TRANSFORMING THE WARFIGHTING LANDSCAPE

DARPA'S Land Warfare Programs Have Influenced Battlefields Around the World

By Glenn W. Goodman, Jr.

From 1958 to 1965, DARPA's research emphasis centered on strategic technologies, particularly in the areas of space, ballistic missile defense, and nuclear-test detection. The agency's first major foray into the tactical realm came in 1961, when the Office of the Secretary of Defense (OSD) directed DARPA to undertake Project AGILE.

Initially aimed at developing and testing new technologies that would support the counter-insurgency warfare needs of indigenous ground forces in South Vietnam and Thailand, the program expanded as direct U.S. military involvement in Southeast Asia deepened during the Vietnam War. DARPA's third largest project by the mid-1960s, AGILE was a key agency counter-insurgency research effort for nearly a decade. It was the first program in which DARPA representatives worked closely with military users in the field to gain feedback for iterative development of technology solutions to meet tactical requirements.

AGILE activities included quick-reaction projects to adapt off-the-shelf technologies to support American forces in Vietnam. A good example was a DARPA-funded effort to provide lightweight armor for use on helicopters. Ceramic armor configurations for aircrew vests were produced that were used extensively in Vietnam to protect U.S. helicopter pilots from small-arms fire. AGILE also encompassed longer-term collection and analysis of environmental data, such as radio wave attenuation in jungle terrain.

AGILE's most enduring success resulted from field tests in Vietnam of a promising new rifle, the Colt-Armalite AR-15 (later renamed the M-16). DARPA's original motivation was to supply South Vietnamese troops with a weapon more suitable for their small stature and for firing at short ranges in jungle combat. DARPA conducted a preliminary test of 10 AR-15s in 1961, followed by field tests approved by Defense Secretary Robert McNamara of 1,000 more the following year. The 5.56 mm M-16 proved to be superior to available alternatives, including the heavier 7.62 mm M-14 already selected by the U.S. Army as its standard assault rifle. Pressure from OSD officials led to limited Army M-16 procurements in 1963-1964, fuller adoption in 1966, and designation as the service's standard infantry weapon in 1967. The Colt M-16 ultimately was adopted by all of the U.S. military services. (Its shortened derivative, the Colt M-4 carbine introduced in 1991, today is the Army's primary individual combat rifle for its infantry and Special Operations Forces.)

As stated in the 1975 DARPA study by Richard J. Barber Associates, "The history of the period indicates that the development of the M-16 would almost certainly not have come about without the existence of DARPA as an alternative source of funding and a vehicle for objective testing. ... DARPA's role as a broker between the 'user' in Vietnam and OSD in Washington was critical to building a case for the weapon which could overcome Army resistance."

In 1972, DARPA created its Tactical Technology Office. One of its aims was to nurture maturing subsystem technologies (e.g., in areas such as sensors, propulsion, and warheads) and integrate them into a system (such as a missile) that could meet a critical tactical need of the U.S. military services. The office typically culminated its larger projects with a system-level demonstration or

One result of DARPA's early involvement in Project AGILE was the M-16 rifle. One measure of the weapon's success is that it is still in use across the world. A carbine version, the M-4, is used today by U.S. Army and Special Operations Forces.

National Archives photo

a "shoot-off" designed to validate the military utility of the integrated system and increase its chances for a successful transition to one or more of the services for further development and fielding.

The period from 1975 to 1990 was one of significant DARPA investment in technologies and air and land systems for improving U.S. conventional armaments in the European theater. The primary goal was to defeat attacking Soviet/Warsaw Pact armored forces in Central Europe in any conventional conflict arising during the Cold War.

TANK BREAKER

DARPA undertook the Tank Breaker program in the mid-to-late 1970s to address deficiencies identified by the Army and Marine Corps in their existing Dragon infantry anti-tank weapon. The initial reaction from industry was that the services' requirements, including significantly lighter weight and "fire-and-forget" capability, were beyond the state of the art. However, DARPA-funded advances in passive-imaging infrared staring focal plane arrays (FPAs) and associated processing technology for target acquisition and tracking ultimately enabled those requirements to be met, including one-man portability and a "lock-on-before-launch" mode of operation.

The Army evaluated two industry Tank Breaker designs against alternatives in a shoot-off conducted in 1987-1988. The results led to selection of the Texas Instruments (later Raytheon) Tank Breaker design based on the DARPA-developed technologies. Department of Defense (DoD) officials approved it for full-scale development in June 1989 under the Army's Advanced Anti-armor Weapon System-Medium (AAWS-M) program. The Army later renamed the weapon Javelin,

which entered full-rate production in 1997. It was the world's first medium-range, one-man-portable, fire-and-forget anti-tank weapon system. With its missile's tandem shaped-charge warhead, the compact, lightweight Javelin remains the most lethal weapon of its kind. The missile's seeker uses a 64 x 64 long-wave infrared staring FPA whose genesis can be traced directly to DARPA's investment in FPAs during the 1970s and 1980s.

A Raytheon-Lockheed Martin joint venture has produced more than 30,000 Javelin systems for the Army, Marine Corps, and the armed forces of 10 allied nations. The Javelin, proven in combat, saw extensive use by U.S. and allied soldiers, Marines, and Special Operations Forces in Operation Iraqi Freedom in 2003.

ASSAULT BREAKER

In 1978, DARPA began what would prove to be one of its most successful tactical warfare programs, a large-scale technology integration and system proof-of-concept effort called Assault Breaker. It ultimately led to the development of the U.S. Air Force's existing fleet of 17 E-8 Joint Surveillance Target and Attack Radar System (Joint STARS) aircraft, that service's air-to-ground BLU-108 Sensor Fuzed Weapon with terminally guided submunitions (TGSMs), and the long-range, surface-to-surface Army Tactical Missile System (ATACMS).

The 1976 Defense Science Board (DSB) Summer Study found that essential airborne-radar, ground-launched missile, and self-guided submunition technologies were maturing under various DARPA, Air Force, and Army research programs. If integrated in a "system of systems," the DSB believed, these technologies could have a dramatic impact on the U.S. military's ability to detect and destroy mobile, second-echelon Warsaw Pact armored forces behind the front lines from a long standoff range without having to use manned aircraft to attack individual tanks. In 1978, Undersecretary for Defense Research and Engineering Dr. William Perry assigned DARPA management responsibility for the integration effort, called Assault Breaker.

The Assault Breaker concept called for an aircraft-mounted, side-looking, ground-surveillance radar that could "peer" into enemy territory from a safe standoff position day or night and detect concentrations of moving vehicles, coupled with a surface-to-surface ballistic missile targeted to attack them and achieve multiple kills with TGSMs. Using only inertial guidance, the missile would fly to a rough location over the target area, where it would dispense a blanket of the anti-armor submunitions, each able to detect and home in on a moving tank as it descended.

Dr. Robert R. Fossum, DARPA's director from 1977 to 1981, recalled in a March 2007 interview, "Our concept was to put together a system which would put at risk second-echelon armored formations, which were really a great threat. In the first stages of the war, [the Army wouldn't] necessarily have all the air assets [it needed], because they were fighting the air battle. So we had to have some weapon system which would prevent those second-echelon forces from reinforcing the main battle. We generated a goal of being able to engage an entire tank company over a substantial ground area in a single attack and destroy [30-50 percent] of its tanks. Now, to do that would be extremely expensive if you tried to attack the tanks individually. So we [had] to devise a 'bus,' which carried [and dispensed] a whole passel of smaller anti-tank weapons. We were trying to take out the entire formation by destroying a high percentage of its tanks."

Assault Breaker's airborne radar required a long-range, wide-area, ground-moving-target-indication (GMTI) capability, a nascent technology in the mid-1970s. DARPA worked with the Air Force under the Pave Mover program begun in May 1978 to modify existing synthetic aperture radar technology to allow it to detect and track moving vehicles. The Army took responsibility for the missile, and both services continued TGSM development programs. In each of the three components of Assault Breaker – radar, missile, and TGSM – two industry contractors competitively developed the technology. DARPA provided substantial funding for the efforts.

The Assault Breaker program culminated in a successful system flight demonstration in December 1982 at the White Sands Missile Range in New Mexico. In the final test, five TGSMs achieved five direct hits, one on each tank in a pattern of five stationary tanks. The DARPA program

The Javelin anti-armor weapon system was the successful product of DARPA's Tank Breaker program. Javelin was first used in combat during Operation Iraqi Freedom. In one celebrated instance, a small Special Forces A Team mounted in soft-skinned Humvees shattered an Iraqi armored column with the Javelin. Here, two U.S. Marine Corps members with the 2nd Battalion, 6th Marines fire a Javelin anti-tank missile at Blair Airfield, Iraq, in support of Operation Iraqi Freedom.

U.S. Army photo

had successfully proven the concept and demonstrated the major technological features of the Assault Breaker capability, whose further development then shifted to the Air Force and Army.

Although Assault Breaker did not remain an integrated reconnaissance/strike system as originally envisioned, individual portions of the capability were fielded and have proven themselves in combat.

Pave Mover became the Air Force-Army Joint STARS program, won by Northrop Grumman in 1985. Each E-8 is a four-engine Boeing 707-300 series commercial airframe that has been remanufactured and equipped with a 40-foot (12-meter) long, canoe-shaped radar dome mounted under the forward part of the fuselage. The dome houses a 24-foot (7.3-meter) long, side-looking, phased-array radar antenna. The aircraft downlinks radar data to Army ground stations as well as targets information to command-and-control centers. With the aircraft flying a racetrack surveillance orbit at altitudes of up to 42,000 feet, the radar can detect, locate, and precisely track vehicles moving on the Earth's surface out to distances in excess of 150 miles (250 kilometers), even in darkness and adverse weather.

The first flight of a prototype aircraft occurred in December 1988, and the first two E-8A prototype aircraft were used in Operation Desert Storm. They provided a real-time tactical view of the battlefield never seen before in the history of warfare. During the massive Iraqi exodus from Kuwait City, Joint STARS pinpointed thousands of fleeing vehicles for coalition attack aircraft.

The missile portion of Assault Breaker became the single-service ATACMS program. The TGSM efforts led to Textron's Skeet anti-armor warhead and Northrop Grumman's Brilliant Anti-armor (BAT) submunition. The Air Force's air-delivered Sensor Fuzed Weapon dispenses 40 of the Skeets, each of which can detect a tank as it descends and fire an explosively formed copper slug that penetrates the vehicle's thinner top armor. The service's attack aircraft first used the Sensor Fuzed Weapon during air strikes in

Operation Allied Force's Kosovo campaign in 1999. BAT, designed for use by ATACMS, is an unpowered glider with acoustic sensors to detect moving tanks and infrared sensors to engage them in a top attack with a two-stage penetrating warhead.

ATACMS entered full-scale development by Lockheed Martin in 1986 and low-rate production in 1989. Two of the 13-foot-long, 2-foot-diameter missiles can be fired from the Army's Multiple Launch Rocket System (MLRS) tracked launcher, or one from its more recent C-130-transportable High-Mobility Artillery Rocket System (HIMARS), a wheeled 5-ton truck. The missile's range far exceeds those of Army cannon and rockets.

The Army fired a total of 32 Block I missiles during Operation Desert Storm, destroying every target engaged. Block I carries 950 baseball-sized unguided submunitions to ranges up to 100 miles (165 kilometers). The Block IA missile, introduced in 1998, added GPS guidance and reduced the payload to 300 submunitions to extend the missile's range to 180 miles (300 kilometers). The Army fired more than 450 missiles successfully from MLRS and prototype HIMARS launchers in all weather during Operation Iraqi Freedom, including a new Block IA Unitary missile with a single-burst warhead providing less collateral damage. Unfortunately, due to budget constraints, the Army cancelled its ongoing development of a Block II missile equipped with 13 BAT submunitions, which had entered low-rate production, and a Block IIA missile with six improved versions of the submunition in 2003.

The surface-to-surface ballistic missile element of DARPA's Assault Breaker program emerged as the Army Tactical Missile System (ATACMS) shown here being launched from a Multiple Launch Rocket System (MLRS) during testing.

The E-8C Joint STARS, updated in recent years with commercial off-the-shelf processors, remains the world's most advanced airborne wide-area ground-surveillance system. Because enemy land forces in mid-to-high-intensity conflicts depend heavily on ground vehicles for their tactical movement as well as for their firepower, armor protection, resupply, and other major battlefield functions, Joint STARS' ability to detect and target enemy movement gives U.S. military commanders a crucial advantage in land warfare. Movement used to mean survivability for enemy ground forces. Today, movement makes an adversary's forces visible and vulnerable to Joint STARS-supported precision engagements by U.S. aircraft or missiles long before those adversary forces can move into close proximity to friendly forces.

Retired Air Force Gen. Chuck Horner, who orchestrated the Operation Desert Storm air campaign as head of U.S. Central Command Air Forces, wrote in a March 2002 *ISR Journal* article that Joint STARS employment in Desert Storm and Allied Force (with only two of the aircraft available in both cases) indicated that using the radar to help target and destroy even a small percentage of the total number of moving vehicles can create paralysis in the enemy's movement. The paralysis results both from fear on the part of enemy soldiers that occupying a vehicle is tantamount to a death sentence as well as the resulting decrease in fuel, ammunition, and supplies delivered to frontline troops.

DARPA's Pave Mover effort pioneered GMTI radar technology. Other military aircraft equipped with GMTI radars today include the Air Force's unmanned Global Hawk, the U.K.'s Airborne Stand-Off Radar (ASTOR), and NATO's planned Alliance Ground Surveillance (AGS) mix of Airbus A321s and Global Hawks.

As Dr. Robert S. Cooper, DARPA's director from 1981 to 1984, noted in a February 2007 interview, "One of the biggest successes we had while I was at DARPA … was the [Pave Mover GMTI] radar system, [which] resulted in the Joint STARS aircraft that has been so effective in doing the

DoD photo by Tad Gockins

Joint STARS was an outgrowth of the Assault Breaker program, one of DARPA's most successful tactical warfare programs. The E-8C Joint STARS side-looking airborne radar system with moving target indication was a major contributor to the destruction of Iraqi forces during Operation Desert Storm.

U.S. Air Force photo

same thing for ground surveillance that the AWACS aircraft had done for air surveillance."

ARMOR/ANTI-ARMOR TECHNOLOGIES

In the early-to-mid 1980s, concerns emerged about the pace of modernization of Soviet armored forces, as manifested by the more frequent Soviet fielding of new tank and infantry combat vehicle designs with heavier frontal armor or external reactive armor tiles. In 1982, DARPA had begun an extended tactical armor/anti-armor research and technology program. A 1985 DSB Summer Study confirmed and reinforced the implications of the growing U.S./NATO disadvantage in armored systems.

The DSB study, together with a lack of focus among the military services' programs in the area, led Defense Secretary Caspar Weinberger in 1985 to direct DARPA to undertake the management of a new joint armor/anti-armor program with the Army and Marine Corps.

DARPA subsequently investigated chemical-energy and kinetic-energy warhead approaches to defeat tank armor as well as improvements in armor protection for U.S. main battle tanks and other armored combat vehicles. In 1988, the agency conducted a technology demonstration "shoot-off" of chemical-energy and kinetic-energy warheads against simulated Soviet equipment. A major objective of the joint program, which was achieved, was to build a capability in industry to design and test armor/anti-armor technologies and systems.

The successes of the DARPA-led program included advances in chemical-energy shaped-charge designs for tank gun rounds and anti-tank missiles that greatly enhanced their armor penetrating power; similar advances in kinetic-energy rounds with metal penetrating rods; and improvements in lighter-weight armor materials that increased the protection level of U.S. armored vehicles.

The 1991 Institute for Defense Analyses study, *DARPA Technical Accomplishments, Vol. II,* stated, "Overall, in managing this program, DARPA has fulfilled one of its important roles, that of facilitating a rapid approach to an important national problem where our technical capability was lagging. To do this, DARPA drew on a long background of involvement in relevant technology matters. The technology from this DARPA effort has impacted a wide variety of defense systems involving armor, guns, warheads and penetrators, programs totaling several billion dollars."