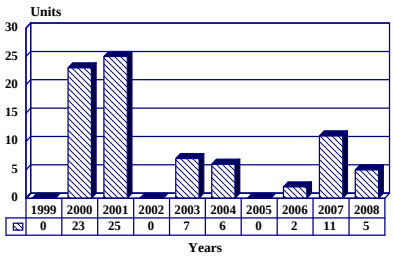
M109 155 mm Self-Propelled Howitzer - Archived 4/2000

Outlook

- Production of new production M109 systems forecast to run through the forecast period, albeit in a mercurial manner
- M109A6 Paladin modernization and retrofit program for US Army to wind up in 1999
- Further modernization and retrofit potential exists
- Bar graph to the right is for new production M109 systems only

10 Year Unit Production Forecast
1999 - 2008



Orientation

Description. A tracked 155 millimeter self-propelled artillery system

Sponsor. The development and United States' procurement of the M109 has been sponsored by the United States Department of Defense through US Army Materiel Command and Industrial Operations Command.

Contractors. This artillery system was originally developed and manufactured by the Cadillac Motor Car Division of General Motors Corporation at the Cleveland Tank Plant; subsequently, Chrysler Corporation also manufactured the M109 at the Cleveland Tank Plant. In 1974, Bowen-McLaughlin-York (later, BMY Combat Systems) began the manufacture of the M109 at its facility in York, Pennsylvania. The present manufacturer is United Defense Limited Partnership, a new firm resulting from the 1994 merger of BMY Combat Systems and FMC Corporation. While headquartered in Arlington, Virginia, the manufacture of new M109 systems still takes place at York, Pennsylvania. Major subcontractors include the Alliant Techsystems, Allison Transmission Division of General Motors Corporation, Detroit Diesel Corporation and Watervliet Arsenal.

Licensees. Otobreda (formerly OTO Melara), La Spezia, Italy, has a license to develop and manufacture the M109 equipped with an indigenous 155 millimeter cannon; this program has been developed into the M109L retrofit and modernization effort. Also RDM Defense Engineering, Rotterdam, the Netherlands, has a license to manufacture M109 components. Samsung Shipbuilding and Heavy Industries has co-produced the M109A2 under license for the Republic of Korea.

Status. The M109 is in production and in widespread service throughout the world. All existing inventories of US M109 systems have been upgraded to the longer barreled M109A1/2/3 standard with most being the A2 or A3. Development of the basic design continues in the United States with the latest standard being type classified the M109A6, called the Paladin. A program to modernize 950 existing US Army M109 systems to the A6 standard is ongoing.

Total Produced. As of January 1, 1999, a total of 8,045 M109 systems of all models had been manufactured by all sources; this DOES NOT include the M109A6 systems completed by that time, as those are rebuilt systems.

Application. Mobile artillery fire support at the battalion and/or division level.

Price Range. The M109A2 was last listed in the Fiscal 1986 government documents at a unit price of $740,000. The recent export contract to Saudi Arabia, discounting the support, documentation, training and spares, yielded a $761,600 unit price in 1989 dollars. Each M109A6 rebuild had an initial (first 164 units) unit price of approximately $1.35 million; this has decreased to $503,000 for the major production. A complete new production M109A6 Paladin (Howitzer Improvement Plan II) has a $2.1278 million unit price in 1999 dollars.

Technical Data

Crew. All versions of the M109 except the A6 Paladin have a six-man crew. The A6, which has an automatic loading system, has a four-man crew.

Muzzle Brake. Double-baffle

Recoil System. Hydropneumatic

Breech Mechanism. Interrupted screw stepped thread -Welin-type

Ammunition. The M109 can fire all US/NATO standard 155 millimeter ammunition including the M107 and M795 (High Explosive); M449A1, M483A1, M692, M718, M731, M741 (submunition dispensing); M549 (High Explosive Rocket Assisted); M454 (nuclear); M110, M116, M825 (Smoke); M121A1, M687 (Chemical); M485, M818 (Illumination); M804 (Practice) and the M712 Copperhead cannon launched guided projectile.

Dimensions. The following data are for the M109A3 with data for the M109A6 Paladin in parentheses where different. The height figure is without a machine gun mounted on the turret.

	SI units	**US units**
Length overall	9.12 (9.80) meters	29.92 (32.15) feet
Width	3.15 meters	10.33 feet
Height	3.28 (3.24) meters	10.76 (10.62) feet
Combat weight	24.95 (28.74) tonnes	27.50 (31.68) tons
Fuel capacity	511 (504) liters	135.9 (134) gallons
Ordnance caliber	155 millimeters	6.10 inches
Cannon length	39 calibers/6.05 meters	39 calibers/19.83 feet

Performance. The automotive performance is on a metalled road and is essentially the same for the M109A6. The cannon range is for the A1 through A5 model with the M185 cannon, with the M284 cannon of the A6 in parentheses; the ballistic performance is with non-assisted ammunition. The rates of fire are for the M109A3; for the M109A6, the burst rate is three rounds in 15 seconds and six rounds per minute for three minutes; the sustained rate is the same.

	SI units	**US units**
Maximum speed	56 kilometers per hour	34.78 miles per hour
Maximum range	346 kilometers	214.9 statute miles
Step	53 centimeters	1.74 feet
Trench	1.82 meters	5.97 feet
Slope	40%	40%
Gradient	60%	60%
Fording	1.06 meters	3.48 feet
Elevation	+75°	+75°
Depression	-5°	-5°
Traverse	360°	360°
Maximum ordnance range	18,100 (24,000) meters	19,794.2 (26,246.4) yards
Maximum rate of fire	4 rounds per minute	4 rounds per minute
Sustained rate of fire	1 round per minute	1 round per minute

The M109A6 is fitted with the M284 155 millimeter cannon, an improved version of the M185; the maximum range of this cannon, using the M864 projectile and Zone 8 charge, is slightly over 28 kilometers (30,620.8 yards).

Engine. Detroit Diesel Corporation supplies the 8V-71T eight-cylinder, liquid cooled, supercharged, two-cycle diesel engine which is rated at 302.13 kW (405 hp) at 38.34 revolutions per second (2,300 rpm). The power-to-weight ratio for the A2 and A3 with this engine is 12.11 kW per tonne (14.72 hp per ton). A 24 volt/100 ampere electrical system with four 12 volt model 6TN batteries is the standard electrical fit of the A2 and A3.

The M109A6 uses the 8V-71T LHR eight-cylinder, liquid cooled, supercharged, two-cycle diesel engine which is rated at 328.12 kW (440 hp) at 38.34 revolutions per second (2,300 rpm). The power-to-weight ratio is 11.41 kW per tonne (13.89 hp per ton). While a 24 volt electrical system with four 12 volt model 6TN batteries is still used, the increased electric power requirements of the Paladin mandated the integration of a 650 ampere electrical system.

Gearbox. The Allison Transmission Division of General Motors Corporation supplies the XTG-411-2A (4A in the A6 Paladin) cross drive gearbox with four forward and two reverse gear ratios.

Suspension and Running Gear. The M109A2 and A3 use an independent torsion bar type suspension with seven dual tired road wheels on each side and no return rollers; the A6 is the same except that it is strengthened for the added weight of the system. The M109A6 is fitted with the improved design T-154 track assembly, provided by Goodyear.

Fire Control. The M109 is normally used for indirect fire missions with the targeting data provided by a forward observer direct or through some sort of a command post. Through the A5 model of the M109, the fire control consists of the M1A1 gunner's quadrant, M15 control, M118C elbow telescope with a magnification of four and a ten degree field of view and the M117 indirect fire telescope with the same performance as the M118C. The autonomous fire control suite of the M109A6 is described below.

Variants/Upgrades

Variants. The following variants have been developed from the basic M109 chassis:

M992. This is the Field Artillery Ammunition Support Vehicle which is covered in a separate report in the Military Vehicles book. More recently, M992 vehicles have been created from older model M109 systems.

Maintenance Assistance Vehicle. The Maintenance Assistance Vehicle is for repair of vehicles in the combat zone. Based on the M992, this vehicle is not yet in production.

Medical Evacuation Vehicle. Another vehicle based on the M992, the Medical Evacuation Vehicle is an armored ambulance; this vehicle is not yet in production.

Fire Direction Center Vehicle. The Fire Direction Center Vehicle is also based on the M992 and is being tested by the US Army Artillery School; 119 have been exported. This vehicle contains command and control and data link equipment for conducting multiple artillery missions.

M975. This is a modified M109 chassis mounting the US Roland surface-to-air missile system. About 30 vehicles, including prototypes, were produced.

Command Post Vehicle. A command post vehicle developed by the US Army Human Engineering Laboratory for use as a test bed to study command, control and communications in nuclear battlefield environments. As of early 1999, a single prototype existed.

M109/IT. This variant, a private cooperative effort between the contractor and Royal Ordnance, integrates the Royal Ordnance International Turret with the basic M109 hull and chassis. This turret is equipped with a new cannon which is 45 cal in length. The new turret features a semiautomatic loading system, new fire-control system and all welded aluminum construction with added Kevlar® armor. The M109/IT weighs 25.991 tonnes (28.65 tons). With the ability to fire all NATO pattern ammunition plus the latest Extended Range Full Bore/Base Bleed ammunition, the M109/IT can conduct fire missions at up to 38.5 kilometers (42,104 yards). A wide range of secondary armament systems, ranging up to the Mark 19 grenade launcher is available. In 1990, this program went dormant.

M109TX. This is a further development of the M109/IT first shown in mid-1986. The TX (Tailored Extra) version integrates Marconi Command and Control Systems' MOGUL gun laying system, a new vehicle

navigation system from Bendix, an improved 8V-71T engine and XTG-411 gearbox with other improvements with the basic International Turret. As of early 1999, this program is dormant.

M109/Gas Turbine. For trials purposes, as part of several proposed upgrade programs for the M109, AlliedSignal (then the Garrett Turbine Engine Company) installed its GT601 vehicular gas turbine in an M109. The installation is essentially a totally new powerpack. The GT601 is rated at 559.5 kW (750 hp), giving a much better power-to-weight ratio. However, as of early 1999, this installation had yet to be adopted by any M109 user.

XM-11S. This is a threat radar simulator developed by the US Army Missile and Space Intelligence Center and modified by General Dynamics.

Retrofit and Modernization Program Overview. In addition to the US Army's own depots at Anniston, Alabama, and Mainz, Germany, as well as United Defense, a major US firm that has long been involved in the M109 modernization and retrofit market is Marvin Land Systems (formerly FMS Corporation) of Los Angeles, California. In addition to offering kits for various system upgrades, this firm can also accomplish complete overhaul and rebuilds for the M109. Other firms and organizations involved in the M109 modernization and retrofit market are Belgian Army/Arsenal du Matériel Mécanique et de l'Armement, Norsk Forsvarsteknologi of Norway, Otobreda of Italy, RDM Defense Engineering of the Netherlands, Rheinmetall Industrie of Germany, Royal Ordnance of the United Kingdom, Schweizerische Unternehmung für Waffensysteme of Switzerland, Thyssen-Henschel of Germany and Urdan Industries of Israel. This list is not all inclusive; a number of nations (such as Spain as detailed below) have used their national arsenals to upgrade their M109 systems.

- M109 and Division Support Weapon System. In the late seventies, the Army began studying the follow-on for the M109. As part of this Division Support Weapon System program, Norden Systems proposed three versions of improved M109 vehicles:

- M109MP3. The same as the M109 with the addition of a modified M199 cannon, new powerpack, command control and communications equipment, automatic fuse and primer feeding mechanism and new cooled nuclear, biological and chemical protective suits for the crew.

- M109MP2. The same as the MP3 but with the addition of a new suspension system, chassis improvements, a new automatic breech mechanism, increased ammunition storage and a semi-automatic projectile loading mechanism.

- M109MP1. All the above improvements plus a fully automatic projectile and propellant loader, new armor and a total environment nuclear, biological and chemical defense system.

In late 1983, it was decided that the M109, in a greatly enhanced form, would fill the Division Support Weapon System mission need. This program was called the Howitzer Improvement Program, sometimes called HIP. The M109A5, described below, is the first stage or level of development, the Howitzer Improvement Program I or HIP I, while the new M109A6 is the second stage or Howitzer Improvement Program II or HIP II.

M109 Howitzer Improvement Program II (M109A6). This is the Division Support Weapon System program developed variant for the M109; it was subsequently designated M109A6 and named Paladin. The main enhancements incorporated in this latest model of the M109 are in the areas of the cannon, with the integration of the 39 caliber M284 ordnance in the M182 mount; new hydraulic control system, recoil system, loader assist mechanism, and traverse mechanism; increased ammunition storage in a new turret with new armor and a full width bustle, engine, gearbox and other automotive and suspension improvements; automatic fire control, navigation and other communications-related and electronic systems; remotely operated powered spades; and survivability improvements including an automatic Halon gas-based fire extinguishing system, new nuclear, biological and chemical defense system components and a micro climate cooling system. The M284 cannon is a modified and improved version of the M185 which is used on the M109A1-A5, which is in turn a version of the M199 which is used on the M198 towed howitzer. The new mechanical assist loader increases the short-term maximum rate of fire to four rounds per minute. Advanced position and azimuth equipment with a digital on-board fire-control computer and upgraded communications equipment have also been installed. Various survivability enhancements, including ones to reduce crew fatigue and heat stress, have been incorporated in the A6 model. Overall, the M109A6 is to be so different from the basic M109 as to be considered a new weapon system. While the M109A6 program is initially being applied to existing M109A2 vehicles as a modernization/retrofit, this standard is the one for serial production for export.

The development program included the separate development of several cannon/armament options. One of these options, the one eventually selected, is the Modified Armament System consisting of the M284 39

caliber cannon, an enhanced version of the M109's existing M185 cannon, with a modified version of the current M178 mount designated the M182. The Advanced Armament System would include either the M283 39-cal cannon which is also based on the M199 cannon used in the M198 towed howitzer, or the XM282 52 caliber extended range cannon. Either cannon would use the M183 gun mount, an armored mount that has redundant recoil and recuperator assemblies.

In 1987, the then Bowen-McLaughlin-York began to produce prototype hardware and initiated component engineering design tests. Tests were conducted on these components and the first ballistic hull and turret were completed during the first quarter of Fiscal 1987.

In Fiscal 1988, Phase II of the development and test program plus assembly of the first five prototype systems was completed during first quarter of the year. A total of 11 M109A6 prototypes were fabricated for the United States (two additional systems were fabricated for Israel). A prototype qualification test was completed in the first quarter of the year: a logistics maintenance demonstration was also held. The Operational Test phase ran into the fourth quarter of Fiscal 1988. A Milestone III type classification initial production review was completed in mid-1990 and a production contract was awarded to the then BMY Combat Systems in September 1990.

Original US Army plans called for 1,750 units of the M109A2 and A3 to be converted to A6 configuration at a rate of 210 per year from Fiscal 1990-1997. Due to some technical problems, this schedule slipped about a year. More recently, the declining defense budgets and the dramatic changes in the threat scenario have resulted in plan changes. As of this writing, the latest number is 950 units to be procured, but this is still subject to change, mainly in relation to the possible stretch in the XM2001 Crusader (formerly the Advanced Field Artillery System-Cannon) program.

The M109A6 rebuild program is so complete that the end system can almost be called a new production item. The M109A2 is sent to Letterkenny Army Depot in Pennsylvania. The depot removes the old turret and completely overhauls the chassis; a number of new components, such as a suspension system, are added as kits supplied from United Defense and other sources. When the hull and chassis are completed, the system is sent by rail to the United Defense manufacturing facility. There, the new turret is integrated with the rest of the system and the M109A6 prepared for delivery to the US Army. Production of the M109A6 Howitzer Improvement Program kits began in late 1990. The first M109A6 production unit was delivered in mid 1992; the production rate has subsequently run around 180 units per year with the last units now expected to be delivered in late 1999.

Israel, which had been involved in the Howitzer Improvement Program, had also planned to convert 400 units of its M109 inventory to A6 configuration. However, budgetary constraints and other factors have put this plan on hold.

Austria and Spain have announced that they are planning to bring their M109 inventories up to A6 standard; however, the Spanish subsequently decided to opt for the A5 enhancement.

Work performed by. The initial system concept studies were executed by the former FMC Corporation, located in San Jose, California, PCF Defense Systems, Renton, Washington, and then United Technologies (Norden Systems Division), Norwalk, Connecticut, in the 1979-1983 time frame under the Enhanced Self-Propelled Artillery Weapon System study. The Army in-house organizations participating in the development program were: the then US Army Armament Munitions & Chemical Command, Tank-Automotive and Armaments Command, and the Communications Command. The prime contractor for the howitzer improvement approved items from both the Howitzer Extended Life Program and Howitzer Improvement Program and was selected in October 1985. A full-scale development contract was awarded to BMY Combat Systems (formerly Bowen-McLaughlin-York) of York, Pennsylvania. BMY Combat Systems formed a team of first-tier subcontractors that includes Alliant Tech-systems of Minneapolis, Minnesota, for fire-control development; Electronics and Space Corporation (formerly Emerson Electric Company) of Saint Louis, Missouri, for loader/rammer mechanisms; RCA of Burlington, Massachusetts, for onboard diagnostics/ prognostics; and a number of smaller firms. The US Army Armament Research & Development Center developed the modified gun mount and advanced gun mount, prototypes of which were built by Rock Island Arsenal. Benet Weapons Laboratory developed the modified and advanced cannon, prototypes of which were fabricated at Watervliet Arsenal. While BMY Combat Systems was awarded contracts for the first 164 rebuilds, in May 1993, the then FMC Corporation won the competition to upgrade the (then) remaining 660 systems. Subsequently, FMC Corporation and BMY Combat Systems merged their operations under the United Defense Limited Partnership organization.

In detail, the M109A6 contains the following improvements listed by area of improvement; these are discussed in detail below.

HULL/TURRET

New production turret
Halon fire detection/suppression
Kevlar spall reduction liners
Increased ammunition storage
Micro-climatic cooling
Diagnostic/prognostic systems
Improved commander's hatch
Full width turret bustle
Improved turret drive system
New turret traverse system
Propellant segregation in turret
Ventilated facepiece
External storage baskets
Crew compartment drains

ELECTRONICS

Automatic fire-control system
Ballistic computer
SINCGARS radio
Built-in training software
Communications Processor Unit
Modular Azimuth Position System
Driver night vision

ENGINE, DRIVETRAIN AND SUSPENSION

Improved version of 8V-71T engine
Segregated hydraulic compartment
Engine/gearbox disconnect for starting
Engine/gearbox removal aids
New engine performance sensors
Improved electrical system components
Automotive reliability improvements
Final drive disconnect
Upgraded suspension components
Improved version of XTG-411 gearbox
Improved hydraulic system with new components
Slave start circuit
Engine sensor connector covers
Radiator crossover tube cover
New 650 ampere alternator
Desert cooling
Air cleaner blower relay
Upgraded final drive components

ARMAMENT

M284 cannon with M182A1 mount
Remotely operated barrel travel lock
Automatic cannon pointing control
New cannon drive servos

The following paragraphs detail the M109A6 enhancements as well as other available modernization and retrofit programs for the M109.

New Turret and Turret Bustle. The M109A6 has a new-production turret based on United Defense's International Turret design that features higher survivability, increased structural integrity and better human factors engineering. The ceiling is raised about 15.24 centimeters (six inches), and the right side turret door is eliminated. The turret facilitates installation of the A6 modernization kit and integration of either the modified armament system or the advanced armament system and has a full-width turret bustle for propellant charge storage. The bustle has a capacity for 45 charges plus space for five projectiles as ready rounds. With the exception of these ready rounds all projectiles are stored below the turret ring in the hull. The initial design was permanently open to the crew compartment, but a revised version separates the storage from the crew compartment with an armored shutter and is equipped with external blow-out panels.

The US Army has adopted the Israeli external storage basket configuration for the forward turret and will be removable for rail, sea, or air transportation. The interior is fitted with Dupont Kevlar spall-suppression liners along the sides and ceiling of the crew compartment.

For the M109A6, the Army chose to go with a new-production turret as modifying existing turrets would be too labor intensive, resulting in a patchwork of fixes and a weakened turret structure with less reliability.

Nuclear, Biological and Chemical Protection. On the M109A6, a United Technologies (Hamilton Standard Division) micro-climatic air conditioning and chemical-filtration system is installed on the turret roof to provide filtered, cool air to a maximum of seven crew stations in the vehicle: one in the driver's compartment and six in the turret. Each station is equipped with umbilical hose connections for an individual M25A1 combat vehicle crewman protective mask (ventilated face piece) and a micro climate cooling vest. Developed by the Army's Natick Research & Development Center, the vest is

worn under the crew member's protective clothing and draws cool air from the system to circulate around the soldier's torso. The M109's alternator capacity has been increased to provide power for the system and other electrical requirements.

As part of an earlier US Army Human Engineering Laboratory concept demonstrator, the Human Factors Howitzer Test Bed, a converted M108, was fitted with an AlliedSignal (formerly Garrett AiResearch) environmental control system, air filtration and over-pressure system. Power for these systems was provided by the Human Factors Howitzer Test Bed's vehicular gas turbine engine (see propulsion section). Due to the porous nature of the M109's design, collective protection via the over-pressure system is difficult to establish and requires the crew to wear protective clothing. However, the over-pressure system would provide the crew with additional time to don their protective clothing during closed down operations once a nuclear, biological or chemical attack alarm was received. While not a part of the A6 program, this enhancement to the M109 remains available.

Fire Suppression System. The Paladin features a new fire suppression system utilizing Halon 1301 which provides an automatic detection and extinguishing capability to the crew and engine compartments. The crew area is fitted with optical sensors, an automatic Halon dispensing unit with both manual and electrical activation back-up and built-in test equipment. The engine compartment has a two-shot continuous wire loop detection capability.

Similar design armored vehicle fire suppression equipment is marketed by the following firms: Santa Barbara Dual Spectrum; HTL Industries Incorporated; Spectrex; Kidde-Graviner Limited; Spectronex; and Napco International Incorporated. This list is not all inclusive.

Remote-Powered Travel Lock. This A6 improvement permits the M284 cannon to be taken out of and returned to the travel lock without a crewman leaving the howitzer when operating in a contaminated environment. It also lessens the time to move out and set up for firing operations during normal conditions. The travel lock is gun tube actuated by incorporating two electrical linear actuators for the raising/lowering of the travel lock and clamping/unclamping of the gun tube.

Remote-Powered Spades. As with the travel lock, the two rear mounted spades can be placed in firing position or secured for travel without external assistance by the crew. An electric winch is incorporated to permit raising and lowering of the spades and a safety interlock prevents the spades from being raised until the weight of the howitzer is removed to prevent damage to the mechanism.

Crew Compartment Subfloor Drain. Fluids such as oil and water which collect in the space between the bottom of the hull and the turret floor can create safety hazards and cause maintenance problems with suspension components. Currently, fluids are disposed of by removing the crew floor sections and dipping or pumping the fluids. The A6 modification installs quick drain plugs in the chassis sub floor.

Improved Commander's Hatch. In the M109A6, an improved hatch for the commander is provided. The new hatch is easier to operate and offers an improved level of overhead protection.

Improved Driver's Hatch. A larger driver's hatch with enhanced viewing capability was also fitted to the Human Factors Howitzer Test Bed vehicle. Instead of opening by sliding to the side as with the current hatch, the revised design opens straight up and is locked in the open position. This provides easier movement into and out of the driver's compartment. It also provides a degree of overhead protection when it is not fully closed and does not interfere in turret traverse while in this semi-closed position. While not a part of the A6 program, this enhancement to the M109 remains available.

Desert Cooling. The engine cooling system of the M109 through M109A5 does not meet the desert cooling requirement of 230°F maximum coolant temperature at 46°C (115°F) ambient temperature with the existing radiator. Additional cooling system maintenance problems are caused by operating the engine with excessively low coolant levels. The solution to this problem includes an improved vertical radiator/fan for the 8V-71T diesel engine and general cooling improvements such as low coolant warning indicator; exhaust duct sealing; oil fume emission control system; and thermal blanket insulation. These enhancements are incorporated in the M109A6.

Radiator Cross-Over Tube Protection. Damage to the radiator cross-over tube as a result of stepping or standing on the tube when engine deck covers are opened is a major cause of cooling system malfunctions in the M109. The fix for this problem that is incorporated in the M109A6 is to add stiffeners and step plates over those segments of the tube most susceptible to damage.

Engine-Gearbox Disconnect. A primary cause of battery failure during cold weather starting is the resistance imposed by internal gearbox drag. This A6 modification permits the gearbox main drive shaft to be disengaged from the engine during starting. After engine start and

warm up, the engine will be shut down, the gearbox engaged, and the engine restarted. A positive lock out/lock in feature is incorporated to prevent disengaging or engaging the gearbox while the engine is operating. This feature, along with a final drive disconnect, also permits easier towing of disabled M109 vehicles.

Hydraulic Improvements. In the M109A6, the hydraulic fluid reservoirs are relocated to the left front portion of the crew compartment where they can be vented outside in the event of a turret fire or hit. The hydraulic lines are fused at several points so that in the event of failure or puncture they can isolate and minimize fluid loss.

Suspension Improvements. The M109A6 has its suspension system upgraded with hydraulic bump stops and re-indexed torsion bars. In addition, new suspension system components are added as required.

A hydropneumatic suspension system is available for the M109 series by the team of John Deere and Air-Log Limited. Called the Tandem Strut System, this is a direct replacement for existing shock absorbers on the M109. Other similar systems are available from Dunlop and other firms.

Power Pack Removal Aids. Damage is often caused to engine components during removal or reinstallation of the engine for maintenance operations. This A6 modification integrates quickly installed devices that permit the removing and reinstalling the engine along a predetermined track, thereby eliminating incidental damage. Continued use of a crane-type hoist is required.

Electrical System Improvements. The following is a listing of the electrical system upgrades for the M109A6. Most of these improvements originated under the Howitzer Extended Life Program and are as follows:

INCREASED ALTERNATOR CAPACITY. The electrical system and components are optimized to provide expanded power output for the communications gear, Battery Computer System components, nuclear, biological and chemical equipment, and the Automatic Gun Positioning System. One objective of the A6 program is to provide adequate power output at minimum engine revolutions. The original 100 ampere alternator is replaced with a unit offering a 650 ampere output.

EXTERNAL POWER RECEPTACLE. This improvement permits the howitzer electrical system to draw power from the auxiliary power unit developed for the M992 Field Artillery Ammunition Support Vehicle. The auxiliary power unit is then capable of charging the howitzers' batteries, thereby reducing the time the howitzer engine is required to operate.

SLAVE START CAPABILITY. This action modifies the vehicle slave start system to eliminate electrical system damage or component failure during slave starts. The use of standardized NATO cables and plugs will continue.

AIR CLEANER BLOWER MOTOR. The air cleaner blower motor is susceptible to water damage which causes shorting of the motor and motor switch relays. This modification waterproofs these components similar to the changes used in the M60. Additionally, the in-tank fuel pumps will be removed from the master switch to air cleaner blower motor circuit and drains will be added to the air cleaner filter boxes.

ALTERNATOR/RECTIFIER AND VOLTAGE REGULATOR RELIABILITY. This A6 modification reduces reliability failures in the alternator, rectifier and voltage regulator by incorporating a matching rectifier and voltage regulator for the selected alternator; and minimizes current flow through the regulator by a control circuit design.

ENGINE STARTER. The present primary cause of starter failure is burnout due to excessive use. To reduce failures, the maximum safe engine turnover time was determined and a device that interrupts and prevents further engagement until the burnout hazard subsides was installed in the A6 program. Provisions for an emergency override feature are also included.

On earlier versions of the M109, work on the starter motor can only be accomplished when the engine is removed, which is time consuming and costly and causes much incidental damage. Another A6 modification corrects this problem by providing access to the starter motor through the hull floor, and a redesign of the starter motor mount with the goal of allowing the removal and replacement of the starter motor in less than one hour at the organizational maintenance level.

PROTECTIVE COVERS FOR ENGINE SENSORS AND CONNECTORS. Sensing units located in the engine compartment are often damaged during routine maintenance operation. This fix provides protective covers to prevent damage by personnel or tools during maintenance.

CAB POWER RELAY BOX. This component is often damaged by high pressure water during cleaning inside the turret due to inadequate waterproofing. The fix in the A6 modernization is to provide better waterproofing to prevent damage to the relays caused by corrosion and electrical shorting.

Re-engining. While a new engine is not part of the M109A6 program, a number of options have been

developed in this area. These are available through a number of firms worldwide.

As part of the Human Engineering Laboratory's Human Factors Howitzer Test Bed, an M109 was re-engined with a AlliedSignal (formerly Garrett Turbine Engine Company) GT601 vehicular gas turbine, rated 477.44 kW (640 hp), replacing the then current Detroit Diesel 8V-71T diesel, which is rated at 302.13 kW (405 hp). The existing Allison XTG-411-2A gearbox was retained. In mobility tests, the GT601 equipped M109 demonstrated that it could provide 40 percent more power in the same space as the diesel engine, but at a lighter weight. It also proved that it could climb 60 percent grades and maintain a 18.15 tonne (20 ton) draw bar pull without overheating or system failure. The gas turbine provides a sufficient source of bleed air to operate the Human Factors Howitzer Test Bed's nuclear, biological and chemical system and does not require the installation of an auxiliary power unit.

The GT601 was a developmental engine. If it were to enter production, the engine will most likely be rated at 559.5 kW (750 hp). As a vehicular gas turbine, the GT601 runs primarily on diesel fuel, but has a multifuel capability to burn other hydrocarbon fuels such as low lead and leaded gasoline, kerosene, methanol and alcohol. However, our research indicates that the probability that the GT601 will ever be retrofitted to the M109 is extremely remote.

Depending on the time frame for such a program, other candidates for re-engining the M109 inventory could include a powerpack developed under the US Army's now completed Advanced Integrated Propulsion System program. This developmental effort involved an advanced semi-adiabatic diesel design from Cummins Engine Company and a vehicular gas turbine design from General Electric Company. Cummins also has a 447.6 kW (600 hp) version of the VTA-903 available and is also involved with Hyperbar diesel engine technology. Another potential candidate is a lower rated version of the Perkins Engines Condor, which has been selected for the designated follow-on to the M109, the XM2001 Crusader (formerly the Advanced Field Artillery System-Cannon).

Gearbox Improvements. The Allison Transmission Division of General Motors Corporation has in production an uprated model of the XTG-411 gearbox, known as the -4 series, that is input rated at 447.6 kW (600 hp). The improvements include a change in the torque converter to provide the power curve of the engine in use; increased reliability of the high range clutch; and an additional brake plate and new friction material added. Two versions of the -4 gearbox are available: the XTG-411-4A and XTG-411-4B. The -4 model has been procured by Israel for its T.55 upgrade program. It is not known at this time if the Israelis will install kits to bring the M109's gearbox up to the -4 configuration. The XGT-411-4A is part of the M109A6 upgrade program.

New Track. Another modification not included in the Howitzer Improvement Program is the installation of new tracks. The greatly enhanced T-154 track assembly is standard on the Paladin. The development of new tracks for military vehicles is ongoing in the United States, United Kingdom, Federal Republic of Germany and other nations. Diehl Group (Track & Suspension Division) of the Federal Republic of Germany offers its Type 109.1 and Type 109.2 track systems for the M109 series. The track is an advanced double pin design that averages about 8,000 kilometers (4,970 statute miles) road life. United Defense offers this track as an option to foreign clients and may eventually be procured for the United States' M109 inventory.

Track and roadwheel replacements are also available from these sources: George Blair plc; Bridgestone-Firestone, Catton and Company and Urdan Industries Limited; this list is not all inclusive.

Smoke Generator. An exhaust smoke generator, while not a part of the Howitzer Improvement Program II, remains a possible near term retrofit for the M109. A number of such systems are available, and some international users such as Israel have fitted such a system to their M109 systems.

Automatic Fire Control System. Developed and manufactured by Alliant Techsystems for the M109A6, the automatic fire control system, called the Automatic Fire Control System XXI, is designed to improve the responsiveness of the M109 in replying to and directing fire missions. Using inputs from all command levels from section chief through battalion to corps, the system computes the system's position and orientation, from which it then calculates the cannon's bearing, elevation and correct projectile/charge load needed to effectively hit the target. It completes the action by automatically laying the gun on target. The gun's section chief decides when to load and fire.

The system is a digital design that utilizes a redundant Military Standard 1553 databus and consists of several components: the section chief's display/control unit with menu driven flat panel display and provision for various interfaces; the Modular Azimuth Positioning System navigation/attitude reference subsystem (further described below); a power conditioning unit with a self-contained battery backup; ballistic computer/servo operated weapon controller; the gun drive servos; and a communications processing unit with encryption capability and the capability of a number of interfaces.

Modular Azimuth Positioning System. The Modular Azimuth Positioning System is a ring laser gyroscope based positioning system that is a major component of the Automatic Fire Control System's navigation/attitude reference subsystem called a dynamic reference unit. The Modular Azimuth Positioning System Dynamic Reference Unit functions in two modes: alignment and survey or navigation. In alignment, the Modular Azimuth Positioning System defines its position in relation to true north. Once this is established, the unit sequences to the navigation mode where it continuously outputs its present position and also provides the howitzer's azimuth, tilt, and elevation. The Modular Azimuth Positioning System is provided by Alliant Techsystems.

Single Channel Ground and Airborne Radio System (SINCGARS). The Single Channel Ground and Airborne Radio System is a modern design multi-mode, secure radio system that employs frequency hopping technology. This new radio was developed to replace the AN/PRC-77 and AN/VRC-12 tactical radios in United States' inventories. This radio has been integrated with the M109A6 program.

It is expected that many international M109 users will install similar new radios through the turn of the century as this technology advances. Most users will employ frequency-hopping tactical communications, especially among the NATO M109 inventories. Plessey Military Communications, Denel, NV Phillips, Racal-Tacticom Limited, Motorola Government Electronics Group and Tadiran Limited are among providers of such equipment.

Vehicle Intercommunications. The standard vehicle intercommunications system for United States armored vehicles is the AN/VIC-1 built by Cincinnati Electronics. The US Army is replacing this system with a unit that is used on, but not unique to the Single Channel Ground and Airborne Radio System. A market investigation the US Army Tank, Automotive and Armaments Command conducted showed that sufficient numbers of "off the shelf" systems are available for evaluation. The development was funded under program element number 64751A SINCGARS-V Engineering, Project 098 - Tactical Radio Accessories.

Position Location Reporting System. The Position Location Reporting System is designed to provide field commanders and their units with precise battlefield position information in near real time for the location and movement of United States and allied forces. The Position Location Reporting System provides position and location accuracies down to ten meters (32.08 feet) or less for slow-moving users and 100 meters (328 feet) accuracy for high-speed airborne users. This equipment operates much like a relay station for transmission and reception of messages between user units and the master station. Hughes Aircraft Company (Ground Systems Division) is manufacturing the system for both services.

Hughes has developed an advanced version of the Position Location Reporting System, designated the Enhanced Position Location Reporting System. This system is part of the US Army planned Army Data Distribution System consisting of a mix of Enhanced Position Location Reporting System and the Joint Tactical Information Distribution System Class Two terminals. The Army Data Distribution System is being developed to satisfy an Army requirement for secure, jam resistant distributed data communications in support of five tactical battlefield functional areas which are: maneuver control; fire support; air defense; intelligence and electronic warfare; and combat service support. The Army Data Distribution System was funded under program element number 63713A while the production of Enhanced Position Location Reporting System began in late 1989.

Diagnostics/Prognostics. Diagnostic and prognostic Built-In Test Equipment, supplied by RCA Corporation, is incorporated in the M109A6. This equipment includes sensors and a processor necessary to permit rapid and accurate weapon system fault diagnosis and fault isolation. The M109A6 is the first Army vehicle equipped with a limited prognostic capability as well. The M109 powerpack is fitted with Simplified Test Equipment/Internal Combustion Engine based an the design used for the M992 Field Artillery Ammunition Support Vehicle. The RCA Simplified Test Equipment, Expendable will supplement the onboard system when needed.

Driver's Night Vision. Improved night vision for the driver is provided in the M109A6 with the addition of the Baird Corporation AN/VVS-2 Driver's Night Vision Viewer which is dismountable for daytime stowage. It has also been modified for mounting in the driver's hatch to preclude interference with tube traverse when the tube is at maximum depression.

Hughes Aircraft Company has developed the advanced Driver's Thermal Viewer, designated the AN/VAS-3, that has been replacing the AN/VVS-2 on the M1 tank and other combat vehicles. This equipment could eventually be installed on the M109.

NAVSTAR Global Positioning System. The NAV-STAR Global Positioning System is designed to provide highly accurate passive position, velocity and time data to users worldwide in all weather conditions. The system will interface with communications, navigation, and weapons systems including the Position Location Reporting System and the Single Channel Ground and

Airborne Radio System in selected applications. The US Army NAVSTAR development has been funded under program element number 64778A - NAVSTAR GPS User Equipment.

Vehicle Electronics. The US Army Vehicle Electronics development effort uses aircraft databus technology to simplify the complex vehicle wiring harnesses now in use and integrate many control and display functions, to improve crew efficiency and combat effectiveness. It will be a modular hardware/software design that will feature microprocessor controlled multiplexing at high-speed rates using communication media comprised of twisted pairs of wires or fiber optics to carry data signals. The types of data display will be digital, audio, and video.

The vehicle electronics design, while envisioned for future armored vehicles, will also be adaptable to current vehicle electrical and electronic hardware and to requirement changes through changes in its software. United Defense, RCA, General Dynamics, Raytheon Systems, and Alliant Techsystems are all involved in vehicle electronics development work with the Tank and Automotive Command. The vehicle electronics development is funded under program element number 0603631A Combat Vehicle Turret & Chassis Subsystems, Project D014 Combat Vehicle Hull & Turret.

Built-in Training Software. This feature of the M109A6 reduces training costs in terms of time and money and results in a more effective crew. It provides for the realistic simulation of a number of practices that are used in combat and allows for training on the actual equipment that will be used in combat.

Vehicle Integrated Defense System. Vehicle Integrated Defense System technology is under development to provide United States armored vehicles with threat-warning receivers and countermeasures reaction hardware that will aid the crew's and vehicle's survivability by detecting and responding to hostile armor vehicle and anti-tank missile threats. While not a component of the M109A6 program, when mature, such technology could be retrofitted to this vehicle.

Howitzer Fire Control Computer. The Howitzer Fire Control Computer was developed by Magnavox Government Electronics Group as part of the United States Army Human Engineering Laboratory's Human Factors Howitzer Test Bed project. The vehicle's fire control system consisted of the Howitzer Fire Control Computer, a Pietzsch stabilized gun sight system, a Magnavox Global Positioning System unit, Litton inertial reference unit and communications gear consisting of a pair of Tadiran frequency-hopping VHF-FM radios and a Royal Ordnance Archer intercom system. The Howitzer Fire Control Computer can be input manually by the crew or by remote signal from a fire direction center or from a forward observer. The Howitzer Fire Control Computer automatically computes the necessary ballistic calculations, controls the projectile ramming of the system's automated electrical loader/rammer and lays the gun. The crew responsibilities are then reduced to loading the charges, securing the breech and firing the weapon.

The Howitzer Fire Control Computer also stores data on targets, communications nets and vehicle ammunition stocks and alerts the crew in the form of visual alarms and a synthesized voice concerning navigation, communication, system faults, check-fire orders, and ordnance problems such as overheating, fusing or ramming.

Modified Armament System. For the M109A6, design changes in the M185 39 caliber cannon and M178 mount of the M109A1/2/3 have resulted in the modified cannon and mount being designated the M284 and M182 respectively. The changes for the M284/M182 include the improved M49 firing mechanism and breech handles/housing assembly; incorporation of an external torque key to absorb the torque moment during firing and increase fatigue life; increasing the durability of the muzzle brake, redesigned chamber, fume extractor, and leaf spring pack; a redesigned set of recuperator seals for better seal life; a new recuperator design; and the addition of a thermal sensor for monitoring temperature. The M284 cannon is 609.6 centimeters (240 inches) long.

Advanced Armament System. This armament enhancement consists of two designs in concurrent development. The first is the XM283 cannon, an advanced 39 caliber cannon that is derived from the M199 cannon of the M198 towed howitzer. The modified breech features an automatic primer feed mechanism; improved handle and firing mechanism; the M198 muzzle brake and a bore evacuator of heavy duty construction to withstand incoming fragmentation. The XM283 has the same ballistic and operational characteristics as the M284 Modified Armament System, but will have greater reliability due to its modular construction and the redundancy of the XM183 gun mount that houses it.

The second Advanced Armament System option is the XM282, a 52 caliber cannon which is also known as the extended range cannon. The XM282 is also of modular construction and incorporates the unicharge technology which greatly reduces the loading time; the cannon is also compatible with the M864 base bleed projectiles and is fitted with the M185 muzzle brake to provide the same recoil distance as the M283. The XM282 has a 52

caliber tube length or 806 centimeters (317.32 inches). Maximum range of the XM282 firing the XM864 projectile is in excess of 40 kilometers. Research indicates that this cannon has already been test fitted to the M109. This cannon is to be fitted to the 48 Paladin systems to be ordered by Kuwait (the final signing of this order was expected as this report was being written). As the XM282 has yet to be type classified and accepted into United States service, the United States had to guarantee the performance of the cannon as well as the complete system in order to win the deal.

Both Advanced Armament System cannon options are designed to utilize the XM183 gun mount. The XM183 is an armored gun mount with two recoil assemblies and two recuperator assemblies providing redundancy that allows the mount to operate in a degraded manner should one of the recoil or recuperator assemblies fail. The mount is also air cooled to allow for a high firing rate. For both of these cannon, the ordnance can be removed from or installed into the breech without removing the breech from the mount or the mount from the turret. This quick change ability is estimated to take one hour at a direct support level maintenance facility.

Fitted to the Advanced Armament System will be the Electronics and Space Corporation semi-automatic loader that permits a rate of fire of six rounds per minute with a burst capability of three rounds in 15 seconds. The semi-automatic loader is being pursued as a means to reduce fatigue stress of the crew during firing missions as well as a way to reduce the size of howitzer crews.

Several other cannon options are now available to permit the international users of the M109 to either upgun or install new replacements for existing cannon. In addition to the United States produced cannon manufactured at Watervliet Arsenal, 39, 47 and 52 caliber cannon systems are available from Royal Ordnance, Otobreda, Schweizerische Unternehmung für Waffensysteme and Rheinmetall Industrie.

New Drive Servos. New drive servos are installed in the M109A6 in order to improve control of the M284 cannon.

Modified Ammunition Handling Components. A new loader/rammer actuator device, provided by the Austrian firm Sondertechnik, has been improved to provide a consistent ramming cycle under any loading conditions. The actuators, which utilize hydraulic power and require no additional operator tasks, will operate in such a way that the ramming stroke is not less than four seconds or more than six seconds. Sondertechnik provides the loading mechanism for the M109A6 and also offers load assist devices for retrofit to other M109 users. KUKA Wehrtechnik has developed the Automatic Ammunition Flow system for the M109. Successfully test fitted, this enhancement has an automatically operating projectile magazine holding up to 32 projectiles, a shell transfer mechanism, hydraulically operated flick rammer, automatically operated primer magazine, projectile hoist and new electrical power supply system. This firm has further developed this concept with the new Ammunition Handling Kit. This modular design equipment now offers several options including an automatic primer magazine, improved firing mechanism and an additional auxiliary power unit. As part of its 47 caliber cannon upgrade for the Swiss M109 systems, Schweizerische Unternehmung für Waffensysteme of Switzerland has developed a flick loading system; the retrofit program was begun in 1998. Israel has developed similar technology as has Bofors of Sweden. United Defense is involved in the advanced development of such a system in the United States. The Electronics and Space Corporation already offers a semi-automatic loading system for retrofit to existing M109 systems; Israel is procuring this equipment.

Traversing Mechanism. The turret traversing mechanism of the M109A6 is upgraded by installing a hydraulically operated clutch and improved sealing techniques for the handwheel housing, shim retainers and mating surfaces of the traverse housing to eliminate electrical and water seepage problems.

Automatic Gun Laying System. An automatic gun laying system has been designed for the M109 by Alliant Techsystems. An electro-optical servo mechanism and digital computer are combined to greatly enhance the gun-laying process. This program became available in 1984 for new production or retrofit to existing vehicles.

Secondary Armament. A new secondary armament to replace the M2HB 12.7 millimeter machine gun and/or the M60/M240 7.62 millimeter machine gun is not likely until after the turn of the century. Such a modification may well be the integration of a 25 millimeter cannon such as the Boeing (formerly McDonnell Douglas Helicopters) M242 that was tested as part of the Human Factors Howitzer Test Bed program. United Defense offers the SACO Mark 19 Mod 3 40 millimeter grenade launcher as an option for its M109TX.

Smoke Grenade Launchers. Some international users of the M109 have opted to mount smoke grenade launchers on their vehicles. This modification has not been suggested in the Howitzer Improvement Program but should find its way into the M109A6 by the time the Howitzer Improvement Program is completed. The M250 six-barrel smoke grenade launcher is now fitted

to the US Army's M60A3, M1/M1A1/M1A2 and M88 recovery vehicle.

German M109G. The German M109 inventory differs in having an improved breech mechanism provided by Rheinmetall Industrie; this sliding breech mechanism has more effective obturation giving enhanced interior ballistics and a slight increase in range. Subsequently, the M109G was updated by the integration of a new 39 caliber ordnance still using the Rheinmetall breech assembly. Other enhancements included in this new model, which is designated M109A3G, include a new projectile magazine in the turret bustle, changes in propellant charge loading and storage, new seals, a blast shield for the panoramic sight, new traverse hand drive mechanism, new elevation balancing cylinders, new ventilation equipment, new barrel clamp, new air filters, changes to the powerpack to allow for easier removal and installation, new instrument panel for the driver, a supercharging system for the engine, reinforced torsion bars, electrical firing circuit, new fire control data panels, modified hydraulic system components and a number of other minor changes. In addition to Germany, Norway has implemented this program to its M109 inventory. In 1995, the as-yet-undetailed AURORA modification program got underway; the contractor is Henschel Wehrtechnik and the modified system is designated M109A3GEA1. In 1997, Germany began soliciting firms to undertake the overhaul and minor modifications of 526 of its M109G systems.

Israeli Howitzer Improvement Program. The model of the 155 millimeter M109 self-propelled howitzer that is specific to Israel is designated M109AL; 530 are in service. Desiring to maintain the viability of these systems, the Israeli Defense Force participated in the joint development of the US Army's Howitzer Improvement Program which ultimately resulted in the M109A6 Paladin. Originally, upwards of 450 M109 systems were to be refurbished and upgraded to the A6 standard at Israeli Ordnance shops, using kits supplied by United Defense. However, constrained funding plus a serious accident in the development and test program killed this planned effort. Following this setback, Israeli officials then decided on a somewhat less ambitious program called Doher. While the complete M109A6 enhancement package was not adopted, portions of the Paladin have been incorporated into the further enhanced M109AL which is now called Doher. For the Israelis, the Doher version of the M109AL retains its M185 cannon but incorporates a modified M178 gun mount which has been integrated with the existing turret. Other changes centered upon the majority of Howitzer Extended Life Program improvements that were incorporated into the Israeli systems including desert cooling; electrical/hydraulic system upgrades; turret drive improvements; Halon fire detection/suppression; and driver night vision viewer. The fire control suite has been converted to a less sophisticated but more reliable and easy-to-use system. The turret is modified where necessary to suite Israeli requirements but has the full-width turret bustle added. The bustle houses upwards of 25 projectiles and an auxiliary power unit. The remaining projectiles and all charges are stowed below the turret ring in the hull. The suspension has been beefed up to the configuration designed for the Advanced Artillery System Howitzer Improvement Program. The new ESCO Electronics Corporation semi-automatic loader has been installed. Survivability enhancements incorporated into the Doher include a nuclear, biological and chemical defense system, the aforementioned automatic fire detection and suppression system and other features. The engine has been fitted with a device to generate a smoke screen, and another machine gun has been mounted on the roof. The vehicle can carry up to seven crewmen. The Doher upgrade was completed in early 1997.

Italian M109L. Italy purchased 221 M109 systems from the United States without armament; the then OTO Melara manufactured the 155 millimeter/23 caliber cannon for these systems. In addition, 62 complete M109A1B systems were procured. In 1970, the then OTO Melara developed a new 39 caliber cannon for the M109 that was compatible with the ammunition used in the FH 155-1 towed system. However, the Italian Army had no requirement for this longer ranged system and the program went dormant. This was later reviewed and, following an evaluation of the 39 caliber cannon on the M109, in 1986, the Italian Army ordered the retrofit of the new cannon to 280 M109 systems. The enhanced M109, designated M109L, is equivalent to the M109A3. In addition to the new 39 caliber cannon, the M109L features new or modified gun mount and control equipment. The first M109L was delivered in 1986 and the program was completed in late 1992.

Spanish M109 Upgrade. Spain is undertaking the modernization of its 96 M109A1B systems in four different models. In the first phase of the program, 24 of the basic and A1 systems will be brought up to A5 configuration. In the next phase, the remaining 72 systems will be brought up to the A4 Plus configuration then to the A5 configuration. All these upgrades are being carried out at the Spanish Army's Number 2 Armored Maintenance Depot, located in Seville; United Defense and Barnes and Reinecke are providing the kits.

Swiss M109 Upgrade. Beginning in the late eighties, the then Eidgenössische Konstruktionswerkstätte Thun (the Swiss Federal Armament Works - Thun) developed an upgrade for Switzerland's M109 systems. Begun in

late 1994, the ongoing enhancement program involves the retrofit of the new 47 caliber cannon with a chrome plated barrel, a new double baffle muzzle brake and fume extractor, the installation of a semi-automatic flick ramming system, increased ammunition storage capacity, hydraulic travel lock, extended turret bustle, blast-proof sliding doors between the crew compartment and ammunition storage and other minor improvements. Another major improvement under this program is the installation of a new electrical system, the Navigation and Positioning System provided by Kearfott Guidance & Navigation Corporation. System components include a ring laser gyroscopes assembly, vehicle motion sensors and control display units. The Swiss have designated the upgraded system M109 KAWEST. The Eidgenössische Konstruktionswerkstätte - Thun firm was subsequently reconstituted as a component of Schweizerische Unternehmung für Waffensysteme (Swiss Ordnance Enterprise). Out of the total inventory of 581 systems, 348 (165 plus 180) were planned for this upgrade with the first upgraded systems delivered in early 1998.

In an agreement with RDM Technology of the Netherlands, the 47 caliber ordnance has been retrofitted to 85 ex-Netherlands M109 systems that were sold to the United Arab Emirates. More recently, in mid-1998, Schweizerische Unternehmung für Waffensysteme and United Defense have reached an agreement whereby United Defense can market and support the Swiss upgrade pattern.

M109UK. About a decade ago, Royal Ordnance and the then BMY Combat Systems teamed up to offer the M109UK, a modernized M109 self-propelled artillery system designed to fill the gap left by the termination of the Panzerhaubitze 155-1 program in 1987. The M109UK is a retrofit option for the Royal Army's original fleet of 119 M109A1/A2 systems that contains many of the improvements standardized for the United States Army Howitzer Improvement Program M109A6, as well as a turret design adapted from the M109TX (International Turret). The main armament selection is an improved 39 caliber cannon with the Rheinmetall flick rammer. The 39 caliber cannon has a range of 24,700 meters with standard ammunition or 30,000 meters with base bleed ammunition. The M109UK is to carry a total of 36 projectiles, 37 charges and associated fuses, of which 16 projectiles and 27 charges are in the turret bustle.

The suspension is beefed up to absorb the weight increases of the M109UK, and the modified vehicle would be fitted with new Diehl tracks with replaceable pads. The horsepower output of the Detroit Diesel 8V-71T engine would be increased to 318.54 kW (427 hp) and the engine will be equipped with a new cooling system. Fire control equipment would be supplied by Rank Pullin, Marconi Command & Control Systems and Avimo. As a result of the British Army adopting the Artillery System 90, the British Army did not procure this program.

Subsequently, Royal Ordnance has integrated several other cannon with the M109. Included in the retrofits are many of the M109UK program features such as the flick rammer. The 39 caliber cannon is the same as that used on the Artillery System 90, while the 52 caliber cannon is the same as that being developed for retrofit to the Artillery System 90. A 47 caliber cannon also has been developed and integrated with the M109. These cannon retrofits are available from Royal Ordnance.

United Arab Emirates Upgraded M109A3. In mid-1995, Abu Dhabi of the United Arab Emirates purchased 85 M109A3 systems from the Netherlands. Before the delivery to the Emirates, the systems are being overhauled and upgraded by RDM Defense Engineering under a contract worth the equivalent of US$32.4 million. The major enhancement is the integration of the new 47 caliber cannon as is being fitted to the Swiss Army M109 systems described above.

Further US Enhancement to Paladin. Beginning in 1994, the US Army began investigating the further enhancement of the M109A6 Paladin. This effort, under a system improvement plan, will address 15 subsystem upgrades in six categories: growth of the computer-related components; increased rate of fire for the cannon; enhanced accuracy of fires; increased levels of system reliability; availability; maintainability; crew safety; and crew comfort. Key to the enhancement is the integration of a 32 bit processor and integration of the Modular Azimuth Positioning System and Global Positioning System technology. Also included in the system enhancement program is the integration of a laser rangefinder. Plans for aiding the rate of fire include the integration of a laser ignition system, automatic fuze setting equipment, and semi-automatic loading system. Other planned enhancements include the integration of a driver's thermal viewer, new crew intercommunication system and other communications improvements, upgrading the prognostic/diagnostic interface, improvements to the crew compartment ventilation system, armoring the turret bustle and several other crew comfort improvements such as a water ration heater.

Opportunities. The demise of the tri-national Panzerhaubitze 155-1 program motivated some NATO users to update their M109 inventories as a near term solution and as a means of establishing some degree of commonality with the M109A6 program. It appears that the retrofit and modernization opportunities for the

M109 are pretty well spoken for through the near to mid term by the contractors mentioned throughout this report. Nations such as Switzerland, Federal Republic of Germany, Belgium and Norway all have modernized their M109 inventory or are in the process of doing so. The Federal Republic of Germany some time ago finished implementing an upgrade program of its M109 inventory to the A3G standard which is fitted with a 39 caliber cannon. The extended range of this weapon has been pushed out to 24.7 kilometers (15.4 miles). This effort is completed, but Thyssen-Henschel is now integrating the as yet undetermined AURORA modification to the inventory. The potential for additional improvements to the German M109 inventory is very low due to the near term introduction of the Panzerhaubitze 2000. Belgium's program was similar to Germany's but less extensive, while the Netherlands' has been scaled back, both in terms of scope and quantity (85 were sold). The 85 systems were sold to the United Arab Emirates, but RDM Defense Engineering is doing a major overhaul and upgrade, including the integration of the Swiss 47 caliber cannon. The United Kingdom's Royal Armament Research & Development Establishment had done considerable testing on M109 improvements, and the Ministry of Defence considered an updated M109UK among other contenders for its interim 155 millimeter self-propelled howitzer requirement. However, this program was killed as a result of the selection of the Artillery System 90. Norway's Norsk Forsvarsteknologi has updated that nation's M109 inventory to A3G standard. Canada has upgraded its M109 systems on an interim basis and has subsequently implemented an additional modernization program which includes the integration of an auxiliary power unit. Of course, any firm offering similar technology for any portion of the various M109 enhancement programs is free to compete in this market, although for the United States and Israel, the chances of breaking in appear to be rather slim. The best opportunities for new firms to gain a share of the M109 retrofit and modernization market lie with those nations possessing a large inventory that have not yet opted for a major enhancement program. The Republic of Korea, Egypt and the Republic of China are all examples here. However, for the possible exception of Egypt, these nations have extensive in-country capabilities. Any firm trying to enter this market will have to deal with the heavyweights already involved, and it appears that this particular market is fairly well sewn up.

Although the A6 program does a lot to improve the overall performance of the M109, the ballistic performance of the 39 caliber M284 cannon is still inferior to a number of other tube artillery systems in the world. The much touted increase in range to 30 kilometer is only achieved with a rocket assisted projectile; this technology takes its toll in payload and increased dispersion at range. A number of the other systems in the world use a 45 caliber cannon and advanced projectile designs to achieve 39 kilometer ranges without rocket assistance. This is the reason for the steadily increasing number of calls to begin examining the integration of the new NATO standard 52 caliber cannon. Due to the otherwise excellent performance of the Paladin and the increasing probability that the XM2001 Crusader (formerly the Advanced Field Artillery System-Cannon) program will slip, as time passes, the chances of a further upgrade to the M109 beyond the A6 appear to be increasing.

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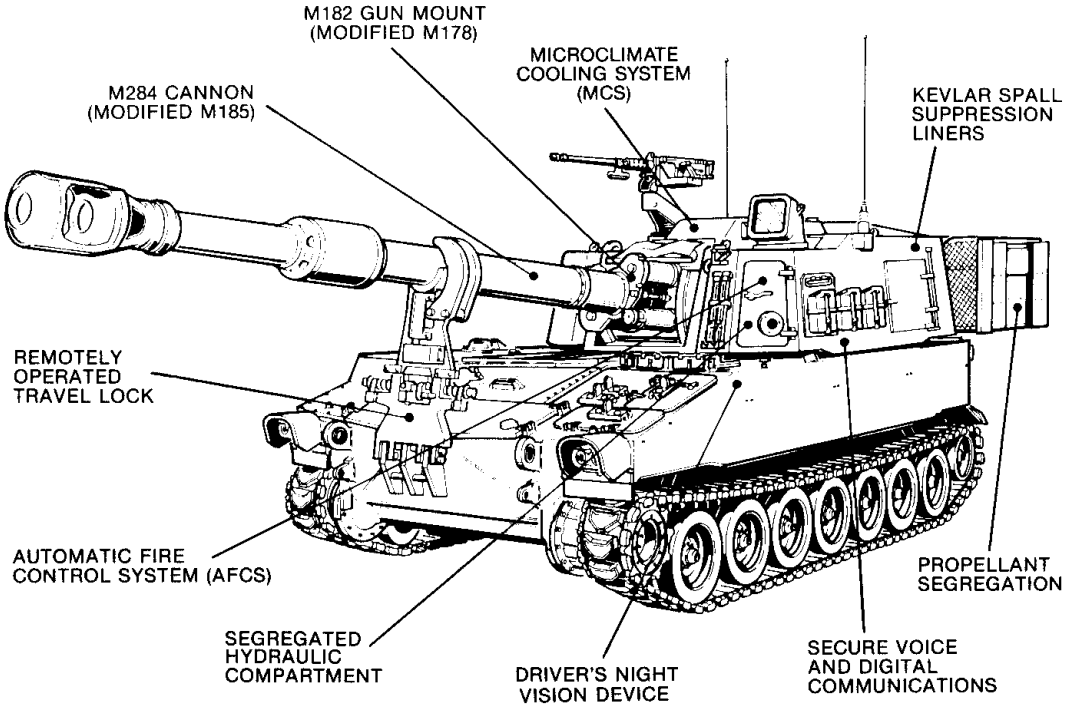
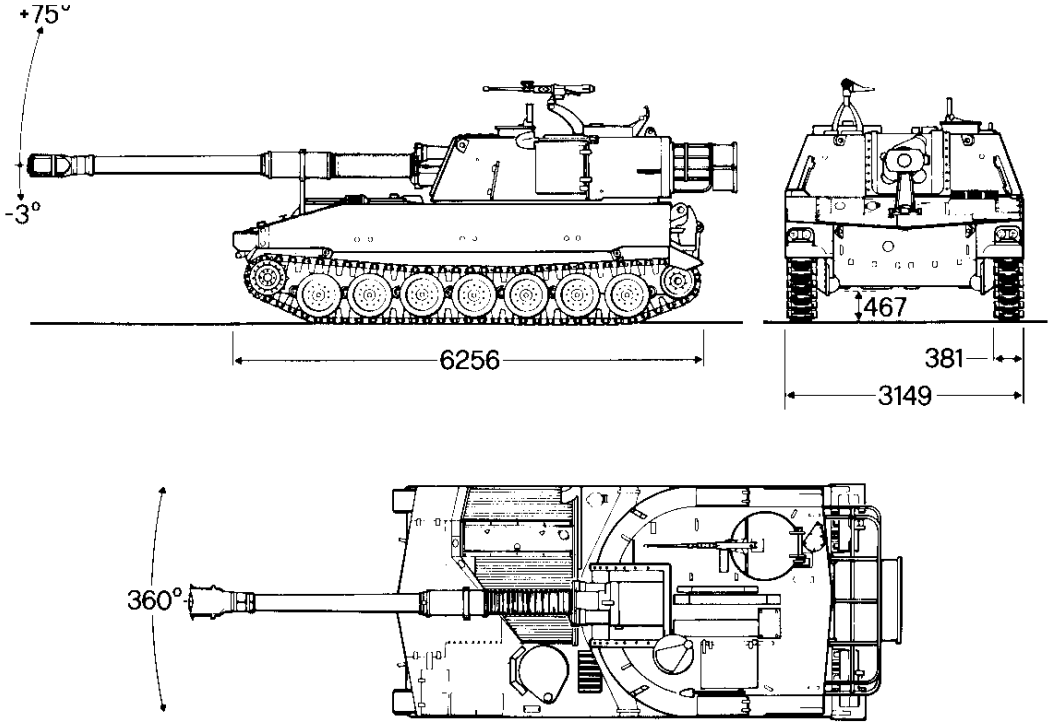


M109A6

Source: United Defense



M109 WITH 39 CALIBRE ORDNANCE

Source: Otobreda