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VIRTUAL REALITY FOR WARFIGHTERS

A SAFE SPACE FOR CONJURING THE FUTURE FLEET

FORECASTING THE MIRROR IN THE SKY

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Front Cover: Designed by Jeff Wright

NOT JUST A FAD: VIRTUAL REALITY REALLY DOES BENEFIT THE MILITARY

By Dr. Karl F. Van Orden, Dr. Jamie Lukos, Dr. Robert Gutzwiller, and Heidi Buck

IT'S EASY TO SEE THE COST SAVINGS OF VIRTUAL REALITY TRAINING—BUT IS IT AS EFFECTIVE AS, OR EVEN BETTER THAN, OTHER TYPES OF TRAINING? THE SCIENCE SO FAR SUGGESTS THE ANSWER TO BOTH QUESTIONS IS YES.

Augmented reality (AR) and virtual reality (VR) systems are increasing in quality and decreasing in price in incredibly short time spans.[1] It is estimated that mixed reality (MR) technologies will have 95 million users by 2020, and that number more than triples by 2025.[2] The military takes an active interest in exploring the advantages of these technologies because of their great potential to help warfighters orient and train for missions in challenging environments, and operate with greater efficiency.

Many current applications of VR have focused on training, where an attempt is made to recreate situations individuals face in tactical environments. One clear example is flight simulators, which have grown in complexity and capability to the point of becoming immersive, challenging, and a valid means of learning how to perform a real-world task. The Federal Aviation Administration regularly provides guidance and directives on flight simulator evaluations and qualifications for pilots of commercial carriers, including how they are used in training and how they represent accurate scenarios involving stalls, recovery maneuvers, inclement weather, and dangerous conditions. Simulator time is put toward basic pilot rating achievement, and the acceptability of these hours is increasing. VR systems can make this training less expensive and more portable.

Space and Naval Warfare Systems Center Pacific has established the Battlespace Exploitation of Mixed Reality (BEMR) lab to demonstrate the art of the possible for applying AR and VR technologies to Navy-relevant areas of interest such as training, maintenance, and new user interfaces for a variety of operational environments. The laboratory has demonstrated capability concepts in the areas of flight deck training, shipboard deck gunner targeting and firing instructions, development of 3D models of actual shipboard spaces for installations and modifications (based upon LIDAR scanning), and specific maintenance training.

In the near future, with the enabling capability of VR, fleet maintenance workers will have the ability to gain expertise in highly skilled tasks that now require significant time and travel to expensive training facilities, and will use AR glasses to complete highly detailed tasks without the need to tediously search through paper manuals. Ship commanding officers and department heads will have instant visibility of critical information to enhance decision making and situational awareness. AR will allow personnel standing watch on the bridge of a ship to see track information fused with their view of the ships (or lights at night) out on the horizon. Special warfare personnel will prepare for and execute missions using VR and AR technologies, equipped with vital information—including navigation and enemy position data—whereas today's warfighters have no direct or fused access.

Beyond the novelty of AR and VR visualization approaches, and the variety of applications outlined above, are there good perceptual and cognitive reasons for using them? Are there scientifically sound reasons to embrace MR technologies, or are we simply enamored with the latest superficial display technologies?

We describe a few of the most important underlying cognitive, sensorimotor, and perceptual processes associated with the success of current technologies and make the case for further exploitation of VR and AR technologies in the military. Although AR technologies appear to have tremendous utility, the rationale for their use is less understood at this time.

Emotional Engagement

An important advantage of virtual reality compared to traditional visual displays is the greater experience of presence, or "engagement." Greater engagement is typically associated with greater excitement, anxiety, or fear. Virtual reality produces more intense emotional responses to evocative images such as snakes, spiders, or faces, than traditional display methods, such as computer monitors.[3] VR seems to increase the salience of stimuli and experiences, perhaps by reducing extraneous distractions, in keeping with applied research on attention and learning.[4] [5] In addition, once in VR one cannot "look away" from the virtual world without taking the device off, removing the capacity for some types of distraction. VR may come with some costs (e.g., motion sickness). If poorly designed, augmented AR displays may also create distractions when overlaid on the real world, such as visually blocking items of interest.[6]

The emotional dimensions associated with VR experiences are important, as we know from decades of work in the neurosciences that experiences containing greater emotional qualities form more durable and lasting memories in the brain.[7] The feeling of presence in VR—as compared to traditional display modes—also has been shown to result in cortical activation responses in the prefrontal brain regions related to visual processing and self-reflective thoughts, regardless of the actual visual stimuli.[8] This biological response is critical if VR is to be used as a training approach for military missions by producing more memorable mental representations of complex processes and procedures.

Photo by Lt. Megan Chester

The greater salience of virtual environments, and subsequent engagement in them, has been central to its use in clinical rehabilitation of service members with post-traumatic stress disorder (PTSD). Patients are first carefully reintroduced via the virtual battlefield by clinical psychologists, who monitor them for adverse stress reactions. The virtual world can be made more or less stressful with various sights, sounds, and even smells. This more immersive technique allows the patient to learn to regulate their emotions in a controlled and constructive way, and, in doing so, successfully desensitize the brain from the traumatic events that produced PTSD.[9] This mode of treatment has been found to be highly effective when compared to traditional treatment models, and has also been used for reducing fear of flying, suggesting its further potential against phobias and other psychological phenomena.[10]

Movement Coordination

Constraints surrounding space, budget, travel, and other factors have shifted the majority of today's military training to noninteractive demonstrations on computer displays. Notably, a lack of interaction violates principles of skill learning especially for complex tasks. Physically engaging in a task or environment is generally more conducive to learning and memory retrieval (remembering what you learned) than static or observational exercises. To that end, VR technologies allow for far more interaction, as they are less resource constrained, remove dangerous conditions, and allow for failures with immediate feedback. For example, learning a new complex motor skill often requires personal, human-in-the-loop familiarity. Although some learning can and does occur through observation, skill consolidation (the strengthening in your performance over time) as well as motor performance are better when participants learn through doing versus observing—particularly for motor sequence timing.[11]

Virtual and augmented reality systems continue to be integrated into the fleet. Here, CWO4 Noel Genao, an instructor at the Littoral Combat Ship Training Facility aboard Naval Station Mayport, briefs Sailors on a virtual-reality training module as part of a tour for the annual reserve leadership symposium hosted by Littoral Combat Ship Squadron 2. Photo by MC2 Michael Lopez

During learning there is evidence that the area of the brain activated during the task shifts from premotor cortex and cerebellum during initial learning, to the frontal cortex during retention.[12] This shift in the cortical activation patterns through physical practice is critical for training effectiveness and retention. VR allows users to interact and move in the environment, building and practicing those skills—and this has been shown to amplify learning rates, particularly when learning novel tasks.[13] VR in sensorimotor rehabilitation after stroke, traumatic brain injury, or amputation, has also shown improvements for motor rehabilitation.[14] [15] For recovery of function in the areas of gait, hand and arm coordination, and balance, there are critical periods where more intensive therapy can make a positive difference, and VR enables more flexible and accessible complex treatment protocols.[16]

Spatial Perception

Another area in which VR is improving our lives is in architecture, where it is helping to overcome our perceptual limitations. For example, architects are sometimes surprised by the structural outcome of their designs, in that the space doesn't have the same feel or look that they had expected. This modeling-to-reality mismatch may have to do with well-known perceptual distortions—the flattening of objects that fall perpendicular to the line of sight. A number of studies have found that the tilt of objects is typically perceived or underestimated as flat to the observer.[17] [18] This tilt results in the common misperception that distant hills appear far steeper than they really are when viewed from up close.[19] Others have found this effect exists for smaller nearby objects as well.[20]

Architects are deriving significant benefit from modeling and experiencing newly designed structures in VR to better understand how spaces will look and feel to inhabitants, discover how spaces will look at different times of day, and share designs with others without needing to be in the same physical space. These benefits will also be recognized by maritime architects and shipboard installers/maintainers in the near future, as it is widely known that individual ships of the same class (even consecutive ships from the same shipyard) have physical differences between them despite being constructed from the same plans. VR has an important advantage in that it allows an observer to experience angular dimensions of objects and spaces by observing them from different perspectives. There are already commercial applications to support this purpose, which basically work by ingesting architectural drawings

A Marine with 5th Battalion, 11th Marine Regiment, 1st Marine Division, loads an electronic M2 .50-caliber machine gun in a combat convoy simulator at Marine Corps Base Camp Pendleton. Photo by Cpl. Demetrius Morgan.

and converting them into virtual space. In addition, the capability to create three-dimensional models from various scanning technologies continues to grow, allowing high-fidelity visualization of unique and complex environments.[21]

Summary

The use of VR technologies for gaming and entertainment has grown tremendously, subsequently driving down cost and enabling significant improvements in performance. The opportunity to apply MR technologies to numerous military applications now is feasible and justified given current perceptual, sensorimotor, and cognitive findings. VR experiences are more engaging, memorable, and perceptually real compared to other methods of training or familiarization. AR displays will soon allow individuals to navigate and gain important information in an entirely "heads-up" manner, without having to look at ancillary displays. Lastly, VR display technology, coupled with 360-degree film technology, will allow military personnel to experience rare or unusual events and become better prepared for, and less surprised by, what they see. Though the future is promising, we still must be cautious in application, as no technology is a cure-all, and a great deal of MR technology still needs to be created, tested, and applied in a user-centered design fashion.

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Photos courtesy of Naval Surface Warfare Center Dahlgren Division

NEW NAVY I-LAB CREATES A SAFE SPACE FOR CONJURING THE FUTURE FLEET

By John Joyce

NAVAL SURFACE WARFARE CENTER DAHLGREN DIVISION HAS A NEW CENTER THAT USES TECHNOLOGY TO MAXIMIZE COLLABORATION AND INNOVATION.

In 2017, the Naval Surface Warfare Center Dahlgren Division (NSWCDD) established the “Innovation Lab,” or I-Lab, as a place to explore transformational ideas. As scientists and engineers use the new lab, NSWCDD officials anticipate a surge of technological advances, approaches, and capabilities to further enhance the capabilities of the nation’s warfighters.

“The I-Lab is engaging our workforce and helping to retain talent through challenging collaborations, critical thinking opportunities, and rewarding problem solving for the warfighter,” said NSWCDD’s technical director, John Fiore. “It is my belief the pursuit of these types of labs will unleash the entrepreneurial spirit of our scientists and engineers to ultimately benefit our customers—Sailors and Marines keeping our nation secure and hoping to come home to their loved ones safe.”

The I-Lab—equipped with state-of-the-art equipment, services, and trained personnel—opened for business over the summer as an intensive collaborative environment where technical experts work to speed up and maximize corporate innovative solutions.

“I am very excited about our new I-Lab that stimulates, promotes, and merges ideas into concepts for analysis, prototyping, experimentation, and transition as needed, but this is only the beginning,” said Fiore. “We have plans to expand our free play environments to include workshops that will allow us to free play with a variety of technologies, machine tools, and 3D printers.”

Innovators are using gear that includes mobile networked touch screens with collaboration Bluescape™ workspace capability, a 3D printer, Surface Pro™ computers, a multitouch collaboration table, self-contained holographic glasses, mobile glass boards, and an unclassified video teleconference capability.

The I-Lab is reconfigurable to support large innovative workshops as well as smaller, more focused events, including classified and unclassified break-out rooms. For example, NSWCDD and the Naval War College cosponsored the command’s first surface warfare innovation workshop in October 2017.

“The workshop was focused on gaining a foundation for current and future warfighting concepts and requirements,” said Fiore. “Presentations and panel talks provided the opportunity for our technologists, engineers, and scientists to learn from OPNAV [Chief of Naval Operations staff] strategic planners, OPNAV surface warfare specialists, and visionaries.”

Robotics and Quantum Computing

Future world models of military-political environments, Navy missions, and warfighting requirements were featured to stimulate possible technology and functional solutions.

“Solutions ranged from continued employment of current functional capabilities to the use of autonomy, robotics, quantum computing, and other advances in science that can be installed in Navy ships and assets,” said Nelson Mills, I-Lab’s director of innovation.

On the event’s first day, flag officers and senior government officials spoke with 60 NSWCDD experts about surface, air, and undersea warfare.

Rear Adm. Jesse Wilson, Naval Surface Force Atlantic commander, emphasizes the importance of innovating to the strategic environment as he spoke to a group of civilian technologists and military officers at the first in a series of Surface Warfare Innovation Workshops held at the Navy’s newest Innovation Lab.

"We gained incredible insights from over 20 senior leaders on a variety of surface warfare topics, challenges, and issues," said Mills. "Team members were exposed to a new brainstorming thought process. They expanded personal networks, met and worked with incredibly talented people, and further developed their ability to innovate while engaging with guest speakers and panels."

Four panel sessions were conducted on surface force strategy, warfighter perspectives, unmanned systems integration, future fleet structure, digital warfare advances, emerging capability requirements, future technologies, and possible warfighting futures. Panel members conveyed their experience, concerns, issues, knowledge, and vision for the future of surface warfare.

In addition, the panel discussed Navy themes related to interoperability, mission planning, enhanced weapons, and an abundance of inexpensive deployed unmanned systems in the fleet.

Throw Away the Rule Book

Naval War College professor Dr. William Bundy encouraged workshop participants to throw away the rule book, think out of the box, think without a box, imagine, and, perhaps most of all, have fun throughout the workshop.

"The workshop enabled Navy leadership to share current and future fleet concerns with our new and midcareer personnel to develop united, focused, and creative solutions," said Mills. "Our innovators were invigorated through motivational speakers as we identified, addressed, and overcame impediments along the way."

Naval Surface Warfare Center Dahlgren Division engineers launch a Scan Eagle unmanned aerial vehicle at the Potomac River Test Range. A panel session on the Fleet's integration and interoperability of unmanned systems, such as Scan Eagle, took place during a Surface Warfare Innovation Workshop. (Photo by John F. Williams)

The participants—mostly civilian scientists and engineers as well as a few active-duty military officers—responded by brainstorming about technology that enables functional capabilities, including sensors, networks, command and control, weapons, distributed lethality, and battle management concepts.

They broke up into groups that tackled a myriad of naval warfighting scenarios generated by the Naval War College for the 2020, 2025, and 2030 timeframes. On the final day, the break-out groups presented their culminating concepts to Rear Adm. Jesse Wilson, Naval Surface Force Atlantic commander.

Wilson emphasized the importance of innovating to the strategic environment and getting new technologies into the hands of Sailors quickly. The next 25 years in the maritime security environment is going to be very different than the last quarter of a century, he told the participants, adding that it's essential to prepare for changes and challenges while innovating to ensure the Navy is ready today and tomorrow.

In all, four teams of NSWCDD scientists and engineers worked with specific scenarios, approaches, and solutions by employing the IDEO (innovation, design, engineering, and organization) process while brainstorming to achieve innovative answers, potential prototypes, and integrated kill chain capabilities. A "kill chain" refers to the process of identifying and thwarting threats, typically from reconnaissance, until the threat is eliminated. It also applies to threats in cyberspace and to the electromagnetic spectrum, identifying and eliminating intrusions in the networks.

The teams' four scenarios were:

- Credible combat power in the sea frontier: protection of the U.S. East Coast, West Coast, and Gulf of Mexico in 2020.
- Securing the maritime commons: antipiracy mission off the Horn of Africa in 2025.
- Maritime strategic deterrence: ballistic missile defense-type mission with 40 percent of the U.S. Navy being unmanned in 2025.

Marine Corps Capt. Daniel Dial, left, an unmanned aircraft system officer assigned to Marine Medium Tiltrotor Squadron 162, 26th Marine Expeditionary Unit, speaks with Navy Rear Adm. Kenneth Whitesell, commander of Carrier Strike Group 4, about the RQ-21 Blackjack aboard the amphibious transport dock ship USS *New York* (LPD 21). A panel session on the Fleet's integration and interoperability of unmanned systems, such as the Blackjack, took place during a Surface Warfare Innovation Workshop. (Photo by Cpl. Jered T. Stone)

- Capstone: maritime battle force, at war in 2030.

Themes comprising autonomy, automation, artificial intelligence, and machine learning were addressed by the teams.

At the conclusion of each scenario, as part of the IDEO framework, the teams described their innovative solutions acquired via brainstorming, introduced possibilities along with prototype ideas, and presented a realistic capability solution using a system integration or kill chain approach.

Technologies for the Future Fleet

NSWCDD is planning future surface warfare innovation workshops to be held at dates to be determined. The events will explore technology and systems development opportunities for the Navy's future surface combatant fleet, potential new capabilities affecting the Navy's most technologically advanced surface combatant, USS Zumwalt (DDG 1000), and autonomy enabled by artificial intelligence and machine learning via unmanned surface ships.

A workshop focusing on the Navy's future surface combatant would assess functional capabilities and alternative sensors, weapons, and control systems envisioned for the future surface combatant fleet.

"NSWCDD innovators can learn what is initially planned for the fleet and offer advances in sensors, control-networks, weapons-effectors, and other technologies," said Mills. "Sponsors for a future surface combatant workshop would include recently hired NSWCDD engineers and technologists, mid-term engineers and innovators, and OPNAV N96 [Director, Surface Warfare] invited surface warfare officers. The outcome of this workshop would provide assessments of planned and alternative payloads, sensors, and systems; create innovative solutions; and offer fleet-perspective learning for NSWCDD staff."

A Zumwalt capabilities workshop—in cooperation with the Navy's surface warfare directorate and the commander of Pacific Fleet—would explore innovative capabilities for Zumwalt-class guided-missile destroyers. It would assess employment roles for these destroyers and explore technologies that will enable role missions, integration, and interoperability with the fleet.

"Participants should include fleet planners, Zumwalt-class guided-missile destroyer officers, OPNAV surface warfare directorate personnel, naval operations for information warfare personnel, OPNAV future fleet design and architecture staff, NSWC engineers, and other participants who can contribute to the workshop goals," said Mills.

A workshop featuring autonomy enabled by artificial intelligence and machine learning through unmanned surface ships could be held in cooperation with the deputy assistant secretary of the Navy for unmanned systems in conjunction with the Navy's surface and undersea warfare centers.

"It would explore near, mid, and far-term unmanned system integration opportunities for unmanned surface ships," said Mills. "These integration opportunities include the range of surface force employment of unmanned surface vehicles and ships. In fact, we identified one functional capability during the inaugural workshop that deserves further assessment and possible technical solutions."

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Photo by MC3 Ian Kinkead

CONDUCTING HEAT STRESS RESEARCH UNDER WAY GETS RESULTS

By Regena Kowitz

HIGH TEMPERATURES IN AND ON SHIPS CAN BE A PROBLEM FOR PERSONNEL AT ANY TIME. SAILORS AT SEA, SUCH AS THIS AVIATION BOATSWAIN'S MATE ABOARD USS *NIMITZ* (CVN 68), ARE WORKING WITH RESEARCHERS TO DISCOVER HOW TEMPERATURE AFFECTS READINESS.

The From the flight deck on an aircraft carrier to the engine room on a destroyer, life aboard a Navy ship can heat up quickly. Extreme heat and humidity in work spaces such as the galley and laundry can create conditions that lead to heat stress and injuries, significantly affecting operational readiness.

When high temperatures cause Sailors to become heat casualties, military operations may be hindered by lost productivity and fewer personnel to carry out mission-essential tasks. In 2016, there were a total of 156 Navy heat-related illnesses, the lowest of all military services, according to a report from the Armed Forces Health Surveillance Center. Fortunately, the Navy has a very effective heat stress prevention program, which likely has prevented that number from being higher.

Maintaining mission readiness and protecting Sailors from becoming heat casualties makes it necessary to reduce exposure to extreme heat by limiting the amount of time personnel spend in hot spaces.

To keep Sailors safe and manage workflows, the Navy has established guidelines that determine how long Sailors can work in specific areas where they are exposed to high heat or humidity—these allowable times are known as "stay times." They are calculated using physiological heat exposure limits (PHEL), which are based on the specific physical demands of job-related tasks (metabolic demand) and the environmental conditions in each workspace. The PHEL is visualized as a curve, ranging from I to VI (low to high metabolic demand)—as the PHEL increases for a particular job, the allowable stay time decreases.

The PHEL curves used aboard ships today were originally established in the 1960s and have helped prevent heat stress injuries for decades. Since then, there have been many advances in shipboard automation and technology. Modern Sailors have high-pressure dishwashers and push-button laundry presses. Jobs that were once labor-intensive are now automated. The PHEL curves that were developed decades ago may no longer accurately represent the current work demands for several shipboard tasks.

Helping Sailors Keep Their Cool

Scientists at the Naval Health Research Center (NHRC) have launched a pilot study to determine if the existing PHEL curves need to be revised by evaluating metabolic demand for Sailors working aboard modern, technologically advanced Navy ships.

Preventing casualties from heat exposure and stress is an area of research that NHRC has been studying for decades. Jay Heaney, lead environmental physiologist for NHRC, has been at the forefront of this research, developing strategies to reduce and prevent heat injuries for nearly 30 years.

In fact, Heaney was one of the scientists who developed the Automated Heat Stress System (AHSS) at NHRC in 1997 to improve shipboard heat stress monitoring. The AHSS provides an accurate measure of thermal conditions in a specific environment by factoring in air temperature, radiant (heat reflected off one object and absorbed by another) or black globe temperature (a combined measure of air temperature and radiant heat), and relative humidity. The AHSS then automatically calculates PHEL curves, a task that once required Sailors to manually take temperature readings in each work area. On a typical Navy destroyer, manual readings could take up to three hours but now, with the push of a button, the AHSS prints out the shipboard heat stress conditions and PHEL curves.

Building on his past research, Heaney and his team are leading the current PHEL study. To collect the most accurate data about shipboard heat exposure conditions and work-related metabolic demands, NHRC researchers are taking science directly to Sailors by getting under way with them.

Shipping Out

Conducting research aboard an operational warship isn't easy, but it is the best place to collect ecologically valid data (data that applies to real-world environments) about shipboard heat stress conditions. Several years ago, NHRC researchers attempted to determine metabolic rates while Sailors were working on ships in port but they quickly realized these activities were not representative of the duties performed at sea.

Before data collection could begin, Heaney and his team had to manage several logistical hurdles. They had to figure out how to transfer research equipment onto a deployed ship, obtain authorization to recruit Sailors for the study, and get the scientists on and off the ship.

After logistical problems were solved, the environmental physiology team was ready for their next step—figuring out how to manage research aboard a ship under way.

In June 2017, the team went aboard USS Nimitz (CVN 68) to test their equipment and determine the best methodology for collecting high-quality data on a deployed aircraft carrier. During this trip, the team also had to work out the challenges inherent to shipboard environments, everything from confined spaces and electromagnetic interference to foreign object containment on the flight deck.

With all the preparations finished, Heaney's team headed out to Nimitz again to begin the first official PHEL data collection session—this time in August, while the ship was deployed in the Persian Gulf.

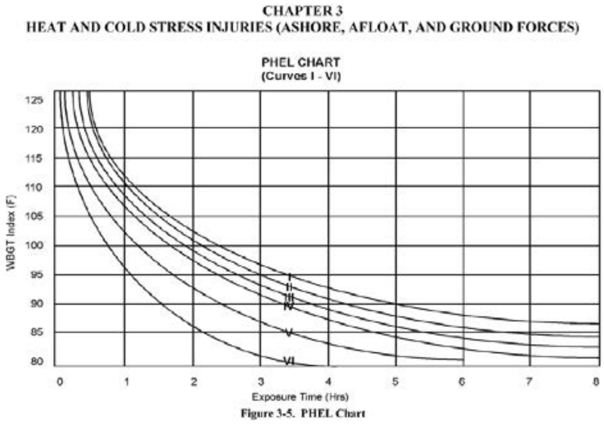
After they arrived, the team had to find a place to set up a "mini lab" where they could prepare and outfit subjects with research equipment, download data, and clean and sanitize equipment. They also needed to identify Sailors who would be interested in enrolling in the study and then recruit, consent, and schedule them. When all this was done, the team was ready for data collection.

Research Under Way

Heaney and his team spent three weeks collecting data aboard Nimitz. During that time, they recruited 35 participants from different work spaces and departments, including the scullery, galley, waste management, laundry, catapult, reactor, flight deck, and the hangar bay.

While the ship was under way and the participating Sailors were performing routine shipboard work, Heaney and his team were in the work spaces right alongside the Sailors,

Jay Heaney, left, an environmental physiologist at the Naval Health Research Center, adjusts heat stress testing equipment during data collection aboard USS Nimitz (CVN 68).Photo by MCSN Jose Madrigal/Released



The physiological heat exposure limit (PHEL) chart helps determine allowable stay times (x-axis) based on one of six PHEL ratings (the curves on the chart) and the wet bulb globe temperature (WBGT) (y-axis). To use the chart, a Sailor would find their PHEL rating (scullery personnel would be assigned a PHEL V) and the WBGT measurement (measured in each workspace), find where they intersect on the chart and drop down to the x-axis to find their stay time. (PHEL Chart from Chapter 3 of the U.S. Navy Bureau of Medicine and Surgery's Manual of Naval Preventive Medicine.)

collecting physiological measures to determine how the Sailors' bodies were responding to heat stress.

Using specialized equipment that included a portable metabolic measurement system, adhesive skin patches for skin temperature, and an ingestible core temperature pill, researchers collected measures for body temperature (core and skin), heart rate, and oxygen consumption (to measure metabolic rate).

Several hours before each data-collection session started, a participant would ingest a core temperature pill and don a wearable heart rate monitor to establish his or her baseline temperature and heart rate. Shortly before the participant reported for duty, a member of the research team would place the adhesive skin patches on the participant to collect skin temperature. The last step was to have the Sailor put on the portable metabolic measurement system, which resembles an oxygen mask. Once all the equipment was in place, the Sailor went to work.

The physiological data collected by researchers, along with information about work space conditions, which was measured using a thermal environment monitor that captured wet and dry temperatures, will help researchers gather important information about the existing PHEL curves and current heat stress conditions.

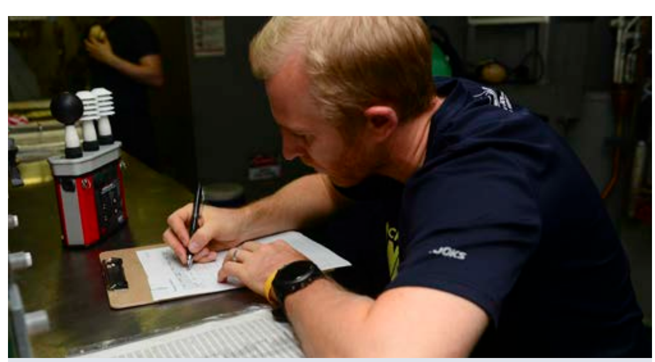
A First Time for Everything

The most significant aspect of the study was being able to collect data for Sailors working on the flight deck, which is one of the most exciting and dangerous places to work on an aircraft carrier. Collecting metabolic work rate data, heart rate, and core and skin temperatures on flight deck personnel during flight operations aboard a deployed aircraft carrier is unprecedented in the field of environmental physiology.

When the original PHEL curves were developed, no data were collected for Sailors who worked in hangar bays or on flight decks. Conditions on a flight deck for a ship deployed to places such as the Arabian Gulf can be extremely hot. The combination of heat and humidity means clothing quickly becomes saturated from a combination of the humid environment and sweat production. Other factors that increase the heat stress experienced by Sailors are the radiant heat from the sun beating down on the deck and the hot exhaust from jets conducting flight operations—it all adds up to make the flight deck a hot place to work.

Being allowed to conduct research on the busy deck of a deployed aircraft carrier, with jets taking off and crew moving about, meant NHRC's scientists had to take several safety precautions. Heaney and his team ensured every piece of data collection equipment was secured safely to study participants who worked on the flight deck. In addition, these Sailors had to be inspected by a flight deck supervisor every time they reported to work wearing the research equipment.

The new data collected by researchers will be incorporated into current PHEL curves, helping to prevent



Doug Jones, an exercise physiologist at the Naval Health Research Center, records environmental conditions from a handheld heat stress monitoring system while conducting research aboard Nimitz. Photo by MCSN Jose Madrigal

To gather data about environment conditions in work spaces aboard Nimitz, Naval Health Research Center personnel used a thermal environment monitor that measures both the wet and dry temperatures. Photo by MCSN Jose Madrigal

heat injuries among Sailors working in these locations and to maintain their readiness.

Research for Readiness

According to researchers, preliminary data support their hypothesis that because of automation and technology there are discrepancies in metabolic demands between the current PHEL curves and the measurements they collected from Nimitz. But there is still more work to be done before they can make a final recommendation about whether the PHEL curves need to be revised.

Data collection aboard Nimitz is complete but Heaney and his team will be collecting more information from two additional ships (a destroyer and amphibious assault ship) in 2018 before finalizing their analysis.

If the science indicates the PHEL curves need to be revised, this could change allowable stay times for Sailors and further reduce the potential for heat stress casualties. With less risk for heat stress casualties, the ships and their crew will be better prepared for conducting combat operations in hot environments.

Ultimately, the work being done by Heaney and his environmental physiology team will help Sailors working in hot and humid workspaces, ensuring they remain healthy, safe, and mission ready.

About the author:

Regena Kowitz is a contractor for Naval Health Research Center public affairs.

HEAT INJURIES

Heat injuries can range from mild (heat rash) to life-threatening (heat stroke) and result in the need for short-term medical care or permanent disability. Within the range of heat injuries, affected personnel can experience symptoms of confusion, fatigue, muscle cramping, nausea, or vomiting—any of which can keep Sailors from performing their jobs.

Physiologically, when a Sailor experiences prolonged heat exposure, core temperature rises and the body works to cool itself. The higher the core temperature climbs, the more strain is placed on the body as it tries to regulate temperature. Significant environmental heat can place too much strain on the body, preventing temperature regulation and leading to a dangerous rise in core body temperature that can cause heat stress injuries. The different types of heat injuries include:

- Heat rash is a skin irritation caused by heat stress exposure. It usually appears as red bumps on the neck, groin area, or under the arms.
- Heat syncope (fainting) is most likely to occur when unacclimated personnel are first exposed to heat stress or by personnel standing still in the heat (for example, standing in formation).
- Heat cramps are painful cramps, usually affecting the extremities and abdomen. They primarily occur in individuals performing vigorous physical exercise in heat stress conditions.
- Heat exhaustion is a more serious heat stress exposure injury. Heat exhaustion may be related to either dehydration or salt depletion. Personnel usually require medical treatment to ensure they are properly recovering and rehydrating.
- Heat stroke results when the body's ability to maintain optimum core body temperature fails. Heat stroke is a medical emergency and can be lethal or have life-long lingering after effects.

TOPSIDE DELIVERS BETTER COMMAND AND CONTROL FOR UNMANNED SYSTEMS

By Susan Farley

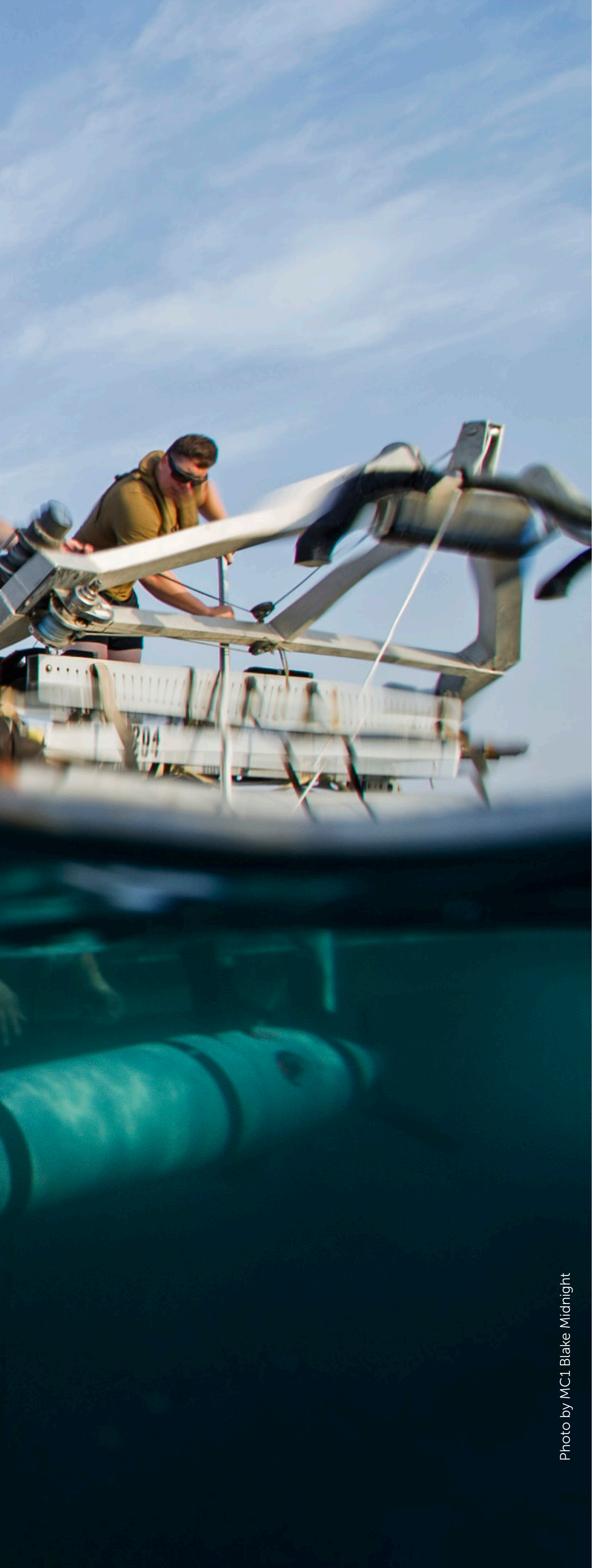


Photo by MC1 Blake Midnight

NEW SOFTWARE INTEGRATES AND DISPLAYS DATA FROM MULTIPLE UNMANNED SOURCES AND SENSORS.

To aid the Navy in its pursuit of advanced unmanned capabilities, engineers at Naval Undersea Warfare Center (NUWC) Division Newport developed Topside Command and Control (C2), a flexible software suite that is easily reconfigured to rapidly prototype new sensors, data feeds, and assets.

Topside was originally developed to monitor sensors for the Undersea Distributed Networked System. The team realized the software could also be used to track unmanned underwater vehicles (UUVs). Topside C2's data collection, mission planning, and piloting station are plug-in-driven, Java-based, and built on NASA's WorldWind, an open-source 3D visualization system similar to Google Earth.

Topside's data fusion and visualization are presented on a unified time axis and include friendly force positions, environmental measurements, a ship automatic identification system, and weather data including ocean model forecasts with ocean currents. Topside provides an intuitive graphical user interface, allowing planners to run real-time acoustic and environmental models, evaluate optimal patrol routes and mission plans, and judge mission duration within the energy limits of various unmanned underwater vehicles (UUVs).

After working on a variety of data-driven projects at NUWC Division Newport, it became apparent to engineer Keith Wichowski that one of the Navy's challenges is the amount of data that is collected but not seen. He created Topside with the intent of figuring out how to show the right information in the right way.

"The goal is to have as few clicks as possible," Wichowski said. "I empathize with people using our stuff. We make sure we work with the Sailors and do 12-hour shifts with them so we know how that interface feels after using it for a long time. They're tired and always have a lot of other things on their minds. When their boss comes by and asks for something, we want Topside to give them the right information. One of our tenets is to only show people the information they have. We don't want users to feel confused or overwhelmed. We don't interpolate data. More information is not what the user needs."

Topside's basic features:

- Source-agnostic data viewer
- All the information is timestamped
- User interface refreshes itself automatically with new data
- Information assurance and cybersecurity requirements are designed into the system so it is accredited every time it goes in the water
- Scalable, user-friendly platform.

Topside users work with a software developer kit (SDK) that allows anyone to develop custom plug-ins for their vehicles. From a software standpoint, the product is scalable and user friendly.

"People who use the SDKs have something working in a couple of days. It's really developer friendly," Wichowski said. "If you're adding a sensor to a vehicle, just write for the sensor—everything else is there."

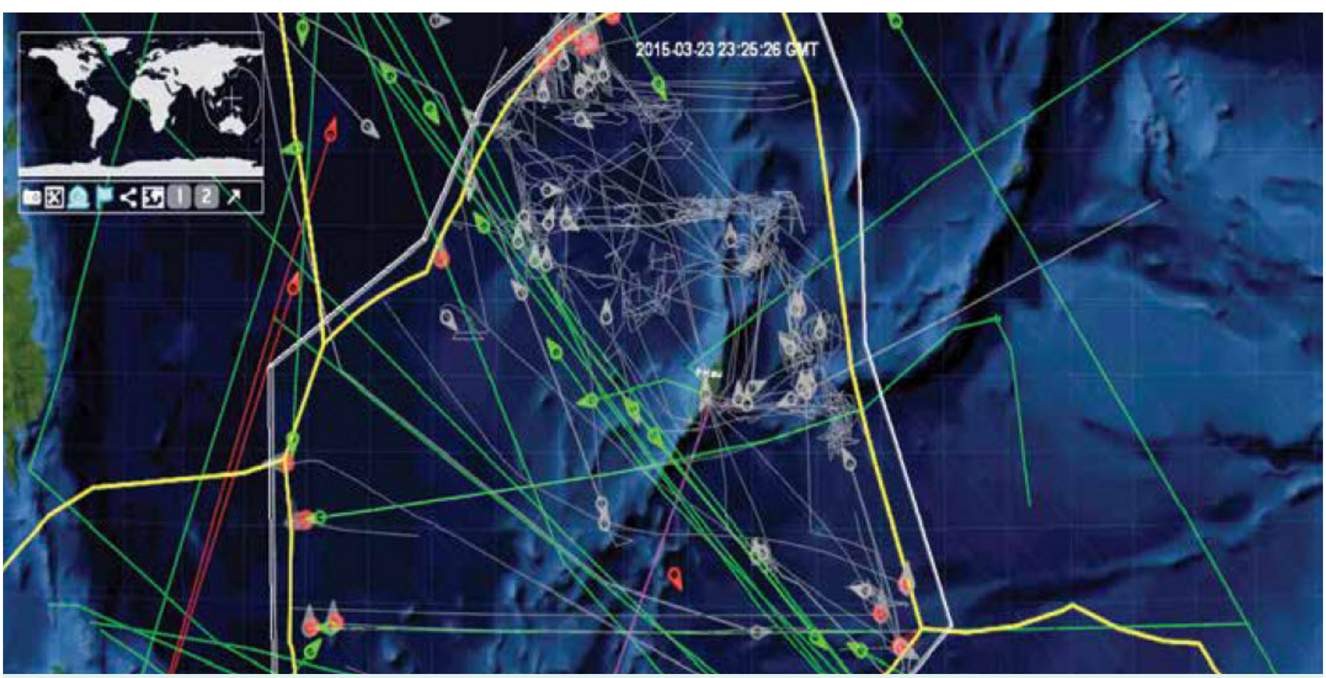
"The SDKs are available now to create plug-ins and all proprietary information remains intact," said Tom Fulton, technical program manager at NUWC Division Newport. "If you're using a supercomputer for your modeling, you can have your algorithms and still tie into Topside."

Mission Support

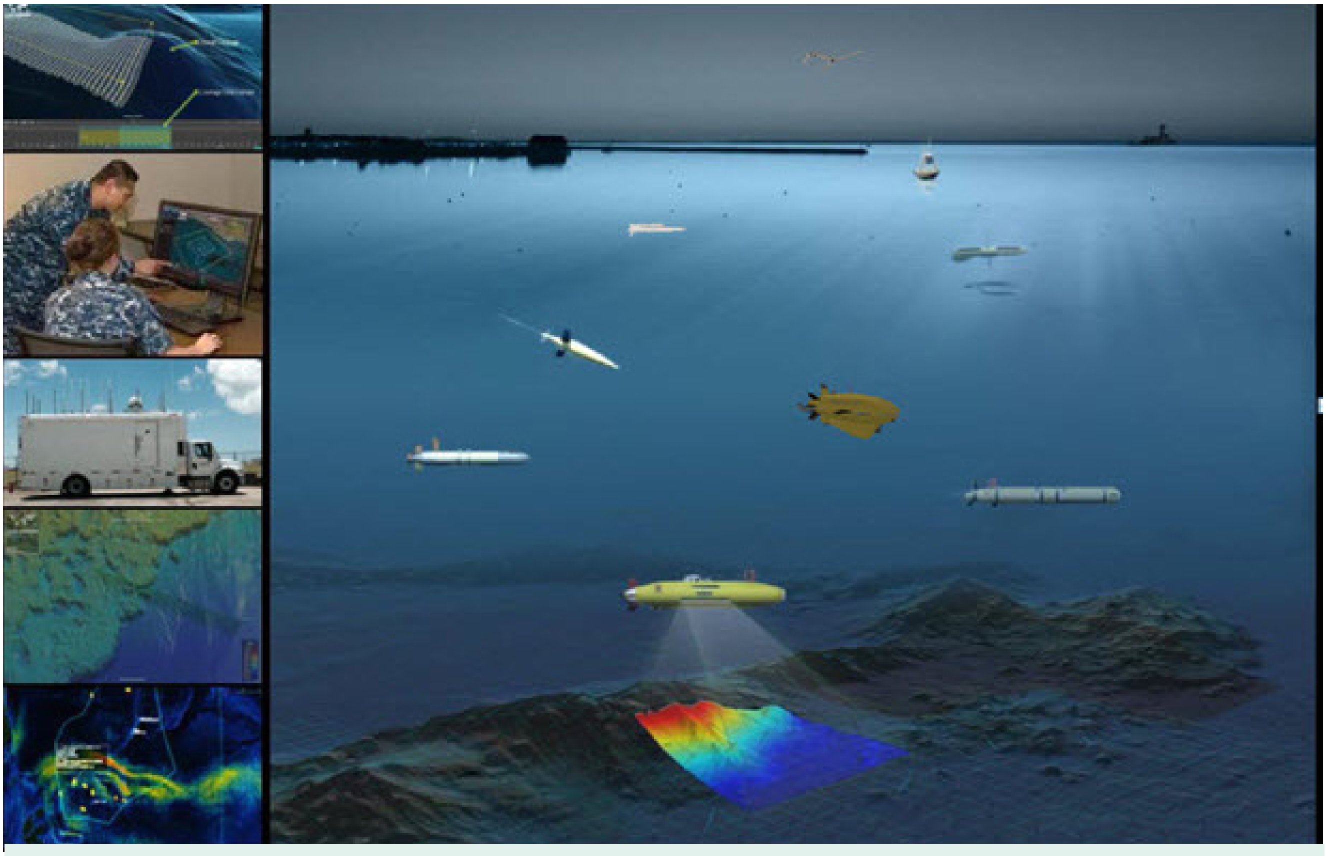
One instantiation of Topside is in the Theater Anti-Submarine Warfare Offset Project, a rapid prototyping effort to develop, deploy, and evaluate maritime intelligence, surveillance, and reconnaissance capabilities. Using Topside as the tactical command, control, and communications architecture enabled the rapid integration of multiple systems and data types to yield an agile, scalable, deployable prototype that is providing capability today and informing future acquisition strategies and operating concepts.

Topside allows Sailors to have the situational awareness of more experienced naval scientists. It is designed with an interface that mimics the widely familiar gaming and smartphone industries, which significantly eases the training period.

To solve problems that arose when testing the hardware and software framework in far flung, resource-limited locations, the Topside team developed a secure command-and-control center that can be rapidly deployed by sea, land, or air, in both a shipping container and a truck version. For even faster deployment, the team developed a compact expeditionary system that can be transported on commercial flights.



Shown here are traffic patterns as depicted in Topside. Illustrations courtesy of Naval Undersea Warfare Center



Topside displays vehicles in the water, bathymetry, and environmental data.

Increased Productivity

The development of the Topside architecture was guided by three objectives: minimize the number of operators to plan, man, and operate the mission; provide continual updates of situational awareness; and make it easy to use. The update rate of information takes into account the human factor issues with the expectation that young Sailors with significant gaming experience are accustomed to a fast user interface with 3D color displays.

Cmdr. Scott Smith of UUV Squadron 1 in Keyport, Washington, has been using Topside for several years as a mission planning tool for operating wave gliders as well as for its data collection capabilities.

"We monitor the health and status of the UUV while it's on its mission," Smith said. "In the future, we'd like to see a post-mission analysis tool added. Because UUVRON 1 employs so many varieties of unmanned vehicles, we'd like to have one system so I only have to train people once. Ultimately, I'd like to reduce the training burden and reduce the footprint needed for systems. I'm very hopeful that Topside solves my manning issues so I'm not training operators on five or six systems. If industry builds the plug-ins for Topside, then I can reduce costs and overhead."

Fleet operators used Topside during the 2017 Advanced Naval Technology Exercise "Battlespace Preparation in a Contested Environment," a joint exercise between NUWC Division Newport and Naval Surface Warfare Center Panama City Division in August, as well as the Naval Oceanographic Office's operational demonstration in the Gulf of Mexico in the spring.

Future Plans

The team is looking for a platform to establish an online community of practice for Topside users to share information sharing about applications, plug-ins, etc.

"Our goal is to have a distributed software team across system commands, not solely Newport developers," Fulton said. "We'll handle the undersea warfare, but we'd like to add mine warfare, urban environments, and surface vessels."

About the author:

Susan Farley is a technical writer with McLaughlin Research Corporation, supporting Naval Undersea Warfare Center Division Newport public affairs.

FORECASTING THE MIRROR IN THE SKY

By Dr. Christoph R. Englert, Dr. Fabrizio Sassi, Dr. Sarah E. McDonald, Dr. Douglas P. Drob, Clayton Coker, Dr. Katherine A. Zawdie, Andrew C. Nicholas, Dr. Scott A. Budzien, Dr. Andrew W. Stephan, and Dr. Daniel Eleuterio


Photo by MC3 Paul Kelly

UNDERSTANDING WHAT'S GOING ON IN THE IONOSPHERE—WHICH CAN AFFECT RADAR AND COMMUNICATIONS—IS VITAL FOR NAVAL FORCES. NEW SPACE-BASED INSTRUMENTS ARE HELPING TO UNDERSTAND WEATHER IN THIS COMPLEX REGION FROM BOTH ABOVE AND BELOW.

Charged layers on the very top of Earth's atmosphere have long been used to reflect radio waves, acting much like a mirror in the sky. This effect has been known and used for about a century, and today it enables skywave over-the-horizon radar and long-distance communication.

While the ionosphere makes these capabilities possible, the high-altitude weather between about 40 and 600 miles (65-1,000 kilometers) can cause significant ionospheric disturbances. These disturbances can cause signal absorption and scattering, which can seriously degrade reflected radio signals. Ionospheric disturbances are often also detrimental to signals that go through the ionosphere for satellite communication or geolocation.

During the day, several layers of charged particles that form the ionosphere are created by the intense solar ultraviolet and x-ray radiation, which ionizes neutral air molecules and atoms. The ionosphere decays at night, with the lower layers decaying quickly after sunset and the top layer lingering until sunrise. It is well known that changes in solar radiation forcing can cause significant changes in the ionosphere. However, we now know that the dynamics and composition of the neutral atmosphere, which still constitutes more than 99 percent of the air mass at these altitudes, also is a significant driver of the ionosphere. It is especially important for the bottom-side of the ionosphere, which is used as the "mirror in the sky" for radio waves. In fact, research performed in the past decade has confirmed that during the long periods without much variation in solar forcing, the meteorological forcing from below can cause ionospheric electron density changes of 50 percent or more.

Forecasting the Ionosphere

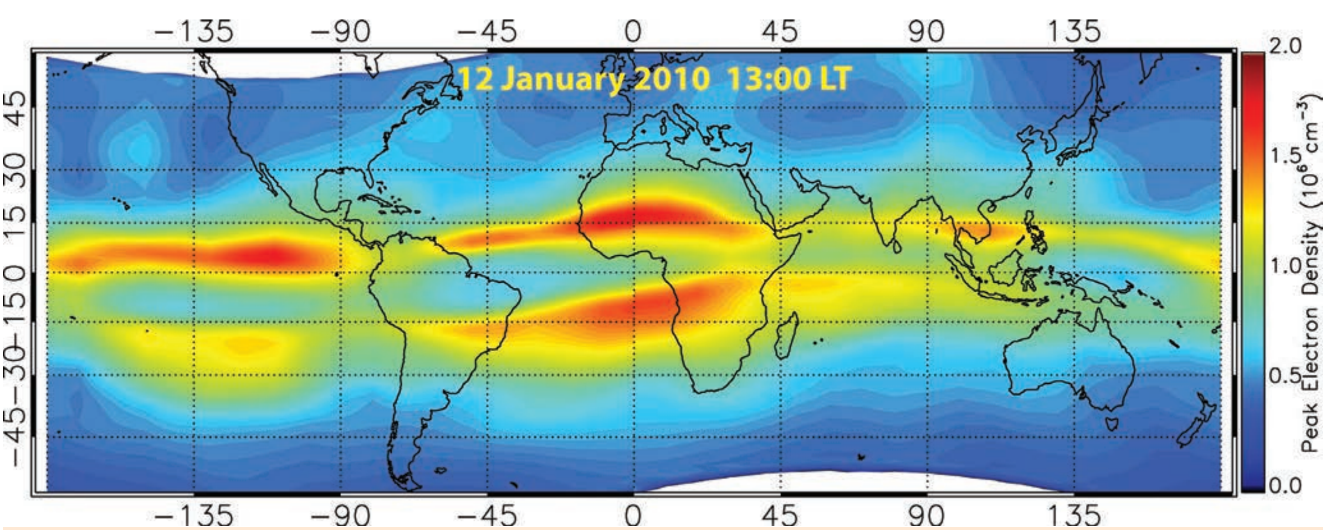
The state of the ionosphere can be measured using a variety of observational techniques. From the ground, the electron density profile of the bottom side ionosphere can be measured using vertically reflected radio signals from a collocated transmitter/receiver pair (ionosonde) or using signal paths from a transmitter to a receiver at a different location (oblique sounder). Another common method is to derive the total electron content or column density between a ground receiver and a GPS satellite by examining the delay of the radio signals going through the ionosphere. Observations also can be made with satellite instruments by observing, for example, the naturally occurring ultraviolet airglow that originates from recombination of charged particles in the ionosphere, or by observing radio signals emitted on the ground or by other satellites.

All these observational techniques have their strengths and limitations—e.g., they might only contain information on the bottom side or the integrated electron content along a given path from emitter to receiver, which complicates forming a complete picture of the global, three-dimensional ionosphere at any given time. There are, however, several models that ingest ionospheric measurements from across the globe to estimate its state. Within the Department of Defense, operational ionospheric specifications and short-term persistence forecasts are currently produced by the Global Assimilation of Ionospheric Measurements model, which runs at the 557th Weather Wing of the US Air Force.

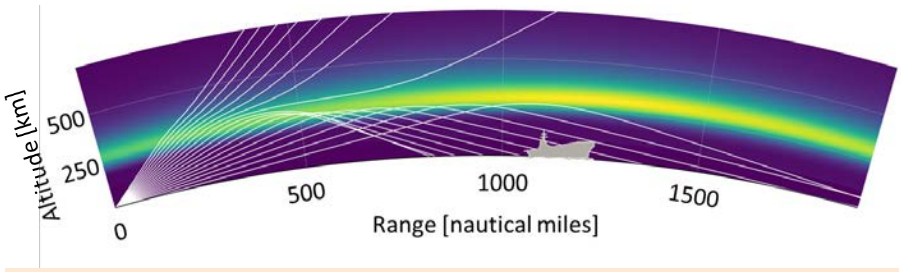
We now know that any skillful, multiday ionospheric forecast must include reliable meteorological forcing from below and solar forcing from above. Civilian and military researchers are working on both of these aspects. Concerning the inclusion of the lower atmospheric meteorology, the community is standing on the cusp of creating a fundamentally new operational capability, by extending lower atmospheric weather prediction systems up in altitude and coupling them to a physics-based ionospheric model. Such a "ground to space" model, coupled with the ingestion of real-time data, is expected to be able to produce previously unavailable, multiday ionospheric forecasts, much like the weather reports for the lower atmosphere, on which we rely on a daily basis.

The Limb-Imaging Ionopheric and Thermospheric Extreme Ultraviolet Spectrograph (LITES) and the GPS Radio Occultation and Ultraviolet Photometer Co-located (GROUP-C) experiments were installed on the outside of the International Space Station in February 2017. Photo courtesy of NASA

A targeted basic research effort to explore the coupling of



Preliminary results from a whole-atmosphere model, coupling the lower atmospheric meteorology to the upper atmosphere, where the ionosphere is formed. The color contours illustrate peak electron densities in the ionosphere. Photo courtesy of Naval Research Laboratory



Radio waves (white lines) emitted from the ground (lower left) can travel up to the ionosphere where they can be reflected and directed back down to the ground, enabling skywave over-the-horizon radar and long-distance communication. The color shading represents the ionospheric electron density. This image was created for radio waves with a frequency of 20 megahertz. Photo courtesy of Naval Research Laboratory

the neutral atmosphere with the ionosphere is currently under way at the US Naval Research Laboratory's space science division. First results of this model coupling show previously observed ionospheric structures that are the signature of lower atmospheric forcing. The figure on the opposite page, for example, depicts the modeled peak electron density across the globe, assuming the local time is close to noon everywhere on Earth (i.e., the daytime ionosphere is well formed everywhere). The image clearly shows two bands to the north and south of the equator, a well-known ionospheric feature called the equatorial arcs, but it also shows a prominent longitudinal structure, peaking over the Pacific, the west coast of Africa and Southeast Asia. This three-peak structure is a consequence of atmospheric solar tides that are excited by thunderstorm activity in the tropical lower atmosphere (below 17 kilometers) and then propagate all the way to the altitudes of the ionosphere.

Similar to the conventional numerical weather prediction, ionospheric forecasting also is an initial condition problem, which means that the current condition of the atmosphere has to be well constrained by observations to provide an optimal initialization of the forecast model. Obtaining measurements of the neutral atmosphere (e.g., winds and temperatures) and the ionosphere (e.g., electron density and electric field) with sufficient global coverage and spatial resolution is difficult and expensive, especially over the oceans where satellite instruments are often the only option. In an effort to develop sufficiently sensitive and economical options for suitable space based instrumentation, the US Naval Research Laboratory is developing novel measurement techniques building on previous payloads, including the operational Special Sensor Ultraviolet Limb Imager sensor on the Defense Meteorological Satellite program satellites.

Recent instruments include the Limb-imaging Ionospheric and Thermospheric Extreme Ultraviolet Spectrograph/GPS Radio Occultation and Ultraviolet Photometer Co-located instrument (launched in February 2017) measuring neutral and ionized constituents by looking toward the horizon, through the upper atmosphere from the International Space Station; the miniaturized Winds Ions Neutrals Composition Suite sensor (next launch in 2018), which measures atmospheric properties at the satellite location; and the Michelson Interferometer for Global High-resolution Thermopheric Imaging instrument (to be launched in 2018) measuring neutral wind and temperature in the lower ionosphere (below 300 kilometers) on board the NASA Ionospheric Connection Explorer mission.

The overall goal of our research efforts is to provide high-altitude specification and forecasting, and necessary high altitude data to the national Earth System Prediction Capability vision, which is to establish a global physical Earth system analysis and prediction system to provide seamless predictions covering hours to decadal timescales including the atmosphere, ocean, land, cryosphere, and space.

About the authors:

Dr. Englert is the head of the geospace science and technology branch of the space science division at the US Naval Research Laboratory.

Dr. Sassi, Dr. McDonald, Dr. Drob, Clayton Coker, Dr. Zawdie, Dr. Nicolas, Dr. Budzien, and Dr. Stephan are researchers in the geospace branch of the space science division at the US Naval Research Laboratory.

Dr. Daniel Eleuterio is the program manager of the earth system prediction capability at the Office of Naval Research.

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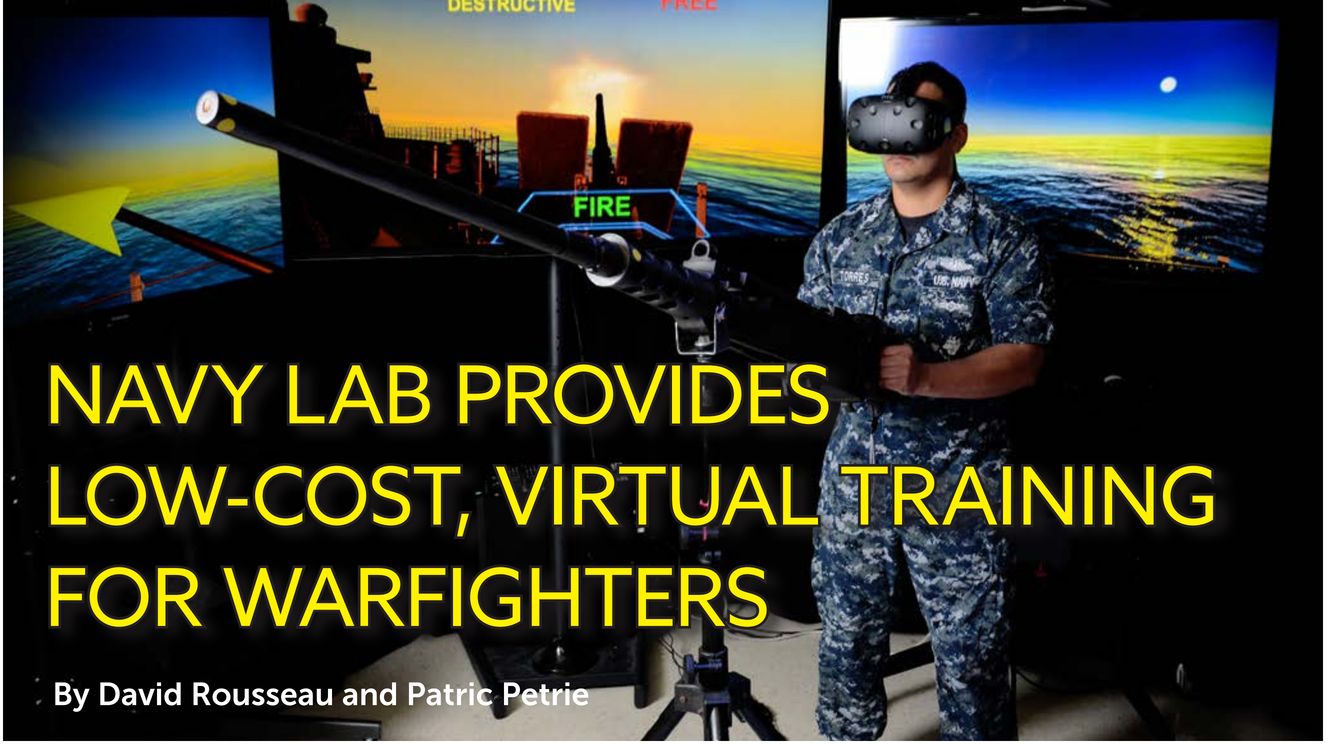

Photo by Alan Antczak

NAVY LAB PROVIDES LOW-COST, VIRTUAL TRAINING FOR WARFIGHTERS

By David Rousseau and Patric Petrie

THE BATTLESPACE EXPLOITATION AND MIXED REALITY LAB ALLOWS WARFIGHTERS TO TRAIN FOR TASKS IN A WIDE VARIETY OF SIMULATED ENVIRONMENTS, EVERYTHING FROM AERIAL REFUELING TO SUBMARINE DOCKING TO SHIPBOARD LOADING.

The Navy conducts a wide variety of training operations, some of which are dangerous, expensive, or infrequently done. The Battlespace Exploitation and Mixed Reality (BEMR) lab, based at the Navy's Space and Naval Warfare Systems Center (SSC) Pacific in San Diego, is using 360-degree videos to provide initial familiarization and virtual experience for these tasks that can significantly reduce the cost and risk.

Midair refueling, for example, is a challenging task that fighter pilots must master. During midair refueling the turbulence around the front of the aircraft makes the refueling "basket" move around. It requires skill and practice to be successful at this task, and the risks of damaging the basket, or having the basket hit the aircraft, can have serious consequences. Letting new pilots virtually experience midair refueling by seeing 360-degree video displayed in all-around viewer such as the Samsung GearVR will prepare them for refueling tasks without the risk and high cost of actual midair refueling operations.

Similarly, docking a swimmer delivery vehicle (SDV) in a dry-deck shelter attached to the deck of a submarine is a highly complex team-effort that is costly, potentially dangerous, and infrequently done. Letting Navy SEAL teams "virtually" experience SDV docking by seeing 360-degree video will prepare them for the docking task without risk and without the high cost of actual SDV docking operations.

SSC Pacific's Role

SSC Pacific's BEMR lab explores, evaluates, and applies virtual reality (VR) and augmented reality (AR) technology for rapid prototyping, operations, maintenance, and training in the Navy and Marine Corps. The BEMR lab has acquired and evaluated several types of 360-video systems and was chosen by the Office of the Secretary of Defense Rapid Reaction Technology office to introduce this new technology.

The lab conducted its first 360-degree video effort during the Rim of the Pacific 2016 exercise. The annual multinational maritime exercise takes place in and around the Hawaiian Islands. The effort used Fleet Combat Camera Pacific personnel to record several 360-videos of their humanitarian assistance and disaster relief tasks.

These included jet skis surveying the mouth of the Pearl Harbor channel; the offload of the Army's USAV *CW3 Harold C. Clinger* (LSV 2) by the Second Navy Expeditionary Logistics Regiment, which moves intratheater supplies; the setup of a 50-bed portable hospital by the Hawaii Disaster Medical Assistance Team; and the transport of patients to Ford Island and casualty triage.

The BEMR lab's BUGEYES project (named after the compound eyes of some bugs that allow them to see in see in 360 degrees) has provided the video systems to several Department of Defense activities, including 360-degree video to various Navy units and students at the Naval Postgraduate School.

The team also has provided 360-degree video systems to the Marine Corps Aviation Weapons and Tactics Squadron One's combat camera unit at Marine Corps Air Station Yuma; the Asymmetric Warfare Group training center; and the Center for Security Forces training unit in Virginia Beach, Virginia. It will soon be providing a 360-degree video system to the Army 18th Airborne Corps in Fort Bragg, Georgia.

One BEMR lab-funded effort is to provide Navy and Marine Corps activities with the ability to create their own 360-degree videos.

These videos are much like the videos you might make with a typical video camera, except that the imagery covers a 360-degree spherical field of view. The videos can then be viewed using a Samsung GearVR or other similar virtual reality display, which enables one to look in any direction during the video. This gives the viewer the experience of actually being in the recorded environment.

The Way Ahead

SSC Pacific's human factors branch and the BEMR team have found several studies that quantifiably demonstrate that experiential learning (such as 360-degree videos and VR) is a significantly more effective delivery system than any other form of classroom training. Ideally, the introduction of VR and AR technology for training not only has the potential to reduce costs and risks, but the training should be retained longer by students.

The Battlespace Exploitation and Mixed Reality lab uses 360-degree cameras to film real-life exercises in the field, allowing the footage to be used back in the lab for hyper-real training.

A warfighter-to-lab demo in the Battlespace Exploitation of Mixed Reality lab at the Space and Naval Warfare Systems Center Pacific. Photo by Alan Antczak

Several Department of Defense organizations already have seen the value of this technology and have contacted the BEMR lab for hardware and software recommendations so that they can acquire their own 360-degree video systems. The use of BEMR's technology will spread throughout the fleet and beyond now that it has been introduced, and its effectiveness and low-cost have been recognized.

The BEMR lab at SSC Pacific is exploring and applying "mixed reality" technology across the spectrum of Navy and Marine Corps operations, maintenance, training, and rapid prototyping.

One of the BEMR lab's goals was to evaluate 360-degree video technology and introduce it to the DoD. The result is that many organizations in the Navy, Special Operations, and the DoD are now acquiring and using this technology to reduce the costs and risks of many types of training and improve after-action review. This technology is especially important for training that is dangerous or that doesn't happen very often because of cost or scheduling.

The BEMR team has also used this equipment to make 360-videos of SEAL team jump-master training for the Navy Special Warfare Advanced Training Center (NSW ATC) in Imperial Beach, California; the Navy Special Warfare Group 3 training unit in Virginia Beach, Virginia; the plane-captain conducting F-35B pre-flight and post-flight procedures; and the F/A-18 plane-captain conducting pre-flight inspections; and for pilots F/A-18 practicing mid-air refueling.

About the authors:

David Rousseau is a researcher at Space and Naval Warfare Systems Center Pacific working on the Battlespace Exploitation of Mixed Reality project.

Patric Petrie is the lead staff writer for Space and Naval Warfare Systems Center Pacific.

PREDICTING THE WIDEBAND RADAR SIGNATURE OF NAVY PLATFORMS AT MILLIMETER-WAVE FREQUENCIES

By Dr. Sadasiva M. Rao

ANTICIPATING THE RADAR SIGNATURE OF SHIPS AND AIRCRAFT BEFORE THEY'RE BUILT IS FAR LESS EXPENSIVE THAN MEASURING A SIGNATURE AFTER CONSTRUCTION. NEW RESEARCH AT THE NAVAL RESEARCH LABORATORY IS HELPING TO MAKE SIGNATURE PREDICTION MORE EFFECTIVE.

The prediction and control of the radar signature of Navy ships and aircraft is essential for ensuring their survivability. Threat radar systems presently operate across a range of microwave frequencies and are expected to move to higher frequencies over time, including millimeter wave frequencies (30-300 gigahertz). Hence, it is important to understand vulnerabilities to such radars at the platform design stage and avoid expensive modifications once a ship is deployed.

During the early stages of platform design, it is customary and economical to employ modeling and simulation (in lieu of time consuming direct measurements) to predict the radar signature. The modeling and simulation step usually involves processing specialized numerical algorithms on large computers. Although commercial algorithms are sometimes used for naval design, these are expensive and inefficient, often require extensive modifications, and may involve security concerns. Hence, it is advantageous for the government to develop specialized algorithms, which are more secure, efficient, accurate, and, in the long run, economical through the ownership of intellectual property.

Until recently, most radar signature prediction algorithms have been developed in the frequency domain (FD) using Maxwell's equations (among the oldest in the field of electromagnetism) as the starting point and assuming time-harmonic behavior. Thus, whenever there is a need for time domain (TD) radar cross section (RCS), the common procedure is: obtain the RCS in the FD at several hundred frequencies each requiring a separate simulation, assemble the results, and then use an additional step of inverse Fourier transform for the final TD results. This procedure, commonly known as Inverse Discrete Fourier

Transform (IDFT) approach, is very inefficient and time consuming. Ironically, Maxwell's equations are explicitly described in the TD with time as an independent variable. However, until now, the common procedure to develop the RCS estimate is to convert Maxwell's equations to the FD and develop numerical procedures in the FD. This is because the FD approach is generally easier to handle in terms of mathematical complexity and software generation. Another contributing factor is the availability of experimental hardware to measure RCS is largely confined to the FD. However, the FD approach is simply not practical for the problems encountered in the mm-wave range.

Predicting the RCS of large platforms in the millimeter-wave range using the conventional IDFT approach is computationally intensive and prohibitive in terms of cost and time. The available techniques are limited in the bandwidth that they predict, requiring multiple iterations to provide the wideband data necessary to perform signature control. The calculations must be repeated for different frequencies whenever changes are made to the platform design. This is because the currently available TD techniques are, in fact, based on FD techniques. While accurate, they are slow, narrowband, and computationally intensive. A fundamentally new approach to signature prediction is needed, and we propose to develop new approaches directly in the time domain.

In theory, direct TD prediction techniques are inherently superior to FD techniques by providing the signature at all frequencies, zero to infinity, from a single set of calculations. The TD solution is invariably obtained by a time-stepping process, popularly known as the Marching-on-in-Time (MOT) method. [1] We note that TD methods provide several other advantages, such as: greater suitability for ultrawideband signature studies, easier for parallel processing implementation, provides better visual representation for understanding the field interactions, and computationally more efficient. In addition, the MOT method requires no matrix inversion, a computationally intensive step in any numerical algorithm. [1] The technique also can be applied to the development of short-pulse radar systems and ultrawideband antennas.

Although TD methods are superior in many respects to FD methods, one major problem associated with them is that the solution tends to diverge after a random number of time steps, a phenomenon commonly known as the "Late Time Instability Problem," as shown in Figure 1.[1] This phenomenon is commonly attributed to the accumulation

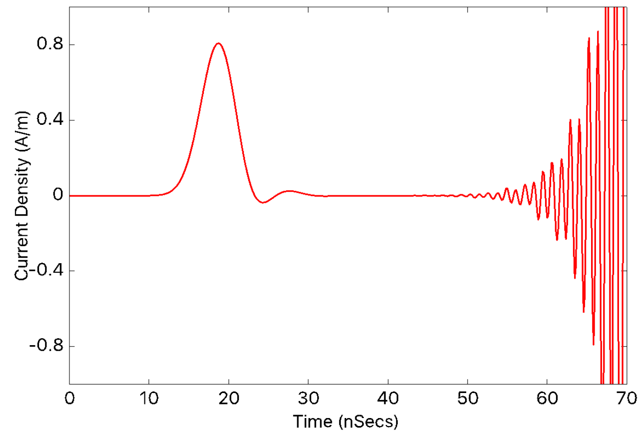

Figure 1: Current induced on the top surface of a 0.5-meter conducting cube illuminated by a Gaussian pulse shown in Figure 2.

of numerical "noise" in the solution and explained as the summation of round-off errors during each computation step resulting from analytical and numerical approximations made in developing the model. Several researchers have proposed numerical remedies to arrest these instabilities, usually after the phenomenon occurs, but have met with only partial success.[2-5] The main reason appears to be the inability to determine the exact instant when the late-time instability problem begins. In addition, there is no scientific proof that the late-time instability problem is solely caused by accumulation of errors for a given model. Thus, in a nutshell, it may be claimed that although TD solutions have several positive advantages, the methodology is unusable except for a very narrow class of applications.

In order to tackle this instability problem in a comprehensive way, a research project has been undertaken at the Naval Research Laboratory to develop a wholly new approach to solve the instability problem and develop a new efficient algorithm to obtain the TD signatures of naval platforms. A successful completion of the research project is expected to result in the development of an ultrafast, accurate algorithm for the prediction of the RCS of Navy ships, subsystems, shipboard antennas, and other large objects at millimeter-wave frequencies. Note that in this frequency range, most Navy platforms are considered to be electrically large objects because of their physical size. This means that the surface area of the given body spans several thousand square wavelengths. The popular method-of-moments (MOM) technique,[6] which is commonly used to handle similar problems at lower frequencies, requires prohibitively expensive computational and memory resources and, hence, is not practical for this frequency range.

In our approach, the main thrust of the research is to do away completely with the time-stepping procedure, thus avoiding the accumulation of errors. Also, to model the time variation of the induced current, a set of Gaussian functions, which decay exponentially as the time progresses, is used to remove the possibility of instabilities appearing in late time. In the following sections, we discuss the solution methodology in detail and present preliminary results obtained for a few canonical problems using the new approach.

Description of the Incident Field

We turn our attention to the incident field term in the TD model. Although any temporal waveform may be used, a plane wave impulse is the most useful. With the impulse response known, the response due to any other plane wave incident from the same direction and with arbitrary time variation may be obtained by a convolution operation. From the viewpoint of limited computer time and storage, an ideal impulse function may not be implemented since its frequency spectrum extends from zero to infinity with constant amplitude. We instead use an approximate smoothed impulse, which has a Gaussian temporal variation, as shown in Figure 2. This type of pulse is effectively time- and band-limited and is well suited to numerical computation. It has a rapid decay to a negligible value in both time and frequency. By changing the pulse width (T), it is possible to make the pulse narrower or broader and, consequently, change the frequency range of the incident pulse. Hence, the wideband information that can be derived from the solution depends on the incident pulse.

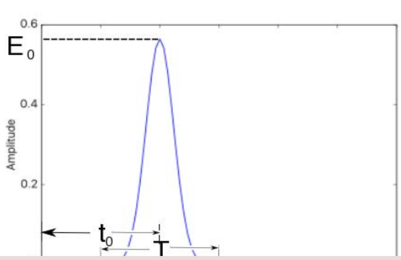

Figure 2: Incident Gaussian Pulse.

Description of the New Method

In the new method, a given object is modeled as a wire-grid as shown in Figure 3. The wire-grid models are usually preferred in the initial stages of development of the algorithm since these models are easy to work, involve simple one-dimensional mathematical procedures, facilitate testing of new ideas, and are general enough to model complex bodies. Using the following mathematical procedures, current induced along the wire-grid by the incident Gaussian pulse shown in Figure 2 is obtained as a function of time.

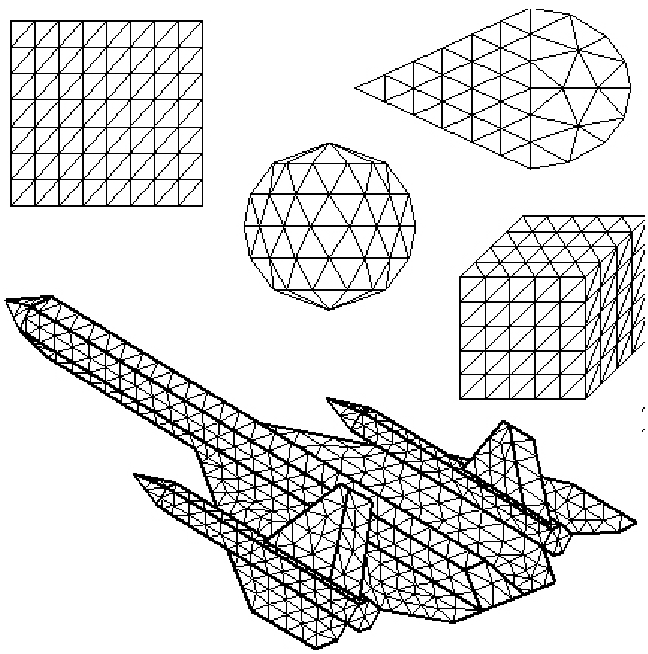

Figure 3: Wire grid models of some typical objects.

Starting from Maxwell's equations and using potential theory and elementary vector calculus, an electric field integral equation as a function of current induced on the wire may be derived.[1] To solve the integral equation using numerical methods, the wire is divided into N+1 linear segments. In addition, we divide the time axis into uniform time intervals given by Δt and denote $t_m = m\Delta t$ for $m=0,1,2,\ldots,\infty$. Next, we approximate the induced current on the wire from 0 to $t_M = M\Delta t$, as

$$I(t,s) = \sum_{m=1}^{M} \sum_{n=1}^{N} I_{m,n} \quad f_m(t) \quad g_n(s)$$

where $\mathbf{I}_{m,n}$ represent the unknown coefficients and fm(t) and gn(s) are known functions. We note that fm and gn must be carefully defined to make the algorithm simple, efficient, and free of late-time instabilities. In this work, we use Gaussian functions for time and pulse functions for length variable. These functions are shown in Figures 4 and 5, respectively.

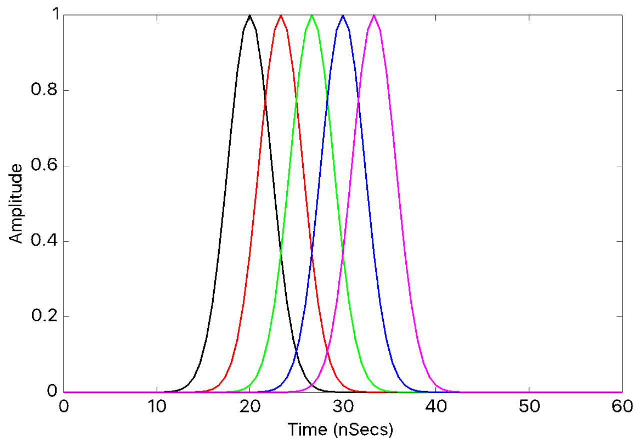

Figure 4: Gaussian functions representing the time variable.

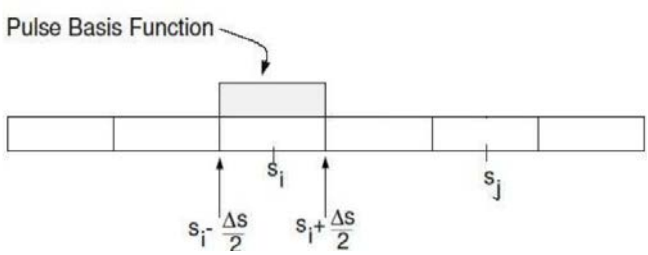

Figure 5: Pulse function representing the space variable.

Next, using the standard method-of-moments solution procedure,[6] the TD integral equation is converted into a matrix equation given by **Z I = V** where **Z** is a real matrix of dimension P= M X N, and **I** and **V** are column vectors of dimension P, respectively. The **V** vector is formed by the information from the incident field and the I vector contains unknown coefficients $I_{m,n}$. By inverting the **Z** matrix and multiplying by **V**, the coefficients $I_{m,n}$ are easily obtained i.e. $\mathbf{I}= \mathbf{Z}^{-1}\mathbf{V}$. Once the coefficients are known, we have the current distribution for the first M time steps i.e. from 0 to t_M. To obtain the current from t_{m+1} to t_{2M} the procedure is repeated. Also, the same procedure can be applied for further time instants. Once the current distribution on the body is obtained as a function of time, it is quite a simple task to obtain RCS of the object, either in the TD or the FD, by a simple integration process.

At this stage, we remark that it is a trivial task to obtain current distributions for multiple incident fields. In this situation, one can re-compute only the vector **V** repeatedly and obtain **I** by the mathematical operation $\mathbf{I}= \mathbf{Z}^{-1}\mathbf{V}$.

We note that the procedure presented in this work does not perform time stepping, which seems to be the source of the late-time instability problem. Further, the usage of Gaussian functions to represent the time variable ensures that no instabilities occur anywhere.

Numerical Results

As a first example, consider a wire-mesh with wire radius of 0.001m arranged in the shape of a square plate of 0.5 X 0.5 m located in the XY-plane. The mesh is illuminated by a Gaussian plane wave travelling normal to the plate and polarized parallel to one of the edges. The induced current at the center of the mesh is obtained using the new procedure and compared with the IDFT solution. For the time domain solution, we choose M=20, N=67, and Δt= 1.0 nSecs. The IDFT solution is obtained by generating data at 128 equally spaced frequency points in the interval 0 - 400 megahertz using the standard FD solution and obtaining the TD solution via IDFT. Both solutions compare very well, as shown in Figure 6. In addition, the new TD procedure remains stable in the late time.

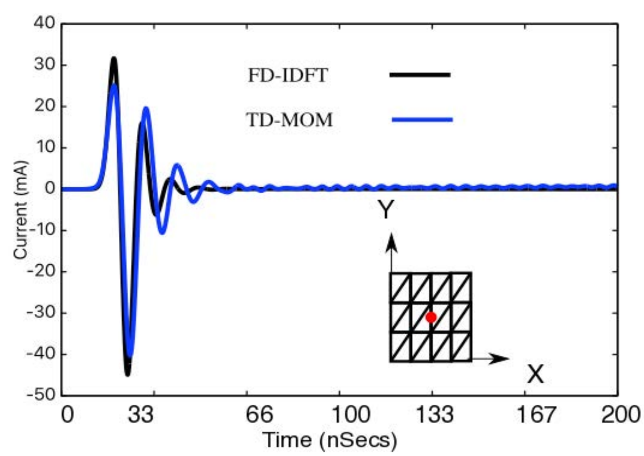

Figure 6: Induced current on a square plate.

Next, we consider a wire-mesh with wire radius of 0.001 meters arranged in the shape of a sphere of 0.5 meters radius located with the center of the sphere coinciding with the coordinate origin. The mesh is illuminated by the Gaussian plane wave described in the first example. The results are shown in Figure 7. The induced current at a selected point, shown as a red dot in the figure, is obtained using the new procedure and compared with the IDFT solution. For the TD solution, we choose M=24, N=559, and Δt= 1.67 nSecs. The IDFT solution is obtained as in the previous example. Again, both solutions compare well and the TD solution remains stable for a long time.

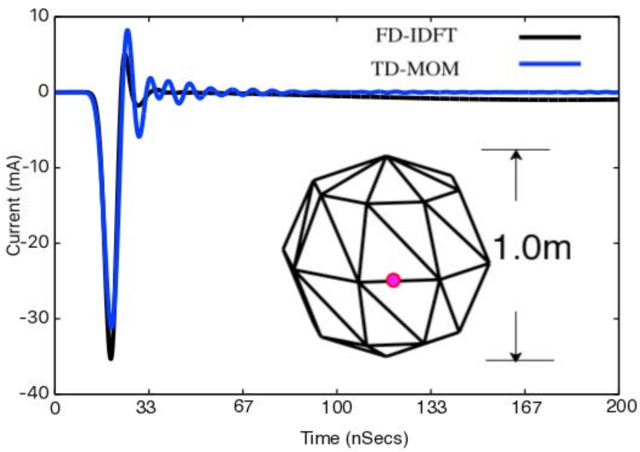

Figure 7: Induced current on a sphere.

As a last example, we consider a wire-mesh with wire radius of 0.001 meters arranged in the shape of a cube of 1.0 meter length located with the center of the cube coinciding with the coordinate origin. The mesh is illuminated by a Gaussian plane wave as in the previous example. The results are shown in Figure 8. The induced current at the center of the top plate is shown using the new procedure and compared with the IDFT solution. For the time domain solution, we choose M=24, N=5479, and Δt= 1.67 nSecs. The IDFT solution is obtained as in the previous examples. Again, as in the previous examples, we see good agreement and a stable TD solution.

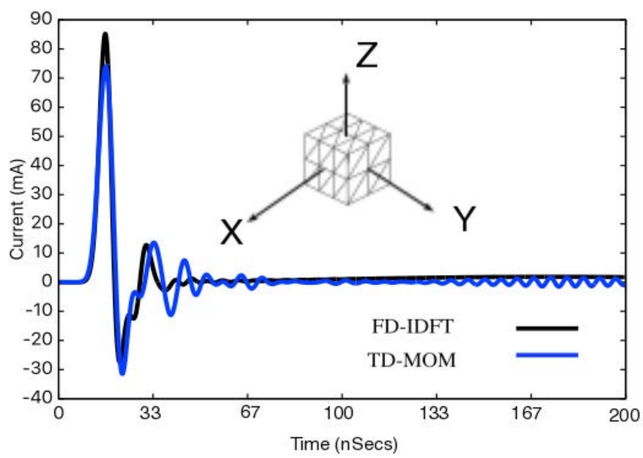

Figure 8: Induced current on a cube.

Conclusion

In this work, we have presented a new and efficient algorithm to obtain the induced current on a wire-mesh directly in the time domain illuminated by a Gaussian pulse. The new algorithm is stable for a very long solution time, primarily because of the elimination of the commonly adopted time-stepping procedures and using Gaussian functions for representing the time variation. Only preliminary results obtained for simple canonical objects are presented. Future work involves applying the algorithm to more complex objects modeling realistic Navy platforms. Successful completion of this work will provide design engineers with a new tool to obtain wideband signature information efficiently during the design stage.

Notes

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About the author:

Dr. Rao is a researcher in the radar division at the US Naval Research Laboratory.

STUDYING WARFIGHTERS IN THEIR

"NATURAL HABITAT"

By Regena Kowitz

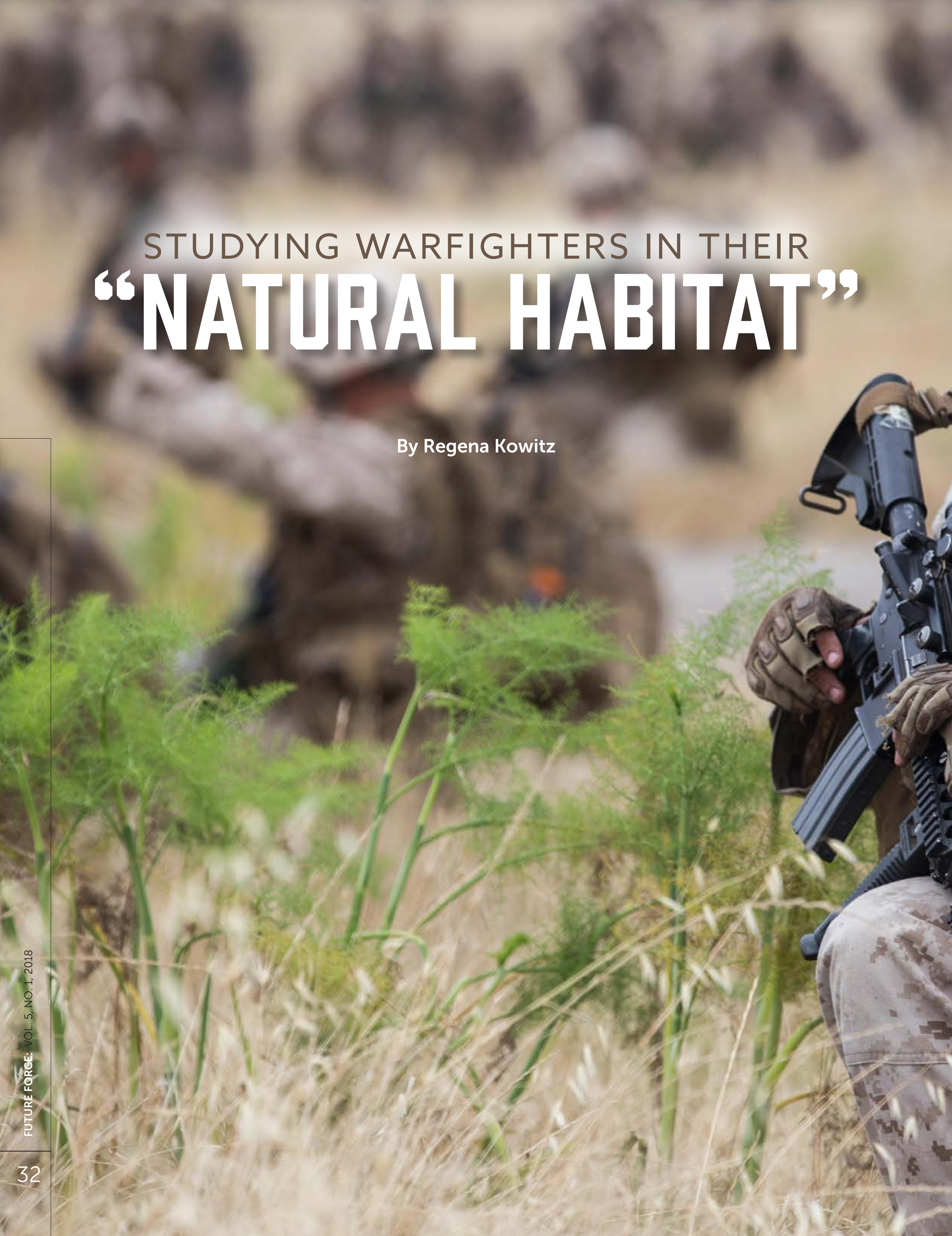


Photo by Lance Cpl. Brandon Maldonado

PACKING 80 POUNDS OR MORE IN THE FIELD CAN TAKE A TOLL ON MARINES' BODIES—AND THE BEST WAY TO FIND OUT JUST HOW MUCH MEANS COLLECTING DATA FIRST-HAND.

When most people picture a scientist who specializes in medical research, the first thing that comes to mind is probably someone wearing a white lab coat working in a laboratory, surrounded by microscopes, test tubes, and gleaming countertops.

They probably don't picture someone sitting on a dock, in the dark, bundled up against the cold night air, waiting for research subjects to surface from beneath the waves.

If you were watching Dr. Karen Kelly, research physiologist at the Naval Health Research Center (NHRC), in action, that's exactly what you'd see because Kelly and her team, the Applied Translational Exercise and Metabolic Physiology team (ATEAM), specialize in field research. They take science to warfighters by adapting traditional laboratory practices to a field setting so ecologically valid data (i.e., data that can be generalized to real-world environments) can be collected.

When the ATEAM heads out to the field, they pack heavy duty cases with all the supplies and equipment they will need to do cognitive and strength testing and collect and store specimen samples in the field.

A typical day of doing research for Kelly, who is part of NHRC's warfighter performance department, is anything but typical—her research subjects usually include elite warfighters and she goes to them to collect study data, whether they're training under the water late at night or conducting field exercises in the blazing Southern California sun in the middle of the day.

At the heart of Kelly's research is the study of hormonal and metabolic changes. These changes affect the health, readiness, and performance of warfighters, and can occur because of extreme conditions and stress. The information and samples collected in the field are analyzed by her team to measure hormone levels, which act as surrogate markers, letting Kelly know how well (or not) organ systems are functioning.

"We collect various biological samples—blood, saliva, and urine as well as physiological data—at different time points," Kelly said. "This allows us to measure changes in hormonal response that indicate how well an individual is handling stress, recovering, responding to rest, or at what point the body is failing."

Kelly's portfolio includes studies that focus on mitigating musculoskeletal injuries, improving stress resilience, optimizing mental skills training, and enhancing human performance in extreme environments. That means her research subjects include military personnel who are most likely to experience those scenarios and challenges—infantry Marines and naval special warfare operators.

"Training and conducting missions in extreme environments, under challenging conditions, is the norm for special operators," said Kelly. "These things can't be replicated in a lab. To really understand the impact this has on warfighter physiology, and take into account all the variables you can't reproduce in a lab such as environment and team dynamics, it's important to collect ecologically valid data in the field—it's a better reflection of what our warfighters actually experience in their daily training and it captures their true physiological status."

By bringing science to warfighters, Kelly says she and her team can provide operationally relevant feedback to the operators and their leaders, while also adding to the scientific body of knowledge about human performance and injury prevention.

"I think the lab is really important for establishing baselines [and] proof-of-concept ideas, but one of the biggest gaps in our understanding of human performance is the field work," said Kelly.

Kelly is no stranger to conducting research in the controlled environment of a lab. She has conducted clinical research in cardiovascular medicine, pathobiology, nutrition, bariatrics, endocrinology, and molecular medicine for the Cleveland Clinic. Collectively, Kelly has 18 years of research experience ranging from basic science to applied physiology.

"You can gather data in a very controlled environment but when you're conducting research to improve warfighter

Dr. Kelly, second from the left, environmental physiologist at the Naval Health Research Center, collects biological samples during data collection at Marine Corps Base Camp Pendleton.Photo courtesy of Karen Kelly performance and affect behavior change that supports that performance, you really need to understand the environment your subjects have to perform in," Kelly said. "A subject who performs or behaves one way in the lab, may have a completely different experience in the real world when faced with all the variables you controlled for in the lab."

When it comes to warfighters, particularly special operators, Kelly emphasizes that their training and mission environments are filled with variables—things that can't be replicated in a controlled environment.

"When you're working in the field, it's dynamic," said Kelly. "Equipment breaks, there are tides to account for, weather, terrain, and group dynamics. All of these factors can impact physical performance and physiology. If we only conducted research and collected data in the lab, we would be missing critical pieces of the puzzle."

One of Kelly's recent projects has been evaluating risk factors for musculoskeletal injuries in infantry Marines. Her goal is to identify optimal fitness levels and body composition that may reduce the risk of injury for personnel in physically demanding military occupational specialties.

For this study, Marine Corps Base Camp Pendleton is Kelly's laboratory. The base, which is the Marine Corps' largest on the West Coast, encompasses more than 125,000 acres of coastal and mountain terrain, from sandy beaches to dusty, scrub-covered hills.

Marines in this study are brought to NHRC's warfighter performance lab prior to the onset of infantry training for a dual-energy x-ray absorptiometry of the whole body to measure bone density as well as body composition. She also captures high-resolution computerized tomography scans of each participant's tibia. Kelly collects baseline data in the lab, but she and her team will collect the majority of data in the field.

Throughout the training cycle, Kelly monitors study volunteers for activity and hydration, body composition, and fitness. Her aim is to collect information on modifiable risk factors for injury and determine optimal fitness and body composition that may be protective against injury. By monitoring the Marines' activity in the field, Kelly can determine the total weight they carry during training to understand how it affects their performance and health.

"The average weight carried by infantry Marines in their combat loads, plus their weapon, can average more than 95 pounds," said Kelly. "The modern warfighter wears body armor with heavy protective plates, they carry mission-essential gear, food, and water—it all adds up. The more weight, the more impact on the musculoskeletal system, particularly the spine."

Kelly and the ATEAM monitor platoons and collect data during hikes, land navigation, and other training exercises.

"With hiking, you can't mimic all the terrain factors in a lab," Kelly said. "You can replicate elevation but you can't recreate all the surfaces and terrain that our Marines face, the slipping and sliding, and the uncontrolled tripping due to fatigue and terrain. We can do a controlled trip in the lab but there is a harness to catch the person due to necessary safety precautions required for human research. In the field, there are no safety harnesses."

Kelly also points out that you miss out on the group dynamics in a lab, which is an important indicator of how people handle the stress of training. Military personnel do not typically work alone, especially infantry Marines. They train at the company level or they're broken down into platoons and squads, but never alone.

"You can bring several subjects into the lab, but not an entire platoon," said Kelly. "Testing someone in isolation versus actually having them in an operational environment with their teammates makes a difference—you see how they tolerate hard training, how individuals help teammates who struggle, and how, as a group, they manage challenges. I have yet to see a perfect training day."

Understanding the physical and metabolic requirements of Navy SEAL Delivery Vehicle (SDV) operators is another project Kelly and the ATEAM are working on. This special class of SEALs has a unique training cycle which requires long periods of time underwater.

"This is one of the first studies to look at SDV operators during unit level training," Kelly said. "They are unique in that they move horizontally in the water, not up and down in the water column like salvage divers. Their gear and equipment is different. Their mission is different. And the physiological impacts are also likely different. But we don't know and that's why we're doing the research."

This study is descriptive, meaning Kelly and her team are gathering baseline data to learn about the physical and

A Naval Health Research Center staff member evaluates a Marine during data collection at Marine Corps Base Camp Pendleton. Photo courtesy of Karen Kelly

physiological characteristics of this population as they go through training. According to Kelly, the goal is to characterize how their bodies are responding over time to the chronic exposure of the undersea environment where pressure and depth challenge the human body.

For this project, the lab and the lab hours are wherever and whenever the operators are doing their training. If Kelly needs to wait on a cold dock until after midnight to collect data from the operators, that's what she does.

"The undersea piece is unique because you can't really mimic the ocean in a lab very well," said Kelly. "You can mimic the temperature but you can't necessarily mimic the currents or ocean elements—things like water clarity or murkiness, sea life, kelp, and terrain—or the dynamics of the operators finning together in a controlled, simulated environment."

Aside from currents and group dynamics, there are other variables that occur in real-world environments that don't get accounted for in a lab.

"There have been several times when equipment issues have altered the training timeline and the duration of the training day and time spent underwater," said Kelly. "More often than not, training goes longer than anticipated. The data we collect is not just about actual training, but also includes the time spent before and after, which can be up to 4-6 hours of additional work time for these guys. In a laboratory protocol, this time often doesn't get accounted for."

In a laboratory, Kelly pointed out, there always are protocols for safety and scientific merit, which are extremely important and vital to the protection of participants. But this is the inherent difference between a controlled environment and a real-time training environment where there is no way to control for everything that might happen. The data collected in the field may be a bit "dirty," Kelly explains, but it has ecological

validity and operational relevance because it reflects the actual demands placed on warfighters during training.

"In the real world, equipment breaks, gear malfunctions, currents change," said Kelly. "We don't want these things to happen in actual operations, but they sometimes do. Field research can help us answer questions about how these variables affect stress load or physiology and we can capture that data, do the science, and help our warfighters better prepare for what they'll face on the battlefield."

It's important to note, added Kelly, that with field data, there are going to be some limitations.

"In the field, there are times when the operators get in and they have to clean their gear right away so there's a little lag in collecting specimens, so we have to accept that margin of error," she said. "In the field and real life, you're not going to have a perfect sequence of events."

There also are several other benefits to collecting data out in the field—for warfighters and researchers.

"Field science is applied science, and it can be quick science," said Kelly. "When we collect urine or do a finger stick checking for blood glucose, we can tell right away if someone isn't hydrated or their blood sugar is low. We can give the warfighter immediate feedback about hydration levels or nutritional requirements—we can let them know they need to drink water or eat something."

When working with the SDV operators, Kelly also works with their human performance specialists. In addition to providing individual feedback to the operators, Kelly shares information with their nutritionist and conditioning coach who can then develop a customized meal plan or strength training regime, based on scientific information, for each warfighter to help improve their performance.

For researchers, the benefits of being in the field also include building relationships with the warfighting community and creating opportunities for new avenues of research.

"When you're in the field, you see the warfighters all the time, they get to know you," Kelly said. "It makes science a little more personal and makes them aware of how science can impact their performance. When they understand why we're doing research, that it's to help them and their team, and that you are there to give back to them by collecting information that can inform leadership, they don't mind volunteering."

Kelly and her team may not be your typical lab coat-wearing researchers, and that's a good thing. All types of science and research, from the lab to the field, are critical for understanding the needs of warfighters and the stress and sweat of field research isn't for everyone.

"It is not for the faint of heart," Kelly said. "The hours can be long and inconsistent. You have to do a lot of advanced preparation because when you're in the field, you can't just run next door and grab something you forgot. You are exposed to the elements—rain, snow, extreme heat, I've been through it all. But we improvise, we adapt, we overcome, we document, and we figure it out—these are the words we live by."

About the author:

Regena Kowitz is a contractor for Naval Health Research Center public affairs.

KEEPING LABS IN THE KNOW WITH SLIDES

By Stephen Pease

THE SCALABLE LIVE INFRASTRUCTURE AND DISTRIBUTED ENVIRONMENT STATUS (SLIDES) SOLUTION COMBINES POWERPOINT AND EXCEL TO PROVIDE MORE EFFICIENT LAB COMMUNICATION BETWEEN TESTERS AND ENGINEERS ABOUT REMOTE SITE CONNECTIVITY.

The intention of this project was to streamline communication and awareness between testers, engineers, and leaders. After completing the system, however, I realized this could reach others and possibly help their missions. Rather than omitting any details, I decided to share the reasons, results, and, most importantly, the steps involved in reaching our success in the hope that another lab or project might benefit from this design.

The development of this system began from a project need—in a word, how do you tell several labs that their network is up or down? Sometimes needs are poorly written, not clearly defined, or even go unnoticed. Our lab is a distributed test environment and relies on efficiency, especially when it comes to communicating. The need flew well under the radar, and stepping back and analyzing the state of the current process was necessary to realize that there was room for improvement. Relaying local and remote system connectivity information to testers in our labs needed reexamining. When an internal system or connectivity to a remote site was lost, the engineers would inform event leads, who would then forward the information to the appropriate testers or leaders in the lab.

To be clear, this worked. Eventually everyone would get the message—but the key word is "eventually." This notion helped to conceptualize our underlying problems:

1. Any connectivity status change was not received quickly by those most concerned
2. Testers would troubleshoot their own hardware or software, suspecting their own equipment
3. Testers would travel to different buildings to ask engineers about the connectivity status
4. If not articulated well by the testers, engineers expended effort on troubleshooting already known issues.

These were the problems. Solutions were needed.

Background

Some background on the existing system will provide a better picture of how this working product came to fruition. Our lab consists of multiple buildings, each with connections to external sites, and these connections run between multiple labs across the nation. Because of the volume of foot traffic in the lab and physical separation between buildings, a bullhorn would not suffice to provide awareness of site connectivity to every tester in each lab space. Currently, a PowerPoint presentation for our lab runs in all buildings from a central location. Designed to inform testers on procedures, upcoming events, important contacts, and standard Navy operational security procedures, this presentation appears on TVs throughout all of our locations. Since this is always running and highly visible, it seemed ideal to have a slide show up every few slides that had the live status of our site connectivity (Figure 1).

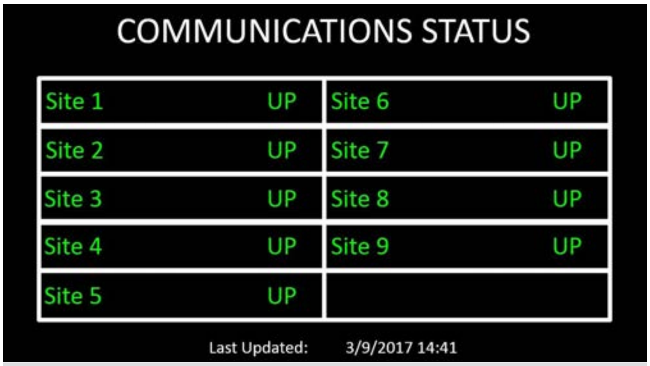


Figure 1. Site Status Board as it Appears in PowerPoint.

The Benefits

PowerPoint slides are simple to update and while changing the status on each slide is possible, it is not practical. Each time the presentation updates for the week or month, slides containing the status board need their text updated. This introduces the potential for errors. This project answers those concerns with three central benefits:

- Security: Changing the text is not possible with a locked Excel and PowerPoint document. The text only changes based on selecting an up arrow or down arrow in Excel. Entering additional, unwanted, or inappropriate text into the presentation is not possible without a password.
- Usability: The only action that needs to take place when a site loses connectivity or becomes live is clicking an up or down arrow in the Excel document. The programming takes care of the rest.
- Reliability: The program has been tested and operating long-term and there have been no failures yet.

Example Use-Case Scenario

Imagine Engineering receives a report, noting that a site is no longer reachable through one of our systems. Preliminary checks demonstrate that the connectivity is down, perhaps because of a bad fiber, malfunctioning crypto, or unplugged power cable. There are many people across our labs that might require this information to be successful. If a tester knows that a site is down, work redirects to alternate tasks until the connection restores. Prior to this system, some may miss the announcement,

Photo by MC3 Gregory Pickett

not be present during the announcement, or forget when that information matters. With this system in place, I walk over to the Excel station, click down on that site, click "put data into PowerPoint" (Figure 2), and the board updates to reflect the correct status of that site on every slide in the PowerPoint presentation containing the status board.

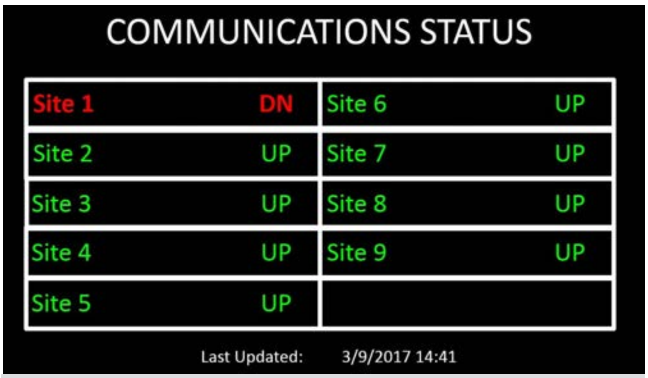


Figure 2. Excel Status Board Control.

Every third slide on the running PowerPoint now shows the text for that disconnected site in red and the text is flashing (Figure 3). Users have learned over a short period to get this information from those slides. This saves our users time from running around trying to find engineers and it saves us from needing to hunt down anyone who would potentially be interested in the outage. In addition, if the engineering staff is not there for some reason, anyone on our operations team can update the PowerPoint presentation to confirm an outage.

Under the Hood Overview

The PowerPoint presentation has a slide that repeats every three slides and resembles Figures 1 and 3. The code that exists in the Excel document affects the green/red text and date/time text in the PowerPoint slide. The Excel document has cells that correspond to the slide number, text box name, and actual text in the PowerPoint text boxes. Also in Excel, a table displays the sites and the site status, and has control buttons that allow changing the site status between up and down. Finally, there is a macro button entitled "Put Data into PowerPoint" that runs the code.

Figure 3. Status Board with Down Site.

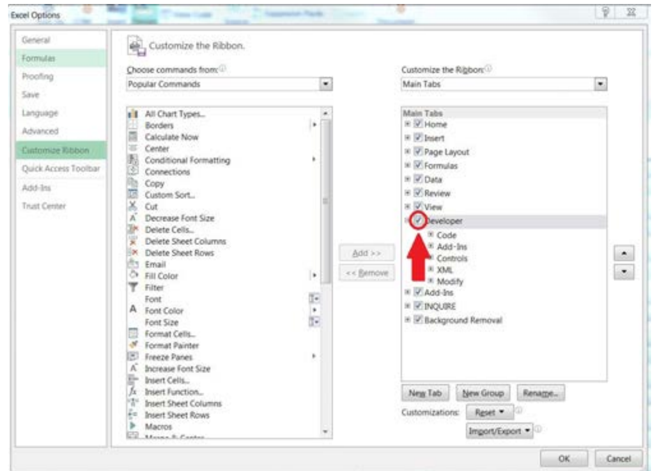


Figure 4. Developer Tab Enabling.

Microsoft Application Setup Details

PowerPoint and Excel both need a few options enabled in order for this project to function because initially of the box they are disabled. Note that certain Defense Department application installations will have these features blocked. First, turn on developer mode (Figure 4) for Excel and PowerPoint. (File>Options>Customize Ribbon>Check Developer).

Next, in both programs, enable the object libraries. This makes coding easier by allowing use of preset phrases that are specific to PowerPoint and Excel. For Excel, enable "Microsoft Excel [version] Object Library" and "Microsoft PowerPoint [version] Object Library," "Visual Basic for Applications" (Figure 5). For PowerPoint, the only requirement in the settings is to enable "Microsoft PowerPoint [version] Object Library." The 1, 2, 3 red arrow steps in Figure 5 are the same for both PowerPoint and Excel.

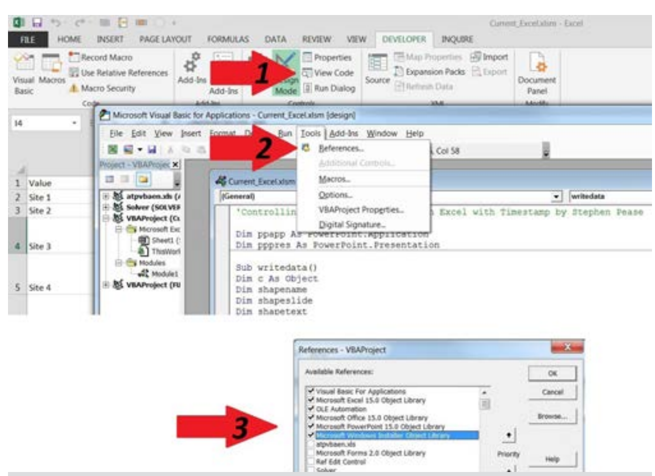


Figure 5. Object Library Navigation.

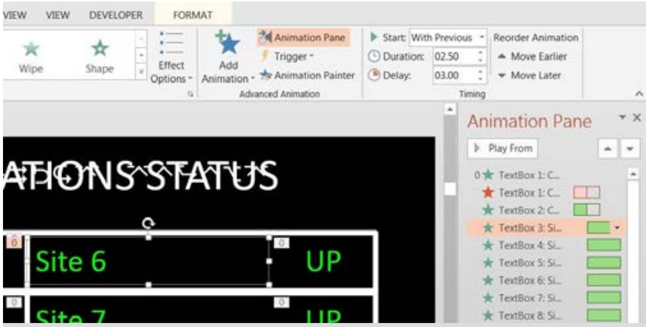


Figure 6. Animation Pane in PowerPoint Showing Selected Text Box.

With both programs set up, next is the structure setup and coding.

PowerPoint

This is the simplest part, because the coding in Excel handles the color change, animation, and text that goes in the text boxes. Our main concern in PowerPoint is that the text box numbering matches the code. To check the text box numbering, open the animation pane (Figure 6) and highlight a text box, then the animation pane will highlight the name of that text box.

Awareness of these text box name locations in PowerPoint ensures correct entry of those names into Excel. It is also good to be aware that there are quite a few text boxes (Figure 7) in the status board slide.

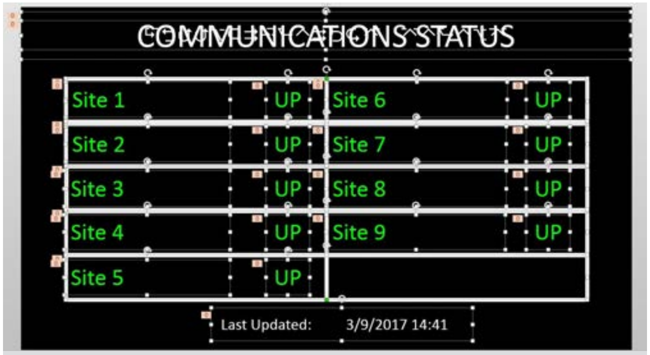


Figure 7. Multiple Text Boxes in Status Board Slide.

The reason for multiple text boxes and this separation was aesthetics. To get site statuses lined up perfectly, I needed to separate site name and status because not all sites had the same length of text.

I have the status board slide set up to cycle every three slides, but that is reconfigurable. If a different frequency of slides is required, it is recommended to duplicate a functioning slide to avoid textbox-numbering mismatch between slides. Creation of a new slide will cause a text box name mismatch.

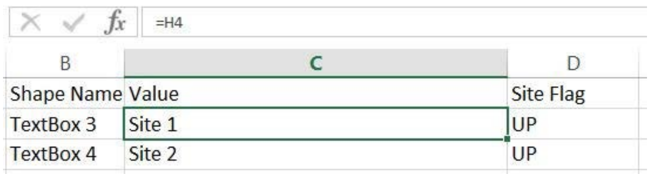
Excel Main Page

Keep in mind that this setup takes place prior to locking the Excel document. Figure 8 displays a portion of the Excel document and cell structure to demonstrate from where the code is drawing its information.

	A	B	C	D
1	Slide Index	Shape Nam	Value	Site Flag
2	6	TextBox 3	Site 1	UP
3	6	TextBox 4	Site 2	UP
4	6	TextBox 5	Site 3	UP
5	6	TextBox 6	Site 4	UP
6	6	TextBox 7	Site 5	UP
7	6	TextBox 8	Site 6	UP
8	6	TextBox 9	Site 7	UP
9	6	TextBox 10	Site 8	UP
10	6	TextBox 11	Site 9	UP
11	6	TextBox 12	UP	UP
12	6	TextBox 13	UP	UP

Figure 8. Portion of Excel Cells Filled.

Column A and B are manually entered, representing slide number (Slide Index) and text box number (Shape Name). Column C and D have formulas that point to the information contained in the cells from the table in Figure 2. Column C is the actual text that goes in the text box and row D acts as a flag, triggering code to make changes to the text color and animation. Everything in row C will be either a site name or "UP" or "DN" because these are the actual text that shows up in PowerPoint. The formula points to the site name in the main table or the status in the main table depending on which text box is referenced in column B. For example, the main table has the name "Site 1" in cell H4, so for the text box that should say "Site 1" in PowerPoint, type in the formula "=H4" in that cell (Figure 9). These columns are long because of the way I designed the PowerPoint slides and the previously



B	C	D
Shape Name	Value	Site Flag
TextBox 3	Site 1	UP
TextBox 4	Site 2	UP

Figure 9. Formula for Inserting a Site Name from the Main Table.

mentioned preference toward the aesthetics of lining up the text in the status board slide.

To create the main table in Excel that displays the status and site names, I inserted a form control button (the up/down button) that can be found in the developer tab (Figure 10). This allows limiting changing the status to only “UP” or “DN.” Select and then draw with the cursor anywhere on the Excel document. I made one and copied so they would all be the same size.

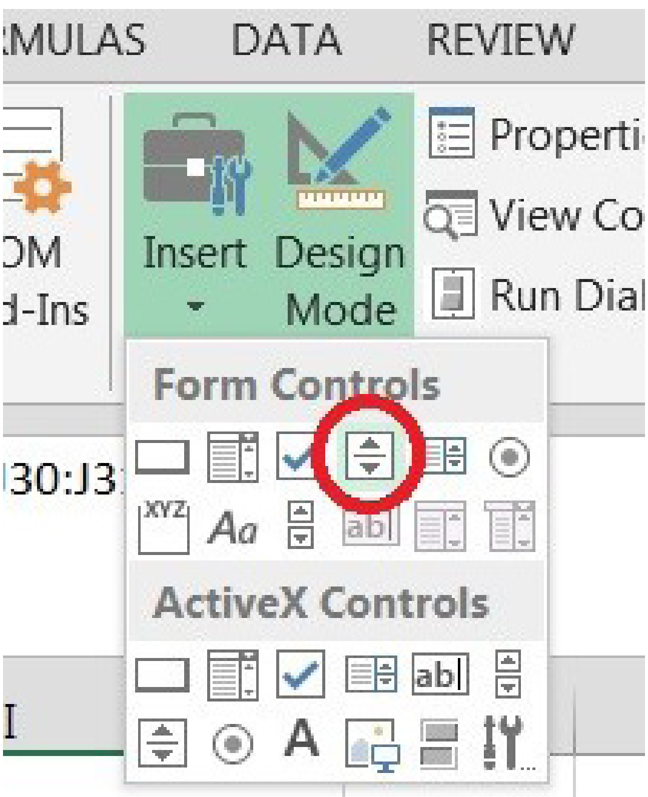


Figure 10. Inserting the Form Control Button.

To setup the control element, first right click the button and select “Format Control,” then apply it to the neighboring cell that is NOT in the main table (i.e., choose the unused cell to the right of the button), and then make the minimum value 1 and the maximum value 2 (Figure 11). This sets the button to allow toggling between two values only.

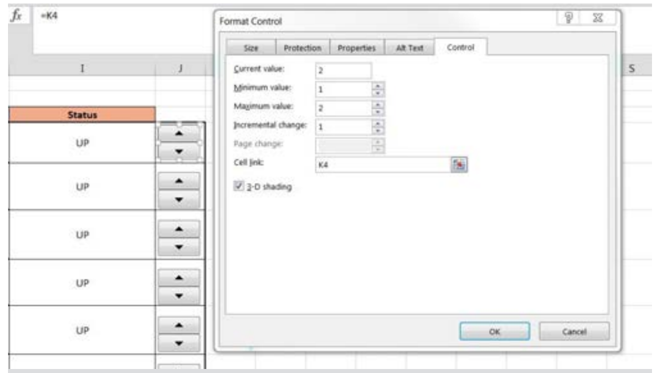


Figure 11. Form Control Button Format Window.

The button will now toggle between values, but it does not yet have data to toggle. The next task is to type “UP” into a random cell then “DN” into the cell beneath it. In my case, I typed “UP” into cell J30 and “DN” into cell J31. Next, type in the formula as pictured in Figure 12 and point to the random cells previously identified (J30 and J31) then the toggle value in the cell next to the button (K4). This causes the text in cell I4 to toggle between “UP” and “DN” depending on the press of the up and down button in cell J4. This is repeated for each site with the random cells (J30 and J31) remaining the same and only needing to change the cell next to the up/down button. For example, the next formula for I5 would be “INDEX(J30:J31,K5).

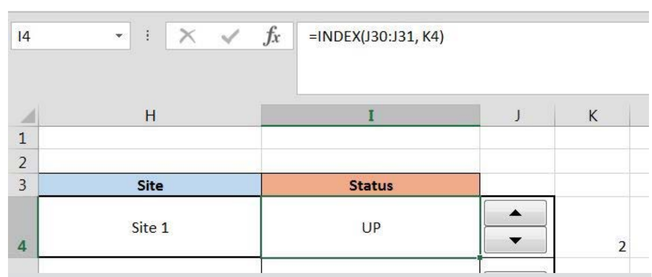


Figure 12. Cell Formula for Accessing Form Button Text.

The Site column contains manually typed in names of the connected sites. This is the case-sensitive text that will show up in PowerPoint text boxes.

The last portion to setup on the front page of the Excel document is to find any random cell and enter in the formula to pull the current time from your computer. The formula is “=NOW()” (without the quotes), and in this project, I placed it out of the way in cell H25. This is useful for determining when the last change was made and when pressed daily lets users know that the site connectivity status is up to date. With the main Excel page setup, next is to complete the VBA code that drives most of the action in this project.

The Excel VBA Code

VBA was the language used because it was a Microsoft product. A jack of many trades and master of a few, VBA coding is not my specialty. While I have coding background, I had not worked with VBA extensively and there involved a bit of a learning curve. The program, however, is functional at this point and operating solidly. A seasoned VBA coder may look at what I wrote and be able to produce a more elegant version, but until then, this program functions perfectly. I did take time to comment on any important lines so that it makes sense what the code is doing on each line. I have singled out three important items worth mentioning in the coding.

The first item to note that prevents this from working after opening the file is that Excel does not know where the PowerPoint presentation is stored yet. The "sPath" variable sets this up (Figure 13).

```
'This specifies what folder path the current powerpoint and current excel file are located
' Remove parenthesis and as an example if the file is on the desktop on Bob's account then
' sPath = "C:\Users\Bob\Desktop\"
sPath = "(Remove the parenthesis and add the path to the FOLDER containing the PowerPoint file)"
```

Figure 13. The sPath line that directs Excel to PowerPoint.

The second item to note is the timestamp portion of the code. This line of code specifies a cell in Excel where the "=NOW()" formula (Figure 14) is located and the PowerPoint text box that should contain that information.

```
'Set Timestamp for when change was made
'This one is specifically called out by cell in Excel and by text box in PowerPoint
timestamptext = (Sheet1.Range("H" & 25).Text)
pPreso.Slides(shapeslide).Shapes("Text Box 28").TextEffect.Text = timestamptext
```

Figure 14. Timestamp Code Pointing to Cell and Text Box.

The third item to note is the animation counting in the code. This number comes from the amount of animations in the animation pane for that slide in PowerPoint. In this example, there are 28 animations before applying any effects to the sites. This is because all of the text boxes and borders fade in from black. When the code (Figure 15) needs to remove an animation (i.e., when a site goes back up) it incrementally counts through permanent animations and removes all after that point.

```
'Also if it doesn't say "DN" Remove Flash Bulb Effect
Set osld = pPreso.Slides(shapeslide)
'The number 28 is only there because there are 28 effects in the slide that should not change (fade in effect)
'If these other effects on the page are NOT needed, then it would be ">0" instead and they would have to be removed
If osld.TimeLine.MainSequence.Count > 28 Then
    For i = osld.TimeLine.MainSequence.Count To 29 Step -1
        Set oeff = osld.TimeLine.MainSequence(i)
        If oeff.Shape.Name Like shapename Then
            oeff.Delete
        End If
    Next i
End If
```

Figure 15. Delete Animation Code.

This is an unfortunate limitation of my programming, as I am almost certain that there is a more elegant way to program the deletion of animations, but I have not yet discovered it. Should more or less animations be required, then the ">28" and "Count To 29" numbers should be adjusted accordingly. For example, if the slide only contained animations for the text boxes to change status and no fade-in was used, the "If" statement could be altered to "> 0" and the "For" statement could be altered to "Count To 1 Step -1" to reset the animations.

The color of the text changes when altering the RGB values and the type of animation changes by adjusting the name and parameters in the code. Unfortunately, a deep dive into those aspects is outside the scope of this article. The remainder of the code runs without any needed alterations from the setup in the Excel document in earlier steps.

Conclusion

This project saved many labor hours, still functions today, and organically became a known entity for information delivery. Testers and leaders know to look at the PowerPoint for up-to-date information and new testers to the labs understand the status board very quickly. We have even received praise from the levels of leadership that just tour our facilities. While not increasing individual productivity, it does remove loss of productivity caused by poor communication, leading to an overall increase in production potential. The few hours put into place for this project easily become worthwhile when considering the hours no longer used searching for site connectivity status.

The future of this project is already in the planning phases and is looking toward more automation. To remove more of the human element, I plan on implementing automation of the up/down aspect, perhaps via SNMP traps or some other form of heartbeat that regularly queries the connection status (get to it scientists!). At the time of writing this, we are planning to add another facility and the only requirement is to add a feed to our running PowerPoint, so the display is relatively scalable. There will be some work required to add additional sites, but the principles remain the same. Ultimately, my hope is that this project can serve as a tool for other organizations facing similar problems or as inspiration for alternate methods of organizational improvement.

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Stephen Pease is a systems engineer for the enterprise engineering and certification lab at Space and Naval Warfare Systems Center Pacific.

Space and Naval Warfare Systems Center Atlantic employee Josh Carter, a member of the Unmanned Systems Research Range team, performs maintenance on an unmanned aerial vehicle. Photo by Joe Bullinger

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