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Innovation and Invention: Equipping the Army for Current and Future Conflicts

by Richard Lim

Introduction

Throughout the history of the United States, military experts have debated how best to provide capability for future military forces. Some who advocate for the technological dimension of warfare have argued that modern weaponry can transform the very nature of war, making it possible for the United States to defeat opponents quickly, economically and with minimal casualties. As stated by former defense official William Perry in 1978, "Precision guided weapons have the potential of revolutionizing warfare. . . . If we effectively exploit the lead we have in this field, we can greatly enhance our ability to deter war without having to compete tank for tank, missile for missile."[1] On the other hand, some have pointed to cognitive, physical and social aspects of war—the human dimension of warfare—as factors equally critical to ultimate battlefield success.[2] They argue that technology is no substitute for leadership development, character and resilience.

Both perspectives have merit. Superior technology has contributed significantly to American victories, notably the 1991 Persian Gulf War. However, technological superiority, on its own, does not guarantee the successful attainment of strategic objectives. As expressed by B. H. Liddell Hart, "In war, the chief incalculable is the human will."[3] Human willpower and determination adjust tactics, mitigate weaknesses, seek advantages and persevere in the face of great odds. History provides numerous examples wherein human persistence and ingenuity have prevailed over a technologically superior enemy.

Despite these caveats, technology remains a critical enabler that allows the U.S. Army to maintain overmatch against its opponents. Through technical superiority, Army forces can capture the initiative quickly and create multiple dilemmas, thereby limiting the opponent's options on the battlefield. In the future, technology will only increase in importance as the joint force faces an expanding range of threats and as advanced capabilities become more affordable and accessible to potential adversaries. This importance is further heightened since the development of weapon systems generally requires a significant amount of time and effort. The Army faces the challenge of how best—in a fiscally constrained environment—to enhance the capabilities of the current force while sustaining those capabilities for the future force. As a result, the Army is simultaneously pursuing near-, mid- and far-term strategies to develop and maintain these capabilities.

First, the Army is pursuing an innovation strategy—leveraging on-hand and mature technologies—to enable its units to maintain technical overmatch for the near term (the next two to three years). Second, the Army is pursuing product improvement programs (PIPs)—upgrades that enhance the operational capacity of a platform in relation to its effectiveness, efficiency or reliability—to maintain technical overmatch in the mid-term (from three to eight or nine years out). Third, the Army is pursuing an invention strategy—leveraging emerging, leap-ahead technologies—to

counter future threats even before they materialize and ensure overmatch for the far term (beyond ten years from now). This paper argues that the Army's multiphase strategy to concurrently pursue innovation, product improvement and invention best positions it to remain the world's most advanced ground force today and in the future.

The Relationship Between Warfare and Technology

While technology alone cannot win wars, history provides numerous examples of its game-changing potential. The 1991 Persian Gulf War, for instance, was a triumph for superior American technology. During the war, the Army's "Big Five" weapons platforms, including the Abrams main battle tank and the Bradley Fighting Vehicle, coupled with new Global Positioning System navigation, provided ground forces with overwhelming firepower and maneuvering capabilities that were critical to ultimate victory.[4]

Technology can be unpredictable. Weapon systems can change missions over time, sometimes providing capabilities beyond their original design. For example, the Army's Patriot air defense system was first fielded in 1983 to protect against enemy aircraft but was modified to destroy ballistic missiles.[5] Technological solutions can also be the result of improvisation. In the first two decades of the 21st century, the Army's Rapid Equipping Force (REF) has successfully exploited the potential of improvised technology to aid Soldiers serving in Afghanistan and Iraq. Through REF, the Army uses government and commercial off-the-shelf technologies to quickly provide materiel solutions in fulfillment of operational needs.[6] These solutions include PackBots that search for booby traps and grenades and Man-Portable Line Charges that neutralize improvised explosive devices.

Finally, technology takes significant investments in time and effort to mature. As a result, the service lives of weapons platforms and systems can run for several decades; the M60 Patton battle tank enjoyed a lifespan of about 40 years[7] and several of the Army's current major platforms were designed in the 1970s and fielded in the 1980s. Decisions made today will determine whether the military can execute the defense strategy both now and in the future. **To best exploit technology, one must keep in mind its game-changing potential, its unpredictable nature and the impact weapons and systems will have over the course of their lifetimes.**

The Current State of the Army's Primary Technological Platforms

The U.S. Army has overcome years of acquisition delays to remain the world's greatest ground fighting force. Its main combat systems—the product of previous innovations, improvements and inventions—continue to outclass competitors. The M1A2 Abrams is widely regarded as the world's best main battle tank, due in part to its superior armor protection and anti-armor capabilities. Depleted uranium, used to reinforce its armor and ammunition—M829 series sabot rounds—provides the Abrams with world-class basic protection and firepower. Additional lethality is provided by the M256A1 120mm smoothbore gun, the 12.7mm M2HB machine gun and the 7.62mm M240 machine gun. The Army's premier Infantry Fighting Vehicle (IFV), the M2 Bradley, boasts a state-of-the-art protection system and is equipped with a stabilized 25mm cannon with a coaxial machine gun and anti-tank guided missiles. In addition, it is equipped with a second-generation forward-looking infrared (FLIR) system and an independent thermal viewer.

The Stryker Family of Vehicles, part of the Army's overall Future Combat Systems initiative as an interim capability and since retained for its long-term utility, features a double-V hull and slat armor—soon to be replaced by explosive reactive armor—that provides world-class system protection. In addition, the Stryker's ammunition system features either a 40mm MK-19 automatic grenade launcher or a .50-caliber M2 Heavy Barrel machine gun.

The Army's helicopter fleet is the best in the world in terms of size and capability. The AH-64 Apache is considered the world's most lethal attack helicopter with its wide assortment of weaponry. The latest variant, the AH-64E, is armed with a 30mm chin-mounted cannon, advanced precision-kill weapon systems and Hellfire laser-guided missiles. In addition, the AH-64E includes new technologies that enhance maneuverability, survivability and lethality, such as an improved drive system, manned/unmanned teaming capability and the Joint Air-to-Ground Missile seeker. The UH-60 Black Hawk is the U.S. Army's premier utility helicopter for squad-size assault operations and also provides general support, command and control and aeromedical evacuation missions. The latest variant, the UH-60M, features advanced digital avionics, such as a digital cockpit and flight controls, improved survivability with a laser warning system and improved infrared suppression. The UH-60M also includes a Rockwell Collins Common Cockpit Avionics Architecture System for improved pilot situational awareness.[8]

These potent fighting machines ensure that the U.S. Army is the most lethal and advanced ground force in the world. However, the U.S. military's present technical superiority over all competitors may well breed complacency among outside observers. This preeminence leads some to believe that technology enables the United States to overcome all potential opponents regardless of training and willpower, that no real capability gaps exist and that the Army's present advantage will continue indefinitely. While the Army's helicopters were modernized relatively recently—Black Hawk, the UH-60M, in 2007, and the latest Apache, the AH-64E, in 2012—it is often ignored that the Army's main fighting vehicles are losing their technical edge over their competitors. The latest Abrams, the M1A2 Special Enhancement Package, dates to 1992 and the latest Bradley, the M2A3, dates to 2000, rendering them dependent on short-term innovations and PIPs.

More significant, all four of these platforms were originally designed in a very different security environment. They were conceived in the 1970s and built in the 1980s during the Cold War as part of the Army's "Big Five" weapon systems. During that time, the Active Defense and AirLand Battle warfighting doctrines dictated the Army's requirements.[9] The Army has relied primarily on these Cold War-based platforms ever since. The military drawdown and the perceived "peace dividend" at the end of the Cold War led to a "procurement holiday" on big-ticket weapon systems. The wars in Afghanistan and Iraq meant that the current force, rather than the future force, absorbed much of defense spending. Since then, the 2011 Budget Control Act, which introduced sequestration, has squeezed the defense budget, impacting readiness and delaying the Army's invention programs even further into the future.[10] As a result of these developments, the Army has relied chiefly on PIPs since the end of the Cold War. While the "Big Five" have retained overall superiority into the 21st century, the world is increasingly achieving parity in land force and air support technology; short-term innovations and PIPs cannot ensure that America's advantage will continue. Eventually, the United States will have to develop the next generation of weapon systems; these transitions usually take decades of planning and resources.

As the world catches up to U.S. technology, gaps are developing in the Army's capabilities. Most of the world's battle tanks, including Russia's third-generation T-90, Israel's Merkava Mk4 and Germany's Leopard 2A6, are equipped with second-generation FLIR systems. Foreign battle tanks also tend to feature high-explosive fragmentation (HE-Frag) rounds, which the Abrams tank lacks. In addition, most of the world's IFVs have higher-caliber guns than the Bradley's 25mm cannon; these include Russia's BMP-3 with its 30mm auto cannon, Germany's Puma with its 30mm MK44 weapon system and Sweden's CV90 with its 40mm cannon. The Stryker armored personnel carrier, with its .50-caliber machine gun, is even more lightly armed compared to foreign vehicles equipped with medium-caliber weapons.

America's overall lead in attack and utility helicopters is shrinking, as most foreign competitors have achieved technical parity. Attack helicopters (such as Russia's Mi-28N Havoc and China's Z-10) and utility helicopters (such as Russia's Mi-171A2 and the European EC725) all feature composite material, all-glass cockpits with large screen, liquid-crystal, multifunctional displays and enhanced survivability. In addition, foreign helicopters are developing niche capabilities that provide them with advantages over the Apache and the Black Hawk. Russia's Mi028N attack helicopter is armed with a 30mm chin-mounted cannon with side-mounted ammunition boxes to prevent jamming, while its Mi-171A2 utility helicopter features robust armament capabilities and navigation FLIRs. China's Z-10 attack and Russia's Mi-171A2 utility helicopters both feature greater maximum ranges than the Apache and Black Hawk.[11]

The lack of an air-droppable, light-armored fighting vehicle, which provides support to airborne forces, remains a conspicuous capability gap in the U.S. Army's inventory. Both the Russian and Chinese militaries include these vehicles in their inventories, the former featuring the BMD-4M (which boasts weight-reducing magnesium alloys) and the latter the ZBD-03.[12] The U.S. Army once had this capability with the M551 Sheridan light tank and had planned the next generation of airborne vehicles with the Mobile Gun System, but both programs were terminated in 1996. The capability gap remains.[13]

The Future Operating Environment

In addition to mitigating the aforementioned capability gaps, tomorrow's operating environment impacts both the current and future Army. Many of the trends that will shape the future environment are already visible today:

- **Increased velocity of change.** In an era of globalization, diverse threats and the faster and wider diffusion of information, crises will develop more rapidly and unpredictably than ever before.
- **The increased diversity of threats.** Whereas traditional opponents have consisted primarily of nation-states, future threats will arise not only from nation-states but also from rogue and failed states, non-state actors (such as terrorist and criminal groups) and individuals.[14]
- **Wider access to lethal and disruptive technologies.** Sophisticated technology, such as robots, unmanned aerial or ground vehicles and weapons of mass destruction, will be increasingly accessible to and affordable for potential adversaries.[15] These opponents will be able to employ conventional, irregular or disruptive tactics, such as cyber warfare.[16] As a result, enemies will likely be increasingly adaptive and unpredictable.
- **Increased prevalence of urban warfare.** As the worldwide urban population is expected to rise from 50 percent today to 60 percent in 2030,[17] the U.S. Army will likely face opponents in high-population centers with limited resources and little room for maneuvering.[18]

In addition to these broad trends, technological trends in foreign weapons platforms have already emerged and are instructive for building the future force. Among them are:

- main battle tanks with increased precision anti-armor weapons for both direct and indirect fire, active protection systems[19] and FLIR sensors;
- IFVs with larger gun calibers, greater protection and high-explosive payloads;
- airborne light-armored fighting vehicles that are highly mobile, well-armed and moderately well-armored; and
- helicopters with composite materials, all-glass cockpits, liquid crystal and multifunctional displays, higher payloads and longer maximum ranges.

As a result of these global and technological trends, it is clear that the world is moving toward achieving parity with the U.S. military. In addition, the velocity of change is increasing and threats are becoming more diverse and unpredictable. It is critical for the U.S. Army to develop multiple capabilities that allow it to adapt and address a wide array of threats. Technologically complex weapons platforms can take years to mature, further increasing the urgency to develop the capabilities to maintain overmatch. The key to achieving the modernized and adaptive force of the future is through a strategy that simultaneously pursues technical innovation, product improvement and invention.

This effort has already begun, as demonstrated by the Army's Network Integration Evaluation (NIE) and the Army Warfighting Assessment (AWA). The NIE, which the Army has conducted semi-annually since 2011, tests and evaluates network programs to meet requirements and validate yearly capability sets for fielding. The AWA, which will replace one of the two annual NIEs, evaluates new concepts that will be developed into network and non-network capabilities.[20] These capabilities will have an emphasis on joint and multinational interoperability and help shape requirements that are aligned with the Army Warfighting Challenges, the Army's framework for integrating efforts across warfighting functions. Through efforts such as the NIE and AWA, the Army is developing not only the capabilities imperative for the future force but also technological innovations, improvements and inventions critical to those capabilities.

The Technologies of the Future Force

While traditional acquisition strategies focus on procuring platforms, the Army is confronting complex and diverse sets of threats by focusing on developing capabilities.[21] To develop these capabilities, the U.S. Army is simultaneously exploring several technological innovations, PIPs and inventions that hold great promise for the main platforms of the near-, mid- and far-term future force. This effort has the potential to reduce the weight and cost of future weapon systems while exponentially increasing their lethality, protective capacity, adaptability and agility. In other words, this strategy has the potential to create multiple game-changing technologies designed specifically to close current capability gaps and meet the full spectrum of the future threat environment.

Innovation

- **Manned–Unmanned Teaming (MUM-T) (Robotics)**: The Army is working to combine the capabilities of unmanned aerial vehicles (UAVs) with its primary weapons platforms. Specifically, it is focused on teaming up the

Apache helicopter with an RQ-7Bv2 Shadow drone, which is used for intelligence, surveillance and reconnaissance missions. An Army aviation battalion out of Fort Bliss, Texas, is the first unit to be equipped with the combined platform.[22] Through MUM-T, the Shadow transmits live, real-time, full-motion video to multiple receivers across the battlefield. Recent improvements in the Shadow's encryption protection for video and control data links have increased interoperability with the Apaches and reduced lifecycle costs. Overall, MUM-T enhances situational awareness for Apache crews, ultimately contributing to their lethality, effectiveness and efficiency.

PIPs

- **Common Fire Control System (Lethality)**: Since 2000, the Army's Armament Research, Development and Engineering Center has taken steps to integrate fire control systems across various weapons platforms.[23] These efforts have resulted in millions of dollars in savings and an estimated 20 years in time saved in fielding. Examples include consolidating the 120mm Mortar Fire Control System (MFCS) ($9.59 million in savings), the M119 howitzer system ($6 million in savings) and the Portable Excalibur Fire Control System ($2.2 million in savings). Soldiers benefit from consolidation, as they obtain weapon systems faster without having to learn new interfaces. While several issues, such as increased vulnerability to a cyber attack or technological glitch, have yet to be addressed, integration has resulted in reduced testing, cost, development time and training and an increase in reliability and maintainability for the Army.
- **Modular Active Protection System (MAPS) (Protection)**: The U.S. Army's Tank Automotive Research, Development and Engineering Center is developing MAPS, which would synchronize everything from sensors to user interfaces to countermeasures on Army vehicles.[24] The entire protection system would be consolidated into a single central processor that could incorporate individual system elements made by different manufacturers. The system is being designed to defeat shoulder-fired rockets, vehicle-launched anti-tank guided missiles, tank-launched and UAV-launched projectiles and artillery shells. MAPS represents a paradigm shift in which active protection systems will become a mainstay in future Army vehicles. Successful fielding could reduce the amount of armor, thereby reducing vehicle weight and costs and increasing overall agility.
- **Third-generation FLIR (Situational Awareness)**: FLIR is a sensor that enables Army vehicle operators to see through darkness, smoke, rain, snow and fog. Upgrading to its third-generation variant will permit unprecedented situational awareness on the battlefield, permitting commanders not only to identify targets but also to determine the target's intent by incorporating an additional band of nonvisible infrared spectrum.[25] The Army plans to award a development contract in 2016 and for production to begin in 2023. The new FLIR will also feature horizontal technology integration, which means that it will fit in different sights and will be compatible on multiple platforms, such as the Abrams and the Bradley. As a result, third-generation FLIR will provide world-class, all-weather situational awareness with a reduced logistical trail, which will be critical in the complex, urban-based battlefields of the future.

Invention

- **Electromagnetic Railgun (Lethality)**: The Army is considering adding the electromagnetic railgun—a weapons platform that could provide high-impact, long-range, offensive firepower at a relatively low cost—to the Future Fighting Vehicle, the Army's current program to replace the Bradley IFV. The railgun generates a high-speed electromagnetic pulse that propels a 23-pound kinetic-energy warhead to a hypervelocity of Mach 7.5[26] and can strike a target more than 100 miles away.[27] While several issues—such as durability and heat management—have yet to be addressed, the railguns are safer to handle and store, as they have no explosive component, and are significantly less expensive to employ. Railguns, a true leap-ahead technology, would exponentially increase the Army's speed, range and impact capabilities at reduced cost.
- **Autonomous Flight (Aviation Capabilities)**: The Army's Aviation and Missile Research Development and Engineering Center and the Rotorcraft Aircrew Systems Concept Airborne Laboratory are currently developing terrain sensors and navigational algorithms that will provide Army rotorcraft with low-level autonomous behaviors. These behaviors include obstacle field navigation, avoidance of high-power lines and other aircraft and safe-landing-area determination.[28] In addition, the Department of Defense's Autonomous Technologies for Unmanned Aerial System is developing the K-MAX power-lift helicopter that can provide time-sensitive cargo

resupply to Soldiers on the ground in high-threat environments.[29] These technologies will be incorporated in the Future Vertical Lift program, which is intended to develop the Army's next generation of helicopters and will require both manned and unmanned flight capability. Unmanned flight has the potential to provide safer, more efficient supply delivery to Soldiers engaged in combat, reducing the load they need to carry on the battlefield and increasing their agility.

- **High-Energy Laser (Protection)**: The Army is working with Boeing to develop a High-Energy Laser Mobile Demonstrator that would produce a 50-kilowatt laser beam to defeat rocket, artillery and mortar threats as well as UAVs. The weapon is intended to be mounted atop an Army vehicle and to operate in all types of weather conditions.[30] Current testing is focused on examining solid-state laser effects, advanced beam control components and increased laser efficiency. The High-Energy Laser would represent a highly efficient, lower-cost protection system for the Army's vehicles.

Materials

The Army is exploring the use of materials, some composite, that could increase the lethality, protective capacity and durability of its weapons platforms while also decreasing their weight and cost. These include the following:

- nanocrystalline tungsten, which may soon be used to supplant depleted uranium, enhancing the explosive power of anti-tank weapons;[31]
- advanced ceramic matrix composites, which may be used to create light-weight, high-temperature components for Apache and Black Hawk helicopter engines, increasing their fuel efficiency and reducing operational costs;[32]
- aluminum alloys, which may be used for lighter and tougher vehicle armor;[33] and
- auxetic materials, which change shape to absorb energy and dissipate the impact of an attack, thereby providing a more resilient material for armor.[34]

In addition, the process of 3-D printing can reduce the time and cost needed for manufacturing complex parts of the Army's weapons platforms; 3-D printing can allow the Army to build more intricate pieces than with conventional manufacturing—at a lower cost and with minimal waste. It even provides the capability to adjust the composition of alloys for strength, rigidity and flexibility. If fully exploited, 3-D printing could revolutionize the Army's manufacturing process, leading to greater protection and durability for its weapon systems at a lower cost. Materials produced with 3-D technology can also be used to develop the air-droppable tank, thus addressing another critical capability gap.

Conclusion

Advanced technology, properly applied, is vital to meeting the challenges of tomorrow's operating environment. While technology is not a panacea, it does provide a significant edge in deterring and defeating potential adversaries. However, technology is unpredictable; it can be very difficult to discern which weapon systems will become game-changers. In addition, the uncertain nature of the threat environment will continue to increase. Therefore, investments in the innovative use and improvement of current technologies and in a wide array of emerging technologies are required as hedges against uncertainty and unpredictability. In today's constrained fiscal environment, it is critical to explore myriad technologies to achieve a lighter, more agile and more adaptive force.

The Army is doing just that. The technological innovations, improvements and inventions it is exploring may close capability gaps and mitigate the specific threats of the future operating environment in a cost-effective manner. Both the Electromagnetic Railgun and common fire control systems may provide the Army's air and ground platforms with exponentially greater lethality to counter potential adversaries' growing defensive capabilities. Robots in the air and on the ground as well as third-generation FLIR can provide the Army with an agility/situational awareness advantage over its adversaries' tanks and helicopters. Lasers and modular protection systems can enhance defensive measures against growing foreign firepower. Composite materials and 3-D printing can increase lethality and survivability at a lower cost and weight and pave the way for lighter, more agile platforms.

These capabilities—increased agility, lethality, situational awareness, protection and cost-effectiveness—are specifically tailored to counter current gaps and meet the challenges of the future threat environment by providing

technological overmatch. In a world where enemies will be more diverse, more agile and more capable and will be able to obtain technologies with greater ease, and where the pace of change will be faster than ever before, an army cannot fail to develop and exploit these advantages. While the U.S. Army faces an uncertain future, technology, as an enabler, enhances the human dimension of warfare and ensures that the clash of wills now and in the future results in an American win in the complex security environment.

Richard Lim is a National Security Analyst with AUSA's Institute of Land Warfare.

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Association of the United States Army
2425 Wilson Boulevard, Arlington, Virginia 22201-3385
703-841-4300 www.ausa.org