



Summer 2014

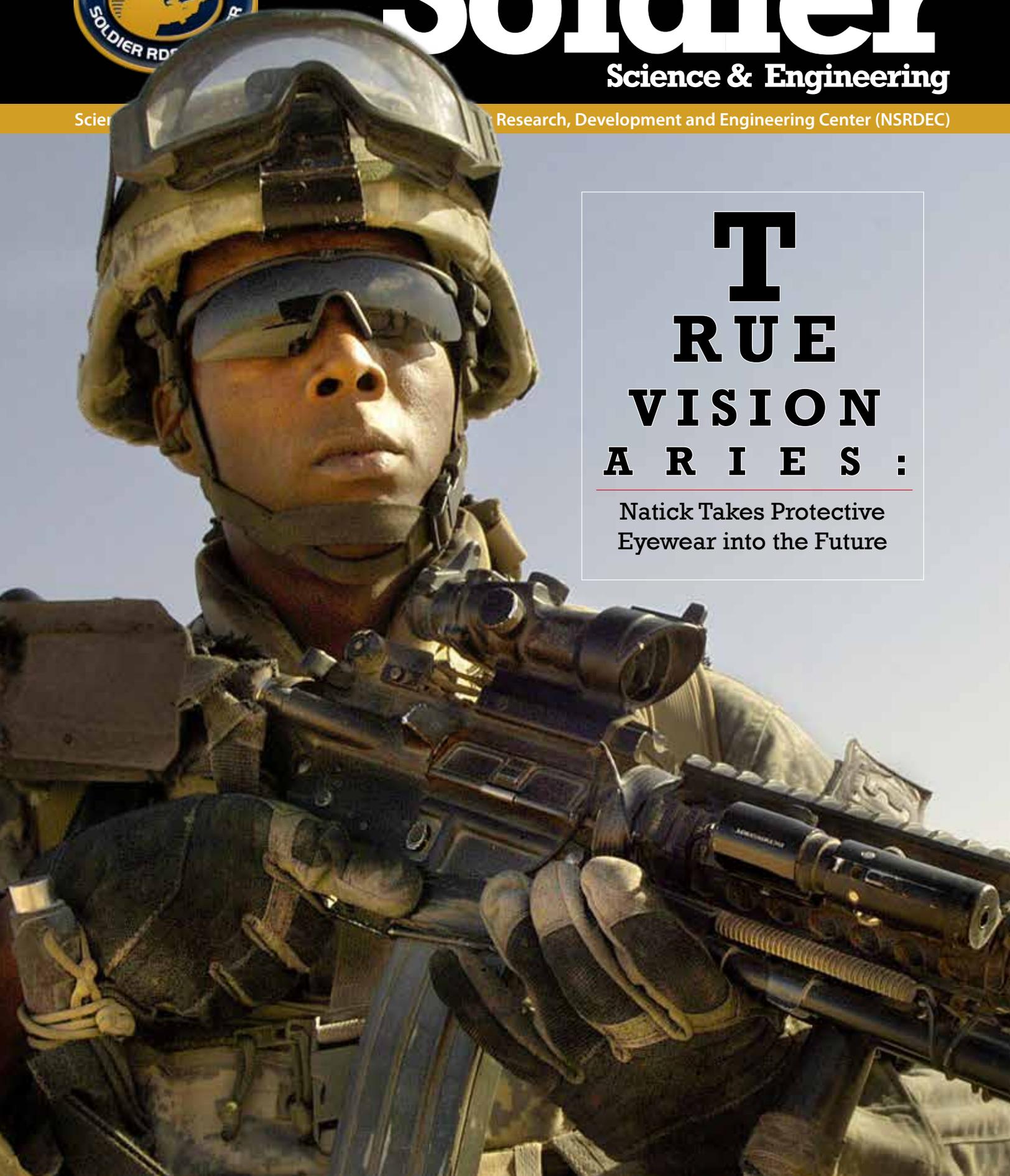
# Soldier

Science & Engineering

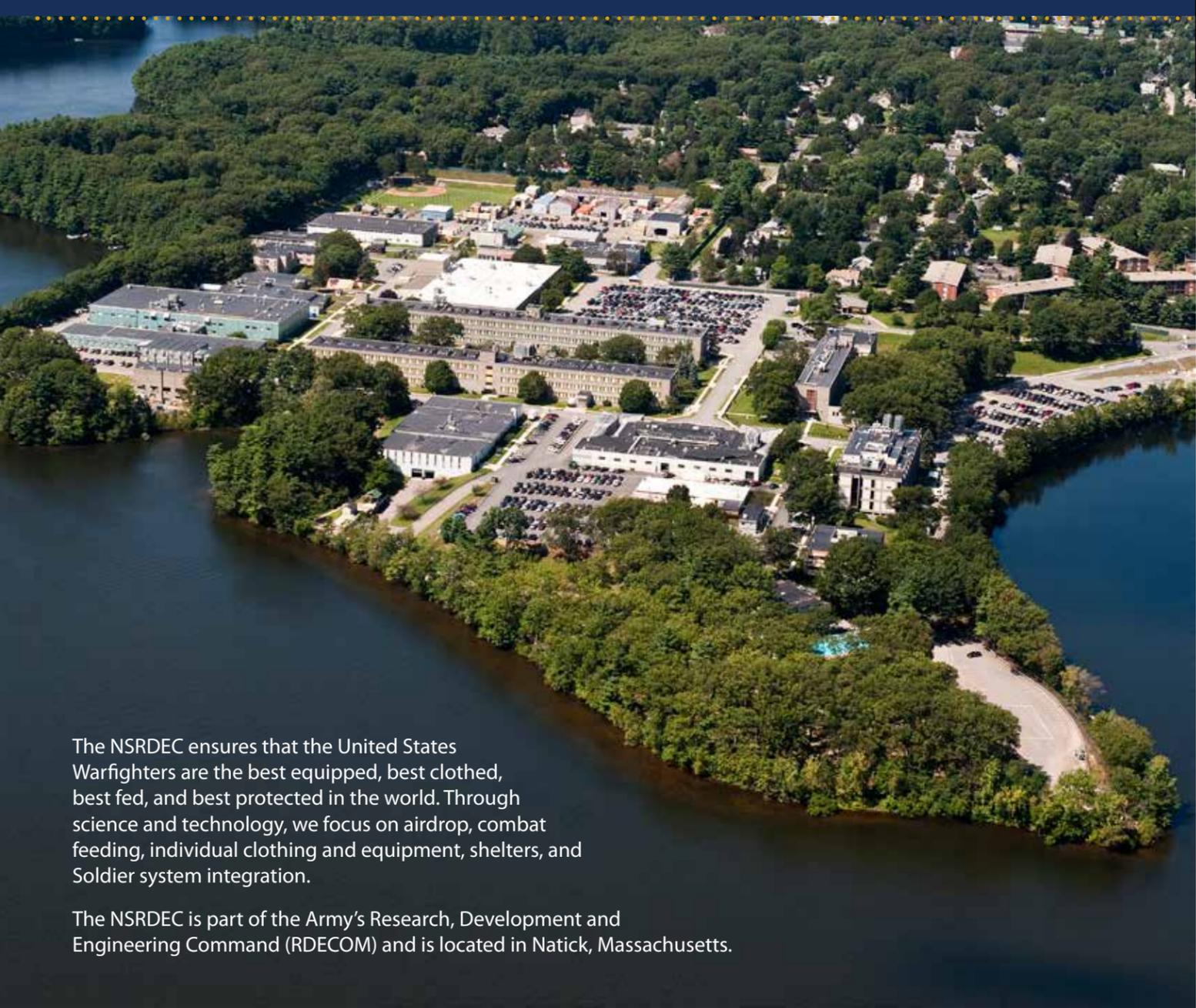
Science and Technology Research, Development and Engineering Center (NSRDEC)

## **T RUE VISION ARRIVES :**

Natick Takes Protective Eyewear into the Future



# U.S. ARMY NATICK SOLDIER RESEARCH, DEVELOPMENT & ENGINEERING CENTER (NSRDEC)



The NSRDEC ensures that the United States Warfighters are the best equipped, best clothed, best fed, and best protected in the world. Through science and technology, we focus on airdrop, combat feeding, individual clothing and equipment, shelters, and Soldier system integration.

The NSRDEC is part of the Army's Research, Development and Engineering Command (RDECOM) and is located in Natick, Massachusetts.

## OUR MISSION

Research, Development and Engineering (RD&E) To Maximize the Warfighter's Survivability, Sustainability, Mobility, Combat Effectiveness and Field Quality of Life by Treating the Warfighter as a System.

## ADDING VALUE THROUGH:

- Basic Science
- Technology Generation, Application, and Transition Enabling Rapid Fielding of the Right Equipment
- Soldier Systems Technology Integration and Transition
- Solving Field Problems Rapidly

## OUR VISION

The Leader in Empowering the World's Most Capable Soldiers

## OUR FOCUS

Deliver world-class research, development and systems engineering and services, with a unique Warrior-centric focus.



# Soldier

Summer 2014

## Science & Engineering

Science and Technology News from the Natick Soldier Research, Development and Engineering Center (NSRDEC)

## Innovation and collaboration

My first few months at Natick have been engaging and invigorating. It has been easy for me to feel at home at a place where the science is cutting edge and the Warfighter is the top priority. At the heart of this vibrant organization is the intellectual curiosity and enthusiasm of its workforce.

This edition of NSRDEC Soldier Science & Engineering covers the Soldier from head to toe—literally. You'll read about the latest developments in eyewear protection, head protection, body-worn cooling systems and combat boots. You'll find out about studies on the interaction of Soldier physical and mental fatigue, as well as the effect of sleep restriction/stress on Soldier immune systems.

Quality of life is at the heart of what we do, and it turns out NSRDEC researchers have devised a way to measure and model Warfighter quality of life. This issue also discusses progress in meeting the most basic of human needs: food and water. Monica Borgogno, a visiting food scientist from Italy, is bringing her unique perspective to Natick while conducting food consumer research. NSRDEC is working on a hand-held sensor to prevent food-related illness and is actually investigating the future 3D printing of food. You'll also find out about the new Insulated Containers for Bottled Water, or ICB.

Natick is a center of expertise in research and development for aerial delivery—so be sure to read about the Joint Technical Aerial Delivery Group, or JTAG, meeting and how it fosters interservice collaboration.

Along with the U.S. Army Research Institute of Environmental Medicine, NSRDEC continues to reach out to the larger community with its involvement in the teachers program for Gains in the Education of Mathematics and Science, or GEMS. Through this program, we provide middle-school teachers with hands-on, real-world experiences with science that they can share with their classrooms.

I am proud to lead this exemplary organization as it continues to serve the Warfighter, the local community and the nation. Always looking forward and always redefining/advancing the possibilities, NSRDEC continues to create the future in the here and now.

Sincerely,

Laurel Allender, Ph.D.  
Director, Natick Soldier RD&E Center



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## Questions regarding NSRDEC Science & Technology?



NSRDEC is part of the U.S. Army Research, Development and Engineering Command, which has the mission to develop technology and engineering solutions for America's Soldiers.

RDECOM is a major subordinate command of the U.S. Army Materiel Command, whose mission is to develop and deliver global readiness solutions to sustain Unified Land Operations, anytime, anywhere.

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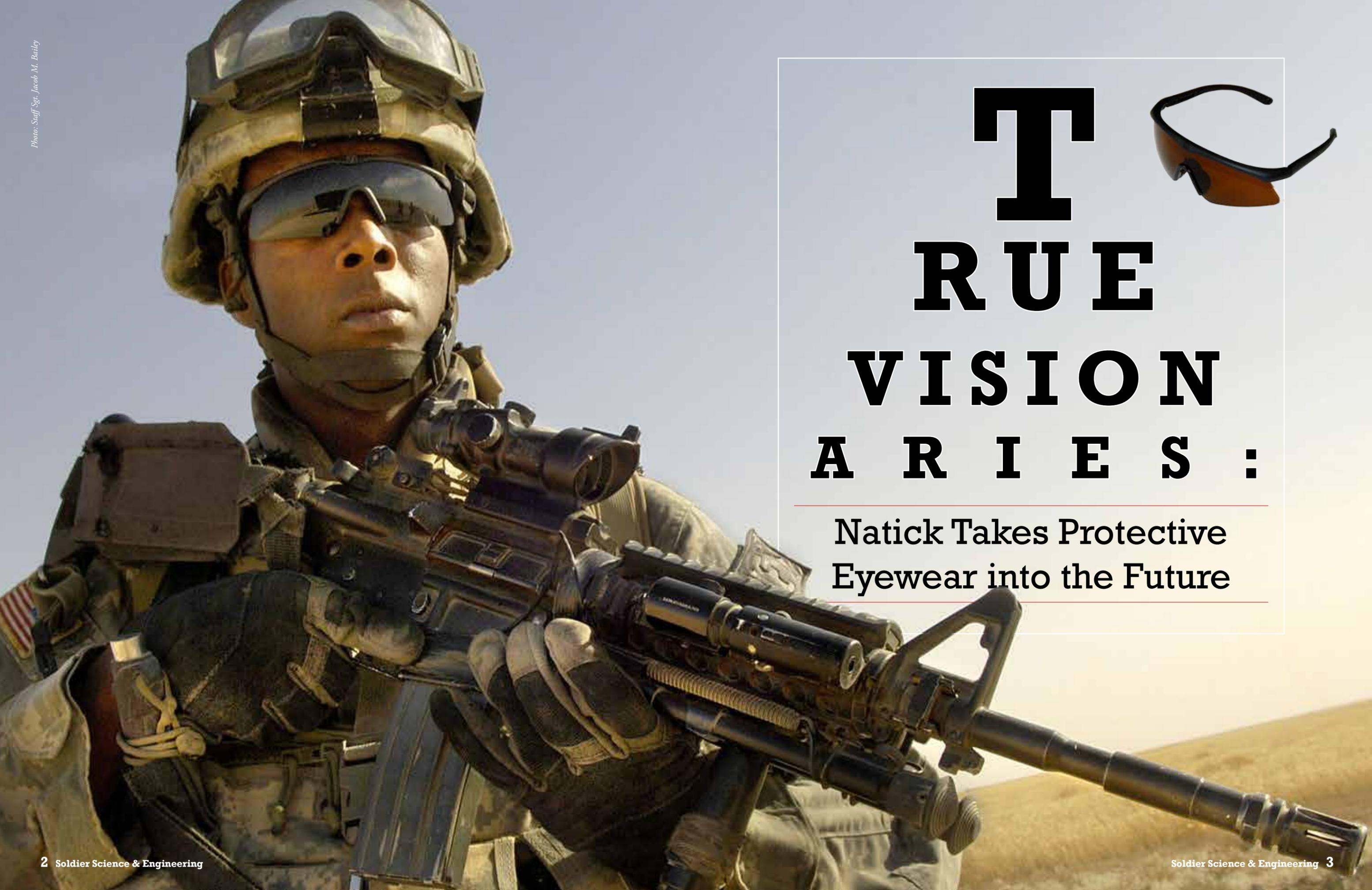
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Natick Takes Protective Eyewear into the Future

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# When it comes to the very best in vision protection for the warfighter, researchers at the Natick Soldier Research, Development and Engineering Center make sure the eyes have it.

When it comes to the very best in vision protection for the warfighter, researchers at the Natick Soldier Research, Development and Engineering Center make sure the eyes have it.

“Eyesight is fundamental to a Soldier’s job, making vision protection of critical importance,” NSRDEC researcher Brian Kimball said.

A warfighter’s vision can be impacted by dust, sand, fog, and changes in lighting. There are also outright threats from ballistic fragmentation and lasers.

NSRDEC researchers are continuously working to find better ways to prevent sight impairment and eye injury, now and in the future, and are also working on cutting-edge technologies for vision enhancement and shared vision applications.

“At NSRDEC, our mission is the Soldier. We are honored and humbled by their service, bravery and dedication, which challenge us to pursue science and technology solutions that will enhance their safety, comfort, and effectiveness,” Kimball said.

“The number of injuries has come down with the use of protective eyewear. Although you can’t prevent all injuries, the majority can be avoided, or reduced in severity, by wearing the proper protection,” said Michelle Markey, who is involved with science and technology research at NSRDEC, as well as end-item technical support for both the Army and Marines.

“Improvements are always ongoing,” Kimball said.

### **Advances are made possible by the spirit of collaboration.**

NSRDEC attributes the success of ongoing vision protection technologies to the collaborative nature of the DOD vision-protection community, which has a long history of working together and sharing resources, capabilities and technology.

“This community consists of scientists, engineers, medical professionals, and dedicated program and project managers,” said Kimball. “These combined resources provide capabilities that could not be realized otherwise.”

### **Ballistic fragmentation protection is a top priority.**

“Ballistic fragmentation protection is always the primary consideration,” Kimball said.

Soldiers face a variety of ballistic fragmentation threats, including debris from explosions and weapons firing. They also face increased threats from improvised explosive devices.

Polycarbonate, known for its durability and manufacturability, has long been the Army’s staple material for impact-resistant eyewear.

Now, however, NSRDEC is taking ballistic fragmentation eye protection into the future. NSRDEC is now working to incorporate new, lightweight, transparent nylon materials into protective goggles and spectacles.

“The material is a significant improvement,” Markey said. “We are looking at a 15 to 20 percent improvement in impact resistance.”

“And it is lighter weight,” Kimball added.

This new material, the result of research conducted by Dr. John Song, a materials research engineer at NSRDEC, is approaching the manufacturing stage of product development.

### **Laser danger**

Lasers are an increasing threat to Soldiers. The word laser is actually an acronym for Light Amplification by the Stimulated Emission of Radiation. Lasers can cause flash blindness, corneal hemorrhaging, retinal lesions and burns, and possibly permanent blindness.

“Laser light is coherent, collimated and of a single wavelength, so that your eye focuses it to a very fine spot. In this way laser light is more intense than regular white light,” Kimball said.

Handheld versions of lasers are readily available to anyone, anywhere. Military system-based lasers are also becoming more prevalent in theater operations. Laser hazards can come from systems such as target designators and laser-range finders.

Current laser protective lens technologies use dyes and/or optical films to absorb or reject laser energy. Natick researchers are aiming to increase the survivability and mobility of warfighters in situations where lasers pose a threat and/or hazard. They are working to provide protection in low-light conditions, especially protection that will work better at night. Their goal is to make laser protection part of a single, multifunctional lens system.

### **Sand, fog and scratches pose ongoing challenges.**

Researchers continuously face the difficult challenge of developing scratch- and fog-resistant coatings that do not interfere with ballistic fragmentation or laser protection. Solving this problem is an important priority, because Soldiers tend to take off their eyewear if it is scratched or remove their eyewear when it fogs—thus, sacrificing protection altogether.

“The most common complaints they have in the field are scratching and fogging,” Markey said. “We are always looking into new technologies.”

Researchers also discovered during desert conflicts that improved scratch resistance coatings are needed to protect lenses against blowing sand abrasion, such as that from sandstorms.

NSRDEC, with support from PM-Product Manager Soldier, devised new methods of evaluating abrasion and fog resistance. “We are perfecting and finalizing these new methods of testing and will be investigating new coatings,” said Kimball.

### **A prescription for success**

Many Soldiers wear prescription eyeglasses. Currently, vision is corrected by installing a prescription lens carrier with corrective lenses behind the Soldier’s protective eyewear. Technologies currently being investigated by NSRDEC also have application to prescription lenses, and will help make vision correction part of the single-lens system envisioned for the future. NSRDEC foresees this as a joint venture with the U.S. Army Public Health Command and program offices.

### **The importance of testing**

One of the most important contributors to successful advancements in eyewear protection is early and frequent testing of new materials and coatings to make sure an advance in one area isn’t detrimental to another area. Sometimes, new coatings that may protect against scratching or other problems lessen impact protection and have to be abandoned.

“If we have a new capability, one of the first things I do is shoot it (with a ballistic fragmentation impact simulator),” Markey said.

“The key is to test it as early as you can,” Kimball said.

### **Looking into the future**

Hindsight may be 20/20, but future sight will be even better.

The key to future systems, according to Kimball, is to “do it all in a single-lens format.”

NSRDEC researchers are developing an active eyewear system that will protect the user from ballistic fragmentation and lasers, as well as provide vision enhancement in a single lens. The lens will be able to quickly adjust from very clear all the way down to a true sunglass state, allowing the Soldier to more readily adjust to rapidly changing lighting conditions. The system will protect against dangerous forms of light, including lasers.

In addition to providing protection against numerous threats and adapting to different types of light, the single-lens system would also include vision enhancement.

“The system will have tremendous potential to give the warfighter the edge over opponents and to ultimately lighten their load by providing information and functionality that will one day replace complex, stand-alone systems,” Kimball said.

Soldiers will benefit from features such as zoom magnification, variable polarization, multispectral enhancement, and selective light-filtering capabilities. The technology will allow for increased situational awareness



### **Historical Perspective – Eye protection has come a long way.**

Eye protection for the warfighter was first developed in the 1940s and included goggles that protected from the sun, wind and dust. From the 1980s until the beginning of the new millennium, new advances in impact protection and laser protection became available. Since then, coatings, materials and capabilities have been improved continuously to ensure the warfighter has the very best technology can offer.

Protective eyewear is crucial to preventing permanent or temporary injuries to the eye in

“Eyesight is fundamental to a Soldier’s job, making vision protection of critical importance.”

NSRDEC researcher Brian Kimball

and enhanced target recognition. The single-lens system will also feature improved impact protection and hearing protection/augmentation. Energy-harvesting technologies are also being investigated to make the system self-powering.

NSRDEC researchers are working to ensure that these new developments will be environmentally robust and low in bulk and weight. Nanotechnology will allow for the creation of new materials.

conflicts, past and present. Eyewear protection has proven to be extremely important in recent conflicts in Iraq and Afghanistan, where warfighters face ongoing threats from improvised explosive devices. Protective eyewear has saved the eyesight of countless Soldiers exposed to shrapnel and flying debris common with the use of these devices.

Fortunately for the warfighter, “Warfighter Vision System research is a challenging area that has attracted some of the brightest minds in the country,” Kimball concluded.

# Best Foot Forward

Army testing combat boots, camouflage patterns

Young Soldiers often want to wear a uniform that looks cool, while lawmakers want cost effectiveness, but the Army's priority is protecting the Soldier from harm.

That's what Col. Robert F. Mortlock, project manager for Soldier Protection and Individual Equipment, Program Executive Office Soldier, said he aims for, along with other important goals like comfort, fit, price, protection from the environment and durability.

## JUNGLE BOOTS

As the Army pivots to the Pacific region, it is looking to develop a new jungle boot. Testing of some vendor-supplied prototypes could begin this summer, Mortlock said.

A good jungle boot, he explained, would shed water, meaning it can dry out fast after submersion. It also would be lightweight and breathable to minimize the effects of high temperatures and humidity. The lugs (tread) on the outsole would also be able to trek through mud with minimal slipping. Also, the leather should not dry out and crack from repeated wetting cycles.

The most important factor in the development of the jungle boot — or any new boot for that matter — he said, is Soldier feedback from real-use, rigorous testing.

“We do this rigorous user testing because we want Soldiers to trust and have confidence in their equipment so they can focus on their primary mission. And we've built up that trust over a number of years,” he added.

## BOOT IMPROVEMENTS

One of the biggest recent improvements in boot design is “direct-attach outsoles.” Mortlock explained that soles that are glued, not stitched, to the bottoms of boots, make some pairs of Army Combat Boots up to 1 pound lighter. The direct-attach outsoles are also less apt to separate after long, rough usage.

But equally importantly, he said, direct-attach outsoles have reduced lower leg injuries to

Soldiers because they reduce the shock transferred to the foot and leg.

The adoption of “universal sizing” is also important. Until the Army adopted universal sizing, a Soldier wearing size 10.5 boots and who ordered another pair of the same size from another vendor might find the new boots somewhat smaller or bigger than the boots being replaced. This is because commercial vendors use different molds, or “lasts” for building their footwear. The Army now requires that a universal “last” or mold, be used by all of its boot vendors to ensure that Army-issue boots have universal sizing. This will reduce the logistics trail and save time for Soldiers and their units, Mortlock added.

Another criteria, that doesn't really relate to safety and comfort, is that any boot that's produced for Soldiers and issued by the Army has to be made entirely in the U.S. out of U.S.-manufactured textiles and materials, per the Berry Amendment, which was originally passed by Congress in 1941, and codified into law as 10 USC 2533a. Soldiers are authorized to wear boots of their choosing, even if they are not Berry Amendment compliant, as long as these boots conform to

“We do this rigorous user testing because we want Soldiers to trust and have confidence in their equipment so they can focus on their primary mission. And we've built up that trust over a number of years.”

Col. Robert F. Mortlock

Photo: Staff Sgt. Isaac A. Graham

Army Regulation 670-1 “Uniform Appearance Regulation.” Soldiers are authorized to use their clothing replacement allowance for these.

Master Sgt. Benjamin Owens, a 20-year Army veteran who was interviewed along with Mortlock, said that even though many Soldiers opt to buy their own footwear, in his opinion, the best boots are standard issue.

“As a drill sergeant, I’ve foot marched hundreds of miles in different terrains in these,” he said, pointing to the standard-issue boots he was wearing.

“Younger Soldiers sometimes go for a flashy look in a boot,” he said, adding that they often pay a price for doing so.

Adding to Owens’ comment, Mortlock said, “Any time you choose a different boot, you’re trading off something: durability or breathability, or something else.”

When Soldiers first join the Army, they’re issued two types of standard Army Combat Boots, the hot weather and temperate weather variants. Soldiers later receive an annual clothing replacement allowance for boots.

Other specialized boots are issued for specific mission requirements. Soldiers deploying to Afghanistan are issued mountain combat boots, tailored for rough, mountainous terrain found in the eastern part of that country. That too comes in a hot-weather and temperate weather variant.

Aviators and vehicle combat crewmen are issued flame-resistant boots that fit their mission.

There are also intermediate cold/wet-weather boots and extreme cold-weather boots.

Specialized boots are not part of the Soldier’s annual clothing replacement allowance, so Soldiers are simply issued new ones when their old boots wear out.

#### **CAMOUFLAGE PATTERNS**

The Army just completed the most extensive uniform camouflage testing in history, in which thousands of Soldiers participated over multiple lanes of effort, Mortlock said.

He explained the importance of camouflage to a Soldier’s mission:

“The bottom line is the enemy can’t kill, hurt or injure who they can’t see,” explained Mortlock. “We have testimonials from Soldiers in theater close enough to the enemy to hear them saying they can’t see the American.

That’s powerful. That’s a combat multiplier.”

Although much has been done, camouflage testing continues, Mortlock said. The Army evaluates “all the options” and is reviewing the fiscal year 2014 National Defense Authorization Act to ensure any camouflage decision is in full compliance with the NDAA. The NDAA states that the Army can “use existing uniforms and patterns and use the patterns of sister services.”

The ongoing tests will continue this month and next at Fort Benning, Ga., and will be followed up at Fort Polk, La., and Yuma Testing Ground, Ariz.

The tests are seeking to determine a family of camouflage patterns that perform better than the present Universal Camouflage Pattern, known as UCP. Separate patterns designed for arid, transitional semi-wooded, or heavily wooded terrain tend to perform better than a single pattern, which seeks to provide concealment in all three environments.

Criteria for testing the patterns, Mortlock said are “detection and blending.”

For those criteria the Soldiers wearing the different patterns are put at a variety of distances, lightings, backgrounds and movements from Soldiers who serve as spotters. These Soldiers are timed as they try to pick the camouflaged Soldiers out from the environment.

So far, tests show that at a range between 25 and 50 meters, the pattern matters, meaning it is critical for blending in the environment. At distances greater than 50 meters, the pattern itself is less important than the general colors of the camouflage.

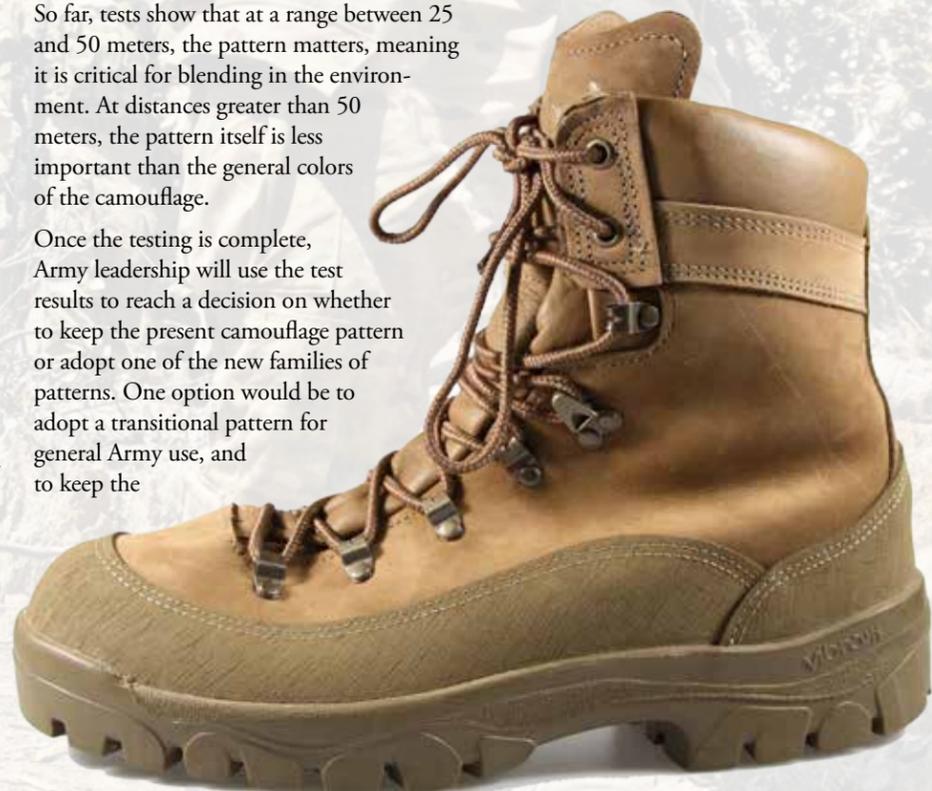
Once the testing is complete, Army leadership will use the test results to reach a decision on whether to keep the present camouflage pattern or adopt one of the new families of patterns. One option would be to adopt a transitional pattern for general Army use, and to keep the

more specialized arid and woodland patterns in reserve until they are requested by a combatant commander.

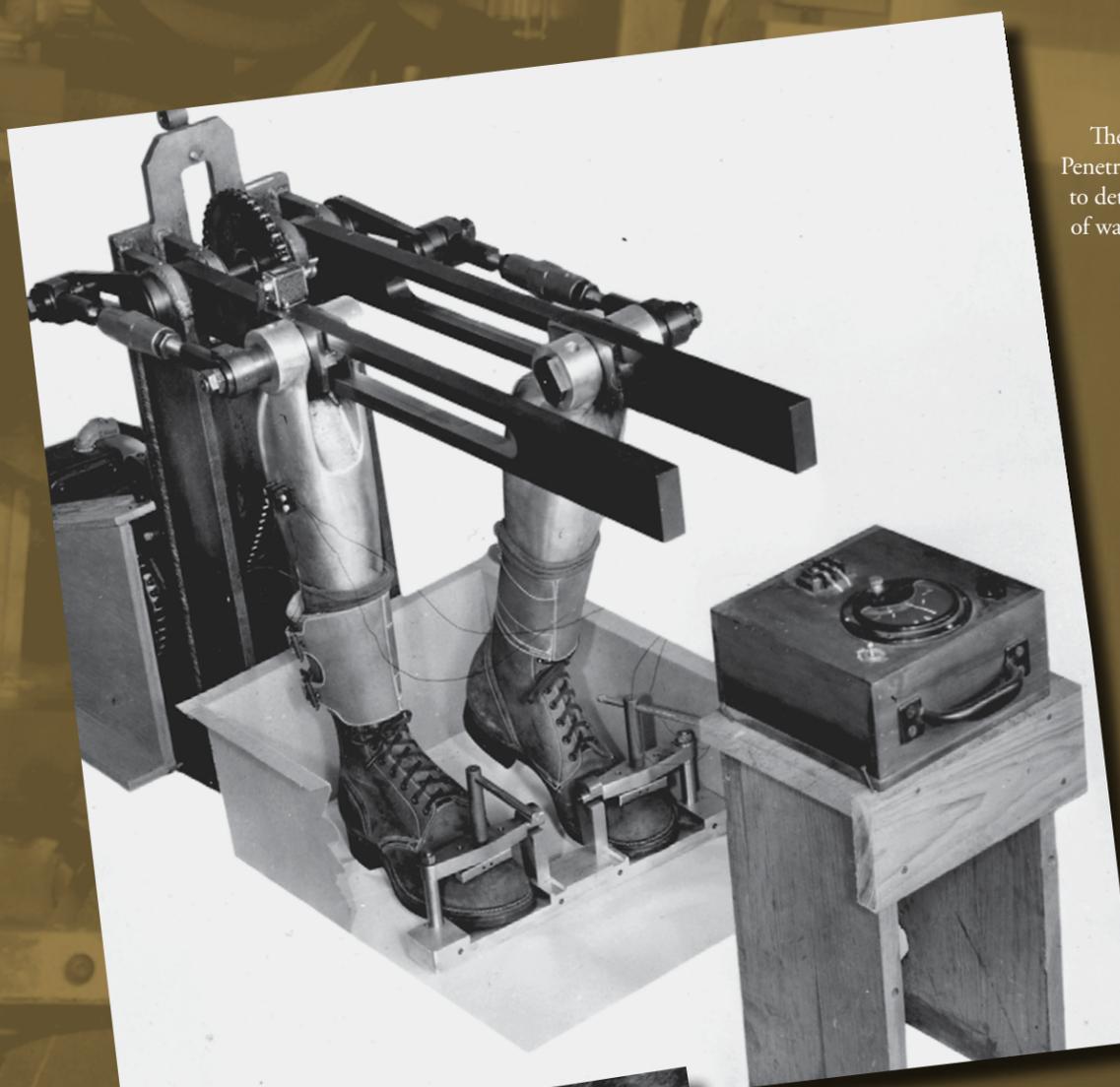
“The other thing about camouflage that sometimes gets lost is, we’re not changing the combat uniform,” Mortlock added. “It’ll still be called the Army Combat Uniform. All that we’re doing is updating the camouflage on the Army Combat Uniform.”

“Whatever we do, we’re going to do in a fiscally responsible manner,” Mortlock said.

A number of organizations collaborate in the science, research, development and testing of combat boots and camouflage uniforms. These include PEO Soldier; the Army Test and Evaluation Command, Aberdeen Proving Ground, Md.; the Maneuver Center of Excellence, Fort Benning, Ga.; U.S. Army Training and Doctrine Command, Fort Eustis, Va.; and the Natick Soldier Research Development and Engineering Center, Natick, Mass. The effort also benefits from interaction with commercial vendors who develop and produce combat boots, uniforms and other gear.



Shown is another Natick machine for testing boots.



The Maeser Walking Water Penetration Machine was used to determine the effectiveness of waterproofing applications on leather shoes.

## Looking back at Natick

Boot research (see page 6) didn’t begin yesterday at Natick. Archival photos prove that Natick researchers have worked for decades to provide functional, comfortable footwear for warfighters.

# TESTING | BOOTS

*U.S. Army Natick Laboratories*



Photo: David Kamm, NSRDEC Strategic Communications

Military food inspectors may one day hold the key to avoiding foodborne illness in the palms of their hands. The U.S. Army Natick Soldier Research, Development and Engineering Center is working to develop a small, sensitive, hand-held device that will both capture and detect dangerous pathogens that can cause food-related illness.

The effort received a 2013 U. S. Food and Drug Administration leveraging and collaboration award. Under the award, scientists from Food Protection Team and Macromolecular Sciences and Engineering Team at NSRDEC, are collaborating with the FDA Winchester Engineering and Analytical Center, and the Massachusetts Institute of Technology. The award is for “Designing Handheld Resistance Based Biosensors Utilizing Conducting Nonwoven Fibers for In-Field Microbial Pathogen Detection.”

NSRDEC originally came up with the idea of conductive membrane sensors and performed the initial research under the Army’s 6.1 basic research programs. This research is the basis for the collaboration with the FDA and MIT. The NSRDEC scientists involved in the project include Andre Senecal, Kris Senecal, Joshua Magnone, Patrick Marek, Shannon McGraw and Philip Pivarnik.

The food inspection tool will reduce the danger Soldiers face from contaminated food. Food safety is critical to combat readiness. Soldier performance, quality of life, and health can be seriously affected by undetected pathogens in food.

“Military operations at some overseas locations where food is procured locally and food safety laws are lenient, are especially problematic. Soldiers can lose a lot of time from work because they get sick from pathogens present in water and food,” Andre Senecal said. “We are starting our work with E. coli 0157:H7, but the goal is to look at all microbial pathogens and toxins that they produce.”

“The leading cause of illness among troops has historically been gastroenteritis, with

one of the primary culprits being E. coli,” McGraw explained.

Biosensors consist of a biological component, such as an antibody or DNA that is capable of capturing, detecting and recording information about a measurable physical change in the biosensor system.

# Safe Bet

## Hand-held inspection tool to prevent food-related illness in Soldiers

When bacteria are present on the device, it impedes the flow of electricity from one side to the other side, McGraw said. This change in the electrical connection tells the user that the sensor has encountered a dangerous food pathogen.

The sensor will be a marked improvement over current detection methods because of its portability and simplicity in a field environment. Current methods use cumbersome, sometimes heavy equipment, including tubing and reagents.

Since the sensors would capture and detect on the same device, the need for some peripheral equipment is eliminated, Marek said.

“It will be portable,” added Kris Senecal.

“And the device will be reusable and the detection membranes disposable, and (it) will hold up in a field environment,” McGraw said.

The biosensor will concentrate pathogens that could help eliminate the need to grow the bacteria, which can take eight to 30 hours, Andre Senecal explained.

“We thought we could incorporate Kris’s work on electrospinning and use nanotechnology and fibers as a way of simplifying the process of extracting and concentrating the bacteria on one platform,” he said.

Kris Senecal is working to put conductive polymers on nanofibers, which she said work better at detection than a flat surface.

“Nanofibers are one-billionth of a meter, and nanomaterials are cheap, one-use, and super lightweight,” Kris Senecal explained. “Nanofibers may be used for food safety. Antibodies can be added to the nanofibers, which have a lot of surface area to which you can add

antibodies that can catch single-cell bacteria, and other pathogens. The sensor will provide protection from E.coli, Listeria, general food threats, and Salmonella.”

“It will be very helpful in preventing illness. Everyone is looking for something better, cheaper, faster,” McGraw said.

“If it can be used for the military, it can be used elsewhere,” Pivarnik said.

“This could also help farmers since not all farmers use safe, municipal, chlorinated water,” Andre Senecal added.

“It definitely has commercial applications,” Kris Senecal said.

# Natick's 'HEaDS UP' Leads Way

By T'Jae Gibson, ARL Public Affairs / April 24, 2014

The U.S. Army Research Laboratory's prototype exoskeleton, the Vertical Load Offset System or VLOS, could one day lead to new helmet technology that displaces the static load of the helmet onto the shoulders and enables the Soldier to tolerate much higher levels of protection and device capability.

It's being considered as a candidate technology for the U.S. Special Operations Command's ambitious "TALOS" demonstration program, which seeks superior protection of "first in" forces involved in highly dangerous and unpredictable scenarios, said Dr. Shawn Walsh, the principal investigator for the VLOS concept development.

The Natick Soldier Research, Development and Engineering Center's "HEaDS UP" Program provided both the context and impetus to aggressively explore new approaches of integrated head protection, as well as the operational needs and environments that made VLOS a practical alternative for improved head protection, he said.

Results from recent tests of Soldiers wearing this head system prove promising in moving head protection system technology forward in ways that could allow more equipment like night vision goggles, batteries, radios, etc. to be mounted on helmets of future Soldiers without adding weight on their heads and necks.

Postulating the future technology needs of America's fighting forces is "the quintessential role of ARL," said Dr. Jeffrey Zabinski, chief of ARL's Materials and Manufacturing Division of the Weapons and Materials Research Directorate at Aberdeen Proving Ground, Md. It is through this "informed imaginings" that ARL can leverage basic scientific research to conceptualize, discover, innovate and eventually transition scientific breakthroughs to military systems for Soldiers who need them most.

Such was the case with upgrades for ground vehicles, combat helmets and ammunition, for example.

The MRAP, one of the most iconic weapon systems deployed during America's last major conflict, changed the course of war, thanks to research in material and detonation science that traces back almost 200 years to the Army Research Laboratory's legacy in Watertown, Mass.

The Watertown Arsenal was established in the early 1800s for the receipt, storage and issuance of ordinance. The arsenal remained active until the Defense Secretary's Commission on Base Realignment and Closure identified the Army Material Technology Laboratory at Watertown for closure in December 1988.

The MRAP's V-shaped undercarriage helped deflect the impact of blasts from improvised explosive devices, a ferocious enemy weapon in Iraq.

In 2008, ARL researchers started looking at a material and manufacturing process that hadn't changed since the early 1970s, and by 2010, had created a new manufacturing capability using a little-known lightweight material – an ultra-high molecular weight polyethylene, a type of thermoplastic – that revolutionized ballistic helmets. The ECH is expected to be fielded by Army and Marine combat forces in 2014.

Also in 2010, ARL's technical expertise in ballistics and lethality research led to the fielding of the M855A1 Enhanced Performance Round. The new, better performing small caliber munition was the result of collaboration among ARL, PEO Ammunition, Project Manager for Maneuver Ammunition Systems at Picatinny Arsenal, the Research Development and Engineering Command and defense contractor Alliant Techsystems. It marked the first time since the 1980s the

U.S. Army fielded a new ball cartridge for its 5.56 mm small-caliber weapon system.

"Investigations of tough challenges ARL started 10 to 20 years ago are now maturing and poised to help future warriors face combat uncertainty with innovative technological solutions. That's the strength of Army basic research and the essence of our work at the Lab," said Dr. Patrick J. Baker, director of the laboratory's Weapons and Materials Research Directorate. "We're taking multidisciplinary approaches to push the frontiers of fundamental science and technology that result in transformational capabilities.

"We've teamed with academia and industry, and other government partners to invest in science and engineering as well as manufacturing expertise needed to drive innovation, and mature and demonstrate technological capabilities with our partners to provide future warriors with what they need to maintain a decisive technological edge," he said.

This is paramount to the future warrior, who, unlike those who fought conflict during the past 12 years, is expected to face down more technically capable enemies in more complex, more contested environments like urban territories in more advanced societies. To confront those challenges, ARL is on the brink of transitioning prototype technologies to military users who need them most.

"A great thing about working in the Army lab is that we have a lot of smart people with open minds working in different areas. If you discover or invent something revolutionary that may be big payoff, it won't be tossed aside just because it is different than how the Army fights today. For a scientist who wants to have an impact, that keeps you pretty excited," said Baker.

ARL's vertical load offset system is a prototype exoskeletal device designed to displace the static load of the helmet onto the shoulders, proven in recent studies to reduce apparent strain overall on a Soldier's head and neck.

Photo: Army Research Laboratory

Natick tests lightweight, body-worn system

# Helping Aircrews Keep Their Cool

By Bob Reinert, USAG-Natick Public Affairs / NATICK, Mass. (May 29, 2014)

For years, helicopter pilots have kept cool by plugging into aircraft-mounted microclimate cooling systems, but their crews have used them less frequently to avoid becoming entangled in the tethers that connected them to the systems.

That's why researchers at the Natick Soldier Systems Center have been testing the "Light-Weight Environmental Control System," or LW ECS, a body-worn microclimate cooling system that allows crew members to move around inside the aircraft without tripping on tethers, and to exit the aircraft while still being cooled.

"Basically, it's a small refrigeration device," said Brad Laprise, a mechanical engineer with the Warfighter Directorate, Natick Soldier Research, Development and Engineering Center, or NSRDEC. "It's the same technology that's in your air conditioner or in your refrigerator, except instead of conditioning air, it chills a fluid. And then it pumps that fluid through a tube-lined cooling vest."

The cooling unit is a cylinder 3 1/2 inches around that connects to a cooling vest and provides 120 watts of cooling. The vest has approximately 110 feet of tubing through which fluid can pass, and it is worn against a Soldier's skin. The system is powered by a plate-like conformal battery that can fit inside body armor.

"So we're hoping that this small, lighter-weight system would give them a lot more autonomy in the rear of the aircraft," said Laprise, "and to allow them to get the cooling when they need it."

Researchers from NSRDEC and the U.S. Army Research Institute of Environmental Medicine, or USARIEM, working with Product Manager Air Warrior, have been

testing LW ECS at Natick's Doriot Climatic Chambers. With the assistance of volunteers wearing MOPP 4 chemical-protective gear, they have been simulating 11-hour missions in desert and jungle conditions.

"We've been living in the desert for the last 20 years, but we also know that the Pacific Rim is the next area that we're looking at," said Bruce Cadarette, a research physiologist with USARIEM's Thermal and Mountain Medicine Division. "We've been providing microclimate cooling for the pilots ... for 16 years now. It made them be able to prolong their mission, their endurance time, and able to perform at a higher level."

The hope is that their crews will be able to realize similar benefits with LW ECS, without being tethered to an aircraft-mounted system.

"Right now we're looking at crew chiefs that have to load and unload cargo and maintain the cargo," Cadarette said. "They also have to sit as rear gunners in some of the helicopter frames."

"The other people that we're concentrating on ... are the medics, who have to fly out in the back of the helicopters and who have to go out and treat wounded in the field, load them onto stretchers, (and) get them onto the back of the helicopter."

Over two weeks, the five test subjects each took two turns in the simulated desert conditions and a pair in the jungle conditions – one using the cooling system and one without it – in the chamber.

"It's really a critical step, ... proving out the efficacy of this microclimate cooling technology and the capability that it provides," Laprise said. "If we don't have Doriot, we need to find somewhere else to do it, and I'm not

so sure there's a place in the world where we can do this testing. So it is absolutely critical that we have this capability here at Natick."

The cooling systems and the volunteers performed well, according to the researchers.

"We really haven't had any issues with (the LW ECS)," said Laprise, who looked at the fluid temperature before and after it passed through the system, and monitored flow rate. "By and large, they've been very reliable."

Cadarette said the same for the volunteers, who sat for 50 minutes and walked for 10 minutes each hour to simulate missions during which they would get off and back on the aircraft.

"A lot of the day is not heavy work, but for brief periods of time, they work very, very hard," Cadarette said. "Now you've got a battle between your muscles calling for blood in order to exercise and your skin calling for blood in order to cool off."

During the 11-hour sessions, Cadarette and his team monitored core and skin temperature, heart rate, and everything that went into or came out of the subjects' bodies.

"From our point of view, we monitor everything we can, physiologically," Cadarette said. "So now we know, are you doing better with the cooling?"

Cadarette has a great deal of data to sift through, but the early indications are that the LW ECS is making a difference.

"Physiologically, we're seeing that their body core temperatures are lower, their heart rates are lower," Cadarette said. "So far, what I'm seeing looks really good. I think we can show that the cooling portion of this does what we're asking of it."

Volunteers wear MOPP 4 gear during testing of a body-worn microclimate cooling system for the helicopter aircrew members in Doriot Climatic Chambers.



Photo: David Kamph, NSRDEC Strategic Communications



Photo illustration: Philip Fujaua

*During combat missions, water bottles can become dangerous projectiles in explosions.*

# Water Hazard

## Natick researchers develop insulated containers

By Alexandra Foran, NSRDEC Public Affairs / NATICK, Mass. (April 30, 2014)

**A**rmey Army researchers answered the call for insulated bottled water containers for Soldiers in the field. The result may be a life-saving product to protect Soldiers in vehicles during combat missions when water bottles could become dangerous projectiles during explosions.

Researchers from the U.S. Army Natick Soldier Research, Development and Engineering Center responded to the Joint Program Office for Mine-Resistant, Ambush-Protected Vehicles with a container to not only insulate and protect the water bottle, but also make bottled water easy to reach and cool enough for Soldiers to want to consume it.

The prototype is known as the Insulated Containers for Bottled Water, or ICB. The NSRDEC Aerial Delivery Directorate and the Combat Feeding Directorate worked together on the project.

“We came up with initial prototypes that were large, medium and individual with minimal funding using the project manager’s concept and Combat Feeding’s concept, so we just fabricated it,” said Laura Winters, team leader for the Aerial Delivery Design and Fabrication Team, Aerial Delivery Directorate.

Through their work on systems that have to survive intense airdrops, Winters’ team has developed the skills and equipment necessary to handle creating a prototype with blast survivability for water bottles and rations, which will most often be Meals, Ready-to-Eat, or MREs.

Initial concepts for the system included a zipper that went around the storage bag.

Unfortunately, zippers tend to fail, and if the zipper breaks, the bag will no longer keep water cool and protected.

“You need some level of redundancy with this system because if one fails, then the system is no good,” Winters said.

The final prototypes utilize webbing wrapped around the bag to encase the material instead of relying on a zipper, or seams, to hold the bag together. The webbing has a minimum breaking strength of 6,000 pounds, which provides the necessary strength to the overall system to successfully retain all contents.

“Your weakest link is going to be your closure and your seam, so by reinforcing it with the webbing, you are improving the strength and the performance of it,” Winters said. “We also put in hook and loop, too, just so that there is some level of redundancy if the closure system fails.”

The large system holds 36 water bottles, or 28 MREs. The medium bag holds 15 water bottles, or six MREs, and the small individual bag holds five water bottles. NSRDEC is working with the Tank Automotive Research, Development and Engineering Center’s Occupant Centric Protection, or OCP, on integrating the ICBs into the next generation of vehicles. User evaluation testing and blast testing should occur this year.

“We’ve done drop testing, vibration testing, flammability testing, performance testing at the Doriot Climatic Chambers, and abrasion testing,” said Ben Williams, ICB project officer on the CFD Systems Equipment and Engineering team.

“We also linked up with Johns Hopkins University’s Applied Physics Lab to conduct in-vehicle blast testing, because our customer’s number one requirement was that these bags needed to be blast-proof in an [improvised explosive device] scenario.”

Containing the bottles within the bag ensures that they do not become projectiles that could harm Soldiers. Keeping water palatable is the other concern.

“The temperature of the water is a big factor when keeping the Soldiers hydrated,” Williams said. “We’ve done lots of studies on what water temperatures are most palatable for Soldiers. Soldiers drink more water when it’s cold and remain hydrated for longer periods of time because they are consuming more water. This improves Soldier endurance. We consider it a force multiplier.”

Temperatures in areas of operation can reach 95 to 120 degrees Fahrenheit on average in the summer months, creating an even greater demand for cool water as Soldiers exert themselves every day.

Drinking water, safely contained and cool, is often taken for granted by many in the U.S. For Soldiers serving abroad, however, it is an extremely valuable commodity.

# Heavy Load

## Looking at Soldiers' physical, mental fatigue

By Alexandra Foran, NSRDEC Public Affairs / NATICK Mass. (May 30, 2014)

A new collaborative study at Natick Soldier Research, Development and Engineering Center looks at biomechanics and cognitive responses simultaneously to help determine how fatigue affects both the mind and body of Soldiers.

Researchers at NSRDEC are testing Soldiers as they complete a prolonged march while carrying a load totaling 88 pounds. The Army is developing future predictive models of Soldier performance, including load carriage.

“What we are striving to do with our current research is to identify the biomechanical markers at the onset of fatigue and supply data for validation purposes to analyze what happens to the Soldier over time during prolonged marching tasks,” said Dr. Leif Hasselquist, NSRDEC biomechanist. “In addition to the collection of biomechanical and physiologic data, we’re administering cognitive tests that will allow us to evaluate both the biomechanical and cognitive changes that occur over time during a march. This research is unique in that we are combining our traditional biomechanical tests with dynamic cognitive tests. This hasn’t really been done before – especially with Soldiers.”

Every Soldier’s peak  $VO_2$  – maximal oxygen intake – is measured and used as a measure of his or her fitness level. During the studies, Soldiers are pushed past 50 percent of their peak  $VO_2$ . This is the level of exertion used in this research to define the onset of fatigue for Soldiers.

Biomechanical and cognitive measures are analyzed to reveal how the Soldiers are changing their gaits and cognitive functions as they continue to fatigue. The first phase of testing, completed last year, involved Soldiers marching on a treadmill for a two-hour march, or six miles, at a four-percent grade uphill.

While continuing to analyze data from the first phase of the study, Hasselquist said that “our goals of achieving the onset of fatigue

were met. During that second hour, we see a creeping up in the energy cost over the 50 percent peak  $VO_2$  levels.”

The second phase, currently ongoing, looks at recovery from fatigue. The Soldiers march uphill for one hour and then either descend at an eight-percent grade during one condition or march at varied grades during the second hour (uphill four percent, level and downhill eight percent).

NSRDEC’s biomechanics lab has unique motion-capture system and integrated force plate treadmills that allow scientists to record this data from Soldiers during prolonged load carriage. The lab can capture biomechanics and physiologic measures in a synchronized fashion.

“I like to say that Soldiers are like athletes,” said Hasselquist, “except athletes perform and they’re done. Soldiers have to do a six- to 12-mile road march and get in there, and then they have to perform, so you want them optimized. If we can find strategies to mitigate or predict how fatigue from load carriage affects the Soldier, our research will be helpful.”

**“It’s a complete look at the Soldier, not just one segment, one task or one response at a time.”**

Dr. Leif Hasselquist, NSRDEC biomechanist

Cognitive testing ranged from simple to complex tasks that looked at different brain functions throughout the march. During one test, Soldiers received audio cues of either AK-47 or M-4 fire. They then had to differentiate friendly fire from opposition fire and respond through a trigger switch on their weapons.

A visual task using state-of-the-art eye-tracking glasses monitored Soldiers’ eye

movements as they scanned environments for targets on TV screens. At detection of pop-up targets, the Soldier was required to respond as quickly as possible though the trigger switch. Response time and whether or not they were making the right choices were recorded.

“This is a synchronized evaluation of the Soldier in the biomechanics lab,” Hasselquist said. “It’s a complete look at the Soldier, not just one segment, one task or one response at a time. You get the whole picture of what’s going on with the Soldier.”

Markers are placed on Soldiers’ bodies, as in the video gaming industry, to build physics-based models of Soldiers through the motion-capture software. Electromyography, or EMG, is also used and measures the muscle activity from the Soldiers’ muscles. Researchers are able to detect the intensity and fatigue in the leg muscles over time, and the cognitive responses during the march are overlaid on top of these results.

In the past, researchers looked at biomechanical, physiologic and cognitive studies separately. Now, NSRDEC’s study brings those key pieces together to improve the understanding of the science behind the Soldier as all of the data is captured simultaneously.

Information acquired in this study is critical for accurate representation of the capabilities and limitations of the dismounted warfighter in Soldier models and simulations. The data acquired will result in recommendations regarding existing and future load carriage strategies, route-planning tools, Soldier performance expectations, and improvements in designs of future load-carrying equipment.

It is the goal of the NSRDEC researchers to apply the current research strategies to a third phase of research. New technology in biomechanical sensors and cognitive measures will allow the Soldier’s biomechanics, physiology and cognitive responses to be captured outside the laboratory during field exercises.



A Soldier marches with full combat gear including body armor, a 50-pound rucksack, his weapon and a basic load of ammunition, at Fort Benning, Ga.

Photo: Eric Kowal, RDECOM

# Sleepless in Natick

## Study examines stress, Soldiers' immune systems

By Bob Reinert, USAG-Natick Public Affairs / NATICK, Mass. (March 21, 2014)

Training and operations can put such tremendous physical and psychological stresses on warfighters that their immune systems may be compromised.

A study being conducted by the U.S. Army Research Institute of Environmental Medicine at Natick Soldier Systems Center will examine how sleep restriction — the stressor — affects wound healing and whether nutritional supplements can help offset the effects. In a sub-study, the effect of sleep restriction on friend-foe recognition during marksmanship is also being observed.

“Immune responsiveness is suppressed in warfighters exposed to physical and psychological stress,” said Tracey Smith, Ph.D., a research dietitian with USARIEM’s Military Nutrition Division, who used Ranger School and Special Forces Assessment School as examples. “Research has shown that modest improvement in immune responsiveness, as determined from blood markers, was noted when Soldiers were provided a nutritionally fortified energy bar during Special Forces Assessment School.”

Smith said the Special Forces research didn’t focus on whether nutrition helped wounds to heal or defend against a virus, however.

“Immune markers measured from blood samples provide an indication of systemic immune response,” said Smith, “but the systemic immune response does not necessarily reflect the functional status of the immune system — for example, wound healing time.”

In the study, male and female Soldiers were given suction blisters on their forearms. Some volunteers slept at least seven hours per night, and the current group is undergoing 50 hours of sleep restriction, with Soldiers allowed just two hours of sleep per night over that period.

“This was the amount of time that we thought would cause decrements in healing time and immune responsiveness at the wound site in young adults,” Smith said. “This model may provide a way to more effectively study effects of stress on wound healing, and a means to test prototype countermeasures, like nutrition interventions, to stress-related effects on healing.”

“We are using the suction blister model as a tool for studying immune responsiveness of warfighters coping with stress, and nutrition interventions to mitigate decrements in immune responsiveness caused by stress.”

Capt. Adam Cooper, Ph.D., a research psychologist at USARIEM, piggybacked his marksmanship research on Smith’s study.

“We are interested in how sleep restriction differentially affects marksmanship performance during a simple versus mentally challenging friend-foe task,” Cooper said. “The factors we are examining are reaction time, accuracy and correct decision.”

“Once it is known what factors are affected during low versus high mentally demanding marksmanship tasks, leaders can make

more informed decisions concerning what types of missions their Soldiers will be able to successfully complete given their current state of rest.”

Smith said that the marksmanship “keeps the volunteers awake, engaged and, hopefully, adds to the sleep restriction stressor.”

The USARIEM study is using 60 volunteer Soldiers, split into groups of four per session. Smith and her colleagues will soon examine preliminary data from eight volunteers to see if the sleep restriction is an adequate stressor to slow healing time. Once they are confident with the stressor, they will move on to test nutrition interventions to promote immune recovery.

“Blister wounds typically heal in five days for volunteers who receive adequate sleep,” Smith said. “We expect healing time to be delayed by one to two days in volunteers who are sleep restricted, and we expect that healing time will be back to five days in volunteers who consume a specially prepared nutrition beverage during sleep restriction and in the recovery period.”

Smith and her colleagues hope to provide warfighters with a food item or beverage that they can consume during and after periods of stress that will support their immune system and promote recovery.

Pvt. 2 Daniel Pardo dozes off after a period of sleep restriction in a study conducted by the U.S. Army Research Institute of Environmental Medicine to see how nutritional supplements might help wounds heal in warfighters under stress

# Joint meeting helps aerial delivery collaboration take off

By Jane Benson, NSRDEC Public Affairs / NATICK, Mass. (June 4, 2014)

Where do you go to find out user needs and what all the services are doing to advance aerial delivery? JTAG, you're it.

The Joint Technical Aerial Delivery Group, or JTAG, enables interservice agencies responsible for the aerial delivery mission to share information, discuss technologies, and formulate joint service programs. The need for interservice cooperation has increased due to the development of multipurpose airborne systems and blended technologies. Avoiding duplication of effort is particularly important given budget constraints. The meeting is attended by the Army, Air Force, Navy, Marines and Special Operations.

"The meeting enables information sharing between all the services to make sure we are working well together and are sharing information," said Richard Benney, director of the Aerial Delivery Directorate at the Natick Soldier Research, Development and Engineering Center, or NSRDEC.

The meeting takes place every couple of years at different locations, with NSRDEC hosting the most recent meeting.

"JTAG gives engineers the chance to get smarter on what the users want," Benney said. "Natick is the largest R&D facility in the world regarding aerial delivery. We do a lot of work for the other services. This is a center of expertise. The (JTAG) meeting gives us a chance to get an overview of what other people are doing and for them to find out what we are doing. Sometimes, other services let us know what their future needs are – not just what they are doing right now."

"JTAG is to the airdrop community what Facebook is to teenagers. It is a forum where everyone gets together and shares all the information about aerial delivery," said Gary Thibault, Cargo Aerial Delivery team leader, Product Manager Force Sustainment Systems, or PM FSS, at Natick Soldier Systems Center.

"The meeting is used, a lot of times, to bring in physical prototypes. It is great for a hands-on exchange of ideas and displays," Thibault added.

JTAG helped advance the Joint Precision Airdrop System

The meeting connects people with points of contact and gives them access to subject matter experts, or SMEs, from all services, which can lead to funding and testing opportunities, as well as the sharing of assets, including aircraft, riggers, and crew SMEs. The meeting can also promote partnerships that may result in faster product maturation/fielding.

For example, during a past JTAG meeting, a SOCOM operator stated that he considered the NSRDEC-developed prototype of the Joint Precision Airdrop System Mission Planner to be "essential mission equipment" for high-altitude airborne operations. JPADS uses GPS, steerable parachutes, and an on-board computer to direct loads to a designated location. The JPADS Mission Planner hardware and software give the aircrew the capability to plan the mission, make changes in flight, if necessary, and direct the aircraft to the drop location.

Soon after the meeting, the Air Force started serious planning and agreed to participate and contribute dollars and people to support JPADS Advanced Technology Concept Demonstration.

"I believe that the USAF interest in maturing and developing a program of record for the JPADS Mission Planner was kick-started as a result of a JTAG," Benney said.

JTAG accelerated the Advanced Emergency Bailout Parachute program

"In September 2009, the Army faced the unanticipated requirement to issue a bailout parachute to jumpmasters by September 2013," said Takis Blanas, Personnel Airdrop team leader, Product Manager Soldier Cloth-

ing and Individual Equipment, or PM-SCIE.

PM-SCIE was able to leverage the Navy's existing Thin-Pack Parachute, which has a longer shelf life and takes up less space than its predecessor, to create the Advanced Emergency Bailout Parachute, or AEBP.

"The JTAG provided a forum over the years that made all the services aware of this Thin-Pack program. So everybody was ready to just jump on it and leverage it because it was well known to everyone," Thibault said.

"Because of the JTAG, the Army was able to adopt the Navy Thin Pack as the Army AEBP and field it to all units by the deadline of September 2013, allowing airborne operations to continue uninterrupted," Blanas said.

JTAG enables Natick to better serve the user community

"The meeting can help ensure that early on, for early S&T, you can help formulate requirements based on what they need, and what is the state of the possible, what is actually achievable – based on physics, often – and help us to better understand from the user community what they want to be able to do and translate that into engineering specifications or engineering requirements," Benney said.

"The warfighter has become a significant presence at the meeting ...," Thibault said. "You've got to listen to them, regardless of their rank, because they understand the equipment ... It's important to have the technical perspective, but you need that user perspective to understand if what you are doing technically meets their requirements."

"Technically, we might think it is the best thing since sliced bread. But you give it to a Soldier, they might be thinking not only is this bread horrible, I won't even eat it. You got to listen to these folks, and you have to make the right bread," Thibault added.



Monica Borgogno, a visiting food scientist earning her Ph.D. in science and agricultural biotechnology from the University of Udine, Italy, conducts consumer research on energy bars for NSRDEC.

# A Bit of Italy

## Scientist lends international flavor to Natick

By Jeff Sisto, NSRDEC Public Affairs / NATICK, Mass. (May 16, 2014)

Researchers at the U.S. Army's Natick Soldier Research, Development and Engineering Center are leveraging the unique perspectives of visiting international scientists through a program with the U.S. Army International Technology Center – Atlantic.

The USAITC-A promotes cooperation between the U.S. Army Research, Development and Engineering Command and international researchers in order to advance broader science and technology knowledge as well as the technical capabilities for U.S. Army missions.

Based in London, the USAITC-A facilitates relationships with international partners by connecting foreign scientists and engineers with U.S. research organizations. One of those connections resulted in a collaborative research approach for several ongoing NSRDEC projects.

Monica Borgogno, a food scientist earning her Ph.D. in science and agricultural biotechnology from the University of Udine, in northern Italy, was accepted for a three-month stay with NSRDEC as a visiting scientist.

"My program encourages students to work abroad in the final year of their Ph.D.," said Borgogno, who graduates in December. "It's important to gain experience with how outside people work."

When her professor told her about the opportunity to work with the U.S. Army, she

jumped at the chance to come to Natick.

"I knew it would be an honor to work with Dr. Cardello," said Borgogno, referring to NSRDEC's senior scientist, Dr. Armand Cardello. "He is known all over the world in my field."

It would prove to be a mutually beneficial relationship.

Borgogno already holds both a bachelor's and a master's degree in food science and technology from the University of Florence, Italy, and has experience working in the Italian commercial sector conducting quality control for Latte Trento, a dairy producer in that country. She has also worked in the development of olive oil, wine and ham.

"Monica's background was a major factor in my support of her visit," said Cardello. "She has tremendous expertise in sensory and consumer science, especially with regard to perceptual mapping of product spaces."

"This involves using techniques that enable us to understand how the consumer or Soldier perceives food products in terms of their similarities and dissimilarities to other products."

During her three-month stay at Natick, Borgogno worked on three projects for the NSRDEC: the Macro-nutrient Optimized Dense Ration Components project, a study on the emotional response to foods, and another basic research study to understand how foods and meal situations influence a person's sense of well-being.

As a specialist in sensory science, Borgogno used her expertise to determine the design and decision-making for experiments.

In the MODRaC study, Borgogno sampled and analyzed the perceptions of three flavors of energy bars developed by NSRDEC's Combat Feeding Directorate, compared to those of commercial energy bars. Subjects expressed their perceptions of the products by physically placing them on a large mat and arranging them so that the distances between them reflected the similarities and differences among them. This procedure produced a perceptual map from which differences in appearance, flavor, texture and overall acceptance can be discerned.

The results from the data Borgogno collected will guide further development and refinement of MODRaC products in order to provide an energy-dense, portable ration component capable of maximizing the warfighter's performance.

"I hope my contribution will help the Army find the best way to determine what is needed in the energy bars," she said.

In the emotion study, Borgogno examined the effect of emotion words on consumer responses using both the check-all-that-apply and rating response formats. Her analysis showed that both the total number of checked emotions (CATA) and the total number of non-zero ratings (rating) varied with the number of emotions on the questionnaire, signifying that the number of available emo-

Photo: Jeff Sisto, NSRDEC Public Affairs



tion words directly influences the number of emotions described by the consumer.

In the well-being study, the objective was to develop and assess different evoked meal scenarios to determine their ability to affect well-being regarding the physical, spiritual, emotional, social and intellectual domains.

"We performed focus groups to understand differences among the concepts of health, wellness and well-being to better understand the five dimensions of well-being, and to assess how foods impact each of them," said Borgogno.

"These results will be employed to understand how different rations and meal situations could affect perceived well-being of American Soldiers and consumers."

To Borgogno, the most notable difference in working here was the approach to the research.

"In Italy, the boss decides, and you do it," Borgogno said. "Here, it is more collaborative. Everyone has a say. It is continuous involvement and improvement."

"Also, we didn't have as many labs to develop prototypes."

While the knowledge and experience she gained will undoubtedly propel her career, it is the people she met that made Borgogno's stay most enjoyable.

"I love the people here," she said. "If I needed something, they were always there to help."

As the Army continues to operate in a con-

strained resource environment, Cardello said he believes engaging in more international partnerships will be of critical importance in addressing the challenges faced in future Army research and development.

"Only through such person-to-person, scientist-to-scientist communications and collaborations can leveraging of new ideas and approaches be made," he said.

"Future breakthroughs on all major problems faced by the Army and by the international scientific community can only be made through the exchange of ideas and joint research."

Researchers at the U.S. Army Natick Soldier Research, Development and Engineering Center's Combat Feeding Directorate, or CFD, are investigating ways to incorporate 3D printing technology into producing food for the Warfighter.

CFD's Food Processing, Engineering and Technology Team, led by food technologist Lauren Oleksyk, is investigating possible 3D applications for food processing and product development. Team member and food technologist Mary Scerra is performing extensive market research to see what can be learned from the commercial sector.

The team is also looking into collaborations with the Massachusetts Institute of Technology's Lincoln Laboratory. Scerra and senior food technologist Tom Yang, Ph.D., visited the Rapid Hardware Integration Facility at Lincoln Laboratory and met with experts to discuss the feasibility and applications of using 3D printing to produce innovative new military ration products.

CFD has an impressive history of inventing its own food, food technologies and processes serving the Warfighter. CFD also leverages and advances already available technologies through their partnerships with industry and academia.

"Many people are building or buying 3D food printers just for their specific application," Scerra said. "Some 3D printers have the hardware to attach a 3D scanner."

"The printer is connected to software that allows you to design what you want to build in layers. Say you wanted to print a candy bar – there are different cartridges that are filled with ingredients that will be deposited layer upon layer. The printer will switch the cartridges as needed as you build each layer. This is being done already. This is happening now," Oleksyk said.

**A food revolution (or let them eat 3D cake)**  
"It is revolutionary to bring 3D printing into the food engineering arena. And to see in just a couple of years how quickly it is advancing, I think it is just going to keep getting bigger and bigger in terms of its application potential," Oleksyk said.

Oleksyk believes that her team is the first to investigate how 3D printing of food could be used to meet the needs of Soldiers. The technology could be applied to the battlefield for meals on demand, or to food manufacturing, where food could be 3D printed and perhaps processed further to become shelf stable. Then, the foods could be included in rations.

technologies to create nutrient-rich foods that can be consumed in a Warfighter's specific environment on or near the battlefield.

Nutritional requirements could be sent to a 3D food printer so that meals can be printed with the correct quantity of vitamins and minerals, thus meeting the individual dietary needs of the Warfighter.

"If you are lacking in a nutrient, you could add that nutrient. If you were lacking protein, you could add meat to a pizza," Oleksyk said.

"You could take into account your needs at that time. Say you were on a difficult mission and you expended different nutrients, while I was on base and didn't need as many nutrients — a printer could print according to what your needs were at that time," Scerra said.

"This technology does allow for that type of customization," said Oleksyk.

"It could reduce costs because it could eventually be used to print food on demand," Scerra said. "For example, you would like a sandwich, where I would like ravioli. So, instead of assuming everyone gets ravioli, you would print what you wanted, eliminating wasted food."

**Forage and create a 3D-printed porridge**  
In the future, making something from scratch may have a completely different meaning.



## Igniting a Passion for Science

By Kelly Field, USARIEM Public Affairs / NATICK, Mass. (April 25, 2014)

During the April school vacation week, Massachusetts teachers were treated to a preview of the Gains in the Education of Mathematics and Science, or GEMS, program at Natick Soldier Systems Center.

Teachers from a variety of school districts throughout MetroWest in grades six through nine participated in this program, which was created as a collaborative effort between the U.S. Army Research Institute of Environmental Medicine and the Natick Soldier Research, Development and Engineering Center.

"As Lab Champion of the GEMS program, I was approached with the idea of offering GEMS to teachers so that they can have a better handle on what the students are experiencing through the summer program," said Army Capt. Carrie Quinn, a research physiologist at USARIEM, who also serves as the GEMS program director and co-creator of the GEMS for Teachers program. "So it was a natural fit for me to lead the GEMS for Teachers program."

GEMS for Teachers was created at NSSC and is the first program of its kind aimed at giving middle-school teachers the hands-on op-

portunity to engage in real-world science and to take those experiences back to their own classrooms. At the end of this unique week, the teachers received a Science, Technology, Engineering and Mathematics Kit that had starter pieces for a variety of the experiments they conducted throughout the week, so that they could then implement those experiments in their classrooms.

Quinn also asked the resource teacher and Near Peer Mentors who run the summer program to be a part of this session. In using this format, the teachers could get a real feel for the summer GEMS program for middle-school students, and the mentors gained invaluable lessons in leadership.

"The Near Peer Mentors are in charge of the curriculum and instruction for the summer GEMS program, so it was important that the teachers receive their instruction from the Mentors that are vital to our summer program," Quinn said.

"This way, the teachers could offer tips and guidance to the Mentors, and the Mentors could provide vital insight on what works and what doesn't for each of the lab experiments

and what excites the students and encourages the most 'ah-ha' moments relative to other experiments," she added.

Joanna Graham, the STEM outreach coordinator for NSRDEC who co-created the GEMS for Teachers program with Quinn, agreed that the value of this program is in the reciprocity of learning.

"The model set up through the summer program, by design, has middle-school students instructed by high school students," Graham said. "This allows for the middle-school students to learn from Near Peer Mentors close in age to engage the students in the process. This also gives the Near Peer Mentors critical leadership and life skills equally as important as the technical STEM-related skills."

According to Graham, NSRDEC supports the GEMS summer program through tours of the testing facilities on post. Their goal for this session was to equip teachers with the same interactive STEM-related activities that the summer students receive so they can incorporate the experiments into their annual curriculum.

"This week was about offering the highly successful GEMS summer program to middle-school educators of the Commonwealth," Graham said. "There has been so much positive feedback from the middle-school students over the summer that we wanted to take that valuable information and turn it into a teacher training."

Teachers who attended this program said that it was not only entertaining, but it gave them ideas and tools to bring back to their classrooms.

"I really like what you are doing here," said Jackie O'Brien, a sixth-grade teacher at the Up Academy Leonard, a tuition-free Lawrence public middle-school with students in grades six through eight. "My goal as a teacher is to get kids interested in learning and create a passion for lifelong learning. I definitely want to try so many of the activities I learned here."

With all the excitement generated from this GEMS for Teachers session, Quinn is eager to capitalize on the program's popularity and begin the summer session of GEMS.

"Ideally, the GEMS for Teachers program will help us promote the GEMS summer program and expand our enrollment to areas outside of Natick," Quinn said. "This will diversify the student base that we are able to expose to the amazing science we engage in at NSSC."

## Printing Chow

By Jane Benson, NSRDEC Public Affairs / NATICK Mass. (May 30, 2014)

Will 3D revolution come to combat feeding?

"The mission of CFD's Food Processing, Engineering and Technology Team is to advance novel food technologies," Oleksyk said. "The technologies may or may not originate at NSRDEC, but we will advance them as needed to make them suitable for military field feeding needs. We will do what we can to make them suitable for both military and commercial applications."

### It's already happening.

"Printing of food is definitely a burgeoning science," Oleksyk said. "It's currently being done with limited application. People are 3D printing food. In the confectionery industry, they are printing candies and chocolates. Some companies are actually considering 3D printing meat or meat alternatives based on plant products that contain the protein found in meat."

"We have a three-year shelf-life requirement for the MRE, for instance. So, we're interested in maybe printing food that is tailored to a Soldier's nutritional needs and then applying another novel process to render it shelf stable if needed," Oleksyk said. "For example, we are looking at ultrasonic agglomeration, which produces really compact, small snack-type items. Combining 3D printing with agglomeration could yield a nutrient-dense, shelf-stable product. Another potential application may be 3D printing a pizza, baking it, packaging it and putting it in a ration."

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Currently, most 3D printed foods consist of a paste that comes out of a printer and formed into predetermined shapes. The shapes are eaten as is or cooked. CFD food technologists hope to further develop 3D printing

"We are thinking as troops move forward, we could provide a process or a compact printer that would allow Soldiers to print food on demand using ingredients that are provided to them, or even that they could forage for. This is looking far into the future," Oleksyk said.

"If you have to forage, wherever you are, whatever environment you are in, and you forage for raw basic ingredients and you have access to a printer, you could make something out of the ingredients that you can consume. You wouldn't have to carry the ingredients," Scerra explained.

Oleksyk, who was a little skeptical when she first heard that 3D printers could be used to engineer food, now marvels at the possibilities.

"I've been here long enough to see some of these 'no ways' become a reality. Anything's possible," Oleksyk concluded.



## Measuring Soldiers' quality of life

Jane Benson, NSRDEC Public Affairs / NATICK, Mass. (April 28, 2014)

Natick researchers on the Consumer Research Team have devised a way to measure and model warfighter quality of life in base camps serving fewer than 1,000 personnel.

The model and tools have been developed in support of the Technology Enabled Demonstration Capability for Sustainability/Logistics-Basing, known as TeCD 4A, which aims to reduce fuel, water and waste at base camps while maintaining quality of life.

"This project is the first ever to model and quantify quality of life in a base camp. Under TeCD 4A you can't just reduce fuel, water and waste, you also have to maintain the quality of life. A metric previously did not exist to assess if quality of life is impacted by these reductions," said Justine Federici, a researcher at the U.S. Army Natick Soldier Research, Development and Engineering Center. "Without a way to measure QoL, there was no good way to trade off fuel, water and waste savings against impact on QoL. For example, a camp can save a lot of water by only letting Soldiers shower once a week—the minimum allowed under current regulations—but this would definitely hurt quality of life."

Why is it important to be able to measure Soldier quality of life? Natick researchers have found that quality of life has an impact on Soldier readiness and morale. Soldiers said it best in QoL interviews:

Taking a running-water shower "makes you feel human."

"When a guy is out on patrol, the first thing he is thinking of when he gets back is a hot meal."

"The ability to take a shower and wash all the grime off had the most gratifying effect. . . It gives you that feeling 'well, it's not that bad here.'"

To develop the QoL model, NSRDEC researchers began by interviewing Soldiers who had experience living in remote base camps with up to 1,000 personnel. These interviews revealed attributes of a base camp that affect Soldier quality of life, such as the availability of hot and fresh food, air-conditioning in billets, the ability to take a shower, and MWR resources such as a gym and Internet. A group of senior NCOs and officers confirmed these attributes in a war game conducted in partnership with the Maneuver

Support Center of Excellence at Fort Leonard Wood. The insights gathered from Soldiers were combined with information from other experts to create a survey that would let researchers measure the effect of every base camp attribute on Soldier quality of life.

"The survey was tested in March of 2013," Federici said. "The team got valuable feedback from Soldiers during the test, which has been folded into a new version of the survey, which will be given to 1,200 Soldiers this August at four different installations. To make the survey more interactive and engaging, the survey was designed to run on tablet computers with a touch screen interface."

"This quality of life research work will enable the Army to identify critical expeditionary base camp services that maintain or enhance Soldier readiness," NSRDEC's Claudia Quigley said. "As a member of the G4 Contingency Basing Quality of Life Working Group, this research is in collaboration with other Quality of Life projects across the Contingency Basing community. This important research also supports TeCD 4A and PEO CS&CSS Contingency Basing Infrastructure needs for defining essential QoL factors on Contingency Bases."

NSRDEC researchers on the Consumer Research Team developed this first-ever survey and model to ascertain which systems have the greatest impact on quality of life. The Consumer Research Team's mission is to research the needs, attitudes and behaviors of the warfighter as they pertain to the selection and use of Soldier products and new capability concepts. This work on quality of life benefits from the team members' extensive background in conducting operationally relevant surveys and gathering consumer insights on acceptance of Soldier Systems products ranging from combat rations, to expeditionary shelters, to combat clothing and equipment.

By creating a way to measure quality of life and model it — just as you can with fuel, water, waste and other physical resources — NSRDEC will be able to help make sure new base camp technologies are developed with the Soldier in mind. Sometimes something as simple as a warm shower can make all the difference to a Soldier deployed to a remote area, far from home. In the words of one Soldier, "It's the little things."

In just her second full week as acting director of the Natick Soldier Research, Development and Engineering Center, Dr. Laurel Allender was already hopping a work-related flight.

Jokingly referring to it as "a TDY within a TDY," Allender was off to Washington, D.C., having accepted an invitation to attend the "Third District Day 2014," a legislative issues seminar hosted April 8 by U.S. Rep. Nikki Tsongas of Massachusetts.

"I'm really glad to hit the ground running . . . to show the continuity of leadership," Allender said. "Before I got here, I had a letter of welcome from Representative Tsongas. Clearly, NSRDEC and the Soldier Systems Center here (have) a very special relationship with the state and national representatives."

Allender replaces Dr. John P. Obusek, who retired March 27 after serving as NSRDEC director since February 2011. She comes to Natick from the Human Research and Engineering Directorate (HRED), Army Research Laboratory, where she had served as director. In all, she has nearly 30 years in government service.

The new NSRDEC acting director holds a bachelor's degree in psychology from the University of Northern Colorado, and a master's degree and a doctorate in cognitive psychology from Rice University.

Allender has earned a number of honors, including the Superior Civilian Service Award in 2011.

"I'm pleased to be here," Allender said. "I had known Dr. Obusek when he was commander at (U.S. Army Research Institute of Environmental Medicine) and worked very closely with some areas of NSRDEC already."

Allender pointed out that with HRED, she gained great familiarity with NSRDEC's modeling and simulation work. She added that she believes she can add further emphasis to the NSRDEC-led Soldier Systems Architecture.

"The Army is really attending to Soldier research, Soldier capability at that individual, small squad, small unit level," Allender said. "And NSRDEC is so well poised to be leading that conversation."

Allender admitted that the conversation takes place in an era of fiscal restraint.

"Budget's a concern," Allender said. "I know that as we look at what's currently planned, there are some programs at NSRDEC that have maybe more concern today than others. So that clearly will be a priority for me to un-



## New NSRDEC acting director 'hit the ground running'

By Bob Reinert, USAG-Natick Public Affairs / NATICK, Mass. (March 28, 2014)

derstand why there could be some shortfalls, how we can address those, and ensure that there isn't a real impact.

"NSRDEC has some unique roles that are really not funded anywhere else — and that's obviously the Combat Feeding program and the Airdrop program. So I intend to understand those programs a little more fully and see how we can better enable those conversations."

Allender acknowledged that leadership changes can be difficult for organizations such as NSRDEC.

"I know people get nervous," Allender said. "People like to prepare for the worst so when the worst doesn't happen, they can feel better. I firmly believe that we don't have to prepare for the worst, because it's a vibrant organiza-

tion and it's got a very important part to play as we go forward."

NSRDEC's people have been understanding, said Allender, as she tries to absorb a great deal of information in a short time.

"Everybody has also already been very kind in letting me go back to the table at the buffet two or three times — not insisting that it be one pass through and that I've got to have it all," Allender said. "There's also just been a lot of great support."

Allender said that she hopes to "contribute directly" to the important work underway at NSRDEC. Toward that end, she will get out of her office, make the rounds and meet people.

"Look for me," Allender said. "I'll be coming around."



**Soldier**  
Science & Engineering

## **Soldier Science & Engineering**

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