Ammunition Loading Systems for Future Tanks

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Introduction

The past three decades have witnessed a profound and ever broadening interest in the development of automation for armored combat vehicles. This has evolved through "human factors engineering" to "man-machine interface" to "Manprint," with the ultimate goal being to achieve autonomous operation of many complex subsystem functions with minimal labor or human intervention. The major drivers in this trend toward autonomous operation have been lethality, survivability and strategic transportability, as well as the ever-increasing complexity of combat vehicle systems introduced by rapid technological change. One of the last frontiers in the U.S. main battle tank is the inevitable automation of the Ammunition Loading System (ALS).

Advanced electro-optics, fire controls, kinetic penetrators, and turret stabilization systems enable the crew to acquire, engage, and destroy targets at greater ranges while aggressively moving cross-country. This accurate, fire-on-the-move capability is now limited only by the loader's ability to ram another round into the breech while undergoing the disorienting effects of roll, pitch, and yaw in a 40 m.p.h.-capable M1A1/A2 Abrams Tank! Automation can provide consistent and high reload rates under fairly extreme cross-country conditions.

One of the advanced survivability features of the current Abrams Tank is the compartmentalization of the 120-mm ammunition, which affords the crew a high level of protection from the effects of secondary explosions if the magazine is penetrated. This protection is diminished during round transfer for loading, at which time the large magazine door is briefly opened. Automation of the loading process can reduce the time period of exposure, as well as reduce the area which must be opened to handle the round.

Future tanks will be required to provide the same (or higher) level of crew protection as the M1A2 Abrams, but at a substantially reduced gross vehicle weight (40-50 tons). Some weight reduction will be realized through advanced composite armor and active vehicle defense systems, but most weight savings will be realized through the reduction of the overall armor envelope. This means lowering the crew size, which in turn requires reducing the crew's workload and enhancing crew efficiency and combat effectiveness through automation. The reduction in tank size will positively affect survivability and significantly enhance the ability to deploy U.S.-based combat power abroad.

The Future Main Battle Tank (FMBT) must capitalize on a revolutionary design and development philosophy as a completely integrated, multipurpose weapon system. Since one of the principal contributors to lethality is the main gun rate of fire (ROF), it must be considered as a major design driver for any future tank configuration. Consequently, future tanks (and major upgrades to existing tanks) will most likely be equipped with an Automatic Loading System (ALS) that reduces crew workload and allows an unprecedented, continuous rate of fire while on the move. The main gun and the ALS must be considered as a fully integrated weapon system to reflect the close interrelationship and dependency between the gun, ammunition, and lethality.

FMBTs and major tank upgrades will be equipped with state-of-the-art Battlefield Management Systems (BMS) and fire control systems. These systems will be comprised of multi-sensor targeting and fire control with automatic air/ground target acquisition through thermal imagery and/or millimeter-wave radar processing and tracking. The BMS will provide a day/night integrated armament system capable of automatically engaging multiple targets, with the option of no human intervention. A high rate automatic loader must be incorporated to fully exploit the capability of modern battlefield management systems and "fire-on-the-move" lethality. Automation lessens the crew workload and makes it feasible to contemplate novel tank configurations and smaller tank crews.

An automatic loading system permits development of an unmanned turret and lends itself favorably to the reduction of the four-man crew. It substantially increases the rate of fire under all conditions, provides the capability to rapidly engage multiple targets and ultimately contributes to the tank's overall survivability. An unmanned turret dramatically reduces volume and weight, yielding a much lighter tank with a smaller silhouette. If the conventional manned turret arrangement is maintained in the future, or if an automatic loading system is introduced into an existing tank turret, the fourth crew member's role could be expanded to data management and target acquisition, or else eliminated. For example, the introduction of battlefield management into the M1A2 may be best exploited by a full-time data manager. Tank maintenance, perimeter security and the 24-hour battlefield are other considerations in establishing crew size (The three-versus-four-man-crew is a doctrinal issue and should not be driven by engineering considerations.)

Since lethality is a principal design driver, any rational design approach for a future main battle tank will commence with the selection of the armament system, to include the main gun and the ALS, continue with the selection of a conventional or unmanned turret, and conclude with the remainder of the tank literally "built" around the integrated weapon system.

The purpose of this article is to discuss various design approaches to Automatic Loading Systems (ALS) and to outline the effect they may have on the overall tank configuration and its combat effectiveness. Our commentary will be based upon the design experience accumulated through 16 years of involvement in various U.S. ammunition autoloading development programs, and through expertise the authors have developed over a career of involvement with main battle tanks of European, U.S., and Soviet design. In the discussion of different design approaches, we will provide a brief overview of previous experience in various ALS design and development programs undertaken for the U.S. military.

General Dynamics Tank Test Bed Demonstration Vehicle

In 1983, the U.S. Army Tank Automotive Command (TACOM) awarded a contract for design, fabrication, and demonstration of a 120-mm "brassboard" autoloader transfer mechanism. This device was required to cycle ammunition from a designated storage position to a simulated gun breech and back, at 12 rounds/minute, while leaving no witness marks on the fragile combustible case after the completion of 20 loading repetitions per round. Following successful demonstration of this "proof-of-principle" device, a follow-on contract was awarded to design, build, and test the full-up autoloader in the Tank Test Bed turret.

The TTB Autoloader, as depicted in Figures 1 through 3 (showing the autoloader major components and the Transfer Unit in particular), was a conspicuous success. The system consisted of a 44-round capacity "carousel" type mechanized magazine, located in an unmanned turret basket; a fully articulated Transfer Unit (including a rammer) positioned at the rear of the M256 120-mm cannon in the turret bustle; and a microprocessor-based, Electronic Control Unit (ECU).

The system was electrohydraulically powered to utilize the existing turret power supply, and established a new performance baseline in the heretofore unpretentious field of ALS.

The TTB Autoloader successfully performed an entire array of designated functions which are typical requirements for a "generic" main battle tank autoloader:

- Rapid fire reloading of the M256 cannon at a maximum rate of 12 rounds/minute.
- Automatic ejection of spent stubcases through a small door at the rear of the turret.
- Ejection of misfired rounds.
- Restoring and optimally rearranging (inventorying) unfired rounds in the carousel as a result of a cease fire or change of fire command.
- A "soft-present" mode of operation which allows the crew to easily and safely download ammunition from the weapon station through the ejection door at the rear of the turret.
- An upload mode, also performed at the rear of the turret at a rate of 6 to 8 rounds/minute.

The control system performed an inventory management function allowing it to quickly cycle to the nearest available selected round while minimizing center of gravity offsets and power re-

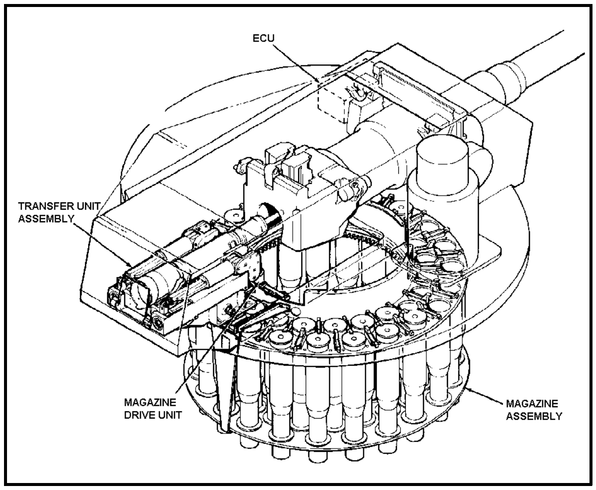


Figure 1
TTB autoloader system general overview and major components.

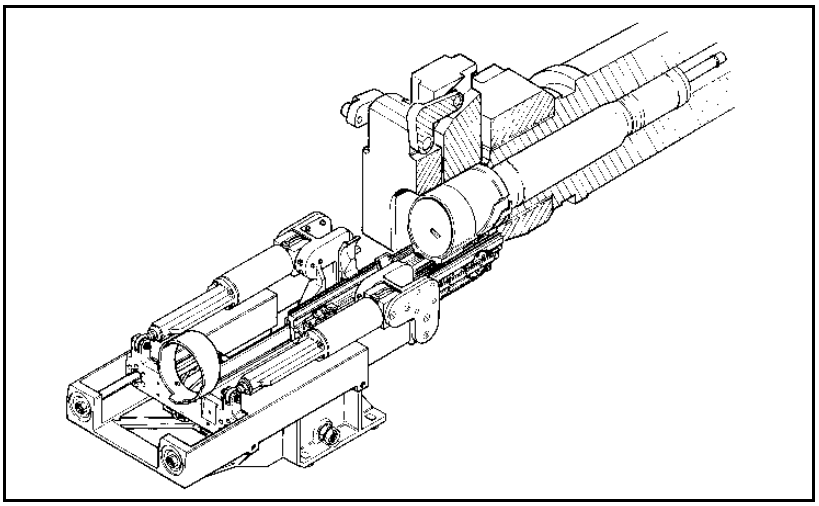


Figure 2
TTB 120mm autoloader transfer unit in loading position.

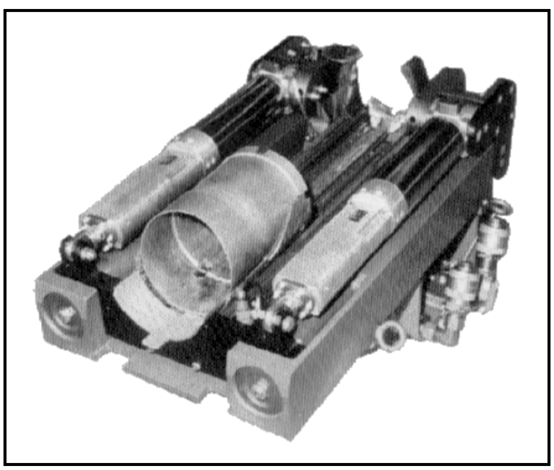


Figure 3
Autoloader transfer unit.

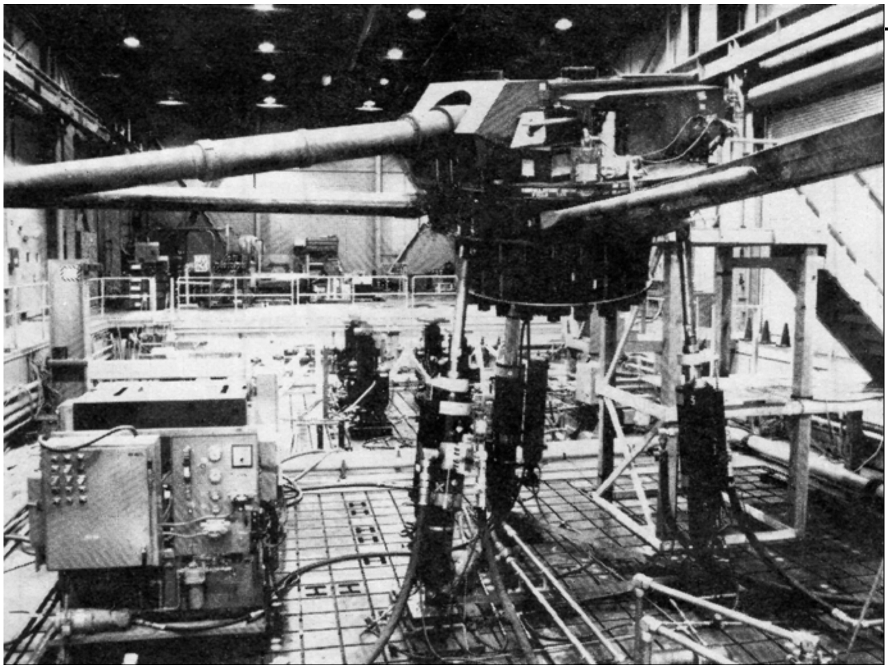


Figure 4. Tank Test Bed turret on TACOM's vehicle motion simulator.

quirement fluctuations. The system incorporated complete actuator redundancy, which allowed continued operation, albeit at a lower rate, when a single point actuator failure occurred. This added reliability feature proved the feasibility of a remotely operated weapon system, and allowed consideration of a three-man vehicle crew as well.

System cycling tests exceeded 66,000 total rounds loaded and were highly successful in their results. Testing included an extensive demonstration period completed on the TACOM Vehicle Motion Simulator, during which ammunition was cycled while the weapon station was concurrently being "shaken" in a true fire-on-the-move simulation as depicted in Figure 4.

The Tank Test Bed system consisted of two major mechanical subsystems:

1) A rotating magazine below the turret ring that stored 44 rounds of ammunition; and
2) A Transfer Unit assembly which provided all functions required to load, unload, present, on-load, off-load, and immediately dispose of spent stub cases and misfires.

The autoloader was designed to accommodate a sustained rate of fire of 10 rounds/minute (with a maximum of 12 rds/min.) and had an empty weight of less than 1,400 lbs. The 44 rounds stored in the magazine were individually protected, supported, and isolated by full-length canisters, which enveloped and supported the rounds. The magazine design allowed ready capacity expansion to 48 rounds, if required, and up to a 60-round complement was feasible.

Electric power consumption was negligible, limited to that required to command pilot operated servo valves and low power sensors. The system was unique in that it was a "no-spring" design and did not rely on spring-loaded components of any kind for autoloader operation.

The transfer unit featured a hydraulically actuated rammer system designed to limit tensile loads applied to the stub-case to 110 pounds maximum (approximately 2 g's, including gravity) and to limit compression loads applied to 220 lbs max (approximately 4 g's). Stub-cases and misfires were ejected overboard at a velocity of approximately 11 ft/sec. Ejection was due aft and level through a single ejection port/loading access door.

FASTDRAW Mechanized Magazine

In the mid-1980s, an alternative ammunition handling system was considered for the M1A1 that incorporated a mechanized rotary magazine, as depicted in Figures 6 and 7. Developed in cooperation with General Dynamics, FASTDRAW was an extremely lightweight, robust, and reliable system with numerous important advantages over "traditional" stationary rack-type storage systems. The 36-round system (identical twin magazines) was designed for the 120-mm equipped M1 tank series, but can feasibly be reconfigured for a reduced ammunition complement in lighter vehicles and in smaller (105-mm) caliber ammunition. The most consequential features of the FASTDRAW approach to tank ammunition storage were:

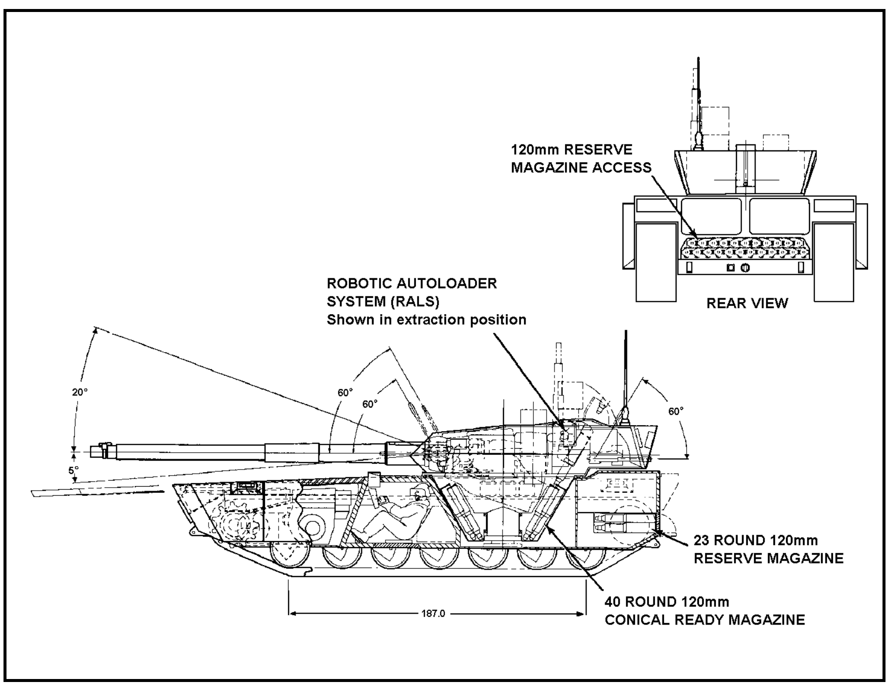


Figure 5. Future MBT showing RALS and reserve magazine.

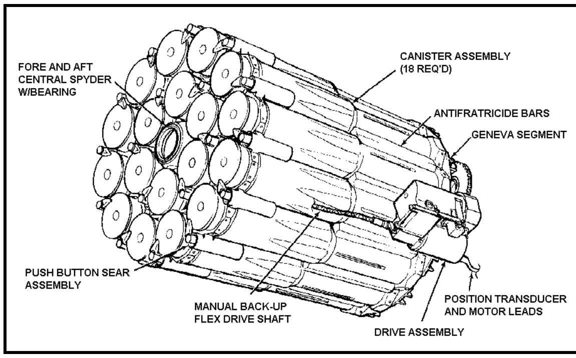


Figure 6. FASTDRAW magazine assembly.

- Significantly reduced blast door complexity and sealing requirements, which yielded enhanced crew safety and survivability.
- Complete separation of the two ammunition compartments by a solid armored wall, which would provide enhanced vehicle survivability and fightability in the event of an ammunition compartment penetration.
- Automatic presentation of the selected type of ammunition to the loader, as opposed to the loader searching the rack for the required type of round.
- Reduced bustle structural weight and complexity — in the case of the M1A1 tank, 350 lbs.
- Instant accessibility of all of the stored rounds, no "disassembly" of the rack required to reach rounds in the corners of the bustle.
- Complete inter-round fratricide protection.

FASTDRAW could have been powered either electrically or hydraulically through a simple, precise Geneva drive mechanism. FASTDRAW's weight advantage resulted from the honeycomb-like structural assembly, wherein the canisters themselves provide mutual support and rigidity, eliminating the need for heavy fore and aft structural support plates.

The FASTDRAW approach also provided the intrinsic benefit of built-in growth options, or pre-planned product improvements. The function of the carousel(s) bringing the ammunition to a single extraction point, lends itself favorably to the replacement of the fourth crewman with a robotic ammunition transfer unit. This transfer unit would work the same way as the TTB device, with the exception of an additional lateral pair of actuators required to shift the transfer unit from the magazine pick-off plane to full alignment with the gun tube and breech at the loading position.

Block III Tank Autoloader

The joint venture company AVTA (FMC/General Dynamics Land Systems), was awarded a contract for design, development, prototype fabrication, and test of a next-generation main battle tank, which incorporated a 140-mm autoloader system. This highly complex requirement involved storage, transfer and loading of an extremely fragile, "two-piece" 140-mm round that measured 1.5 meters in overall length. The round's fragility required particular attention to shock and vibration during storage, handling, and transfer, with emphasis on controlled deceleration to ensure "soft" stops.

Figures 8 and 9 are illustrations depicting several conceptual Block III designs which took into consideration an overall vehicle integration approach. Figure 8 depicts the ALS with a 40-round capacity transverse magazine arrangement, a "round swapper," a 4-round carousel, and a transfer unit. The principal round path is from the storage magazine through the swapper, to the carousel, to the transfer unit, and finally to the gun. Figure 9 depicts a different configuration of the ALS, with a longitudinal magazine arrangement, turntable, dual round swappers, an elevation rack mechanism, and a transfer unit. Both approaches utilized a canister (which may or may not be an integral part of the ammunition packaging) that provides the necessary protection and ensures round integrity at all times. The introduction of the canister concept requires the utilization of a swapper to swap full with empty canisters. The concept depicts a well integrated ALS in the tank and shows the feasibility of such a system when incorporated into a new tank design configuration.

The Block III Tank Program was terminated due to reprioritization of the threat, although the 140-mm cannon development will most likely continue. Due to the still-current sensitivity of the technology involved with this program, much detail of our ALS design cannot yet be released.

Future Main Battle Tank (FMBT)

Figure 5 shows a conceptual design of an ALS for a FMBT based on the TTB autoloader prototype. This concept was a winning entry in a contest held by *ARMOR* magazine for the design of a FMBT. This innovative derivative provides continuous theoretical 15-16 rounds/minute loading rate capability. The system is automatic, compact, computer controlled, electrically operated, lightweight, highly reliable, and remotely operated. It stores forty rounds of all types, which are readily available in a rotary, conical-shaped magazine with anti-fratricide provisions. The autoloader is integrally installed in an unmanned, turreted

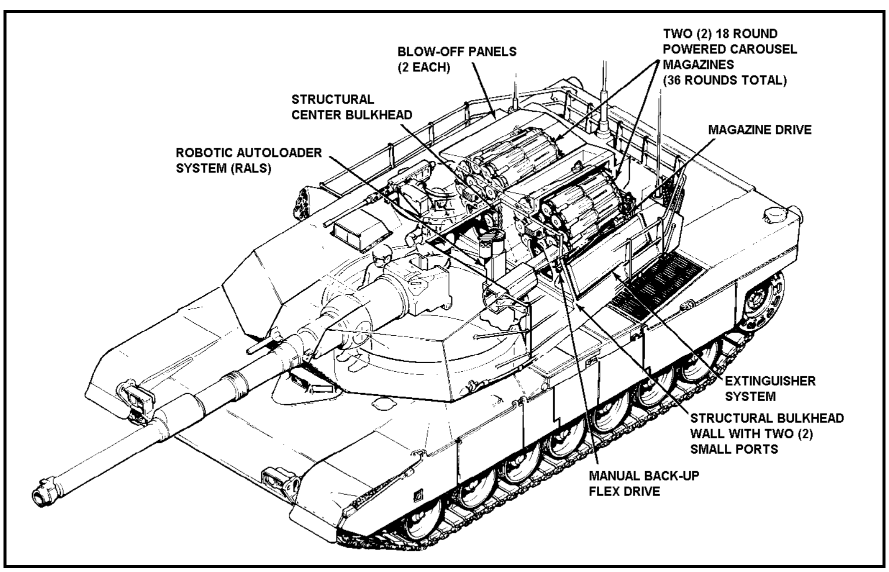


Figure 7. FASTDRAW application to M1A1 concept.

"weapon station" with maximum protection for the crew and ammunition by way of compartmentalization and positioning of warheads as low as possible in the hull, adjacent to "blow-off" panels.

This conceptual system offers full inventory control, optional round replacement and a misfire ejection port that will interface with an automated reload system such as the Future Armor Resupply Vehicle (FARV). An additional 23 rounds are stored low in the rear of the hull in a reserve magazine. An additional transfer mechanism can be devised to automatically transfer rounds from the reserve magazine to the ready magazine. This arrangement would make the entire complement of 63 rounds available to the ALS without the crew leaving its compartment. This feature is particularly important when the tank is operating in a contaminated NBC environment, where leaving the crew compartment is undesirable. The ALS and the Battlefield Management System combined provide a superior kill capability and substantially increase shock effect and weapon system lethality.

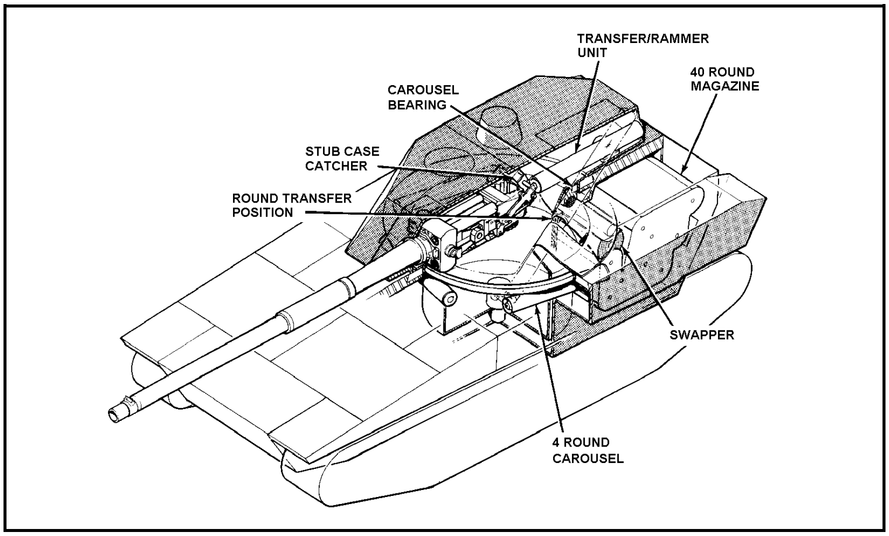
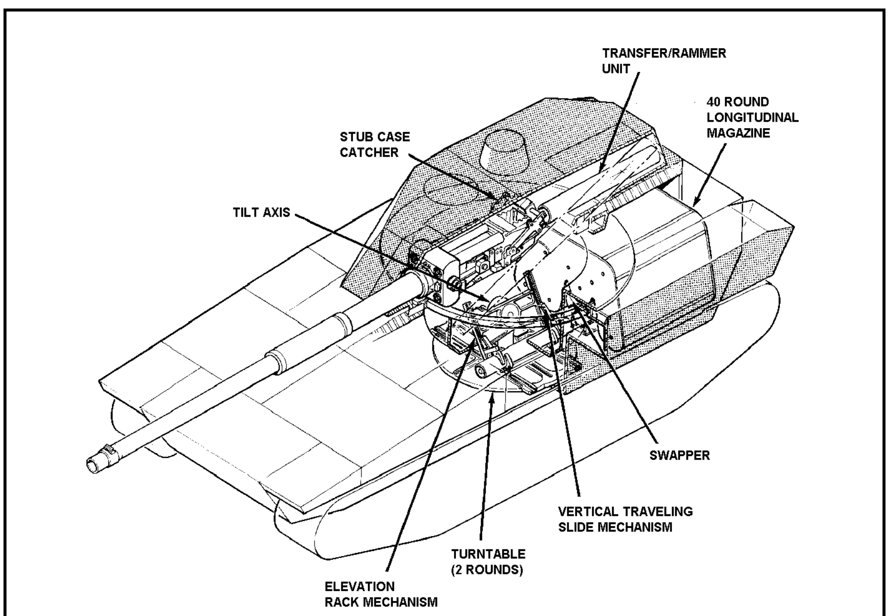


Figure 8. (Above) In this tank, the RALS feeds rounds from a transverse magazine.

Figure 9. (Below) a general overview of the RALS adapted to a tank with a longitudinal magazine arrangement.



Conclusion

The main battle tank will remain a viable, necessary weapon system for the foreseeable future. Continued technological improvements will result in reduced volume and lighter vehicles, but the tank's historical mission will remain the same: shock, mobility, and firepower. Automatic loading systems will become standard, providing reliable, rapid reloading, thereby increasing lethality. Crew member duties will be readjusted to address other battlefield management technological needs. Efforts at TACOM and Picatinny Arsenal to develop a 120-mm compact tank autoloader and a 155-mm howitzer autoloader are indications of this trend. Just as we would never consider sending an infantryman into battle with a bolt-action rifle, future tank designs will fully automate the loading function.

Western Design Corporation (WDC), a small defense company in Irvine, California, specializes in the design, development, and production of ammunition and material handling systems for the U.S. and international military markets. WDC's track record includes a variety of air, land and seaborne weapon systems that require automated feed, resupply, and optimized ammunition packaging.

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