

# National DEFENSE

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SPECIAL  
REPORT

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# Energetics

## Community Warns of China's Edge Developing Explosive Materials

BY SEAN CARBERRY

**WEST LAFAYETTE, Indiana** — Should a conflict break out tomorrow in the South China Sea

over Taiwan, the U.S. military could be at a tactical disadvantage, experts said, because of China's advances in the use of energetic materials — the chemicals used as propellants, pyrotechnics and explosives.

“Modern combat capability is a function of range, speed, terminal effects, signature management and safety, and it's fundamentally born from energetics,” Ashley Johnson, technical director of the Naval Surface Warfare Center Indian Head Division, said at the 2022 Breakthrough Energetics Conference held at Purdue University recently. The event was organized by the National Defense Industrial Association's Emerging Technologies Institute.

“We built up a huge lead [in energetics] coming out of World War II into the Cold War, and the dogged fight with a determined and capable adversary honed our capability set to a very high level,” he added. “Then we were forced to deal with [the global war on terrorism],” which Johnson said required different tactics and systems that did not rely on advances in energetics.

“It has been a bear market in energetics and munitions for well on 30 years, and urgency is now high based upon the threats,” he said. “Our diminished capacities and

capabilities, knowledge, skills, abilities and infrastructure are becoming more and more exposed.”

China and other adversaries are developing weapons using more powerful chemicals. Such energetic materials can propel warheads longer distances or allow ships and planes to carry more munitions because they can be made smaller and lighter yet still pack the same explosive punch, experts at the conference said.

“There are few things that I've come across in my studies and wargaming on future warfare and future force development that have as significant a potential impact on operational success as that of energetic materials,” said Tim Barrick, director of wargaming in the Marine Corps University's Krulak Center for Innovation and Future Warfare. “Regaining advantage in energetic materials must be a strategic imperative for the United States,” he added.

The conference was an outcome of a congressionally mandated study released in June 2021 by the Energetics Technology Center, a co-sponsor of the event.

“Energetics and Lethality: The Imperative to Reshape the U.S. Military Kill Chain,” found that energetics development has stagnated in part because the Defense Department has not made a priority of increased explosive power, greater range, smaller form factor or other characteristics.

Hence, the U.S. military has continued to rely on the same critical

chemicals it has since the 1940s: RDX and HMX, developed 120 and 70 years ago respectively.

“RDX and HMX together represent the last significant innovations in [energetic materials] to have found widespread use in U.S. systems,” according to the ETC study.

The report noted that researchers at the Naval Surface Weapons Center at China Lake, California, developed a far more powerful material in the 1980s. “The explosive and propellant properties of CL-20 exceed those of RDX and HMX by significant margins,” the report stated.

But CL-20 is not used by the U.S. military today.

John Fischer, lead scientist at the Energetics Technology Center, said he left the energetics field in 1989 because every goal that was laid out for the energetic materials community was not only met, it was exceeded by CL-20.

However, “we could not get it across the finish line,” he said.

The collapse of the Soviet Union reduced the urgency for more powerful explosives, the cost of testing and fielding the new material was high and since there was no requirement, the acquisition community had no interest in CL-20, despite it being 40 percent more powerful than HMX explosives in some applications, Fischer said.

China experimented with it and has incorporated CL-20 into weapons systems. Yet, the Defense Department has not heard the alarm, according to participants at the conference.

“The requirements aren't being passed down,” said Teresa Mayer, one of the authors of the study and executive vice president for research and partnerships at Purdue.

“As we think about the research-and-development and the [science-and-technology], that ability to transition has been greatly limited because if you don't have performance drivers that are prioritized above and beyond risk-to-schedule and cost, then we can be doing great science-and-technology, but we're trying to push rather than pull.”

In contrast, she noted, there is commercial and Defense Department demand for advanced microelectronics. That demand pulls innovation from the research community and transitions new technologies across the “valley of death” that currently consumes innovations in energetics, she said.

“There’s no one place that we can just go put money to fix this,” said Mike Holthe, director of the platforms and weapons technologies office in the Office of the Undersecretary of Defense for Research and Engineering.

“We can’t just take money and put it in the [science-and-technology] land and go out and develop new whizbang, great awesome energetics — which we’ve been doing for decades,” he continued. “We have to fundamentally rethink how we approach energetics and how we approach our munitions enterprise” to invigorate the industrial base and inform requirements.

If advanced energetic materials — or the effects those materials deliver — are not baked into requirements, acquisition officials aren’t going to take risks on new materials.

“The operators have to identify what requirements they actually have from an operational perspective,” said Tom Russell, president of Defense Science and Technology Consultants, and former deputy assistant secretary of the Army.

“Right now, the challenge on that [requirement development] is done at the system level, and energetics are a commodity within the system, so you sort of have to devolve a requirement out of that,” he said.

And operators, the people who drive the development of requirements, were absent from the conference, he noted.

“So, it tells me there is a disconnect in the community and that we’re not getting the message to them, and they’re not actually understanding the importance of our message to determine whether this could help them change their requirements ... to improve the capabilities,” Russell added.

Part of the problem is how the message is being conveyed, said one Defense Department official.

“Most people in the Pentagon can’t spell energetics,” said Christopher O’Donnell, deputy assistant secretary for platform and weapon portfolio management.

“[We] can barely get people interested in munitions ... and as we can see what’s going on in Ukraine ... munitions are it,” he said.

“If you go in and say my energetics material is two-times, or four-times or 10-times better than the current energetics, that just goes right past people,” he said. “You really have to put it in the context of

the warfighting advantage that I’m going to get if I do these things.”

While panelists debated how to get that message across, there was no argument about the need to reinvigorate the manufacturing base for energetic materials. The supply chain for energetics spans the globe, and often the Pentagon does not know who is supplying the chemicals that contractors and their subcontractors source.

The war in Ukraine has brought supply chain concerns front and center, said Christine Michienzi, chief technology officer for the deputy assistant secretary of defense for industrial policy.

“We are giving munitions to Ukraine and also having to figure out how we’re going to restock our inventories as well as some of our partner and allied inventories, and do that more quickly,” she said.

The U.S. industrial base does not have the surge capacity to replenish munitions stocks quickly, and one of the constraints is the production of the energetic materials, she said.

“Our demand is small and unsteady,” she said. “Large commercial chemical companies really have no interest in the DoD market. The industry writ large ... has really been driven by efficiency, not resiliency or national security.”

As a result, some chemical producers have left the market, which has led to China being the sole source of many critical chemicals used in U.S. weapons. And in cases where materials are produced in the United States, it is often at one facility, creating backlogs and single points of failure.

Like many studies and conferences, it is often easy to identify the problems and recommend solutions, but implementing the fixes is not so easy. The hard work is just beginning, Energetics Technology Council members said in interviews after the conference.

Two primary areas of focus will be developing supply chain diversity and resiliency and building a bridge between the requirements and acquisition personnel and the scientists and innovators.

“If I could do one thing just one thing, I would steal a page out of the playbook of the pharmaceutical industry and move it over into the Department of Defense weapons world,” said Fischer.

The pharmaceutical industry developed a close relationship with

the National Institutes of Health and implemented a model called “transitional medicine,” he said.

“What that means is that if there is a promising drug candidate out there, the laboratory gets together with the pharmaceutical industry and the people that potentially manufacture the drug, and they actually start sharing information early on,” he said.

That eliminates the time-consuming linear development and production process and gets all parts of the chain coordinating their pieces early, so when a product is ready for manufacture, the process is ready to go. It’s how COVID-19 vaccines were produced so quickly, he noted.

“So, if we could take that approach into the munitions industry, now we have DoD labs, Department of Energy labs, academia working with industry and whomever is involved. There’s no surprises in it. It comes into a concurrent process where everybody is working towards the same common goal,” Fischer added.

“It would not be easy to implement by any means, but if we could do something like that the opportunity for getting new materials into the system would just fly off the charts,” he said.

One way the Energetics Technology Center is hoping to make progress is through engagement with lawmakers.

“We recognize Congress has to be involved in this,” said Bob Kavetsky, founder and CEO of the ETC. He said the center has been aggressive in its outreach to Congress because it controls the money and because it can help twist arms in the Pentagon.

“Sometimes the DoD is not moving in the direction we think they ought to,” said Kavetsky. “We can use the Hill folks to apply a little



bit of appropriate pressure.”

The challenge is creating a sense of urgency to act before there is a crisis like a Chinese attack on Taiwan.

“We’re walking a fine line and not being Chicken Little,” said Kavetsky. “We’re claiming there’s a big problem. What’s that galvanizing thing without being a galvanizing thing?” **ND**

# Kamikaze Drones

## Loitering Munitions Proliferate as Tech Changes Battlefield

BY STEW MAGNUSON

**P**ARIS — If there was ever one-stop shopping for anything an army would need as far as loitering munitions, it was all the way back in Hall 6, aisle F at the Eurosatory trade show in Paris in June.

There, attendees found the Uvision booth and its complete lineup of so-called “kamikaze drones,” ranging in six sizes along with all the accessories, including controllers and training systems.

A quadcopter drone also hung on display from the booth’s ceiling.

“Is that a loitering munition, too?” a reporter asked a company representative, having never seen a vertical takeoff and landing drone armed with a warhead.

“No, just for surveillance,” said the representative.

“But it could be armed. It is possible, right?”

“Anything is possible,” he responded.

Whether they’re called loitering munitions or kamikaze drones, the weapon system has come into its own in recent conflicts, especially in Ukraine, where they were likely being deployed against Russian invaders the very week of the trade show.

Their origins are rooted in World War II tactics. Their basic technology was developed for hobbyists, and their evolution was spurred by terrorists’ use of improvised explosive bombs in Iraq.

*National Defense* spotted the first “non-improvised” flying munition created by an Eastern European contractor at the IDEX trade show in 2009.

More than a dozen years later, the technology is proliferating both at defense exhibitions and on battlefields. Vendors from all over the world came to Eurosatory to exhibit the latest in loitering munitions technology, which — as the name suggests — can fly in patterns serving as a reconnaissance platform until it spots a potential target. If an operator decides to attack, the drone can nosedive toward the target, striking it while detonating a warhead.

Although explosives aren’t always necessary.

Yaniv Ben-Itzhak, director of mar-

keting and business development at Elbit Systems, showed a video of one of its medium-sized SkyStriker drones slamming into a tactical wheeled vehicle at some 200 kilometers per hour, basically slicing it in half without the use of explosives.

“That was just a demonstration.” The warhead was removed for safety reasons, he explained.

The Israeli-based company is looking to create synergy between mobile rocket launchers and its SkyStriker loitering munitions, allowing operators to select one or the other and fire them from the same tube.

“In terms of firepower, you have a complete offering from the same platform,” he said. The SkyStriker has about a 400-kilometer range, he said. He touted its high-resolution target-seeker camera and the 5-kilogram warhead.

Like all loitering munitions, it has a dual purpose as a recon platform. It can relay target information back to the mobile platform if the operator wants to use a rocket instead. If no target is selected, it autonomously returns to its home base and parachutes to the ground for reuse.

Such tactics have been used in Ukraine against Russian combat vehicles, but military analysts truly took notice of the hybrid weapons during the Nagorno-Karabakh conflict between Armenia and Azerbaijan in September 2021, said Jorge De León Rivas, director of the robotics and autonomous systems department at Madrid-based defense contractor SDLE, which markets Uvision’s drone in Spain.

“The battlefield changed,” said Rivas, who is also a lieutenant colonel in the Spanish army’s reserves.

Azerbaijan effectively deployed loitering munitions, which destroyed hundreds of Armenian tanks.

“That made the difference in the war,” said Rivas. The drones were made in Israel and Turkey, according to numerous news outlets reporting during the conflict.

For Rivas, the advantages of loitering munitions are obvious. A missile

is “thrown away” the moment it is fired. Perhaps it hits its target, and perhaps there is collateral damage that could result in unnecessary deaths.

An operator using a loitering munition can be more selective and even abort a strike if he sees civilians at the last second.

“You only strike what is really needed, and you’re not just killing people for nothing,” he said.

The smaller versions are also said to be quiet and hard to detect by modern air defenses.

The U.S. Marine Corps, in Rivas’ estimation, is far ahead in developing tactics, techniques and procedures for loitering munitions.

U.S. forces — and now Ukraine — have been using AeroVironment’s Switchblade loitering munitions.

At Eurosatory, the U.S. company marketed two models: the Switchblade 300, a 2.5-kilogram drone with 10-kilometer range and 15-minute endurance and the 54-kilogram 600-model, with a 40-plus kilometer range and 40-plus minutes of endurance. Both are launched from mortar-like tubes placed on the ground.

Turkey’s Rocketsan also used the exhibition to introduce a new armed drone as part of its MAM family of “smart micro munitions,” said Furkan Zeki Ayhan, special engineer at the Ankara-based munitions manufacturer.

The MAM-T is a new 95-kilogram fixed wing drone that has a 30-plus kilometer range, he said. The MAM-C and MAM-L — both introduced in 2016 — have 8- and 15-kilometer ranges respectively.

Unlike the other tube-launched systems, Rocketsan’s three models are designed to be launched from medium-sized drones or light attack aircraft, he said.

One potential customer at Eurosatory said he was sold on loitering munitions’ utility.

Col. Arnaud Goujon, chief of plans at the French army headquarters, said the service is looking to add loitering munitions to its inventory later in the year.



“You need something that is different than a mortar or an artillery shell,” Goujon said. “If it is the same price of a mortar round that goes about three kilometers away and flies for 15 minutes, then it’s interesting,” he said. If it costs 10 times as much as a mortar or an artillery round with the same range, then it’s less interesting, he added.

If it can fly 30 or 50 kilometers away and endure for two to four hours, “then it’s a different animal,” he said.

Goujon indicated that the French army would start off by acquiring the smaller Switchblade.

Peter W. Singer, senior fellow at the New America think tank, and the author of several seminal books on robotics and warfare, said in the near future, the skies over battlefields — and at sea — will feature more drones than ever, including loitering munitions.

What do I want to launch from my aircraft? Is it just a singular guided munition or hundreds, or even thousands of loitering munitions?” he said in an interview.

“The future of the battlefield is not merely a few loitering munitions, but an airspace that’s literally filled with them,” he added.

Back at the Uvision booth, company chairman Yair Ramati, wasn’t shy about calling the technology a “battlefield game changer.”

Its series of six models ranges from the HERO-30, which weighs 7.8 kilograms with its cannister launcher and travels 15 kilometers, to the HERO-1250, which weighs 155 kilograms, is launched from a rail, and has a range of 200-plus kilometers.

The Tira, Israel-based firm has sold its models on almost all the continents, to NATO nations and to U.S. customers such as the Marine Corps, he said.

As for Ukraine, the technology is proving its worth every day, he said.

Attacks on Russian convoys serve as one example. Anti-tank missiles such as the Javelin have received about as much publicity as the Switchblade

and other loitering munitions, but those require a soldier to approach within the line of sight, perhaps 3 to 5 kilometers away, he said.

“Even if you know where exactly is a convoy of 20 to 30 kilometers long — maybe 50 — you need to be close to it in order to hit it,” he said.

A loitering munition is a good choice of weapons when a user knows there is a target out there he wants to strike, but doesn’t know the precise location, such as when he is receiving mortar or indirect fires. The seeker capability can find the target.

A more typical scenario is that intelligence knows there is a convoy somewhere on a road that extends 50 or 100 kilometers. The loitering munition can search and find it at a safe standoff distance.

Then there is the precision: “Do you want to hit the lead resupply vehicle? Do you want to hit it before it reaches a bridge, on the bridge or after it crosses the bridge?” Ramati asked.

“That is why there is a tremendous demand for these types of weapons right now,” he added.

Training is also an issue. It can’t take six to nine months to learn how to fly a medium-altitude, long-endurance unmanned aerial vehicle such as Predator.

Uvision seeks to train the basics of flying in a few hours, Ramati said. It offers the HERO Simulator to get trainees started.

There are finer points that take more time to learn, such as whether to attack using a high, medium or low angle, depending on the target and the type of warhead, he said.

And while the company does not yet offer a quadcopter vertical take-off and landing loitering munition, a Sofia, Bulgaria-based company at the Eurosatory conference did.

Hades Defense Systems was displaying its “Spark vertical attack programmable kamikaze quadcopter,” which can ascend at 5 meters per second and fly at 47 kph with a range of 7 kilometers.

The company touted its quiet propellers, low reflective surface to avoid radars and anti-jam capability. It also carries a fragmentation warhead.

“It positions itself above its target at a precise altitude, reverses its propellers’ direction, speeds up [as it goes] down and attacks from above,” company literature said.

Maya Pangarova, Hades commercial director, said the company has big ambitions beyond hand-launched loitering munitions. It is also developing a jet-powered kamikaze drone.

The “Nemesis Kamikaze Attack Jet Drone” is still in development using internal research and development funds and could only be seen on a company fact sheet.

Hades envisions it flying at 600 kph, using terrain mapping and a variety of anti-jamming devices and radar spotting systems to avoid detection, the company literature said.

It would be catapult-launched with a range of 190 kilometers, maximum altitude of 4,500 meters, and guided remotely or run on autopilot.

Company engineers were still working on how large of a warhead it could carry, she said.

The company hopes to have something physical to display at the IDEX conference in Abu Dhabi being held in early 2023, Pangarova said.

Singer said he has little doubt Hades, or any other company, could convert an aircraft intended for the commercial market to some kind of rudimentary loitering munition.

“You’re really getting into a fuzzy definitional line between loitering munitions and cruise missiles,” he said of jet-powered drones that can convert themselves into bombs.

Along with the military utility of doing so, there are questions about international laws that prevent sales and trade of missiles that could potentially deliver weapons of mass destruction.

Meanwhile, there is much for military strategists to ponder as loitering munitions proliferate. There is a disconnect between the major military programs the U.S. armed forces have been fielding over the last decade and drone warfare, Singer said.

“What does a future with massive numbers of loitering munitions mean for major military platforms that are the [service’s] centerpieces? That goes for land, air and sea. Those kinds of connections have not been fully made yet.” **ND**

# New Artillery Rounds to Help Army Reach Longer Distances

BY SCOTT GOURLEY

**L**AS VEGAS, Nevada — A new family of 155mm ammunition is being developed to help the Army achieve its goal of improving the reach of its long-range precision fires.

Even before Russia's invasion of Ukraine — and the resulting spotlight on the likely need for ammunition logistics replenishment — the Army had tapped long-range precision fires as one of its top modernization priorities.

The Army's next generation 155mm artillery ammunition is one part of the campaign to increase the range of its howitzers and its new 58-caliber Extended Range Cannon Artillery platform.

The new cannon is one of 24 new technologies Army Chief of Staff Gen. James McConville has publicly vowed to field by the end of 2023.

The new family of 155mm ammunition is being developed to increase the maximum range of the current howitzer fleet using 39-caliber length tubes. The 39-caliber fleet will replace the current 14-mile range M795 high-explosive projectile with the 18.5-mile XM1128 base-bleed projectile and replace the current 18.5-mile M549A1 rocket-assisted projectile with the 25-mile XM1113 rocket-assisted projectile.

Base-bleed artillery shells expel gas in flight behind the shell to reduce drag and give them longer range.

The 58-caliber Extended Range Cannon Artillery will be utilizing the XM1210 rocket-assisted, high-explosive projectile — formerly designated XM1113ER — to hit targets out to nearly 45 miles.

As noted in the ammunition descriptions, much of the range enhancement relies on the use of either “base-bleed” or “rocket-assisted” designs.

Kyle McFarland, chief technology officer at General Dynamics Ordnance and Tactical Systems, said he expects to provide the shell bodies for the XM1128 and is the systems contractor for the XM1113 “all up” projectile.

The base-bleed design features a relatively small amount of propellant

on the back end of the projectile. That propellant is ignited by the gun gases and the burning propellant reduces drag on the projectile to provide a modest range extension. The relatively small amount of propellant used in base-bleed designs requires only minor tradeoffs with the explosive payload.

“By contrast, with the rocket-assisted projectile, the back half of the round is going to be filled with a solid rocket motor with a nozzle at the end to direct its thrust,” he said.

“That nozzle has some elements in it that are also ignited by the gun gases, which then ignite the rocket motor. The rocket motor gives you a limited amount of thrust during the initial part of the projectile flight. But, as you get more range extension, you have a greater trade-off with your high explosive,” he added.

The new base-bleed and rocket-assisted projectiles will be assembled at the Iowa Army Ammunition Plant, where metal components from places like the General Dynamics operations in Scranton, Pennsylvania, are combined with propellant from Nammo Defense Systems in Mesa, Arizona.

Moving any program from development to production provides its share of challenges. In this new family of artillery projectiles, one of the challenges involves providing adequate amounts of propellant for the base-bleed and rocket-assisted projectiles to meet anticipated production quantities.

Andy Davis, chief technology officer at Nammo Defense Systems, said the XM1128 base-bleed round has approximately 3 pounds of propellant mass at the back end, while the XM1210 rocket assisted round has approximately 12 pounds of propellant.

Davis likened the propellant production process to “making a cake.”

They take liquid polymer, an oxidizer, which is the ammonia perchlorate, and a fuel like aluminum powder and put it in a mixer, he said in an interview on the sidelines of the Shooting, Hunting, Outdoor Trade Show in Las Vegas, Nevada.

“It's essentially very similar to a KitchenAid mixer you might have in

your house, except we have two blades that spin,” he said.

Just like baking a cake, they pour in the liquids, and add the solids in a little bit at a time because if they are put in all at once they are left with something resembling wet sand, he said. They mix it for about 20 hours.

He continued: “What you get at the end of that mixing is uncured propellant, which basically looks like uncooked cake batter. We then pour that into the molds that will make these rocket grains and put them into an oven for a certain amount of time — three days or so — and out pops cured rocket grains.”

Unlike throwing a log on a fire where all surfaces would burn, a second molding step is used to inject an inhibitor, basically a rubber coating with no oxidizer, that helps limit burning only to specific surfaces needed for performance, he added.

“We will eventually ship the propellant to General Dynamics for integration into the rocket motor hardware that gets threaded on the back of the shell,” he said.

Both the rocket-assisted and the base-bleed projectile rounds are made the same way, in the same mixer, he added.

“The modes are different because the base-bleed grains are little squat doughnut-shaped grains, while the range extension grains are about 12 inches long. So, there is a slightly different formulation for the propellant, but the processing is identical.”

Early discussions with the Army had pointed to the possibility of a requirement for 1 million rounds of XM1128s over 10 years — at a rate of 100,000 rounds a year — along with 100,000 rounds of XM1113s.

There is the potential for foreign military sales that could double those quantities, Davis said.

But here's where the numbers started to get challenging, Davis noted. Until now, all that propellant was produced in a single 50-gallon mixer capable of producing a total of only 500 to 550 pounds of propellant per batch.

“It was going to be impossible to support those [projected] acquisition quantities with that mixer,” he said.

In recognition of that reality, the company invested in the development of a new facility that includes a 300-gallon mixer capable of producing nearly 3,500 pounds of propellant per batch.





“What we did is to build a facility where I can meet the Army’s demand out of a single mixer,” Davis said. “If demand increases, I can essentially knock down one wall, double the size of the building and put in a second mixer,” he said.

Nammo could even go to a larger 420-gallon mixer, or run two mixers under the same roof, he said.

“Not only are we also building a mix building, but you also have to have the facilities to grind the oxidizer into a smaller particle size to help control the burn rate,” he said.

“I need a facility to do that grind work. I need a facility to cast the uncured propellant. I need an oven building to cure the propellant. So, in this project, we’re building nine buildings that will basically run as a factory in a factory,” he said.

The new facility was officially opened on May 25.

Col. Anthony Gibbs, project manager for combat armament systems in the Joint Program Executive Office for Armaments and Ammunition, at the opening said it was “a really important day for the Army,” noting the service’s

renewed emphasis on long-range precision fires.

The new Extended Range Cannon Artillery will effectively double the range of the service’s current capabilities, he said.

“Now, that’s a big deal,” he asserted. “And what we have in development right now, two of the projectiles ... the XM1113 and the XM1128 ... these things work with the propulsion system that Nammo provides, working in concert with the cannon to help us to extend that range,” he said.

The Army will be increasing the range of its current fleet of howitzers by about a third, he said.

“So, a 33 percent improvement just with these new projectiles that are going into the field,” he said.

The Extended Range Cannon Artillery platform, which is still in development, has shot about 45 miles, more than doubling the range of its predecessors.

“That is a really big deal as we put that capability out there into the field,” Gibbs said.

“Critical to this effort to deliver this new capability by next year is not just

the development, but it’s also the production. And that’s what this facility really represents,” Gibbs said, referring to McConville’s deadline for fielding the system.

The Army hasn’t produced a rocket assisted projectile since the late 1980s, he added.

The M549A1 has served the Army well. It has been a very reliable high performing projectile. But it’s nearing the end of the expected service life, he said.

“Completion of this facility couldn’t come at a better time, not only to meet our modernization priorities, but also because what we see going on in Ukraine right now,” Gibbs said.

Russia’s invasion of Ukraine once again highlighted not only that it’s important to have a trained and ready force, but also to have domestic production capability so industry can scale up when needed, he said.

“We are now once again being called on to serve as the Arsenal of Democracy. And so far, we have answered that call and moving forward, this facility is going to help us do that,” Gibbs said.

**ND**

# First Soldiers Will Get Next-Gen Squad Weapons in 2023

BY MIKAYLA EASLEY

**T**AMPA, Florida — For the first time in decades, the Army will employ brand new rifles, automatic rifles and ammunition calibers, with the first unit receiving the next-generation squad weapons by fall of 2023, according to the makers of the weapons.

After years of development and intense competition between major gun makers, the Army announced in April that Sig Sauer Inc. will manufacture the service's next-generation squad weapons. The 10-year firm-fixed-price follow-on production contract is worth \$4.5 billion and covers the delivery of two variations of the weapon — the XM5 Rifle and the XM250 Automatic Rifle — as well as the 6.8x51mm FURY hybrid ammunition.

Sig Sauer plans to send the first round of new weapons and ammunition to an Army unit by next year, CEO and President Ron Cohen said May 18 on the sidelines of the Special Operation Forces Industry Conference in Tampa.

“Fundamentally, they want to start deployment of the first unit around spring or summer of next year,” Cohen told *National Defense*. “This will reshape all infantry warfare in a way that hasn't changed since the early 1960s.”

The first delivery order is worth \$20.4 million and will include 25 XM5 Rifles and 15 XM250 Automatic Rifles and ammunition that will undergo testing, Col. Scott Madore, the Army's project manager for soldier lethality, told reporters last month during a media event.

The XM5 Rifle will replace the M4 carbine used by the close combat force, while the XM250 Automatic Rifle will replace the M249 Squad Automatic Weapon. Each weapon will also come with Sig Sauer's suppressors meant to reduce harmful gas backflow, sound effects and flash.

Both fire 6.8mm ammunition, an innovative bullet that is faster, more lethal and has greater accuracy than what is currently used by the Army, Cohen said.

Steve Rose, executive vice

president at Sig Sauer, added its 6.8mm caliber ammunition is where the key innovation is.

“The ammunition is the technology. It is the leap forward in capability,” he said. “The guns, although it's great to talk about them, they're simply the vehicle to deliver the technology and enable the ammunition to shine.”

Cohen explained that historically, increasing the lethality and speed of a bullet required manufacturers to also increase cartridge size



to accommodate for the increased pressure needed to shoot. Additionally, the weapons would also have to get bigger and heavier.

Sig Sauer developed a lightweight metallic casing to pair with 6.8mm ammunition already designed and manufactured by the United States. This allows a cartridge to withstand more pressure than conventional ammunition, resulting in greater velocity and accuracy without having to make the weapon physically bigger, Cohen said.

The design solves lethality and range challenges the Army has faced while using the M4 carbine and M249 Squad Automatic Weapon, he added.

At about two-thirds the weight of the M249 machine gun, Sig Sauer's XM250 Automatic Rifle is much lighter than what soldiers have been carrying, Cohen said. However, the company did have to make the XM5 Rifle heavier than the M4 carbine, although Cohen ensured they did so with the least amount of additional weight possible.

Another key design element of the next-gen squad weapons is their

similarity to what they're replacing, said Jason St. John, director of government products at Sig Sauer.

“We thought it important to give them an [automatic rifle]-style weapon system if we could,” St. John said, referring to the XM5 Rifle. “The soldiers would embrace it easier, but the Army would also embrace it because the training curve to implement that weapon system is now almost non-existent.”

St. John also said the capability provided by the 6.8mm ammunition allowed the company to develop the XM250 Automatic Rifles without having to extend the barrel beyond the requirements from the Army — keeping it similar to belt-fed machine guns in platoons.

In all, the contract calls for a total of 400,000 weapons and 1 billion rounds of ammunition from Sig Sauer, according to the company.

That would include 107,000 XM5 Rifles and 13,000 XM250 Automatic Rifles for the Army's entire close combat force, Brig. Gen. Larry Burris, commander of the Army's infantry school at Fort Benning and director for the soldier lethality cross functional team, said last month during a media event.

Despite the weapons and ammunition being brand new, Sig Sauer expects no production issues to match the demand, Cohen said. The company plans to expand facilities throughout the country and make production for the weapons and ammunition a top priority, he added.

Competition to produce the next-gen squad weapon began in 2017 and included a rigorous 27-month prototyping and evaluation effort of tests and soldier feedback. Although multiple companies fought for the lucrative contract, it came down to Sig Sauer and a team of LoneStar Future Weapons and BerettaUSA in the final stages.

The weapons will be paired with the XM157 Fire Control, a ruggedized advanced fire control system that increases accuracy and lethality for the close combat force, made by Vortex Optics.

It also integrates a number of advanced technologies, including a variable magnification optic (1X8), backup etched reticle, laser range-finder, ballistic calculator, atmospheric sensor suite, compass, Intra-Soldier Wireless, visible and infrared aiming lasers and a digital display overlay. **ND**

# European Manufacturers Tout Armament Innovations

BY MIKAYLA EASLEY AND STEW MAGNUSON

**P**ARIS — European and Israeli defense companies showcased scores of innovative armaments and vehicles at the Eurosatory Conference in France in June.

Here are a just few of the featured technologies.

Excalibur Army from the Czech Republic introduced a prototype for its new self-propelled howitzer concept called Morana.

The company, which designs a range of military vehicles, unveiled Morana during the conference. Its 155 mm weapon system and 52 caliber barrel — coupled with a suite of digital capabilities — ensures the howitzer can deploy and fire as quickly as possible, said Frantisek Krompolc, project manager at Excalibur Army, on the sidelines of the conference.

“For Morana, it takes less than 40 seconds after stopping to provide aiming, loading and to shoot the first round,” he said. “Then to leave that firing position, it takes less than thirty seconds.”

The howitzer carries 45 ready rounds. With automatic loading capabilities, Morana can fire up to six rounds in under one minute from establishing its initial position.

The howitzer’s armored cab seats a three-person crew — a driver, commander and weapons operator — and features subsystem displays onboard to help a crewmember complete multiple tasks at once.

For example, during a demonstration, the commander’s position displayed one computer that performs ballistic trajectory calculations based on the environment and mission and another panel to control hydrological and mechanical components of the weapons.

Among the features onboard Morana are navigation tools for the driver, an automated weapon aiming system, combat controls and ammunition management tools.

Krompolc noted that the weapon system can also fire multiple shots and time them to hit the same target at once, a technique known as “multiple rounds simultaneous impact.” The howitzer begins by shooting a round at

a maximum elevation, and then fires consecutive shots as the barrel lowers — all timed to hit the target together.

Depending on the distance of the intended target, Morana can fire up to five rounds using this technique, Krompolc said. The ballistic calculations to make this possible are all done using the howitzer’s digital tools, he added.

Instead of being mounted in the center of the chassis, Morana’s superstructure is situated in the very back of the vehicle with the power unit located behind the cabin.

The entire vehicle includes an independent tower artillery system and armored cabin mounted on a 9.8-foot-wide chassis made by Czech Republic-based Tatra Force. This combines the mobility of a lightweight truck-mounted gun with the lethality of heavy artillery from the armament.

Elbit Systems of Israel introduced its latest turret — a system for light-weight tanks that can be customized for both crewed and uncrewed vehicles.

The Sabrah light-tank turret was designed for Elbit’s light tank and other armored vehicles that are small in size and weight without compromising lethality. The turret can be outfitted with either a 105mm or 120mm rifled gun, said Gal Raviv, vice president of land combat systems for Elbit Systems.

Light tank variants are designed for rapid movements in and out of combat to complement larger armored fight-

ing vehicles. Because of the need for better mobility and ease of transport, they usually are smaller, have thinner armor and use less powerful weapons.

“The main idea is to be able to provide lethality, maneuverability and capability for the battle tank but not without the same level of protection,” Raviv said.

The turret made its public debut at the conference atop an ASCOD armored fighting vehicle made by General Dynamics European Land Systems, which the Elbit light tank is modeled after.

The light tank features an automatic loader with 12 rounds at the ready and an additional 24 in the hull. The tank also carries a 7.62mm coaxial machine gun, eight smoke grenades and two optional anti-tank guided missiles, according to the company.

The system can be fitted onto both two-person manned and unmanned fighting vehicles. Raviv said they designed the two variants in parallel so that end users could choose which capability best suits their current and future needs.

“Most of [the customers] will want, we believe, manned options today,” he said. “If you look at the future, we are supporting the unmanned capability from day one.”

Meanwhile, German automotive and arms company Rheinmetall rolled out a new main battle tank, built nearly from scratch, that it says will set “new standards” for armored vehicles.

The KF51 Panther made its debut in Paris. The tank features a new armament system, comprehensive situational awareness tools and a completely digital architecture, making it ideal for the fast-changing scenarios expected in future battlefields, according to the company.



The vehicle was not developed by request of any Rheinmetall customer, but a company spokesperson said that the KF51 Panther will be marketed toward NATO companies.

The KF51 Panther is entirely brand new, minus some elements of its chassis that are derived from the Leopard 2 main battle tank's chassis made by Rheinmetall, the spokesperson said.

The vehicle was developed in parallel to the Main Ground Combat System, a joint French and German project to replace both their Leopard 2 and Leclerc main battle tanks. Although the countries are still refining the requirements of the replacement tank it will need, Rheinmetall decided to debut a Leopard 2 replacement now, the spokesperson said.

"There are 19 nations that use Leopard 2 at the moment, but only maybe one or two countries that will be involved with the Main Ground Combat System project," he said. "So, what should we do with the other ones?"

One idea was to develop this type of tank." The main feature of the tank is its Future Gun System, which consists of a 130mm gun and fully automatic ammunition handling system — giving the KF51 Panther an improvement in effectiveness and range over current systems that use 120 mm armaments, according to the company. An autoloader carries up to 20 rounds ready for fire in the back of the vehicle separate from the crew.

Several options exist for lethality, the spokesperson said. Along with a coaxial machine gun that complements 130 mm weapon, larger ammunition can be put into the back of the autoloader, remote-controlled weapon stations can be attached, and launchers for loitering munitions can be integrated, he explained.

The KF51 Panther holds a crew of three people, including a commander and gunner sitting in the turret and a driver in the chassis. A fourth crew member is available to house a weapons or subsystem specialist — or even battalion commander — when needed, the Rheinmetall spokesperson said.

In addition, as a "fully digitized tank," the battle management system can share a common operating picture with other platforms on the battlefield, he said. Operations can also be transferred between crew members digitally.

Rheinmetall plans to have the KF51 Panther ready for production in 2025.

Answering the call for survivability

in battlefields where time spent lingering can result in being an instant target for armed drones or other high-tech weapons, three European companies have partnered to create a mobile mortar system that can stop, fire and depart in under a minute.

French vehicle manufacturer Arquus has attached a deployable mortar created by Spain's NTGS to one of its Sherpa Light 4x4 armored vehicles. The system includes a 120mm mortar rifle barrel manufactured by France's Thales.

After coming to a halt, the Sherpa A2M can automatically deploy the mortar in 20 seconds, Arquus spokesman Marin Tollet said at the company's booth at the trade show. After acquiring a target, a soldier can grab a round, insert it in the tube and fire in about six seconds, he said.

The vehicle could stay parked longer depending on how many rounds are fired. The Sherpa can carry up to 40 rounds. One operator must get out of the vehicle to load the rounds, which weigh about 20 kilograms.

The driver and the loader would make up the two-person crew, although one can imagine the system being operated by a lone soldier if needed, he added.

Retracting the system takes another 20 seconds. In an emergency, the Sherpa could take off before the mortar is locked back in, but that wouldn't be ideal, Tollet said. The typical mortar used has a range of 8.2 kilometers with a five-meter accuracy. It can fire any type of Thales ordnance that fits in the barrel, he added. A self-propelled or laser-guided round could extend the range, he added.

But the system is really about the mobility, he said. "Even before the Ukraine war, you could have proven the validity of the concept."

Russian forces staying still for too long have been easily spotted by drones that relay targeting information back to Ukrainians employing indirect fires. Armed drones and loitering munitions are also part of modern battlefields. "It's a vulnerability — the lack of the ability to shoot and scoot," he said.

The wheeled Sherpa Light with 215 horsepower engine provides the ability to drive in off-road conditions, plus it can reach 110 kilometers per hour on paved roads, he noted. It has been used as a special forces and scout vehicle since introduced in 2006, according to company information.

Both the mortar the tube and the vehicle are NATO qualified technologies. The NTGS fire control system in the back of the vehicle conveys information about targets and can automatically target the rounds. It can be switched to manual mode if needed, Tollet said.

And it "all comes at the fraction of the price of a self-propelled gun," according to an Arquus statement.

Finally, a pair of European defense companies conducted a live test firing of a robotic wingman combat vehicle.

Estonia's Milrem Robotics and Norway's Kongsberg Defence & Aerospace conducted the first firing of the Type-X Robotic Combat Vehicle in Slovenia in June, Gert Hankewitz, director of market and export control at Milrem, said.

Milrem provided the robotic vehicle and Kongsberg the Protector RT40 turret, which includes a Bushmaster 30 mm cannon and a linkless ammunition handling system, a statement from the companies said. It is still in prototype phase, Hankewitz added.

The live-fire was a step toward the companies' joint project of developing the Nordic Robotic Wingman — a robotic fighting vehicle that addresses Nordic and Western European countries' requirements, but also current U.S. Army desire to field a robotic wingman that can accompany manned fighting vehicles on the battlefield, the statement said.

Unlike other robotic vehicles that are adapted from manned versions, Milrem designed the tank-like chassis from the ground up. That allowed the company to make the vehicle lighter and lower to make it harder to see and expendable. Customers are asking that the wingman be one-third the cost of a manned fighting vehicle, he added.

The vehicle is semi-autonomous. It cannot fire the cannon without a human pulling the trigger, he said. It has waypoint navigation so it can autonomously go to a predesignated position or return to base on its own, he added.

The purpose is to support main battle tanks like the Leopard 2 and infantry fighting vehicles like the CV90.

The remote turret can accommodate different weapon systems depending on the customer, the statement said. The prototype featured a laser range finder and shot detection system, but the type of sensors that go on top of the turret are also customizable, he said. **ND**

## ANALYSIS

# Ukraine War Proves Big Guns Are Back

BY MICHAEL PECK

**F**or centuries, artillery was called the king of battle, and great commanders relied on masses of cannons to dominate the battlefield.

But then came the invention of the airplane. Since 1945, “flying artillery” has replaced big guns as the favored source of fire, especially in advanced Western-style militaries such as those of the United States, NATO nations and Israel. Mobile, long-range and glamorous, aircraft were seen as a high-tech, low-manpower instrument for delivering precision strikes in conflicts such as Vietnam, Sinai and Desert Storm.

But the Ukraine war has been different. Airpower has played a relatively limited role, while artillery has emerged as the dominant weapon. For both sides, how to employ — or destroy — those howitzers and multiple rocket launchers has become a priority.

Ukraine may offer a glimpse into the future of artillery. As Russia’s erstwhile blitzkrieg fizzled into trench warfare, the conflict has become the infantry’s nightmare but the gunner’s laboratory. On display in Ukraine is the full panoply

of modern artillery: a bewildering array of towed howitzers, truck-mounted cannons, self-propelled armored guns and multiple rocket launchers manufactured by numerous nations.

“Ukraine is providing a very good study when assessing the future of artillery,” said Nick Reynolds, land warfare analyst for Britain’s Royal United Service Institute.

At the least, it suggests that cannons are back with a bang.

There are local reasons why airpower has not been a major factor in Ukraine, such as the small number of Ukrainian aircraft or the timidity of the Russian Air Force. Despite initial successes, even attack drones have become less effective.

But in an era of high-performance air-defense systems, airpower may have less freedom to operate in contested skies such as Eastern Europe or Taiwan. At the same time, highly expensive aircraft and limited stockpiles of smart munitions may be allocated to distant targets in the enemy flank, rather than close-air support.

While less flexible than aircraft, artillery does offer firepower 24/7 under any weather conditions and without relying on airbases vulnerable to bombardment.

The Russo-Ukraine War also highlights the importance of range. With its pre-war Soviet-era artillery being pummeled by Russian counterbattery fire, Ukraine quickly clamored for longer-range Western artillery and rockets. Delivery of U.S. and NATO 155mm and 105mm howitzers — and

especially M142 High-Mobility Artillery Rocket System, or HIMARS, multiple rocket launchers, which can shoot GPS-guided projectiles out to 50 miles — has enabled Ukraine to conduct devastating strikes against Russian ammunition dumps, command posts and key bridges and do so without suffering crippling losses to counterfire.

“Range has proven very important as a factor in force protection as much as the ability to strike the enemy deep,” Reynolds said.

This should especially interest the U.S. Army, whose artillery had atrophied after nearly two decades of focus on counterinsurgency warfare.

Compared with weapons such as Russia’s BM-30 Smerch multiple rocket launcher — with a range of around 45 miles — the U.S. M109A7 Paladin 155mm self-propelled howitzer only has a range of around 15 miles with conventional shells, and 20 miles with rocket-assisted projectiles. The Army is belatedly trying to catch up with its Extended Range Cannon Artillery, an upgraded Paladin with an autoloader and, perhaps more importantly, rocket-assisted projectiles such as the XM1210, which has successfully hit test targets at 43 miles.

Another issue highlighted by the Ukraine war is mobility. Historically, the problem for artillery was keeping pace on the battlefield with the infantry, cavalry and tanks. But in Ukraine, mobility has become synonymous with survival. Drones and counterbattery radar, which can instantly pinpoint artillery as it fires, have made

M109A7 Paladin



Army photo

shoot-and-scoot tactics a necessity.

Ukrainian glee at receiving U.S. M777 105mm howitzers was tempered by the realization that they are towed rather than self-propelled weapons, which can take three or more minutes to displace after firing. To some extent, that vulnerability has been muted in Ukraine. Because Ukrainian and Russian kill chains are slow, “systems such as towed artillery remain potent and viable despite being hypothesized as too vulnerable to counter-battery fire in high-end warfighting,” Reynolds said.

But kill chains will only grow faster as nations develop tighter command systems, such as the U.S. military’s joint all-domain command and control, or JADC2, concept.

David Johnson, a former U.S. artillery officer and now a principal researcher for RAND Corp., believes mobility is an incentive for future artillery to be self-propelled. Towed guns have the advantage of being simpler than a tank-like weapon such as the Paladin, which tasks the crew with not just firing the cannon, but also all the strenuous maintenance of a heavy armored vehicle.

Towed guns “are a lot easier to train people on,” Johnson said. “They’re a lot more durable as far as being moved around a lot, and there are fewer maintenance requirements for a howitzer towed behind a truck, especially if you have long distances to cover.”

Towed guns are fine against a poorly armed or trained opponent, Johnson said. But an enemy with advanced skills and weapons is a different matter.

“Towed systems take longer to displace,” he said. “If you’re fighting a competent adversary who really knows how to do cannon fire, you shoot and then you move because they’re going to shoot where you were. If you’re not moving quick enough, you’ll get caught in the counterfire.”

Johnson is intrigued by truck-mounted weapons, especially France’s Caesar, which is a 155mm howitzer mounted on a six-wheeled truck. China also uses wheeled artillery, including the new PCL-181 155-mm gun. Wheeled guns have the firepower and mobility of an armored self-propelled howitzer, without the weight and maintenance issues.

“It’s the best of both worlds in some ways,” Johnson said. “The only challenge is that wheeled vehicles don’t have much off-road mobility.”

Nonetheless, Johnson still prefers armored self-propelled howitzers. The ability of tracked vehicles to maneuver in rough or muddy terrain is useful, as is the armor protection.

“For a high-intensity conflict in Europe, I’d rather have an armored system like a Paladin or a German PzH 2000,” he said. “You can’t always assume you’re going to be fighting against incompetent adversaries.” The fact that Extended Range Cannon Artillery is a beefed-up Paladin indicates that the Army will continue to rely on heavy-armored howitzers.

The Ukraine war also demonstrates that artillery is not just a big gun, but an entire ecosystem of weapons, sensors and networks. For example, both Ukraine and Russia employ drones to locate each other’s artillery,



a technique that “has proven vastly superior to other targeting capabilities such as radar or acoustic detection,” Reynolds said. But they don’t function in a vacuum. “Without electronic detection and counterbattery radar providing general direction-finding capability, [unmanned aerial vehicles] cannot be directed to hunt the right areas for enemy artillery.”

Indeed, drones may be the key enabler for armies with limited capabilities for directing artillery. In Ukraine, “both sides seem to underutilize forward observers compared to what more capable NATO militaries would employ, probably as a result of poor communications systems and skill limitations,”

Reynolds said. He also believes that shells and rockets deserve attention.

“Lethality and destructive power of munitions is also proving to be very important, given the prevalence of mechanized forces, dug-in defensive fortifications and the need to be able to destroy targets such as large ammunition depots,” he said.

He also points to the significance of industrial infrastructure to support artillery, such as “depth of munitions stocks, munitions manufacturing capability and sovereign manufacturing capability of replacement parts such as barrels — which require some specialist engineering, which is not easily established.”

The Ukraine war also points to what seems to be a growing convergence between howitzers and rocket launchers. World War II-style MLRS like the Katyusha fired huge salvos of unguided rockets that were notoriously inaccurate but could devastate a target

through sheer weight of high explosive. Today’s rocket launchers, such as HIMARS, fire just a few guided rockets accurate enough to destroy a pinpoint target like a bridge, with accuracy similar to that of howitzers. Conversely, new howitzers like ERCA are designed to fire long-range projectiles that are a cross between a rocket and a traditional artillery shell.

Johnson sees the perfect artillery weapon as having a high rate of fire, high mobility, some degree of armored protection and the ability to quickly process targeting data. There-

in lies the classic dilemma — familiar to designers of tanks and battleships — of how to balance firepower, protection and mobility. New technologies such as robotics, electric-powered vehicles and longer-range shells and rockets may tweak the variables somewhat. But the dilemma will remain.

All of which suggests that the future of artillery will include armored and wheeled guns as well as towed weapons for austere theaters or for armies needing simpler weapons.

“There is going to be a mix of artillery,” Johnson said. “What really matters is how you employ them.” **ND**

*Michael Peck is a freelance journalist.*

# Subterranean Showdown

## DARPA Pushes Underground Robots To Their Limit *BY MEREDITH ROATEN*

**L**OUISVILLE, Ky. — It was 6 a.m. and Lt. Col. Dan Riley was laying in his hotel room, staring at the ceiling. Though he is an active duty Air Force officer, Riley was not “chair flying” an airplane, a pilot’s way of practicing procedures before a flight.

Instead, his mind was far below ground — running through every possible obstacle facing the menagerie of robots under his control in a network of caves, tunnels and urban underground environments.

As an operator in the final competition of the Defense Advanced Research Projects Agency’s Subterranean Challenge, he was the only one on his assembled 16-person robotics team MARBLE who was allowed to issue commands during the perilous hour of competition.

Only the day before, professional sportscasters hired by DARPA analyzed and speculated about failed unmanned aerial system take-offs, friendly robot collisions and fog-obscured sensors in the challenge’s preliminary runs. He also was the lead for the competition that took place in the virtual realm, helping write the code for the autonomous systems to explore a cave and tunnel simulation. But Riley’s long history in the Air Force equipped him for racing against the clock and operating delicate systems under pressure, he said.

“There’s definitely a lot of stress involved,” he said. “You feel the weight of everyone’s expectations riding on what you’re going to do.”

This challenge was the final round of DARPA’s SubT project aimed at accelerating the development of autonomy and robotics for search-and-rescue operations. Firefighters and first responders could soon command fleets of robots capable of pinpointing unseen hazards and locating survivors, Program Manager Tim Chung

said in late September under the glow of the stage lights that filled the event’s watch party at the Louisville Mega Caverns in Kentucky.

With \$3.5 million on the line for the final challenge, it was not the time to play it safe.

On the surface, the eight teams competing in the systems challenge had a simple objective: locate as many objects as possible in one hour. But as the three winners who left the caverns with huge, lottery-style checks for \$2 million, \$1 million and \$500,000 would find out, the labyrinth that took weeks to construct would test the limits of mapping, autonomy, robotics and communications capabilities that some of them had been developing for years.

The course was designed to highlight what is possible for the warfighters and first responders who could one day use the mapping, austere navigation, robotics and autonomous hardware and software to conduct subterranean operations, Chung said.

Prize-winning teams Cerberus and CSIRO Data61 scored 23 points, and the lowest scoring teams — Robotika and Coordinated Robotics — each detected two objects.

After an earthquake or a collapsed building, “There’s always a gear turning in the back of my head — and for many of our competitors I’m sure — that in the event of some kind of emergency, what one of our robots could go out and help?” he said. “You’ve been able to push the entire frontier of this technology, but there are many people out there in this audience are grateful for even just the one piece of technology that you’ve advanced. That’s so meaningful to me.”

During the competition, each team had one hour to deploy robots onto an obstacle course made up of three subdomains — cave, tunnel and urban underground — which was a combination of the terrain from the previous

three competitions in the subterranean series. DARPA hid “artifacts” such as thermal vents, mannequins, cellphones and backpacks for contestants to locate using the robots.

Once the systems detected an object using the laser beam scanning technology lidar or other sensors, they would report the location to their operator. If the location reported was within five meters of the actual location, the team scored one point. If the robot made a mistake, the team lost one of their available 45 report attempts and didn’t score. The fastest time for the final point would decide the winner of the competition if there was a tie.

This configuration emphasizes accuracy, which first responders will need because the stakes are high, Chung explained. The robots could potentially save lives by both locating survivors and identifying hazardous areas first responders should avoid.

“What they really need is the ability to understand where the dangers lie, even before they want to dispatch their units to respond to a natural disaster or a similar scenario,” he said.

Because of that, there is no minimum score needed for teams to demonstrate that they have technology that could be useful for first responders, he noted.

Chung said he hoped the teams would connect with representatives from the Army, Marine Corps and civilian agencies to further their technology.

“[I] encourage you now that you’ve developed this capability to go to ... those firefighters and those first responders and find out really what they are needing, if there’s a little deviation that will make an impact on their day-to-day” efforts, he said.

The teams — and the technology — have come a long way since the series of SubT-related events began in 2018, Chung said. He joked that there was a lot of “colorful language” used to describe the level of difficulty of the first circuit in 2019.

“[Chung] came in with a vision, which all of us inside DARPA thought was crazy,” said Stefanie Tompkins, the agency’s director. “I heard somebody say off to the side and somebody say directly to my face that when they first heard about this, they were absolutely positive [that] it was impossible. So thank you for ignoring your gut instinct and diving into the competition,” she told competitors.

The majority of the eight teams in

the final competition scored in the double digits, a marked improvement from the two teams that earned double digit points in the 2019 tunnel circuit.

Additionally, the competition proved that technological innovation doesn't have to come at the expense of the government, Chung said.

According to budget documents, DARPA's bill came out to about \$82 million over the course of five fiscal years, as innovators put their own dollars on the line as well.

Team CoSTAR's Joel Burdick, one of the few participants who had been in the running since 2019, said DARPA's funding wasn't enough to cover the bills for its "Spot" legged vehicles, wheeled vehicles and aerial drones. The team had to look for other methods such as grants or equipment donations from "day one," he said. "Any way you can stretch a buck," said the professor of mechanical engineering and bioengineering at the California Institute of Technology.

Similarly, Coordinated Robotics, another team made up mostly of student researchers and their professor from California State University-Channels Islands, had to get scrappy to deploy their fleet of 10 robots. The team was self-funded for the last round of competition, and it couldn't afford the legged robots built by Boston Dynamics that many other teams used, said Hugo Quintero, a member of the pit crew.

"It would have been an amazing opportunity to work on a Spot, but now, we have plenty of work here with these, and they did pretty well," he said.

Different obstacles represented real challenges that could arise in disaster settings, said Viktor Orekhov, designer of the course and a Booz Allen Hamilton contractor. The mobility, perception, autonomy and networking of the robots were tested by different artifacts and their locations, he said.

To measure mobility, the course had a variety of different environments for the robots to traverse. For example, stairs, which were easy for the legged robots, were harder for wheeled systems. One treaded robot jumped its tracks when it tried to go over railroad tracks DARPA put in its path, Orekhov observed.

The large size of the cave and the sheer distance the robots had to travel to communicate tested the limits of the robots' programmed autonomy. Only the operator had contact with the

machines throughout the run. If the algorithms failed, the robots could end up circling endlessly in one area — like a one-legged unmanned ground vehicle that traveled up and over a bridge did during the competition.

"It's autonomously exploring, so it kind of got caught in the loop and it went up and over that bridge probably seven times in a row," Orekhov said. While the system was confused, it still managed to complete a great feat, he noted. "It's autonomously exploring and managing to traverse a terrain — that's a big deal."

Building trust in autonomy for the first responders who will eventually use the tech is partly why the challenge is important, Orekhov said. If the robots are going to save lives, first responders have to trust that the machine will be able to return with valuable information.

"In disaster response scenarios, there are lives on the line. If I send a robot out, if I only restrict it to communications range, it's only useful so far," he said. "But if I can trust it beyond communications range ... now that system is way more useful and beneficial to humans."

The length of the course — about 2,900 linear feet — pushed communications to the limit. Distance between the home base forced teams to figure out new ways to transfer information, including dropping communications nodes for navigation and a truck that was designed to carry a very long ethernet cord into the course, extending the comms range.

Dynamic obstacles like fog and smoke could damage the robots' sensors, impairing their ability to perceive their surroundings. The diversity of artifacts meant that it wasn't enough for the platforms to have one kind of sensor.

The course was so difficult that there was one artifact — a fire extinguisher — that was not found by any robots on any run, Orekhov noted.

The amount of fog in the area prevented the systems from detecting its existence. By the time the fog cleared out, most robots had moved on to the other sections of the lengthy cave, he said.

The COVID-19 pandemic produced its own set of challenges. CSIRO Data61, the team that won \$1 million for a second-place finish, had members who were prevented by Australia's travel ban from leaving their country to work on the robots, said Navinda

Kottege, the group's leader. The Commonwealth Scientific and Industrial Research Organisation had to ship its platforms to its counterparts at the Georgia Institute of Technology and train technologists there to operate and adjust the robots.

"Our biggest concern was damage



to hardware, because we couldn't send down our engineers and electronic materials," he said. "In the competition that we've had in the past, there had been some damage after each run and we were nervous about that."

At one point, the team considered not deploying any robots for the preliminary rounds to protect them from the treacherous falling ceilings, sharp drop-offs and railroad tracks that lay in store.

"Given that, for us to come on top of the leaderboards in preliminary rounds, that was completely unexpected," he said.

Kottege himself maintained a presence in the team garage by video conferencing into the cave using an iPad



on a Segway scooter.

Another international team from the Czech Republic, CTU-CRAS-NORLAB, was not able to start practicing with its robots until August because of delays in funding, explained Tomas Svoboda, a program lead.

“We really had no time to do a real

groups to invest in legged robots from the beginning because it had a vision for employing their advanced mobility. For example, legged robots can walk down stairs and can right themselves if they are knocked over.

Developing the robots from scratch gave the engineers the advantage of

5 cm, the most accurate in the competition. According to Kottege, other teams also used CSIRO’s mapping technology.

“For us, that’s a great outcome to have it used by multiple people,” he said.

But even lower performing teams brought unique advancements. CTU-CRAS-NORLAB finished with just seven points in the final systems competition. However, its electric six-legged robot that was developed for the competition still could have an impact on the industry, said Svoboda. The team decided not to use it in the competition because it was too big for some of the constrained tunnels, but he said it could have implications for robotic mobility. The robot measures the level of force needed to push against the terrain as it moves instead of relying on sensors to determine how much force is needed, he explained.

“It’s also interesting to control it in a reactive way,” he said. “For instance, if you enter some slippery terrain and the robot starts drifting, you can somehow do the countermeasures against it.”

While the systems competition didn’t pan out for CTU-CRAS-NORLAB, the team took \$500,000 for the virtual contest.

At the end of the day, the determination and grace under fire for Riley’s team MARBLE paid off. MARBLE won \$500,000 for its third-place finish with 18 points and achieved the balance of autonomy and human interaction that DARPA was looking for, he said. He recounted one moment in the final run when he was able to tell a robot to defy its programming and keep going through the fog. Because he was able to turn the platform around, the team scored five more points.

“Being flexible was key to our success in the end,” he said.

Chung added that because DARPA was ahead of industry in solving subterranean problems, the mission needs — such as improved mapping and reliability — have stayed consistent. Now, there is a foundation from which everyone can build, he said. For example, the testbed used for the virtual competition is available online for any interested technologists to put their own autonomous software through its paces.

“There’s no limit to where these technologies can go from here,” Chung said. **ND**



integration test,” he said. “We were preparing, we were designing [the] payload, integrating the sensors and preparing for that. ... [But] this was actually the first time the complete system ran together.”

While all of the teams in the systems competition — and the virtual competition that took place simultaneously — developed techniques to push the boundaries of robotics capabilities, some of the competitors stood out.

Cerberus, one of the only groups to utilize legged robots throughout the entire competition, developed its own variation of Boston Dynamics’ “Spot” robot, which they called the ANYmal.

Kostas Alexis, program lead for the team, said his was one of the first

having access to the low-level capabilities of the systems, he said.

“That means we can make them more adjusted to the competition because we have access to the software up to the last detail,” he noted.

Additionally, simultaneous localization and mapping, or SLAM, was used by robots to create a map and calibrate their position using data collected from their sensors. The CSIRO Data61 computer engineering team has been refining its proprietary technology package called Wildcat SLAM to maximize its accuracy in the competition, Kottege said.

In addition to its second-place finish, DARPA recognized the team for reporting the location of a drill within

# New Tech Gives Robots Sense Of Touch

BY SEAN CARBERRY

**M**ilitary use of unmanned, autonomous or robotic devices is only increasing as technology evolves and allows people to step back from danger while machines do the work, and one company has announced a technology that will give robots another edge: the sense of touch.

BeBop Sensors — which manufactures intelligent fabrics and haptic

gloves — has developed RoboSkin, a flexible fabric loaded with sensors that mimics human touch when applied to a robotic fingertip.

“We have sensor density on fingertips that has better spatial resolution than human fingertips, and also has a greater range of response in terms of force,” said Keith McMillen, founder and president of BeBop Sensors.

Each fingertip has 80 sensors that can measure pressure from 5 grams to 50 kilograms. The technology essentially creates a nervous system and enables robots to perform with greater dexterity and autonomy, according to a promotional video.

“If we expect robots to work with us, they need to fit through our doors and use our tools, and sensing their environment as people do is essential,”

McMillen added.

RoboSkin, which is less than 1mm thick, starts with a polyester or nylon non-woven fabric, which is then treated so the outside of each fiber is conductive. “And then as the fabric is disturbed — either by pressure, shear, bend — its electrical characteristics change because those fibers have a different relationship to each other,” added McMillen. “And then we pull signals off of the fiber. Then we can process them and produce very detailed and accurate data.”

That data allows robots to adjust to changing conditions and modulate how they move or grip objects. And that data can also be transmitted to a human through haptic gloves.

“So, it allows a person working in robotics ... to feel objects, sense their shape, heft their weight, know if they’re connecting,” said McMillen.

While the skin could be applied to robots performing tasks ranging from health care to manufacturing, there are many potential military applications. For example, robots are routinely used for explosive ordnance disposal.

“Most of the robotic tools just have like a gripper that opens and closes, and it doesn’t provide any feedback,” said McMillen. “So, if you have a pair of data gloves that has haptics ... you can be remote and you can have a manipulator and end effector on a robot that matches your movements, senses what it’s touching and sends that data back to your fingertips.”

BeBop already produces such data gloves, which are used by the Air Force. BeBop received a direct to phase II Small Business Innovation Research contract from the Air Force a few years ago to provide gloves that work with virtual reality goggles for remote training.

“So, they didn’t have to bring the whole planes or jets into a classroom-like situation where they would be grounded while someone sat there and learned it,” said McMillen. “They were learning it virtually using our data gloves.”

McMillen said he envisions building potentially millions of RoboSkin devices.

“We also consider this project where we’re like tailors, like on Savile Row,” he added. “People will have different hands and fingers for their applications, and we can tailor the robot skin relatively quickly to fit different robotic finger, or hand or foot shapes.” **ND**



BeBop Sensors photo

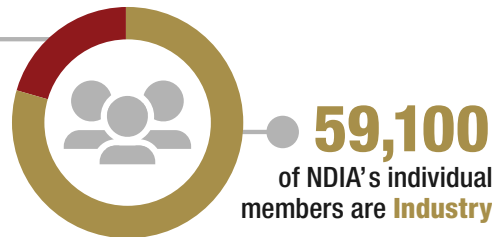
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AT THE HEART OF THE MISSION SINCE 1919



# Army, Industry Have Faith in New Approach for Bradley Replacement

BY MIKAYLA EASLEY

**A**fter a handful of unsuccessful attempts to replace the Army's aging Bradley fighting vehicle, the service hopes it is finally on the right track.

Known as the optionally manned fighting vehicle, or OMFV, the program is the Army's latest attempt to replace the Bradley following years of cost and requirements issues. Five manufacturers are competing to build a new prototype that officials hope will meet the growing need for next-generation land capabilities.

Maj. Gen. Ross Coffman, director of the next-generation combat vehicle cross-functional team at Army Futures Command, said the OMFV is his team's top priority as legacy systems rapidly age. As the Reagan-era M-2 Bradley — which is made by BAE Systems — inches toward being mothballed, the Army is aiming for a replacement platform that can enter full-rate production by 2030.

Following program cancellations and restarts, the service is taking a new approach to OMFV. Rather than forcing contractors to meet a list of requirements, the Army is simply asking defense companies to bring their capabilities to the table.

"This is going to be the basis for all future vehicle requirements and procurement," Coffman said in October during the Association of the United States Army's annual conference in Washington, D.C. "We believe that we're going to learn a lot of lessons."

The Army has been working to replace the Bradley since 1999. It started two different programs — Future Combat Systems and the Ground Combat Vehicle — but without success, according to a July Congressional Research Service report, "The Army's Optionally Manned Fighting Vehicle (OMFV) Program: Background and Issues for Congress." The efforts were later canceled due to program- and cost-related concerns, said the report's author, Andrew Feickert, CRS specialist in military ground forces.

In its most recent failed attempt to replace the vehicle, the Army had issued a request for proposals for the

OMFV platform that included a list of requirements Coffman described as "aggressive" at the time. But the Army canceled the program after receiving only one proposal from industry.

Based on feedback from industry, the Army canceled the solicitation in January 2020 and took a step back from the effort to reboot. In April 2020, the service released new guidance that listed nine characteristics required for the OMFV system. These included survivability, mobility, growth, lethality, weight, logistics, transportability, manning and training, according to the contract notice.

After receiving preliminary design proposals, the Army contracted five companies — American Rheinmetall Vehicles, BAE Systems, General Dynamics Land Systems, Oshkosh Defense and Point Blank Enterprises — to lead industry teams and create initial digital designs of the fighting vehicle in July 2021.

Moving into the next phase of the program, James Schirmer, deputy director of the Army's program executive office for ground combat systems, said his office is reviewing initial concept designs from each team. The service will then plug each designs' data into models and run them through simulations to evaluate their performance.

"We're going to take that feedback, and [Coffman's] team will then refine that requirement space," he said. The process is like "a funnel that's narrowing down into something more specific."

Based on the results of the simulations, the Army will move into an open competition and issue a request for proposals for the detailed design and prototyping phases around May 2022, Coffman said. Up to three companies will be selected from the bids.

The Army will then again use digital engineering to test the selected prototypes' performances in a simulated 3D battle before moving into physical

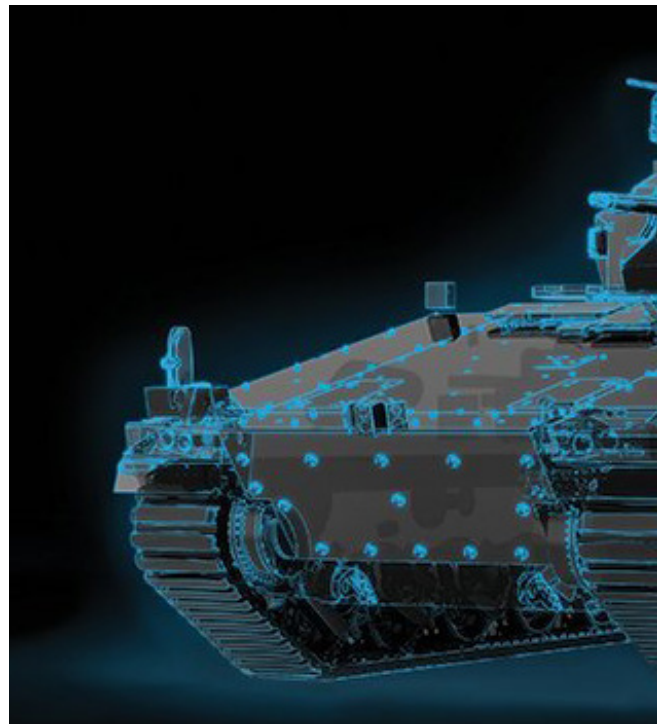
testing.

While the service is still working out the model-based environment, it is looking at cloud-based technology so it can evaluate the designs and simulation results while they are still in a digital format, Schirmer said. This will hopefully avoid costly failures during physical testing, he added.

The service plans to downselect to a single contractor by fiscal year 2027 with the goal for full-rate production to begin in fiscal year 2030, according to the CRS report.

The Army has also placed a heavy emphasis on industry's ability to implement an open systems architecture in their designs, which would enable cross-platform and cross-domain commonality of capabilities for easier upgrades as technology develops.

"We don't need to own all the black boxes, but if we control the interfaces



and we define those interfaces, that architecture will allow us to make upgrades more rapidly in the future," Schirmer said.

While much of the OMFV's development has been done behind closed doors, industry teams had the chance to showcase preliminary prototypes of technologies and capabilities that could be a part of the final fighting vehicle during the recent AUSA show.

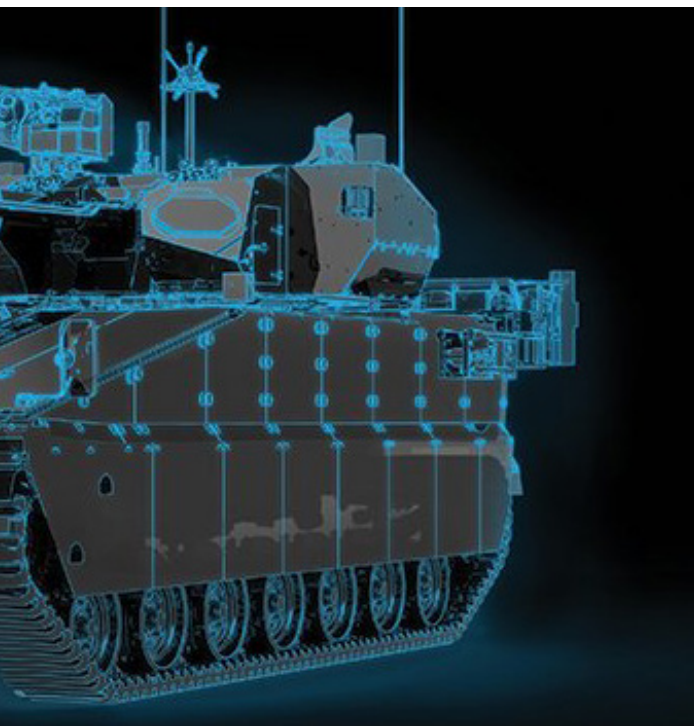
American Rheinmetall Vehicles displayed a large-scale model of its Lynx OMFV platform. The design is adapted

from the company's Lynx KF41 combat vehicle, said Michael Milner, director of business and development strategy for American Rheinmetall.

The platform's biggest point of departure from the KF41 is its remotely operated turret that allows for the vehicle to work with a two-person crew. The prototype leverages the modular open systems approach, or MOSA, architecture already fielded by the Lynx KF41, he added.

The company's concept also features an Allison Transmission that enables the vehicle to produce about 220 kilowatts of electricity, which gives it a "mild-hybrid capability," Milner said. Battery storage limitations prevent the concept from being completely hybrid-electric, he noted.

Oshkosh Defense also displayed a 2D rendering of its preliminary design, which incorporates South Korean-based Hanwha Defense's Redback



chassis and turrets built by Israel-based Rafael Advanced Defense Systems.

Having never built a combat vehicle before, it was crucial for Oshkosh to partner with experts from that arena while leveraging its experience building tactical wheeled vehicles, said Pat Williams, vice president and general manager of the company's Army and Marine Corps programs.

Other vendors chose to bring test vehicles to the show to better demonstrate specific elements of their

designs.

For example, BAE Systems brought its infantry vehicle "rolling lab" — the RB301. The test vehicle was equipped with a medium-caliber 30 mm turret built by the company's partner Elbit Systems of America, an electric vehicle architecture, and advanced situational awareness sensors and systems, said Jim Miller, senior director of business development at BAE. The RB301 is not BAE Systems' concept design, but rather a means to test potential capabilities, he explained.

General Dynamics Land Systems also rolled out a one-off test vehicle at AUSA featuring its next-generation electronic architecture called Katalyst, which has 360-degree situational awareness, obstacle avoidance, automation target prioritization and other advanced capabilities, according to the company.

The contractor also showcased terrain mapping and geospatial capabilities provided by its sister unit, General Dynamics Mission Systems, said Tim Reese, director of business development for U.S. operations at General Dynamics Land Systems.

GDLS is working with two California-based companies, AeroVironment and Applied Intuition, on the program. The demonstration vehicle featured a switchblade loitering munition drone and autonomous driving capabilities designed by each partner, respectively, Reese said.

After being the sole contractor to submit a bid in the Army's previous attempt to procure OMFV vehicles in 2019, Reese said GDLS is embracing

the service's new approach.

Meanwhile, the company received some notes from Coffman's team on its concept design that are already being considered for the next round of feedback, he said.

"There are some things we can work on that ... weren't 100 percent in line with the Army's requirements, but I think that's just the nature of this new technique they've come up with," Reese said. "I think anybody that says they have a design today ... that's ready to go is not listening."

Because the current design phase isn't a competition and each company was instead selected for a contract, Coffman noted how beneficial it is to be able to communicate with each firm individually.

"We can have iterative conversations with each industry partner — all five of them — and see where the trade space is to inform the eventual requirement that the chief of staff of the Army will eventually have to approve," he said.

The industry teams were given feedback and recommendations at AUSA, Coffman told reporters.

The ability to openly communicate with the government has helped ground vehicle newcomers Point Blank Enterprises refine its design before executives begin building physical prototypes, said Mark Edwards, the company's executive vice president of military sales and business development.

"We've been perfecting the design with the iterations going back and forth with the government," he said. "I would say that what we went in with in terms of the concept has been changing, but not dramatically."

The Indiana-based company is offering the Liberty platform which is designed with the Army's modular open systems approach in mind. It is a hybrid-electric concept that has a "tremendous" amount of exportable power, he added.

Because the manufacturer has no past experience building military vehicles, Edwards said the Army's new approach truly "opened the door" for them.

Other members of industry echoed Edwards' remarks. Praising the Army for embracing new ideas, Milner spoke of how American Rheinmetall struggled with the initial requirements set by the service, particularly being able to fit two vehicles on a C-17 aircraft in full combat configuration and ready for battle in 15 minutes.

Williams said he appreciated the Army's new take on vehicle acquisition, emphasizing that it allows a variety of participation from companies like Oshkosh that may not have immediate experience in developing combat vehicles.

"It gives [the service] the opportunity to provide multiple points of view and multiple solutions that they can then assess as they dial in what their requirements will eventually become," Williams said. **ND**

## COMMENTARY

# The Meanings of 'Attritable' And 'Expendable' BY STEW MAGNUSON

**T**hink of a typical family car or SUV and put an average price on it. How about a nice round number for the purposes of this article — \$25,000.

A typical American family doesn't have that kind of cash sitting around. Most have to finance the purchase.

Then there are those Americans who can tool around in high-end sports cars — the kind you see pulling up to casinos in James Bond movies.

The absolute lowest priced Lamborghini currently available runs about \$211,000, according to MotorTrend.

Spending that much on such a vehicle for the average American taxpayer is the stuff of fantasies.

Compare that to the price of a Joint Light Tactical Vehicle. The last time the government published an average price for the U.S. military's work-horse non-combat vehicle was 2015. It totaled \$365,000 back then, and it would be higher now adjusting for inflation.

The public's perception of the cost of military platforms may be increasingly relevant as the Pentagon continues on the path of swapping out manned for unmanned aircraft, ships, submarines and ground vehicles.

Military leaders and thinkers have been tossing the terms "low cost" and "attritable" around to describe some of the platforms, as new warfighting concepts take hold such as swarming drones, loyal wingman and manned-unmanned teaming.

The Mosaic Warfare concept in air warfare, for example, calls for multiple robotic jet fighters to accompany a piloted jet that serves as a quarterback. The robo-jets are stripped down air-

have five targets to defeat instead of one. Those four other jets are often described in PowerPoints presentations as "attritable," but what exactly does this word mean?

What does "low cost" mean to a public that has to make monthly payments on a \$25,000 car?

The first immediately observable thing about "attritable" is as one types it, Microsoft Word's spellcheck gives it a red underline, meaning it doesn't even recognize it. Going to Google, a search reveals few references to the word outside of these warfighting concepts.

This pegs "attritable" as pure military jargon.

Participants at defense conferences who see the word used in presentations no doubt understand it, but do members of Congress and the general public?

The root word, "attrition." Sure. Easily understood.

As an adjective, "attrit-able" is literally "able to undergo attrition."

One of the Google references noted that it is not synonymous with the word "disposable," but I have yet to hear a military leader at a presentation emphasize that point.

In fact, the word used in a cavalier way — and as described in these warfighting concepts — may easily be misunderstood as "disposable."

Further muddying the picture is another often used term by military leaders: "expendable." That is better understood as meaning something that can be lost without much impact.

So, what can be lost with little impact: a \$1 million aircraft, \$5 million, or \$20 million? What's the threshold?

And — getting back to that typical family car that costs \$25,000 — the fact that the military wants to populate the battlefield with platforms that cost about the same as the most expensive Lamborghini, about \$500,000, and upwards, might shock lawmakers and their constituents alike — especially if they believe such systems are perceived as throwaways.

Meanwhile, the public doesn't hear much about the "multiple dilemma"

concept for robotic systems. It isn't what's being sold. It's the cost of saving lives.

Moviegoers back in 2009 first saw this in action during the opening scene of the Academy Award-winning film, *The Hurt Locker*. They saw an explosive ordnance disposal robot travel down a dusty road in Iraq to disarm a roadside bomb while its operator stood back at a safe distance.

An off-the-shelf medium-sized EOD robot back then cost about \$125,000, not counting maintenance and sustainment costs. Calling them "disposable" was perfectly fine. No one ever questioned the cost-benefit of using EOD robots then, or now, because they saved lives and limbs. They were a triumph and a "good news" story for the military technology community.

But "taking warfighters out of harm's way" is just one of many reasons why military leaders want to proliferate robots enabled with artificial intelligence and machine learning on the battlefield.

Marine Corps Commandant Gen. David Berger foresees battlefields with a variety of robotic systems aiding troops.

He was asked at a media availability last year what "expendable" means and where the thresholds were for a robot that was low cost enough to be destroyed without anyone caring. He admitted that he didn't have all the answers yet, but this was the path the Corps was on.

"We're going to have to get comfortable with throwaway things," he said.

He used helicopters as an example. An unmanned low-cost rotary-wing aircraft could be used to transport supplies on the battlefield. He asked: How many sorties could it do in a cost-effective way before it would be considered expendable?

Some of the questions are "moral and ethical," he noted.

What if that low-cost unmanned helicopter was transporting casualties "MASH-style" when lives are at stake?

"If it's faster to get an unmanned platform there and pick you up, are we OK with that? Where we're headed in is an area where we haven't gone to before," Berger said.

Meanwhile, when it comes to explaining the direction the U.S. military is going with robotic systems to the public, leaders should take care to explain exactly what "attritable," "expendable," "disposable" and "low-cost" means. **ND**



craft that might serve only one function such as sensing or shooting, or even be a decoy meant to be targeted.

They would present multiple dilemmas for the enemy, who would

# Military Preparing for New Era of Explosive Ordnance Disposal BY JON HARPER

**C**OLUMBUS, Ga. — With the Iraq and Afghanistan Wars in the rearview mirror, the Defense Department is preparing for a new era of explosive ordnance disposal that will bring fresh challenges and require new technology solutions.

Improvised explosive devices planted by insurgents were one of the top threats during the post-9/11 conflicts. But now, the U.S. military is refocusing on neutralizing bombs and mines that it could face in future conflicts against more advanced adversaries such as China and Russia.

“We have a lot of great capabilities,” said Air Force Brig. Gen. William Kale, a member of the Pentagon’s EOD program board. However, “what’s good today is not good tomorrow, and there’s definitely a lot of areas where we need to get after it.”

“We need to find out what that new technology is and be able to exploit that technology to be effective for the near peer competition,” he said at the Future Force Capabilities Conference and Exhibition in Columbus, Georgia, hosted by the National Defense Industrial Association.

The military needs to be prepared for large-area clearance operations, officials say.

“We’re starting to get after this from a joint perspective,” said Air Force Senior Master Sgt. Cole Pasley, superintendent of the Defense Department’s joint EOD technology division. “A large area for [the Air Force] in our next wars will likely always be some sort of an airfield.

For the Marines, it could be a beach. For the Navy, a carrier. For the Army, a huge mass of land somewhere.”

The military is pursuing new technology to address these challenges.

A science-and-technology effort is underway to find a next-generation breacher to replace the legacy mine-clearing line charge. The concept calls for mounting payloads on robotic combat vehicles that can help defeat minefields by using sensors to detect hazards, launching payloads from a standoff distance, and employing guidance systems that can tailor payloads for precision or scalable effects.

“We need industry’s innovative

ideas, whether kinetic or non-kinetic, on what the next-generation breacher will look like and how the entire kill chain can be integrated,” said Army Col. Russ Hoff, project manager for close combat systems at the joint program office for armaments and ammunition.

Another large-area clearance challenge that officials are worried about is rapid airfield damage recovery, which could be required if U.S. air bases are hit by Chinese or Russian munitions.

In that scenario, EOD technicians and civil engineers would be expected to perform damage assessment, mitigate potentially thousands of explosive hazards, and repair extensive damage to the airfield — and do it all so quickly that aircraft could be launching from the runway again within eight hours of an enemy assault.

For the purposes of area denial, an adversary could drop thousands of submunitions that would have to be cleared. Additionally, penetrating munitions could create craters that would have to be repaired before resuming flight operations, noted Dr.

John Olive, an EOD expert at the Air Force Civil Engineering Center.

The Pentagon is putting resources toward addressing the challenge. The Air Force has invested more than \$4 billion into rapid airfield damage recovery capabilities, according to Olive, who said they are a “huge priority” for the service.

One such technology that officials have high hopes for is a directed energy system known as Radbo, which features a Parsons-made Zeus laser mounted on a mine-resistant ambush protected vehicle. It is intended to zap large numbers of explosive hazards from up to 300 meters away and neutralize them.

The Air Force has been testing a Radbo prototype at Tyndall Air Force Base, Florida. The first production model of the 15 currently under contract was slated to go to Nellis Air Force Base, Nevada, in November. Additional systems are to be deployed at other bases in the United States and overseas beginning in 2022, according to Olive.

Another capability in the works is



an armored front-end loader which is to be paired with a large clearance blade assembly and robotic applique to enable efficient removal of unexploded ordnance from airfield surfaces.

The clearance blade assembly — which was developed by Redstone Arsenal in Alabama — is about 4 inches thick, 16 feet wide and 4 feet tall. It was made with special durable material, Olive noted.

“It’s basically indestructible,” he said. “You can run it and it won’t miss a piece of ordnance.”

With a few of these systems, technicians could clear a 10,000-foot-long runway of explosive hazards in just a couple of hours, he said.

The Air Force plans to buy 86 systems, and the first tranche is already on contract with Caterpillar. They take about 15 to 18 months to build, Olive said. “We’re looking forward to getting those before too long.”

However, those technologies might have trouble addressing what officials say is currently the biggest capability gap within the rapid explosive hazard mitigation portfolio: SLAM. The acronym stands for subsurface locate and mitigate, and refers to finding and neutralizing underground threats.

Penetrating bombs could leave holes in an airfield that have to be cleared, including unexploded ordnance, Olive explained. “Right now, we don’t have a great rapid way to do that, let alone detect the penetrator to let an [EOD] operator know exactly what depth and how it’s orientated ... to rapidly mitigate it.”

Kale noted the military has been using handheld devices to detect and locate underground threats.

“That’s not going to be a good thing in the future, in particular with the larger munitions that our near-peer competitors are going to throw at us, and the potential of them getting buried under airfield pavements,” he said. “This is not something that I think will be hugely effective, and we need your help to ... figure out how to get after this,” he told members of industry.

What are some potential solutions?

“I would assume that eventually we could probably come up with some sort of unmanned aerial system that would have some sort of X-ray-like technology that can fly over an airfield and detect those things, and do so in a way that is precise,” Kale said. It would also be helpful if such a platform could identify the specific types of munitions that are present so that “if we do

have to send the EOD tech out there to get after it, they can do so knowing what they are dealing with,” he added.

Pasley highlighted another problem: current EOD capabilities for identifying and accessing subsurface munitions can cause additional damage to a runway after an enemy attack.

“As we start addressing this buried munition problem, how do I get access to some sort of an ordnance that’s beneath my commander’s runway without blowing numerous more holes into his or her runway and making that eight-hour [timeframe] ... just an unfeasible task to repair that, because my EOD team has gone out and created a dozen more holes looking for something?” he asked.

Kale said the military needs better tools for mitigating that type of threat.

“I would hopefully think that we could do that from a standoff position,” he said. Additionally, “we want to disable these munitions where they don’t have a huge second-order blast because we have to go in and repair those runways after and fly aircraft. ... There’s a lot of opportunity for industry to look at these things and provide” solutions.

Olive said there is “no doubt” the Defense Department is going to continue to invest research-and-development dollars to try to find better SLAM capabilities.

Pasley noted that at some point in the future, the hope is that rapid airfield damage recovery operations can be conducted autonomously.

Robotics and machine learning are going to be “huge on that mid- to long-term vision of where all this capability goes,” he said.

Maj. Ben Olsen, an EOD capabilities developer at Army Futures Command, noted that his service’s explosive ordnance disposal community already has three programs of record for robotic platforms: Common Robotic System-Individual, a small backpackable robot; Man-Transportable Robotic System Increment 2, a medium-sized platform that weighs a little over 100 pounds; and a larger platform known as the Common Robotic System-Heavy.

But the Army is also keeping an eye out for other technologies that could be useful, to include non-tracked platforms that may be less vulnerable to flipping over, he noted.

The service is looking at small drones that could scan areas that would be difficult for ground robots to reach, such as the top of a building

or the opposite side of a wall or other obstacles. The platforms could be used to look for explosive hazards and drop charges to neutralize them, he added.

“Having a small UAS capability ... is going to be extremely beneficial and very useful,” Olsen said.

The Army also plans to integrate multiple disruptors on its robotic platforms to provide additional stand-off capabilities for mitigating threats using percussion actuated non-electric rounds or other types of energetics, he noted.

Additionally, there is a requirement for extended range mesh networking to enhance communications between machines and EOD technicians.

“Looking at built-up cities, anybody who’s ever operated the robot knows that as soon as it starts turning the corner, you’re going to start losing comms,” Olsen said. To address the problem and extend their range, platforms need the ability to “drop repeater nodes as we go along,” he said.

For future increments of robots, the Army is looking at semi-autonomous features that would enable point-to-point navigation.

“As the team arrives, they can say, ‘Hey, I’m here, I need the robot to go to this location just by point and click,’ and the robot will choose its own path there — the best path possible — and make sure that it’s avoiding the obstacles,” Olsen said.

Machine learning and artificial intelligence could also enable robots to scan the surrounding environment while they are on the move and identify potential threats, he noted.

Pasley said moving away from the “one man, one bomb” model for explosive ordnance disposal will be key to increasing operational speed and keeping EOD technicians out of harm’s way in future operating environments.

“One, it’s time consuming, so we can’t do [the mission] within that established timeline. But two, you’re going to have attrition,” he said.

Leveraging unmanned systems and other emerging technologies will be critical, he noted.

“We took a lot of losses during OIF and OEF,” he added, referring to Operation Iraqi Freedom and Operation Enduring Freedom. “We want to try not to do that in this future fight, right? So the more things we can build and create more tools for the operators where they can either do [EOD] remotely or do it more safely, ... that’s where we want to go.” **ND**



# Marine Corps Deploys Robot For Underwater EOD BY MIKAYLA EASLEY

**A**n unmanned system is giving the Marine Corps eyes and arms to neutralize explosive threats underwater.

In September, Marine Corps Systems Command began fielding an explosive ordnance disposal remotely operated vehicle — a box-shaped robot that allows Marines to identify and neutralize explosive threats from a distance.

Designed by Strategic Robotic Systems Fusion of Redmond, Washington, the system is outfitted with high-definition video capabilities and an articulator arm, which decreases the risks posed during complex and tiring underwater operations, said Master Sgt. Matthew Jack-

son, a staff non-commissioned officer in charge of the 1st EOD Company's Littoral Explosive Ordnance Neutralization section.

"There's everything from hazards, dangers from currents, water temperature — [the platform] mitigates all this by being a robotic system that doesn't get hungry, doesn't get tired," Jackson said in an interview. "All you have to do is put batteries in it and then you can keep the man away from the minefield."

The robot can swim to depths of up to 1,000 feet and is equipped with both sound navigation and sonar sensors for increased situational awareness in low visibility underwater environments, he said.

Beyond disarming explosives,

Jackson said the system is useful in other potentially hostile or dangerous environments. For example, the robot could survey areas after natural disasters or investigate sunken vessels.

The platform also requires less training to operate compared to other unmanned underwater systems, according to the service.

"Instead of sending a Marine to a course for seven or eight weeks, it takes about four days to learn basic operations for successful employment," Jackson said.

The device is the first of the Littoral Explosive Ordnance Neutralization Family of Systems, a series of EOD systems to be fielded gradually by Marine Corps Systems Command in the next several years. The platforms will provide support in the underwater environment, "along with bringing communications topside from the underwater environment up and out to anywhere that we need to pipe the data," Jackson said. **ND**



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