation-based quantitative analysis.

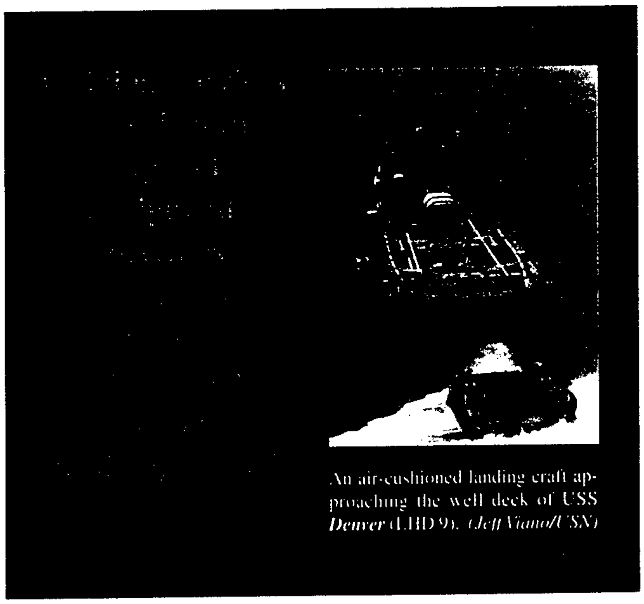
Additionally, analysts will be able to examine, more fully, force-deployment options, operational plans and strategies, and alternative future force structure mixes. For mission planners — from the unit level to CINCs — we intend to provide a locally tailorable, coherent set of M&S tools to assist in the development, assessment and preview of naval plans in the Joint Maritime Command Information System and Global Command and Control System environment.

The tool set will cover the full spectrum of requirements from force level to unit level, for all aspects of littoral warfare, and function within the demanding timelines of contingency operations. An integrated, distributive, operations planning process will allow mission planners to construct battle plans quickly, examine alternative courses of action, explore "what if" excursions, conduct rehearsals and pass final plans up and down the chain of command. These same tools — principally the Naval Simulation System — will also facilitate development of warfighting doctrine, an especially important requirement as we move toward the uncharted waters of a new mode of warfighting. The unique contribution of M&S in doctrinal development is at the leading-edge of modeling human behaviors. In all of these efforts, the intelligent integration of M&S tools will help us better plan for the future.

M&S will allow us to meet the Chief of Naval Operations' goal to "Take training to sea." The concept, stated simply, is: "...the ship, when properly supported, presents the most effective training site for appropriate operational and functional training." This concept would enable warriors at all levels to train on their own equipment, resulting in greater efficiency as training is accomplished on the actual platform vice land-based mock-ups or simulators throughout interdeployment training cycles.

M&S will provide the "proper support" to make realistic training *in situ* a reality. We'll be able to inject credible synthetic (computer-generated) forces to stimulate our systems, operators and staffs. We've already taken the first steps to demonstrate this capability in both the Atlantic and Pacific Fleets. We'll also be able to create large-scale distributive training exercises linking widely dispersed units (in port and at sea) in a common tactical picture.

A fleet commander or battle group commander will be able to construct a rigorous multithreat exercise to stress the command and control system — from top to bottom — without having to have all players at sea or having to provide "Orange" forces.



An air-cushioned landing craft approaching the well deck of USS *Denver* (LHD 9). *(Jeff Viano/USN)*

This marriage of M&S and C4ISR systems will yield high-fidelity training at affordable cost. Such challenging training is absolutely essential to attain the speed of command demanded by Network-Centric Warfare. Our principal program fulfilling this vision is the Battle Force Tactical Trainer, which will embed simulation capabilities in shipboard combat systems for unit-level training. For JTF-level simulation, we are participating in the development of the Joint Simulation System (JSIMS), which will provide the architecture to support large-scale multiservice simulations for commanders and battle staffs. JSIMS will facilitate training in all phases of military operations, including *operations other than war*.

The acquisition arena is one in which modeling and simulation has already been extensively employed in design, development and production. Acquisition M&S tools are stand-alone, single-purpose applications. Now we're moving M&S to the core of the acquisition process, in what we call "Simulation-Based Design."

The key technology in achieving this process is the "smart product model," a comprehensive digital representation of the developmental system, which can be shared by all functional areas in the acquisition process (design, assessment, test and evaluation, training and support). We're also moving away from a "Design-Build-Test-Rebuild" methodology to a "Model-Test-Model-Test...Build" scheme, in which designs are developed through multiple iterations of the smart product model tested in a virtual environment.

Our goal is to use M&S to streamline the acquisition process by allowing us to manage complexity better. By streamlining I mean using M&S tools to solve problems earlier in the developmental process when they are easier to solve. By moving the complex problem forward and handling it in a virtual environment, we save time and money when we begin "cutting metal." The ultimate goal is to get higher-quality systems and platforms into the hands of the operators significantly faster.

Network-Centric Warfare is the most sweeping change in the nature of maritime warfare since the introduction of radio. The battlefield of the 21st century will be one in which the force with the mastery of the information spectrum will prevail. In the past a "go slow" approach to such a comprehensive transformation would have been considered the safest course. In the information age, however, going slow is neither conservative nor safe. We cannot stop, slow down, or control the information explosion — but we can harness it.

As we move forward, our burgeoning modeling and simulation capabilities will help us capture the benefits of information technology to transform radically how we assess our plans, acquire our systems and train our forces. We are excited by the promise of harnessing these new technologies in the service of the warriors of the Navy-Marine Corps team.

Surface Warfare

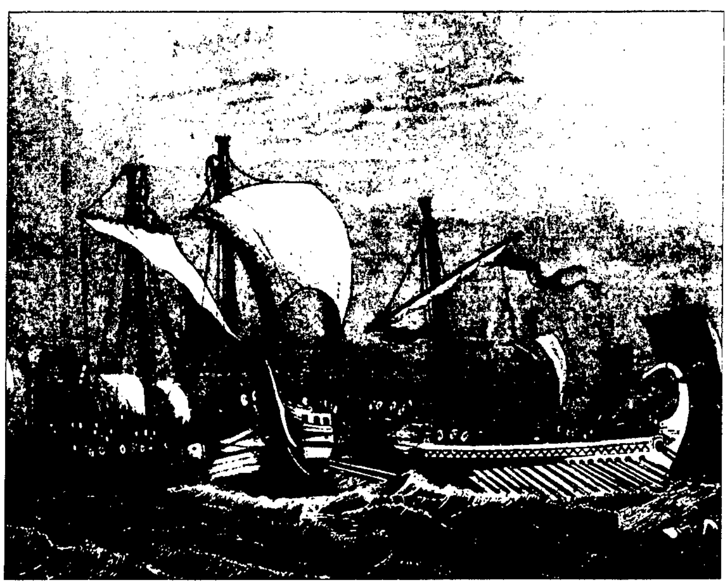
War is permeated by technology to the point that every single element is either governed by or at least linked to it.
— Martin Van Creveld, Technology and War

Advantage: Navy

by Capt. Richard L. Wright

In the nine decades between Napoleon's defeat at Waterloo and the introduction of HMS ***Dreadnought*** in 1905, the world's most technologically superior maritime force, Britain's Royal Navy, moved from wooden sailing vessels to steel, turbine-driven ships that fired 20 times the range of HMS ***Victory***'s main battery used to such devastating effect at Trafalgar.

Yet, for all its well-deserved reputation as the most forward-thinking, progressive navy of the 19th century, it took the Royal Navy *46 years*, from the introduction of steam propulsion in HMS ***Lightning*** in 1823, to build its first warship without sails, HMS ***Devastation***, in 1869.



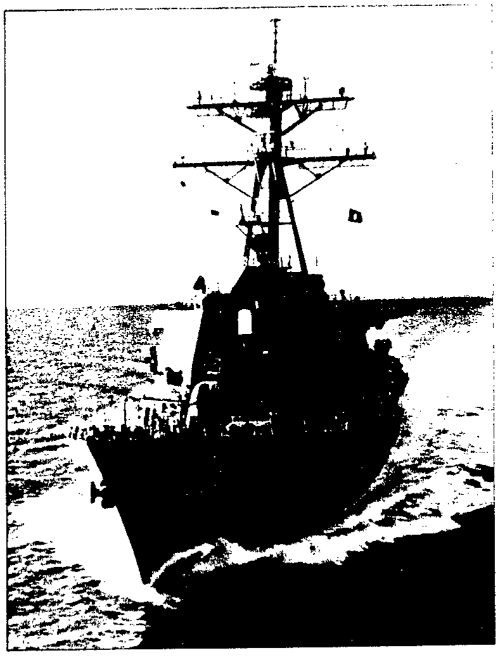
Greek trireme *(Naval Historical Center)*

Revolutions at sea do not happen "on the quick," yet within the United States Navy, in developing operational constructs to realize the fundamental tenets of Network-Centric Warfare as outlined by Vice Adm. Arthur K. Cebrowski in the preceding article, we stand at the threshold of the most dramatic change in warfare since the advent of military aviation. From the days of Greek triremes in the Mediterranean, through the Spanish Armada, English sea dogs from Drake to Nelson, and fast carrier groups in the Western Pacific in World War II, a ship's combat effectiveness in battle was determined by two primary attributes: its organic sensors — from the lookout's eyes to radar; and its installed weapons systems — from catapults and legionnaires, through three-pound carronades, 12-pound smoothbores and 16-inch rifled-guns, to Hellcats, Tomcats, and now, Super Hornets and Tomahawks.

The primary role of sensors was that of providing information on the location and disposition of the enemy. Sensors, and the information they provided, supported the weapons systems, but it was the platform itself that determined the concept of fleet operations, from Salamis to Desert Storm. Hence, naval operations from the Greeks to today have been, by their very nature, "platform-centric."

In the next decade, that centuries-old truism will change. Not just the Surface Navy, but the United States Navy, as the 21st century's paramount maritime force, will evolve from "Platform-Centric Warfare" to "Network-Centric Warfare." No longer will the combat effectiveness of a given surface, subsurface or air platform be constrained by the range and capability of its organic sensors.

In Network-Centric Warfare, information available from national and joint force systems, "on the Grid," will provide the target set to be serviced by the platform and weapon best equipped to do the job, as determined by the naval or joint force commander. The availability of information to our forces, and denial to an adversary of his own information systems and capabilities, will become as much a "weapon" in the 21st century as combat systems, cruisers, submarines and jet aircraft are today. By dramatically increasing the distribution of data on the Grid, the U.S. Navy's ability to widely distribute offensive combat capability will become a reality in the first decade of the 21st century.



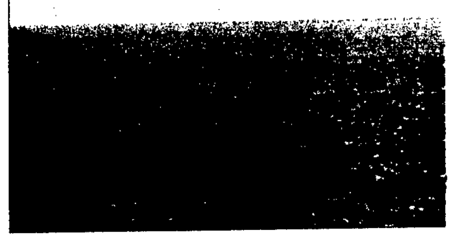
The impact of Network-Centric Warfare will render many of today's surface platforms, including USS ***Curtis Wilbur*** (DDG 54), obsolete beyond 2030. *(Debbie Huston/BIW)*

In the Surface Navy, we are moving away from a Cold War construct. By shaping ourselves as an offensive maritime force with two basic missions, precision land attack and theater air dominance, we will provide the geographic commanders in chief with more flexible and adjustable combat capability. The end result will be sea-based, tactical capabilities able to conduct precision engagements from the shoreline to 1,600 miles inland. *(Note: By way of comparison, in the 90 years between 1815 and 1905, the range of the Royal Navy's guns increased 20-fold. From the 12.5 mile maximum effective range of today's 5-inch/54-caliber gun, to the advent of tactical Tomahawk in 2003, a scant five years from now, the ability of the U. S. Surface Navy to affect the land campaign at a tactical level, in terms of range, will increase 128-fold!)*

But it is important to realize that this dramatic increase in capability will *only* become reality if the Surface Navy has resident in its platforms the assured connectivity required to realize the full potential of these weapons systems. The complexity of the 21st century joint battlefield, in terms of sensors, weapons, command and control, and individual service and joint doctrines, portends a challenging hurtle in terms of "battlespace sovereignty" that must be cleared. And while many "Revolution at Sea" timelines are ill-defined and necessarily uncertain, the "resolution" of the 21st century joint battlefield will have to be accomplished by 2008, when the Surface Navy's precision land attack and theater air dominance capabilities will be introduced concomitant with *Operational Maneuver From the Sea* becoming doctrine.

How will the reality of Network-Centric Warfare, and its combat subset, offensive distributed firepower, affect the employment of the Surface Navy in the 21st century? Initially, the distribution of offensive firepower among a large number of surface platforms with the required connectivity will mark the beginning of a significant broadening of operational focus beyond today's necessary emphasis on large-deck aviation and amphibious platforms. DD 21, the Land Attack Destroyer, first ship of the 21st Century Surface Combatant class, will also be the first platform built from the keel up with Network-Centric Warfare and offensive distributed firepower as fundamental design tenets. It will enter the fleet in 2008, a harbinger of things to come.

In 2020, the second generation 21st Century Surface Combatant will be delivered as a truly revolutionary platform, fully wedded to the concept of Network-Centric Warfare. Its developments, in terms of employment, modularity, manning, training and sustainment, will be revolutionary as the conversion from sail to steam. But while the Royal Navy took almost five decades to realize the full impact of steam propulsion on



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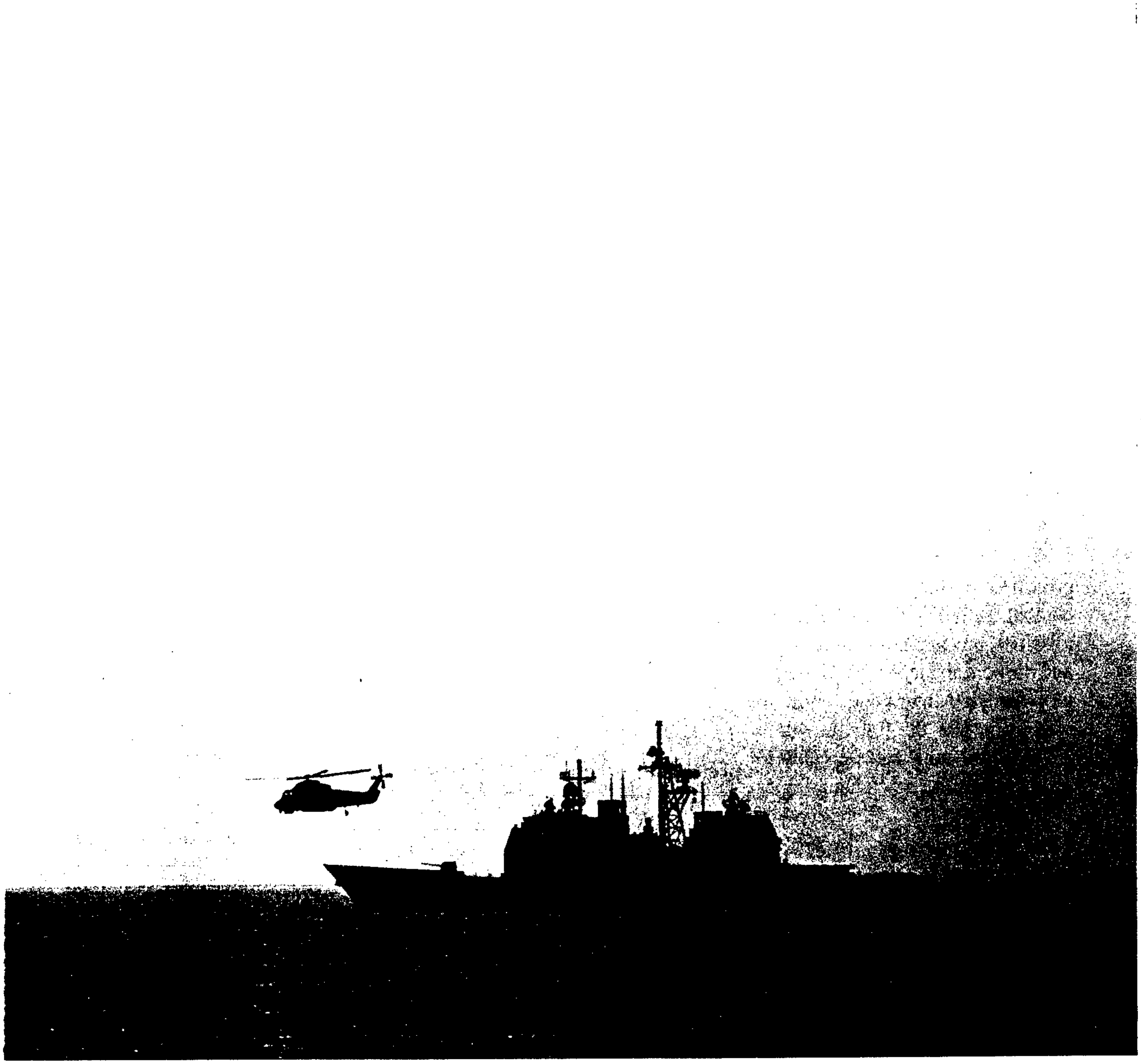


ship design, the United States Navy will make a similar transition in less than two decades.

Introduction of the second generation 21st Century Surface Combatant will coincide with the final resolution of doctrinal and systems operational concepts that will see Network-Centric Warfare encompass the entire 21st century joint battlefield.

By 2030, as the "Grid" develops a space-based constellation of satellites affording a complexity and "granularity" technologically infeasible today, each service's sensors and weapons systems will be "unburdened" to the Grid, permitting the joint force commander total freedom to match each target set with the best platform and weapon to get the job done.

Beyond 2030, the impact of Network-Centric Warfare will render many of today's surface platforms as anachronistic as "flush deck and four pipe" destroyers of an earlier era. Surface, subsurface and air platforms will largely become weapons carriers, servicing the target set generated on the Grid. Their shape, form and manning levels will be determined by the operating environment and assigned mission. The complex combat systems to achieve detection, engagement, destruction and battle damage assessment will be found, not on the platform, but on the Grid.

In the Revolution in Military Affairs at Sea, this will be the End Game: Checkmate!

Editor's note: Capt. Wright leads the Policy, Requirements and Assessment Branch (OPNAV N861).

Taking the Laboratory to Sea

Fleet Battle Experiment

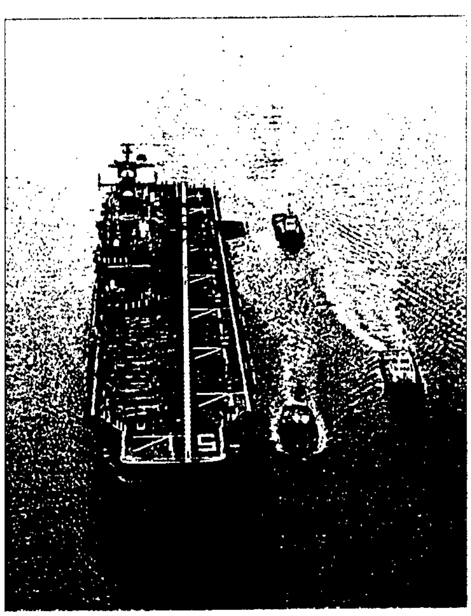
by Capt. Richard L. Wright

The complexity of the 21st-century joint battlefield in terms of sensors, weapons, and command and control requires a different approach to "pushing the envelope" in developing sea-based combat capability. Given the Surface Navy's two primary missions, precision land attack and theater air dominance, and the complexity of the 21st-century operating environment, how do we ensure that the force at sea in 2008 and beyond will be ready to fully exploit the new technologies available?

In 1997, little more than a decade remains before *Operational Maneuver From the Sea* (OMFTS) becomes doctrine in 2008. With most of the new naval capabilities to realize the OMFTS vision still on the drawing board, in the laboratory or at field testing sites, it is time to ask the question, "What is the process by which the United States Navy will implement the Revolution in Military Affairs in support of the theater land and air campaigns of the next century?"

It will doubtlessly be a multistep, iterative process, but two initial efforts seem warranted. First, we need to capitalize on the technologies already in the fleet (like the Cooperative Engagement Capability being installed in our Aegis cruisers, carriers and large-deck amphibious ships) and those nearing Initial Operational Capability (like Tactical Tomahawk), and ask ourselves, "Have we broken down the barriers in our thinking processes to fully exploit the tactical advantages these new capabilities will afford the at-sea warfighter?"

We've faced this dilemma in the U.S. military before. It is not hard to envision some Lieutenant Commander in Newport in the 1880s asking his superiors who sailed with Farragut at Mobile Bay, "Why are we retaining sails when reliable steam propulsion is available?" ...or some First Lieutenant at Fort Leavenworth Command and General Staff College in the 1900s asking a veteran who chased Geronimo in the Arizona territory in the 1880s, "Why are we staying with the comfortable familiarity of horse cavalry when mechanized brigades of armored vehicles are available?"



USS *Peleliu* (LHA 5) was one of the participants during this fall's Fleet Battle Experiment Bravo that demonstrated offensive distributed firepower and the impact of precision land attack capabilities on the 21st-century joint battlefield. *(Rex Cordell/USN)*

It is clearly time to start thinking "beyond the lifelines" of our ships. "Pushing the envelope" in developing new operational concepts and future constructs for employment of sea-based combat capability should not be confined to the Johns Hopkins Applied Physics Laboratory, the Naval Post Graduate School, the Naval War College and the Strategic Studies Group. Our wardrooms, afloat staffs and schoolhouses, need to get involved, for we are at the threshold of a fundamental change in the culture of the Navy and Marine Corps as we approach the new millennium.

We need to develop the tactics, techniques and procedures to match the technologies and combat systems capabilities being introduced during the next decade. We need to address the mechanisms by which the reality of offensive distributed firepower and Network-Centric Warfare will affect the employment of sea-based combat capability in the 21st century. Going beyond new approaches to warfighting, we need to explore basic changes in the organizational concepts that govern routine fleet operations including such basics as deployment patterns, rotational crews and maintenance procedures.

Certainly no one individual or organization has the "right" answer to all these questions, and the Navy recognizes the fallacy of solely relying on laboratories, "think tanks" and Washington to provide all the impetus for change. It is to specifically address the issue of transitioning from hardware and software developments in the labs and industry to operational concepts relevant to the 21st-century joint battlefield that the Fleet Battle Experiment process has been implemented.

Charged with closing the traditional gap between introduction of new technologies and resolving tactics, techniques and procedures to exploit these new capabilities, the Fleet Battle Experiment process, by conducting paralleled efforts at sea employing these advanced capabilities, will keep pace with technology. The Fleet Battle Experiment process will be the principal vehicle to introduce fleet operators to the future ...and the research and development community to the realities of an unforgiving at-sea environment.

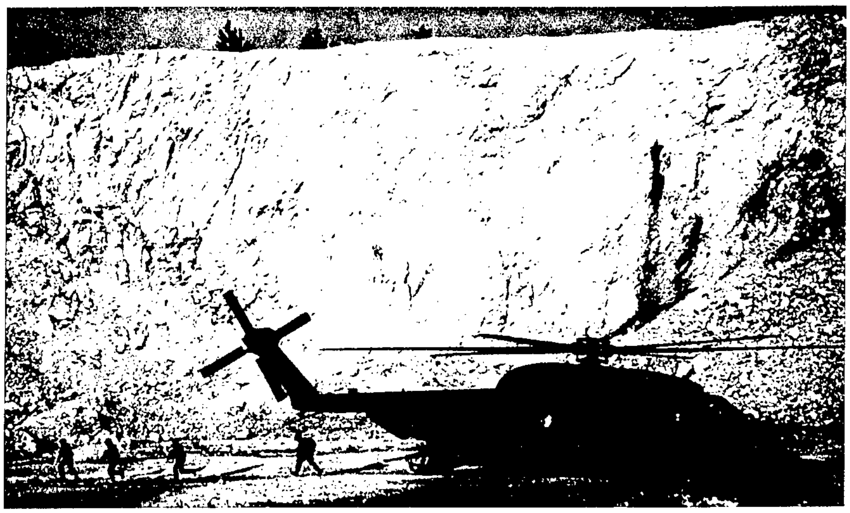
Fleet Battle Experiments will be conducted in a multistep process. First, operational concepts for fleet experimentation will be nominated from within the fleet, OPNAV and others. Second, new operational concepts then will be matched with prototype systems being considered for fleet introduction. These prototypes then will be taken to sea or inserted ashore depending on the system and concept being examined. Feedback from fleet users then will be used to refine the prototypes, document the problems encountered, and provide feedback to stimulate new ideas from the R&D, educational and operational communities.

Two Fleet Battle Experiments, Alfa and Bravo, both led by 3rd Fleet aboard flagship USS ***Coronado*** (AGF 11) and supported by the Naval War College and others, have been conducted to date involving Pacific Navy and Marine Corps units. Alfa, conducted this past spring, demonstrated that new land attack capabilities and concepts being developed by the Navy and Marine Corps can shape the 21st-century battlespace. From a constructive arsenal ship, USS ***Benfold*** (DDG 65), employing simulated precision land attack weapons, to a carrier air wing aboard USS ***Constellation*** (CV 64) specifically augmented and employed to facilitate the land campaign, the fundamental tenets of achieving offensive distributed firepower across the joint battlefield were explored for the first time. Also addressed was the challenge of achieving direct sensor-to-shooter connectivity and providing responsive fires from surface ship and naval aviation in support of deeply inserted ground forces involved in the Marine Corps' Hunter Warrior exercise being conducted at the same time.

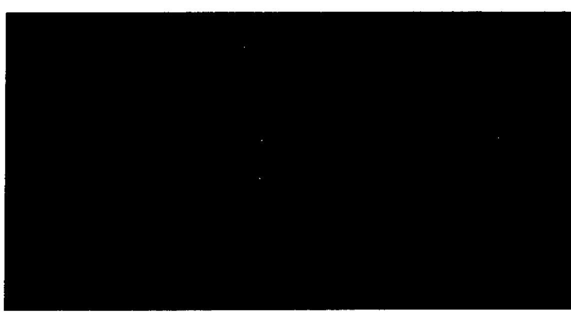
As would be expected of an "experiment," the results in areas such as airspace deconfliction and obtaining a common operational picture indicated the need for further work, but taken as a whole, the results were impressive. By employing 3rd Fleet's "Ring of Fire" joint distributed fires network (conceptually developed by a junior officer assigned to the 3rd Fleet staff) digital calls for fire and new land attack weapons dramatically influenced the battlefield ashore. Analysis indicated a ninefold increase in targets that could be struck, with a reduction from 144 hours to 24-36 hours the time needed to complete the assigned target set.

This fall the second Fleet Battle Experiment, Bravo, was conducted with the ***Peleliu*** (LHA 5) Amphibious Ready Group and the ***Nimitz*** and ***Constellation*** Battle Groups. Building on the concept of offensive distributed firepower and the impact of precision land attack capabilities on the 21st-century joint battlefield, and benefiting from feedback and "lessons learned" in Alfa, a more sophisticated approach to the "Ring of Fire" joint fires coordination process and the joint task force targeting process was conducted. Closely examined were weapon target pairing, force inventory management and the interoperability of land artillery, naval surface fires, close air support, and deep strike land attack systems employing a variety of weapons including Tactical Tomahawk, Extended Range Guided Munitions, Harpoon and Navy TACAIR, all within the "Ring-of-Fire" network. From experience in Fleet Battle Experiment Alfa, additional work was conducted on establishing a common tactical picture and integrating the Army's Field Artillery Tactical Decision System (AFATDS) ashore with the Navy's at-sea systems.

While the final results of Fleet Battle Experiment Bravo have yet to be officially promulgated, Quicklook Report "lessons learned" are already being considered in developing future experiments to afford the naval or joint force commander command and control capabilities to take full advantage of the synergy which the ground, air and maritime components of a 21st-century joint task force will bring to the joint operating area. Suggested themes for future Fleet Battle Experiments, to be conducted in both 2nd and 3rd Fleets, include theater air defense and attack operations, combat ID, countering nontraditional (asymmetric) threats, naval fires logistics and sustainment, increasing real-time battlespace awareness and implementing the *Operational Maneuver From the Sea* and support to the Marines Corps's Urban Warrior Warfighting Experiments.



With less than 10 years to go before OMFTS becomes doctrine, it is time to ask what is the process by which the U.S. Navy will implement the Revolution in Military Affairs. *(Todd P. Cichonowicz/USN)*



In Lord Nelson's famous Trafalgar Memorandum on the eve of the naval battle that would change the course of world history, he advised his captains that "nothing is sure in a sea fight." The fundamental truth of that statement remains relevant two centuries later, but through the Fleet Battle Experiment process we are seeking to reduce some of that "uncertainty," while at the same time encouraging the freedom of new ideas, initiative and experimentation that was so much a part of the Nelsonian ethic that would see Britain rule the seas for the century of *Pax Britannica*.

RING *of* FIRE

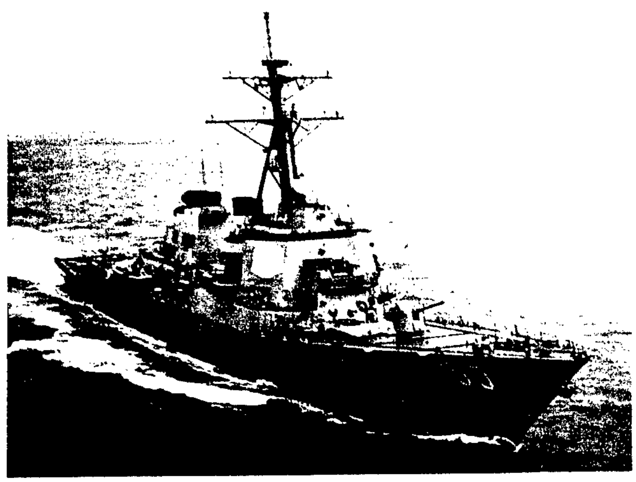
A Quantum Leap in Warfighting

by JO3 Kip Wright

With several clicks of a computer mouse, Marine 1st Lt. Steve Kettell can determine the most effective munitions in a varied and deadly arsenal to destroy any target appearing on the screen of his personal computer.

Kettell, an artillery officer from Camp Pendleton, Calif., is called the "weapons pairing officer" in the "Ring of Fire" operations room aboard USS *Coronado* (AGF-11). A member of Fox Battery, 2nd Battalion, 11th Marine Regiment, Kettell is a key member participating in Fleet Battle Experiment Bravo.

The 3rd Fleet flagship tested some of the most sophisticated command and control systems in existence during its 10-week deployment across the Pacific.



The Ring of Fire computer network allows numerous calls-for-fire to be answered at *one time* instead of one at a time by a specific ship, such as USS ***Russell*** (DDG 59), in a specific sector. *(Ingalls Shipbuilding)*

Its new systems greatly enhance the 3rd Fleet commander's ability to execute missions as a sea-based joint task force commander. The new systems also allow the commander to operate with other Pacific commands that might be involved in a regional crisis.

"I am absolutely convinced that we have improved our capabilities, and that we have built a very reliable and maintainable command and control ship," said Vice Adm. Herb Browne, 3rd Fleet commander.

The other phase of Fleet Battle Experiment Bravo, "Silent Fury," examined the targeting processes involved while using new GPS-guided munitions that soon will be available to the Navy. *(Ted Banks/USN)*

The experiment is somewhat unusual because most of the technologies being used, such as personal computers, digital cameras and GPS, are available at commercial outlets including computer, camera and boating supply stores.

Browne called Fleet Battle Experiment Bravo "exciting" because "it uses new off-the-shelf technologies in combination with civilian and military expertise."

Members of the academic, scientific and engineering communities were on board ***Coronado*** working closely with Navy and Air Force personnel.

Browne said Fleet Battle Experiment Bravo fits well with the Information Technology for the 21st Century (IT-21) project.

There were two phases to Fleet Battle Experiment Bravo, "Ring of Fire" and "Silent Fury."

The Ring of Fire phase, according to Lt. Cmdr. Ross Mitchell, is a targeting experiment using several computers together in a network system. In it, one computer operator receives calls-for-fire and identifies and organizes targets. Another person next to him or her — the weapons pairing officer, such as Kettell — would determine what type of munitions would best destroy the target. A third person takes all the information from the previous two people and assigns a platform — an F/A-18 from a specific carrier or a Tomahawk cruise missile from a specific ship — to each target.

"By effectively coordinating available firepower, this computer network will greatly increase the response time, accuracy and volume of naval support."
Lt. Cmdr. Ross Mitchell
"Father of Ring of Fire"

"By effectively coordinating available firepower, this computer network will greatly increase the response time, accuracy and volume of naval support," said Mitchell — "Father of Ring of Fire." He also said one of the biggest challenges during the experiment was preventing collisions in airspace shared by missiles and aircraft.

During Ring of Fire, simulated calls-for-fire were made by members of the 13th Marine Expeditionary Unit in Oahu's Makua Training Area. Computers on board ***Coronado*** then went to work plotting targets, assigning weapons to targets, and assigning ships or planes to launch weapons — with a click and a drag with a mouse on color monitors like the ones in the home or office. All of this activity occurred within two to seven minutes.

The Ring of Fire computer network allows numerous calls-for-fire to be answered at *one time* instead of one at a time by a specific ship in a specific sector, as was usually done. In the future, Navy officials are hoping sectors will be eliminated and the resulting integration will allow for quicker responses and the use of more weaponry.

The other phase of Fleet Battle Experiment Bravo, "Silent Fury," examines the targeting processes involved while using new GPS-guided munitions that soon will be available to the Navy. GPS coordinates soon may replace lasers in targeting enemy buildings, equipment and personnel. While ***Coronado*** is deployed, experiments are expected to be conducted on the accuracy, volume and timeliness of systems using GPS.

Part of this new technology employs computer networks, giving new meaning to the term "net surfing."

For example, "Quantum Leap," a part of Ring of Fire that took place Aug. 28, used classified military websites to acquire targets and assess bomb damage.

In it, Navy SEALs, operating in the China Lake Air Weapons Center, Calif., photographed the target — a bridge — with a commercial digital camera and transmitted the image via satellite to a classified web page.

Targeting teams on ***Coronado*** then pulled the image of the bridge from the web page into the Rapid Targeting System (RTS) computer system. The RTS stores large amounts of map databases and high-resolution imagery from the National Reconnaissance Office (NRO), in Washington, D.C.

Operators on the ship combined the photograph from China Lake with NRO imagery and computer maps to make pictures that were transmitted to an F/A-18 aircraft.

As the pictures appeared in a cockpit display screen, the pilot could match the transmitted images with views from his jet, creating a visual road map to follow to the target.

After the bridge was bombed, SEALs then transmitted a photograph of the damage so analysts aboard ***Coronado*** could determine whether another bomb run was needed.

Editor's note: JO3 Wright is a staff member of the Pacific Fleet Public Affairs Office.

The Battle Force Tactical Training System

by Capt. Herbert Hause

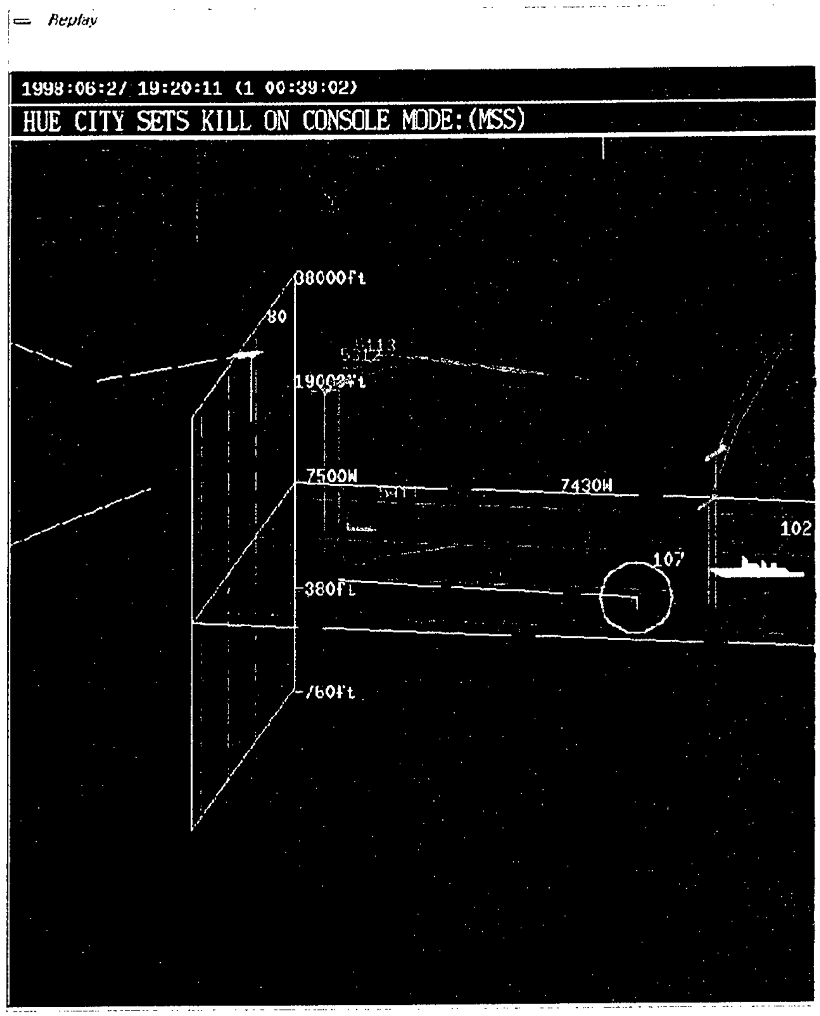
The information revolution is rapidly changing the way militaries wage war, automating combat functions and extending the vision of sensors and the reach of weapons farther than ever before.

This new, network-centric way of fighting demands a new style of training. Classroom instruction and "canned" exercises may have sufficed for training combat teams to operate the less complex, stand-alone weapon systems of the past. But today's highly integrated combat environment and tomorrow's netted sensors and precision weaponry demand more realistic training. Combat teams must train as they will fight.

Training Philosophy

The Navy's 1989 tactical training study concluded that *shipboard* training is far more effective than training in centralized training schools

USS **Barry** (DDG 52) *(Ingalls Shipbuilding)*



ashore because it provides a real-world operating environment and the opportunity for a combat team to train as a unit. As a result of that study, the Surface Navy is moving towards a team approach to training that builds effective combat teams. Battle Force Tactical Training (BFTT) incorporates individual performance skills into group behavior. This *team-dimensional* training focuses on four performance dimensions: leadership, situational awareness, communications and team building.

- **Leadership** stresses an individual's agility and flexibility, essential for operating advanced combat systems where the electronic and physical environments increasingly merge and perceptions can shift dramatically in a matter of seconds. The leadership dimension enables the team to refocus its effort, reordering its priorities as the tactical situation changes. While respecting command relationships, it prepares *all* team members to exercise initiative and take leadership roles when they recognize the situation demands a change in focus.
- **Situational awareness** ensures that the *team* does not lose track of an increasingly complicated environment as it repeatedly shifts focus to keep up with a tactical situation.
- **Communication** means exchanging clear and concise information in a timely manner.
- **Team building** requires team members to realize when their shipmates need help and provide that help without being asked. It is the essential complement of leadership because it ensures that, as different members take the lead in refocusing the group's effort, others are moving just as rapidly, on their own initiative, to give the leaders the necessary cooperation and support.

Together, these training concepts constitute the advanced training model on which BFTT is based and prepare combat crews for high-tech warfare in the demanding littoral environment.

The BFTT Model

The BFTT system moves real ships and their combat crews *electronically* into 16-million square miles of battlespace in a synthetic theater of war (STOW) for interaction with real and simulated units and threats.

In developing an exercise, trainers set the baseline conditions that define the STOW scenario, including the political situation, available intelligence, rules of engagement, weapons-release condition and material readiness condition. As the action unfolds, scripted events trigger reactions by the participants. The participants, which could include a ship's combat team or multiple ships, interact not only with the synthetic elements of the STOW, but also with one another. BFTT updates, redefines and synchronizes the "operational situation" to reflect those interactions and ensure realistic consequences.

The participants interact with the STOW through the same shipboard equipment they would use in combat, with the STOW providing the same situational cues and stimuli. Throughout the scenario, BFTT records the combat systems team's reactions and the performance of the equipment.

The ship's training facilitators — or the exercise controllers for a multiship assessment — then debrief the participants on their strengths and weaknesses. BFTT's rapid feedback and high degree of automation make it possible to build team proficiency by repeating a scenario in identical or somewhat altered form.

Physical Layout

The physical configuration of the BFTT system consists of three segments: the shipboard installation, the shore site, and the communications network. The heart of the shipboard equipment is a local area network (LAN) linking all on-board trainers in an open system architecture that will accommodate new training equipment as it is developed. Through the LAN and the on-board trainers, BFTT can stimulate shipboard sensors and provide operator cues, integrating all of the equipment linked to the on-board segment into a single, coherent training scenario.

The capabilities resident in BFTT shore sites enable it to augment single-ship training. But the ideal function of a shore site is to serve as exercise controller for a multiple-ship training exercise. The shore site generates the exercise scenario and controls the scenario through a distributed interactive simulation network that interfaces combat systems with simulators, on-board trainers and data-collection modules. Operators at consoles "role-play" computer-generated forces, collect all information, and use that information to generate force-level briefings.

BFTT's communications segment links the shore site with the shipboard segments aboard multiple ships in multiple homeports. A training data link, with an exercise coordination circuit and tactical circuits, handles the high-volume data transfers needed to create and maintain the STOW, as well as to gather and disseminate debriefing information. BFTT also will have the ability to communicate with units from other services during joint exercises. As BFTT's communications segment matures, it eventually will provide connectivity to other emerging systems like the Theater Missile Defense System Exerciser or the National Test Bed.

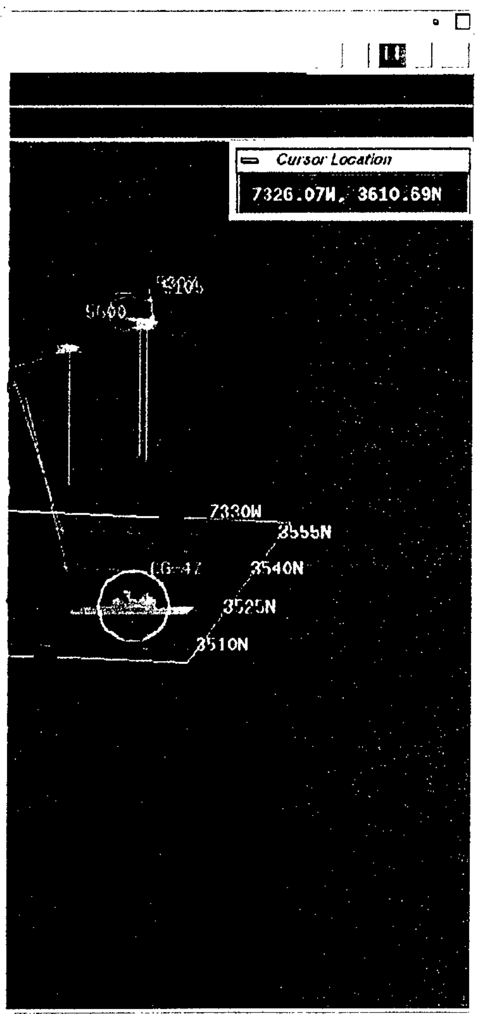
BFTT Assessment

BFTT has made dramatic strides since approval of the operational requirements document in 1992. Earlier this year, the ***John F. Kennedy*** Battle Group used BFTT for an advanced warfare team training exercise inport.

In BFTT-equipped ships, the scenario stimulated sensor consoles for sonar, radar and the Advanced Combat Direction System (ACDS). It did not stimulate consoles in non-BFTT ships, although those ships did receive the scenario data on their ACDS. The distributed scenario enabled the battle group, which was in the latter part of its pre-deployment training cycle, to fine-tune the skills of its combat system teams before setting out for its final at-sea training exercise.

BFTT has grown steadily since installations began in 1995. Nine ships so far have received the system, including aircraft carriers, ***Spruance***-class destroyers and amphibious platforms, with installation underway in two additional ships. More than 140 ships will receive BFTT by 2003.

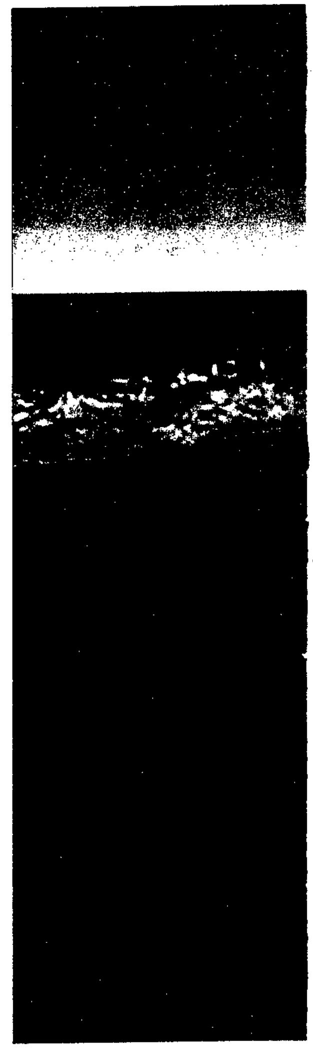
Editor's note: Capt. Hause is the Combat Systems Training Program Manager (PMS 430) in the Program Executive Office for Carriers, Littoral Warfare and Auxiliary Ships.



The BFTT system moves real ships and their combat crews *electronically* into 16-million square miles of battlespace in a synthetic theater of war. *(Naval Warfare Assessment Division, Corona, Calif.)*

Real-Time *Awareness*

The Virtual Reality Responsive Workbench



by James Durbin and Dr. Larry Rosenblum

Achieving situational awareness in today's world of computers, satellites and digital communications, is becoming more of a challenge because of an unending cascade of information.

How are commanders, especially in joint and allied operations, to keep up with this "info-glut?" How can all the information be collected, assimilated, correlated and presented so command elements can quickly see it, grasp the situation, choose a course of action, collaborate on their decisions and forward it quickly to deployed forces?

A powerful, new situational awareness system, the Virtual Reality Responsive Workbench, developed by the Naval Research Laboratory's Information Technology Division, addresses these questions.

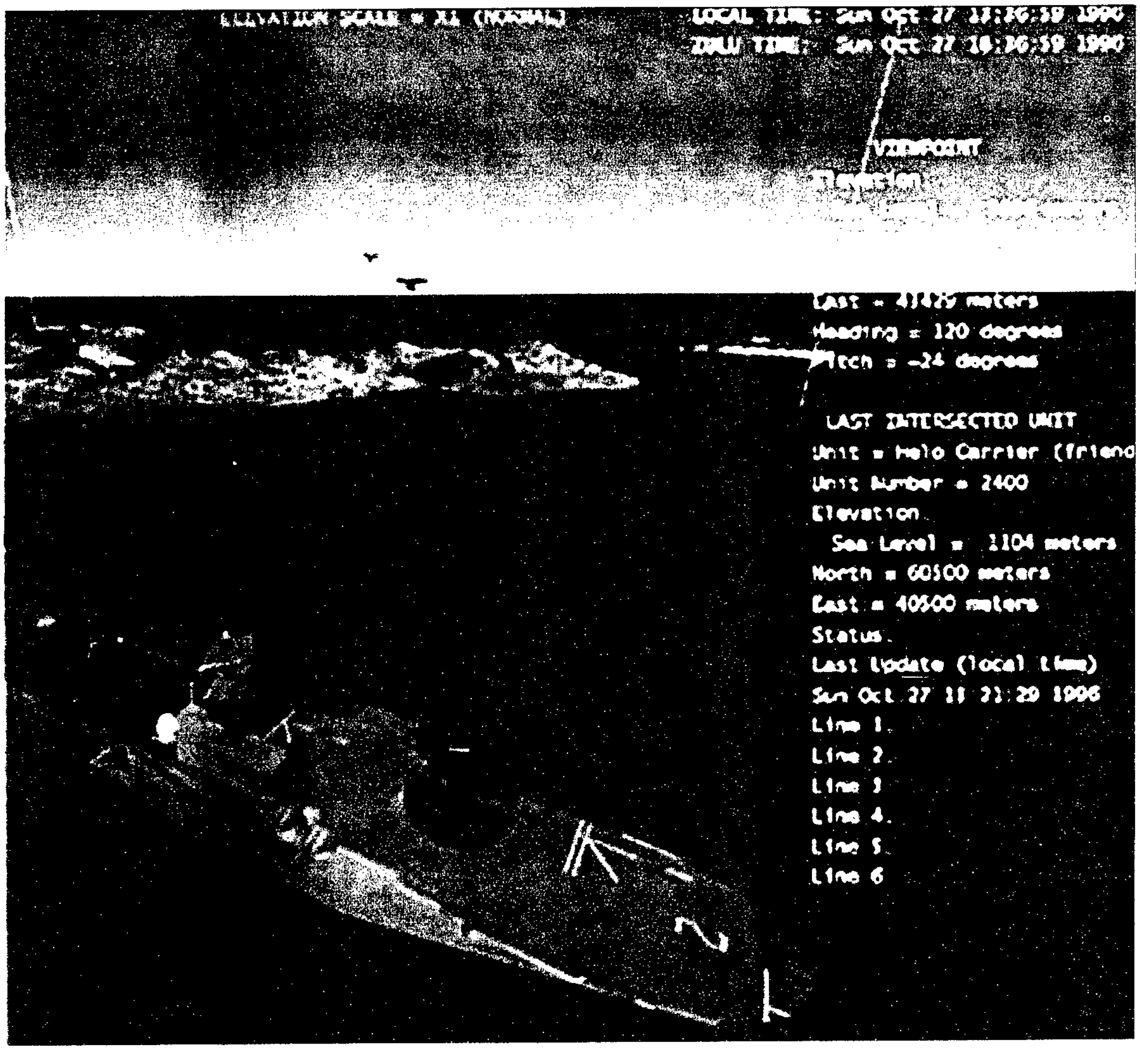
> *"Know yourself, your enemy, the terrain and the weather, and you will prevail."*
>
> —Sun Tzu, characterizing the fundamental challenge of situational awareness

In its naval application, the Workbench could be installed on board amphibious ships in Marine Corps CIC, receiving its information via the ship's JMCIS architecture. The Workbench enables commanders to see, as a group, a 3-D representation of the battlespace that is continually updated by a live-feed of incoming data. This 3-D representation enables the commanders to query individual units remotely, issuing new orders as appropriate. This system can be used to command and control naval forces at sea, air assets in the air, and ground forces on land equally well.

Battlefield Visualization

Almost all of the information available on the modern battlefield spends at least part of its life in digital format. Often, it is only useful to a highly-trained technician who can translate the data into useful information. Much of this data can only be accessed by a particular computer system, eliminating its availability to potential users with other computer systems.

To correct this deficiency, the Virtual Reality Laboratory (VR-Lab) of NRL's Information Technology Division is creating a suite of data translators to convert digital data into a common format by fusing multiple data streams from numerous systems into an overall picture of the



The Workbench is considered a *virtual reality* system because the viewers, who can see the image on the screen in stereo, are partially immersed in its presentation. *(NRL)*

battlespace. The Workbench translates the raw data into graphical pictures, a process commonly known as "visualization." Through visualization, data is translated into information useful to a wider audience.

The Workbench concept has been applied to medical and architectural visualizations, which naturally lent itself to situations where a group of viewers want to look down onto a shared, common picture. Battlefield visualization is a natural extension of these applications.

Traditionally, area maps are spread out as a reference point for battlefield tabletop discussions. Similarly, sand tables are commonly used as models by ground operations units to "walk through" a given operation prior to execution.

In contrast, the Workbench is a tabletop projection screen system. A high resolution computer display is projected from below the Workbench onto a large, tiltable screen. Viewers can gather around the Workbench, as they would a plotting table, to view the display. It is considered a *virtual reality* system because the viewers, who can see the image on the screen in stereo, are partially immersed in its presentation. One of the viewers (typically, the senior commander) is tracked electronically, so that as his head moves, the viewpoint of the display changes accordingly.

It is *responsive* because the display responds directly to the operator's wishes. By using a separately tracked wand, the operator can change his viewpoint into the 3-D display of the battlespace, as well as "fly" through it. He then can point at units represented within it, querying them for updates, moving them to desired coordinates and issuing new orders to them.

Practical Application

In July 1996, the Marine Corps Warfighting Laboratory (MCWL) approached the VR-Lab to participate in the Sea Dragon development process — a warfighting concept placing small, highly-mobile Marine units ashore to focus fires on key targets, preparing for the arrival of follow-on forces. The Marine Corps was seeking an innovative solution to the significant challenge of maintaining a shared awareness during these warfighting experiments. During Hunter Warrior, an exercise conducted last March in conjunction with the Navy's Fleet Battle Experiment Alpha, the VR Workbench was used as a situational awareness commander's station, called "Dragon." The objective was to demonstrate the potential of the Workbench immersive displays in collaborative battlespace planning.

The Workbench used Digital Terrain Elevation Data Level 1 (with "posts" set at about 100 meter intervals) as the foundation for its displays, giving viewers a ground reference. A "skin" was applied graphically over the posts to represent terrain. The terrain was visually textured with the same digitized, raster graphics maps that the commanders used in the Experimental Combat Operations Center (ECOC). These maps include gridding, contour intervals, range markers and feature designations. To enhance the 3-D view, elevations were exaggerated by a factor of two, relative to distance. An ocean was synthetically inserted into the data set to simulate a coastal area from which Marines were "landing." All participants then were drawn into the view using a 3-D model icon or Intelligence Preparation of the Battlefield symbol, as preferred by the operator. These entities were drawn in with an equivalent size of about 500 meters to make them visible; they could be scaled up or down from there as needed.

Unit information was fed into the Workbench software via the Global Command and Control System, Maritime (GCCS-M) variant in near-real time. GCCS-M was used by the Special Purpose Marine Air-Ground Task Force-Experimental to correlate all of the incoming battlefield data. Each ground unit team was equipped with an Apple Newton Personal Data Assistant, a GPS receiver and a voice/data radio. Digital reports then were sent to the ECOC and tagged with unit identifications and GPS locations. The Workbench software received these reports as text. A simple parser pulled out information relevant to the displays and used it to position the models throughout the display. Each entity model contained the latest text message, which the operator could view simply by pointing to the unit's model.

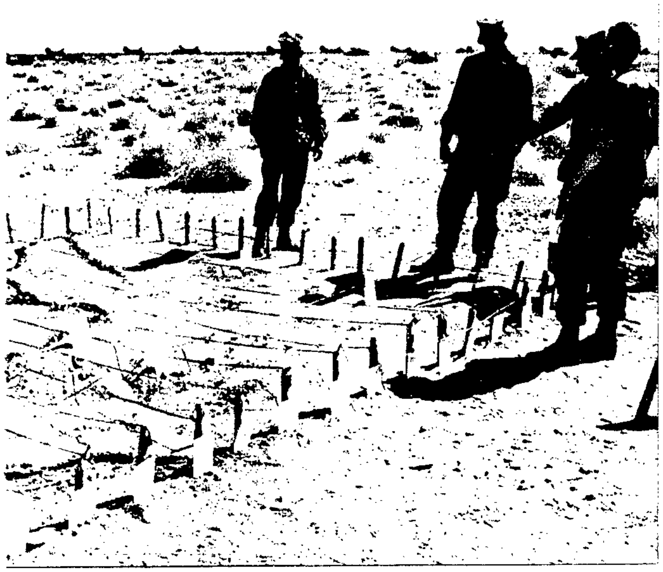
The operator uses a wand (a tracked, floating joystick) to interact with the Workbench. The wand is represented as a "laser beam" in the battlespace, which the operator can use to translate, rotate and zoom the display. Equivalent to bringing the display closer to his face, lifting the wand to zoom in results in additional detail being drawn in the display. The operator can optionally choose to "fly through" the display, as if on a magic carpet. The operator then can use the wand to point to individual units for queries.

When selected, a unit model is highlighted, with its data popping up in a separate window "pasted" atop the 3-D display. The operator can visualize potential future movements by repositioning the unit models within the display. Models can be picked up and moved quickly to any location. Air-unit models hold their assigned altitudes; ground-unit models return to the surface directly below the place where the operator releases them. If a unit's data are being displayed during an update through GCCS-M, the update appears live. At any time, the operator can save the battlefield state, taking an electronic snapshot from his current viewpoint. Likewise, data are constantly transcribed to create an historical playback capability for after-action review.

After the debut of the VR Responsive Workbench at Hunter Warrior, MCWL developed a "wish" list for additional capabilities. In the interim, while the requested improvements were incorporated, the second generation of the Workbench Dragon System was operationally tested during the Joint Countermine Operational Simulation (JCOS) exercise this past August.

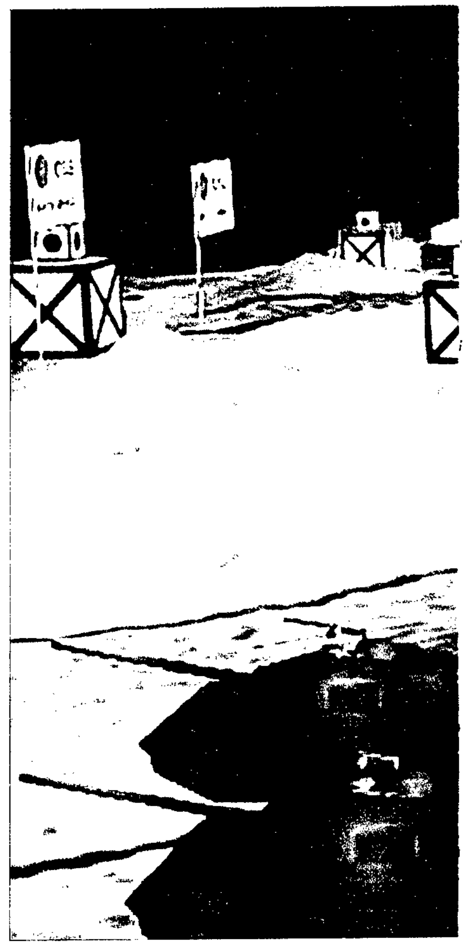
During the JCOS exercise, the Workbench was used primarily as a view port into the simulated world of battlefield units. Thus, the data were fed into the Dragon software from Distributed Interactive Simulation Protocol Data Units (a DOD standard for simulation systems) rather than from GCCS-M. The data feed enabled the Workbench to display the "ground truth" of the exercise simulations. In JCOS, the Dragon system only presented information; viewers could not direct entity actions from the Workbench.

The JCOS implementation features several technical extensions of the Workbench's capabilities, enhancing both the flexibility of the back end (where the data come in via legacy formats) and the power of the front end (where viewers see the battlespace stereo-optically). The fly-through viewing method is enhanced adding the ability to save preset viewpoints. This enhancement, addressing concerns raised during Hunter Warrior about speed and ease of use, makes it easier to examine individual unit operations in detail, as opposed to the more global, map-centric approach of manipulating the viewpoint of the whole battlespace.



Traditionally, sand tables are used as models by ground operations units to "walk through" an operation prior to execution. *(Kurtis Cantiberos/DOD)*

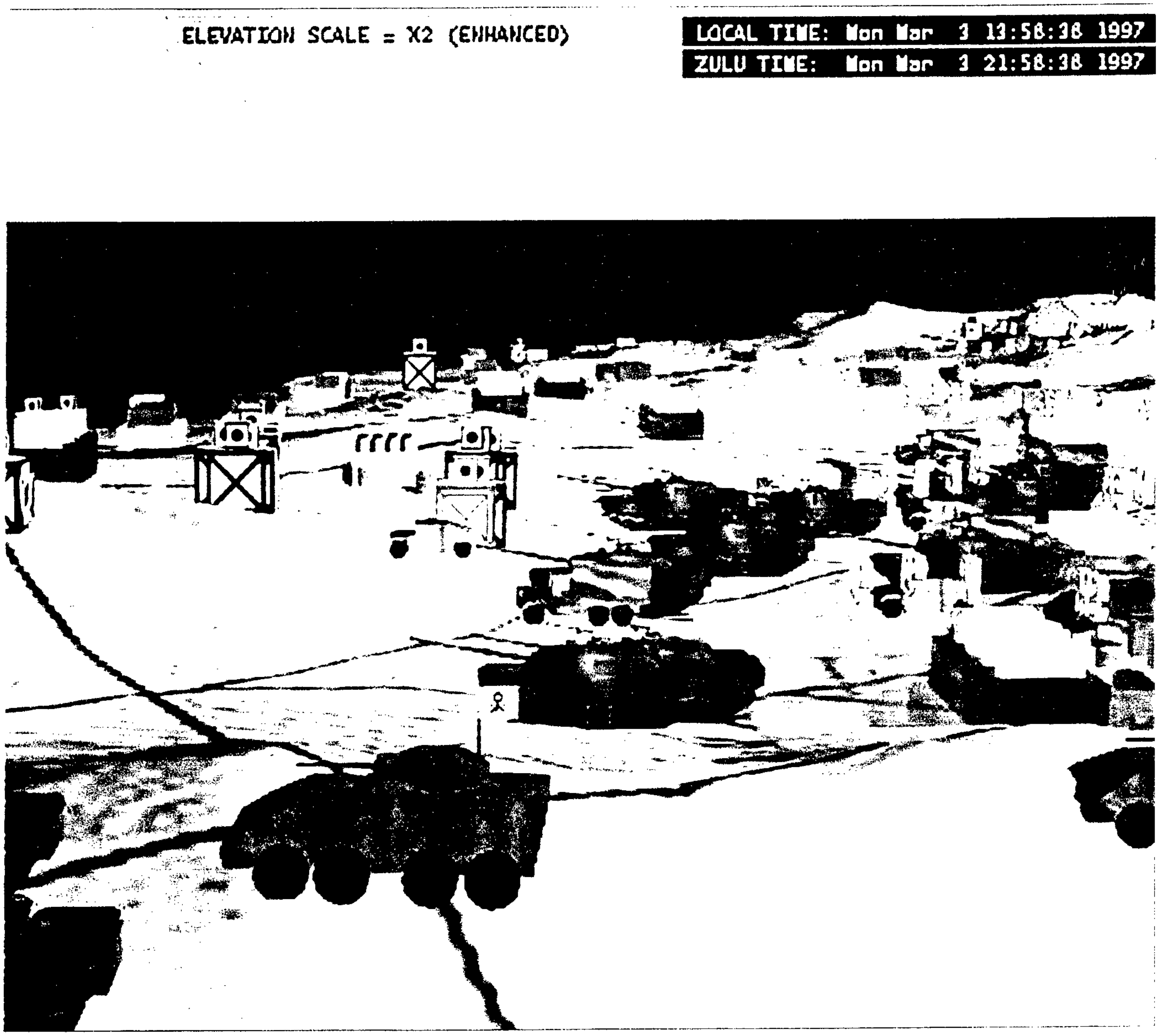
The strength of the VR Responsive Workbench lies in a strong, immersive, visualization environment with a consistent user interface manipulating both the user's view of the synthetic world and the objects portrayed within it.



Sea Dragon Pushing Workbench Developments

The Marine Corps' Sea Dragon process is a driving application, pushing development of the Dragon system on the Workbench. Current efforts are focused on the ambitious Urban Warrior Advanced Warfighting Experiment, scheduled for spring 1999. MCWL is sponsoring the VR-Lab and a small team of contractors to implement a common information-management layer, providing a common interface for passing numerous types of data from multiple sources into the Dragon system.

Beyond these direct applications, the Work-



bench is still a research platform. Several technologies are on the horizon that will help realize the ultimate goal of a convenient, seamless information presentation. Networking the Workbench to distribute it to multiple sites is a first step. Moving to other display hardware, such as advanced, large-screen, flat-panel displays, will be a requirement if the Workbench is to become a viable display alternative for mobile ECOC or shipboard combat information center applications. Moving the software system from current, very-high-end graphics workstations to more affordable PC-based systems is a cost necessity, but that awaits significant improvements in PC architecture and graphics capabilities.

The interface is also ripe for innovation. This includes simple additions, such as drawable overlays, multiple terrain-texturing and insertion of live video. Further enhancements include speech recognition and a natural language capability to provide hands-free operation.

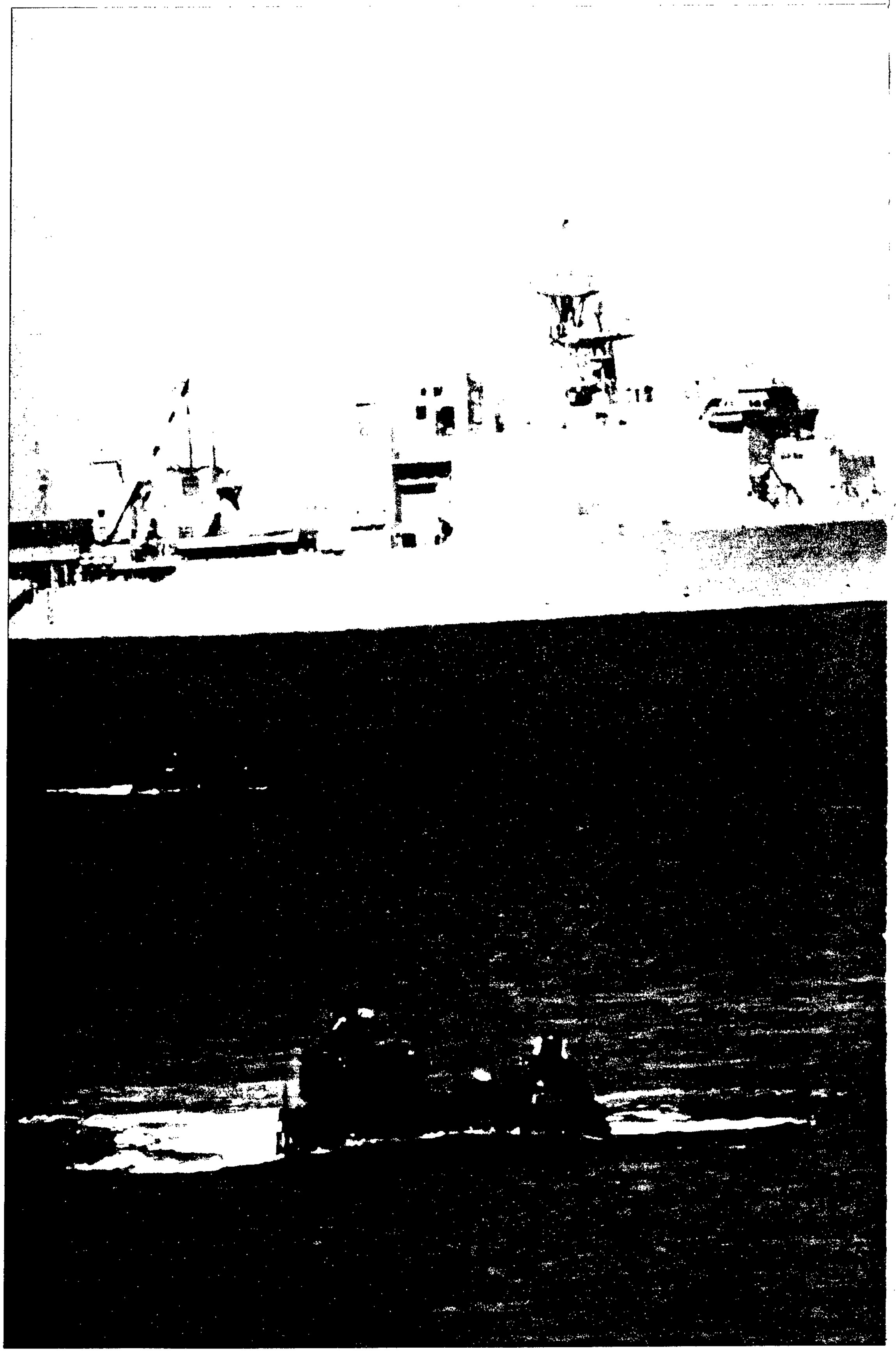
But beyond all of this direct technology application lies the challenge of turning raw data into knowledge and situational awareness. While the Virtual Reality Responsive Workbench is hardly the last word in the evolution toward this state, it is a *revolution* in visual presentation and interaction for operational commanders.

Editor's note: The Virtual Reality Responsive Workbench was invented by Wolfgang Krueger of Germany and has been applied to medical and architectural visualizations. The Workbench, however, naturally lends itself to situations where a group of viewers want to look down onto a shared common picture. Battlefield visualization is a natural extension of these applications.

Above: Using a wand (a tracked, floating joystick) to interact with the Workbench, the operator can "fly through" the display, as if on a magic carpet. *(NRL)*

Apart from the profound impact the Workbench has on the Marine Corps' ability to maneuver from the sea and the Navy's ability to support that maneuver, there is fundamental potential inherent in this system. The Workbench could control a battle group: positioning friendly assets; and providing situational awareness of enemy forces. The Workbench also could keep track of inbound munitions, display status of weapons systems status, and aid in littoral navigation.

Mr. Durbin is a computer scientist for NRL's Information Technology Division. Dr. Rosenblum is NRL's VR Lab Director.



Modeling and simulation tools have proven useful in dealing with post-Cold War issues. *(DOD)*

Analyzing Naval Expeditionary Operations in Support of *Joint Vision 2010*

Shape, Respond, Prepare

The year is 2010. A crisis situation is unfolding. A small nation, important to U. S. national interests, is experiencing internal unrest. Rebel bands, having gained significant footholds in a number of rural areas, show signs of operating under a centralized authority and pose a threat to the capital city.

The nation's government, generally stable and considered friendly to the United States, has asked for help. A show of force, it is thought, will convince the rebel leaders of our determination to defend the legitimacy of the current government, thereby averting a coup d'état. The nearest U.S. military force is an Amphibious Ready Group (ARG) with a Marine Expeditionary Unit (MEU) embarked. What will we do? If we choose to get involved, will the naval expeditionary forces arrive on time? Will the show of force have the desired effect? What if it does not? These questions and a multitude of others must be answered quickly. Time is running out.

Reality? No — this time it is only a simulation. But the dilemma is familiar — one faced by the National Command Authority with increasing frequency since the end of the Cold War. This scenario represents just one of the operations other than war (OOTW) commonly facing today's military. The OOTW predicament described serves as the starting point of an analysis effort currently being conducted.

Before describing that effort, we will digress slightly and discuss why analysis of such situations is needed in the first place and what it entails, point out what the context of future defense analysis is expected to be, and introduce a modern set of modeling and simulation (M&S) tools that have proved useful in dealing with post-Cold War issues.

Analysis assists decision-makers by illuminating pertinent issues, identifying alternative decisions and clarifying the consequences of each. Analysis in support of DOD procurement and employment decisions has had to adapt in the aftermath of the Cold War because the number and nature of potential threats to U.S. national security, and of missions to which military forces

by John G. Burton and Brian D. Engler

may be assigned, have become far less clear, and can be expected to vary widely over time.

The analysis process includes: issue identification, scenario development, measure of effectiveness (MOE) selection, modeling and simulation, collection and analysis of M&S results and communicating results and insights to decision-makers.

Most military analysis techniques and tools, including numerous Cold War models, were developed for individual service needs. They are not readily adaptable to analysis of joint forces, which is increasingly the focus both of real-world operations and of analysis for force planning. Simply blending the approaches of service-specific analyses to a joint campaign's course and outcome is usually less than satisfactory.

For example, analysis objectives, MOEs and levels of resolution or detail frequently differ not only between services but also within each of them. Since preventing or limiting conflicts, rather than just fighting and winning wars, is viewed as a prominent goal of force usage, the analysis techniques and tools needed to examine these new missions may differ from their Cold War predecessors.

Improving Modeling and Simulation

Analysis efforts began several years ago to automate the labor-intensive Program Objective Memorandum (POM) assessment process which helps assess the value added by Navy and Marine Corps systems to joint force operations. Previous analysis tools supporting the CNO's Navy Assessment Division (N81) focused principally on combat operations and generally required work be conducted off-line for data input or for integrating systems, platforms and engagement models to obtain campaign-level results.

The process of automating analysis and integration has since evolved into a flexible and dynamic global-crises analysis modeling environment called the GCAM Core Tool Suite (GCAM-CTS). GCAM-CTS not only integrates existing M&S models, but also improves scenario development and the ability to construct tailored, stand-alone applications in a stochastic object-oriented simulation environment with system functions embedded at a user-selectable level of detail. This integration speeds the MOE-analysis process by detailing risk-levels and enhancing decision-making.

The flexible modeling environment of GCAM-CTS allows each user to focus on specific analytical applications. For example, NSWC Coastal Systems Station is principally concerned with mine warfare; Marine Corps Combat Development Center with amphibious warfare and land combat; CINCPACFLT and Joint Chiefs of Staff (J8) with operational planning; and the Naval Postgraduate School with education.

Defense Analysis Environment

The *shape-respond-prepare* defense strategy articulated in the *Report of the Quadrennial Defense Review* states that current and future naval forces must be capable of responding to various contingencies while maintaining peacetime forward-presence, participating in training exercises and fulfilling other commitments that contribute to shaping the global environment. This strategy echoes *Joint Vision 2010* and its emphasis on full-spectrum dominance: dominant maneuver, precision engagement, full-dimensional protection and focused logistics.

The Department of the Navy uses analysis resources to assess policy, force structure and modernization decision-making for Navy and Marine Corps performance in joint operations

(R.L. Kugler/USMC)

In the past, the inclusion of joint operations was not considered as critical as it is today, and, for the most part, combat operations were assumed.

around the globe. Traditionally, warfare analysis was not so complex. For example, in the past, the inclusion of joint operations was not considered as critical as it is today, and, for the most part, combat operations were assumed.

Today, a spectrum of potential crises exists, and virtually every military operation is joint. Large-scale contingencies, such as major theater wars (MTWs, formerly called major regional contingencies), encompass intense and sustained combat operations. The impact of top-level decisions on force capabilities to fight and win in such situations requires continuous assessment, regardless of how unlikely their occurrence is perceived to be.

Smaller-scale contingencies (SSCs) and other OOTW situations refer to operations that fall short of MTW. These situations, like MTWs, could involve all the armed forces, nondefense agencies, civilian organizations and other nations. They could be classified as either combatant or noncombatant. The terms SSC and OOTW are simply a way to subdivide the extraordinary breadth of OOTW types, emphasizing the rapidly changing nature of all OOTW situations.

SSC defines OOTW operations that evolve into combat and escalate into MTW. Similarly, while some types of OOTW can occur during peacetime, it is useful for analysis purposes to separate routine peacetime operations, such as forward presence, training and exercises, from OOTW contingencies, which is why modeling tools need to be flexible enough to encompass a wide range of events.

Joint Publication 3-07 (Joint Doctrine for Military Operations Other Than War) lists many types and examples of OOTW such as: humanitarian assistance operations such as Operation Sea Angel in Bangladesh (1991-1992); noncombatant evacuation operations (NEO) such as Operations Eastern Exit in Somalia and Quick Lift in Zaire (both in 1991); enforcement of exclusion zones such as Operation Deny Flight in Bosnia (1993); and numerous show-of-force operations.

GCAM Core Tool Suite

GCAM-CTS is a Windows PC-based tool suite designed for global crises analysis modeling. GCAM-CTS can examine events — from traditional warfare, through the OOTW spectrum, and up to a "portfolio analysis" — and then integrate a series of global crises with the peacetime forward presence situation.

It enables operations research analysts to apply their warfighting or operations research experience, to rapidly develop object-oriented stochastic modeling applications for military or other situations, tailored to a specific purpose and at varied levels of resolution.

GCAM Cases, which are individual modeling applications, consist of user-defined objects that interact in an environment including map-based movements, sensors, logistics and inventory control, conditional unit orders and operational planning alternatives. The analyst can define the functional performance of command and reporting architectures that link the decision-making process to the perceived operational or battlefield situation.

The performance of systems, units or groups can be characterized in a GCAM Case from lower-level modeling, studies and war games; by embedding functions of existing models; by developing innovative ways of characterizing functions; or by a combination of all of these methods. It is particularly important to understand that individual GCAM cases are equivalent to instances of warfare models in the traditional sense. In contrast to their static predecessors, however, these cases are custom-built for current issues.

GCAM cases may be run in one of two modes. A batch mode generally is used to collect statistics over hundreds of individual model runs. This mode is important because it is what allows users to capture distributions of results and examine risk or uncertainty in those data. Before batch processing begins, the user must ensure that the particular simulation meets the requirements.

The GCAM-CTS graphical mode helps the user visualize the scenario. The graphical mode helps to explain baseline scenarios and important excursions to decision-makers and to gain insights into things such as why particular engagements turn out the way they do, what the stressing elements of an operational situation might be, and where forces might either be reconfigured or reassigned to improve the outcome.

Users of any warfare model or simulation must understand that the outcomes of individual iterations are not predictive in any real-world sense. Even the expected values that can be assigned to outcomes of a series of model runs are useful not so much as predictors of operational success or failure, but rather as foundations upon which the user and decision-maker can build an understanding of the scenario dynamics, sensitivities to factors such as threat or own-force capabilities, and the potential shifts in outcomes that might be engendered by trading off policy, force structure or modernization alternatives.

Using the GCAM Core Tool Suite

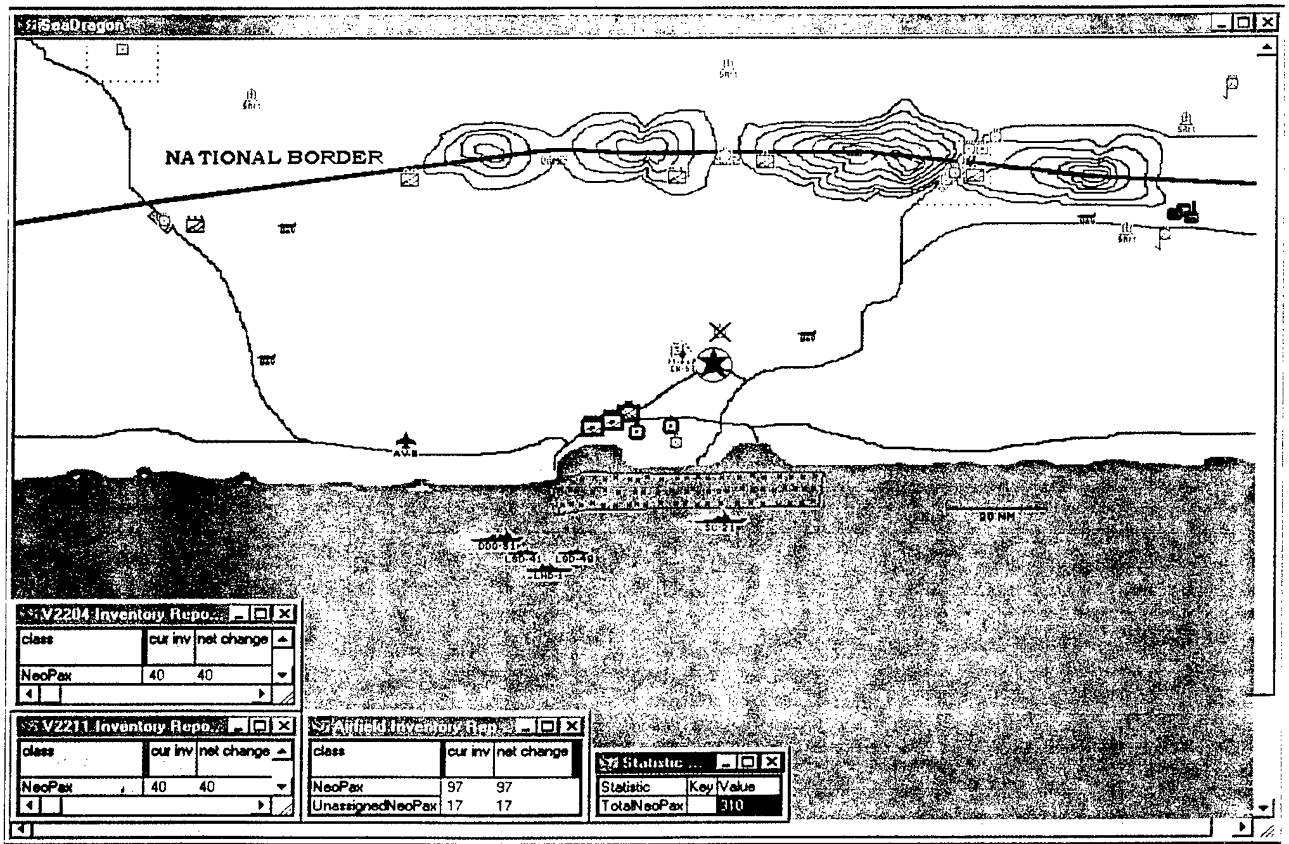
GCAM Cases have been developed for a wide variety of operational situations ranging from dual MTWs to peacetime forward presence. To illustrate the sorts of insights provided through the use of GCAM-CTS, a particular GCAM Case addresses the problem introduced earlier.

As the crisis continues to unfold, the National Command Authority has made the decision to get involved. An Amphibious Ready Group with a MEU embarked has arrived offshore, only to find that circumstances have changed: a minefield and a rebel coastal cruise missile launcher have been added to the enemy's arsenal. The ARG is ordered to land forces.

The GCAM tool suite now is a very valuable resource to decision-makers because it is tracking the commander's perception of the tactical environment, in addition to the ground truth.

Although OOTWs vary in detail and type, they all are extremely reliant on a complex logistical chain to be complete an operation successfully. GCAM-CTS permits detailed and explicit modeling of all elements in that chain, if the user chooses to exploit that capability. Inventories of weapons, ammunition, POL (petroleum, oils and lubricants) and consumables are tracked and updated automatically. In fact, virtually anything can be treated as an inventory item. For instance, in the ARG scenario, the opposed NEO itself is explicitly modeled. GCAM-CTS lets the user dynamically track MOEs such as the numbers of evacuees already aboard ship, at the airfield, or on board individual aircraft.

Throughout any crisis situation, the ability of GCAM-CTS to track, automatically, details of resources consumed not only serves to provide information on the situation at hand, but also simplifies the process of force regeneration planning for follow-on contingencies. GCAM-CTS also enables users to automatically generate spreadsheet-based graphical displays of MOEs to the required level of detail. The individual elements of GCAM-CTS collectively empower the military analyst to examine and quantify, logically and in as much detail as desired, operational situations from peacetime presence, through OOTW, to full-scale war.



The process of automating analysis and integration since has evolved into a flexible and dynamic global-crises analysis modeling environment called the GCAM Core Tool Suite (GCAM-CTS). *(Systems Planning and Analysis, Inc.)*

Editor's note: Mr. Burton is vice-president of SPA. Mr. Engler is a program manager and military analyst with SPA.

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From *Sea* to *Land*

Joint Countermine Operational Simulation providing seamless transition

by Rosemary Seykowski

Because future opponents are expected to include mines in their arsenals, countermine technologies are a vital component of the Navy/Marine Corps team's plans for littoral engagements.

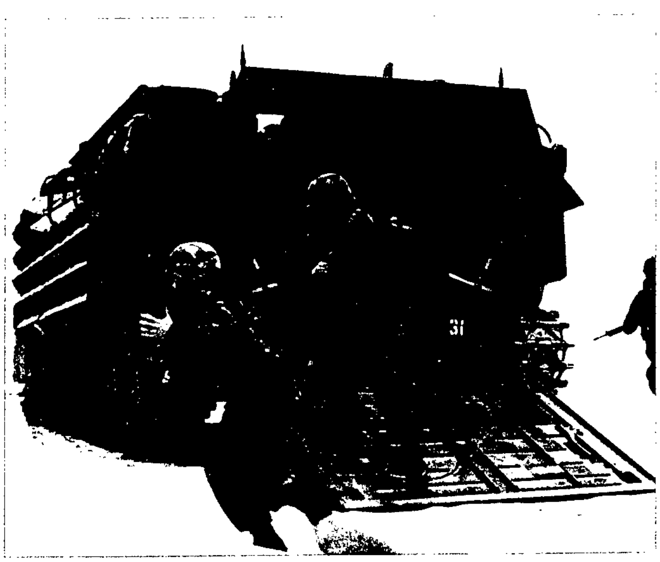
To effectively transition these technologies from development to the fleet, the Joint Countermine Operational Simulation (JCOS), a component of the Joint Countermine Advanced Concept Technology Demonstration (JCM ACTD), established three goals: conduct assessments of the warfighting utility of new technologies and approaches, develop new tactics that exploit these new or enhanced capabilities and provide training for staffs to plan for the employment of novel countermine systems.

The JCM ACTD, a five-year program, will demonstrate the capability to conduct seamless mine countermeasures (MCM) operations from sea to land. This will be accomplished by integrating U.S. Army, Navy and Marine Corps mine countermeasure technology developments and fielded military equipment. The goal is to develop improved mine countermeasure equipment, operational concepts and doctrine to support amphibious and other operations involving the *Operational Maneuver From the Sea* and to support follow-on land operations.

The JCM ACTD is using advanced modeling and simulation (M&S) to assess the military utility of the new systems under development. JCOS, a robust M&S effort, is used to evaluate the operational utility of countermine systems, develop plans to accomplish exercise objectives and assess doctrine and tactics in a variety of scenarios and tactical situations. Technological developments are modeled as unique entities within JCOS. These entities are then employed in realistic scenarios. With this approach, the system's impact on forces and operational plans can be readily assessed, and new tactics can be developed in real time.

The JCOS goal is to provide an end-to-end simulation capability for joint MCM operations. JCOS is capable of simulating and analyzing joint warfighting operations in a mined environment across the operational continuum, from deep water, through the littoral, to inland objectives.

JCOS supports three JCM ACTD activities.



(Joe Clark/USN)

First, JCOS provides an environment that allows users to develop scenarios. These scenarios then are transformed into military objectives that would be developed by a battle staff. Second, JCOS provides live exercise participants with reports of simulation events through incorporation of a C4I gateway. With this simulation-to-real-world link, the joint force commander and other battle staffs are able to view operations, both live and simulated, as one seamless operation using fielded C4I systems. Third, JCOS analyzes the conduct and outcome of the operation based upon data gathered during each phase.

JCOS Components

JCOS consists of a number of components. Four entity-based synthetic force (SF) applications, one for each service, provide the environmental, behavioral and systems representations for simulating warfighting and mine countermine objects. Other components required to round out a true end-to-end simulation capability: an After Action Review System (AARS), a simulation — C4I gateway, an Exercise Management and Control System (EMCS) and a 3-D visualization system or display.

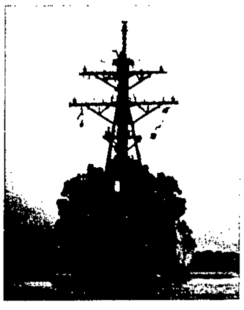
Synthetic force applications are used within JCOS to represent military operations at the entity level using the Advanced Distributed Simulation (ADS) architecture to connect live and virtual exercise participants in a synthetic environment. These SF applications are identical to those being developed for the DARPA Synthetic Theater of War (STOW) Program.

Entity representations for many legacy military systems are included in the STOW releases of the SF applications. Countermine functionality, developed under the auspices of the JCOS Program, includes mines (both land and sea), legacy countermine systems and novel countermine systems being introduced by the JCM ATD.

The After Action Review System, the analytic component of JCOS, is an interactive web-based system that supports the after-action review process. Previously, after-action review consisted primarily of subjective observations of an exercise but with JCOS AARS, *quantitative* analysis is now possible.

The JCOS AARS supports five after-action review functions: exercise preparation and planning, simulation data preparation, unit performance evaluation, data analysis and playback. This low-cost, web-based approach facilitates multiuser, end-to-end simulation and analysis capability.

The JCOS AARS uses the Universal Joint Task List to develop a Joint Mission Essential Task List, the commander's guide for implementing missions and assessing force performance. The JCOS AARS also supplies tools to extract simulation data and graphic captures. Standard analysis products are generated that include losses over time, killer-victim scoreboards and firing accuracy tables. Customized analysis is supported by the capability to incorporate feedback, to access data across multiple simulation runs and to customize playback options with track histories and detection overlays.



USS *Sullivans* (DDG 59) *(Jack Gallant/USN)*

The JCOS C4I gateway has the capability to exchange formatted and free-text information between the JCOS synthetic force applications and selected C4I systems by monitoring the simulation network, gathering information about entities and their interactions, responding to C4I system reports and constructing military service messages in a variety of formats. The JCOS C4I gateway function is linking the simulated JCOS world and with the real-world C4I system (e.g., the joint countermine application). The gateway supports data exchange using U. S. Message Text Format and Over-the-Horizon-Targeting Gold (OTG) message formats and can communicate bidirectionally with the Maneuver Control System and Joint Maritime Command Information System. The gateway provides the capability to transfer simulated situational awareness from battlefield simulations to fielded C4I systems.

The Exercise Management and Control System (EMCS) allows a user to select and remotely operate a variety of ADS software components including SF applications, simulation data loggers, visualization systems and software utilities that run on the EMCS user's machines. Using the EMCS, a single user at a single machine can easily set up a run that encompasses multiple components and then repeat the same run with minimal commands. The ability to repeat runs allows comparisons to be made across runs.

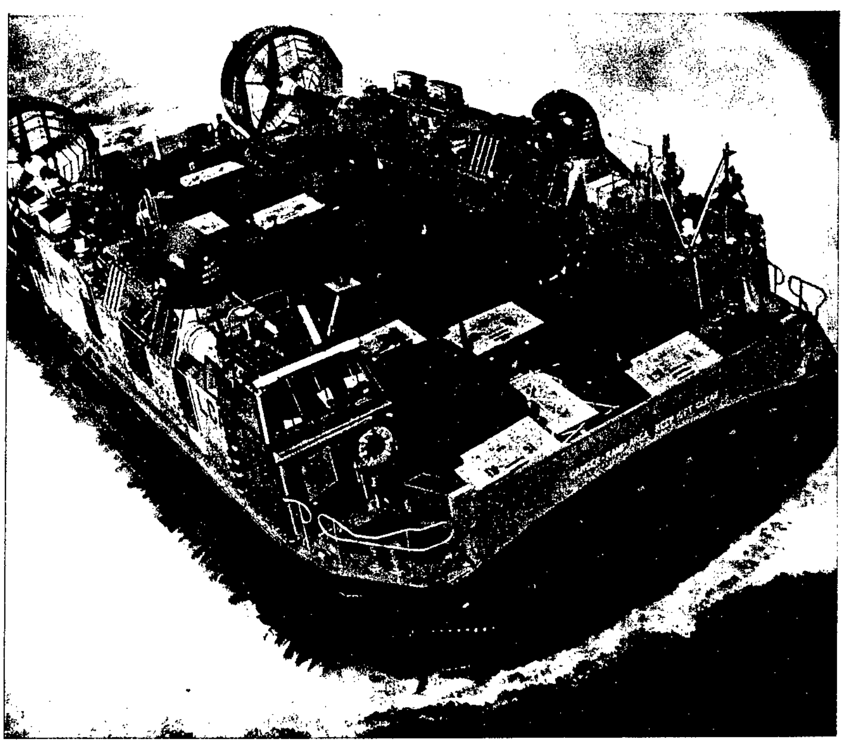
The display provides a 3-D view of SF-simulated scenarios. This view shows realistic models of the entities as well as terrain features. Large-scale engagements can be viewed by moving the display to the appropriate position on the battlefield.

JCOS Exercise Participation

A number of new JCM ACTD-developed systems were demonstrated last summer during Joint Task Force Exercise 3-97 (JTFEX 3-97) at Camp Lejeune, N.C. JCOS was used to plan and visualize several components of the countermine operations and beach assault. Scenarios and plans based on input from established doctrine and from system operators were set up within the simulation. Simulation runs were executed to support an assessment of the planned course of action, which was then revised and the simulation rerun. The Marine Corps used JCOS extensively and showcased its capability in the Command Operations Center in the Littoral Warfare Training Center. Additional simulation runs were made with and without novel systems to assess their potential impact on expeditionary force operations.

During the exercise, JCOS injected three simulated Explosive Neutralization ATD (ENATD) into the C4I system. (ENATD is a novel system with explosive line charges and nets deployed from a landing craft, air-cushion to clear mines in the surf zone.) First, a scenario was developed in JCOS that simulated the ENATD lane clearance operations. The C4I Gateway then listened to the simulation network traffic identifying key events such as entity state information, mine detonations and land clearance areas. This information was converted to OTG format and transmitted to the C4I network.

JCOS also received tasking during the exercise to inject six amphibious assault vehicles (AAVs) into the C4I system to represent a concurrent AAV landing at an adjacent beach when the real AAVs landed as part of the exercise. The real AAVs were instrumented so their positions also could be shown in the C4I system. The performance of the simulated forces was so close to the live play that special designators were required on the C4I display to distinguish between the two.



JCOS received tasking during JTFEX 97-3 to inject six AAVs into the C4I system to represent a concurrent AAV landing at an adjacent beach. *(USN)*

JCOS is scheduled to participate in a second demonstration in 1998 that will highlight and assess the military utility of additional systems.

The success of JCOS in JTFEX 3-97 is only the beginning. JCOS provides the opportunity for large-scale exercises to be conducted with minimal live systems — simulated systems can be injected for those not present — and with lower costs. JCOS also showcases the importance of mine countermeasures in littoral warfare. With tools of this nature, mine countermeasure operations can be "mainstreamed" into future wargaming, exercise and planning operations. Mainstreaming is imperative if MCM is to be an integral part of expeditionary warfare.

Editor's note: Ms. Seykowski is lead operations research analyst at Mitre Corp, which is providing contract support for the JCM ACTD.

SIMULATION

Virtual Environments for Naval Training

The Virtual CIC closely resembles that aboard USS *Cape St. George* (CG 71) and other ships of the class. ***(NRL)***

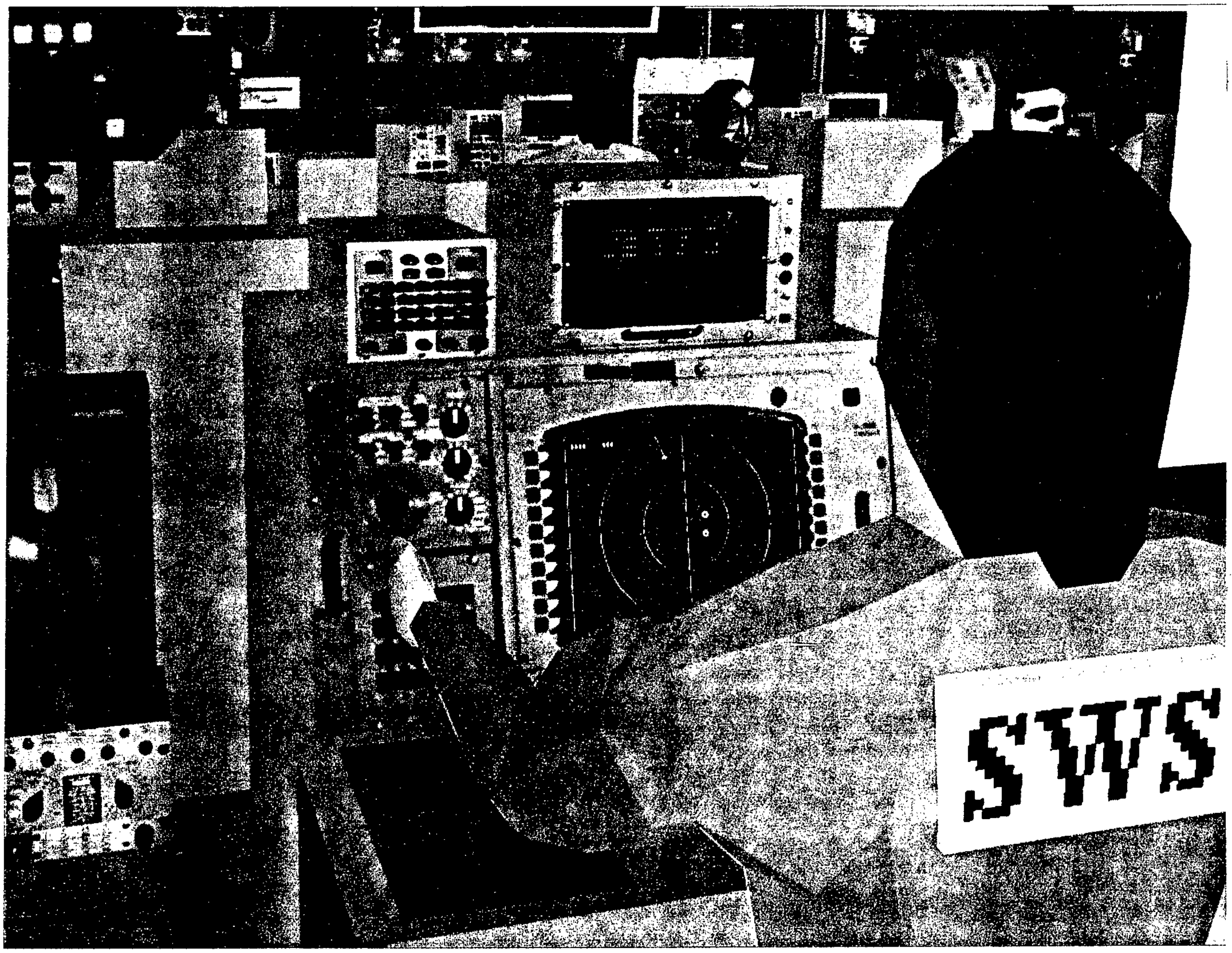
by Karl B. Washburn and Henry C. Ng

When Sailors train for watchstation operations in an Aegis Combat Information Center (CIC), they use consoles at shore-based facilities. Anticipating the trends in defense funding and the impact those trends will have on training system availability, the Aegis Training Center (ATC), Dahlgren, Va., is exploring technological aids to increase training capabilities. The projected need for these enhancements is highlighted in concepts such as "Horizon," recently published by the Strategic Studies Group at the Naval War College. The Horizon concept calls for semi-permanent, forward-basing of U.S. warships in international waters near critical locations. Crews would be rotated to the ships directly from CONUS rather than transiting. Faster, more flexible and more realistic training, both ashore and afloat, enables such manning concepts.

n anticipation of these future training concepts, ATC is exploring technologies that take advantage of the power of modern information technologies. The Naval Research Laboratory, Computing Systems and Visualization Section is working with ATC on one such concept, "Simulation-Based Virtual Environments." It marries three different computer technologies: distributed simulation, virtual reality and multimedia training aids. At the heart of this project is the "Virtual Combat Information Center," an *exact*, 3-D representation of the ***Ticonderoga***-class CIC, running on graphics workstations.

The primary goal is to provide distributed, simulation-based, immersive virtual reality (VR) systems to complement current training systems. When completed, this system will allow crew members, each at separate locations, to participate in the same Virtual CIC, conducting training simultaneously.

Distribution of the system over a network allows for many different configurations: from multiple consoles within one room; to multiple rooms within one building; to multiple buildings at one site; to worldwide connectivity, including afloat platforms. By being *simu-*



A view over-the-shoulder of an "operator" at the OJ-451 with a nominal display. The human figures are "queried" by students in the tutorial walkthrough. *(NRL)*

lation-based, the system is capable of linking with other simulation systems using the new DOD interface standards. This interface enables the training crew to link into joint forces exercises, as well as explore advanced system concepts such as Theater Missile Defense — all from the same virtual environment. A virtual environment is synthetically generated from graphics workstations.

Feel and Impact of Real Presence

Making the environment immersive gives the feel and *impact* of real presence. Realism is achieved in the visual and aural environment, in the simulation of that environment and its participants, and in the responses of the modeling systems. Multimedia training aids are included within the VR environment to provide immediate, online feedback and additional information at user-variable depth.

The distribution of the systems on a network creates a whole that is greater than the sum of its parts. Networking frees both trainees and instructors from being tied to a single location. Sailors can train wherever the necessary computer hardware and a network link are available. This distribution can scale geographically to nationwide or even global links, including afloat units.

Virtual environments create a new level of training by making the training experience "realistic." The trainee can go "beyond the console" — visualizing the entire battlespace, including sensor and weapons coverage, emission restrictions, operational boundaries and doctrines, and the external "real" environment. Immediate feedback is available on the external consequences of a trainee's actions.

Simulation-based virtual environments bring enormous flexibility to training. They provide for variable fidelity, that is, the level of realism required to meet training objectives. Additional fidelity can be not only incorporated as needed, but also lowered when it is not appropriate, helping trainees focus on new topics. The latest revisions in console and system capability are more easily incorporated in a virtual environment with the added benefit that systems that are still on the drawing board can be exercised before the metal is bent.

Adding the visual dimension to what was formerly text-only instruction enables much faster absorption of introductory information by the trainees. The increased availability of the training environments and the ability to extend instructors' capabilities enable *more* training objectives to be met *faster*. Some of these capabilities can be taken shipboard, where crew members can receive tutorials and additional training without interfering with operational watches. The Navy is actively pursuing such "interactive courseware" in several programs within its systems laboratories.

Ultimately, a simulation-based virtual training environment must be flexible, reconfigurable, and scalable.

It must be *flexible* enough to be deployed wherever the computing power is available, on shore or afloat, with or without a network infrastructure.

It must be easily *reconfigurable*: allowing scenarios to be loaded quickly and easily, allowing mixing of any console or group of consoles and accommodating different crew groupings. In addition, it must be able to accommodate newly available simulation models through a well-defined interface.

The system has to be scalable: running from the laptop (where interactive courseware guides individual crew members through tutorials and allows them to "play" defined scenarios) to full, wide-area networks of graphics workstations (where full CIC manning would be emulated and high-fidelity system models exercised).

Creating the Immersive CIC

In creating an immersive CIC environment, there are several key features. The presentation must have the "look" and "feel" of an actual combat information center. This realism requires the full, 3-D modeling of all the stations and important physical structures within the CIC, including accurate photo-texturing of the models. The visualization hardware must display these models to the trainee accurately, quickly and smoothly. Audio presentation also is important, not only for the obvious communications activities, but also for "over-the-shoulder" instructor guidance and for creating the general ambiance of a "busy" CIC.

Immersion can occur at several levels, depending on available resources. Shipboard or ashore, a crew member could use stand-alone systems like laptops or PCs for tutorials and refreshers. At training sites, VR-viewing paradigms could range from desktop graphics workstations with mouse inputs, to multiscreen projected displays with joysticks or spaceball inputs, to head-mounted displays with interactive gloves which "touch" objects in the synthetic world. The hardware can be mixed and matched according to cost considerations and requirements. The software supports all the viewed paradigms, enabling different users to choose appropriate hardware to "plug and play" in the distributed environment.

The use of multimedia features as training aids also is important. The student must have online access, within the immersive environment, to hypertext-based manuals that provide multiple levels of detail. Online video and audio clips should be included to give strong "presence" to the manuals' information. This type of immediate, visual feedback has proven successful in enhancing training; once a user is familiar with the tasks, the features can be disabled. Until then, however, they provide guidance that is quickly absorbed by the student relative to reading through extensive text.

Teaching Via Telepresence

There is significant power in the simulation-based virtual environment approach for instructors. This power is achieved through "telepresence." The instructors observe the trainees through their own immersive systems. When appropriate, they contact trainees verbally through the audio link. Additionally, they can highlight console actions directly within the students' environments, even appearing as a human figure if necessary. Using the power of the networked computers to act as instructor's aids, "intelligent agents" can move through the network during training exercises, tracking student actions, evaluating them and predicting their future performance. They aid in recommending additional topical reinforcements as needed for each student. The instructor's horizon is expanded; the number of students the instructor can oversee is increased without a concomitant increase in workload. Instructors track student progress, not only in a single session, but from day to day and even beyond, both locally and remotely. One such system, the Intelligent Tutoring System, is under development; NRL will link the simulation-based virtual environment to it when both are ready.

NRL's Virtual CIC development is planned across four major phases. Phase I is a virtual walkthrough and self-guided tutorial of the Aegis cruiser CIC. This phase was completed and delivered to the Aegis Training Center this year. An accurate 3-D model of the CIC, with photo-textured representations of all of the consoles, the Aegis Display System (ADS), and other displays and equipment has been completed. The student, viewing the scene in high-resolution stereo, can move through the environment, querying watchstation operators for hypertext discussions of their roles, responsibilities and location within the functional organization.

The OJ-451 console and the ADS have notional display capabilities. The Virtual CIC runs on a network where it is simulated by the Advanced Multiwarfare Assessment and Research System (Advanced MARS), a naval warfare engagement simulator. Thus, when entities in the Advanced MARS simulation fall within range of the SPY-1B radar model, they appear on the consoles, and the state of the radar is, in turn, available to radar-sensitive entities in the simulation.

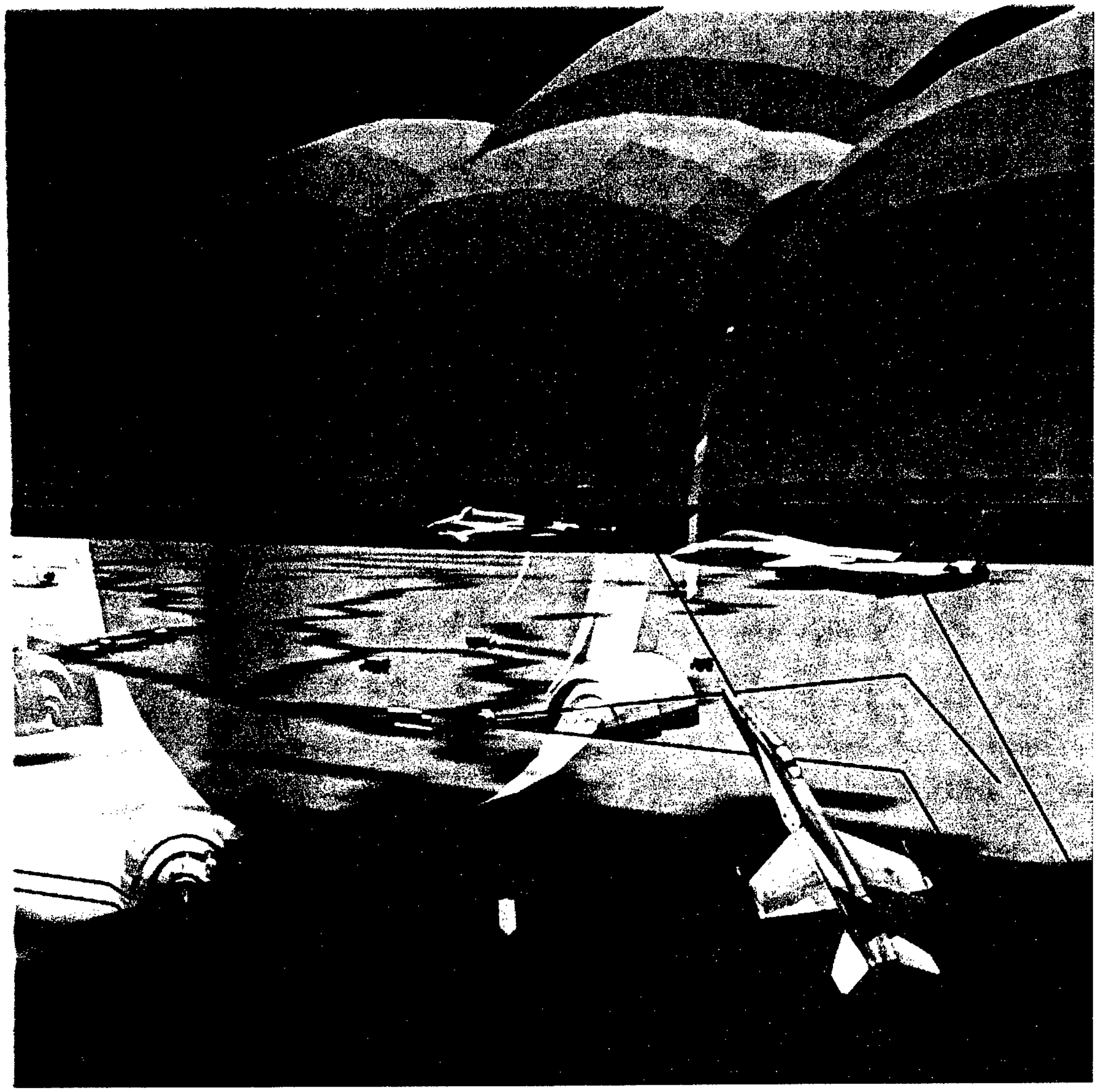
Phase II focuses on individual watchstations; the virtual OJ-451 and other console models will have sufficient functionality, with active switches and accurate displays, to accommodate task training.

In Phase III, multiple virtual watchstations will be networked together at one site to provide for cooperative crew training exercises with realistic engagement simulations. At this stage, the prototype Intelligent Tutoring System (ITS) will be introduced.

Phase IV will take the networked system and drive it over a wide-area network, enabling geographically distributed training. The ITS then will support instructors in teletraining crew members. The current goal through Phase IV is to create a full-up Virtual Ship CIC training system, with support for 10 to 12 simultaneous watchstation operators in a fully immersive environment which is networked and geographically distributed.

System Architecture

What goes into a simulation-based virtual environment like the Virtual CIC? The system architecture has three primary components: a scenario/simulation generator, a VR environment, and a system controller. The scenario generator is the stimulus to training activities. It is a reconfigurable, real-time set of warfare engagement models which provides objects whose interactions and behaviors are realistic. "Objects," in this context, doesn't just mean simple, kinematic ships and aircraft. It can include full en-



Virtual environments enable the trainee to go "beyond the console" -- visualizing the entire battlespace, including sensor and weapons coverage, emission restrictions, operational boundaries and doctrines, and the external "real" environment. *(NRL)*

gineering models of sensor systems, weapons systems, even the weather. These models are currently provided to the system by the Advanced MARS. The VR environment is the hardware and software which presents the computer-generated world to the viewers. The Phase I Virtual CIC can run on a range of graphics workstations, and can be displayed at a graphics console, projected on a large-screen display or viewed within a head-mounted display.

In all three cases, it can be displayed stereoscopically. The system controller manages the whole menagerie: starting, pausing, and stopping the simulations; marshaling the Intelligent Tutoring System; and monitoring the entire system. The hardware components include multiple VR stations, simulation engines, data collection, logging and databasing systems, and network monitoring gear. All the components hang together on a standard computer network.

The technologies that make simulation-based virtual reality useful as a training tool have a broader scope of applicability. They are being applied to test and evaluate systems and doctrines and examine functionality, performance and procedures. Standardized interfaces developed by DOD enable near "plug-and-play" incorporation of specific system models. The reconfigurability of the simulation systems allows for almost any imaginable scenario to be played out, allowing exploration of doctrinal issues.

- Simulation and virtual environments are being applied to the design and acquisition process. Virtual environments are excellent stepping stones to system integration, allowing planners to examine console connectivity, to explore crew interaction in realistic environments and to check for combat system compatibility. These applications are intended to reduce the time from design to deployment of naval systems. In the specific case of the CIC, new consoles, displays and spaces can be designed and "built" without expensive mock-ups, going straight from computer-aided designs to functioning virtual environments. This approach is being actively pursued for the next-generation Surface Combatant (SC 21), carrier (CVX) and attack submarine (NAS).

The Navy and Marine Corps have dedicated themselves to providing ever-improving training and readiness in an era of shrinking resources. Harnessing the immense power of information technologies is a necessity in achieving these goals. NRL's Simulation-Based Virtual Environments is just one technology being applied to address new training and design paradigms. The naval crews of the next century will have significant training advantages when they report for their watches.

Editor's note: Mr. Washburn is an electrical engineer at NRL. Mr. Ng is a research physicist at NRL.

Mission Planning in 3-D

SEEING BEYOND THE Obvious

by James B. Hofmann and Dennis Gallus

As computing power increases, more and more engineering, medical and entertainment applications are using 3-D visualization to present information to the user. In addition, 3-D visualization is being used in some military applications such as mission rehearsal and satellite orbit and footprint (coverage) display. Despite increasing use, however, the value of 3-D displays is, as yet, unproven in most fleet applications.

Because 3-D displays place heavier demands on computers, adding a 3-D capability can significantly increase system cost by requiring the use of graphics-intensive equipment. To permit interactive visualization of a 3-D data set that varies with time, the computer requires sufficient memory to hold the data set, and a graphics subsystem to draw world coordinates and to render lines and polygon shapes into a view that the user can interpret. Whether 3-D is cost-effective is debatable. A recent experimental deployment of 3-D technology has presented a timely opportunity to explore the value of 3-D to mission planning and rehearsal systems in an operational context. This experience has implications to aviation as well as surface weapons systems.

Background

A Naval Research Laboratory (NRL) study suggested that computer-based automation and visualization could improve the quality and timeliness of battle planning. This study led to the Advanced Power Projection Planning and Execution (APPEX) project, a technology demonstration to significantly increase automated planning tools. In 1994, the APPEX project began in with a laboratory-based concept demonstration based on an analysis of the current mission-planning process that identified key areas for computer-based solutions.

Various aviation mission-planning systems have been used since the mid-1980s. Yet for most of the Navy, including the aviation community, operations planning remains a manual and time-consuming process. User-acceptance of existing systems has been hampered by the perceived user-hostility of the software. Improved ease (and consequently speed) of planning became a primary goal of APPEX development. Another goal was to provide a 3-D viewer to serve as a mission preview and rehearsal tool to facilitate strike plan briefings.

Two features of the recent APPEX experimental deployment of 3-D technology deserve emphasis. First, the demonstration took place in an operational setting. Second, the demonstration featured extended user involvement rather than a comparatively brief user review.

After testing by Carrier Air Wing 3, APPEX was installed in 1996 on USS ***Theodore Roosevelt***'s (CVN 71) carrier intelligence cen-

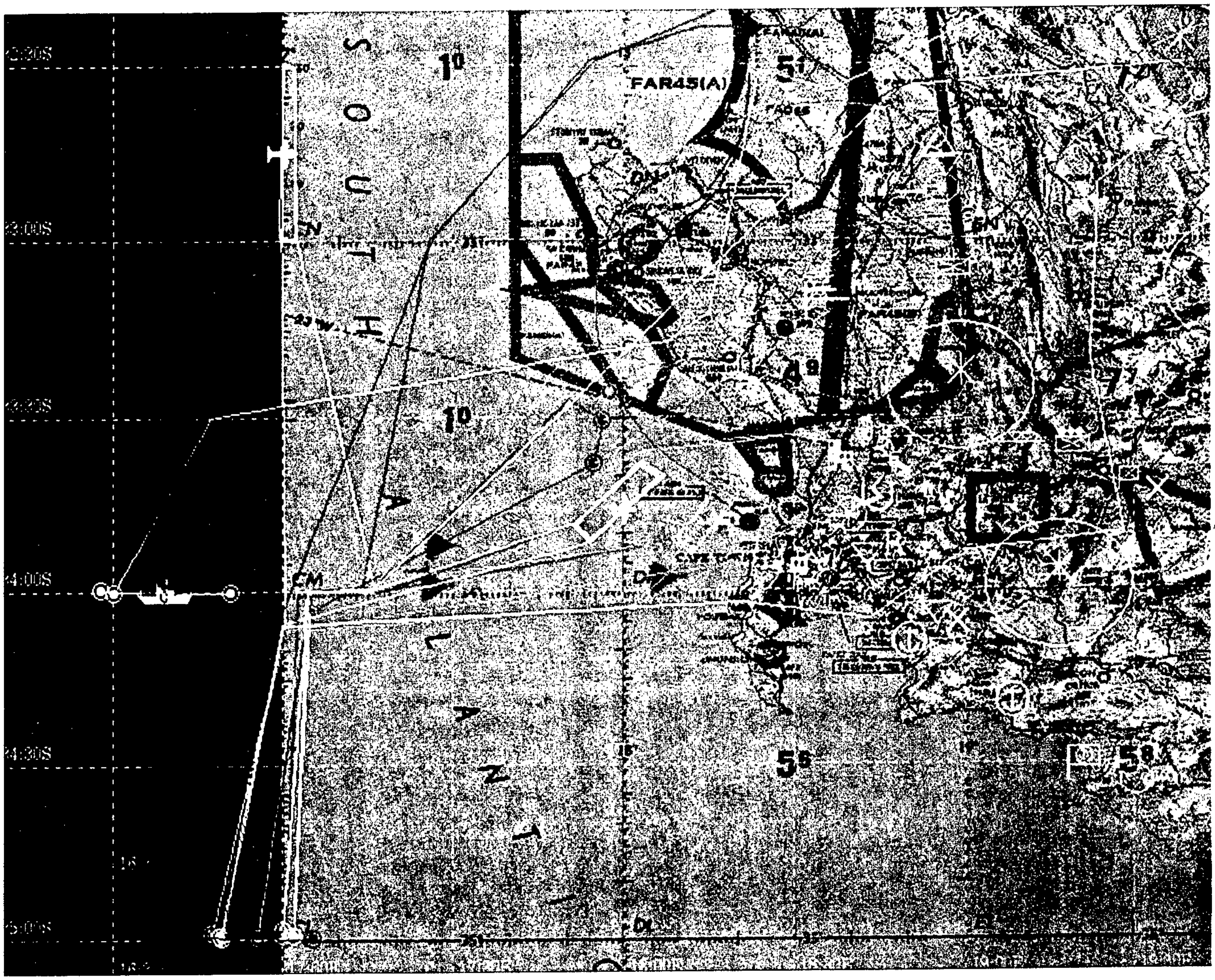


Figure 1 *(NRL)*

ter (CVIC) workstation and two F/A-18 squadron ready room workstations. The workstations were used during several fleet exercises and were integrated into air wing operations. Workstation suites were networked from CVIC to the ready rooms (and to various databases) over a high-speed network.

Building Aircraft Missions in APPEX

Equipment: An APPEX workstation suite consists of two networked computers, with planning software hosted on a TAC-4 series computer running the Joint Maritime Command Information System (JMCIS). This system permits easy access to current naval intelligence and track data, considerably streamlining the planning process. The 3-D visualization runs on a graphics workstation. (The second workstation brings other benefits, like access to a secure web browser, word processing, spreadsheet and software for constructing strike briefings.)

Graphical Route Entry: **Figure 1** displays a screen snapshot of the chart on which missions are entered graphically. In this example, planners are using an arc digitized raster graphics (ADRG) chart for mission planning. Icons indicate type of platform, and color of track indicates specific mission. The user designates the type of mission and then points and clicks to enter the waypoints that form the route. This approach facilitates rapid route entry and early spatial deconfliction between platforms.

Vertical Profile: The user also can adjust flight altitude and obtain additional information regarding the various legs of the mission through use of this vertical profile. The various waypoints are displayed over the terrain. The user can select a waypoint, modify its altitude by dragging the point up or down and receive specific information about that leg of the mission. Using these graphical methods, a rough route can be entered in less than a minute; for aircraft, this route includes the altitudes flown on the various legs of the route.

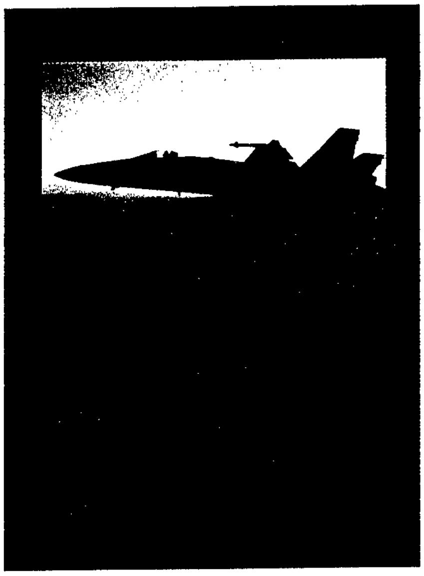
Timing and Coordination: These missions then can be viewed on a timeline where the horizontal axis represents time. This horizontal axis is "elastic;" segments of the axis can be nonlinear to spread out and align events in time. The various missions are stacked vertically and can be slid up or down relative to one another.

Individual waypoints can be assigned special symbols and colors to increase plan understanding. High-speed antiradiation missile launches are shown by the red triangular symbols; the "tails" to the right of each HARM launch graphically depict time of flight, which is calculated by the software. Other symbols can be used to indicate rendezvous, tanking, air-to-ground delivery and navigation points.

The timeline also is interactive, allowing the user to adjust mission events by selecting one or more waypoints and moving them forward or backward as desired. Thus, the user can align specific events with respect to clock time (e.g., ordnance impact at a specific instant), or relative to one another (e.g., jamming will begin when an aircraft enters the maximum detection envelope of a specific radar).

Plan Visualization

After developing the plan, the user can display the missions in 3-D as they play out in time, and in relation to terrain, geography and threat systems. The location of the individual missions at each instant are shown by color-coded 3-D models or icons, depending on user preference. The models show direction of flight and shadow.



The preview can be played at various speeds from real-time to more than 60 times real-time. At any time, the preview can be paused, the play speed altered, the view zoomed, or the position of the eye point changed by keystrokes and mouse actions. Positioning the eye point overhead is useful to show the position of aircraft routes with respect to both threat systems and other aircraft. Rotating the eye point down 90 degrees from overhead gives a view tangent to the earth's surface, and facilitates altitude deconfliction of the aircraft; it also can be used to illustrate terrain or missile-envelope clearance. Views from between overhead and 90 degrees give a 3-D perspective view, showing the positions of various strike elements as they move in relation to one another. The user also can "attach" his viewpoint to any object, including moving objects such as strike aircraft. This can be used to give a pseudo-cockpit view of the strike.

The user can drape Landsat, Spot or other imagery over digital terrain data. Radar volumes can be displayed either as maximum range, or as maximum range modified by terrain masking. When jamming begins, the effects of the jamming on these radar volumes is dynamically calculated and displayed.

Why 3-D Visualization?

During both the workups and the ***Theodore Roosevelt*** deployment, even the most carefully planned strikes benefited from 3-D preview because the preview provided situational awareness. Even strike plans that had all the elements positioned perfectly and at the correct altitude, with timelines carefully adjusted, often would contain surprises during preview—such as two aircraft (generally belonging to different elements of the strike) coming nose-to-nose at high speed. Such "beak-to-beak" situations could be the proximate cause of blue-on-blue engagements, particularly if the pilots involved did not have complete situational awareness beforehand.

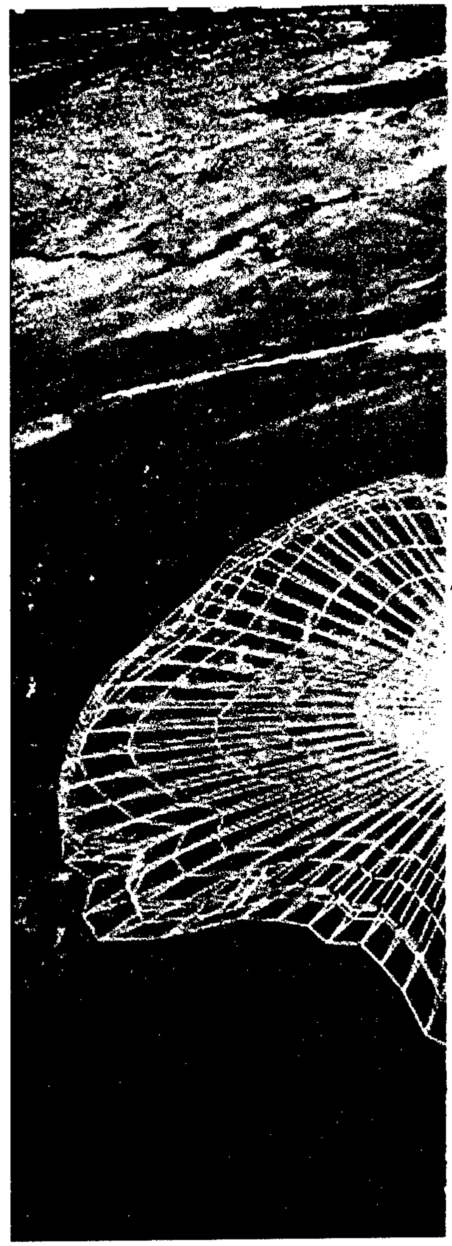
In a sense, it was the fourth dimension of the preview, the dynamic flow of events in time, that was most effective in increasing situational awareness. The time-ordering of events was initially more important than the 3-D perspective feature. Many strike planners chose to present their previews with the eye positioned directly overhead the scene — essentially a 2-D view with the flow of events added. But the 3-D perspective was praised for display of threat areas, and for altitude deconfliction between aircraft.

Being able to see the entire strike plan before the strike completed the planning process and provided invaluable quality control. APPEX helped strike planners visualize the impact on the strike plan of potentially wrong decisions early in the planning process, thereby preventing strikers from having to learn from mistakes while airborne.

Carrier Air Wing 3 compared the 3-D preview with the Tactical Air Combat Training System (TACTS) presentation used to critique completed strikes at the Naval Strike and Air Warfare Center in Fallon, Nev., but with an important difference: At Fallon, aviators watch a 3-D replay of their strike about an hour after they fly the mission. With APPEX, strikers can review, edit and replay a 3-D portrayal of their strike *before* they fly it.

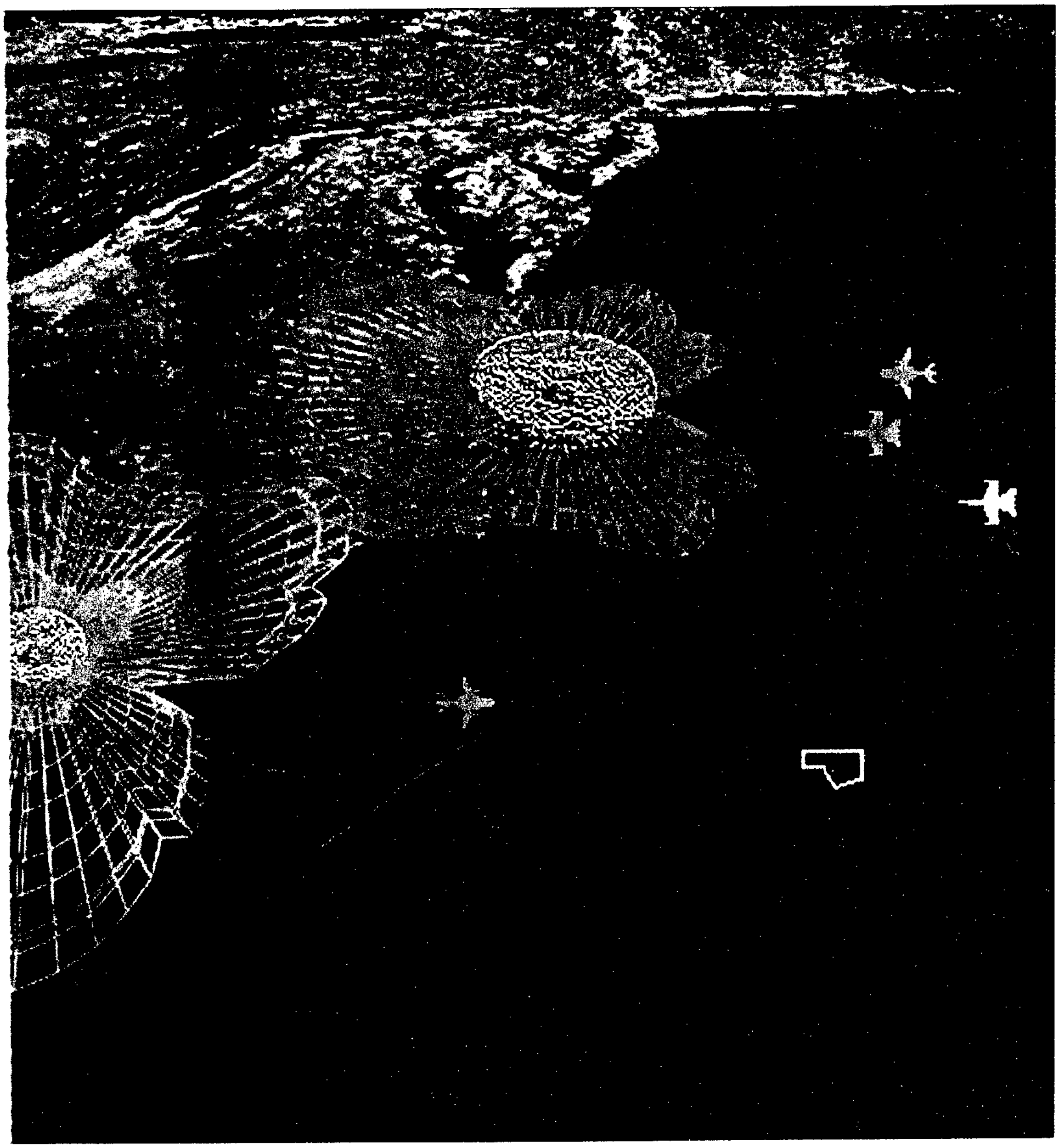
Information dissemination is an important part of the planning process, and the APPEX 3-D preview has become an indispensable part of the strike briefing process. To this end, a three-eyed color projector was installed in CVIC. Strike planners were able to plan their missions using APPEX and make slides; the resulting strike briefing was projected on a wall-sized screen in CVIC for review. Because typical strike plans have many elements (for example, a fighter sweep element), not all strike participants will have a clear mental picture of the intended flow of the strike. The 3-D preview augments the traditional strike briefing and conveys a clear picture of the strike plan to all involved.

The ability to preview gave new quality and depth to strike plans. Being able to see the timing and coordination simulation faster than real-time on APPEX provided for deconfliction in air-to-air, timeline adjustments in jamming and ARM launches and coordination with escorts.



Surface Warfare Applications

APPEX also has demonstrated a capacity for air defense planning against both conventional air strikes and theater ballistic missiles. The ability to portray radar coverage as a 3-D volume would be a useful augmentation to the current 2-D displays of Aegis radar systems. In a recent demonstration at the Naval Surface Warfare Center, Dahlgren, Va., APPEX was linked to a simulated Aegis ship combat system. Aegis antiair warfare doctrine regions were then displayed both on the APPEX planning screen and in the



The jammed radar of two surface-to-air missile sites are displayed in 3-D. *(NRL)*

3-D visualization.

APPEX 3-D radar visualization for Aegis ships would be particularly useful when operating in littoral areas where radar terrain masking could be a major determinant of radar performance. Reference to a 3-D display would, in part, determine optimum Aegis ship stationing. The potential benefits of 3-D SPY radar visualization could be tremendous, particularly for displaying radar coverage against high-flying targets such as theater ballistic missiles. Although only a limited demonstration of this capability has been attempted operationally, since APPEX was located on the aircraft carrier during the deployment and not on the cruisers, the exposure was enough to generate interest among Aegis operators.

The various communities in the Navy can sometimes misunderstand each other's capabilities. The magnitude and overall importance of such misunderstandings are potentially greater in the joint arena where there is typically less foreknowledge and exchange of information. But 3-D visualization has the capability to increase situational awareness in the joint arena.

Results and Future Plans

APPEX provides a 3-D visualization of missions in relation to terrain, threats and forces to support the planning, briefing and execution phases of a strike. APPEX provides the following advantages: reduced planning time, allowing more time to develop contingencies; deconfliction of individual plan elements; and an unequaled situational awareness through the 3-D plan preview and consolidated timeline generation. Current plans for APPEX include the extension of the planning tools into real-time battle management. Battle management experiments will continue at the Naval Surface Warfare Center in Dahlgren, and the Naval Strike and Air Warfare Center (NSAWC) at Fallon.

Editor's note: Mr. Hofmann is a supervisory electronics engineer at NRL. Mr. Gallus is a senior analyst at Metron, Inc.

Simulation-based

Acquisition

Can modeling and simulation (M&S) truly help the program manager navigate to project success over the life cycle?

Traditionally, program managers navigate the life-cycle process using a variety of tools, including M&S. So, what is the M&S "revolution" all about?

by Lorraine Shea and Michael Pobat

As a system grows throughout the engineering and development phase, simulation-based acquisition (SBA) allows a conceptual model to grow in functionality and specification. The end result is a well-understood, credible system representation, augmenting developmental and operational testing. This model then can be used during deployment and preplanned product improvements. Although the basic model's level of abstraction may change from application, a pedigree is established based on a common system representation that becomes the standard for any application. Hence, an adaptive life-cycle tool evolves for the program manager.

To evaluate M&S capabilities in acquisition, a set of possible Advanced Distributed Simulation (ADS) pilot programs was proposed by the Program Executive Office (Theater Air Defense) Technology Directorate. These proposals were in response to the 1994 Naval Research Advisory Committee study endorsing the use of ADS in support of the acquisition process. Of the options, the Navy selected the Integrated Ship Defense (ISD) pilot because of the program's maturity.

ISD Overview

To defend against an increasing antiship cruise missile threat, an operator requires an automated detect-to-engage capability to reduce reaction time. The operator then has the capability to correlate multisensor data to provide a sensor-fused composite track, assuring a high level of certainty in target identification and classification. Flexible doctrine supporting layered defense engagements provides the operator automated control of the system functions and actions. Once the system presents and displays an accurate and comprehensive picture of the tactical situation, the operator then can override, abort or alter doctrine as necessary. Ultimately, the intent is to provide a fully automated ISD capability.

ISD Technical Issues

The ISD Pilot Program addresses the shortfalls of the existing M&S capabilities. Improvements incorporate reactive threats and operational environments to improve the realism and credibility of the results. As a first step, it builds on an established set of engineering-level models with known capabilities, by linking them together via a high level architecture (HLA)-compliant run-time infrastructure (RTI). Ultimately, the ISD Pilot Program must address the following technical issues:

In the past, program managers [illegible]

- Evaluate and quantify weapons and threat interaction (performance) with the environment (reactive threat, dual mode RF/IR);
- Evaluate and quantify weapons interaction (performance) with the threat;
- Evaluate and quantify sensors' interaction with the threat and the environment;
- Evaluate and quantify HK envelopes for probability of kill;
- Evaluate and quantify HK and EW weapons' interactions and effectiveness;
- Generate accurate and repeatable system analysis data for ISD verification and problem isolation;
- Evaluate and quantify system effectiveness using performance measures; and
- Create common-usage, controlled environment and scenario representations.

A thorough understanding of the capabilities, limitations and interactions of weapons and sensors in complex land, sea and littoral environments is required to solve these technical issues. To evaluate system performance, hi-fidelity, physics-based engineering simulations must reflect these complex system interactions as well as dynamic environmental effects. Consideration of these interdependencies between sensors and weapons, weapons and threats, and between sensors, weapons and the environment, dictates a departure from the traditional, isolated system and subsystem engineering analyses and simulations.

In the past, program managers studied these interdependencies in the real world, through expensive exercises and testing. Regrettably, in many cases the complexity of today's weapons systems surpasses the affordability of complete, real-world testing. The simulations proposed for the ISD Pilot Program will provide the capability to augment analyses and evaluations thereby reducing costly ship, personnel, and test and evaluation resources, and lay the groundwork for advancing SBA initiatives.

ISD Pilot Program Overview

The goal of the ISD Pilot Program is to develop and demonstrate a comprehensive M&S capability that supports the design and evaluation of components and systems. The ISD ADS Pilot Program will be conducted over three years. Each phase will retain its own set of objectives and will build on the capabilities demonstrated in the preceding phase. The objective is to improve the simulation set and, eventually, implement a superset of simulations.

Phase I

The development team intended this phase to provide a benchmark for the ISD federation development. A federation is a collection of models and simulations integrated using a common runtime infrastructure. Accordingly, system designers, modelers and testers will address the inherently complex test and evaluation issues. Of particular interest is the ability to perform HK/EW integrated modeling in a distributed environment using a HLA-compliant RTI. As a result, the approach is conservative and tailored to achieve the greatest capability possible within a year. One year permits the development team to garner the necessary experience to accomplish more complex configurations in subsequent phases. To minimize risks, the simulations will be developed at the developer's site. The integration, however, will be accomplished in a laboratory, with the simulations interconnected via the RTI, but using a local area network. The products of Phase I are:

- first-time, integrated, hi-fidelity detect-to-engage simulation capability;
- hi-fidelity, integrated HK/EW assessment capability;
- threat reactive, common to all combat system elements;
- preliminary federation for transition of DARPA-sponsored, simulation-based design tools;
- contribution to joint synthetic test and evaluation battlespace;
- established foundation for Phases II and III;
- PEO(TAD) established as a beta test site for Defense Modeling and Simulation Office RTI; and
- verification and validation of the federation.

Phase II

The intent in Phase II is to use the experience gained in Phase I to increase the federation's capability by incorporating additional federates. This complexity will enable a close examination of sensor integration and permit a continued investigation of HK/EW coordination. Models will reside at the developer's site and be interconnected, through the RTI, via a geographically distributed network.

Additional reactive threats will be added. The intent is to add threats whose performance stresses the ISD combat system's capabilities. In this way, the federation can explore the reaction times of different combat systems configurations to stressing situations. The products of Phase II are:

- active electronic attack assessment;
- realistic representation of operational environment;
- additional threat families represented;
- geographically distributed simulation; and
- verification and validation of the federation.

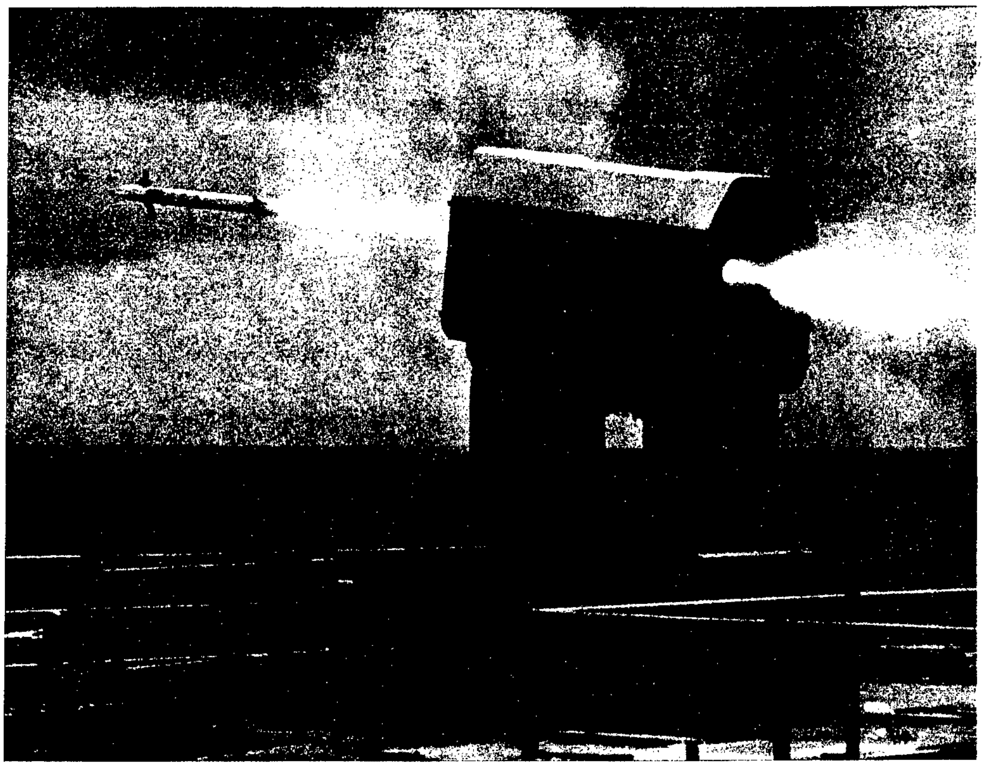
Phase III

The intent of Phase III is to produce a federation that provides a capability to model conceptual systems of the next generation combat system. This phase will enable the federation to simulate a multiwarfare exercise.

This link would permit communications between a federation operating with engineering-level simulations and a federation operating at an engagement-level simulation (i.e. lower fidelity). Phase III products include:

- IR sensor, environment and threat modeling;
- conceptual ship and combat system models;
- advanced threat models (full complement of ISD threat representative models);
- advancement of SBA initiatives through multifidelity simulation and collaborative-design demonstration using DARPA developed SBA tools;
- interfederation linking (gateway federate); and
- verification and validation of federation.

Declining budgets and technically advanced



Simulation-based acquisition evaluates ship self-defense weapons systems such as RAM. *(USN)*

support SBA initiatives for future acquisition programs.

To provide a realistic operational environment, this phase will complete the addition of propagation, clutter and weather models to achieve a dynamic multispectral environment, enabling the examination of both RF and IR threats in a "stressing" environment. To provide detection of these dual-mode threats, this phase also adds an IR sensor federate.

The gateway federate will be employed and tested, enabling communication and interaction between two federations. The intent is to link the ISD federation to the Joint Countermine Operational Simulation (JCOS) federation to

systems are driving DOD to increasingly rely on the benefits of M&S. But the foundation that makes that reliance possible must be established first. Program managers must have a high degree of confidence in their models and the subject matter experts who operate them. This confidence must be built over time by demonstrating the merits of M&S and as a first step in moving toward SBA.

Editor's note: Ms. Shea is the Deputy Director for Modeling and Simulation for the Program Executive Office, Theater Air defense. Mr. Pobat works for Litton/PRC in support of PEO(TAD).

Environmental Simulation

Replicating real-world elements vital to robust synthetic battlespace

To ensure a robust synthetic battlespace, the Office of the Oceanographer of the Navy is developing standard ocean models. Here, a visualization of anticipated surf lines — critical to a landing force. *(Bill Smith/IGS Inc.)*

by Dr. Edward Whitman and Edward Weitzner

As the Surface Warfare community becomes increasingly dependent on modeling and simulation (M&S), the "synthetic battlespace" is empowering the warfighter to develop doctrine, assess system acquisition options, train and conduct mission rehearsals. The vitality of the synthetic battlespace, however, is contingent on replicating the environment — ocean, atmosphere, terrain and space — with sufficient fidelity that simulated platforms, sensors, weapons and personnel respond as they would in the "real world." Since models only replicating ideal conditions would be suspect, the simulated environmental factors must account for all weather conditions — wind, sea state, visibility, bottom topography, etc. — to provide, as much as possible, a true representation.

To ensure a robust synthetic battlespace, the Office of the Oceanographer of the Navy is developing standard ocean models ranging from acoustic propagation, noise and reverberation models — through representations of surface and subsurface currents, waves, surf and tide — to detailed bottom bathymetry.

These models and databases allow for day-to-day meteorological and oceanographic (METOC) support of fleet operations, while providing a global infrastructure for collecting and assimilating weather and ocean data, implementing numerical models, and pushing the results into tactical decision aids both ashore and afloat.

M&S Applications

In general, M&S applications incorporate two types of METOC representations. The first representation is embodied in analytical or numerical models — often developed from databases of physical parameters — and reflects atmospheric or oceanographic effects on simulated system performance. Examples are predicted radar and sonar ranges, visibility effects, detection and kill probabilities.

The second representation can be categorized as *visualizations*, providing human operators with visual or auditory scenes for *total immersion*, heightened awareness or decision support.

Since much of modern surface warfare is "fought" at computer terminals in command centers and shipboard CICs, visualization will likely play a different role in the surface community than it will, for example, in tactical aviation where cockpit simulators provide an "outside" view of the world.

Introducing weather and ocean effects into the simulated common operational picture can be accomplished using most of the tools and approaches already in place for tactical fleet support. Generating symbolic and analytical representations of weapons, sensors and platforms and then creating synthetic screens portraying complex surface warfare scenarios is, in fact, even easier.

Environmental simulation in M&S applications — from system design to training — is being incorporated into three flagship programs: Battle Force Tactical Training (BFTT); Joint Simulation System (JSIMS); and Joint Warfare Simulation (JWARS).

BFTT is based on the premise that on-board tactical training is most effective when it is performed on the ship's combat system. It lends itself directly to *analytical* simulation — the creation of a coordinated and consistent scenario-generated tactical picture for display on own-ship and off-board tactical terminals.

The role of *environmental* simulation is to factor the effects of weather and ocean phenomena into the underlying scenario and the associated displays. For example, sensor-detection performance could be modeled in accordance with both the tactical geometry and the reigning acoustic conditions as an antisubmarine warfare training scenario evolves.

Ultimately, as the ability to implement multiplatform and multiservice training and exercise scenarios develops, the capabilities of BFTT for simulating naval warfare at the unit and battle force level will interface with the larger purview of JSIMS. JSIMS will eventually simulate interactions across the spectrum of joint warfare entities — from platforms, weapons and sensors, through organizational units and the C4I infrastructure, all within a designated area of operations influenced by the environment.

The naval warfare subset, JSIMS Maritime, will provide realistic functionality to support the unified commands, naval component commanders and joint force maritime component commanders for training in maritime operations, including mobilization, deployment, employment, sustainment, redeployment and operations other than war. JSIMS, necessarily, will treat the air/ocean environment on a broader, theater scale, more akin to synoptic METOC representations, but consistency will need to be maintained with and among the more fine-grained environmental phenomena modeled at the platform and weapon levels.

JWARS will be a closed form, constructive simulation of multisided joint warfare, specifically intended for analyzing alternative courses of action, force sufficiency, new requirements and operational effectiveness. JWARS is not intended to be interactive, or to support real-time mission execution or training. Instead, it primarily will be used to measure the statistical variability of various outcomes.

As in BFTT and JSIMS, the effects of the physical environment will be strongly represented, but they will be subsumed largely in regional measures of average behavior, such as sortie generation rates, weapon and platform effectiveness and attrition. In a strike warfare scenario, for example, percentage cloud cover drawn from model outputs might be used to estimate the accessibility of targets from the air. Primarily, JWARS will be a warfare analysis tool, and as such, environmental visualization will be relatively rare.

Customizing Client-Server Delivery

The challenge is creating an infrastructure to distribute accurate ocean, atmosphere, space and terrain models to users. Differing applications will demand differing degrees of detail, fidelity and complexity. Some will require only analytical or numerical simulations; others will demand realistic visualizations. In the long-term, "distributed interactive simulation" will create a "client-server" structure in which specialized functional repositories will deliver simulation objects on client demand. These simulations typically will be specific models or targeted data sets drawn from within a specialized resource. Environmental data, models and simulations will need to be created and disseminated within this same context and make seamless use of both the computer infrastructure and the communication networks implemented to serve the M&S community as a whole.

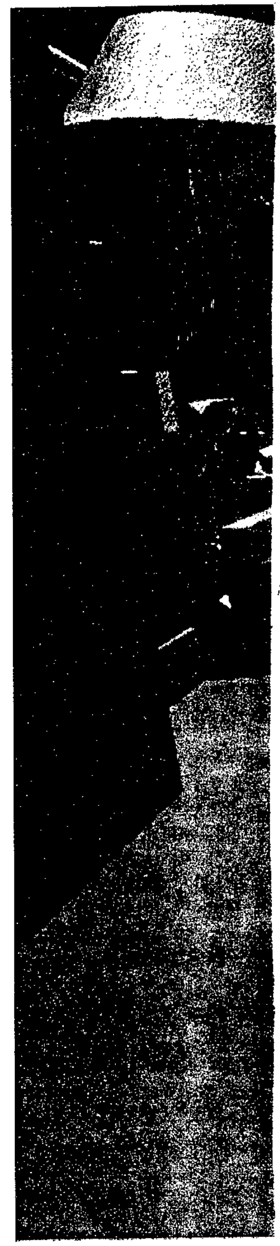
The Defense Modeling and Simulation Office, under the management Oceanographer of the Navy is developing the Master Environmental Library (MEL) — a key element of this environmental sub-architecture. MEL is an Internet-based data discovery and retrieval system providing access to geographically distributed oceanographic, meteorological, terrain and near-space databases. It will provide real-time, historical, climatological or model-generated data sets for all simulations requiring environmental data. Users will query the master "card catalogue" to retrieve descriptive metadata about regional METOC resources. By examining these metadata, users can identify specific data and/or products of interest and order them from the regional sites through the MEL infrastructure. Data results then would be delivered through real-time file transfer, e-mail or physical media (such as computer disks or tapes).

Operational exercises have demonstrated that shore-based METOC support for afloat units in an increasingly network-centric Navy can enhance understanding of the ocean and the atmosphere. Evolving information networks also will customize environmental characterizations generated at central sites for use in supporting M&S applications afloat and ashore. Future surface warriors will use M&S in all aspects of their training, planning and operations, and the ever-present background of wind and waves will be accurately portrayed in the virtual reality environment.

Editor's note: Dr. Whitman is Technical Director, Office of the Oceanographer of the Navy. Mr. Weitzner works for Planning Systems, Inc.

Turning 'Bytes' into Steel

Virtual Shipbuilding



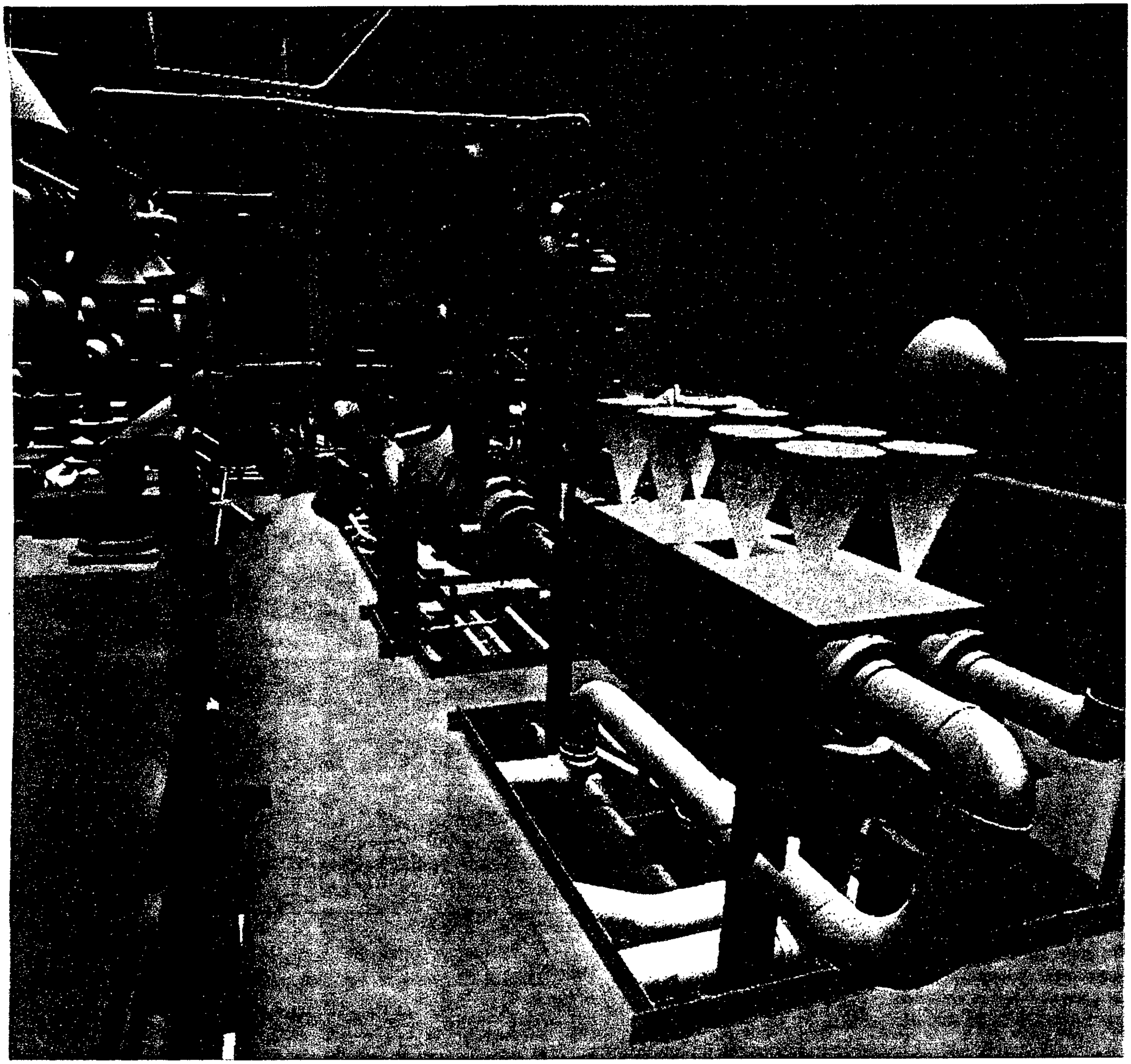
By seeing an engineering space as it actually appears, craftsmen can interact with the ship in a virtual environment *prior* to construction. *(BIW)*

The still waters part willingly as the greyhound glides past the fog-shrouded shoreline. Silently prowling through the dark, the vessel tenses as it nears its objective. Without warning, the electronic warfare supervisor blanches as alarms erupt in CIC. Two vampires scream toward a "hot spot" reflecting off the ship's mast. The crew has only enough time to brace for shock as the missiles lock on...

...just as the hot spot disappears.

With a sigh of relief and the click of a mouse, the designers vaporize the offending hot spot, instantly reshaping the "virtual" mast. Once again, a disaster is averted before the ship is even built.

by Lt. Steven C. Sparling and Robert F. James



Modeling and simulation (M&S) is proving invaluable, allowing the warfighter to analyze battlefield data, model engagement scenarios or train warriors to fight. But before Sailors and Marines can bend the battlefield to their will, naval architects and craftsmen must bend ship's steel using one of the most important tools in their design arsenal — modeling and simulation.

Two shipyards, Ingalls Shipbuilding in Mississippi and Bath Iron Works in Maine, actively employ M&S tools in the development and design of fleet-ready, as well as conceptual, cruisers and destroyers.

The CAD/CAM Revolution

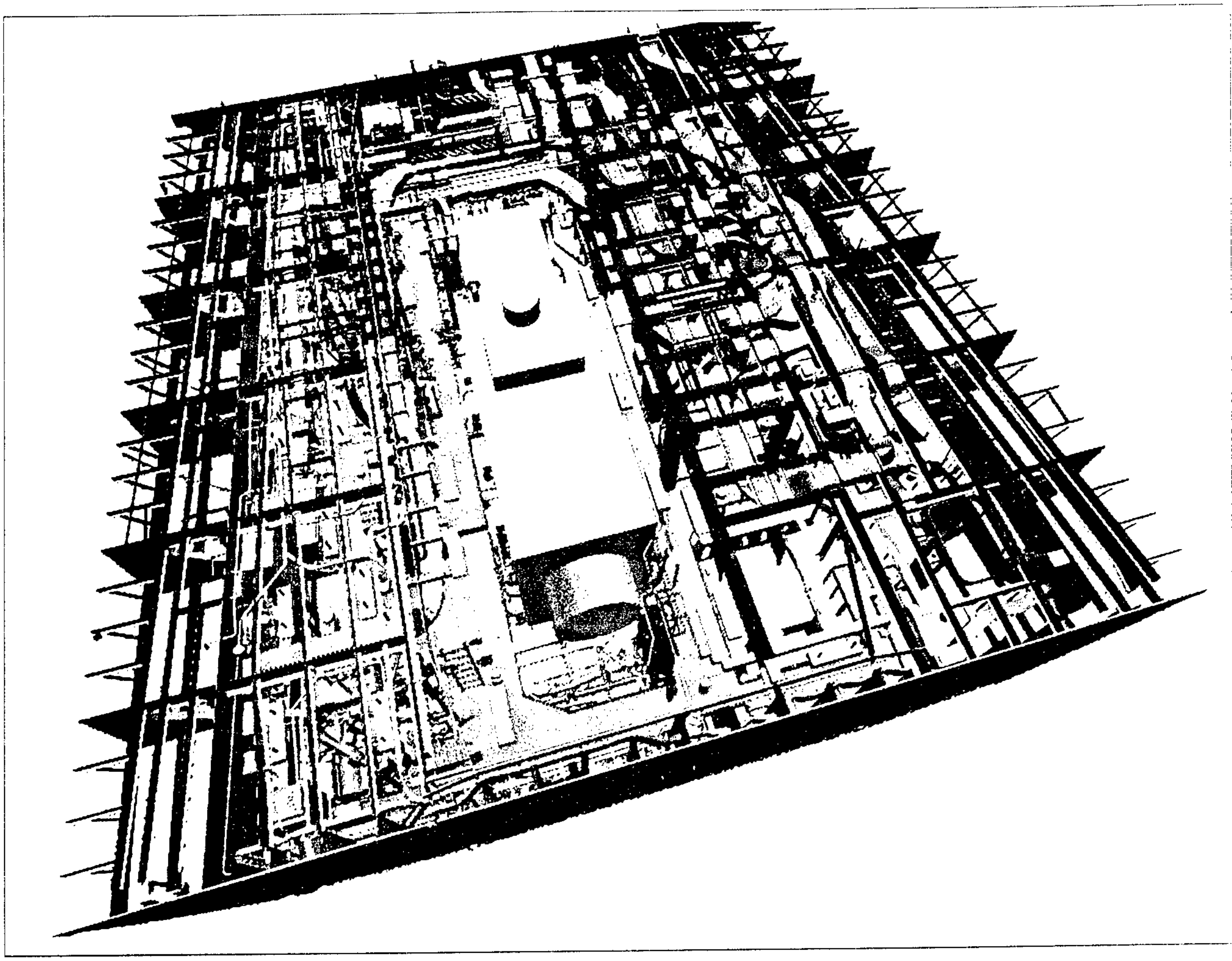
M&S is not a new shipbuilding tool. In the late 1970s, 3-D computer-aided design (CAD) models emerged as a valuable design tool. Before the advent of the computer model, 2-D blueprints and drawings were the state-of-the-art. The only way to test a ship's hydrodynamic design was to build a scale model and test it in a model basin. While this method still must be utilized in some fashion, the obvious limitation of this design process is an inability to accurately model *environmental* elements, such as high sea-state, or account for mission threats, such as shock waves. As a result, the test results were necessarily flawed.

In the final analysis, the only way to validate a new ship design was through the actual *construction* of that ship and then to test it. After building and testing the lead ship, the lessons learned would *then* be translated into follow-on construction and design modifications.

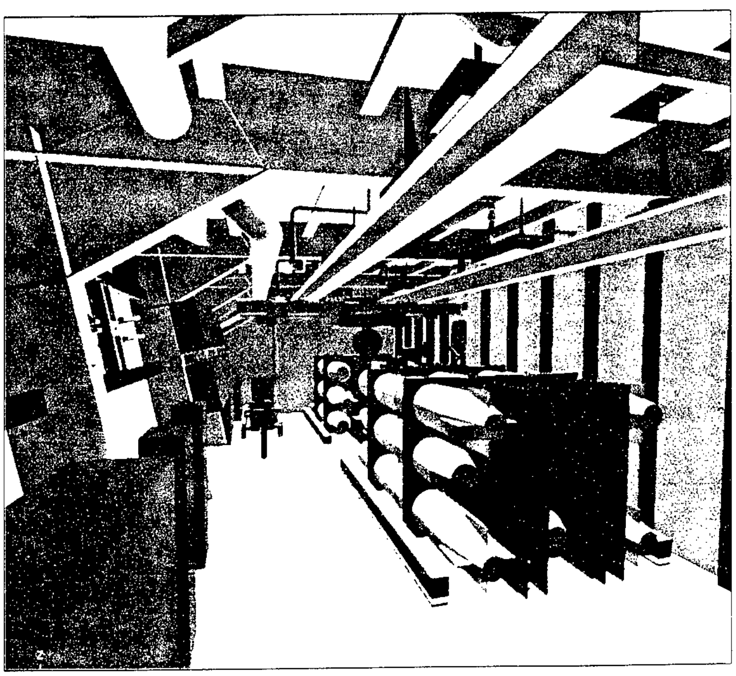
In the 1980s, the shipyards integrated 3-D CAD models with computer-aided manufacturing (CAM) models, introducing new efficiencies to shipbuilding through automated links to cutting machines. Later, robotic welding, pipe bending, design capability improvements and system compatibility analysis were incorporated. This integration dramatically reduced the number of design and construction errors.

Advantages of 3-D Visualization

While the informational concept of a 3-D model is not different from a traditional 2-D view, the actual model content and *perception* is. Instead of gathering around a table and looking down at a blueprint, craftsmen and engineers can "walk



As the model is refined, levels of detail are layered one on top of the other until the design phase is completed. *(BIW)* **Below:** Modeling provides the opportunity to flesh out practical details within the ship's design such as door swings, maintenance envelopes and equipment removal routes. *(BIW)*



through" the design that is being projected on a floor-to-ceiling screen. By seeing an area as it actually appears, craftsmen can interact with the ship in a virtual environment *prior* to construction and can then provide feedback to designers. This critique is important because, for the first time, the practical insights and concerns of the craftsman are incorporated into the ship's design *while it is still in the computer.* Before CAD/CAM, ship production followed a design-construct-redesign-reconstruct-deliver sequence. Visualization through 3-D modeling, however, provides for a streamlined design-*redesign*-construct-deliver sequence.

In addition, craftsmen can access the entire catalogue of specifications contained within the model. By selecting a component within the field of view, a data box displays all the information about that component instead of having to consult a bill of material to determine what the component is, what it is made of, size, military specifications, etc. This accessibility enhances the decision-making process because it provides immediate access to relevant data.

The versatility of the virtual environment extends beyond straightforward design constructs. This modeling provides the opportunity to flesh out practical details within the ship's design such as door swings, maintenance envelopes and equipment removal routes. In this detailed application, modeling addresses the practical concerns facing the ship's crew. The models also extend visualization beyond the physical construction of the compartment by incorporating environmental factors such as different lighting conditions. By simulating these various conditions, such as red lighting, designers can account for human-engineering concerns by identifying potential hazards, as well as other ergonomic challenges.

Just as important as *what* can be modeled, is *how* it can be modeled. For instance, each "virtual" space appears just as it will during the construction phase. When pipe hangers are welded into the overhead, for example, the entire space will be inverted so that the welder is standing on the overhead. If the virtual compartment were presented in its final configuration, it would not be as relevant. As a result, the model also must be inverted, so that the welder is afforded the same level of input as other craftsman.

Outside the compartment-level, visualization impacts ship design as a whole by demonstrating interactions between compartments. Designers can simulate the impact of a particular system on the ship as a whole (i.e. predicting the effects on the electrical system when activating a fire pump).

Model Validity

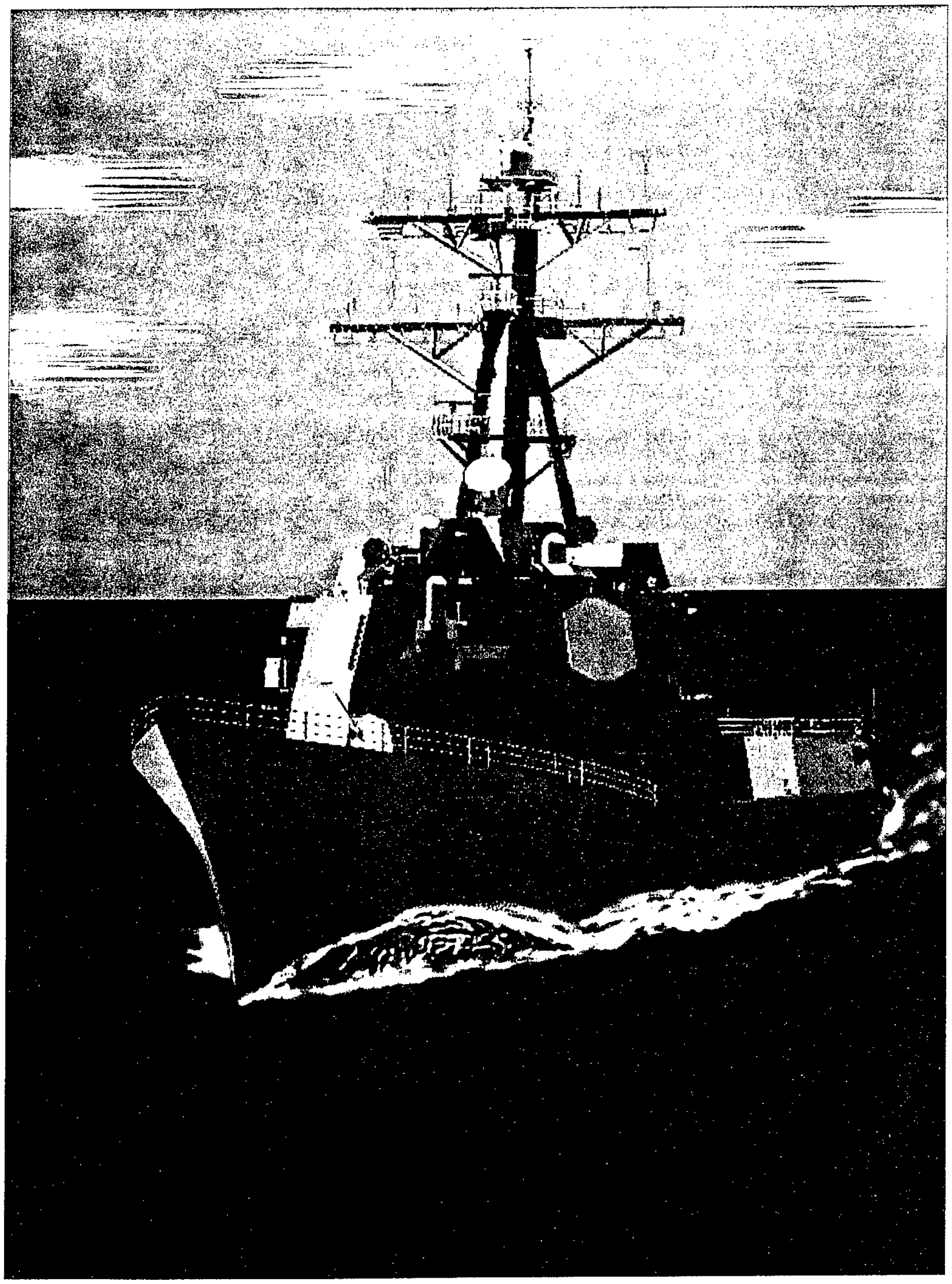
Simply building a model is not sufficient. The model is only as good as the accuracy of its representation of the real world. This accuracy is determined by two factors: physical characteristics and environment. Physical characteristics represent constants such as geometry, weight, center of gravity and behavioral characteristics. Environmental factors account for the influence of external effects such as wind and sea state and radiated energy. How closely the model replicates the ship's interaction with these real-world concerns determines its predictive capability.

No *one* model is capable of portraying every aspect of ship design. Today, some shipbuilders draw on a library of 150-200 proven models. The difference between a proven and an experimental model is performance. Proven models can closely predict the actual performance of the ship, but experimental model prediction must be validated through live testing. The challenge is to establish enough test data to prove the model's predictive capabilities.

Beyond the challenges of any single model are the even greater challenges of identifying and integrating accurate models into a composite simulation to predict actual performance. While one goal is to accurately model an entire ship, that capability currently does not exist, but it will.

Current modeling starts with a rough configuration of the ship that helps determine signature or hydrodynamics. For these kinds of broad predictions, a detailed component model is not necessary. This model, though, is refined as the program develops. Levels of detail are layered one on top of the other until the design phase is completed. This evolution allows the same model to be used throughout a ship's life cycle.

Although the capabilities of today's modeling and simulation inspire awe and wonder, tomorrow's models and simulations promise radical possibilities.



While one goal is to accurately model an entire ship, that capability currently does not exist — but it will soon. *(BIW)*

SITREP

USS *Callaghan* Seizes Cocaine Catch Worth $165 Million

by Ensign Chris Cooper

USS ***Callaghan*** (DDG 994) intercepted a transfer of narcotics in the eastern Pacific Ocean Sept. 27, seizing more than 3.5 metric tons of cocaine — with an estimated street value of more than $165 million.

Minutes after ***Callaghan*** picked up the contact 14,000 yards off her starboard bow, the boat closed to 8000 yards. ***Callaghan***, undetected, pursued the contact for an hour until sunrise.

As the sun came up, ***Callaghan*** visually identified the contact as a "go-fast," a 45-foot speed boat with four outboard engines and a V-shaped hull. At about the same time, the speed boat, realizing it was being followed, increased its speed to 35 knots, and began zigzagging through the water in an effort to evade ***Callaghan***. ***Callaghan*** ordered the boat to stop over bridge-to-bridge radio and a loud hailer from the bridge wing. Instead of stopping, the crew members began dumping large, white bales over the side of the boat.

"At first they were just throwing the bales over the side," said a ***Callaghan*** lookout, "then they started hacking them up with a machete so they would sink."

With its load lightened, the go-fast increased speed to 40-knots and began to pull away from the ***Kidd***-class destroyer. After launching its embarked Seahawk helicopter, ***Callaghan*** continued the pursuit. Helicopter Antisubmarine Squadron Light 43 Detachment 9 maintained contact and took digital photographs of the boat as it raced towards the Colombian coast. After more than three hours of surveillance, the helicopter was relieved by a P-3 Orion aircraft.

Callaghan back-tracked to the detection area in search of a possible transfer vessel and the discarded bales. The white bales were wrapped in several layers of shrink-wrap plastic and rubber, allowing them to float on the surface. With the assistance of Coast Guard Law Enforcement Detachment 8F from Corpus Christi, Texas, and ***Callaghan***'s boat crew, 121 sixty-pound bales were recovered. Random samplings from the bales tested positive for cocaine.

A Sailor from USS ***Callaghan*** helps off-load bails of cocaine from the ship at Naval Station San Diego. This was the largest seizure of illegal narcotics by a Navy ship so far in 1997. *(Felix Garza/USN)*

Changes of Command

September-October

SURFLANT
Carrier Group 8
Rear Adm. William W. Copeland relieved
Rear Adm. Gregory G. Johnson

Destroyer Group 8
Rear Adm. Scott A. Fry relieved
Rear Adm. James B. Hinkle

USS ***Austin*** (LPD 4)
Cmdr. Richard S. Callas relieved
Cmdr. William D. Valentine

USS ***Avenger*** (MCM 1)
Lt. Cmdr. Stephen C. Shoen relieved
Lt. Cmdr. David M. Fillion

USS ***Blackhawk*** (MHC 58)
Lt. Cmdr. Mark H. Williams relieved
Lt. Cmdr. Bruce W. Nichols

USS ***Cole*** (DDG 67)
Cmdr. Richard J. Nolan Jr. relieved
Cmdr. Michael S. O'Bryan

USS ***Conolly*** (DDG 995)
Cmdr. George L. Ponsolle relieved
Cmdr. Joseph B. Marshall

USS ***La Salle*** (AGF 3)
Capt. Bruce W. Clingan relieved
Capt. Mark S. Caren

USS ***McInerney*** (FFG 8)
Cmdr. Terry A. Bragg relieved
Cmdr. Derk Deverhill

USS ***Monongahela*** (AO 178)
Cmdr. David W. Faasse relieved
Cmdr. Steven E. Lehr

USS ***Moosbrugger*** (DD 980)
Cmdr. Dennis Ourlian relieved
Cmdr. Dennis T. Stokowski

USS ***Pioneer*** (MCM 9)
Lt. Cmdr. James R. Boorujy relieved
Cmdr. Shaun Gillilland

USS ***Robert G. Bradley*** (FFG 49)
Cmdr. Richard W. Bump relieved
Cmdr. Mark A. Stearns

USS ***Robin*** (MHC 54)
Lt. Cmdr. Roman D. Bowles relieved
Lt. Cmdr. Mark J. Murphy

MCM Rotational Crew Hotel
Lt. Cmdr. Timothy T. Smith relieved
Lt. Cmdr. Anthony E. Mitchell

SURFPAC
Maritime Prepositioning Ships Squadron 3
Capt. Fred S. Bertsch relieved
Capt. Paul C. Striffler

USS ***Chancellorsville*** (CG 62)
Capt. Vincent J. Andrews relieved
Capt. Edward R. Hebert

USS ***McClusky*** (FFG 41)
Cmdr. Michael J. Turner relieved
Cmdr. Peter J. Frothingham

USS ***Merrill*** (DD 976)
Cmdr. Tim McCully relieved
Cmdr. Peter J. Healey

Command Master Chief Moves
November-December

DPCM Norman Allen	USS *Cole* (DDG 67)
HTCM Dennis Bearce	USS *Scott* (DDG 995)
GMCM Dennis Boddie	USS *Boxer* (LHD 4)
DCCM Robert Conklin	USS *Barry* (DDG 52)
EMCM William Daffern	USS *Tarawa* (LHA 1)
MMCM Timothy Flournoy	USS *Boone* (FFG 28)
YNCM James Gamiao	USS *Essex* (LHD 2)
BMCM Carl Gardley	USS *Rainier* (AOE 7)
ETCM Douglas Graves	USS *Germantown* (LSD 42)
MMCM Mark Hardin	USS *Frank Cable* (AS 40)
STGCM Patrick Johnson	USS *Doyle* (FFG 39)
BMCM Robert Likely	USS *Ashland* (LSD 48)
BMCM Charlie Lovett	USS *Saipan* (LHA 2)
BMCM Robert Muckerheide	USS *Chancelorsville* (CG 62)
MMCM Dale Orren	USS *Pensacola* (LSD 38)
RPCM Roland Paulk	USS *Oakhill* (LSD 51)
CTOCM John Phillips	USS *Carr* (FFG 52)
MMCM James Russell	USS *John C. Stennis* (CVN 74)
FCCM Darrel Shefstad	USS *Rodney M. Davis* (FFG 60)
OSCM Adrian Williams	USS *Lake Erie* (CG 70)
AVCM Joe Wright	USS *Princeton* (CG 59)

USS *Hopper* Commissioned


Rear Adm. Grace Hopper *(USN)*

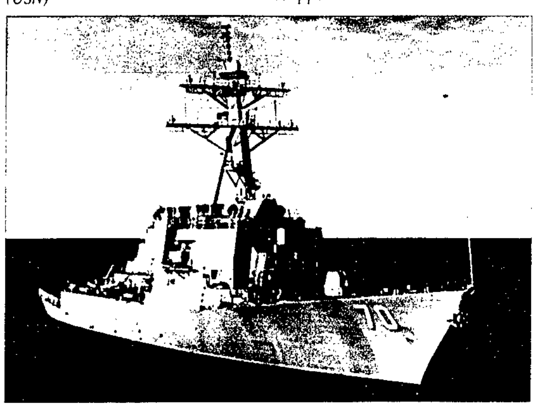
USS ***Hopper*** (DDG 70) was commissioned in San Francisco Sept. 6. The Navy's newest Aegis guided-missile destroyer was named to honor the late Rear Adm. Grace Murray Hopper, the first woman to achieve two stars.

"Grace Hopper would have been very proud," said Lt. Cmdr. Robert Kerno, executive officer of ***Hopper***.

It was Rear Adm. Hopper's pioneering spirit in the field of computer technology that led the Navy into the age of computers. During her career, she was known as the "Grand Lady of Software," "Amazing Grace" and "Grandma Cobol" (after co-inventing COBOL (common business-oriented language)). COBOL made it possible for computers to respond to words instead of just numbers, thus enabling computers to "talk to each other." She also is credited with coining the term "de-bugging," after discovering and removing a moth that had blocked a relay switch.

Hopper retired from the Naval Reserve in January 1967, but was recalled to active duty in August 1967 by President Lyndon B. Johnson for her much-needed expertise in applied computer science. She retired a second time in August 1986. She died on Jan. 1, 1992. This honor is the first time since World War II, and only the second time in Naval history, that a warship has been named for a woman from the Navy's ranks.

Hopper is the 20th of 38 ***Arleigh Burke***-class ships authorized by Congress and will homeport in Pearl Harbor, Hawaii. — *Navy News Service*


USS ***Hopper*** (DDG 70) *(USN)*

New Ship System Given Passing Grade

The new Ship Self-Defense System (SSDS) aboard USS *Ashland* (LSD 48) has been recommended for fleet introduction after successfully completing extensive tests this summer.

The first distributed, open-architecture combat system in the world, it detected, tracked and destroyed more than 200 targets presented during multiple missile attacks. Using the ship's dual RAM missile launching systems, Phalanx gun mounts and decoy chaff launchers, the SSDS provides ship protection against antiship cruise missiles.

The system will be installed in other ***Whidbey Island***-class LSDs, as well as the LPD-17 class and selected aircraft carriers. The recommendation to outfit other ships came from Commander, Operational Test and Evaluation Force after evaluating test results.

SSDS was developed by the Naval and Maritime Systems division of Hughes Aircraft Company and the Applied Physics Laboratory, Johns Hopkins University, under the direction of the Program Executive Office for Theater Air Defense. — *Navy News Service*

Navy Commissions Amphibious Assault Ship *Bataan*

The Navy commissioned its newest amphibious assault ship, USS *Bataan* (LHD 5), Sept. 20.

Bataan is the fifth of seven ***Wasp***-class amphibious assault ships authorized by Congress and the second U.S. Navy ship to bear this name, which commemorates the heroic defense of the Bataan Peninsula on the western side of Manila Bay in the Philippines by Navy, Marine Corps, Army and Filipino forces during the early days of World War II.

Bataan's mission is to serve as a primary landing ship for assaults from the sea to defend positions ashore and will be homeported in Norfolk, Va., as an element of Amphibious Group 2. The crew consists of a ship's company of 1,200 and a Marine Detachment of 2,000. —*Navy News Service*

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U.S. Navy Commissions USS *Cardinal*

The Coastal Mine Hunter USS ***Cardinal*** (MHC 60) was commissioned in Alexandria, Va., Oct. 18.

Three previous minesweepers have borne the name ***Cardinal***. The first, AM 6, operated along the California coast for most of her career; the second, AM 67, patrolled the 5th Naval District (Norfolk, Va. area) during World War II; and the third, YMS-179 (a wooden-hulled coast mine hunter), was decommissioned in 1957.

Cardinal is the 10th of 12 ***Osprey***-class ships authorized by Congress. The ship's hull is a solid, continuous monocoque structure laminated from special fiberglass and resin. It is easy to maintain and will flex to absorb the violent shock of an underwater mine explosion. The ships are designed to have very low magnetic and acoustic signatures, giving them an added margin of safety during operation.

The crew of the Navy's newest coastal mine hunter USS ***Cardinal*** "mans the ship" during its commissioning ceremony near Washington, D.C. *(Todd Stevens/USN)*

It is 188-feet long, has a beam of 36 feet, and has a draft of 12 feet. It displaces 895 metric tons and has a top speed of over 10 knots. The ship's primary mission is reconnaissance, classification and neutralization of moored and bottom mines in harbors and coastal waterways. The ship is armed with two .50-caliber machine guns, a high-definition, variable-depth sonar used to search for mines, and a remotely-operated robotic submarine used to neutralize mines.

Cardinal will join the U.S. Atlantic Fleet, reporting to commander, Mine Warfare Command, and will be homeported in Ingleside, Texas. *—Defense News*

Navy Christens USNS *Fisher*

The newest roll-on/roll-off cargo ship was recently christened at Avondale Industries, New Orleans. USNS ***Fisher*** (T-AKR 301) honors Zachary and Elizabeth Fisher, two Americans, who, through their generous support, have committed their lives to improving the quality of life of the nation's Sailors, Marines, Airmen and Soldiers. The couple's many efforts on behalf of military personnel include donations to the families of slain service members, scholarships and the Fisher House Program. Fisher Houses are located at military installations and VA Hospitals across the country. They provide a comfortable temporary home for service members' families who have been hospitalized far away from home. No previous U.S. Navy ship has been named Fisher.

The second in the new ***Bob Hope***-class of Large, Medium Speed, Roll-On/Roll-Off (LMSR) sealift ships, ***Fisher*** is a noncombatant vessel, crewed by civilian mariners and operated by the U.S. Navy's Military Sealift Command, Washington, D.C. Its roll-on/roll-off design makes it ideal for transporting helicopters, tanks and other wheeled and tracked military vehicles. The ship will have approximately 390,000 square feet of cargo carrying space. ***Fisher*** is 950 feet in length, has a beam of 105 feet and displaces approximately 62,000 tons. The diesel-powered ship will be able to sustain speeds up to 24 knots. — *Defense News*

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f.	38,000	38,450
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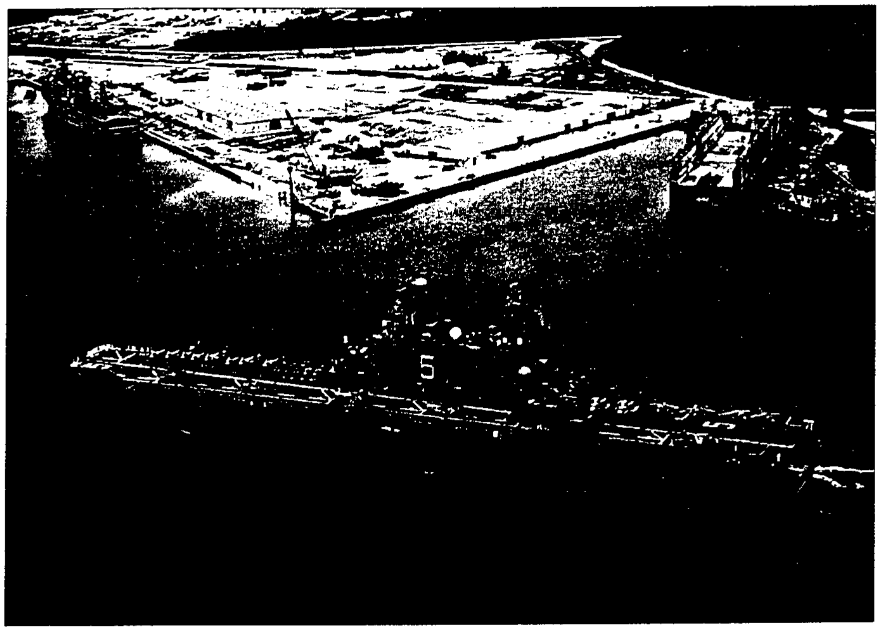

USS *Peleliu* (LHA 5) *(USN)*

Arabian Gulf
USS ***Ardent*** (MCM 12)
USS ***Benfold*** (DDG 65)
USNS ***Catawba*** (TATF 168)
USS ***Comstock*** (LSD 45)
USS ***Dextrous*** (MCM 13)
USS ***Elrod*** (FFG 55)
USS ***Ford*** (FFG 54)
USS ***Gary*** (FFG 51)
USS ***Harry W. Hill*** (DD 986)
USS ***Juneau*** (LPD 10)
USS ***Kinkaid*** (DD 965)
USS ***Lake Champlain*** (CG 57)
USS *Nimitz* (CVN 68)
USS ***O'Bannon*** (DD 987)
USS ***Peleliu*** (LHA 5)
USS ***Port Royal*** (CG 73)
USS ***Sacramento*** (AOE 1)
USNS ***Sirius*** (TAFS 8)
USNS ***Tippecanoe*** (TAO 199)

Atlantic
USS ***Arctic*** (AOE 8)
USS ***Carter Hall*** (LSD 50)
USS ***Cyclone*** (PC 1)
USS ***Hue City*** (CG 66)
USS ***John F. Kennedy*** (CV 67)
USS ***John Hancock*** (DD 981)
USS ***Monongahela*** (AO 178)
USS ***Peterson*** (DD 969)
USS ***Ponce*** (LPD 15)
USS ***Spruance*** (DD 963)
USS ***Taylor*** (FFG 50)
USS ***Tempest*** (PC 2)
USS ***Thomas S. Gates*** (CG 51)
USS ***Vicksburg*** (CG 69)

Caribbean
USS ***Capable*** (AGOS 16)
USS ***Chandler*** (DDG 996)
USS ***Comte De Grasse*** (DD 974)
USS ***De Wert*** (FFG 45)
USS ***Lewis B. Puller*** (FFG 23)
USS ***McInerney*** (FFG 8)
USS ***Squall*** (PC 7)
USS ***Stalwart*** (AGOS 1)
USS ***Ticonderoga*** (CG 47)
USS ***Whidbey Island*** (LSD 41)
USS ***Zephyr*** (PC 8)

Mediterranean
USNS ***Apache*** (TATF 172)
USS ***Ashland*** (LSD 48)
USS ***Boone*** (FFG 28)
USS ***Carney*** (DDG 64)
USNS ***Concord*** (TAFS 5)
USS ***George Washington*** (CVN 73)
USS ***Guam*** (LPH 9)
USS ***John Rodgers*** (DD 983)
USNS ***Kanawha*** (TAO 196)
USNS ***Laramie*** (TAO 203)
USS ***La Salle*** (AGF 3)
USS ***Normandy*** (CG 60)
USS ***Oak Hill*** (LSD 51)
USS ***Seattle*** (AOE 3)
USS ***Shreveport*** (LPD 12)
USS ***Simon Lake*** (AS 33)
USS ***Sirocco*** (PC 6)
USS ***South Carolina*** (CGN 37)
USS ***Typhoon*** (PC 5)
USS ***Underwood*** (FFG 36)

Pacific
USS ***Belleau Wood*** (LHA 3)
USS ***Blue Ridge*** (LCC 19)
USS ***Bunker Hill*** (CG 52)
USS ***Coronado*** (AGF 11)
USS ***Curtis Wilbur*** (DDG 54)
USS ***David R. Ray*** (DD 971)
USS ***Dubuque*** (LPD 8)
USS ***Fife*** (DD 991)
USS ***Frank Cable*** (AS 40)
USS ***Fort McHenry*** (LSD 43)
USS ***Germantown*** (LSD 42)
USNS ***Guadalupe*** (TAO 200)
USS ***Guardian*** (MCM 5)
USS ***Independence*** (CV 62)
USS ***John S. McCain*** (DDG 56)
USNS ***Kilauea*** (TAE 26)
USS ***Mobile Bay*** (CG 53)
USNS ***Narragansett*** (TATF 167)
USNS ***Niagara Falls*** (TAFS 3)
USS ***O'Brien*** (DD 975)
USS ***Patriot*** (MCM 7)
USNS ***Pecos*** (TAO 197)
USS ***Rentz*** (FFG 46)
USS ***Rodney M. Davis*** (FFG 60)
USNS ***San Jose*** (TAFS 7)
USNS ***Spica*** (TAFS 9)
USS ***Stethem*** (DDG 63)
USS ***Thach*** (FFG 43)
USS ***Vincennes*** (CG 49)
USNS ***Yukon*** (TAO 202)