NAVAL SCIENCE AND TECHNOLOGY

FUTURE FORCE™

FALL 2014

Enhancing Warfighter Performance

P. 10 | Mastering the Human Element of Immersive Training

P. 20 | The Changing Role of Women in the Marine Corps

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Future Force is a professional magazine of the naval science and technology community. Published quarterly by the Office of Naval Research, its purpose is to inform readers about basic and applied research and advanced technology development efforts funded by the Department of the Navy. The mission of this publication is to enhance awareness of the decisive naval capabilities that are being discovered, developed, and demonstrated by scientists and engineers for the Navy, Marine Corps, and nation.

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Front Cover: *Enhancing Warfighter Performance*, Illustration by Alvin Quiambao

SPEAKING OF S&T

By Vice Admiral David A. Dunaway, USN

Never in the history of the U.S. Navy has the advancement of—and investment in—science and technology been more important than it is today. I am thrilled that the Office of Naval Research has launched *Future Force* as a means to inform us about our basic and applied research and advanced technology development efforts. This edition focuses on warfighter performance.

At Naval Air Systems Command (NAVAIR), we are executing our strategy of maintaining effective warfighting capability and readiness at the best value to the taxpayers. We have narrowed our focus to three areas: Preparing our people, delivering integrated warfighting capabilities (IWC), and improving affordability. These three elements reinforce and amplify one another.

With IWC, naval aviation has broadened its perspective from a focus on individual weapons, platforms, and systems to the capabilities they provide. We have embraced a forward-thinking innovative concept to realign "stove-piped" programs to a "system-of-systems" (SoS) perspective. Often referred to as integration and interoperability, this perspective requires us to link explicitly our technical expertise and solutions with operational tactics.

Today, NAVAIR is actively engaged in the SoS process by which we derive and fund requirements and develop technical solutions with mission outcomes in mind from the very start of acquisition. Our platforms, weapons, networks, sensors, and training are undergoing alignment to integrate and deliver intended effects naturally. Our people, processes, and systems are actively engaged in creating a "warfighting whole" more powerful than the sum of its parts—and the end result is IWC.

We have identified and are maturing the processes, skills, infrastructure, and relationships needed to increase teamwork and collaboration between multiple programs and system boundaries from the start. We continue to pursue common standards and assume the role as "lead capability integrator" across a spectrum of efforts. These efforts include: rapid insertion of new or existing technologies to solve an urgent fleet need (rapid response), integrating existing programs of record into an SoS to achieve a mission-level outcome, and designing new capabilities from a full SoS context at the very beginning of longer-term developmental efforts.

We also have proven that we can reduce overall development costs by utilizing and integrating government and industry laboratory assets, live-test events, and constructive simulations into a live, virtual, constructive (LVC) battle-space environment. As you'll read in this edition, LVC mixes aircraft simulators, virtual environments, and live-fly training to promote naval aviation readiness. Our challenge is creating LVC environments where we can pull complex SoS together at critical times—and in relevant operational environments—to ensure they perform as intended. Fortunately, LVC capabilities have been systematically improved every year, allowing training to be more economical by creating more complex scenarios while improving responsiveness at a reduced cost.

We are using our already considerable infrastructure, hardware-in-the-loop, installed systems test, and statistical methods to address operational effectiveness and suitability through LVC test and evaluation. This approach helps ensure SoS mission effects are a deliberate consideration in early program planning. As we strive to pass a final exam that includes SoS capability, our program decisions will naturally drive to that goal.

Architectures such as SoS and LVC are inherently compatible with much of the Defense Department's national test capability and its test ranges, facilities, and system integration labs. Efficiencies are gained through the purposeful reuse of code, models, threat signal definitions, scenarios, and interface standards that drive down the costs of extending battlespace simulations, and reduce the time to integrate new capability into the battlespace model environment. Maturing this focus will vastly improve integration and interoperability and accelerate the delivery of rapid response and irregular warfare solutions—enabling our warfighters to continue to deter any threat, to fight, and to win.

Vice Adm. Dunaway serves as Commander, Naval Air Systems Command.

Warfighter Performance:

Warfighting performance includes technologies that enhance individual and team decision making and combat effectiveness, improve human-system efficiencies, and ensure health and viability.

Photo by MC1 Eric Dietrich

HOW WE GOT HERE

By Dr. Ken Nahshon, Jamie Cruce, Michael Miraglia, and Dr. Paul Hess

HOW DID HUNLEY'S CREW DIE?

Photos by John F. Williams

Raised from its resting place off Charleston, South Carolina, in 2000, the Confederate submarine *H.L. Hunley* is still revealing secrets about the fate of its crew on the night of its sinking in 1864.

On 17 February 1864, the Confederate submarine *H.L. Hunley* attacked USS *Housatonic*, a Federal sloop-of-war participating in the blockade of Charleston, South Carolina. The explosion resulting from the *Hunley*'s torpedo sank the 1,240-ton ship in a matter of minutes, securing *Hunley*'s place in history as the first submarine to sink an enemy combatant. Although the attack on *Housatonic* was successful, *Hunley* was lost at sea due to unknown circumstances with no survivors. Though various theories about the cause of *Hunley*'s loss have existed for some time, the sequence of events during and after the attack remains a mystery.

In 1995, marine archaeologists sponsored by author Clive Cussler located *Hunley*'s wreck off the coast of Charleston approximately 1,000 feet from the wreck of *Housatonic*. Five years later, *Hunley* was raised from the sea bottom and moved to a specially prepared tank facility at the Warren Lasch Conservation Center (WLCC), located at the Charleston Navy Yard in South Carolina. Once there, a team of archaeologists and conservators from Clemson University began working on studying and preserving the submarine.

What Happened?

Motivated by recent archaeological findings made at the WLCC, engineers in the Naval Surface Warfare Center Carderock Division's Survivability and Weapons Effects Department hope to shed light on what may have happened to *Hunley* and its crew using the Navy's most advanced modeling and simulation software and computational capabilities.

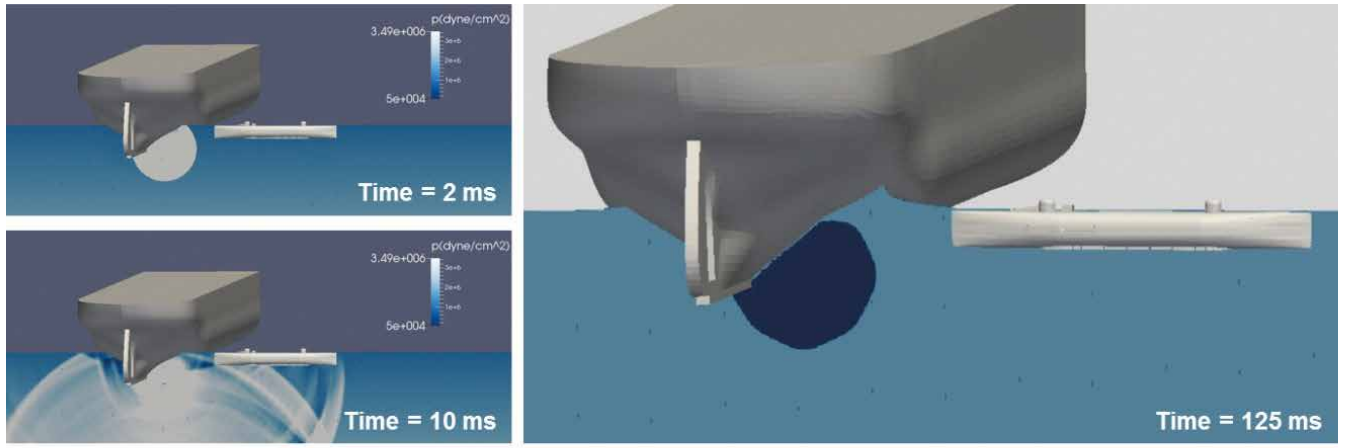
Recently, archaeologists at the WLCC uncovered a long wooden pole of a spar torpedo weapon system. It had been previously reported that *Hunley* used a line-operated torpedo system—one that was operated from a distance using a line to set off its explosive charge. In contrast, Civil War-era spar torpedoes usually consisted of an explosive charge fastened to a fixed-length spar used either in contact or proximity to the target vessel. Thus, *Hunley* would have been separated from the explosive charge only by the spar's length, generating a far more severe loading environment than that from a line-operated system. The Confederacy's largest spar torpedo, Singer's Torpedo, consisted of 135 pounds of black powder and a spar length of approximately 16 feet, along with a contact fuse. In this current study, the use of Singer's Torpedo is assumed; while it is possible a different design was utilized, it is likely the largest available spar torpedo would have been selected.

The Team and the Tools

Realizing the significance of this finding, researchers at the WLCC, together with Dr. Robert Neyland, head of the Underwater Archaeology Branch at the Navy History and Heritage Command, contacted Carderock for assistance in interpreting the implications of this finding on *Hunley*. Fortunately, Carderock's Survivability and Weapons Effects Division—which performs analyses, testing, and vulnerability assessments of underwater and air-delivered threats on Navy ships, Marine Corps vehicles, and other structures—possesses the necessary computational capabilities to evaluate *Hunley*'s attack on *Housatonic* using modeling and simulation.

With financial support from both the Office of Naval Research (ONR) and the Naval Surface Warfare Center, Carderock engineers began applying a newly developed high-fidelity modeling and simulation tool, Navy Enhanced Sierra Mechanics (NESM). This tool, developed jointly by Sandia National Labs and Carderock, consists of a structural simulation finite element code, Sierra Mechanics, fully coupled to a computational fluid dynamics shock-physics code for underwater explosions, DYSMAS/FD, developed by the Naval Surface Warfare Center Indian Head Division. Using NESM, the fully coupled interactions between explosive products, water, and the responding structure can be captured. These features are critical to obtaining the correct response of a floating or submerged structure to an underwater explosion event.

To perform numerical analysis of a

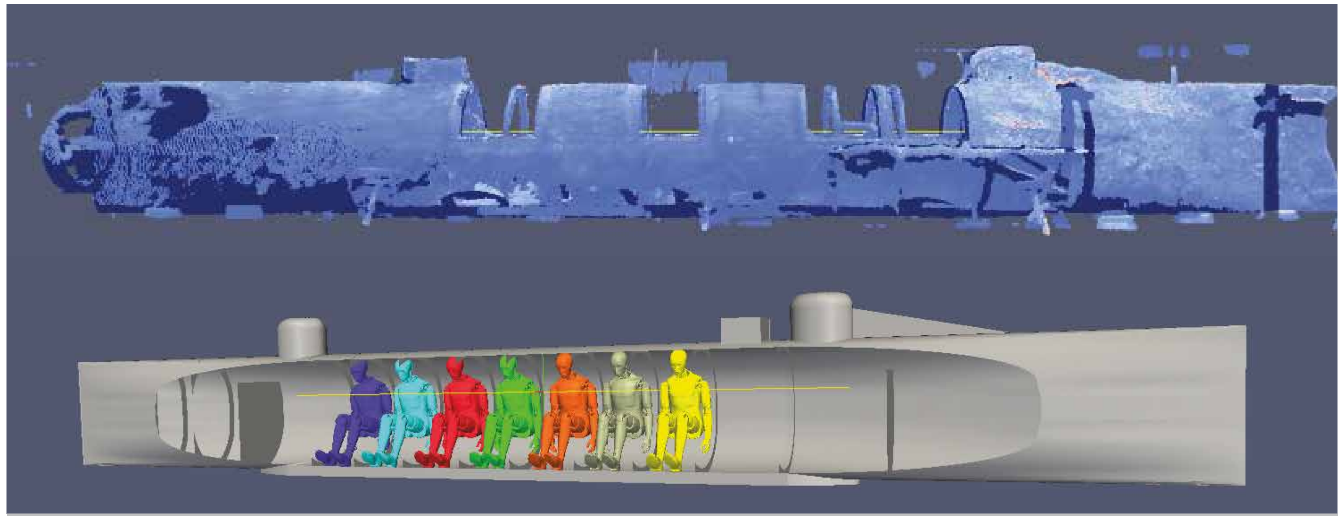


This simulation of the explosion that rocked USS *Housatonic* shows the contours of pressure indicating the elevated pressure regions in white (left) and a view of the bubble created by the explosion, in dark blue, at its maximum size (right).

ship, submarine, or other platform in NESM, an appropriate numerical description, in the form of a finite element model (FEM), is required. The FEM consists of a numerical description that includes both geometrical and material properties. Fortunately, archeologists at the WLCC were able to provide the necessary details to develop the FEM including photos, drawings, and geometrical point-cloud scans of *Hunley* generated using both structured light and laser scan techniques. The scans provided the exact shape and dimensions of *Hunley* and were used to generate an FEM of *Hunley*.

In addition to the FEM, the project developed a numerical description of the loading generated by a Singer's Torpedo. In contrast to modern mines or torpedoes filled with high explosives, the Singer's Torpedo was filled with black powder, a propellant. Unlike high explosives, propellants do not readily detonate, meaning the conversion of explosive to reaction products occurs on a relatively slow timescale. In addition, black powder is known to burn, or deflagrate, in a way highly dependent on pressure and the size of powder grains. To capture the appropriate physical phenomena, Carderock engineers developed a suitable burn model using a gas-injection feature originally developed to capture the behavior of underwater air guns.

With a model to capture the loading implemented and an FEM ready to be exercised, Carderock engineers began their analysis of the response of *Hunley* and its crew to the torpedo explosion using NESM on a supercomputer, Kilrain, located at the Navy's Department of Defense Supercomputing Resource Center at Stennis Space Center, Mississippi.



Geometrical scans of the submarine (top) and the placement of crash test dummies to capture the response of *Hunley*'s crew during its engagement with the *Housatonic*.

Analysis

Initial analysis results indicate the presence of a long-duration, elevated pressure loading near the explosive charge. This is a direct result of black powders' slow-burning nature. In contrast to a high explosive, however, the observed pressures were found to be modest and result in a steady heaving motion of *Hunley*. Simulations indicated that the hull would not exhibit structural damage. This finding is consistent with what is being found during archaeological excavations but not intuitive given *Hunley*'s proximity to the explosion.

In contrast, the bubble resulting from the explosion's reaction products was found to be in direct and sustained contact with *Housatonic*'s hull, providing a long-duration, high-pressure loading that would be more than capable of rupturing the ship's hull. Interestingly, the standoff of the torpedo's spar was just long enough to prevent direct bubble loading on *Hunley*.

Despite the apparent lack of hull damage to *Hunley*, these heaving motions may have injured or incapacitated the submarine's crew, caused failure on seals and other openings resulting in rapid flooding, or resulted in an unrecoverable trim state. It is important to note that no apparent evidence suggesting an escape attempt by the crew has been found—all crew member remains were found in their battle stations, all hatches were in a closed configuration, and all detachable ballast weights were found to be attached.

Personnel from the Naval Surface Warfare Center and Office of Naval Research, along with faculty and students from the University of Michigan, collect necessary measurements for the development of a numerical model of *Hunley*.

Current analysis efforts are focused on evaluating the potential for crew injury, particularly blunt trauma. To capture the crew response to the explosion and resulting motions, an FEM of an automotive anthropomorphic test device, commonly known as a "crash-dummy," is being used. The device is close in size to the average *Hunley* crew member as estimated by the discovered human remains.

In addition to Carderock's effort, a separate ONR-funded effort being performed by Dr. Matthew Collette of the University of Michigan Department of Marine Engineering and Naval Architecture is examining the weights and stability of *Hunley*'s design, as well as paths in which the boat may have sank to its final resting place. This effort already has found that even a small inflow of water or an unstable trim state resulting from the heaving motions during the attack could have resulted in *Hunley*'s sinking.

Once the current analysis efforts are completed, Carderock engineers should be able to help uncover the mystery of why *Hunley* sank. In addition, the continued development of modeling and simulation capabilities to perform advanced analyses such as those described above will facilitate an ever-increasing ability to design against or evaluate future threats to the Navy.

About the authors:

Dr. Nahshon, Jamie Cruce, and Michael Miraglia serve in the Hull Response and Protection Branch at the Naval Surface Warfare Center Carderock Division.

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Photo by John F. Williams

Mastering the Human Element of Immersive Training

By Dr. Gregory Welch, Dr. Arjun Nagendran, Dr. Jeremy N. Bailenson, Dr. Charles E. Hughes, Pete Muller, and Dr. Peter Squire

"I've Done This Before"

A natural disaster has struck a country located in the Pacific region. The U.S. Navy and Marine Corps are on their way, charged with rendering aid and security to a population facing desperate circumstances. In the midst of the chaos, the Marines will have to interact with civilians who are in shock and even angry about their situation. The environment, the people, and the chaotic circumstances would normally be completely unfamiliar to, for instance, a young Marine from the Midwest. Yet before the Marines step off the ship, or even know about this specific disaster, they will have experienced similar settings and interacted with humans in comparable chaotic and emotionally charged situations—all through a range of immersive training.

The physical terrain cannot be replicated exactly, but a similar atmosphere can be created using the environmental stimuli (sights, sounds, smells, etc.) that Marines will encounter. Although an entire culture cannot be imported into military training, surrogates (technological or human substitutes) can replicate human interactions under varying cultural and emotional situations. And while one cannot predict every situation Marines may face, numerous scenarios can be constructed for them to experience. From thousands of miles away, before the engagement ever occurs, all a lance corporal may need to do is put on a special pair of glasses and an earpiece, walk into the village, and face the civilians.

Training is a critical part of preparing for any operation such as this one.

Over the past two decades, the Office of Naval Research (ONR) has been at the forefront of developing immersive training capabilities that seek to provide a sense of "presence" for warfighters. Immersion refers to an objective level of fidelity in an environment or with a human surrogate. Presence refers to a user's psychological sense of being in an environment that is, with a human surrogate, often measured by the trainee's verbal, physiological, and behavioral characteristics.

One example is the Infantry Immersion Trainer (IIT) facility at Camp Pendleton, California, where ONR's TechSolutions group transformed a former tomato packing plant into a state-of-the-art training facility. The IIT replicates a Middle Eastern village comprised of life-sized physical structures such as apartments, alleys, and a marketplace. It is inhabited by a mix of real human actors, animatronic (robotic) humans, and projected virtual (digital) humans.

The Future Immersive Training Environment (FITE) Joint Capability Technology Demonstration was a three-year, ONR-led initiative aimed at demonstrating the value of advanced small-unit immersive infantry training systems. FITE included demonstrations of animatronic humans and projected virtual humans, but also visually immersive head-worn displays.

Patrick Air Force Base, researchers at the University of Central Florida's Synthetic Reality Lab are developing mediated experiences for equal opportunity training and addressing military sexual trauma. Using our Avatar Mediated Interactive Training and Individualized Experience System (AMITIES) infrastructure, coordinator candidates can interact with virtual military personnel, helping these trainees develop the knowledge and human-to-human skills required to address the needs of potential victims. The ultimate goal is to provide a wide variety of experiences without involving actual victims who could be severely damaged by interacting with an inexperienced coordinator.

> "Subjects often do not seem to treat technology-based surrogates as humans, but as tasks or games that must be mastered via a formulaic interaction. The problem is that real humans are complex cognitive and emotional beings, and for most training scenarios such rote behavior is likely undesirable."

The Human Element

There is a wide gulf between machine versus human simulation. Today's flight simulators, for example, are so effective that in some cases it is possible for pilots to do 100 percent of their training in simulators and be certified to fly the real aircraft with real passengers. One reason flight simulators can be so effective is that they are simulating the behavior of a machine made by humans.

Unfortunately, the detailed "processing" (thinking) and behavior of humans is much more difficult to model. In this article, we focus on practical and effective human surrogates—simulated humans to be used in immersive training of human-human interactions. Human surrogates can be virtual, physical, physical-virtual, and even real.

Virtual human surrogates are realized using computer graphics models of humans and displayed on a large flat panel display, on a projection screen, or in a head-worn display. The purely computer-generated nature of such virtual humans offers the flexibility to change their apparent sizes, skin tones, personalities, genders, or other qualities. In addition, they can be realized using off-the-shelf computers and display systems and are relatively simple to maintain.

Virtual human surrogates can be used in a stand-alone training scenario. For example, in collaboration with the Defense Equal Opportunities Management Institute at

Virtual human surrogates also can be embedded or integrated into a physical environment designed to mimic a real location. This can be accomplished by embedding displays and screens into the physical structure, as is done at the IIT facility in Camp Pendleton. "Immersive" head-worn displays can be used to replace a user's view with the dynamic imagery and sounds of virtual environments and virtual humans, and "see-through" head-worn displays can visually overlay virtual humans onto a real scene.

Physical human surrogates include role players (such as paid actors) or human-shaped animatronic robots that have rubber "skin" and are clothed to look and move like specific humans. Compared to purely virtual human surrogates, physical human surrogates occupy a space with a realistic human form. From a training perspective this is interesting, because there is some evidence that proximal humans are typically more engaged with physical surrogates than they are with virtual surrogates. On the other hand, purely physical human surrogates such as Disney-type animatronics will look like the same person until the rubber face "mask" is changed. In addition, the fidelity of facial and body movement is limited by the mechanical design, which cannot be easily altered after being manufactured.

Physical-virtual human surrogates can be realized by combining dynamic computer graphics with human-shaped (and potentially dynamic) physical forms. A physical-virtual surrogate comprises a combination of realistic shapes and realistic appearance (color and texture). Such a manifestation shares features of both virtual and physical surrogates; they have realistic physical human shape and size, and they can appear with different races, genders, personalities, etc.

The behavior or "soul" of the human surrogate can be supplied by a computer, a remote human, or some combination. When controlled autonomously by a computer, the surrogate often is referred to as an embodied agent. With support from ONR and the Department of the Army, researchers at the University of Southern California's Institute for Creative Technologies have been pushing the boundaries of what's possible with such agents. When controlled by a human, or "inhabiter," the surrogate is often referred to as an avatar. The AMITIES infrastructure supports a blend of autonomous-human agency, which provides the fidelity and flexibility of a human while minimizing the cognitive and physical demands on the human operator.

Photo by John F. Williams

Marines from 3rd Battalion, 1st Marines, confront avatars, or virtual humans, while clearing a room at the Infantry Immersion Trainer located at the I Marine Expeditionary Force Battle Simulation Center at Camp Pendleton, California.

Getting the Human Surrogate Right

There is a widespread and understandable desire to use technology-based human surrogates rather than live role players. Real human surrogates are typically very good at what they do, but they are expensive and not necessarily as controllable (or as consistent and reliable) as one might like. There is, however, some evidence in the literature, as well as anecdotal accounts from the IIT, that subjects often treat technology-based human surrogates (virtual, physical, or physical-virtual) differently from humans. In fact, subjects often do not seem to treat technology-based surrogates as humans, but as tasks or games that must be mastered via a formulaic interaction. The problem is that humans are complex cognitive and emotional beings, and for most training scenarios such rote behavior is likely undesirable. The sub-human perceptions of technology-based surrogates are not understood in any systematic way, so there is little or no guidance on what factors are important for the design and use of technology-based human surrogates.

As a step toward developing formal knowledge guiding the design and use of technology-based human surrogates, we are undertaking a strategic effort to assess the effectiveness of alternative manifestations under different circumstances. We are carrying out studies where we manipulate the characteristics of the human surrogates in a controlled manner and measure the effects on the human subject (the trainee).

There are three broad characteristics of human surrogates we can manipulate: cognitive characteristics, such as the surrogate's apparent ability to "think" (e.g., to be reactive or proactive); perceptual characteristics, such as the fidelity of the surrogate's size and shape, visual appearance, voice, and movement; and social/cultural characteristics, such as personality, gender, socio-economic status, age, and ethnicity. The chosen surrogate's characteristics affect the interacting human's apparent beliefs and illusions, behavior, physiology, thoughts, and trust.

To facilitate the evaluation of the effects, we have created a laboratory-based test bed comprising various changeable human surrogate forms; an underlying software framework supporting consistent control; and various mechanisms for measuring the effects on human subjects. Examples of human surrogate manifestations in our test bed include virtual surrogates appearing on projection displays; virtual surrogates appearing in see-through head-worn displays; animatronic surrogates; a custom-built, physical-virtual surrogate with realistic physical body and a dynamic computer graphics face; and a commercial physical-virtual surrogate called the RoboThespian.

To measure the effects on human subjects of our controlled manipulations of the human surrogates, we instrumented our laboratory with systems for wide-area body tracking, eye tracking, heart/pulse sensing, skin conductance response (sweat) sensors, and video/audio recording and analysis. We are developing a software-based framework for online, real-time monitoring and statistical analysis of the human-surrogate state and events. This allows us to observe things such as where the human subject is looking while a surrogate is talking and whether the human subject appropriately moves in response to threatening statements or movements by a surrogate.

We are conducting various controlled studies where we manipulate surrogate characteristics and observe the effects on people. For example, we are examining the effects of the "physicality" of the surrogate (virtual vs. physical-virtual); whether or how gestures by the surrogate affect the subject's perception of the surrogate; whether it matters if the surrogate visually attends to places of mutual interest (e.g., if the subject points to something, does the surrogate look there?); and how/whether the perceived location and fidelity of the surrogate voice impacts the subject's perception of the surrogate. Beyond our own controlled studies, we are also in the process of carrying out a formal meta-analysis of prior research related to human surrogate interactions.

Future Challenges and Opportunities

Our strategic goals with respect to human surrogates include defining an immersive science space where characteristics and guidelines achieve some desired goals, such as levels of empathy, trust, or engagement. This is not simply a matter of cost effectiveness, but also training effectiveness. Over the next few years we will be developing and aligning methods and measures within the lab and training environments, collecting data, and beginning to develop an overview and guidelines for the design and use of human surrogates.

With respect to immersive sciences more broadly, we want to emulate/simulate future crisis environments within a training environment today. We want to understand how to replicate the scenario from the safety of a training facility or a personal training system and determine how best to use that training time to enhance skills. We need to determine how to define the immersive space that could be replicated within a training environment, determine the critical measures needed to assess the variables within that immersive space, and understand the accessibility and functionality of the methods and measures from laboratory to training environment.

The knowledge we develop in this endeavor should influence applications beyond military training. Many other disciplines rely on effective human-human interactions and could benefit from human-surrogate training. For example, school- teachers need to effectively communicate and interact with an increasingly complex student population, and healthcare practitioners need to understand and empathize with their patients as part of effective diagnosis and treatment.

The challenge before us is to reproduce the cognitive and perceptual characteristics of a human surrogate with such fidelity and consistency that the trainee is not conscious that both the situation and the surrogate are contrived. Instead, we want the trainee to be so engaged with—and perhaps so emotionally affected by—the other "human" that the Marines or Sailors being trained must focus on managing their own emotions while interacting with the "human" to carry out their jobs.

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How Can We Make Computer-Generated Forces More Real?

By Lt. Cmdr. Brent A. Olde, USN, and John DiCola

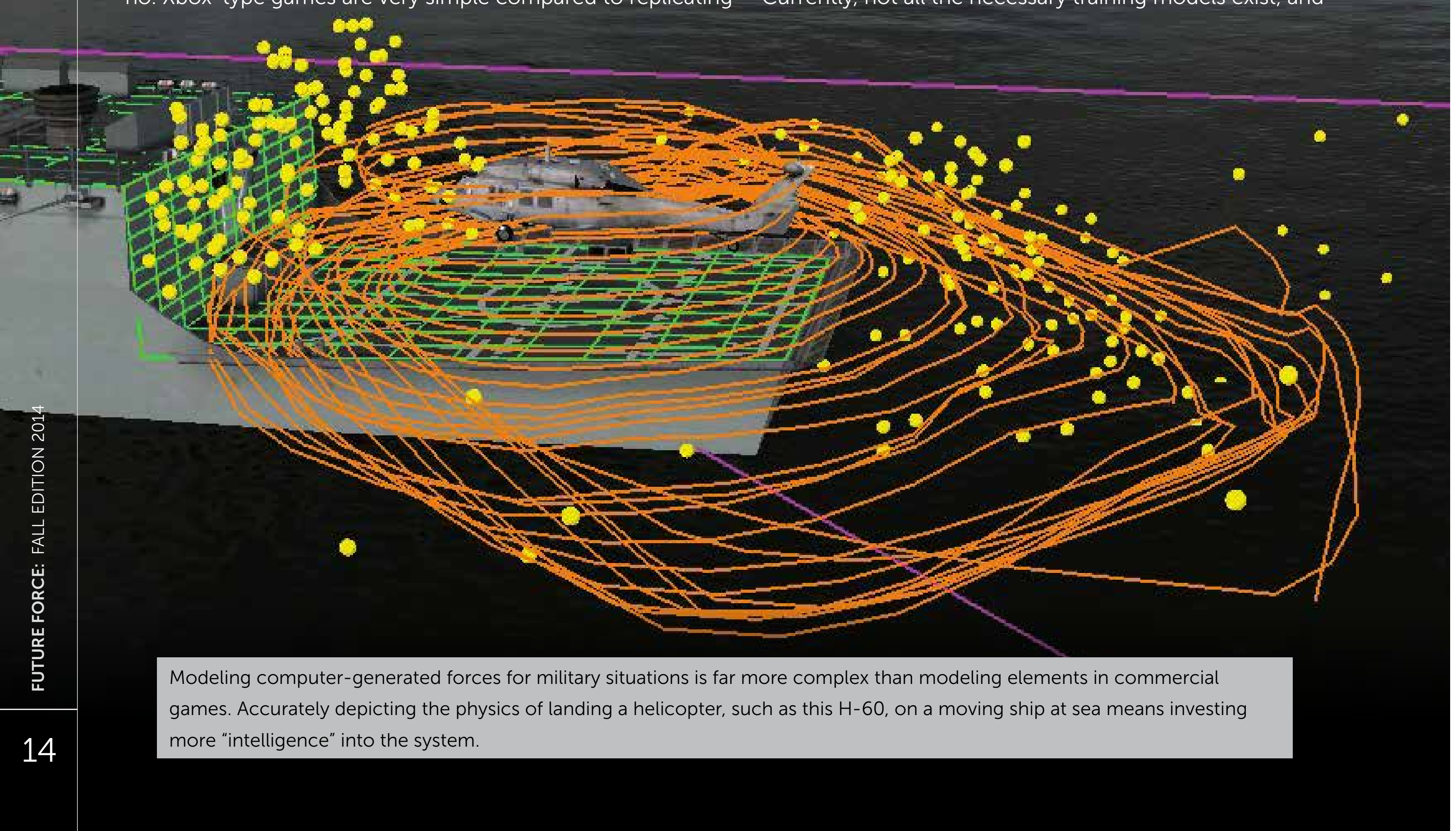
A naval aviator wants to hone his skills, so he jumps into a simulator to train. He selects a mission profile and a level of difficulty; because he feels that his last few training sessions were not challenging enough, he selects a more difficult scenario and begins to fly. The blue, white, and red forces (friends, neutrals, and foes) all behave realistically in all respects; the aircraft systems, environment, communications, jamming, radar, weather, weapons, aircraft maneuverability, air flow, etc.—all work (or don't) in the same manner as they would during a real mission.

The mission can be flown again and again, adjusting difficulty and exploring tactics and techniques, while the computer tracks and learns, building a master tactical database and a performance profile capable of providing detailed feedback. Not only can this training happen without the assistance of the instructor, but all the entities could be computer-generated forces (CGFs) with no need for human participants in the roles of the other players.

A reasonable question would be: Can't current gaming technology do all this already? Unfortunately, the answer is no. Xbox-type games are very simple compared to replicating an actual tactical mission. The actions used in games are scripted, and their realism is superficial. For example, in computer games, bombs have big explosions and always take out their targets, when in reality the material properties of a brick building will sustain very different battle damage than one made of reinforced concrete.

Commercial games are created to be fun and entertaining, and a high degree of accurate physics and controls would be excessively complex for the user and probably rather boring. Games don't incorporate all the specifications, technologies, and capabilities of actual military systems. Our warfighters need to "train like they fight." This means training at night, in bad weather, when their systems are not operating at optimal levels of performance, being jammed, when the "fog of war" is clouding operators' ability to communicate, and when they have limited intelligence about the enemy and the environment.

Though our current simulation systems are highly capable, quite a few hurdles must be overcome before the services can execute training in the manner described above. Currently, not all the necessary training models exist, and



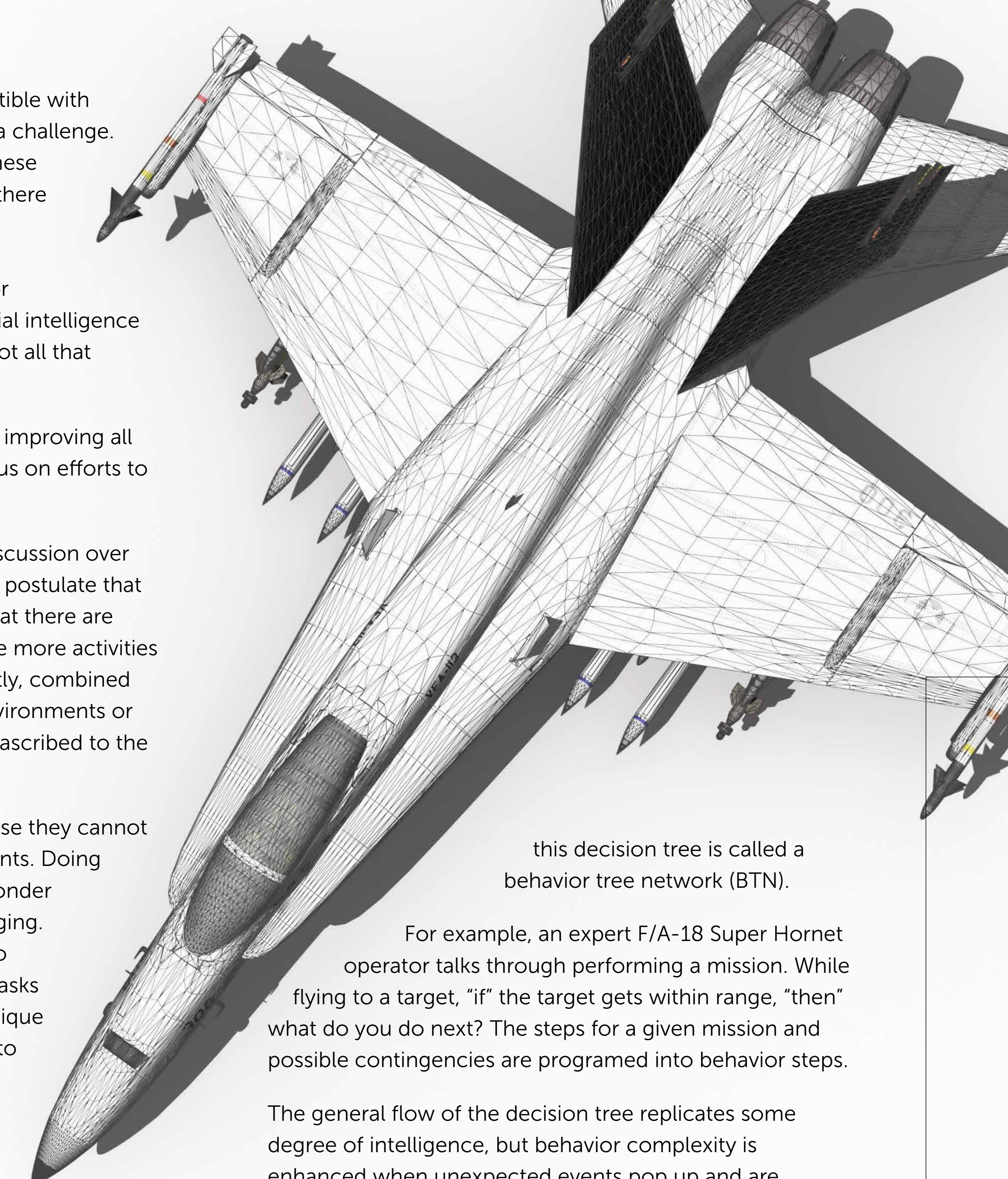
Modeling computer-generated forces for military situations is far more complex than modeling elements in commercial games. Accurately depicting the physics of landing a helicopter, such as this H-60, on a moving ship at sea means investing more "intelligence" into the system.

the ones that do are not all compatible with others, making training continuity a challenge. The high degree of realism turns these trainers into classified systems, so there are numerous security concerns, as well as lack of standards and infrastructure, and limited simulator availability. Furthermore, the artificial intelligence (AI) inherent in CGFs is, in reality, not all that "intelligent."

The Navy is making great strides in improving all these areas, but this article will focus on efforts to improve CGF intelligence.

Without getting into an esoteric discussion over the definition of "intelligence," let's postulate that AI is like human intelligence and that there are varying degrees of intelligence. The more activities a system can perform independently, combined with the ability to adapt to new environments or situations, the more intelligence is ascribed to the system.

In nature, species go extinct because they cannot adapt to their changing environments. Doing so is not an easy task, so it is no wonder programming this ability is challenging. Thus most AI systems are limited to narrowly focused, clearly defined tasks and tend to fail when inputs are unique or unanticipated. The challenge is to develop systems with human-like flexibility and capability to adapt to novel situations.



The first implementations of CGF in the military have been fairly "unintelligent." For example, ships sometimes maneuver over land, and Humvees drive vertically up buildings and park on rooftops. Our favorite scenario was where students became very frustrated during a training event where they were supposed to find a computer-generated submarine. The sub turned out to be hovering in midair and was eventually found by an aircraft.

The Office of Naval Research's Warfighter Performance Department is pursuing a couple of CGF improvement projects that hope to make such stories a thing of the past.

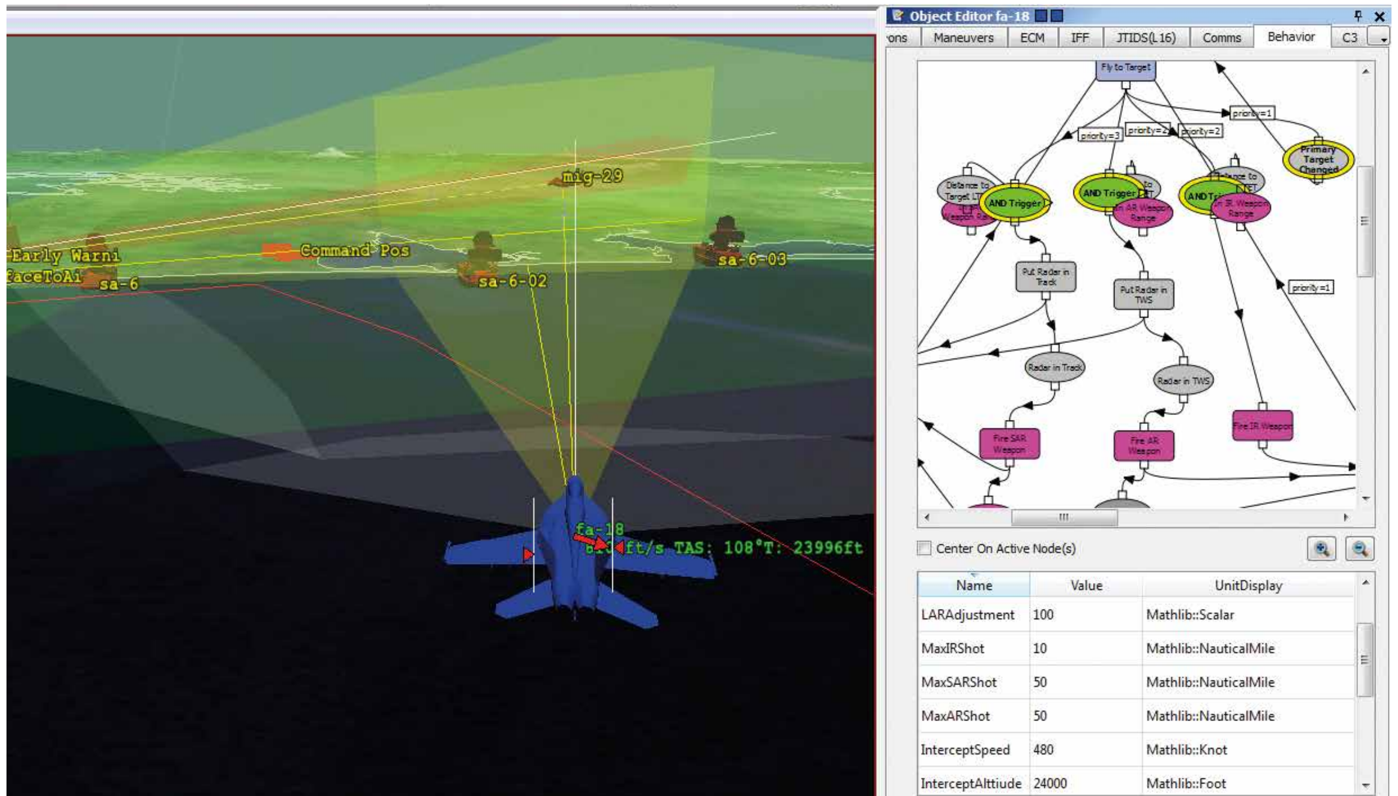
Let's first aim at a general understanding of how CGFs get their intelligence. There are many ways to build intelligence into a system, but one is simply to use "if/then" statements that branch into different logical paths for every decision. A graphicalrepresentation of this decision tree is called a behavior tree network (BTN).

For example, an expert F/A-18 Super Hornet operator talks through performing a mission. While flying to a target, "if" the target gets within range, "then" what do you do next? The steps for a given mission and possible contingencies are programed into behavior steps.

The general flow of the decision tree replicates some degree of intelligence, but behavior complexity is enhanced when unexpected events pop up and are accommodated by the behavior tree. In one scenario, "if" while flying your mission you suddenly get an indication of a surface-to-air missile site locking its radar on your aircraft "then" what do you do? This decision has a higher priority than any other current task, so you discard the current behavior tree you are following and shift to one that specifically addresses a similar contingency.

These BTNs can be highly complex, with thousands of nodes and branches. They can take many months of operational experts working closely with computer scientists to develop. This is an expensive process and must be altered when tactics and aircraft capabilities change.

But what if an expert could simply jump into a simulator and fly a mission that demonstrates new tactics? The computer could just watch, learn, and build the BTN on the fly. What if the aircraft's sensors could record an actual mission and subsequently download the data



Making computer-generated forces more intelligent involves mapping the decision trees of likely situations. For an F/A-18 Hornet pilot flying to a target, for instance, "if" the target gets within range, "then" what do you do next?

to the computer? The computer would watch, learn, and automatically generate a new training scenario, with new entities and their accompanying BTNs. This is the technology currently being explored by ONR; a prototype that models simulator data is expect to be delivered in 2016 while replicating actual missions is planned for 2018.

Once developed, libraries of intelligent CGFs could be used to dramatically enhance the realism and complexity of training; but they also could be used to develop new tactics, explore new missions, and analyze new system designs. CGFs could be pitted against one another to quickly assess system capabilities. For example, would the probability of conducting a successful mission increase if the capabilities of an aircraft were modified, say, to enable it to carry different sensors or weapons or more fuel? If so, these modifications could be specified as new requirements for future aircraft system upgrades.

If the intelligence in these systems is sufficiently proven, they could be used to control unmanned systems, introducing a level of autonomy only seen in science fiction movies.

There are many uses for intelligent CGFs. Primarily they will allow the Defense Department to deliver unparalleled training in a cost-effective manner, but they also will allow tacticians to develop and test battle plans, and acquisition professionals to examine and define design requirements.

These systems, and the intelligence that underlies them, are a key step toward a future where humans and computers interact as naturally as humans do with one another.

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HEAR NO EVIL: Protecting Against Noise

By Kurt Yankaskas

Sailors and Marines are surrounded by sound—much of it far louder than anything encountered in the average daily life. Naval researchers are looking into a range of ways to help protect our ears from damaging noise. Photo by MC2 George M. Bell

Imagine standing next to an F/A-18 fighter jet revving its engines at full power on the flight deck of an aircraft carrier. It is so loud, it shakes your chest. Then imagine, after a 12-hour workday, going directly below deck to try to sleep during flight operations. Or riding in a high-powered armored vehicle. Or hiking in mountainous terrain, listening for soft sounds that may be clues to the enemy's whereabouts, only to have your buddy fire several rounds nearby. Then, in any of these scenarios, having to take a critical phone call.

Hearing is believing—but our Sailors and Marines experience serious dangers to their hearing on a regular basis.

Communicating is a critical capability in all military operations. While most people first think of communications in the voice range, the sound spectrum is far more dynamic. At one extreme, below voice level, are the faint sounds of adversaries' movements and sound minimized to ensure stealth. On the other end of the spectrum is the thunderous noise of artillery, high-powered machinery, vehicles, and tactical aircraft, as well as the staccato of small-arms fire.

These environments of intense noise easily cause injury to the human ear, with its 40,000 moving parts. Noise is a complex problem, and no one solution will address all the issues associated with auditory injury. Recognizing that, given the same noise exposure, not every individual will suffer an injury.

Hearing loss increases the costs of service-related disability when personnel leave the Navy or Marine Corps, and it inevitably leads to additional costs of training replacements for those who leave because of hearing injuries. A comprehensive study by Accession Medical Standards Analysis & Research Activity shows that Sailors and Marines who received waivers for hearing loss prior to entering the service had a significantly higher attrition rate than those who passed their enlistment audiogram. Reflecting the importance of hearing acuity, the Navy no longer waives hearing loss upon service entry.

Photo by MC2 John Herman

Earplugs, properly used, can provide about 30 decibels of hearing protection. In the future, hearing loss may be prevented by tailoring protection to individuals' unique needs.

The Office of Naval Research's (ONR) Warfighter Performance Department is supporting research to develop solutions to noise-induced hearing loss (NIHL)/tinnitus from many different angles with the goal of maintaining operational effectiveness while protecting capability and resources.

Personalized Medicine

Genetic analysis is proving to be an exciting area of NIHL research. Advances in an ONR initiative called Personalized Medicine use selected features of genome analysis to address new avenues for therapeutic interventions on behalf of individuals. According to a genome-wide association study, genetic factors are an important component of NIHL susceptibility. By identifying genetic differences associated with NIHL, we may be able to predict sensitivity to noise and vulnerability to hearing loss.

Such predictions may enable the Navy to design protective equipment adapted specifically to the needs of individual Sailors and Marines, and to identify personnel who would benefit from medical interventions either before or after exposure. The genetic data also would allow identification of personnel who may have difficulty fulfilling their career potential because of hearing vulnerabilities.

The NIHL community recognizes that high noise levels and/or long exposures damage the hair cells in the inner ear called the cochlea. Recent research has discovered that long-term noise exposure also damages nerve cells and causes them to disconnect from the hair cells in the cochlea. Over the next few years, ONR hopes to understand how this damage progresses. The long-term research will address the potential for reconstructing damaged parts of the cochlea, starting with the regeneration of cochlear hair cells in neo-natal mice, a process once considered impossible in mammals.

Personalized Medicine has promising applications for treating hearing injuries in the future. New developments include the discovery of 18 new genes involved in the biomolecular pathways associated with hearing loss. The biomolecular pathways will be critical for the future development of medicines that have the potential for treating hearing injuries. In the long-term, some of these compounds may provide protection from high noise exposures. These developments also will enable hearing conservation programs to tailor personal protective equipment training and assessments to those individuals who are sensitive to noise exposure, thus conserving program resources.

In this exciting field, researchers are testing compounds that foster the regeneration of nerve cells. The research is aided by developments in high-power confocal microscopes, which are able to generate images of neo-natal mouse hair cells and the development of nerve cells. Over the next several years, these projects can be expected to restore hearing in those who have experienced extensive hearing loss caused by high noise exposures.

What We Need to Do Today

It is critical for all Sailors and Marines to have—and use—hearing protective devices such as ear muffs or plugs to reduce exposure to hazardous noise for short-term noise exposure. Hearing protection in acute or chronic noise exposures, however, is also dependent on the skill, knowledge, and motivation of the wearer.

Two longtime challenges to the effectiveness of foam earplugs have been users' ability to insert them fully, and the persistent outward pressure they exert on sensitive bony portions of the ear canal. The ability to insert "universal-fit" earplugs in the ear canal can be addressed during training, but the inability to do so can be attributed to a physical incompatibility—for example, a narrowing or turn in the ear canal that prevents insertion of the earplug past that point. Deep-insert custom earplugs, unlike foam earplugs, are designed to match each ear canal's width and contours to, or just beyond, the second bend of the ear canal.

Earplug attenuation is dependent on their correct fit and retention in the ear canal. However, adult ear canals vary in length, and have two compound bends of varying angles. Tissue/skin up to the second bend is thick and produces oil, sweat, and hair. Beyond the second bend, the skin is 10 times thinner, bony, and sensitive to pressure.

Earplugs that seal or apply outward pressure in this bony region provide more protection but can be extremely uncomfortable. For classic expanding foam earplugs to provide maximum attenuation, they must be inserted approximately 20 millimeters into the ear canal and expand to a diameter of about 14 millimeters, or 10 millimeters wider than the smallest ear canal diameter.

Advances in personal ear protection, in terms of custom devices or filtered hearing protection, introduce a trade-off in personnel performance. Modern, properly selected and fitted hearing protection devices can provide approximately 30 decibels of protection. While this level of noise reduction is generally adequate for many noise sources, fitted protection also makes it more difficult to detect very faint sounds, thereby compromising the ability to hear cues in combat scenarios.

Engineers and scientists are working diligently to solve the operational performance/protection dilemma. One approach is adapting custom-molded hearing protection with embedded circuitry (microphones and speakers) for detecting faint noises while blocking high noise levels. This type of device was adapted by the naval aviation community and further developed in the music industry, which improved acoustic fidelity by adding more speakers to provide a wider frequency range for musicians. Researchers at Virginia Tech are pursuing several research efforts to investigate the nuances of localization and detection in operational settings and how to best integrate improved microphones and speakers into operational hearing protection.

Despite all of these advances and research efforts, the open ear still has an advantage in open-field situations. That is why ONR's investigation continues, developing electronics and standards for future advanced tactical hearing protection and communication devices.

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"FLEXIBILITY AND ADAPTABILITY": The Changing Role of Women in the Marine Corps

By Dr. Katelyn Allison, Dr. Scott Lephart, and Cmdr. Katie Shobe, USN

Women serve throughout the U.S. military, but until recently they were officially barred from serving in ground combat assignments and units. On 24 January 2013, then-Secretary of Defense Leon Panetta and Chairman of the Joint Chiefs of Staff Gen. Martin Dempsey rescinded the direct ground combat definition and assignment rule. In addition, they set a deadline of 1 January 2016 for the integration of women into all combat roles.

This modification of a longtime Defense Department policy warrants the evaluation of current standards and the validation of gender-neutral performance and training standards across all the services. The standards must ensure proper selection of personnel for the respective military occupational specialties (MOSs) based on the skills and capabilities required, regardless of gender.

In anticipation of formally moving female Marines into combat roles, Commandant of the Marine Corps General James F. Amos directed that "measured and responsible research" be conducted to provide him with the "information and data necessary to make an informed and educated recommendation on potential policy changes." As outlined in an All Marine Message, ALMAR 012/12, released in April 2012, the research will include an exception to the ground assignment policy, quantitative research, and a total force survey.

As part of its implementation plan, the Marine Corps already has assigned female officers and staff noncommissioned officers in open MOSs to more than 20 previously closed, non-infantry combat arms battalions.

The Corps also has afforded female officers and enlisted personnel the opportunity to volunteer for infantry training. Several female Marines successfully completed the enlisted Infantry Training Battalion (ITB) on an experimental basis. Although these women graduated from ITB, they will remain in their originally assigned MOSs through the Corps' research phase. In September 2014, three female Marine officers successfully passed the combat endurance test, part of the Infantry Officer Course at Quantico, Virginia.

The Marine Corps also began to explore gender-neutral training standards by reconsidering the requirements for upper body strength in the Marine Corps' annual physical fitness test, working toward a minimal standard for pull-up performance for both male and female Marines.

Ground Combat Element Integrated Task Force

Analyzing gender-neutral physical, physiological, and tactical requirements for ground combat arms MOSs is necessary to determine whether the physical readiness standards are appropriate for both men and women to meet safely and successfully the specialties' demands. All this needs to be done, in the commandant's words, while "sustaining unit effectiveness, readiness, and cohesion."

A Marine Administrative Message, MARADMIN 252/14 released in May 2014, announced "a deliberate, measured, and responsible approach" to studying the integration of women into combat units by establishing a Ground Combat Element Integrated Task Force (GCE ITF) as an experimental unit that will integrate women into MOSs and combat units.

The Marine Corps Operational Test and Evaluation Activity, supported by outside agencies, will evaluate the unit's performance in an operational environment over 12 months. The research team includes the RAND Corporation, Center for Naval Analyses, Naval Health Research Center, and the University of Pittsburgh. Through an Office of Naval Research grant, University of Pittsburgh's Neuromuscular Research Laboratory/Warrior Human Performance Research Center is providing this effort with a number of resources.

Pfc. Christina Fuentes Montenegro was one of the first three women to graduate from the Marine Corps' Infantry Training Battalion in October 2013. Placed in harm's way in supporting roles for more than a decade, female Marines may now have the opportunity to join combat units. Photo by Sgt. Tyler Main.

Warrior Human Performance Research Model

The University of Pittsburgh's Warrior Human Performance Research Model (WHPRM) addresses the culturally specific injury prevention and human performance needs of tactical athletes. It was developed originally for the 101st Airborne Division based on the university's successful research on anterior cruciate ligament injuries in female athletes.

The WHPRM uses an expanded public health approach to determine injury patterns, risk factors for injury, and effectiveness of intervention programs in this unique population based on their occupational requirements.

The Pittsburgh team has successfully employed the WHPRM for the U.S. Special Operations Command's components, including Naval Special Warfare Command and Marine Corps Special Operations Command through Office of Naval Research grants, as well as the Air Force and Army special operations commands.

The University of Pittsburgh's GCE ITF research objectives include several specific phases consistent with the WHPRM that will enable a thorough scientific approach to testing and analyzing tactical requirements and developing musculoskeletal and physiological profiles of Marines. In the first phase, the WHPRM provides recommendations on test protocols to determine predictors of MOS school and GCE ITF unit integration. Baseline physical, physiological, musculoskeletal, and performance laboratory and field screening characteristics will be tested to provide correlates/predictors of school and unit integration outcomes.

The testing also will provide a longitudinal assessment of physical, physiological, and performance characteristics during GCE ITF unit integration. The assessment will enable the team to identify changes in these characteristics as male and female Marines are integrated within the GCE ITF combat arms unit.

For the second phase, the model surveys and analyzes musculoskeletal injuries during MOS school and GCE ITF unit integration. Detailed demographic, medical, injury, training, and nutrition history will be collected during baseline testing and integrated into the University of Pittsburgh Military Epidemiology Database. Prospective injuries will be tracked in this database, and data collected as part of the first phase will be used to determine risk factors for injury during the GCE ITF evaluation.

The Infantry Training Battalion's Delta Co. was the first unit to fully integrate female Marines into an entire training cycle. This and future companies will evaluate the performance of the female Marines to help determine the possibility of allowing women into combat-related job fields.

Photo by Sgt. Tyler L. Main

The third WHPRM phase is performing task-and-demand analyses of MOS school and GCE ITF unit integration to study the specific musculoskeletal and physiological needs and nutritional demands of female and male Marines performing MOS tactical activities.

Task-and-demand analysis uses portable field instrumentation to provide qualitative and quantitative analyses of parameters that influence tactical performance or are associated with injuries during activities. The third phase effort also will evaluate the relationship between the analysis of tactical requirements and laboratory/field data collected as part of the first aim.

The overall goal is to assess the capabilities of both male and female Marines to safely and successfully perform within integrated combat units. Through laboratory and field testing, data collected will be able to establish predictors of injury and determine musculoskeletal and physiological standards for MOS school and unit success.

Future Research

At the request of the Marine Corps Training and Education Command, the University of Pittsburgh also plans to conduct a longitudinal study with the Marine Corps, beyond the GCE ITF, to assess long-term force-wide readiness. This phase will initiate research for prospective, longitudinal surveillance of injury, health, and performance by identifying the scope and magnitude of musculoskeletal injuries of female and male Marines. The research also will identify predictors of injury and optimal performance and provide results of research findings to the Marine Corps' Training and Education Command.

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Photo by John F. Williams

MULTIMISSION TRAINING FOR THE SYNTHETIC AGE

By Dr. Harold Hawkins, Glenn White, Gregg Smith, and Annetta Burger

The Fleet Integrated Synthetic Training and Testing Facility in Hawaii lets strike group commanders train for a variety of scenarios involving actors and threats on, above, and below the water.

1800Z, 24 November: Somewhere in the Indian Ocean

Capt. Christopher Finch is a commodore commanding a squadron of guided-missile destroyers assigned to a carrier strike group. Finch also is the group's sea combat commander. The strike group is executing two missions: protecting commercial vessels against swarms of small fast-attack craft known to operate in the region, and providing integrated air and missile defense against aircraft and anti-ship missiles.

For the latter mission, Finch must coordinate the use of shared air assets with the carrier air wing commander, who has allocated the majority of his air wing for overland operations.

Finch faces several other challenges. According to intelligence reports, one or more enemy diesel submarines are nearby and could threaten the strike group and commercial shipping in the area. And the strike group also is detecting increased electromagnetic spectrum activity in the area, possibly associated with multiple small boats approaching from the coast. Finch must determine quickly how to deploy his limited assets to counter the hostile submarines and boats, while remaining able to engage any other as-yet-undetected threats.

This scenario is considerably more complex than any Finch has previously experienced, either in operational settings or during training.

Synthetic Multimission Training

Multimission training normally is provided to strike group warfare commanders prior to a deployment such as the fictional one described above. This training occurs in the integrated phases of training, culminating with readiness certifications during live underway events such as strike group pre-deployment rehearsal activities called composite training unit exercises and joint task force exercises.

Emerging operational requirements, however, often demand that a strike group and its warfare commanders be "surged" forward on deployment prior to participation in these training exercises.

In addition, as threats increase both in numbers and sophistication, live exercises typically have lacked realistic threat presentations. Representations of opposing forces used in live training often do not replicate accurately the electromagnetic and/or acoustic signatures of actual threats, nor do they reflect adequately the threat density and intensity that may be encountered in operational settings.

To address these training shortfalls, the Office of Naval Research (ONR), Naval Warfare Development Command (NWDC), Navy Undersea Warfare Command (NUWC) Keyport Detachment, and industry partners have developed and demonstrated a low-cost, synthetic, multimission, and multiplatform training capability called the Fleet Integrated Synthetic Training and Testing Facility (FIST2FAC) housed in a NUWC Keyport-owned building on Ford Island in Pearl Harbor, Hawaii.

The FIST2FAC program began in 2010 to serve as both a live and virtual scenario-based anti-submarine warfare training system. Initially, the facility was populated with modeling and simulation products previously developed through ONR science and technology investment. These products were computationally efficient models of two types: synthetic tactical entities—intelligent, realistically behaving adversary and friendly forces—and realistic environmental models, including models of underwater acoustic propagation loss, reverberation, biologics, scatter, and targets. These models had earlier been incorporated into both air and surface anti-submarine warfare training systems, which included emulations of aircraft or shipboard weapons systems driven by the same tactical software used in shipboard systems. The intended users at FIST2FAC would be a sea combat commander and staff. As the concept matured, the developers decided to incorporate capabilities for training of additional missions that could be conducted simultaneously.

To give just one example of the possibilities: In FIST2FAC training, a sea combat commander could pursue both over-the-horizon strikes as a primary mission, and anti-submarine warfare as a secondary mission. The commander must distribute those assets across multiple missions based on a number of tactical considerations, and carry out all missions while providing effective strike group self-defense—a substantially more difficult set of command responsibilities than those faced in single-mission scenarios.

Overall, the combination of the Ford Island facility and FIST2FAC advances allow training in a range of multimission scenarios, including anti-submarine warfare, fast-attack craft and fast-inshore-attack craft, anti-surface warfare, and over-the-horizon strike. In coming years, the FIST2FAC team will add training for mine warfare, electromagnetic spectrum maneuver warfare, assured access/area denial, cooperative engagement capability, and a naval integrated fire control-counter air capability.

Evolution

The program's development began on Ford Island in 1,200 square feet of space renovated by NUWC Keyport. In 2010, NWDC provided FIST2FAC connectivity to the Navy Continuous Training Environment, the Navy's integrated synthetic training network. The same year, ONR invested in a five-year research program to develop the basic anti-submarine warfare training capability for scenarios in which ASW is not the primary mission. FIST2FAC incorporated realistic, artificially intelligent, synthetic tactical entities to increase the complexity of training scenarios without increasing participant costs.

This basic capability was expanded in 2012 with an additional simulated air asset command and control system (carrier tactical support center) used in the fleet, and a virtual carrier platform developed by ONR. Operationally, a carrier tactical support center provides increased situational awareness by enabling exchanges of tactical and sensor data between the carrier and its multimission helicopter, the MH-60R Seahawk. The virtual carrier platform is an intelligent filtering system that provides realistic sensor and tactical data from the Navy's integrated combat simulation environment, Joint Semi-Automated Forces.

The virtual carrier platform contributes realism, not only at FIST2FAC but also for the Navy's major synthetic combat training events, called fleet synthetic training. Without the platform, the synthetic sensor and tactical data provided to decision makers on the carrier was considered "ground truth": unrealistically complete information about sources numbers, types, exact locations, and bearing of enemy submarines. The virtual carrier platform transforms these data into the common tactical picture—what the carrier tactical support center could realistically be able to detect, given environmental conditions and behaviors of opposing forces.

Since late 2012, the virtual carrier platform has been successfully integrated into seven carrier strike group fleet synthetic training events.

The virtual carrier platform also represents a second important aspect of the FIST2FAC training capability—its role as an incubator for the development of training systems for use outside Ford Island. That incubator function is exemplified by the role played in developing a strike group-level training capability in electromagnetic maneuver warfare (EMW). Recognizing the critical importance of the electromagnetic spectrum for command, control, and information systems, the Chief of Naval Operations has designated EMW as an operational imperative for ensuring access to and freedom of action in the spectrum—while denying its use to our adversaries.

In FY 2015, ONR will begin a four-year program to develop an EMW training and experimentation capability for FIST2FAC. The initiative will require the conceptualization, development, and validation of classified offensive and defensive electronic warfare and cyber effects, threat models, and automated EMW performance measurement methodology—all of which will support training assessments and evaluations of concepts of operations and tactics, techniques, and procedures. Much of this effort will focus on the electronic warfare battle management role and the skills of carrier strike group information operations warfare commanders and their watch teams.

FIST2FAC also has supported NWDC for the development of visualization standards that can be used with commercial as well as government-owned technologies and proprietary virtual reality display technologies. These standards were used at FIST2FAC in 2013 to guide development and demonstration of an anti-swarm training capability from the perspectives of a H-60 Seahawk helicopter, a strike group small-caliber arms team, and a destroyer's bridge and bridge wings.

As part of this demonstration, an ONR-developed mission rehearsal tactical team trainer emulation was upgraded

Photo by John F. Williams

The FIST2FAC facility integrates the live and virtual to create a more realistic training environment.

to run the H-60 tactical software for a realistic helicopter crew trainer, called BRASS, which provides all types of H-60 sensor data to the carrier tactical support center. BRASS has been integrated into a low-cost .50-caliber-gun solution that allows the helicopter crew to train in anti-swarm tactics in coordination with a destroyer. The same low-cost gun solution will allow a destroyer's small-caliber arms team to participate in future unit- and integrated-level training events.

The Future

FIST2FAC will help ensure that the Navy's training capabilities keep pace with operational developments, and that strike group operational proficiency remains ahead of the threat.

In the years ahead, we will expand the number of simultaneously played missions for training and experimentation and develop computational models to support simulations for these missions. We also will develop FIST2FAC's ability to connect with capabilities within several domains.

Using the Secure Defense Research and Engineering Network (SDREN) and the Navy Continuous Training Environment, FIST2FAC will be connected to the Pacific Missile Range Facility, an instrumented live test and training range on the Hawaiian island of Kauai, to allow more extensive live, virtual, and constructive training and experimentation centered at Ford Island.

SDREN will be used to pass data to and from the Maui High-Performance Computing Center, furthering the capacity to store and analyze the large datasets expected from many training events and experiments. SDREN also could pass data between FIST2FAC and academia and other members of the science and technology community including the military laboratories and university-affiliated research centers such as the Massachusetts Institute of Technology's Lincoln Laboratories—creating new opportunities for experimentation while enhancing further the significant value FIST2FAC already provides to the Navy and Marine Corps.

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INTEGRATE MANPOWER INTO THE SHIP-DESIGN LIFECYCLE

By William Krebs, Angela Maggioncalda, Brian Beechener, and Bill Bartko

Photo by MCSA Oscar Albert Moreno Jr.

What is the most expensive system ever fielded on a U.S. Navy ship or submarine? A Sailor. Manning and maintenance usually account for the largest cost of U.S. Navy platforms—but can manpower be considered a system?

Based on how the Navy has historically addressed platform manning, the answer is "no." But what improvements, efficiencies, and optimization could be realized if the Navy answered "yes" to that question?

Consider the role of people in the conduct of missions, battles, or other deployments. The dynamic interactions between humans and shipboard systems/equipment are prolific and crucial to a platform's success. Humans are the operators, aligners, repairers, decision-makers, watchstanders and damage controllers for all capabilities that the shipboard systems provide. Human beings are not equipment—but if they were, they would be the most used, required, adaptive, and expensive component of every U.S. Navy ship.

Despite the important role of shipboard personnel, assessing a platform's manpower needs typically has been more art than science. The Navy seeks to optimize manpower in step with the platform system's design development. Here's the problem: Analyzing the required manpower actions in conjunction with system responses is very difficult.

Historically, labor assessments have either inadequately captured system responses and/or relied on manual best-practice methods. The limitations of these assessments are many, and results often are unreliable. Recent Navy acquisition programs experienced a 10- to 47-percent increase in manpower allocations between Acquisition Milestone A (after the need for a system has been established but before technology development) and delivery of the first ship/platform.

Enter the Simulation Toolset for Analysis of Mission, Personnel, and Systems (STAMPS) Future Naval Capability, which is being developed by the Office of Naval Research's Capable Manpower program.

STAMPS is a set of computer-based tools that will assess Navy staffing levels for platforms—both those being designed now and those fielded already—in a probabilistic manner that defines the relationship between system designs and crew components.

The STAMPS toolset will use realistic scenarios to assess the ability of the platform's crew to conduct a wide range of operations, such as deployments, damage situations, maintenance periods, and warfighting. The toolset also will assist Navy users in identifying areas where the design-manpower relationship could be enhanced and/or optimized. The resulting toolset will provide manpower assessment capabilities for multiple Navy organizations, such as those in acquisition, manpower planning, individual naval platform specific offices, and oversight agencies.

Assessing how manpower and systems work together to get the job done has a wide variety of applications, including: a program manager trying to design a ship with a reduced crew; a system designer attempting to calculate the return on investment for expensive automation; an overhaul organization assessing the workload and training implications for two competitive upgrades; or a platform's commanding officer preparing a crew for an upcoming deployment.

STAMPS will provide ship designers with the ability to assess manpower requirements on a timeline basis, underscoring specific events that drive spikes in personnel requirements. Ship designers will be able to create custom scenarios that were previously impossible to analyze. STAMPS integrates labor assessments into the baseline design process to evaluate how design changes impact manpower and costs, and the STAMPS toolset also allows manpower assessments to be conducted in phase with the ship's design spirals.

The STAMPS capability brings two key components to the manpower assessment process in an integrated manner: a ship system simulator that identifies actions required for the system and equipment to respond to a wide range of scenarios; and a statistical model that takes into account variations in human responses. These seemingly divergent areas are brought together through the use of scenario timelines, which include specific operations that the platform must conduct. Existing ship system simulators assume manpower will always be available to perform required tasking. Existing human response models assume all system tasking can be completed by the allocated watch stations. STAMPS is the first model to test the interaction of system responses and the crew.

Use of the STAMPS software starts with a user-generated timeline of platform events. The program populates the timeline with the specific actions required to perform the subtasks associated with these events. System and equipment actions are identified, including system alignment, equipment start/stop, infrastructure open/close, equipment rotation, required maintenance, and damage responses. The toolset identifies crew actions, including those of watch standers, own-unit support, firefighting, facility maintenance, etc. When the timeline is fully populated, STAMPS assesses the probability that a designated crew would be able to perform all assigned actions.

The STAMPS toolset is integrating the Human Injury and Treatment (HIT) software developed through ONR's Force Health Protection Future Naval Capability. HIT predicts human injury incapacitation, medical response requirements, patient outcomes associated with casualties resulting from combat operations in shipboard environments, and the ability of wounded crew members to return to duty.

Two types of reports are generated: holistic or discrete. Holistic reports provide findings across multiple events and/or scenarios, such as crew usage rates or specific task burdens on crew members. Discrete reports identify specific points in a scenario timeline where the crew has a low probability of conducting required tasks (e.g., too many tasks for the number of crew members with the requisite skills and knowledge).

STAMPS also can conduct "what-if" assessments. Designers and fleet organizations can alter the crew criteria or the design, rerun the scenarios, and compare results from multiple design-crew arrangements. These assessments are enabled by using data packages from the ship design and manpower communities. The data packages allow STAMPS to maintain up-to-date versions of the design and crew with minimal manual intervention.

A beta version of STAMPS is being tested through 2015 against realistic battle damage scenarios on the Navy's new destroyer, USS *Zumwalt* (DDG 1000). This double-blind assessment will compare STAMPS-developed scenarios to manually generated timelines from the *Zumwalt* system and manpower experts. Results from the two sets of scenarios will be assessed and used to enhance STAMPS' predictive responses.

In 2016, an updated STAMPS beta version will be tested against four shipboard simulations of battle damage aboard the *Zumwalt*. Each of the four scenarios will be simulated, with the crew and ship configured for combat. The unsuspecting crew will respond to simulated damage events (the crew will be aware that a drill is being run, but will not know the weapon type, hit location, damage, and required response). Results from the shipboard simulation will be compared to the prediction and employed to enhance the final version of STAMPS.

Using this iterative build-test-build method, the Navy will demonstrate STAMPS' ability to predict integrated system and manpower responses for extremely complex scenarios, including battle damage.

Program stakeholders also will have data to demonstrate probabilistic performance against the established programmatic objectives, including reducing the cost of manpower assessments, allowing these assessments to be conducted quickly, and providing more accurate data—all with the goal of eliminating the expansion of crew-size requirements during acquisition. When completed, STAMPS will close current gaps in the ability to assess manpower as an integral component of ship design and operation.

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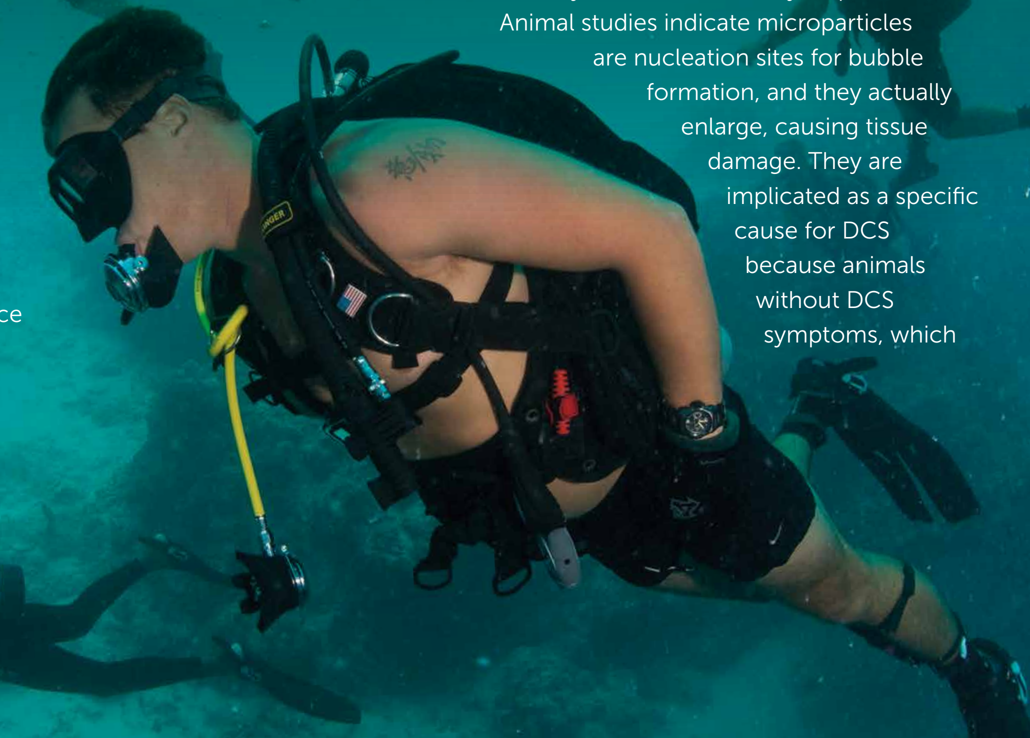
Unbending Navy Divers

By Dr. William D'Angelo, Robert Bolia, and Dr. Stephen Thom

Diving is a fundamental operational capability for any modern Navy. Diving tasks include ship repair, underwater construction and demolition, salvage, rescue, reconnaissance, route clearance, and infiltration/exfiltration from the sea. To perform these tasks, the U.S. Navy employs a diverse range of diver specialists, including underwater construction divers, explosive ordnance disposal operators, and elite SEAL combat swimmers.

Since the 1950s, the Office of Naval Research (ONR) Undersea Medicine program has supported biomedical research to improve diving and submarine operations. The program seeks to compensate for human physiological shortfalls and the risks inherent in operating underwater. The two main ways to achieve these goals are by enhancing human physiology with pharmacological or other therapies and providing protective technology.

In 2006, the Navy designated Undersea Medicine as a National Naval Responsibility, and chartered the program to carry out several critical missions: sustaining a robust international research capability; supporting the Navy undersea medicine laboratories; cultivating a pipeline of scientists and engineers; and providing science and technology products that will ensure future superiority in the undersea domain. Along with support for general diver and submariner health and performance, the main medical thrust of the program is to understand and overcome two significant dangers faced by Navy divers: hyperbaric oxygen toxicity and decompression sickness (DCS).



Microparticles May Be the Key

Researchers understand that nitrogen is taken up by tissues in proportion to the amount of pressure as the diver descends. When pressure is reduced as the diver returns to the ocean surface, nitrogen is released from tissues in the form of bubbles. The bubbles form around what are referred to as gas cavitation nuclei. These nuclei, with a diameter of about 0.0000394 of an inch, are too small to be seen by the naked eye.

Over the past five years an exciting new perspective on the cause and possible treatment for DCS has emerged. Microparticles are spherical cell fragments that circulate in the blood stream, roughly the same size as the gas cavitation nuclei. Formed from shed portions of the cell membrane, microparticles originally were called "cell dust." While present in healthy human bodies, they are known to increase in response to trauma, inflammatory disorders, and moderate-to-heavy exertion.

ONR has sponsored research showing that the number of microparticles goes up in animals and humans after actual or simulated diving. Researchers found a direct correlation between the number of microparticles and the number of bubbles detected in the diver's bloodstream. These microparticles associated with diving have been shown to cause body-wide inflammatory responses. Animal studies indicate microparticles are nucleation sites for bubble formation, and they actually enlarge, causing tissue damage. They are implicated as a specific cause for DCS because animals without DCS symptoms, which

The Persistent Problem of "the Bends"

Decompression sickness (DCS), also known as "the bends," was first identified in caisson workers on bridge projects during the mid-19th century. Physicians noted that laborers working in caissons (watertight enclosures used to build the bridges' foundation on the river bottom) often developed severe joint pains when they spent a significant time in the pressurized environment and that these symptoms worsened with both duration and depth. Frequently, DCS symptoms resolved themselves with time, although more serious cases resulted in permanent paralysis and even death. Physicians also noticed that workers who ascended slowly to the surface experienced reduced incidence.

French physiologist Paul Bert was the first to investigate the causes of DCS in 1878. He hypothesized that the higher gas pressures induced by hyperbaric exposure led to the formation of bubbles in the blood and tissues. Oxygen was not likely to be the culprit, as it is consumed in the process of respiration. Nitrogen, on the other hand, played no role in the body's metabolic processes. Bert suggested that increased nitrogen pressures led to the saturation of body tissues, which would form bubbles in cases of rapid decompression. Further research indicated that the key to safe decompression was a slow ascent to the surface. A corollary of these findings was that, if bubble formation caused by rapid decompression resulted in DCS, an effective treatment may involve recompression of the diver, followed by a slow ascent.

Today, DCS usually is thought of as a diving disease, due largely to the growth in popularity of recreational diving. More than a century of occupational and recreational diving has led to thousands of cases of DCS, allowing the medical community to characterize its symptoms, which include long-lasting joint pain, skin rashes, or paralysis. The exact mechanism that leads to DCS—how bubbles form, how gas diffuses into tissues, etc.—remains poorly understood. The continued decline in the incidence of DCS today reflects not an improved understanding of the underlying physiology, but rather the practical application of lessons learned.

Divers in the early 20th century, primarily from the U.S. Navy, Britain's Royal Navy, and the Canadian Navy, were subjected to different dive depth/time profiles that formed the basis of today's "dive tables." The profiles and dive tables are based on mathematical models of the diffusion of nitrogen in the tissues and adjusted based on the real-world incidence of DCS in the experimental dives.

For recreational and commercial divers, these dive tables tend to work very well, with few cases of DCS among those divers who comply with the tables—especially with the advent of dive computers that use algorithms based on the tables. As technology has progressed to permit more challenging dive profiles and inclusion of novel gas mixtures, however, the applicability of the standard dive tables lessens. Each new gas mixture or depth profile requires development and testing of a new set of dive tables. In many cases, the time required to decompress safely from a dive can exceed the actual work time of the dive by five to one.

The Undersea Medicine program continues to pursue solutions for DCS, which also is associated with high-altitude aviation and space exploration. An understanding of the physiological mechanisms underlying DCS could allow more accurate predictions of DCS episodes and lead to improved treatment. Today, when operational needs arise or emergencies occur and divers experience DCS, the only treatment is to rush patients to a recompression facility or transport a recompression chamber to the accident scene, an extremely expensive and logistically difficult operation.

Photo by MC3 Christian Senyk

The traditional method of DCS mitigation involves the use of decompression chambers, which can be time consuming. Current research is focused on finding a pharmacological solution.

are injected with microparticles from decompressed mice exhibit the same damage that occurs in animals with DCS.

Microparticle dynamics in humans are influenced by pressure, exertion, and the combination of gases in breathing mixtures. Studies show promise for improving understanding of what causes DCS, and further research may uncover novel ways to reduce risk, as well as treat divers who develop DCS. The cascade of inflammatory responses triggered by microparticles and the activation of certain enzymes by high-pressure gases, in particular, may help to explain why the onset of DCS symptoms can at times be delayed for many hours after decompression.

The Future of DCS Mitigation

A key goal is to develop the ability to avoid DCS with a pharmacological treatment. Researchers at the Naval Medical Research Center recently found that perflourocarbon, injected intravenously, can in some cases prevent DCS in large animal models without the use of a recompression chamber. Perflourocarbons are thought to be useful against DCS because they may be breaking up the bubbles formed by microparticles and absorbing the excess nitrogen in the blood. For the Navy, relief from the logistical burden of maintaining recompression chambers, plus the decrease in response time in an emergency situation, makes decompression via syringe a bright prospect.

Another initiative is to engineer a "human factors-based" integrated diving system using decompression calculations from the dive computer and biometric monitoring. In this case, the accuracy of the dive tables can be improved, which will decrease decompression times and improve safety—although long decompression and off-gassing times will not be avoided.

The development by ONR and the Naval Sea Systems Command of a next-generation hard diving suit will eliminate the need for decompression in many cases. The hard diving suit avoids the gas uptake in the blood and tissues. While it could not be used for all missions, a lighter-weight, more maneuverable, and more versatile suit would be an important asset for many operations. However, in emergencies, a recompression chamber still would be required.

Manned diving will always remain an important operational capability for the Navy, even with the advent of unmanned assets that will reduce the need for a person to do the dull, dirty, and dangerous underwater jobs. Most likely, manned and unmanned assets will work in unison, complementing each other's strengths, as we already see today. The Navy will continue to pursue science and technology solutions so that its divers maintain their undersea advantage.

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Military personnel use a training system to simulate real-world missions. By incorporating live aircraft and computer-generated entities in virtual scenarios, training optimization and readiness can be achieved. Launched in 2007, this training of the future mixes tactical simulation in a video-gaming-like virtual environment with live-fly training to promote readiness within naval aviation.

Game On: LIVE, VIRTUAL, CONSTRUCTIVE TRAINING CAN IMPROVE READINESS

By Cindy Mattingly, Dr. Ami Bolton, Melissa Walwanis, and Heather Walker Priest

As the Department of the Navy transitions to a multifaceted approach to warfighting, the services are refocusing their aviation training investments on a revolutionary capability called live, virtual, constructive (LVC) training.

This futuristic training mixes aircraft simulators, virtual environments, and live-fly training to enable military forces to defend against current and potential adversaries. The computer-generated atmosphere allows for diverse operating scenarios, realistic adversary capabilities, and predicted operational environments, including with joint and partner-nation forces.

What Is LVC?

"LVC is a new way of looking at training," said Capt. Craig Dorrans, Naval Aviation Training Systems (PMA-205) program manager, whose office is collaborating with a number of stakeholders in developing LVC. "It combines the strengths offered by each area: live flight, virtual man-in-the-loop simulation, and constructive entities in a gaming environment to build a more realistic and valuable training opportunity for aircrew and maintainers."

The "live" component consists of humans operating actual aircraft and weapon systems in a real combat environment or training scenario. Like the live component, the "virtual" piece also includes real people, but they use simulated aircraft in a synthetic environment. The "constructive" part incorporates computer-generated people, systems and environments that are used to enhance the training scenario.

Here's how an LVC scenario could work: A live F/A-18F Super Hornet flies a strike mission using a training range. The aircrew interfaces with E-2D Hawkeye simulators using the Navy Continuous Training Environment (NCTE), a system that connects dispersed simulators and systems with geographically separated forces and offers training on demand. The aircrew members using simulators are providing battle management support. Computer-generated enemy aircraft are being uploaded to the systems of both the live and simulated aircraft, allowing instructors to insert training events and execute enemy behaviors on the fly. The two platforms must work together to overtake the adversaries and complete the training mission scenario.

"LVC allows aviation training to be more economical by creating more complex scenarios while improving responsiveness at reduced cost," said Cmdr. Justin Shoger, former PMA-205 LVC integrated product team lead. "Fewer live-threat systems and adversary aircraft will be needed, and training events will not be as constrained by current physical range limitations." In this regard, LVC offers a clear opportunity to achieve cost savings, reduce wear and tear on live assets, and reduce fuel consumption.

"The concept is expected to improve the readiness of the warfighter, while offsetting costs of current and future aviation training," Dorrans added.

Before LVC, training was either live or computer-generated. Meeting operational training challenges, such as limited range availability or airspace size, was not feasible or affordable. Traditionally, training and readiness missions that used actual aircraft were vulnerable to detection from satellites or other observers, Marine Corps officials said. Through interoperability, such as using network exercise control centers, which allow classified training missions to be conducted, LVC both extends that airspace by incorporating virtual elements and enables more covert practice of emerging tactics, maximizing the probability of a real-world mission's success.

"The intent is to integrate all new systems, and legacy systems, if feasible, into LVC training," said Dorrans, whose office is aligned under the Naval Air Systems Command (NAVAIR) and based at Naval Air Station Patuxent River, Maryland. "Aircrew will have more flexibility to be trained and tested in a demanding scenario that can be dialed up or down based on their individual or mission needs. It's an exciting time."

Fulfilling a Need

Today, naval aviation faces challenges to develop the necessary levels of readiness and training for combat. Pilots and aircrew must be proficient with the increased capabilities and complexity of the modern weapon systems being installed on their aircraft. The cost of live-flight training has increased, as has the amount of maintenance needed on aircraft and the requirements for multiple independent platforms working together as part of a larger network.

"Training is getting more and more complex," said Dorrans. "Instead of single stove-piped capabilities, we have networked systems, all contributing to a warfighting capability that requires you to train as a team instead of as an individual. Coordinating training across multiple aircraft platforms requires networked simulators." All these requirements are making naval aviation training even more challenging.

As a result, traditional ideas of training, such as the Fleet Response Training Plan, are becoming less applicable as the need for larger, networked exercises highlight the misalignment of training between platforms. Although the plan provides an overall training pipeline that has proved very effective for individual platforms, it has resulted in each community having its own training timeline and technology, using different mixes of live and virtual training. For example, the Government Accountability Office reported in 2012 that the submarine community conducts almost all of its predeployment training in shore-based simulators, while surface ships conduct just over half of their training synthetically, varying among missions and individual ships.

The incorporation of LVC has the potential to ease the alignment of training opportunities across platforms by allowing the different platforms to maintain their desired technologies to train based on skill set and training timelines, while still participating in larger, team-of-teams exercises (e.g., virtual simulations for E-2C/D crews doing joint exercises with live carriers using constructive enemies).

To take advantage of these benefits, the technology must promote a realistic training environment. Shoger said LVC offers more realistic and complex training and could augment live training. Initial efforts are focused on research revolving around training fidelity and ensuring aviation training devices are connected to the NCTE network. Pursuing technologies to develop diversified training activities has led to the LVC model.

LVC and Training Fidelity

Approaching the problem using LVC will allow the fleet to identify and resource the right mix of live and synthetic training to meet the needs of combat aviation training in the future. Based on current technology readiness and LVC's complexity, a number of significant challenges remain that the Navy is addressing through research and development.

One issue being addressed is the required fidelity to ensure training is realistic and complex enough to promote transfer to the real world. In addition to the focus and technological enhancements, this research incorporates the application of training strategies that will reduce costs and risks and achieve performance gains through the magic of simulation.

For example, researchers in the Training, Readiness, and Usability in System Technologies Laboratory at the Naval Air Warfare Center Training Systems Division have partnered with PMA-205 and the Office of Naval Research (ONR) to develop a way to meet these challenges. These efforts, known collectively as the LVC Training Fidelity program, aim to push the state of the art and science in three ways: understand the impacts of merging virtual and constructive entity representations onto avionics displays on safety and training for live simulation; understand the fidelity necessary to achieve more training and readiness in virtual simulators; and develop constructive computer-generated forces that demonstrate tactically realistic and learner-aware behaviors.

This goal consists of technologies for integration into existing systems as well as techniques and recommendations for training that will feed into the pipeline's optimization across platforms. For example, there are plans for constructive technologies to be integrated with the Next Generation Threat System to make computer-generated forces more realistic and easier to execute starting in fiscal year 2015. Technological upgrades for visual optimization and motion are being evaluated for F/A-18 simulators. Recommendations for when and where to use these technologies will be developed with an eye across platforms to help implement alignment and optimize training.

To increase the proficiency of naval aviators and flight officers, Commander, Naval Air Forces, developed the Navy Aviation Simulation Master Plan to improve simulated flight's realism and increase simulator fidelity. In addition, the Navy has collaborated with the U.S. Air Force in various LVC pilot-project demonstrations. The demonstrations assisted with further development and determined the training efficacy and applicability to various aviation training scenarios.

Meeting the Needs of Marines

The Marine Corps Aviation Distributed Virtual Training Environment (ADVTE), which is expected to support LVC, is an immersive distributed training environment that links virtual aircrew training systems and constructive players through network exercise control centers located at 2nd and 3rd Marine Aircraft Wing aviation training system sites. The goals were to allow warfighters to conduct multiship, multiplatform, and multiplayer networked training in a realistic, high-fidelity simulated training environment while freeing aircraft for real-world operations. By fielding an integrated, tactically relevant training system consisting of nationally networked trainers, it is now possible to shift more training mission events to simulators from aircraft, creating the opportunity to enhance significantly combat mission readiness without the use of actual aircraft.

"ADVTE allows geographically dispersed Marines the capability to link together for training and mission rehearsals," said Col. David Owen, PMA-205 Marine Corps training systems lead. "As with other simulation, ADVTE provides the opportunity for considerable savings. Since trainers can be linked during training, ADVTE can be viewed as a cost-savings multiplier."

On 4 May 2014, the 2nd Marine Aircraft Wing demonstrated the ADVTE capability at Marine Corps Air Station (MCAS) Cherry Point and MCAS New River, North Carolina, and MCAS Beaufort, South Carolina. The capability linked AV-8B Harrier flight simulators from Cherry Point with MV-22 Osprey and UH-1Y Venom devices from New River and F/A-18 Hornet simulators from Beaufort. ADVTE currently supports virtual and constructive networked training that links devices together from the previously mentioned locations as well as MCAS Miramar and Camp Pendleton, California, and MCAS Yuma, Arizona.

Training Together as a Team

LVC also includes Naval Integrated Fire Control-Counter Air (NIFC-CA) training, an interoperable warfighting capability integrating E-2 and F/A-18 aircraft and the Aegis combat system. NIFC-CA provides the Navy with expanded over-land and over-water engagement ranges and extends the firing surface ship's over-the-radar horizon. PMA-205 has developed a fleet-wide LVC blueprint to support NIFC-CA's launch in 2015. The team compiled a comprehensive training strategy that integrated and expanded existing aviation and surface platform training capabilities, which, until now, were independent.

The PMA-205 team recognized that existing systems were designed primarily to train operators at the platform level and that integrated warfare training demanded a new paradigm. NIFC-CA and other integrated and interoperable warfighting capabilities rely on more than an individual weapon system: They require the entire combined team working as networked system contributing to the effective weapon execution, from launch to engagement. To be

An E-2C Tactical Operational Flight Trainer similar to this one was used to simulate the cross-platform warfighting capability known as Naval Integrated Fire Control-Counter Air, or NIFC-CA, The exercise, conducted at E-2 Systems Test and Evaluation Laboratory at Naval Air Station Patuxent River, Maryland, was the first time Airborne Command and Control Squadron (VAW) 125 aircrews participated in NIFC-CA training.

effective, naval aircrew and surface warriors, along with key staff, must regularly train as a team to develop proficiency, confidence, and trust, PMA-205 officials said. To answer these emerging training requirements, PMA-205 and ONR are supporting a research effort with the Naval Air Warfare Center Training Systems Division that will result in a gap analysis and training requirements report, along with prototype training tools that leverage LVC capabilities and target the development of competencies that facilitate cross-platform interactions.

PMA-205 also organized fleet events that used the E-2 Hawkeye Systems Test and Evaluation Laboratory (ESTEL) at NAS Patuxent River to support this critical NIFC-CA cross-platform training capability in the near term. Airborne Command and Control Squadron (VAW) 125 aircrews used the lab for initial NIFC-CA hands-on training with both stand-alone scenarios generated at ESTEL and distributed events, including Center for Surface Combat Systems instructors participating from Wallops Island, Maryland.

The Surface Combat Information Center team trainer events led to Naval Sea Systems Command's recognition of the virtual training value between ESTEL and Wallops Island labs, enabling operators to learn from each other as tactics and techniques are being developed. By leveraging existing performance abilities and providing a new training paradigm that contributes to the effective execution of the concept, PMA-205 has provided a crucial interim capability to ensure NIFC-CA exercises will be available to aircraft and ship crews preparing to deploy.

"The virtual and constructive approach for NIFC-CA played a huge role in providing warfighters with a way to experience the complex capability that would have been impossible just a few years ago," said Dorrans. "Linking airborne and surface test devices was an innovative approach that provided needed training prior to deployment."

As the military develops innovative technologies for the future, it must define contemporary training curricula to teach military personnel to operate them. LVC offers just that—whether it is individual proficiency training or an integrated system-of-systems approach, the capability ensures warfighters are prepared for all real-world scenarios.

"Slated to support formal training events no later than 2020, LVC offers limitless possibilities," said Dorrans, "As it evolves, its training capabilities will increase the proficiency of the next generation of naval aviators."

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Building a More Resilient Mind

By Dr. Karl F. Van Orden

When placed under stress, some people shine while others are less resilient. The Naval Health Research Center is looking into ways that can help improve stress responses. Photo by MC2 David Hooper

What makes some individuals thrive under stress while others falter? That question is central to understanding what factors contribute to the development of post-traumatic stress disorder, which has become a serious byproduct of the last 13 years of war.

Understanding psychological resilience—the ability to withstand, endure, and recover from stress—is the primary focus of scientists with the OptiBrain Center research consortium. The center is a collaboration between the University of California, San Diego (UCSD), the Naval Health Research Center (NHRC), and the Naval Special Warfare Command. They have set out to address resilience by studying elite adventure racers, Navy SEALs, Marines, and college students. With support from the Office of Naval Research (ONR), they have enrolled research participants who viewed emotionally provocative stimuli and performed tasks under moderate stress levels while their brain activity was scanned with functional magnetic resonance imaging (fMRI).

"We found significant differences in brain areas associated with the processing and regulating of information coming from the body," said UCSD researcher Dr. Martin Paulus. "The differences between elite and average individuals seem to be reliable over the course of several studies."

Along with well-known changes in stress hormones and performance decrements, the brain dynamics of resilience indicate very different stress response profiles between more and less resilient individuals. Both groups have an initial flood of stress hormones, as well as elevated heart rates and breathing rates associated with a stress encounter. More resilient individuals, however, are able to harness the adrenaline rush to improve performance and then return to baseline levels much faster after stress than less resilient individuals. In addition, they may display lower anticipatory stress reactions. In other words, more resilient individuals are able to better control their reactions.

Such findings raise the nature/nurture question: Are some individuals simply born with greater resilience, or is it learned? Dr. Douglas Johnson of NHRC has studied the effects of mind/body mindfulness training on predeploying Marines. Mindfulness training in this study included 20 hours of classroom instruction plus daily homework exercises over an eight-week period. The exercises involved attending to internal states, focused attention, and tolerance of present-moment tasks. Previous studies have shown that practicing various forms of meditation can enlarge some brain centers, indicating greater neural growth and change. In his study, Johnson measured biomarkers, brain activity, cognitive performance, and self-reported sleep quantity and quality in 281 Marines, 147 of whom received the mindfulness training.

The results, reported recently in the August 2014 issue of the American Journal of Psychiatry, indicated that those Marines who underwent mindfulness training had a more robust stress reaction to an intense predeployment training exercise, as measured by heart rate, but a more efficient recovery, as measured by heart rate, breathing rate, and stress hormone measures as compared with untrained Marines. In addition, the mindfulness-trained Marines demonstrated lower brain activity in key brain areas when challenged with a moderately stressful, restricted-breathing task, based on individual fMRIs.

"Our measures are comprehensive, but there's more work to be done," said Johnson. "There may be other forms of training that are effective, and we don't yet know about longer-term mental health outcomes."

With support from both ONR and the Bureau of Medicine and Surgery, Johnson and his team are conducting a more rigorous follow-on study in Marines undergoing basic reconnaissance training, using an even larger suite of measures that includes operational tasks that measure training effectiveness. These results will be applicable to numerous military communities.

"This research is both allowing us to better understand the underpinnings of resilience within our operators and to apply and implement the findings within our programs," said Cmdr. Eric Potterat, force psychologist with Naval Special Warfare Command.

Although military experience and mindfulness training indicate that some level of resilience can be learned, the role of genetics and basic neurobiological traits cannot be overlooked. Dr. Marc Taylor of NHRC is studying variations in specific serotonin and corticosteroid receptor genes in humans that may be related to acute and chronic stress reactions. These genes work to regulate stress hormone control systems. His study of 144 military men completing a strenuous survival and captivity training course found that the gene combinations result in distinct groups defined by high, medium, and low stress buffering capacities. Stress buffering works to protect and regulate the body and arousal systems therein from the deleterious effects of high-stress hormone levels. In highly resilient individuals, peripheral mechanisms interact with central brain systems to regulate, and even exploit, acute stress responses, and more efficiently return to baseline levels following stress. Less resilient individuals have system components that operate with far less efficiency. In the future, Taylor's group hopes to modulate the action of these genes with nutritional supplements or other means and, in effect, give a greater percentage of individuals a neurobiological head start in the resilience-building domain.

Despite the promising results, there remain significant challenges to building more resilient minds in service members. Operations in Iraq and Afghanistan and previous conflicts have taught us that the mental component of warrior readiness needs to be seriously considered. Military members from top to bottom will need to acknowledge that mental health is as important as physical health to readiness, performance, and post-deployment recovery, and then take active steps to improve psychological readiness. These challenges should be easier to face with research-supported, evidence-based, resilience-building strategies.

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Photo by Sgt. Earnest J. Barnes

WANT TO IMPROVE PERFORMANCE? GET BACK TO SLEEP

By Sara Bessman

This scout sniper in Afghanistan enjoys a little sleep after a long night of patrolling. In the military professions, jobs have to get done no matter what the hour or how long they take. Research may help determine just how much sleep Marines and Sailors really need to accomplish their missions.

Imagine you are being held hostage, and explosives are involved. A specialized unit is en route to disassemble and dispose of the explosives, but in order for the team to reach you, they must embark on a very long and strenuous hike to a remote location after already being awake for 20-plus hours. When the team arrives, they are dehydrated, hungry, and exhausted. At this point you may be wondering whether the crew has been compromised by these factors and whether they will be fit to accomplish their mission. In fact, this is a justifiable concern.

According to the 2008 Human Performance Report by the Office of Defense Research and Engineering, the most important human performance factor in military effectiveness is degradation of performance under stressful conditions, particularly sleep deprivation.

A team of expert scientists and investigators at the Naval Health Research Center (NHRC) are researching sleep and its effects on warfighter performance and resilience. Through ongoing experimental sleep research, including the evaluation of promising new mobile sleep monitoring technologies and various countermeasures for restoring physiological functions during sleep loss, the team hopes to identify innovative solutions that will have a tremendous effect on the health and welfare warfighters.

The primary purpose of sleep remains a mystery, but it is indisputable that lack of sleep has significant negative consequences. In fact, studies have demonstrated that missing just one night of sleep results in cognitive performance impairments similar to those observed in individuals who are intoxicated.

"Inadequate sleep has many immediate near-term consequences including difficulty concentrating, impaired learning and memory, and emotional instability," explained Dr. Rachel Markwald, sleep physiologist and lead investigator in NHRC's Physical and Cognitive Rehabilitation Environment Laboratory. "The longer-term health consequences of inadequate sleep, if sustained, include an increased risk of obesity, developing diabetes, hypertension, and heart attack."

It is not surprising that the effects of sleep deprivation are often exploited during warfare by using tactics that prevent opposing forces from obtaining sleep. The Human Performance Report notes that any method for improving how soldiers behave under sleep deprivation will have significant consequences for either our own forces or an adversary that learns to solve this problem.

"Whether we think of the aviation, submarine, surface warfare, special operations, or any other warfighting community, maintaining conditions for proper rest to optimize health and performance, both inside and outside their operational environments, is of utmost concern," said Navy Lt. Seth Reini, NHRC's research physiologist.

How can we learn to solve this problem of performance degradation after sleep deprivation? The answer requires going back to sleep.

To accurately assess sleep, the current gold standard in clinical practice is by way of polysomnography. This procedure requires careful application of electrode sensors to the scalp, face, and other locations on the body, which can only be done by trained, skilled technicians and typically requires an overnight stay in a laboratory or hospital setting. Physiological signals are recorded from the brain by what is known as the sleep electroencephalograph (EEG). In combination with information about eye and skeletal muscle activity, the EEG provides detailed information about the different sleep stages that we cycle through over the course of a night.

"Interestingly, each of these stages looks like a completely different physiological state in terms of brain activity and muscle tension," said Dr. Gena Glickman, sleep and circadian biologist and lead investigator in NHRC's Biobehavioral Sciences Lab. "It is, therefore, fair to say that not all sleep is created equally, and, further, it is likely that these different stages also have different functions."

Additional vitals are often monitored simultaneously, including respiratory function and heart rate. This detailed observation of sleep is necessary for identifying and distinguishing between various sleep disorders and determining the most appropriate treatment.

"Unfortunately, obtaining proper measurements of sleep quality outside of a highly controlled sleep lab has historically been difficult and not very practical," Reini said. "Traditional, gold-standard sleep monitoring technologies are invasive and immobile."

Not only does sleep cycle in stages over the course of a night, but a typical night of sleep will vary over the course of a career as well. This is particularly true in active-duty service members who must contend with frequently changing work demands and environmental conditions across various phases of the deployment cycle.

Beyond these changes in sleep that occur within an individual, there is significant variation between individuals in terms of the amount of sleep required to perform at optimal levels. For warfighters, these differences must be considered when optimizing performance, resilience, and reset. Traditionally, the only option to characterize these important differences was with polysomnography. Because of the technical requirements and costs associated with performing, analyzing, and interpreting the data, however, it is not a logistically feasible method for monitoring sleep health in active-duty service members while on deployment.

"Validation of noninvasive, highly mobile sleep monitoring technologies would allow for more robust monitoring and evaluation of sleep within a patient's natural sleeping environment," said Reini. "We could monitor sleep both at home and in the operating environment."

At the NHRC, sleep researchers have identified a need for a portable, cost-efficient, and validated sleep monitoring device that can measure sleep in a more detailed fashion akin to polysomnography. Several studies are currently under way testing the efficacy of various technologies that have the potential to assess sleep health in the field.

The sleep research team is seeking tools with the precision and detail necessary for rigorous characterization of sleep quality, identification of sleep disturbances, and, ultimately, earlier and more individually tailored countermeasures.

"Finding this could be a true game-changer," said Reini. "For researchers and medical experts to be able to track and improve sleep quality for our warfighters, this could have a major impact on the overall health and performance of our warfighters."

The team's long-term goal includes developing a model of warfighter readiness that includes information about warfighters' sleep histories to predict future performance. Specifically, the ability to assess repeatedly and accurately sleep patterns over time will be necessary for understanding and tailoring performance optimization strategies for every warfighter.

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▶▶ By Dr. Sunny Fugate and Patric Petrie

eGlove

The battles of the future may not be won using only tanks, aircraft, or ships. The future is likely to include bipedal robotic helpers, augmented reality displays, and methods for exploring and interacting with and melding the worlds of the physical and the virtual.

Consider these three real-world scenarios:

- A Marine hunkered down in the heat of battle, where communications across battle lines can be nearly impossible
- A firefighter battling flames, whether in a raging wildfire or a darkened commercial space ripe with flash points, while also combating disorientation from obscured lines of sight or scant lighting
- A Navy explosive ordnance disposal team attempting to defuse or remove live ordnance while facing threats from a hostile environment.

Now here's a possible solution that could help those on the front lines in each of these scenarios and more: the "eGlove." In 2006, researchers at the Navy's Space and Naval Warfare Systems Center Pacific (SSC Pacific) began developing a next-generation communications technology to help warfighters in dangerous situations—an electronic glove that controls small devices and communicates via gestures.

Anytime an individual is in a sound-challenged, strenuous, or distracting environment, gesture-based approaches can enable and enhance communication and the control of devices large and small.

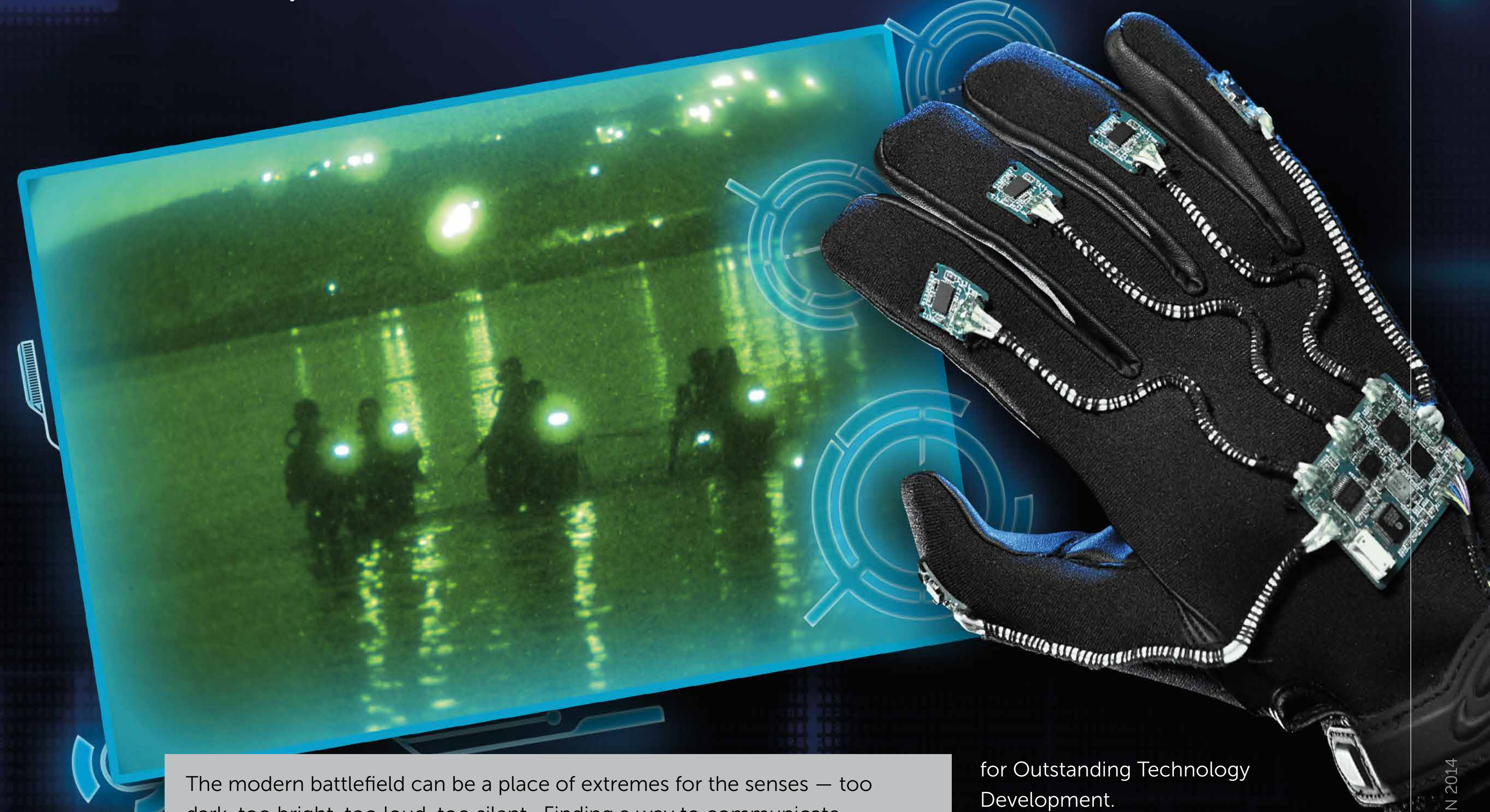
The eGlove was created by SSC Pacific engineer Nghia Tran in his home workshop using a golf glove, a handful of accelerometer sensors, and an LCD display. The eGlove prototype could provide a way for deaf individuals to communicate at a distance and to compose written works using American Sign Language. This proof-of-concept prototype inspired a group of Nghia's colleagues to tackle the sign language recognition problem and to search for novel applications for gesture-based and other forms of visual communication. In addition, a wide range of military applications have also been considered for the eGlove.

Illustration by Alvin Quiambao

In the future, the eGlove technology may be used by Navy divers, NASA astronauts, firefighters, or police officers for computer control while driving or even for intuitive control of autonomous vehicles.

Just by using simple hand gestures, this technology also may be used by:

- Personnel who cannot type on a keyboard, read a screen display, or hear voice communications because of hazardous conditions
- Chemical-biological disposal personnel in mission-oriented protective-posture gear (the highest level of protective gear used in a toxic environment) or Federal Emergency Management Agency and Department of Homeland Security personnel in hazardous material gear
- Military personnel and first responders in noisy, dusty, or smoky environments
- Navy and Coast Guard personnel under noisy storm conditions



The modern battlefield can be a place of extremes for the senses — too dark, too bright, too loud, too silent. Finding a way to communicate with something other than sight, speech, or keyboard is vital for today's warfighters. Photo by Cpl. Lena Wakayama

- Personnel without line-of-sight contact, in conditions with little or no ambient light, or who need covertness/silence
- Sight- or hearing-impaired individuals.

The first version of the eGlove recognized fingerspelling (which is the generic term for a wide range of hand-based languages, American Sign Language being an example). Current versions of the device are far more capable. The eGlove has been used for non-line-of-sight communication, controlling the manipulator of a ground robot for grasping and picking up objects, and directly interacting with computer software user interfaces. It has also been integrated into pilot flight gloves.

In the past few years, gesturing has become a key element of human-computer interaction. Today, we are seeing new incarnations of these ideas in commercial products such as Leap Motion (a plug-in device that detects motion in a limited area), the Myo (worn on the arm), or the Fin (worn as a ring), each enabling gesture-based control of various consumer devices. Navy researchers are investigating how integrating these approaches would make an even better eGlove.

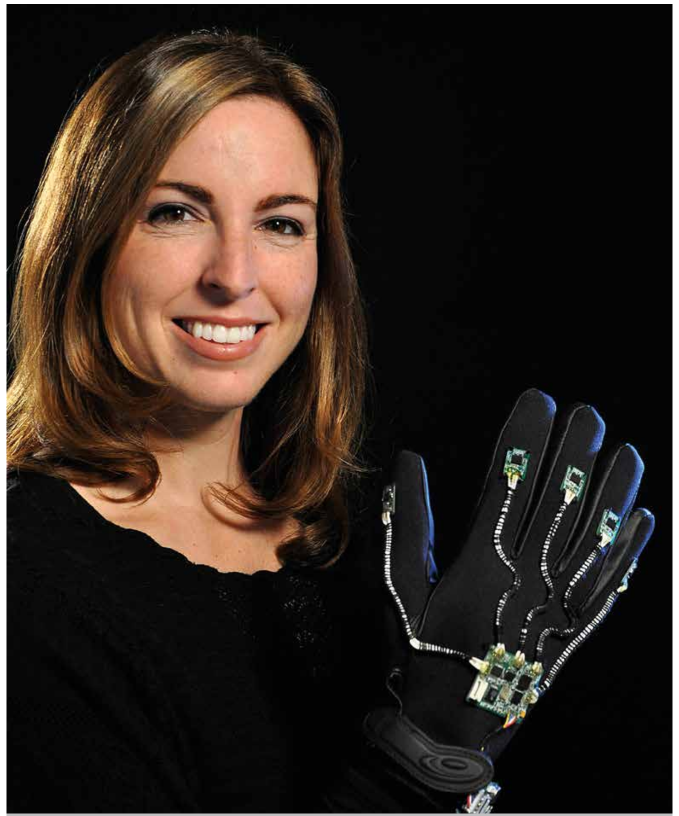
The eGlove is a government-developed technology originally supported as a Science and Technology Challenge project at SSC Pacific. The eGlove technology and the SSC Pacific team have received multiple awards, including the Federal Laboratory Consortium Far West Award for Outstanding Technology Development.

Dr. LorRaine Duffy and her team developed several versions of the eGlove, including a "haptic glove" capable of sending and receiving messages by movement of fingers and hand gestures. Each finger is fitted with an accelerometer and a vibration motor that creates "sense-of-touch" feedback. Movements are translated into language and sent wirelessly from one eGlove wearer to another and sensed by the receiver as vibrations on each fingertip.

The Tactical Situation Assessment Technologies project was a five-year research program examining the use of visual and iconic language and innovative "inscription" devices to improve operator efficiency. This project resulted in numerous papers, multiple patents, an approach for visually augmenting textual displays, and a field-tested electronic glove.

Work on the eGlove continued in the form of a chem-bio glove, or CBGlove, that acts as a human interface for the Joint Warning and Reporting Network system—a command-and-control software application that provides situational awareness for nuclear, biological, and chemical defense.

The eGlove and CBGlove represent some of the most advanced gesture-recognition devices available, but there are complementary technologies under development. SSC Pacific and the CBGlove team also have sought partnerships with commercial companies with inertial-sensor-based gloves. One such company, Anthrotronics, developed the "Acceleglove" electronic glove using similar methods to those of SSC Pacific researchers. The Acceleglove was the result of the company's Haptic Automated Communication System project, an Office of Naval Research (ONR)-funded small business effort to develop a bidirectional communication system using hand gestures and vibrotactile feedback. In parallel to SSC Pacific eGlove efforts, they also have demonstrated an instrumented glove for control of a robotic manipulator arm and control of computer software user interfaces.



The eGlove was developed at SSC Pacific originally as a way for deaf individuals to communicate at a distance.

Recent advances in display technology such as Google Glass and Occulus Rift have created new opportunities for commercial applications for gesture recognition, and are likely to advance the state-of-the-art, highlighting Navy-developed technologies.

SSC Pacific is involved in the Chief of Naval Operations-funded Sea Glass project to identify Navy capability requirements that can be met by devices such as Google Glass. At the same time, ONR TechSolutions, the Defense Advanced Research Projects Agency, and the broader commercial markets are seeking advanced display technologies as well as methods for easily interacting with mobile computing platforms.

Researchers at SSC Pacific are convinced that inertial-sensor-based technologies will eventually expand into broader markets and widespread use, and be combined in clever ways with other human sensor systems such as: myoelectric (sensing electric fields produced by muscle activity), tactile (sensing and interacting with touch perception), haptic (sensing and responding to touching and grasping of objects), proprioceptive (sensing and responding to movement), object recognition and image processing, and even brain-computer interfaces (sensing and responding to brain waves).

About the authors:

Dr. Fugate is an SSC Pacific engineer, scientist, and innovator with more than a decade of experience as a researcher for the U.S. Navy.

Patric Petrie is the lead staff writer for SSC Pacific's public affairs office and a former Navy hospital corpsman.

By Dr. Peter Squire and Pete Muller

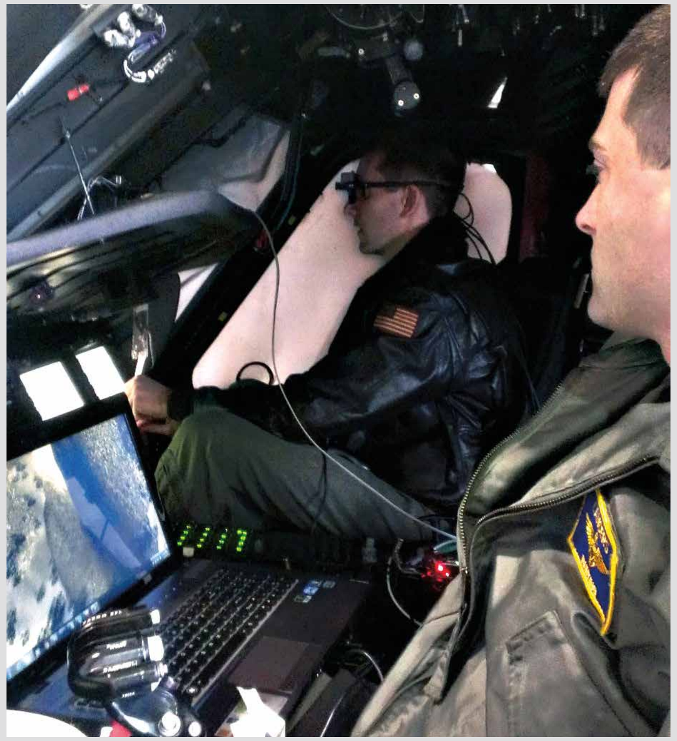
MAKING AUGMENTED REALITY... A REALITY

Lt. Smith wakes up and puts on her augmented reality (AR) glasses. As she walks into her kitchen she says, to no one in particular, "Coffee on." As the coffee starts to brew, she says, "Show schedule," and her daily schedule appears in front of her. After one cup she does some quick stretches and then goes for a run. Her AR display shows her the route to take with discrete arrows and gives her pace and heart rate. "Find me some hills," she commands, and the AR guides her to a new route. Stopping at a traffic light, she sees an acquaintance. Just above his face, a little text marker says his name is John Miller. "Hi, John — how's your run going?" she asks. "Great, thanks!" he answers as the light changes and she speeds off. "Competition," she says, and three virtual runners appear instantly in front of her, accelerating slowly. After passing the "competition," she jogs back to her house. Walking up to the door, she ponders for a moment how she ever lived without AR. She thinks back to the days when she had to look at different devices (coffeemaker, computer, heart-rate monitor, mobile phone, etc.) for information and recalls how annoying and time-consuming it was to interface with all of them.

In this example of an augmented reality system, red LED lights are shown on the person's hands and head. Above him are cameras that track the location of the LEDs to provide information about where the hands and head are positioned. Photo by John F. Williams

Evaluating a Deployable Augmented Reality Display

By Lt. Lee Sciarini, USN



The Deployable Embedded Training System evaluation effort began as a Naval Postgraduate School class project on the topic of human factors in system design, completed by several Navy test pilot candidates: Lieutenants Jason Elfe, Tim Shilling, and Eric Martin. The three students were asked to identify an operational need and propose a novel solution. All three were keenly aware of the pressures of the current aviation environment and the limited ability of simulator training systems to be deployed. The three proposed a solution that would take advantage of an emerging augmented reality (AR) display system. While completing their project, they discovered the CastAR system created by Technical Illusions.

CastAR consists of two main components: a set of stereoscopic projector glasses and retro-reflective material. Together these provide the pilot with an interactive, immersive virtual display outside the aircraft cockpit that is similar to simulators currently in use. With the support of the Naval Modeling and Simulation Office, the group was able to arrange for a subjective evaluation of the CastAR system with multiple aircraft (E/A-18G, E/A-6B, and MH-60S) and naval aviation subject-matter experts at Naval Air Station Whidbey Island.

(Continued on page 48)

AR is a technique that overlays computer-generated imagery on a user's view of the world. If you watch television, you've been exposed to several forms of AR. The yellow first-down line in football broadcasts is the classic example of an AR application. So is the weather map behind the weatherman. Neither element is visible to people who are physically there. AR becomes even more interesting when it is not seen statically through a TV, but dynamically in the real world.

AR is important to the Navy and Marine Corps because of its potential to lower the costs and staffing requirements of live training, which is incredibly expensive and manpower-intensive. As the services begin to balance training needs against limited resources, they must consider combining live-fire training with more cost-effective methods. The aviation community has long been driven to simulator use by the high cost of flight operations. Simulation training has proved to be the only way to get the training needed with limited resources. AR will someday provide a similar simulation capability for infantrymen, allowing them to maneuver around a real environment that enables them to train as they fight.

Two Decades of Support

The Office of Naval Research (ONR) has been pursuing an AR vision for more than 20 years. In 1991, Dr. Steven Feiner at Columbia University received an ONR Young Investigator Program award for research on "Automated Generation of Three-Dimensional Virtual Worlds for Task Explanation." The idea was that by using AR to help with maintenance tasks, one's hands would be free to do the maintenance instead of constantly going back to a maintenance manual.

This early work caught the attention of Dr. Larry Rosenblum, who left ONR Global in 1994 and founded the Naval Research Laboratory's Virtual Reality Laboratory. Under his leadership and vision, ONR continued to fund research to tackle AR's major scientific challenges. Much of that work shaped future efforts, laying the foundation for commercial mobile applications that are available today on smartphones.

One of the critical challenges for AR is "tracking." The AR system needs to accurately calculate the user's head position so it can display the augmentation in precisely the right position. Many early AR research efforts and applications took place indoors in an area tracked by a number of cameras. The cameras track reflective markers, or LEDs, installed on users' heads and objects of interest. These types of systems can produce very high position accuracy, but they are expensive and require a specially instrumented tracking area of limited size. Another type of tracking system uses special 2-D markers, known as fiducials, tracked with a head-mounted camera. While requiring less infrastructure and expense, markers need to be placed everywhere the user is.

Augmented reality allows virtual or constructed elements, such as this T-72 tank, to be integrated into live video feeds.

The ideal tracking system doesn't require any special markers, infrastructure, or technical expertise to configure and use. In 2010, the ONR-managed Future Immersive Training Environment (FITE) joint capability technology demonstration produced the first demonstration of AR over a wide area without using any special markers or infrastructure. The event showcased infantry training in which virtual characters were inserted into a live environment. The research, performed by SRI Sarnoff in Princeton, N.J., combines GPS, inertial sensors, magnetometers, and vision-based tracking. The equipment was bulky and the characters ghostlike, but it demonstrated the art of the possible.

ONR's Augmented Immersive Team Training (AITT) program is continuing to break new ground in AR applications. AITT is a five-year effort (fiscal year 2011-2015) to transition AR technology to the Marine Corps. In early prototypes, ONR concentrated on a Joint Terminal Attack Controller application. Marines and Sailors could observe virtual targets on a live range, control virtual aircraft or artillery, and observe the virtual effects on the live battlefield. The command's current focus is on calls for fire for mortars and artillery, so that observers in live force-on-force exercises can call in and adjust virtual fires.

One of several challenges unique to AR advances is that observers don't just look at the world with their eyes; they use optical systems such as binoculars. To satisfy this need, ONR developed special AR props, including an AR version of the Marine Corps' Vector 21B human-portable laser rangefinder, which functions like binoculars with an integrated laser range finder, compass, inclinometer, and computer. ONR also developed a Portable Lightweight Designator Rangefinder prop, which replicates the form, fit, and function of a Marine Corps laser designator. Both of these props use video cameras to display a properly magnified image with augmentation overlaid on top. The inserted objects must appear stable in the display and cannot jitter and drift as the user pans around and examines the scene with the binoculars; this requires the development of an extremely accurate pose-tracking system for augmentation of the zoomed-in images.

(Continued from page 46)

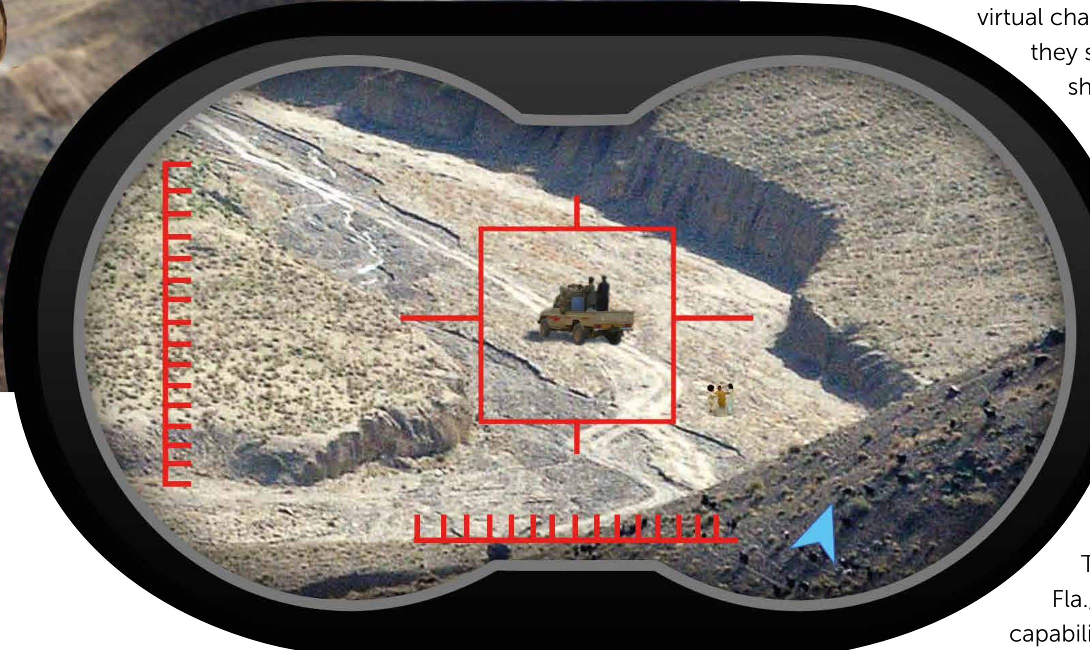
Results revealed that, on average, participants agreed that embedded training could be used to train personnel on emergency procedures, crew resource management, basic flight operations, mission rehearsal for navigation, and mission rehearsal for weapons deployment. If areas averaging greater than neutral ("neither agree nor disagree") but less than "agree" are included, the list of tasks expands to include daytime field landings, nighttime field landings, nighttime ship operations, search and rescue, anti-submarine warfare, low-level navigation, tactical formations, and aerial refueling. When the post-flight results are compared with preflight opinions, participants reported a higher opinion of an embedded system's ability to accomplish training tasks in 12 of the 18 areas with an additional two remaining at least equal to their initial opinion of embedded training.

The results suggest that the aviators have a generally high opinion concerning the potential for embedded systems to preform important familiarization and tactical flight tasks. Perhaps more important, experiences with the CastAR prototype in most cases equaled or exceeded those initial opinions, suggesting that the novel approach used, with continued development, could serve as the visual display system for embedded training.

Proficiency is important to maintaining a high level of operator performance. This is especially true in aviation, where seemingly minor mistakes can have catastrophic results. In an environment of increased deployment lengths and extended intervals between training, it is important to acknowledge the potential for decreases in pilot proficiency and mission readiness. The use of embedded simulation can be an effective method of providing aviators with the training they need and can use while deployed. In addition to being portable, embedded simulation with AR facilitates realistic training by combining actual equipment and a synthetic environment to provide a sense of presence to the user that he or she would not experience otherwise. The potential to provide deployable, embedded training using real aircraft cockpits surrounded by a virtual environment is now firmly in the realm of the possible.

About the author:

Lt. Sciarini, Ph.D., a naval aerospace experimental psychologist, is an assistant professor in the Operations Research Department in the Graduate School of Operational and Information Sciences and the Modeling, Virtual Environments and Simulation Institute at the Naval Postgraduate School.



Current systems use video see-through headworn displays, but within the next year they will integrate optical see-through displays, where the user looks through a transparent display and sees the actual world with augmented reality imagery overlaid.

Another AR challenge that AITT is tackling is creating realistic visuals of virtual battlefield objects, such as tanks and aircraft, and battlefield effects, such as detonations and smoke, with these low-cost wearable systems. While mobile computing technology is rapidly improving, trainers' demands for smaller size, lower weight, and longer battery-powered run time make efficiency paramount. The challenge is compounded by the need to match closely the inserted visuals to the surrounding real-world environment. To accomplish this, natural light sources, the light-diffusing impact of clouds and shadows, and the blurring introduced by the physical limits of real-world optics and video systems all must be reflected in the rendered augmentation. In addition, visuals are not the only cue required to provide a realistic augmented experience. Sounds associated with aircraft and detonations must realistically reflect Doppler shift, flash bang time, and the impact of sound speed on the perception of high-speed aircraft.

AITT is currently using video see-through head-worn displays, but within the next year it will integrate optical see-through displays. With video see-through, the user looks at a video screen that displays both the real world as seen by a camera and the overlaid AR imagery. With optical see-through, the user looks through a transparent display and sees the actual world with AR imagery overlaid. Optical see-through is much more convincing than traditional AR, since the user is looking directly at the environment as opposed to looking at a screen. Ideally, the head-worn display would support the field of view, resolution, and brightness range of natural human vision while being no bulkier than sunglasses. While ONR performers are making progress, displays still need significant improvements before they will be useful for an outdoor infantry use. ONR has sponsored a number of small business programs to improve the brightness, reduce the cost, and increase the field of view of displays.

Future Challenges

One of the big challenges will be designing the human-computer interaction. How much information is needed, and how should it be displayed? It is very easy to provide lots of information, but it is very difficult to provide it in a meaningful and efficient way—not just in your field of view, but in the right place for the task. In a maintenance trainer, for example, the system can highlight the next bolt that needs to be removed. Future research is needed to examine questions of visualization and interaction with information while maneuvering around an environment.

Many of the interesting AR applications will require a significant amount of artificial intelligence. The virtual characters will need to know what they should be doing and how they should be doing it. In the AITT system, we have a sophisticated simulation running in the background that controls the virtual entities.

ONR is just scratching the surface of AR capabilities in the AITT program. The organization is collaborating with the Army Research Laboratory Human Research and Engineering Directorate's Simulation and Training Technology Center in Orlando, Fla., to develop an AR training capability, and the Army Research Institute is funding an ONR team to apply AR technology to the Stryker vehicle, as well as for guidance and repair of vehicles. More can always be done, however, and ONR continues to look for partnerships.

Thanks to ONR's foundational research, military trainers soon will employ AR to combine the best of traditional live and virtual training. In an era of reduced budgets, this will enable more affordable, widely available, and realistic training.

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A LOOK AHEAD
POWER PROJECTION

►► Dr. Walter F. Jones

The next edition of *Future Force* will focus on "power projection." It is a fitting topic to remind us all that our ultimate customer is the men and women in uniform who serve and protect our country, every day. The science and engineering community develops technological advantages to ensure that, when called upon, our Sailors and Marines never have to settle for a fair fight.

In addition, the winter issue will coincide with publication of the new *Naval S&T Strategy* and our community's premier event, the Naval Future Force Science and Technology Expo, to be held 4-5 February 2015 at the Walter E. Washington Convention Center in Washington, D.C. (see: www.onr.navy.mil/expo to register). Power projection is just one of nine focus areas in the new strategy that will be fully explored with participants at the expo.

U.S. naval capability must be respected around the world and decisive when needed. The *Naval S&T Strategy* guides research investments today to ensure the Navy and Marine Corps will remain relevant to a dynamic world by maintaining a broad portfolio of science and technology initiatives to build the future force.

Accordingly, the *Naval S&T Strategy* is simple, yet bold: "To discover, develop and deliver decisive naval capabilities, near to long term, by investing in a balanced portfolio of breakthrough scientific research, innovative technology, and talented people."

Consequently, the power projection focus area aims to strengthen and enhance naval power-projection capabilities and integrated layered defense by improving manned and unmanned platforms, payloads, and weapons. This will enable U.S. and partner nations' forces to complete missions at extended ranges within hostile environments by avoiding, defeating, and surviving attacks.

Future adversaries will seek to neutralize U.S. conventional advantages by capitalizing on asymmetric capabilities that incorporate mobility, range, speed, and deception. The power projection focus area will help naval forces to defeat these emerging and proliferating threats. At the same time, the fleet/force must be able to strike effectively at targets with survivable, scalable, and cost-effective weapons that have sufficient range, speed, and accuracy to complete a variety of missions. In addition, this technology should reduce risk to our warfighters without creating unnecessary collateral damage or loss of life.

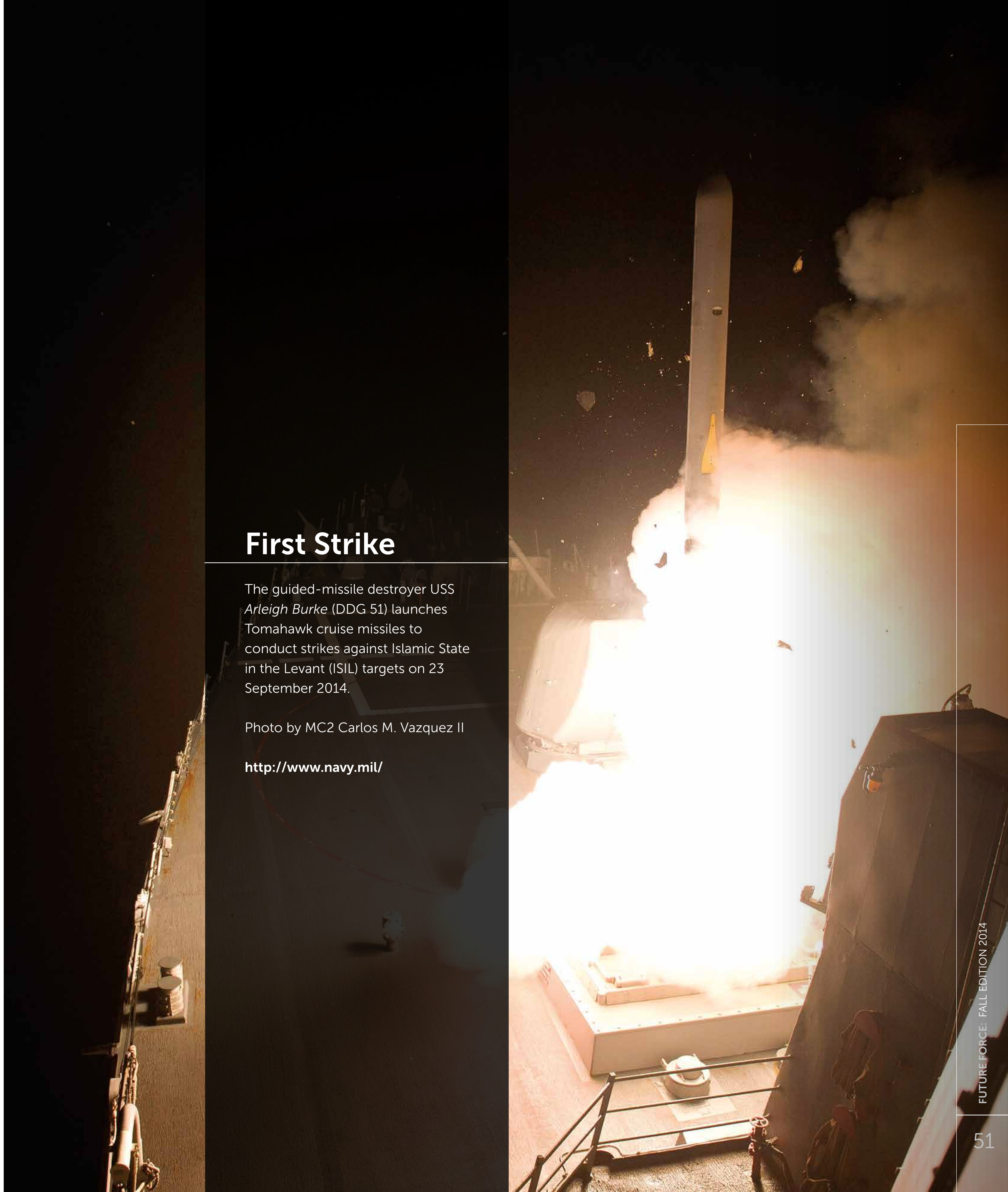
New research-and-development initiatives in standoff, electromagnetically launched hypervelocity projectiles, hypersonic missile propulsion, scalable weapon effects, and directed-energy weapons will deliver game-changing capabilities and drive favorable cost/benefit ratios for these investments. In addition, other efforts will exploit the emerging concept of distributed lethality of the force and gains in time-sensitive strike capabilities to improve the ability of naval forces to engage the enemy at extended ranges across the maritime domain in the littorals, inland, and on the high seas.

In short, power projection is about giving our naval commanders the advantage throughout the spectrum of scalable effects: to deter, damage, or destroy an adversary.

The winter issue will explore multiple programs and perspectives of power projection. It also will be distributed to participants at the Naval Future Force S&T Expo along with the new *Naval S&T Strategy*, so that participants can discuss the objectives of all nine focus areas, the status of key programs, and new research opportunities.

I hope to see you at the expo in February!

Dr. Jones is the executive director of the Office of Naval Research.



First Strike

The guided-missile destroyer USS *Arleigh Burke* (DDG 51) launches Tomahawk cruise missiles to conduct strikes against Islamic State in the Levant (ISIL) targets on 23 September 2014.

Photo by MC2 Carlos M. Vazquez II

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