Fueling the future

The U.S. Army is tapping various electric and electronic power-supply technologies for next-generation Future Combat Systems soldiers and vehicles.

BY COURTNEY E. HOWARD

"The best way to predict the future is to invent it," remarked pioneering computer scientist Alan Kay more than three decades ago.

The parties involved in the Future Combat Systems (FCS) program—including the U.S. Army, the Defense Advanced Research Projects Agency (DARPA), and various technology vendors and systems integrators—are focused on doing precisely that: inventing the future.

The U.S. Army, with the help of DARPA, is undergoing a significant, structured transformation—which will involve substantial innovations in power-electronics technologies to help fuel the nation's growing appetite for lightweight electronics on the emerging digital battlefield.

A123 Systems has worked with the Natick Soldier Center to produce a lithium-ion battery for the Future Force Warrior program.

Leveraging the lessons learned in Operation Iraqi Freedom and the Global War on Terrorism, the Army is developing a network-centric force that lends itself to more effective peacekeeping and swifter defeat of enemies in battle. FCS involves the development and fielding of a networked system of systems, a Future Force that encompasses soldiers and vehicles that are versatile, responsive, lethal, survivable, and suitable for the full spectrum of military operations.

Those involved in FCS face the critical challenge of arming this future fighting force, often referred to as the Army After Next, with the latest electronic advancements and, more important, a reliable, lightweight, and rechargeable solution for powering these devices.

The power supply, although often overlooked, sits at the core and very heart of future combat systems. It is arguably more integral to the success of a mission than the network on which FCS is based. After all, what good is a network without the energy to power it?

When the source powering the network-centric electronics of an FCS soldier, for example, fails or runs out, the soldier too is lost—from the network, the mission, and perhaps worse. A loss of battery life could potentially contribute to the loss of life in FCS soldiers or vehicles. It is little wonder, then, why the Army and its technology partners are working diligently to develop and field the optimal power electronics solution for the FCS project.

The soldier as a system

The FCS project involves two pillars of transformation for the Army, says Dutch DeGay, equipment specialist with the Future Force Warrior (FFW) technology program office (TPO) at the Natick Soldier Center in Natick, Mass. "One is a new suite of vehicles and the network that those vehicles will operate in, and the other is the next-generation soldier who will be a node, if you will, to plug into that network and interact with those vehicles."

The Natick Soldier Center is the Future Force Warrior technology program office (FFW TPO), the facility that is responsible for the program and, as a result, maintains the contracts and works with the lead technology integrator (LTI) and subcontractors.

"What we're trying to do with the FFW itself, kind of tongue in cheek, is make an F-16 on legs—give the soldier the same capabilities, lethality, and standoff that we have traditionally given vehicles," DeGay explains. "We look at the soldier as the next-generation platform. The Star Trek analogy is the Borg, a group of people who are plugged into a supercomputer and part of the collective, so they can share information and push data back and forth; what one person knows, everybody knows."

The first phase of the FFW program is to reduce the soldier's load weight and power requirements, while improving his or her lethality, situational awareness, communicability, and protection. To this end, the Army is not only conducting its own research and development efforts, but also eliciting the help and technologies of various industry vendors.

The Natick Soldier Center initiated a load-carriage study in Afghanistan in 2002, which proved to be the first such study to be performed in the Army since the mid-1940s. It revealed that the average dismounted soldier carries approximately 120 pounds of external load. Soldiers throughout history have carried as much as four times what they need; they prefer to have it and not need it, than need it and not have it.

Nonetheless, the results indicate a serious need for smaller, lighter devices; and, given that the battery pack traditionally constitutes the largest portion of the weight load, the FFW's portable power supply is the focal point of much of this research.

"We are trying to redesign the soldier to make the soldier lighter," DeGay says. "We have stripped the soldier down to skin, we have a list of capabilities and technologies that we want to have the soldier possess, and we are building that system around the soldier. When the U.S. Air Force, for example, builds a new aircraft, they understand that the most important thing is the individual sitting in the cockpit. Subsequently, the cockpit is built around the individual. That's what we're trying to do with the soldier."

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Quest for power

Debate currently rages among major industry players—largely the electronics manufacturers and the power source suppliers—about whether systems designers should reduce the power consumption of electronic devices or providing more power in smaller packages.

To the benefit of the industry, businesses are hard at work to attain both goals, which are not mutually exclusive. There is a very real need now for advancements on both ends of the spectrum. The FFW program is designed to infuse the soldier with significant capabilities, challenging the Army and technology vendors to develop lightweight power supplies and low-power electronic devices.

The U.S. Department of Defense (DOD) has issued a mandate that calls for rechargeable batteries. Soldiers in the FFW program, in particular, will carry two lithium-ion batteries, which provide roughly 40 hours of power. Because the batteries are hot-swappable, soldiers are able to use one battery and remove and charge the other, without the system powering down. Additionally, a supporting unmanned ground vehicle will serve as a rolling battery charger to the foot soldier.

The Natick Soldier Center is working with A123 Systems in Boston to develop next-generation batteries for the FFW program. According to DeGay, they are investigating a combination of rechargeable technologies, not the least of which are lithium-ion and nickel metal hydride.

"Lithium-ion is probably the best short-term answer for us," DeGay says, "It gives us not only the ability to have anywhere from 18 to 20 hours of battery life, but also a recharging capability."

In April, Brig. Gen. Roger A. Nadeau, commander, U.S. Research, Development and Engineering Command, unveils the Army's first fuel-cell-powered truck. Equipped with two hydrogen-fuel-cell stacks, the truck can travel up to 125 miles at a time, carry up to 1,600 pounds, and achieve a top speed of 93 mph.

In conjunction with the lithium-ion cells, Natick Soldier Center is using a zinc air extender, a manpackable battery technology that provides a greater power yield. When the soldier plugs the zinc air extender into his onboard computer system, the computer batteries begin to trickle charge, or parasitically charge, off the zinc air device.

"The only issue with the zinc air extender is it has to draw air," notes DeGay. "It has to breathe air, which is the reason why it's on a backpack and not on the body. We're venting the backpack so the conversion motor can draw air, power the system, and charge the onboard batteries."

Although the FFW program has found a short-term solution in lithium-ion and zinc air technologies, Natick Soldier Center personnel and various vendors contracted under the FFW project continue to investigate alternative power sources.

"There's a huge program in DARPA pursuing fuel cell technology, so we're working very closely with them," DeGay says. "The problem is right now we don't have a man-portable fuel cell that's the size or weight bogey that we need. We're looking for onboard power being no greater than about four pounds. Whether one battery or two, four pounds is the threshold for battery on the body."

The Natick Soldier Center also investigated sensors that convert a soldier's body motion into energy. Currently, the hardware involved in reaping that energy weighs roughly 15 pounds and the power draw off the body is only 1 watt per day. A traditional electronic system on the FFW, however, requires approximately 14 watts a day.

"We want to build the lighter, more lethal, more survivable soldier, so we're looking at those kinds of capabilities and we're trying to figure out how much power the FFW needs on the body and what the work cycle of the battery will be, for example, in a 24-hour period," DeGay says.

Less-voracious vehicles

Weight is a significant issue concerning the other pillar of the FCS project—next-generation military vehicles. The Army is looking to lightweight solutions like lithium-ion for the vehicular arm of the FCS endeavor.

"The big challenge for the Future Combat Systems vehicles is they all are required to be transported on airplanes," says Glen Bowling, general manager of the space and defense di-

DARPA invests in photovoltaics

The Defense Advanced Research Projects Agency (DARPA) in Arlington, Va., is pursuing radical new technologies in search of an efficient, portable, reliable power source, which is of paramount importance to the success of various military programs, systems, missions, and end users.

To that end, DARPA has launched the Very High Efficiency Solar Cells (VHESC) program, dedicated to the discovery of new small-size power generation and storage solutions incorporating solar rechargers.

DARPA's VHESC program is designed to bring about the development and demonstration of 1000 prototype devices. It further stipulates that solar cells must each attain a minimum of 50 percent efficiency.

This high level of efficiency is intended to increase energy output and to reduce the physical size of the solar cells—ideally to the point at which solar rechargers could fit on the handle of a flashlight or top of a laptop PC and potentially reduce the weight of a soldier's portable power source by roughly half.

Leading VHESC program developments is the University of Delaware in Newark, Del. This work incorporates the efforts and expertise of Corning Inc. in Corning, N.Y.; Emcore Corp. in Somerset, N.J.; BP Solar in Frederick, Md.; DuPont in Wilmington, Del.; Blue Square Energy in North East, Md.; the Massachusetts Institute of Technology in Cambridge, Mass.; the University of California at Santa Barbara; the University of Rochester; and the National Renewable Energy Laboratory in Golden, Colo.

The VHESC team is concentrating on three areas of development: biosynthetic materials processing, non-imaging optics, and solar cell architectures.

Other DARPA power-related projects include: Direct Thermal to Electronic Conversion, for converting thermal energy to an energy supply; Palm Power, investigating fuel cell and energy conversion technologies; Mobile Integrated Sustainable Energy Recovery, to convert packaging and trash on the battlefield to a fuel source; and Micro Power Generation, using micro-scale power to run microsensors and micro-actuators equipped with wireless communication.

The first Manned Ground Vehicle to come to fruition is the Non-Line-of-Sight Canon (NLOS-C).

vision, part of the specialty battery group at Saft Batteries in Cockeysville, Md. "Light weight is critical, and lithium-ion is by far the lightest weight system you can use."

"Lithium-ion is becoming more accepted throughout many different applications," says Thomas Alcide, general manager of the specialty battery group at Saft Batteries. "We hold the contract for the development of the battery for the Joint strike fighter—an Air Force, Navy, and multinational next-generation fighter plane and a program nearly as big as FCS—which is going to use lithium-ion. It offers light weight and savings if you use it in a hybrid format."

Saft Batteries was also recently awarded a $2 million multiyear contract by BAE Systems Ground Systems Division in Santa Clara, Calif., for the design and production of high-power lithium-ion battery modules for hybrid-electric FCS manned ground vehicles (MGVs).

BAE Systems and General Dynamics Land Systems Division in Sterling Heights, Mich., are developing a family of eight transportable, lethal, survivable MGVs that will serve as nodes in the network and provide firepower to future soldiers as they work to complete their missions. The MGVs are required to meet a 20-ton weight limit, as they are to be transported by C-130 aircraft, and must employ a hybrid-electric drive system.

Hybrid adoption

The power industry is involved in furthering the development of electric systems, as evidenced by news of an all-electric ship and all-electric aircraft. The same push toward electric vehicles is occurring to a large extent within every segment of the defense industry. The Army, for one, is moving away from historically unreliable solutions, such as hydraulic and pneumatic systems, and toward hybrid electric drive systems.

COMPANY INFORMATION

A123 Systems
Watertown, Mass.
617-778-5700
www.a123systems.com

Aeroflex Inc.
Plainview, N.Y.
631-231-9100
www.aeroflex.com

Aitech Defense Systems Inc
Chatsworth, Calif.
888-248-3248
www.rugged.com

Behlman Electronics Inc., Orbit International Corp.
Hauppauge, N.Y.
631-435-0410
www.behlman.com

Eldec Corp., a division of Crane Aerospace & Electronics
Lynwood, Wash.
425-743-1313
www.eldec.com

EnerSys
Reading, Penn.
800-538-3627
www.enersys.com

ITT Power Solutions
West Springfield, Mass.
413-263-6200
www.kandm.com

Martek Power Abbott Inc.
Los Angeles, Calif.
310-202-8820
www.martekpowerabbott.com

Micro Power Electronics Inc.
Hillsboro, Ore.
800-693-7600
www.micro-power.com

Millennium Cell Inc.
Eatontown, N.J.
732-542-4000
http://millenniumcell.com

North Atlantic Industries Inc.
Bohemia, N.Y.
631-567-1100
www.naii.com

Pico Electronics Inc.
Pelham, N.Y.
800-431-1064
www.picoelectronics.com

Protonex
Southborough, Mass.
508-490-9960
www.protonex.com

Saft
Cockeysville, Md.
410-771-3200
www.saftbatteries.com

TDI Batteries, a division of Tyco Electronics
Lombard, Ill.
650-361-2055
www.tycoelectronics.com

Transistor Devices Inc. Advanced Conversion Products
Cedar Knolls, N.J.
973-267-1900
www.tdipower.com

Ultralife Batteries Inc.
Newark, N.J.
315-332-7100
www.ultralifebatteries.com

Vicor Corp.
Andover, Mass.
978-470-2900
www.vicr.com

VPT Inc.
Blacksburg, Va.
425-353-3010
www.vpt-inc.com

Protonex delivers P2 soldier power system to Air Force

Protonex Technology Corp., a Southborough, Mass.-based maker of fuel cell power systems for portable and remote applications, has presented the U.S. Air Force with advanced prototypes of its P2 soldier power system for evaluation.

The Air Force Research Laboratory (AFRL) at Tyndall Air Force Base, Fla., will subject the P2 prototypes to a series of tests to evaluate the reliability and durability of the devices.

The P2 system achieves up to 50 watts of continuous power through a combination of Protonex fuel cell technology and a chemical hydride fueling subsystem. The subsystem is based on technology licensed from Protonex partner Millennium Cell Inc. in Eatontown, N.J.

The P2 solution is designed to be a low-cost, rugged, and lightweight replacement for batteries currently employed in portable military equipment. Moreover, the P2 soldier power system is engineered to offer a wide operational temperature range.

The delivery of prototypes signifies the completion of the two-year Dual Use Science and Technology (DUST) program that the Air Force awarded to Protonex in April 2003.

The U.S. Air Force is evaluating prototypes of the Protonex P2 soldier power system, designed to replace batteries in portable military equipment.

The AFRL has notified Protonex and Millennium Cell of its intention to award a $1.02 million program dedicated to the enhancement and manufacturability of the P2 system, as well as to the procurement of additional systems for reliability and performance testing.

Millennium Cell receives grants to further battery and fuel technologies

The U.S. Air Force Research Laboratory (AFRL) at Tyndall Air Force Base, Fla., and National Science Foundation (NSF) in Washington have awarded grants to Millennium Cell Inc., a developer of hydrogen battery technology in Eatontown, N.J., to develop new fuel options for military applications.

Both contracts are intended to further the development of an affordable, lightweight, portable, and high-energy power source for military, and perhaps industrial and commercial, applications.

The AFRL issued a Phase I Small Business Innovation Research (SBIR) program contract to Millennium Cell to develop a sodium borohydride–based fuel cartridge design. To this end, the new design is intended to work with premixed sodium borohydride solutions or solid fuel packets that can be combined with available water or bodily fluids, benefiting the soldier in the field with a reduced pack weight.

"The Air Force is aggressively pursuing innovative ideas and major performance advances in power generation and energy storage," notes Dr. Thom Reitz, AFRL program manager.

The contract work also is designed to assist the military in determining the best option for re-fueling and distributing man-portable hydrogen batteries, especially to those in remote locations or under extreme conditions.

"We welcome the U.S. Air Force's leadership and vision in funding the development of our hydrogen battery technology for use in a variety of military applications," says Adam P. Briggs, Millennium Cell president. "This new program will provide the military with a flexible fuel cartridge design that can be shipped dry and field hydrated. When dry, this system will be one-fifth of the weight of the batteries in use today."

The NSF also awarded the company a Phase I SBIR program grant to produce new hydrogen storage technology based on solid fuel blends that include borohydrides. Such technology would contribute to new class of safe, reliable, energy-dense hydrogen batteries for use in various portable devices used by military, medical, industrial, and consumer electronics customers.

Hybrid vehicles is a main thrust of the Army right now, explains Mike Henderson, director of marketing and business development at the Transistor Devices Inc. (TDI) ACP division in Cedar Knolls, N.J. "There are a couple things they are trying to react to: they realize that the price of fuel is certainly not going down," he says. "We're paying $3 or so for a gallon of gas here; if you're out on the battle field, you're probably closer to $200 a gallon. That's not an easy pill to swallow, even for the Army."

"It's definitely the cost of fuel driving hybrid use," Bowling says. "The cost of fuel for the government is in the hundreds of dollars per gallon frame—not the dollars per gallon frame—by the time they get it where it needs to be and get it distributed. Fuel is a much higher cost to the military than it is to civilians because there is no distribution system; and so for them, it is very critical to reduce the amount of fuel they use."

"The other thing is a real need for silent operation," Henderson adds. "You have a lot of off-vehicle communications equipment—such as satcom devices—that has to be running; yet, the folks on the trucks don't necessarily want to be giving their positions away. It has got to be silent operation, which means you can't have the engine running and you can't have a generator running. What they do is they operate off of large banks of batteries onboard the vehicle."

TDI is involved in powering the Future Tactical Truck System (FTTS), a program that involves a maneuver-sustainment vehicle (MSV) the size of a truck, and a smaller utility vehicle aimed at replacing the common Humvee and serving a wide variety of uses.

"Certainly, there's a lot of technology going into these new programs," Henderson says. "One common theme, regardless of whether it's the truck or the replacement of the Humvee, is that it's going to be a hybrid electric vehicle."

The FTTS-Maneuver Sustainment and FTTS-Utility vehicles are in the early stages of development.

"I'm sure several changes will come about, but the one thing that's going to stay constant is the hybrid electric end of it," says Henderson. "They may decide to widen the truck, or add a few other things onto it, but it's almost a guarantee that they have to be hybrid-electric vehicles. There's just no other way to do it."

Doubtless, the combat systems of the future—soldiers and vehicles—will be well equipped with the most innovative electronics solutions to date.

"Power consumption from the standpoint of the power users is increasing right now at 10 to 20 times what it was in the past," says Henderson. "At the same time, the efficiencies of the power sources are only increasing by 10 to 20 percent, leaving a gigantic gap between power sources and power users—and that gap is only widening. It is a huge problem, but things are happening out there that are attempting to bridge that gap."