Pushing the Envelope of Battlefield Superiority:

American Tank Development from the 1970s to the Present

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"I was tired of being bombed all day and night. Then I was run over by American tanks, I have had enough."

(Iraqi POW statement quoted by MG Thomas C. Foley during briefing at NATO Commanders Conference, May 29, 1991)

This is the third in a series of articles written on behalf of the Directorate of Force Developments. The earlier articles (Sep-Oct 97 and Jul-Aug 98) addressed the design and development of the principal tanks used by the U.S. Army from World War I to the 1970s. This article focuses upon the latter half of the Cold War to the present. It identifies the M1-series tanks as the culmination of nearly 40 years of pioneering and developmental efforts in the design of tanks and their components. The M1-series provided U.S. Army with an overmatch quality long desired and it provided the springboard for further expansion of this superiority into the 21st century. The author also wishes to acknowledge the guidance and input provided by the command and staffs of the Directorate of Force Development and TRADOC Systems Manager for Abrams Tank Fleet.

In the 1950s and 1960s, the U.S. Army struggled to develop a tank superior to Soviet designs. These efforts resulted in designs too complex and costly to produce. Instead the Army fielded tanks only moderately superior to their Soviet counterparts. By the 1970s, the emergence of the T62 and the proliferation of anti-tank guided missiles threatened even this limited superiority. Worse, the Vietnam War drained funding from tank procurement. Of the reduced number of tanks actually produced, many went to Israel to cover losses suffered during the 1973 Arab-Israeli War. The cancellation of the MBT70 and XM803 programs, coupled with continued problems with M60A2 and M551 development, left the Army with no viable replacement to the M60-series. Congress became skeptical about the Army's ability to build a tank in a timely and efficient manner.[1]

The M60A1 made up the bulk of the Army's first-line tank force confronting Warsaw Pact forces in the Federal Republic of Germany. This tank was considered inadequate for offensive operations or sustained off-road action. Although one of the largest tanks in the world, it lacked sufficient protection against newer Soviet hypervelocity kinetic energy rounds or shaped-charge weapons. The M60A1's fire control system also suffered from a high failure rate. The tank's poor night-fighting and fire-on-the-move capability further undermined its ability to fight continuous mobile actions.[2]

The Army needed a new tank. Congress agreed, but it sought strict oversight to prevent excessive cost overruns. A new design would have to be cost effective, simple, reliable, possess superior survivability, and accommodate future upgrades. It would have to be a major improvement over the M60A1 to justify the investment. Designing a tank to meet these criteria required time. In the interim, the M60A1 would be upgraded through a series of product improvements.

In 1969, the Senior Officers Materiel Review Board recommended a series of modifications to improve reliability, mobility, night operability, and fire-on-the-move capability. Between 1971 and 1975, the Army acted upon these recommendations. A top-loading air cleaner increased engine life by reducing dirt intake. The Reliability Improved Selected Equipment (RISE) engine, coupled with improved electrical components, increased service life. During testing, this engine averaged 5,000 miles of operation before replacement. New T-142 tracks with replaceable pads and provision of a deep water fording kit enhanced mobility. The M60A1 received passive night vision devices that intensified ambient light. On moonless nights, however, such devices became useless. Therefore, the tank retained its searchlight, although its use revealed the vehicle's position. The appearance of the night-sight-equipped T62 in the 1973 Arab-Israeli War spurred this attention to night actions. Israeli experience with the M60-series in the same conflict revealed the existence of a shot trap between the turret chin and ring. These areas received additional armor. An add-on gunnery stabilization system made fire-on-the-move a worthwhile capability. In test environments, the probability of hitting targets while moving increased from near zero to fifty percent.[3]

A second set of improvements became standardized as the M60A3 in 1978. These upgrades focused upon a fire control system capable of a "… quantum improvement in hit performance and enhancement of range capability during adverse weather, smoke, fog, haze and dust."[4] Key components of the fire control system included a laser rangefinder with a five kilometer range, a thermal sleeve to prevent gun tube warping, a wind sensor to provide input on wind conditions, and an analog ballistic computer. The computer reduced the number of manual calculations required of the gunner. Data input included the range, wind, target tracking rate, atmospheric conditions, and ballistic solutions for each of the four ammunition types available. With this input, the computer determined the proper azimuth and elevation for the gun.

The computer increased the complexity of the fire control system, but — unlike earlier systems — it simplified the gunner's action. It also possessed a self-diagnostic capability for troubleshooting. The new fire control system raised the probability of a first-round hit to 75% at 1,500 meters — significantly better than that achieved by Soviet tanks.[5]

Desired Characteristics for a New MBT[9]

Feature	Requirement
Weight	46-52 tons combat loaded
Operating radius	275-325 miles
Survivability	armor protection against the Soviet 115-mm gun, internal compartmentalization, external fuel stowage, interior spall liner
Armament	105-mm or 120-mm main gun; 1 x .50 caliber MG; coaxial 25-mm Bushmaster cannon; turret mounted 40-mm grenade launcher
First round hit probability (service test with kinetic energy round at 1500 meters range)	Stationary vehicle vs. stationary target: 92% Moving vehicle vs. moving target: 58%
Road speed	25 miles per hour
Dash speed	40-50 miles per hour
Mobility	35% of operation off roads

Other new features supplemented the fire control upgrade. Coaxial machine guns on American tanks had been plagued by unreliability for much of the Cold War. In the M60A3, this problem ended with the adoption of the superior M240 7.62-mm machine gun. A Kevlar lining helped to minimize the effects of spalling inside the turret. Survivability also benefited from the addition of an automatic fire suppression system that relied upon sensors within the tank to detect heat and light from fires. The sensors in turn activated Halon fire extinguishers that suppressed the fire.

In 1979, the tank was fitted with M239 grenade launchers, based upon the launchers used on the British Chieftain tank. They provided an umbrella of smoke to mask movement. Following the pattern of Soviet tanks, the M60A3 also received an engine smoke generator in 1983. A tank thermal sight replaced the gunner's passive night sight. Gunners now identified targets by their heat signature without reliance upon an independent light source. The new sight could be used through smoke, inclement weather, and on moonless nights.[6]

The first M60A3 left the Detroit Arsenal Tank Plant in 1978. In 1979, the 1-32 Armored Battalion became the first unit in Europe to receive the "new" tanks. Initial production plans called for a total of 7,352 M60A3s. However, most would be converted M60A1s, with only 1,686 new production vehicles. Implementation of production and fielding occurred slowly, resulting in an M60 fleet of multiple configurations. Despite resultant training and maintenance problems, no all-encompassing retrofit program was adopted. Instead the Army opted to channel funding toward the development of a replacement to the M60-series. With the M60A3, the M60's evolution ended. No further major upgrades were planned.[7]

Unfortunately, Soviet tanks continued to evolve, gaining in the critical areas of survivability and lethality. Initial uncertainty about the capabilities of the T64 and T72 led to fears that the M60-series would be outclassed in the event of war. These fears influenced the Army's new tank design. In 1972, the Main Battle Tank Task Force was established at Fort Knox, Kentucky. Chaired by Major General William R. Desobry, the Armor Center commander, the task force established the basic characteristics of the new tank. The table above outlines the task force's key requirements. Subsequent Department of Army staff reviews aimed at eliminating unnecessary items and lowering cost.[8]

These basic characteristics reflected a sober extrapolation of current tank capabilities and battlefield threats. The Task Force sought a low cost yet capable tank that could accommodate improvements. In selecting a conventional gun for the main armament, the task force reversed the trend toward missile and rocket weapons begun in the 1950s. While the Shillelagh gun/missile system suffered from a variety of problems, the conventional gun offered simplicity, reliability, and cost effectiveness. Moreover, advances in kinetic energy ammunition and stabilization systems had eroded many of the advantages associated with missile weapons.[10]

Based upon analysis of combat in the 1973 Arab-Israeli War, the Army made crew survival the top priority. Army studies of combat operations identified antitank guided missiles and shaped-charge weapons as principal threats to the tank. Heavy losses among Israeli tank crews further underscored the need for more effective protection. This need was realized in several ways. The design — designated XM1 — dropped the commander's cupola typical of American tanks in the Cold War era. By also placing the driver in an almost horizontal position, the vehicle height fell from the M60A3's 129.2-inches to 93.5-inches. Armored bulkheads separated the crew from the fuel cells. Main gun ammunition was stowed in the turret rear behind an armored door. In the event of a penetration of this compartment, blowoff panels in the turret roof ensured that the effects were vented upward and outward away from the crew. This configuration helped to protect the tank from the catastrophic explosions experienced by Israeli crews in the M60 and American M4 crews in World War II. A spall liner and Halon fire extinguishing system similar to that developed for the M60A3 further reduced the chance of a catastrophic kill.[11]

Ballistic protection benefited from the British development of composite armor. The Royal Ordnance Research and Development Establishment at Chobham, England, found that layered armor separated by various materials and placed at angles provided unprecedented protection against shaped-charge weapons. Britain made this technology available to the United States, where it underwent improvement at the Ballistics Research Laboratory. At the direction of Army Chief of Staff Lieutenant General Creighton W. Abrams the tank's weight increased to 58-tons to maximize the benefit of this new armor. Abrams and many of the personnel who participated in the XM1's development remembered firsthand the problems American tankers faced in World War II engagements with German Tigers and Panthers. The increased weight limit indicated a determination not to send under-armored tanks into combat.[12]

The XM1 also became the first American tank to use a gas turbine engine. The concept was not new, having been continuously studied since the end of World War II. However, by the 1970s advances in gas turbine technology made possible a reliable engine of great power. Moreover, the experience of military helicopters equipped with turbines indicated that such engines possessed longer service lives and lower maintenance costs. Con-

Early production M1 turrets move down the Chrysler production line.

sequently, the Office of the Secretary of Defense mandated that XM1 prototypes include the AGT 1500 gas turbine engine. This engine provided 1500 horsepower and a 26:1 power to weight ratio, compared to 13:1 for the M60A3. It provided rapid acceleration and allowed cross-country speeds over thirty miles per hour. The torsion bar suspension and rotary shock absorbers ensured a smooth ride, for a tank. The suspension system, however, did not apply new concepts; instead it represented the evolution of World War II technology.[13]

The fire control system benefited from the steady pioneering efforts undertaken since the 1940s. It integrated the main gun with an analog ballistic computer, stabilization, thermal sights, a laser range finder, ballistic solutions, and environmental inputs. This system was similar to that developed for the M60A3 but added a muzzle reference sensor that compensated for gun tube droop. The overall system also proved easy to operate. Essentially, the gunner selected the ammunition type, tracked the target in his sight, and fired. The computer automatically adjusted for target lead, eliminating the need for a gunner's estimation.

The XM1 carried the same 105-mm gun as the M60A3. However, future modifications would install the more powerful, German-developed Rheinmetall 120-mm gun, still under development in the 1970s.

The secondary armament of the XM1 was simplified in response to recommendations by the U.S. Army Armor Center at Fort Knox. Analysis of the 1973 Arab-Israeli War indicated no need for a 25-mm cannon or 40-mm grenade launcher. Tank crews tended to prefer machine guns for use against helicopters and personnel, while using the main gun for any vehicular target. The specialized weapons were replaced by machine guns. More space became available for main gun rounds.[14]

In 1973, Chrysler Corporation and General Motors Corporation received contracts to build prototypes. In 1976, Chrysler beat GMC in competition for the XM1 engineering contract. Chrysler built 11 prototype tanks and implemented a schedule of overlapping development and operational tests in 1978-1979. This pace left little time for problems identified during the development tests to be remedied before soldiers began field testing them. Preparations to train soldiers to operate and maintain the tank lagged, along with preparation of the technical manuals. When operational tests began at Fort Bliss, Texas, the results were poor. Sand clogged the air filters, tracks were thrown easily, and soldiers struggled to learn a tank fundamentally different from the familiar M48s and M60s. As problems mounted, these difficulties were reported to a public already primed for failure. The XM1 became the target of growing criticism.[15]

However, continued exposure gradually provided a cadre of crews and maintenance personnel familiar with the tank. Technical problems were solved, including those plaguing the air filters and tracks. Press criticism continued, despite an extensive series of live fire tests against a combat-loaded vehicle that demonstrated a major improvement over the M60-series in survivability. In 1979, Chrysler received authority to build 110 XM1s for more extensive field tests in various weather, topographical, and radioactive environments. The success of these tests resulted in the vehicle standardization as the M1 in 1981. The same year Chrysler ended its association with Army tank production when it sold its tank production facilities to General Dynamics.[16]

In 1982, the 3d Infantry Division became one of the first combat formations in Europe to receive the M1. After several months of operations, the new tank's popularity rose. During gunnery, tank battalions averaged a 75% or better first round hit probability. The tank proved reliable and not too complicated to service — as long as the technical manuals were followed. The clarity and simplicity of these manuals helped to avoid many of the complications that arose with the M60A2 and M551. The same year the 3d Infantry Division's M1s made their debut in the annual NATO wargames. There, the quietness of the turbine and its fire-on-the-move capability earned the tank the nickname "Whispering Death."[17]

Fielding of the M1 continued throughout the 1980s. All combat units in Europe had received the new tank by 1989. The M1 was expected to be the Army's principal tank into the 1990s, and it had been designed to accommodate upgrades. Improvements to previous tanks had been reactive solutions to problems, but the M1 design sought to anticipate future upgrades before the first tank was fielded. Consequently, a series of upgrades occurred with minimal changes to the basic design and at a reduced cost. The first modification included increased frontal armor, more external stowage, and suspension improvements. The result became the Improved Performance (IP) M1. In 1984, the M1A1 entered service, featuring the M256 120-mm gun and an NBC system that worked on the principal of overpressure. By maintaining a higher air pressure inside the tank, toxic vapors were kept outside. By 1989, all European tank units fielded the M1A1. The addition of depleted uranium mesh led to the M1A1 Heavy Armor (HA), but not all tanks carried this additional armor. By providing an add-on package to meet Marine Corps needs, the Army avoided building a separate, special tank for amphibious operations.[18]

The 1991 Gulf War demonstrated the tank's true effectiveness. The M1A1 comprised the bulk of the American tank strength, but it was not faultless. Sand clogged the air filters, requiring stops every few hours for clearance; the turbine engines consumed four gallons of fuel per mile traveled; gun sights could not effectively identify friend or foe at longer ranges; the thermal sights overheated and required shutdown periods to cool. Yet the tank obtained speeds over forty miles per hour cross-country. Its thermal sights allowed target engagement in smoke, sandstorms, and at night. The tank proved reliable and robust, with operational readiness rates over 90 percent. The NBC system served a dual role, helping to cool the crew stations. First round catastrophic kills at ranges from 2,000 to 3,000 meters were common. Nor were targets behind berms safe from destruction. Although not invulnerable, the tank's compartmentalization minimized crew casualties. Cost became the principal determinant of whether to repair or write off a damaged tank.[19]

3rd Armored Division tankers pause to blow out their air cleaners during Desert Shield.

Following the Gulf War the U.S. Army downsized. The collapse of the Soviet Union ended the Cold War and with it public willingness to sustain high levels of military spending. The Army began to close its bases overseas and changed to a power projection force, largely stationed in the United States. Preparations for the future focused upon a smaller, lighter, and more lethal force structure capable of supporting rapid worldwide deployments. In the Information Age, the Army would rely upon digital communications technology and satellite feeds to provide and disseminate accurate information about the enemy. Such information permitted a faster operational tempo. Doctrine focused upon nonlinear operations that exploited information technology.

In the changed environment of the post Cold War era, airborne and early entry forces needed a reliable and easily deployable armored vehicle. Such a vehicle would provide the armored muscle necessary to perform reconnaissance, security, and peace operations. The M551 did not meet expectations. After intermittent design work on a replacement in the 1970s and 1980s, the Army awarded FMC, in 1992, a contract to build the Armored Gun System (AGS). Following engineering, user, and low velocity air drop tests, the AGS appeared ready to enter limited production, but a final decision was delayed. Nevertheless, six prototypes had been built with a seventh vehicle under construction for demonstration to potential foreign buyers. The AGS featured a 105-mm gun, an autoloader, two machine guns, a fire control and stabilization system similar to that of the M1-series, and a 1553 data bus to monitor vehicle subsystems and facilitate linkage to the Army's emerging tactical Internet. Powered by a 6V92 TIA diesel engine that provided 550 horsepower, it obtained maximum speeds over 40 miles per hour. It also featured add-on armor packages, permitting the protection level to match the anticipated threat during a mission. With a three-man crew, the small-silhouette vehicle was intended to simplify and minimize support requirements. The power pack, for example, could be easily rolled out for inspection or repairs.[20]

Despite the advanced state of development, the Army cancelled the AGS program in 1996. Budget considerations had become the principal determinant of materiel development. Weapon systems competed to survive. The Army opted to cut entire programs to fund others rather than disrupt their procurement and fielding schedules. The AGS became a casualty. Its termination freed $1 billion in long-term spending.[21]

The incorporation of digital technology into a tank resulted in the M1A2. The original design of the M1 included plans for future upgrades. The first set of improvements led to the IPM1, M1A1, and M1A1HA. The second upgrade package focused upon the vehicle's electronics. The core electronic architecture included a 1553B Data Bus and RS-485 Power Bus. Multiple linked subsystems ran simultaneously and shared data without any crew input. A computer automatically processed data regarding navigation, tactical operations, and fire control, displaying the information automatically to the crew and/or to other vehicles. It also ran a continuous series of self-diagnostic tests to determine mechanical and electronic failures. The computer identified the problem and automatically reconfigured the vehicle's hardware to optimize performance. Two duplicate computer systems — hull processing unit and a turret processing unit — provided a redundant capability. Damage to either system would not impair the tank's operation. Behind this digital capability lay a desire to unburden the crew from routine, time-consuming reporting and monitoring tasks.[22]

The M1A2 retained the 120-mm gun, but used information technology to enhance combat effectiveness. It featured a Commander's Independent Thermal Viewer that allowed the tank commander to select one target while the gunner engaged another. This "hunter-killer" system decreased target acquisition time and improved the ability to engage multiple targets. Originally developed for the MBT70, it had been omitted from the M1 as a cost-cutting measure. The Gulf War, however, indicated a need for the device to permit tank commanders a better view of the battlefield. The tank commander's station benefited from better protection and improved visibility when buttoned up. The Intervehicular Information System (IVIS) informed the crew of the locations of themselves, friendly, and enemy forces. Automatically updated, this system also permitted a single tank to designate targets for other friendly elements to engage, including fire support. The commander could also send and receive messages and overlays. The M1A2 included a global positioning system receiver that assisted navigation. The driver had the ability to steer the vehicle to preselected waypoints determined by the commander. The tank automatically tracked its own location and fed this input to IVIS. Collectively, these features sought to provide the crew with better situational awareness and permit them to exploit this information. The same principle applied to the Army's overall digitization effort.[23]

The Army received the first prototype M1A2 in 1990. Testing and evaluation began in 1991. Initially, the new tank showed little improvement over the M1A1. The sophisticated electronics package proved temperamental and the software unreliable. However, during operational tests conducted in 1993, the M1A2 outperformed the M1A1. The M1A2's better situational awareness improved navigation, movement, target acquisition, and hit probability. Yet its reliability remained too low for combat missions due to electronic problems. This situation gradually improved. By 1998, the M1A2's maintenance system was considered more effective than that of the M1A1.[24]

As reliability improved, a series of safety problems emerged. Unannounced and uncontrolled gun and turret movements led to a delay in testing in 1995. Data processing problems occurred, impacting the tank's operation. A series of hardware and software changes followed. During another series of tests in 1996 involving gunnery, road marches, and tactical maneuvers, these problems did not recur.[25]

The last completely new production tank intended for the U.S. Army left the production lines in 1993. Other new production went to Kuwait and Saudi Arabia. These foreign purchases helped to keep the M1A2 program alive and sustain a tank production capability. For the U.S. Army, only a few prototypes and 62 M1A2s were entirely new production vehicles. The rest of the M1A2 fleet now in production comprises conversions of older M1 tanks.[26]

In 1995, the 3-8 Cavalry Squadron became the first combat unit to receive the M1A2. The rest of the 1st Cavalry Division began to receive the tank in 1996, followed by the 3d Armored Cavalry Regiment. Yet before fielding had begun, a decision was taken in 1994 to modify the M1A2 with a system enhancement package (SEP). The SEP aimed at immediately adapting the IVIS digital communications system to the new Army Standard and leveraging new proven technology. The SEP will be cut into the M1A2 production line in 1999. It will upgrade the tank's electronic architecture to incorporate the latest advances in computer technology. Future upgrades can then be enabled without requiring costly modification to the configuration or computer hardware. Changes will allow the M1A2 SEP to be compatible with the Army's Common Operating Environment for digitization. The SEP also includes the use of lighter tracks and titanium parts to lower the vehicle's overall weight. Other features include an environmental cooling system to protect the electronics, second-generation forward-looking infrared optics to clearly identify targets at four kilometers and beyond, and an under-armor auxiliary power unit. The last item will allow operation of the electrical systems without running the engine, thereby reducing fuel consumption. The Gulf War demonstrated the value of using satellite feeds to navigate via a global positioning system. The SEP incorporates this technology to improve the vehicle's position and navigation system.[27]

"The M1A2 and envisioned FCS rely upon technology to a greater extent than any previous combat vehicle. They symbolize a trend in American armor development toward increased use of advanced technology."

Army force modernization strategizing led to discussions regarding the numbers of M1A2 SEPs to be built. Although the M1A2 SEP is considered the centerpiece of the Army's ground force digitization, budgetary limits will permit building only 1,150. To achieve this figure, older M1 configurations will be rebuilt directly as M1A2 SEPs and M1A2s will be retrofitted to the SEP configuration. This approach leaves the Army with a large M1A1 fleet that will continue to be the

The AGS light tank system, shown here with the heaviest of its three levels of add-on armor, was intended as a replacement for the M551. It was designed to be delivered by air to provide 105mm firepower for light forces. But after several prototypes were built and testing had begun, the project was canceled to save money.

mainstay of the tank inventory into the 21st century. Fleet sustainment has become a critical issue. The Army recently embraced the Abrams Integrated Management XXI. Under this program each M1A1 will be completely rebuilt. This process will permit the incorporation of new technologies as they become available, resulting in a longer service life and improved effectiveness. To permit interoperability with digital forces, the Army also plans to provide the M1A1 an add-on communications package and the designation M1A1D.[28]

Senior Army leadership has decided not to incrementally evolve the M1-series into a future main battle tank. Instead, in a series of annual Armor Caucuses that began in 1995, the Army opted to focus more resources upon a new revolutionary vehicle, using the term Future Combat System to encourage fresh ideas. Initial characteristics for the FCS include the ability to destroy multiple targets at five kilometers and beyond, a cross-country dash speed of one hundred kilometers per hour, digital communications system, capacity for continuous operations in all battlefield environments, a logistics tail half that required for the M1-series tanks, and ease of air transportability. Protection would rely less upon armor and more upon active systems that detected and destroyed incoming projectiles before they hit the vehicle.[29]

In 1996, the Armor Center formed an integrated concept team to examine technology and alternatives. The following year, the team began a series of briefings on the FCS intended to stimulate comments and ideas. Weight considerations drifted downward from 40-tons to the 20-ton level. Army emphasis upon deployability and the need for greater mobility influenced this change. Development of an emerging Army After Next concept created an environment that did not favor heavy vehicles intended for the close fight. The enemy would not be primarily destroyed through a series of head-on firefights. Instead, he would be first engaged from afar and, as necessary, forced into a close fight that he could not win. By 1998, the Armor Center's FCS concept had triggered the creation of an overarching Future Combat Vehicle effort at HQ, TRADOC. The TRADOC-level analysis included multiple briefings on technology to the Deputy Commanding General. The complex issue of how to modernize includes industrial base sustainment, future force structure and design decisions, as well as an analysis of potential threats. A new azimuth for Armored Vehicle Modernization is expected within the next year.

The M1A2 and envisioned FCS rely upon technology to a greater extent than any previous combat vehicle. They symbolize a trend in American armor development toward increased use of advanced technology. With its electronic architecture, for example, the M1A2 has much in common with a jet fighter. In fact a "pre-flight" checklist for tank crews is under development. The greater reliance upon sophisticated technology, however, underscores the importance of the combat development process. Systems must be financially viable, fielded in a timely manner, and meet soldier needs.

In 1917, the U.S. Army's tank force relied entirely upon foreign technology and tactics. Today the U.S. Army is a world leader in armor, and its tanks are the standard of comparison for foreign militaries. Following are several conclusions based upon this transformation.

- Effective tank designs depend upon the availability of expertise in the areas of design, development, and production. The absence of such expertise led to combat units receiving inadequate and unwanted materiel such as the Ford 3-ton light tank of World War I. It also resulted in the failure to produce an effective tank in a timely manner, evidenced by the failure of the United States to build more than a handful of 6-Ton Light Tanks in 1917-1918, despite possession of detailed blueprints, an industrial base, and a demonstrated need.
- Tank designs have been successful when they relied upon proven technologies. The M60A2 and M551 relied upon the revolutionary but problem-prone Shillelagh gun/missile launcher. Neither tank realized its expectations. The M1 incorporated proven components or technology in an advanced state of development. It proved successful and reliable.
- Tanks must be versatile. Single purpose vehicles possess limited utility and become too expensive to retain in a peacetime environment. Built to counter a particular threat, such weapons lose their value once the threat disappears. In World War II, the tank destroyer found itself performing artillery missions, infantry support, and convoy escort once German tank masses ceased to appear. The weapon disappeared after the war. Unsuited for multiple roles, the heavy tank gave way to the main battle or universal tank concept. Conversely, the M48 was built to fight Soviet tank masses in the Fulda Gap, yet proved equally adept as a jungle-buster in Vietnam.
- Tank designs must reflect real world developments. American tank doctrine in World War II emphasized the use of tanks against soft targets in the enemy rear areas and not hostile armor. Consequently, the M3/5 Light Tank and M4 Medium Tank possessed excellent mobility and reliability but carried weak armor and armament. They operated at a disadvantage when confronted by more powerful German tanks whose doctrine stressed the use of armor to blunt enemy tank action.
- Tank development must be clearly linked to force structure and evolutionary trends. In the 1920s, tank development occurred in a vacuum with little or no coordination with Army development. No coherent Army-level plan integrated future battlefield operations with tank usage or the type of vehicles that would be required. Consequently, the Army's tank fleet continued to comprise obsolete vehicles until 1939.
- The user, developer, and industry must coordinate their efforts throughout the design, development, and acquisition process. Such coordination ensured the rapid production of the M3 and M48 Medium Tanks. It also guaranteed that the M1 provided a major improvement over the M60-series capable of accommodating future upgrades. The absence of this coordination led to the production and fielding of the M26 Heavy Tank too late to play a major role in World War II. It also led to program termination and over-reliance upon interim solutions in the case of the MBT70 and M60, respectively.

American tank designs since World War I reflect the steady advance of technology. They also illustrate the advances made in linking Armor combat needs with the broader needs of the Army. In the 81 years since the first attempts to build a light tank, Armor combat developments continuously introduced new technology into weapon systems that in turn reflected major advances in lethality, survivability, mobility, deployability, and sustainability. These efforts established a solid foundation for the development of new systems for Armor in the Information Age, symbolized by the emerging vision of the FCS.

Notes

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[7]Hunnicutt, *Patton*, p. 215; Foss, *Jane's Main Battle Tanks*, p. 146.

[8]XM1 Program Manager's Office, "XM1 Baseline Cost Estimate; Management Review I; 105mm and 105mm/120mm Programs," undated, p. 1-1.

[9]Main Battle Tank Task Force, "Final Report," pp. 11-23.

[10]As an example of cost effectiveness, in 1972 a single armor piercing discarding sabot round cost $290 against $3,021 for one Shillelagh missile. Source: Main Battle Tank Task Force, "Final Report," Annex C, p. 8.

[11]"XM1 Baseline Cost Estimate," pp. 1-13 to 1-14; Steven Zaloga and Peter Sarson, *M1 Abrams Main Battle Tank 1982-1992* (London: Reed International Books, Ltd., 1993), pp. 5-6.

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