Defense One

Battlefield 2050

How Today's Cutting-Edge Technologies Are Shaping the Future of Warfare

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Battle In the Machine Age

Inventor and futurist Ray Kurzweil predicted that between 2000 and 2025, humanity will experience more technological progress than was experienced during the entire 20th century, which, in turn, saw more than our species encountered during the previous millennium.

It's an incredibly optimistic projection – and one that humanity is on track to realize. Consider that even a first-generation Apple iPhone costs 10 times less, weighs nearly 100 times less, and is 100 times more capable than the best desktop computers of 25 years before. This is the story of Moore's Law, radically reshaping the world through exponential improvements in information technology. It's no wonder new gadgets, breakthroughs, internet-based services seem to emerge daily.

Among these trends: we stand on the threshold of a new era of capability in artificial intelligence and autonomy. The machines we create next will resemble us—and surpass us—in ways that would have seemed impossible a generation ago.

It's an exciting time to be a consumer or producer of technology. But for the United States military, charged with predicting and defending against strategic surprise, the rate of technological advancement heralds both promise and danger. The power to invent and harness technologies of global consequence has migrated from nation-states to corporations to, increasingly, individuals.

In this volume, we look at how the Defense Department and the wider national security community are preparing to defend the nation in the age of rapid technological evolution against increasingly capable adversaries and threats.

Patrick Tucker
Technology Editor
Defense One

When Robots Start Conflicts

An Army-sponsored workshop on the future of conflict explores how artificial intelligence will shape the national security environment in the decades ahead.

BY PATRICK TUCKER

UBISOFT

In April, thought leaders from the Defense Department, the U.S. Army Research Lab, the Institute for Defense Analysis, and national security thinkers across academia met for a two-week workshop on the next three and a half decades of war. The report they recently produced reads like a Tolkien-esque saga set in the future, a fascinating mashup of futuristic concepts, far-off capabilities, and emergent technologies that play off one another, competing and evolving at hyperspeed. Among the report's most significant conclusions: faster "battle rhythm" will increasingly push human beings out of the decision-making loop. The future of war belongs to the bots.

Keep in mind that the authors of the report ("Visualizing the Tactical Ground Battlefield in the Year 2050") note that their views "do not reflect positions or views of their employers or any organizations with which they are affiliated." It's easy to see why. Many of them diverge considerably from standard military talking points.

Consider the use of armed drones. Even as military leaders push to increase autonomy, they insist that a human will always decide when and

whether to pull the trigger. (Robots don't kill you, people do.) The report foresees a slightly different future: humans won't be entirely cut out of lethal engagements, but they'll play umpire, rather than pitcher. It's the difference between being "in the loop," or simply "on the loop" as an observer.

Those people, too, will be getting a technological upgrade. "The battlefield of the future will be populated by fewer humans, but these humans would be physically and mentally augmented with enhanced capabilities that improve their ability to sense their environment, make sense of their

> **The presence of super humans on the battlefield in the 2050 timeframe is highly likely because the various components needed . . . already exist and are undergoing rapid evolution.**
>
> FROM THE REPORT "VISUALIZING THE TACTICAL GROUND BATTLEFIELD IN THE YEAR 2050"

"The difference being that in the former, human decisions are a required step in a process and thus humans are exercising positive control; while in the latter, humans can only observe the behaviors that are taking place (and in some cases the decisions that have been made and the reasons why), but they can only act after the fact or in anticipation of expected behaviors," says the report, which adds that top-down human control will be replaced by "large-scale self-organization" among swarming robots and human teammates.

environment, and interact with one another, as well as with 'unenhanced humans,' automated processes, and machines of various kinds," says the report.

What exactly constitutes an enhanced human is a matter of technical dispute. After all, night-vision goggles represent a type of enhancement, as does armor. The military has no problem discussing future plans in those areas, but what the workshop participants anticipate goes well beyond flak jackets and gear.

> **We won't experience 100 years of progress in the 21st century — it will be more like 20,000 years of progress (at today's rate).**
>
> RAY KURZWEIL IN HIS ESSAY "THE LAW OF ACCELERATING RETURNS"

Here's another area where the workshop's military participants predict a future that conflicts with today's stated military policy. Talk to officials at the Defense Advanced Research Projects Agency, and they'll tell you that soldier enhancement involving surgery or genetic manipulation is not an area of active interest. Certainly the prospect brings up ethical concerns and it may pose a number of legal ones as well. As bioethicist Patrick Lin has observed, a permanently enhanced soldier might constitute a new type of weapon that conflicts with international law. Regardless, the military has dabbled in the field, as Noah Shactman revealed in this 2007 article for *Wired*.

The report envisions enhancement taking several robotic steps forward. "To enable humans to partner effectively with robots, human team members will be enhanced in a variety of ways. These super humans will feature exoskeletons, possess a variety of implants, and have seamless access to sensing and cognitive enhancements. They may also be the result of genetic engineering. The net result is that they will have enhanced physical capabilities, senses, and cognitive powers. The presence of super humans on the battlefield in the 2050 timeframe is highly likely because the various components needed to enable this development already exist and are undergoing rapid evolution," says the report.

Sensors will be "ubiquitous" and that will include "sensors on and inside humans." But every enhancement introduces new vulnerabilities and attack vectors as well. The report imagines that all of that data could enable enemy forces to monitor U.S. troops' biophysical signals and possibly even their brain states or decision-making abilities. The report calls this "cognitive modeling," and notes that this creates great risks and opportunities. "In addition to having the information available to vastly improve individual cognitive modeling, such models offer the opportunity to disrupt adversary organizations and operations in a cost-effective manner," says the report.

All this recalls the phrase "radical evolution," a technofuturist term that's key to understanding the report's central themes and assumptions. It's an idea borrowed from inventor and futurist Ray Kurzweil, who is largely credited with the observation that technological progress in information technology is not linear but exponential. That means that every leap in technological innovation begets two, which begets four, which begets eight, etc. When you arrive at the point where you are multiplying very large numbers by other very large numbers, the effect is a rapid explosion in technological capability. Kurzweil argues that computers' rapid decrease in size and cost has brought us to precisely that moment in history. In his seminal 2001 essay, he says that "we won't experience 100 years of progress in the 21st century — it will be more like 20,000 years of progress (at today's rate)."

Imaginary or not, it's that future explored in the workshop report: a future in which humanity can no longer control the rate or the effects of technological progress, at least not in the way that we attempt to do so today. That may be far more threatening than any particular enemy. in enormous, fragmentary and sometimes contradictory literatures and databases, so no single human can understand a really complicated system in its entirety. Computers must help us."

USAF Master Sgt. Jennifer Oberg explains the features of a ground control station to Staff Sgt. Jason Avera and Senior Airman Raquel Martinez.

Laser-Armed Drones Will Arrive by 2020

Remotely piloted vehicles are about to merge with next generation direct-energy weapons.

BY PATRICK TUCKER

Flying military robots armed with high-energy lasers? It's a future that is exciting, terrifying — and perhaps just two years away.

General Atomics Aeronautical Systems, Inc., or GA-ASI, the San Diego-based company that makes the Predator and Reaper drones, is undertaking a privately funded study to integrate a 150-kilowatt solid-state laser onto its Avenger (née Predator-C) drone. If the company succeeds, a drone with a high-energy laser will be a reality at some point in 2017, company executives told *Defense One*.

"We're funded right now to develop a laser module compatible with the aircraft and study putting it on the Avenger," Michael Perry, Vice President for Mission Systems at GA-ASI, told *Defense One*. "We hope to be funded to do that," he said.

The company is far better known for its MQ-1s and MQ-9s — the backbones of the Pentagon's drone strike force — than for its work with lasers. But in June, the company delivered a 150-kilowatt liquid laser to the Pentagon for extensive testing at the White Sands Missile Range in New Mexico. For

U.S. AIR FORCE PHOTO BY VAL GEMPIS

comparison, the 30 kw laser (output) currently on the Ponce in the Persian Gulf has more than enough output to destroy an enemy drone or blow a hole in a boat. In addition to five times the power, the increase in beam quality provides higher lethality than the system on the Ponce.

> **Before you spend any money on a laser you better darn well show that you can acquire, ID, and track the objects of interest so that you could put a laser on them.**
>
> MICHAEL PERRY, VICE PRESIDENT FOR MISSION SYSTEMS AT GA-ASI

Bringing these two technologies together involves a lot more than strapping a laser cannon under the drone's wings. Hitting a target with a laser mounted on a vibrating platform moving quickly through air laden with dust and water vapor is tougher than launching a Hellfire at a moving vehicle.

"Before you spend any money on a laser you better darn well show that you can acquire, ID, and track the objects of interest so that you could put a laser on them," said Perry. "You have to be able to compensate for aero-optic distortion."

After you solve the targeting problem, the laws of physics present their own challenges. Lasers in the 150-kilowatt range are big, heavy, and power-hungry. Shrinking size-weight-and-power, or SWAP, scores to workable levels remains the biggest obstacle to arming aircraft with lasers. Weight alone will likely bar 150-kw lasers from the MQ-1; engineers have set their sights on building weapons for the Predator-C and its 3,000-pound payload capacity.

GA-ASI has designed a power system for drone lasers that works almost like a hybrid car, the non-plugin kind. "You use the aircraft power to charge an intermediate storage system, and then that runs the laser when it's doing laser shots," said Perry.

He said the current design can get off five or six shots before needing to recharge, which happens in the air, over the course of several minutes.

"If there's enough time between shots you never have to recharge at all. It depends on how much time you have to re-target," said Perry.

While GA-ASI is underwriting the current research, the military is keen get lasers onto aircraft. The Missile Defense Agency, or MDA, has funded research on tracking and targeting capabilities for drones.

"The work that we're doing with the General Atomics Reaper and the work that we did with the Boeing Phantom Eye starts to show it can be done, in terms of these long-range sensing and tracking capabilities that we need," MDA director Vice Adm. James Syring told reporters last month.

"We've been funded for years to develop high-energy laser systems. The maturity of our approach

is further along than others because we've been working on it for a long time, for 15 years. [high-energy laser research is] coming out of the laboratory in a leakage-type way," GA-ASI's Perry said.

The company has another advantage over its competitors in the race to build laser-armed drones: they make the ground control stations, including the next generation ground control station that the Pentagon hopes will improve the dreary job of drone operation. This gives them an advantage when it comes to creating the virtual gunsights and trigger for the laser.

If GA-ASI — or someone else — succeeds in making lasers into a practical wing-mounted weapon, it will usher in a new battlefield role for medium-sized tactical drones. Perry imagines a completely different mission than simple loitering and striking targets, one more geared toward protecting U.S. forces from enemies that are firing on them.

"You would have a capability for close-air support, aircraft defense, counter-air, and even some types of non-lethal actions. You would really be expanding the mission space…The focus at this point is principally defensive missions," he said.

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> MICHAEL PERRY, VICE PRESIDENT FOR MISSION SYSTEMS AT GA-ASI

"What we've shown is that the laser control is compatible with the new ground station," he said. "From a hardware standpoint, all the hardware exists to control it inside the station."

However, Perry says that laser drones will require an entirely new software load, and that's not all: "You'll have a whole new concept of operations. Completely new training will be required," he said.

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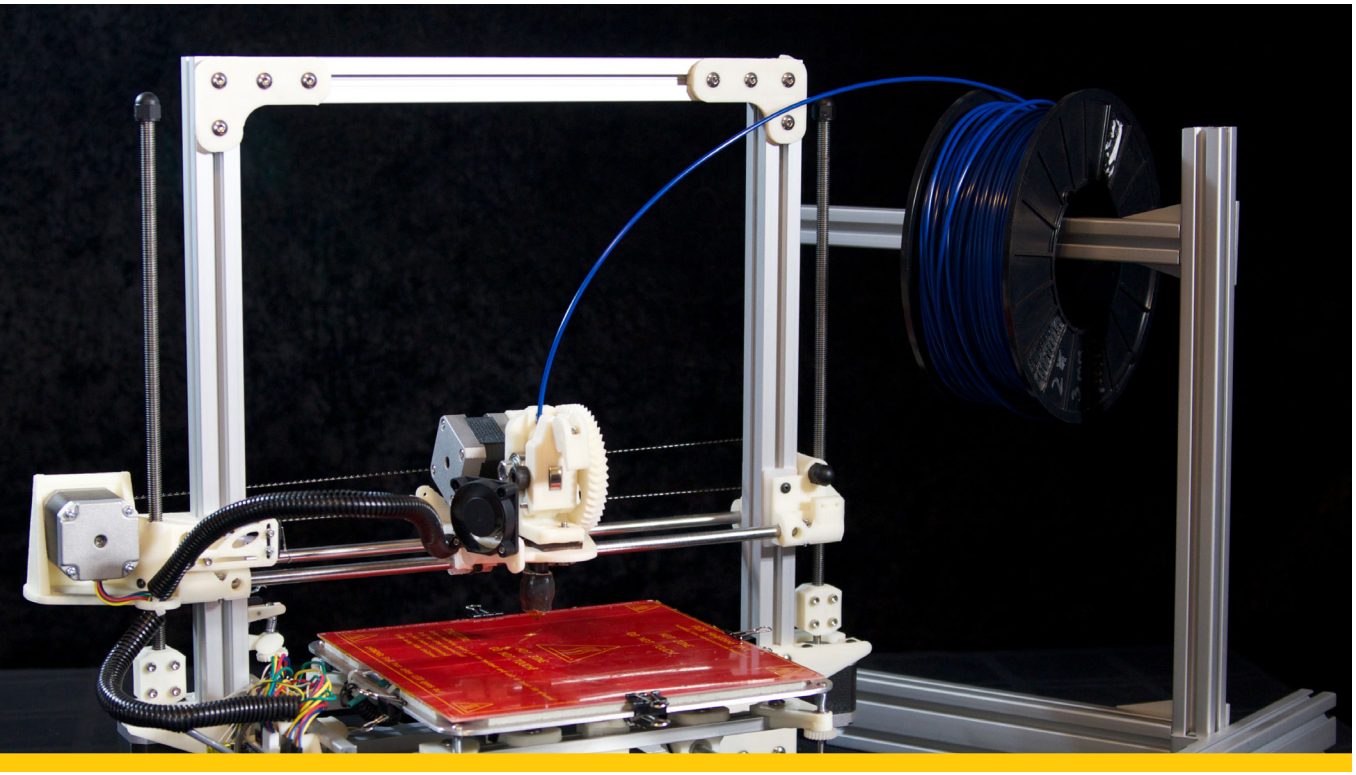
How 3-D Printing Will Revolutionize the Army

Additive manufacturing has hit a speed bump in mass commercialization. But it could revolutionize life on remote military bases.

BY PATRICK TUCKER



If you go by the Hype Cycle — Gartner's annual tech-buzz assessment — then consumer 3D printing is about to tumble from the "peak of inflated expectations" into the "trough of disillusionment," part of the coming five- to 10-year slog to the practical applications that await atop the "plateau of productivity." But Larry "L.J." Holmes, the principal investigator for materials and technology development in additive manufacturing at the U.S. Army Research Laboratory (ARL), isn't waiting around for that.

In a presentation last month at the Intelligence and National Security Alliance summit, Holmes sketched out a variety of potential uses for 3D printing for the military, ranging from intelligence to communications to terraforming the battlefield. Here are a few highlights.

Plastic antennas

As the electromagnetic spectrum gets packed tighter with cell phones, radios, and other tech, keeping comms up in the war zone will increasingly require more highly specialized

antennas and other equipment. Rather than trucking or airlifting in the gear and replacement parts, Holmes said, troops might print dielectric antennas from nonconductive materials like ceramic or plastic. Recent research out of the University of Texas at El Paso involved making a dielectric antenna from plastic.

> **Imagine if I have a helmet. You can put it in this [3D printing] machine, tell this machine to scan it, then go back and say, 'Oh, this mission requires some communication device that I don't have.'**
>
> LARRY HOLMES, PRINCIPAL INVESTIGATOR AT THE U.S. ARMY RESEARCH LABORATORY

"It works just like a copper patch," Holmes explained. "It works by the dielectrics that are internal to the structure, solely because of the shapes you can make through 3D printing." In other words, it's a not a replacement part per se, but an entirely new type of electronic communication that uses geometry to compensate for a lack of atomic conductivity in the material.

Such 3D-printed antennas made from plastic could "help us reduce logistics and the logistics trail but also help with signature management," he told the crowd, in other words, helping a group of soldiers avoid detection when communicating.

Hidden bugs and spy cameras

Multi-material printing, which allows printed objects to incorporate working electronics, is in its infancy. But as the field develops beyond expensive toys, it will open up a host of potential applications for the military, including intelligence gathering.

Example: a milk carton with a sensor — resistor, capacitors, etc. — manufactured into the cap. Of course, real-time assessment of spoiled milk isn't really a military concern, but this kind of thing could aid intelligence gathering in hard-to-reach places, or from stand-off distances. Everyday objects with the capacity to record voices or take pictures could do some of the work of flesh-and-blood intelligence assets.

Breakthroughs in multi-material 3D printing will also help make electronics smaller, or better shaped, for tight spaces like airplane wings, combat boots, etc.

Biometric communication

What does 3D printing have to do with brain-to-brain communication? Potentially, a lot.

The Army has been funding cutting-edge research in brain-to-computer communications for years. In 2008, it sent a $4 million grant to researchers at UC Irvine, the University of Maryland, and Carnegie Mellon University to study "synthetic telepathy" via EEG sensor data. No, a sensor can't hear your thoughts and understand them as intelligible language. But they can be sensitive enough can pick up your brain's electromagnetic pulses. Think about raising your arm, or respond to a visual cue, and you create an alpha wave between 8 and 12 hertz.

Those signals can, in theory, be translated into a crude form of speech, like Morse Code. Those signals can then be conveyed to someone else, through a technique called transcranial magnetic stimulation.

Last year, a team of Spanish researchers demonstrated brain-to-brain communication via EEG, so a real-world proof exists. But getting a fully functional EEG into a helmet isn't easy. After all, helmets are designed to protect the head from force, not send brain scans. This is where 3D printing comes in, with its unique ability to produce otherwise-impossible shapes and designs.

"Imagine if I have a helmet. You can put it in this [3D printing] machine, tell this machine to scan it, then go back and say, 'Oh, this mission requires some communication device that I don't have," Holmes said during his talk. "I can tell [the printer] to rebuild this helmet and incorporate the device into this helmet as I'm building it, antennas, structured sensors. Whatever."

> **[3D printing] isn't officially an Army goal yet.**
>
> LARRY HOLMES, PRINCIPAL INVESTIGATOR AT THE U.S. ARMY RESEARCH LABORATORY

In his presentation, Holmes described how materials that showed various levels of resistance to hand movement could also serve as a means of biometric communication.

"We know that soldiers do a lot of communication with their hands," he said "With this technology, instead of having to move their entire upper body for communication," they could use their hands and perhaps avoid detection.

Robots that build beachheads from found objects

What if you could send robots ahead of your troops to set up bases on hostile territory?

"This isn't officially an Army goal yet," Holmes said of a 3D printing project of his own conception called forward operations for reconnaissance and terraforming, or FORT.

It's a concept that amounts to invasion via MakerBot. Here's how he described it: "We drop a black box in a place where you wouldn't want to send your soldiers. It could be a biohazard area, a radioactive area, dense jungle, the top of a mountain, a dangerous extreme environment, etc. Through a suite of sensors, this manufacturing unit senses what's around it, what minerals are in the sand, and what trees are around it. It then prints robots to go collect those materials, to collect sap from trees, mud and straw to make bricks. These robots bring those materials back."

The box uses the materials to build whatever you need: a containment unit, a helicopter pad on the side of a mountain…That's where technology is pushing us in the future," Holmes said.

He acknowledged that figuring out how to program a series of machines—robots in various forms—to achieve that goal is a decades-away ambition. But "the manufacturing, data and sensing technologies already exist," he says.

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Holmes isn't the only 3D printing fan dreaming of self-replicating robots conquering new, hostile territory. FORT bears a lot in common with a concept called Luna Ring from the Japanese construction company Shimizu. To harness solar power from space – where it can be gathered ten times more efficiently than on Earth –robots would travel to the moon to build more robots and solar panels and other pieces of equipment from lunar dirt.

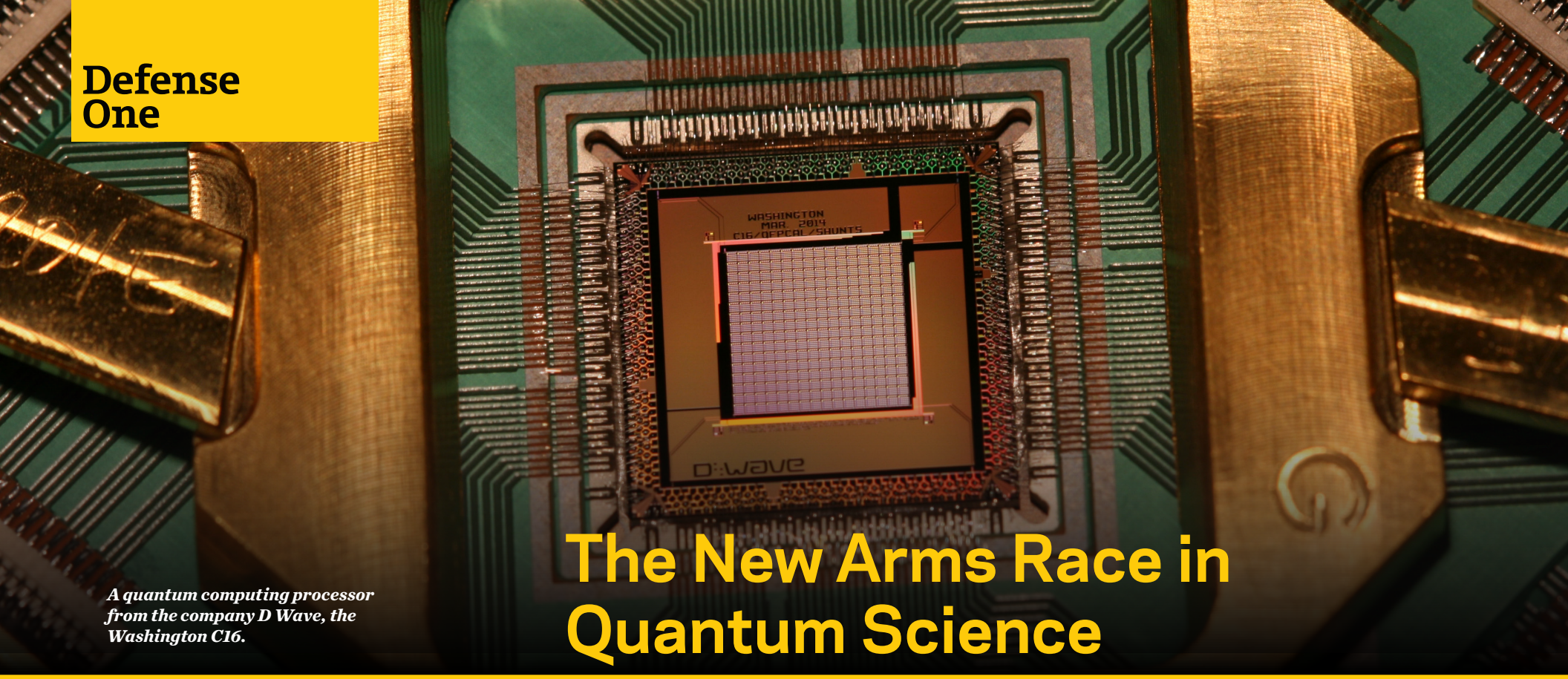
Advanced robotics for additive manufacturing is also an area that the Defense Advanced Research Projects Agency has looked at through a program called Magnetically Actuated Micro-Robots for Advanced Manipulation Applications.

Of course, these sorts of projects are decades away, and the trough of disillusionment looms near. While 3D printing for rapid prototyping has been around for more than a decade, it was only last year that the Navy permanently installed a 3D printer on a ship for the first time. The printer aboard the USS Essex amphibious warship was used not to building replacement parts but to make scale models and syringe caps.

Printing objects that can actually match military specifications is a big hurdle. Holmes says this is one reason why some of the most fertile ground for military 3D experiments will be in the special operations community, which can work around some of the bureaucracy of military certification. The Army's Rapid equipment force already owns five 3D printing stations, two of which were sent to Afghanistan in 2012 to print replacement parts.

It's also an issue of money and politics. 3D printing will be revolutionizing broad areas of logistics and supply chain management long before black-box factories can be deployed to hostile zones to ready the ground for invasion. If additive manufacturing is going to save the military and taxpayers billions, it will do so at the of cost of billions in lost revenue to suppliers. If a part can be printed for pennies at the site of use that will replace something that costs thousands, then it falls on the maker of the more expensive part to defend the high price tag – which they may do by blasting the integrity or structural soundness or design security of 3D printed parts.

The trough of disillusionment can be both deep and wide.



A quantum computing processor from the company D Wave, the Washington C16.

The New Arms Race in Quantum Science

The quintessential, forever "emerging" technology remains full of promise and mystery. Can you spot hype even when its subatomic?

BY PATRICK TUCKER

An assortment of super powers awaits the superpower that harnesses quantum science: unhackable communications, radars that see underground, supercomputers that make today's biggest machines look like first-generation Ataris. But which of those goals are achievable in the near future, and at what cost?

Earlier this summer, the Pentagon announced a $45 million research effort into quantum networking. Meanwhile, China hopes to complete construction of the world's largest quantum communication network and become the first nation to put a quantum communications satellite into orbit. But other military-funded research has suggested that quantum comms and cryptography may prove too complicated to warrant the effort, while quantum computing will remain out of reach for a decade or more. (Some argue that's being very optimistic.)

All of this power, and all of this hype, emerges

COURTESY PHOTO D WAVE

> **Much like autonomy, quantum sciences is an area that could yield fundamental changes in military capabilities.**
>
> FRANK KENDALL, DEFENSE UNDERSECRETARY

from a source almost unfathomably small: atomic and subatomic particles that behave differently than larger objects, especially at very cold temperatures. It's enormously difficult even to study quantum objects; simply observing them generally changes their behavior.

The Holy Grail of applied quantum science is quantum computation, which is as different from regular computers as humans are from jellyfish. Whereas conventional computing uses electrical impulses running through transistors to manipulate bits, or binary values of one or zero, quantum machines track the strange behavior of ultracold atoms that can exist in two states at once — a one, a zero, or both. If you've got two qubits in the same so-called superposition, you have what's called an entanglement gate. They're atomically linked even if they're miles apart. And this opens up the possibility of massive parallel calculating. What would you use that for? Think about cracking a code: you try one combination after another after another. But if you can try all the possible combos at once, you arrive at the solution instantly.

"Much like autonomy, quantum sciences is an area that could yield fundamental changes in military capabilities," Defense Undersecretary Frank Kendall said at a Defense Department Lab day in June. "Examples include non-GPS [position, navigation, and timing], remote detection of submarines, remote mapping of tunnels and underground facilities … secure wireless communications and many others."

Last November, the government of China announced two ambitious goals: the construction of a 1,240-mile quantum computer network stretching from Beijing to Shanghai, set to go live in 2016; and the launch of a quantum communications satellite. As of February, both projects were on track, according to Wang Jianyu, deputy director of the Chinese Academy of Science's (CAS) Shanghai branch, who spoke at a conference.

In June, U.S. Deputy Defense Secretary Robert Work announced a $45 million quantum science research effort that would bring together the Air Force, Army, and Navy research labs to create a scalable quantum network with memory — on in which a quantum state is maintained without a loss of coherence. "This team is trying to figure out how to encrypt and then transmit information across long-range military networks for the war-fighter in a provably secure and robust fashion," said Work. Such a network, which would allow quantum data to flow between physically separate systems, could support further research on quantum computing and quantum cryptography.

The United States does about one-quarter of the research and development in quantum science right now, at least as measured by articles in scientific journals, says Werner J.A. Dahm, who chairs the Air Force's Scientific Advisory Board. Dahm's board recently wrapped up a study of the field and its potential. Among its findings: some quantum-enabled tools may not be enough of an improvement over current methods to be worth the difficulty of developing them.

One potentially over-hyped area of investment is quantum encryption. It works like regular key distribution, with sender and receiver able to see the message only after they have exchanged a secret cryptographic key. But unlike some cryptographic solutions, no third party can

penetrate it without being detected. Because subatomic particles change when they are viewed, any attempt to intercept the message would corrupt it in a conspicuous way, allowing sender and receiver to know immediately, and with certainty, that the message had been compromised.

"Rather remarkably, the study found that the Air Force has other alternatives for enhancing security of communications that don't have as much of a complexity burden associated with them," Dahm told reporters recently. "Most of what the study saw in the quantum area with regard to communications, the Air Force has equally good or better alternatives with other approaches."

But other areas are more promising. In the near term, Dahm said, the most important thing quantum science can do for the Air Force is help it leave behind the expensive and aging Global Positioning System.

"These quantum navigation systems can allow very, very high accuracy and they can't be jammed," he said. "The drift rates are much lower than traditional [Inertial Measurement Units] have. That gives the Air Force very important utility for operating in a GPS-denied environment."

Such positioning systems "are making remarkable progress and could be brought to a level of maturity that they would be valuable to the Air Force at a time scale that's of interest to the Air Force. It's not 30 or 50 years out," he said.

Indeed, prototype quantum navigation and timing systems already exist, but they're too large for many airplanes, missiles, and drones. That's because they take advantage of the behaviors of atoms when they're at their lowest level of energy, a state achievable only at incredibly cold temperatures — in some cases, a billion times colder than outer space. Cooling atoms to those depths requires lasers and energy. "It's now a matter of shrinking down, and the study actually recommends the Air Force take the lead on that and invest, at a modest level, in miniaturizing these kinds of systems," Dahm said.

> **These quantum navigation systems can allow very, very high accuracy and they can't be jammed.**
>
> WERNER J.A. DAHM, CHAIRMAN OF THE AIR FORCE'S SCIENTIFIC ADVISORY BOARD

Similarly, large quantum-enabled sensors already exist for looking underground. Oil and gas companies use quantum sensing to map subterranean cavities and hydrocarbon deposits. Very small changes in mass composition can have gravitational effects, far too subtle for

today's instruments to sense, but detectable at the quantum level. If such sensors could be made smaller and better, militaries might use them to pinpoint underground bunkers — or spot enemy submarines. But gravitational sensing for the military will be limited by how close sensors can get to their potential targets, Dahm said.

> **Even if you had a quantum computer existing today, you can't run regular software on a quantum computer. It doesn't work that way.**
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> WERNER J.A. DAHM, CHAIRMAN OF THE AIR FORCE'S SCIENTIFIC ADVISORY BOARD

The government has been funding quantum computer research for more than a decade, primarily for code-breaking. Last year, the *Washington Post* reported that the NSA was spending $80 million on a program called Penetrating Hard Targets to build a quantum system to crack the world's toughest encryption standards.

But code-breaking isn't the only place massive parallel-processing could be useful. "There are lots of Air Force problems to which quantum computing could be applied," said Dahm. "Think about an aircraft and trying to compute…a signature in the [radio frequency] domain, let's say. That is a massive computational problem. We throw large amounts of traditional computing power at those types of problems. If we could do that with a quantum computer you would be able to get it to a level of precision where you almost wouldn't need a test range."

But the barriers to real, provable, and practical quantum computing remain seemingly insurmountable. Even as quantum computing companies such as D-Wave claim to have achieved 512-qubit entanglement, the question of how to even to write code for a quantum computer remains a topic mostly of mystery.

"While the hardware side of quantum computing has made substantial progress, even if you had a quantum computer existing today, you can't run regular software on a quantum computer. It doesn't work that way. A quantum computer is not just a regular computer. It's fundamentally different. Forget the software; the algorithms themselves on which the software is based have to be completely different," said Dahm.

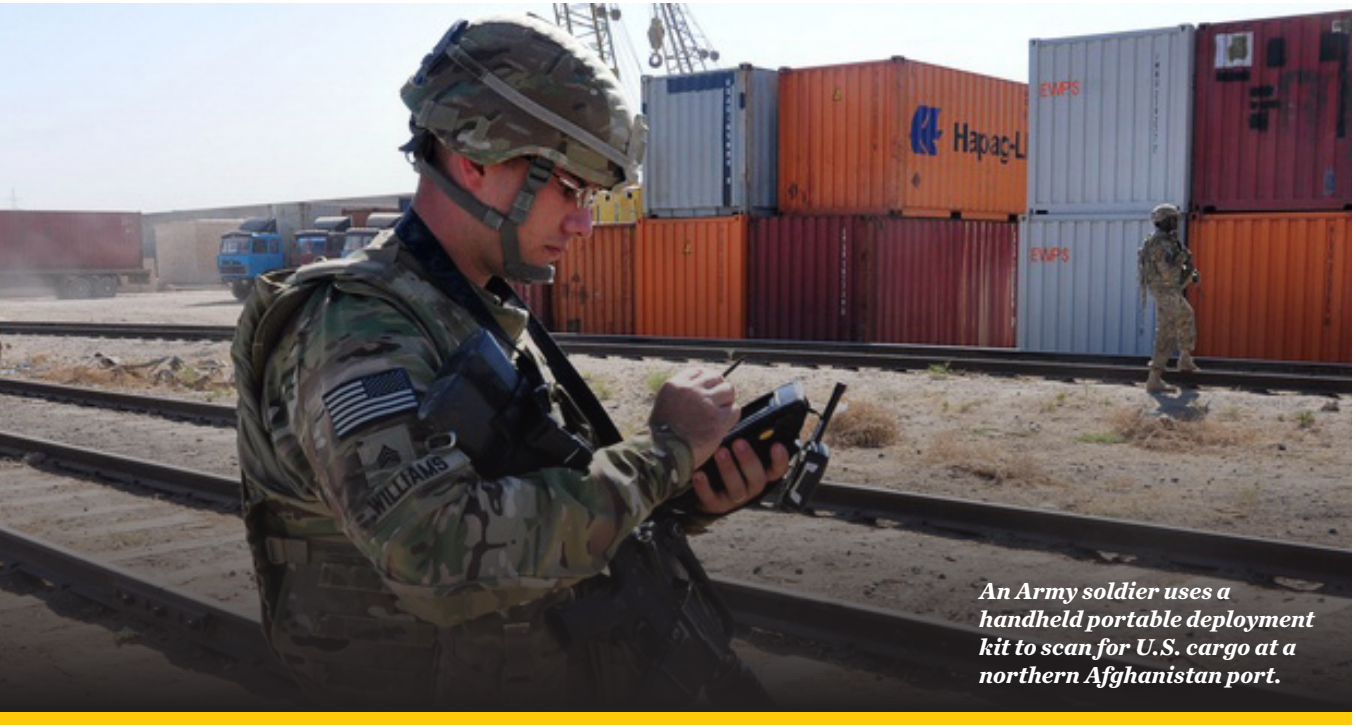
It's an area replete with promise, but little hope of near-term payoff. The Air Force science board study recommends "a modest, continued effort with a focus on the software rather than the hardware."

Even with world powers in the running, then, the race to harness quantum science will likely be a slow and steady one.

Beaming Power to Tomorrow's Battlefield, from Space?

Power at the front lines remains a difficult and dangerous challenge. Nascent breakthroughs in wireless power beaming through Wi-Fi could make a decisive difference on future battlefields.

BY PATRICK TUCKER



An Army soldier uses a handheld portable deployment kit to scan for U.S. cargo at a northern Afghanistan port.

HUSSEIN MALLA/AP

Dismounted soldiers and Marines often carry upwards of 100 pounds of gear, much of it power-hungry radios and night-vision goggles and sensors (like these tiny drones). Each requires batteries and extra batteries — and that makes the prospect of delivering electricity over a Wi-Fi signal very attractive indeed.

In May, researchers from the University of Washington unveiled a paper, "Powering the Next Billion Devices With Wi-Fi," that describes how to power a small camera with a Wi-Fi signal. In essence, the camera's 2.4-GHz antenna becomes an energy harvester that transforms radio frequency signals into DC power. Unlike some other ambient power schemes, this one doesn't interfere with the functioning of the router. (WIRED took note, declaring "Wi-Fi to power your gadgets is closer than you think," and then walked back expectations with "Wi-FI charging is real, but probably won't charge your iPhone.")

But is this breakthrough relevant for the men and

women who lug hot and heavy batteries across mountaintops in places like Afghanistan?

Wi-Fi power has "any number of applications" on the battlefield, said Paul Roege, a retired Army colonel who also served as chief of the Army Operational Energy Office. Those include "inductive charging pads in a vehicle seat that could recharge soldier batteries on the ride to battle to a laser beaming power from an aerostat to a small patrol, either moving or stopped." Over the last few years, he said, he has encouraged the Army to explore wireless energy for a variety of uses. "The Army actually has it on their screen today," he said.

The amount of power that Vamsi Talla and his UW colleagues demonstrate in their paper might be enough for a wide variety of devices. "For example, if you have a bunch of sensors that could be arrayed near a hotspot, you can expand the idea a bit by having a battery or capacitor that charges up over time for use during the occasional powered activity — picture-taking, measurement, or even transmission," said Roege. He added that there were some big limitations, including proximity to the hotspot. They might also power very small LED lights, of the sort that the Air Force Research Laboratory is implanting into gloves as part of the Batman program. But it's not going to power your drone-killing laser — at least not yet.

The Past and Future of Wireless Power Beaming

The idea of beaming power from an aerostat — a big, tethered drone blimp — is not that far-fetched. On June 5, 1975, the NASA Jet Propulsion Laboratory used microwaves to transmit 34 kilowatts of power some 1.5 kilometers. Two years later, the Department of Energy and NASA began an ambitious research initiative to explore beaming power from space to Earth. It's 10 times more efficient to generate solar power in space, free of interference from clouds, ozone, and airborne particles. But much of that surplus is lost in the effort to get the energy to the ground.

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WATTS OF ENERGY THAT FLOW CONTINUOUSLY FROM THE SUN TO THE LUNAR SURFACE

One of the more interesting space-based power schemes to emerge lately, the LUNA RING proposal from Japanese construction company Shimizu, involves sending robots to the moon to construct solar panels around the lunar equator from moon dirt. The hope was to harness the 13,000 trillion watts (terawatts) of energy that flows continuously from the sun to the lunar surface — some 650 times the amount that all human civilization needs to sustain economic growth. The collected energy would be beamed from the lunar surface via microwave and laser to satellites and finally to power receiving stations at sea. It is—to say the least—a lofty notion.

The Silicon Valley rush to space could push space-based power from fiction to fact in coming years. In April, SpaceX founder and Silicon Valley megafauna Elon Musk filed a petition with the FCC to orbit

4,000 mini satellites that would beam Internet signals to Earth. It's not much of a leap to think that such a constellation might some day double as power stations.

Back on Earth, Wi-Fi as a battlefield power source remains at least several tweaks away from practicality, says Roege. For instance, most wireless routers send out signals in all directions. That's ideal for a home or office where lots of devices may be scattered about. But for an environment with fewer devices, focusing the Wi-Fi signal through a series of directional antennas makes more sense, according to Roege. "The [Talla] article at hand speaks to common existing Wi-Fi technology. Imagine using a dynamic directional antenna that tracks the soldier's antenna and concentrates its radiatiave power on that location. You could deliver much more power, use less transmitting power, and be harder to detect," he says.

Another key will be making the devices much more power-efficient. "Radio transmission currently takes the lion's share of soldier power — so, try to minimize bits of information being sent — or create a passive communicator that passes information by virtue of selective absorption of the RF energy in the Wi-Fi signal," Roege suggests.

But Roege believes these are just bumps on the road to an unwired world. "The power/Wi-Fi concept not only will soon be available for soldiers, but will become common to hotspots in the civilian world," he said.

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>
> PAUL ROEGE, RETIRED ARMY COLONEL

About the Author

PATRICK TUCKER

Patrick Tucker is technology editor for *Defense One*. He's also the author of *The Naked Future: What Happens in a World That Anticipates Your Every Move?* (Current, 2014). Previously, Tucker was deputy editor for *The Futurist* for nine years. Tucker has written about emerging technology in *Slate*, *The Sun*, *MIT Technology Review*, *Wilson Quarterly*, and elsewhere.