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ARMY AL&T

JANUARY-MARCH 2018

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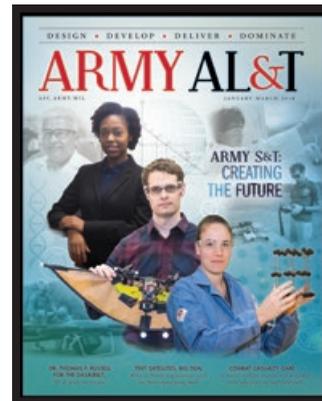
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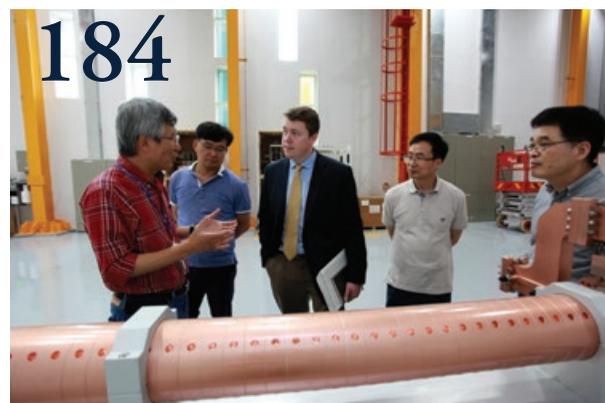
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From the Editor-in-Chief

Today, our houses are smarter than many of us. They communicate to our smartphones what's going on in every room; the refrigerator can order milk without us; and intelligent personal assistants not only can help plan our day but also execute many of the to-dos. Heady stuff, but what we take for granted today was eons in the making, the result of science and technology.

Fire wasn't a scientific creation, of course, although humans have harnessed it to make so much scientific progress possible. Fire was discovered—approximately 1.6 million years ago at sites in the Lake Turkana region of Kenya, thanks to the Oldowan hominid—and would prove to be one of humanity's earliest scientific advances. The wheel—invented and in popular use by about 3500 B.C.—originated among people in what is now Poland and elsewhere in the Eurasian steppes. Electricity was discovered around 650 B.C., and since then greatly refined in any number of technological milestones. Since the Industrial Revolution, which came to define daily life by the mid-1800s, science and technology have proliferated at a breakneck speed, bringing us steam engines, light bulbs, radios, internal combustion engines, telephones, powered flight, computers, robots, lasers, space vehicles ... the pace of progress has been dizzying.

So what can we expect for the eons to come? In a very real sense, we are living Moore's law for science and technology (S&T), wherein Intel Corp. co-founder Gordon E. Moore posited that the number of transistors in a dense integrated circuit doubles approximately every year. It seems we're facing a virtual doubling of technology every year, allowing for artificial intelligence in daily use, making space tourism possible, and putting atoms and photons to work for us through quantum mechanics computing—things unimaginable only years ago.

For Army Acquisition Workforce professionals, these are truly halcyon days for S&T. The Army is right up there with the best of commercial industry in S&T innovation. There are approximately 30,000 unclassified patents associated with the Army, including a dengue virus immunization, an augmented reality simulator, quantum particle imaging, a

nanotube field effect transistor array, a laser-initiated ignition apparatus and a levitation system using permanent magnets.

In this issue we highlight some of the products, processes and procedures—not to mention the people—that take an idea and turn it into reality, applying the best in S&T to ensure that our Soldiers are the best-equipped on the battlefield. Follow along with the robotic wingman supporting the next generation combat vehicle in “Wingman Is First Step Toward Weaponized Robotics,” Page 86. Read about how the Army aims to increase Soldiers' lethality by allowing them to see the battlefield before they get there, using 3-D-enriched urban terrain visualization (“A ‘Map’ for the Multidomain Megacity,” Page 146). Take a look at 21st century medicine in the form of front-line battlefield treatments for wounded warfighters (“Speeding Combat Casualty Care,” Page 36) and advances in tissue injury and regenerative medicine (“Hope Regenerated,” Page 51).

Of note, this issue is going to print just as the Army makes significant changes in its acquisition process to accomplish a sweeping modernization strategy. In October, then-Acting Secretary of the Army Ryan D. McCarthy and Army Chief of Staff Gen. Mark A. Milley announced their plan to synchronize stakeholders across the requirements and acquisition enterprise. Cross-functional teams, initially focused on the Army's modernization priorities and comprising warfighters, developers and resource planners, will prepare sound capability documents enabling the rapid and frequent delivery of advanced capabilities to the warfighter.

Senior Army and DOD leadership emphasize that S&T will play a huge role in accomplishing vitally necessary modernization. With this issue, Army AL&T shows how, and we will continue to keep you apprised of cutting-edge developments.



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Nelson McCouch III
Editor-in-Chief



SEASON *of* CHANGE

ASA(ALT) set for new leadership

New leadership appears set to take charge of the Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology (OASA(ALT)) before year's end, with a new principal deputy ASA(ALT) already on board.

As of this writing, the Senate is considering the administration's Oct. 5 nomination of Dr. Bruce D. Jette to be the next ASA(ALT). Jette had a confirmation hearing Nov. 9 before the Senate Armed Services Committee, in which he pledged to "work tirelessly to truly make a more effective acquisition system that meets current, emerging and long-term operational needs; [and] helps us leap back into an overmatch position, and do so in a timely manner."

Jette, the founder, president and CEO of management and technical consulting company Synovision Solutions LLC, played an early role in rapid acquisition for the Army. In May 2002, as an Army colonel, he told the Senate committee, he formed a small team that integrated robots developed by the Defense Advanced Research Projects Agency with government and commercial off-the-shelf items and fielded them within a month for deployment in caves in Afghanistan "rather than sending [in] Soldiers with grappling hooks and grenades." He became the first director of the Rapid Equipping Force, established later that year, which introduced to the Army its first enduring model of rapid acquisition.

A 1976 graduate of the United States Military Academy at West Point, Jette served in the Army for 28 years, and developed an operational perspective on the evolving threats to the U.S. military and the inadequacies of the Army acquisition system to address them. He also served as strategic science adviser to the chief of staff of the Army, senior research officer in the U.S. Army Research Laboratory, and brigade and battalion operations officer in numerous Army units in the U.S. and Germany. "The Army is replete with dedicated, talented people," Jette said

in his Senate confirmation statement. "They need senior leadership guidance, encouragement and reassurance to be innovative, understand and accept responsibility and reduce a risk-averse culture."

Jette holds an M.S. and Ph.D. in electronic materials from the Massachusetts Institute of Technology and a B.S. in nuclear engineering and chemistry from West Point. Among his honors, Jette was named the 1996 Acquisition Product Manager of the Year.

Pending Senate confirmation of a permanent ASA(ALT), Jeffrey S. White leads the organization in an acting capacity. White was appointed Nov. 6 as principal deputy to the ASA(ALT). As acting ASA(ALT), he is also serving as Army acquisition executive and senior procurement executive. White, who was appointed in November to the Senior Executive Service (SES), is a retired Army colonel who most recently was vice president of business development for Siemens Government Technologies Inc., one of several leadership positions he has held in the company.

He was also the assistant deputy undersecretary of the Army from October 2006 to October 2011, leading initiatives toward greater efficiencies, business transformation, deployment of Lean Six Sigma and strategic human capital programs. White holds an MBA from the University of Tennessee, a Master of Strategic Studies from the U.S. Army War College, an M.A. in national security and strategic studies from the U.S. Naval War College and a B.A. in psychology from Shippensburg State College. (For more detail on White, see "On the Move," Page 262.)

White replaced Steffanie B. Easter as acting ASA(ALT). Easter remains with the organization as special assistant to the ASA(ALT) and has assumed the temporary role of senior official performing the duties of the principal deputy ASA(ALT), a role that's familiar for her.

Steffanie B. Easter

Jeffrey S. White

Bruce D. Jette



Easter was named principal deputy ASA(ALT) effective March 7, 2016, supporting the Hon. Katrina McFarland, who served as acting ASA(ALT) from February 2016 through October 2016 before retiring from civil service. A member of the SES since 2002, Easter came to OASA(ALT) from the Department of the Navy, where she was executive director for the F-35 Lightning II Joint Program Office, the most recent of several leadership positions as a Navy civilian.

“When I arrived in March 2016, I could not have envisioned just a few months later taking on increased responsibilities” as acting ASA(ALT) and the Army acquisition executive, said Easter in an Oct. 13 email to the ASA(ALT) team. “This honor has been one of the most rewarding experiences of my civilian career. Leading the dynamic Army Acquisition Workforce and witnessing firsthand the extraordinary work you do every day for our Soldiers has been a great privilege.”

In more than 30 years of federal service, Easter received several awards, including the Navy Meritorious Civilian Service Award, the Navy Superior Civilian Service Award, the Navy Distinguished Civilian Service Award, the National Women of Color Award for Managerial Leadership and the Black Engineer of the Year Award for Professional Achievement.

Easter is credited with bringing a broader perspective to Army acquisition, based on her extensive Navy experience. As acting ASA(ALT), she presided over a number of significant developments, including:

- The first year of the new Army Rapid Capabilities Office, formed in August 2016 to engage with traditional and nontraditional developers and use creative contracting and collaboration mechanisms to encourage capability breakthroughs from the commercial sector.
- Establishing a strategy for the Army Acquisition Workforce (AAW) to successfully support the Soldier, based on nine objectives embracing efficiency, adaptability, knowledge, innovation and other key principles of professionalism.
- Large-scale efforts for continuous improvement of the AAW, such as the Human Capital Strategic Plan, a five-year plan to help establish goals, objectives and initiatives that support the AAW and help strengthen its foundation for the future.
- A renewed focus on acquisition reform from Army senior leadership, centered particularly on strategic acquisition, i.e., applying a more holistic approach across the acquisition life cycle and the entire Army enterprise to achieve greater efficiency, responsiveness and timeliness to meet current and future threats.

Easter’s leadership style also helped in this past year of transition. Upbeat and unruffled, she “brings a calm” to the challenges facing the AAW, said Joan L. Sable, chief of the Human Capital Initiatives Division in the Army Director for Acquisition Career Management Office, within the U.S. Army Acquisition Support Center. “Her style is to expect and demand expertise, and she holds all accountable.” At the same time, Sable noted Easter’s talent for making herself and the complexities of acquisition accessible. At a contracting leader-development session in June 2017, for example, “Ms. Easter spoke of the ‘four Cs of leader development’—commitment, communication, collaboration and courage—and emphasized each with a leadership story from her past that also focused back on contracting.”

“The transition [from McFarland to Easter and then to the present] was practically seamless because of the program and technical expertise as well as leadership Ms. Easter brought to the Army,” said Sable, who also noted that “having a black female at the helm of Army acquisition has been an opportune sight and has had a huge impact within our Army Acquisition Workforce. She makes a difference within our community.”

—MS. MARGARET C. ROTH



FACES *of the* FORCE

MR. STEVEN SCHULTZ

COMMAND/ORGANIZATION:

U.S. Army Tank Automotive Research, Development and Engineering Center; assigned to the Joint Program Office for Joint Light Tactical Vehicles, Program Executive Office for Combat Support and Combat Service Support

TITLE: Chief integration engineer

YEARS OF SERVICE IN WORKFORCE: 18

DAWIA CERTIFICATIONS: Level III in engineering

EDUCATION: M.S. in automotive engineering, Lawrence Technological University; B.S. in mechanical engineering, University of Michigan

AWARDS: David Packard Excellence in Acquisition Award, 2009, 2013 and 2015

"Early in my career in modeling and simulation, I often took the initiative to work with PMs to find out what problems they needed help with, rather than waiting for them to approach my team."

Integrating people, processes for program success

Considered the top team award in acquisition, DOD's David Packard Excellence in Acquisition Award recognizes groups and organizations that have demonstrated exemplary innovation using best practices to achieve excellence. It's rare to receive more than one, rarer still to be in a program that's twice honored. It's even more uncommon to have three such certificates on your wall. Steven Schultz finds himself among that small number.

An engineer with the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) for 18 years, Schultz was part of a Mine Resistant Ambush Protected (MRAP) All-Terrain Vehicle (M-ATV) team that received the award in 2009, and part of Joint Light Tactical Vehicle (JLTV) teams similarly honored in 2013 and 2015.

"Each of the David Packard Awards was truly unique," said Schultz, chief integration engineer assigned to the Joint Program Office for JLTV (JPO JLTV), within the Program Executive Office for Combat Support and Combat Service Support. "The M-ATV award stands out, as I was part of a leadership team that was addressing an urgent need to get a more mobile version of the MRAPs to the field quickly. It was clear from the beginning that the M-ATV vehicle was needed for a specific environment that required more mobility and just as much protection as the earlier MRAPs. The fact that the M-ATV is still seen as a great platform today is a proud moment of my career," he said.

"The award for JLTV in 2013 was special, as the JLTV program really went through some significant changes at milestone B," including leadership



ACQUISITION

changes, budgetary ups and downs and a complete requirements and cost analysis, Schultz said. “Getting through milestone B required a complete team effort to prepare and brief the results of those changes to senior Army and Marine Corps officials, all the way up to the defense acquisition executive leadership. Working on a cross-functional team to accomplish milestone B approval created professional relationships that I still rely on.”

Schultz’s title as chief integration officer relates not so much to the systems on the vehicle as to the people who put those systems together. “My official title really goes toward managing the integration of the people and processes between TARDEC and JPO JLTV,” he said, noting that many of the people on the team are from TARDEC and that JPO JLTV relies on TARDEC for many of the engineering tasks. “I’m the conduit to ensure that the people have a connection back to their home organization and to identify additional resources that would help the JPO in day-to-day tasks, as well as helping to see that those tasks get delivered on time and within budget.”

Schultz has been in acquisition since he was in college, getting his start through a TARDEC internship program. His first assignment was in modeling and simulation. “I was always interested in computers and analysis, and working with models to generate vehicle dynamics data gave me my first exposure to military requirements, meeting performance benchmarks and the associated verification methods.” From there, he worked in science and technology programs with many program management offices; he has supported the High Mobility Multipurpose Wheeled Vehicle, the Family of Medium Tactical Vehicles, the Stryker and the MRAP in some capacity over the course of his career.

He has been a part of the JLTV program since the technology development (TD) phase. “Seeing the design take shape from requirements—and being a part of a program that is seen as a model for acquisition—brings a sense of pride, and it has been very rewarding to be part of building the next truck to be fielded to the warfighter,” he said.

The JLTV has undergone a lot of changes between TD and low-rate initial production (LRIP), Schultz noted. JLTV was unique in that the program management office was able to evaluate competitive prototypes in TD and in the engineering and manufacturing development (EMD) phase, he explained. “In the TD phase, the program was really testing requirements compliance, and we learned some things that set thresholds for achievable requirements. In EMD, we saw a new set of contractors perform against that new set of requirements, and saw more technology trades come into play as the contractors tried to meet cost targets. For LRIP, the contract award went to one of our EMD contractors, who improved the design based on testing performed in EMD, improving durability and better positioning the vehicle for manufacturing and meeting the platform cost goals.”

Schultz noted that his work requires a great deal of hands-on engineering and problem-solving over a wide range of areas, something that often surprises those not familiar with his work. “I think typically there are engineers who are specialists in a single technology. Working in JPO JLTV, there are platformwide solutions needed across many of the subsystems involved, spanning the range from working with paint to more complex engines, for example.”

Working on a range of projects—whether assigned to do so or just volunteering—

has served Schultz well throughout his career. “One of the best pieces of advice I give to others is don’t wait for someone to give you permission to do something you want to do. Just start doing it. It is very rare anyone will tell you no.”

He knows whereof he speaks. “Early in my career in modeling and simulation, I often took the initiative to work with PMs to find out what problems they needed help with, rather than waiting for them to approach my team. This developed into many positive relationships based on addressing their needs, which often resulted in more opportunities for new projects,” he said.

That same mindset served as the impetus for him to get involved in new projects related to the JLTV, he said, “because I thought I could add value and maximize the chance for success.” JPO JLTV is currently performing laboratory durability testing, and Schultz used his leadership connections to ensure that the requisite agreements, funding and planning were in place for the testing. Additionally, he recently led a contract to develop a camouflage paint pattern for the JLTV. “We didn’t really have a true expert on paint, and based on my platform knowledge, I felt I could succeed in that task.”

His contributions haven’t gone unnoticed. Because of his ability to delve into engineering matters as well as his cross-organizational management experience, Schultz was selected to fill in as JPO JLTV engineering director when the previous director retired. “If you are committed and contributing, more opportunities will come your way and others will seek you out,” he said.

—MS. SUSAN L. FOLLETT

STRONGER AND FASTER

ARL's DOD Supercomputing Resource Center uses high-performance computing to increase mission effectiveness and advance Army modernization priorities. More than 60 Army programs of record depend on the service's use of advanced computing and networking resources, and upgrades implemented in May 2017 allow researchers to design and improve systems at an even faster pace. (U.S. Army photo)





World-Class *TECH*, ACCORDING *to Plan*

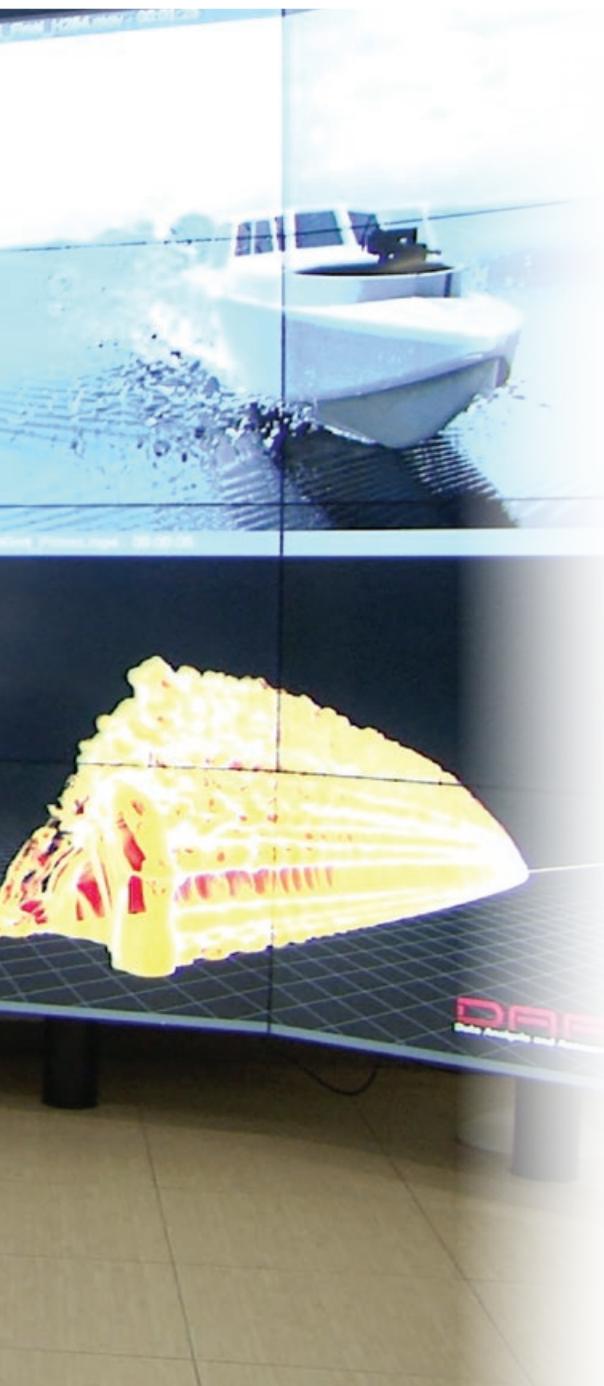
The Army's science and technology arm revamps its approach to speed modernization in line with Army priorities.

by Ms. Argie Sarantinos-Perrin

Information-gathering drones swarm the sky as unmanned Army vehicles push just ahead of infantry Soldiers into a megacity overflowing with people, vehicles and high-rise buildings. Army cyber warriors fight a silent battle for the city's internet of things while an unmanned warship shoots down an aircraft, which explodes in the air, creating a massive fireball and a barrage of fragments that plummet to the ground. Meanwhile, the first artillery crew to the battle is trading targeting and friendly forces information with Air Force bombers and Navy gunners.

The technologies in this future multidomain battle scenario may seem far-fetched, but the Army's primary science and technology arm, the U.S. Army Research, Development and Engineering Command (RDECOM), is developing many of them now. As the link between Army readiness today and for the future force, RDECOM is overhauling how it does the business of science and technology (S&T) to posture itself to make a reality of the six modernization priorities outlined by then-acting Secretary (now Undersecretary) of the Army Ryan D. McCarthy and Army Chief of Staff Gen. Mark A. Milley in October: long-range precision fires, Future Vertical Lift (FVL), the Next Generation Combat Vehicle (NGCV), air and missile defense, the network and Soldier lethality.

"The range of threats the nation faces has prompted the Army chief of staff to mandate a change to the way the Army modernizes its forces," said Maj. Gen. Cedric T. Wins, RDECOM commanding general. "That means RDECOM



will have to change the way we do business to support a new focus. Our campaign plan is the road map to do that.”

The goal of the plan’s four lines of effort is to focus the 24,000-strong command more tightly on the capabilities that Army leadership has made its top priorities while maintaining the balance needed to make the new discoveries and develop the new technologies that will become the capabilities the future force needs to be dominant. The lines of effort are: integrated technology development and engineering services; talent management and infrastructure; business process and resource optimization; and strategic communications.

RDECOM is leveraging its campaign plan to optimize resources and collaborate across the Army community and with industry, academia and international partners to inform S&T requirements and execute research and technology that will deliver required capabilities for Soldiers.

RDECOM, a major subordinate command of the U.S. Army Materiel Command, also works closely with its fellow Army S&T partners—the U.S. Army Space and Missile Defense Command, U.S. Army Medical Research and Materiel Command and the U.S. Army Engineer Research and Development Center—to round out its portfolio.

LICENSE TO INTEGRATE

The integrated technology development and engineering services line of effort is intended to focus the command on identifying and inserting the right research and technology to fill gaps in current and future capabilities, as well as synchronizing RDECOM’s major S&T efforts with the chief of staff’s six modernization priorities. A number of RDECOM’s efforts that currently link directly to the Army’s priorities include robotics, artificial intelligence and autonomy. These technologies will enable the NGCV and FVL to perform both manned and unmanned operations, which will be required for the joint force in future air and ground domains. RDECOM also

continues to develop technologies that provide assured positioning, navigation and timing and support cyber and electronic warfare, critical components for both long-range precision fires and the network.

Integration across its six research, development and engineering centers (RDECs) and the U.S. Army Research Laboratory (ARL) is an important component of this line of effort.

For example, plans for FVL will leverage multiple areas of expertise within RDECOM, including engineers who can produce technology that allows platforms to perform complex navigation and a communication system that will operate in anti-access and aerial denial (A2AD) environments. Because of anticipated future threats, FVL platforms also will need active protection systems for maneuver and enhanced weapon systems for lethality. As stand-alone efforts, these systems are impressive, but maintaining the dominance the Army needs requires a fully integrated suite of capabilities that



LIVE, VIRTUAL AND INSTRUCTIVE

A Stryker vehicle commander interacts in real time with a Soldier avatar that is operated remotely from a collective trainer. ARL, University of Southern California’s Institute for Creative Technologies, the U.S. Army Combined Arms Center and the Program Executive Office for Simulation, Training and Instrumentation are working together to develop a synthetic training environment that links augmented reality with live training—one of several RDECOM efforts that link to the Army’s modernization priorities. (U.S. Army photo)



CONSIDER THE POSSIBILITIES

Alfred Yu, a psychologist with ARL, speaks to students at the Black Engineer of the Year Awards (BEYA) in February 2017. To attract and keep a more diverse workforce, RDECOM's human capital team plans to attend more events like BEYA, and offers other incentives—funding to pursue research opportunities, leadership development and educational programs, as well as the opportunity to work in state-of-the-art labs around the world. (U.S. Army photo by Tom Faulkner, RDECOM)

allow the Soldier to focus on the mission, not switch back and forth between technologies.

“Integration is one of RDECOM’s charter missions for a reason,” Wins said. “Recent modernization efforts focused on adding new capabilities to existing platforms. That allows Soldiers to regain lost capabilities, but not being fully integrated imposes a cognitive load on the Soldier. Multidomain battle will only add to that. We need to take a cue from industry. They’re proving every day that when you integrate technologies—in their case the phone, the tablet, the computer, the TV, the cloud, etc.—you give the end user capabilities beyond what each technology can offer.”

RDECOM plans to conduct technology demonstrations in 2018 that showcase robotics and autonomy, as well as efforts involving precision fires and network command, control, communications and intelligence. Also planned for FY18 is Cyber Quest, the annual competition conducted by the U.S. Army Cyber Center of Excellence’s Cyberspace Battle Lab, which will

demonstrate cyberspace electromagnetic effects technologies being developed by the U.S. Army Communications-Electronics Research, Development and Engineering Center. Exercises in the Pacific theater that will start this spring and continue through FY19 will allow the new Multi-Domain Battle Task Force (MDTF) pilot program to evaluate specific technologies, including long-range precision fires, precision navigation and timing, intelligence, electronic warfare and cyberspace, additive manufacturing sustainment and logistics support. The MDTF was established to determine the requirements for a new military formation that will address the warfighting capability required in an A2AD environment.

While the goal of these demonstrations is often an early assessment of how to apply the technology for military use, RDECOM works closely with the U.S. Army Training and Doctrine Command (TRADOC) Army Capabilities Integration Center to inform the requirements. TRADOC uses a “campaign of learning” approach to determine the doctrine, organization, training, materiel, leadership and education, personnel, facilities and

policy implications of the capability. As technologies mature and transition into a program of record, the program manager uses the data from the demonstrations to chart a path for fielding the equipment and providing capability to the warfighter.

THE RIGHT MIX OF PEOPLE

The human capital team within the talent management and infrastructure line of effort is responsible for maintaining the right mix within RDECOM's global workforce of almost 24,000 civilians, military personnel and contractors, including nearly 10,000 scientists and engineers. The human capital team is ramping up its efforts to attract and hire the next generation of technology leaders by visiting colleges and universities and holding conferences to recruit students interested in careers in science or engineering.

"Recruiting is an ongoing effort within RDECOM because scientific breakthroughs create new opportunities to advance the state of the art, which means having scientists and engineers at the forefront of their fields is essential," Wins said. "RDECOM also teams with academia and industry, but having the right people within the command is key to bringing new capabilities to the force."

To reach the right mix of people, the human capital team created a centralized process to determine which recruiting events the command should attend, as well as metrics for measuring the return on investment from those events. The team also initiated a speaker series aimed at keeping employees engaged, motivated and current in their fields, which should help employee retention.

"Many people outside of RDECOM don't realize we have six RDECs and ARL, and sometimes it's confusing when multiple groups exhibit at the same event," said Deborah Dawson, the command's human resources director. "If it is a recruiting event for students, we match them with the correct RDEC, according to their area of study."

RDECOM leaders found that the different perspectives inherent in a more diverse workforce help teams avoid groupthink and becoming stale. The command mapped out visits to a number of historically black colleges and universities and minority institutions where Wins discussed career opportunities with students and partnership opportunities with the universities. The human capital team also will lead recruitment and outreach efforts at the Hispanic Engineer National Achievement Awards Conference, the Society of Women Engineers and the Becoming Everything You Are conference.



I CAN SEE THE FUTURE FROM HERE

Wins, RDECOM commanding general, tries out the HoloLens, Microsoft's advanced holographic glasses. The technology combines a holographic computer built into a headset that lets users see, hear and interact with holograms within a simulated environment such as a living room or an office. Researchers are using the glasses to get a better understanding of how blast injuries affect Soldiers. (U.S. Army photo by Conrad Johnson, RDECOM)

As part of its recruitment effort, RDECOM also offers incentives, such as funding to pursue research opportunities, leadership development, educational and publication opportunities, as well as the opportunity to work in state-of-the-art labs around the world. These labs are vital to RDECOM since they are often where new ideas turn into next-generation technologies.

Having the right facilities for new technological undertakings is also important to success. "The right number and mix of buildings is a moving target," said Carl Boquist, RDECOM facilities, logistics and environmental director. For example, as part of efforts to hit that target, RDECOM is looking to build the Soldier and Squad Performance Research Institute, which will consolidate five laboratories into one and provide direct readiness to Soldiers with projects that improve their cognitive, physiological, physical and nutritional performance. The lab will be part of the U.S. Army Natick Soldier Research,

Development and Engineering Center in Massachusetts and build on research already completed.

MAKE FINANCIAL TRANSPARENCY EASIER

Operationalizing the command and delivering technology quickly, which Wins calls “speed of delivery,” requires collaboration and planning between the command and its research and development centers and labs because the command has personnel in more than 100 locations, in 11 countries and across five continents. The business process and resource optimization team is standardizing the command’s financial processes and identifying more efficient ways to conduct business.

“When we get an urgent request for information or work to be done, we want to be able to move quickly,” Wins said. “One key to doing that is having visibility on what everyone across the command is

doing and standardizing business processes so we can move at the speed of the technology, not the speed of the bureaucracy.”

The business process and resource optimization team issued standardized budget guidance to maintain consistency and transparency across the command to the RDECs and ARL before the FY18 budgets were developed. Once the budgets were finalized, they were added into an internal RDECOM system, the Financial Integrated Reporting Environment (FIRE). One of the benefits of loading detailed budget information into FIRE is that it is automatically fed to the government financial accounting system so that it can be extracted easily if a customer needs more detail or supporting information. The final step before the budgets were sent for approval was a robust review process.

“With all of the changes that the team has added, we have a more transparent system that will allow us to troubleshoot financial challenges that arise,” said Paul Dunaway, RDECOM resource management director.

‘TELL SOLDIERS WHAT WE CAN DO FOR THEM’

Strategic communication is important to RDECOM, which relies extensively on collaboration and partnerships to bring the best technology to Soldiers.

“Our science and technology doesn’t do the Soldier any good if nobody knows about it,” Wins said. “Strategic communications help us develop the ecosystem we need to remain at the forefront of the many areas we work in, both internally and externally. It helps us tell Soldiers and battlefield commanders what we can do for them.”

The command’s goal is to increase outreach efforts by attending more S&T and recruiting conferences, exercises and technology demonstrations to exhibit RDECOM’s latest technologies and receive feedback from its stakeholders. These events offer opportunities to collaborate with industry and demonstrate how innovative technologies and experimental prototypes can transition to program executive offices and program managers for further development and fielding.

CONCLUSION

By collaborating across the command and working with academic and industry partners, RDECOM maintains a steady stream of world-class technology. These technologies will not only fill current and emerging capability gaps, but they also will mirror the modernization priorities set by Army leadership and enable RDECOM to continue developing and delivering capabilities that empower, unburden and protect the warfighter.

“We will use our campaign plan as a guideline while we determine which technologies to focus on and how fast we can make them available for Soldiers,” Wins said. “Speed of delivery is key to our mission.”

For more information, go to <http://www.rdecom.army.mil/> or contact RDECOM Public Affairs at 443-395-3922.

MS. ARGIE SARANTINOS-PERRIN, a public affairs specialist for Huntington Ingalls Industries – Technical Solutions Division, provides contract support to RDECOM. She holds an M.S. in professional writing and a B.A. in mass communications from Towson University. She has 12 years of public affairs experience supporting DOD.

“We need to take a cue from industry. They’re proving every day that when you integrate technologies — the phone, the tablet, the computer, the TV, the cloud, etc. — you give the end user capabilities beyond what each technology can offer.”

THIS IS ONLY A DRILL

The 8th Theater Sustainment Command (TSC) conducted an active-shooter exercise in September 2017 at the command's headquarters on Fort Shafter, Hawaii. First responder communications are supported by LMRs, now supplied through an innovative arrangement involving two contractors and two enterprise LMR locations. Each contractor supplies the primary core for one location and the secondary core for the other location. (U.S. Army photo by Staff Sgt. Michael Behlin, 8th TSC)



HOLDING ALL THE 'ACE'S

How one Army product office used strategic acquisition to drive competition and improve readiness in a specialized market dominated by two vendors.

by Ms. Kimberly Davidson and Mr. James Christophersen

Late on a January afternoon in Texas in 2015, gunfire shattered the typical silence and echoed through the halls of a U.S. Department of Veterans Affairs medical clinic at Fort Bliss. In a scene too familiar to Americans today, active shooter alarms sounded in the William Beaumont Army Medical Center and two nearby schools—thousands of innocent people were suddenly in danger.

Within two minutes of the first shots, a handful of first responders entered the building. Behind the scenes, multiple 911 calls poured in, and the computer-automated dispatch system aided coordination of a swift and decisive response. Within 30 minutes, more than 300 first responders from Fort Bliss' Military Police, the El Paso Police Department, the El Paso SWAT team, the El Paso Independent School District Police Department, the U.S. Department of Homeland Security's Immigration and Customs Enforcement and Customs and Border Protection agencies and the FBI had responded.

Equipped with interoperable land mobile radios (LMRs), the diverse team coordinated actions under the direction of a single incident commander. Acting with the efficiency that comes from good communication, the team evacuated more than 3,000 civilians and secured the crime scene in less than seven minutes. Two people were killed. The fast and effective actions of first responders, however, prevented a terrible situation from becoming much worse.

Timeliness is critical during active-shooter incidents to minimize casualties. The ability to communicate in a disaster is one of the most overlooked factors in maximizing the efficiency of response and minimizing damage. LMRs are the first line of communication for first responders at all Army installations. First responders are the heroes; LMRs make the heroes more effective.

'BEYOND THE BRICK'

Colloquially known as a “brick” for its iconic appearance, the subscriber unit radio—the technical term for

the carried or mounted radio unit—is the most visible asset of an LMR system. Most users take no interest in how the system actually works—just as most people don't think about what goes into making their cellphone work. But unlike a firearm, flashlight or other tool on a first responder's duty belt, the radio requires a vast behind-the-scenes network to provide state-of-the-art communications capability at the push of a button. Looking beyond the brick reveals the LMR system as a true system of systems, typically consisting of handheld portable radios, mobile radios, base stations, radio towers, software and other network components to extend the range and capability of each radio.

Part of the Program Executive Office for Enterprise Information Systems (PEO EIS), the LMR product office is responsible for the whole system—managing, engineering, acquiring, delivering and supporting the total architecture of the LMR system on Army installations worldwide. In just the continental United States (CONUS), that amounts to 68 stand-alone systems at 68 installations in 38 states and the District of Columbia. The nontactical LMR systems that the product office fields support installation management and force protection, public safety and homeland security.

A STACKED DECK

In 2014, the LMR product office recognized two mounting threats to the future readiness of Army CONUS LMR systems: a complex requirement and minimally competitive industry base; and a widening shortfall in appropriated funds to procure and sustain aging systems. Similar to many segments of the U.S. defense industrial base, the industry for Army LMR is narrow because few commercial LMR suppliers meet the Army's information assurance and

cybersecurity requirements. Just as Boeing Co., Northrop Grumman Corp. and Lockheed Martin Corp. dominate military aircraft manufacturing, and General Dynamics and Huntington Ingalls Industries dominate the Navy shipbuilding market, Harris Corp. and Motorola Solutions Inc. are the dominant competitors for Army LMR.

Although two industry partners generate more competition than one, the modularity and uniqueness of systems for each individual post, camp and station meant that one company would sometimes enjoy a competitive advantage over the other. For example, if the Army used Motorola products at Camp A, it would make the most sense to use products from the same

vendor for replacements and upgrades at Camp A for ease of compatibility. That left Harris with an uphill battle to win the contract—which, as the saying goes, often makes the juice not worth the squeeze. In such cases, the competition for a contract evaporated and left one company with a corner on the market.

In a cash-strapped Army, resources directed away from operations and maintenance to meet more urgent readiness requirements and fight existing conflicts left many systems in “break-fix” status, meaning systems were only fixed and restored as they failed. Information assurance accreditations expired at numerous installations, putting long-term operational readiness in jeopardy.



TRAIN AS YOU FIGHT

Wisconsin law enforcement personnel from several counties participate in a training scenario in September 2017 at the Combined Arms Collective Training Facility at Fort McCoy, Wisconsin. LMR is the first line of communication for all first responders at Army installations, and recent efforts by PEO EIS will make the system easier to maintain—an important improvement since support for fielded LMR systems is not a primary duty on most Army installations. (U.S. Army photo by Scott T. Sturkol, Fort McCoy Public Affairs)

Without sufficient funds to maintain all 68 CONUS systems, the LMR product office and its customers, the U.S. Army Network Enterprise Technology Command and the U.S. Installation Management Command, had to look for alternative solutions.

THE ARMY'S 'ACE'

To solve both issues and ensure readiness for LMR systems, the product office introduced the Army CONUS Enterprise (ACE) LMR System. ACE consolidates 68 localized LMR core systems into two enterprise LMR systems. The ACE model provides fully redundant LMR systems throughout CONUS with a core infrastructure hosted at Joint Base Lewis-McChord in Washington and Fort Drum in upstate New York.

Here we come to the acquisition card trick. The LMR product office designed the ACE acquisition as a limited-source, dual-award contract with both major contractors—Harris and Motorola—supplying the primary core for one location and the secondary core for the other location. The result? A Motorola primary and Harris secondary at the first location, but a Harris primary and Motorola secondary at the second. The ACE LMR system will provide an enterprise-level LMR system while maintaining competition at the installation level on each delivery order for new radios, towers, dispatch consoles and other infrastructure. With ACE, both major contractors enjoy the same incentive to compete for every LMR procurement for every Army post, camp and station in CONUS, while the Army reaps the benefits of competition.

LESSONS LEARNED THROUGH IMPLEMENTATION

In designing the ACE architecture, the LMR product office developed a new contracting model that may prove useful



THE ROOM WHERE IT HAPPENS

Ralph Edmonds, left, showcases a portion of Fort Belvoir's LMR equipment to Brig. Gen. Patrick W. Burden, program executive officer for EIS. In 2014, PEO EIS' LMR product office began developing a plan to address a handful of threats to the readiness of Army LMR systems in the U.S., including a complex requirement, only two suppliers and a shrinking pool of appropriated funds. (Photo by James Christopherson, Project Manager for Defense Communications and Army Transmission Systems (PM DCATS))

to other network efforts facing challenges with competition. The product office also learned many valuable lessons that are applicable to any office on any effort.

Challenge 1: Communication

No battle plan survives first contact with the enemy, and no request for proposal (RFP) survives first contact with industry partners. RFPs are prepared deliberately, thoughtfully and thoroughly, but they represent only the government side of the conversation. Government acquisition teams and industry partners both have phenomenal people with brilliant ideas and different perspectives. That often produces different ideas on how to solve the same problem. By communicating first, frequently and openly, government and industry partners can better complement one another's efforts.

When issuing its RFP, the product office was confident that its industry partners would repurpose existing core systems from current installations to the new ACE sites to save on costs. They were then shocked to learn through initial industry proposals that none of the fielded cores was technically suitable to handle the volume of traffic required for a regional core. Both government and industry partners were in sync on the big picture, but they found key differences in proposed solutions.

The product office plans to mitigate confusion on task orders for individual site installations by using face-to-face initial proposal meetings with industry to discuss, clarify and shape proposals through dialogue. Rather than asking the companies to prepare their proposals in a



THE STRUCTURE OF INFRASTRUCTURE

Equipment and infrastructure like this LMR tower at Fort Belvoir, Virginia, and repeaters, which retransmit low-level radio signals at a higher level so the signal can cover longer distances without weakening, enable first responders to communicate clearly when it matters most. (Photo by James Christopherson, PM DCATS)

vacuum as with the initial RFP, the product office is putting the “partner” back in “industry partner” and collaborating to provide best-value solutions.

Challenge 2: Acquisition Agility

In a joint statement Sept. 27, 2017, to the House Armed Services Subcommittee on Tactical Air and Land Forces, Lt. Gen. Bruce T. Crawford, Army chief information officer/G-6, Maj. Gen. James J. Mingus, director of the Mission Command Center of Excellence, and Gary Martin, program executive officer for Command, Control and Communications – Tactical, stated, “Our current acquisition process does not allow the Army to rapidly acquire and integrate emerging capabilities, allowing the warfighter to keep pace with technology and stay ahead of the evolving threat.”

Although their statement was directed to tactical networks, the same challenge is aptly illustrated by ACE LMR. Building newer, more resilient and reliable systems requires time, especially for modern communications systems. To go from concept to contract for ACE took 3 1/2 years. Now in post-award, the product office projects another 18 months to deliver the first installations. Updating all 68 CONUS LMR systems will continue incrementally over the next five to 10 years as funding priorities permit. That totals 10 to 15 years from concept to completed fielding. As ACE LMR illustrates, the Army acquisition machinery is a battleship that cannot abruptly change direction. Major network improvements do not happen overnight.

Army Chief of Staff Gen. Mark A. Milley has identified readiness as his No. 1 priority and devoted specific attention to the Army’s communications networks. Time and long-range planning are necessities to achieve Armywide readiness. As it plans regionalization efforts for Army installations in Europe and the Pacific, the LMR product office is applying lessons from ACE to streamline those acquisitions.

CONCLUSION

Through it all, the LMR product office demonstrated that a small, dedicated team of acquisition experts—six people in all—accustomed to the routine of cookie-cutter acquisitions can adapt to create something completely new. Without adding any new staff, the team drew on its familiarity with the product and the industry to develop and implement innovative solutions that will fundamentally alter the Army’s future LMR acquisitions. Their dedication and focus will produce three distinct benefits for the Army:

- The Army will enjoy immediate cost savings: At a unit price of \$800,000 to \$1 million per core, a reduction of 64 cores suggests a conservative cost savings estimate of \$51.2 million for the cost of the systems alone.
- The Army anticipates additional life cycle savings through reduced operations and maintenance (O&M) costs: Acquisition theory teaches program managers to plan for 60 percent of the cost of a product over the life cycle to fall into O&M. The bulk of the savings is realized years after installation. The Army expects to realize a cost avoidance by reducing the number of O&M contracts from 75 to two. Additionally, O&M costs will be further reduced by decreased redundancy in site surveys, operations, information assurance accreditation, software updates and maintenance.
- ACE LMR reduces workload and improves readiness: On many Army installations, support for fielded LMR systems is not a primary duty. The

system manager typically has one, two or even three other primary duties. The burden of programming radios, updating software and other O&M efforts for LMR often competes with unrelated duties, leaving resources strained. ACE reduces the workload for system managers by centralizing many tasks and assigning them to dedicated system managers based at the two core sites. Reducing the hands-on labor required to manage and maintain the fielded systems improves readiness and resiliency for first-responder communications.

For more information about LMR, go to <http://www.eis.army.mil/programs/lmr>, or contact Brandy Jackson at brandy.a.jackson6.ctr@mail.mil or 703-806-9713.

MS. KIMBERLY DAVIDSON has been the product lead for LMR since 2011, managing the acquisition, management, installation and delivery of the Army's LMR systems worldwide. She holds an

M.S. in program management from the Naval Postgraduate School and a B.S. in secondary education with a specialty in mathematics from Nova Southeastern University. She received a Commander's Award for Civilian Service in 2011 and 2014. She is Level III certified in program management.

MR. JAMES CHRISTOPHERSEN is a contractor and public affairs professional supporting the PM DCATS within PEO EIS. He has supported various offices in the Army acquisition enterprise since 2014, including the Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology. He holds a B.S. in psychology from LeTourneau University, and a Project Management Professional certification.



SIMULATED CASUALTY, REAL RESPONSE

Firefighters from Fort Bragg Fire and Emergency Services evacuate a simulated casualty from a UH-60 Black Hawk helicopter during an emergency training scenario at Fort Bragg, North Carolina, in July 2017. To ensure readiness for the LMR systems that support communications during actual events as well as training exercises, the LMR product office consolidated nearly 70 localized systems into two enterprise-wide systems. (U.S. Army photo by Sgt. Paige Behringer, 49th Public Affairs Detachment)



LIGHT LOAD

Soldiers from the 2nd Brigade Combat Team (BCT), 101st Airborne Division (Air Assault) move away from a CH-47 Chinook after successfully hanging the Tactical Communications Node – Light during a sling-load exercise at Fort Campbell, Kentucky, in June 2017. The new systems can be sling-loaded from a helicopter or rolled onto a C-130 aircraft, improving agility and operational flexibility and aiding Army efforts to deploy right-sized units across contested domains at every stage of operations. (U.S. Army photo by 1st Lt. Daniel Johnson, 2nd BCT, 101st Airborne Division Public Affairs)



Changing NETWORK, New Name



In continuing evolution of its network, Army renames WIN-T program office PM Tactical Network.

by Ms. Amy Walker

As the Army continues to modernize its network in today's complex world, it has renamed its tactical communications network transport program office from the Project Manager for Warfighter Information Network – Tactical (PM WIN-T) to PM Tactical Network.

The new name, which the Army initiated over a year ago, more accurately reflects the numerous programs within the PM's portfolio, not just the core at-the-halt WIN-T Increment 1 and on-the-move WIN-T Increment 2. PM Tactical Network still manages WIN-T Increment 1 and WIN-T Increment 2, and those names will remain the same. But PM Tactical Network also manages many other expeditionary line-of-sight and beyond-line-of-sight capabilities. Together, these programs provide the Army with an agile, modular toolkit of unified satellite and radio network capabilities to enable uninterrupted mission command and secure reliable voice, video and data communications at every point on the joint operational spectrum.



THE ROAD TO IMPROVEMENT

Vehicles equipped with mobile WIN-T, including the Stryker at the end of this convoy at the National Training Center (NTC), Fort Irwin, California, enable mobile mission command, advanced communication and a real-time common operating picture from anywhere on the battlefield. PM Tactical Network will continue to improve WIN-T, as well as the rest of the Army's tactical network, across all echelons and domains. (U.S. Army photo courtesy of the NTC Operations Group)

BETTER ALIGNMENT

The new name better suits the program office's holistic mission and vision. The program office will continue to develop, field and manage the Army's tactical network transport systems to support reliable, expeditionary global network connectivity, but it will accomplish its goals from an all-encompassing viewpoint.

"Our new name is not only a reflection of our continued dedication to our mission, but a new way of doing business across the Army and joint forces," said Col. Greg Coile, PM for Tactical Network. "Our one-network vision sees the network as a whole, from the Soldier on the ground, to the commander maneuvering on the battlefield in his networked vehicle, to network connectivity back to home station. It's all one network, no matter the domain, the location or the joint or coalition battlefield partner."

Additionally, the PM's subordinate product managers for WIN-T Increment 1 and WIN-T Increment 2 will be renamed the product managers for Network Modernization and Mission Network, respectively.

PM Tactical Network delivers a scalable suite of integrated tactical network communication and network and cyber management capabilities to support

today's complex joint, coalition and civil missions worldwide. PM Tactical Network will still manage the core at-the-halt and on-the-move WIN-T network transport equipment, enhancing network mobility, simplicity and cybersecurity, and will augment these core capabilities with robust expeditionary network transport equipment.

A 71-YEAR LINEAGE

The lineage of PM Tactical Network dates to 1946, with the advent of satellite communications at the U.S. Army Research and Development Laboratories at Fort Monmouth, New Jersey. Later, military operations in Desert Storm, as well as in Operation Enduring Freedom and Operation Iraqi Freedom, revealed that the outdated mobile subscriber equipment could no longer keep up with the pace of battle. WIN-T was conceived to solve this problem and enable mobile mission command on the battlefield. The fielding of the initial Joint Network Node (JNN) capability started in 2004 to support operations in Iraq and Afghanistan. In June 2007, the WIN-T program was restructured into four increments, and the JNN program was then absorbed into WIN-T Increment 1.

PM Tactical Network is assigned to the Program Executive Office for Command,

Control and Communications – Tactical (PEO C3T), which develops, acquires, fields and supports the Army's mission command network to ensure force readiness. This critical Army modernization priority aims to enable commanders and Soldiers to stay connected and informed at all times, even in the most austere and hostile environments. PEO C3T is delivering the network worldwide, providing high-speed, high-capacity voice, data and video communication capabilities to

"The world is changing, the fight is changing, and we must continue to evolve the Army's tactical network if we want to dominate on the battlefield."



MAINTAINING THE MISSION

During a training mission in May 2017, the Army's Global Response Force successfully used the En-route Mission Command system developed by PM Tactical Network to enable real-time joint intelligence, communications and collaboration capabilities on a flight from Fort Bragg, North Carolina, to New Mexico. While the program office's name is new, its mission is not: to provide warfighters unified satellite and radio network capabilities to enable uninterrupted mission command and secure communications across the joint operational spectrum. (U.S. Army photo by 2nd Lt. Zachary Jacobson, 50th Expeditionary Signal Battalion, 35th Signal Brigade)



ALL SYSTEMS GO

In support of Army efforts to deploy a more agile and ready force, PM Tactical Network's Transportable Tactical Command Communication (T2C2) Lite and T2C2 Heavy inflatable satellite terminals provide robust network communications supporting critical mission command requirements for early-entry and forward-edge operating forces. The Army successfully executed the T2C2 operational test at Joint Base Elmendorf-Richardson, Alaska, in March 2017. (U.S. Army photo by Staff Sgt. Garcia Bibian Pedro, Combat Camera)

Soldiers and the Army's joint, coalition and other mission partners.

CONCLUSION

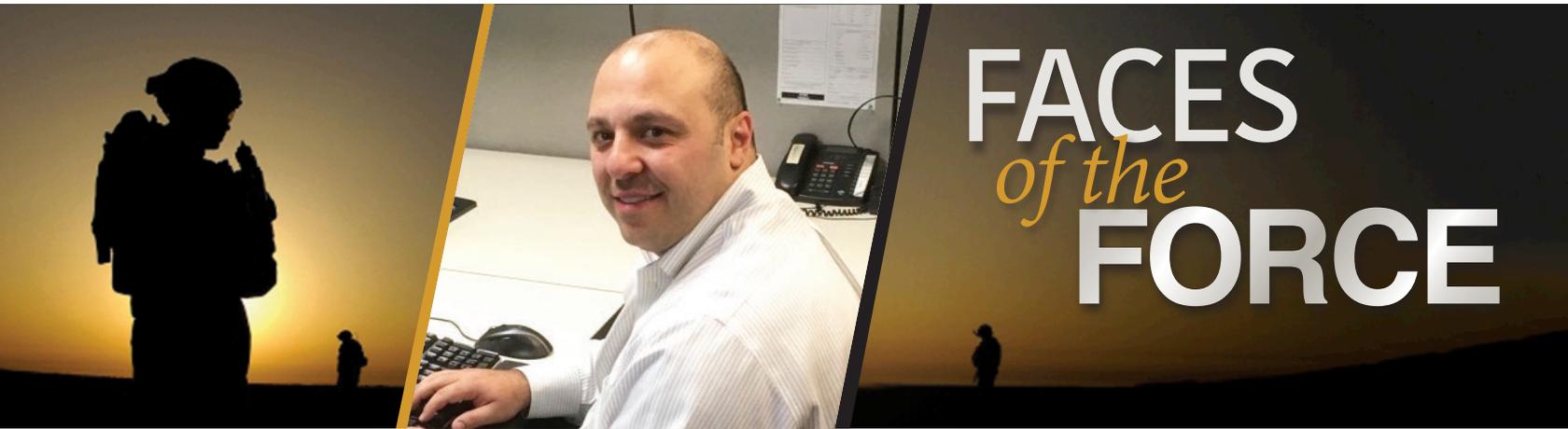
Today, as potential peer and near-peer enemies continue to advance their technological capabilities, the Army is pushing to improve its readiness to rapidly deploy, maneuver and fight right-sized units across multiple contested domains at every stage of operations. Likewise, PM Tactical Network will continue to improve the Army's tactical network, enhancing its management, operation and defense across all echelons and domains.

To meet the Army's strategic priorities for readiness, responsiveness and regional engagement, ongoing capability advances in the tactical network programs are improving simplicity, mobility, modularity and agility. The Army's continuously evolving suite of expeditionary network transport equipment enables commanders to see first and act first, while increasing speed of maneuver and operational flexibility.

"The world is changing, the fight is changing, and we must continue to evolve the Army's tactical network if we want to dominate on the battlefield," Coile said.

For more information, go to <http://peoc3t.army.mil/c3t/>, or contact the PEO C3T Public Affairs Office at 443-395-6489 or usarmy.APG.peo-c3t.mbx.pao-peoc3t@mail.mil.

MS. AMY WALKER has been the public affairs lead for PM Tactical Network since 2009. She has holds a B.A. in psychology from the College of New Jersey.



FACES *of the* FORCE

DR. JOHN PUTRUS

COMMAND/ORGANIZATION:

U.S. Army Tank Automotive Research, Development and Engineering Center; assigned to the Joint Program Office for Joint Light Tactical Vehicles, Program Executive Office for Combat Support and Combat Service Support

TITLE:

Mechanical engineer; power and mobility engineer

YEARS OF SERVICE IN WORKFORCE: 9

DAWIA CERTIFICATIONS:

Level III in engineering; Level I in program management and in test and evaluation

EDUCATION:

Ph.D. in mechanical engineering with a concentration in thermal sciences; M.S. in mechanical engineering with concentrations in solid mechanics, dynamics and vibrations; B.S. in mechanical engineering with concentrations in automotive and mechanical systems engineering, all from Lawrence Technological University

AWARDS:

David Packard Excellence in Acquisition Award, 2013 and 2015; Federal Executive Board for Exemplary Civilian Service; Achievement Medal for Civilian Service

Helping to shape the Army's vehicular backbone

“**W**hen I tell people what I do, they're often surprised by all the things a DOD engineer does.” For Dr. John Putrus, mechanical and power and mobility engineer with the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC), the average day might include holding a design review, writing a multimillion-dollar contract, driving trucks, testing vehicles under extreme conditions or briefing a general officer.

Assigned to the Joint Program Office for Joint Light Tactical Vehicles (JPO JLTV) within the Program Executive Office for Combat Support and Combat Service Support (PEO CS&CSS), Putrus is responsible for electrical power and mobility systems for the JLTV program—components such as the cooling system, engine, transmission, alternator, batteries, chassis and suspension. He's also the engineer responsible for requirements development, system design, testing and production for these components, a position he has held since the program began in 2006.

“My primary goal as a JLTV engineer is to develop the best on- and off-road light tactical vehicle” to replace the High Mobility Multipurpose Wheeled Vehicle (HMMWV), he said. “I am working on something that really matters, and I get to do it with the best team and leadership in DOD.”

“No one here will tell you you cannot get involved, and that mindset results in some of the most well-rounded engineers available.”

The JLTV is not just another car or part, but rather something that Soldiers and Marines will use for the next 50-plus years. LTVs are the backbone of the Army, which makes being part of the program even more special to me.”

Putrus grew up near the Detroit Arsenal, which is home to PEO CS&CSS, the PEO for Ground Combat Systems, TACOM Life Cycle Management Command and TARDEC. It was also home to the Detroit Arsenal tank plant, which closed in December 1996. “I always loved looking at the military vehicles in front of the arsenal and wanted to be a part of that,” he said. As a college student, he opted to intern with AM General, an original equipment manufacturer (OEM) that builds HMMWVs. “When I saw what they did, I was immediately hooked.”

After graduating, he spent four years with AM General, working directly for the chief engineer on multiple vehicle programs from their inception, including the Future Tactical Truck System Utility Vehicle, the Expanded Capacity Vehicle II and the JLTV. “That gave me firsthand engineering design experience with tactical wheeled vehicles that I directly carried over to JPO JLTV,” said Putrus. “The engineering experience helped me a great deal in multiple design reviews and engineering efforts throughout the JPO JLTV program, and has helped me understand how things are really done on the OEM side and what is actually possible.”

His first job with TACOM was as program manager for the Hybrid Electric Vehicle Experimentation and Assessment Program. “I wanted to be involved with the development of next-generation military vehicles, and working at TACOM is the best place you can do that.” TACOM gives engineers the opportunity “to be involved with much more than what a standard engineering position offers,” he added. “You control your destiny here and can be involved with as much as you want to be. No one here will tell you you cannot get involved, and that mindset results in some of the most well-rounded engineers available.”

He’s learned a great deal over the course of his career, including one lesson he picked up early on: the importance of building relationships. “I have taken the time to build as many relationships as I can with multiple government organizations, defense OEMs, suppliers and co-workers. I’ve found that if you work to help people quickly and effectively, those people will make sure to return the favor by responding quickly to you when you need help. This has allowed me to be very efficient and perform much better at my job.”

The JLTV program will field roughly 55,000 combat vehicles to Soldiers and Marines, with the bulk of those going to the Army. JLTVs will close capability gaps related to payload, performance and protection while increasing, maneuverability and battlefield network connectivity. While the program is now on solid footing and in low-rate initial production, Putrus noted that “there was a point in the JLTV program where the program’s survival was at serious risk. In 2011, Congress considered terminating the JLTV program over concerns about technology maturity and cost. We had to find a way to efficiently and effectively reduce the cost of the truck by almost 50 percent in order for the program to continue.”

The JLTV team performed a comprehensive cost-informed trade-study analysis (CITA) that resulted in optimized requirements and a truck that met the program’s cost targets. Putrus was tasked with working on multiple design options, requirement changes and cost analyses that led to the CITA, which was approved by the vice chief of staff of the Army and allowed the program to proceed to milestone B.

“Being successful in this effort was critical to me, as I had spent my entire career developing the truck to replace the HMMWV, and no one on our program wanted to fail. Thanks to the personal involvement of the vice chief of staff of the Army and assistant commandant of the Marine Corps, along with some clear affordability targets and the CITA, funding was on track in early 2012.”

Putrus was a member of the JPO JLTV team that twice received DOD’s David Packard Award for Acquisition Excellence for its work to implement better buying power practices and its efforts to keep costs low and timelines short. “The Packard awards stand out to me because the JLTV program has allowed me to truly learn the defense acquisition life cycle,” he said. “I have been lucky enough to be a part of the program from when it was an advanced concept technology demonstrator through the present day, where we’re in low-rate initial production and have built hundreds of vehicles. Once the project reaches full materiel release and sustainment, I will have worked in all phases of the defense acquisition life cycle—that’s something that very few get to do.”

—MS. SUSAN L. FOLLETT



A BRIGHTER IDEA

AMSAA is researching advances in solar energy to power the batteries in the Army's TWWs. (U.S. Army Reserve photo by Master Sgt. Michel Sauret, 200th Military Police Command)



HARNESSING THE SUN

AMSAA looks at advances in solar energy as a way to maintain the batteries powering infrequently used Army vehicles.

by Mr. Kevin Guite and Mr. Brian Frymiare

For those holding onto a restored 1968 Camaro in the garage or that old Ford F100 inherited from your uncle and sitting under the backyard tree, it should not be a shock to find that the batteries in those vehicles exemplify the axiom “use it or lose it.” The Army faces a similar challenge, though one of far greater magnitude, with its vast fleet of tactical wheeled vehicles (TWVs), which make up nearly 65 percent of the Army’s total vehicle inventory. The TWV category—approximately 400,000 vehicles—includes everything from lighter vehicles like the High Mobility Multipurpose Wheeled Vehicle and its variants all the way up to massive, multiton vehicles like the Palletized Load System.

Most of these vehicles stand by until needed, which means that nearly 75 percent of the TWV fleet can be characterized as low-usage, or operated fewer than 3,000 miles each year. Low-usage TWV systems have proven to be a big part of the Army’s battery failure-and-replacement cycle. These vehicles are critical components of the global sustainment mission, needed to transport supplies and equipment to and around the battlefield. But the reality of a use-it-or-lose-it approach to battery life quietly attacks the readiness of the fleet.

Data acquired through the Army Sample Data Collection and Analysis (SDC&A) program highlights the accelerated battery replacement rate for the TWV fleet. The SDC&A program, established through DOD Directive 4151.18, collects

and analyzes data to support cost, reliability, availability and maintainability studies; special requirements; and Army staff programs. The U.S. Army Materiel Systems Analysis Activity (AMSAA), as the Army's responsible official, administers the program as prescribed in "Army Regulation 750-1, Army Materiel Maintenance Policy." Based on SDC&A information, the Army is replacing some batteries only one-third of the way into their expected minimum life and one-sixth of their expected life based on proper maintenance.

For example, SDC&A data showed that over the past three years, the absorbent glass mat (AGM) battery used in the TWV fleet was being replaced every 13 months on average, when maintenance technicians detected the failure of the vehicle batteries. The expected minimum life of the AGM battery is three years per

manufacturer warranty, with an expected full life of approximately six to eight years when treated properly. The Army chose the AGM as its standard vehicle battery for its improved performance and spill-proof design based on the use of highly porous microfiber plates that absorb the battery's electrolyte.

Replacing batteries has become a tremendous burden for the Army logistics enterprise. Maintenance personnel spend time assessing and recharging batteries, removing and replacing spent ones and managing temporary storage locations for batteries that are no longer useable. Removing the batteries from the site requires involvement of the Defense Reutilization and Marketing Office or local contractors paid to remove and recycle the batteries. During FY16, DOD spent more than \$80 million replacing more than 373,000 vehicle batteries. The

cost and effort being expended on low-usage batteries begs for a better way to manage this challenge.

A SOLAR SOLUTION DAWNS

Now engineers with AMSAA's Operational Sustainment Analysis Team (OSAT), in coordination with other Army organizations, are exploring the possibility of using modern solar charger technology to solve the problem of prematurely replacing Army batteries. OSAT engineers, charged with detecting systemic materiel readiness issues in fielded systems and influencing improvements using data-driven analyses, are studying small solar panels that, when attached to the hood or roof of TWV platforms, can provide from 20 to 60 watts of power to charge and maintain batteries on those vehicles. Once attached, the solar panel can remain with the vehicle wherever it travels and requires no interaction or maintenance from the vehicle's operator.

By converting the sun's power into electricity, solar panel solutions have the potential to increase the readiness of low-usage vehicles while reducing maintenance costs and the logistics burden caused by excessive battery management.

Solar panels are an old but still evolving technology that have gone through many advancements over the years. Bell Labs introduced solar cells for space activities in the 1950s that boasted 6 percent efficiency in converting light to power. Today's panels, capitalizing on years of design and manufacturing improvements, are capable of converting sunlight into power at an efficiency level of about 20 percent.

AMSAA's analysis of previous efforts from as early as 2004 seeking to introduce solar chargers to Army vehicle maintenance programs uncovered problems in design



TESTED TOUGH

Not even the weight of a forklift can damage some of today's solar panel products. The solar panel industry studied the shortcomings of earlier products and applied lessons learned to today's products; AMSAA engineers are now working to develop requirements for a solar-powered charger system to mount on the Army's light tactical vehicles. (Photo courtesy of SOLARA)

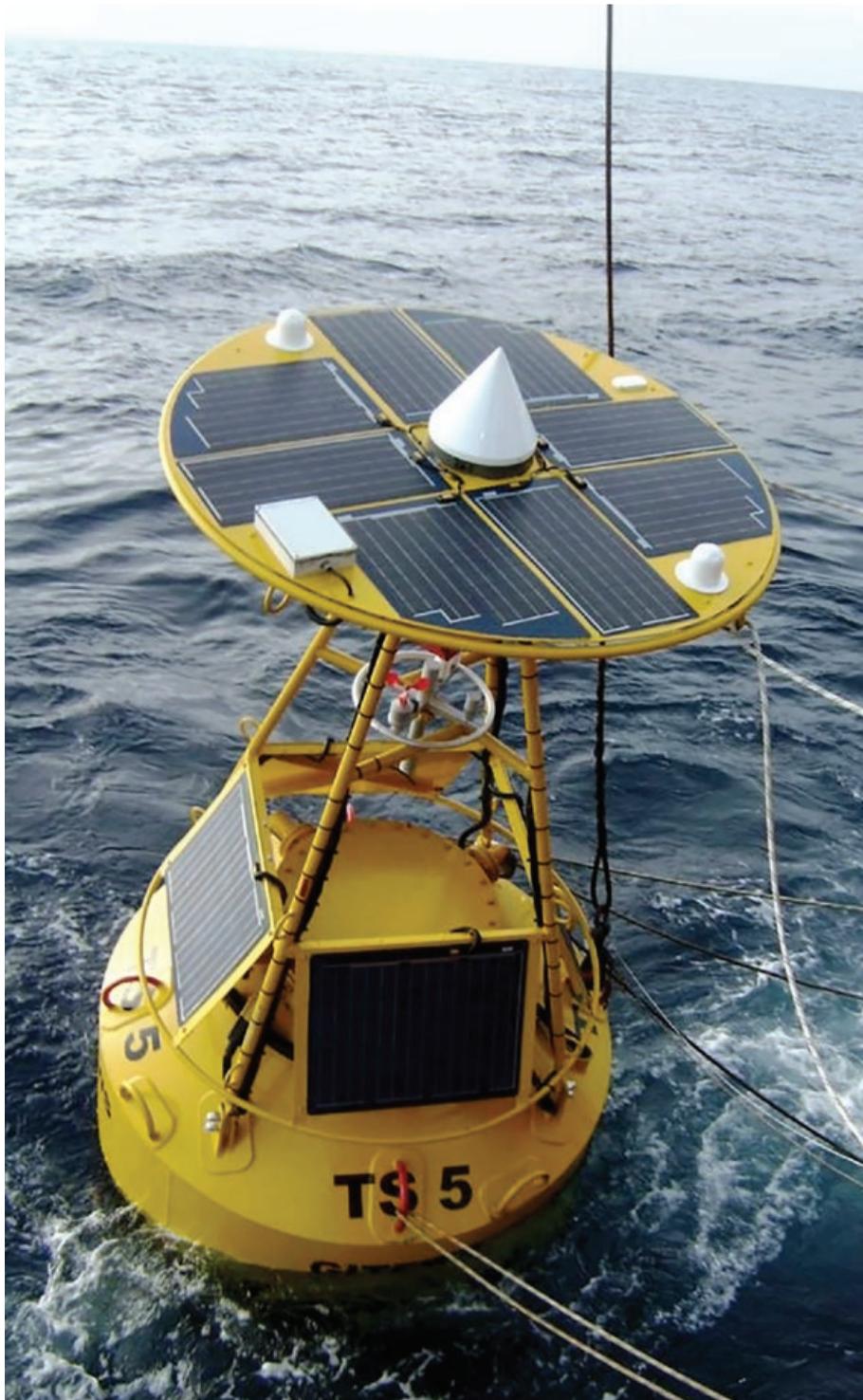
and implementation. At that time, the solar panels selected were too small for the load placed on them, and the panel controllers needed to govern battery-charging voltages were not watertight or fused to protect electrical components in case of an electrical short. Multiple-battery configurations required for Army vehicle loads became unbalanced and were not properly regulated. Panels were not shade-tolerant, so the whole system stopped working when part of a cell was blocked from the sun. In addition, the panels ultimately were found to be too large, too heavy, too fragile and too expensive.

The latest generation of solar panels and controllers resolves many of the problems and concerns of earlier models. The solar panel industry has studied the problems experienced in the past, noted lessons learned and applied them to today's products. Newer, lighter, flexible, more durable and less expensive panels are now operating with greater efficiency, reducing the size and number of panels required for the amount of power produced. Such panels can be found on rooftops, cars, street signs, buoys, remote communication equipment and even recreational vehicles.

Waterproof controllers are now available that have been proven during marine applications, and have well-designed voltage regulators. Additionally, panels now include bypass diodes that can route power around shaded or damaged cells, allowing a solar panel to incur multiple gunshots and continue to produce power without shorting out.

CAN IT POWER THE ARMY?

The unique requirements of the Army's military vehicle platforms pose challenges to fully maximizing solar panel advances. First, unlike conventional automobile



ON THE LOOKOUT

A buoy equipped with solar panels monitors for tsunamis in the Indian Ocean. Solar panels today are lighter, more durable and more efficient than previous generations of the technology, requiring fewer panels to generate a given amount of electricity. (Photo courtesy of SOLARA)

During FY16, DOD spent more than \$80 million replacing more than 373,000 vehicle batteries. The cost and effort being expended on low-usage batteries begs for a better way to manage this challenge.

battery requirements, the Army's more robust vehicles require more voltage and power. Therefore, the Army uses batteries connected in strings of 12 and 24 volts in series and in parallel.

For example, some TWVs require a configuration of four large 120-amp-hour AGM batteries. These vehicles require both 12- and 24-volt power to accommodate legacy and newer electrical components that have specific requirements for those voltage levels. The differing electrical loads they place on the vehicle's battery bank often lead to large battery voltage imbalances. Research has shown that a one-volt difference between the two 12-volt battery strings is not uncommon, but that one-volt difference in an AGM battery is the difference between being 100 percent charged and approximately 20 percent charged. The huge discrepancy can cause many problems for military vehicle platforms.

AMSAA engineers, in coordination with other Army organizations, are leading an 18-month analysis initiated in June 2017

that will research, configure and test various solar panel and controller options for onboard vehicle battery charging of Army AGM battery configurations. The objective of the analysis is to identify requirements for a system that can cost-effectively charge, maintain, balance and restore Army TWV batteries.

Research efforts to date have uncovered a number of products that appear to be suitable for the evaluation. The analysis will assess the various solar product configurations against a collection of new and discharged AGM batteries representing differing states of charge to determine if today's solar panel products are able to maintain new batteries, remove sulfation from the battery plates that limits battery power capacity, and restore undercharged or dead batteries.

AMSAA will study controllers for their ability to govern power distribution to banks of batteries and to operate in adverse weather conditions. The analysis also will consider panel size, flexibility and survivability in a variety of Army

INTO THE STORM

A lifeboat equipped with solar panels endures harsh maritime conditions. Testing under such conditions has resulted in waterproof controllers with well-designed voltage regulators. When the Army first began investigating the use of solar panels to charge vehicle batteries, the inability to keep water out of controllers contributed to poor test results. (Photo courtesy of SOLARA)





POWER TO THE VEHICLE FLEET

Wisconsin National Guard's 32nd Infantry Brigade Combat Team relied on TWVs, among other materiel, for its Team Warfighter Exercise in August 2017. The Army's massive fleet of TWVs, most of which are used only for such training, requires a way to keep batteries from dying when not being used regularly. (U.S. Army photo by Scott T. Sturkol, Fort McCoy Public Affairs)

operating environments. The ultimate goal is to be able to produce requirements that the Army could adopt for a solar charger system that could be installed easily on fielded and future TWV platforms to extend vehicle battery life.

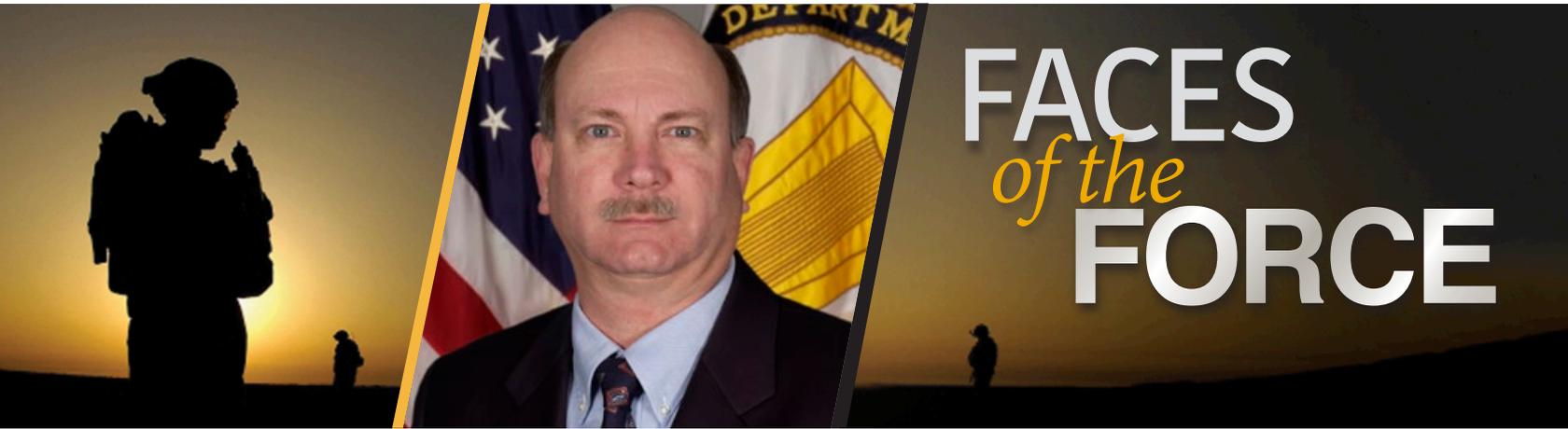
CONCLUSION

Given the recent advances in solar technology, the time is right for the Army to consider the use of solar charging systems. By properly using efficient and robust solar charger systems, the Army will be able to maintain vehicle batteries within its low-usage TWV fleet so that they will not need to be replaced until after they've completed the full expected life of six to eight years. The current generation of solar products is considerably less expensive than those from just a few years ago. The Army stands to benefit greatly from that cost reduction, by identifying and implementing a cost-effective solution to solve a historically challenging maintenance concern.

For more information on this and other AMSAA OSAT efforts, contact the authors at kevin.m.guite.civ@mail.mil or brian.e.frymiare.civ@mail.mil, or go to <https://osat.amsaa.army.mil>.

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MR. BRIAN FRYMIARE is a general engineer for AMSAA. He holds an M.S. in management from the Florida Institute of Technology and a B.S. in general engineering from Widener University. He is Level II certified in test and evaluation and in engineering.



FACES *of the* FORCE

DR. KENNETH A. BERTRAM

COMMAND/ORGANIZATION:

U.S. Army Medical Research and Materiel Command, U.S. Army Medical Command

TITLE: Principal assistant for acquisition

YEARS OF SERVICE IN WORKFORCE: 8

YEARS OF MILITARY SERVICE: 24

DAWIA CERTIFICATIONS:

Level III in program management and in science and technology management

EDUCATION:

M.D. and Ph.D. in microbiology, University of Minnesota; B.S. in microbiology, University of Illinois at Urbana-Champaign

AWARDS:

Decoration for Exceptional Civilian Service; Meritorious Civilian Service Medal; Superior Civilian Service Medal; Legion of Merit; Order of Military Medical Merit; U.S. Army Meritorious Service Medal; U.S. Army Commendation Medal

Keeping an eye on ‘true north’

Ask anyone in acquisition what they’d change if they were king for a day, and the answers abound. Most hew toward minimizing or eliminating hurdles that slow the contracting and acquisition process, and debate rages over which are the highest of those hurdles. For Dr. Kenneth A. Bertram, principal assistant for acquisition for the U.S. Army Medical Research and Materiel Command (USAMRMC), that question is far less pressing than what must remain constant.

Bertram pointed out that acquisition at USAMRMC differs from the usual Army process in that the medical research laboratories, advanced development and logistics teams, as well as contracting, are all under a single commanding general, Maj. Gen. Barbara R. Holcomb, and a single milestone decision authority, Bertram. In fact, he noted, USAMRMC already looks much like the cross-functional teams that will be a key part of the Army modernization command spelled out by Army leadership and slated to debut later this year.

“I agree with others that our requirements and contracting process and our ability to partner with industry must be improved,” he said. “But I don’t consider the MRMC acquisition processes for ACAT [Acquisition Category] III programs—in marked contrast to ACAT I or II programs, which MRMC does not have—overly burdensome. Our product and program managers would probably say we should get rid of AOAs [analyses of alternatives] or market studies, but I think all of those things are necessary to what we’re doing.”

The mission of USAMRMC’s Office of the Principal Assistant for Acquisition and its advanced development product and support teams is to develop, transition and field medical materiel solutions to optimize readiness and to protect, care for and heal the warfighter. “As principal assistant for acquisition, I lead those product

SCIENCE & TECHNOLOGY

teams and integrate the warfighter's needs, the military's acquisition procedures, the U.S. Food and Drug Administration's regulatory requirements and our academic and industry partners' processes, to provide sustainable solutions," Bertram explained. "The greatest satisfaction of this position is providing the warfighter or warfighter medic with a new capability—a battlefield oxygen generator, for example, or new protection, such as the ability to rapidly diagnose an infectious disease."

Therein lies his focus as an acquisition professional—that which never changes, the "true north" of Army acquisition. Keeping warfighter needs, capability gaps and solutions "as the 'true north' is necessary to avoid becoming trapped in changing resource environments, mission drift and other people's agendas," he said. Bertram spent 24 years in the Army, retiring in 2009 and becoming a member of the Senior Executive Service in July of that year. Having served in leadership positions throughout his active-duty career, he's well-versed in the problems that warfighters face in the field and in garrison, and that knowledge "enables USAMRMC to focus on developing the solutions that are needed in a prioritized fashion," he said.

Anyone in his position needs two skills, he said: the ability to listen and the ability to make a decision. "You won't ever get all the information you need, but you have to make a decision: You can't flounder in the land of indecision."



LEADING FROM THE FRONT

Dr. Kenneth Bertram addresses the workforce during the 2016 Decision Gate Awards ceremony at USAMRMC headquarters at Fort Detrick. (U.S. Army photo by Crystal Maynard, USAMRMC)

He got his start in acquisition when he was recruited in the late 1990s to serve as the deputy director for Congressionally Directed Medical Research Programs at Fort Detrick, Maryland, managing an annual budget of roughly \$200 million in research, development, test and evaluation funds. "While those funds were primarily to support extramural or university research in cancer—at the direction of Congress—the funds and research needed to be managed according to DOD acquisition regulations and processes. So, I began work toward Level III certification in science and technology management. I transitioned to a greater product development focus—especially for drugs and vaccines—as a result of my command time at the Walter Reed Army Institute of Research, and earned Level III certification in program management."

He started in his current role in 2009. "When I started, I noticed that our staff had much of the training and certification they needed. But what I didn't realize is that many had gotten that training a long time ago. What they learned wasn't applicable to the way we do contracting now, or they worked in just one area and weren't well-versed in how other processes worked. We spent a lot of time getting our staff the right training."

The other challenge he faced was demonstrating to stakeholders the importance of USAMRMC's work. "We've spent a lot of time with [the assistant secretary of the Army for acquisition, logistics and technology], the G-8, the House and the Senate, getting them to understand the value of what we do," he said. "We've walked people through the process of using our products as if they were a recruit, on the battlefield or recovering from injury, to demonstrate how our products work and how they help the warfighter."

Keeping an eye on true north is good for the career, too. "If you succeed on behalf of the warfighter, career opportunities will present themselves abundantly."

He also noted the importance of career-broadening opportunities, networking with other services, agencies and industry, and completing required and recommended acquisition training. "Lead something," he said. "Solutions for the warfighter only happen when someone provides initiative, responsibility and direction. Let that someone be you."

—MS. SUSAN L. FOLLETT

CARE WHERE IT COUNTS

Soldiers from the 3rd Infantry Division Headquarters Battalion perform combat casualty care as part of medical evacuation training last April at Fort Stewart, Georgia. The Army is looking for smaller, better technologies to operate in combat situations where prolonged field medical care will be common. (U.S. Army photo by Staff Sgt. Candace Mundt, 3rd Infantry Division)



SPEEDING COMBAT CASUALTY CARE

In future conflicts, with communication channels and evacuation routes contested, a lot more casualty care might happen right there on the battlefield.

by Mr. Ramin A. Khalili

Dr. Elliot Botvinick sits in his office on the campus of the University of California (UC), Irvine, holding a tiny device in the palm of his hand. It is smaller than a garage door opener, smaller than a standard business card even, and is so slight and inconspicuous that he might be able to stick one on a passing student without their noticing.

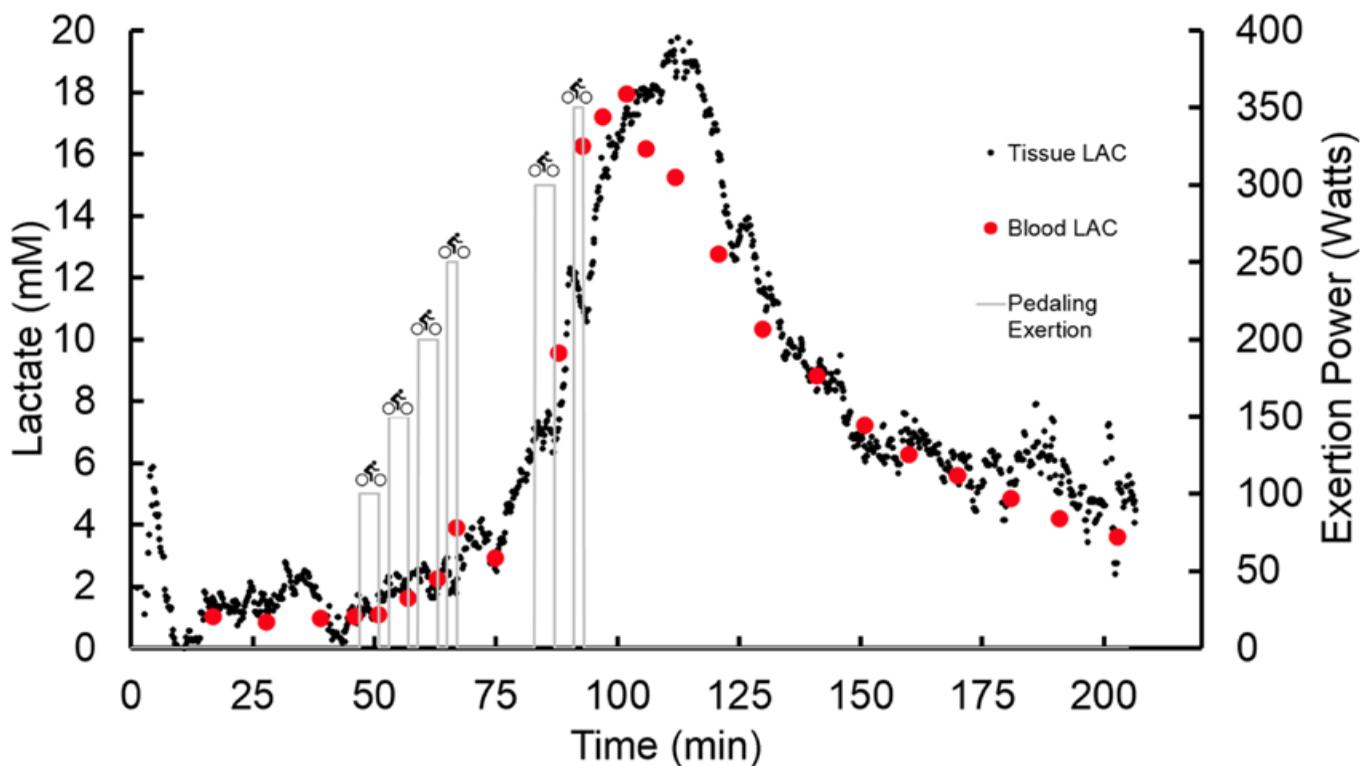
It also might be the future of battlefield medicine, according to the U.S. Army.

Minds like Botvinick's may be exactly what's needed to conquer approaching combat scenarios that experts predict will look starkly different than the current version, ones where the efficient use of targeted medical knowledge may be the single most important key to victory.

Botvinick's handheld lactate monitor fits in perfectly then, as it features a wearable, subcutaneous microsensor designed to detect lactic acid levels, which rise in the body during episodes of critical illness and internal bleeding, both of which cause symptoms that aren't always visible to the naked eye.

"We're feeling pretty confident," said Botvinick, a biomedical engineer. But while he is modestly optimistic, the Army expresses its faith in new medical technologies with a bullhorn.

To hasten the monitors' delivery, the Army is looking to the Combat Casualty Care Research Program (CCCRP) of the U.S. Army Medical Research and Materiel Command (USAMRMC). "Our focus is squarely and specifically on the health and welfare of the warfighter," said U.S. Air Force Col. Michael Davis, the newly installed CCCRP director.



CHARTING EXERTION LEVELS

A readout of lactate levels over time as measured by a continuous lactate monitor over a period of cycling. Lactic acid levels rise during episodes of critical illness and internal bleeding, which may not be visible to the naked eye. (Image courtesy of UC Irvine)

In his role as an investigator with the CCCRP’s portfolio for Photonics and Light-Based Innovation for Severe Injury, Botvinick’s lactate monitor satisfies the Army’s desire for smaller, better technologies to operate in combat scenarios that will likely play out in denser, more urban areas, and in which prolonged field medical care will likely be the norm. Lactate is the chemical form of lactic acid that the body produces and uses.

“The vision [for the device] is something like a blister pack that you would peel open in the field and then a medic would just slap it on the body,” says Botvinick. “And in that simple act of slapping, an insertion needle would be guided just

under the skin [...] and then by pulling back on a sticker or tab, that needle would be removed and just a flexible fiber would remain.”

That tiny fiber would then interrogate the tissue around it, asking how much lactate exists in the area, according to Botvinick. From there, the assembled information would then be transmitted via Bluetooth technology to a wearable unit on the skin.

While measuring lactate is not currently the standard of care in the field (chiefly because current protocol requires blood samples to be drawn and then sent to a lab for study, a logistical nightmare in the field), Botvinick’s sensor measures

lactate faster than the lactate level within the body can change, which makes it ideal for the fluidity of long-term transport situations, as well as transportation between levels of care. As such, a number of prototype devices are being prepared for shipment to the U.S. Army Institute of Surgical Research in San Antonio for animal model testing.

This is just one example from a research program rich with potential solutions.

BATTLEFIELD MEDICINE

Based in a small building on the southern edge of Fort Detrick, Maryland, the CCCRP is the only federal entity specifically tasked with developing the tools

and knowledge required to aid injured warfighters on the battlefield. It comprises four portfolio management areas: Hemorrhage Control and Resuscitation; Neurotrauma and Traumatic Brain Injury (TBI); Prolonged Field Care and En Route Care; and the aforementioned photonics portfolio.

The Army is leaning on CCCRP to produce the next generation tools it will need to conquer and secure the rather bleak battlefield projected for the 2025-2040 timeframe. Specifically, experts predict the U.S. will likely encounter far more sophisticated enemies in the future than in previous conflicts, as well as enemy forces with the capabilities to degrade and inhibit U.S. access and superiority in the domains of air, maritime, cyberspace and emergency medical service.

That puts the execution of prolonged field care in the spotlight. A recent capability needs assessment commissioned by military leadership named prolonged field care as the No. 1 capability gap across the entire Army. Indeed, experts say future battlefields will require medical efforts to be more assertive at the point of injury as opposed to standard forward aid locations, a shift that also radically changes the concept of the “golden hour” standard of care, which

relies on traditional medical transport to get service members treated within the first hour after injury.

INVESTMENT BATTLE PLAN

“We’re going to need lighter, leaner, better capabilities than we currently have,” said Air Force Col. Antoinette Shinn, Ph.D., then-manager of the CCCRP’s Prolonged Field Care and En Route Care portfolio. “For instance, how are we going to maximize tele-health efforts in ways that will assist a far-forward medic, or maybe even no medic at all, in providing life-sustaining care for up to 72 hours?”

Shinn’s portfolio is currently investing heavily in noninvasive hemorrhage detection capabilities for situations in which a warfighter sustains an injury but is neither overtly bleeding nor visibly symptomatic yet. The latter falls into the burgeoning area of “intelligent tasking,” whereby physiology will ultimately determine a patient’s medical needs.

A more fully realized version of the CCCRP’s technological vision for the future is in the program’s Neurotrauma and Traumatic Brain Injury portfolio, where a slew of recent investments have evolved into a variety of potential solutions, each with substantial benefits. With more than 370,000 cases of

TBI across all military branches since 2000, progress in this discipline is a top priority.

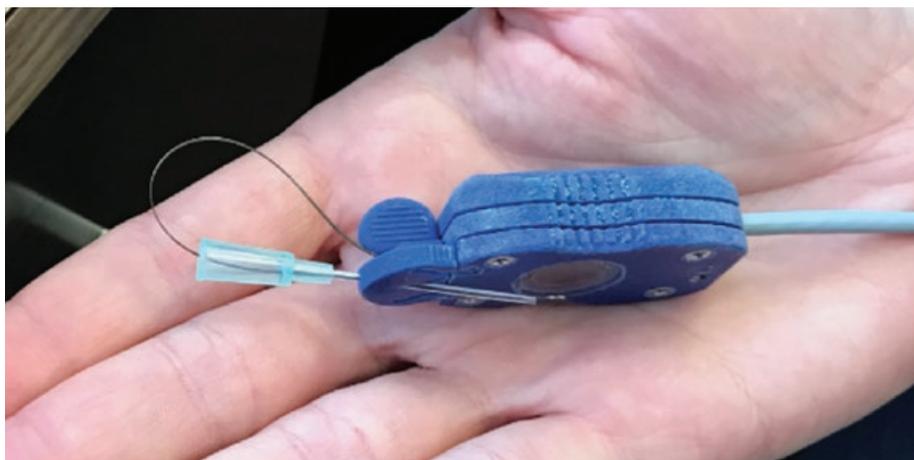
“We’ve got a number of promising technologies, but it’s not going to be just one of them that has all the answers for all environments,” said portfolio manager Dr. Tammy Crowder. “It’s not going to be like the chickenpox vaccine where everybody gets the shot and then we’re all protected.”

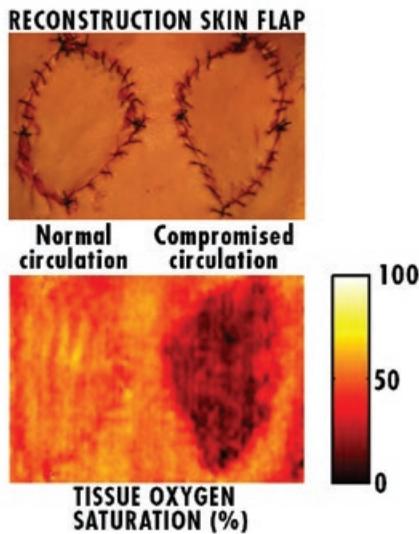
The portfolio’s standout performer so far has been the I-Portal PAS tool, developed by Pennsylvania-based Neuro Kinetics Inc. (NKI). The device uses a virtual-reality headset to assess possible brain injury by measuring a series of oculo-motor pathways, or, more simply, basic eye movement. The user completes more than two dozen tests over 25 minutes, after which a clinician analyzes eye movement and effective neuro-functional capability to determine if a TBI is present. Following initial feedback, NKI is in the process of reducing the exam time from 25 minutes to five while using the same battery of tests.

Crowder’s team is looking for other technologies as well, including balance boards and additional virtual-reality devices that measure separate oculo-motor pathways.

GLIMPSE OF THE FUTURE?

The Army believes the continuous lactate monitor could play a key role in future battlefield medicine. This prototype features a wearable, subcutaneous microsensor designed to detect critical illness and internal bleeding. (Photo courtesy of UC Irvine)





EARLY EVALUATION

SFDI surgical camera images show reconstruction skin flaps with normal circulation, upper left, and compromised circulation, upper right. SFDI images enable physicians to make early and accurate assessments of tissue viability for burn and wound management, reconstructive surgery and progressive monitoring of grafts and wound healing. (Photos courtesy of UC Irvine)



CUTTING-EDGE CARE?

A clinician operates an SFDI unit, which is being developed and commercialized by California-based Modulated Imaging Inc. SFDI uses the principles of diffuse optical spectroscopy to determine whether burned tissue is suitable for reconstructive surgery. (Photo courtesy of UC Irvine)

“We’re literally throwing the long ball with this one,” said Crowder. “But these kinds of efforts will hopefully enable first responders to offer more complete care.”

‘MOTHER NATURE GETS CONFUSED’

For Dr. Lynn Drake, a faculty member at Harvard Medical School and the Wellman Center for Photomedicine at Massachusetts General Hospital, both in Boston, partnering with the U.S. military requires a commitment to accuracy and consistency and a forward-leaning mindset.

“We’ve got about 23 clinical inventions that are now in use worldwide,” said Drake, an investigator with the CCCRP’s photonics portfolio, “plus another 14 platform technologies that have multiple applications, and then I’ve got another 60 things in our pipeline.”

One of those technologies is a cutting-edge fractional laser developed specifically with the military community in mind. In essence, the laser helps to remodel painful scars by creating thousands of tiny holes on the scarred area, which data shows heal faster and cleaner than the original wound.

“Mother Nature gets confused when she tries to heal a bigger wound,” Drake said, adding that fractional lasers are used in the medical community to reduce pain, minimize disfigurement and even erase some scars entirely. That same technology might be used for future skin-grafting efforts and other therapies. Devices for this kind of skin grafting have U.S. Food and Drug Administration (FDA) approval and are commercially available.

The Wellman Center has been partnering with DOD for 20 years; currently more than 20 percent of its overall efforts

are dedicated to the well-being of the warfighter.

The lab is also working to use light to make blood platelets last longer. “The military came in one day and said, ‘We need a way of making platelets last longer,’ ” said Dr. Conor Evans, a faculty member at Wellman. “And so now we have a project underway that we think will extend platelet storage time dramatically.”

That research is all the more important given the forecast for future battlefield scenarios where evacuation to external care facilities may not be immediately possible. According to the CCCRP’s Hemorrhage Control and Resuscitation portfolio, current investments are geared toward developing an FDA-approved dried plasma product, while the goal for future blood products is to ensure survivability for at least six to 12 hours—a number that jumps to 72 hours for potential prolonged field care scenarios. According to Evans, the early data is “fairly outstanding.”

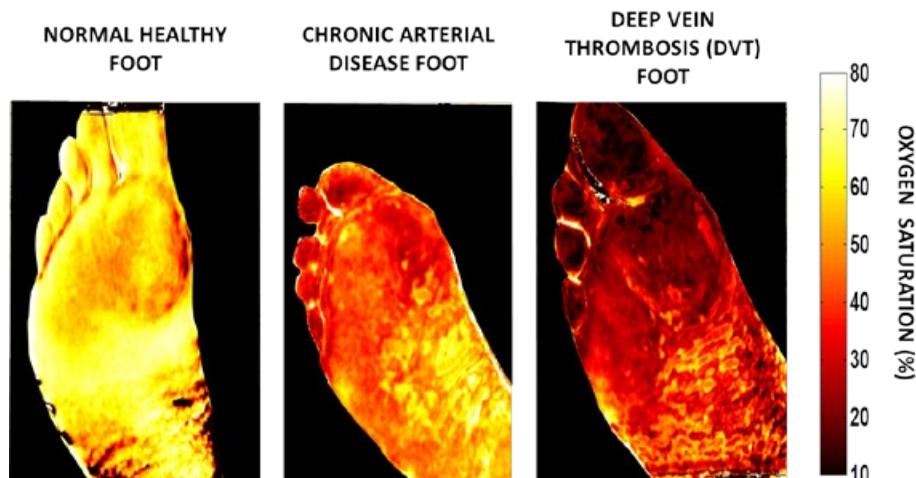
WHEN PHYSICAL, PSYCHOLOGICAL MEET

Back at UC Irvine, the conversation grows subdued as it turns to treating burn injuries. While injuries thought to be fatal just a few years ago are no longer considered as such, burns are still complicated by infection and other variables. For Dr. Anthony Durkin, associate professor at the university and the adjoining Beckman Laser Institute and Medical Clinic, relief for burn victims is as much a matter of tissue as it is time.

“Burns are psychologically difficult,” said Durkin, an investigator with the CCCRP’s photonics portfolio. “Someone who has a burn wants to know as soon as possible whether they’re going to need more surgery or not. Plus, the longer you

A CLEAR PICTURE

The images produced by an SFDI surgical camera show parameters such as oxygen saturation, water content and total hemoglobin. Despite advances in technology, burns remain difficult to treat, and CCCRP is exploring new ways to speed healing and reduce infection. (Photos courtesy of UC Irvine)



wait to take action, the infection rate goes way up over a few days. The risk of scarring and all the nightmares that go along with scarring go up, too.” According to the current standard of care, it can take up to three days after a burn for laser Doppler imaging to be performed, which determines whether the injured tissue is structurally sound enough to be reconstructed. So Durkin’s team developed the cutting-edge spatial frequency domain imaging (SFDI) camera to assess the reconstructive potential of the tissue involved in burns and other wounds.

The SFDI camera uses diffuse optical spectroscopy to take a snapshot of an affected burn area, with the resulting image providing an almost real-time visual map of parameters such as oxygen saturation, water content and total hemoglobin for each pixel. Clinicians can then evaluate tissue viability in wounded areas and determine whether that tissue is a suitable candidate for reconstructive surgery, all within just a few hours. “We think we can buy a couple of days that can dramatically decrease the risk of scars and infection,” Durkin said.

In addition to being a noninvasive technology, the SFDI can differentiate

between superficial partial thickness burns and deep partial thickness burns, a relatively muddy area of wound designation within the medical community, according to Durkin. The SFDI, which is being developed and commercialized by California-based Modulated Imaging Inc., recently received a grant to perform a tissue viability analysis in a variety of wounds relevant to the military. As a result, Durkin’s team has received FDA approval for its technology for research purposes and began efforts to secure FDA clearance for a miniature version of the same device at the end of 2017.

CONCLUSION

The fruits of the CCCRP’s military medical mission often translate to the civilian world, and the lactate monitor is no exception. “The diabetes community has caught on to what I’m doing,” Botvinick said, “and they’re very interested in knowing if lactate can help them safely control sugar and exercise routines in diabetes patients.”

For as much effort and investment goes into the CCCRP’s litany of products and projects, so many of those same efforts—tourniquets, a balloon-tipped catheter that stops bleeding known as the REBOA and many knowledge products—have

gone on to improve and save the lives of countless American citizens.

While that is not the stated priority of the CCCRP and its associated technologies, it is a substantial benefit to the taxpaying public. After all, if a resilient military can help develop a resilient population which, in turn, continues to fuel an even more resilient military—that’s the very definition of achievement.

For more information, contact Chelsea B. Bauckman, USAMRMC Public Affairs, at chelsea.b.bauckman.civ@mail.mil or go to <http://mrmc.amedd.army.mil/>.

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GETTING ACQUAINTED

ECBC research chemist Dr. Terrence D'Onofrio collaborated with U.K. researchers on Porton Man, a sensor-equipped mannequin capable of detecting and evaluating the impact of chemical and biological agents on warfighter uniforms, gloves and other outerwear. (Photo courtesy of Dr. Terrence D'Onofrio)

OVERSEAS OPPORTUNITIES

The Army's Engineer and Scientist Exchange Program gives researchers a chance to grow professionally while collaborating with U.S. allies on new technologies.

by Ms. Gabriella Krohmal and Mr. Adam Genest

In Japan, U.S. Army software engineer Ross Arnold surveys what's left of the town of Arahama, four hours north of Tokyo. Arahama was destroyed in 2011 by the Tohoku earthquake and tsunami that devastated Japan, killing 15,894 people and destroying more than 120,000 buildings, including every building in Arahama except the schoolhouse. Arnold, who's assigned to the U.S. Army Armaments Research, Development and Engineering Center, hopes that the new software algorithm he's been working on with Japan's Air Systems Research Center will help U.S. and Japanese forces use drone swarms to conduct search-and-rescue operations during the next natural disaster.

In Spain, Mark Cumo, an engineer with the U.S. Army Communications-Electronics Research, Development and Engineering Center who specializes in counter-improvised explosive device (IED) technologies, executes a research plan for studying the fragmentation effects of suicide vests used against U.S. troops stationed around the world as well as our European allies. Cumo designed a cooperative research project in 2016 involving the NATO Counter-IED Center of Excellence, Spanish National Police and Guardia Civil and the German Federal Criminal Police. The results of these experiments, as well as designs for protective vests and other equipment, ultimately will be available to DOD and U.S. law enforcement agencies for use in counterterrorism activities.

In Chile, U.S. Army biologist Leanne Chacon visits Chilean army logistics regiments, conducts market research and advises the army’s health directorate on which biological identification technology and equipment will most effectively assist its efforts to identify biological agents in food, water and other vectors. In 2014, when Chacon was there, the Chilean army desperately needed this expertise and equipment, and quickly. Ebola was ravaging West Africa, and that February, Chile confirmed the first case of indigenous transmission of the Zika virus, on Easter Island.

All three scientists are part of the U.S. Army’s Engineer and Scientist Exchange Program (ESEP), a government-to-government effort aimed at increasing international cooperation between the U.S. and its allies in military research, development and acquisition.

Managed by the deputy assistant secretary of the Army for defense exports and cooperation (DASA(DE&C)), ESEP allows U.S. military and civilian personnel to be placed in foreign defense establishments, and foreign defense personnel to be placed in U.S. Army laboratories, research centers and program



GROUP DYNAMICS

U.S. Army Engineer Research and Development Center scientist Todd Rushing, in back row, second from left, poses with co-workers during a hike in Deogyusan, South Korea. By building personal and professional relationships, Rushing left his ESEP assignment with a better understanding of that country’s challenges and of how Americans are perceived by their Korean counterparts. (Photo courtesy of Todd Rushing)

offices. These engineers and scientists work collaboratively with their foreign counterparts to conduct experiments, develop military materiel and technologies, and increase standardization and interoperability between the U.S. Army and its allies.

The program’s roots go back several decades. On June 25, 1963, President John F. Kennedy, speaking before leaders of the West German Bundestag,

proclaimed that Germany’s problems were America’s problems. “For we live in an age of interdependence,” he declared. “Partnership is not a posture but a process—a continuous process that grows stronger each year as we devote ourselves to common tasks.”

Secretary of Defense Robert S. McNamara signed the first-ever ESEP memorandum of understanding with West Germany that same year. Over the ensuing 54 years, the U.S. and Germany have exchanged more than 1,500 engineers and scientists. The U.S. has signed 15 other ESEP memorandums with strategically important allies and partners in Europe, East Asia, Oceania and South America.

UNIQUE ACCESS TO FOREIGN TECHNOLOGY

ESEP aims to leverage the military research, development and acquisition work of U.S. allies and partners while providing opportunities to identify and develop potential international cooperative research, development and acquisition activities for the future. It is the only

“ESEP participants need to be willing to talk to people, willing to learn about new people and cultures. You can’t be pedantic. It’s important to come over with a little humility and be prepared to listen with an understanding that an exchange is a two-way street.”

DOD program that affords civilian scientists and engineers the opportunity to embed within a foreign partner's laboratories and test centers and work side by side with experts around the world.

"In every country we visit, it is well-recognized that the U.S. is a global leader in military technology. Everyone feels like they need to work with the U.S. to stay relevant," said Lt. Col. James T. Naylor, director of the U.S. Army International Technology Center – Atlantic in Paris, an international outreach program of the U.S. Army Research, Development and Engineering Command (RDECOM). "But foreign partners always want to know why we want to work with them. I tell them: 'We have funding and state-of-the-art facilities. But we want your ideas.' Financial constraints in other countries require them to think creatively about materiel and affordability. In the U.S., we frequently drive toward the high-end technology by default."

By sending U.S. engineers and scientists overseas, the Army can learn how its allies conduct research and development activities. U.S. personnel learn new technical skills by working with different software, technology, munitions, systems and codes. ESEP participants also identify opportunities for future collaboration with U.S. allies in strategic focus areas, such as Soldier lethality and protecting the warfighter from chemical and biological attacks. The focus areas link directly to the chief of staff of the Army's priorities for Army modernization.

In the United Kingdom (U.K.), the Defense Science and Technology Laboratory has developed a one-of-a-kind mannequin capable of running, sitting, kneeling and lifting its arms to fire a weapon. Porton Man, as it is called, is covered with hundreds of sensors capable



IT'S NOT ALL WORK

Moving a family overseas for an ESEP assignment is a decision requiring considerable thought, but the benefits of the program can exceed the challenges of being far from home. David Quinn and his family—from left, his wife, Melinda, and daughters Charlotte and Rachel Sage—spent a year in France in 2014 during his assignment for AMRDEC, and he found it "very enlightening to experience the culture and real people of France, not as a tourist but by working side by side." (Photo courtesy of David Quinn)



PARTNERS IN THE FIELD

Leanne Chacon and her Chilean supervisor traveled to a logistics regiment in Coyhaique, Chile, during her ESEP assignment in 2014. Chacon, a biological agent detection expert for ECBC who had spent most of her Army career studying ways to detect airborne biological threats, helped Chilean officials detect food- and waterborne pathogens. (Photo courtesy of Leanne Chacon)

of detecting and evaluating the impact of chemical and biological agents on warfighter uniforms, gloves and other outerwear.

Dr. Terrence D’Onofrio, a research chemist from the U.S. Army Edgewood Chemical and Biological Center (ECBC), has been working with the U.K.’s Defence Science and Technology Laboratory as an ESEP participant since October 2015. ECBC, like the Army’s research, development and engineering centers, is part of RDECOM.

“There is an opportunity for the U.S. and the U.K. to begin a new collaboration and leverage the Porton Man capability as an acquisition program of record,” D’Onofrio said. “The U.S. conducts experiments using human volunteers in a simulated environment. The U.K. uses the Porton Man mannequin, which can go all day, eliminates human differences and can demonstrate different factors” such as postures and environments, he said. Research undertaken with Porton Man also could uncover how armor affects chemical or biological protectors in warfighter suits, for example, D’Onofrio said, or whether U.S. Army operational requirements should change. “Experiments with Porton Man will help ensure that the warfighter is protected from any chemical or biological challenge,” he noted.

The U.K. is just one of many partners working on capabilities that could greatly benefit the U.S. warfighter. Dr. Mark Griep’s ESEP assignment took him to South Korea, where he participated in pioneering work in nanomaterials. (See “ESEP Spotlight,” Page 49.) Because of geopolitical realities, South Korea is expediting its efforts in portable energy and is eagerly anticipating immediate payoffs from this technology. Griep hypothesized that South Korea could fully field lithium-air battery technologies to South Korean troops several years before what the U.S. acquisition system could be expected to accomplish, and that through connections he forged as an ESEP participant, the U.S. Army could have access to these advancements far sooner than had the U.S. decided to go it alone.

A BOON FOR PERSONAL DEVELOPMENT

In addition to allowing the U.S. to learn from its allies’ technological capabilities and research methods, ESEP enhances the professional development of those who participate. The scope of work for most ESEP assignments differs from the participants’ day-to-day work in the U.S. If an ESEP participant were a project manager or chief engineer at their home organization, for example, ESEP might offer the opportunity to reconnect with the basics by working directly in a laboratory. If an ESEP participant developed software to control artillery fire at their home



LASTING RELATIONSHIPS

AMRDEC’s David Quinn, center, who worked with French air force personnel on software development, found his ESEP assignment to be beneficial personally and professionally. Now stateside, he continues to use the contacts he made overseas in his work for AMRDEC. (Photo courtesy of David Quinn)



OPERATING AT A NEW LEVEL

ECBC biologist Leanne Chacon, shown here with members of the Chilean army in Putre, Chile, about 11,500 feet above sea level, traveled extensively through Chile in 2014 to ensure that pathogen detection systems would perform as needed in different climate conditions. (Photo courtesy of Leanne Chacon)

organization, those same skills might be applied to search-and-rescue technology abroad.

ESEP offers participants the opportunity to build upon their areas of expertise while exploring new, challenging work in a similar but different environment or field of study. Chacon, a biological agent detection expert for ECBC who is matrixed to the Joint Program Executive Office for Chemical and Biological Defense, spent most of her Army career studying ways to detect airborne biological threats, such as weaponized pathogens. But when she arrived in Santiago, Chile, for her ESEP assignment, she learned that airborne biological threat detection was not the Chilean army's priority. Instead, the Chileans needed help with a more pressing concern: identifying and protecting against water-, food- and vector-borne biological agents.

The new work opened Chacon's professional horizons, exposing her to a wide range of testing environments that she had not worked in previously and to acquisition management. The Chileans were keen to use commercial off-the-shelf technology to meet their biological agent needs, and they tasked Chacon with finding and recommending devices from commercial vendors in and around Chile. "Chile has a lot of different environments, from deserts to mountains, tundra to the oceanfront," Chacon explained. "The Chileans were interested in cost-effective, highly mobile biological agent detection technology that could be used in a wide range of conditions."

Chacon engaged with Chilean industry and her contacts back in the U.S., finding commercial technologies and meeting with the Chilean vendors to determine whether the devices met the Chilean army's needs. She briefed senior Chilean

leaders, advising them on the available equipment and making recommendations on which devices not only identified the desired agents, but also could be used in a variety of environments.

Upon her return to the U.S. after a year in Chile, Chacon found that the skills and knowledge she had developed in Chile were highly applicable to her new role. "The Chileans wanted to use our technology for bio threat detection in soil and water, even though it wasn't designed for that. Now I'm working within the U.S. Army to further develop technology specifically for that purpose."

Adapting to change and exploring a new area of research also helped build Chacon's confidence. "When I went [to Chile], I thought I could speak Spanish, but I learned I couldn't speak 'Chilean,'" Chacon recounted. "Now I'm more flexible and able to adapt to any situation. I used to be nervous conducting briefings and doing public speaking, but now that I've experienced briefing senior Chilean leaders in Spanish, doing the same in the U.S. is much easier—after all, at least it's in English!"

STRENGTHENING DIPLOMATIC TIES

ESEP also enables diplomacy through personal contact and military-to-military cooperation. Strengthening alliances and attracting new partners is one of the top priorities spelled out by Secretary of Defense James Mattis. "History is compelling on this point: Nations with strong allies thrive, while those without stagnate and wither," he wrote in an Oct. 5, 2017, memorandum. "We will continue to work with our allies, partners, and coalitions ... to reinforce the safety and security that underpins peace and economic prosperity for all nations."

David Quinn, team lead for the Aeromechanics Division at the U.S. Army Aviation and Missile Research, Development and Engineering Center (AMRDEC), found that his ESEP experience, working to help the French air force validate new software for the Airborne Warning and Control System electronic flight bag, was akin to a diplomatic mission.

"In many ways, I felt like an ambassador every day, going to work, going to the market, paying bills as an American in France. It was way more than a technical exchange—it was building relationships, and it was very enlightening to experience the culture and real people of France, not as a tourist but by working side by side," he said. Since his return to the U.S. in 2015, Quinn has participated in AMRDEC's work on the Rotary Wing Aeromechanics and Human Factors Integration Technologies Project Agreement with France. The network of contacts he

It is the only DOD program that affords civilian scientists and engineers the opportunity to embed within a foreign partner's laboratories and test centers and work side by side with experts around the world.

made in France continues to pay dividends for U.S. cooperative efforts.

Todd Rushing, a research scientist from the U.S. Army Engineer Research and Development Center's Geotechnical and Structures Laboratory, found his ESEP assignment in South Korea to be an immersive experience that helped him understand the world from the viewpoint of U.S. allies. "ESEP has benefited me by expanding my perspective on the world and helping me to build a global network," Rushing said.

"The assignment allowed me to develop an appreciation for the point of view and motivations of our ally the Republic of Korea and its people, based on their unique geopolitical environment and the potential threats that they live with every day. I will also be able to improve the way I communicate with and relate to our international partners by better understanding how the U.S. is perceived by others," he said, adding that the assignment "allowed me to create international friendships that I plan to maintain into the future."

HOW PROGRAM FUNDING WORKS

To encourage U.S. participation in the program, DASA(DE&C) provides central funding to U.S. Army commands for the associated costs of sending their engineers and scientists overseas to work in allied and friendly countries' defense establishments. In dispersing these funds annually through a competitive nomination and selection process, DASA(DE&C) covers labor, allowances and travel expenses. It doesn't cost DOD organizations much to participate.

The program has enjoyed a steady increase in interest across the Army, with a substantial year-over-year increase in

applications from Army research organizations, including RDECOM; the U.S. Army Corps of Engineers; U.S. Army Medical Command; U.S. Army Test and Evaluation Command (ATEC); and U.S. Army Space and Missile Defense Command.

Even with the program's successes and benefits, ESEP has suffered the same resource constraints that programs and offices have experienced across DOD over the last several fiscal years. In FY16, with a budget of \$2.2 million in operation and maintenance funds, DASA(DE&C) supported 11 U.S. overseas exchange assignments. A 50 percent cut in appropriations in FY17 reduced the number of centrally supported overseas assignments to five, and resource constraints projected in FY18 mean a continued reduction in supported overseas assignments, despite growing interest in the program.

WHO SHOULD APPLY AND HOW

The ESEP program is aimed at mid-level professionals (GS-12 to GS-14 or equivalent). Most applicants learn about the program through their command structures, either via email or in a job announcement. The program isn't for everyone, participants cautioned; moving your family overseas and establishing yourself in a foreign country can be a challenge and should not be taken lightly. But for those seeking an international experience in which they can grow their careers and pursue new opportunities, ESEP is a great option.

"Flexibility is the name of the game," said Kristi Sanchez-Vahamonde, an engineer and new ESEP participant from ATEC, as she prepared to head to Germany for an assignment with the Bundeswehr Technical Center for Protective and

Special Technologies. "I haven't even boarded the airplane yet, and I've already grown a lot, learned a lot. It's not easy, but it's a once-in-a-lifetime experience."

Foreign language skills are not required, though they are helpful. "Personality is the most important factor," noted Naylor. "ESEP participants need to be willing to talk to people, willing to learn about new people and cultures. You can't be pedantic. It's important to come over with a little humility and be prepared to listen with an understanding that an exchange is a two-way street."

DASA(DE&C) will release the next ESEP call for nominations in May 2018. Selected applicants will deploy overseas in October 2019.

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 ESEP SPOTLIGHT

For ARL engineer assigned to South Korea,

THERE'S ENERGY IN THE AIR

This column is the first in a series of articles profiling the work of defense science and technology personnel participating in the Engineer and Scientist Exchange Program, managed by the deputy assistant secretary of the Army for defense exports and cooperation. The program's mission is to increase international collaboration in military research, development and acquisition, as well as to provide career-broadening work assignments for U.S. military and government defense personnel in foreign defense establishments.

U.S. and South Korean civilian defense scientists are working together to create energy from thin air.

Dr. Mark Griep, a U.S. Army Research Laboratory (ARL) biomedical engineer who recently participated in the Engineer and Scientist Exchange Program (ESEP) in Daejeon, South Korea, invented a material that could do just that.

“Korea is making a major thrust in materials development to improve power and energy,” Griep explained. “If lithium-air batteries can convert oxygen into energy, batteries will be much lighter to carry but can theoretically reach the same energy density as gasoline.”

From October 2015 to September 2016, Griep worked within South Korea's Agency for Defense Development (ADD), where he translated his expertise with nanomaterials into a groundbreaking new material for lithium-air batteries. These energy technologies could revolutionize portable Soldier energy—a critical readiness objective for the U.S. Army.

“Korea has a different level of urgency, given their proximity to the threat.”



SCIENCE WITHOUT BORDERS

Griep, center, his wife, Katy Hanczewski, and then-U.S. Ambassador to South Korea Mark W. Lippert celebrate the Fourth of July at an embassy-hosted event in 2016. (Photo courtesy of Dr. Mark Griep)

Beyond giving U.S. Army scientists access to allied research and development efforts, ESEP enables the U.S. to leverage foreign partners' testing and acquisition systems. "My work in the U.S. had primarily focused on fundamental research," Griep said, "while Korea is quicker to field their technology."

A prototype resulting from Griep's research now is being scaled and fielded to fit on backpacks at ADD. Its ultimate success could result in better equipment to improve the readiness of U.S. and South Korean forces on the peninsula. "Korea has a different level of urgency, given their proximity to the threat," said Griep.

ESEP provides Army scientists a pathway to broaden their horizons and expand the international reach of their work. "I first heard about the Engineer and Scientist Exchange Program when I arrived at ARL as a Ph.D. student," Griep said. "I'd done a year in Taiwan as a Fulbright [scholar] and was always interested in international [work]. My field of nanomaterials is an important research area in Southeast Asia right now, and the ESEP provided a great opportunity for me to learn more about Korea's pioneering work in nanomaterials."

Outside the laboratory, Griep formed invaluable bonds with his South Korean colleagues. Through daily hikes with co-workers, pitching for ADD's softball

team and trying new and exotic foods—including live octopus—Griep made lifelong friends and garnered a strong appreciation for Korean culture.

Since his return to the U.S., he has been working on publishing several articles and has connected his former South Korean colleagues with U.S. scientists working at ARL's Sensors and Electron Devices Directorate. In August 2017, Dr. Yusong Choi from ADD arrived at ARL as an ESEP participant, ensuring that the mutual benefits derived from U.S.-Korean cooperation in energy technologies will continue well into the future.

—**MS. GABRIELLA KROHMAL**
and **MR. ADAM GENEST**

HOPE REGENERATED

Wounds that used to kill don't, but IED attacks leave many service members with severe, lasting damage to legs or arms. So the Tissue Injury and Regenerative Medicine office stamps a high priority on extremity repair.

by Ms. Kristy Pottol, Lt. Col. Melinda Eaton and Lt. Col.(P) David Saunders

Compared with the Vietnam War, body armor and improved battlefield resuscitation have increased survivability in recent conflicts in Iraq and Afghanistan; however, the downstream effect is a greater number of extremity wounds leading to higher levels of disability.

Improvised explosive devices (IEDs) often cause serious damage to the limbs. As many as 50 percent of service members with extremity injuries suffer from severe impairment and long-term complications. Although many injured personnel want very much to return to their units and continue their assignments, the prognosis is poor for regaining all the function they had in the limb before the injury.

To improve the prognosis for extremity wounds, the Tissue Injury and Regenerative Medicine Project Management Office (TIRM PMO) of the U.S. Army Medical Materiel Development Activity (USAMMDA) has placed a high priority on extremity repair, with an emphasis on regenerative medicine. Based on the state of the science, four promising focus areas exist for extremity repair: permanent vascular repair, peripheral nerve repair, muscle repair, and bone and connective tissue repair.

VEIN REPAIR

The current standard of care for permanent vascular repair involves three types of procedures: autografts, synthetic grafts and endovascular grafts. The most common of the three,



As many as **50** percent of patients are left with severe impairment and long-term complications, and face poor recovery.

Throughout Operations Iraqi Freedom and Enduring Freedom, approximately **1,700** limb amputations were needed.

Approximately **14** percent of patients who initially had their limbs saved had to eventually undergo delayed amputation.

Only **20** percent of service members suffering severe extremity trauma are returned to active duty.

THE CURRENT PROGNOSIS

By almost any measure, service members whose arms or legs are injured in combat face a grim outlook. Few recover the full use of the injured extremity. USAMMDA breaks the task of improving this prognosis into four focus areas: repairing blood vessels, repairing nerves, preventing muscle loss and stabilizing complex bone fractures. (SOURCE: USAMMDA)

autografts, require that a donor blood vessel be taken from the patient, often from the leg. While this is the most permanent solution for vascular repair, damage to lower limbs may limit this approach. Currently available synthetic grafts made of Dacron or Teflon are sometimes used, but the high risk of infection makes these a distant second choice.

Endovascular grafts, inserted through a special catheter, are being used increasingly for smaller injuries since they avoid the need for open surgery. However, these require highly specialized equipment and training, limiting their use to stateside facilities. Advances in regenerative medicine have created grafts that model themselves after the patient's own vessels, resist infection and mature into vessels that look much like the patient's own.

Vascular repair is an area with numerous commercial civilian applications, including heart and leg bypass grafting, dialysis for patients with kidney disease and others. Because of the large potential commercial market, DOD investment is focused on studying these novel grafts in trauma patients in accordance

with the U.S. Food and Drug Administration. A bioengineered blood vessel in phase three of clinical trials may prove useful for repair of injured arteries and veins.

SPEEDING NERVE REGROWTH

Although peripheral nerves—those that control sensation and movement—can regenerate in the body after injury, they do so very slowly. Furthermore, after initial injury the nerves lose function, often for several months. As a result, although the nerves regrow, the muscles powered by these nerves deteriorate and lose function temporarily. Using current technology, surgeons cannot predict which nerves will regrow successfully; therefore, the injury often leaves patients with poor functional outcomes. Options for treatment are limited; the current standard of care involves transferring the patient's own nerves from other areas of the body, such as the leg, to restore function in the hand.

Areas of intended DOD investment in this area focus on products that can speed nerve regrowth. In addition, DOD is evaluating products that can preserve muscle and nerve

function and prevent further degeneration during injury healing. Examples of products being developed by academia and industry include nerve growth factors, bioengineered scaffolds and tools to prevent degeneration.

KEY TARGET: MUSCLE REPAIR

Major muscle tissue loss following combat-related trauma is complicated by infection or damage to the surrounding bone, nerves or blood vessels. Unfortunately, little can be done to combat volumetric muscle loss as muscle regenerates poorly and there are limited options for surgical repair.

Current treatment of volumetric muscle loss is geared toward rehabilitation to preserve the patient's remaining muscle

function. In certain cases, surgeons can use muscle from elsewhere in the body (known as a muscle flap transfer) to repair more critical areas such as the hand or face. However, these procedures are plagued by complications and poor outcomes, with little academic or industrial research being conducted because of a very small potential commercial market. As a result, DOD-targeted investments in volumetric muscle loss treatment are likely to have the greatest overall impact as compared to the other areas.

BONE AND CONNECTIVE TISSUE REPAIR

While bone normally repairs spontaneously after a fracture, munition blasts can create complex fragmented injuries that do not heal, as it is much like trying

to reassemble shattered glass. In such cases, our immediate focus is on products that stabilize complex bone injuries using materials that are integrated into the body, prevent infection and promote healing.

Long-range targets will support prevention and treatment of post-traumatic osteoarthritis, which causes damage to joints following severe injuries, similar to deterioration experienced in old age.

FROM BENCH TO BATTLEFIELD

The TIRM PMO works with a broad network of collaborators in industry, academia and government to accelerate the development of new medical products, specifically regenerative medicine technologies. The overriding goal is to rapidly acquire emerging technologies to make wounded service members whole again by restoring form, function and appearance. Because trauma is relatively rare compared with chronic diseases such as cancer and diabetes, the challenge for DOD has been selecting commercially viable candidates to meet a military need among a rapidly growing field of cutting-edge technologies.

DOD has invested in regenerative medicine through different mechanisms because of new scientific breakthroughs in the field, which emerged in the early 1990s and allow scientists to better harness the body's own healing powers through the use of stem cells and tissue engineering. Regenerative medicine is about growing specific cell types and directing these cells toward a final outcome such as new skin, blood vessels or muscle.

This technology advancement led to the 2008 launch of the Armed Forces Institute of Regenerative Medicine by

TISSUE	CURRENT DEVELOPMENT STAGE	MILITARY EMPHASIS	CIVILIAN INDICATIONS	COMMERCIAL MARKET
Skin/burn wounds	Phase 2/3 clinical trials in patients	Burns, trauma	Burns, chronic wounds (diabetes)	Medium
Blood vessels	Phase 2/3 clinical trials in patients	Trauma	Heart attack, stroke, kidney dialysis	Large
Nerves	Early human studies	Trauma	Carpal tunnel syndrome, neuroma	Medium
Bones	Early human studies	Trauma	Arthritis, bone fractures	Large
Muscles	Large animal studies	Trauma	Rare conditions, e.g., muscular dystrophy	Almost none

MEASURING UP

The TIRM PMO collaborates with industry, academia and government to accelerate the development of new medical products for commercial and military applications. In 2008, USAMRMC launched the Armed Forces Institute of Regenerative Medicine, which translates scientific research into clinical outcomes. Several projects, including permanent vascular grafts and skin substitutes, are moving through the acquisition process. (SOURCE: USAMMDA)



BIOENGINEERED VESSEL

The TIRM PMO is working with industry partners to realize an organic, “human” product that will afford a more permanent solution to repair damaged vessels after traumatic injury on the battlefield. The best option available for many service members right now is for doctors to take a blood vessel from the leg and transfer it to the injured limb. (Photo courtesy of Duke University)

the U.S. Army Medical Research and Materiel Command, USAMMDA’s higher headquarters. The institute has translated scientific research into clinical outcomes, which indicates to the TIRM PMO that the technology is ready for robust product development. A number of projects are moving through the acquisition process, notably the permanent vascular graft and skin substitutes.

LIMB LOSS TOLL STILL HIGH

Current options for patients who lose a limb can range from simple prosthetics to more advanced robotic limbs to entire hand transplants. At the simplest level, rudimentary prosthetics provide basic functions such as grasping and walking. More advanced robotic prostheses provide greater functionality, including the ability to manipulate larger objects, run and perform more subtle movements, particularly of the arm and hand. These advanced systems have become highly sophisticated, allowing direct patient control, in some cases through “rewired” amputation stumps.

Another newly available option includes transplant of hands from deceased donors. This emerging surgical technique offers the possibility of far greater control and sensation from a living hand. However, as with other types of organ transplants, the patient must take lifelong medicines to prevent rejection of the donated hand. Both hand transplant and robotic arm prosthetics remain limited in availability to a few national academic centers. The associated high costs and experimental nature also present challenges in health insurance coverage, which remains a necessity for lifetime support of the patient.

None of these emerging technologies can wipe away the emotional and mental toll of traumatic injury. Even the successful adoption of a prosthetic or transplanted limb requires tremendous patience and perseverance for the patient’s journey to a new “normal” life. Current medical solutions simply may not make wounded warriors whole again.

CONCLUSION

USAMMDA maintains a team of specialized acquisition professionals committed to translating cutting-edge research into fielded products to maintain a medically ready force. As part of the current military acquisition program, the TIRM PMO expands collaboration across the civilian sector to bring leading-edge regenerative medical solutions to warfighters who may return home from battle with lasting physical and mental complications.

Thousands of service members have fought across the globe to protect American freedom, and many have given their lives to defend the American way of life. Unfortunately, some returning warfighters must bear physical and mental scars from the sacrifices of armed conflict. Although military medicine now saves more lives than ever before, for some service members this progress comes at a cost: the vast number of devastating injuries leading to lifelong disability.

TIRM PMO team members realize the urgency to accelerate development as much as possible. Looking ahead to the future fight and support for a medically ready force, we must discover effective regenerative medicine solutions to restore form and function. We remain confident that our collaborations with a diverse array of industry, academic and government partners will make possible that which previously seemed impossible.

For more information, contact Kristy Pottol at Kristy.s.pottol.civ@mail.mil.



SEIZE THE 'GOLDEN HOUR'

New techniques in extremity repair are centered on restoring blood flow to trauma wounds as close as possible to the point of injury. DOD investment in trauma-specific injuries and medical procedures is important because trauma sends far fewer civilians to the hospital than other injuries, so the medical industry conducts less research in this area. (U.S. Army photo by Sgt. Michael J. MacLeod)



MEDICINE, RIGHT OF BOOM

Body armor and better battlefield resuscitation are keeping more service members alive after explosions. A second-order effect of this is the large number of extremity wounds Army medical personnel now see. As a result, the TIRM PMO is focusing on harnessing the ability of human cells to regenerate—to regrow—and offering that solution to injured service members. (Photo courtesy of Sharilyn Wells, Paraglide)

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(Image by U.S. Army Acquisition Center/Nongkran_ch/iStock)



DEPUTY ASSISTANT SECRETARY OF THE ARMY
FOR RESEARCH AND TECHNOLOGY

SCIENCE & TECHNOLOGY/ DASA(R&T)



Dr. Thomas P. Russell

It's all about the SCIENCE

...and the people who do it,
and the problems they solve.

by Mr. Steve Stark

Winning in a complex world, the multidomain battlespace: These are extraordinarily complex concepts. How will the Army operate in an area that a peer or near-peer adversary has worked very diligently to make sure that the Army cannot operate in? How will the Army counter swarms of networked, unmanned systems?

For Dr. Thomas P. Russell, the deputy assistant secretary of the Army for research and technology (DASA(R&T)), envisioning and developing the capabilities and the technologies that the Army will need in five years or 30 years is not a job that includes crystal balls or tea leaves. It's science, and lots of it, done by scientists, and lots of them.

Science, he said in an Oct. 27 interview with Army AL&T, is a process of discovering and understanding the world we live in. "As we discover more and more about the world we live in, and we understand those fundamental principles, eventually we start thinking about how we can use that knowledge we've developed to start solving problems."

Right now, Army science and technology (S&T) is working to solve a lot of problems. “We’re developing new capabilities or technologies that could serve to either help the military or help the commercial market space.” Those capabilities, of course, are intended first for the military. And the problems to be solved are specific:

- Precision fires and air and missile defense.
- Next Generation Combat Vehicle.
- Future Vertical Lift (FVL).
- The network and command, control, communications and intelligence.
- Soldier lethality.

In addition, there are the people and the laboratories that make those things possible, which includes the Army’s S&T laboratory enterprise network, S&T workforce development, Army collaboration with the other services, international partners and industry. Finally, there’s the issue of transitioning technology, or getting needed capabilities into the hands of Soldiers.

A REBALANCING ACT

Russell earned his doctorate in chemistry in energetic materials, which are substances that contain lots of energy and release it rapidly to “do work,” in the physics sense of the term—moving energy from one place or form to another. When he went to work for the U.S. military in 1990, Russell didn’t think it would become his career. However, like a lot of those in the acquisition, logistics and technology fields, he found the research meaningful, a way to be a part of something greater than himself. Plus, he found the hard problems DOD was trying to solve to be deeply engaging.

He started his career with DOD working as a research scientist with the Navy,



GETTING SMARTER

A Patriot missile radar system set assigned to 1st Battalion, 1st Air Defense Artillery Regiment during the unit’s table gunnery training exercise on Kadena Air Base in Japan, in October. Precision fires and air and missile defense are top priorities in Army S&T research, and newer versions likely will be smarter and more accurate. (U.S. Army photo by Capt. Adan Cazarez, 94th Army Air and Missile Defense Command)

spent several years working with the Air Force and came to the Army in 2013 as the director of the U.S. Army Research Laboratory.

It was, in fact, Russell who suggested the science and technology theme of this edition of Army AL&T, and he backed up the suggestion with more than two dozen articles in this special section on rebalancing the Army’s S&T portfolio.

Rebalancing the portfolio is a process, he said, of “looking at the potential threats in the future from our adversaries. What I mean by that is, we’ve been operating at war for probably a decade and a half or more. And our adversaries have been watching the way we operate. They’ve been building capabilities to offset or

attempt to offset those strategic advantages we have today.” And that presents the possibility that, in the future, those “threats may put us in a situation where we’ll be overmatched by our adversaries. So rebalancing is about how we strategically align the S&T portfolio to address those emerging or evolving threats that our adversaries will present to us.”

The emphasis is on the evolutionary nature of the threats. “That’s not just now in the near term. ... We’re not focused on just where the puck is today, but where the puck will be in the future,” he said, paraphrasing hockey great Wayne Gretzky.

Rebalancing, he continued, “is aligning ourselves to more effectively address the

potential future threats and beginning to look at what technologies we need to create to evolve our capabilities. It's also about ensuring we have a more balanced investment portfolio for the future of the Army."

Modernization, Russell said, can and should encompass both the near and long term. "There are very specific things we're doing today in the Army to address near-term shortfalls, or to modernize our equipment to ensure that we have the capability that we need today. But there are also, in the S&T investments, things that we're doing that I would say would potentially modernize our force in 2030. It's all part of modernization." And all part of the same evolutionary process.

PRECISION FIRES, AIR AND MISSILE DEFENSE

Precision fires and air and missile defense are top priorities in Army S&T research. The former is about more accurate artillery and surface-to-surface missiles, which the Army calls kinetic capabilities. Those capabilities will be more accurate, smarter and with longer range. Or, the future could be artillery- or missile-like capabilities in an environment where artillery or missiles could not be used. Missile defense will include nonkinetic capabilities, such as directed-energy weapons.

THE PATH TO IMPROVEMENT

JLTVs perform demonstration runs around Marine Corps Base Quantico, Virginia, in June. Army S&T programs are exploring ways to improve vehicle platforms by leveraging developments in artificial intelligence and advanced sensors to improve vehicle autonomy. (U.S. Army photo by David Vergun, Defense Media Activity – Army)

The future—and the midterm—will include precision missiles with a 35-kilometer range that can loiter, provide operators with a full-motion video view-on-target on a linked tablet, and eliminate tanks or other high-value targets. The portfolio of capabilities also includes the ability to defeat collaborative or swarming threats. In the successful proof-of-principle phase, the goal was for a single operator to be able to fire and guide six missiles against four static and two moving targets.

For other means of air and missile defense, directed-energy weapons, specifically high-energy lasers, offer a lot of promise as part of a layered defense, said Russell. While they may not be the ultimate weapon, they will have a use on the battlefield of the future. "It's going to be a partnership between kinetic capabilities and directed-energy capabilities, including lasers, because lasers and directed-energy capabilities aren't going to be able to provide a single solution to every challenge we face from an air missile defense perspective." In the nearer term, Russell said, one of the benefits will be the lower overall cost of laser defenses.

An example of the utility of directed-energy weapons is defense against the increasing use of small unmanned aerial systems (UASs), either as intelligence, surveillance and reconnaissance

platforms or as mules for explosives. "At least in the near term, its benefit is based on the cost equation," he said. While "it does cost quite a bit to build a laser system," after that initial outlay, lasers are a great deal cheaper to use. The real issue is "how much it costs me for the stored energy to be able to provide a laser pulse that will take down a target."

In the case of small UASs and "other lower-cost targets, you don't necessarily want to spend lots of money with missile systems to take out a counter-UAS," which would not only be expensive but could be far less accurate, like using a shotgun to take out a fly.

While lasers have been around since the 1960s and commercial lasers are everywhere, Russell noted that "we haven't really gotten to the point where we've been able to operationalize lasers at the cost-effective size, weight and power necessary to make them operationally relevant. I think we're on the verge of being able to do that. I think, in this evolving modernization process, you'll see laser systems coming online over the next 10 years that provide defensive capabilities for both mounted and unmounted units." Those capabilities will continue to evolve and will become another "tool in the toolbox. It won't be the only tool in the toolbox. ... But it's very exciting."





ARMED FOR THE NEXT FIGHT

A Soldier assigned to the Mississippi Army National Guard's 155th Brigade Combat Team provides security during Decisive Action Rotation 17-07 at the National Training Center (NTC), Fort Irwin, California, in June. Decisive action rotations ensure that units remain responsive and consistently available for current and future contingencies—"not focused on just where the puck is today, but where the puck will be in the future," said Russell. (U.S. Army photo by Spc. Daniel Parrott, NTC Operations Group)

NEXT GENERATION COMBAT VEHICLE

When Russell talks of the Next Generation Combat Vehicle, it's about a host of possible concepts and platforms. So, while the Joint Light Tactical Vehicle (JLTV) "is where we're at today," it's a long way from what the Army may need in the future. For example, Russell said, autonomy, whether in the air or on the ground, is a big part of where the Army sees its vehicular strategy going. The S&T programs are looking at autonomy and teaming, meaning that both air and ground unmanned vehicles will be able to operate and navigate by themselves as part of a collaborative, man-unmanned team, without a pilot actively guiding the vehicle. The man-unmanned teaming approach launched in 2009 (See "Wingman Is First Step Toward Weaponized

Robotics," Page 86), and has already shown great promise. The future, however, will see a great deal more collaboration between platforms.

S&T programs are looking to answer difficult questions about where vehicle autonomy can go, aided by artificial intelligence and advanced sensors. "Can we enhance the mobility, and can we increase the speed, the speed-to-contact, maneuver-to-contact?" Russell said. Or, how can a manned ground vehicle teamed with unmanned air or ground vehicles find, engage and defeat an adversary that's entrenched and well-protected, before the enemy detects a potential attack?

"If I look out 10 years from now, there may be other ground-vehicle capabilities that we need that would be the next generation. And again, it's not just JLTV we're talking [about]," Russell said. "Are we going to have Abrams [tanks] for the next 50 years, or are we going to develop something that would be different from a tank? Or do we really even need a tank? Could we develop a different concept of operations, based on new ground vehicle capabilities that emerge from technologies" the Army is developing or looking to develop now?

Part of that next generation vehicle strategy is the Robotic Wingman program. The potential there is huge, not just for applying more force, but also for using those vehicles for sensing, for scouting and providing highly accurate situational awareness. "When I say a Soldier is operating three wingmen, it could be one air vehicle and two ground vehicles," Russell said.

As to the probability that a potential future adversary could be working on similar technology, Russell said, it's not just about the machines, it's also about the people, and that's where he thinks the United States has the advantage. It's about "humans and how you train, and the rest of the DOTMLPF [doctrine, organization, training, materiel, leadership and education, personnel and facilities]," he said.

"In the end, I think one of the things that is to our strategic advantage over a lot of our adversaries is our DOTMLPF process. And that's how we integrate material and technological solutions and how we use them to our advantage based on the overall process."

FUTURE VERTICAL LIFT

The current Army fleet of rotary-wing aircraft are Cold War-era relics. They've been upgraded and enhanced over the years again and again, but, according to Russell, the basic platforms

“We have to start thinking about the different clock cycles of updating and modernization of the force. The software piece is going to probably occur at a much faster time scale than the hardware piece.”

have reached the limits of their potential. “The three major things we’re trying to overcome today are speed, range and maneuverability at the X,” he said. The X is where the craft is going to land. “That’s been a lot of the focus today. Right now, rotorcraft aircraft have limitations—what their speed is, which relates to range, and then of course there’s maneuverability.” So the issue with vertical lift is much like the issue with combat vehicles: It’s all about mobility. That, Russell continued,

is “part of this integrated multidomain battle problem.”

Currently in S&T, Russell said, “we’re looking to see if we can move beyond” the limits of available technology as it has been applied to current vehicles. “Are there ways that we can actually change that, or can we design different kinds of vehicles and structures that would take us to the next level of range, speed, maneuverability, which includes a lift-of-weight capability?”



TEAMING IN THE FIELD

Soldiers with 38th Cavalry Regiment, 1st Security Force Assistance Brigade build their communications system during a field training exercise in October at Fort Benning, Georgia. Today’s networks are not nearly as mobile and self-contained as they will need to be in the future, Russell said. (U.S. Army photo by Sgt. Arjenis Nunez, 50th Public Affairs Detachment)

The Joint Multi-Role (JMR) demonstrator is the next step, he said. JMR is an ongoing technology demonstration process, which is a program of record to further FVL (see “Science and Technology Supporting Future Army Aviation” on Page 96). “JMR is a technology demonstrator. There are currently two companies [Sikorsky Aircraft with Boeing, and Bell Helicopter] that are technology demonstrators, one of which is rotary-wing capability [Sikorsky-Boeing], and the other one [Bell] is a tilt-rotor.” Sikorsky-Boeing’s prototype has counter-rotating rotors, which provide more stability than conventional single-rotor aircraft, plus greater efficiency and lift capacity.

FUTURE NETWORK

Another major focus of this rebalancing act is the network. “In the S&T world today, we’re looking at a variety of different programs that will help us understand what the network of the future will look like. There’s nothing wrong with the network that we’re developing today. It’s a good capability.” Still, it’s today’s capability.

In the future, multidomain battle will “require something that’s probably much more robust, much more interoperable. It may be highly heterogeneous, and what I mean by that is that a dismounted group may need a network that’s different than a mounted group of Soldiers, but those networks need to be interoperable so that they can communicate,” the way that cellphones move seamlessly between networks. There is also the coalition environment to consider, he said. “How do I do that exact same thing with my coalition partners? How do I know what information I can and can’t share?”

And then there’s mobility, which is a major thrust. “In the future, I don’t want to have a network guy, I don’t want to



EXPANDING SOLDIER CAPABILITIES

The Joint Tactical Autonomous Resupply System (JTARS) is designed to move materials from the rear of the battlefield to the front line, without requiring a manned convoy operation. Improving Soldier lethality involves more than just improving weapons: It also involves providing the kinds of technology, like JTARS, that will make Soldiers more resilient and responsive. (U.S. Army photo by C. Todd Lopez, Army News Service)

sit and wait for a bunch of signal Soldiers that are going to be setting up the network.” That future network would come into whatever environment and it would “basically set up itself, sort of like what happens with your cellphone. I get off a plane in another country and it detects the network, and [based on my plan] it connects me to that network.” Unlike with a cellular network, its infrastructure would follow it.

Today’s networks are robust, but not nearly as mobile and self-contained as they will need to be in the future, Russell said. “When we talk about all these technologies, they become highly dependent upon our connectivity and having this robust, heterogeneous, highly dynamic network that is going to evolve as partners and as different capabilities come and go within that operational space.” It’s the military’s own internet of things that “drives different technologies and capabilities that we, militarily, will need.”

SOLDIER LETHALITY

Increasing a Soldier’s capacity to be more lethal is only partly about weapons. It can also mean seeing the battlespace more clearly than the enemy, as well as gaining a better understanding of Soldiers to help them be more resilient and make decisions more quickly—and providing the kinds of technology that will enable that.

Continuously improving Soldiers’ situational understanding is a major part of this. That means, Russell said, ensuring “that

they get information that’s required for them to execute the mission ... without overloading them to the point that they’re not able to execute.” There could be a variety of new ways to keep the Soldier aware, using different mechanisms to help update information. That could include augmented reality that overlays information on the Soldier’s field of view, haptic feedback (the most common haptic feedback mechanism is phone vibration) that tells the Soldier to duck, turn left or turn right, or even audio feedback.

“We’re not there yet,” Russell said, but there are “technologies currently—it’s in some of the laboratories—where I can actually fuse [situational awareness] information through” a heads-up display so that “it’s projecting the environment, the sensory environment, the information [networked sensors are getting] onto the Soldier’s field of view.” That technology is not a reality, yet, but “it’s a major focus in Soldier lethality.”

“It’s really the integration of all these things to enhance situational awareness,” Russell continued. “One of the things you have to be careful about is not overloading the human. That’s why there’s a focus on technologies that help to reduce the Soldier’s cognitive load. On a future battlefield, the difference between us and them could come down to whose warfighters are less burdened by needless information.

“A real challenge to this is not the materiel piece,” Russell said. “It’s really understanding how the human can receive and process information so that we can actually optimize their ability to make those decisions with these decision aids.”

ARTIFICIAL INTELLIGENCE

The future of autonomy, software-intensive weapon systems, advanced networking and lots of sensing technologies will not be possible without decision-support capabilities to help Soldiers not get instantly overloaded with information. That’s where artificial intelligence (AI) comes in. While we encounter AI on a daily, even hourly basis, from personal assistance technologies like Amazon’s Alexa and Apple’s Siri to Microsoft Word’s grammar-check function, there’s a big difference between the home or office and the battlefield.

To make the best use of AI and all of the other software that the Army will employ, Russell said, the Army will have to code and update code much faster than it does today. The auto industry, he said, is doing interesting things with software updates and patches. The “vehicle itself actually updates on a regular basis. ... They download software to update the algorithms.”

That could make a big difference in the Army's next generation combat vehicles. If "I can update the algorithms for efficiencies in the engines, if I can put sensors on and change how the sensors actually behave and the way they detect and so on, based on software updates," Russell said, it increases the capabilities available to the Soldier. "We have to start thinking about the different clock cycles of updating and modernization of the force. The software piece is going to probably occur at a much faster time scale than the hardware piece."

The other part of that equation, Russell said, is that, with more recent weapon platforms being more software-based, "they have to be updated on a much faster timeline," and to do that "we need to do the science and engineering to look at how you validate software that's being developed. How do you ensure you have protected environments where, in a developmental process," the software doesn't inadvertently provide a way in for people who should not have access to the software? "There is a lot to do in a software-based" future, and that's why

"We haven't really gotten to the point where we've been able to operationalize lasers at the cost-effective size, weight and power necessary to make them operationally relevant. I think we're on the verge of being able to do that."

"you really need to move to more of an open architecture so that we can actually take advantage of this multiple time scale for modernization."

CONCLUSION

The United States has a lot of catching up to do after a decade and a half at war in Iraq and Afghanistan—a particular kind of war that global rivals and potential adversaries have observed intently. Russell has no doubt that the Army's capabilities will be up to the task if called upon to confront and defeat a near-peer adversary.

For Russell, the key to all of Army S&T is the S&T workforce. Indeed, he refers to the personnel of the Army S&T enterprise as "the crown jewel of the laboratory community." Maintaining that workforce is "about being able to recruit and retain the best and brightest people that are interested in solving challenging problems that have tremendous purpose, and that purpose is protecting Soldiers on a daily basis—and national security. And there are a lot of us that are more interested in serving in this way, than [in] money," he said.

"There's a significant portion of our population in the science and engineering field that are really interested in serving," he continued. Maybe that's not in uniform, but by contributing—as Russell himself has done—to national security, to what the Soldier needs every day. "The laboratory system actually provides that unique opportunity if you're coming out of graduate school and you want to be a scientist or engineer but you want to serve your country in a way that will protect its security," you can.

It's an attractive proposition, because for budding scientists and engineers, the Army has "a bunch of very interesting

problems," Plus, he said, "There's a purpose to what we do. It's not just science for science's sake. It's not just engineering for engineering's sake. There's an outcome, and I think that's a tremendously satisfying experience as a scientist or engineer."

The biggest issue, Russell said, has been getting the word out to future Army scientists and engineers about "what happens in our laboratory systems so that they can decide whether they want to work in the commercial world or in the government world." That's changing, he said, because "we're now beginning to do a much broader outreach across the country in trying to get exposure of what we really work on in the laboratories." Internships are particularly effective because future workforce members think, "I just had no idea what you guys really did here. This is fabulous, how do I get a job?" At that point, it's no longer about could I make an extra \$10,000-20,000 a year. It's about, "These are really interesting problems."

That's not too different from how DOD snagged Russell. "Speaking for myself," he said, "coming to the government to work in the laboratory," he'd figured he would maybe work three to five years in a government lab. "Here I am, 28 years later, still serving as a civilian but serving at the Department of Defense as a scientist and engineer to ensure that we can maintain our principles as a nation."

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IN ALLIES' DEFENSE

Soldiers from the 7th Air Defense Artillery Regiment engage targets with Patriot missile systems at the NATO Missile Firing Installation in November at Chania, Greece, during Artemis Strike, a German-led multinational air defense exercise. Fires leaders and Soldiers will need to conduct both LRPF and air and missile defense tasks in a variety of settings—some more supported, some more austere—to support joint and multinational operations in the future battlespace. (U.S. Army photo by Sgt. 1st Class Jason Epperson, 10th Army Air and Missile Defense Command)





PRECISION FIRES *TILT* the FIELD

New technologies give the U.S. greater precision at greater range; stronger air and missile defense.

by Mr. Michael Holthe

Imagine a battlefield where U.S. forces do not enjoy freedom of maneuver, where supporting forces cannot guarantee dominance of the airspace above us or even the ability to communicate or track and locate threats. Imagine a battlefield where friendly forces are not only overmatched by range but where the enemy can employ myriad electromagnetic effects to deny or degrade our ability to locate targets. Such a scenario is not only fast approaching, but is in many cases already upon us.

These very real, very urgent challenges are what drive the Army science and technology (S&T) strategy for lethality, both now and in the future. Our lethality strategy is anchored in its goal to regain and ensure overmatch against any adversary, at any time and in any environment to enable decisive joint warfighting capability and ensure freedom of maneuver to close with and engage with our adversaries.

Among the critical modernization priorities, as identified by the secretary of the Army and chief of staff of the Army, that are key to U.S. forces seizing the initiative and owning the battlespace remain the ability to employ

precision fires—that is, the ability to precisely place a mortar round, artillery shell, cruise missile, etc., exactly where it will be most damaging to the enemy, at greater range than our adversaries—and the ability to protect those fires assets as well as our maneuvering forces as they drive toward the objective.

As the Army develops future long-range precision fires (LRPF) capabilities for both missile and cannon artillery, its requirements for what that system can do must take into account multiple, complex and integrated threats across the range of military operations in anti-access and area denial (A2AD) environments. Future LRPF must enable the joint force to continue to deter adversaries and, when necessary, enable fires overmatch and freedom of maneuver through the destruction, neutralization or suppression of adversary capabilities.

LRPF units must be mobile, expeditionary and prepared for global threats—an important emphasis as adversaries are investing in technologies to obtain a differential advantage and undermine the United States' ability to achieve overmatch. Those threats include precision-guided rockets, artillery, mortars, aircraft, satellites, electronic warfare and ballistic and cruise missiles that challenge traditional U.S. dominance in land, air and maritime domains. Success in this future battlespace also will require the ability to adapt to multiple scenarios. To overcome these challenges, the Army S&T community is exploring the development of technologies that will restore LRPF overmatch and protect friendly forces from air and missile defense threats.

In multidomain battle, future Army LRPF forces must provide precise, responsive, effective and multifunctional fires to enable maneuver forces as they fight across complex A2AD environments that include cyber and PNT contested spaces, electronic warfare and dense urban environments, to maintain overmatch in seizing, retaining and exploiting the initiative. Multifunctional capabilities will provide the commander with sufficient scale and endurance to support joint combined arms operations with limited assets. This complementary relationship between fires and maneuver is the foundation of multidomain battle. In the future, the Army must be able to achieve increased standoff, expand fires across any domain of battle, converge multifunctional capabilities, enhance the link between battlefield sensors and the Soldiers operating fires weapon systems, and leverage joint, interorganizational and multinational capacity to ensure domain superiority.

Being precise means operating with accuracy to achieve desired effects only on desired targets. Future fires forces must have

adequate range, precision and mass to offset threat capabilities and defeat threat forces throughout the depth of the battlefield in all domains. Future fires leaders and Soldiers must conduct both LRPF and air and missile defense tasks in a variety of conditions and missions to support multifunctional, joint combined arms operations. Future fires formations are envisioned as flexible, expeditionary and sustainable—mission-tailored organizations whose agile leaders and Soldiers will integrate and employ multirole and multimission weapon system capabilities, such as the Multi-Mission High Energy Laser system, which will provide short range air defense for the maneuvering force as well as enable counter-battery fire capabilities for the fires force, using a common mission command network and procedures.

To enable this future concept of operations, Army S&T is developing technologies in mutually supportive areas of precision fires as well as air and missile defense. The LRPF capabilities provide the land component of the joint force the ability to detect and engage enemy targets at extended ranges well beyond those of the adversary. They, in concert with air and missile defense capabilities, also enable freedom of maneuver and protection of friendly forces as they assemble to maneuver, close with and defeat enemy forces at both the operational and tactical levels.

Fires missions, particularly ballistic missile defense and counter-fire, place a premium on the ability to react rapidly to battlefield stimuli and are time-sensitive by nature, requiring rapid responses for success. LRPF units must detect adversary targets before U.S. and friendly units can be detected and rapidly deliver devastating fires and effects beyond the counter-battery fire range of the enemy. These long-range precision missiles and cannon artillery provide layered and overlapping ranges of indirect fires to regain operational advantage.

Air and missile defense capabilities provide improved protection for the joint force against enemy manned and unmanned aircraft, cruise missiles, rockets, conventional artillery and mortars. To increase survivability, units must operate with greater dispersion and range while improving the capability to concentrate fires and effects. To operate with greater dispersion, units are protected by layered air and missile defense countermeasures that provide protection at multiple distances and against diverse threats such as counter-unmanned aerial systems, as well as “shieldlike” protection from enemy observation, indirect fires, surface-to-surface weapons and air attack. The Army must be able to see and fight across wider areas to counter adversaries that have long-range and precise lethal capabilities.



LAYERED DEFENSE

A U.S. Air Force fighter jet flies overhead as two Soldiers raise a signal tower for a Patriot missile system during a training exercise in October at Kadena Air Base in Japan. Protecting fires assets requires layered air and missile defense countermeasures that provide protection at multiple distances and against diverse threats. (U.S. Army photo by Capt. Adan Cazarez, 94th Army Air and Missile Defense Command)

In support of Army modernization priorities and the Army S&T vision for LRPF and air and missile defense, the Army lethality strategy prioritizes investment in several key technology areas:

- **LRPF:** Projection of extended-range point target and area effects: Significantly increase ranges as well as the ability to identify and target threat systems with ground-based missile and cannon artillery systems at ranges beyond the firing distances of adversary systems. Deliver overwhelming lethality and massed-area effects to produce a resulting fires forces with overmatching fires capability at extended tactical and operational ranges.
- **Air and missile defense:** Protect maneuvering forces and provide cost-effective, 360-degree battlespace depth capability. Provide layers of lethal countermeasures for formations. Technologies in this area include lower-cost extended-range air defense missiles for countering cruise missiles and strategic unmanned aerial systems (UAS); high-energy lasers for countering rocket, artillery and mortar threats; and tactical

UAS and gun-based air defense systems for tactical UAS. This layered approach ensures “shieldlike” protection for both the fires and maneuvering forces.

To achieve success in these two primary investment areas, several key subcomponent technologies are vital as well, such as:

- **Navigation, guidance and timing:** Provide navigation technology to enable precision guidance in GPS-degraded or -denied environments. Develop assured position, navigation and timing capabilities to prevent near-peer threat detection, denial and exploitation of GPS capabilities affecting weapon systems and geolocation of units.
- **Cooperative and collaborative engagement:** Provide the ability to perform coordinated precision strikes against both hard and soft targets and enable collaborative engagement of multiple targets simultaneously or sequentially to optimize the effectiveness of precision strikes.

PROTECT THE BASE

Air and missile defense capabilities, like this Terminal High Altitude Area Defense weapon system assigned to the 94th Army Air and Missile Defense Command at Andersen Air Force Base, Guam, will provide improved protection for the joint force against enemy manned and unmanned aircraft, cruise missiles, rockets, conventional artillery and mortars. (U.S. Army photo by Capt. Adan Cazarez, 94th Army Air and Missile Defense Command)



- **Weapons fire control, targeting and sensor fusion:** Provide fires, target identification, discrimination, deconfliction and fire control in land, air and maritime domains. Provide fused data from air, land, maritime, cyber and warfighter-borne sensors to achieve real-time integration and optimization of targeting data.
- **Advanced energetics, propulsion and warheads:** Provide advanced energetics and warhead technologies for maximum fragmentation radius, maximum blast, reduced collateral damage, and penetration against targets. Propulsion technologies for increased range and energy management.
- **Novel materials and structures:** Allow weapons to survive higher Mach speeds with increased lethality through the use of robust high-compression strength composites, advanced material technologies with superior thermal and structural properties, and insulation

materials that reduce volume and weight.

- **Image processing and target tracking:** Increase performance in high-clutter, networked environments; provide capability for autonomous engagements and secure data links; and develop multipurpose sensors for LRPF that include anti-ship capabilities to enable freedom of maneuver.
- **Modeling and simulation:** Enable deeper understanding of warfighter needs and impacts of alternative designs through the use of models to characterize changing operational contexts; capabilities for data-driven trade space exploration; and analysis for multidimensional generation and evaluation of alternative designs.

CONCLUSION

As investments for the future, these technologies will enable the Army to emplace assets and to engage and destroy targets

that are inaccessible with current ground-based fires capabilities, as well as increase its capability to support maneuver, defend against enemy air attack and counter enemy long-range systems. The following articles on high-energy lasers, the Single Multi-Mission Attack Missile and Missile Multiple Simultaneous Engagement Technologies, and research on distributed and cooperative engagements in contested environments examine key capabilities that Army S&T is investing in to inform future systems and not just level the battlefield, but tilt it in our favor.

For more information, contact the author at michael.j.holtbe2.civ@mail.mil.

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The Army must be able to see and fight across wider areas to counter adversaries that have long-range and precise lethal capabilities.



WHEN BEAMS COMBINE

With high-energy lasers, the Army looks to optimize lethality and efficiency against multiple threats and targets.

by Dr. Kip R. Kendrick



LASERED OUT OF THE SKY

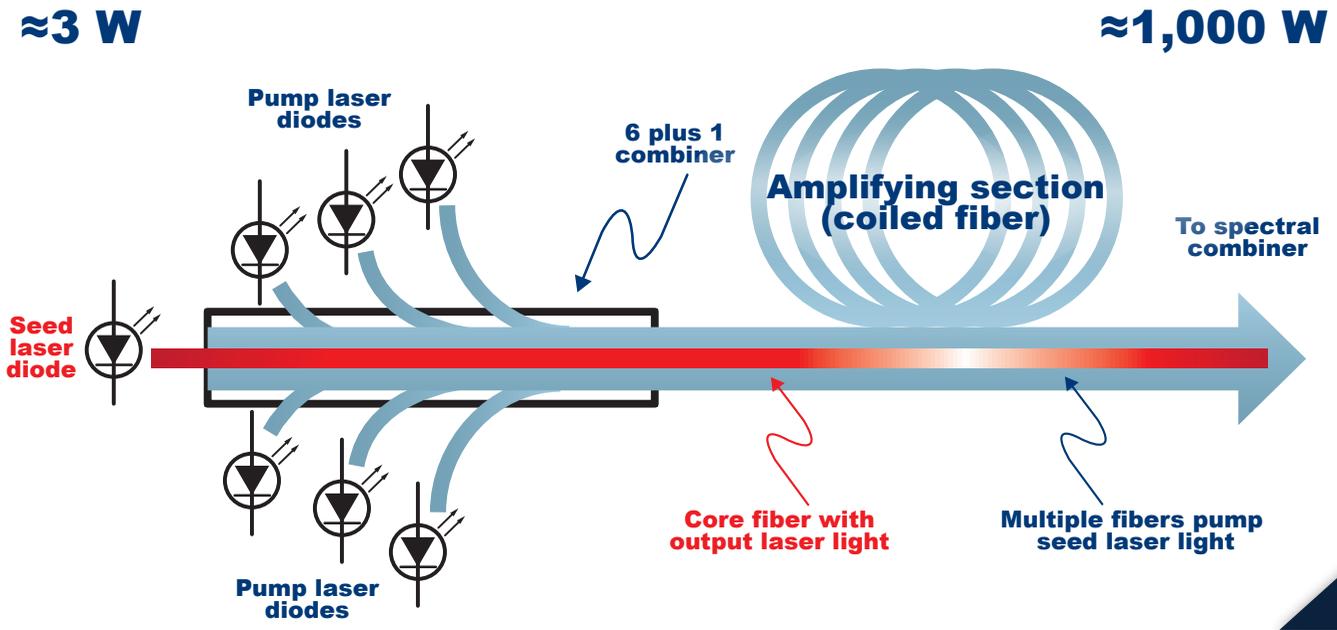
One of the drones shot down by a MEHEL-equipped Stryker in April at Fort Sill during MFIX-17. Lessons learned during MFIX-17 will make the MEHEL easier for Soldiers to operate. (U.S. Army photo)

Solid-state laser weapons offer warfighters unique capabilities for the battlefield: precision, controllability, predictability, repeatability and flexibility. These laser systems will enable Soldiers to defeat multiple threats and affect materiel targets. Each engagement, whether disabling an enemy's communications antenna or causing low-order detonation of an artillery round in flight, has an average cost of \$30.

During the 1970s, the Army investigated carbon dioxide lasers. But there were issues with beam transmission through the atmosphere and difficulty focusing the beam to a small spot at the target. Both factors reduced the lasers' effectiveness. Chemical lasers provided improved performance, but the hazardous materials required to generate the laser beam posed significant risk to warfighters.

A safer, more efficient alternative to chemical lasers, solid-state lasers generate their beam by converting electricity into tightly focused laser light. There are two main types of solid-state high-energy lasers—greater than 1 kilowatt (kW)—in development today: thin-sheet and combined-fiber lasers. Of these two, combined-fiber lasers show the greatest promise for laser weapon systems on tactical and combat platforms because of their efficiency in converting electrical power to power on target. The Army, working with the High Energy Laser Joint Technology Office, initiated the Robust Electric Laser Initiative (RELI) effort in 2010. Four contracts were issued under RELI. The Army retained two of the contracts and later elected to scale a combined-fiber laser, designed by Lockheed Martin Corp., to a 50-kW class power level.

FIGURE 1



POWERING UP

Combined-fiber lasers show great potential for use in laser weapon systems on tactical and combat platforms because they convert electrical power efficiently to power on target. However, today’s fiber laser modules are limited to a little over a kilowatt. So, to reach higher power levels, the individual fiber laser modules must be combined into one beam. This diagram shows how the combination process works. (SOURCE: SMDC/ARSTRAT)

FIBER LASER BASICS

A fiber laser module begins with pump laser diodes to create light energy from electrical energy. The light from the pump laser diodes is then fed into a special optical fiber where the power from a seed laser diode is amplified. (See Figure 1.)

Today’s fiber laser modules are limited to a little over a kilowatt. To reach higher power levels, the individual fiber laser modules need to be combined into one beam. The Lockheed Martin design uses a spectral-beam-combining architecture whereby laser beams of different frequencies are transmitted to a grating and combined into a single beam that is transmitted out of the laser at many tens of kilowatts.

To understand the spectral-beam-combining process, imagine shining a beam of white light through a prism: The prism bends each of the frequencies differently, scattering the original beam of light into multiple beams of various colors. The spectral beam combiner does the opposite: It combines the different frequencies of each fiber laser module into a single beam. (See Figure 2.) Another beam-combining architecture, coherent-beam

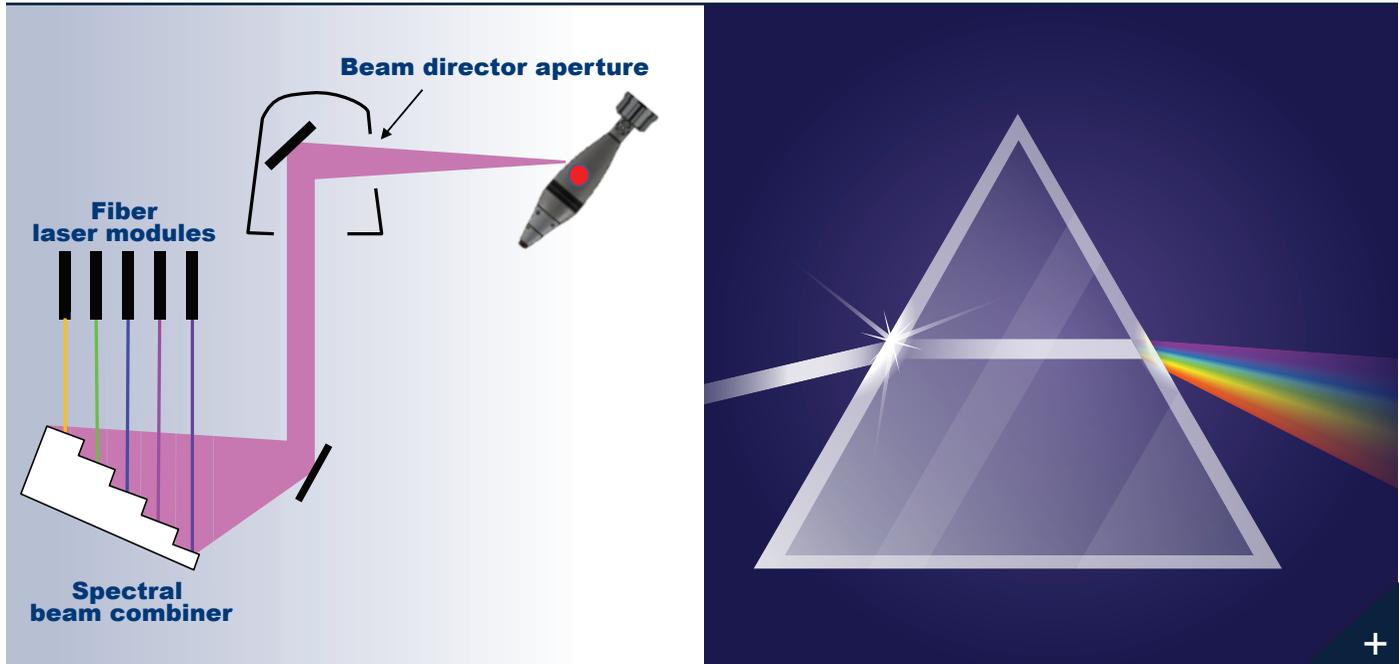
combining, is also being developed and matured within the high-energy laser science and technology community.

GETTING SOLUTIONS TO SOLDIERS

The Army’s Indirect Fire Protection Capability, Increment 2 – Intercept (IFPC Inc 2-I) is an acquisition program designed to provide a materiel solution to protect troops from cruise missiles, unmanned aerial systems (UAS), and rockets, artillery and mortars (RAM). IFPC Inc 2-I has a Block 2 milestone decision in FY24 to add the counter-RAM capability to the program.

The U.S. Army Space and Missile Defense Command/Army Forces Strategic Command (SMDC/ARSTRAT) is developing the 100-kW High Energy Laser Tactical Vehicle Demonstrator (HEL TVD) to address the counter-RAM requirements for IFPC Inc 2-I, Block 2. The HEL TVD will be integrated on the 10-ton variant of the Family of Medium Tactical Vehicles. In FY22, the HEL TVD will demonstrate target acquisition, tracking, aimpoint selection and maintenance, to defeat selected rocket, artillery and mortar threats.

FIGURE 2



COMBINE, CONTRAST

A spectral beam combiner does the opposite of a prism. It combines the different frequencies of each fiber laser module into a single beam. By contrast, when a beam of white light shines into a prism, the prism bends each frequency of light contained within the beam, scattering the white light into multiple beams of various colors. (SOURCE: SMDC/ARSTRAT and Oceloti/iStock)

Multiple subsystems are under development for integration into the weapon system. They include laser, beam control, electrical power, thermal management and fire control. The goal of the FY22 demonstration is to confirm that a pre-prototype laser system can defeat RAM threats in an environment similar to the battlefield.

To reduce risk and provide information for HEL TVD development, the Army is using its High Energy Laser Mobile Test Truck (HELMTT). The HELMTT has demonstrated laser lethality against small-caliber mortars and Group 1-2 (hobby-size) UAS using a slightly modified 10-kW commercial off-the-shelf fiber laser.

In FY14, this system underwent several proof-of-concept demonstrations, defeating small-caliber mortars and UAS. In FY16, the HELMTT was part of the Maneuver Fires Integrated Experiment (MFI) 2016 at Fort Sill, Oklahoma, exposing the warfighter to the military utility of laser weapons. HELMTT also was used in the Joint Improvised-Threat Defeat Organization's

UAS Hard-Kill Challenge in FY17. In addition to these demonstrations, the HELMTT has collected laser propagation data in a variety of environments, from coasts to high deserts. These data helped anchor models used to predict laser effectiveness on the battlefield.

The 10-kW laser subsystem has been removed from the HELMTT to modify the platform for integration of the Lockheed Martin RELI 50-kW-class laser. The Army will test the 50-kW HELMTT against a variety of RAM and UAS targets in late FY18. This demonstration is designed to verify laser lethality against RAM threats for the HEL TVD effort.

To ensure that laser weapons will be lethal against assigned threats, the Army is developing vulnerability modules for RAM and UAS. The Solid State Laser Testbed on the High Energy Laser Systems Test Facility at White Sands Missile Range, New Mexico, collects lethality data for these targets. Engineers there analyze each threat to determine the best aimpoints, as well as the total laser energy required to defeat the threats. The results

are threat-specific vulnerability modules in a format common across the DOD laser community. Laser lethality is one of a number of areas in HEL technology development where the services and agencies work together and share data.

FINDING THE RIGHT PLATFORM

The Army has been working with industry on a concept for a high-energy laser combat platform to be used in warfighter experimentation. Integration of existing laser subsystems began in January 2016; within four months the Mobile Expeditionary High Energy Laser (MEHEL) participated in MFIX-16 at Fort Sill.

A 2-kW fiber laser system, integrated on a Stryker platform, was the first high-energy fiber laser on a combat vehicle. The MEHEL defeated hobby-size quadcopters and some ground targets during MFIX-16. While defeating targets shows the potential for lasers on the battlefield, the main objective of the MEHEL is to support the development of tactics, techniques and procedures and concept of operations for future laser weapons. Late in FY16, the 2-kW laser was replaced with a 5-kW fiber laser. The Army designated this new 5-kW configuration MEHEL 2.0.

In preparation for MFIX-17, contractors trained Soldiers to operate the MEHEL 2.0. During the integrated experiment, these Soldiers shot down small fixed- and rotary-wing UAS—a first for the Army. The Army is using lessons learned from MFIX-17 to make the MEHEL easier for Soldiers to operate. MEHEL 2.0 will also be part of MFIX-18.

MULTI-MISSION HIGH ENERGY LASER

The Multi-Mission High Energy Laser (MMHEL) is a technology maturation initiative starting in FY18. Technology



ARMED AND DANGEROUS

A MEHEL-equipped Stryker shot small fixed- and rotary-wing UAS out of the sky using a 5-kW fiber laser in April during MFIX-17 at Fort Sill, a first for the Army. (U.S. Army photo by C. Todd Lopez, Army News Service)

maturation initiatives facilitate the transition of key technologies to acquisition programs. The MMHEL will be a 50-kW laser system on a Stryker, designed to reduce risk and inform requirements for the Maneuver-Short Range Air Defense objective capability. The MMHEL will undergo an operational demonstration in FY21 to validate the laser system’s counter-RAM, counter-UAS, counter-battery targeting and counter-materiel capabilities.

In addition to the HEL systems developed for data collections and demonstration, the Army is conducting basic and applied research in HELs. The basic research is focused on developing technologies for next generation high-energy lasers, tracking systems and control algorithms. The Mobile Beam Control System Integration Laboratory will be built to investigate, mature and verify the performance of next generation beam control technologies. This trailer-mounted laboratory will provide the ability to collect performance data on beam control components in a variety of atmospheric environments.

CONCLUSION

The Army recognizes the many advantages that HEL weapon systems may

provide the warfighter and is developing HEL technologies to satisfy requirements for programs of record. High-energy laser weapons simplify logistical support, requiring only diesel fuel, which is easily converted into electricity to power the laser. High-energy laser weapons also have the flexibility to defeat or affect many different types of threats, making the laser a potential air-defense solution for maneuvering forces and forward bases. These characteristics, coupled with a low cost per shot, will provide a battlefield advantage for U.S. forces.

For more information, contact the SMDC/ARSTRAT Public Affairs Office at 256-955-3887 or 719-554-1982, or at P.O. Box 1500, Huntsville, AL 35807; or go to www.youtube.com/armysmdc.

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SURVIVE and PROJECT INDIRECT FIRES

AMRDEC pursues two missile technology solutions to strengthen the Army's hand in close combat.

by Mr. Spencer Hudson and Mr. Shannon Haataja

One of the top U.S. Army modernization priorities is increased precision and effects at extended range in all operational environments. This is part of a broader strategy to make warfighting units more lethal to regain overmatch against peer and emerging threats. In response, the deputy assistant secretary of the Army for research and technology's lethality portfolio is investing in a layered, extended-range precision fires solution across operational levels to shape deep and close fights. The lethality portfolio represents science and technology (S&T) investments at the U.S. Army Aviation and Missile Research, Development and Engineering Center (AMRDEC) and other contributing elements of the Army S&T enterprise.

The close fight, or close combat, is the final engagement phase, wherein U.S. ground forces maneuver to seize and control key terrain and destroy enemy forces. This fundamental building

block of operational success may be challenged by highly capable peer threats, particularly in anti-access and area denial threat environments where U.S. forces may lack traditional close air support, and where U.S. anti-tank guided missiles may be outnumbered.

To address this gap, two midterm S&T investments in close combat missiles are focused on giving small expeditionary units increased stand-alone precision and lethal effects at extended ranges to enable freedom of maneuver to decisively defeat the enemy.

The Single Multi-Mission Attack Missile (SMAM) is an emerging precision loitering missile capable of engaging enemy tanks and other high-value targets out to 35 kilometers or farther. Loitering refers to a missile's ability, when commanded by the operator, to fly a specified flight path to a known target location, circle in a holding pattern once in the target area, and engage or wave off and

FIGURE 1



COVERING ALL THE OPTIONS

SMAM is capable of precisely targeting and defeating hard and soft targets at extended ranges and can be integrated on a range of Army ground vehicle and aviation platforms as well as maritime platforms. (Images courtesy of the authors)

then re-engage the same or a different target of interest.

Soldiers operate the SMAM with a commercial tablet-based controller. The system’s two-way data link provides full-motion video for positive target identification. The operator selects the target using a track box once it comes into the field of view. Image processing software then automatically locks on to and

guides the missile to terminal engagement with no operator intervention required. The operator has the ability to wave off and redirect the missile to another target, making it extremely effective in urban terrain and helping to avoid collateral damage. (See Figure 1.)

SMAM includes a self-contained launch tube and a portable mast-mounted antenna. With a total weight, including

the missile, of 50 to 70 pounds, the system is easily transportable and can be readily mounted on a range of Army ground vehicle or aviation platforms.

AMRDEC and partnering organizations have been developing this emerging capability for several years. The organizations achieved a major milestone in June 2015 with a successful proof-of-principle, live-fire range demonstration that resulted in direct hits on a 12-man mannequin array and a sport utility vehicle, both located 25 kilometers from the launch point.

The AMRDEC Enhanced SMAM S&T program, getting underway in FY18, will focus on precision navigation and targeting at extended ranges in contested, GPS-denied and electronic-jamming environments, as well as optimizing war-head technology to defeat main battle tanks.

AMRDEC is also working on another system: Missile Multiple Simultaneous Engagement Technologies (MSET) is a suite of technologies providing the capability to rapidly defeat swarming and dispersed threats, providing simultaneous multiple launch, control and supervised autonomous terminal engagement of multiple missiles against various targets.

MSET is configured as a kit that could be hosted on a variety of manned and future unmanned Army ground vehicles and aviation platforms. (See Figure 2.) This allows it to leverage existing organic intelligence, surveillance and reconnaissance targeting sensors such as small unmanned aircraft systems, day and night cameras and forward-deployed radars. Both SMAM and MSET are designed to directly accept precise target location coordinates transmitted over the tactical network from external targeting sensors.

Two midterm close combat missile S&T investments are focused on giving small expeditionary units increased stand-alone precision and lethal effects at extended ranges.

FIGURE 2



AMRDEC initiated a rapid prototyping effort for MSET in 2016 that involved modifying and integrating existing technologies to demonstrate concept feasibility. The goal was for a single operator to be able to fire and control six loitering precision missiles against four static targets and two moving targets, using an Android application to simultaneously control the surrogate missiles and then sequentially perform the terminal engagements.

Targeting data was provided by a surrogate radar feed. AMRDEC successfully conducted extensive hardware-in-the-loop integration and testing, coupled with six risk-reduction flight test events over a nine-month period. This culminated in a proof-of-principle range flight demonstration conducted by AMRDEC in November at Dugway Proving Ground, Utah.

Future AMRDEC S&T efforts on MSET will focus on developing image-processing algorithms to enable supervised autonomous terminal engagement, i.e., moving from “man-in-the-loop” to “man-on-the-loop,” where the operator can still observe an engagement while retaining the ability to abort the mission once the target has been positively identified by the operator. AMRDEC’s future efforts also will focus on developing key operator fire control and data link technologies that will scale the system up from six simultaneous engagements to as many as 20.

CONCLUSION

S&T programs for SMAM and MSET will demonstrate key technologies to enable U.S. Army multidomain battle and the manned-unmanned teaming operating concepts of decentralized, expeditionary maneuver in contested environments. Once fielded, those technologies will provide brigade combat

OBJECTIVE: OVERMATCH

MSET works by relaying sensor target inputs to a vehicle-mounted command-and-control and fire-control system. That system determines grid coordinates, generates flight paths and launches the appropriate number of missiles. Those missiles are guided via real-time waypoint updates to the target location, and image processors on the missile provide positive identification, target lock-on and track to terminal.

teams with precision strike capability at extended ranges against hard armor and high-value targets in scenarios that demand increased autonomy while providing increased Soldier survivability. These close combat investments are part of the lethality portfolio’s integrated strategy to achieve the Army’s precision fires modernization priorities.

For more information on MSET, refer to Sources Sought W31P4Q-17-R-0132, released June 22, 2017.

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ON TARGET

Experts at ARL are looking deep into the science of the future battlespace and trying to answer questions that have no simple answers, such as how to deliver the power of a tank without a tank.

*by Dr. Frank Fresconi, Dr. Scott Schoenfeld
and Dan Rusin, Lt. Col., USA (Ret.)*

The notion of winning in a complex world requires envisioning a battlefield that is so complex and multidimensional that, more often than not, it's referred to as a battlespace. With good reason: The kind of warfare that the Army must prepare for, and for which experts at the U.S. Army Research Laboratory (ARL) at Aberdeen Proving Ground, Maryland, are developing new technologies, would include everything from the most conventional kinds of warfare, to electronic warfare, to warfare that employs technologies not yet invented.

To understand the difficulty of the questions that the Distributed and Cooperative Engagements in Contested Environments program is trying to answer, imagine a foreign city under siege. The city is in a NATO country that adjoins a hostile power. That hostile power invaded and took over the city months ago, and now it's the Army's job to help our NATO ally dislodge enemy forces and take back the city. The adversary has had plenty of time to dig in and fortify its positions. In addition, it has deep influence on both the electric and electronic infrastructures.

This is a city in a friendly nation, so the Army wants to damage enemy capabilities without devastating the city, which is important to the global economy. Soldiers need to be smart for this to work, and so does nearly every bit of their equipment.

BIGGER IMPACT, SMALLER FOOTPRINT

Future collaborative weapons will be so precise that they will challenge the age-old concept of mass. These interconnected weapons will have shared sensing, computing and navigating capabilities that deliver the desired battlefield effect with fewer, more precise and smarter warheads. (SOURCE: Shutterstock)



Yes, smart equipment.

If Soldiers are denied global positioning systems, they will have to navigate under pressure. Tanks might not fit within the infrastructure of this environment. So, if the force requires a tank's capabilities, they'll have to come from something other than a tank.

If Soldiers require artillery, but conventional artillery conflicts with civilians in close proximity, they will have to find something that can provide the effects of artillery without artillery.

ARL is developing the technologies to fit a set of tools that will be smarter, more aware, connected and autonomously collaborative. These interconnected weapons will operate along the lines of shared sensing, computing and navigating, with the goal of delivering the battlefield effect by actually using fewer but more precise, smarter, warheads.

A NEW VOCABULARY

To understand the new battlespace, it helps to understand some of the concepts, both old and new, that ARL is working with, because in the future we may look to provide new ways to deliver existing

weapons to oust an enemy. Soldiers may be effective in one case by using one weapon directed at a single target, and, in other cases, by delivering artillery shells that loiter over an area and mass until needed. Position, navigation and timing will be key in overcoming challenges. The outcomes, or effects of future warfare, will need to be both kinetic and nonkinetic. Use of a precision missile would deliver the kind of physical damage that is common in warfare—a kinetic effect. A less traditional, nonkinetic effect would be knocking out an enemy's communication system.

Kinetic and nonkinetic assets of the future will be networked and able to

collaborate at scale. The landscape of battle that we expect will expand beyond the mounted and dismounted Soldiers to which we have grown accustomed, and will include robots of different shapes and sizes. The interesting, complex and, as yet, nonexistent nonkinetic effects that will have a major impact could include electronic warfare assets dispersed in the battlespace by Soldiers, small unmanned aerial vehicles or munitions with varieties of electronic payloads.

Military leaders have indicated that future fights could be waged with weapons that will take orders from unit commanders and then, after launch, would have to "talk" to each other on the fly, figure out

Words of Future War

Kinetic: Traditional explosive weapons that physically damage things.

Nonkinetic: Novel effects that stop electronics, disturb sensors or influence people.

Distributed: Multiple sensors, multiple warheads of various types, at several locations.

Collaborative: Cooperative computing, distributed computing, sharing information.

Contested: Enemy actions to retaliate, such as jamming or anti-aircraft/anti-artillery.

Effect: The physical or behavioral state of a system that results from an action.

Even these words are novel and in development. Many are not even included in the DOD Dictionary of Military and Associated Terms at http://www.dtic.mil/doctrine/new_pubs/dictionary.pdf.

Sometimes what's needed is a really big bomb.

what to do, and make course corrections according to the changing position of the enemy or intelligence. These are just some of the difficult scenarios that ARL grapples with. Another issue is adapting to a common operating picture.

HARD QUESTIONS

The U.S. intends to defeat near-peer adversaries who have had time to establish themselves in a foreign city. Scientists prepare by taking a hard look at how to deliver firepower to difficult targets in places that are farther away. Can we deliver artillerylike effects without an artillery cannon? What else can we put in the weapon round to make it infallible? Can weapons talk to each other on the fly? Can these collective communications be made to resist misinformation?

To address these questions without clear answers, we have to think in terms of the outcomes that will best serve combatant

commanders. For instance, scientists are taking steps to design approaches to disable enemy equipment that is fixed, hiding, moving or attacking at a high rate of fire and volume.

The U.S. must recapture overmatch and avoid technological surprise by empowering Soldiers with the capabilities of a main battle tank, empowering squads with the full flexibility of combined arms and empowering armored brigades with full freedom of maneuver in the most challenging environments.

Our intention is to develop the science to enable battlefield assets to be effective in dispersed positions. This requires weapon systems that communicate with one another, make autonomous decisions and maneuver to provide desired effects. By combining various weapons over the distributed battlespace, working together to provide the right lethal or

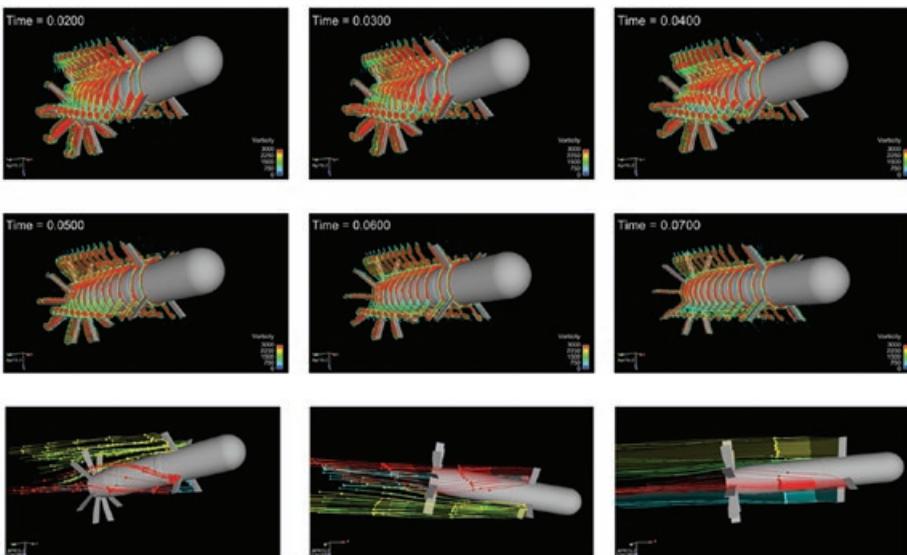
nonlethal effects on target, Soldiers will deliver fewer high-explosive rounds that are more precise.

THE HURDLES WE FACE

Technical gaps exist between the desired and current states of U.S. land forces' capability to implement distributed and cooperative engagement in contested environments. ARL improves the odds of technological success by identifying technology gaps and conducting basic research from the earliest stages of the technology life cycle.

Here are four known barriers to realizing the capability:

Navigation: Navigation is the fundamental feedback required to deliver weapons on the battlefield. Advances in weapon navigation are hindered by technical limitations associated with algorithms, sensing on dynamic vehicles, real-time processing, cost and extreme weapon dynamics. Some weapons are subject to accelerations 100,000 times the acceleration of gravity from being launched to speeds four times the speed of sound. Other weapons are spun thousands of times per second to maintain flight stability—to fly accurately



A COMPLEX FUTURE

ARL uses defense high-performance computing, advanced computational fluid dynamics and other techniques to model aerodynamic interactions. Future engagements will likely employ weapons that incorporate advances in propellants and aerodynamics to allow them to maneuver and change course based on a commander's guidance. (SOURCE: ARL)



SETTING THE SCENE

To achieve the upper hand on a battlefield that's expected to be complex and multidimensional, ARL is developing interconnected weapons that will incorporate advances in shared sensing, computing and navigating. (Image by Evan Jensen, ARL)

on a line to the target and not tumble over. ARL predicts that future technologies will face challenges against threats such as jamming, spoofing, camouflage and decoys, radar or laser warning receivers and active protection. The performance degradations that come with counterattack will be amplified if the enemy has numerical superiority in troops, platforms and weapons.

The strategy of this research is to use multiagent collaboration to address these threats and technical gaps. Multiple dispersed entities equipped with varied, low-cost components can gather the navigation information required to deliver the weapons in a contested environment where a single, high-cost weapon may fail. For instance, six or 12 smaller lethal agents packed into a transport carrier may be less expensive than a \$1 million missile. One approach is to use many “dumb” weapons that would take orders from a “sophisticated” parent that would in turn communicate back to the warfighter and the network of sensors.

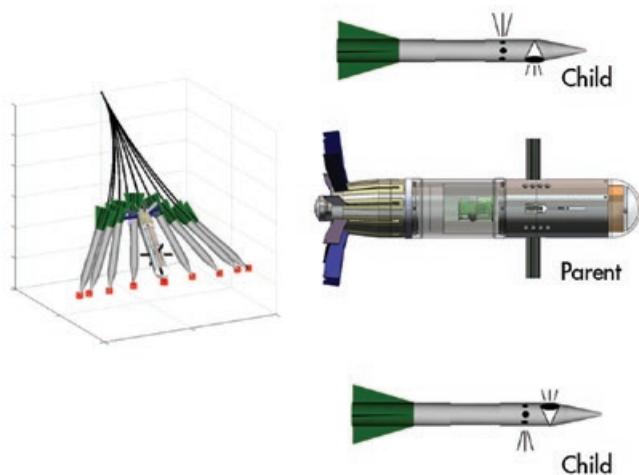
The focus of navigation research is on strong, robust software algorithms. New software algorithms that are able to perform in uncertainty, and despite denial, deception and misinformation, will be able to share appropriate information for group action. Several approaches are being developed and implemented on real-time processors with associated components for concept demonstrations that overcome these technical barriers, including:

- Image processing algorithms to identify friend from foe. In the past, these algorithms used rigid models. However, recent advances in machine learning techniques may enable these algorithms to detect and classify complex targets more powerfully.
- Communication between weapons and networked assets to rapidly share information and coordinate massed effects in the battlespace. Scientific insights must be gained into communications to overcome limitations in the amount

of information that can be shared and to protect information from adversarial intent.

- Algorithms to fuse sensor data (e.g., images from a camera and inertial measurement tools such as those used in cellphones) from different weapons and determine the critical information for autonomous group decisions within a short timeline as a weapon is flying toward the target. The current state of the art relies heavily on linear models for a single weapon, but research will improve performance by focusing on incorporating nonlinear behaviors of the threat and extending the techniques to multiple weapons.

In the same way that many eyes looking out of many windows from many vantage points can give a total composite picture, we can combine the sight-picture of several weapons as they approach the target to provide a better solution. ARL is leveraging the ongoing revolution in the microelectronics industry that aims to



PARENTAL AUTHORITY

The concept of “parent” and “child” weapons uses distributed computing and communications to achieve the desired effects. Child weapons take orders from a parent—which has more onboard computing capability for communications and processing—that would, in turn, communicate back to the warfighter and the network of sensors. (SOURCE: ARL)

reduce size and cost and improve the performance of real-time processing and sensors in the weapons environment.

Each of these complicated weapons comes with its own additional challenges, such as the need for power. As new sophisticated electronic components are developed, they must be made rugged for flight or ballistic delivery. They also must use tiny amounts of power. Further, while all these weapons will demand much less power than today, some of the “parent” weapons will have to have more computing capability on board for communications and processing.

Maneuverability: We want to develop one weapon that flies like an airplane most of the way and then performs like a precision bomb at the last second. This may mean turning very quickly and actually changing the shape of the aerodynamic parts while flying. Maneuverability enables extended-range engagements by using glide aerodynamics, the interception of moving targets, the evasion of defensive suites and favorable shaping of the terminal approach. This would allow new U.S. warheads to strike dug-in targets, effectively hitting targets on the far side of obstacles from multiple directions. We will be able to hit the back of enemy fortifications or fly the weapon into doors or tunnels. Hardening for the weapons environment

and reducing the size and cost of technology for maneuverability to allow more precision engagement means less ammunition will be fired. Increased battlefield effectiveness will come from smaller, more precise weapons that talk to one another. For the warfighter, having maneuverable weapons means that their truckload of ammunition will last longer, do more and require resupply less often.

For larger, fast-moving artillery or missiles, knowledge gaps inhibit our ability to predict and characterize controlled flight for maximal maneuverability. Additionally, we lack the technology to outmaneuver threats while subjected to the extreme environment. Research is specifically designed to find weapons that fly farther, faster, with more precision and maneuver control to penetrate an enemy’s increasingly complex network.

ARL is solving several problems of very fast flight. For instance, when very fast bodies fly near each other, the air vortex can sometimes cause individual rounds to remain very close or impact each other. This is undesirable, to say the least. The science that ARL will develop will include optimal flight vehicle design using an understanding of close-maneuvering aerodynamics.

This understanding will be demonstrated using small weapons carrying launch-hardened components, flying from subsonic to supersonic speeds with the ability to drastically change shape in adapting to emerging conditions. This morphing weapon will have to make its own last-second decisions based on complex rules governed by a simple interface that the warfighter controls.

Modular and scalable lethality: Cooperative weapons will require efficiencies and mechanisms for concepts that execute cumulative lethality. We envision that individual munitions in the flight group may not carry similar payloads; these payloads may be significantly reduced when compared with conventional payloads with strikes that are sequenced for multiple impacts. As such, we need to carefully understand the variety of lethal mechanisms and the sequencing of impacts to provide effects against dismounts, protective structures, aircraft, tactical vehicles, hardened combat platforms and even adversarial inbound munitions.

Sometimes what’s needed is a really big bomb. But more often, a more precise approach with smaller explosions is preferred. ARL’s computing expertise and its interaction with other DOD laboratories are very important here. The ARL team is fully linked with other groups of DOD scientists to develop the models, simulations and computational codes required for success.

Protection: Weapons need protection against an enemy who will be fighting back. Kinetic, directed electromagnetic and electronic mitigation of a peer adversary is part of the solution. To fight in the future battlespace requires the assessment of an unpredictable enemy, but one who has similar peer technology. Our systems must be able also to attack and defeat their systems, which are also increasingly electronically complex, highly maneuverable and guided by autonomous programs.

As our weapons head to the target, the enemy will be fighting back. Our weapons will have to perform very fast evasive maneuvers and generate their own force field or “cloaking-device,” because the enemy will be defending its site with anti-aircraft or anti-artillery-type defenses. These are all extremely hard science problems.

Crippling blows of the future will rely on a small number of dispersed entities to deliver overwhelming kinetic and non-kinetic effects by combining omni-speed, radical maneuverability and navigation in contested environments and efficient payload-kill mechanisms. Omni-speed and radical maneuverability depend on long-range advances in propellants and aerodynamics so that a weapon can maneuver and change course based on a commander’s guidance. Navigation of teams of projectiles will require each round to be able to communicate with

the collaborative munitions on the team while on the path to the target.

CONCLUSION

Through the fundamental research program at ARL, scientists dig into problems and move beyond the least likely approaches, in search of the one or two solutions that advance the technology through the Army’s research and development engineering centers.

The benefit of the Distributed and Cooperative Engagements in Contested Environments research is effects that can be deployed either mounted on a vehicle or carried by dismounted Soldiers—consistent value regardless of what munitions it takes to deliver a desired outcome. Such future engagements will involve cooperation among munitions on the attack path and communication with warfighters, who will continue to retain ultimate control. These highly intelligent weapons will combine effects and mechanisms, maneuver and make high-speed robust decisions.

All these efforts underway in ARL’s research program combine electronics, energetics, propulsion, navigation and other technologies to cooperate in the battlefield of the future, and provide technology to the warfighter on the line and on time.

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ARL is developing the technologies to fit a set of tools that will be smarter, more aware, connected and autonomously collaborative.



FUTURE TRENDS

To develop and field the next generation of combat vehicles, the Army needs to overcome the current problem: Adding new capabilities and systems is complicated by the weight-bearing and power-generation constraints of the original platforms. (Images courtesy of DASA(R&T))



THE *NEXT* GROUND COMBAT *VEHICLES*

The next generation of Army combat vehicles will need to include manned, unmanned and optionally manned variants that include the most advanced protection, mobility, lethality and power generation capabilities to ensure that our Soldiers can survive first contact and defeat any adversary.

by Mr. Andy Steel

The modern battlefield has combined the air, land, sea, space, cyber and information battlespace into blended domains as simultaneous operations must be conducted over a dispersed battlefield. This requires the Army to design, equip and train forces capable of defeating adversaries with advanced capabilities to prevail in complex and multidomain environments. While the Army's current fleet of ground vehicles maintains a tactical overmatch or close parity with our adversaries, additional upgrades are proving challenging to these platforms given their current size, weight and power limitations. The ability to add evolving technologies to existing ground vehicles is rapidly diminishing as the weight-bearing capability, power generation and available footprint to support these technologies has exceeded the original design.

Our adversaries have paid careful attention to the last decade and a half of combat operations conducted by U.S. forces and modified their tactics, techniques and procedures to hide from our strengths and exploit our vulnerabilities. When U.S. forces deploy, the enemy usually is operating from a "home field" advantage or is at least in position and prepared for conflict. Adversaries are well aware of the disadvantages of giving U.S. forces the time to deploy, position and amass firepower in an uncontested environment before any potential engagement. They understand that letting U.S. forces



LASER FOCUSED

The Army is looking to leverage investments in high-energy laser applications to develop vehicle platforms with improved operational capabilities at significantly smaller sizes, offering defense capabilities against unmanned aerial vehicles, rockets, artillery and mortars.



A SMALLER FOOTPRINT

The Army is focusing vehicle technology investments on vehicles that are smaller, lighter, intelligently interconnected, safer and more lethal than current combat platforms.

gain superiority in any domain can raise their likelihood of failure immensely.

Survivability in the future battlespace will be challenging. Our near-peer adversaries have combined enhanced long-range sensors with the effects from long-range precision fires. This is forcing a careful review of the requirements for future combat vehicles. Army leadership recognizes that the Army must develop the critical enabling technologies to support the next generation of combat vehicles. Increased capabilities, including advanced mobility, lethality and power generation, are required to operate smartly in the current operational environment.

Additionally, vehicle survivability can be greatly increased with intelligent sensors that are integrated with the hardware, software and effectors to create an overarching, layered system of passive and active self-defense measures. Examples include protective systems that could prevent an adversary weapon system from engaging a U.S. platform or identify an incoming threat and electronically render it ineffective or physically engage to defeat its lethal mechanisms. These overlapping and multiaspect methodologies would sequentially complement each other to defeat adversarial capabilities and protect friendly forces.

To expand its combat capability, the Army is exploring the use of unmanned vehicles teamed with manned control vehicles to support a yet-to-be defined role in multidomain operations. Surviving first contact and dominating in the dispersed battlespace will require the integration of a range of ground and air systems: semiautonomous, fully autonomous, optionally manned, tethered and untethered. Autonomous unmanned systems will have the maneuverability to travel over complex terrain and

environments with greater capabilities than their manned counterparts. These systems will extend the reach of U.S. forces and will allow them to initiate contact with their adversaries under the most favorable conditions. These platforms will extend the maneuver force’s understanding of the combat environment, increase survivability and extend lethality. Autonomous systems also will perform some of the dangerous, physically demanding and mundane tasks required of Soldiers.

Areas of specific focus supporting the Army’s next generation ground vehicles include:

- **Sensors.** Improved sensors will provide increased capability to detect, recognize, identify and locate entities rapidly and precisely, at extended distances and with greater image resolution.
- **Directed energy and energetics.** The Army is investing to leverage the effects of directed energy in lethal, nonlethal and protection applications that can lead to reduced logistics and vehicle platforms that have significantly improved operational capabilities at significantly smaller sizes. For example, Army investments in high-energy laser applications are leading to effective defense capabilities against airborne threats, including unmanned aerial vehicles, rockets, artillery and mortars.
- **Power generation and management.** The Army is investing in vehicle platforms that require less fuel yet have greater operational range and generate more power, improving mobility, survivability and lethality.
- **Advanced armor materiel solutions.** Army science and technology is investing in lighter and more capable armors that can, when augmented with other



PUTTING THE PIECES TOGETHER

Surviving first contact in the dispersed battlespace of the future will require a range of ground and air systems to extend the maneuver force's situational awareness, increase survivability and enhance Soldiers' lethality.

layers of defense capabilities discussed in this article, improve survivability while enhancing operational combat effective range.

- **Vehicle protection suites.** The Army is making investments in active and passive protection systems that allow for reduced armor requirements (weight), enable pre-shot understanding of the threat and post-shot protection from incoming threats. Vehicle protection applications that optimize passive armor and active protection systems allow for a decrease in vehicle size, thus improving deployability, mobility and protection.
- **Maneuver robotics and autonomous systems.** Investments in semiautonomous, fully autonomous, optionally manned, tethered and untethered ground and air systems will expand the next generation ground vehicle's understanding of the operational environment, increase survivability and potentially extend lethality.

Army leadership faces profound challenges in developing its next-generation combat vehicle to protect Soldiers on the modern multidomain battlefield. Soldiers need the capability and skill to deploy rapidly, close with and destroy adversaries throughout

the battlespace. The Army's goal is to focus its vehicle technology investments to develop a generation of vehicles that are not only more lethal and survivable than current combat platforms but much smaller, lighter, more fuel-efficient and intelligently interconnected for shared battlespace awareness. The following two articles on the Army's development of Robotic Wingman, its first armed and unmanned ground vehicle, and the potential applications of artificial intelligence illustrate the critical enabling technologies the Army is pursuing to increase Soldiers' operational capabilities and survivability. Army leadership is fully engaged to provide Soldiers with the best possible capabilities for future combat operations.

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WINGMAN *is first step* *toward* WEAPONIZED ROBOTICS

The Army's first armed and unmanned ground vehicle is in the works.

by Mr. Thomas B. Udvardi

In 2014, the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) and the U.S. Army Armaments Research, Development and Engineering Center (ARDEC) teamed up to integrate a remote weapon system on a robotic vehicle to see if that system could become certified on a Scout Gunnery Table VI course, the same course used to train and qualify ground combat vehicle crews.

The vehicle was a High Mobility Multipurpose Wheeled Vehicle (HMMWV), and its “brain” was the TARDEC-developed Robotic Technology Kernel. ARDEC contributed the prototype wireless system known as the Picatinny Lightweight Remote Weapon System, which it had developed. The command-and-control HMMWV consists of the Warfighter Machine Interface, developed in-house at TARDEC, which controls and operates the robot and weapon system. Collectively, this Wingman capability allows Soldiers in a command-and-control vehicle to remotely operate an unmanned ground vehicle weapon system.

Initial experiments have met with limited success, but the Wingman program has ignited further investigation into weaponized robotics and how keeping the Soldier-in-the-loop could mitigate many of the gaps seen in today's autonomous systems.



WINGMEN

From left, the Wingman command-and-control vehicle and the unmanned Wingman. The command-and-control vehicle is mounted with a Long Range Advanced Scout Surveillance System providing target designation and handoff capability. Equipped with unmanned mobility, automated target tracking and a remotely operated weapon system, the robotic Wingman vehicle permits engagement of targets from covered positions. (U.S. Army photos by Keith Briggs, TARDEC Ground Vehicle Robotics)

In 2016, the U.S. Naval Surface Warfare Center Dahlgren Division (NSWCDD) joined the Wingman team with its target acquisition and tracking system, the Autonomous Remote Engagement System. With the addition of the NSWCDD, the Wingman program received three years of funding to demonstrate the technology. The program will culminate in a military utility assessment at an Army national training center or equivalent between 2019 and 2020. TARDEC engineers say Wingman is the research and development (R&D) community's first step toward weaponized robotics.

TACTICAL ADVANTAGE

"The Wingman technology developed today will be foundational for tomorrow's advanced fighting vehicles," said Dr. Robert Sadowski, TARDEC chief roboticist. "The Wingman technology will extend the warfighters' reach and direct-fire engagement range, allowing our Soldiers to dominate more terrain while keeping them out of harm's way."

TARDEC is leading the Wingman development effort with technical partners ARDEC, NSWCDD and the U.S. Army

Research Laboratory (ARL), which provides the analysis necessary to assess the Wingman technology from a Soldier's perspective for operational and training purposes.

Military ground elements in first contact with the enemy often uncover obstacles, suffer the highest casualties and become decisively engaged, limiting friendly freedom of maneuver. Capable autonomous systems could provide a tactical advantage for these operators. However, aggressive state and nonstate actors are also pursuing the development of armed lethal robotics. As the level of autonomous capability increases, automation will spiral into weaponized systems. Unmanned systems deployed by our adversaries could impact the advantage our current reconnaissance forces have in the fight for information and increase the already high mortality rates of these units.

The Wingman technology demonstration program will investigate how to use unmanned assets to project lethality and move effectively with a mounted formation and engage ahead of or along

with manned platforms without increasing manpower requirements. The team believes that unmanned assets can reduce casualties by extending the reach of the warfighter through unmatched advanced situational awareness, platform autonomy and targeting in a weaponized unmanned ground vehicle (UGV).

Wingman will begin to develop the concept of operations and tactics, techniques and procedures to integrate weaponized, unmanned systems into the current force and increase operational standoff.

Initiating contact with UGVs gives commanders flexibility and maneuver space to effectively respond to enemy threats, and eliminates some of the risks of casualty extraction. The Wingman technology will allow friendly commanders the ability to disperse manned systems without creating exploitable gaps and seams in their own formation.

TECHNICAL ADVANTAGE

In 1997, a computer named Deep Blue beat world chess champion Gary Kasparov. By 2005, two amateur chess players using three personal computers

won a chess tournament against supercomputers and grand masters. Teaming amateurs with computers produced a significant advantage over the computers or the grand masters.

Current autonomy technologies aren't as capable at their tasks as Deep Blue was at its in 1997. Most have gaps in the perception and cognition areas. The use case for lethal robotic ground systems requires a Soldier-in-the-loop in order to pull the trigger. Wingman seeks to combine the perception and judgment of the Soldier with the speed, power and precision of the machine to produce an effective unmanned ground weapon system.

Currently fielded autonomous ground systems require a high degree of Soldier oversight and tend to be limited to a specific mission. They often fail to meet warfighter expectations because of limitations in the autonomy or robustness of the integrated hardware and software systems. These constraints make it difficult to field an effective weaponized robotic platform. The Wingman technology demonstrator will address some of these limitations with today's autonomous technology by developing manned-unmanned teaming behaviors to iteratively define and decrease the gap between autonomous vehicle control and the required level of human interaction.

“Unlike other autonomous systems that seek to eliminate the operators, weaponized autonomous systems will leverage the Soldier-in-the-loop to automate operations and enhance the



ON ITS OWN

The Robotic Wingman vehicle maneuvers semiautonomously through a Scout Gunnery Table VI course at Fort Benning, Georgia, in late 2017. This is the same course manned combat vehicles and their crews must pass before moving on to live fire training; there is thus plenty of data about how manned vehicles handle the course, which the unmanned Wingman's performance can be measured against.

Soldier's reach,” said Keith Briggs, TARDEC's technical manager of the Wingman program.

The prototype system complies with DOD Directive 3000.09, “Autonomy in Weapon Systems,” and will be used as a surrogate to inform the development of future unmanned weapon systems.

ROBOTIC VEHICLE SUBSYSTEMS

The Wingman Weaponized Robotic Vehicle is an M1097 HMMWV and contains three primary subsystems:

- First is the TARDEC-developed Robotic Technology Kernel (RTK), the autonomy system for planning and controlling the vehicle's mobility. RTK contains driving cameras for remote operation, LIDAR sensors (light detection and ranging) for object classification, stereo cameras for terrain classification, computers for computation, radios for communication, and all the essential hardware, cables and mounts. The system can be manually driven through teleoperation or autonomously driven through waypoint navigation.
- The second subsystem is lethality, which uses the Picatinny Lightweight Remote Weapon System. That system can use an M134 Gatling-style minigun or an M240B machine gun. Wingman is currently investigating changing the M240B for an ARDEC-developed Advanced Remote Armament System. This will provide additional capabilities, such as an externally powered, purpose-built weapon to improve reliability and accuracy, the ability to load and clear the weapon remotely and an increased stowed ammunition load without decreasing aim or stabilization.
- The Autonomous Remote Engagement System (ARES) is the third subsystem. It provides automated engagement capabilities to decrease target acquisition time with vision-based automatic target detection and user-specified target selection. This system will decrease engagement time and overcome wireless control latency through video tracking, user assisted fire-control and control of the weapon.

COMMAND-AND-CONTROL VEHICLE

The Wingman Joint Capability Technology Demonstration (JCTD) is currently using an M1151 HMMWV as its command-and-control (C2) vehicle. The C2 vehicle contains the Soldier-machine interface that the Soldier uses to remotely operate the weaponized robotic vehicle. Five Soldiers currently man Wingman's C2 vehicle. In front sit a driver and a vehicle commander. In the rear seats are a wireless remote weapon system

AIM HIGH

The ARES optical system, developed by the NSWCDD, is mounted on ARDEC's Picatinny Lightweight Remote Weapon System and coupled with an M240B crew-served weapon. These are two of three subsystems that make up the Wingman.



operator, the robotic vehicle operator and a manned machine gun operator through the hatch. The Soldier in the hatch also uses a Long Range Advanced Scout Surveillance System to designate targets and send the coordinates to the robotic vehicle for engagement.

The C2 vehicle contains the TARDEC-developed Warfighter Machine Interface, which provides customized interactive displays for the vehicle commander, robotic vehicle driver and remote weapon system operator. These interfaces will be expanded to accept voice commands to naturally communicate with the robot and provide real-world data on the surrounding environment.

ASSESSMENT AND CERTIFICATION

The Wingman program will assess the performance and feasibility of the technology against a Scout Gunnery Table VI course, which the Army uses to train and certify crews for Army combat vehicles. The course also evaluates the vehicle's ability to move, shoot and communicate. Generally, a crew and its vehicle must pass the Table VI course—during which they engage both moving and stationary targets—annually, before participating in live fire training or deploying. Putting a robotic vehicle through the Table VI course will allow the team to quantify the

tactical performance of an armed UGV and directly compare this to how manned platforms perform.

During a Table VI, the vehicle crew conducts 10 engagements on 16 targets. Target ranges vary depending on the weapon system, and target types vary from infantry silhouettes to armored vehicle silhouettes. To pass, the crew must obtain 700 out of 1,000 possible points. The Wingman program plans to field the first robotic vehicle to obtain a certification on this course.

MODELING AND SIMULATION

Along with hardware and software, TARDEC, NSWCDD and ARL are standing up a modeling and simulation capability through the development of a Wingman System Integration Laboratory (SIL), which will be used to develop and verify software before conducting expensive live testing. The lab also will make it easier to conduct Soldier virtual experiments to inform and develop future capabilities and train Soldiers before they use the system in live experiments on the range. The SIL integrates the real-world vehicle software within a simulated environment for rapid prototyping, software development and early assessment of interactions between the manned vehicle team and the vehicle.

CONCLUSION

Current autonomous systems face many issues in the areas of perception, cognition, classification and communications—which prevent fielding effective unmanned weapon systems, especially in hostile environments—Wingman will address these issues by exploring new ways to use the situational awareness of the Soldier-in-the-loop to supplement these capabilities and mitigate gaps in critical areas. As the R&D community's first step toward weaponized robotics, Wingman aims to reduce casualties and increase standoff for Soldiers, especially those units in first contact.

For more information, go to <https://www.army.mil/tardec>.

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The **ARTIFICIAL** *Becomes* **REAL**

A back-and-forth interplay of government and commercial funding and research has brought AI to the edge of a breakthrough.

by Dr. Alexander Kott

Few fields of technology are as paradoxical as artificial intelligence (AI). For one thing, since its official inception in the mid-1950s, AI has experienced multiple cycles of boom and bust. Time and again, AI would be proclaimed a miracle technology; an intense hype would build up and last for a decade or so, only to be followed by an equally intense disappointment and sense of abandonment. Similarly, human emotions around AI seem to run to extremes.

Back in the 1950s, many a life was changed by fascinating visions of the future depicted in the robot stories of Isaac Asimov. Sixty years later, science and technology experts, including astrophysicist Stephen Hawking, Microsoft's Bill Gates, Apple co-founder Steve Wozniak and Tesla's Elon Musk, have warned that humankind could be extinguished by AI. It is hard to imagine more passionate attitudes toward what is, after all, merely software.

This brings to mind yet another paradox: As soon as a research topic in AI achieves practical maturity, it is invariably demoted to "just a computer program."

Thirty years ago, finding an efficient route on a complex, realistic map while taking into account traffic conditions and road closures was considered a major topic of AI research. Today, it is merely a GPS app on your smartphone, and nobody calls it AI anymore.

While no definition of AI seems quite adequate for such an unconventional field of endeavors, one way to describe AI is the ability of computer-enabled agents (e.g., robots) to perceive the world, reason and learn about it, and propose actions that meet the agent's goals. Equipped with AI, agents—whether purely computer-resident, like a highly sophisticated version of Amazon's Alexa, or physical robots—become capable of autonomy. Autonomy means the ability of a system to perform highly variable tasks with limited human supervision (e.g., dealing with unpredictable obstacles and threats). Another often-heard term, machine learning, is a subfield of AI; it refers to improving machine knowledge and performance via interactions with the environment, data, people, etc.

The last few years have seen dramatic yet uneven advances in AI in application to both physical



GAME OF DRONES

Scientists gather information about unmanned aerial vehicles in August through an Army alliance of government, academic and commercial partners known as the Micro-Autonomous Systems and Technology Collaborative Technology Alliance. The Army's long-term focus includes collaboration among highly dissimilar entities—teams of large and small air and ground robots and Soldiers—spread over large contested environments. (U.S. Army photo by Jhi Scott, ARL)

robots and software-only intelligent agents. Some capabilities, like answering questions (IBM's Watson), "deep learning" (Google's TensorFlow machine learning) and self-driving cars, have achieved significant breakthroughs. But others see ongoing exploration without any dramatic advances—yet. Almost all initial breakthroughs (all of those named above) came, to a large extent, from government's pioneering research funding. Only later, when the research efforts showed commercial potential, were they picked up by industry, which then invested much more in these technologies than the initial government funding.

Considering the recent, enormous growth of interest in AI shown by both the public and industry, the interplay between government and commercial investments is interesting and complex. Published estimates of global commercial investment in AI (including autonomy) vary widely, between \$20 billion and \$50 billion per year. The major commercial markets include

retail, telecommunications, financial, automotive and industrial assembly robots. In comparison, the Army's science and technology (S&T) investment in AI and autonomy is two to three orders of magnitude lower. If so, why should the Army bother? Why not let industry take the lead and wait until its enormous investments produce the AI technologies the Army wants?

First, the Army S&T community is well aware of the industry efforts and products; it uses these products extensively in Army-focused research, often tailoring them as needed. In their autonomy research, for example, Army scientists and engineers use industrial or industry-supported robotic platforms, such as iRobot's widely used small unmanned ground vehicle PackBot and the popular Robotic Operating System (ROS)—open-source middleware supported by a number of corporations. (See "How Many Robots Does It Take?" Page 269.) Computers and processors also come from industry: NVIDIA Corp.'s graphic processing unit, which helps accelerate deep learning, is one



MAP TO THE FUTURE

Just 30 years ago, finding an efficient route on a complex map with current traffic conditions and road closures was considered cutting-edge AI research. Today, it's commonplace—just one more app on your smartphone. (Photo by NEstudio/Shutterstock)

example, as is IBM's TrueNorth chip, which emulates brain neurons for power-efficient computations. For machine learning, Army S&T uses well-developed software tools such as TensorFlow.

At the same time, the focus of the Army S&T community is on problems that are quite distinct and are not going to be addressed by commercial applications. For example, much of Army research and development (R&D) investments in autonomy are focused mainly on autonomous convoys traveling in adversarial environments on terrain other than conventional roads; on robotics for manned-unmanned teams for reconnaissance, surveillance and target acquisition and breaching; and on AI for military

intelligence data analysis. These are not yet areas of significant interest to commercial developers, who focus on lucrative consumer markets.

Furthermore, there are deep, foundational differences in the scientific and technical challenges that Army-specific AI problems present, and which are not typical—or at least not a high priority—compared with the problems targeted by commercial investments. For example, AI and machine learning for self-driving cars, although initially spurred by the Defense Advanced Research Projects Agency's Grand Challenge competitions, are currently being developed by industry and optimized for relatively orderly, stable, rule-driven, predictable

environments, such as the highways and streets of modern cities. Nothing could be further from the environments where the Army-specific AI will have to operate—unstructured, unstable, chaotic, rubble-filled urban combat.

As another example, the recent explosion of successes in machine learning has been connected with availability of very large, accurate, well-labeled data sets, which can be used for training and validating machine learning algorithms and, given lengthy periods of time, for the learning process. But Army-relevant machine learning must work with data sets that are dramatically different: often observed and learned in real time, under extreme time constraints, with only a few observations (e.g., of the enemy techniques or materiel); potentially erroneous, of uncertain accuracy and meaning; or even intentionally misleading and deceptive. In other words, some of the very foundations of commercial AI algorithms diverge strongly from what the Army needs.

MANNED-UNMANNED TEAMING

Human-agent teams—Soldiers teamed with robots and other intelligent systems operating with varying degrees of autonomy—will be ubiquitous on the future battlefield. These systems will selectively collect and process information, help Soldiers make sense of the environment they're in, and—with appropriate human oversight—undertake coordinated offensive and defensive actions.

Many will resemble more compact, mobile and capable versions of current systems such as unattended ground sensors, unmanned aerial vehicles (drones) and fire-and-forget missiles. Such systems could carry out individual actions, either autonomously or under human control,

collectively provide persistent and complete battlefield coverage as a defensive shield or sensing field, or function as a swarm or “wolf pack” to unleash a powerful coordinated attack.

In this vision of future ground warfare, a key challenge is to enable autonomous systems and Soldiers to interact effectively and naturally across a broad range of warfighting functions. Human-agent collaboration is an active research area that addresses calibrated trust and transparency, common understanding of shared perceptions, and human-agent dialogue and collaboration. Army S&T is focused on the fundamental understanding and methods to design and develop future Army autonomous systems that will interact seamlessly with Soldiers.

One function with technology that has relied on a foundation of government research is question answering—the system’s ability to respond with relevant, correct information to a clearly stated question. The recent question-answering successes of commercial technologies like IBM Watson and Apple’s Siri are based on several decades of government leadership in related research fields.

They work well for very large, stable and fairly accurate volumes of data, like encyclopedias. But such tools don’t work for rapidly changing battlefield data, which can be distorted by adversaries’ concealment and deception. Commercial question-answering systems cannot support continuous, meaningful dialogue in which both Soldiers and artificially intelligent agents develop shared situational awareness and intent understanding. The Army is performing research to develop human-robotic dialogue technology for warfighting tasks, using natural voice, which is critical for reliable battlefield teaming.



FROM CHAOS, ORDER

Army AI and machine learning involve unique challenges for Soldiers, including operations in unstructured, unstable, rapidly changing, chaotic and adversarial environments where gathering information is difficult, and the information gathered may be potentially erroneous, misleading and deceptive. (Image courtesy of ARL)

Also critical is the self-organization of robotic team members. By leveraging available commercial technologies like the Robotic Operating System and commercial robotic platforms, Army scientists are performing research to address Soldier-robotic teaming on complex ground terrain. For example, the Army recently demonstrated leader-follower driving of resupply trucks in which several unmanned vehicles autonomously follow a human-driven truck, on narrow forest roads with tree canopy, at tactically appropriate speed and with long gaps between the trucks.

When a team includes multiple artificial agents, or when multiple teams must work together, new challenges arise: decentralized mission-level task

allocation; self-organization, adaptation, and collaboration; space management operations; and joint sensing and perception. Commercial efforts to date have largely been limited to single platforms in benign settings. Within the Army, some programs like the U.S. Army Research Laboratory’s (ARL’s) Micro Autonomous Systems and Technology Collaborative Technology Alliance (MAST CTA) have been developing collaborative behaviors for unmanned aerial vehicles. Ground vehicle collaboration is challenging and is largely still at the basic research level. The Army’s long-term focus is on enabling collaboration among large numbers of highly dissimilar entities, such as large and small teams of air and ground robots, as well as human Soldiers, distributed over a large contested environment. To



IN THE AI LOOP

Thanks to advances in AI, human-agent teaming and machine learning, Soldiers will provide commanders with real-time information about the enemy gathered from a variety of different sources, including possible courses of action, which will help them to make better decisions in battle. (Image courtesy of ARL)

address such challenges, ARL has started Distributed and Collaborative Intelligent Systems and Technology, a collaborative research alliance between academic scientists and ARL government scientists.

MACHINE LEARNING

Machine learning is a key precondition for human-agent teaming on a battlefield, because agents will be neither intelligent nor useful unless they are capable of learning from experiences and adapt what they know while acting on the battlefield. For example, ARL has been working on learning algorithms for small ground robots that are able to learn the conditions of the ground (wet, slippery, sandy, etc.) and learn the appropriate modifications that control the turns and the speeds of their tracks. In

another example, academic scientists collaborating with ARL in the framework of the recently completed MAST CTA developed a small rotorcraft that can execute aggressive maneuvers while flying through unfamiliar, highly cluttered indoor environments. The rotorcraft does so by continually learning the probability of collision directly from an onboard video camera. It recognizes new scenes and continually updates its knowledge.

Machine learning, although not yet capable of addressing the complexities of battle, has seen dramatic advances using “deep learning” computer algorithms known as deep neural networks. To deal with the unique nature of Army-specific machine learning, ARL is researching specialized extensions to commercial algorithms such as the TensorFlow software toolkit.

Yet another challenge that is uniquely exacerbated by battlefield conditions is constraints on the available electric power. Commercial AI relies on vast computing and electrical power resources, including cloud computing reachback when necessary. Battlefield AI, on the other hand, must operate within the constraints of edge devices: Computer processors must be relatively light and small and as frugal as possible in the use of electrical power. Additionally, the enemy's inevitable interference with friendly networks will limit opportunities for using reachback computational resources.

HUMAN LEARNING

Human learning and training for the complex battlefield of the future needs AI for building realistic, intelligent entities in immersive simulations. The Army principle of “train as you fight” places high importance on training experiences with the realism to match operational demands. Immersive training simulations must have physical and socio-cultural interactions with the fidelity to meet the training demands of strategic and operational planning and execution. Modeling and simulation capabilities must also match the complexity of the operational environment so that simulated interactions enable effective transfer of skills and knowledge to the operational environment.

Game-based training provides cost-effective development of immersive training experiences. Still, game-based training is not a silver bullet. Mismatches between the gaming environment and the real world may cause unintended effects, such as giving users an unrealistic framework for combat. Army training simulations need to include realistic sociocultural interactions between trainees and simulated intelligent agents. The actions of human actors teaming



TIP OF THE RESEARCH SPEAR

Popular technologies that are sold commercially, such as intelligent personal assistants on mobile devices and driverless cars, began with government research funding and were matured later through industry. (Image by posteriori/Shutterstock)

with robots and other intelligent agents will be pervasive in the complex operational environments of the future.

Army training simulations build on advances in commercial game engines like Unreal, which powers the game “Kingdom Hearts III,” and adapt that kind of action role-playing to meet the unique needs of the Army in programs like the \$50 million Games for Training, overseen by the Program Executive Office for Simulation, Training and Instrumentation.

ARL is also at the cutting edge in computer generation of realistic virtual characters that are needed to enable realistic sociocultural interactions in future Army training applications. More than once, Hollywood studios have sought technologies from the ARL-sponsored Institute for Creative Technologies at the University of Southern California to create realistic avatars of actors. These technologies enable film creators to digitally insert an actor into scenes, even if that actor is unavailable, much older or

younger, or deceased. That’s how actor Paul Walker was able to appear in “Furious 7,” even though he had died partway into filming.

CONCLUSION

That is a glimpse of perhaps the greatest paradox of AI: its looming power to erase the divide between the real and the imaginary, the natural and created. To defy, indeed, the very notion of artificial.

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SUNSET ON THE APACHE

Army aviation S&T is investing in a portfolio of enabling technologies as a precursor to fielding a replacement for the AH-64 Apache helicopter, including these from the North Carolina Army National Guard's 1st Battalion, 130th Aviation Regiment, positioned in the Mojave Desert in May at the National Training Center, Fort Irwin, California. (Mississippi National Guard photo illustration by Staff Sgt. Tim Morgan, 102nd Public Affairs Detachment)



Science and Technology *Supporting* **FUTURE ARMY AVIATION**

Research in several areas will mature new capabilities to make Future Vertical Lift possible.

by Mr. Todd Turner and Mr. Matthew Simone

In the future, Army aviation systems will need to operate in an anti-access and area denial (A2AD) contested airspace against adversaries that have advanced capabilities that constrain freedom of maneuver. To be effective in these environments, future aviation systems will need extended range, increased situational awareness and higher speed to maneuver into positions of advantage, survive and engage the adversary. There also will be a need for increased use of unmanned systems to penetrate this contested airspace.

The investments in the air systems science and technology (S&T) portfolio are dedicated to discovery, innovation and transition of products to enable U.S. technical superiority and combat overmatch for current and Future Vertical Lift (FVL) systems. The portfolio is invested in five broad areas of research:

- Platform design and structures to focus on extending the range and speed of vertical lift systems.
- Investments in power to ensure that systems can achieve higher speeds and improved efficiency to achieve extended ranges.
- Mission systems technologies to ensure that once the platform is in the operational environment, it can provide the desired lethality and survivability.
- Unmanned aircraft autonomy and teaming to extend reach and lethal effect while also providing the ability to penetrate A2AD environments.
- Investments in maintainability and sustainability to ensure that platforms are capable of high operations tempo while reducing logistics demand.

PLATFORM DESIGN AND STRUCTURES

Ultimately, the desired effect on the battlefield for aviation systems, whether assault, attack, lift, reconnaissance or medical evacuation, is provided by the platform. That platform may be manned, optionally manned or unmanned, depending on mission and environment. The focus of S&T in platform design is to support FVL. S&T in this area encompasses concept development and design analysis through system development and demonstration.

This includes current efforts such as the Joint Multi-Role Technology Demonstrator (JMR-TD) and future efforts such as Next Generation Tactical Unmanned Aircraft Systems (NGTUAS). The JMR-TD is demonstrating platform and mission systems technologies in support of FVL. NGTUAS is focused on the development and demonstration of technologically feasible and affordable unmanned air vehicle technologies and capabilities that provide improvements in flight performance, survivability and reliability. Long-term efforts are focused on vertical lift technologies that enable both high speed and efficient hover.

POWER

One of the most important areas of technology needed to dominate the future operational environment is aircraft power systems. This area includes technologies that advance the capabilities of turbine engines and drivetrains. Current vertical lift turbine engines and drivetrains are designed to operate at a fixed speed and lift; forward movement is produced by adjusting the pitch of the helicopter rotor blades. These turbine engines and drivetrains are optimized for this fixed speed but are at their limit of efficiency and power.

To meet the requirements for range and speed with maximum efficiency, technologies like variable-speed turbine engines and multispeed transmissions are being developed. To build these future power systems, new turbine designs, materials and components will need to be developed through innovative manufacturing capabilities like additive manufacturing. Additionally, engine designs will need to be highly reliable to meet the demands of the future operating environment, which will be fast-paced and require much longer operation between maintenance sessions than today’s aircraft. Leap-ahead technologies like hybrid-electric power systems are also being investigated and developed. These technologies combine the efficiency of electric motors and optimized engines, not unlike current hybrid-electric cars. Combining all of these new technologies and capabilities will be required in order to enable the FVL aircraft to meet all of its future requirements.

MISSION SYSTEMS

The goal of the mission systems area is to mature and validate man-machine mission equipment software and hardware technologies to enable overmatch and survivability in the future operating environment. If the airframe, engines, transmission and rotors are the body of FVL, then the mission systems can be thought of as the eyes, ears and brains. To allow for a holistic approach to mission system development and employment, open systems architectures will be required to allow Soldiers to “plug and play” future reconnaissance, survivability and lethality systems.

Current sensors and payloads are federated, meaning they don’t interoperate much. In order to install updated payload equipment, an aircraft upgrade would likely need to be developed, which would increase cost and aircraft downtime. The Army’s air systems S&T portfolio is conducting research in



A BIRD IN THE HAND

Spc. Derek Ophof of the 3rd Brigade Combat Team, 82nd Airborne Division winds up to throw an RQ-11 Raven unmanned aerial vehicle to scan the field where Soldiers had just jumped from an aircraft during a deployment readiness exercise at Fort Bragg, North Carolina, in July. This kind of teaming between unmanned systems, Soldiers and manned systems is an important area of investment and research for Army aviation. (U.S. Air Force photo by Staff Sgt. Andrew Lee)



ONE POSSIBILITY

The JMR-TD is demonstrating platform and mission systems technologies to help the Army make decisions about FVL capabilities, which could look like this hypothetical rendering. The demonstrator effort is managed jointly by a team led by the U.S. Army Aviation and Missile Research, Development and Engineering Center (AMRDEC). (U.S. Army graphic by AMRDEC VizLab)

multifunctional sensors so as not to overload the size, weight and power of the aircraft. An example of this type of sensor would be one that has a combination of situational awareness and targeting capabilities.

The mission systems also need to be designed so that the FVL aircraft can operate anywhere, anytime and in any weather condition. This calls for systems that increase situational awareness and survivability but also reduce the cognitive burden on pilots that can come with data overload from these advanced sensors. New types of algorithms for artificial intelligence are being researched and developed to create this new pilot modality, called “supervised autonomy,” whereby pilots oversee instead of execute lower-level flight functions. Speaking at an aviation forum held Sept. 7, 2017, by the Association of the United States Army, Maj. Gen. Bill Gayler, commander of the U.S. Army Aviation Center of Excellence at Fort Rucker, Alabama, said supervised autonomy would “aid a human in the loop and

augment the pilot rather than replacing the pilot.” All of these new advanced capabilities will transform the way FVL is operated and will enable survivability in the fast-paced, dynamic future operating environment.

AUTONOMY AND TEAMING

In the future, unmanned aircraft systems (UAS) may be used to extend the reach of manned systems while removing the Soldier from dangerous conditions. Potential applications include reconnaissance, attack, resupply and casualty evacuation. Research in this area is focused on technologies for the next generation of UAS to support manned-unmanned teaming in combined arms operations. This includes a wide spectrum of research, from control interfaces to advancing autonomous behaviors.

Research in these areas needs to be conducted in parallel to realize the potential of unmanned systems. Common human-machine interface efforts are focused on human-system interface



UP AND AWAY

Chief Warrant Officer Natalie Miller, assigned to Company B, 2-238th General Support Aviation Battalion, leaves Greenville, South Carolina, in February 2017 aboard a CH-47F Chinook heavy-lift cargo helicopter, bound for a weeklong training mission focused on high-altitude flight operations. FVL platforms will need to operate at extended ranges and endure difficult conditions longer and with less-frequent maintenance. (U.S. Army photo by Staff Sgt. Roberto Di Giovine)

designs to improve mission effectiveness in airborne operations. Areas of investigation include cockpit designs with advanced cueing, controls and displays. In autonomous teaming, the focus is on the development of autonomous algorithms to allow one pilot to control UAS, and cognitive decision aids to reduce the time a Soldier has to spend in direct control of a UAS. The long-term goal is to extend UAS capability beyond remote control or teleoperation to truly autonomous capability, to allow combined manned-unmanned platform teaming in contested environments, through

the realization of systems that adapt to changing battlefield conditions.

MAINTAINABILITY AND SUSTAINABILITY

Maintainability and sustainability focus on the development of technologies and methodologies to enable more reliable designs, the ability to forecast component failure, and technologies to reduce maintenance and the logistics burden, one of the biggest cost drivers for Army aviation. Specific areas of research include integrated health management, efficient component design for optimized

reliability, material failure modes, and the effects of thermomechanical and electromagnetic loading. The iterative goals are to move from maintenance based on time-on-aircraft to condition-based maintenance and, ultimately, to predictive maintenance.

CONCLUSION

The S&T investment in air systems is positioned to deliver the next wave of capabilities that will ensure that our vertical lift and UAS are capable of providing close air support and maintain U.S. dominance on the battlefield. The following articles discuss in more detail some specifics of the FVL S&T portfolio: architecture specification, collaborative air systems and aircraft survivability.

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Strength in ARCHITECTURE

Development of a government-led architecture specification promises to transform Army aviation mission systems.

by Mr. Scott Wigginton and Mr. William “Bill” Jacobs

Mission systems provide crucial elements of our warfighting capabilities—in the case of aviation mission systems, components integrated directly onto an air vehicle and encompassing traditional avionics (communications, navigations and displays, for example) as well as specific warfighting capabilities (weapons and sensors).

Current methods of acquiring these systems, however, lead to duplication of effort and a multiplicity of requirements for different contractors providing essentially the same capability. The Aviation Development Directorate (ADD) of the U.S. Army Aviation and Missile Research, Development and Engineering Command (AMRDEC) is researching new methods of acquiring aviation mission systems through a government-led architecture specification. This specification will describe the desired system characteristics, or “-ilities,” such as reusability, portability and interoperability, and document enforceable requirements for these characteristics. This approach will foster competition and reuse across systems, and reduce timelines for managing obsolescence and acquiring new capabilities.

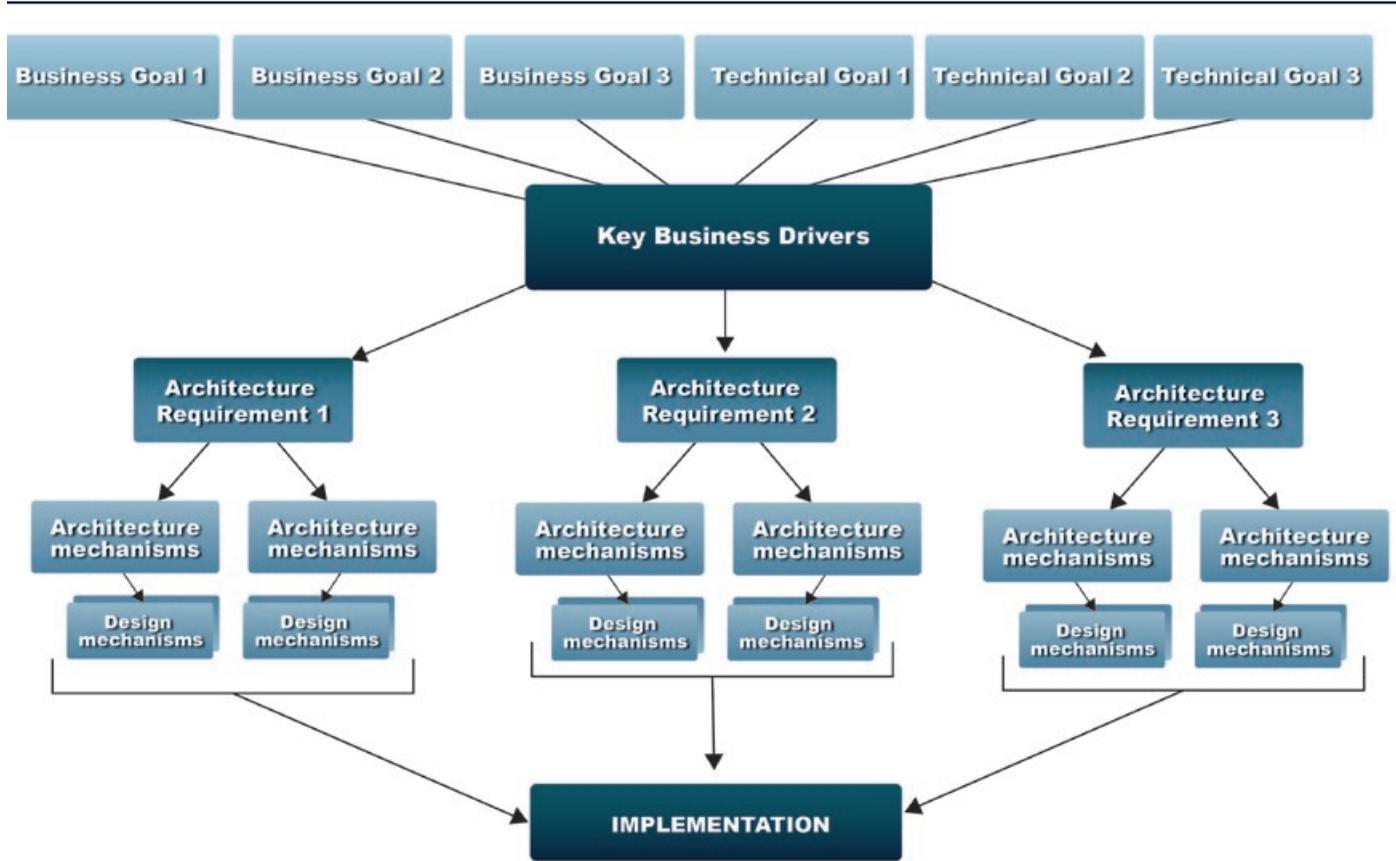
A NEW APPROACH NEEDED

Military services develop aviation mission systems from a program-centric perspective. In other words, each program is singularly responsible for satisfying its system performance requirements. This approach makes sense from the program manager’s perspective, as they are able to manage cost, schedule and performance. The disadvantage, however, is that contractor-unique solutions are likely to preclude any component reuse across programs.

Often, the Army acquires the same basic capability multiple times through independent procurements, each with unique sets of requirements implemented by different contractors. Additionally, any modifications or modernization almost certainly will have to come from the initial contractor, impeding a program’s long-term supportability by limiting competition.

Throughout the life cycle of a system, many common functions need upgrading, with repeated development, integration, testing and qualification. Using a program-centric approach may reduce initial development cost and schedule, but it sacrifices long-term affordability and

FIGURE 1



SENSIBLE REQUIREMENTS

The JCAS takes a multitiered approach to provide enforceable, traceable requirements for future procurements to conform to explicitly stated standards, processes or practices. The strategy is designed to lead to systems that are implemented in a specific, consistent manner. (SOURCE: AMRDEC)

supportability by making it impossible to share the upgraded capabilities across programs. Additionally, nonfunctional requirements such as openness, interoperability, upgradability and maintainability become secondary to system performance requirements and are often compromised in favor of near-term program performance.

Overall, this program-centric perspective results in a loss of competition and innovation and increases long-term costs.

DOD acquisition processes focus on what performance is required and not how it should be implemented, providing limited insight and understanding of the reasons behind the “how.” When the government procures a capability this way, it

inherits the business objectives of the contractor, which may not align with those of the government. The organization’s business and technical goals influence the architecture of that system, substantially affecting its life cycle. The government needs a systematic method to convey a system’s characteristics accurately from a broader, enterprise perspective. This method would drive architecture decisions for the system and lay the groundwork for development and sustainment decisions.

DOD has tried to tackle these challenges through an open systems architecture (OSA) approach that combines business and technical objectives that yield systems with severable modules that are subject to competition. But program-centric attempts and broad mandates to implement an OSA have yet

to adequately improve life cycle affordability, enable competition or shorten fielding timelines in the aviation community. This is because achieving and assessing many life cycle characteristics such as openness are subjective and are pursued without coordination between the program offices and other stakeholders. To achieve the potential benefits of an OSA, the Army needs to apply a comprehensive, systematic approach across the aviation enterprise.

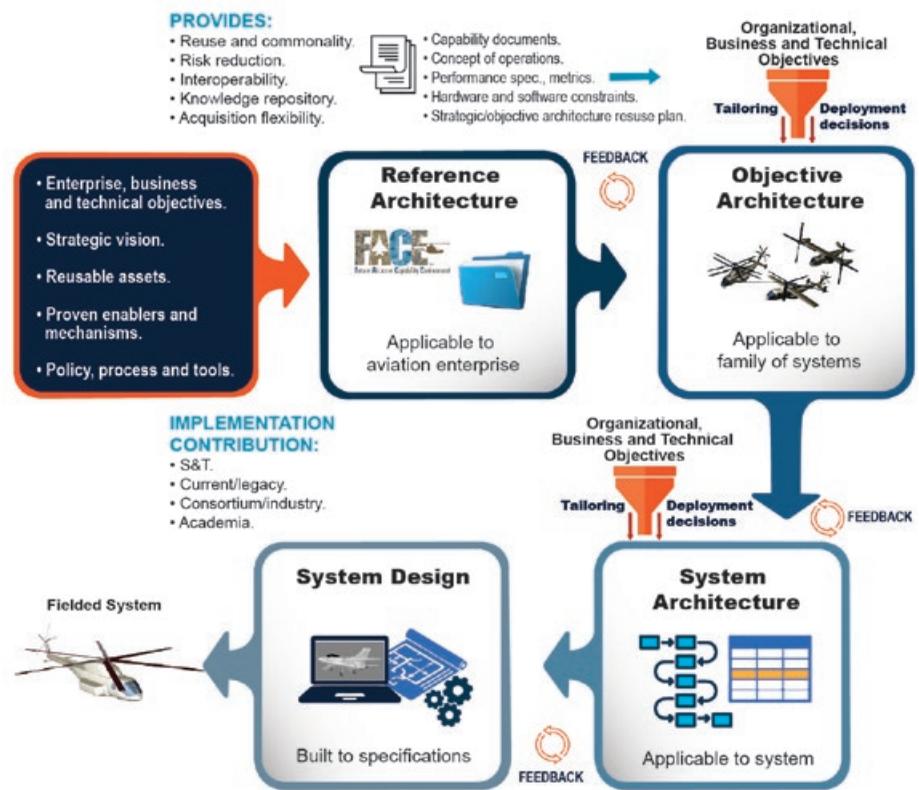
SHIFTING PERSPECTIVES

ADD is investigating an approach to prioritize the government's business and technical objectives as part of the Joint Multi-Role Technology Demonstrator (JMR-TD), a science and technology program to demonstrate transformational vertical lift capabilities to prepare DOD for decisions regarding the replacement of the current vertical lift fleet. The JMR Comprehensive Architecture Strategy (JCAS) supports efficient development and sustainment of open and interoperable aviation mission systems.

The JCAS is based on analyzing, documenting and tracing the government's business and technical goals, including key business drivers (for example, affordability, time to field, tactical overmatch, etc.), policy and processes. This analysis and documentation result in enforceable architecture requirements for aviation mission systems.

The JCAS provides a layered architectural management approach to inform and constrain subsequent development activities. It also provides enforceable, traceable requirements for future procurements to conform to explicitly stated standards, processes or practices. (See Figure 1.) It specifies a measure or verification method to prove desired characteristics or attributes. By providing traceability

FIGURE 2



THE ARCHITECTURE OF DEVELOPMENT

The three-level JCAS system was developed by AMRDEC's ADD as a way to eliminate shortcomings in the current method of acquiring avionics systems and improve cost and interoperability. JMR-TD's capstone event, planned to begin this year, will provide proof of concept. (SOURCE: AMRDEC)

of the desired attributes and the means for achieving them, the strategy will lead to systems that are designed and implemented in a specific, consistent manner to achieve enterprise goals.

The JCAS proposes three levels of architectural management: reference architecture, objective architecture and system architecture. Throughout these levels, methods exist to enable identified improvements or changes as the JCAS matures. (See Figure 2.)

The **reference architecture**, the highest level of architecture in the JCAS, is intended to guide and constrain the development of subsequent levels of architectures. The reference architecture represents strategic-level interests by combining stakeholder concerns reflecting both business and technical perspectives. Its requirements are independent of a specific solution but still support desired stakeholder objectives, such as affordability and interoperability, in a common, consistent manner.



TAKING CHARGE

A UH-60M Black Hawk helicopter, right, and a CH-47 Chinook helicopter, both from the 2nd General Support Aviation Battalion, 149th Aviation Regiment Task Force Rough Riders, land in August before inserting paratroopers from 2nd Brigade Combat Team, 82nd Airborne Division, during an aerial response force exercise at Camp Taji Military Complex in Iraq. It is in the government's best interest to develop an aviation mission systems architecture that will encourage shared capabilities. (U.S. Army photo by Capt. Stephen James, 29th Combat Aviation Battalion)

A reference architecture provides common language and terminology, guides the application of technology, supports traceability of requirements to validate future architectures and provides a method to adhere to common standards and patterns. It facilitates the development of cross-platform capabilities by constraining the ability to develop unique architectural approaches. Options within the reference architecture apply to all programs within the organization's influence and include elements such as purpose, principles and standards.

The **objective architecture** derives from the reference architecture and represents a way to identify opportunities for commonality across related programs, such as in a family of

systems. Whereas the reference architecture is an overarching set of options, the objective architecture represents the selections that meet the desired technical and business decisions for the family of systems. The objective architecture documents the tailoring and refinement by an organization to meet the missions of the related programs, as well as documentation of the methods to meet the requirements defined in the reference architecture.

At the lowest level of architectural specification is the **system architecture**, which the procuring organization develops by further refining and tailoring the objective architecture to satisfy the performance requirements of a specific system. The system architecture further guides and constrains the architectural principles and methods that the system developers may use while still adhering to the higher-level organizational objectives. Because the system architecture is focused on architectural principles, it does not prescribe the system design and implementation decisions, leaving flexibility for many potential designs.

CONCLUSION

The JMR-TD is pursuing a series of demonstrations to mature various concepts of open systems. The final event, the capstone demonstration, begins with anticipated awards in June 2018 and runs through the end of 2020. It will help mature and validate the JCAS concept by determining if multiple related programs can use the same systematic approach to architecture to achieve desired characteristics. In the long term, the requirements to achieve these characteristics, which may provide the basis for a new generation of mission systems, will be encapsulated in a best-of-breed specification that leverages the observations and learning gained through the JMR demonstrations.

Military services develop aviation mission systems from a program-centric perspective. In other words, each program is singularly responsible for satisfying its system performance requirements.



BETTER SUPPORT FOR MULTIPLE AVIATION SYSTEMS

Rows of U.S. Army 1st Air Cavalry Brigade, 1st Cavalry Division helicopters—UH-60 Black Hawks, CH-47 Chinooks, AH-64 Apaches and HH-60 Medevac Black Hawks—leave Chièvres Air Base, Belgium, for Germany, Latvia, Romania and Poland in October in support of Operation Atlantic Resolve. Aviation mission systems developed from a program-centric perspectives make component reuse across programs difficult or impossible. (U.S. Army photo by Visual Information Specialist Pierre-Etienne Courtejoie, Training Support Activity Europe)

To achieve the desired life cycle characteristics for air vehicles, the government must take a leading role in describing and specifying the architecture of its aviation mission systems. Ultimately, the JCAS is intended to be a basis for future procurements of aviation mission system capabilities, reducing the likelihood that individual programs will develop unique and difficult-to-support solutions. Such an approach will be needed to achieve and maintain capability overmatch in a rapidly changing world with ever-evolving threats.

For more information, email usarmy.redstone.rdecom-amrdec.mbx.amrdec-add@mail.mil with the subject line “AL&T Article: Strength in Architecture.”

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SMART AIRCRAFT

A drone directed by one or more Soldiers through uncontested skies is a thing of the past. Army aviation is developing collaborative and intelligent systems for manned and unmanned fleets in contested airspace.

by Mr. Kevin Kee

Future warfare will present challenges to Army aviation assets not seen since the contested airspace of World War II. Communication, navigation and command-and-control systems will be degraded and jammed, and aircraft will encounter air defense threats with new capabilities. While sobering, these challenges offer an opportunity to leverage autonomy and teaming in both manned and unmanned aircraft.

Army aviation uses a manned-unmanned teaming (MUM-T) capability first fielded in 2009. This capability provides full-motion video in an AH-64E Apache cockpit from an RQ-7 Shadow or MQ-1C Gray Eagle unmanned aircraft system (UAS). It also offers multiple levels of control of the UAS, from the ability to view and control the electro-optic payload and laser designator to remotely controlling the vehicle's flight. These systems allow the MUM-T operator to identify and fix the laser designator at targets, allowing HELLFIRE and other smart missiles to guide to and destroy the target. MUM-T is enabled by the Mini-Tactical Common Data Link, which transmits UAS or aircraft sensor video to a ground or airborne One System Remote Video Terminal. With this capability, UAS can provide reconnaissance, targeting and security to an Army brigade.



RAVEN VISION

Staff Sgt. Justin Higginbotham, a U.S. Army Reserve Soldier from the 346th Military Police Company, launches an RQ-11 Raven at Fort Riley, Kansas, in October. The Raven increases operational visibility in austere environments, helping Soldiers see the battlespace from above. (U.S. Army Reserve photo by 1st Lt. Kirk Westwood)

MANNED PLATFORMS

The MUM-T link, while providing great operational benefit, has also introduced new challenges to the manned aircraft fleet. In the AH-64E, both the pilot and the gunner must balance the needs and requirements of flying the aircraft with the operation and control of the UAS over the MUM-T link. Much like driving while talking on a cellphone, multitasking limits the effectiveness of the capability.

To address these shortcomings, the U.S. Army Research, Development and Engineering Command (RDECOM) is increasing investment in human machine interface (HMI) technologies to reduce

MUM-T workload. A touch interface, voice commands, and a head-tracker that knows where the pilot or gunner is looking are promising technologies in this area.

RDECOM is expected to reach a major milestone in its Synergistic Manned Unmanned Intelligent Teaming program, which focuses on assessing new technologies in the areas of HMI, decision aiding and autonomy as well as new ways to employ those technologies. In 2019, RDECOM will demonstrate an air mission commander that uses one crew station to manage up to eight unmanned systems to execute scout, attack and air assault missions with less workload than is required to control one UAS today.

UNMANNED PLATFORMS

Current UAS platforms have served the Army well in counterinsurgency operations by offering a durable, relatively cost-effective platform with a sensor and, on the Gray Eagle, HELLFIRE missiles. In Iraq and Afghanistan, these unmanned platforms are able to circle high above the battlespace, providing continuous information to the commander. In the future, however, such uncontested environments are likely to be the exception. Current UAS platforms require a runway for operations, and their limited airspeed means that they must be operated from many locations to provide the coverage required, requiring many more platforms and infrastructure to support operations.

The rise of UAS platforms has also led countries all over the world, including the U.S., to develop counter-UAS systems. These systems vary but generally have the ability to jam or degrade data links and GPS signals, or to simply shoot down the UAS. Commercial UAS platforms have been hacked numerous times, degrading the platform, so this possibility must be considered for any existing or future Army UAS.

These factors are driving a need to develop new UAS platforms that balance endurance with greater speed and range. Most important is the ability for the UAS to operate independently of a runway, so that a division or brigade does not have to depend on a fixed air base. RDECOM is exploring these platform configurations and developing ways to increase survivability while driving down cost. The rapidly growing commercial industry offers new opportunities to team and leverage commercial advances.



CONTROLLING CONTROLS

Currently fielded teaming capability provides the crew of an AH-64E Apache with full-motion video and multiple levels for controlling a UAS while balancing the demands of flying the aircraft. (Image courtesy of AMRDEC)

A NEW DOG IN THE FIGHT

The combination of new UAS designs and HMI technologies enables the next level of MUM-T capability: true teamed operations. Current MUM-T missions involve many Soldiers, including the pilot, the MUM-T controller and ground control station operators. All of these Soldiers must coordinate and hand over control of individual UAS platforms while coordinating with other aircraft on the mission. But the Army could take a lesson from game hunters to streamline this manpower-intensive process. Every game hunter knows the value of using a hunting dog or a bird dog to find prey or retrieve game, and this relationship between hunter and dog provides a model for what true teaming should be.

The operational concept can be as simple as the pilot directing the UAS to provide reconnaissance of a particular area, so that the UAS—like the bird dog—would travel to the objective without continuous monitoring. A much more complicated MUM-T mission could involve multiple UAS platforms and manned platforms locating and tracking a target and then maneuvering to engage and destroy it.

This complex coordination of manned and unmanned platforms is enabled by RDECOM investment in airspace command-and-control systems that can translate a high-level group command—to scan an area, for example—into specific orders for each aircraft. Additionally, the system must have a self-healing capability to rapidly determine whether a UAS has to return to base or is destroyed and would, as a result, require a manned or unmanned platform to continue its task. These future MUM-T systems also would enable ground commanders to assign tasks directly to air platforms, demonstrating a new level of combined arms coordination.

AUTONOMOUS OPERATIONS

The ultimate goal of air systems is fully autonomous operation for all aviation mission sets. Already RDECOM has demonstrated an autonomous cargo delivery system called Autonomous Technologies for Unmanned Aerial Systems (ATUAS). In December 2011, it became the first aerial system to deliver cargo in theater, for the U.S. Marine Corps. Two aircraft deployed for a six-month demonstration period that was extended to 2 1/2 years. RDECOM is building upon this success to explore autonomous operations for other aviation missions.

Fully autonomous operations are less vulnerable to data-link jamming since an autonomous vehicle can act on its own, given initial commands from an operator, and does not require



MOVING IN THE RIGHT DIRECTION

Current large UAS platforms like this Gray Eagle provide important capabilities but need a runway to take off. These systems also have lower airspeeds and depend on data links and GPS signals. Future systems will need to be more independent to operate in a complex battlespace. (Image courtesy of AMRDEC)

constant updates. When fully realized as a swarm, this capability provides an operational benefit greater than what manned aviation could provide alone. These benefits come with the added challenge of platform complexity, however. Manned aircraft and human pilots have the ability to adapt to any condition on the battlefield, including system failures, changes in weather conditions and adjusting the mission based on new information. An autonomous or artificial intelligence pilot requires programming to exhibit these humanlike behaviors to provide the same flexibility. Additionally, starting in 2019, RDECOM will explore autonomous reconnaissance and target acquisition in complex environments where the enemy is hidden or camouflaged.

Any autonomous system has to interface with a Soldier at some point, and this is another technology focus. The automotive industry provides some examples and recommendations as it develops similar standards. Imagine, in the not-too-distant future, sitting in the driver's seat of an

autonomous car watching a movie and not having to pay attention to the road. If you were fully engrossed in the movie, it would be very difficult to take control of the car if the auto-steering system suddenly disengaged. You would need even more notice if you were traveling on curvy roads during icy weather. And how would such a system operate if the car were struck by lightning? The Army needs to explore the same issues and develop systems that can degrade gracefully—slowing and landing an aircraft in a safe area, for example, as soon as the autopilot starts failing.

Current aircraft undergo block upgrades to modify hardware and software to improve performance and capability. The software of any weapon system is underpinned by system architectures, which are traditionally difficult to modify or upgrade. Much research is being done in this area, but for future air systems, what's needed is development of open system architectures that are designed to make adding, upgrading and swapping

components easy. For an autonomous system, the use of machine learning, the continuing pace of commercial and government research, and upgrades to the autonomy system from operations are going to stress the traditional block upgrade scheme. Similar to smartphones,

In Iraq and Afghanistan, these unmanned platforms are able to circle high above the battlespace, providing continuous information to the commander. In the future, however, such uncontested environments are likely to be the exception.

PICKUP AND DELIVERY

AMRDEC’s Aviation Development Directorate (ADD) conducts autonomous dual-lift operations with two RMAX UAS carrying a 20-pound payload through a set of hover and low-speed maneuvers at Moffett Federal Airfield, California, in September. The helicopters are an autonomous flight resource developed by ADD and have been used for numerous flight experiments since 2002. (U.S. Army photo)



the autonomous UAS of the future will require the ability to securely update and obtain the latest security patches and algorithm updates.

Last—but most important for any autonomous system—is trust. Global investment in autonomy and artificial intelligence is massive and growing every year, and new technologies appear frequently. The specific technologies required to demonstrate an autonomous system are not completely understood yet, but it is likely that the algorithms will exhibit learning behavior.

For a Soldier to fully trust an autonomous system requires a thorough understanding of the system design and its behavior at any point. The operational requirement for the system, however, will require more flexibility and more humanlike behavior to truly provide operational benefit. It is important to balance these two demands, both to ensure safety and to provide trust in the system.

CONCLUSION

Developing the future of collaborative and intelligent air systems involves continually balancing investment priorities in MUM-T and its enablers. Investment and innovation will occur throughout the joint community, industry and academia, and the Army must be ready to adjust investment in response to

these external sources. Especially important is coordination in the DOD Autonomy and Air Platform Communities of Interest to leverage investments and share knowledge.

RDECOM has already had success in demonstrations of the ATUAS cargo delivery system and technologies that will lead to the fielding of MUM-T. Over the next decade, the organization will build upon this success to develop and demonstrate new UAS platforms, autonomy and teaming technologies. This will culminate in a series of demonstrations to highlight the capability and its benefit to the Army. Overall, RDECOM’s focus in this area will ensure that the Army’s manned and unmanned aircraft are ready to overmatch any potential adversary.

For more information about AMRDEC, part of the RDECOM, go to <https://www.amrdec.army.mil/> or contact usarmy.redstone.rdecom-amrdec.mbx.pao@mail.mil.

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KEEPING AIRCRAFT IN THE FIGHT

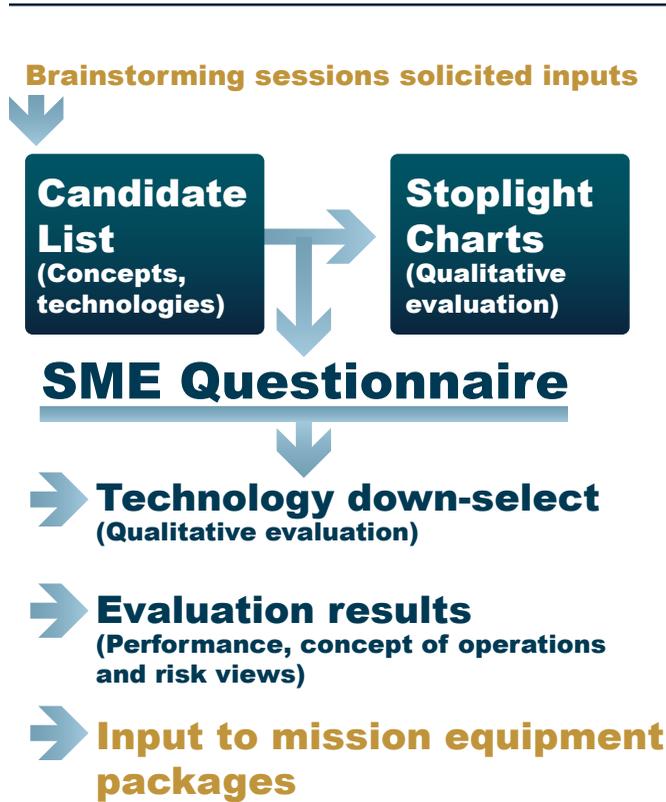
Working group identifies new suite of technologies to boost aircraft survivability.

by Mr. Mark Calafut

U.S. Army aviation faces a diverse threat environment, spanning broad categories of threats from ballistic munitions and guided missiles to directed energy and cyber weapons. It also spans generations of technology, ranging from constantly evolving sophisticated systems to widely proliferated legacy equipment. The modern threat environment presents both a technical challenge and a moving target to Army aviation. Historically, the science and technology (S&T) community has played an important role in developing advanced technologies to outpace the evolution of the threat. In an increasingly challenging threat environment, S&T is now even more critical.

This has driven the S&T community not only to begin developing nontraditional technologies for advanced protection, but also to establish new practices and processes to evaluate them. In May 2016, the U.S. Army Communications-Electronics Research, Development and Engineering Center (CERDEC) and the U.S. Army Aviation and Missile Research, Development and Engineering Center (AMRDEC) jointly formed an advanced protection working group to answer key questions for Army aviation. In its first year, the goal of the advanced protection working group was to identify the best technologies to protect the future force. The working group began its analysis from the

FIGURE 1



PROCESS OF PROCESSES

The working group performed market research, conducted technology surveys and talked with SMEs before identifying 160 promising technologies. The list was narrowed to 70 unique technologies for formal evaluation after review. (SOURCE: CERDEC)

fundamental premise that there is no “silver bullet” technology capable of addressing all future threats and operational scenarios. Instead, the solution for future aircraft survivability would be a range of technologies to avoid, detect and defeat the emerging threat. This group would identify that solution.

CERDEC and AMRDEC structured the working group to include both breadth and depth of technical knowledge, as well as to engage with the intelligence, requirements and acquisition communities. The core team of the working group was responsible for performing technical analysis and developing the group’s recommendations. The team was composed of technical experts from within CERDEC and AMRDEC, as well as from the U.S. Army Research Laboratory, the U.S. Army Armament Research, Development and Engineering Center, the Institute for Defense

Analyses and Massachusetts Institute of Technology’s Lincoln Laboratory. The core team also regularly consulted with subject matter experts (SMEs) from other government and academic organizations, such as the Defense Advanced Research Projects Agency and the Air Force Research Laboratory. To ensure that the technical analysis was performed in the broader context and to facilitate engagement with the stakeholder community, the group also included representatives from the intelligence, requirements and acquisition communities.

The advanced protection working group began by adapting proven system engineering processes that are measurable and repeatable into a standardized method to evaluate technology. The group used this method to determine the performance of technologies with respect to classes of threats rather than with respect to any individual threat. This approach was intentionally designed to identify technologies whose capabilities span multiple threats and provide broad protection.

To ensure that all technical options were considered, the working group performed market research, conducted technology surveys and initiated discussions with SMEs. The working group initially identified 160 technologies; after review, it narrowed this list to 70 unique technologies for formal evaluation. These technologies include advanced sensors, defensive electronic attack capabilities and signature reduction technologies. A quantitative methodology enabled the working group to perform sensitivity analysis and assess the specific benefits and risks associated with each potential technology (See Figure 1).

DISPARATE TECHNOLOGIES

Technology evaluation was inherently challenging across this wide range of disparate technologies. The working group categorized the 70 technologies into several subareas, including topics

The agreement on a common road map also has driven participating organizations to alter their planned S&T investments and more closely coordinate development efforts into common programs.

FIGURE 2



GETTING AT THE CORE OF THE PROBLEM

Technical experts from across an array of disciplines and research organizations make up the working group’s core team. They work to generate solutions to challenging S&T problems. (SOURCE: CERDEC)

such as aircraft survivability equipment (ASE)—electronic systems to detect and defeat threats—and vulnerability reduction—technologies to reduce the damage a threat delivers to the aircraft and crew (See Figure 2.). To minimize subjectivity in the analysis, the working group established a process of processes, where each of these technology subareas was evaluated with a process appropriate for its characteristics and technical maturity. For example, in the area of ASE, there are experimental data and established

modeling and simulation (M&S) tools available from across DOD. For many ASE technologies, including traditional electronic support sensors and electronic attack countermeasures, it was appropriate to use historical data or M&S tools to assess performance. In contrast, in the area of nontraditional susceptibility reduction (NTSR), the working group was specifically looking for unconventional concepts that had not been previously considered for the survivability application. The NTSR assessment

included technology options ranging from wild ideas that push the limits of the possible to proven components adapted from different applications. In many cases, NTSR technologies did not have appropriate M&S tools to support an assessment similar to the one conducted for ASE. Therefore, a unique assessment was developed specifically for the NTSR subarea. This process included an initial technology assessment followed by a selection process performed through structured SME assessment. To maximize objectivity, each technology was assessed by experts from different backgrounds to obtain multiple data points and provide a full perspective.

Overall, the working group engaged more than 15 SMEs to assess the 70 technologies. The experts evaluated each technology according to the process for its technology area and assigned a numerical value to its performance. They also provided confidence representing the body of evidence behind the performance value. In the next step, stakeholders developed weights for each evaluation criterion based on priority, and the working group calculated a normalized composite score for each technology. This score represents a concise estimate of the relative performance of each technology.

After assessing the technologies individually, the working group determined the optimal suite of technologies. The working group envisioned a spectrum of technologies integrated into a layered survivability suite. When a threat is encountered, the survivability suite autonomously employs appropriate technologies throughout the tactical timeline to maximize survivability. This concept makes the most effective use of each technology available to defeat the threat given the unique parameters of an engagement. The working group systematically



SEEKING SURVIVABILITY

Infantrymen with 3rd Armored Brigade Combat Team ("Iron Brigade"), 4th Infantry Division (3-4 ABCT), conduct an air assault in August with 3rd General Support Aviation Battalion, 10th Combat Aviation Brigade during the U.S. Army Europe Combined Resolve IX exercise at Grafenwoehr Training Area, Germany. Army S&T is pursuing aircraft survivability technologies across a spectrum of technologies and areas of expertise. (U.S. Army photo by Capt. Scott Walters, 3-4 ABCT)

combined the highest-scoring technologies and considered technology dependencies to create candidate technology suites. The more threat characteristics that a technology suite addressed and the higher the priority of those characteristics, the greater the protection capability of the suite. Finally, the working group went beyond performance and considered the potential multi-functional applications of the suite and calculated the platform's size, weight and power requirements. The working group then agreed on a recommended technology suite for future survivability. The group will use these processes to refresh its technical solution and road map every three years, or more frequently if events drive a significant change in the threat picture or the state of technology.

10-YEAR ROAD MAP

The last step was the creation of a common 10-year technology development road map. The agreement on a common road map also has driven participating organizations to alter their planned S&T investments and more closely coordinate development efforts into common programs. This includes cross-cutting S&T areas that will require the joint attention of multiple laboratories, on topics such as M&S, power generation and storage, and common architectures that enable compatibility and data exchange. The road map was designed to include the development of enabling technologies with broad applicability, as well as more targeted efforts specifically designed to invest in identified S&T gaps.

To balance and manage risk, the road map includes critical decision points. Often, potential leap-ahead technologies are technically immature and high-risk. For these elements, the road map includes one or more critical decision points, where the result of technical analysis or a technology maturity assessment determines whether investment should continue. This allows the S&T community to contribute to Army aviation by providing new advanced technologies as well as by determining the practical viability of potential leap-ahead technology paths.

The working group completed its first phase of analysis in July and has established the common objectives and decision points for the S&T community. Over the coming months, the group will present its results and recommendations to Army leadership for review and concurrence.

CONCLUSION

The advanced protection working group already has led to several major benefits for the S&T community. Foremost among these is the repeatable process it has established to assess a broad portfolio of technologies together and in an objective manner. This facilitates the development of common S&T programs



FACE THE THREAT

Helicopters from 1st Battalion, 3rd Aviation Regiment, 12th Combat Aviation Brigade (CAB), depart Katterbach Army Airfield, Germany, in June bound for Cincu Training Area, Romania, for Exercise Noble Jump 17. U.S. Army S&T plays a critical role in developing advanced technologies to help Army aviation take on diverse threats. (U.S. Army photo by Capt. Jaymon Bell, 12th CAB Public Affairs)

and demonstrations, improves targeting of investments and return on investment, and documents the contribution of each technology to the larger solution. Overall, the activities of the advanced protection working group demonstrate that S&T is about much more than technology: It's about creating and using balanced

processes to help the Army identify cross-domain solutions to its most challenging problems.

For more information or to contact the author, go to www.cerdec.army.mil.

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The working group categorized the 70 technologies into several subareas, including aircraft survivability equipment—electronic systems to detect and defeat threats—and vulnerability reduction—technologies to reduce the damage a threat delivers to the aircraft and crew.



TOMORROW'S COMMAND POST

The Missouri Army National Guard's 35th Aviation Brigade sets up a command post under the Milky Way in May 2017 at the National Training Center (NTC), Fort Irwin, California, in support of the 155th Armored Brigade Combat Team's NTC rotation. Army S&T investments will support mobile, scalable, tailorable command posts through servers, infrastructure and vehicle and equipment packages. (Mississippi National Guard photo by Staff Sgt. Tim Morgan, 102nd Public Affairs Detachment)



NETWORK C3I

Targeted S&T supports new directions in network modernization by focusing on command, control, communications and intelligence capabilities for expeditionary operations featuring active electronic warfare.

by Ms. Nora Pasion

Army senior leaders have identified network command, control, communications and intelligence (C3I) as one of the Army's six modernization priorities. Consistent with guidance from the chief of staff of the Army (CSA), the Army will move away from the existing network modernization path that lacked survivability, effectiveness, interoperability and suitability, and toward an expeditionary network enabling the Army to fight and win in all environments and against all enemies. To support this way forward, the Mission Command Network Modernization Implementation Plan will drive the development of the future Army network through four lines of effort (LOEs):

1. Unified network.
2. Common Operating Environment.
3. Joint and coalition interoperability.
4. Survivability and mobility of command posts.

The Network Modernization Implementation Plan defines each LOE in support of the CSA's intent. LOE 1, unified network, will address unified transport

and the supporting network enablers to provide assured network transport in a contested and congested environment. The second LOE, Common Operating Environment (COE), will focus on integrating the Joint Information Environment (JIE) and the associated applications that support commanders and leaders at echelon.

LOE 3 addresses interoperability in both JIE and mission partner environments, and supports the overall COE. Lastly, LOE 4 addresses the mobility and survivability of command posts (CPs), focusing on the capabilities that enable combat formations to conduct distributed mission command in an increasingly contested and congested environment against a peer adversary. This plan is grounded in the CSA's first principles of modernizing to achieve critical operational requirements.

To provide warfighters with the necessary equipment to support the CSA's modernization objectives, the Army

is investing in science and technology (S&T) in the following network C3I and enabling areas: tactical communications and networking; assured positioning, navigation and timing (PNT); electronic warfare (EW); and cyber-electromagnetic activities (CEMA); mission command applications; persistent intelligence, surveillance and reconnaissance (ISR); and command post.

Following this article are three articles addressing select S&T concepts and research that support the network C3I portfolio across the near term (through 2025), midterm (2026-2035) and far term (beyond 2035): sensing in complex and congested environments; future Army Networks; and novel distributed processing approaches.

TACTICAL COMMUNICATIONS AND NETWORKING

To ensure information dominance on the battlefield, the Army's tactical network must provide assured communications in

contested, congested and degraded environments. This supports communications at the point of need and enables timely, decisive action. Army S&T investments are addressing these challenges through the research and development of automated and intelligent networks, anti-jam voice and data, autonomous platform communications, spectrum situational awareness (SA) and high-bandwidth commercial technologies.

ASSURED PNT

Unified land operations in multidomain environments require Army forces to access and integrate capabilities across space, cyber and EW domains to gain and maintain PNT superiority in support of joint operations. Transmission platforms that support unified land operations with unified action partners (or, "military forces, governmental and nongovernmental organizations, and elements of the private sector with whom U.S. Army forces plan, coordinate, synchronize, and integrate during the conduct of

WEEDING OUT DIFFERENCES

Sgt. Joshua Burnette of 1st Stryker Brigade Combat Team, 25th Infantry Division instructs a member of his squad during Exercise Orient Shield 2017 at Camp Fuji, Japan, in September. The exercise is designed in part to enhance U.S. and Japanese combat readiness and interoperability at the tactical level, which is also a focus of S&T efforts for C3I. (U.S. Navy photo by Mass Communication Specialist 2nd Class Christopher Lange)



WHAT'S ON THE HORIZON?

An Expeditionary CEMA Team member surveys the battlefield near the mock city of Razish at the NTC in May as part of a training rotation for the 2nd Armored Brigade Combat Team, 1st Infantry Division under the CEMA Support to Corps and Below Initiative. Led by the U.S. Army Cyber Command (ARCYBER), the initiative started as a pilot to explore cyberspace capabilities and doctrine, and grew to encompass the integration of cyber with warfighting disciplines such as EW, information operations, intelligence and network operations. (U.S. Army photo by Bill Roche, ARCYBER)



operations," according to Army Doctrine Reference Publication 3-0, "Unified Land Operations") must be assured and secure to deliver on-time situational awareness that allows operational units to act quickly and outmaneuver adversaries.

U.S. forces need the ability to prevent, degrade, eliminate and mitigate threats aimed at joint unified land operations while preserving friendly freedom of movement and action. S&T investments provide technologies that enable monitoring and control of the navigation warfare environment. Supported capabilities include electronic protection, support and attack; denying PNT capabilities to adversaries; and demonstrating quantum-based, GPS-independent, ultra-high precision PNT in any environment. Other research efforts include developing modular GPS-independent sensors, open architecture sensor fusion capability and leading DOD's PNT modeling and simulation collaborative initiative.

ELECTRONIC WARFARE

EW provides an advantage over the adversary by enabling forces in operational

areas to conduct electronic attack (EA), EW support (ES) and electronic protection (EP), in combination with other tactics. Army S&T investments are providing EW technologies for the mid and far term to enable ES, EA and SA through the foreseeable future. Research efforts are also producing standards-based, multifunction platforms in support of the Army EW strategy for unified land operations in 2025 and beyond.

CYBER-ELECTROMAGNETIC ACTIVITIES

Technologies are needed that harden critical network and weapon systems and protect these vital assets from emerging cyber threats as well as those that exploit the electromagnetic spectrum. These S&T investments deliver technologies that enable the resilience to fight through an attack and to acquire SA by leveraging tactical assets. These investments are expected to provide rapid access and effects to gain an advantage over adversaries.

Research efforts are also developing system architectures that support a

warfighting network platform in order to increase interoperability across operational domains, decrease the burden of training and enable the tactical delivery of cyber-electromagnetic effects.

MISSION COMMAND APPLICATIONS

Mission command applications must rapidly correlate and integrate data into useful information, enable rapid and accurate SA and reduce the number of Soldiers required for command post operations. Key capabilities include a common operating picture and awareness of cyberspace and the electromagnetic spectrum, which support commanders and leaders at all echelons and enable all warfighting functions.

Army S&T investments are delivering decision-support tools that implement standardized digital plans, model-based decision tools, automated sensor feed discovery, predictive visualization and machine learning to improve Soldier understanding, response time and accuracy, regardless of the tempo of operations.

DATA TRANSFER DUTY

Combat Cameraman Spc. Christopher Bellafant tests a data transmission system as part of tactical digital media training at Aberdeen Proving Ground, Maryland, in October. Army S&T investments in network modernization are focused on expeditionary, mobile and agile capabilities that increase combat effectiveness and improve decision-making and targeting. (U.S. Army photo by Dan Lafontaine, Program Executive Office for Command, Control and Communications – Tactical)



PERSISTENT ISR

To overcome range limitations and deliver accurate long-range precision and area fires, Army S&T provides capabilities that enable assured maneuverability through continuous battlespace SA. Enhanced SA reduces tactical surprise and prevents detection. Additionally, these assets increase the probability of target acquisition and deliberate operational engagement to defeat adversaries in an attack. S&T investments in this area include affordable, precision, standoff target identification and geolocation capabilities for mounted and dismounted Soldiers.

These programs are intended to assure speed and protection for ground forces. Complementary investments will include autonomous sensing of potential threats, sensor interoperability, multifunctional sensing, automatic target acquisition and data processing and synthesizing for Soldiers and units to employ for exploiting and disseminating information.

COMMAND POSTS

CPs enable commanders and their staff to visualize, comprehend, direct and synchronize operations continuously in all phases of unified land operations. CPs must enable units to conduct distributed operational mission command ranging from while en route to a crisis, during early entry to major combat operation and while rapidly integrating warfighting functions.

These CP capabilities are necessary to facilitate planning, collaboration and synchronized unified land operations with unified action partners, while reducing electronic and physical signatures to prevent hostile detection and targeting from enemy fires. Additionally, CP infrastructure must be deployable, mobile and survivable in a fast-paced, lethal fight. Army S&T investments will support a mobile, scalable and tailorable CP with improvements to CP infrastructure (including servers),

power generation systems, vehicle and equipment packages, and other enabling technologies.

CONCLUSION

Focused network modernization is critical to achieve the Army’s desire to fight and win in any environment against any foe. In support of the Army’s top modernization priorities, Army S&T develops network C3I and enabling technologies in tactical communications and networking; assured PNT; EW; cyber-electromagnetic activities; mission command applications; persistent ISR; and CP technologies.

Collectively, these technologies enable expeditionary, mobile, agile, survivable, situationally aware and interoperable capabilities that increase combat effectiveness and improve decision-making and targeting in future conflicts. To enable the Army to execute the conduct of war and remain prepared for war, these efforts are critical to aligning modernization efforts with the Army’s first principles.

For more information, go to <https://www.army.mil/asaalt>.

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COMPLEX ENVIRONMENTS CALL FOR BETTER SENSORS

Or multiple sensors that work better together.

*by Dr. Richard Nabors, Dr. Donald A. Reago Jr.
and Mr. Nathan Burkholder*

“**W**ar is the realm of uncertainty; three quarters of the factors on which action in war is based are wrapped in a fog of greater or lesser uncertainty,” wrote Carl von Clausewitz in his 1832 treatise “On War.” The dictum still holds for modern warfare. Confusion, chance, chaos and resistance are as much factors in modern warfare as they were in Napoleonic times. Weather and terrain, misunderstandings and inaccurate intelligence, a creative and adaptive enemy and a civilian population in the battleground are just a few of the contributors to the “fog of war” that have always challenged the warfighter.

However, modern warfare is becoming dramatically different from warfare in the past, with multiple, shifting players operating within complex, dynamic environments. At the Oct. 4, 2016, Association of the United States Army’s annual Eisenhower Luncheon, Gen. Mark A. Milley, Army chief of staff, warned that “we are on the cusp of a fundamental change in the character of ground warfare. Land-based forces now are going to have to penetrate denied areas to facilitate air and naval forces,” Milley said. “This is the exact opposite of what we have done for the last 70 years, where air and naval forces have enabled ground forces.” The nature, location or duration of the next conflict cannot be predicted accurately. With continually changing coalitions, alliances, partnerships and actors, the operational environment has become extremely multifaceted and fluid. No longer a battlefield, the complex operational environment has become a battlespace—jungle, forest, city, desert, arctic and cyber—where the enemy is already entrenched and knows the operational environment.



EYES UP

Sgt. Luciano Batista, left, and Sgt. Michael Hughes react to a simulated attack at the 2017 U.S. Army Reserve Best Warrior Competition at Fort Bragg, North Carolina, in June. Several Army working groups are looking at ways to field better sensing technologies that will help Soldiers react faster and more accurately. (U.S. Army Reserve photo by Sgt. David Turner)



BEYOND NIGHT VISION

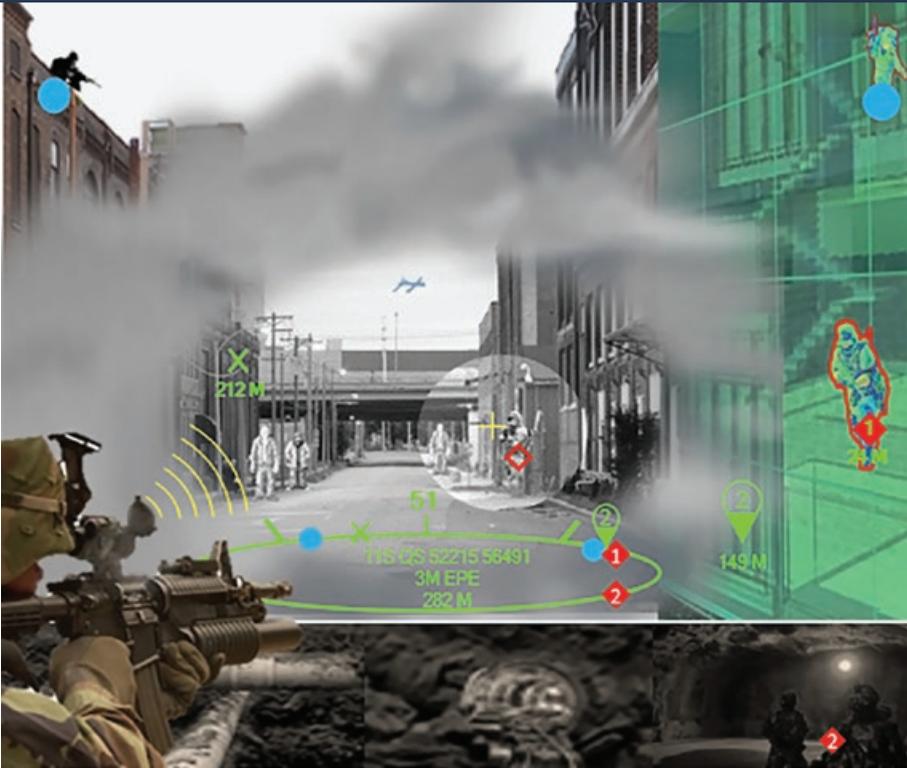
A Soldier assigned to the 3rd Brigade Combat Team, 82nd Airborne Division watches as troops move to cover while clearing buildings as part of a deployment readiness exercise, Panther Storm, at Fort Bragg, North Carolina, in August. Night vision and other advanced sensing technologies have given U.S. forces a strong advantage, but the complex, dense environment where future conflicts are likely to be fought reduces that advantage considerably. (U.S. Air Force photo by Staff Sgt. Andrew Lee)

NECESSARY UPGRADES, TECHNICAL CHALLENGES

Military technology combined with superior training and the unmatched excellence of our Soldiers has given the U.S. military significant means of reducing the fog of war, leading to decades of overmatch. For example, the U.S. military's ability to "own the night" through night-vision technologies has provided 40 years of military dominance over both near-peer and hybrid threats. The volatile and complex environments of tomorrow will require a move from owning the night to owning the environment. Improvements in sensing that extend beyond simple awareness of activities concealed by darkness is an imperative.

Complex and congested environments level the field between the United States and its adversaries by reducing standoff and line-of-sight advantages. Expected advances in Army sensing capabilities will directly address operational vulnerabilities in future environments, including intelligence, surveillance and reconnaissance (ISR) by a concealed enemy, and poor visibility and short lines of sight against positioned and moving threats in urban environments. These needed advances will buy back the field of view lost to clutter, and reinforce and expand small units' ability to sense the adversary across modalities (maneuver, surveillance, targeting, engagement, etc.). They also will provide the small unit with an understanding of the operational environment that the adversary lacks. These sensors will provide local ISR by collecting, sorting and fusing real-time data and sending it to the point of need, significantly reducing the fog of war.

These changes will restore the military advantages that the United States has had in employing the movement and maneuver functions necessary for successful



NEW ENVIRONMENT

Though the Army has fought in urban areas before, it's not just the density of a city that challenges scientists designing the sensor equipment to help Soldiers navigate future operating environments. The electromagnetic spectrum, where communications and navigation information flow, is also more crowded, and jamming, denial and disinformation campaigns will clog and obscure the battlespace. (U.S. Army graphic by Sonya Beckett, CERDEC NVESD)

land warfare. If the United States is going to maintain its historic advantages, then it will need continued, sustained investments to nurture the technology development required to maintain overmatch capabilities. Some of the technical challenges we will need to address to secure this future include:

- Fusion of disparate sensors into a combined capability.
- Tactical computing resources.
- Network connectivity and bandwidth.
- Sensor suitability for environmental observation.
- Reduced power requirements.
- Tailored, individual mechanisms through “sensored” Soldiers.
- Disguised unmanned systems to gather and communicate intelligence.

CONCLUSION

The Army has several groups working to identify and assess innovative concepts that could provide a significant advantage to U.S. forces and their partners in complex environments. Enhancing human vision beyond traditional night-vision

technologies, integrating computers into sensing systems to detect and identify items of interest in real time, using augmented reality to overlay computer vision with human vision and fusing data together from multiple sensor sources to provide a comprehensive understanding, will allow Soldiers to make better, faster decisions while operating in complex environments against a resolute and adaptive enemy. Because network coverage in these future environments will be volatile and intermittent, it is important for these sensors to be able to work autonomously to support local operations as well as converge and diverge as needed.

Many science and technology (S&T) labs and centers within the Army, including the U.S. Army Communications-Electronics Research, Development and Engineering Center (CERDEC) and the U.S. Army Research Laboratory, are working on programs of significant impact in bringing needed sensing capabilities to our Soldiers. Army S&T is dedicated to investing heavily in technology areas that support our Soldiers’

constant situational understanding of the battlespace.

“On the future battlefield, if you stay in one place longer than two or three hours, you will be dead,” Gen. Milley said at the Eisenhower Luncheon. In the future, there will be no clear front line, no secure supply lines, no large bases. Small units will be on their own, far from friendly forces, in constant motion to avoid detection and targeting by enemy forces. The most valuable asset and advantage of the U.S. military, as Milley said, is that Americans are improvisers, innovators and problem-solvers with the initiative to act independently. Equipped with the best technology in sensing, weaponry and defense, Soldiers will be empowered to adapt to changes in real time in spite of a complex and congested operational environment. Continued technology improvements will ensure future success and overmatch.

The Army must be effective across the entire spectrum of conflict. To do so requires understanding the operational



THE FOG OF WAR

Soldiers assigned to 2nd Armored Brigade Combat Team, 1st Armored Division conduct sentry duty in August during Decisive Action Rotation 17-08 at the National Training Center, Fort Irwin, California. The battlespace where modern wars will be fought layers new sources of uncertainty and confusion on top of the factors that already produce the fog of war. (U.S. Army photo by Spc. Dedrick Johnson, Fort Irwin Operations Group)

No longer a battlefield, the complex operational environment has become a battlespace — jungle, forest, city, desert, arctic and cyber — where the enemy is already entrenched and knows the operational environment.

environment and how Soldiers and units accomplish missions. In complex environments, the gathering and fusion of information lead to greater understanding. Improved sensors, remote and near, manned and unmanned, can both save Soldiers' lives and make them more lethal.

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SENSOR OVERLOAD

An S&T objective looks to 'ExpED'ite and improve processing and exploitation of the avalanche of raw intelligence data.

by Mr. Michael Pellicano and Ms. Danielle Duff

At the tactical level, a commander depends on the depiction of accurate and timely battlefield situational understanding on the common operating picture (COP) to support the decision-making process. This picture is directly influenced by intelligence analysts using an institutionalized workflow called tasking, collection, processing, exploitation and dissemination, which turns raw intelligence data into actionable intelligence that is then fed into the COP.

Over the previous decade, driven by the demands of war and technological advances, significant enhancements in the capabilities of sensors and collection platforms have led to collection systems that generate extraordinarily large amounts of data, which has the potential to provide a rich and more accurate understanding of the battlefield. Unfortunately, the wealth of data overwhelms analysts' ability to turn it into actionable intelligence. To put this in perspective, William M. Arkin writes in his book "Unmanned: Drones, Data, and the Illusion of Perfect Warfare," that "the amount of visual data collected each day [is] five seasons' worth of every professional football game played—thousands upon thousands of hours."

But drones are just one of the many sensors on the battlefield. Arkin notes that "the next generation of wide-area motion imagery sensors will be capable of collecting 2.2 petabytes per day, bringing 450 percent more data into the network than all of Facebook adds on a typical day." As a result, data is left unprocessed,

unexploited and unavailable for future analysis. This inefficiency leads to gaps in situational awareness and sometimes duplicative collections.

The Defense Science Board in February 2011 came to a similar conclusion, stating: “[T]he rapid increase of collected data will not be operationally useful without the ability to store, process, exploit, and disseminate this data. ... Current collection

generates data that greatly exceeds the ability to organize, store, and process it.” There are not, and never will be, enough analysts to review the massive amount of raw intelligence collected on the battlefield.

To complicate this already difficult problem, the Army is consolidating analytic personnel, setting up centralized sites outside of conflict zones where specialized Soldiers can support operations by focusing on exploiting sensor data. However, legacy systems were not designed to move this amount of data across the network or support the collaborative analyst workflows needed to support decentralized processing, exploitation and dissemination (PED).

The Intelligence and Information Warfare Directorate of the U.S. Army Communications-Electronics Research, Development and Engineering Center (CERDEC), a subordinate organization of U.S. Army Materiel Command’s Research, Development and Engineering Command, initiated the Extensible Processing Exploitation and Dissemination (ExPED) Science and Technology Objective (STO) in October 2016 to improve the process of converting raw sensor data into usable situational understanding. A STO is a three- to five-year critical science and technology (S&T) project that has direct oversight from the Warfighter Technical Council, a one-star-level governing body that addresses strategic program topics, recommending and reviewing major new S&T investment efforts. The STO comprises several research focus areas combined under one program to work collaboratively on high-priority Army capability gaps, which for ExPED is “developing situational understanding.”

The program title, ExPED or Extensible PED, refers to the desired capability to adapt Army PED operations based on mission needs and available resources such as sensors, computers and human analysts. Under optimal conditions, tactically deployed intelligence analysts will develop and refine the intelligence COP by combining data from multiple organic and strategic sensors with the help of advanced processing resources and subject matter experts who may be distributed around the world. The tools used to perform PED must support these distributed workflows and also adapt to more constrained conditions where networks or limited timelines don’t allow for an enterprise solution.

The ExPED effort began with an intensive effort to analyze and study the PED process, by observing and interviewing analysts to determine what architectures, systems and sensors exist in the tactical environment and how these capabilities



GATHERING INTEL—THEN WHAT?

A Soldier with the Regimental Engineer Squadron, 2nd Cavalry Regiment assembles an RQ-11 Raven unmanned aerial vehicle during a surveillance mission in May during Saber Junction 17 at the Hohenfels Training Area, Germany. Saber Junction is designed to assess the readiness of the regiment, which is assigned to U.S. Army Europe (USAREUR), to conduct unified land operations, with an emphasis on operational and tactical decision-making, among other skills. The collection, analysis and dissemination of intelligence play an indispensable role in accurate, timely decision-making in combat. (U.S. Army photo by Spc. William Marlow, Viper Combat Camera Team, USAREUR)



ALL TOGETHER NOW

An AH-64 Apache attack helicopter provides security while CH-47 Chinooks drop off supplies to Soldiers with Task Force Iron at Bost Airfield, Afghanistan, in June 2017. The Soldiers' mission is to provide accurate fires capabilities in support of Task Force Southwest and Afghan national defense and security forces during current operations. One of the objectives of the ExPED STO is to identify sensor solutions with scalable open architectures that will adapt to the echelon in which they will operate in a tactical environment, thus facilitating integration with other ISR systems and the sharing of valuable information using the proper security boundaries. (U.S. Marine Corps photo by Sgt. Justin T. Updegraff, Resolute Support Headquarters)

are used to create intelligence products. The program then created a PED model and ran it through different scenarios to see where breakdowns might occur. Along the way, this effort identified the following top-level problems: the lack of automated processes to support multiple sensor and multiple intelligence (multi-INT) data; the high probability of missing significant events as data volume increases; and the lack of awareness of sensor collection plans.

With these findings, the ExPED team started an extensive system engineering process that identified basic PED use cases and then developed sequence diagrams to define how current PED processes functioned and to identify areas where applying S&T resources could have high payoff in PED workflows. The program designated three focus areas: PED architectures; data processing and analytics; and collaboration and visualization.

OPEN ARCHITECTURES IMPROVE INTEROPERABILITY

Recent combat operations necessitated focusing intently on immediate PED needs—narrowly targeted, evolutionary improvements, without appreciation for broader capability alignments; integration into the intelligence, surveillance and reconnaissance (ISR) enterprise; or life cycle cost. For the sake of speed, new sensor systems were developed and fielded as stovepiped systems, each with a dedicated processing system and dedicated analyst. This allowed for faster design, development and testing, whereby the engineers controlled all aspects of the system. In addition, sensors and PED systems are stovepiped within security boundaries because of classification of the systems or the data they collect. However, valuable information could be shared across security boundaries if the proper processes were in place.



GETTING THE BIG PICTURE

Spc. Clayton P. McInnis, a human intelligence analyst with 1st Battalion, 155th Infantry Regiment of the Mississippi Army National Guard, reviews reports in the unit's tactical operations center in June, at the National Training Center, Fort Irwin, California. The ExPED STO is designed to improve the conversion of large amounts of raw sensor data into usable situational understanding. (Mississippi National Guard photo by Staff Sgt. Shane Hamann, 102nd Public Affairs Detachment)

These stovepipes hinder the ability to conduct multi-INT analysis, to hand off targets between sensors (cross-cue) or to share data with other systems. Stovepiped systems also present unscalable and unsustainable costs for the doctrine, organization, training, material, leadership and education, personnel and facilities aspects of maintaining the ISR enterprise.

Instead, sensor solutions need to use industry standards, be scalable—capable of handling a growing amount of work—and built on open architectures designed to support rapid integration of new capabilities by making it easy to add, upgrade and swap components. These architectures should adapt to the echelon in which they will operate, provide a framework for distributed PED and facilitate integration with other systems.

Data services, an essential architectural component, must provide data management and delivery to the right user; this includes enabling access to joint, interagency, multinational, NATO, allied and national operations. Some currently fielded sensor architectures provide sensor data and status. However, these architectures are not tailored for tactical environments with limited communications, cannot be easily

reconfigured during missions and are not designed to support multi-INT fusion—the process of comparing and correlating data from multiple sources and disparate types, including human inputs, collected signals, measurements and imagery, and then generating more useful observations.

The ExPED program is investigating and developing sensor architecture prototypes that will dynamically tie together PED resources (sensors, analytics and analysts) across the tactical space. This will provide the ability to reconfigure resources in changing conditions and make better use of constrained tactical bandwidth, thus increasing awareness and discovery of significant events.

REDUCING ANALYST WORKLOADS

The Army continues to add sensors that are capable of collecting greater volumes of data, but we can't afford to move all of the data around our networks, and we don't have enough analysts to look at all of it. Analytics provide process automation, smart logic, computation and threat trending that expose nuggets of relevant information to the analysts.

Taskable automated and semiautomated multi-INT analytics and processing—whereby the user (or multiple users

simultaneously) can seek and detect particular features for a particular mission or at a specific time, for example, a red truck or people with white shirts—are needed closer to the sensor to increase the Army's ability to manage and exploit the breadth and scale of collected data. Distributed data processing—using multiple computers across different locations to divide the processing load—can help reduce the amount of network traffic by filtering and compressing data as it moves through the network, increasing system performance in bandwidth-limited environments. These capabilities will create opportunities to leverage remotely stored data to glean new insights.

ExPED is investing in the development of prediction, fusion, correlation and alerting capabilities that are critical to managing the big data challenge and are necessary to reduce an analyst's workload. ExPED is working with Army and industry stakeholders to define standards for analytic interoperability so that more sophisticated mission-specific solutions can be built from existing analytic toolsets.

To validate these standards, the ExPED program is developing multi-INT analytics to merge radar tracks, full-motion video and electronic signals to provide greater confidence in the data and lessen

the time for alerts to significant events. The analytics also need to be scalable and extensible so that the user can execute them wherever it makes sense across the tactical space. For example, an analytic can run on a multisensor platform, ground station or sanctuary, depending on the mission's concept of operations and communications links.

COLLABORATION AND VISUALIZATION

As the Army moves more toward centralized PED sites, collaboration is going to be all the more important. The Army has been realigning how it organizes and employs its human analysts as part of the PED process. One idea is setting up centralized sites outside of conflict zones where specialized Soldiers can focus on exploiting sensor data and feeding situational awareness back to theater. However, bandwidth constraints will limit scalability of this solution. Additionally, analysts who are not on the ground lack the mission context to fully exploit the data.

Reliance on the current system of countless chat windows to collaborate is inefficient and not scalable. Therefore, the Army requires a solution that allows for PED operations to move seamlessly between tactical and remote PED analysts.

Usability and software interface design are critical for handling, filtering and understanding the data and analytics, as well as providing an environment for analysis and user collaboration. Development and integration of techniques for big data visualization, collaboration and workflow management are essential for common understanding. These tools will enable management of tasks across echelons, provide mission context to facilitate situational understanding and reduce cognitive burden on analysts.

The ExPED program is developing a sensor COP to support all parts of the PED process, from tasking sensors to exploiting data to use of the intelligence. This includes developing an interface that is tailorable to all users in the PED process, including mission managers, exploitation analysts and analysts at every echelon. The ExPED sensor COP is a shared collaborative environment where all parties can interact and conduct their respective tasks and workflows—in real time, if communications allow.

The ExPED sensor COP is extensible, allowing applications to be built into it. This will allow data to move from one phase to the next with collaboration along the way, and will task and automate processes effectively to reduce analyst workload.

CONCLUSION

Current Army PED operations are not extracting the maximum amount of intelligence from existing sensors. The Army can get additional value by better leveraging the opportunity for multi-INT processing and exploitation, cross-cueing between sensors, forensic analysis and increased awareness and use of available resources.

The S&T community has the opportunity and imperative to work outside the narrow bounds of acquisition programs of record in order to design and demonstrate standards-based interoperable systems. By implementing a common framework of interoperable PED components, such as those being developed and demonstrated under the ExPED STO, Army PED operations will realize improvements in efficiency and capability such as:

- Moving processing closer to sensors to improve the timeliness of actionable

intelligence and reduce the bandwidth necessary to transmit raw data.

- Automated or semiautomated cross-cueing of sensors for faster target acquisition and tracking.
- Use of advanced analytics to increase the speed and effectiveness of extracting intelligence from high-volume and high-speed sensor feeds.
- Better leveraging of distributed sensors, processing systems and analysts to execute ISR missions.

Commanders rely on situational understanding to make timely decisions, but more data does not equal situational understanding. Understanding will be accomplished only by providing analysts with the tools to process, exploit and disseminate the extensive amount of sensor data collected across the battlefield.

For more information or to contact the authors, go to www.cerdec.army.mil.

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PROCESSOR SWARM

Inherent in the coming internet of battlefield things are challenges that commercial products don't face. But those products might have solutions to the Army's problems, which is why ARL and its partners are exploring novel distributed processing approaches, a domain the Army practically invented.

by Dr. Raju Namburu and Dr. Michael Barton

Distributed processing—using multiple computers to run an application—is not a new idea. But as technology advances, opportunities arise for new and novel distributed processing approaches that take advantage of nascent network-based communication, computing systems, innovations in algorithms, and software.

First realized around 1983 at Aberdeen Proving Ground (APG), Maryland, distributed processing has evolved over several decades as information technology has expanded exponentially. It will be a key technology for future Army operations, especially complex Soldier situational awareness.

As computer and network capabilities grew, distributed processing also grew to mean multiple, interconnected processors or computers working together to perform a common calculation or to solve a common problem. The Ballistic Research Laboratory, predecessor to the U.S. Army Research Laboratory (ARL), implemented network communication protocols—now known as internet communication protocols—for communication among four processors.



INTERNET OF THINGS

Novel distributed processing is essential to leverage the knowledge from many connected devices in time to quickly affect outcomes. (Image by Shutterstock/chombosan)

With each generation of distributed processing, more capable processors are pushed further out into organizations and society with more functionality, greater interaction and improved communication among different tiers of processing with greater integration among them, culminating in the internet of things: the proliferation of processors, mobile devices and sensors that are embedded in the physical objects—appliances, vehicles, buildings and other items—that surround us in our daily lives.

SITUATIONAL AWARENESS COOKIES

Today, a primary motivator for novel distributed processing is recognition of the enormous potential that resides in both the unused and dedicated processing power of many connected devices and the need to know more, sooner, and to leverage that knowledge to affect immediate future events. In the same way that every webpage you visit serves up advertisements based on browsing habits, the Army needs to be able to do something similar with intelligence, surveillance and reconnaissance systems so that Soldiers get served up what they need for superior situational awareness.

The Army faces directly analogous technical challenges—Soldiers need to know more and sooner (situational awareness) to allow rapid, decisive action. Now, and even more so in the future, the battlespace is characterized by highly distributed processing, heterogeneous and mobile assets with limited battery life, communications-dominated but restricted network

capacity, and operating with time-critical needs in a rapidly changing hostile environment. Capabilities to be developed for the Army for enhancing situational awareness in contested battlefield environments are different from traditional commercial applications, which are targeted at exploiting the consumer. Essentially, the Army needs to be Facebook in reverse—exploiting the data for the use of the consumer, not exploiting the consumer for the use of data.

Distributed processing is one of the essential technologies for maintaining overmatch in the land domain in various operational and contested environments, including cyber and artificial intelligence. Some examples of future operational environments where innovative distributed processing approaches are essential include:

- Real-time situational awareness.
- Distributed machine learning and relearning.
- Distributed intelligence.
- Human-machine teaming.
- Delivery of big data analytics at the right place in a timely manner.
- Operations in megacities.
- Cooperative and collaborative engagements.
- Cyber and electromagnetic engagements.
- Accelerated learning.
- Augmented reality.



INFORMATION FOR ACTION

Soldiers need to know more and sooner—without being overwhelmed with information—to allow rapid, decisive action. (U.S. Army illustration)

The Army needs to be Facebook in reverse — exploiting the data for the use of the consumer, not exploiting the consumer for the use of data.

HOW WE GOT HERE

Large, expensive computers with interconnected processors were available to a small number of expert users in the 1980s. By the 1990s, the industry had moved away from custom processors to commodity chips, co-processors and shared software. The concurrent growth and proliferation of internet-enabled distributed processing, most notably in applications like SETI@home (the University of California, Berkeley-based Search for Extraterrestrial Intelligence, with 5 million internet-connected devices) and in processors like Rosetta@home (molecular biology, with 1.6 million internet-connected devices or processors). For these applications, algorithmic innovations took advantage of

unused computer time donated by people worldwide.

They also benefited from the asynchronous nature of applications, in which every calculation is independent of every other calculation. These projects showcased more than a billion operations per second to achieve exascale computing. Exascale computing is not achievable by any single supercomputer that exists today.

By the 2000s, the internet brought about service-oriented architectures with seamless web access. Later, hardware virtualization allowed software to emulate an entire computer infrastructure, which culminated in the popularity of hosting

pictures and other personal data in the cloud. We refer to the cloud as distributed processing, since it literally is distributed all over the world. But its purpose is to centralize computing infrastructure. It relieves the end-user organizations of having to invest individually. DOD's Distributed Common Ground System is an excellent example of cloud computing at the edge.

As opposed to cloud-computing, emerging technologies in ad hoc networked mobile devices, the internet of battle-field things, special purpose robotics, unmanned vehicles and social networks will produce enormous amounts of data. It is critical for Army scientists to explore novel distributed processing approaches for Army-specific applications, especially those distributed approaches that have potential to enhance the speed of decision-making.

THREE EVOLVING NOVEL APPROACHES

Distributed processing “at the edge” is a new paradigm in which we see

convergence of computer processing with low-power processing, intelligent networking, algorithms and analytics as one entity, as opposed to stovepiped technologies. Distributed processing at the edge—referred to as edge computing, fog nodes, cloudlets, micro data centers and micro-clouds—is simply localized, trusted, resource-rich computers that are connected.

Edge computing requires a lightweight solution using containers for distributed processing. Instead of a physical canister that stores things, these containers optimize computer data by processing it near the source of data. The draw is that containers can be tailored to single solutions, such as a machine-learning container or a video-processing container. Army scientists want to figure out how to harness the benefits of edge computing with containers while navigating the challenges of doing it with mobility, such as intermittent bandwidth, ad hoc networking and policy-based environments.

Emergent computing is another evolving form of distributed processing. Information processing and control emerge through the local interaction of many simple units that exhibit complex behavior when combined. Intelligent software agents are in this arena: sophisticated computer programs that act on behalf of their users to find trends and patterns.

There are also multiagent systems that are loosely coupled networks of intelligent agents that interact to solve problems outside of what any one agent would accomplish.

Neural-inspired computing is fast becoming an option for low-power novel distributed processing. Neural-inspired computing mimics the neurons and synapses of a biological brain. Another characteristic is that communication processing in neurons and synapses uses efficient digital or analog techniques such as two-dimensional (2-D) atom-layered nanotechnologies. An example of 2-D is a crystalline material that has a single layer of atoms with unusual



THE SHAPE OF NEXT-GEN PROCESSING

ARL has internal programs aimed at the capabilities of the next generation of distributed processing, and is working with partners at academic institutions and in industry. (U.S. Army graphic by Peggy Frierson, Defense Media Activity)

semiconductor and neuromorphic characteristics at the nanoscale.

In addition to continuous innovations in scalable algorithms and software, future computing architectures like quantum networks, data flow computing, and cyber- and electromagnetic-secured heterogeneous processors are going to play a role in overcoming distributed processing shortcomings that surface in military scenarios.

DISTRIBUTED PROJECTS FOR DISTRIBUTED RESEARCH

ARL is working toward the capabilities of the next generation of distributed processing, in collaborative projects with academic institutions and industry and in internal programs.

External collaborative programs that address challenges with distributed processing from algorithms and theory include the international technology alliance with the United Kingdom Ministry of Defense, the internet of battlefield things, distributed and collaborative intelligent systems and technology, the U.S. Army High Performance Computing Research Center, the Center for Distributed Quantum Information and ARL's Single-Investigator Program,

executed through the Army Research Office.

There are also internal projects that lay some of the foundation. For example, we work with IBM, Purdue University and the Lawrence Livermore National Laboratory in understanding the programming and use of neuromorphic processors—brain-inspired computing. These neuromorphic processors have proven quite adept at machine-learning tasks, yet consume 1,000 times less power than conventional processors.

CONCLUSION

The Army has been at the forefront of computing and distributed processing and continues to make investments in related research to shape how the future Army will fight and win. The complexities of distributed processing become more clear as the way in which humans will engage with distributed artificially intelligent systems becomes more defined.

The reliance of intelligent systems on wireless communication and networked processes makes them vulnerable to cyber, physical and electronic attacks. Thus, it is necessary to develop technologies that mitigate those risks and keep systems functional in the face of such

attacks. In the current and future world, this requires innovations in distributed processing and computation on and off the battlefield.

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First realized around 1983 at Aberdeen Proving Ground, distributed processing has evolved over the last several decades as information technology has expanded exponentially.



Path of **GREATEST RESILIENCE**

Facing an enemy intent on creating a highly contested electromagnetic environment, S&T investments in Army networks focus on mobility, redundancy, ease of use and detection avoidance.

by Mr. Seth Spoenlein, Mr. James Snodgrass, Mr. Michael Breckenridge and Dr. Brian Rivera

The expeditionary nature of the future force will require mobile, secure communication networks that are dynamic—able to survive in active electronic warfare environments and available in all environments to ensure continuous mission command. However, obtaining and sustaining the higher ground in a network context will not come easily in the future battlespace.

The enemy will have advanced technologies designed specifically to create a highly contested electromagnetic (EM) environment, disrupting our ability to communicate, degrading our performance and injecting uncertainty into our decision cycle. To address these challenges and provide robust EM defense of information exchange, we need to develop mobile communication networks that can make optimal use of the EM spectrum, enhance EM security and reduce the probability of detection or intercept.

In addition, the network must be resilient to attacks in both the cyber and land domains by responding and adapting

much more rapidly than today's networks. It must have low EM signatures and operate on-the-move. The entire network setup, from spectrum allocation to subnet configuration and security monitoring, must be automated to simplify network operation. Today's tactical Army networks are reliant on conventional radio-frequency (RF) technologies, which limits our ability to maintain communications in a contested environment.

Therefore, Army science and technology (S&T) is investing in innovative mobile communication platforms that employ advances in RF and nontraditional portions of the EM spectrum; highly directed adaptive anti-jam antennas to mitigate effects of multipath interference; and new algorithms and software to predict network performance, enhance cybersecurity and provide network self-configuring and self-healing capabilities.

Maintaining persistent connectivity, or network resilience, amid the noncontiguous and disrupted communication links



GRID SEARCH

Sgt. Rogelio Hercules, the network operations noncommissioned officer in charge assigned to the 44th Expeditionary Signal Battalion, 2nd Theater Signal Brigade (TSB), configures equipment during Saber Guardian 17, a U.S. Army Europe-led, multinational exercise held in Bulgaria, Hungary and Romania in July. The future force is expected to be more expeditionary, and as a result will require dynamic communication networks capable of operating in active electronic warfare environments. (U.S. Army photo by Staff Sgt. Brian Cline, 2nd TSB)



To achieve spectrum awareness, we will leverage every receiver on the battlefield as a spectrum sensor to yield relevant data for signals intelligence, electronic warfare and radio frequency communications.

in a tactical environment will require an automated intelligence system. Automation and intelligent network switching capabilities will simplify Soldier operation and guarantee the ability to quickly adjust based upon the mission needs and the enemy’s action, in order to establish, adapt and maintain communication in a complex, contested environment.

To accomplish this network resilience and agility, Army S&T is looking to the use of multiple redundant network links, a diverse selection of alternate networks, and efforts to decrease the likelihood of disruption by an enemy. Network diversity will require separate physical connections to the tactical internet, the “final-furlong” squad area networks and long-haul networks. Effective network and spectrum diversity allows Army units to communicate regardless of what happens to the physical infrastructure over which those communications are transmitted.

CHOICES MAKE THE DIFFERENCE

Commercial technology has implemented automated processes in mobile devices (smartphones, tablets, etc.) to autonomously transition media among differing network connections without user selection or decision-making about which network to use. For example, automated network selection occurs when someone walks inside their home with a cellular device; that phone is programmed to autonomously switch to a home Wi-Fi network that has higher throughput and better signal strength; the device also uses Bluetooth to automatically discover a smart high-definition TV to telecast video or a speaker system to stream audio. In this commercial implementation, the source and destination devices are linked over a network infrastructure with redundant, highly reliable communication links.

The same cannot be said for current tactical Army networks where users may be located in physically and logically separated subnetworks and where the reliability of communication links can be intermittent, especially in contested spectrum environments. Army units need the flexibility to discover and leverage all viable network options, allowing multiple pathways to critical networks and data sources.

For ease of interaction with the network, an automated network selection system must maintain awareness of all available network connections, the status of each link and the source and destination of data to traverse the network. This system automates the planning methodology practiced by units to designate the primary, alternate, contingency and emergency (PACE) means of communication used to build a mission-based communication plan.

In tactical Army networks, different communication solutions are available to provide connectivity between users across varied environments. These solutions vary widely by technology, protocol, throughput and other factors that must be evaluated for priority in a PACE plan. Most Soldiers are not specialists in establishing or maintaining the network. We must reduce the need for a Soldier to be an expert for every configuration interface of every network radio. An automated PACE system will ease Soldier interaction with data traversing the network without concern for how the data flows from source to destination. The automated network selection system can automatically,

intelligently and seamlessly route data over the available network connections as the PACE plan executes.

Another major element of network resilience is the need to decrease the probability of detection, as well as jamming and other types of interference. Future systems will minimize, or at least control, the spectrum signature a unit produces during normal operations, in order to defeat detection and eventual disruption. The automated PACE system is also a means to mitigate spectrum interference. When an enemy is successful with interference, the automated PACE system can maintain user-to-user connectivity during primary link disruption, and allow continued communications for units to accomplish mission objectives. Development of solutions for use at-the-halt or near the tactical edge will include technologies from unconventional regions of the spectrum that are difficult to detect or jam, such as terahertz and ultraviolet radiation.

An increased understanding of the spectrum environment amid interference and congestion will enhance situational understanding by helping to pinpoint sources of interference and their targets, and this will enable persistent network connectivity. To achieve spectrum awareness, we will leverage every receiver on the battlefield as a spectrum sensor to yield relevant data for signals intelligence, electronic warfare and radio frequency communications. Often, the same dataset can be used to support related mission needs, such as those of electronic warfare or offensive cyber operations. The spectrum data not only feeds



SHRINKING SIGNATURES

Army communication systems of the future will minimize a unit's spectrum signature to thwart detection and disruption. To that end, Army S&T is developing technologies that use nontraditional portions of the EM spectrum. (U.S. Army photo by CERDEC)



HYBRID NETWORK

Soldiers assigned to the 44th Expeditionary Signal Battalion, 2nd TSB assemble a dedicated antenna to support the command post of the Georgia National Guard’s 648th Maneuver Enhancement Brigade during Saber Guardian 17 in July. The Army is developing technologies to operate in multiple bands, from low VHF to millimeter wave band and optical band, enabling a hybrid network that can adapt autonomously to attacks, connectivity problems or congestion. (U.S. Army photo by Staff Sgt. Brian Cline, 2nd TSB)

Army units need the flexibility to discover and leverage all viable network options, allowing multiple pathways to critical networks and data sources.

the network automation, but is also consumed by purpose-built systems that will effectively visualize this data and provide wide-scale situational understanding.

In addition, the Army will need to protect the network from adversaries attempting to geolocate our EM emissions and target them with long-range fires, making it critical to identify capabilities that lower the probability of detection and interception to increase network survivability. Future systems will minimize, or at least control, a unit’s spectrum signature in order to defeat detection and eventual disruption.

Successful operations will require the ability to use nontraditional portions of the EM spectrum and to make it harder for the adversary to deny spectrum use to the force. Army S&T is developing technologies to operate in multiple bands from low VHF to millimeter wave band and optical band. Each of these bands has different performance constraints and capabilities, but together they will enable a hybrid network that can adapt autonomously to electronic warfare attacks, connectivity problems or congestion, thereby increasing the resilience of Army networks.

Key to this is spectrum awareness. To achieve this, we are developing approaches to leverage every receiver on the battlefield as a spectrum sensor to yield relevant data for signals intelligence, electronic warfare and RF communications.

Longer-term, we are developing technologies to enable combined RF and cyber effects that increase the uncertainty of friendly forces’ locations in both the physical (RF) and cyber environments, as well as the use of quantum encryption methods to enhance network security.

CONCLUSION

The future Army network will possess intelligent automation, network resilience and situational understanding to enable automatic execution of PACE plans. The network will provide fast and reliable communications in anti-access and area denial environments. Simultaneously, flexible and tunable communication platforms will be less susceptible to detection and jamming.

Built-in network resilience is a foundational element of network EM security and reliability of operations. Implementation of components that enable spectrum diversity with failover capabilities—the ability to switch to backup systems after the initial system fails—will achieve more resilient network performance. By coupling varied mission needs with available



BOUNCING BACK

A Soldier prepares to copy a grid coordinate during Decisive Action Rotation 18-01, conducted in October at the National Training Center (NTC), Fort Irwin, California. To ensure that Soldiers have a network that's both resilient and agile, Army S&T is looking to the use of multiple redundant network links, a diverse selection of alternate networks and efforts to decrease the likelihood of enemy disruption. (U.S. Army photo by Spc. Audrey Ward, NTC Operations Group)

spectrum data, limiting the need for Soldiers to interact with configuration interfaces and automating PACE transition across a diverse network, we can enable units to meet multiple mission aspects with optimal bandwidth use, fast reconfiguration time and effective self-healing.

For more information, go to www.cerdec.army.mil or www.arl.army.mil.

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AUGMENTED TRAINING

Sgt. 1st Class Taikeila Dale uses the Mk-19 simulator with augmented reality head-mounted display while visiting the Army Research Laboratory – Orlando, Florida, in August. Researchers at ARL-Orlando developed the trainer, which enables training in smaller spaces and has a shorter reset time to provide more opportunities to refine necessary skills. (U.S. Army photo by C. Todd Lopez)

The CHANGING FACE of SOLDIER LETHALITY

From the tangible to the cognitive, squad weapons to casualty care to performance-enhancing training, Army S&T is exploring and finding materials, technologies and methods in six focus areas to provide land forces the capabilities they'll need for overmatch.

by Ms. Karen M. Burke and Lt. Col. Eric J. Wagar

Twenty years from now, Soldiers and small units will operate very differently than they did during the last two decades in Iraq and Afghanistan. As the Multi-Domain Battle Operating Concept emerges in the next 10 years, Soldiers will fight in multidomain environments characterized by dispersed, high-tempo operations that require small units to act independently in denied and austere regions.

Soldiers will operate with shorter lines of sight and a reduced standoff advantage in their intelligence, surveillance and reconnaissance and long-range strike capabilities. Dense electromagnetic environments will make it difficult to establish and maintain persistent, trusted communication links. Soldiers will also face large, culturally diverse populations of noncombatants with whom they will need to communicate and who they will have to monitor for threats and protect from engagements, particularly in increasingly crowded urban regions such as coastal cities.





UHM, WHAT?

The Army's Enhanced Combat Helmet uses composite fibers developed from UHMWPE—high-performance, ultrahigh molecular weight polyethylene. The inset image, obtained using scanning electron microscopy, reveals a permanent indent from a test bullet on the surface of polycarbonate material, in contrast with polyurethane urea elastomer materials, where no damage was observed after impact. (U.S. Army illustration)

Mitigating the impacts of these emerging challenges calls for Army science and technology (S&T) investments in Soldier lethality that account for the world's complexity—operational, technological, societal and cultural. The three articles that follow highlight examples of capability investments in innovative, technologically advanced, potentially game-changing solutions focusing on 3-D enriched urban terrain visualization, improved performance and resilience, and augmented and mixed reality.

DIMENSIONS OF LETHALITY

What makes a Soldier and a small unit lethal? The Army's S&T investment strategy addresses this question in both tangible and intangible ways.

Tangible materiel elements of lethality include Soldier and squad weapons,

communications, situational awareness and protection systems that allow Soldiers to shoot, communicate, maneuver and survive in varied terrain and phases of conflict. Capabilities that support a Soldier's lethality include foundational training in executing missions and individual tasks, prolonged field medical care to treat injuries and sustain optimal performance, and physical and cognitive augmentation solutions such as wearable powered devices and nutrient delivery methods that increase strength and endurance. These will help direct Soldiers and squads and provide the speed of information that is becoming the cornerstone of overmatch.

Equally important are the less tangible lethality capabilities that contribute to total Soldier and small unit performance, such as cognitive aids, conditioning,

leadership and resilience training. These intangible enabling technologies work in concert with Soldiers and their equipment to create a professional, well-equipped force.

To maintain the Army's strategic, operational and tactical advantages, Army S&T is exploring and identifying materiel and nonmateriel solutions in six key areas of Soldier lethality that leverage technology advances to offer land forces the vital capabilities they will need in the mid- to far term. These six areas are Soldier and squad weapons; Soldier protection and equipment; situational awareness; physical and cognitive performance, along with Soldier-optimized performance; prolonged field medical care; and training.

SOLDIER AND SQUAD WEAPONS

Small units require weapon systems that enhance lethality, accuracy and mobility to achieve and maintain overmatch against current and emerging adversaries' technologies and operating tactics. Just as our adversaries invest in improving their weapons technology, Army S&T has the responsibility to modernize our legacy weapons ammunition and accessories.

S&T support for next-generation weapon investments includes research into lighter-weight materials, improved ammunition design and penetration, modular component designs and integrated enabling technologies such as fire controls, optics and powered rails. The Army's improved weapons and munitions need to be able to defeat adversaries who are using partial and full defilade to protect their positions and equipment, limiting the effects of our direct-fire small arms and indirect fire systems. In response, Army S&T seeks to reduce the precision, size and weight of counter-defilade capabilities for

small units, putting counter-defilade in the hands of Soldiers and small units in combination with more lethal weapons and enablers, to keep pace with and overmatch the capabilities of adversaries.

SOLDIER PROTECTION AND EQUIPMENT

Army S&T seeks a balance of protection, mobility and the impact of such enhancements on lethality. It boils down to a weight race, as the Army adds equipment to the Soldier kit faster than it can reduce weight through materials research, miniaturizing components and integrating capabilities into ergonomically designed systems and components.

Research continues on lower-weight protection options for increased mobility and lethality as emerging directed-energy and ballistic threats proliferate. We also seek to reduce battery-related Soldier load with research on power harvesting, battery chemistries and energy management—all with the goal to extend dismounted Soldier operations for a 72-hour mission using adaptive systems that supply continuous power generation for up to six days.

Army S&T is exploring bio-enabled and protective materials that combine protection against multiple environmental, detection and ballistic threats for clothing and individual equipment. It is also looking at signature management technologies to decrease the probability of a Soldier being seen and heard because of the thermal, electromagnetic or visual characteristics of the gear they wear and carry. Midterm body armor research focuses on vital torso protection against ballistic and blast threats, adding to earlier research on technologies that reduce Soldier-generated electromagnetic and auditory signatures.

A related research area is developing mechanisms to understand human response and injury in blast, ballistic and directed-energy trauma. Army S&T also seeks to create injury-based performance criteria to support readiness determinations and product design.

SITUATIONAL AWARENESS

Information overmatch, by allowing Soldiers to surprise the enemy, increases the chance of mission success. Army S&T is developing strategic technologies to

enhance our ability to outthink and outmaneuver an adversary with Soldier-wearable technologies. Small units must have situational understanding and a common operating picture to operate in close contact with the enemy and to conduct continuous security operations.

To achieve state-of-the-art situational awareness, Army S&T is investing in three areas:

- **Advanced sensors and displays for dismounts**—Our focus is on low-cost Soldier-borne sensors, combat optical weapon sights and imaging and non-imaging sensors for individual and crew-served applications. These sensors will provide day-or-night capabilities enabling precision targeting and pointing, target marking and designation and obtaining accurate target locations at extended ranges.
- **Soldier system interfaces and integration**—These tactical system interfaces and decision aids reduce the cognitive overload caused by too much visual information, and support the 3-D visualization of mission command

HELPING HANDS

Lt. Col. Tyler Harris, M.D., an orthopedic surgeon at Womack Army Medical Center (WAMC), Fort Bragg, North Carolina, works remotely with a physician assistant during a surgical procedure in May. The surgical scenario explored the feasibility of training physician assistants to perform lifesaving measures when there isn't time or capability to get service members injured in theater to a surgeon. Future operational threats like anti-access and area denial could make it difficult to evacuate Soldiers to surgical treatment. (U.S. Army photo by Eve Meinhardt, WAMC)



and sensor data to enhance tactical decision-making during dismounted operations.

- **Soldier data management**—We are developing Soldier-borne data management and distribution technologies whereby Soldiers can assess and maintain situational awareness and understanding, to enable real-time decision-making during dismounted operations. Hardware and software development address Soldier-centric integration and analysis of wired and wireless data management technologies, including Intra Soldier Wireless technologies and architectures, low-power sensor networks and Soldier-borne information assurance solutions.

Emerging wearable technologies provide an unprecedented ability to collect high-resolution data continuously over significantly longer periods compared to the handheld and head-borne display systems in use today. Sensor data, combined with advanced modeling techniques and machine learning, have the potential to enhance cognitive performance and provide state-of-the-art situational awareness.

Army S&T is exploring bio-enabled and protective materials that combine protection against multiple environmental, detection and ballistic threats for clothing and individual equipment.

SOLDIER PERFORMANCE

Soldier load, a combination of cognitive and physical stressors, has increased as battlefield scenarios become more complex and Soldiers’ gear increases with the proliferation of capabilities and technological advances. Army S&T addresses physical and cognitive performance through our medical and human system integration (HSI) communities. Current operating concepts assume that Soldiers can comprehend large amounts of dynamic, complex data arising from dense, urban, technology-laden terrain, and make efficient and effective decisions.

Our research focuses on predicting the range of Soldier comprehension given varying quantities of information and tasks, in varying environments. Army S&T aims to enable Soldiers and small units to maneuver rapidly and engage adversaries in all environments, from dense urban areas to deserts, rolling terrain, mountains and jungle, and to operate in distributed small units as well as larger formation missions. S&T investments in medical and nonmedical augmentation technologies look to improve Soldier performance while reducing the physical, perceptual and cognitive workload and enabling units to operate at a sustained high tempo.

Applying HSI principles and practices before designing equipment is a key to achieving physical overmatch in a dynamic operating environment and improving Soldier and team performance. HSI applications include man-machine interface, brain-computer interaction and joint human-intelligent agent decision-making, with a focus on early integration of humans and systems. Common human-machine interfaces ensure that Soldiers have flexible, tailorable analytic tools for laboratory-grade,

high-resolution assessment of dismount-robot interactions in complex environments.

The S&T medical community is the major contributor to research on optimizing Soldier performance, through its individualized regimens of nutrition, “nutraceuticals,” pharmaceuticals and synthetic biology to prevent disease, speed recovery and augment human performance. Some of the major goals are to manage fatigue effectively, optimize nutrition and maximize physical and cognitive performance in dynamic operating environments. The field of Soldier-optimized performance delivers technologies that combine physical, metabolic and cognitive sensors to enable Army leaders to make decisions faster and to sustain resilience, protection and mobility.

PROLONGED FIELD MEDICAL CARE

The Army’s last 16 years of contingency operations have demonstrated that surgical intervention within 60 minutes of injury—the “golden hour”—significantly increases the chances of casualty survival. Because operational threats such as anti-access and area denial challenge the Army’s ability to evacuate Soldiers to surgical treatment within that hour, Army S&T is researching medical materiel and knowledge solutions to accelerate delivery of lifesaving medical care. Our two major programmatic efforts are prolonged field care and autonomous evacuation.

Prolonged field care will enable medical personnel, such as combat medics and battalion surgeons, to stabilize wounded personnel for extended periods of time until evacuation is feasible. The capability initially will consist of advanced medical devices to control bleeding from wounds for which tourniquets are



TOMORROW'S PATROL

By 2025, the Army sees ground troops conducting foot patrols in urban terrain with robots—called Squad Multipurpose Equipment Transport vehicles—that carry rucksacks and other equipment. Unmanned aircraft could serve as spotters, according to the Army's new strategy for robotic and autonomous systems. They could also deliver cargo, reducing reliance on rotary-wing support and facilitating sustainment. (U.S. Army image)

not effective, and a closed-loop, extracorporeal (that is, outside the body) life support system to provide lung and kidney function to patients who need it.

When medical evacuation is not feasible, the Army will use autonomous ground or air platforms, in conjunction with autonomous life support equipment, to move casualties to surgical care facilities. These platforms also will be useful for resupplying medical personnel during sustained operations. Army S&T investments in autonomous systems and advanced medical devices will provide tomorrow's force the dramatic increase in survival rates that the Army's first aeromedical evacuation brought to wounded Soldiers in Korea.

NEW NEEDS FOR TRAINING

Increasingly complex equipment, the rise in speed of conflict and increasing demands for diverse skills, such as cyber and languages, are driving Army S&T to research state-of-the-art methodologies and tools to support learning and training. These tools must outpace the learning demands arising from complex environments and provide Soldiers the expertise and confidence to synthesize information, rapidly make decisions and act upon those decisions to outmaneuver adversaries.

New training technologies and environments will allow Soldiers to train and rehearse warfighting skills such as faster decision-making to gain the advantage of speed over adversaries, with integrated capabilities such as intelligent agents that challenge the Soldier to improve individual and team performance and develop agile, adaptive leaders. As Army training missions increase, S&T has the challenge of replicating sufficient

knowledge and time for every small unit on dispersed and varied battlefields. Investments in training tools such as simulations and synthetic training environments will increase retention, enhance situational awareness for cognitive overmatch, and improve Soldier and team performance while reducing training time and cost.

CONCLUSION

The future vision of land warfare is being shaped by today's S&T investments across many mature and emerging disciplines. The capabilities described in this article will start to bear fruit in three to 10 years in rapidly advancing information technology and physical and cognitive augmentation technologies, with solutions expected in 10 years or beyond in such areas as biomaterials and artificial intelligence.

The Soldier lethality S&T portfolio is shaped by a diverse community of scientists, innovators, end users, technology and global forecasters, and intelligence experts who identify and define the challenges and threats of the future. It employs an iterative analytical process to continually refine its investments and priorities so that future Soldiers maintain the lethality advantage on the future battlefields that are being conceived today.

For more information on Soldier lethality investments, go to <https://www.army.mil/asaalt>.

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A 'MAP' *for the* MULTIDOMAIN MEGACITY

Army scientists pursue advances in situational awareness, 3-D modeling and real-time data updating to help units make better decisions faster in urban combat.

*by Dr. Robert E. Davis, Dr. Kevin R. Slocum,
Dr. Tad T. Brunye and Dr. Aaron L. Gardony*

Today's Army leaders consider it inevitable that U.S. ground forces will engage in combat in dense urban environments, including building interiors and subterranean spaces.

These settings eliminate or severely degrade many of the technological advantages that U.S. forces and their global (near-) peers have developed over several decades, and they also may provide sanctuary to friend or foe. Dense urban environments also heighten broader risks of unintended consequences in combat.

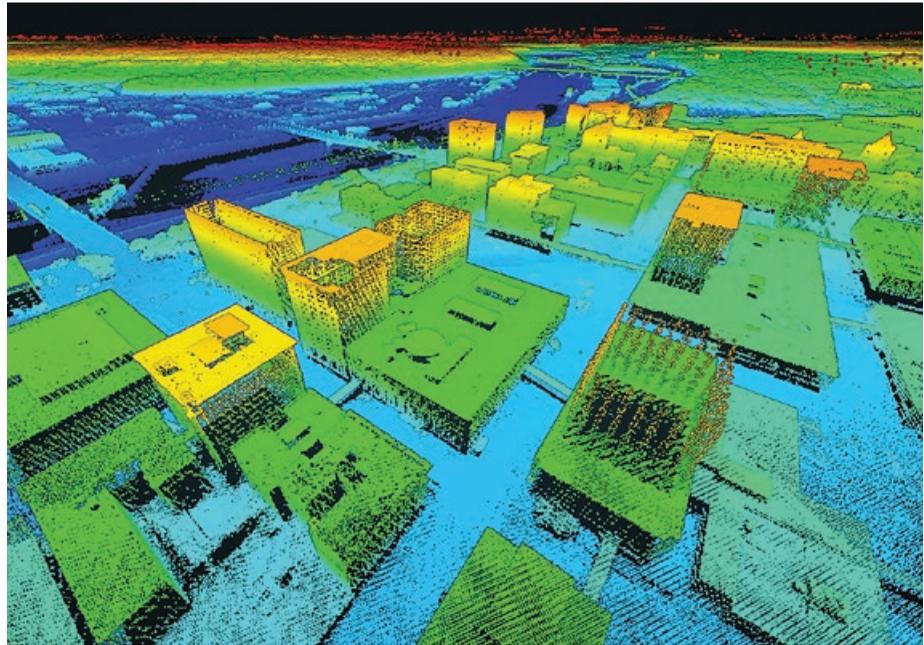
A broad spectrum of existing and emerging research topic areas has shown the potential to develop significant capability for providing small disaggregated mounted and dismounted teams the ability to act independently, to outthink and to outmaneuver the enemy in close combat despite limited and intermittent access to higher-echelon command and control. Most of the promising science and technology (S&T) development

focuses on major advances in situational awareness in urban settings and how they can lead to better decisions faster, presenting dilemmas to an adversary.

The Army S&T community has adopted the premise that urban combat, considered as a flowing series of tactical unit decisions and actions, will greatly benefit from rich and intuitive space and event and trend context. Accordingly, near-term and emerging research areas at the U.S. Army Engineer Research and Development Center (ERDC), the U.S. Army Research Laboratory (ARL) and the U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC) include investigations into the design and formulation of new urban terrain data models, frameworks and cognitive display approaches. The goal is to identify solutions compact enough that many Soldiers and every vehicle can carry them along for sharing and analysis, while meeting a variety of needs for display

A LABOR-INTENSIVE PICTURE

This information architecture represents a high-density point cloud, viewed obliquely. A point cloud is a set of points on a coordinate plane; in this case, the data points are the edges of buildings and other structures in this dense urban area. Taken together, they create a 3-D visualization of a space. ARL is looking for a way to collect this kind of data about an urban environment from multiple sources and craft it into a usable map, without the many human analysts currently required to do so. (Images courtesy of the authors)



on different equipment. Research interest across the ERDC and the U.S. Army Research, Development and Engineering Command also has focused on characterizing, moving and communicating within the confined space of building interiors and subterranean infrastructure.

Results of this research will shape design and development of techniques for much more rapid data generation, tailored dissemination, change analyses and visualization. In other words, Soldiers will learn as they go, and retain this spatial knowledge. This new direction, in most cases, markedly departs from the commonplace use of flat maps, in perspectives that may include 3-D features and immersive training environments.

The Army geospatial enterprise uses a concept called standard sharable geospatial foundation (data models and information architecture), which will allow for horizontal and vertical interoperability and sharing of geospatial information from the national level to the tactical edge. Built on this concept and the need for high-resolution 3-D topography of urban spaces, and working across Army platforms and applications, Army research efforts face technology-limited challenges from the near term to the far term. In the mid to far term, these include investigations of methods to introduce a user to semantically and digitally enriched information that is key to combat activities, from training through rehearsal to combat operations. Semantic markup may include street names, for example, or symbols

referring to unit positions, while digital markup can refer to coordinates used in routing or targeting.

A critical line of research on visualization in a mobile context involves developing automated and rapid georegistration without delays during motion, which can distract attention or exacerbate motion distress. Some symbols and features added to displays, such as the user's location, range to objects in the distance, etc., stay in the same position regardless of changing viewpoint. Other augmenting features, such as building outlines, need to remain fixed in the real 3-D world even when the user's perspective moves.

We can expect improved and more diverse techniques to produce accurate, updatable geometries of urban infrastructure, including relevant materials and functions. The need to support decision-making and faster action also shapes research on what makes terrain visualization intuitive, cognitively low-cost, measurable by operators and interactive when needed. The following sections describe Army S&T research on the military-unique aspects of high-resolution 3-D enriched terrain data while leveraging commercial and academic innovation.

THE 3-D URBAN 'MAP'

The goal of Army geospatial research is to design, develop and test a new, multidimensional 3-D "map" of urban infrastructure geometries, materials and functions. This capability would

provide the context and baseline for a variety of Army operations. Current research efforts focus on some key attributes that such a map—really an information architecture—would include:

- Available on demand to Soldiers and their applications, particularly in its small units.
- Measurable and supporting a variety of automated analyses.
- Updatable as conditions change.
- Intuitive displays for more rapid decision-making.

Let’s consider a requirement for 3-D urban terrain data available to the Soldier before deployment. First, by the time Soldiers deploy, the standard urban geospatial load may not have the most up-to-date geometries and other relatively static conditions in the area of operations. Second, units may need to know what has changed during the course of combat operations. Accordingly, we must consider the need for an organic capability to rapidly generate new 3-D data to upgrade gaps or other uncertainties in the standard geospatial load. This same function also becomes a change detection capability when comparing new data with existing information.

These two key considerations support sequential, in-stride rehearsal, movement and maneuver, targeting and battle damage assessment: Navigation, targeting and other sensing systems can “see” the real urban environment and compare that, in real time, with urban information on board to move, learn and assess. Think of three tiers in an open modular architecture for 3-D enriched urban terrain information, two of which involve inspecting the operational environment, while the third deals with improving support for decision-making and execution by analyzing data in hand.

At the highest level, we consider the creation of a 3-D, high-resolution geospatial foundation focused on complex and built-up areas. Currently, dedicated and analyst-intensive technologies exist to acquire, store, process, manage and distribute imagery and point clouds, a set of ranging data points that represent the surface of an object as obtained from either active or passive collection modes, from overhead or from ground-based sensing systems. From point clouds, mature exploitation technologies can identify shapes, edges and corners to model the urban objects, and can classify and label objects in the data space. The products

have a variety of formats, nearly all requiring significant analyst involvement to make, large volumes to store, considerable cost to analyze, and substantial time delays related to access and visualization.

In the context of training environments, high-level mission planning and other activities, the main near-term research objectives involve designing and integrating a variety of tools for visualizing diverse data sets—such as point clouds, imagery, semantic descriptors and so forth—from diverse collectors. In the farther term, emphasis shifts to consolidating standard analyses and products into a common set of highly compact and manipulable formats.

For training purposes and tactical uses, the gross geometries of urban infrastructure, for example, should have a high level of precision, so that the buildings and other objects look right and building models overlay the real buildings in their actual locations. Important research investigates how to automate the functions of representing infrastructure as compact formats. Another area of research attacks the problem of automatically assigning functions (e.g., residential, commercial, industrial, transportation,



PLAN FROM ALL PERSPECTIVES

Data-rich 3-D maps would let Soldiers spend time viewing terrain from a variety of perspectives to gain an intuitive sense of the battlespace before operations begin. That basic understanding of the physical environment and how to navigate it improves spatial memory.

etc.) and functional attribution of infrastructure objects and features in military and civilian context. For example, the interior complexity of a building and the building's use are major factors in the efficiency of precision targeting or clearing.

Other near-term to midterm research seeks to dramatically reduce collection time, particularly since the U.S. cannot forecast with certainty where conflict will require our forces. Other areas of effort, also spanning the near term and midterm, investigate techniques to automatically filter and remove ephemeral features and objects—such as vehicles, people and urban clutter—to produce a time-stable foundation that contains only the horizontal and vertical infrastructure. Researchers also are designing and testing compact and common frameworks for adding back currently observed or projected ephemera, whether natural (e.g., ice, snow, water) or man-induced, like traffic on our day-to-day personal navigation applications.

CAPABILITY AT BRIGADE AND BELOW

When it comes to the next tier of 3-D, high-resolution terrain data generation, management and dissemination, the Army S&T community is exploring the need for tactical capability at brigade and below. In the 2030 to 2040 time frame, the brigade combat team will have a variety of laser, LIDAR and imaging systems for characterizing urban infrastructure. This expectation necessitates an organic capability to improve gaps in a standard geospatial load, to perform change analysis and to collect and overlay real-time information. Urban operations also may need purpose-designed kits for exploration of interior and subterranean spaces by Soldiers or robots.

To deal with all of this effectively and efficiently, the tactical user will need an operational data environment where generation, processing and dissemination of 3-D urban data can remain local for some period, avoiding the delays currently experienced in vetting and validating authoritative data.

As a third and directly actionable tier of a future capability, we can consider the examples of derived information layers and terrain reasoning related to METT-TC, the military acronym for mission, enemy, terrain and weather, troops and support available, time available and civil considerations. Many mature derived-information products have become standards, such as line-of-sight analysis, trafficability (the ability of a vehicle to traverse a specified terrain) and mobility analyses and the identification of helicopter landing zones. For near-real-time information to serve tactical operations, a capability would require accurate georegistration to the foundation data, despite



THREE DIMENSIONS, FOUR WAYS

These are some of the views possible with an enriched, 3-D visualization of a given area: Clockwise from upper left, a high-resolution representation; a version that filters out ephemeral objects such as passing cars; augmented reality view with edges and corners georegistered and attributed; and extracted edges and corners.

GPS degradation or denial, and precision sufficient to automatically identify movement of people and platforms and an update rate of a few seconds. Movement assessment would require a latency of less than about 10 seconds and an update rate of only a few seconds.

Critical research objectives at the ERDC, ARL and elsewhere in the near term to midterm include developing algorithms and techniques for robust and fully automated collection, buffering, processing and tailored direct distribution, all in a communications-challenged environment. Near-term research seeks to integrate on-demand and automated processing of products such as these with near-real-time updating, using data derived from battlespace sensing.

FORM, FIT AND FUNCTION

The prospect of 3-D enriched, high-resolution urban terrain with near-real-time updated tactical overlays does not necessarily constitute operational improvement and leap-ahead advantage. We can observe in the world every day the distraction and operational slowing caused by visual displays, personal and otherwise, as well as our dependence on them. To integrate and distill sufficient situational context—METT-TC—so

that leaders of small units can make better decisions faster, a relatively new body of research is looking into the form, fit and function of visualization to catalyze a strengthening of intuitive understanding. From training to rehearsal to operational use, visualization requirements differ. With immersive training and research toward a fully synthetic training environment, and with mission planning at brigade and above, research challenges—near-term and enduring—appear well-defined.

For close-quarter combat in complex and especially dense urban environments, questions about what, when and how to visualize the data products described above become paramount. For example, the ability to move at will in dense urban environments and simultaneously force dilemmas on an adversary, as well as to manage risk, may depend on very short-lived multisensory (i.e., audio, visual, tactile) cues that bolster the retrieval and application of spatial memory. Can we train, rehearse and cue a Soldier to navigate in the city as effectively as the native city dweller?

Recent Army research at NSRDEC has demonstrated important trade-offs among the timing and type of information conveyed to a user, the attentional demands of the information and outcomes for individual and small unit performance. If, during mission planning and preparation, Soldiers visualize the intended operating area in 3-D from multiple perspectives and orientations, their spatial memory can improve; this increases their ability to move effectively through complex environments with constantly changing situations and demands on their attention.

NOT A SILVER BULLET

Army research has demonstrated that during combat operations, standard navigational displays can induce complacency, divide attention and disengage navigators from their environment. This can impair the development of flexible spatial memories Soldiers must rely on during times of heightened stress. These and other research outcomes present a challenging focal point for developing next-generation visualization technologies, such as chest-, helmet-, eyewear- and torso-mounted information systems that provide timely and relevant information without compromising the ability to think and act quickly and effectively. The Army's geospatial, training and Soldier S&T communities are working collaboratively on this challenge, including developing scenario-based virtual test beds to predict and quantify performance outcomes of future systems, the development and application of which span from the near to the far term.

CONCLUSION

With our current technology and doctrine, we can level the playing field in complex and congested environments—including dense urban and megacity domains—by degrading standoff and other advantages. Integrating capabilities like next-generation autonomous networked sensor platforms, heads-up situational awareness for small units and enhanced fusion and targeting has the potential to restore U.S. tactical advantage. Providing rich, detailed and actionable place and event context through analysis and visualization has great promise to give options to tactical commanders among integrated and available capabilities to make our adversaries' intentions unattainable.

For more information, go to <https://www.nsrdec.army.mil/> or <http://www.erdc.usace.army.mil/>.

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FIT, NOURISHED *and* RESILIENT

Human performance optimization aims to take Soldiers to higher and higher peaks of physical and mental fitness.

by Dr. Stephen Muza and Ms. Mallory Roussel

Let's flash back to the U.S. military in 2006.

The U.S. had been engaged in Operation Enduring Freedom and Operation Iraqi Freedom for five and three years, respectively. In a post-9/11 environment with a higher operations tempo and longer and more frequent deployments, the U.S. military had an ongoing need to enhance mental and physical resilience and decrease injuries among deployed service members.

In June of that same year, the Uniformed Services University of the Health Sciences hosted a conference titled "Human Performance Optimization in the Department of Defense: Charting a Course for the Future," with the goal of developing a strategic plan for human performance optimization (HPO). That conference marked DOD's acknowledgment of the importance of promoting warrior wellness and modernizing, training and structuring the force by leveraging cutting-edge science and technology (S&T) that would optimize the

performance of servicemen and women in all stages of their careers. Such an approach would set the conditions for a more lethal force by ensuring that warfighters would be ready to respond to present and future threats. The conference was when the HPO effort officially emerged.

Flash forward to 2017, when knowledge and technologies to enhance and sustain warfighters' health, well-being and performance as part of the HPO effort continued to evolve. DOD now considers HPO fundamental to accomplishing the military's mission. For the U.S. Army Research Institute of Environmental Medicine (USARIEM), HPO is a newer, shorter term to describe the research that the small Army medical lab in Natick, Massachusetts, has been doing for more than 50 years.

CONTINUOUS OPTIMIZATION

The USARIEM team prioritizes Army readiness by engaging in essential medical research focused on optimizing

WEARABLE INFORMATION

A Soldier puts on an Equivital chest harness, which incorporates USARIEM's ECTemp algorithm to record heart rate changes over time. The heart rate indicates how much blood flows to muscles and the skin, from which researchers can extrapolate how much heat is being generated and lost by the body. Medics and leaders looking to prevent heat illness in Soldiers can monitor Soldiers' body temperatures if the ECTemp technology is included in a wearable monitor like the chest harness. (U.S. Army photo by David Kamm, RDECOM)



servicemen and women's health and performance during training and on the battlefield. "USARIEM partners with DOD, other federal entities, universities, nonprofits and industry stakeholders extensively to answer military-relevant questions and optimize Soldiers' health, resilience and performance," said Col. Raymond Phua, commander of USARIEM.

USARIEM's location at Natick Soldier Systems Center, a 30-minute drive west of Boston, puts the lab in close proximity to the extensive academic, federal and commercial knowledge and research assets of the Northeast corridor, giving researchers access to top potential collaborators. USARIEM is one of the very few labs in the world where all aspects of HPO come together.

While the lab looks at HPO through a biomedical or a bioengineering lens, USARIEM's holistic approach to attaining an "optimized performance state," as Dr. Karl Friedl, USARIEM's senior research scientist for performance physiology described it, sets the lab apart. Friedl also explained that the unique and critical research capabilities that USARIEM provides to the DA, DOD and the nation are the synergy of subject matter expertise on performance, nutrition, environmental stressors and biomedical modeling from civilian researchers and Soldier scientists.

"The Army will always have Soldiers holding terrains in parts of the world that have extreme environments, and as long as we continue to encounter threats near and far, warfighters will always encounter risks," Friedl said. "This makes an optimized performance state sound like an elusive goal. While we cannot eliminate these risks, we can mitigate them.

"USARIEM is the only lab that has looked at all aspects of Soldiers' physical and cognitive performance, in terms of health, occupation and the environments they work in. We aim to sustain the health and fighting ability of warfighters by developing military medical doctrine and technology that will give warfighters the ability to meet the physical and cognitive demands of any combat or duty position, accomplish the mission and continue to win present and future fights."

USARIEM's internationally recognized research leaders are executing and supporting key products and strategic doctrine shifts, which include the U.S. Army Training and Doctrine Command (TRADOC) project to examine the knowledge, skills, abilities and other attributes associated with military occupational specialties (MOSs), as well as the Army surgeon general's 2020 strategy of shifting to a system of health through the areas of performance and nutrition, with the goal of attaining high-quality, longer lives free of preventable disease, disability, injury and premature death.

Here are some of the emerging USARIEM technologies, medical doctrine and future research efforts to optimize warfighter health and performance in a variety of occupational environments and situations.

EMERGING USARIEM TECHNOLOGIES

The Estimated Core Temperature (ECTemp) algorithm accurately estimates a Soldier's core body temperature simply by analyzing heart rate changes over time. Physiologically, heart rate reflects both the blood flow to the muscles and the rate of blood flow to the skin, containing information about both heat production and heat loss from the body. ECTemp can be

incorporated into wearable technology, such as a chest harness with a physiological status monitor, which mission leaders and medics can monitor with a phone to detect if one or more Soldiers are at increased risk of heat illness. USARIEM developed ECTemp based on years of physiological data collected from multiple studies. By providing accurate core temperature information, the ECTemp can help military leaders make timely, critical training and mission decisions in hot, humid and unpredictable environments. The ECTemp has opened the door to future monitoring apps and wearable technology for the military.

Unit leaders can use the Altitude Readiness Management System (ARMS), an Android-based app, to plan missions with appropriate expectations. By using data from more than 25 years of USARIEM's altitude studies, ARMS predicts how likely Soldiers are to experience acute mountain sickness during a mission, and how severely. ARMS also calculates how much time Soldiers need to complete missions and acclimate to a variety of altitudes. Unit leaders can use this easily accessible information to alter high-altitude missions before deployment in order to prevent hypoxic events. The app is now fielded on the Nett Warrior platform and is being fielded through the TRADOC online app store this year.

The Soldier Water Estimation Tool (SWET) is an Android-based smartphone app and mission planning tool that can predict average water needs for groups of Soldiers for defined periods of time. The app uses a validated, updated sweat prediction equation based on five decades of USARIEM's research on sweat loss and hydration. A unit leader can plug in the temperature, humidity, cloud cover, type of clothing worn and

Soldiers' workload. The app does the rest of the work. SWET supports the use of real-world planning in military settings in a variety of outdoor conditions. The app is now fielded on the Nett Warrior platform and, along with ARMS, is also being made available on the TRADOC app store this year.

The Performance Readiness Bar (PRB) is a calcium- and vitamin D-fortified snack bar developed to optimize bone health in basic trainees. The snack bar was distributed at Fort Benning, Georgia, in the summer of 2017 and will be distributed at all four Army basic training locations in 2018. Calcium and vitamin D have already been proven to be necessary nutrients to improve bone health. However, USARIEM researchers' findings indicated that basic trainees needed higher-than-average amounts of calcium and vitamin D to support bone health during initial military training.

According to the Military Health System, recruits often arrive at basic training with poor calcium and vitamin D status, making their bones more vulnerable to stress fractures and other injuries. PRB is one solution to this problem that will reduce attrition and personnel costs associated with initial military training, increasing Army readiness.

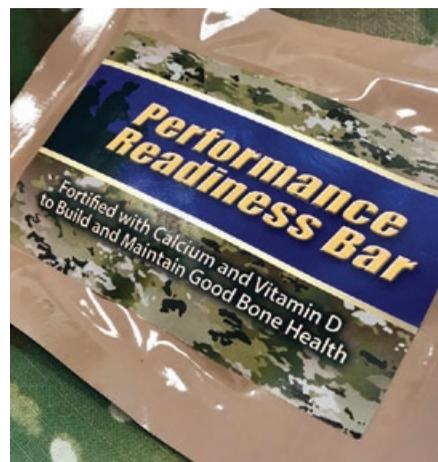
The Occupational Physical Assessment Test (OPAT) was part of the TRADOC Soldier 2020 initiative, which would help set the standards necessary for Soldiers—male and female—to perform in combat MOSs. USARIEM researchers broke down those specialties into essential physical capabilities that a Soldier needs to be trainable for a given specialty.

Throughout 2016, USARIEM researchers conducted more than 27 field studies in initial military training settings at Fort



SWET THE DETAILS

Operations in extreme heat or cold, or at high altitude, can be unpredictable. Decades of USARIEM research informs the SWET app, left, and the ARMS app, which give unit leaders objective information to adjust deployments and prevent disastrous casualties. (U.S. Army photo by Mallory Roussel, USARIEM)



EDIBLE READINESS

The Performance Readiness Bar, a calcium- and vitamin D-fortified snack bar developed under the research guidance of USARIEM's Military Nutrition Division, will soon be available Armywide. The new snack was prompted by military health researchers' realization that basic trainees are doubly vulnerable to bone injury. (U.S. Army photo by Mallory Roussel, USARIEM)

Benning, Georgia, Fort Leonard Wood, Missouri, and Fort Sill, Oklahoma, administering a robust battery of physical performance tasks and questionnaires before and after training. This effort resulted in the OPAT, which contains a battery of four tests: a standing long jump, a medicine ball throw, an incremental squat lift and an interval aerobic run. During this project, the USARIEM team validated the predictive ability of the OPAT to accurately place Soldiers into seven combat specialties.

As a result of their efforts, the OPAT was fully implemented starting in 2017; it is now required for all Army candidates seeking to enter active, reserve or National Guard duty. The USARIEM team now is conducting a longitudinal study in which it is following volunteers for the next two years of their service to assess how successful they are in their assigned specialties after receiving their OPAT results. This data will provide the Army information on injury and dropout rates in basic training, showing how much time and money used to rehabilitate and recycle Soldiers could be saved.

The Combat Rations Database (COMRAD) is an interactive, educational website that provides warfighters and military dietitians with information about military rations and the potential for affecting warfighters' diets and mission readiness. With COMRAD, warfighters and dietitians can view nutrition information for entire menus and even specific food components, like drinks and side dishes, in three types of rations: Meals, Ready to Eat; First Strike Ration; and Meal, Cold Weather/Long Range Patrol. COMRAD is based on a nutritional database created in collaboration with USARIEM's Military Nutrition Division. All nutritional information is accurate, and all menu components have been chemically analyzed, making COMRAD the go-to application for precise,

easily accessible nutrition information on individual items, menus and daily food intake.

FUTURE RESEARCH TO OPTIMIZE THE WARFIGHTER

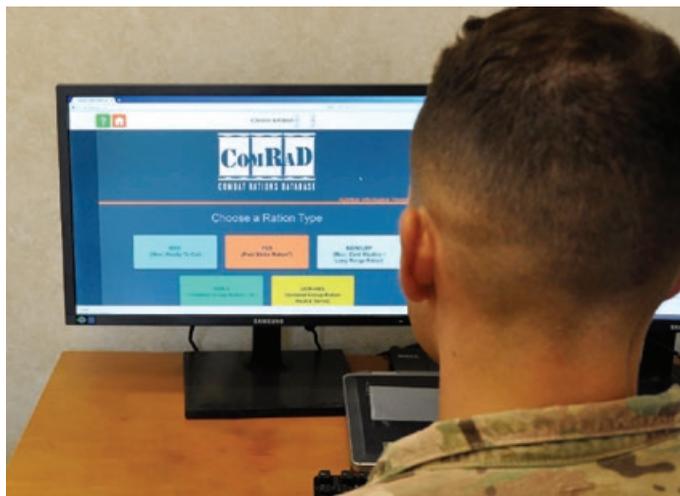
Warfighters engage in combat in all kinds of environments, including cold weather, such as in the Arctic. The question is: Are they prepared? USARIEM is conducting multiple research efforts, called Cold Weather Dexterity in Arctic Warfare, related to cold weather fighting protection. One of the biggest problems Soldiers can face is the loss of hand function and manual dexterity in the cold. This can happen when Soldiers do not wear gloves, causing the blood flow to the hands and fingers to decrease. Yet Soldiers can also experience reduced touch sensation and fine-motor dexterity by wearing gloves.

Either scenario could prevent warfighters from using their weapons or other sophisticated equipment that is required for the mission. USARIEM is collaborating with U.S. Army Alaska and the U.S. Army Mountain Warfare School to research and develop technologies to increase warmth and blood flow to the fingers and face. This effort could optimize performance in Arctic missions while preventing frostbite and other cold weather injuries.

Because of the unique multistressor environment of Army basic combat training, musculoskeletal injuries are common in recruits. The ARIEM Reduction in Musculoskeletal Injuries (ARMI) Study is a four-year research collaboration between USARIEM and the U.S. Army Public Health Center to develop evidence-based, actionable recommendations to Army leadership for strategies to reduce musculoskeletal injuries in basic combat training without reducing training standards.

FUEL FOR THE BODY

A Soldier uses COMRAD, an online resource that gives troops, military dietitians and food service officers the opportunity to learn about the nutritional value of the food they eat. The database is the result of a collaborative effort between NSRDEC, USARIEM and DOD's Human Performance Resource Center. (U.S. Army photo by Mallory Roussel, USARIEM)



WHAT ARE WE LOOKING FOR?

Marilyn Sharp, right, the USARIEM principal investigator in the OPAT research effort, consults with a drill sergeant before gathering physiological data that helped set physical standards for about 100,000 recruits and thousands of cadets training for various military occupational specialties. OPAT sought to identify the key physical capabilities Army recruits needed to succeed in one of the seven combat specialties. (U.S. Army photo by David Kamm, RDECOM)



USARIEM researchers will be tracking 4,000 recruits throughout and for two years after basic combat training to identify risk factors and evaluate the effectiveness of ongoing musculoskeletal injury prevention and related initiatives.

Bullets and rockets are not the only things servicemen and women contend with when they deploy. Often, gastrointestinal illnesses, like travelers' diarrhea, can decrease Soldiers' performance, prompting USARIEM's Nutrition Interventions. For the last few years, researchers from USARIEM and the Combat Feeding Directorate of the U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC), an element of the U.S. Army Research, Development and Engineering Command (RDECOM), have been working together to understand the complex relationship between our health and the tens of trillions of microorganisms—including at least 1,000 known species of bacteria—living in our intestines. USARIEM researchers have conducted a series of field studies, from Natick to Pikes Peak in Colorado to Norway to characterize how different military stressors affect the gut microbiome and impact warfighter health. Some of these studies have shown that high altitudes,

high physical stress and diet affect Soldiers' gut health. USARIEM researchers plan to start testing for dietary interventions based on the findings of these and future gut health studies.

CONCLUSION

In the perpetually changing world of U.S. military S&T, HPO is one of the newer terms and efforts. Yet USARIEM has been doing research on HPO for decades and will continue to do so. By tapping into civilian and military expertise in performance, nutrition, environmental stressors and modeling, as well as additional local and international partnerships with academic, federal and commercial knowledge and research assets, USARIEM has been able to generate knowledge, products and technologies that optimize the performance of servicemen and women throughout their careers.

For more information, go to www.usariem.army.mil.

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pharmacology from the University of North Dakota and a B.A. from Miami University. After seven years of active-duty service in the U.S. Air Force and the U.S. Army, he served in a civilian research physiologist position in 1991 and became USARIEM's Thermal and Mountain Medicine Division chief in 2012. He was appointed to his current post in September 2016. In addition to conducting numerous hypobaric chamber and Pikes Peak research studies, he has led biomedical expeditions to the base of Mount Everest, Nepal, and the summit of Mount Kilimanjaro, Tanzania. He is an international expert in environmental physiology and medicine with an emphasis in high-altitude medicine, and serves on many scientific panels, including those of the U.S. Army Medical Research and Materiel Command and the Defense Health Agency.

MS. MALLORY ROUSSEL is a science writer for the Science Strategic Management Office of USARIEM and a research fellow in the Oak Ridge Institute of Science and Education program. She holds a B.A. in English from Boston University. She has written about diverse subjects, from anatomic avatars to mission planning technology and military nutrition interventions.

A BETTER 'REALITY'

Technologies to enhance what Soldiers 'see' in complex, congested environments promise to improve the information available to make decisions quickly.

*by Dr. Richard Nabors, Dr. Robert E. Davis
and Dr. Michael Grove*

Information overload! How many people have suffered from the feeling? A 2009 study, published by the University of California, San Diego, stated that an average American in 2008 consumed an average of 34 gigabytes of information every day from more than 20 different sources. And this was before the smartphone became ubiquitous. Such a deluge of information could overload even a powerful computer, let alone the average American.

As information technology has become more available to the military, it presents Soldiers in complex operational situations with significantly more information than in the past, and in a broader variety. Just as the average American can be overwhelmed by data, Soldiers receiving information from multiple sources in addition to their own senses can suffer from information overload, decision gridlock and mental exhaustion.

On the battlefield, Soldiers cannot afford to be mentally or physically fatigued. They do not have the leisure to sort through every bit of information, or the time to judge the value of the information received. Yet Soldiers must do these things, and they must do them quickly and decisively, constantly adapting to the changing situation. At the same time, information is often clouded by the "fog of war," limiting the Soldier's ability to make reality-based decisions on which their lives and others' depend.

To allow maximum latitude to exercise individual and small-unit initiative and to think and act flexibly, Soldiers must receive as much relevant information as possible, as quickly as possible. Sensor technologies can provide situational awareness by collecting and sorting real-time data and sending a fusion of information to the point of need, but they must be operationally effective. Augmented reality (AR) and mixed reality (MR) are the solutions to this challenge. AR and MR



NEW TACTICAL REALITY

In augmented reality, computer-generated or real-world sensory content is placed on top of a Soldier's view of the real-world environment. (U.S. Army photo)

technologies have shown that they make sensor systems operationally effective.

DIGITAL, REAL WORLDS UNITE

AR digitally places computer-generated or real-world sensory content on top of a Soldier's view of the physical, real-world environment. In MR, the scanned information about the user's physical environment becomes interactive and digitally manipulable. AR and MR function in real time, bringing the elements of the digital world into a person's perceived real world and thus enhancing their current perception of reality. Examples of AR and MR familiar to any National Football League fan are the blue and yellow overlays that appear on the television screen showing the line of scrimmage and the first down line, respectively. This overlay is intuitive and designed not to distract from the game, requiring no training and significantly enhancing the fan's experience.

On a Soldier's display, AR can render useful battlefield data in the form of camera imaging and virtual maps, aiding a Soldier's navigation and battlefield perspective. Special indicators can mark people and various objects to warn of potential dangers. Soldier-borne, palm-size reconnaissance copters with sensors

and video can be directed and tasked instantaneously on the battlefield at the lowest military echelon. Information can be gathered by multimodal (visual, acoustic, LIDAR or seismic) unattended ground sensors and transmitted to a command center, with AR and MR serving as a networked communication system between military leaders and the individual Soldier.

When used appropriately, AR and MR should not distract Soldiers but will give pertinent information immediately, so that a Soldier's decision will be optimal and subsequent actions relevant and timely. AR and MR allow for the overlay of information and sensor data into the physical space in a way that is intuitive, serves the point of need and requires minimal training to interpret. Thus both information overload and the fog of war are diminished.

INFORMATION IS POWER

On the future battlefield, increased use of sensors and precision weapons by U.S. adversaries, as well as by the U.S., will threaten the effectiveness of traditional 20th century methods of engagement. Detection will be more difficult to avoid, and deployed forces will have to be flexible, using multiple capabilities and surviving by reacting faster than the adversary.

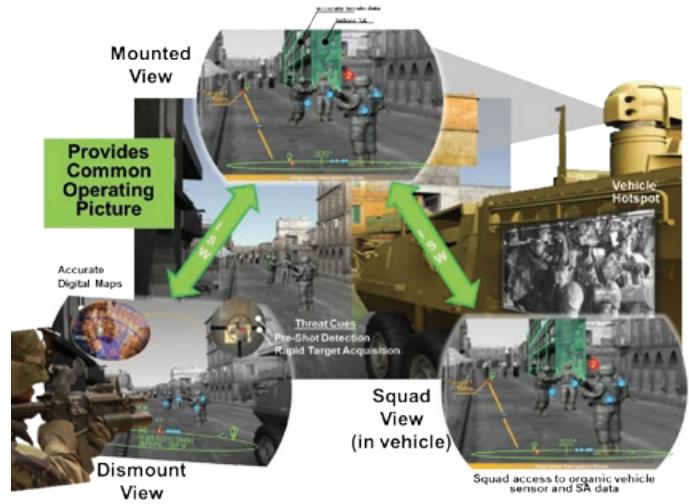
As networks of sensors integrate with greater numbers of autonomous systems, the need for faster decision-making will increase dramatically. With autonomous systems becoming more prevalent on the battlefield, adversaries who do not have the same human-in-the-loop rules of engagement may be quicker than the U.S. to effectuate lethal responses. Because speed in decision-making at the lowest military echelon is critical, accelerating human decision-making to the fastest rates possible is necessary to maximize the U.S. military’s advantage.

AR and MR are the underpinning technologies that will enable the U.S. military to survive in complex environments by decentralizing decision-making from mission command and placing substantial capabilities in Soldiers’ hands in a manner that does not overwhelm them with information. As such, the Army has identified AR and MR as innovative solutions at its disposal as it seeks to increase Soldier safety and lethality as a priority of its modernization strategy.

MEETING THE CHALLENGES

The challenge for AR and MR is to identify and overcome the technical barriers limiting their operational effectiveness to the Soldier. For example, as Soldiers’ operational information needs become more location-specific, the need for AR and MR to provide real-time, immediate georegistration will be increasingly important. To prevail in this near-term technical challenge and several others like it, the Army research and development (R&D) community is investing in the following technology areas:

- Technologies for reliable, ubiquitous, wide-area position tracking that provide accurate self-calibration of head orientation for head-worn sensors.
- Ultralight, ultrabright, ultra-transparent display eyewear with wide field of view.
- Three-dimensional viewers to provide the Soldier with battlefield terrain visualization, incorporating real-time data from unmanned aerial vehicles and the like.



NETWORKED COMMUNICATION

A vision of the Army’s future augmented reality capabilities. Augmented reality and mixed reality will provide a networked communication system between military leaders and the individual Soldier in the field. Information will be gathered by a variety of unattended ground sensors and transmitted to the command center. (U.S. Army graphic)

In the mid term, R&D activities are focusing on:

- Manned vehicles developed with sensors and processing capabilities for moving autonomously, tasked for Soldier protection.
- Robotic assets, teleoperated, semi-autonomous or autonomous and imbued with intelligence, with limbs that can keep pace with Soldiers and act as teammates.
- Robotic systems that contain multiple sensors that respond to environmental factors affecting the mission, or have self-deploying camouflage capabilities that stay deployed while executing maneuvers.
- Enhanced reconnaissance through deep-penetration mapping of building layouts, cyber activity and subterranean infrastructure.

In the far term, the R&D community can make a dent in key technological challenges once AR and MR prototypes and systems have seen widespread use. Research on Soldier systems will help narrow the set of choices, explore the options and reveal available actions and resources to facilitate mission success. This research will focus on automation that could track and react to a Soldier’s changing situation by tailoring the augmentation the Soldier receives and by coordinating across the unit.

Just as the average American can be overwhelmed by data, Soldiers receiving information from multiple sources in addition to their own senses can suffer from information overload, decision gridlock and mental exhaustion.



IMAGE IDENTIFIED

As a result of improvements in AR and MR, real-time sensor data from unmanned aerial vehicles will allow Soldiers to better visualize battlefield terrain, providing geographic awareness of buildings, roads and other structures before a mission. (Image courtesy of U.S. Army Communications-Electronics Research, Development and Engineering Center)

In more long-term development, sensors on Soldiers and vehicles will provide real-time status and updates, optimizing individually tailored performance levels. Sensors will provide adaptive camouflage for the individual Soldier or platform in addition to reactive self-healing armor. The Army will be able to monitor the health of each Soldier in real time and deploy portable autonomous medical treatment centers using sensor-equipped robots to treat injuries. Sensors will enhance detection through air-dispersible microsensors, as well as microdrones with image-processing capabilities.

In addition to all of the aforementioned capabilities, AR and MR will revolutionize training. Used as a tactical trainer, AR and MR will empower Soldiers to train as they fight. For example, Soldiers soon will be able to use real-time sensor data from unmanned aerial vehicles to visualize battlefield terrain, providing geographic awareness of roads, buildings and other structures before conducting their missions. They will be able to rehearse courses of action and analyze them before execution to improve situational awareness. AR and MR are increasingly valuable aids to tactical training in preparation for combat in complex and congested environments.

CONCLUSION

Currently, several Army laboratories and centers are working on cutting-edge research in the areas of AR and MR with significant success. The work at the U.S. Army Research, Development and Engineering Command and the U.S. Army Engineer Research and Development Center (ERDC) is having a significant impact in empowering Soldiers on the ground to benefit from data supplied by locally networked sensors.

AR and MR are the critical elements required for integrated sensor systems to become truly operational and support Soldiers' needs in complex environments. It is imperative that both technologies mature sufficiently to enable Soldiers to digest real-time sensor information for decision-making. Solving the challenge of how and where to use augmented reality and mixed reality will enable the military to get full value from its investments in complex sensor systems.

For more information or to contact the authors, go to www.cerdec.army.mil.

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LOOK FURTHER

Despite challenges, Army STRLs are making significant strides—including work by the U.S. Army Space and Strategic Defense Command/Army Forces Strategic Command to advance high-energy laser weapons, like this one. They have the potential to be a low-cost, effective complement to kinetic energy to address threats from rockets, artillery and mortars, as well as from cruise missiles and unmanned aerial systems. (Images courtesy of DASA(R&T))





INVESTING IN ARMY LABORATORY INNOVATION

You need good labs and smart people to turn out good science and technology. If the Army wants innovative solutions backed by solid R&D, it needs to pay for them.

by Dr. Matt Willis

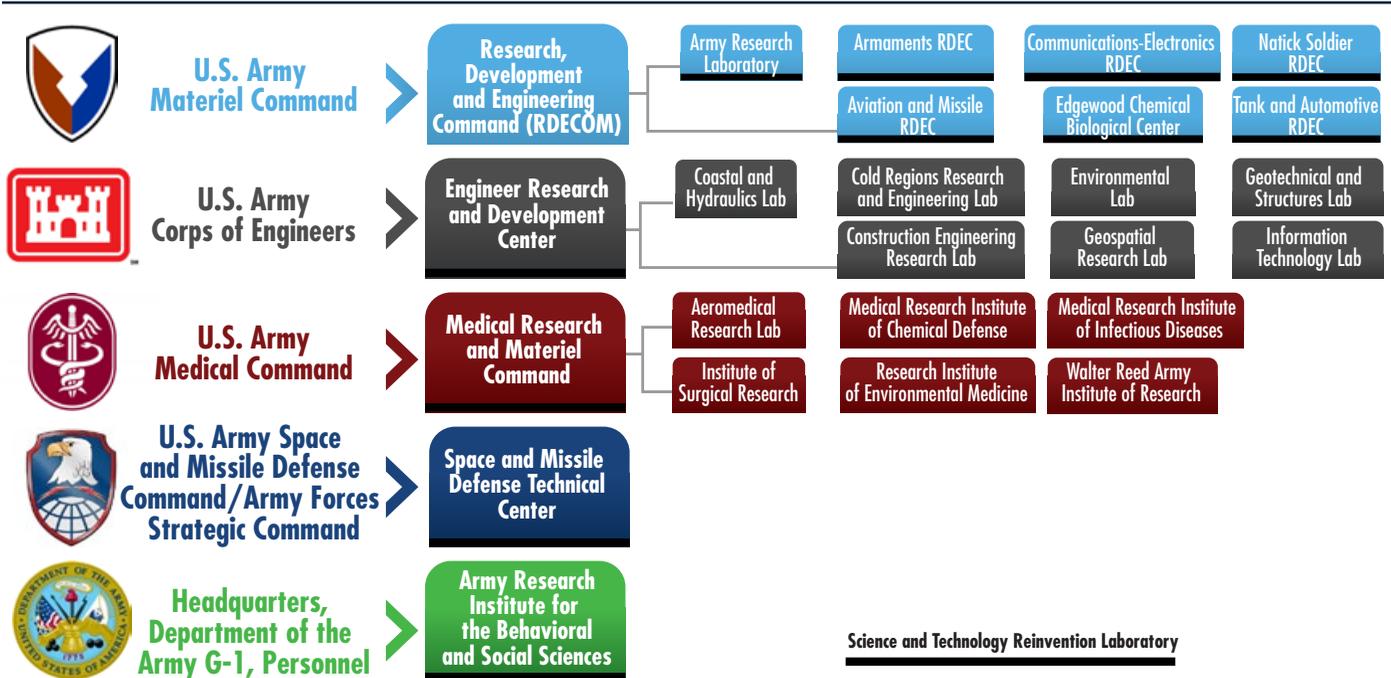


A rmy laboratories work diligently and collaboratively to deliver technology-enabled solutions for current conflicts and to develop technologies to prepare the Army for multiple futures by enhancing the force's ability to prevent, shape and win future conflicts. The Army labs are national assets, ensuring Army dominance in an asymmetric and complex warfighting future. The underpinnings of a robust Army laboratory network include strategic and focused workforce and infrastructure policies; collaborations with traditional and nontraditional defense partners; mechanisms for dynamic technology transfer to internal and external partners; and a science, technology, engineering and mathematics (STEM) ecosystem that promulgates a highly skilled, technically competent and diverse cadre of scientists and engineers at the Army laboratories. The assistant secretary of the Army for acquisition, logistics and technology (ASA(AL&T)) provides a strategic focus and policy framework to instill these organizations with the means and capabilities to develop

critical Army technologies for the current and future force.

To stay at the cutting edge and provide continued dominance to our Soldiers, Army labs need the right facilities, equipment and workforce. It's a challenge to get them, however. Nationally, the number of U.S. students pursuing STEM degrees has declined for several years, and the Army faces stiff competition from the private sector for the limited talent pool once students graduate. The Army must continue to invest in STEM education to ensure a continuing supply of domestic scientists and engineers who can get security clearances in a timely manner, and who consider the Army for a long-term rewarding STEM career. Furthermore, Army labs have an average facility age of more than 50 years. Modern buildings, equipment and adequate resourcing are vital to developing cutting-edge technology and to recruit and retain the most talented scientific personnel. Minimizing the impact of aging infrastructure and maintaining world-class research facilities will require

FIGURE 1



RESEARCH BRANCHES OUT

Army STRLs encompass a wide-ranging and diverse but complementary network of 11 distinct laboratory organizations operating specialized labs, research institutes and research, development and engineering centers (RDECs) in more than 80 locations, 32 states and 15 countries.

strategic planning from the Army science and technology (S&T) community.

Congress has recognized the unique challenges that Army and other government-owned and government-operated laboratories face to remain competitive. The National Defense Authorization Act for Fiscal Year 1995 designated several Army laboratories as Science and Technology Reinvention Laboratories (STRLs) and delegated unique workforce and infrastructure authorities to these organizations. There are several criteria for an organization to be designated an STRL:

1. The laboratory must meet the definition of a research and development laboratory, as defined in paragraph 3.2 of “DOD Instruction 3201.4, In-House

Laboratory Independent Research Program,” whose scientific and engineering workforce is principally involved in performing exploratory development, research work or a combination of both.

2. A significant portion of the laboratory’s staff should be scientists or engineers who spend a substantial amount of time personally performing exploratory development or research work.
3. Research and development efforts are preferably in at least two well-defined specialty areas.
4. The facility should have a significant portion of its programmatic effort in tech-based activities, as defined in DOD’s Financial Management Regulation, Volume 2B, Chapter 5. The regulation organizes research, development, test and evaluation (RDT&E)

appropriation into seven basic areas: basic research; applied research; advanced technology development; advanced component development and prototypes; engineering and manufacturing development; RDT&E management support; and operational system development.

5. A significant portion of research and development activities should be conducted in-house, so as to require and ensure continued development of in-house expertise.
6. At least one segment of the mission effort should be unique to that facility, at least within its own service.
7. Professional recruitment activity should include at least one critical hard-to-hire, high-demand occupation or area where there is considerable competition for trained personnel.

The list of government laboratories designated as STRLs has evolved numerous times since 1995; all Army laboratories executing S&T are now designated STRLs, with the associated workforce and infrastructure authorities. The Army STRLs are distributed among the U.S. Army Materiel Command, U.S. Army Medical Command, U.S. Army Corps of Engineers, U.S. Army Space and Missile Defense Command and HQDA G-1. The STRLs consist of 11 distinct laboratory organizations distributed across more than 80 locations, 32 states and 15 countries, each with distinct but complementary mission sectors and core competencies. (See Figure 1.)

The organic Army S&T workforce includes approximately 28,350 employees around the world, at over 80 sites in 32 states across the U.S. and in 14 additional countries. The economic impact that the labs have on their local communities should not be understated. Figure 2 depicts a density plot of Army scientists and engineers across the U.S. for each S&T command; the size of the circle is proportional to the number of civilian, military and contractor personnel at each site. Annual RDT&E activity across the Army STRLs is greater than \$11 billion.

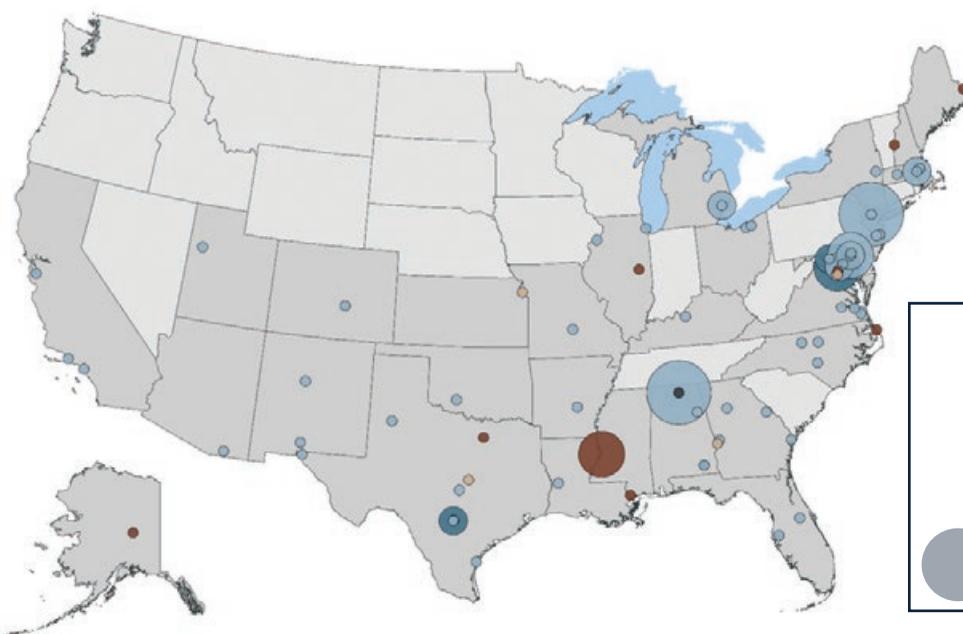
Army labs have had great technological successes, including providing novel armor solutions for vehicles and Soldier protection; adaptive Soldier protection capabilities; lower-cost air defense



CHECKING FOR BRAIN INJURY

The work of STRLs includes research into warfighter health. As the incidence of traumatic brain injury rises, developing a tool to quickly and correctly diagnose head injuries is vitally important. These I-Portal PAS goggles, funded in part by U.S. Army Medical Research and Materiel Command's Combat Casualty Care Research Program, use virtual reality technology to assess possible brain injuries. The device has received financial support from DOD and the National Football League and is being evaluated in clinical trials at several military medical facilities.

FIGURE 2



MAP OUT THE IMPACT

The Army S&T workforce numbers more than 28,000, with employees in 32 states across the U.S. and in international locations, making important contributions to the economy of the communities in which they operate. Annual RDT&E activity across the Army STRLs exceeds \$11 billion.

EMPLOYEES BY COMMAND	KEY
● ≤ 500	■ HQDA G-1 [128]
● 501-1,500	■ USACE [2,954]
● 1,501-3,000	■ SMDTC [282]
● 3,001-8,800	■ MEDCOM [4,814]
	■ RDECOM [21,192]

systems; and optimized Soldier-system integration and training technologies. Army leadership should invest in the current and future organic Army S&T workforce and facilities to foster overmatch for a complex and uncertain future, ensuring a deliberate investment in incremental and disruptive innovation.

The following articles explore some of the contributions Army labs have made, and highlight ways to keep those labs staffed with talented, dedicated people to continue the legacy of achievement.

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DR. MATT WILLIS is the director for laboratory management in the Office of the Deputy Assistant Secretary of the Army for Research and Technology (DASA(R&T)). As such, he shapes policies that impact the workforce, infrastructure, technology transfer and STEM educational outreach posture at the Army STRLs. He holds a Ph.D. and an M.S. in chemical engineering from the University of Illinois at Urbana-Champaign and a B.S. in chemical engineering from Cornell University. He is Level II certified in science and technology management and is a member of the Army Acquisition Corps.

ANSWERING HARD QUESTIONS

Army labs are invaluable assets in ensuring Army dominance in the complex battles of the future. However, new approaches for strategic planning and investment are needed as facilities age and competition for a shrinking pool of qualified candidates grows more difficult.

ARMY LABORATORIES



The U.S. Army Materiel Command's Research, Development and Engineering Command provides innovative research, development and engineering to support the joint warfighter and the nation. The U.S. Army Research Laboratory explores the art of the possible, while the research, development and engineering centers mature product development within armaments, aviation and missiles, communications and electronics, chemical and biological defense, Soldier systems, and tank and automotive systems.



The U.S. Army Corps of Engineers' Engineer Research and Development Center solves the nation's most challenging problems in civil and military engineering, geospatial sciences, water resources and environmental sciences for the Army, DOD, civilian agencies and our nation's public good.



The U.S. Army Medical Command's Medical Research and Materiel Command (MRMC) is the Army's medical materiel developer, with responsibility for medical research, development and acquisition and medical logistics management.

The MRMC's expertise in these critical areas helps establish and maintain the capabilities the Army needs to fight and win on the battlefield.



The U.S. Army Space and Missile Defense Command Technical Center (SMDTC) is part of a single, synchronized team charged to provide dominant Army space, missile defense and high-altitude capabilities to the Army, joint force, allies and partners. SMDTC manages S&T and R&D and conducts test programs for space, integrated air and missile defense, directed energy, hypersonics and related technologies.



The U.S. Army Research Institute for the Behavioral and Social Sciences provides the Army with scientific research concerning cognitive and noncognitive personnel testing and performance measurement, individual skills training and learning, leadership and leader development, recruiting and retention of the force, and strategic organizational issues.

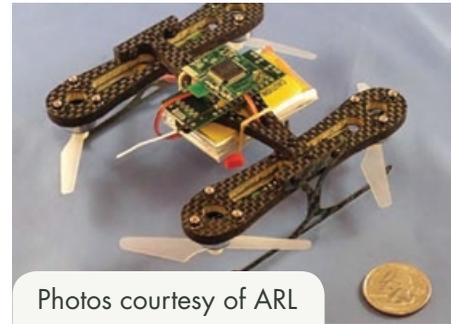
TECHNICAL ACHIEVEMENTS

U.S. ARMY RESEARCH LABORATORY (ARL)

Micro-Autonomous Systems and Technology Collaborative Technology Alliance (MAST CTA)

MAST CTA, a basic research program that ran from FY08 to FY17, was designed to enhance the tactical situational awareness of the dismounted Soldier in urban and complex terrain by enabling the autonomous operation of a collaborative ensemble of micro-autonomous systems. Since its inception, the program has advanced technology to reduce the size, weight and power of autonomous systems; increase operational speed in complex environments; develop obstacle detection, perception and mapping capabilities; and provide new understanding in bio-inspired agility and maneuverability. Several research efforts are ongoing and have advanced expertise within the Army to continue improving autonomous systems. Current research areas include:

- Development of bio-inspired sensors and controls, including sensor integration, human-in-the-loop controls and position, navigation and timing.
- Aeromechanics, soft materials, fluid and flight dynamics.
- Manipulation and mobility, e.g., self-righting and grasping.
- Collaboration behaviors, network-aware communications and GPS-denied navigation.



Photos courtesy of ARL

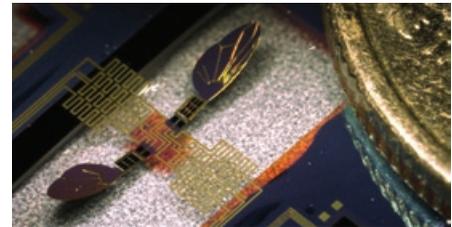


Photo courtesy of CERDEC



U.S. ARMY COMMUNICATIONS-ELECTRONICS RESEARCH, DEVELOPMENT AND ENGINEERING CENTER (CERDEC)

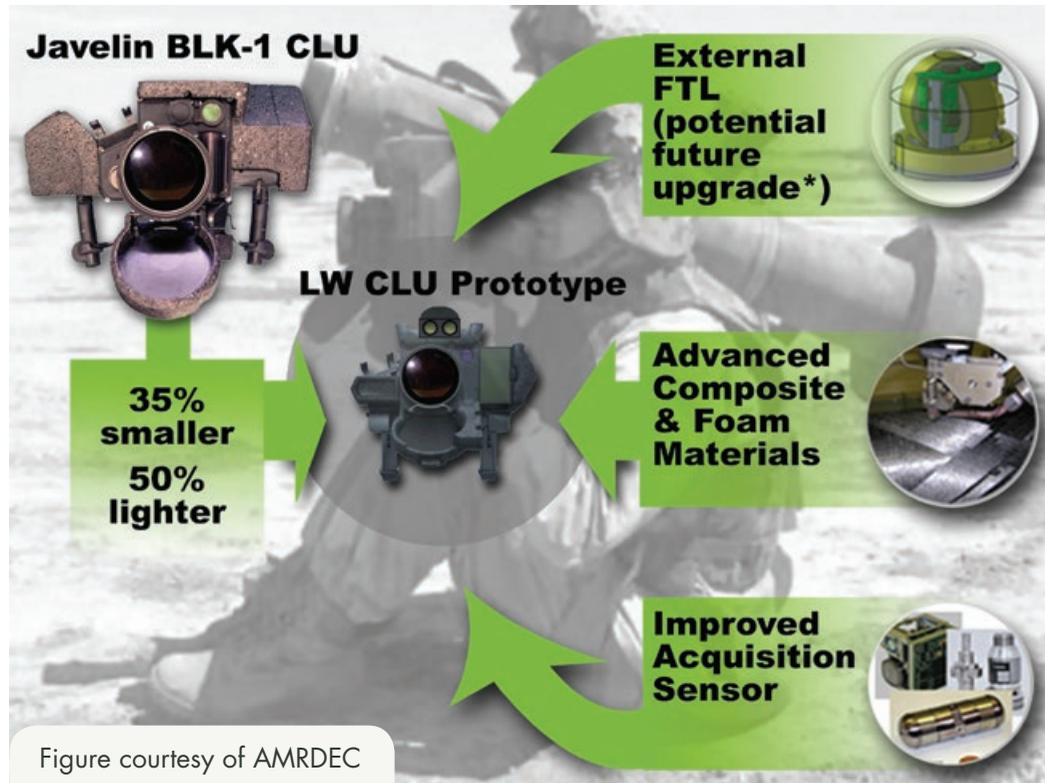
Vital Infrared Sensor Technology Acceleration (VISTA)

The VISTA program was a multiyear Army-led initiative that also involved the Navy and Air Force. The effort began in 2011 and aimed to maintain U.S. military superiority in infrared sensor capabilities. Products delivered from VISTA will enable the next generation of sensors to perform at the levels necessary to maintain overmatch and allow for multiple functions, including search, identification and tracking; wide area persistent surveillance; and operations in degraded visual environments. VISTA focused on III-V antimony-based infrared focal plane arrays, which use an entirely new class of materials that improve affordability, manufacturability and performance, while also offering size, weight and power advantages for advanced infrared systems. The technology developed in this program is already available in some defense products and will be transitioned to multiple programs of record. Ultimately it will facilitate warfighter overmatch in any environment. Over its five years of effort, VISTA created an entire new industry base for producing III-V antimony-based infrared focal plane arrays. Its use of domestic commercial compound semiconductor foundries, which sell products like cellphone chips and are not reliant on DOD for their survival, provide flexibility, producibility and affordability.

U.S. ARMY AVIATION AND MISSILE RESEARCH, DEVELOPMENT AND ENGINEERING CENTER (AMRDEC)

Javelin Lightweight Command Launch Unit (CLU)

The technology behind the Javelin Lightweight CLU reduces the weight of the system by 50 percent and decreases the overall size by 35 percent while providing equal or greater detection, recognition and identification performance than the current Javelin CLU. AMRDEC’s investments in critical technologies provide the capabilities to reduce Soldier load, greater force protection to ensure survivability, and persistent surveillance and acquisition to enable battlefield dominance. A smaller infrared target acquisition sensor provides increased detection, recognition and identification performance, and advanced composite and foam materials used in the CLU housing improve strength, thermal management and shock absorption. Production is planned for FY20.

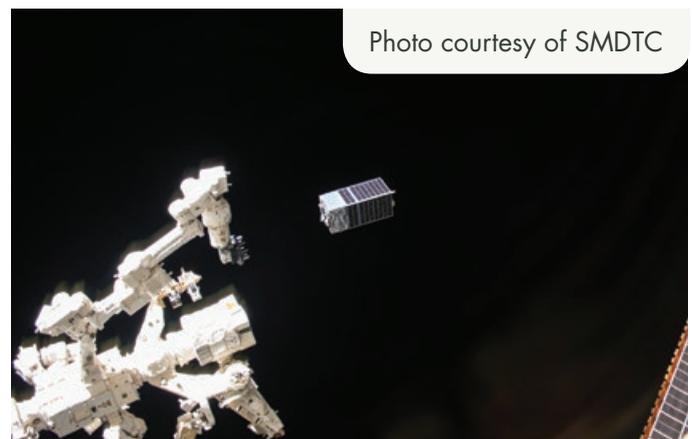


U.S. ARMY SPACE AND MISSILE DEFENSE COMMAND/ARMY FORCES STRATEGIC COMMAND TECHNICAL CENTER (SMDTC)

Kestrel Eye

The Kestrel Eye is a small, low-cost, visible-imagery satellite prototype designed to provide near-real-time images to the tactical-level ground Soldier. Kestrel Eye was launched to the International Space Station (ISS) as a payload aboard the SpaceX Falcon 9 from Kennedy Space Center in Florida on Aug. 14, 2017, as part of the ISS cargo resupply mission. The system was subsequently deployed into space and activated on Oct. 24. “Kestrel Eye is a technology demonstrator, but it holds the promise of providing tactical imagery to the Soldier on the ground, and to do it responsively, persistently and reliably,” said John R. London III, chief engineer for the Space and Missile Defense Command’s Space and Strategic Systems Directorate. “For the

first time, commanders in the field will be able to control the entire imagery process from end to end, from the tasking of the satellite all the way through to the dissemination of the data to the Soldiers who need it.”



U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES (ARI)

Tailored Adaptive Personality Assessment System (TAPAS)

Army recruits complete a series of screenings to be deemed eligible to join. Most notable is the Armed Services Vocational Aptitude Battery (ASVAB), a cognitive ability measure required for entry and job placement. The U.S. Army Research Institute for the Behavioral and Social Sciences developed TAPAS to supplement the ASVAB and predict success in the Army, the first major change to Army accession testing since the 1990s. TAPAS is a computer-adaptive personality assessment tool, based on personality theory, psychometrics and advanced testing technology, that assesses 26 personality attributes, including achievement, leadership, adjustment, tolerance and team orientation. Preliminary results indicate that TAPAS facilitates prediction of technical performance, is a strong predictor of motivational outcomes and attrition, and is a useful tool to improve in-service assignment selection. The Walter Reed Army Institute of



Photo courtesy of ARI

Research (WRAIR) found strong relationships between those who score lower on TAPAS and mental health diagnosis and medical attrition. Expanded screening, including noncognitive assessments like TAPAS, can reduce attrition and behavioral health risks, and improve readiness and performance.

Photo courtesy of USAMRMC



U.S. ARMY MEDICAL RESEARCH AND MATERIEL COMMAND (USAMRMC)

Occupational Physical Assessment Test (OPAT)

OPAT is a battery of four physical performance tests that the Army has administered since 2017 to all candidates seeking to enter active, Reserve or National Guard duty, to identify who is most likely to succeed in combat military occupational specialties (MOSs). The U.S. Army Research Institute of Environmental Medicine (USARIEM), a subordinate command of MRMC, began conducting field studies in 2016, in initial military training settings at Fort Benning, Georgia; Fort Leonard Wood, Missouri; and Fort Sill, Oklahoma. The effort resulted in the four OPAT tests—a standing long jump, a medicine ball throw, an incremental squat lift and an interval aerobic run—and validated the predictive ability of the OPAT to place Soldiers into seven combat MOSs. USARIEM is now in the first year of a two-year longitudinal study to assess how successful Soldiers are in their assigned MOSs after receiving their OPAT results. According to an Army Times article, Army statistics from late October 2017 indicate that since administering the OPAT, injuries in basic combat training have dropped by 17 percent, and on-time graduation rates have jumped from 85 percent to 93 percent.

U.S. ARMY MEDICAL RESEARCH AND MATERIEL COMMAND (USAMRMC)

Zika virus vaccine

The Zika virus, which originated in the Zika forest in Uganda, has now infected humans around the world, causing fevers and rashes along with more serious nervous system complications such as Guillain-Barre syndrome and microcephaly. U.S. service members and their families are at higher risk for Zika virus infection than the general U.S. population as they often deploy to areas with active transmission of Zika. In an unprecedented 180 days, USAMRMC and WRAIR developed a Zika purified inactivated virus (ZPIV) vaccine candidate and published

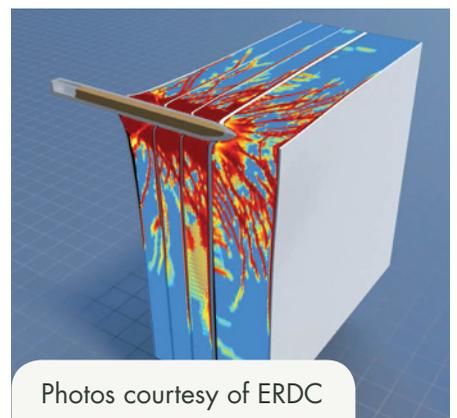
preclinical findings in Nature and Science. Three initial ZPIV human trials began in 2016, each addressing a unique question about background immunity, vaccine dose or vaccination schedule. The results of these trials, published in November 2017, showed that the vaccine induced a robust immune response and was safe and well-tolerated in healthy adults. A fourth ZPIV trial is still underway in Puerto Rico, where the population has natural exposure to other viruses in the same family as Zika, such as dengue.



U.S. ARMY ENGINEER RESEARCH AND DEVELOPMENT CENTER (ERDC)

Countering anti-access and area denial (A2AD)

ERDC collaborates with the U.S. Army, Air Force, Navy, Marine Corps and others to solve significant projection and protection challenges facing Soldiers in A2AD environments. ERDC's force projection research is focused on developing and demonstrating technologies for planning and conducting forcible entry operations with nonexistent, damaged or destroyed infrastructure to ensure that the joint force can operate in any environment, at any time, regardless of terrain. Recent successes include demonstration of rapid airport and seaport repair solutions; terrain surfacing kits for unmanned aircraft landing strips, helicopter landing zones, and logistics over shore operations; and remote monitoring technologies and decision support tools for assessing critical infrastructure and littoral zones. To protect facilities that allow the U.S. to project force into denied areas, ERDC is exploring advanced materials and unique structural components that are incorporated into structural hardening solutions, as well as decision support tools that aid vulnerability assessments of critical facilities and mission impact.



Photos courtesy of ERDC

BROAD ROOTS GROW STRONG STEMS

Army Educational Outreach Program aims to engage, inspire and attract the next generation of science, technology, engineering and mathematics talent.



BUILDING BLOCKS

AEOP and its participants develop and implement programs for students and teachers that aim to attract the next generation of STEM talent and tell them about DOD STEM careers. Almost 2,000 Army scientists and engineers participated in the programs in the 2016-17 academic year, and students and teachers have worked in 22 laboratories and 118 universities across the country. (SOURCE: The author)

by Dr. Matt Willis

The United States’ science, technology, engineering and mathematics (STEM) capabilities are critical to the nation’s innovation, economic competitiveness and national security. Protecting and equipping our most critical asset, the U.S. Soldier, depends on thoughtful solutions that can thrive only if we are constantly ahead of our adversaries in science and technology innovation and manufacturing. Globally, STEM fields will drive the solutions to our most critical challenges in health, safety and the environment.

Recent studies illustrate a clear and alarming erosion in the United States’ STEM capabilities, evident in both the skills gap plaguing our major industries and our students’ lagging achievement in mathematics and science compared with peers worldwide. Since the National Academies’ seminal report, “Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future,” brought this issue to the forefront a decade ago, partners across just about every sector have answered the call for a coordinated federal effort to reposition the U.S. as a leader in STEM.

To date, this coordinated federal effort has had mixed results in improving STEM throughout the school-to-career pipeline. Thanks to strong bipartisan support, STEM education has become a highly visible and widely championed issue in the business, education and STEM communities.

However, U.S. students still rank only 35th in mathematics and 18th in science in the most recent Program for International Student Assessment, and economic data show that roughly 1 million additional highly qualified STEM graduates will be needed over the next decade. Though student proficiency is beginning to increase in these subjects, the U.S. has a long way to go before its students have the knowledge and skills they'll need to succeed in tomorrow's jobs.

ARMY EDUCATIONAL OUTREACH PROGRAM

To address the challenge of attracting students to STEM careers in support of both DOD and the nation, the Army has curated a portfolio of STEM-rich programs for students and teachers that engage and inspire the next generation

of STEM talent and provide exposure to DOD STEM careers. The Army Educational Outreach Program (AEOP) provides students and teachers from elementary school through college access to collaborative, high-quality STEM programs that encourage a STEM-literate citizenry, STEM-savvy educators and future STEM leaders nationwide. AEOP engages scientists and engineers from across the network of Army laboratories as mentors and guides, bringing young people directly into our laboratories and research assets for hands-on STEM challenges with real-world applications. The Army strives to build a diverse, well-prepared, STEM-literate workforce in support of the defense sector and the broader national STEM challenge. By leveraging the Army's strengths and leaning on the strengths of partners, the Army is addressing the STEM crisis on multiple fronts, with promising results.

The Army provides strategic direction and oversight for AEOP. The program is executed through a cooperative agreement managed by Battelle, a global research and development organization based in Columbus, Ohio, that also

coordinates STEMx, a platform to share and disseminate STEM educational tools across the country. Additional partners for the cooperative agreement include the Purdue University College of Education; Widmeyer Communications, a Finn Partners Company; MetriKs Amérique LLC; Tennessee Technological University's Millard Oakley STEM Center; the National Science Teachers Association (NSTA); the Technology Student Association (TSA); the Academy of Applied Science; the Mathematical Association of America; and the National Inventors Hall of Fame.

Each partner plays an important role, from recruiting volunteers to supporting communications and administering programs. AEOP partners provide the STEM education component to maximize the benefits and use of Army research assets. Additionally, they help reach a much broader network of STEM educators through networks such as STEMx and through NSTA and TSA, with a combined active membership of over 300,000 students, educators and business professionals.

TAKE A CLOSER LOOK

David Bogema, a civil engineer with the U.S. Army Corps of Engineers (USACE) Nashville District, talks with students from the Central Magnet School in Murfreesboro, Tennessee, during the STEM Expo at Tennessee State University in April 2017. Student proficiency in STEM fields is on the rise, in part because of events like this one, but more progress is needed to keep the U.S. competitive and secure. (Photo by Mark Rankin, USACE Nashville District)



EXPLORE THE OPTIONS

Children learn to use computer-aided design and drafting software at STARBASE Summer Camp at Camp Mabry, Texas, in August 2017. Funded by DOD and now in its fifth year, STARBASE encourages children in areas that are historically underrepresented in STEM—inner cities or rural locations, for example, or those that are socioeconomically disadvantaged—to get involved in STEM disciplines through hands-on challenges and networking with positive role models. (U.S. Army National Guard photo by Sgt. Michael Giles)



AEOP is investigating new and innovative ways to forge mutually beneficial relationships with organizations and technical associations that have similar STEM goals, specifically serving students from underserved populations and military dependents. In collaboration with our strategic STEM partners, AEOP is empowered to leverage their partners' robust and established STEM networks, build on and synergize with existing relationships and promote its portfolio of enriching STEM opportunities for educators and students. The intent of the AEOP Strategic Outreach Initiatives, started in April 2016, is to broaden student participation in the AEOP portfolio to better

reflect the nation's demographics. AEOP selected partners specifically for their leadership in STEM learning and outreach to African-American, Hispanic, female and military-connected students. Current partners include the Society of Women Engineers, the Tiger Woods Foundation, Harmony Public Schools, DC STEM Network, Carnegie Academy for Science Education and the EduCare Foundation, among many others. Through these strategic partners, AEOP is able to broaden its network far beyond the Army laboratories and our university partners.

The AEOP strategy has also significantly improved the Army's ability to capture

measures of success, to identify STEM program gaps, to maximize resources, and to create, train and defend a sustainable STEM infrastructure. These investments center on a measurable and defensible value stream that affects an expanding workforce, including Americans in rural and urban settings, as well as other underrepresented groups in STEM fields. The program tracks improvements in these areas and analyzes the effectiveness of each AEOP STEM effort.

HEIGHTENED INTEREST IN STEM

Most important of all, the AEOP programs work. Students have reported a deeper interest in STEM after completing just one of the AEOP enrichment programs, competitions or apprenticeships. Program impact has been captured through survey data. Furthermore, AEOP alumni attest to how the AEOP experience dramatically improved their understanding of STEM careers in DOD and beyond and set them on a path to pursuing a STEM-related career. A recent initiative evaluated the impact of AEOP activities on the 21st Century

Recent studies illustrate a clear and alarming erosion in the United States' STEM capabilities, evident in both the skills gap plaguing our major industries and our students' lagging achievement in mathematics and science compared with peers worldwide.

Skills Framework, representing the skills and knowledge students need to succeed in work, life and citizenship. Preliminary results suggest a statistically significant improvement in skills such as creativity and innovation, critical thinking and problem-solving, as well as productivity, accountability, leadership and responsibility. Teachers who participate in AEOP programs are better able to engage students in hands-on STEM learning in the classroom. Results also indicate that even Army civilian mentors gain valuable skills and insight through their work to inspire a new generation of STEM talent.

Across the country, the programs are showing significant progress. In the 2016-17 academic year, AEOP received 39,715 online applications and placed 32,792 students in programs, representing a 15 percent increase in both applications and participants from 2012. Additionally, 2,568 teachers had authentic laboratory experiences—a threefold increase in four years. Nearly 2,000 Army scientists and engineers participated in the programs, and students and teachers worked in 22 participating laboratories and 118 participating universities across the country. This success is a helpful case study for other programs and stakeholders looking to make a real impact on students from all communities.

CONCLUSION

It is an exciting time in the U.S. for STEM, and the momentum continues to grow. However, this momentum will not spur dramatic improvements in students' preparedness for tomorrow's STEM-driven careers if stakeholders fail to partner and work together toward measurable outcomes. We also won't get far if African-American, Hispanic, female and military-connected students continue to lack access to the quality STEM exploration and courses of study they need to



LET'S TRY THIS

1st Lt. Robert Leisinger, executive officer for the 3rd Battalion, 15th Infantry Regiment, 2nd Infantry Brigade Combat Team, 3rd Infantry Division (2-3 IBCT), helps students assemble a robotic car at Snelson-Golden Middle School in Hinesville, Georgia, near Fort Stewart, in November 2016. The students were participants in Z Space, the school's STEM program. Encouraging kids to consider careers in STEM fields early in their education is important: Roughly 1 million additional highly qualified STEM graduates will be needed over the next decade. (U.S. Army photo by Spc. Efrén Rodríguez, 2-3 IBCT Public Affairs)

thrive. The STEM workforce will continue to grow, not just in importance, but also in size and complexity. U.S. competitiveness—and our children's future—is at stake. Together, we must ensure the next landmark STEM report tells a different, triumphant story.

For more information, go to www.usaeop.com.

DR. MATT WILLIS is the director for laboratory management in the Office of

the Deputy Assistant Secretary of the Army for Research and Technology. As such, he shapes policies that impact the workforce, infrastructure, technology transfer and STEM educational outreach posture at the Army science and technology research laboratories. He holds a Ph.D. and an M.S. in chemical engineering from the University of Illinois at Urbana-Champaign and a B.S. in chemical engineering from Cornell University. He is Level II certified in S&T management and is a member of the Army Acquisition Corps.





BENCH-BUILDING at ARMY LABS

Attracting an elite cadre of scientists and engineers is essential for the Army mission; Army labs need to be able to offer better pay and shorter hiring timelines to do so.

by Dr. Matt Willis

A core enabler for technology superiority in a constantly evolving and asymmetric threat landscape is technological excellence at the Army laboratory enterprise, empowered by a strategically shaped and highly competent technical workforce. Attracting, recruiting and retaining an elite cadre of Army scientists and engineers is essential for success in the science and technology (S&T) domain that is critical to the Army's mission. Army scientists, technicians, engineers and mathematicians—among other technical specialists—make fundamental S&T contributions to national security and to the nation as a whole. The Army must instill an open laboratory culture—steeped in innovation and collaboration, and a systems thinking approach—that is accommodating to creative, free minds and a stimulating atmosphere to break through the bureaucracy and attract future technical experts.

The Army, as an S&T incubator, competes with the private sector and academia for high-demand science, technology, engineering and mathematics (STEM) professionals. Army S&T success—and by proxy, dominance in the future fight—depends on tenets such as:

- The dynamic recruiting of high-caliber, future-focused STEM professionals, with timely initial hiring and flexible compensation.
- The responsibility, authority and flexibility for Army laboratories to manage workforce strength, structure, positions and compensation unencumbered by limitations on appointments, positions or funding.
- Talent management policies and strategies that fuel growth, innovation and

FIGURE 1

S&T COMMAND	TYPE	AUTHORIZED	USED	% USED
<i>U.S. Army Corps of Engineers Engineer Research and Development Center</i>	BACHELOR	69	48	70%
	ADVANCED	58	45	78%
	VETERANS	39	14	36%
<i>U.S. Army Medical Research and Materiel Command</i>	BACHELOR	36	12	33%
	ADVANCED	61	36	59%
	VETERANS	12	7	58%
<i>U.S. Army Materiel Command Research, Development and Engineering Command</i>	BACHELOR	557	286	51%
	ADVANCED	501	161	32%
	VETERANS	265	38	14%
ALL	BACHELOR	662	346	52%
	ADVANCED	620	242	39%
	VETERANS	316	59	19%
	TOTAL	1,598	647	40%

HOW DIRECT-HIRE IS USED

Direct-hire authority lets Army labs hire who they need without regard to regulations that slow down other federal hiring—but that authority is limited. This shows the Army laboratory use of the direct-hire authority in 2016. The number of direct-hire actions per calendar year is limited to a given percentage of the total number of scientists and engineers at the STRL in the previous fiscal year. For potential hires with an advanced degree, a lab can use direct-hire authority to bring on board 5 percent of the previous year’s workforce level; for those with a bachelor’s degree, it’s 6 percent; veterans, 3 percent; and students, 10 percent. (SOURCE: The author)

market advantage with an agile and flexible operational structure designed to accomplish evolving S&T priorities.

- A robust group of senior STEM leaders to enable effective and efficient execution of S&T programs, with support from a balanced blend of administrative, technical and professional staff.

ARMY STEM WORKFORCE

The Army must instill innovative workforce management practices to empower the Science and Technology Reinvention Laboratories (STRLs) to be an attractive venue for technical careers.

The Army STRLs—all Army labs that execute joint S&T funds are designated as such, which confers additional authorities in how they’re run—represent a unique segment of the broader Army workforce, including a highly educated, highly technical and highly recruited population. Recruiting and hiring into specialized positions within the Army STRL enterprise is often inhibited by the traditionally tepid hiring timeline and smaller compensation packages as compared with the private sector or academia. An innovative S&T enterprise requires

Case Study – USAMRMC

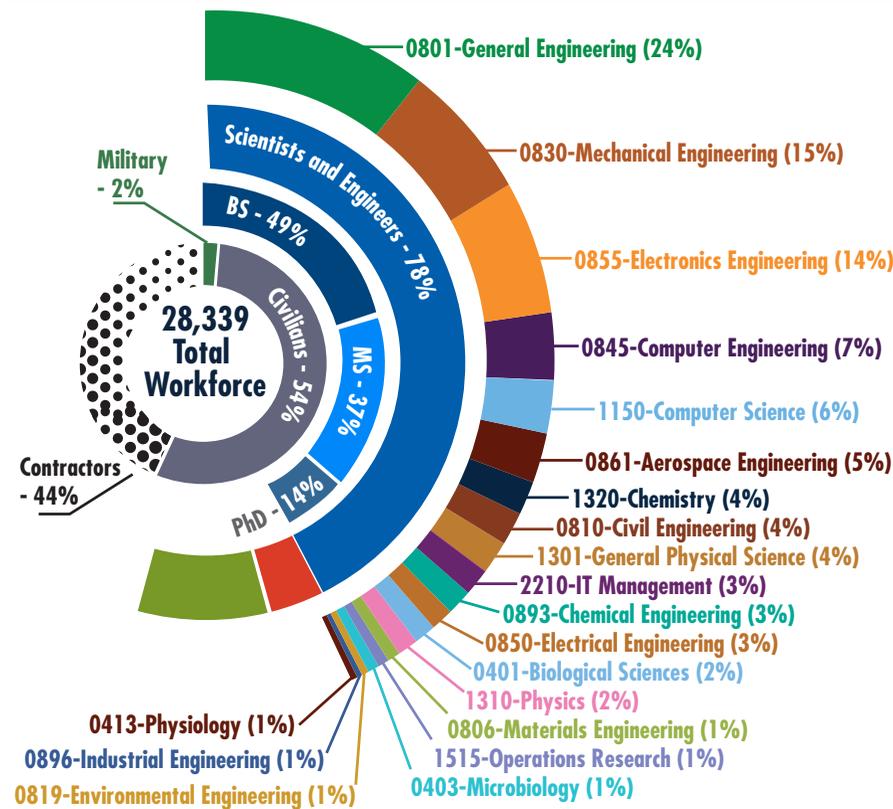
The U.S. Army Medical Research and Materiel Command (USAMRMC) has had challenges recruiting certain key technical personnel as civilian employees because of the inability to provide salaries competitive with what the pharmaceutical and biotech industries can offer. The national median salary for a senior-level life scientist is \$244,000 a year; the maximum salary for civilian employees under the USAMRMC Laboratory Demonstration Project is \$172,000 per year. Based on special authorities provided to the U.S. Department of Health and Human Services, top-level life scientists at the National Institutes of Health have salaries ranging from \$194,000 to \$240,000 a year.

This individual worked for a major pharmaceutical company at a higher salary than could be provided to a civilian employee. The only way this person could be attracted to work in the USAMRMC was to be hired through a contracting company. This incurred a significantly greater cost to the government and deprived USAMRMC of technical personnel who can manage employees and programs and make decisions on behalf of the government.

By being able to provide competitive salaries, USAMRMC would be better equipped to recruit top-performing medical researchers to its laboratories.

—DR. MATT WILLIS

FIGURE 2



WHO'S WHO

Seventy-eight percent of Army civilians are specialized scientists and engineers, sorted into 42 U.S. Office of Personnel Management occupational codes, ranging from microbiology (0403) to aerospace engineering (0861) to physiology (0413) and chemistry (1320). More than half of the Army S&T workforce hold an advanced degree, with 14 percent holding a doctorate. (SOURCE: The author)

an agile policy posture and hiring construct to attract, recruit and retain the current and future Army STEM leaders.

STRL WORKFORCE AUTHORITIES

Unique personnel and operational authorities are required for the labs to develop the S&T that is critical to success in the future asymmetric multidomain battle. In recognition, Congress established Section 342(b) of the National Defense Authorization Act (NDAA) for Fiscal Year 1995, which authorizes the secretary of defense to conduct personnel

demonstration projects at DOD STRLs. The personnel management authorities granted in the original provision have evolved into a permanent, continuing program to give all Army labs the freedom to build the necessary S&T workforce without the constraints that govern most federal hiring.

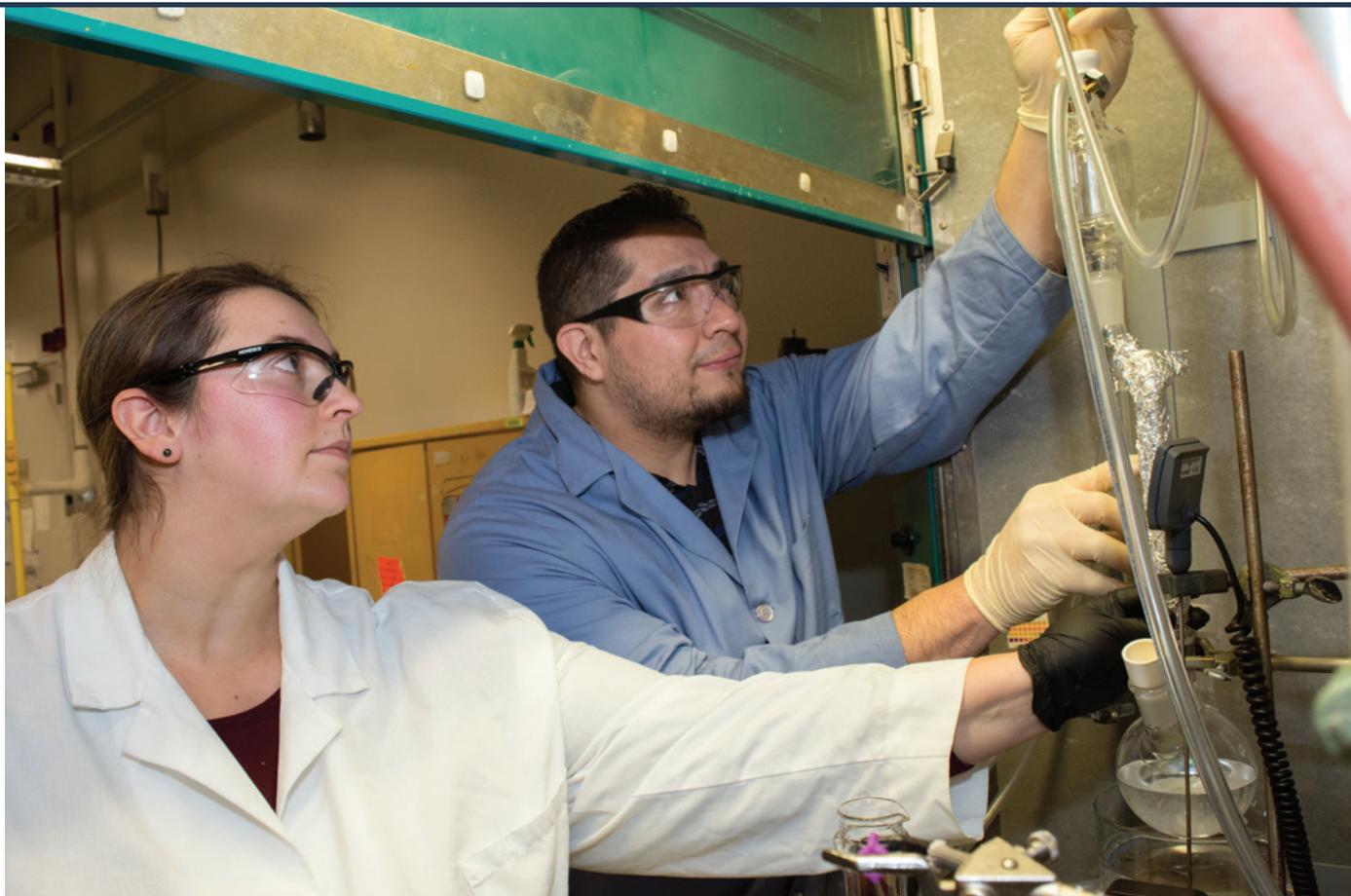
The STRL personnel management demonstration projects involve broadbanded pay systems and simplified classification; compensation linked to performance; recruitment and staffing changes; and enhanced training and development,

including critical skills training, distinguished scholastic achievement authorities, modified term appointments, voluntary emeritus appointments, an entrepreneurial leave program and sabbaticals.

The purpose of the STRL personnel management demonstration project is to demonstrate the efficacy of specified management changes in improving the productivity and effectiveness of basic and applied research and exploratory development at the STRLs, while attracting high-impact STEM leaders. Further, the laboratory demonstration project provides a suite of dynamic tools that allow STRL directors to shape the mix of technical skills and expertise in the workforce to achieve one or more of the following strategic goals:

- To meet organizational and DOD-designated missions in the most cost-effective and efficient manner.
- To upgrade and enhance the scientific quality of the workforces of such laboratories. (See Figure 2.)
- To shape such workforces to better respond to such missions.
- To reduce the average unit cost of such workforces.

Title 10 of the U.S. Code (USC), Section 2358a permanently codifies additional authorities for directors of the STRLs. The directors manage each STRL's workforce strength, structure, positions and compensation without regard to any limitation on appointments, positions or funding and in accordance with the budget available to the facility. The directors are further authorized to implement a direct-hire authority, which expedites hiring by eliminating procedures such as competitive rating and ranking, and veterans' preference. (See Figure 1.) All laboratories are under



NEW HIRES BREAK NEW GROUND

Dr. Leah A. Wingard and Dr. Pablo E. Guzmán, researchers with the U.S. Army Research Laboratory (ARL), work on safer chemical and synthetic materials for products like explosives and propellants. Wingard has a background in inorganic chemistry, and Guzmán—who was hired after completing postdoctoral study under a Nobel laureate—has a background in synthetic chemistry. Relaxing hiring restrictions at Army research facilities could help the Army attract talented S&T professionals who often opt for similar work in the private sector. (Photo by David McNally, ARL)

command-imposed hiring restrictions that inhibited full use of the direct-hire authority. Direct-hire authority has reduced the elapsed time between the close of the job application and the conditional offer to the candidate from more than 90 days to often less than 20 days. The Laboratory Personnel Management Demonstrations Project has allowed Army labs to remain agile and competitive with the private sector, providing job offers in a matter of weeks versus months, with the option to offer more competitive compensation.

Congress has further embraced a future-focused STEM-oriented workforce and innovative laboratory enterprise by initiating a pilot program for operational streamlining of DOD laboratories. Section 233 of the NDAA for Fiscal Year 2017 challenges STRL directors to instill innovation in their organizations by

streamlining management operations, rapid deployment of warfighter capabilities, experimentation, prototyping and partnership with universities and private-sector entities to generate greater returns on research and development activities. The Section 233 pilot program is a tailorable solution that will enable efficient and effective customization of activities such as facility management, construction and repair; business operations; personnel management policies and practices; and intramural and public outreach. The pilot program is authorized through the end of FY22.

CONCLUSION

Structured organizations like the Army are constrained in their ability to evolve toward a flexible, cross-organizational STEM workforce. Cross-organizational workforce utilization



SAMPLES FROM SPACE

Bintu Sowe, an associate scientist at the U.S. Army Center for Environmental Health Research at Fort Detrick, Maryland, processes samples in June 2017 from a bone healing experiment conducted aboard the International Space Station. Sowe's lab is part of the U.S. Army Medical Research and Development Command (USAMRMC), which historically has struggled to recruit experts when they can make twice the amount of money that the government can offer by working for the pharmaceutical or biotech industry. (U.S. Army photo by Crystal Maynard, USAMRMC)



I'M WORKING ON TUNNELS. YOU?

Jen Picucci, a research mathematician at the U.S. Army Engineer Research and Development Center's Structural Engineering Branch, explains tunnel detection equipment at the Pentagon's lab day in May 2017. Smart, technical specialists seek the stimulation and creativity of an "open lab" where scientists interact across disciplines and organizations. (Photo by David Vergun, ARL)

allows the Army to broaden capacity for critical focus areas while increasing efficiency within each organization. Congressional leadership has recognized the unique personnel recruitment challenges at Army STRLs and has given unique hiring and retention authorities to the laboratories, via mechanisms such as the direct-hire authority, 10 USC §2358a and the Section 233 pilot program.

However, challenges remain. Many STRLs remain subject to command-imposed hiring restrictions, inhibiting the laboratories' ability to reshape the workforce and keep pace with the rapid change of technology. Every echelon of Army leadership must embrace a paradigm shift to a flexible Army operational structure, ensuring clear goals and personnel accountability while fostering a systematic approach that prioritizes success but does not punish failure.

For more information, contact the author at matthew.p.willis.civ@mail.mil.

DR. MATT WILLIS is the director for laboratory management in the Office of the Deputy Assistant Secretary of the Army for Research and Technology. As such, he shapes policies that impact the workforce, infrastructure, technology transfer and STEM educational outreach posture at the Army STRLs. He holds a Ph.D. and an M.S. in chemical engineering from the University of Illinois at Urbana-Champaign and a B.S. in chemical engineering from Cornell University. He is Level II certified in S&T management and is a member of the Army Acquisition Corps.

FROM *MINDS* TO *MARKETS*

TechLink public-private intermediary helps small businesses access Army inventions, benefiting the U.S. military and the national economy.

by Mr. Thomas Mulkern and Mr. Troy Carter

Putting Army research and technology in the hands of capable partners in industry is crucial for fielding decisive Army capabilities. To be successful, technology transfer requires dedication, commitment and trust.

Since 1999, Army research labs have trusted TechLink, DOD's national partnership for technology transfer, to help bring innovative technology advances to the marketplace and the warfighter, supporting the U.S. military and the national economy and proving the value of the Army laboratory enterprise.

The Army conducts large amounts of scientific research that leads to cutting-edge inventions in virtually all technology fields, with the primary goal of maintaining our battlefield dominance. From 2014 to 2016, for example, the U.S. Patent and Trademark Office granted the Army an average of 151 patents per year on new inventions.

TechLink, based in Bozeman, Montana, is an outreach center at Montana State University with 38 full-time employees that is wholly funded by DOD through a partnership intermediary agreement. TechLink helps the DOD lab system transfer its patented technologies to businesses nationwide, primarily by marketing DOD inventions and helping establish license agreements for them. TechLink is involved in about 60 percent of DOD's license agreements across the U.S.



MARKETING TECHLINK

Tim Giles pilots a drone during the ThunderDrone Tech Expo at SOFWERX in September in Tampa, Florida. Before the development of TechLink, DOD labs relied on their own websites and trade shows like ThunderDrone to showcase their marketable technologies. (U.S. Air Force photo by Master Sgt. Barry Loo)

MISSED CONNECTIONS

Until recently, DOD had trouble connecting with small, entrepreneurial companies, which are eager adopters of new technology, willing to serve small specialized markets and able to develop new products rapidly for those markets.

The problem was one of DOD's approach to technology transfer. Traditionally, DOD labs posted their inventions on their websites and featured some of them at trade shows. However, most small companies and entrepreneurs were not aware that Army research and development (R&D) labs were generating patented inventions or that companies could acquire the rights to use those inventions to develop new products.

TechLink's traditional way of bridging the gap was to frequently review all new DOD inventions, assess their commercial potential and market the most commercially viable inventions to industry, using highly targeted website searches to identify companies that appeared to be good matches.

While successful in reaching well-established companies, this approach failed to identify smaller or newer companies that lacked a well-developed website but could be promising licensees.

EXPANDING THE UNIVERSE

In 2015, TechLink and the Leeds School of Business at the University of Colorado Boulder conducted an economic impact study of all DOD technology licensing from 2000 to 2014.

This study showed that the overwhelming majority of companies that licensed DOD technology were small businesses with fewer than 100 employees. In fact, most of those had fewer than nine employees.

The question TechLink then asked was: How can we market Army technology to small companies that might not even have a website? The answer was to let those small companies find TechLink.

In 2017, TechLink launched a new website that makes it easier to search for

DOD technologies—by keyword, industry area and laboratory—and greatly expand DOD's connection to companies and entrepreneurs nationwide.

"We paired this new website with a robust digital marketing strategy that can leverage the power of the internet and social media to greatly expand our outreach," said Austin Leach, senior technology manager at TechLink. "This allows us to move beyond the traditional marketing approach that reaches hundreds of companies per year to a potential reach in the tens of thousands."

NEXT STEP: EXPRESS LICENSING

The online presence of Army technology began to expand in 2016, when the U.S. Army Research Laboratory (ARL) moved to improve technology transfer by increasing public access to its patents through a novel process called express licensing.

"This was a team effort utilizing two of ARL's existing partners in the technology

transfer arena, TechLink and Leidos,” a private, for-profit defense solutions company based in Reston, Virginia, said Jason Craley, the ARL technology transfer specialist who led the project.

The team began in January 2016 by identifying 40 patents believed to be good candidates for express licensing, notably those approaching their second maintenance fees at 7½ years. (Maintenance fees are required by the Patent and Trademark Office to maintain a valid patent.) Army policy is to not pay second maintenance fees on patents for technologies that are not being used or have not garnered outside interest.

The team selected half of the 40 patented technologies, conducted detailed interviews with inventors and gathered marketing materials. TechLink posted the inventions on ARL’s Intellectual Property (IP) Store, which is hosted by

TechLink’s website and is also accessible through ARL’s home page.

ARL’s IP Store currently features 433 patented technologies, of which 30 are available via express licensing. Companies or entrepreneurs can browse these technologies, select a specific opportunity, download the patent and published papers, then apply for a license to make, use and sell the technology—all online.

“A few of our patents were sunseting before the marketplace was ready or before we could adequately advertise them,” said Craley. “Our hope is that by placing ARL’s technologies in the online store and making them conveniently accessible through express licensing, we’ll boost their exposure and reduce transaction costs to licensing. This is part of our push to reduce obstacles for small business,” he said.

A BOOST FROM NATICK LABS

In June 2017, the U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC) began publicly offering express licensing on the TechLink website, which currently features a total of 112 NSRDEC technologies available for licensing.

Entrepreneurs and businesses can shop those patented technologies online, including the Insulated Container for Cold Beverages, a high-tech ice chest that keeps water bottles cool for 56 hours in 100-plus-degree weather—far longer than existing ice chests—resulting in less waste, better hydration and improved Soldier morale.

The Army’s patented invention is constructed with Modular Lightweight Load-carrying Equipment webbing for secure storage, addressing concerns about traditional ice chests becoming projectiles



TECHNOLOGY LAUNCH

Sgt. Justin Carrington, unmanned aircraft system repairer with 2nd Infantry Brigade Combat Team, 3rd Infantry Division (2-3 IBCT), prepares an RQ-7 Shadow unmanned aerial vehicle for flight at Evans Army Airfield near Fort Stewart, Georgia, last January. TechLink’s website makes it easier to search for Army technologies that are available for license—by keyword, industry area and laboratory. A search for "UAV," for example, brings up an Army system for collisionless flying. (U.S. Army photo by Spc. Efren Rodriguez)

**Technology Transfer:
The Economic Impacts**

- \$20.4 billion in total sales of new products and services.
- \$3.4 billion in sales of new products to the U.S. military.
- \$48.8 billion in total economic output nationwide.
- \$1.6 billion in new tax revenues (federal, state and local).
- 182,985 full-time jobs created or retained.
- 12,199 full-time jobs per year with an average salary of \$71,337.

(SOURCE: “National Economic Impacts from DoD License Agreements with U.S. Industry, 2000-2014,” <https://techlinkcenter.org/wp-content/uploads/2017/01/2016-DoD-Licensing-Study-E-Publication.pdf>)

inside vehicles hit by explosions. The U.S. Army Tank Automotive Research, Development and Engineering Center has slated the improved cooler for use in future Army ground vehicles, and several small businesses are pursuing licensing the design for production.

“The express licensing portal enhances the visibility of technologies that are valuable to the warfighter but may have significant commercial applications as well,” said Sheri Mennillo, technology transfer manager at NSRDEC. “The simplified online process featuring standardized terms reduces the uncertainty of the negotiation process, which may be particularly attractive to small business and entrepreneurs.”

The TechLink website provides a summary of each available technology. For technologies eligible for express licensing, it also gives standardized, prenegotiated financial terms for the types of licenses being offered. The types include exclusive, partially exclusive (limited to a particular field) and nonexclusive. Items that have the “express license” designation are eligible for the faster automated process.

“Express licensing provides transparency to industry, lowers barriers for everyone involved and reduces transaction costs,” said Dan Swanson, TechLink’s licensing lead. Above all, express licensing accelerates the process of getting cutting-edge Army inventions into production, where they can support the U.S. defense mission, help save lives and boost the nation’s economy.

The Army’s technology transfer partners—mostly small and midsize companies—also build surge capacity into the defense supply chain. This is especially true with dual-use inventions like improved batteries and pest control devices. By licensing these inventions, the Army develops a reliable supply chain of companies that are manufacturing dual-use products on an ongoing basis for their commercial customers. This increases the likelihood of timely supply when the product is needed.

The economic impacts are impressive. A 2015 survey by TechLink and the University of Colorado showed that DOD technology license agreements between 2000 and 2014 led to more than \$20 billion in sales of new products and services, including \$3.4 billion in sales back to the military. The 602 companies in the survey generated a total of \$48.8 billion in economic output from those licenses, along with the direct support of 182,985 full-time jobs with an average annual salary of more than \$71,000.



IMPLEMENTING INNOVATION

U.S. Army Spc. Victor Ramirez, 3678th Combat Sustainment Support Battalion, 191st Regional Support Group, replaces a reverse osmosis water purification unit filter in November 2017 in Quebradillas, Puerto Rico. The Army’s scientific research leads to cutting-edge inventions in virtually all technology fields. Licensing those inventions pays numerous dividends for the Army as well as private industry. (U.S. Army photo by Sgt. Avery Cunningham)

IMPORTANCE OF PATENTING

Years of working with Army laboratories has convinced TechLink Executive Director Will Swearingen that without intellectual property protection, private firms rarely make the investment needed to bring new technology to the market.

“Without patent protection, other companies can simply copy the product, making it difficult for the company that developed the product to recoup its investment and make a profit,” Swearingen said. “That’s why we encourage labs to patent their inventions. It’s essential to technology transfer and convincing a company to invest its resources in converting a lab invention into a commercial product the DOD can procure.”

Patents also recognize the effort that scientists and engineers have made, conferring prestige that encourages continued excellence in the field. Last but not least, they provide a quantifiable measure of lab productivity. Some Army researchers are extremely productive. Herbert A. Leupold, a recently retired ARL physicist whose discoveries advanced radar, satellite communications and electronic warfare systems, received

116 patents assigned to the secretary of the Army dating back to the 1970s—the record for an Army employee, according to the Patent and Trademark Office database.

COST BENEFITS FOR DOD

“Typically, the DOD’s investment in a new defense-related product, licensed from a DOD lab, is only around 15 percent of the total investment necessary,” said Swanson. “By licensing to industry, DOD can offload the large expense of converting an early-state prototype into a final product. It’s a very cost-effective way to acquire cutting-edge technology.”

Many products derived from Army inventions have both military and civilian applications. In those cases, the Army frequently saves money on procurement because it benefits from manufacturing economies of scale. Where there is a sizable commercial market for a dual-use product, the Army will need to spend far less on acquiring that product than if it contracted with the defense industry to develop it. For example, rate-actuated tethers invented at ARL, which stretch and relax easily at normal stress but provide dramatically increased resistance

force when pulled quickly, are being explored by small businesses for health care and sports applications. (See “Per Vivo Labs warms to tech transfer,” Page 183.)

“Contracting with a prime supplier for a custom design and production of a defense product is usually far more expensive,” Swanson said. “By patenting its inventions, the Army also protects itself from defense contractors and others laying claim to a technology,” he added. “Without patent protection, the Army and other branches can end up paying twice for a product—once for the original R&D, and a second time by paying the contractor a premium price to use the patents that should belong to the DOD.”

Finally, when licensing its inventions to industry for commercial use, the Army earns revenue and is no longer responsible for patent maintenance costs.

CONCLUSION

Partnerships between the private sector and the Army’s science and technology community benefit the warfighter and the American taxpayer, and help grow the national economy.

COOL CUSTOMERS

This insulated container for cold beverages, a high-tech ice chest that keeps water bottles cool far longer than existing ice chests, is one of 112 technologies developed by NSRDEC that are available for licensing. (U.S. Army photo by David Kamm, NSRDEC)



“Businesses provide upfront payments and ongoing royalties on the inventions they license. That enhances the return on the R&D investment while keeping the fighting force at a technological advantage,” said Swanson. “And by bringing industry partners into the fold, TechLink helps the Army’s science and technology community continue to innovate in ways that benefit the acquisition workforce.”

For more information, go to <http://techlinkcenter.org> or contact Will Swearingen at wds@montana.edu.

MR. THOMAS MULKERN is chief of the Technology Transfer and Outreach Office at ARL, Aberdeen Proving Ground, Maryland. He is responsible for directing technology transfer programs as well as support for outreach programs in science, technology, engineering and mathematics. He holds an M.S. in plastics engineering from the University of Massachusetts and a B.S. in mechanical engineering from Northeastern University. He has published dozens of technical papers on polymer matrix composite research, and holds one U.S. patent. He is Level II certified in program management.

MR. TROY CARTER is the senior writer and editor at TechLink. He provides original reporting on technology transfer, visual media and marketing activity in support of the DOD laboratory system. He holds an M.A. in political science from American University of Beirut and a B.A. in political science from the American University in Cairo. He is a former infantry sergeant and combat veteran from the Army’s 10th Mountain Division, serving in Afghanistan in 2003-04 and in Iraq in 2005-06.



PER VIVO LABS WARMS TO TECH TRANSFER

In 2005, Russ Hubbard went through boot camp like everyone in the Army, and he saw fresh-faced recruits overheat even while they chugged canteens of water and bawled: “Beat the heat, drill sergeant, beat the heat.”

After several overseas deployments, Hubbard left the Army in 2012, transitioned back to civilian life in Kingsport, Tennessee, and founded Per Vivo Labs Inc. to address some of the problems plaguing Soldiers.

The startup’s first product was called Polar Skin Ice Sheets, a highly portable lifesaving solution for on-site treatment of heat injuries. The company’s first customer was the U.S. Army Cadet Command.

After the success of the ice sheets, Hubbard began exploring new mission-focused technologies for the U.S. military. And for that, he began looking within the DOD lab system, assisted by TechLink. “We’re expanding,” Hubbard said recently, “and TechLink has been helping us access the technology to do so.”

Two technologies identified by TechLink caught his attention. The first was rate-actuated tethers, which contain a shear-thickening fluid first explored by the Army for body armor applications. Shear-thickening materials stiffen when exposed to high strain. The original ballistic application involved aramid fibers in a shear-thickening fluid pouch. It was envisioned that at low rates (walking or running), the armor would be flexible. When impacted by a bullet, the armor would stiffen at the point of impact and provide increased ballistic protection. The tethers exhibit the same behavior: Pull slowly and the tethers stretch. Pull quickly and the tethers resist. Hubbard envisioned physical therapy applications, such as braces and resistance bands.

The second technology was a Navy-developed training device for bomb-sniffing dogs. The mixed odor delivery device (MODD) enables safer, more effective K-9 training on homemade explosives without actually blending oxidizers and fuels.

Developing those products meant licensing patented DOD technology. While the rate-actuated tethers are still being developed, Hubbard began selling the MODD in October 2017,

under the trademark Odor Trace, to military and law enforcement customers.

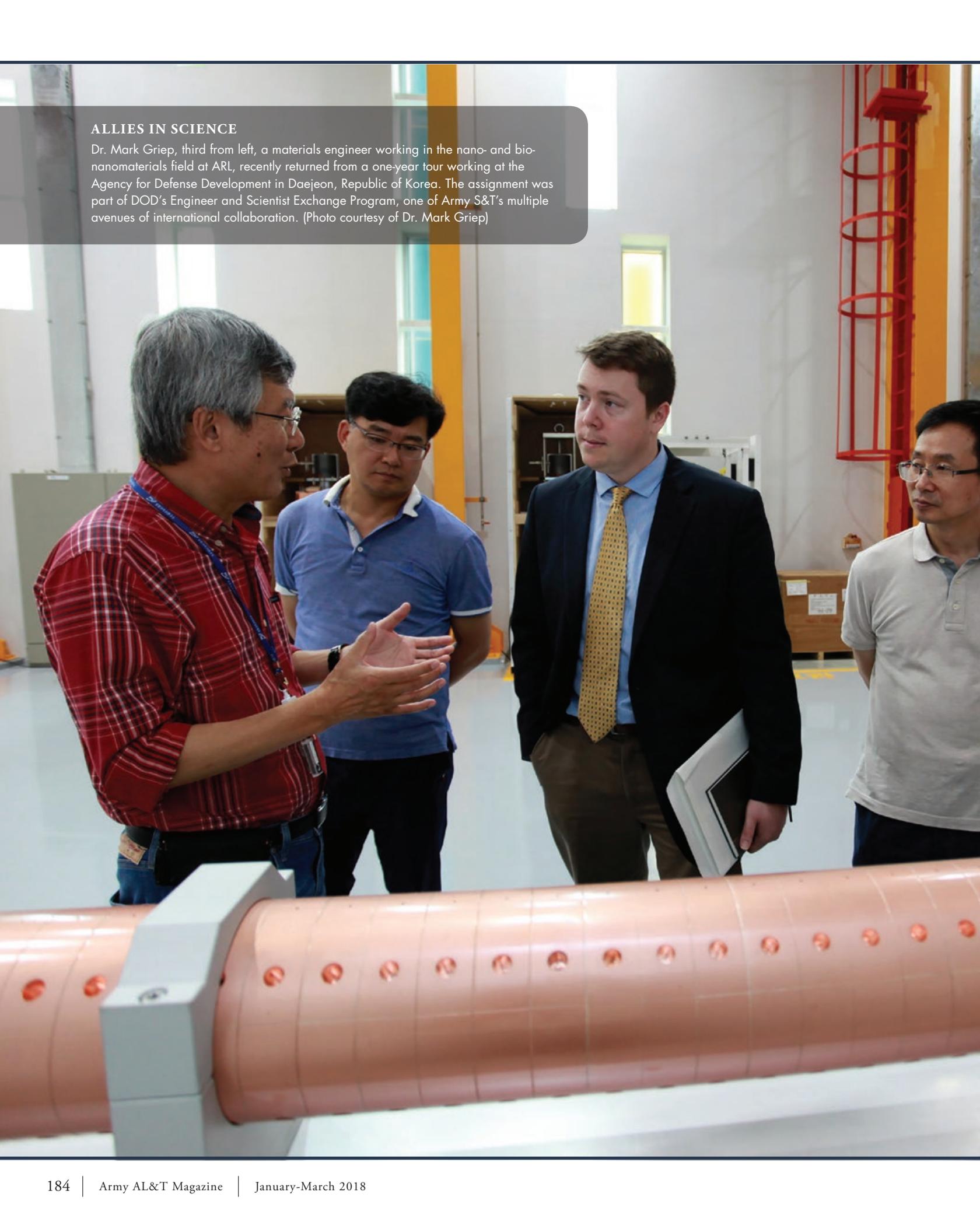
Per Vivo Labs is just one example of how the well-orchestrated transfer of DOD technology can reap benefits for industry and the economy. The same DOD technology can benefit multiple businesses simultaneously. As an example, Per Vivo Labs is now partnering with other small businesses to develop the rate-actuated tethers for applications including chin straps and ankle braces.

—MR. TROY CARTER



ALLIES IN SCIENCE

Dr. Mark Griep, third from left, a materials engineer working in the nano- and bio-nanomaterials field at ARL, recently returned from a one-year tour working at the Agency for Defense Development in Daejeon, Republic of Korea. The assignment was part of DOD's Engineer and Scientist Exchange Program, one of Army S&T's multiple avenues of international collaboration. (Photo courtesy of Dr. Mark Griep)





CRITICAL COLLABORATIONS

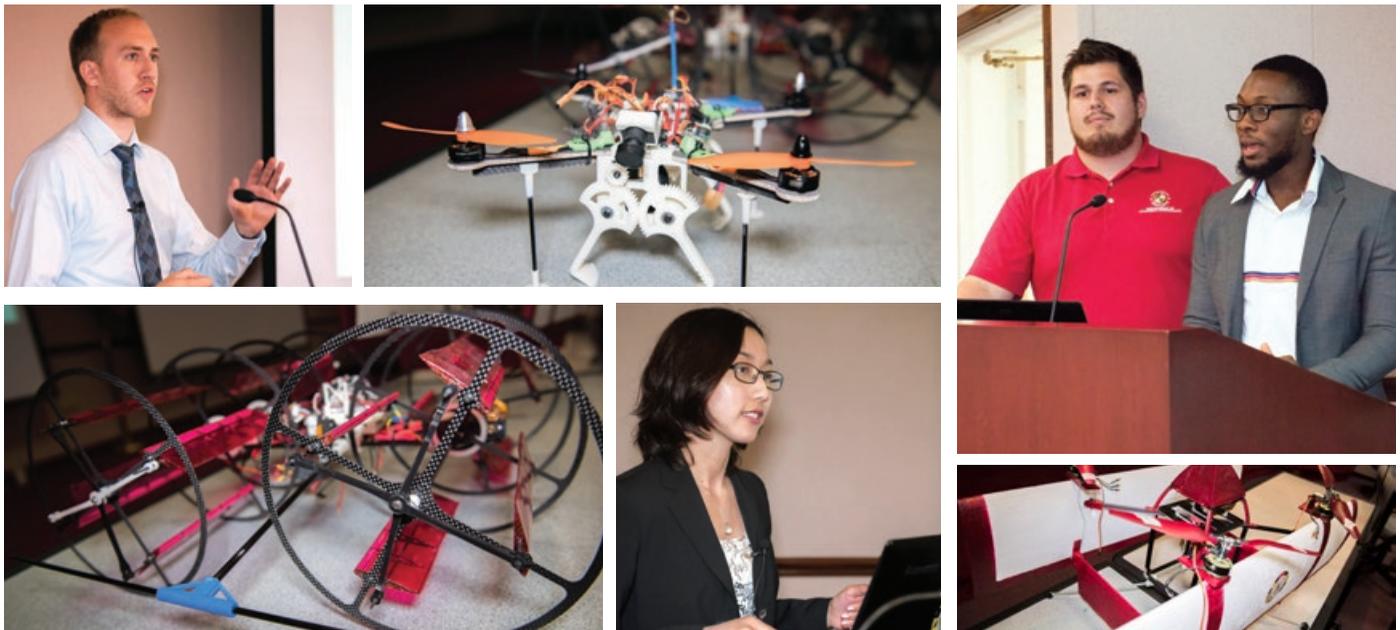
Bringing industry, academia, other government agencies, and international and nontraditional partners into the Army S&T enterprise.

by Dr. Matt Willis

The Army science and technology (S&T) program is critical to ensuring that the U.S. Army—America’s principal land force—can continue to operate and dominate in complex environments characterized by adaptive adversaries employing conventional, unconventional and hybrid methods that are designed to challenge U.S. national security and vital interests. The future operational environment—2025 and beyond—for the Army and joint force will demand land power dominance through increased flexibility, adaptability and speed of response; mechanisms to mitigate or wholly eliminate tactical surprise; improved joint interoperability and compatibility; an ability to effectively accommodate evolving alliances and partnerships; and seamless Soldier proficiencies across myriad functional domains.

Such dominance will be critical to prompt, sustained and synchronized operations, as will a force that can adapt to mission demands and readily execute both combat and noncombat missions in air, ground, maritime, space and cyberspace. Excellence and overmatch in an extremely diverse spectrum of technical competencies are predicated on modernization—building greater capacity and capabilities in the longer term to prevail in future conflicts.

This section will explore Army S&T’s growing engagement with international partners in cooperative S&T efforts, as well as the U.S. Army Research Laboratory (ARL) Open Campus, devised to cultivate a 21st-century research ecosystem that brings together government laboratories, academic institutions



AN OPEN DOOR TO ACADEMIA

Students from the University of Maryland and Penn State University deliver presentations and display their micro air vehicles for Army researchers during a visit in July 2017 to Aberdeen Proving Ground. The students designed and built small aerial vehicles that could fly autonomously around obstacles and identify targets for a May 2017 competition that caught the attention of ARL researchers. (Photo by David McNally, ARL)

and the private sector to address tough Army challenges. The potential partners within the federal sphere alone are numerous, including the other services, National Institutes of Health, U.S. Department of Energy, federally funded research, development and engineering centers and university-affiliated research centers.

The two follow-on articles explore in depth two approaches the Army S&T enterprise is taking to broaden collaboration in the United States and overseas: strategic international S&T engagement and ARL's open-door approach to innovation.

A MODERN S&T ECOSYSTEM

State-of-the-art technical facilities are essential to positioning the Army's S&T enterprise for discovery and maturation of technologies that are expected to be critical to Army and joint force operations well into the future. Because of myriad contributing factors, many technical facilities used by the S&T enterprise have become obsolete and require revitalization and recapitalization. Renovations and upgrades to existing facilities or construction of new ones will vastly improve safety,

innovation and the Army's posture for exploring emerging scientific fields that would be difficult, if not impossible, to pursue using current facilities.

An enterprise-wide approach to modernizing this technical infrastructure will provide an integrated system of facilities accessible to technical personnel from across Army S&T, allowing the Army to execute its S&T strategy:

- Pursuing foundational technology developments for the future.
- Maturing technologies into innovative, affordable and sustainable solutions over the full system life cycle.
- Executing fundamental S&T initiatives that will ensure breakthroughs for affordable, decisive warfighter advantages.

The U.S. Army, however, cannot expect to be subject matter experts in all iterations of future S&T. Rather, it must promote critical cross-disciplinary research via mechanisms such as Open Campus; public-private partnerships and infrastructure investments; engaging nontraditional partners such

as the entrepreneurial high-tech community and small businesses; and developing targeted and strategic international partnerships.

OPEN CAMPUS

ARL launched the Open Campus initiative in 2014 with the goal of integrating government laboratories, academic institutions and the private sector, including nontraditional partners, into a global collaborative network to address multiscale and multidomain Army S&T challenges. Open Campus lays the foundation for a global S&T ecosystem to pursue groundbreaking advances in basic and applied research areas of importance to long-term national security.

The model is based on three primary tenets:

- Modern government workforce and management.
- Sharing of facilities among government, academia and the private sector.
- Collaborative culture that fosters an entrepreneurial and innovative environment.

A NEW INFLATION MECHANISM

Army researcher Anthony J. Roberts, working in the lab in July 2017, inflates a balloon with hydrogen produced from a chemical reaction between water and an aluminum nanomaterial powder discovered at ARL at Aberdeen Proving Ground. ARL, through its Open Campus, has a leading role in fostering a 21st-century research ecosystem where government laboratories, academic institutions and the private sector can collaborate freely. (Photo by David McNally, ARL)

Many of these strategically targeted initiatives to connect diverse S&T partners have started to bear fruit.

Since its inception, ARL has developed a diversified hub-and-spoke infrastructure to partner across the national and international S&T ecosystem. Active Open Campus sites are co-located with ARL labs in Adelphi and Aberdeen Proving Ground, Maryland. ARL has also established hubs in California, Texas and Illinois, is exploring a future hub in Massachusetts, and has expanded internationally, with a presence in Tokyo, London and Sao Paulo. Through the Open Campus framework, ARL scientists and engineers work side by side with visiting scientists in ARL facilities and as visiting researchers at collaborator institutions.

P4 COLLABORATIONS

Public-public and public-private (P4) collaborations represent an innovative strategy for infrastructure modernization and access, including voluntary relationships between federal and non-federal entities (NFEs) through which the parties leverage each other's expertise, resources and incentives to address technical opportunities with greater speed, effectiveness, efficiency and residual benefit than they could achieve individually. P4 arrangements require no monetary transaction between parties. Collaborators may establish mutually useful, state-of-the-art technical infrastructure to pursue common goals. They have the flexibility to build





NETWORK OF EXPERTISE

Dr. Robert Hebner, director of the Center for Electromechanics at the University of Texas at Austin, stands in the collaborative ARL – University of Texas additive manufacturing laboratory. ARL South, part of the ARL Open Campus initiative, is an effort to co-locate Army research and development personnel in the southern and central U.S. to gain access to subject matter experts, technical centers and universities not well-represented on the East Coast. (Photo by Joyce Conant, ARL)

and configure facilities to support multiple public and private sector entities simultaneously.

Potential partners include a broad array of NFEs, including businesses, non-government organizations, foundations, academic and research institutes, state and local governments, community-based or other nonpublic organizations, and international entities. P4 collaborations instill and establish a flexible, cross-functional Army intellectual infrastructure with surge capacity for critical Army modernization priorities.

NONTRADITIONAL PARTNERSHIPS

The Army also embraces partnerships with organizations it has not traditionally worked with, such as startups, the venture capital-funded technology sector, the federally sponsored Manufacturing USA network of innovation institutes, and small businesses. The Small Business Innovation Research and Small Business Technology Transfer Research programs, as governed by 15 U.S. Code 638, provide a unique mechanism for aligning small businesses with critical Army modernization priorities and capability gaps.

In addition, the Army leverages mechanisms such as cooperative research and development agreements, other transaction authorities (e.g., the Consortium for Command, Control and Communications in Cyberspace), Defense Innovation Unit Experimental in the Office of the Secretary of Defense, and the Federal Laboratory Consortium for Technology Transfer to interface with nontraditional innovators.

INTERNATIONAL S&T COLLABORATION

U.S. Army hegemony on the future battlefield is intrinsically linked with the interoperability and compatibility of joint systems and the ability to accommodate evolving alliances and partnerships. The Army S&T enterprise focuses on research areas synergistic to allies' S&T portfolios, thereby leveraging allies' expertise versus investing in duplicative areas.

The Army also uses the Engineer and Scientist Exchange Program to promote

An enterprise-wide approach to modernizing this technical infrastructure will provide an integrated system of facilities accessible to technical personnel from across Army S&T.

international cooperation, in this case through the exchange of defense scientists and engineers among allied and friendly nations, including the United Kingdom, France, Israel, Chile, Germany, South Korea, the Netherlands and Australia. (See “Overseas Opportunities,” Page 42.) The program leverages defense S&T of U.S. allies and partners, while providing opportunities to identify and develop potential international cooperative research and development partnerships for the future.

CONCLUSION

Many of these strategically targeted initiatives to connect diverse S&T partners have started to bear fruit. For instance, over 700 Open Campus participants have conducted research in ARL laboratories, including 80 international collaborators from 22 countries. Layered security mechanisms, commercial network access and the implementation of new security policies and procedures shield sensitive programs. These measures thus enable U.S. and international partners to pursue fundamental research collaborations on-site with ARL scientists and engineers.

Since establishing Open Campus, ARL has experienced, on average, a 40 percent year-over-year increase in the volume of collaborative research partnerships. Examples include multiple ARL collaborations in areas such as bioscience and additive manufacturing with the University of Texas system, and a NATO-aligned joint project involving ARL and Bulgarian and Ukrainian institutes to combat disinformation attacks in cyberspace.

Furthermore, within the last five years, the Army has entered into 180 different cooperative agreements with partnering countries. In 2017, the Army invested approximately \$70 million in international collaborations through its international S&T portfolio. Army S&T is developing an integrated, country-specific road map to prioritize research efforts, efficiently allocate resources and ensure that cooperative agreements are integrated into overarching department-level engagement plans. Restructuring the Army’s domestic and international S&T engagement strategy will allow for the development of leap-ahead technologies that will keep the U.S. Army ready for future conflicts.

For more information, contact the author at matthew.p.willis.civ@mail.mil.

DR. MATT WILLIS is the director for laboratory management in the Office of the Deputy Assistant Secretary of the Army for Research and Technology. As such, he shapes policies that impact the workforce, infrastructure, technology transfer and educational outreach in science, technology, engineering and mathematics at the Army Science and Technology Reinvention Laboratories. He holds a Ph.D. and an M.S. in chemical engineering from the University of Illinois at Urbana-Champaign and a B.S. in chemical engineering from Cornell University. He is Level II certified in S&T management and is a member of the Army Acquisition Corps.



HOT ITEM

A new, fully articulating thermal mannequin, developed under a U.S. Navy Small Business Innovation Research contract by the Navy Clothing and Textile Research Facility, undergoes a burn test inside the Ouellette Thermal Test Facility. Ouellette, a joint Army-Navy facility, is managed by the U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC) in Natick, Massachusetts. (Photo by Jeff Sisto, NSRDEC Public Affairs)

BORDER CROSSINGS

Modernization priorities spur the Army to take a more strategic approach to international engagement with S&T partners.

by Dr. Arthur J. Goff III

The future operational environment demands that the Army act now to increase flexibility and adaptability, improve interoperability and compatibility and effectively accommodate evolving alliances and partnerships. To meet these demands and maximize effectiveness for the warfighter, the Army is focusing its science and technology (S&T) investments on six modernization priorities: precision fires; Next Generation Combat Vehicle; Future Vertical Lift; network and command, control, communications and intelligence; air and missile defense; and Soldier lethality. Underpinning these modernization priorities are a series of cross-cutting topic areas and capability gaps: multidomain battle, manned-unmanned teaming, faster decision-making and asymmetric vision.

While we have great capability in U.S. Army laboratories to develop leading-edge technologies in support of these priorities and have some of the world's experts in many Army-unique areas, we also are looking to leverage S&T investments for leap-ahead capabilities wherever we can, especially with our international partners.

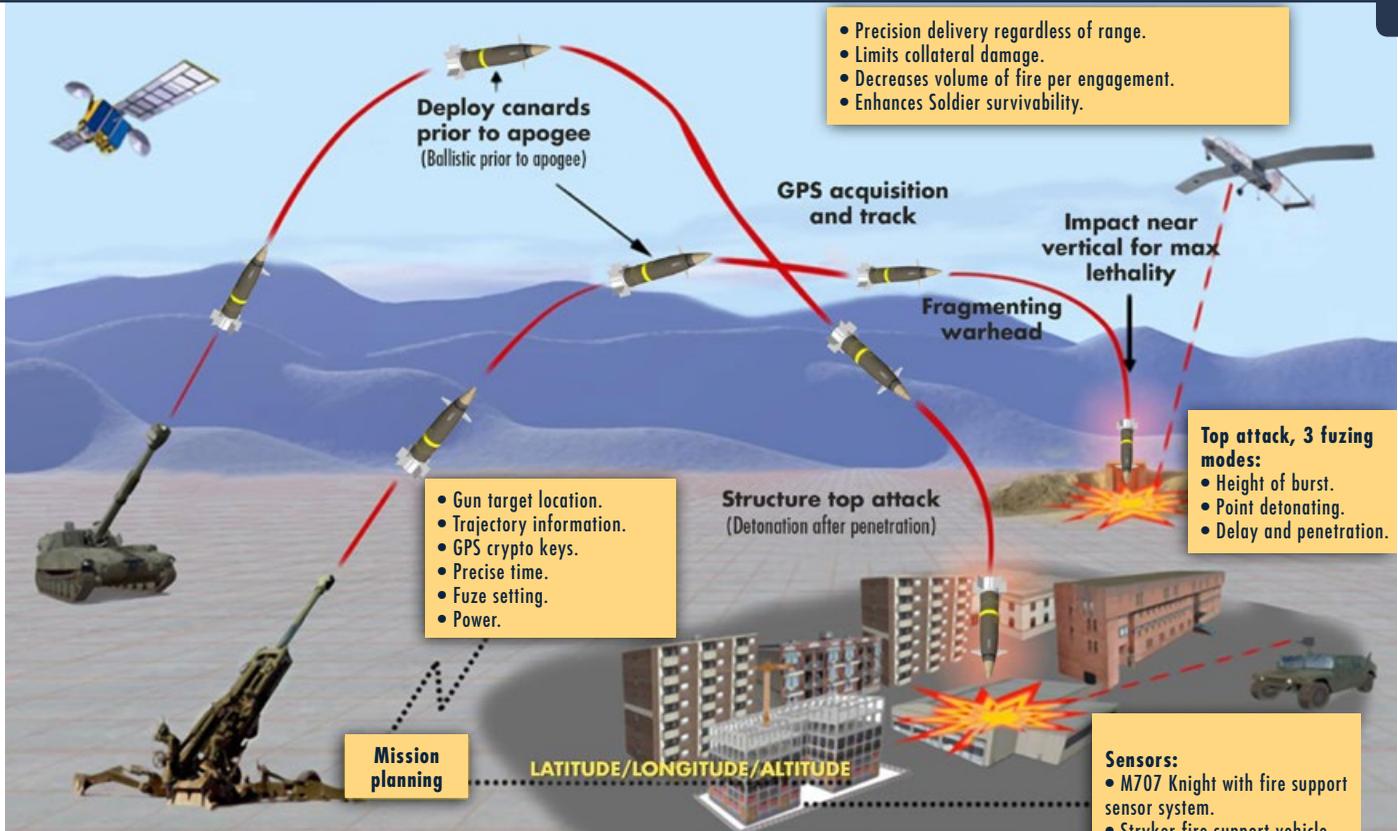
Engaging international partners is a vital part of the Army S&T program and is essential to keep the Army at the leading edge of technology development. International engagement allows us to

expand the available pool of leading scientists and engineers to help us maintain technical superiority and avoid technological surprise. In addition to developing technologies to achieve overmatch, interoperability is key to accomplishing missions across the range of military operations. Consequently, it is a significant factor when choosing to develop particular technologies with partnering nations. The technical edge in a particular area is important, but it is not the sole driver of cooperative engagement.

MONEY BETTER SPENT

Over the last five years, the Army has entered into 150 different cooperative agreements with more than 20 partnering countries. In 2017, the Army invested approximately \$70 million of its international S&T portfolio in international collaborations, typically at the principal investigator level. However, this approach does not meet Army requirements in the most effective and cost-efficient manner. The Army needs an integrated, country-specific S&T road map to prioritize research efforts, efficiently allocate resources and ensure that cooperative agreements are in sync with overarching strategic S&T engagement plans.

A vivid example of the importance of international cooperation is the development of Excalibur, a 155 mm, GPS-guided, extended-range artillery projectile, by the U.S. Army and the



EXCALIBUR AT WORK

The Excalibur, a GPS-guided, extended-range artillery projectile used by the U.S. Army in Operation Iraqi Freedom as a precision munition, was developed by the Army in partnership with the Swedish army. Developing relationships with international partners expands the pool of potential contributors developing solutions to future warfighting challenges, and is essential to keeping the Army at the leading edge of technology development. (SOURCE: DASA(R&T))

Swedish army, leveraging Sweden's advanced artillery projectile technologies. The U.S. Army used Excalibur as its next-generation cannon artillery precision munition in Operation Iraqi Freedom; it provided greatly improved fire support to the maneuver force commander, increased lethality and reduced collateral damage. Additionally, the munition represented a leap ahead in the ability to attack a target with precision from greater distances. Sweden contributed the projectile design work, interior and exterior ballistics, and gun-hardening technology.

Beginning in FY18, the Army will evaluate all established, developing and potential international agreements for their contribution to enabling the six modernization priorities. The Army is increasingly using

data analytics to assess the technological edge that a cooperating nation may have, as well as its resource investment in a particular technology area. A review of data from the last five years will guide HQDA in deciding which nations we should partner with to develop technologies of strategic importance. In addition to technical capabilities, we will consider partnerships that offer strategic benefit geographically or logistically.

In one example of how the data analytics will be used, querying open literature sources provides information on how many publications a particular country has produced in a particular technical area. (See Figure 1, page 192.) The technical areas chosen for this search reflect cross-cutting topic areas related to the six

modernization priorities. In this example, we searched the past five years and analyzed the output of 10 collaborating nations.

Based on this small data set, shown in Figure 1, Country E has produced the most publications (127) in the field of swarming unmanned vehicles. This demonstrates, at a minimum, that Country E has invested significant resources in this area and may have demonstrated leap-ahead technological capability. If this technical area were one that the U.S. Army had not invested in, it would make sense to partner with Country E. In contrast, if the Army needed to develop a capability in command, control, communications, computers, intelligence, surveillance and reconnaissance, then it

FIGURE 1

TOPIC AREA	A	B	C	D	E	F	G	H	I	J	TOPIC AREA TOTALS
Modeling and Simulation (Training)	102	116	200	117	193	54	181	103	28	29	1,123
Machine Learning	119	120	158	108	217	12	130	87	47	19	1,017
Position, Navigation and Timing	123	166	194	106	139	23	102	67	37	55	1,012
Human Performance Augmentation	100	81	164	101	204	10	136	69	30	25	920
Multispectral Sensing	70	76	219	156	136	31	106	85	11	25	915
Heads-Up Display	53	91	167	140	136	34	128	91	14	14	868
Swarming Unmanned Vehicles	53	54	90	63	127	7	78	91	12	10	585
Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance	70	113	89	11	109	11	75	26	21	40	565
Automatic Fires Control	32	47	101	57	99	12	68	49	10	33	508
Scalable Protection	18	22	77	68	48	3	33	44	6	11	330
COUNTRY TOTALS	740	866	1,459	927	1,406	197	1,037	712	216	261	

ANALYZING PARTNERS’ INTERESTS

To determine the expertise of 10 collaborating nations in technical areas related to the Army’s six modernization priorities, several open literature sources were studied to determine how many publications a particular country has produced in a particular technical area over the past five years. For operational security, the countries were coded A through J. (SOURCE: Virginia Tech Applied Research Corp.)

likely would not be beneficial to partner with Country F, which had only 11 publications in this topic area.

and resources on maintaining and in some areas achieving the technological edge.

For more information, contact the author at arthur.j.goff.civ@mail.mil.

CONCLUSION

Today, the threat of near-peer and peer conflict is evident in the Pacific and Eastern Europe. The conflicts in which the U.S. Army has engaged over the last 15 years in the Middle East and Afghanistan have forced us to focus on incremental advances to maintain already fielded solutions. While we continue to maintain these fielded solutions for today’s Soldier, we must refocus our attention

Our Army must modernize continually to increase our lethality against emerging regional and global near-peer adversaries and outpace their development to ensure our overmatch. Restructuring the Army’s international S&T portfolio will allow for the development of leap-ahead technologies that will enable the U.S. Army to succeed in the operational environment of the future.

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Open-Door POLICY

ARL implements a new business model to pursue collaboration with academia and industry in a 21st century research culture.

by Ms. Wendy Leonard

The U.S. Army of 2040 and beyond will operate in rapidly changing domains with unparalleled complexity. Army leadership has long recognized the need to invest in science and technology (S&T) to empower the discovery and innovation needed to maintain technological overmatch and win future battles in an increasingly complex environment. In response, the U.S. Army Research Laboratory (ARL) has implemented a new business model, Open Campus, to pursue leading-edge basic and applied research in a truly collaborative fashion by enabling the continuous flow of people and ideas among government, academia and the private sector. This model creates a 21st-century research culture that could serve as a model to transform the entire U.S. defense laboratory enterprise into an agile, efficient and effective laboratory system capable of nimbly transitioning to address the complex problems of the future.

ACCELERATING INNOVATION AND DISCOVERY

ARL's Open Campus was launched in 2014 with the goal of bringing together government laboratories, academic institutions and the private sector to form a global collaborative network to address tough Army challenges. Open Campus lays the foundation for a global S&T ecosystem enabling long-term national security. Its model is based on three tenets:

- 1.** Modern government workforce and management.
- 2.** Shared facilities among government, academia and the private sector.
- 3.** A collaborative culture that fosters an entrepreneurial and innovative environment.

To create the Open Campus ecosystem, ARL implemented policy and business practice changes to enhance the professional and technical development of its workforce, develop critical research facilities, and create interactions and engagements with public and private-sector entities with common technical interests. These changes require strategic investment in and leveraging of human capital, facilities and technical infrastructure across government, industry and academia, while increasing public involvement and understanding of defense science, technology and exploration.

Since 2014, ARL has developed a diversified, national hub-and-spoke infrastructure to more effectively partner

across the national and international S&T ecosystem, tapping into technology centers across the country to gain access to regional talent that previously was underrepresented in Army labs and centers. ARL now has open campuses co-located with its laboratories in Adelphi and Aberdeen Proving Ground (APG), Maryland. Adding to the collaborative strength from the long-standing co-location with the University of Central Florida, ARL has established hubs in California (ARL West), Texas (ARL South) and Illinois (ARL Central), and is in the process of opening a hub in Massachusetts (ARL Northeast). ARL has also expanded internationally, with an Army Research Office presence in Tokyo, London and Sao Paulo.

The Open Campus initiative is also using enhanced use lease authority, a tool for using underused government property, to offer opportunities for public-private partnerships with a vision toward building research park environments on U.S. Army installations where ARL resides. ARL will anchor the Army Innovation Hub at APG, which serves as the epicenter for foundational research, engineering, test and evaluation, acquisition and sustainment in command, control, communications, computers, intelligence, surveillance and reconnaissance; chemical and biological defense; human performance; maneuver; materials; and protection sciences.

These environments will enable a broader range of collaboration, development of

A dramatic increase in newly signed patent license agreements realized since the start of Open Campus is projected to continue.



MORE THAN CAPABILITIES

Aurora Flight Sciences, an engineering firm in Manassas, Virginia, hosted ARL aerospace engineers in August 2017 to look at technologies to achieve high-speed, high-endurance and high-payload capabilities for vertical lift platforms. ARL's Open Campus model enables researchers to develop relationships with industry and academia, with the goal of creating a defense research environment that's more responsive to future national security challenges. (U.S. Army photo by David McNally, ARL)



SWITCHING PERSPECTIVES

Research partners prepare an autonomous unmanned aerial vehicle for flight during demonstrations at the capstone event for the Micro Autonomous Systems and Technology (MAST) program at APG in August 2017. ARL staff is encouraged to serve as researchers, professors or technologists at companies conducting joint research in ARL laboratories and the laboratories of their ecosystem partners. (U.S. Army photo by Jhi Scott, ARL)

co-located academic consortia to provide graduate education opportunities to ARL staff and residents of the local community, and strengthening of the international S&T network.

COLLABORATION TOOLS

ARL is working hard to create the policy framework necessary to support these new avenues of global collaboration to quicken the pace of future discovery and innovation. The primary mechanisms used to establish Open Campus collaborative partnerships are cooperative research and development agreements (CRADAs) and educational partnership agreements (EPAs).

CRADAs, governed by 10 U.S. Code §3710a and used in Army research for more than 25 years, remain critical to the success of Open Campus. CRADAs are formal agreements between one or more federal laboratories and one or more nonfederal parties (e.g., small business,

industry or academic institutions) under which the government and the non-federal party jointly provide personnel, facilities, equipment or other resources to conduct specific research or development efforts that are consistent with the mission of the laboratory. The CRADA defines intellectual property protection for all parties and is appropriate when ideas, staff, materials and equipment are to be shared over a period of time for the purpose of collaboration or if an invention may result. Joint work statements, developed by the collaborating principal investigators, outline each collaborator's contributions and the research to be performed.

CRADA use has expanded dramatically with academic, corporate and small business institutions, and has been useful to protect the intellectual property of all partners while streamlining collaboration. ARL has 126 CRADA collaborators (56 from academia and 70 from industry

or small business) and is currently in negotiations with an additional 106 potential collaborators.

Eight international CRADAs have also been established, and an additional five are in negotiation. Examples include multiple ARL collaborations in areas from bioscience to additive manufacturing, under an agreement with the University of Texas; new and expanded long-term relationships with historically black colleges and universities and minority institutions and their research staffs; 3D Systems, a company that has a reputation as an international leader in three-dimensional manufacturing; a NATO-aligned joint project with ARL and Bulgarian and Ukrainian institutes on the theoretical foundations of real-time analysis of cyber intrusion events; and a collaboration with General Motors Co. on the spray and combustion behavior of a novel, variable-area, high-pressure diesel injector at real engine conditions.



INNOVATION IMPLEMENTATION

The concept for the Army Innovation Hub is to accelerate Army innovation by using collaborative partnerships of government, industry and academia within a global network based at APG. (Image courtesy of ARL)

Since establishing Open Campus, ARL has realized an average annual growth rate of 40 percent in the volume of CRADA actions, and ARL's S&T funding has been matched by \$51 million in-kind for projects that address Army-specific problems. (See Figure 1, Page 198.)

EPAs are established between ARL and academic institutions to encourage and enhance joint education and research opportunities with academia in science, technology, engineering and mathematics (STEM) disciplines relevant to ARL S&T programs. Under EPAs, visiting students and professors, including those with international citizenship, can access ARL's research facilities and collaborate with experts in their fields of interest.

Benefits to educational institutions include access to ARL's specialized research facilities, receipt of ARL's excess laboratory equipment, research experiences on Army projects, and the opportunity to enhance students' interest in STEM disciplines through collaboration and internships. EPAs also provide a mechanism for ARL researchers to serve as adjunct

faculty, collaborating with educational institutions and helping to develop and implement cooperative education programs for undergraduate and graduate education.

RESEARCH CENTERS

As another means to advance collaborative fundamental research, ARL has initiated 14 research centers in strategic, enduring S&T areas of critical importance to the Army, including additive manufacturing, artificial intelligence and atmospheric sciences. The centers are being established across the country as a consortium of Open Campus partner organizations leveraging expertise, facilities and capabilities on an international scale to address challenging research problems. For example, the ARL Center for Research in Extreme Batteries, established with the University of Maryland and the National Institute of Standards and Technology, focuses on the fundamental science for batteries with extreme properties, operating in extreme environments for defense, space and biomedical applications. At a recent meeting, more than 100 additional participants expressed interest in joining this center.

PERSONNEL EXCHANGES

Through the Open Campus framework, ARL scientists and engineers work side by side with visiting scientists in ARL's facilities and as visiting researchers at collaborators' institutions. ARL is committed to a goal of having 10 to 15 percent of its approximately 1,300 Army civilian research staff on rotational assignments outside of the laboratory at partner locations, with at least that number of collaborators actively participating at ARL locations.

More than 700 participants established collaborative partnerships in ARL laboratories through the third quarter of FY17. These include 80 international collaborators from 22 countries, including China, India, Germany and Iran. Layered security mechanisms, commercial network access and the development and implementation of new security policies and procedures shield sensitive programs and enable U.S. and international partners

to pursue fundamental research collaborations on-site with ARL scientists and engineers. In addition to collaborative engagement in existing ARL facilities, future phases of ARL's Open Campus will include opportunities for partners to establish new on-site facilities on our campuses.

Currently, ARL seeks to attract academic, government, small business and industry partners for collaborative engagement. More information on ARL's strategic research interests and collaborative research opportunities can be found at www.arl.army.mil/opencampus.

In addition, ARL staff are encouraged to pursue entrepreneurial opportunities in high-risk, high-payoff areas of potential strategic value to the Army through implementation of innovative workplace policies. ARL established the Entrepreneurial Separation Program as a means to assist ARL researchers in establishing

collaborative partnerships. If a current ARL civilian employee decides to pursue an entrepreneurial opportunity, the employee resigns from federal service but is eligible for "priority consideration" for up to five years from the date of separation for positions that are similar to the one they vacated. Since 2015, eight employees have separated from ARL to pursue entrepreneurial opportunities in areas such as cybersecurity, solid-state batteries, natural language processing, high-performance computing and manufacturing technologies.

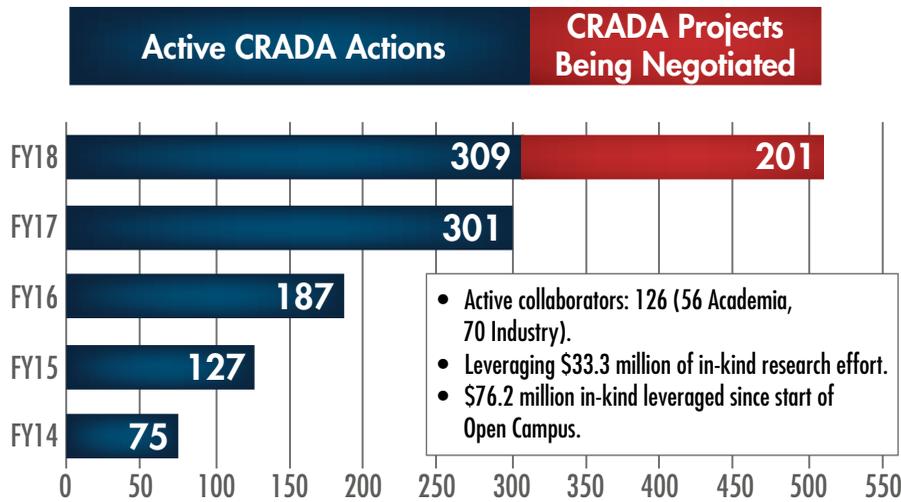
ARL researchers are encouraged to serve as visiting researchers, professors of practice at universities or as technologists at cutting-edge companies conducting joint research in ARL laboratories and the laboratories of their ecosystem partners. Open Campus relationships forged with academic partners expand opportunities for both faculty and ARL researchers, providing insight into the complex boundary

READY TO SET SAIL

Dr. Giuseppe Loianno, a research scientist at the University of Pennsylvania, readies a self-navigating drone for a demonstration at ARL's Aberdeen facilities in August 2017. The demonstration was part of the MAST program, which gave participants from industry and academia the chance to work with ARL to explore technologies that would enable autonomous micro-robots to work together. (U.S. Army photo by Jhi Scott, ARL)



FIGURE 1



BUSINESS IS BOOMING

CRADAs have grown rapidly in both number and diversity since ARL implemented the Open Campus approach. The number of CRADAs has increased each year by an average of 40 percent. The CRADAs also have generated millions of dollars' worth of in-kind research effort for projects that address Army-specific problems. Agreements have been developed for a range of efforts, including additive manufacturing, 3-D manufacturing and cyber intrusion. (Image courtesy of ARL)

conditions of defense-relevant problems. These partnerships can contribute to each academic institution's curriculum and breadth and provide unique insights into challenging defense problems that would be difficult to obtain otherwise. Collaborations between ARL and academia help shape the future national security workforce, provide exciting employment pathways for highly trained graduates of STEM academic programs, and help academic institutions build programs

and attract new faculty by offering established links to the Army and DOD S&T network.

ARL and industry and small business staff exchanges with leading technology companies also help shape technology maturation timelines for transfer to the industrial marketplace and provide ARL and partner researchers with a view of the state of the art in many critical fields, and generate insight into emerging

government and industry practices regarding technology development. These exchanges will encourage and provide incubation opportunities, empowering and leveraging the novel approaches of these entrepreneurs through access to infrastructure and through unique engagement and partnership opportunities between scientists and engineers.

TECHNOLOGY TRANSFER

The Open Campus business model fosters the generation of joint intellectual property, incubation of spinoff companies for the pursuit of S&T innovations, and maturation and rapid transition of intellectual property and technologies to the industrial marketplace. A critical element of ARL's Open Campus strategy is technology transfer.

In FY17, the ARL Technology Outreach Portal was launched. It includes easily accessible information about almost 400 patents, a unique view of the facilities and equipment at ARL locations and e-learning modules for both ARL researchers and stakeholders external to ARL. A

Since 2014, ARL has developed a diversified, national hub-and-spoke infrastructure to more effectively partner across the national and international S&T ecosystem.

dramatic increase in newly signed patent license agreements realized since the start of Open Campus is projected to continue. These new mechanisms include licenses with academic, industry and small business partners, both domestic and international, in military as well as commercial applications.

For example, ARL's fundamental research in lithium-ion battery interfaces led to a 5-volt cathode with 30 percent increased energy that is safer and more stable than existing commercial solutions. A patent is pending, and the Canadian firm Hydro-Quebec has licensed the technology and is providing a 50 percent cost-share to further develop it. Another example is Per Vivo Labs Inc., which is licensing rate-activated tethers that incorporate new stretchable materials into resistance bands and other physical therapy aids. (See "Per Vivo Warms to Tech Transfer," Page 183.)

COMMERCIALIZATION AND INCUBATION

To help promote the commercialization of ARL intellectual property, ARL has developed partnership intermediary agreements (PIAs) with several partners. PIAs increase the likelihood of success in conducting cooperative or joint activities with STEM-oriented nonprofits, small businesses, educational agencies and colleges and universities, with partners serving as a liaison with outside, nonfederal entities.

In one such arrangement, the Energetics Technology Center (ETC) established incubator capabilities near ARL facilities in Adelphi, and recently conducted several lunch-and-learn and tech talks and two lean startup sessions. Sessions focused on ARL patents and were designed to help promote the commercialization of ARL intellectual property by providing a place for ARL researchers to collaborate with entrepreneurs and

BRANCHING OUT

ARL researcher Dr. Steven D. Keller, foreground, works with Dr. Do-Hoon Kwon, associate professor at the University of Massachusetts Amherst, in Kwon's lab. Keller, part of the Antennas and RF Technology Integration Branch within ARL's Sensors and Electron Devices Directorate, recently completed a three-year detail at UMass Amherst on antenna research and fabrication that included the co-mentoring of doctoral students. Such relationships are encouraged by ARL and facilitated by the Open Campus framework. (Photo courtesy of University of Massachusetts Amherst)

businesses interested in licensing ARL's patents. Three small business startups occupy space at the 7,000-square-foot incubator in Adelphi. ARL also established a PIA for using a small business technology incubator near its campus on APG.

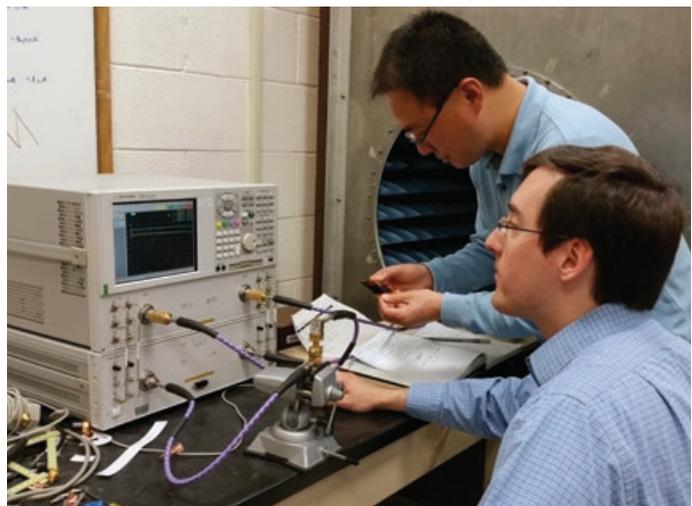
CONCLUSION

ARL's Open Campus is creating collaborative possibilities to generate a more adaptive, efficient and effective defense research environment that is responsive to future national security challenges. ARL continues to pursue academic, government, small business and industry partners for collaborative engagement.

The formal and informal interactions among scientists, engineers and business and technology specialists with multiple technical disciplines and globally diverse perspectives will lead to new fundamental knowledge, enhance the frequency of scientific and engineering breakthroughs and innovation, effectively transition technologies into engineered systems, and help guide strategic science, technology and acquisition policy.

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EARLY PROTOTYPING, REDUCED RISK

A Medium Mine Protected Vehicle Type II, with a deployed interrogation arm, prepares to investigate a suspected roadside hazard during operational testing in October 2017 at Fort Leonard Wood, Missouri. Experimental prototyping gets S&T products into Soldiers' hands early, enabling further evaluations and reducing the risk for transition. (U.S. Army photo by Clay Beach, U.S. Army Operational Test Command Visual Information)





TECHNOLOGY MATURATION

Army unifies diverse efforts to bridge the gap between concept and acquisition for successful technology transitions.

by Ms. Julie I. Locker

Technology transition is the process by which a technology is determined mature enough to move from science and technology (S&T) into a DOD acquisition program. Transitions play a critical role in bridging the gap between technology development and implementation within a future Army system.

Successful transitions begin early during S&T development with the establishment of strong working relationships between the Army technologists within the research laboratories and the Army program executive officers (PEOs) and program managers (PMs). Through these relationships, stakeholders accomplish the ever-important early interpretation of user requirements and identify the technologies needed to meet user goals. The PM and the S&T developer can then forge technology transition agreements to establish a joint commitment based on a shared understanding of technology objectives and the associated technical hurdles and risks.

In 2017, the deputy assistant secretary of the Army for research and technology (DASA(R&T)) established a new portfolio to focus on key aspects of technology transition and innovation. The maturation portfolio magnifies the focus on improving transitions by merging several efforts under one technology portfolio: red teaming of S&T technologies; development of experimental prototypes through the Technology Maturation Initiatives Budget Activity (BA) 4; advanced development of manufacturing processes through the Army Manufacturing Technology (ManTech) BA7; and Small Business Innovation Research (SBIR).

The Army S&T enterprise develops and advances technologies for ground maneuver, aviation, medical, Soldier, and command, control, communications and intelligence (C3I) that are critical to the Soldier's success. Specifically, these technologies are key to the successful fielding of the Army's six high-priority modernization efforts for long-range precision fires, the Next Generation Combat Vehicle, Future Vertical Lift, the network and C3I, air and missile defense, and Soldier lethality.

The maturation portfolio supports these priorities by determining ways to transition technologies rapidly as affordable, reliable systems. Following this article are two case studies of successful Army S&T efforts in technology maturation: the Third Generation Forward Looking Infrared (3rd Gen FLIR) and the Affordable Protection from Objective Threats (APOT) project to mature lower-hull manufacturing technologies associated with combat vehicles, providing advanced protection.

It is critical for technologists to understand the requirements that the PEOs and PMs have in order to meet the transition timelines for insertion into their

acquisition programs. Technology road maps for these efforts are key to effectively managing advanced technology development efforts, with a stage-gate approach to measure progress along the way.

The stage gates represent checkpoints along the planning timeline that mark the achievement of a specific technology objective, associated metric or both. They support an overall progress check for the effort and serve as decision points as to whether a desired technology is achievable and whether the Army should continue investing in the technology. Road maps should also consider when to effectively initiate red teaming, Technology Maturation Initiatives and ManTech efforts to reduce the risk for transition.

RED TEAMING

The Army's S&T red teaming program provides early, in-depth vulnerability assessments of S&T products. To achieve these ends, the program conducts virtual, laboratory-based or live conceptualization, threat emulation and technology assessment. The timing, sequence and structure of these activities are tailored to the evaluation of individual technologies or groups of technologies.

An example of an S&T effort that greatly benefited from red teaming was individual blade control (IBC) technologies, which offer substantial improvements for rotorcraft flight control and performance. A series of red teaming assessments looked at the vulnerability of the IBC to ballistic threats; the results were critical in helping reduce the risk of potential IBC implementation in future aviation platforms. Efforts conducted as part of red teaming serve to make our S&T technologies stronger in hostile environments and reduce risk for their successful transition.

IDENTIFYING TECHNOLOGIES FOR MATURATION

When an S&T component, subsystem or system has been demonstrated in a relevant environment, then it has reached technology readiness level 6. Further maturation of the technology may be required to successfully integrate and transition it within an acquisition program.

The purpose of the Army's efforts on this front is to further mature technologies through experimental prototyping in advance of a future program of record. Experimental prototyping provides an

EXAMINING THE OUTCOME

Todd M. Turner, air portfolio director in the Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology, observes the effects of simulated ground fire on a rotor blade section. IBC technologies improve rotorcraft performance and were among the many Army S&T efforts improved by red teaming, now a core part of Army S&T's maturation portfolio. (U.S. Army photo by Conrad Johnson, U.S. Army Research, Development and Engineering Command)



opportunity to get S&T products in Soldiers' hands early, thereby facilitating further evaluations to inform detailed system requirements and reduce the risk for transition.

The Army uses a strategically guided, top-down approach to manage Technology Maturation Initiative efforts. A four-star governance body called the Army's Science and Technology Advisory Group, co-chaired by the vice chief of staff of the Army and the Army acquisition executive, provides strategic guidance to the two-star Executive Steering Group chaired by the DASA(R&T). The steering group, in turn, provides guidance to the S&T community, executing commands for development and selection of future Technology Maturation Initiative efforts. Strategic top-down guidance and approval ensure that the efforts receive the necessary level of senior leader oversight to ensure alignment with the secretary of the Army's priorities.

An example of a system being matured through Technology Maturation Initiatives is the Modular Active Protection System (MAPS), which will enable the Army to provide optimized, layered defenses against the most advanced combat vehicle threats. This effort will develop and demonstrate experimental prototypes that fully integrate the MAPS architecture with advanced, autonomous countermeasures on ground platforms. The results will inform the Army's requirements for the Vehicle Protection Suite (VPS) and reduce the risk of rapidly transitioning VPS capabilities to the Army's combat vehicle fleet.

ARMY MANTECH

During S&T technology development, it is important to understand if there are any associated issues with the manufacture of technologies that could affect the ability

to produce an item, or its affordability. Exploration of methods to manufacture technologies, in parallel with the execution of S&T efforts, ensures that any new manufacturing processes required for these technologies have been developed before transition. The Army's ManTech Program develops and refines manufacturing processes for affordable products, thereby reducing the risk of transition to programs of record.

The program leverages manufacturing research conducted jointly by the services through the Joint Defense Manufacturing Technology Panel. The panel of representatives from the Army, Navy, Air Force, Defense Logistics Agency, Missile Defense Agency and Office of the Secretary of Defense exists to avoid redundancies, identify and integrate requirements, and conduct joint planning.

ManTech yields reduced costs and improved products for the warfighter. As one example of numerous successes, its APOT project has matured lower-hull manufacturing technologies associated with combat vehicles, providing advanced protection. This effort enabled the U.S. to domestically produce a new aluminum alloy with processes needed to form, forge and weld it into a structure for the underbody hull, providing a new standard in blast protection. The successes from APOT are informing requirements for future combat vehicles.

SBIR PROGRAM

The SBIR Program fosters innovation in all phases of S&T and shapes successful transitions by aligning small businesses directly with technology capability gaps. For instance, the 3rd Gen FLIR sensor suite leveraged small business efforts from the SBIR program. With the shift of Army S&T efforts toward mid- and

far-term technologies, SBIR efforts are critical for filling near-term technology needs.

The Army is providing additional strategic guidance to the SBIR community to ensure that its work aligns with the Army's modernization priorities. The additional guidance will help small businesses focus investments in areas where the Army has critical needs.

CONCLUSION

Strengthening a transition and reducing risk to an existing or future program of record require detailed action plans to effectively link planned S&T advanced technology development, Technology Maturation Initiatives and ManTech, while using SBIRs to promote innovation throughout the technology development life cycle.

A proactive, forward-focused strategy is critical. Managing the maturation efforts within one S&T portfolio helps to ensure alignment with Army priorities and ensure that action plans are in place to link efforts, ultimately reducing overall risk and ensuring successful transition to the PEOs and PMs.

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A *FLIR* for Innovation

Moving objects appeared as glowing blobs in early infrared vision equipment. Clarifying the picture so Soldiers could distinguish people from background objects, combatants from non-combatants, required imagination, initiative and information.

by Dr. Richard Nabors and Mr. Nathan Burkholder



PROTOTYPE FOR SUCCESS

The 3rd Gen FLIR products seen here are examples of a new and innovative program from the research community making the sometimes treacherous transition into field use. (U.S. Army photo by CERDEC)

Innovation isn't just a matter of creating something new. Rather, it's the process of translating an idea into goods or services that will create value for an end user. As such, innovation requires three key ingredients: the need (or, in defense acquisition terms, the requirement of the customer); people competent in the required technology; and supporting resources. The Catch-22 is that all three of these ingredients need to be present for innovation success, but each one often depends on the existence of the others.

This can be challenging for the government, where it tends to be difficult to find funding for innovative ideas when there are no perceived requirements to be fulfilled. With transformational ideas, the need is often not fully realized until after the innovation; people did not realize they "needed" a smartphone until after the iPhone was produced. For this reason, revolutionary innovations within DOD struggle to fully mature without concerted and focused efforts from all of the defense communities: research, requirements, transition and acquisition.

Despite these challenges, the Army has demonstrated its ability to generate successful innovative programs throughout the years. A prime example is the recently completed Third Generation Forward Looking Infrared (3rd Gen FLIR) program. It exemplifies the Army process of transitioning a new and innovative program from the research community into the military platforms in use today.

WHAT'S THAT BLOB DOING?

The first implementation of FLIR gave the Army a limited ability to detect objects on the battlefield at night. Users were able to see “glowing, moving blobs” that stood out in contrast to the background. Although detectable, these blobs were often challenging to identify. In cluttered, complex environments, distinguishing nonmoving objects from the background could be difficult.

These first-generation systems were large and slow and provided low-resolution images not suitable for long-range target identification. In many ways, they were like the boom box music players that existed before the iPhone: They played music, but they could support only one function, had a limited capacity, took up

a lot of space, required significant power and were not very portable. Third Gen FLIR was developed based on the idea that greater speed, precision and range in the targeting process could unlock the full potential of infrared imaging and would provide a transformative capability, like the iPhone, that would have cascading positive effects across the entire military well into the future.

Because speed, precision and accuracy are critical components for platform lethality, 3rd Gen FLIR provides a significant operational performance advantage over the previous FLIR sensor systems. With 3rd Gen FLIR, the Army moved away from a single band (which uses only a portion of the light spectrum) to a multiband infrared imaging

system, which is able to select the optimal portion of the light spectrum for identifying a variety of different targets.

The Army integrated this new sensor with computer software (signal processing) to automatically enhance these FLIR images and video in real time with no complicated setup or training required (similar to how the iPhone automatically adjusts for various lighting conditions to create the best image possible). Third Gen combines all of these features along with multiple fields of view (similar to having multiple camera lenses that change on demand) to provide significantly improved detection ranges and a reduction in false alarms when compared with previous FLIR sensor systems.



RAPID AREA SEARCH

U.S. Army Spc. Roland Merrill of 1st Brigade Combat Team, 3rd Infantry Division watches over tanks in his unit with a 3rd Gen FLIR-equipped Long Range Advanced Scout Surveillance System during Decisive Action Rotation 18-01 in October 2017 at the National Training Center (NTC), Fort Irwin, California. With its wider fields of view and increased resolution, 3rd Gen FLIR allows Soldiers to rapidly search an area and identify objects with a much higher degree of confidence than older infrared imaging equipment. (U.S. Army photo by Master Sgt. Horace Murray, NTC Operations Group)

Using its wider fields of view and increased resolution, 3rd Gen FLIR allows the military to conduct rapid area search. This capability has proven to be invaluable in distinguishing combatants from noncombatants and reducing collateral damage. Having all of these elements within a single sensor allows warfighters to optimize their equipment for the prevailing battlefield conditions, greatly enhancing mission effectiveness and survivability. Current and future air- and ground-based systems alike benefit from the new FLIR sensors, by enabling the military to purchase a single sensor that can be used across multiple platforms and for a variety of missions. This provides significant cost savings for the military by reducing the number of different systems it has to buy, maintain and sustain.

Third Gen FLIR was effective in implementing the three key ingredients mentioned above (requirements, expertise and available resources). A closer look explains how the 3rd Gen FLIR program

helped solve some of the challenges it faced in those areas to arrive at its accomplishment today as an Army innovation success.

REQUIREMENTS

The 3rd Gen FLIR program struggled early in its development, as do most new and innovative efforts, to identify requirement documentation crucial to help support the planning and resourcing necessary to sustain a successful program. Without the user community understanding what could be possible, the requirements at the time were all based around the perceived limitations of what technology could provide. To reiterate the old adage attributed to Henry Ford, “If I had asked the people what they wanted, they would have said faster horses.” To overcome this, the research community developed a comprehensive strategy for educational outreach on the full potential of what 3rd Gen FLIR could achieve and executed it to help inform the Army’s requirement developers, military officers and industry. This campaign highlighted not only the need, but also what was possible, and served as the catalyst to bring the entire community together to make 3rd Gen FLIR a reality for the warfighter.

EXPERTISE

The expertise required to achieve 3rd Gen FLIR success was spread across a variety of organizations and industries. More than 16 significant research and development projects from multiple organizations were integrated to create this program:

- Thirteen percent were from Small Business Innovation Research program efforts, which brought in companies outside of the traditional large defense contractors.
- More than 25 percent of the activities involved applied research funding,

which served to partner in-house expertise with external communities through cooperative research and development agreements.

- Thirty-one percent of the efforts were Manufacturing Technology (Man-Tech) initiatives, working with focal plane array and substrate manufacturers to develop the technology necessary to drive down future costs and ensure the stability of long-term manufacturing capabilities. (Focal planes are like the digital film in modern digital cameras that record the images.)
- Thirty-one percent of activities were executed through advanced technology development funding with traditional large defense contractors who work on sensor development and system integration.

All of these ingredients were critical to create the 3rd Gen FLIR system. But ingredients by themselves do not make a masterpiece; a chef is needed to bring them together in the right sequence with the proper proportions to achieve the desired result. For 3rd Gen FLIR, the talented workforce across the Army research community played this vital role, strategically aligning these individual activities and working them together to provide a comprehensive, interconnected final solution.

RESOURCES

Neither requirements nor expertise would count for much were there not appropriate, sustained investments over time to support the development of 3rd Gen FLIR. The program took many years of consistent investments into



UNLOCKED POTENTIAL

A Soldier views the 3rd Gen FLIR’s capabilities. Third Gen FLIR enables greater speed, precision and range in the targeting process and promises to unlock the full potential of infrared imaging. (U.S. Army photo by CERDEC)



BETTER SIGHT FOR MULTIPLE PLATFORMS

An MQ-1C Gray Eagle unmanned aerial system, equipped with 3rd Gen FLIR sensors and belonging to Company D, 10th Aviation Regiment, prepares to conduct a mission from Al Asad Air Base, Iraq, in September 2017. Third Gen FLIR sensors are used in current and future air- and ground-based systems, allowing the military to purchase a single sensor that can be used across multiple platforms and for a variety of missions, at significant cost savings. (U.S. Army photo by Staff Sgt. Isolda Reyes, 29th Combat Aviation Brigade)

innovations and breakthroughs in areas such as substrate growth (the digital film that converts light into signals), dual-band focal plane arrays (digital film that can capture two different types of light at the same time), variable apertures (adjustable focus), modeling and simulation (automated computer optimization of imagery), and sensor miniaturization (portability).

Obtaining the support of industry and leveraging their internal research and development investments required the Army to build trust in the overall program through focused, appropriately timed acquisition activities conducted simultaneously across multiple fronts. By creating partnerships with others, such as the U.S. Army Communications-Electronics Research, Development and Engineering Center (CERDEC) Night Vision and Electronic Sensors Directorate (NVESD) and ManTech, 3rd Gen

FLIR was able to integrate multiple funding sources to ensure a secure resource foundation.

CONCLUSION

As the Army reorganizes to modernize its capabilities, it can look to the success of the 3rd Gen FLIR program as a prototype. The program has demonstrated several key elements critical to the successful implementation of an innovative program, which illustrates the transition from good ideas into actual capabilities in the hands of warfighters.

It exemplifies how the military can benefit when Army communities work together to combine requirements with resources, technology innovation and cooperation. With all of the participants collaborating, from the requirements community to the acquisition and development communities, the Army overcomes barriers and is able to create an environment where

innovation thrives, equipping its warriors with the best technology in the world.

For more information or to contact the authors, go to www.cerdec.army.mil.

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A TEAM EFFORT

Award-winning ManTech program to create a new kind of blast-resistant aluminum vehicle hull resulted from a variety of new and existing R&D.

by Dr. Bryan Cheeseman

During the autumns of 2014 and 2015, the Army demonstrated a force protection capability using a newly designed aluminum hull for combat vehicles. These tests involved a large underbody blast gauged on enemy threats as part of the U.S. Army Manufacturing Technology (ManTech) project called Affordable Protection from Objective Threats (APOT).

The research and development (R&D) on the APOT program offers tremendous improvements and great promise in force protection for the future. APOT focused on the maturation of lower hull manufacturing techniques, pulling together a number of applied research, advanced technology development, operational systems development and Small Business Innovation Research (SBIR) programs, along with efforts being conducted as part of a cooperative research and development agreement (CRADA) and a U.S.-Israel project agreement. The result was the fabrication of multiple lower hulls into notional ballistic hull and turrets (BH&Ts). (A BH&T is a bare vehicle structure used for ballistic testing. It does not typically contain a functional powertrain, suspension, communication equipment, etc.)

After the APOT team outfitted the BH&Ts with energy-absorbing and impulse-mitigating technologies and anthropomorphic test devices (crash dummies), the BH&Ts were tested with an explosive charge significantly larger than a previous test or a typical improvised explosive device (IED) used by adversaries in Iraq and Afghanistan. Assessments of the dummies indicated limited or no injuries. Results from this



MAIDEN VOYAGE

The forged aluminum hull, affixed to a massive test rig, undergoes an objective-level underbody blast test. The test, conducted in October 2014, resulted in minimal hull deformation. (U.S. Army photo)

collaborative effort provided experts at the U.S. Army Training and Doctrine Command (TRADOC) Maneuver Center of Excellence (MCOE) with data to write requirements for underbody blast protection.

The APOT ManTech project advanced lower hull manufacturing technologies for aluminum-hulled combat vehicles and provided a better means of maturing several structural features for validation and incorporation into the Armored Multi-Purpose Vehicle. The program achieved these results—and received the 2017 Defense Manufacturing Technology Achievement Award—through cooperation across multiple agencies, programs and even nations.

INADEQUATE PROTECTION

Aluminum-hulled combat vehicles historically have been vulnerable to underbody blasts. Fielded in the 1960s, both the M113 Armored Personnel Carrier (APC) and M551 Airborne Reconnaissance Assault Vehicle were required to be air-droppable, which restricted their weight and corresponding aluminum armor

thicknesses. Requirements writers at the time deemed anti-tank mine resistance to be impractical for air-droppable vehicles; therefore, these vehicles were developed with only a modicum of blast resistance, equivalent to an anti-personnel mine. Their vulnerability to underbody blast events soon became evident when they were deployed in Vietnam.

Fielded in 1981, the M2 and M3 Bradley Infantry Fighting Vehicles featured a lower hull similar in design and armor thickness to the M113 APC, with the exception of an additional steel armor plate under the front third of the vehicle. It too proved vulnerable to underbody blasts, in this case IEDs in Operation Iraqi Freedom, so a steel add-on armor kit for the Bradley was fielded expeditiously. However, when this configuration was tested by the Office of the Secretary of Defense Live Fire Test and Evaluation (OSD LFT&E) program in 2012, the results indicated “severe vehicle and occupant vulnerabilities.” OSD’s evaluation set the foundation for the APOT effort, which began in 2012.

HARNESSING OF EFFORTS

The APOT ManTech effort sought to mature more effective manufacturing methods to provide protection not only from typical conventional underbody blast devices, but from blasts many times the power of a typical IED explosion (defined as objective level) and significantly more than the amount of explosive used in the OSD LFT&E evaluation of the Bradley. In after-action accounts of hull failures caused by large underbody blasts, battle damage assessments noted that hulls failed because of welds rupturing and the relatively thin aluminum belly plates fracturing.

To mitigate these failures, APOT sought to fabricate thicker aluminum hulls using fewer welds. Specifically, APOT matured the forging of a monolithic aluminum hull; the forming of a hull from thick aluminum plate; and the welding of thick aluminum plate using high energies, which reduces the number of weld passes by up to 90 percent as compared with typical hand welds. Industrial partners for these efforts were Alcoa Defense with Alcoa Forgings and Extrusions (now

Arconic Inc.), Constellium N.V. and BAE Systems Inc., respectively. The forged-hull effort was the first innovation and is the focus of this article.

Stakeholders from the U.S. Army Research, Development and Engineering Command (RDECOM), the Program Executive Office for Ground Combat Systems (PEO GCS) and the MCOE determined the desired results for the APOT project. PEO GCS experts sought affordable hull designs with integrable manufacturing techniques, while the MCOE needed hard data to inform underbody blast requirements being drafted for a number of programs.

While experts agreed that manufacturing a lower hull and live-fire testing with an explosive charge similar to an IED would be useful, that would not answer the essential question: “What does it mean for force protection for the Soldier?” Experts concluded that to answer this question would mean taking the lower hull and fabricating an entire BH&T, installing energy-absorbing seats and floors along with crash dummies, conducting live-fire testing and then assessing injuries. To accomplish all this, the team looked for partners.

Fortunately, at the time, the Defense Advanced Research Projects Agency

(DARPA) Soldier Protection Systems (SPS) program was also “developing and demonstrating lightweight armor material systems to defeat current and potential ballistic and blast threats with performance substantially better than today’s protective armor systems.” As part of that effort, it awarded BAE Systems a project to develop an aluminum combat vehicle hull capable of withstanding very large underbody IED blasts. Collaboration among APOT, SPS and BAE Systems project managers led them to agree that the APOT underbodies would form the basis for the SPS designs. Select designs would be fabricated into BH&Ts to demonstrate the first element of force protection.

A HULL NEW DEFENSE

The forged hull effort kicked off in summer 2013; APOT forming and welding efforts started a year later. Acquisition stakeholders required material used for the hull to be weldable using conventional Army practices, and TRADOC requested data in one year. The APOT effort was scheduled to produce a hull in 18 months; however, Alcoa made it possible to accelerate the program by funding the massive 180-ton steel die set required for forging.

During fall 2013, the forged hull geometry was developed and refined through

modeling and simulation. The hull design, along with the material requirements, drove the team to select a European aluminum armor alloy, 7020, which had never been produced commercially nor forged in the United States. Fortunately, the U.S. Army Research Laboratory (ARL) studied aluminum alloy 7020 in a 2011-13 foreign technology assessment program and developed a good understanding of its weldability and ballistic response. However, as 7020 had never been manufactured in the United States, the Army needed to develop the alloy chemistries and process parameters for large-scale domestic industrial production.

In fall 2013, the U.S. Army and the Israeli Ministry of Defense were closing out capability assessment activities as part of the Ground Combat Vehicle analysis of alternatives. The Israelis learned of the forged hull effort and expressed interest in collaborating. Since high-performing, energy-absorbing technologies were required for the BH&T, a U.S.-Israel project agreement on armored vehicle underbody blast testing allowed energy-absorbing technologies developed by Israel to be adapted and installed into the forged BH&T.

During this time, RDECOM’s Tank Automotive Research, Development and

SINGLE HULL FORGED

This single-piece hull of 7020 aluminum alloy was successfully forged by Alcoa (now Arconic) in July 2014, one year after the APOT program’s kickoff. It’s the world’s largest aluminum forging. (Photo by Arconic Inc.)





READY FOR TESTING

The forged BH&T, which BAE Systems worked rapidly to fabricate from the forged hull, complete with energy-absorbing seats, floors and crash dummies, sits on the test pad at the Aberdeen Test Center, Maryland, in December 2014, awaiting live fire testing. (U.S. Army photo)

Engineering Center (TARDEC) was executing the Concept for Advanced Military Explosion-mitigating Land (CAMEL) Occupant Centric Protection Technology Enabled Capabilities Demonstrator. As part of this effort, TARDEC developed high-performing, energy-absorbing seats and floors for the CAMEL wheeled combat vehicle demonstrator. The APOT program presented a great opportunity for the engineers working on the demonstrator to determine the effectiveness of its technologies in the APOT BH&T. Additional energy-absorbing seats were provided from ongoing DARPA and ARL efforts.

ALUMINUM BEARING FRUIT

By spring 2014, all of the R&D projects were effectively aligned, and as a result, the APOT program began to make rapid progress. Alcoa forged the one-piece

aluminum hull, the largest aluminum forging ever performed. BAE Systems worked rapidly to fabricate the BH&T from the forged hull and to install the energy-absorbing technologies. The BH&T was delivered and outfitted for the live fire test.

While the assessment showed injuries to the crash dummies during testing, the forged BH&T itself was relatively unscathed. Subsequently, the BH&T was refurbished, re-outfitted with the same energy-absorbing technologies, and through an RDECOM CRADA, Ten-Cate Advanced Armor USA provided and installed an active blast defense system. The BH&T was again tested with an objective-level charge, with remarkably positive results. Through the effective alignment of multiple R&D efforts that brought together alternate

manufacturing methods and advanced protection technologies, the project answered the essential question, “What does it mean for force protection for the Soldier?” For this case, no injuries occurred in an objective-level underbody blast test.

CONCLUSION

The Army ManTech APOT project matured lower hull manufacturing techniques and demonstrated aluminum hulls that can withstand objective-level underbody blasts. In addition, APOT served as a focal point to bring together a number of R&D efforts from several DOD agencies, along with SBIR, CRADA and international activities, which collectively answered the essential question and demonstrated what can be achieved through careful planning and collaboration.

This work has had an impact on both current vehicle design and future vehicle requirements, ensuring a lasting legacy for the APOT effort.

For more information, go to <http://www.armymantech.com/APOT.php>.

DR. BRYAN CHEESEMAN is the rapid technology transition team leader for the Materials and Manufacturing Sciences Division at ARL, Aberdeen Proving Ground, Maryland. He received his Ph.D. and M.S. in mechanical engineering and a Bachelor of Mechanical Engineering from the University of Delaware and joined ARL's Weapons and Materials Research Directorate in 2000. He is the recipient of the Army Achievement Medal for Civilian Service and the Defense Standardization Program Award for Excellence.



FACES *of the* FORCE

MS. MARY HERNANDEZ

COMMAND/ORGANIZATION:

Army Contracting Command – Warren, Michigan

TITLE:

Supervisory contract specialist

YEARS OF SERVICE IN WORKFORCE: 13

DAWIA CERTIFICATIONS:

Level III in contracting; Level I in program management and in information technology

EDUCATION:

M.S. in administration, Central Michigan University; B.S. in business administration and marketing, Eastern Michigan University

AWARDS:

Secretary of the Army Contracting Professional of the Year; Commander's Award for Civilian Service; Achievement Medal for Civilian Service; U.S. Army Materiel Command Frank S. Besson Jr. Award for Contracting Excellence – Civilian Intern

Success brackets a 13-year career

“That’s the reason I do what I do. Knowing my work contributes to helping keep someone’s son, daughter, mom or dad safe is priceless to me.”

Not long into her acquisition career, Mary Hernandez received the U.S. Army Materiel Command’s Frank S. Besson Jr. Award for Contracting Excellence in the civilian intern category. “I was very humbled to receive that award,” she said. “When I started at the Army Contracting Command – Warren, we were in the middle of conflict [the wars in Afghanistan and Iraq], and I was asked to work on projects that probably wouldn’t have gone to an intern under normal circumstances. There was no other choice than to sink or swim, and I’m grateful that I had those opportunities.”

It turns out she’s a pretty good swimmer, named the Contracting Professional of the Year by the secretary of the Army in 2016. “I was really honored to receive [that] award, especially since the recommendation that I be nominated originated with my customer,” she said.

Hernandez is a group chief in the Stryker/Light Armored Vehicle (LAV) Contracting Division at Army Contracting Command (ACC) – Warren, Michigan, procuring Stryker vehicles, vehicle upgrades and system technical support services.

She received the secretary of the Army award for her contribution to developing and managing innovative contracting approaches for two high-priority missions within the Stryker Combat Team Project Management Office. First, she played an important role in supporting an operational needs statement (ONS) to add a 30 mm direct fire weapon to the Stryker Infantry Carrier Vehicle, a \$450 million effort. Hernandez helped develop a three-phased contracting strategy that condensed the acquisition lead time and met tight schedule deadlines, in part by eliminating redundant documentation and using urgent acquisition mechanisms.

She was also involved in an \$858 million effort to replace flat-bottom hull Strykers with double-V hull (DVH) Strykers to improve survivability, a project that also included modernization to address space, weight and power-cooling issues. Hernandez's team conducted a successful Defense Procurement and Acquisition Policy review, receiving approval to award the production exchange requirement.

One of her first assignments in the Stryker/LAV division was incorporating the DVH into Stryker production in 2010, an enhancement urgently needed in theater to mitigate threats from improvised explosive devices (IEDs). "When the DVH Stryker vehicles were fielded to the Stryker units in theater, we started hearing from Soldiers who were involved in IED blasts," Hernandez explained. "The DVH survivability enhancement was the reason they were still alive. That's the reason I do what I do. Knowing my work contributes to helping keep someone's son, daughter, mom or dad safe is priceless to me."

Hernandez has been with ACC-Warren for 13 years, joining the organization after an internship in logistics didn't pan out. "I graduated from Eastern Michigan University with a marketing major, and the only available jobs I found were sales positions. I knew I didn't want a career in sales, so I started talking to family and friends about their jobs," she explained. "My dad's cousin worked at the U.S. Army TACOM Life Cycle Management Command and told me that most of the career fields were hiring interns." Hernandez was hired in 2004 as a logistics management specialist intern within TACOM's Integrated Logistics Support Center.

"After a little while, I figured out that the position was not a good fit for me," she said. "Six months later, I applied for and was selected as a contract specialist intern within ACC-Warren. What I love about the contracting field is the variety of assignments, the challenge of negotiating with the contractor to get

the best value for the taxpayer and, most of all, the overall positive impact the contracted goods and services have on the Soldier."

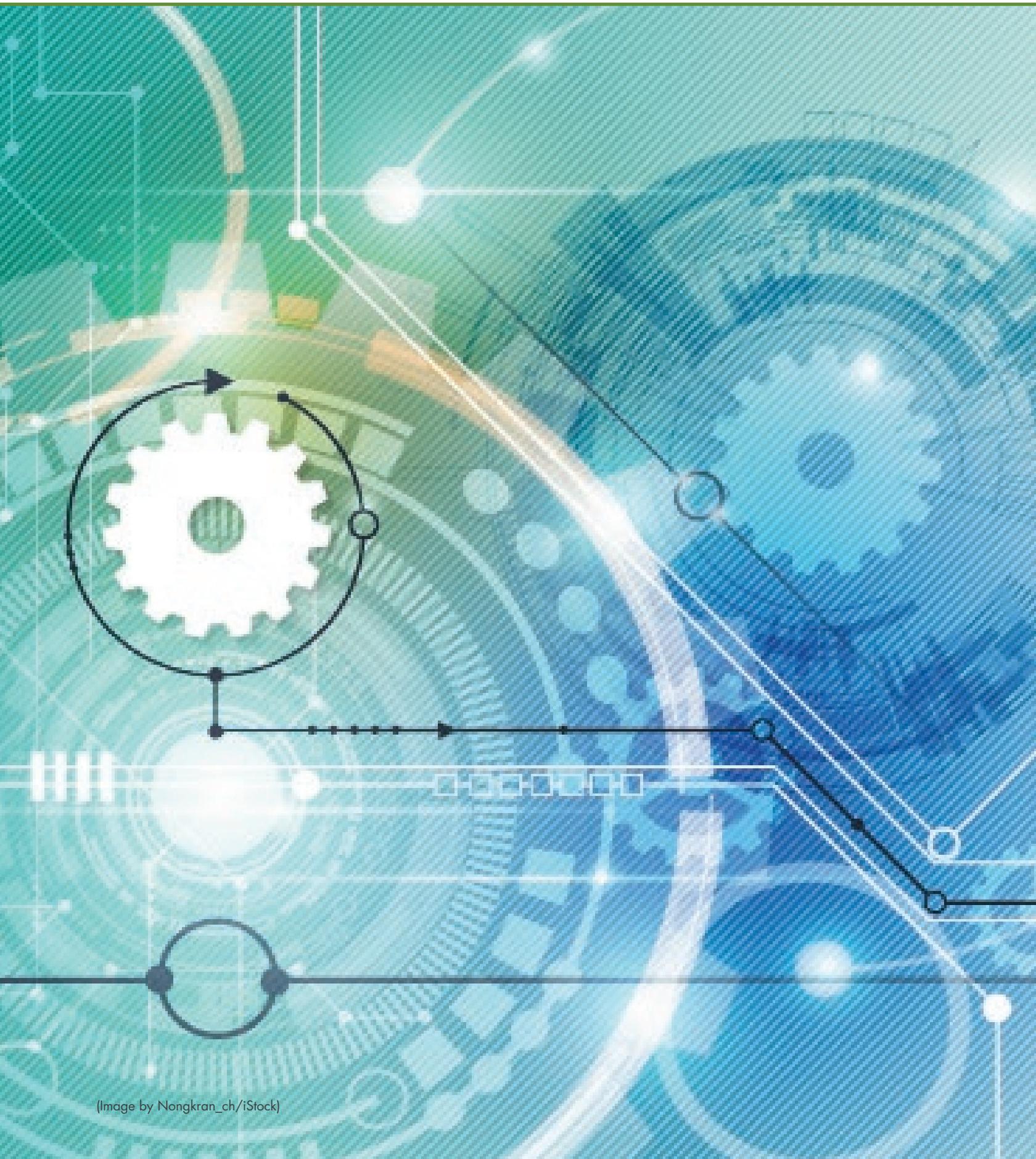
While Hernandez finds her work rewarding, she concedes the process is not perfect. "When I tell people we buy Stryker vehicles, they think it sounds awesome, but the length of time the procurement process takes often surprises people. There is a lot of red tape involved in the procurement process. Numerous regulations to follow; many stakeholders involved in defining the requirements, and challenging negotiations with the contractor; political pressure and budget constraints—all of that feeds into the procurement process. A lot of blood, sweat and tears goes into the final contract document."

Procurement actions can take as little as a month or as long as several years, she said, depending on the complexity of the task. "If I were in charge, I'd change some of the approval thresholds," Hernandez said. "Some actions are reviewed, and decisions are made, at the highest levels of the Department of the Army. In my humble opinion, not all of the documents need that level of review. I'd also consolidate some of the documentation we're required to provide. Many of the documents we produce overlap, and eliminating duplicate work would help shorten the process."

Her career has afforded her numerous opportunities to take advantage of training and educational programs, including leadership training offered through the University of Virginia's Darden School of Business and Eckerd College. One assignment in particular during the Darden Women's Leadership Program, known as Reflected Best-Self, "really stuck with me," she said. "While many leadership training classes focus on improving your weakness areas, this assignment forced me to analyze times I felt I was at my best, request feedback for times others felt I was at my best, and then create a self-portrait discussing the patterns in my strength areas."

That focus on strength also is rare in the workplace, she said, but "identifying strengths in ourselves and others is a key to effective leadership. It's been my experience that if you take the time to develop people, help them overcome roadblocks and show you appreciate them, everything else falls into place."

—MS. SUSAN L. FOLLETT



(Image by Nongkran_ch/iStock)

BETTER, FASTER, CHEAPER

PEO EIS' Defensive Cyber Operations office is achieving rapid acquisition of constantly evolving IT by using consortium-based other transaction authority.

by Lt. Col. Scott Helmore and Tom Cole, Brig. Gen., USA (Ret.)

How to acquire and provide capability better, faster and cheaper has been a consistent theme in defense acquisition for decades. In this era of cyber, information technology (IT) and software-intensive systems, technology moves faster than the traditional acquisition system can support. Traditional timelines for requirements, funding, development, production and fielding span years. By the time systems are delivered to Soldiers, the need they were designed to fill may be several years old.

This problem has confounded Army leadership, which demands a more expedited acquisition system that can measure success in months or less. One example of a more expedited acquisition approach is underway in Defensive Cyber Operations (DCO), part of the Program Executive Office for Enterprise Information Systems (PEO EIS). DCO is implementing an acquisition strategy that incorporates the use of consortium-based other transaction authority (OTA) to inform requirements. The result is to deliver early capabilities with the acquisition efficiency necessary to provide a suite of defensive cyber capabilities in a relatively short amount of time.

In December 2016, the Army acquisition executive formed Product Manager DCO within PEO EIS,

designating it as the office responsible for nontactical materiel solutions to counter cyber threats. DCO is a capability provider for the Army's cyber protection brigades, teams and other cyber mission forces operating in a complex multidomain battlespace. The immediate challenge facing DCO is how to provide effective and relevant tools in a timely manner.

The concept of operations for defensive cyber is complex, with capabilities dispersed across the battlespace and continually adapting to an evolving threat. To accommodate this environment, DCO capabilities and requirements need to address passive and active threats as well as multidomain integration. They need to focus on protecting data, networks and net-centric operations. Finally, they must be interoperable with other IT and software-dependent systems.

The proper identification of DCO requirements and their operational interrelationships is difficult to conceptualize and can be extremely labor intensive. To help overcome this challenge, DCO recognized that rapid prototyping, coupled with early and continuous collaboration with industry, is essential to effective delivery of cyber capabilities. DCO is using the Consortium for Command, Control and Communications in Cyberspace

(C5), established in September 2011 by Army Contracting Command – New Jersey, to enable this collaborative prototyping model to provide innovative solutions quickly to the Soldier. The C5 OTA provides government offices with the necessary problem-solving environment, leveraging nontraditional defense contractors, small businesses and more traditional defense partners.

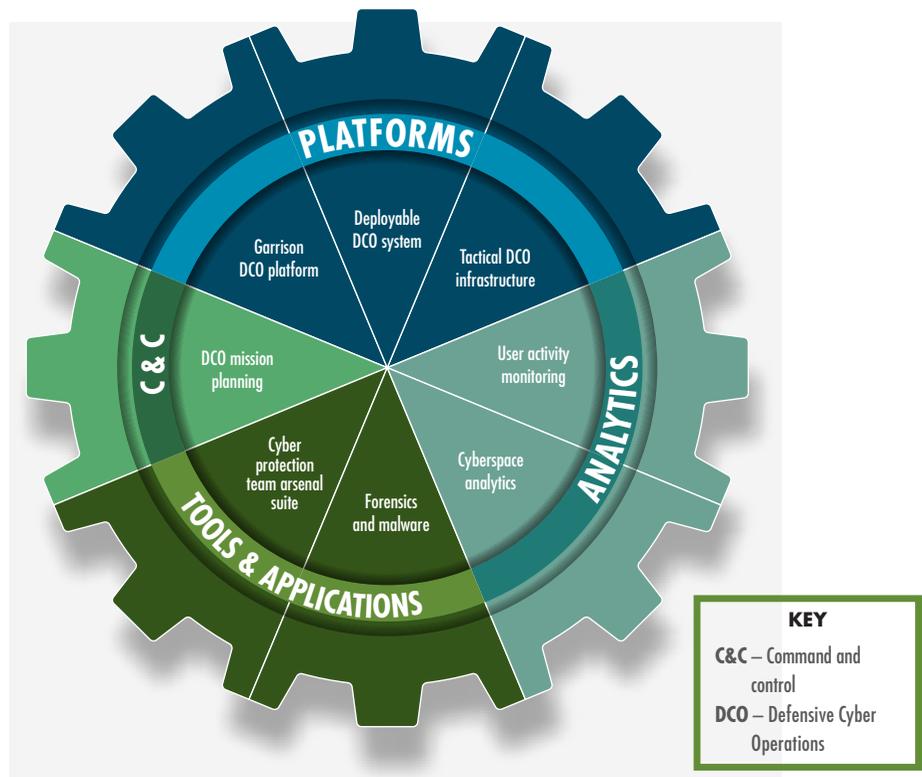
WHAT’S THE DIFFERENCE?

DCO is focused on providing capabilities to address the 2016 Joint Staff-approved DCO Information Systems Initial Capabilities Document (ICD). This ICD uses the Joint Capabilities Integration and Development System IT Box method, an adaptable and flexible requirements approach that provides rapid capabilities to the Soldier through a further delegated requirements process. Under the IT Box, services are delegated the approval for all derived requirements within the limits of specified cost and scope thresholds. The IT Box establishes the overarching authority to create the DCO family of systems; currently, there are 11.

The 11 systems comprise six initial programs of record, all expected to be Acquisition Category III, with an additional five programs identified for future development. The initial six capabilities focus on giving cyber protection teams platforms that provide remote access to key terrain in cyberspace. These platforms are either embedded at vital garrison locations or in tactical formations, or used as flyaway systems (that is, transportable on commercial airlines) that give the teams a foothold from which to unleash their other capabilities—cyber protection team tools and mission planning capability.

In addition to these platforms, the initial DCO capabilities provide the early

FIGURE 1



ALL IN THE FAMILY

Product Manager DCO’s mission is to provide essential capabilities to Army cyber protection teams in a streamlined, efficient and integrated approach. Each system in the DCO family of 11 systems can operate autonomously or be combined into an integrated capability. (SOURCE: Product Manager DCO)

warning or reconnaissance capability via the Army’s Big Data Platform. This platform monitors cyber data, performs analysis and provides cyber defenders with an aggregation capability that is always looking for the unknown. To perform missions, whether on-site or remotely, cyber defenders need effects (the ability to deny, degrade, disrupt, destroy and manipulate), which are provided through a variety of commercial, open-source and government-owned tools. Finally, a mission planning platform—currently based on the Defense

Advanced Research Projects Agency’s Plan X project—enables users to visualize, plan, command and manage the force.

Combining all of these capabilities gives the cyber protection teams an integrated cyber defense capability, in the same way that combining Stinger missiles, a High Mobility Multipurpose Wheeled Vehicle, Sentinel radar, and forward area air defense command, control, communications and intelligence provides air defense units with short-range air defense. Each

FIGURE 2

cyber system can operate autonomously or be combined into a mutually supportive integrated capability. (See Figure 1.)

To meet the flexibility of the IT Box method, Product Manager DCO has recognized that traditional acquisition processes focusing on the refinement of requirements and risk-reduction prototyping through a balance of Joint Capabilities Integration and Development System (JCIDS) documentation and milestone decisions, contracting and documentation tasks would simply not be responsive enough. Adversaries develop new threats like the WannaCry ransomware, Zeus Trojan or Petya malware and exploit U.S. systems weekly; cyber defense technologies emerge just as quickly.

DCO designed an evolving acquisition strategy with continual prototyping to test technologies, inform requirements, deliver capabilities and allow rapid technology insertion, thereby staying ahead of the ever-evolving threat. A correspondingly flexible acquisition vehicle is essential to allow innovative technology to be incorporated into evolving capability enhancements. DCO capabilities are less focused on the engineered solution than on solution modularity—how easy is it to adapt, interface or replace.

INSIDE OTA

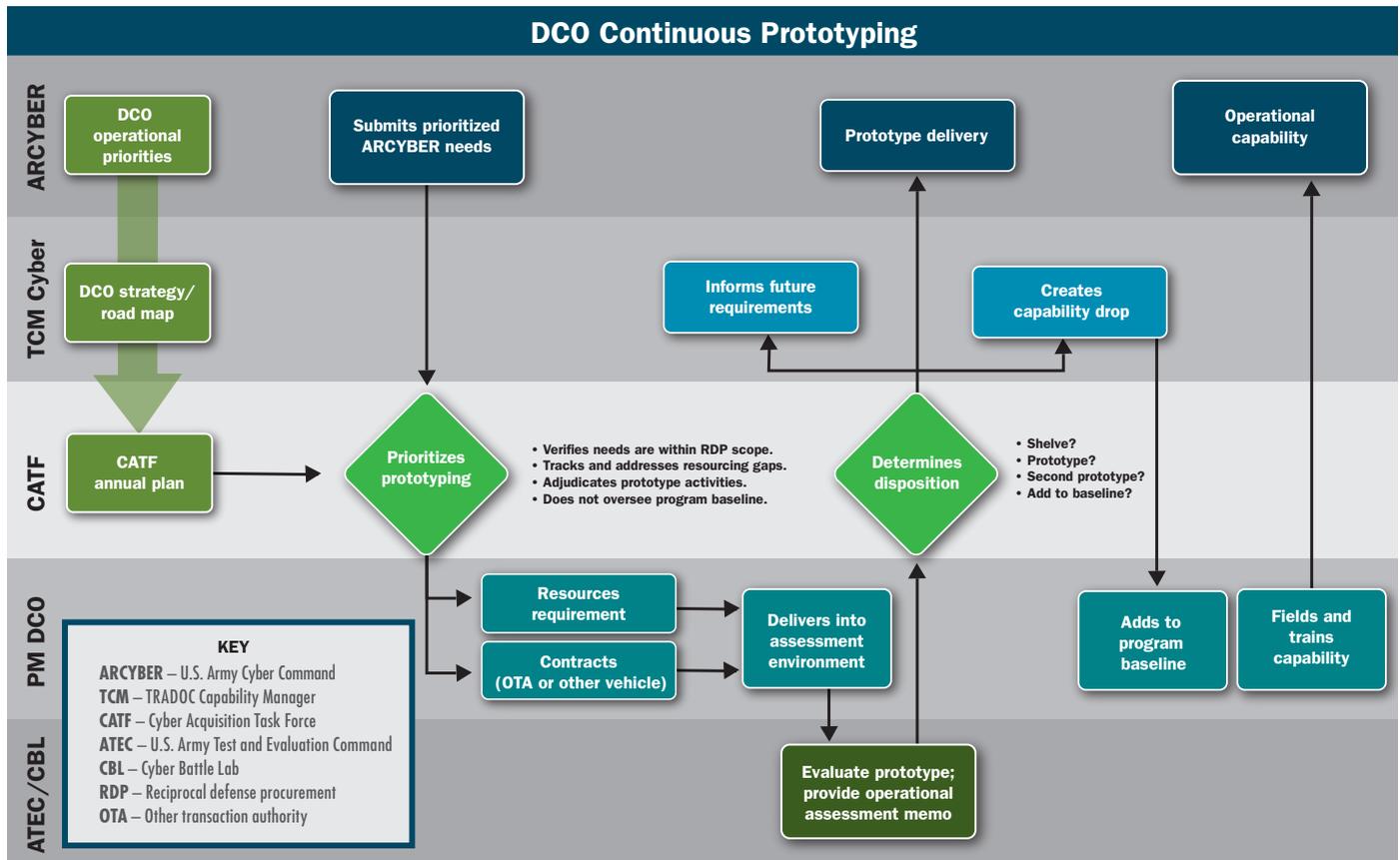
Additionally, DCO requires a strategy that fosters continual industry collaboration and innovation to take full advantage of the problem-solving and development of effective solutions through prototyping enabled by C5 and OTA. Leveraging the skills of a consortium of experts to combine solutions into an integrated, potentially game-changing capability offers a higher potential for success than depending on a single provider.



PATH TO A SOLUTION

The C5 process starts with the government user providing the C5 consortium with a concise statement of needs. C5 members are notified by the Consortium Management Group, a nonprofit that administers the consortium. Members propose solutions. The U.S. Army Contracting Command reviews the proposed solutions and can combine multiple ideas. The awardee and any subcontractors then build the government a proof-of-concept prototype and potentially continue with follow-on production. (Graphic by Product Manager DCO)

FIGURE 3



EVOLVING CAPABILITIES

DCO delivers technology enhancements, improved efficiency or new specific-use capabilities every three to four months. The evolving capabilities are then assessed, refined and integrated into the baseline capability. (Graphic by Product Manager DCO)

The consortium-based OTA construct allows government participants to collaborate with innovative industry experts and then award an agreement to build a prototype that demonstrates solutions to problems. This strategy capitalizes on acquiring innovative cyber, IT and software-intensive capabilities comparatively quickly—a model that DCO plans to use to address evolving threats and technologies.

OTAs are not new, although most acquisition professionals have not used them. They have existed since 1958, under authority initially granted by Congress to NASA to support development of space exploration technologies with a responsive approach. Over the years, through separate and specific statutes, 11 federal departments and agencies have added OTAs to their models,

including the departments of Defense, Energy, Health and Human Services, Homeland Security and Transportation.

Recently, Congress amended and further expanded DOD’s OTA under Section 815 of the National Defense Authorization Act for Fiscal Year 2016, 10 U.S.C. §2371b, adding the ability for the government to easily transition a successful OTA prototype project directly to a follow-on production contract when the initial prototype effort is competitively awarded.

The consortium-based OTA is in itself a competitive environment. C5 is operated by a nonprofit company, Consortium Management Group (CMG), created to establish, operate and manage consortia formed under the National Cooperative

Research and Production Act to use OTA. This Section 815 OTA provides the legal framework and contractual means for C5 industry members to collaborate with government customers and other members and subcontractors to provide innovative solutions for DOD. With over 400 industry representatives and established processes, C5 balances a collaborative environment, access to emerging technology providers and to nontraditional DOD innovation, and the potential to team with traditional DOD industry expertise.

The consortia are designed to have broad technical focus areas to accommodate many different types of prototyping efforts. The C5 process starts when the government user, such as an Army program manager (DCO, for example) provides the C5 Government Acquisition Liaison Office at Picatinny Arsenal, New Jersey, with a concise statement of needs. (See Figure 2, Page 217.) CMG notifies the C5 consortium members of a particular need in a request for white papers; those members that believe they have a good approach propose solutions. The government reviews the industry white papers and may combine multiple ideas into a best-of-breed solution for a prototype.

This is unlike the traditional process, based on the Federal Acquisition Regulation, whereby the government generally must either select the contractor that is closest to its requirement or reject all proposals and restate the requirement—a time-consuming, “good enough” method. With the C5 OTA, the government collaborates with industry to put together a solution and optimizes innovation. Once they’ve agreed on the solution, they document their approach in an other transaction agreement. The entire process, which generally takes about 90

days, allows the awardee to build the government a proof-of-concept prototype and potentially continue with a follow-on production.

ANATOMY OF AN ACQUISITION

The DCO acquisition strategy takes advantage of flexibility in requirements and contracting methods to adopt practices from rapid software and hardware development. DCO is delivering capabilities as an evolving “build” or “drop” every three to four months—not necessarily the complete solution but rather technology enhancements, improved efficiency or new specific-use capabilities that are assessed, refined and then integrated into the baseline capability. (See Figure 3.)

By using the C5 OTA, the product office can build continuous prototypes to assess capability gaps and insert mature technologies into the baseline program. (See Figure 4, Page 220.) At the same time, the OTA prototyping strategy informs the U.S. Army Training and Doctrine Command capabilities manager and provides the basis to discuss requirements, potentially refining key performance parameters by adjusting capability drop documentation under the IT Box construct. The end result is the most

DCO designed an evolving acquisition strategy with continual prototyping to test technologies, inform requirements, deliver capabilities and allow rapid technology insertion, thereby staying ahead of the ever-evolving threat.

advanced capability that industry can provide, properly aligned with program requirements that integrate attributes of doctrine, organization, training, materiel, leadership and education, personnel and facilities in a rapidly moving acquisition scenario.

DCO expects that using C5 and incorporating OTA prototyping will result in acquisition of a capability that is:

- **Better**—Continuous prototyping will allow DCO to provide capabilities that respond to evolving needs and align properly with requirements.
- **Faster**—Timelines are at least 50 percent shorter, compared with traditional acquisition methods.
- **Cheaper**—Prototyping reduces a product’s life cycle costs by providing a tangible solution that can integrate with existing systems and be tested up front for long-term suitability before full production decisions and the associated expenses.

CONCLUSION

In this era of expanding cyber technologies and threats, as well as IT capabilities, traditional acquisition methods and approaches generally deliver obsolete capabilities too late and over budget.

FIGURE 4

Deliver new capabilities through prototyping every four months.

- Focused on:
 - Increased efficiency.
 - Technology insertion.
 - New operational use or threat.
- Operational evaluation and assessment (ATEC).
- Baseline recommendation by governance.

Other Transaction Agreements

- Prototyping: C5.
- Collaborative environment.
- Maximizes innovation; easy to enter.
- Non-DOD focused.
- Authorize direct production.

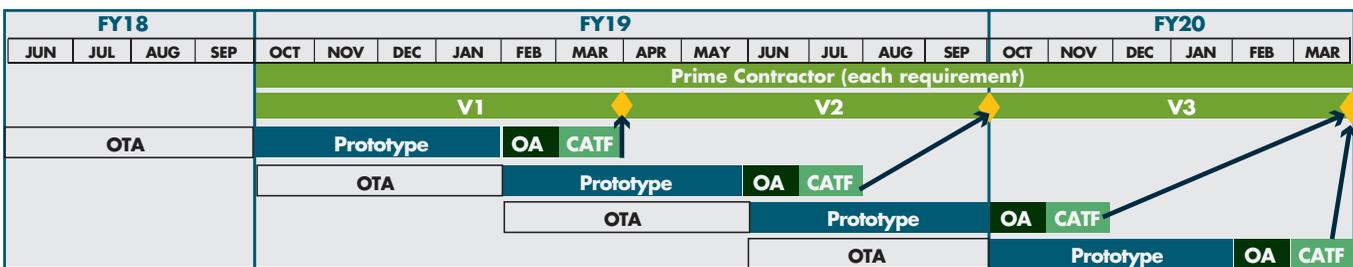
Semiannual decisions for baseline insertions (engineering changes).

Monthly technical interchange meeting or design review.

Configuration steering board (CATF).

Prime Contractor

- Integrates prototypes.
- Trains and maintains.



KEY ATEC – U.S. Army Test and Evaluation Command
 CATF – Cyber Acquisition Task Force
 OA – Operational assessment
 OTA – Other transaction authority
 V – Version

CONSTANT PROTOTYPING

DCO, under a C5 OTA, builds prototypes continuously to assess capability gaps. (Graphic by Product Manager DCO)

Through more innovative approaches, such as use of the JCIDS IT Box requirements process and consortium-based OTA, acquisition can move closer to the goal line of a better, faster, cheaper solution that harnesses the continual emergence of new technologies and the risk-reduction capabilities of prototyping.

There is no more urgent time than today, as we fight ongoing cyber battles in industry and government, for acquisition professionals to improve their use of innovative tools like OTAs and maximize collaboration with industry. Through use of the C5, monthly technical interchange meetings and rapid prototyping, DCO intends to demonstrate the might of combined industry solutions and collaborative acquisition to provide the most responsive capabilities possible.

For more information on DCO, go to <http://www.eis.army.mill/programs/dco>. For more information on C5, go to <https://c5technologies.org>.

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TOM COLE, BRIG. GEN., USA (RET.), currently serves as an independent consultant. He completed over 30 years of active Army service, with 22 years in defense acquisition. He was the program executive officer for Intelligence, Electronic Warfare and Sensors from November 2007 to September 2010. A graduate of the United States Military Academy at West Point, he holds an M.S. in aerospace engineering from San Diego State University and an M.S. in national resource strategy from National Defense University's Industrial College of the Armed Forces.

SIMPLE INTENT, COMPLEX MISSION

An eight-month assignment as chief of contracting in Kandahar yields an abundance of lessons learned.

by Maj. Michael Z. Keathley



THE TEAM ON THE GROUND

From left, Col. Joshua Burris, commander, ECC-A; Sgt. 1st Class Katrina Tolbert, noncommissioned officer in charge for RCO-S; the author; and ECC-A Command Sgt. Maj. Charles Williams. (U.S. Army photo by Staff Sgt. Jeremy Kinney, 410th Contracting Support Battalion)

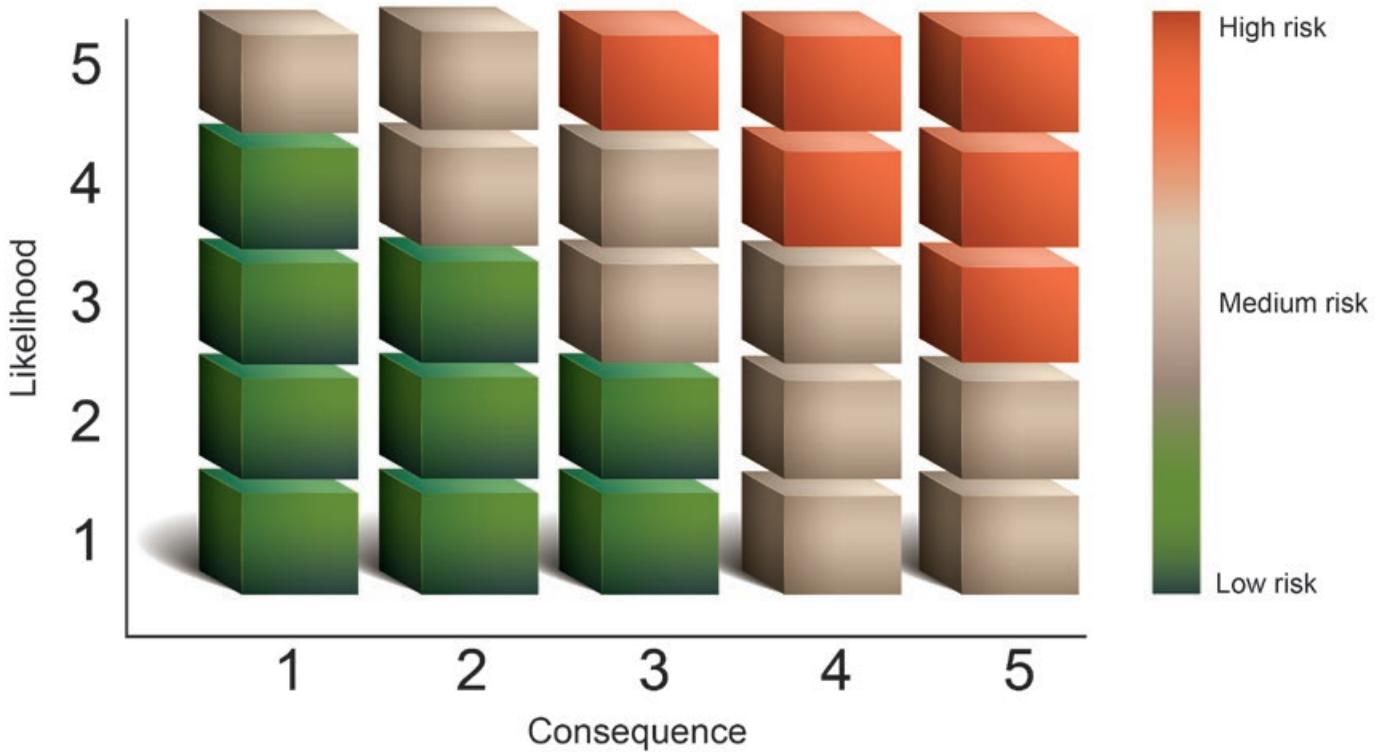
The commander's intent for U.S. Army Expeditionary Contracting Command – Afghanistan (ECC-A)—the clear, concise expression of what the force must do and the conditions it must establish to accomplish the mission while allowing subordinates the greatest possible freedom of action—directs Soldiers and civilians to “stay left of bang,” “exploit the data” and “leave lasting footprints.”

These three axioms have worked well to produce successful contracting operations. But between the seemingly simple principles and the successes is a universe of best practices based on lessons learned in contracting environments that are anything but simple. As the ever-eloquent Mike Tyson once said, “Everybody has a plan until they get punched in the mouth.”

As the chief of contracting at Regional Contracting Office – South (RCO-S) at Kandahar Airfield, Afghanistan, from November 2016 to July 2017, I had the opportunity to see these three directives in action, to apply them in the operation of RCO-S and, along the way, to survive the punches and learn a few lessons about expeditionary contracting operations.

The chief of contracting at RCO-S is responsible for the contract administration of the Logistics Civil Augmentation Program (LOGCAP) task order for southern Afghanistan. LOGCAP, dating to 2007, is the primary contract vehicle for base life-support services—everyday services such as electricity, waste management and dining facility operations—at all enduring and contingency bases in theater. RCO-S provided support and oversight of about \$300 million worth of contracts in FY16. Like all other U.S. Army organizations, RCO-S had a mission statement. Ours was simple: “Provide professional contracting support, on time, to the warfighter.”

FIGURE 1



Likelihood		Consequence
5	There is a high probability a nonconformance will occur that could adversely affect customer services if current conditions are not addressed immediately.	Failure would result in loss of life or serious injury to the user or impact mission readiness.
4	Government or contractor performance data indicates non-conforming trends that cast doubt on the ability of the process service controls to consistently meet PWS requirements.	Failure would adversely affect services necessary to maintain mission readiness.
3	It is unlikely that customer services will be interrupted; however, contractor performance data is unavailable or too inconclusive to reliably predict future outcomes.	Failure would impact reliability and maintainability of the service and result in possible partial mission capability.
2	Government or contractor performance data indicates that process controls are assessed frequently and services will continue to meet PWS requirements.	Failure would not adversely affect mission readiness immediately, but periodic surveillance should be established to ensure that service interruptions are addressed in a timely manner.
1	There is little or no possibility that an undetected nonconformance would escape contractor process controls, and the contractor is providing consistent services that meet PWS requirements.	Failure to control this process would have little or no adverse effect on mission readiness.

RATING RISK

Each service the contractor provided to installations in Afghanistan under the PWS was rated high, medium or low risk during the author’s tenure as chief of contracting at RCO-S. The author’s team conducted regular in-person checks on high-risk services like dining facilities, since they could decrease Soldiers’ readiness if not provided properly, and audited low-risk services as time allowed. (SOURCE: The author)

RCO-S, responsible for three locations supporting nearly 8,000 Soldiers, Airmen, Sailors, Marines and civilians, consisted of me, my noncommissioned officer in charge, a civilian administrative contracting officer (ACO) and three quality assurance representatives (QARs). The three locations were reachable only by helicopter and required significant planning and coordination to schedule visits. To support the contingency contract administration services mission, I and one civilian held ACO warrants that gave us authority to direct the LOGCAP contractor. All RCO-S personnel were located at Kandahar Airfield, save one QAR who lived at one of our outlying bases.

RCO-S has been supporting contracting operations in southern Afghanistan for more than a decade, and it has seen its personnel turn over every six to 12 months. My assessment of its operation when I arrived was overwhelmingly positive, but one of my intentions was to leave it better than I found it. Our day-to-day challenge was to apply the commander's intent to accomplish our contracting mission. Managing a life-support contract serving so many people across such a large footprint is complex, to say the least. Doing so with simple guidance was fundamental to our success.

OVERSIGHT LEFT OF BANG

This axiom means, essentially, to identify and mitigate issues or risks before they became problems, i.e., be proactive versus reactive. We accomplished this through relentless oversight of the contractor.

The performance work statement (PWS) for the LOGCAP contract in the south contained 75 "lines," or services to be performed. For example, one line was waste management. The contractor was expected to execute that service in a particular way, on a particular schedule,

using particular manuals and instructions, all detailed in the PWS. This "parent" service encompassed "child" services: emptying dumpsters, servicing portable toilets, operating a landfill, etc. Each service was assigned a risk rating of high, medium or low. (See Figure 1.)

The services with a "high" risk rating were deemed to have the potential to hurt the warfighter's readiness or even cause actual harm if not executed correctly. For example, food service operations was a high-risk service. Food service must be done correctly, without fail, guaranteeing that the contractor provided patrons with the nutrition they needed, served food properly and maintained a prescribed degree of cleanliness. On the opposite end of the spectrum, morale, welfare and recreation (MWR) services were assigned a low risk. The warfighter's readiness was unlikely to suffer if an MWR building did not fully function.

To ensure that the contractor upheld its end of the contract and avoided service disruptions, my QARs conducted periodic audits of performance lines. An audit was as simple as an on-the-spot observation or as detailed as reviewing the contractor's execution of a task. My QARs conducted an average of more than 100 audits each month on most PWS lines for the LOGCAP task order, a significant increase compared with the practices of previous staffs. Our goal was to audit all high- and medium-risk services each month, including all parent and child services. That schedule gave my team frequent opportunities to witness contractor performance and to identify opportunities to mitigate perceived or possible issues.

On several occasions, particularly in dining facilities, my QARs and I made on-the-spot corrections relating to

cleanliness, waste management and food preparation. For instance, we noticed that one of the dining facilities was temporarily storing food waste immediately outside the dining facility, violating a regulation that trash was to be kept at least 250 feet from the building at all times. Food waste brings insects, rats and other vermin, all unacceptable visitors in a dining facility. A quick discussion with the dining facility manager resolved the issue, which was minor but could have grown into a bigger problem if not addressed.

My office was allotted only three QARs, so we relied heavily on contracting officer's representatives (CORs) to perform surveillance of the contractor. QARs are specially trained on how to read and interpret a PWS and are very familiar with the associated technical manuals the contractor is legally bound to follow. A QAR is also well-versed in the basics of contracting—what is expected of the contractor as well as the government. My QARs kept the pulse of the contractor with regard to performance across the breadth of the LOGCAP contract, but I had only three of them, and they couldn't be everywhere, all the time. By contrast, 33 CORs were available, on average, throughout our three locations; however, executing their COR duties was often secondary to their primary job.

The CORs monitored all performance lines and recorded their findings monthly in the COR Tool (CORT). CORT is an online database for collecting the numerous COR reports submitted each month, simple digital files answering pertinent questions on contractor performance. This database is accessible to the CORs and all contracting officers assigned to a given contract. A monthly requirement for the ACOs at RCO-S was to review these forms to ensure their validity and accuracy and accept them into CORT.

This review, I found, was essential as some CORs submitted hurried work, much of which was unhelpful from a contracting perspective.

My team and I quickly discovered that all the CORs had other jobs to do. For example, some CORs were infantry platoon leaders, responsible for planning and executing combat patrols almost daily. Such an operations tempo is not conducive to effective surveillance of contractors. It became apparent that each organization slated to deploy should determine what its COR requirement will be and identify individuals likely to have the most time to devote to that task. Ample foresight benefits both the unit supplying the CORs and the contracting office.

CORs in the LOGCAP environment are invaluable to the ACO. However, it was difficult to monitor all 33 of them closely. On more than one occasion, one of our CORs issued direction to the contractor, something they do not have the authority to do. In each instance, I required retraining for the COR. In retrospect, to stay left of bang, I think it would've been more beneficial for me to conduct that training personally. I also should've mandated that every COR training session contain my personal instruction regarding the limits of their authority and the potential ramifications of violating them.

COR training must explain in great detail how the contractor can misinterpret a COR's opinion as an official government request. For example, if a COR mentions to the contractor, "The trash pickup for this site needs to be changed to one hour later," the contractor could interpret that as direction from the government. Only a contracting officer can make such a change, so



PARTNERSHIP ENABLES ALLIANCE

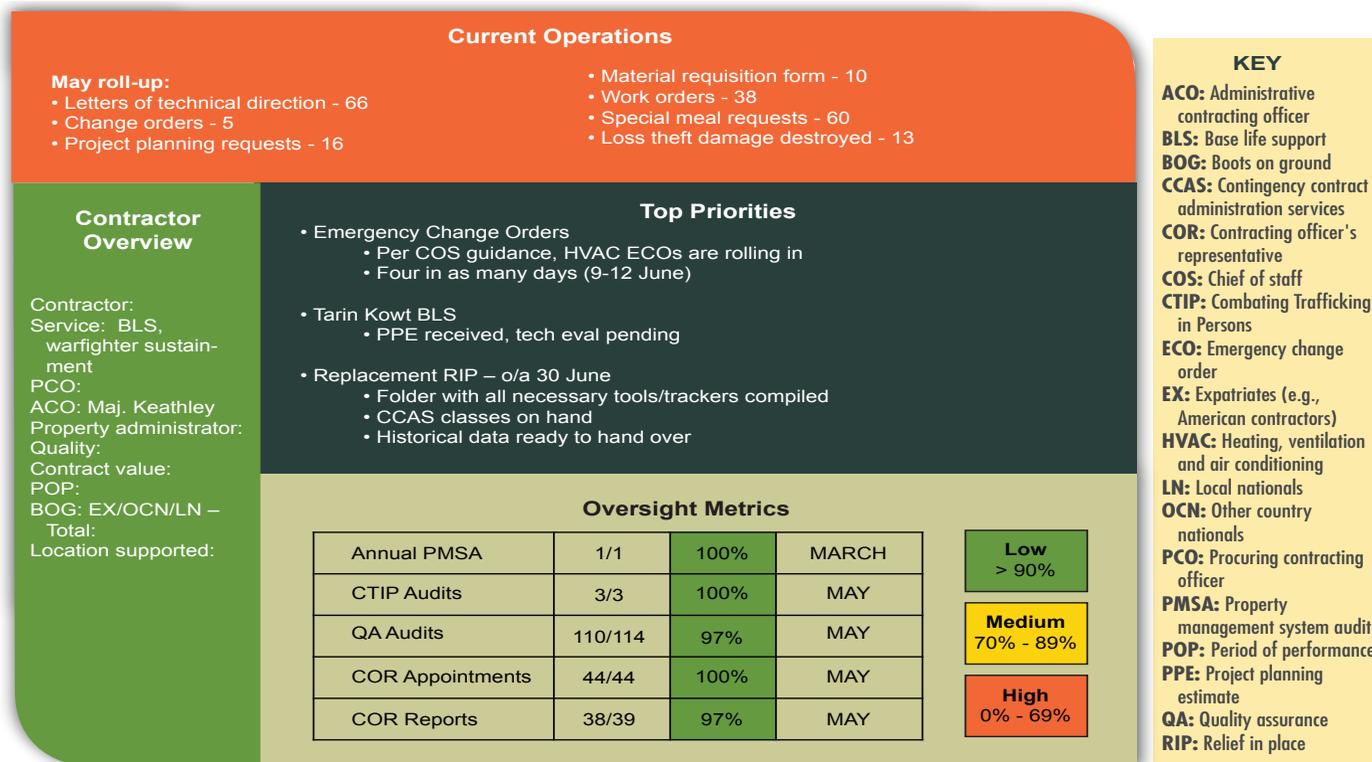
Maj. Gen. Richard G. Kaiser, center, commanding general of Combined Security Transition Command – Afghanistan (CSTC-A), meets with Col. Carol Tschida, left, then ECC-A commander, in December 2016 at Bagram Airfield, Afghanistan, to discuss improving the partnership between the two commands. ECC-A Soldiers and civilians provide direct contracting support—coordinating plans and exercising oversight, among other things—to CSTC-A, to keep U.S. forces ready to support their Afghan partners. (U.S. Navy photo by Lt. j.g. Egdanis Torres Sierra)



EQUIPPED TO EXPLOIT DATA

Michael A. Cooper is a DA civilian supporting ECC-A at Bagram Airfield. All ECC-A personnel, civilian and uniformed alike, follow the commander's intent to exploit the data, leave lasting footprints and stay left of bang. Relentless oversight of the contractor and audits, both scheduled and unannounced, were key to preventing a contracting "bang" such as spoiled food in a dining facility. (U.S. Army photo by ECC-A)

FIGURE 2



KEEP TRACK

The audit tracker, established by previous RCO-S staff and shown here in generalized form, helped the regional contracting team manage the work of CORs scattered around southern Afghanistan installations. During the author's time as chief of contracting, the team averaged 100 audits a month on all service lines of the task order. (SOURCE: The author)

it's important that CORs choose their words carefully when talking to the contractor.

CORT posed another time-consuming challenge for the RCO-S team. The tool is not an intuitive one, which presents problems when warfighter units arrive in theater. There is a rather steep learning curve in gaining access to the system, negotiating the site and uploading reports. Without fail, units and civilians slated to deploy should train the people who will be serving as CORs before they leave the United States, so that the CORs can hit the ground running and use the tool effectively in theater.

VALIDATING DETAILS BIG AND SMALL

We constantly received data from the contractor indicating work it had completed and other performance markers. Exploiting this data consisted of delving into the finite details to validate it

in an effort to prevent the contractor from painting a one-sided picture. This is not to suggest that the contractor was known to submit fraudulent data. Rather, it was important that the RCO-S team, as the administering office, be vigilant to ensure that what the contractor was providing was accurate.

Most of the data collected by the LOGCAP contractor was published daily, weekly and monthly on contract data requirements lists from the contractor's contracts management division. For example, the contractor provided my office a daily water production report that listed how much nonpotable and potable water was on hand, produced and issued. (The contractor is required to maintain a certain number of days' worth of water supply.) Once a month, I tasked my QARs to go to the water production site while the contractor recorded the daily numbers, to observe how it was done.

HOME BASE

Cessna C-208B Grand Caravans, used by the Afghan air force as basic training and light lift aircraft, sit on the ramp at Kandahar Airfield, in March 2016. The author's assignment as chief of contracting for RCO-S at Kandahar, overseeing LOGCAP, provided firsthand experience of the importance of proper COR training and contractor oversight. (U.S. Air Force photo by Tech. Sgt. Robert Cloys)



This task served two purposes: Besides making sure the contractor was reporting water production data accurately, it demonstrated to the contractor that its data was being monitored and validated. Service orders, work orders, fuel issuance and billeting management were other areas where we visited work sites to ensure that the contractor was reporting data accurately.

Something I could have done better to exploit data was arming myself with appropriate manuals or regulations. I routinely made unannounced observations, but rarely did so with the guidance of an appropriate supporting manual. In many parts of the LOGCAP PWS, for example, the requirement would be simply that “the contractor will conduct food service operations in accordance with Technical Bulletin, Medical (TB MED) 530, Tri-Service Food Code.” This supporting publication is over 300 pages long and

discusses everything from the maximum lead content acceptable in food to the capacity of the kitchen drainage system.

In retrospect, at least weekly I should have found a specific requirement in a referenced manual, regulation or publication and checked the contractor's compliance. This wouldn't have been to catch the contractor in the wrong but simply to enforce the requirements. This also would have made it crystal clear that the government was enforcing compliance not only with the large items in the PWS, but the minutiae as well.

LEAVING A BETTER SYSTEM

Before I entered the contracting career field, I served in the maneuver community as an armor officer in the 3rd Infantry Division and the 1st Cavalry Division. In that community, “leave lasting footprints” meant “constantly improve your battle position.” Looking at the concept from

a contracting perspective, I considered it an edict to make systems and processes better than I found them, to improve the contracting support that each subsequent RCO chief can provide the warfighter.

Management of CORs is one area I focused on improving. At RCO-S, we managed our active CORs through face-to-face interaction and by using a few tools we created. The first tool was our COR tracker: a spreadsheet containing COR names, locations, email addresses, phone numbers, the date they were appointed as a COR and, most important, the number of days remaining until their redeployment back to their home station. This information gave us everything we needed to manage each person and to ensure that we identified their replacements before they departed theater.

Another tool in our COR management was our audit tracker. Established at



RCO-S long before I arrived, it laid out all the PWS lines of the LOGCAP contract and provided the name of the COR assigned to each. It also displayed the risk rating for each PWS line, which drove the frequency of audit. The tracker also listed what audits were due for which PWS line for each month, and provided a column to indicate if the audit had been completed as well as a column for pertinent comments. These tools gave us the necessary awareness of our CORs' status and the status of their reports. (See Figure 2, Page 225.)

CONCLUSION

As I write this, my RCO-S replacement and his team are carrying on with the timely contract support the warfighters in Afghanistan have grown accustomed to.

My advice to anyone going to Afghanistan as part of this support is to ask themselves these three questions once a day: What am I doing to stay left of bang? How am I exploiting the data the contractor is giving me? How am I leaving lasting footprints, and making systems and processes better for those who come after me? If all else fails, look to the contracting officers, contracting specialists and other contracting professionals to your left and right. They possess a wealth of historical know-how.

The U.S. military has been in Afghanistan for 16 years now, and all the while we've been conducting contracting support. There isn't a single coalition service member who isn't supported by a contract in some capacity, be it the food he eats or the electricity she uses. While the commander's intent may change from time to time, the three simple axioms executed by the motivated, professional and knowledgeable personnel of RCO-S and U.S. Army Contracting Command have been integral to maintaining that support, whether we were aware of it or not.

For more information, contact the author at Michael.z.keathley.mil@mail.mil. For more information about U.S. Army Contracting Command, Expeditionary Contracting Command – Afghanistan's parent command, go to <http://lacc.army.mil/about/>.

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A LITERAL GOLD MINE

This open-pit mine in Kokpatas, Uzbekistan, operated by Navoi Mining and Metallurgical Combinat, a state-owned company, began operating in the mid-1990s and has been expanding ever since. "We are a commercial-first company," Schingler stresses, primarily interested in helping customers make better business decisions. But Planet believes its imagery can also contribute to better stewardship of the world's resources, and its images are useful to organizations monitoring conflict and humanitarian situations and regulating natural resource extraction. (Images courtesy of Planet)

CRITICAL THINKING

Very small SATELLITES, Very **BIG** Deal



Mr. Robbie Schingler

A flock of Doves takes detailed pictures of the whole Earth every day. You've probably seen their photos, or read a headline informed by the data they gather. What can the Army learn from these birds and the former NASA engineers who set them aloft?

by Mr. Michael Bold

As wildfires raged through half a dozen Northern California counties in October, a San Francisco company offered free access to its satellite photos of the devastation to the public, first responders, aid providers and media.

What made the company's photos of the burning wine country worth studying was that they were taken daily from 230 to 310 miles above Earth. The company, Planet, operates the largest constellation of satellites ever—more than 190 at last count.

Planet's story began in 2010, when three aerospace engineers left the NASA Ames Research Center in Mountain View, California, to start an audacious business: a private satellite company.

The trio—American Robbie Schingler, Briton Will Marshall and Australian Chris Boshuizen—built their first prototype satellites in Schingler's garage, basically taking apart a cellphone and adding a telescope, extra battery power and some other features. They moved their lab to San Francisco in 2011 and founded Planet Labs Inc., now known simply as Planet. (Boshuizen left the company in 2015.)



BE AWED, BUT NOT OVERAWED

Among other benefits, the smaller size of Planet's Dove satellites—about as big as a loaf of bread—brings the satellite down “off the pedestal,” in Schingler's words, letting engineers see the whole system instead of just the subsystem they work on and think more critically about what it can do.

Their idea was revolutionary. Satellites typically weigh over 3 tons and are about the size of a bus, take a decade or more to design and build and, by the time they're deployed, are running on obsolete computing systems for the 10 or so years they're in use. What Planet does is turn all that on its head. Each of their satellites (called Doves, and launched in Flocks) is roughly the size of a large shoebox and is built using commercial off-the-shelf technology.

They're constantly being upgraded with the latest available technology (the Dove is on its 14th iteration) for the roughly three years they'll be in orbit. They take continuous daily photographs of Earth. The difference between their images and, say, Google Earth's is that Planet's images are updated daily, rather than every few months, and are compiled into a cloud-based database, allowing users to compare changes to areas both large and small over time.

The satellites, as Planet describes it, “act like a line scanner for the planet.” Custom automation software allows Planet's Mission Control team to schedule imaging windows, push new software in-orbit and download images to 30 ground stations worldwide. The constellation of 190-plus satellites is akin to what the Army foresees as it pursues networked swarms.

But it's once all those images get back to Earth that the real magic begins. Planet has developed analytical algorithms that produce an array of products for:

- **Agriculture**—Planet's continuous images of their fields allow farmers to understand changes in soil, crops, irrigation and disease, allowing them to farm more efficiently, profitably and sustainably.
- **Governments**—Planet's imagery lets local governments track urban growth, unpermitted building and changing land use, and allows them to better manage regional transportation budgets, land use policy, economic development plans, disaster response, crisis management and humanitarian aid, such as in the case of the Northern California fires and Hurricanes Harvey and Irma.
- **Intelligence and defense**—Planet provides transparency into global events, constantly photographing broad swaths of Earth and targeted areas of interest. The images allow for monitoring of man-made and natural disasters; ports and shipping; and population shifts. Planet's images after the recent North Korean nuclear test showed widespread landslides in the area surrounding the test site, suggesting to experts that the explosion was much larger than originally thought.
- **Forestry**—Images allow for improved monitoring of forest health, tracking of illegal logging and planning of timber-harvesting operations.

Planet also offers products for mapping; energy and infrastructure; and finance and business intelligence.

Other companies, known as analytics-as-a-service companies, use their own algorithms to sort Planet's data, and many of them, in turn, have partnered with Planet. A Jakarta-based analytics company, Dattabot, used satellite data from Planet to help secure loans for Indonesian farmers.

Planet is at the leading edge of an exploding wave of space privatization, its satellites having hitched rides on U.S., Indian, Russian and private rocket launches. Planet and other satellite startups, including UrtheCast Corp., DigitalGlobe Inc. and Orbital Insight, are making Earth-imaging resources once reserved for governments available to businesses and the public. Companies such as Elon Musk's SpaceX, Orbital Sciences Corp. and Blue Origin, owned by Amazon founder Jeff Bezos, are launching their own rockets into space.

LA NIÑA'S EFFECTS

On a rare clear February day during California's rainy 2017 winter, a satellite snapped this picture of Planet's San Francisco headquarters. It shows not only the Golden Gate Bridge, top left, but also the sediment washed by rains from the 4,600 square miles of the watershed muddying the San Francisco Bay. A scientist measuring how water quality changes as runoff increases could supplement data from water samples with satellite imagery from the same days—since Planet re-images the entire planet every day—to develop a broader understanding of the daily impact of sediment.



Planet's medium-resolution Dove satellites (in the aerospace industry, satellites are commonly called "birds") got the name because they are "peace-bringing satellites, enabling commercial, humanitarian, and environmental applications at a scale that has never been attempted before," according to the company website. As of October 2017, there were more

than 175 of them circling the Earth. In a single launch in February, Planet sent 88 satellites aboard an Indian rocket into orbit. Another 48 were launched in July aboard a Russian Soyuz rocket.

Also in Planet's constellation are five medium-resolution RapidEye satellites, acquired when it bought BlackBridge in 2015; seven high-resolution SkySat satellites acquired when Google sold its Terra Bella subsidiary to Planet in February 2017 (as part of which, Google acquired an equity stake in Planet and entered into a multiyear agreement to purchase SkySat imaging data); and six SkySats launched in October.

Not that the private satellite business is without its risks. In October 2014, an Orbital Sciences Antares rocket, whose payload included 26 Doves bound for release from the International Space Station, exploded shortly after launch off the coast of Virginia. In June 2015, a SpaceX Falcon 9 rocket broke up during takeoff from Cape Canaveral in Florida; eight Doves were aboard.

While Planet is most definitely a business—according to a Bloomberg Business

article from June 29, 2017, Planet has raised more than \$180 million in venture capital and is valued at more than \$1 billion—it sees its mission as making the world a better place by changing the way we understand, and ultimately manage, the Earth's resources. "Whether you're measuring agricultural yields, monitoring natural resources or aiding first responders after natural disasters," says its website, "our data is here to lend businesses and humanitarian organizations a helping hand. Planet believes timely, global imagery will empower informed, deliberate and meaningful stewardship of our planet."

Schlinger, 38, Planet's co-founder and chief strategy officer, spoke with Army AL&T on Oct. 11, 2017. He worked for 10 years at NASA, where he helped build the Small Spacecraft Office at NASA Ames and pursued new business opportunities for the Transiting Exoplanet Survey Satellite, a planned space telescope that's part of NASA's Explorers Program.

Schlinger later served as NASA's open government representative to the White House and as chief of staff for the Office of the Chief Technologist at NASA. He

Satellite Imagery Resolution

Remote sensing images are composed of a matrix of picture elements, or pixels, which are the smallest units of an image.

If a sensor has a spatial resolution of 20 meters and an image from that sensor is displayed at full resolution, each pixel represents an area of 20 meters by 20 meters on the ground.

(SOURCE: Natural Resources Canada)

received an MBA from Georgetown University, an M.S. in space studies from the International Space University of Strasbourg, France, and a B.S. in engineering physics from Santa Clara University. He was a 2005 Presidential Management Fellow.

Army AL&T: Planet Labs can photograph nearly all of the Earth's surface every day, which is something not even the U.S. government can do. To what purpose?

Schlinger: The purpose for us is to do a global monitoring mission at this spatial resolution [how small an object you can see]. So that's important. ... Actually, just to correct you, the U.S. government is mapping the whole Earth every day with the MODIS satellite, which is 500 meters per pixel. One satellite. But what we do is image the whole world every day at 3 meters per pixel. And that spatial resolution allows for us to build a data set that lends itself to analytics. So when you apply the analytics technology to this data, you can come up with some really interesting insights.

We are a commercial-first company—we have a lot of customers in agriculture and in finance sectors, and they're interested in making a better decision on either a trade or when to plant and cultivate. And [with] the spatial resolution and the temporal resolution [the precision of a measurement with respect to time] that we have, they're able to measure economic stops and flows on the planet.

Now, it turns out from a government perspective ... the same pixels and the same analytical capabilities can be used to modify our government's workflow as well, on the civil side and on the military intelligence side. On the military intelligence side, the time-series nature of this—the term of art has been “activity-based intelligence,” or patterns of life. ... When you can classify that change, that pattern of life, and identify a signature that then can become an early indication of something about to happen, then you can better allocate your scarce resources—either high-resolution capabilities, pixelated aircraft or human—in order to then anticipate what's about to happen and, in some cases, mitigate something from happening.

Army AL&T: You guys made it big by going small, by building not only very small satellites but a lot of them. Is there a lesson for DOD and the Army about going small, and about using off-the-shelf technology?

Schlinger: Absolutely. I believe that the future of space is to continue to have very, very high value, unique, one-of-a-kind assets—whether they're flagship astrophysics missions or they're used for national technical needs. When it comes to things that are a bit more operational, that have commercial utility, I think the Army and the government in general should be really adoptive, should embrace these newer technologies and allow for [the government] to then, on the space side of things, focus on the harder things, and focus further out. Something that gives them an offset.

Now, lessons specific for the Army, around using small satellites, is just: Get on with it. You know, this is actually a really, really good training capability for young [engineers]. Give them the ability to innovate within a box, you know, whether it's size



We see the federal market as the largest market in geospatial today. And so we definitely need to service that market by selling a commercial service to them. But that's very different from going inside the government and being a systems integrator or being a contractor.

or whether it's cost or whether it's time, or all three, and see what they can do. By treating the satellite like a robot, which is what it is, rather than something up on a pedestal—that maybe you influence one appliance or one component within one subsystem within one mega-satellite over a decade—you have a different relationship with it as an engineer.

And so by iterating on that relatively quickly, you really understand the system dynamics of the hardware, which then allows you to think about the system dynamics of the entire system. It's not just the sensors that you launch into space, but you think about the entire

value chain. Ultimately, the reason why we're going into space is to collect unique information—and, with that unique information, to allow for people to make better decisions. ... We also go to space for other signals like PNT [positioning, navigation and timing], and for [communications], but largely for all the other applications, it's really about getting unique information to make better decisions.

So the faster that we can speed that up, from asking a question to getting an answer ... is really smart. There are places to innovate—not just on the hardware that goes into space but on the

network of the ground stations. Then also the data exploitation platform that allows for an end user to ask a question and get an answer.

What's very interesting about this trend of small satellites that would interest your readers in the Army, and the growing proliferation of unclassified and commercial imagery we see, is that users that want to use this ... more tactically rather than strategically, can now get access to space. And so that's one of the beauties of our constellation [of satellites'] capabilities. By remaining unclassified, it means that you don't have to have four stars on your shoulder to get access to what was once an extremely strategic capability. It now can be done in more of a day-to-day operational modality.

Army AL&T: The satellites get all the attention, and rightly so. They're very sexy. But what about the analysis of that data? The possibilities seem to be almost limitless. And in fact, you're partnering with a number of companies that take your data and analyze it differently than you do. Talk about that.

GROUNDED

Planet has 30 ground stations worldwide, including this one in Awarua, New Zealand. Planet satellites have customized automation software, which lets the company's Mission Control team prompt the satellites to take pictures at a certain time, push new software to the satellites while they're aloft, and download images to ground stations.





IMAGES AS DATA

Tankers unload crude oil and take on refined products at the sprawling Mailiao Refinery in Taiwan in May 2016. Satellite pictures like this one are just part of what Planet sells to customers; the rest of the package is analysis of the data drawn from the images. Planet has developed specialized analytics for energy companies, agriculture, financial services, forestry and other fields.

Schlinger: OK, that's a great question. And I'm glad that you brought up a number of our partners and customers, because it's absolutely key for this to really grow the market and allow for something, again, that was once strategic use for government to actually make its way into better decision-making tools in the economy. And that's what we're absolutely focused on doing, growing the number of users who can get access to this information.

Our industry, remote sensing, is a very special theme-strategic industry that was primarily driven by the intelligence community for decades. And we called it the tradecraft, being able to exploit ... and promote remote-sensing information. You know, you had to have a master's and a Ph.D. in order to understand what you were looking at. I think what has evolved over time is [that] the IT [information technology] companies of the world have really commoditized ... cloud-based technology. And that begins to open-source a variety of computer-vision and machine-learning algorithms. And machine-learning algorithms need

data. They need data in order to actually train those algorithms so that they become more accurate.

So at Planet, we see ourselves as collecting unique information and bringing that unique information with other spatially explicit information to analytics. When you add data plus analytics, that's really what our product is, it's a platform that has core machine-learning analytics baked into it.

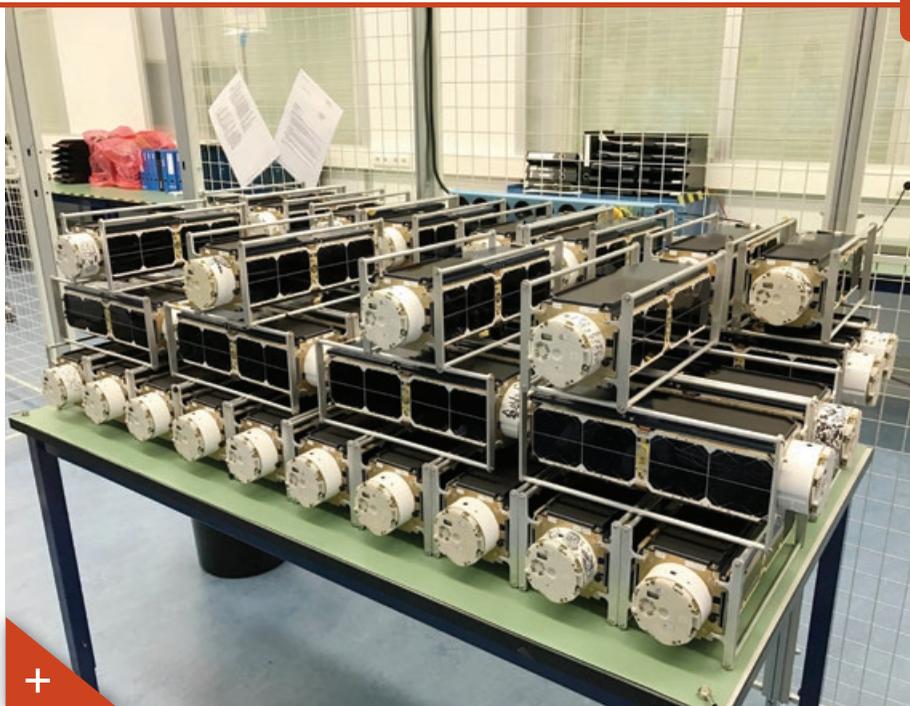
We're trying to decrease the barrier for our users to ask questions and get answers. In order to do that, we partner with a variety of companies that have access to our data and core analytics in order to allow for them to build a product that focuses on the customers' needs.

You know, we have customers that are building applications specific for farmers or specific for a commodity trader or that is specific for an insurance provider or for a small holder in agriculture capability. We have hundreds of customers. Our

customers operate in over 100 different countries and are really focused on actually building businesses, building a product that can scale and that will really solve the problem. So we see ourselves as more of a platform and an enabler that allows for people to come up with new products and services that were not possible before. Because we're doing a lot of the hard-core remote sensing work to get all of that data co-registered, co-aligned, activated to the cloud, then also with the core machine-learning analytics that allow for our users and customers to build novel products and solutions. So that's the reason why we partner with a lot of people that actually are building applications that are derived from Earth observation data.

Another program, I think, that's really specific and useful for the Army and the government in general is that we are an unclassified and commercial company. And there are many workflows and use

Ultimately, the reason why we're going into space is to collect unique information — and, with that unique information, to allow for people to make better decisions.



FROM LAB TO LAUNCH

Forty-eight of Planet's Dove satellites—known as Flock 2K—are prepped for launch. Launch prep includes planning for possible failure: Planet lost 26 satellites when the rocket they were attached to blew up on the launch pad. Planet owns satellites, but not rockets, so the company has negotiated with India, Russia, the U.S. and private companies launching their own rockets, to send Doves into space.

cases that we aren't aware of that the government has and truly needs. So we have a partner program for system integrators and for companies that exist to help the government solve their problems. And they are able to take this new commercial tool and then customize elements of it so that they can modernize internal workflow within the U.S. government. That's something that I think is just beginning. It takes quite a bit of time in order to modify a workflow. By blending in some automation, you can really increase the ROI [return on investment] of the people and the assets that are already deployed to solve government needs.

Army AL&T: I wonder if you could talk for a minute about failure. It seems like a certain amount of failure is built into your business plan. You've lost satellites when rockets exploded on the launch pad.

Your satellites have a life span of about three years, but you're constantly tinkering and upgrading and changing.

Schlinger: We test, learn and iterate on our technology constantly, whether it's a new sensor or a new technology in space, or whether it's how we manufacture our satellites or how we build out our ground stations or build out our automated mission control and our data pipeline and our analytics. We abide by the popular principle of a highly aligned and loosely coupled organization. That allows for each of those nodes to be constantly upgraded over time. That then ends up increasing the value that comes out in the end for the user and for the customer. That's how we actually develop the technology.

The way that we operate the technology is to be reliable, because what comes out in

the end is we want to have a service-level agreement that we can live up to and that our customers can expect. And so those two things, being agile and being reliable, are two values that we have in the company. You can't really have one without the other if you want to keep inventing new technology. But then you also want to anchor in that type [of] project in the world, in the market.

That same methodology fits all those in the company: We really wanted to be able to build satellites in a very different way and to iterate on the learnings of the technology and to pull into the satellite new chips and components when they just come out on the market. And knowing specifics in space, you can take those chips and components and actually build

out a system that can then work well in space today.

We have a very, very robust, high-performing satellite in a 5-kilogram package. Part of the reason we wanted to go small, too, is so the launch costs are less per satellite. If the launch costs are less per satellite, then the total cost of the system is less. If the total cost of the system is less, then if you lose one or two or three [satellites], that's part of doing business. But if you lose one or two or three, then that means that you'll take a bigger step with the new technology that you develop. And so by taking a bigger step, that means that you actually are bringing the future forward even faster. You can see how that's a positive feedback for accepting risk, and reasonable risk.

That being said, you know, when we launched 88 satellites, that's kind of putting a lot of eggs in one basket. And so, of course, we accepted that risk but we hedge it by buying insurance. There are ways that you make sure that these things aren't catastrophic for the organization.

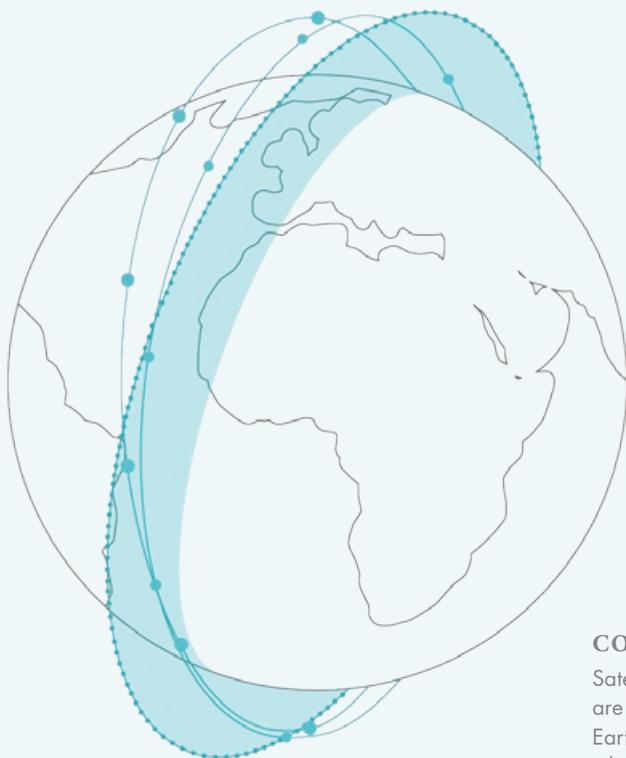
I think that's the main thing, is you don't ever want to have an existential thing that's out of your control actually impact the viability of an organization. And so in space, we always want to launch more than we need so that we can basically degrade [as satellites go offline].

Army AL&T: Is there anywhere you would draw the line in terms of working with the government?

Schlinger: Planet is a commercial organization. We see the federal market as the largest market in geospatial today. And so we definitely need to service that market by selling a commercial service to them. But that's very different from going inside the government and being a systems integrator or being a contractor. Our reason for being is to bring global change to the enterprise and to bring geospatial into a workflow of business at the speed of business. That's how we've chosen to focus, and it's different from going inside to the government and being one custom solution for a very, very large, important problem. But the ecosystem is much larger than that. So we're purposefully selling the same thing to the federal government that we would sell to an agriculture company or to a financial data services company.

Army AL&T: You worked for the government, for NASA.

Schlinger: Yeah, for 10 years.



COVERAGE PLAN

Satellites in Planet's constellation are spaced out in lines around Earth, to photograph the whole planet, every day. Each one orbits the poles every 90 minutes.



SINGAPORE STRAIT

A ship leaves or arrives in the Port of Singapore every three minutes. Keeping the congested waters off the port safe while keeping tabs on what passes through is a tall order. Recurrent images of the port help, but using human eyes to inspect the images is time-consuming and difficult. Programming image software to count ships in seconds unlocks more possible uses for the data; Planet develops some tools like this, and outside companies also contract with Planet customers to analyze image data algorithmically.

Army AL&T: What, if you were put in charge of NASA tomorrow, would you change?

Schlinger: I would invest in small launch, number one. Number two is I would do procurement reform in order to allow for the government to be a good customer, rather than only seeing industry as being a contractor. And number three is I would have a portfolio of projects that allows for my creative engineers and younger engineers to prototype and integrate and invent new technologies for government-specific needs.

Army AL&T: Is there anything you would like to add?

Schlinger: I actually want to highlight what this is going to mean for the Army mission. You guys have a global mission. And a lot of it is used to keep the peace. And many missions today are done with collaboration, with our allies. And one of the unique things that really comes out of this commercial space revolution, and coming up with these unclassified data sources, means that you could get data just as fast. The person in the field can get it and share it and collaborate with an allied partner at

the same rate that the intelligence community gets it or that the strategic community gets it.

So this is a game changer. It allows for people to have fresh, unique information. It's unclassified and shareable, so you can come up with interesting and custom workflows. And it means that it speeds up the decision-making process. So the people on the ground will have greater situational awareness and understand what's about to happen probabilistically. So I really do encourage your leaders to take stock of the direction where this is going, because it really is going to, I think, change the day-to-day workflow of people in the field.

MR. MICHAEL BOLD provides contract support to the U.S. Army Acquisition Support Center. He is a writer and editor for Network Runners Inc., with more than 30 years of editing experience at newspapers, including the McClatchy Washington Bureau, The Sacramento Bee, the San Jose Mercury News, the Dallas Morning News and the Fort Worth Star-Telegram. He holds a B.J. in journalism from the University of Missouri.



Recovery

ROCKY ROAD TO RECOVERY

Getting the Javelin program back on track required projecting how much more money the development team would need and determining how much more time would be necessary. (Image by Duncan_Andison/iStock)



BEEN THERE, DONE THAT MONEY TO BURN



Making sure your 'burn rate' doesn't overheat can be the difference between a successful program and toast.

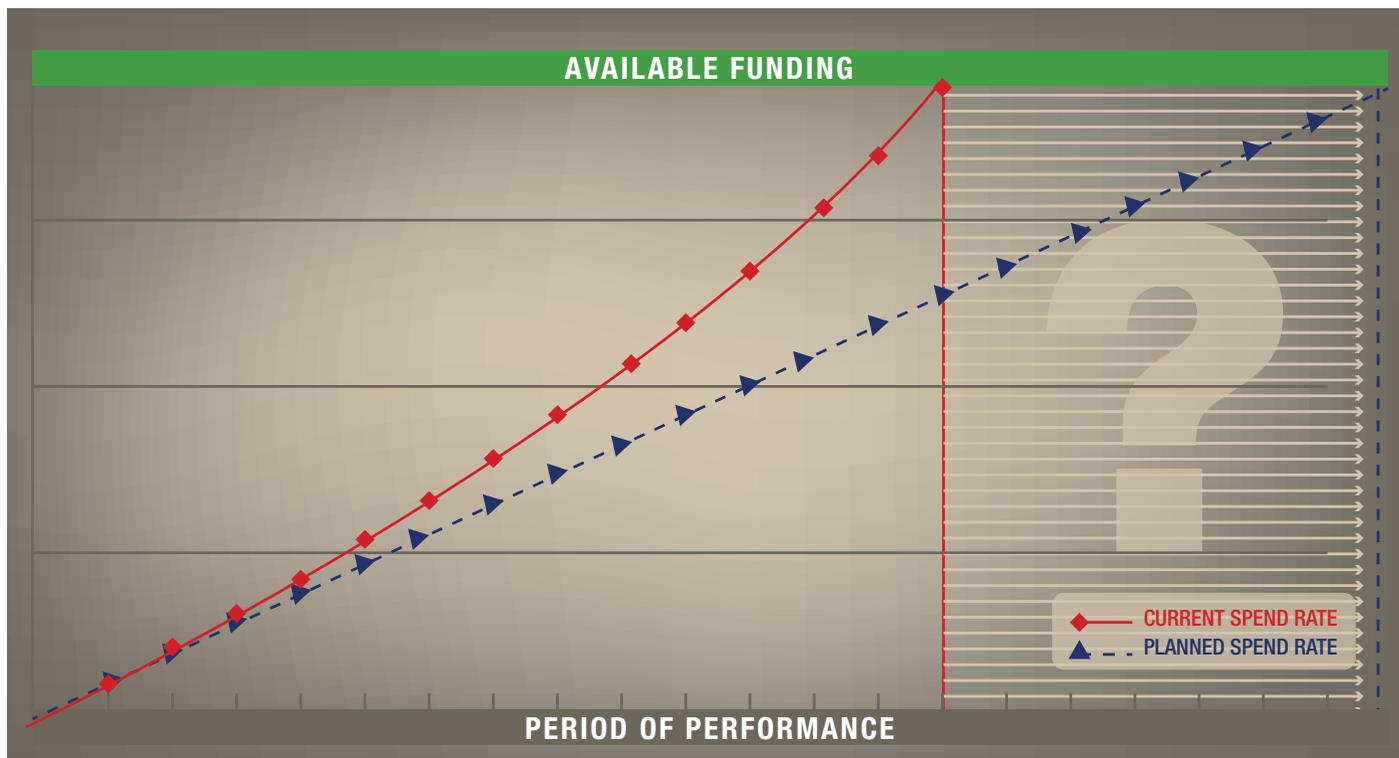
by John T. Dillard, Col., USA (Ret.)

I still remember how it went that day in November. It was way back in the 1990s, and at the time I was a major serving as the assistant project manager for the development of the Javelin anti-tank missile system. We were right in the middle of our 36-month engineering and manufacturing development (EMD) effort.

The boss assembled a few of us in the conference room. He said, "We have to call for a DAB [Defense Acquisition Board]—this program is going to need a formal re-baselining. I woke up at 3 o'clock this morning and did a quick calculation: At the rate we're spending, we're going to run out of money before the next fiscal year starts! And what's worse is, I think we're going to blow through our budget at completion."

I had just joined the program a month earlier and was pretty excited about getting the needed capability into the hands of my infantry branch brothers. They wanted and needed a true "fire and forget" anti-armor weapon to replace the less effective Dragon, introduced in the mid-1970s. I thought, "How could we be in so much trouble? And how could the boss know at this juncture that we were going to fail to stay within budget for the remainder of the program?"

FIGURE 1



BURNING TOO HOT?

When available funding is projected to run out before the performance period ends, programs need to adjust their burn rates. (Graphic by U.S. Army Acquisition Support Center)

The DAB, marking formal notification of a major problem in need of senior leadership guidance, was a big enough crisis. It was going to get a lot uglier as we all began to realize this would also constitute a Nunn-McCurdy breach and need congressional approval to continue by moving the funds around to fix it. I got with our program analyst and started looking at the earned value management (EVM) figures and the prior monthly contractor performance reports. I knew EVM, as a program management tool, was a long-standing specification that we added to cost-reimbursable contracts and was rapidly becoming an industry-wide standard for estimation of the true value of work performed to date, as opposed to simply a metric to show the difference between what was budgeted and what had been spent.

If the bean counters were correct, our performance and schedule indices showed a pretty large jump in what would be the final

tally for this program; just how large was to be determined. But to me it looked like they just used a ruler to extrapolate our current inefficiencies and overruns out to the end of EMD. Was there no chance for improvement? Could we not “get well”? We wanted to be optimistic, but we were falling behind schedule as we failed to meet our own specs.

I helped prepare the information briefings as we went up the command chain to tell the bad news about the Javelin program. Once inside “the building”—the Pentagon—I found out we weren’t alone: Lots of programs were busting cost and schedule thresholds and needed more money and time. It wasn’t a good time to have our hands out, with a big drawdown underway—but it never is. The contract for EMD was bid and awarded at \$170 million, but the government felt the program was still fairly high risk, so close to an additional \$100 million was budgeted for it. Now, just 18 months into the program, we already

could forecast that even that much money wouldn't be enough.

BURN RATE 101

For professional military officers, it certainly isn't easy to admit failure, or to predict that you're going to be a failure in 18 months or less. It took us the better part of a year and about four more meetings of the non-milestone DAB to formally re-baseline the program—recalculate and revise the costs and schedule for the remaining work—by deferring our production and recoloring the near-term money, etc. It was painful.

One of the main difficulties was not only projecting how much more money we would need to finish development, but how much more time as well. Red teams, blue teams, tiger teams—the bureaucracy assigned any number of “experts” to help us figure it all out. The Office of Cost Assessment and Program Evaluation, back then called the Cost Analysis Improvement Group, was heavily involved in getting to the root causes of our troubles and identifying the resources needed to proceed. We had been spending about \$10 million per month, and we were going to need about \$180 million more. What no one seemed to be able to decide was how much more time should be added to the original 36-month schedule.

There were 40-month estimates, and 42- and 48- and finally 54-month versions of the revised EMD phase. We finally arrived at the 54-month estimate—18 additional months for the additional \$180 million. How about that! We could've done some pretty simple math to arrive at that schedule figure once we got the latest revised bottom-up engineering estimate. But believe it or not, there weren't that many people who even considered the burn rate in their estimates of the schedule needed.

The idea of burn rate, or spending rate, was an important takeaway for me from all this. (See Figure 1.) EVM “gold cards,” provided by Defense Acquisition University, and their published instructions tell you all about various ways to figure out a new estimate at completion (EAC). But the EVM readings and formulas available to all of us don't adequately teach us how to estimate schedule when they take us through these concepts of planned, actual and earned value. The squiggly lines and values typically guide us toward estimation of a new budget at completion or EAC, but they don't elaborate on how much more time might be needed. And time is indeed money.

It's possible, perhaps, to apply cost performance index and schedule performance index calculations against the original budget to project a new version of the program schedule. But current EVM instruction is really lacking when it comes to how to deal with the extra funds you receive if you're unlucky enough to need them and lucky enough to get them.

It turns out, as I discovered during the Javelin recalculations, that once development programs get underway, their staffs of various engineers burn resources at a fairly consistent rate. For us, we were involved with knowledge work at that point; no missiles had yet flown. But lots of chemical, mechanical, electrical and software engineering was in flow, as well as all the work of the business types: admin, scheduling, management and indirect costs, for example.

LESSON WELL LEARNED

Frequently, we work EVM problems here at the Naval Postgraduate School. I ask my students how much more money and time will be required for a program running behind schedule and over budget. Unlike common stock shares' technical

analysis charts, EVM is indeed a predictive tool. And as with an artillery shell just one millimeter off its deflection or azimuth, a cost or schedule variance vectors out over distance to become quite large depending on range (or time remaining).

Most often, students come up with a nice combined index formula for a pessimistic estimate—maybe the more pessimistic, the better—but then they expect to spend many more millions of dollars in only a few months added to EMD. It just isn't likely to happen, because practically, industry cannot simply add staff to “crash” the program and finish it rapidly. They'll most likely continue at their current systemic rate of cost and schedule inefficiency. Hopefully, the earned value you attain during the extension will be the same or better than what it's been so far—but we can't expect miracles.

This knowledge would serve me well a few years later when I took over my own program. It was amazingly similar to the

I thought, “How could we be in so much trouble? And how could the boss know at this juncture that we were going to fail to stay within budget for the remainder of the program?”

Javelin program in programmatic terms. At my change of charter ceremony, a nice lady came through the receiving line to introduce herself and shake my hand. “Hi, I’m Barb,” she said cheerily. “I’m your program analyst. It’s April,” she continued, stating the obvious, “and, if my projections are correct, you’re going to be out of money by July.” I stood dumbly, taking in what she said, before she added, “There’s cake in the conference room. Enjoy!” I was a bit taken aback—but I knew exactly what to do.

A quick phone call to my industry counterpart, and we were soon developing a spend plan for the rest of the year—a contractor’s “diet” that he and his crew would have to adhere to strictly in order to get to Oct. 1 and a new supply of money. We published that spending plan to all program stakeholders to increase the pressure and have everyone stick to it.

I also asked for a “manpower off-ramp” chart. Since we were nearing the end of development, I wanted to see design engineers rolling off my program and on to other work at their companies. Sure, there would be production and quality types coming aboard, but I wanted to see billings for design work taper off as the design was completed. We did a little scrub of scope that the government had requested two years earlier—a variety of unnecessary contract data requirements lists, mostly—and got back about six weeks of an eight-week slip situation, arriving on budget for that year. Whew!

CONCLUSION

The moral of this little story is to know your burn rate in addition to all the other numbers floating around. As the PM, you have a lot on your mind financially: How much have I spent this fiscal year, internally to the program management office, externally to support contractors and



SPENDING IS A MOVING TARGET

Members of the 2nd Infantry Brigade Combat Team, 4th Infantry Division fire an FGM-148 Javelin anti-tank missile during a training exercise at Grafenwoehr Training Area, Germany, in May 2017. In the 1990s, 18 months into developing the Javelin, members of the project management team, including the author, learned the program was rapidly running out of money. (Photo by Pvt. Nicholas Vidro, 7th Mobile Public Affairs Detachment.)

government labs, test ranges, etc., and how much to the system prime contractor? How much is in the colors of money that I have in the Future Years Defense Program and program objective memorandum (POM)? What is my spend (burn) rate? How much of the fiscal year is left? When is the budget going in for next year and for how much? Does it reflect what I need, and does the POM fully reflect where we are event-wise in the program?

There’s so much to be fully situationally aware of on the business side. If only that were all you had to worry about. But maybe you can ask the question about “our current burn rate” next time the discussion rolls around to funds needed. You just might be the smartest person in the room!

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An Outsider's Take on ACQUISITION



Army acquires tactical communications equipment; units lack time, resources to train with it; some deploy without it. A PEO's liaison to the operational force breaks down this dilemma.

by Brig. Gen. Karl Gingrich

I arrived at the Program Executive Office for Command, Control and Communications – Tactical (PEO C3T) in June 2016 as an outsider to the Army's acquisition community. Given that I had no acquisition credentials or signal experience, many found the assignment curious, but the Army knew exactly what it was doing and why. It was specifically the lack of credentials and limited knowledge of the tactical communications portfolio that enabled me to do what the Army wanted—bring a new perspective to what we are acquiring, how we are fielding and how we are sustaining systems throughout their life cycle.

My official position was assistant PEO for operations, readiness and fielding. The charge from my boss, Program Executive Officer Gary Martin, was even clearer—become the face of the PEO to the operational force and maximize their readiness. To enable this, he gave me unfettered access to all forums and programs and free rein to travel to gain information, coordinate actions and affect change, and speak for the PEO. The access I was afforded, as a general officer, to operational units further enabled my mission, as did the ability to leverage a large network of my peers, and my extensive experience within the Army enterprise. In all of this, my ultimate objective was to be an advocate for Soldiers, commanders and



NETWORK MUST WORK HERE

During its training rotation at the Joint Readiness Training Center (JRTC) at Folk Polk, Louisiana, in April 2017, the 2nd Brigade Combat Team, 10th Mountain Division used the mobile WIN-T network to provide on-the-move mission command, situational awareness and voice, video and data exchange. The author, whose status as a general officer gave him greater than usual access to operational feedback, heard over and over again that such systems need to be smaller, simpler and more rugged. (U.S. Army photo by JRTC Public Affairs)

Until we can align our institutional training and business processes, far too much burden is being placed on our unit commanders.

signalers in the field. The purpose of this article is to provide some broad insights I gained from the yearlong experience and to advocate for more assignment opportunities like this for my peers.

First, the United States Army remains tremendously capable and continues to emphasize increased readiness as it builds strong momentum on modernization efforts. The pace of operations is as high as it has been in the past 16 years, and units are as busy at home as they are when they are deployed, in part because of training and proficiency requirements and systems maintenance to support readiness. To facilitate home station training and deployed operations, our Soldiers are demanding a network that is less complex. As I met with operational units and commanders during my time at PEO C3T, this prevailing theme cemented our

efforts to not only simplify technology but, more importantly, to change business practices in the way we field, train and maintain network capability.

With the high tempo of home station activities and deployments, one of the greatest challenges we face today is that Soldiers do not have sufficient time to train on these advanced communications systems such as the Warfighter Information Network – Tactical (WIN-T), tactical data radios and mission command applications. More simply, Soldiers are not getting enough repetitions on the systems that we are fielding. Time is a precious resource to commanders.

‘MAKE IT SMALLER’

The acquisition community can help maximize commanders’ time and training resources by working to engineer

complexity out of our systems, simplify and standardize user interfaces, and teach Soldiers through apps, videos and chat how to reinforce or in some cases replace over-the-shoulder training on systems that do not require it. But the acquisition community can only do so much on this score, as true proficiency requires repetitive hands-on experience with the systems. Commanders must ensure that units are exercising their communications systems, incorporating them into training events at every opportunity and prioritizing communications training as part of sustainable readiness.

However, in order for this to happen, the development and acquisition community needs to help our commanders. The community must design and improve systems to be less burdensome to integrate into home station training events by making them smaller, faster, simpler, more rugged and easily transportable. These are all common refrains I heard while talking to operational units. If we don't work across the community to heed these requirements, units will continue to leave their fielded systems behind at home station and deploy with less capability. This is problematic, as we must stay ahead of

our potential adversaries and continue to leverage rapidly changing commercially available technology.

'MAKE IT SIMPLER'

Based on feedback from operational units, the evolution of the threat environment and the pace of information technology advancement, we are now improving our business practices. We are pushing our research and development efforts, as well as the defense industry, toward simplification and standardization.

Key to these efforts are movement to a standard common software baseline across our mission command systems, simplifying user interfaces, virtualizing hardware components where technology allows and fielding smaller and more expeditionary communications capability. PEO C3T is addressing these concerns and issues across the portfolio, including fielding the air-transportable Tactical Communications Node – Light, which provides light infantry units with vehicle-mounted (on the High Mobility Multipurpose Wheeled Vehicle) mobile, high-bandwidth connectivity; a lightweight satellite communications capability called Transportable Tactical

Command Communications, which will provide a satellite link that's easy to set up during early phases of operations; and continuing development of the Command Post Computing Environment, which reduces the number of stovepiped mission command systems and hardware in the command post.

The above efforts, and others, aim to develop a network foundation for achieving mission command, assured and interoperable communications, and information links across a multidomain architecture. But change does not come quickly, and we must continue to support the near-term readiness of our formations with better and more numerous training opportunities while we try to field less complex, more robust capabilities.

From an institutional perspective, the Army needs to strengthen integration and synchronization across doctrine, organization, training, materiel, leadership and education, personnel and facilities, to better support the readiness of our formations. The Army is working toward an integrated approach across new equipment, institutional and sustainment training.

FRESH LOOK

The author inspects equipment newly fielded to the 2nd Infantry Brigade Combat Team, 4th Infantry Division, at Fort Carson, Colorado, in February 2017. He had no acquisition experience before arriving at PEO C3T to be the face of the organization to the operational units designated to use the network and communications equipment it acquires. (U.S. Army photo)



Synchronizing fieldings, along with units' other tasks, will produce better-trained Soldiers who are more confident in their skill sets. Well-trained Soldiers also will help the Army reduce its reliance on contracted logistical support, to achieve time and cost savings. The Army's C4ISR (command, control, communications, computers, intelligence, surveillance and reconnaissance) Home Station Training Initiative, which is executed by the U.S. Army Communications-Electronics Command with support from PEO C3T, helps address these issues. Trainers and readiness resource managers catalog information (trouble tickets) on systems that units had difficulty using during operational training, to determine which systems see the most requests for field support assistance; the unit is then informed on how to receive additional training support for its personnel from the training providers available to them at home station.

Unfortunately, this is not enough, and we must begin to produce new Soldiers and leaders proficient on the systems they will find in their units. Until we can align our institutional training and business processes, far too much burden is being placed on our unit commanders.

One aspect of the Army's institutional business approach to total life cycle management is producing positive outcomes. The Army's C4ISR community at Aberdeen Proving Ground,

Smaller, faster, simpler, more rugged and easily transportable. These are all common refrains I heard while talking to operational units. If we don't work across the community to heed these requirements, units will continue to leave their fielded systems behind at home station and deploy with less capability.

Maryland, functions as a single team for life cycle management of our equipment. The U.S. Army Research Laboratory explores how emerging science and engineering could be transitioned into applied research for near- and long-term capabilities. The U.S. Army Communications-Electronics Research, Development and Engineering Center (CERDEC) executes engineering and prototyping, in coordination with partners such as PEO C3T and PEO Soldier at Fort Belvoir, Virginia. CERDEC's activities then transition into acquisition through its relationships with PEO C3T, PEO Enterprise Information Systems and PEO Intelligence, Electronic Warfare and Sensors. The Communications-Electronics Command, including Tobyhanna Army Depot in Pennsylvania, completes the collective approach to addressing readiness issues. The field support initiative—whereby Soldiers are once again the primary operators and maintainers of C4ISR equipment at the unit level—is pushing down to our tactical units.

TRANSFORMATION, NOT TRANSACTION

I personally dedicated much effort to fostering and strengthening these relationships and orienting their collective efforts on the challenges our tactical commanders were facing.

Finally, I gained an appreciation of just how complex our acquisition process is and the commitment of our acquisition professionals. PEO C3T has a tremendously professional workforce, composed of both civilian and military staff. They are laser-focused every day on the readiness of our formations and the needs of the future. They are meeting the challenges from senior Army leaders—including those from the assistant secretary of the Army for acquisition, logistics and technology and the U.S. Army Materiel Command—for greater innovation across the phases of research, development, engineering and acquisition. The PEO, like all others, is more closely managing risk as it accelerates capability generation and fieldings. The challenge is to remain focused on the Soldier while being transformational instead of transactional.

As an outsider, I would like to think I helped in this area the most. By challenging the common assumptions, focusing our program managers on outcomes and not process, advocating for our Soldiers and their desires, and being willing to underwrite risk for our acquisition leaders, the PEO continues to improve and thrive.

CONCLUSION

My time at PEO C3T has been a great opportunity and one of my most valued assignments. I believe the Army made a wise



CAPABILITY AND TRAINING

The author, center, traveled to Fort Carson, Colorado, in February 2017 for a capability set fielding visit with the 2nd Infantry Brigade Combat Team, 4th Infantry Division. One takeaway from his time as assistant PEO C3T is that whether Soldiers get enough time training on a system matters just as much as what the Army designed the system to do. (U.S. Army photo)

investment in my development, as I left with a stronger appreciation of our materiel life cycle processes and the professional workforce that executes these difficult missions every day.

I look forward to continuing to serve this great Army and to applying what I have learned. My hope is that I left a similar impression on the PEO and that the change I helped foster will endure. This was a unique opportunity the Army afforded me, and I highly recommend that the Army expand this approach and provide other general officers, many of whom could bring their expertise and years of experience into the process, the same opportunity to contribute new perspectives for improving our network capabilities.

The Army should focus not just on the network, but should expand this approach to our other challenging capability portfolios like ground combat vehicles and intelligence. I will forever

cherish my time at Aberdeen and the C4ISR community and look forward to future opportunities to serve in this community again.

For more information, go to <http://peoc3t.army.mil/c3t/>.

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CALLING IN SUPPORT

Soldiers with 2nd Brigade Combat Team, 101st Airborne Division (Air Assault) call on the radio while conducting a live fire exercise during Network Integration Evaluation (NIE) 17.2, conducted in July at Fort Bliss, Texas, and White Sands Missile Range, New Mexico. During NIE 17.2, the Army Rapid Capabilities Office assessed mounted and dismounted electronic warfare systems that provide new electronic detection, support and attack capability in contested and congested environments. (U.S. Army photo by Sgt. Maricris C. McLane, 24th Press Camp Headquarters)

START THE FIRE

As it has done in the past, the Army needs to leverage innovation for modernization success.

by Col. Joseph Capobianco

A spark, fuel and oxygen. As simple as these elements are, if one is missing, fire won't exist. Similarly, there's a triad of elements that must come together for innovation to occur. The Army is now trying to leverage this "fire" of innovation to solve the modernization problems of the past two decades.

Achieving innovation requires much more than looking at resource use, assigning priorities or adjusting organizational constructs. It demands addressing the driving force (the spark), building talented teams (the fuel), and fostering a supportive environment (the oxygen). Real innovation also has a cost: change, internal conflict and often destruction of the present organization, processes and capabilities. Remember, for example, the tanks that replaced the Army's beloved horse cavalry.

MORE THAN A BUZZWORD

Not a day passes without a discussion, an article or a speech that mentions innovation, and senior leaders have committed significant time and resources to boosting innovation within DOD. In August 2017, Secretary of Defense James Mattis announced his plans to maintain several DOD innovation initiatives and organizations his predecessors had established. At the Association of the United States Army (AUSA) Annual Meeting and Exposition in October 2017, Ryan D. McCarthy, then-acting Army secretary, and Gen. Mark A. Milley, chief of staff of the Army, announced that the Army will reform its approach to requirements generation and weapon system modernization

by creating new organizational constructs and processes to maintain, or in some areas regain, operational overmatch.

These efforts indicate that the Army is attempting to move beyond identifying and clarifying the modernization problem to actually address it by leveraging modernization. It is one thing to announce change, claim its importance or provide top-level guidance to “innovate.” It is quite another matter to fund, educate and build organizational teams working in an environment that can make innovation a reality—and provide the U.S. Army the advantage in deterring, shaping or winning any conflict.

THE SPARK: OVERTURN THE INDUSTRIAL AGE MODEL

The Army modernization problem is clear. The major weapon systems developed in the 1970s and fielded in the 1980s are marking four decades in service, with dozens of upgrades and strapped-on fixes to maintain operational readiness and provide incremental, evolutionary improvements. During the past decade, near-peer competitors have worked to close the gap in our systems’ current advantages. As McCarthy wrote in a modernization priorities memo in October, the consequence of this modernization problem is the Army’s loss of competitive advantage against emerging threats, competitors and adversaries.

Senior leaders trace the current modernization model to the Industrial Age, and cite the need to reform processes that are slow, overly bureaucratic and stove-piped. This top-level problem has three distinct parts: requirements generation, technology integration and improvement of acquisition processes. The challenge is well-framed and understood, serving as the spark to leverage innovation as a solution.



ACQUISITION MISSTEP

The Small Unmanned Ground Vehicle was part of the canceled Future Combat Systems (FCS). The overly ambitious FCS program was intended to usher in a new generation of capabilities, but in a major blow for Army acquisition, DOD canceled the program in 2009. After FCS, the Army acquisition enterprise preferred incremental improvements to existing systems over risky, large-scale innovation. (U.S. Army photo)

So what does it mean to innovate? Webster’s Dictionary describes innovation as “a new idea, device, or method, or the act or process of introducing new ideas, devices, or methods,” but it can be further broken down into two categories: evolutionary and revolutionary innovation.

Evolutionary innovation is synonymous with incremental change, which builds upon known products or capabilities. It is relatively low-risk with predictable and advantageous outcomes. Revolutionary innovation involves breakthroughs that address problems from a completely new



angle. It is higher-risk, often described as serendipitous, and produces greater rewards. These innovations are radical or disruptive, often changing the landscape of currently accepted approaches or capabilities. The cost of this innovation is the obsolescence of today's organizations, processes and capabilities. Revolutionary innovations are often seen early in capability development, while evolutionary innovations generally take the form of improvements that are identified and implemented as that capability is fielded and adopted for wider use.

Revolutionary innovation, whether in the military or in the private sector, requires the triad of elements: a driving force, a talented, funded and supported team, and a viable environment. It's simple to start a fire by lighting a gas grill on the back porch. It's a lot harder to light a fire at a windy, rainy campsite. Likewise, fostering innovation in organizations varies based on needs, people and culture. No matter the conditions, you need all three—spark, fuel and oxygen—at one place, at the same time for the fire of innovation to occur. The guidance is clear: "Go innovate!" What is less clear are the critical parts required to make that innovation happen and produce tangible results.

FROM THE BIG SIX TO THE CFT

The good news is the Army has a demonstrated history of success in leveraging revolutionary innovation to modernize. In the 1970s, the Army developed the major weapon systems that came to be known as the "Big Six." They include the M270 Multiple Launch Rocket System; the M1 Abrams main battle tank; the Bradley Fighting Vehicle; the AH-64 Apache and the UH-60 Black Hawk helicopters; and the Patriot Air Defense System. In the 1980s, the Army fielded these six modern weapon systems to achieve operational overmatch in Operations Desert Shield



CHALLENGE DELIVERED

U.S. Army Chief of Staff Gen. Mark A. Milley delivers his State of the Army address at AUSA's Eisenhower Luncheon on Oct. 10, 2017. He announced new initiatives, including the creation of a new modernization or futures command, six modernization priorities and the establishment of eight cross-functional teams. (U.S. Army photo by Daniel Torok)



PROTOTYPE AS BRIDGE

A Counter-Unmanned Aircraft System (C-UAS) Mobile Integrated Capability (CMIC) vehicle is loaded onto a C-17 in February 2017 at Lawton-Fort Sill Regional Airport in Oklahoma before being transported to Europe. The Army Rapid Capabilities Office is using prototypes, such as the CMIC, as a natural bridge between emerging technologies and more mature solutions that are part of official programs of record. (U.S. Army photo by Keith Pannell, Fort Sill Public Affairs)

and Desert Storm, and the Cold War against the Soviet Union. No shots were fired in Europe in part because of the known overmatch of our formations and their weapon systems. The Big Six also facilitated overmatch in Operation Iraqi Freedom.

The keys to the success of these systems were clear: threat-based requirements documents, maturation of technologies, prioritization, adequate funding and, most importantly, patience to see the systems to fruition. This modernization happened over decades that included failed air defense, tank, aircraft and artillery efforts.

As successful as the Big Six fieldings were, however, the past two decades have not been so kind. Lawmakers, senior leaders and Soldiers have been frustrated with the Army's inability to modernize and field new capabilities. After repeated failures that ranged from the RAH-60 Comanche helicopter to Future Combat Systems—the most ambitious acquisition program in the service's history and central to its modernization efforts from 2003 to 2009—the Army's answer became to take steps, not leaps. Instead of new systems that would usher in the next revolutionary generation of capabilities, leaders chose the path of evolutionary upgrades to the Big Six.

However, the recent resurgence of near-peer threats in Russia, North Korea, China and Iran has demonstrated the need to modernize on a larger scale. One positive step toward meeting that need came from Congress in the form of the National Defense Authorization Act for Fiscal Year 2016, which assigned the service chiefs a greater role in weapon system development and modernization.

Using that expanded role, Milley and several Army secretaries took action on

three key initiatives. First, they placed a renewed emphasis on the Army Requirements Oversight Council (AROC) by focusing all requirements on technical feasibility and affordability. Secondly, in concert with the AROC, the G-8 developed the strategic portfolio analysis review (SPAR), which became the de facto program objective memorandum guidance and prioritization, with three clear categories—accelerate, maintain or stop—across the Army's 15 portfolios. The third effort was the establishment of the Army Rapid Capabilities Office (RCO), which is based on the Air Force's successful RCO construct and charged with rapidly developing and delivering prototypes to combatant commands to close high-risk, strategic operational gaps. The AROC, SPAR and RCO are serving as the foundation in addressing the modernization problem.

Army leadership also announced other modernization initiatives at AUSA:

- Creation of a new modernization or futures command.
- Publication of the Army's six modernization priorities and acquisition reform plans.
- Establishment of eight cross-functional teams (CFTs).

The CFT pilot, outlined as “an innovative organizational construct to integrate and synchronize processes across multiple stakeholders,” will use teams to transition leader-approved capability requirements to the Army acquisition system, allowing faster and more affordable capability development. The need for technology integration is addressed through the CFTs' requirement to leverage experimentation and technology demonstration to inform and mitigate risk to the longer-term programs of record.

FUEL AND OXYGEN

The Army is great at creating organizations, such as the RCO, CFTs and the new modernization or futures command. But to fuel innovation, such organizations have to be led and staffed by curious people who question the status quo and are not averse to risk. McCarthy's acquisition reform directive specifically addresses the need for talent management within the acquisition formation. This emphasis needs to carry over to the CFTs and modernization or futures command to ensure that the right people are in the right roles to support the revolutionary innovation that's needed.

The last and most critical piece to consider is the environment—the oxygen for the innovation fire to start and thrive. Starting with the secretary and chief of staff of the Army and continuing to the Army acquisition executive, to program managers and on down the line, the Army must foster a culture that celebrates risk acceptance, early failure and frequent experiments. Incubating informal networks that work in parallel with well-defined Army processes promotes cross-pollination and idea generation. The Army RCO has forged such a network through its Emerging Technologies cell, which focuses on assessing capabilities such as robotics, artificial intelligence and counter-unmanned aerial systems, and coordinates with nontraditional innovators and organizations like the Defense Innovation Unit Experimental and the DOD Strategic Capabilities Office to potentially apply their technologies to Army needs and programs.

Of the three components required for revolutionary innovation, the environment, or oxygen, is the most crucial, and is often not specifically addressed in memos, constructs or conversations. The Army can provide the oxygen for innovation through greater risk tolerance and



ATTENTION ON DECK

Soldiers assigned to 1st Brigade, 147th Air Assault Helicopter Battalion and 2nd Brigade, 149th Air General Support Aviation Battalion conduct a deck landing qualification with a UH-60 Black Hawk on a U.S. Navy ship in August 2017 in the Arabian Gulf. The Black Hawk is one of the military systems developed in the 1970s known as the Big Six. It remains a core element of the Army's military power today. (U.S. Army photo by Staff Sgt. Jeremy Miller, 35th Infantry Division)

an increased emphasis on prototyping and experimentation—allowing us to place lots of little bets with the understanding that many will fail, but one might be revolutionary.

CONCLUSION

The Army has a plan to leverage the fire of revolutionary innovation to address the modernization problem. We have the spark: The modernization problem is well-understood, with emphasis on requirements generation, technology maturation and integration, and acquisition process improvements. We have the fuel: the formation of new and innovative teams, through the RCO, eight planned CFTs and the modernization or futures command.

The area that requires the immediate and continued emphasis is the oxygen, environment. The leadership must create and foster an innovative environment that tolerates risk, accepts failure early and often, and promotes teams and individuals who further the fielding of near-, mid- and long-term modernization capabilities. The cost of innovation—change, organizational conflict and destruction—is the price to proceed.

The Army has a long and proud, though sometimes sporadic, modernization history over its 240-plus years of existence. It must and will undoubtedly modernize again, fielding revolutionary capabilities that win back dominant overmatch against emerging threats, competitors and adversaries.

For more information, please visit <http://rapidcapabilitiesoffice.army.mil>.

COL. JOSEPH CAPOBIANCO is the chief of staff for the Army RCO. He previously served as the program executive officer for Special Operations Forces – Warrior at the U.S. Special Operations Command. He holds an M.S. in national resource management from National Defense University's Dwight D. Eisenhower School for National Security and Resource Strategy, an M.S. in aerospace engineering from the Georgia Institute of Technology and a B.S. in electrical engineering from Norwich University. He is Level III certified in program management and Level I certified in test and evaluation. He is a member of the Army Acquisition Corps.



LT. COL. BEIRE CASTRO

COMMAND/ORGANIZATION:

Product Manager for Force Protection Systems,
Project Manager for Terrestrial Sensors,
Program Executive Office for Intelligence,
Electronic Warfare and Sensors

TITLE:

Product manager

YEARS OF SERVICE IN WORKFORCE: 9

YEARS OF MILITARY SERVICE: 24

DAWIA CERTIFICATIONS:

Level III in program management

EDUCATION:

MBA in defense acquisition and contract
management, Naval Postgraduate School;
B.A. in criminology and criminal justice,
East Tennessee State University

AWARDS:

Bronze Star Medal; Meritorious Service
Medal (2 oak leaf clusters (OLCs)); Army
Commendation Medal (5 OLCs); Joint Service
Achievement Medal; Army Achievement Medal
(1 OLC)

‘Acquisition seemed limitless’

A chance encounter with acquisition workforce members brought Lt. Col. Beire Castro to the Army Acquisition Corps nine years ago. Since then, he has managed to pack a lot of experience into a relatively short career—including an invaluable stint on Capitol Hill that saw him working to advance the Army’s legislative agenda “one staffer and one coffee shop at a time,” he said.

Since June 2016, Castro has been the product manager for Force Protection Systems within the Program Executive Office (PEO) for Intelligence, Electronic Warfare and Sensors. As such, he is responsible for providing most of the base defense equipment and capability to deployed forces—the Integrated Base Defense Program and the Base Expeditionary Targeting and Surveillance Systems – Combined, for example, which includes the Rapid Aerostat Initial Deployment and Cerberus towers—as well as security systems for installations in the continental United States.

The job of a program manager, “ensuring that we provide the best capabilities, on time and at the best cost, is pretty straightforward,” said Castro (whose first name is pronounced “Barry”). “The true art is in aligning the myriad stakeholders to get you there. They all get a vote, and each can say no and stop you. The program manager is the only one accountable for a program’s success or failure. But it is fantastic when you are able to bring everyone together to focus on ensuring success of the mission.”

Castro, who is the son of Cuban immigrants and whose father served in the Cuban army, enlisted in the Army in the early 1990s. “The only thing I’ve ever wanted to do is be a Soldier. My parents came to the United States as young adults and always reminded my siblings and me how blessed we were to be



Americans. I grew up believing in the American dream and fell in love with what I saw as the protector of that dream: the American Soldier.” He left active duty to attend college through a Green to Gold Scholarship and was commissioned in 1998 as an armor officer.

During a deployment to Iraq in 2007, Castro explained, “a lieutenant colonel came to field a new system for us. He and his staff came from out of nowhere, it seemed, and provided us this gift of a new capability, and they took notes as we told them what worked and what didn’t—it was fantastic. At that time, I was starting to plan for the next phase of my career, and I knew that I liked being a Soldier and taking care of Soldiers. The next major step for me in combat arms was battalion commander, and I knew what that position was like. But acquisition seemed limitless. There are so many different programs to manage.”

His first acquisition assignment was assistant product manager within the PEO for Soldier, where he served from late 2010 through November 2013. “It was a fantastic first assignment. It was so easy to be passionate about what we were doing because it was so easy to draw a direct line from what we were doing in the program office to how it affected Soldiers.” The assignment also provided him with a variety of experiences: managing multiple programs, including cold weather gear, fire-resistant clothing and tactical communications; a monthlong fill-in stint as a DA systems coordinator (DASC); and a year as the executive officer to the PEO.

Castro then served in the Pentagon as a legislative liaison in the Army’s Office of the Chief Legislative Liaison (OCLL), which is responsible for coordinating the Army’s congressional agenda. “The interaction between Congress and the Pentagon is very similar to the interactions within the defense acquisition enterprise,” he explained. “The success of the mission hinges on prioritizing your most important efforts and then aligning the resources and stakeholders to execute them. While some of the players are

different—and at times, the playing field may have a more narrowly tailored strategic focus—the playbook is essentially the same. It’s always about people: aligning their interests and motivations to achieve a desired outcome.”

During his OCLL assignment, he worked to help advance the Army’s legislative priorities, meeting with members of Congress and their staffs to discuss funding priorities and issues in congressional districts that might affect Army budgets. “At the OCLL, we did a lot of groundwork—meeting with staffers, gaining an understanding of congressional concerns and priorities and communicating them to senior leaders—so that those senior leaders could go into meetings with congressional leadership informed on what the key issues are and how they dovetail with what the Army is trying to accomplish. It’s all about building relationships. If you’re at your desk, you’re doing it wrong.”

Having served for two legislative cycles, in 2014 and 2015, Castro noted that the assignment yielded numerous dividends. “First, it allowed me to work within and understand the Army Staff and Secretariat, including the assistant secretary of the Army for acquisition, logistics and technology [ASA(ALT)]. Understanding the intricacies of how the Army and Pentagon work is essential for being successful in a PM [program manager] position. It enables you to understand and anticipate potential impacts to your program before they occur and to determine the best course of action in response.”

The OCLL assignment also included strategic planning and messaging, with attendance at strategy meetings where senior leaders discussed Army modernization issues, all of which helped Castro put into context the importance of the work being done at the program level. “Pentagon jobs provide such a layered understanding of how the acquisition enterprise works, and that understanding is invaluable later on,” he noted.

The position also gives Soldiers the chance to work in a strategic position at the Army enterprise level, a must for those who want to build potential for future assignments with increased responsibility, Castro said. “To learn how the Pentagon works, how the Army Staff functions on the Hill and how money works was something I got a glimpse of when I worked as a DASC, but that was just for a month. To have two years to build relationships, think strategically and work with PMs, the Army staffs, congressional committees and staffers and ASA(ALT) staff was a tremendous opportunity.”

“It’s too easy to get dismayed by the bureaucracy. Don’t let it discourage you. Our job is to get capability to the warfighter, despite the challenges.”



THE VIEW FROM THE HILL

Castro, fifth from the left in the back row, spent two years working on Capitol Hill as a legislative liaison in the OCLL. “Pentagon jobs provide such a layered understanding of how the acquisition enterprise works,” he said, including strategic planning, funding and the importance of building relationships. Working with Congress develops additional insight. (Photo courtesy of Lt. Col. Beire Castro)

Now that he’s a product manager, he uses that experience to help identify the issues that his boss communicates to the PEO and the issues that the PEO, in turn, communicates to senior leadership. “It’s working behind the scenes to learn nuances and positions and strategies to shape engagements that will make my senior leadership successful,” he said. “Working in the OCLL taught me the importance of thinking two or three moves ahead: What are the potential outcomes? Who else needs

to know? Who are the key stakeholders we’ll need to build a consensus?”

One of the challenges he faces in his current role is keeping track of all the layers—the numerous regulations, policies and laws that govern defense acquisition. “It takes years to develop an understanding of all of it, and I find that I learn something new every day,” he said. “But it’s too easy to get dismayed by the bureaucracy. Don’t let it discourage you. Our job is to get capability to the warfighter, despite the challenges.”

Any additional advice? “Do the best you can with the first job you have, wherever that is. Use that position to get as much experience in different aspects of program management or your particular career field. Talk to leaders you admire or those who are doing things you’d like to be doing. Ask them how they got there and ask them to share their experiences with you. Some may not be as open, but through that process you’ll find leaders who are willing to invest in your professional development.”

—MS. SUSAN L. FOLLETT

“I grew up believing in the American dream and fell in love with what I saw as the protector of that dream: the American Soldier.”



FROM THE DIRECTOR OF
ACQUISITION CAREER MANAGEMENT
MR. CRAIG A. SPISAK



TOOLS *for* TALENT

There are many ways to motivate our Army Acquisition Workforce

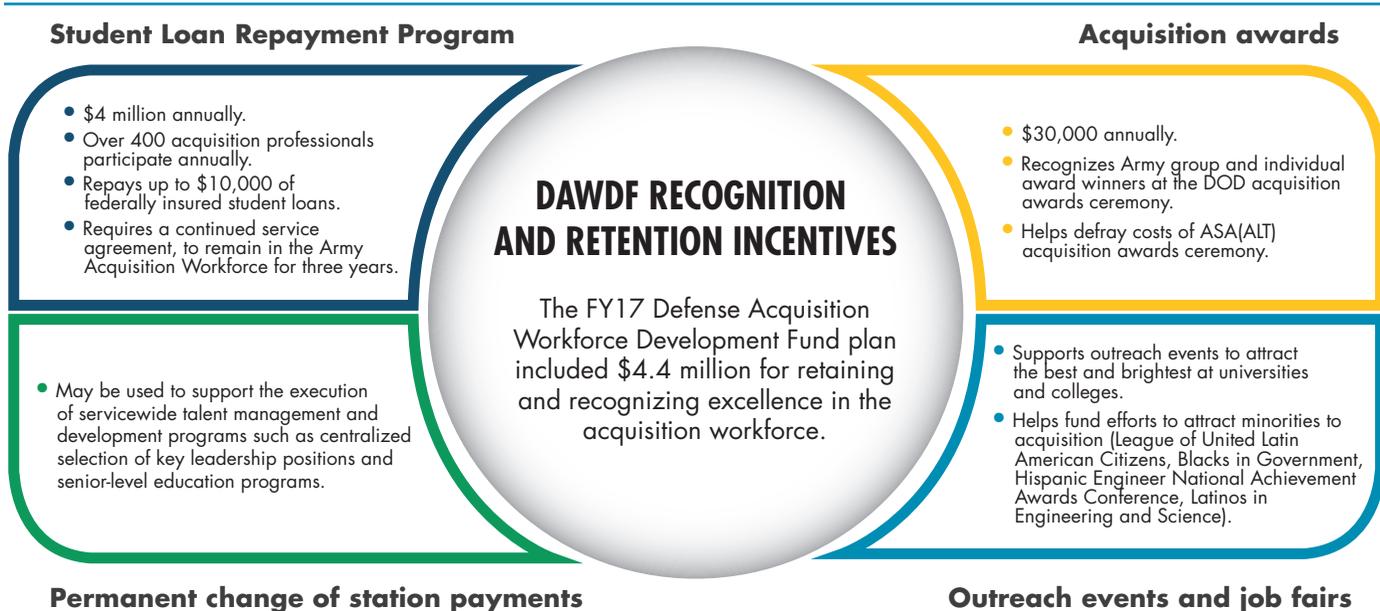
Recognizing people by taking the time to nominate them for an award is probably the strongest message you can send.

Our work as Army acquisition professionals involves everything from helicopters to radios, tanks to software, body armor to missiles, and so much more. But at the end of the day, it really is all about talent management: finding a way to put the right person in the right job at the right time. There are a number of tools that have long been available for what we call the three R's: recruiting, retention and relocation. We also have some relatively new tools, such as expedited hiring and direct-hire authority.

The new year provides a fresh opportunity to look at the tools we have for managing talent, particularly in recruiting and retaining it. It starts with having honest and frank conversations with people, reviewing their performance against their objectives from the past year. It's also about discussing their objectives leading into the coming year. And across the board, it's about finding ways to reward those who've succeeded as well as motivating the entire team, even those who have fallen short of expectations.

When it comes to competing for talent, we have to be creative in finding ways to not make more barriers than we already face. If the choice of employers is

FIGURE 1



EXCELLENCE PAYS DIVIDENDS

A mainstay of the incentives available to recruit and retain members of the Army Acquisition Workforce, DAWDF sustains the Student Loan Repayment Program—budgeted at \$4 million of \$4.4 million in FY17 money for DAWDF incentives—among other tools it funds to attract talent and encourage and reward excellence. (SOURCE: U.S. Army Director of Acquisition Career Management Office)

the government versus a big defense company, the odds are that industry can afford to pay somebody more than we can. And the odds are that industry can execute hiring, relocation and other things faster than we can. So we have to make sure that we don't put up unnecessary obstacles beyond existing regulations and policies.

We need to accentuate what we offer people that others can't: the value of being a public servant and of working for DOD; the type of work we do; the fact that people who come into this business get an opportunity early on to assume more authority and responsibility than they would in private industry. And that a lot of what we do is truly unique work that they can't do elsewhere. So use the authorities and the incentives that are in place—and don't get in your own way.

The Defense Acquisition Workforce Development Fund (DAWDF) provides some incentives we can offer our workforce. (See Figure 1.) A tremendous part of that is the Student

Loan Repayment Program. Over 90 percent of those who've been in the program remain in the workforce beyond their required three-year commitment. That's a remarkable success rate that we can all be proud of and point to when telling our story about why everyone should strive to join our team.

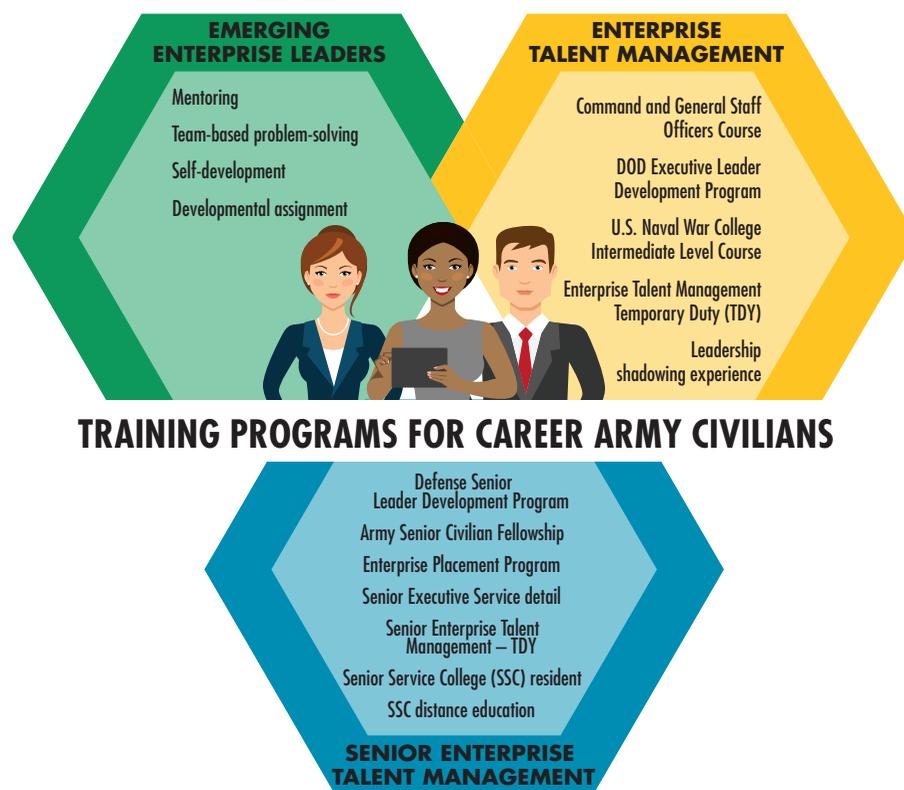
But recruitment and retention are not always about money. Quite often, people aren't looking for some great monetary reward. At the end of the day, one of our best tools for motivating that talent and garnering great performance from the workforce is really just a little bit of recognition.

It doesn't cost you anything more than time to give recognition. And it doesn't cost you more than time and effort to nominate people for awards given throughout the year: the Army Acquisition Executive's Excellence in Leadership Awards; the Secretary of the Army Excellence in Contracting Awards; and the David Packard Excellence in Acquisition Award from the Office of the Undersecretary of Defense for

FIGURE 2

MANY ROUTES TO ADVANCEMENT

Encouraging and nominating staff to attend training and development programs such as these is a small step that goes a long way in developing Army acquisition professionals who are engaged and effective. The skills they acquire through Senior Service College, leader development programs, mentoring and other development opportunities will put them on solid footing when competing for the next promotion. (SOURCE: Civilian Senior Leader Management Office, Office of the Assistant Secretary of the Army for Manpower and Reserve Affairs)



Acquisition, Technology and Logistics. Recognizing people by taking the time to nominate them for an award is probably the strongest message you can send. You've recognized their hard work, you've seen their successes, and you want to share those successes with our broader acquisition community.

Here's a challenge to supervisors, second-level supervisors, managers and leaders of organizations inside Army acquisition: Find ways to take care of your people. Use the tools that are there for particular classifications and job series, career fields and categories, most of which are available to almost every organization and member of the workforce. Nominate people for the awards mentioned above, among many others out there. Nominate them for training and development programs under Senior Enterprise Talent Management, Enterprise Talent Management and Emerging Enterprise Leaders, among numerous other growth opportunities. (See Figure 2.) If you do that, your people will be a step ahead of some of their peers when it comes time to compete for the next promotion.

Be creative and encourage creativity, when and where it makes sense, by offering incentives such as telework, alternate work schedules, compressed work schedules and flexible leave. Use programs like the Voluntary Early Retirement Authority and Voluntary Separation Incentive Pay.

Another way to retain your best talent? Give back with coaching and mentoring.

Take the time to personally engage your people so they understand that not only are they a valuable part of the team and well-appreciated, but they're also getting regular interaction with somebody who can show them what the future might hold and prepare them to continue on to a long and successful career.



ARE YOU RELEVANT?

DAWIA requires career-long education for AAW members; it's up to you to make the most of it.

*"Intellectual growth should commence at birth and cease only at death."
—Albert Einstein*

And if you're a member of the Army Acquisition Workforce (AAW), intellectual growth in the form of continuous learning is just as it sounds—continuous. When the Defense Acquisition Workforce Improvement Act (DAWIA) became law in 1990, it envisioned a professional acquisition workforce that not only was well-educated in the acquisition process, but also constantly upgraded that education.

The Continuous Learning Policy was enacted to make certain that, for members of the AAW, education is a career-long process. AAW members must acquire 80 continuous learning points (CLPs) every two-year period—two fiscal years. The current CLP period began Oct. 1, 2016, and ends Sept. 30, 2018.

The Army Director for Acquisition Career Management (DACM) Office suggests front-loading a "glide path" of

CLPs to avoid a rush at the end of the two years:

- 45 CLPs acquired during the first six months.
- Five more by the end of the first year (for a total of 50).
- 10 more at the 18-month mark (a total of 60).
- The final 20 to finish the two-year period at the required 80 points.

That's according to Scott Greene, chief of the Leader Development Branch of the Army DACM Office. "A lot of people wait until the last couple of months," he said. "We strongly suggest workforce members, in coordination with their supervisors, develop a training plan."

Points are awarded for academic and training courses, including courses required for DAWIA certification; professional activities related to acquisition, such as exams, licenses or certificates; teaching or lecturing;

making presentations at or attending symposiums or conferences; and writing for publications (such as Army AL&T). While there are guidelines for point credits, it's up to each supervisor to make the decision on point awards. Points can only be awarded for the fiscal year in which they were accomplished.

Selecting which CLPs to pursue should not be a random exercise, Greene said. "It shouldn't be about the amount you do; make it about the quality."

Remember, Greene said: You're your own best career manager. If you find a program you like, add it to your Individual Development Plan (IDP) and discuss it with your supervisor. (For more on IDPs, see "The Individual Development Plan," Army AL&T, July – September 2017, Page 101.) "Make it about something you want to do," he continued. "If you've already got your certification, continuous learning



RECOMMENDED CLPS

CREDITABLE ACTIVITIES	POINT CREDIT*
ACADEMIC COURSES	
Quarter-hour	10 points per quarter-hour
Semester hour	15 points per semester hour
Continuing education unit (CEU)	10 points per CEU
Equivalency exams	Same points as awarded for the course
TRAINING COURSES/MODULES	
DAU courses/module	10 points per CEU (see DAU catalog)
Awareness briefing – no testing or assessment associated	0.5 point per hour of instruction
Continuous learning modules – testing or assessment	1 point per hour of instruction
Other functional training	1 point per hour of instruction
Leadership or other training	1 point per hour of instruction
Equivalency exams	Same points as awarded for the course
PROFESSIONAL ACTIVITIES	
Professional exam, licensing or certificate	10 to 30 points
Teaching or lecturing	2 points per hour; maximum of 20 points per year
Symposium or conference presentation	2 points per hour; maximum of 20 points per year
Workshop participation	1 point per hour; maximum of 8 points per day and 20 points per year
Symposium or conference attendance	0.5 point per hour; maximum of 4 points per day and 20 points per year
Publications	10 to 40 points
EXPERIENTIAL/DEVELOPMENTAL LEARNING ACTIVITIES	
On-the-job experiential assignment	Maximum of 20 points per year
Rotational assignment	Maximum of 40 points per year
Training with Industry	Maximum of 40 points per year
Integrated product team (IPT) or special project leader	Maximum of 15 points per year
IPT or special project member	Maximum of 10 points per year
Mentor	Maximum of 5 points per year
*All activities may earn points only in the year accomplished, awarded or published.	

WAYS TO EARN

Take classes or rotate through a temporary posting to a different organization; attend or, better yet, present at a conference—the knowledge and experience these activities confer are reflected in the continuous learning points AAW members earn for participating in them. (SOURCE: Army DACM Office)

is about making sure you're still relevant. ... Make it relevant to your actual job.”

Multiple avenues to pay for training are available to the AAW: command training funds, career program money for civilians, central funding opportunities and the Defense Acquisition Workforce Development Fund.

It's up to each employee to keep track of CLPs, which is easy to do on the IDP, accessible through the Career Acquisition Personnel and Position Management Information System (CAPP MIS) portal at <https://rda.altess.army.mil/camp/>. CAPP MIS also contains all the information employees need to access training funds, Greene said. (A Common Access Card is needed to log in.)

Supervisors play a key role in continuous learning. They must provide adequate time for the continuous learning activities and help the employee plan and document their CLPs. A new dashboard feature on the January 2017 update to the IDP uses a “stoplight” color scheme to signal, among other things, the employee's CLP status. For CLPs that don't automatically enter into CAPP MIS, your supervisor can agree on the CLPs claimed, or decide that more or fewer CLPs are merited.

The Army DACM Office tracks CLP compliance at the organizational level, not for individuals. Supervisors, acquisition career management advocates and organizational acquisition points of contact receive monthly email blasts on their organization's compliance level.

For more information, go to <http://asc.army.mil/web/dacm-office/>.

—MR. MICHAEL BOLD

ON THE

MOVE

OFFICE OF THE ASSISTANT SECRETARY OF THE ARMY FOR ACQUISITION, LOGISTICS AND TECHNOLOGY



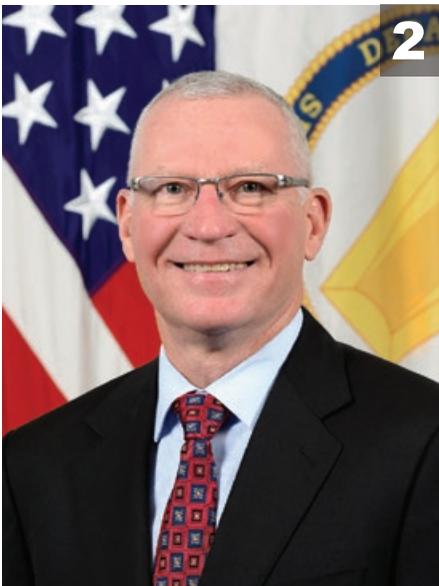
1: PRINCIPAL DEPUTY SELECTED

Jeffrey S. White was appointed Nov. 6 as principal deputy assistant secretary of the Army for acquisition, logistics and technology (ASA(ALT)) and has been named acting ASA(ALT). White, who was also appointed to the Senior Executive Service (SES), is a retired Army colonel who most recently was vice president of business development for Siemens Government Technologies Inc. (SGT). Previously he was SGT's vice president of federal energy, infrastructure and health care and vice president of Army programs.

White's appointment marks a return to Army civilian service. He was the assistant deputy undersecretary of the Army from October 2006 to October 2011, leading the Secretary's Task Force on Generating Force Efficiencies, managing the day-to-day execution of the Army's business transformation and deployment of Lean Six Sigma and leading the overhaul of Army strategic human capital programs, among other responsibilities.

As an Army officer from 1979 to 2006 with assignments in armor and aviation, White commanded units in the United States and Germany, including an aviation battalion and brigade. His staff assignments included the Army Staff and Joint Interagency Task Force South.

White holds an MBA from the University of Tennessee, an M.S. in strategic studies from the U.S. Army War College, an M.A. in national security and strategic studies from the U.S. Naval War College and a B.A. in psychology from Shippensburg State College. He is a member of the Army Aviation Association of America and a recipient of the Order of Saint Michael bronze and silver awards.



White replaced **Steffanie B. Easter**, who now serves as the senior official performing the duties of the principal deputy ASA(AL&T).

2: NEW LEADERSHIP FOR DASA(P)

Stuart A. Hazlett has been named deputy assistant secretary of the Army for procurement (DASA(P)), following nearly six years as director of contracts for the U.S. Army Corps of Engineers (USACE). Before coming to USACE, he served as deputy director of program acquisition and strategic sourcing for Defense Procurement and Acquisition Policy. A member of the SES since 2007, he has also held several positions with the U.S. Air Force, including chief of procurement transformation in the Office of the Deputy Assistant Secretary for Contracting and chief of the Contracting Division at Headquarters, Air Force Materiel Command, Wright-Patterson Air Force Base, Ohio.

Hazlett holds an M.S. in resource strategy from National Defense University's Industrial College of the Armed Forces (ICAF), an M.S. in general administration from Central Michigan University and a B.A. in business management and administration from Ohio Northern University. He completed the Senior Acquisition Course at National Defense University, the Defense Leadership and Management Program and the Federal Executive Institute's Leadership for a Democratic Society program, and is Level III certified in contracting and in acquisition. He is a member of the National Contract Management Association and the Society of American Military Engineers.

Hazlett, whose appointment was announced Oct. 13 by then-acting ASA(ALT) **Steffanie B. Easter**, succeeded acting DASA(P) **Brig. Gen. Michael D. Hoskin**, who resumed his duties as the director for contracting in the Office of the ASA(ALT).



3: ACTING DASA(APL) NAMED

Timothy G. Goddette has been named acting deputy assistant secretary of the Army for acquisition policy and logistics, succeeding **Christopher J. Lowman**, the new director of sustainment for the Combined Security Transition Command – Afghanistan. Goddette moves to the temporary assignment from his permanent position as deputy program executive officer for Soldier at Fort Belvoir, Virginia.

Then-acting ASA(ALT) **Steffanie B. Easter**, in announcing Goddette's appointment Oct. 13, noted that the temporary post is a homecoming of sorts for him. Previously Goddette was director of sustainment systems and simulation in the Office of the ASA(ALT) and a DA system coordinator in the Office of the Assistant Secretary of the Army for Research, Development and Acquisition, the precursor to the ASA(ALT). He was selected to the SES in 2013. Goddette is Level III certified in program management and a member of the Army Acquisition Corps.

Goddette holds an M.S. in industrial engineering from the Georgia Institute of Technology, a master's degree in national security and resource management from ICAF and a B.S. in engineering from the University of Vermont.

4: SPISAK NAMED ARMY DACM

Craig A. Spisak has been named Army director of acquisition career management (DACM). Spisak, whose new position was

announced Oct. 20, has been director of the U.S. Army Acquisition Support Center (USAASC) and the deputy DACM since June 2005. He joined USAASC as deputy director in June 2002 and served in various positions in proponentcy, future planning and force structure.

Spisak became an Army civilian in 1997, serving in the Office of the ASA(ALT), formerly the Office of the Assistant Secretary of the Army for Research, Development and Acquisition. His other Army assignments include engineering positions and associated responsibilities in the DOD Project Management Office for Mobile Electric Power and at the Fort Belvoir Research, Development and Engineering Center.

Spisak holds a master's degree in military national resource strategy and policy from ICAF, an M.S. in systems, safety and information science from the University of Southern California and a B.S. with honors in mechanical engineering from The George Washington University. He is a Competitive Development Group program graduate and has completed the Advanced Program Manager's Course at Defense Acquisition University, the Senior Acquisition Course at ICAF and the Leadership for a Democratic Society program at the Federal Executive Institute.

He is a member of the Army Acquisition Corps and is Level III certified in program

management and in engineering. He is Level II certified in test and evaluation and in production, quality and manufacturing. Spisak is a member of Tau Beta Pi, the national engineering honor society; Pi Tau Sigma, the mechanical engineering honor society; and the American Society of Mechanical Engineers.

5: DASA(R&T) WELCOMES NEW DIRECTOR FOR BASIC RESEARCH

Jeffrey Singleton, director for technology in the Office of the Deputy Assistant Secretary of the Army for Research and Technology (ODASA(R&T)), welcomed **Dr. Kimberly A. Sablon** as the new director for the Basic Research Portfolio on Dec. 12. Sablon came from the U.S. Army Research Laboratory (ARL), where she has served as principal investigator and program manager of several energy harvesting and sensing research projects. Sablon becomes one of 11 directors in the ODASA(R&T): six for specific capability portfolios and five for overarching areas of science and technology management. All report to the director for technology.

Sablon has served as the ARL liaison to the DASA(R&T) since October 2016, during which time she developed science and technology strategies for basic and applied research programs; organized workshops to stimulate new ideas and cross-command collaborations; served as technical adviser for the Army's quantum information science program; and helped shape the program objective

memorandum. **Dr. Troy Alexander**, who has been overseeing the Basic Research Portfolio in an acting capacity, is now the ARL liaison.

Sablon received a Ph.D. in microelectronics and photonics with a focus on solid-state physics as well as an M.S. in microelectronics and photonics from the University of Arkansas, and a B.S. in chemistry and physics from University of the Virgin Islands. (Photo by Neal Ahmad, ODASA(R&T))

U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

1: NEW LEADERSHIP FOR CERDEC

Patrick J. O’Neill was named director of the U.S. Army Communications-Electronics Research, Development and Engineering Center (CERDEC), filling a vacancy created by the March 2017 retirement of **Henry J. Muller Jr.** In the interim, **Gary Blohm** and **Dr. Donald A. Reago Jr.** served as acting directors.

O’Neill comes to CERDEC from Redstone Arsenal, Alabama, where he served as chief technology officer (CTO) for the U.S. Army Materiel Command (AMC). He brings more than 30 years of DOD experience to this position. “I am pleased to have him filling such a key role within our command,” said **Maj. Gen. Cedric T. Wins**, commanding general (CG) of the U.S. Army Research, Development and Engineering Command (RDECOM), CERDEC’s higher headquarters.

“I am excited to lead CERDEC and this team of scientists, engineers and technical experts who are the foundation of our Army’s communications and electronics [research and development] enterprise,” said O’Neill, who began his new job in November. “They are key to enabling the Army’s ability to execute multidomain battle.”

O’Neill, who was appointed to the Senior Executive Service (SES) in 2011, assumed the duties of AMC CTO in 2014. Before that, he served in various leadership positions across the U.S. Army Materiel Systems

Analysis Activity within AMC. O’Neill, who has published numerous papers in national and international operations research and military forums, has been recognized for his service with the Meritorious Civilian Service Award (twice), the Dr. Wilbur B. Payne Memorial Award for Excellence in Analysis and multiple AMC systems analysis awards.

He holds an M.S. in national resource strategy from the National Defense University’s Industrial College of the Armed Forces and an M.S. in computer science from Johns Hopkins University, as well as a B.S. in mathematics and computer science from Loyola University. He is Level III certified in engineering and in test and evaluation and a member of the Army Acquisition Corps (AAC).

2: RETIREMENT BRINGS NEW CSM TO RDECOM

Command Sgt. Maj. James P. Snyder, left, departing command sergeant major (CSM) of RDECOM, returned the RDECOM flag to **CG Maj. Gen. Cedric T. Wins** during a change of responsibility ceremony Aug. 25 at Aberdeen Proving Ground (APG), Maryland, marking Snyder’s retirement after 27 years of active duty. Snyder, who received the bronze and silver medals for the Order of Saint Michael, had served as CSM since March 2015 after serving as CSM of the 3rd Combat Aviation Brigade, 3rd Infantry Division.

Succeeding Snyder is **Command Sgt. Maj. Frank Gutierrez**, who has served in the Army for 27 years. He was CSM for the 5th Signal Command in Wiesbaden, Germany, before coming to RDECOM. He began his Army service with the 82nd Airborne Division and has served in the U.S. Army Special Operations Command and U.S. Army Training and Doctrine Command. (U.S. Army photo by Tom Faulkner, RDECOM)

3: NEW EXECUTIVE DEPUTY

John Willison has been named executive deputy to the CG of RDECOM. Willison, who served as acting executive deputy from May to August 2017, has the responsibility to lead organizational efforts in





support of RDECOM's campaign plan and provide oversight on the command's four major lines of effort: command efficiencies; fiscal, human, infrastructure and intellectual resources; research, development and engineering integration; and strategic communications.

A member of the SES since 2011, Willison previously served as director of CERDEC's Space and Terrestrial Communications Directorate at APG and as technical director for the Project Manager for Battle Command within the Program Executive Office for Command, Control and Communications – Tactical.

Willison has an M.S. in software engineering from Monmouth College and a B.S. in electrical engineering from Lafayette College. He trained as a Senior Executive Fellow at the John F. Kennedy School of Government at Harvard University, completed the Executive Coaching for Organizational Well-Being program at George Mason University and is a certified professional coach. He is Level III certified in systems engineering and a member of the AAC.

U.S. ARMY CONTRACTING COMMAND

4: ECC CASES COLORS, REASSIGNS STAFF

Brig. Gen. Paul H. Pardew, left, former commanding general (CG) of the U.S. Army Expeditionary Contracting Command (ECC), and **Command Sgt. Maj. Gerald Wright**, former ECC command sergeant major, cased the ECC colors during a ceremony Oct. 19 at Redstone Arsenal, Alabama.

ECC, which came under U.S. Army Contracting Command (ACC), was discontinued Oct. 1. Pardew now serves as ACC deputy commanding general for OCONUS Operations. In that role, he oversees planning and execution of ACC contracting support for Army service component commanders in support of Army and joint operations outside the continental United States.

ECC's staff was integrated into ACC, and its contracting support brigades report directly to ACC. The merger creates a single, more efficient headquarters, designed to improve ACC's ability to organize, train and equip

its forces and strengthen overseas contracting operations. ACC, a subordinate command of the U.S. Army Materiel Command, awarded and managed nearly 165,000 contract actions valued at more than \$62 billion in FY17. (U.S. Army photo by Lt. Col. David Hylton, ACC Public Affairs)

5: MICC COMMANDER PROMOTED

Brig. Gen. William M. Boruff, CG of the U.S. Army Mission and Installation Contracting Command (MICC), was promoted from colonel effective Nov. 2. Boruff took command of MICC, a subordinate command of ACC, in July 2017. A member of the Army Acquisition Corps since 1995, he holds an M.S. in acquisition and contract management from the Florida Institute of Technology and an M.S. in strategic studies from the U.S. Army War College. In addition to numerous command and staff positions, Boruff has deployed to Iraq and Afghanistan in support of Operation Iraqi Freedom and Operation Freedom's Sentinel.

6: NEW CSM FOR MICC

Command Sgt. Maj. Marco A. Torres, left, received the MICC colors from then-**Col. William M. Boruff** during an assumption of responsibility ceremony Aug. 23 at Joint Base San Antonio-Fort Sam Houston, Texas. Torres, MICC's fifth command sergeant major (CSM), comes to the organization from Fort Hood, Texas, where he served as CSM of the 13th Expeditionary Sustainment Command. He has held a variety of leadership positions, and his operational assignments include deployments to Kuwait, Iraq and Afghanistan.

"I'm humbled and honored at the incredible opportunity to lead the Soldiers and civilians of this amazing organization," he said. "The Army chief of staff's top priority is readiness, and my No. 1 priority is to ensure that our Soldiers and civilians are completely trained and ready when our nation calls upon us." (U.S. Army photo by Daniel P. Elkins, MICC)

7: MICC DEPUTY APPOINTED TO SES

Wade C. "Clay" Cole, deputy to the CG for MICC, was appointed to the Senior Executive Service on Sept. 3. Before joining MICC headquarters, Cole served as deputy to the commander of the 418th Contracting Support Brigade. He has also served as director of the MICC Field



Directorate Office at Fort Hood and director of MICC at Fort Belvoir, Virginia. Cole holds an M.S. in strategic studies from the U.S. Army War College, an MBA from Texas Tech University and a B.S. in political science from Columbus State University. He is Level III certified in contracting and Level II certified in program management.

PEO FOR AMMUNITION

1: NEW PRODUCT MANAGER FOR GLMR

Lt. Col. Phillip Poteet, left, incoming product manager for Gator Landmine Replacement, accepted the ceremonial guidon from **Col. Jonathan Slater**, project manager for Close Combat Systems within the Program Executive Office (PEO) for Ammunition, during a change of charter ceremony Sept. 7 at Pica-tinny Arsenal, New Jersey. Poteet takes over from **Lt. Col. O’Neal Williams**. (U.S. Army photo by Todd Mozes, PEO Ammunition)

PEO FOR COMBAT SUPPORT AND COMBAT SERVICE SUPPORT

2: RETIREMENTS MARK A CENTURY OF SERVICE

Scott Davis, program executive officer for Combat Support and Combat Service Support (CS&CSS), hosted a retirement ceremony Sept. 21 at Warren, Michigan, for three key staff members—**Dorine Miller**, left, **Sharon Elya**, right, and **Cindy Weber**—whose combined federal service totaled 106 years.

Elya, who served as executive assistant for PEO CS&CSS, retired with 37 years of service. She supported four program executive officers, navigating frequent changes in schedules and priorities with speed and attention to detail.

Miller finished her 37-year federal career as PEO C&CSS’ operations analyst. She facilitated support to more than 150 active acquisition programs, shepherding nearly 1,000 taskers, numerous audits and accident reports each year.

Weber retired after 32 years of service, seven of which she spent on the PEO staff as a military and civilian management analyst. She helped create a strong acquisition workforce excelling in Soldier support. (U.S. Army photo by John Otwell, PEO CS&CSS)

PEO FOR COMMAND, CONTROL AND COMMUNICATIONS – TACTICAL

3: NEW CHIEF OF STAFF AT C3T

Col. Michael Thurston has been named chief of staff for the Program Executive Office for Command, Control and Communications – Tactical (PEO C3T), succeeding **Col. William Sheehy**, who retired in July 2017.

Formerly the deputy to the deputy for acquisition and systems management in the Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology, Thurston assumed the new role in September. As chief of staff, he manages and coordinates the PEO

staff; plans and directs administrative, financial, technical and operational activities; provides analysis and advises PEO leadership; assists in the coordination and oversight of the project offices; and is the focal point for coordination with external organizations.

He previously served as project manager for Mission Command and Joint Battle Command – Platform within PEO C3T; assistant executive officer/G-6; product manager for PEO C3T’s Joint Tactical Radio Systems Ground Mobile Radios; U.S. Army Communications-Electronics Life Cycle Management Command trail boss for the 101st Airborne Division; and chief of the Concepts Branch for the U.S. Army Signal Center’s Directorate of Combat Developments.

Thurston holds an M.S. in national resource strategy from National Defense University’s Industrial College of the Armed Forces, and an M.S. and B.S. in electrical engineering from Worcester Polytechnic Institute. He has completed the Executive Program Management Course, U.S. Army Command and General Staff College, the Signal Officer Advanced and Basic courses and the Army Systems Automation Course.

4: REORGANIZATION AT PMO NET E

PEO C3T has combined its Product Lead for Communications Security and Cryptographic Systems and its Product Lead for Key Management into a single product office under the Project Management Office for Network



Enablers (PMO NET E). The new organization, the Product Lead for Communications Security (PL COMSEC), was established in July 2017 and will be headed by **Kevin Walsh**, who previously served as product lead for Key Management. PL COMSEC will develop, procure, test, field and sustain solutions that secure the Army's information infrastructure against cyber threats, increasing survivability and enabling mission command activities.

JOINT PEO FOR CHEMICAL AND BIOLOGICAL DEFENSE

5: NEW PROJECT MANAGER FOR GUARDIAN

Douglas Bryce, joint program executive officer for Chemical and Biological Defense, presented U.S. Air Force **Col. Anna M. Schneider**, incoming joint project manager for Guardian, with the organization's charter during a change of charter ceremony July 12 at Aberdeen Proving Ground, Maryland. Schneider takes over from Air Force **Col. Daniel Garber**. (Photo by Marc Lester, Joint Project Manager for Guardian)

PEO FOR ENTERPRISE INFORMATION SYSTEMS

6: PEO EIS STANDS UP NEW PROGRAM

Lt. Col. Toy Frasier accepted the charter of the Project Office for Army Enterprise Staff Management System (AESMS), a new program under the Program Executive Office for Enterprise Information Systems (PEO EIS), from **Thomas Neff**, project manager for Enterprise Systems, at a Nov. 3 ceremony at Fort Belvoir, Virginia. AESMS procures, develops, delivers and sustains staff management task tracking and correspondence solutions that enable collaboration and application hosting across the Army. (U.S. Army photo by Cavia Mead, PEO EIS)

7: CHANGE OF CHARTER AT I3C2

Brig. Gen.(P) Patrick W. Burden, center, program executive officer for EIS, presided over the change of charter ceremony for the Project Manager for Installation Information Infrastructure Communications and Capabilities (PM I3C2) Aug. 31 at Fort Belvoir. **Michael Padden**, who had served as the

project manager for I3C2 since June 2014, relinquished the charter to **Col. Chad Harris**, right. Padden will remain at PEO EIS as the assistant PEO for network integration. (U.S. Army photo by Racquel Lockett-Finch, PEO EIS)

8: INTERNATIONAL PROGRAMS MOVED, RENAMED

Andrew Strand, right, accepted the charter for PEO EIS' newest program office, Allied Information Technology (AIT), at an Oct. 4 ceremony at Fort Belvoir hosted by **Col. Chad Harris**, project manager for I3C2.

AIT, formerly known as the International Programs Division, supports the Army's security assistance mission by developing, delivering and sustaining nonstandard command, control, communications, computers and intelligence capabilities on behalf of foreign allies and partners, through the foreign military sales process and under various partner capacity-building programs, congressionally mandated funding initiatives and other security cooperation enterprise activities. (Photo by Racquel Lockett-Finch, PEO EIS)



USD(AT&L) ANNUAL ACQUISITION AWARDS

More than two dozen members of the defense acquisition workforce received 2017 Defense Acquisition Individual Achievement and Workforce Development Innovation Awards in a Pentagon ceremony Dec. 6. The awards are sponsored by the undersecretary of defense for acquisition, technology and logistics, **Ellen M. Lord**. The Army garnered two individual awards and one group honor; the recipients are highlighted below.

INDIVIDUAL ACHIEVEMENT AWARD WINNERS

Acquisition in an Expeditionary Environment
Gunnery Sgt. Tamalia C. Adams, I Marine Expeditionary Force

Auditing
Melissa Panarelli, Defense Contract Audit Agency

Contracting and Procurement
Gary V. Trimble, Naval Supply Systems Command

Cost Estimating
Dr. Wilson Rosa, Office of the Assistant Secretary of the Navy (Financial Management and Comptroller)

Earned Value Management
Lt. Col. Andrew R. Vrabec, U.S. Air Force Rapid Capabilities Office

Engineering
Daniel Carroll, U.S. Special Operations Command (USSOCOM)

Facilities Engineering
Valerie Clinkenbeard, U.S. Army Corps of Engineers

Financial Management
Jeffrey M. Martin, Program Executive Office (PEO) for Space, U.S. Air Force

Information Technology
Michael R. Cirillo, Marine Corps Systems Command

Life Cycle Logistics
George N. Graham Jr., USSOCOM

Production, Quality and Manufacturing
Capt. Charles M. Stuart, Naval Air Systems Command

Program Management
U.S. Marine Corps Lt. Col. Thomas A. Atkinson, USSOCOM

Requirements Management
Skip Hinman, Air Education and Training Command

Science and Technology Manager
Dr. Charles A. Bass Jr., Joint PEO for Chemical and Biological Defense

Services Acquisition
Ulises Cartaya, USSOCOM

Small Business
Lee R. Rosenberg, Missile Defense Agency

Test and Evaluation
Thomas Sachse, PEO for Submarines, U.S. Navy

WORKFORCE DEVELOPMENT INNOVATION AWARD WINNER – LARGE ORGANIZATION

Defense Contract Management Agency – Fort Lee, Virginia

WORKFORCE DEVELOPMENT INNOVATION AWARD WINNER – SMALL ORGANIZATION

U.S. Army Contracting Command – Orlando, Florida

OFFICE OF THE CHIEF OF STAFF, ARMY GENERAL OFFICER ANNOUNCEMENTS

The chief of staff, Army, announced the following officer assignments:

Maj. Gen. David G. Bassett, program executive officer (PEO) for Ground Combat Systems, Warren, Michigan, to PEO for Command, Control and Communications – Tactical, Aberdeen Proving Ground, Maryland.

Brig. Gen.(P) Brian P. Cummings, PEO for Soldier, Fort Belvoir, Virginia, to PEO for Ground Combat Systems.

Brig. Gen. Anthony W. Potts, deputy commanding general (CG), U.S. Army Research, Development and Engineering Command (RDECOM) and senior commander, Natick Soldier Systems Center, Natick, Massachusetts, to PEO for Soldier.

Col.(P) Vincent F. Malone II, deputy to the deputy assistant secretary of the Army for plans, programs and resources, Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology, Washington, D.C., to deputy CG, RDECOM; and senior commander, Natick Soldier Systems Center.

SES ANNOUNCEMENTS

The secretary of defense announced the following Senior Executive Service (SES) appointments and assignments:

Eric Chewning, for appointment to the SES and assignment as the deputy assistant secretary of defense for manufacturing and industrial base policy. Chewning was most recently a partner with McKinsey & Co., focusing on the aerospace and defense industry. He is an Army veteran and deployed in support of Operation Iraqi Freedom.

William J. Gillis, for appointment to the SES and assignment as the principal deputy assistant secretary of the Army for energy, installations and environment. Gillis most recently was a director at ScottMadden Inc., and has served as an Army officer.

Veronica B. Daigle, for appointment to the SES and assignment as the principal deputy assistant secretary of defense for readiness. Daigle most recently served as the senior adviser for national security in the Office of Management and Budget, and previously as director of the Force and Infrastructure Analysis Division in DOD's Office of Cost Assessment and Program Evaluation.



THEN & NOW 2007 & 2018

How many ROBOTS does IT TAKE?



Then: a veritable ‘petting zoo’ of 7,000 unique robots, each slightly different to operate and expensive to maintain. **Now:** the challenge of getting all the functions of those 7,000 on just three main robotic platforms.

It’s an arresting image: A dog—well, a “dog”—loose in the Sonoran Desert moves through a group of empty cars and trucks, sniffing around before halting and signaling to its handlers. Army personnel arrive on scene to dismantle the bomb identified by the “dog,” which is in fact a robot equipped with a powerful sensor that detects vapors or particles emanating from explosive devices.

It sounds novel even now, though robotic platforms have proliferated across the battlefield since 2005, when the test—described in a 2007 Army AL&T article—took place at Yuma Proving Ground, Arizona. The problem had particularly desperate urgency when casualties from improvised explosive devices (IEDs) were mounting in Iraq, where IEDs at that time killed 330 service members each month, on average. “We had to do this,” Dr. John A. Parmentola said in an Oct. 21, 2017, interview with Army AL&T magazine. “I saw enough pictures of Soldiers blown up.” Parmentola, then director for Army research and laboratory

management in the Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology, led the team that came up with the robotic explosive-sniffing dog and wrote about lessons learned from fielding it.

The problem persists today: how to keep Soldiers a safe distance from explosive devices and chemical hazards as they go out to find and remove them. And, as robots grow more capable, what other “dull, dirty and dangerous” tasks can they take over from Soldiers?

Parmentola led an early attempt, a quick-fielding project—two years from napkin sketch to 120 units in the field—that put an explosive-sniffing sensor (“Fido”) on robotic legs (called Fido/PackBot). Previously, explosive-detecting sensors were affixed to a handheld wand or device, putting Soldiers too close to the hazards they were looking for. Deploying Fido on a robotic platform kept them out of the way.



LEFT OF THE BOOM

The TALON, shown in use in Tikrit, Iraq, in 2005, was among the first systems that allowed Soldiers to disarm IEDs from a distance, using a remote controller in the EOD vehicle. In an effort to standardize its robotic platforms and reduce its operational footprint, the Army plans to replace the TALON with MTRS, a 164-pound tracked vehicle that can identify and clear land mines, IEDs and CBRN hazards. (Photo courtesy of 22nd Mobile Public Affairs Detachment)

ROBOTS FAR AND WIDE

The first ground robot in wide use, PackBot had been in Afghanistan since 2002. Made by iRobot Corp., it had just a camera and an extendable arm, mounted on a base with two tracked wheels. It could peer around corners and into caves.

By 2007, when the Fido sensor was added to some models, PackBot weighed 42 pounds, could cover 5.8 miles per hour and could flip itself over and keep rolling; some versions could climb stairs. Fido/PackBot could range about 1,000 feet from its operational control unit (that is, the joystick Soldiers used to direct the robot's movements). It could retract the appendages on which its sensors were mounted, to creep underneath vehicles. It could also stand on its tracked base to add another foot of extension to its six-foot robotic arm, to peer inside the cab of a truck or the trunk of a car.

PackBot wasn't alone on the battlefield—indeed, the Army fielded a “petting zoo of various ground robots,” to borrow reporter Jen Judson's phrase from an April 12, 2017, Defense News article. QinetiQ North America's Dragon Runner robots and QinetiQ unit Foster-Miller's TALON platforms—among other robots, acquired as needs arose—rolled ahead of explosive ordnance disposal (EOD)

Soldiers on route clearance missions and stood checkpoint duty.

Their descendants can roam farther, do more and, crucially, will be fewer in type: The Army plans to replace much of its collection of unmanned ground vehicles with just three main robotic platforms: small, medium and large. This is important not only because it's cheaper and easier to maintain fewer multipurpose robots. A Soldier in one unit might become familiar with a particular variant of a small Dragon Runner ground robot—which buttons to push on the controller, how much ground clutter the robot can navigate through. But when he transfers to another unit, which might be using a TALON robotic platform, he has to learn to operate the new platform from scratch.

Consolidating to just three robotic platforms prevents this waste of knowledge. A common chassis and operating system could be configured to carry different tools for different missions, while keeping the basics similar enough that Soldiers don't need to relearn a new system to operate it.

“The Army purchased more than 7,000 unique robotic systems” during the last decade-plus, said Bryan McVeigh, the

Army's project manager for Force Projection within the Program Executive Office for Combat Support and Combat Service Support (PEO CS&CSS), in announcing the Oct. 2, 2017, award of a contract to build the medium-size robot. “That gave Soldiers the capabilities they needed, and it was the right thing to do for the mission. But we bought unique systems that weren't very flexible. The robots often had just one capability [and] used expensive, proprietary software.”

A MORE CLOSE-KNIT FAMILY

Soldiers and engineers at PEO CS&CSS have been sorting through this collection of robots to streamline it.

The medium-size Man-Transportable Robotic System (MTRS) is the furthest along in the trek to the field, and replaces the TALON family of robots. The 164-pound tracked vehicle is operated using a handheld remote controller. Depending on what kind of equipment the base is fitted with, it can identify and clear land mines, IEDs and unexploded ordnance, or chemical, biological, radiation and nuclear (CBRN) hazards. PEO CS&CSS awarded a \$100 million contract (with an option for an additional \$58 million worth of work) to Endeavor Robotics of Chelmsford, Massachusetts, and expects to begin producing MTRS Increment II



for engineer, CBRN and EOD units in FY19.

Part of the MTRS robot's inner workings is the Army's Unmanned Ground Vehicle Interoperability Profile. Akin to the operating system on a smartphone, it is an architecture that governs how the various parts of the robot communicate with one another and how the robot communicates with external command-and-control systems. In the same way that a new app can be downloaded to a smartphone, the interoperability profile makes it possible to apply new payloads or functional tools to the robot.

The profile is also an open system; because the government owns the standards, rather than any one company, it should be easier for Army robots to change and adapt with technology, rather than the Army needing to buy a whole new platform when robotics technology inevitably advances. Should the software that processes the images a robot captures improve, old software can be swapped out and new software uploaded, so Soldiers can take advantage of the better version sooner.

The Common Robotic System (Individual) and (Heavy) round out the planned trio of interoperable robotic platforms; they also will run with the Unmanned Ground Vehicle Interoperability Profile. The individual model will top out at 25 pounds; it is designed so that a Soldier can transport it in a pack and fit it for different missions while in the field. Theoretically, this robot could perform reconnaissance one day, then be reconfigured at the post for an EOD mission the next day. The heavy model, though still in the early stages of acquisition, could reach 1,000 pounds; the ability to disarm vehicle-borne IEDs is one desired capability, which requires a robot of significant size.

DOD is exploring the use of robots in almost every facet of military operations; the Army's near-term priorities are to increase situational awareness and lighten the Soldier's physical and mental load, according to the Army's Robotic and Autonomous Systems Strategy. Based on his experience, Parmentola cautions that solving those specific problems must remain the focus, despite the allure of the high concept and the cutting edge. "I looked at the technology first, and that

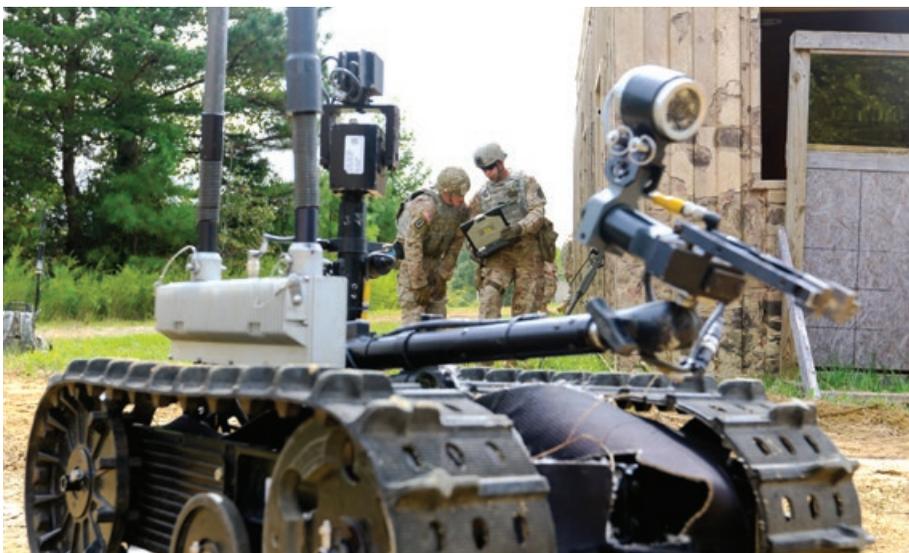
told me something. But I had to go to Fort Leonard Wood [in Missouri] to find out if the technology was really relevant." Soldiers there had identified a need for what the technology could do.

Parmentola continued: "What always matters is: What is the problem you're trying to solve? We were trying to solve a specific problem: how to keep Soldiers out of harm's way while looking for suspicious objects. Define the problem carefully and try to work backward from that, taking into account the operational issues. Most of the time in the Pentagon, I found that people spent the least amount of time defining the problem they're trying to solve."

For more information on the Army's planned portfolio of unmanned ground vehicles, go to <http://www.peocscs.army.mil/pdmugu.html>.

For a historical tour of Army AL&T over the past 56 years, go the Army AL&T magazine archives at <http://asc.army.mil/web/magazine/alt-magazine-archival/>.

—MS. MARY KATE AYLWARD



COME THIS WAY

Sgt. 1st Class Joshua Tygret, left, and Sgt. Austin Murphy, assigned to 744th Ordnance Disposal Company, 52nd Explosive Ordnance Group, navigate the TALON during the EOD Team of the Year competition in September 2017 at Fort A.P. Hill, Virginia. The weeklong competition, one of three sponsored by the U.S. Army Ordnance Corps, recognizes exceptional expertise among EOD Soldiers and provides senior leaders the opportunity to assess ammunition, maintenance and EOD professionals across the institutional Army and the operational force. (U.S. Army photo by Staff Sgt. Lance Pounds, 71st Ordnance Group (EOD) Public Affairs)

THE ORIGIN STORY

In 2005, I was attending a meeting at TARDEC [the U.S. Army Tank Automotive Research, Development and Engineering Center] where TARDEC personnel demonstrated ODIS, a low-profile robotic system. About a month earlier, I had visited the Army[-established] Institute for Soldier Nanotechnologies [at the Massachusetts Institute of Technology] to discover they had taken the Defense Advanced Research Projects Agency's Dog's Nose Program to an operational device, Fido. At the time, it was the world's most sensitive explosive detector.

Because ODIS had a mast that retracted into the robot, a NASA technology, I began to think of putting Fido on the mast and using it to remotely sniff inside a vehicle for explosives, rather than having a Soldier exposed to an IED. The idea began to come together where we could put Fido and a state-of-the-art camera on a robotic system, so if a Soldier had a wearable vest with a display, the Soldier could see what the robot was seeing, and at the same time see an indicator showing whether an explosive is present. [It also had] a joystick used to maneuver the robot to a position where it could sniff something suspicious. The world's first robotic dog that could see and sniff and could be remotely controlled—that was the concept.

BUT DOES SOMEONE NEED IT?

So then I needed to find a mission needs statement, where an Army school identified a need for this. It turned out that Fort Leonard Wood was the place where a need existed. George Anderson was a civilian working there. I connected with him, and he managed to find a mission needs statement calling for a platform that could inspect underneath a vehicle. I asked the proponents of the mission needs statement: "If we gave you much more than that, would you be happy?" They said they would.

If it weren't for George Anderson, we wouldn't have succeeded: He had to make a case for this solution with a culture that opposed using robotic systems.

He demonstrated the kind of courage and persistence you need to accomplish something like this. We assembled the most dedicated, capable team of people I've ever worked with, to work on all aspects of this.

However, we had to do some homework: What specific platform would we use? We needed something low-profile that could go under a vehicle. TARDEC's ODIS was one, iRobot had PackBot [and] Foster-Miller had a candidate robotic platform. I called a meeting among all of those in the Pentagon that touched on this issue: the OSD [Office of the Secretary of Defense] Robotics Office, TSWG [the Technical Support Working Group], Night Vision Laboratory, the Joint Robotics Office at Redstone Arsenal, TARDEC, Army Research Laboratory, etc. I told them we were going to do the fastest acquisition in history. Urgency was the motivation. We wanted to get something out that would save Soldier lives.

We didn't follow a standard acquisition process. We created a single sheet of paper that had the selection criteria on it: low profile, ability to have an articulated arm, to reach high up (at least 6 feet), technical readiness level, etc., and also pan and tilt to look inside the cab or the trunk of a suspect vehicle. I arranged for three contractors to come in to HQ. Each one had half an hour to make a presentation on how they could fulfill the requirements. In two hours we did source selection. PackBot was the best choice, according to the team vote, and the most mature of all the technologies. There were cheaper platforms, but they weren't operationally proven; PackBot was. That led to Fido/PackBot.

Then we had to estimate what it would cost to put together and how long it would take to complete the prototype. As Army director for research and laboratory management, I knew my labs well, and I knew Redstone and AMRDEC [the U.S. Air and Missile Research, Development and Engineering Center] had a well-established prototype integration facility. I contacted a very capable guy there

by the name of Bill Schultz and said, "I want to prove to people that something like this can be done in record time." I wanted to produce a full prototype, test it and have training manuals in 90 days. I told Bill to analyze this, talk to contractors, convince himself and then convince me and the people in my office that this could be done: "If there's too much risk, we'll change the schedule, but I want you to spend some time thinking about it. A week later he said, "I firmly believe we can do this."

Starting from the day we received funding, we managed to pull this whole thing off in 90 days. That was a record; I'll bet it still stands.

FEEDBACK UNDER FIRE

Five units were fully tested. We shipped four to Camp Victory in Iraq and kept one in the U.S. for troubleshooting. Soldiers started to experiment. There was a Marine, Col. Ed Ward, whose dedication to this project was phenomenal. He went into theater around Thanksgiving. He was in a vehicle taking a unit for testing to Abu Ghraib prison and he was sending me emails: "We're under fire."

Feedback from in theater was generally positive in terms of ease of use and effectiveness. JIEDDO [the Joint Improvised Explosive Device Defeat Organization] decided, based on that, to procure 120 units. Over 200 were eventually procured, I believe. In my home I have a plaque with a part of one of them that was blown up by an IED, saving a Soldier's life. It's the most precious and memorable thing I own.

—DR. JOHN A. PARMENTOLA,
as told to Army AL&T

This interview excerpt has been lightly edited for clarity and length. The U.S. Army Materiel Command named Fido/PackBot—officially called the Integrated Robotic Explosive Detection System—one of the 10 best inventions of 2006. Find out more at https://www.army.mil/article/3629/army_recognizes_greatest_inventions_for_2006.

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“We need to take a cue from industry. They’re proving every day that when you integrate technologies—the tablet, the computer, the TV, the cloud, etc.—you give the end user capabilities beyond what each technology can offer.”

Maj. Gen. Cedric T. Wins
*Commanding General,
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