What's So Important about Energetics?

EVERYTHING

By Robert V. Gates

Research and development is waning in a field responsible for advanced naval firepower. We allow this decline to continue at our peril.

In March 2003, a Marine Cobra helicopter hit an Iraqi outpost with a thermobaric Hellfire missile. President George W. Bush later stated: "We used a new Hellfire missile for the first time, which can take out enemy fighters hiding on one floor of a building, without destroying the floors above and below. . . . In the coming years, there are going to be some awfully surprised terrorists when the thermobaric Hellfire comes knocking."[1]

HOME OF ENGERGETICS Research and development at naval labs like this one at the Indian Head, Maryland, Naval Surface Warfare Center is responsible for much of America's military firepower. Right: Indian Head workers prepare a BLU-118B thermobaric bomb for shipping.

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The missile's warhead was developed by naval scientists in a research and development field called energetics. They filled a warhead with plastic bonded explosive, layering it with aluminum powder. On detonation, the powder burns rapidly, producing a devastating pressure. For more than a century, naval labs with this expertise contributed to the firepower that helped establish U.S. naval dominance, provided ordnance for other services, and yielded technologies with broad commercial use. Yet despite growing joint requirements, this R&D field is declining—not only in the Navy, but across the Department of Defense and U.S. industry. It is a decline that must be reversed.

Weapons and their ordnance influence tactics. When Admiral George Dewey ordered Captain Charles V. Gridley to "fire when ready" at Manila Bay in 1898, 20 of the guns fired were 5-inch Dashiells. Built around smokeless powder, with rapid-loading breeches, the guns could fire clear, fast shots. At Santiago, "the rapidity of fire from our guns was so great," stated a writer in 1902, "that there descended upon the Spanish ships a hail of steel so terrific that it searched every port or opening and drove the men from the guns."

The effectiveness of weapons and ordnance depends greatly on propellants, explosives, and pyrotechnics—energy-releasing materials, or energetics. A National Academies of Sciences report noted their importance thusly: "There is no modern defense system or type of weaponry that does not rely on energetic materials."

Naval ordnance has its own demands. The great maxim of naval tactics is attack effectively first. It's not just a sensor problem. Energetics materials are needed to outrange and outrace enemy systems over expansive sea distances, and deliver the right energy on sea, undersea, land, and air targets. This ordnance also must be made relatively safe for storage and handling at sea.

According to historian Rodney Carlisle, the Navy investment in labs that anticipated and met the demands of energetics did not make headlines, but it "laid the groundwork for great leaps forward in the war years." The work of these labs spurred technological revolutions and helped make the U.S. Navy and U.S. Marine Corps team the preeminent naval power in the world.

Transformation of Naval Guns

At the turn of the 20th century, U.S. naval guns ranged to 6,000 yards. By World War II, they ranged more than 30,000 yards, firing munitions with several uses. They penetrated armor, exploding in Japanese ships like the *Yamashiro* and *Mogami* in the Battle of Leyte Gulf. The use of these munitions in amphibious assaults earned the respect of Japanese Lieutenant General Tadamichi Kuribayashi, who stated: "However firm and stout pillboxes you may build on the beach, they will be destroyed by bombardment of main armament of the battleships." Star shells fired nightly over Okinawa also helped repel enemy ground attacks.

Naval labs made this ordnance safe for ships, as they developed a more stable smokeless powder, which previously caused explosions in French and British warships. Instead of volatile nitroglycerin, naval chemists substituted nitrocellulose—later a key ingredient in the making of artificial leather, non-shatterable glass, cellophane, and other products, resulting in hundreds of thousands of jobs. The labs also developed fuzes that armed munitions just before loading and munitions insensitive to shocks.

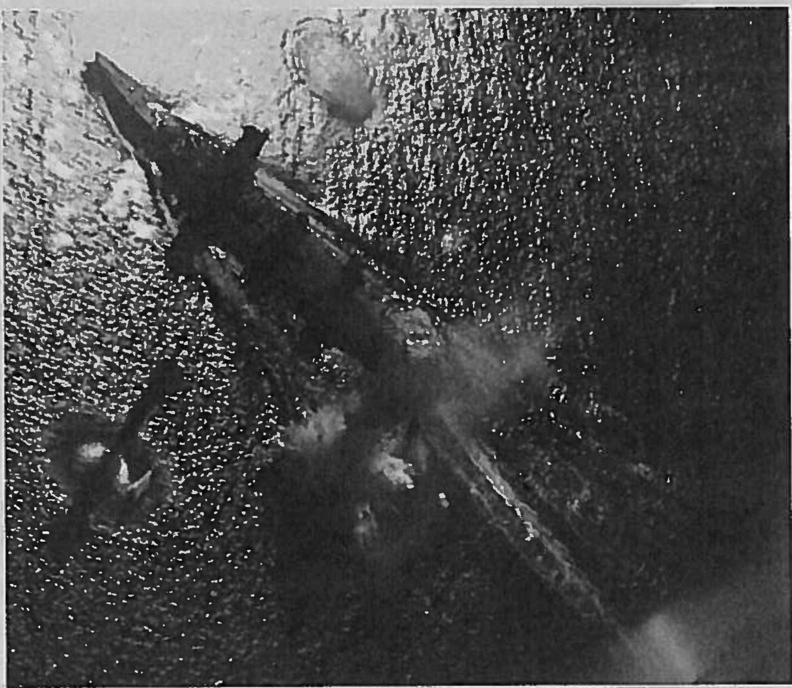
"I looked up to see three black enemy airplanes plummeting towards our ship," wrote Mitsuo Fuchida, a Japanese Navy commander at the Battle of Midway, "then a number of black objects suddenly floated eerily from their wings. Bombs!" Two decades before, naval labs developed and tested aircraft-delivered deck-piercing bombs and aircraft guns. They ushered in a revolution in aircraft weaponry, surpassing naval gun ranges.

In that same period, the labs pursued ship air defense, testing antiaircraft fragmentation and incendiary rounds. Naval historian Samuel Eliot Morison noted the effectiveness of such ordnance: "Antiaircraft fire, helped by the proximity fuzed shell became so deadly that the Japanese were forced to adopt suicide tactics."

The Need for Missiles

The Japanese suicide tactics gave rise to another ordnance need. At Okinawa, kamikazes sank 36 ships and damaged 368. "The Navy reached an important conclusion," wrote naval historian Michael T. Isenberg. "Anti-air warfare, courtesy of the kamikaze, had reached the missile age." In the post-World War II world, ships needed missiles to destroy threats much farther away.

Naval labs had the experts to meet this need. In World War II, they produced propellants for rockets like those fired by Marine aircraft at Japanese strongholds and analyzed captured German V-1 missiles. They later helped provide Navy ships with missiles like the Talos, Terrier, and Tartar, as well as follow-on missiles not only for air defense, but ship and land attack.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NAVAL GUN EVOLUTION From the turn of the 20th century to World War II, the range and power of American munitions grew by leaps and bounds, for the most part thanks to the work at naval labs. The Japanese battleship *Yamashiro* felt the brunt of their handiwork in 1944.

Energetics was responsible for an even bigger revolution—the submarine-launched ballistic missile. The boost needed to get a Polaris missile out of a vertical-launch tube and inbound for Soviet targets came from a mix of powdered aluminum and gum slurry, hardened into a grain propellant, which was much safer on ships than liquid fuels. Naval labs built and tested Polaris motors, leading Soviet Admiral Sergei Gorshkov to comment later: "The imperialists are turning the World Ocean into an extensive launching pad."

From naval energetics also came the seemingly obscure but ubiquitous cartridge and propellant actuated devices. They are used to free aircraft bomb racks, fuel tanks, and missiles from aircraft, and initiate ejection seats. Today, such devices are found in automobile airbags.

And as other needs arose, naval energetics experts tailored ordnance to meet them. They built the motors for missiles that home-in on enemy radars, and ensured ordnance penetrated required depths and densities. And when U.S. forces faced an Iwo Jima-like fight, rooting out al Qaeda and Taliban fighters in Afghan caves in 2001, naval energetics experts helped field in 67 days a thermobaric bomb that produced devastating pressures in deep and winding tunnels.

This expertise became integral to system development. If ordnance needed greater range or speed, energetics experts adjusted propellant volume, burn rates, or used other formulas. If more or less bang was needed, they provided alternative formulas and warhead designs. Recently, the Marines were so impressed with the power of thermobarics in Operation Enduring Freedom that they asked scientists at the naval lab in Indian Head, Maryland, to develop a shoulder-mounted version for them.

Naval labs acquired an unequaled breadth of energetics expertise, often providing assistance and ordnance beyond naval service. For example, the Indian Head lab has been designated a DOD Energetics Center, providing nearly half of its support to the U.S. Army and Air Force and other government agencies. While energetics expertise exists to varying degrees across DOD, no other U.S. lab has the breadth of energetics expertise, spanning cradle to grave.

The Demand Grows

The Defense Technology Area Plan calls for energetics R&D to achieve:

- More lethal warheads, but 30 percent smaller in size
- Hard target munitions that survive Mach 3 impacts and penetrate 20 feet of concrete
- Ordnance components that dispense payloads while passing through an 8 foot high room at 600-900 feet per second, after penetrating up to 6 feet of concrete.
- Ordnance with reactive materials that are not explosives but highly destructive, and which will achieve recognizable kills against an array of ground and air defense targets.

But needs arise faster than plans. Energetics expertise has been used to design blast countermeasures for mine-resistant ambush-protected (MRAP) vehicles as well as ships. Warfighters require rapidly tailorable force applications, changing lethality, or even non-lethality, depending on target and situation. For example, warfighters seek focused lethal munitions for use against enemies in urban areas, while minimizing damage to nearby noncombatants and structures. In addition, the Navy urgently needs a warhead and propulsion upgrade for lightweight torpedoes by 2015, and for heavyweight torpedoes by 2018.

The next revolution requires energetics expertise, too. "The revolution will be in uninhabited robots that search and shoot under amazing modes of self-control," wrote retired Navy Captain Wayne P. Hughes in *Fleet Tactics and Coastal Combat*. Today, warfighters seek ordnance for unmanned ground, aerial, and underwater systems that destroy mines. That means smaller explosives with bigger bangs, among other things.

It is not enough to make warheads and propellants. They must be made to detonate when supposed to and not from another round, fire, or sympathetic detonation. Ensuring munitions insensitivity requires energetics expertise, but is ultimately a system engineering problem. Ordnance detonations in shipboard fires on the USS *Oriskany* (CVA-34) and *Forrestal* (CVA-59)—26 October 1966 and 29 July 1967, respectively—are examples of what happens when this problem is not adequately addressed.

All this requires making energetics experts equal partners in the systems engineering process, just like experts in airframes, sensors, and guidance systems. Energetics expertise is also needed to do several things: give our forces advantages, offensively and defensively; expand existing weapons' capabilities; identify risks, relative to what opponents are doing in energetics; and recognize future possibilities.

But, others want more from energetics, too. Evidence of that is in Iraqi insurgents' transition from improvised explosive devices that destroyed Humvees, to explosively formed projectiles that have taken out Bradley Fighting Vehicles. The House Armed Services Committee in May 2008 noted "recent reports on the advances in energetic materials research, development, and manufacturing technologies by foreign countries."

Future trends are more disturbing. As an example, Russia presently sells a supersonic, antiship Sizzler missile that reportedly travels at Mach 3 some 20 feet above the ocean surface, sprinting the last 10 miles in about 20 seconds. This is a concern. The Commander, U.S. Pacific Command, Admiral Timothy J. Keating recently stated: "We are currently not as capable of defending against that missile as I would like." In the future, follow-on supersonic missiles are expected, and today's importing countries will likely produce their own, according to the Office of Naval Intelligence.

But here is the most disturbing trend. A 2004 National Academies of Science report, Advanced Energetic Materials, states: "There is no question that the nation's capability to discover and to utilize energetic materials is in decline."

Tick Tock

Energetics R&D and its inclusion in systems engineering requires money, people, and time—and all are waning. Between the Berlin Wall's fall in 1989 and 9/11, DOD spending on energetics R&D fell nearly 45 percent. A

ACCIDENTAL SHIPBOARD DETONATION Energetics expertise helps ensure munitions insensitivity, which might have prevented ordnance detonations in the devastating shipboard fire on board the USS *Forrestal* (CVA-59) in 1967.

2001 Department of Commerce study stated the implications: "This reduced investment in RDT&E may slow innovation and hinder the ability of the United States to field cutting-edge munitions technologies."

Since then, energetics R&D has continued to decline. "Almost weekly, I see scientists and engineers retire," stated an energetics engineer at the China Lake, California, naval lab. This lab, once the origin of 80 percent of the world's air-launched ordnance, had about a dozen people performing energetics R&D in 1985. Twenty years later, it was two or three. Today, the Indian Head lab has four scientists doing chemical synthesis and molecular design, but in 1994 it had 13. More will retire in the next six to seven years, and not enough are taking their place.

Energtics labs also cannot just hire scientists and engineers in this field. It is a specialized and almost defense-unique discipline, requiring five or more years to train a college graduate to work with energetics materials.

And there are no substitutes for defense labs in energetics. No company does long-term energetics R&D like the defense labs. Moreover, manufacturers are waning.[2]

HELLFIRE COMES KNOCKING A Marine Corps AH-1W Super Cobra helicopter attacks an enemy antiaircraft gun position in April 2003 with AGM-114 Hellfire missiles in northern Iraq. Research into their thermobaric warheads began 35 years ago, a practice we must sustain.

Once, five major U.S. companies manufactured propellants. Today, only two are producing them.[3] In fact, labs like Indian Head not only do R&D for companies, they also manufacture energetics materials for them. In addition, many of the key chemical ingredients for U.S. energetics come from overseas manufacturers.

There are several reasons for this decline. When Fleet Admiral William Leahy learned of the atomic bomb's development, he stated, "The bomb will never go off." A similar belief exists today. The 2004 National Academies of Science report pointed out several evolutionary to revolutionary energetics technologies that are on the computer drawing board or exist in small lab quantities—nanostructured materials, all-nitrogen and hydrogen energetics, and reactive materials. However, some in DOD believe energetics R&D has reached its plateau.

There is another reason, too. The 2004 report also stated: "The U.S. effort in research and development of energetic materials is small, fragmented, and suboptimal, leaving this critical national technology area at risk."[4] Energetics has no advocate. Consequently, the report "recommends that the Department of Defense consider centralizing its management of energetic materials research and development in order to achieve a longer-term, cross-service perspective."[5]

The clock is ticking. Today's forces benefit from munitions researched and developed more than a decade ago. For example, research leading to the thermobaric warhead like the one in the Hellfire missile was initiated 35 years ago. One of the chemists who further developed themobarics in the 1990s has retired. As talent goes away, the pipeline for improved ordnance dries up, with consequences to come in a decade or more.

Advantage or Mistake?

Since 1981, three studies have said the same thing about U.S. energetics R&D. After participating in the most recent study in 2008, former-Commandant of the Marine Corps General Michael Hagee wrote in the 21 July 2008 issue of *Defense News*: "It would be a strategic mistake for the United States not to have a forward-looking, aggressive energetics R&D program. Its decline must be reversed with significant increased funding."

A fourth study is now under way, congressionally directed after the House Armed Services Committee reported in 2008: "The committee urges the Department to adequately invest in this area to ensure that the United States retains sufficient explosive production capacity, continues to develop future innovative munitions, and continues to develop the next-generation of energetics scientists and engineers." Whatever happens with this study will greatly determine the future of U.S. firepower.

1. President George W. Bush, "President Discusses War on Terror at Naval Academy Commencement," 27 May 2005, http://merln.ndu.edu/merln/pfiraq/archive/wh/20050527.pdf
2. National Research Council of the National Academies, *Advanced Energetic Materials*, 2004, p. 37.
3. White paper entitled, "The Case for Sustained Energetics RDT&E Investment at the Naval Surface Warfare Center, Indian Head Division," February 2008, p. 2.
4. National Research Council of the National Academies, *Advanced Energetic Materials*, 2004, p. 37.
5. National Research Council of the National Academies, *Advanced Energetic Materials*, 2004, p. 2.

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