Beyond the Status Quo

Marines, energetics R&D, and the art of the possible

by Robert V. Gates

Marine firing thermobaric SMAW. *(Official U.S. Navy photo.)*

In 1991 two naval scientists made a big discovery. They found that certain materials impacting a structure produced catastrophic damage. The materials were not explosives and did not just penetrate targets like shrapnel. Rather, their impact caused a reaction that was much more destructive than traditional explosives. The Discovery Channel later said this "reactive material" would enable future munitions to be "500 percent more effective than current U.S. weapons." This concept is now used in the field.

Weapons developers have often overlooked a research and development (R&D) field called "energetics," which pursues propellants, explosives, and warhead designs. However, this R&D can significantly change munitions and help the Marine Corps go where it seeks in future warfighting. It's also a field that other nations are pursuing as well. But getting the most out of this R&D will require user and systems developer involvement from the very beginning.

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Beyond Status Quo Weapons

Recently an unmanned aircraft system demonstrated it could drop an 81mm mortar round on target. To some degree this reflects a tendency to have new weapons systems use existing or modified munitions. There are two major reasons. Within the Department of Defense, some believe that energetics R&D will yield few new advances. Also, U.S. industry often doesn't have the expertise to develop new propellants and explosives. R&D is a costly, long-term endeavor. For example, five major U.S. companies once manufactured propellants. Today, there are only two.

However, "Using yesterday's energetic materials exclusively in today's (or even more so, tomorrow's) battlefield systems would be as effective as trying to run a Ferrari on kerosene," stated the National Academies of Sciences.[7]*As the Academies and the energetics R&D community are finding, advances are being made in energetics, giving rise to the belief that the next generation is emerging.

These energetics are in various stages of development, from initially fielded technologies to those on the computer drawing board. Potentially, these advanced energetics could make new munitions far more effective than present ones that rely on such traditional energetics as plastic bonded explosives and high explosives. They also could help the Marine Corps achieve advances in distributed operations, irregular warfare, and forcible entry.

Distributed Operations: Size and Range Matter

Distributed operations are seen as widely separated but coordinated tactical actions, hitting enemies from seemingly anywhere, while denying them a massed target. These operations are being conducted in Afghanistan, where a 1,000-Marine infantry battalion has covered an area about the size of South Carolina. As one battalion executive officer stated, "You don't get any more distributed than that."[14] Many of the implied needs for future distributed operations are emerging from Afghanistan.

One need is a lighter load. In Afghanistan many Marines carry combat loads of more than 130 pounds, well over the 50 pounds recommended by a 2007 Navy study. And it's taking a toll in muscular injuries. It also impacts effectiveness in combat, in which speed counts. "In order to be fast, you need to be light," stated the Marine Corps Commandant, Gen James T. Conway.[17]

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Lightening that load—and particularly ammunition—is a top priority. A 30-round magazine weighs about 1 pound, and some Marines carry as many as 15 magazines. A 200-round drum for the 5.56mm squad automatic weapon weighs about 7 pounds. And there are 7.62 machinegun belts, hand- and M203-launched grenades, and mortar rounds.

Some initiatives are already pursuing lighter loads. Plastic casings are being tested as replacements for brass casings, which could reduce the weight of 5.56 rounds by 40 percent. Development initiatives investigating lighter materials for helmets and protective vests require energetics expertise to determine what is required to shield blast and fragmentation.

But it is what is in development that holds greater promise for lighter and more effective ammunition. Long anticipated caseless rounds—propellants encasing bullets at half the weight of today's rounds—are showing greater possibility in testing, overcoming previous sensitivity to shocks. The Office of Naval Research (ONR) is currently investing in technology that can provide the next generation of weapons for the Marine Corps. One of these investments, at the Naval Surface Warfare Center (NSWC), Indian Head, MD, is the development of new fuzes based on microelectromechanical systems (MEMS). These new fuzes merge commercial silicon-based batch processing with emerging microexplosive train technology. This allows designers to produce smaller, more reliable, and more affordable munitions for the Marine Corps. One example of this technology being applied to a real-world need is the ongoing development of the 40mm reliability enhanced armor penetrating explosive round. This is an improvement to the existing 40mm M430A1 high-explosive dual-purpose round that gives Marines a lethal and reliable weapon and one that incorporates insensitive munitions characteristics.

There is also a need for greater fire support ranges in distributed operations. Mortars, 81mm and 120mm, and 105mm and 155mm artillery have ranges of 5,600 meters, 7,200 meters, 19,000 meters, and 30,000 meters, respectively. In some cases in Afghanistan, fire support has been needed for a Marine infantry battalion operating over 12,600 square kilometers. Movement of these systems is constrained by rugged terrain, thus limiting their coverage.

Advanced energetics, currently envisioned, could improve munition ranges. They have technical names like "high nitrogen compounds" and "azido-energetic thermoplastic elastomer polymers," and their potential is impressive. They are being investigated for very high combustion rates compared to past propellants, and because they rely less on carbon compounds, they can reduce carbon absorption in steel thus decreasing gun barrel wear.

It also may be possible to alter propulsion speeds, stressing gun tubes less and enabling lighter guns with

*There are a total of 61 footnotes for this article. For those readers who want to read the article with a complete set of footnotes, please go to www.mca-marines.org/gazette. The article is posted on our website.

A prime goal is to lighten the load. *(Official U.S. Navy photo.)*

greater ranges. Different gun propellants could be layered, with faster burning propellant at the core. Thus a munition could launch with the slower burning layer but pick up speed as the faster burning propellant kicks in. It also may be possible to reduce a projectile's thrust and range (as well as increase them) using electrical energy for high temperature to help control chemical energy release in high performance propellants.

Additionally, energetics may give small units more powerful indirect fire support. Taliban insurgents often engaged Marines but dispersed before air and artillery responded. In such cases organic mortars became the indirect fire systems of choice. One Defense Advanced Research Projects Agency initiative seeks to improve the 60mm mortar round, giving it the effectiveness of a 105mm round. It reflects the future—smaller ordnance that does more in terms of effectiveness and functions. ONR is developing a laser guidance package for an 81mm mortar round that will yield improved accuracy and, hence, a more effective round. Improved propellant and a smaller MEMS-based fuze will ensure that the range of the modified mortar round is preserved.

Irregular Warfare: Focused and Specialized Weapons

Irregular warfare is characterized as a violent struggle among state and non-state actors for legitimacy and influence over a population, with adversaries operating in population centers. In this warfare it is not enough for munitions to be precise. Often they must have very focused effects. Any collateral damage risks losing the very people we seek to win to our side, as evidenced by Taliban propaganda after NATO strikes have killed civilians.

Energetics R&D can design focused munitions for such warfare as it has done for operations in Afghanistan and Iraq. Such focused effects are seen with the Air Force's small diameter bomb, half the size of its once smallest bomb, which was 500 pounds. Some Marines also advocate the small diameter bomb for the Joint Strike Fighter. But it is the follow-on "focused lethality munition" that is even more focused. It is accurate to a very few meters and has a 90 percent reduction in collateral damage compared to the small diameter bomb. This is made possible by a "multiphase-blast explosive," which produces a very deadly but controlled blast. It is the harbinger of other munitions spinoffs.

This R&D has also provided very specialized munitions to hit enemies in hardened structures. Previously, attacking hard targets often meant huge amounts of blast and fragmentation munitions. However, such ordnance could not reach Taliban and al-Qaeda hiding in Afghanistan's deep and winding caves in 2001. Thus, the Department of Defense rapidly fielded an air-delivered thermobaric munition that uses heat and pressure to reach inside these caves.

This thermobarics technology has rapidly spread to small units. In the 2003 advance to Baghdad, Marine Cobra helicopters took out Iraqi outposts with thermobaric Hellfire missiles. In subsequent operations like those in Fallujah, Marines collapsed structures that had become enemy pillboxes, using the shoulder-launched multipurpose assault weapon-novel explosive, or what some call the SMAW thermobaric round. To the envy of Marines in Fallujah, Delta operators also used thermobaric grenades to drive up overpressure in confined spaces.

Additionally, energetics R&D can aid the defense in irregular warfare. Army laboratories recently fielded a grenade that doesn't burn but uses titanium dioxide to rapidly produce a powdery cloud that obscures a sniper's vision and infrared systems. And, today, the biggest producer of improvised explosive devices isn't an enemy nation or group. It's the NSWC, Indian Head, which seeks countermeasures, to include helping design protective armor for personnel and vehicles.

Forcible Entry: Smaller Packages, Bigger Bangs

The historic mission remains: the Corps conducts joint forcible entry operations from the sea. So does the pessimism. Strategist Liddell Hart wrote in 1942:

> A landing on a foreign coast in face of hostile troops has always been one of the most difficult operations of war. It now has become much more difficult, indeed almost impossible.[43]

However, similar criticism is heard today as nations adopt antiaccess strategies, supported by integrated air defenses, medium-range rockets and missiles, wide area minefields, coastal submarines, small attack craft, and chemical and biological weapons.

The United States clearly needs access to key areas, and forcible entry remains a relevant means. The alternative is forward bases, but in some regions many are becoming fixed targets. By comparison, forcible entry operations have the advantage of maneuvering at sea and bringing firepower to bear against targets of choice. Several advanced energetic materials can enhance firepower range and effectiveness. But what will also aid forcible entry's viability is enhanced firepower delivered by relatively new platforms—unmanned systems—and lots of them.

Unmanned systems will play prominently in overcoming antiaccess capabilities. Many concepts envision swarms of coordinated unmanned systems operating against enemy systems. Long-range unmanned aircraft systems may help find and prosecute targets independently. Unmanned surface vehicles could conduct surveillance and antiboat defenses, and unmanned undersea systems could search for and neutralize mines. Additionally, networking would allow them to work across their domains, but such uses will depend on the weaponization of unmanned systems, which must differ from the past. To date unmanned systems have been weaponized with existing munitions. The Predator unmanned aircraft system was fitted with two Hellfire missiles. Later the ex-

The supporting arms he is calling for will improve thanks to R&D. *(Official U.S. Navy photo.)*

panded version, Reaper, was built, allowing carriage of four Hellfire missiles, two laser-guided bombs, and a 500-pound joint direct attack munition.

Such future uses imply small unmanned systems and miniaturizing everything on unmanned systems to include weapons with greater effectiveness than previously seen. These miniaturized weapons may be possible with "new integrated energetics," such as synthesizing high-nitrogen and high-oxygen explosives. Another possibility is one of the most powerful nonnuclear explosives called Nitriminotetrazole. These and others will soon be developed to make them more stable, reduce sensitivities, and increase energy output.

Energetics R&D will be critical to developing such weapons for their environments. For example, unmanned undersea vehicles may use smaller and more powerful torpedoes, as the result of materials that react with the surrounding seawater to cause additional shock impulse and bubble energy. This has already been demonstrated in the underwater explosive facility at Indian Head.

Additionally, R&D can design specialized munitions for targets. Use of reactive materials for fragmentation may better ensure very visible destruction of vehicles and systems over an area. They also may be used against hard targets, with reactive materials replacing projectile's steel liners. And while traditional high explosives will not produce sufficient heat to destroy (and are unlikely to contain) biological agents in storage facilities, technologies like the "High Temperature Thermal Radiator" can create temperatures up to 6,000 degrees lasting for minutes.

The Art of the Possible

Achieving advances in future munitions and the associated changes in warfighting can't be an afterthought. Energetics R&D must be integral to future systems development from the start. "It was the alliance of gunpowder with the other resources of the nation state that was to produce the recognizable beginnings of modern warfare," wrote Richard A. Preston and Sydney F. Wise in *Men in Arms*.[56] Weapons developers must begin to use today's emerging propellants and explosives, which are very different from the past. They can help new systems do what old munitions cannot. They can enable smaller, lighter weapons, and they can lead to changes in warfare, to include many sought by Marines and some not yet known.

Moreover, both energetics R&D and users must be part of weapons development. The development of the SMAW-novel explosive is a model. To address an urgent need, Marines; scientists at NSWC, Indian Head; and industry came together. As a result, development went from concept to fielding in 9 months. Such involvement gives all involved an opportunity to make tradeoffs in range and payload effectiveness. It also enables rapid fielding and reduces the risk of fielding a system that users don't want.

Energetics R&D involvement is also needed to ensure warfighting advantage. There have been "recent reports on the advances in energetic materials research, development, and manufacturing technologies by foreign countries," noted the House Armed Services Committee in May 2008.[58] Former Soviet states and China are pursuing energetics R&D and may be exploiting breakthroughs. Russia has already demonstrated a thermobarics capability exceeding ours.

There is a special reason why energetics R&D should involve Marines. LtGen Victor H. Krulak, USMC(Ret), wrote in *First to Fight*:

> The Marines have . . . thought up or caused to come into being some of the most exciting and useful developments in modern operational concepts, weaponry and equipment.[61]

They can use advanced energetics to again achieve the art of the possible for America's future warfighting.

Notes

7. *Advanced Energetics Material,* National Academies of Science Study, published in 2004, p. 9.

14. This quote is attributed to Maj Michael Miller by Marine Corps Center for Lessons Learned, *Distributed Operations in Afghanistan, First Battalion, Third Marines: Observations and Lessons From Operation Enduring Freedom (OEF) VI*, 14 November 2006, cover page, he states, "At the battalion level we were a thousand-man force covering over 12,600 square kilometers; you don't get any more distributed than that."

17. As attributed to Gen James T. Conway by Dan Lamothe in his article, "Corps researching new, lighter combat gear," *Marine Corps Times*, 3 September 2009, available at http://www.marinecorpstimes.com/news/2009/08/marines_high_speed_gear_083109w.

43. As attributed to Liddell Hart by Jeter A. Isley and Philip Crowe, *The US Marines and Amphibious War,* Princeton University Press, Princeton, NJ, 1951, p. 5.

56. Preston, Richard A., and Sydney F. Wise, *Men in Arms*, Praeger, New York, 1970, p. 97.

58. Committee on Armed Services, House of Representatives, House Report 110–652. Duncan Hunter, National Defense Authorization Act for Fiscal Year 2009, 16 May 2008, accessed at http://www.congress.gov/cgi-bin/cpquery/1?&sid=cp110REXEX&xform_type=3&hd_count=3&refer=&r_n=hr652.110&db_id=110&item=1&sel=TOC_281292&.

61. Krulak, LtGen Victor H., USMC(Ret), *First to Fight*, Naval Institute Press, Annapolis, MD, 1984, p. 67.

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