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ADVANCED COMBAT RIFLE (ACR) PROGRAM
VOLUME I, ACR PROGRAM SUMMARY

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US ARMY
ARMAMENT MUNITIONS
& CHEMICAL COMMAND
ARMAMENT RDE CENTER

U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

Close Combat Armaments Center

Picatinny Arsenal, New Jersey

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The ACR final report was prepared in a multivolume format to permit separation of major subject areas. The ACR Program Summary (Volume I) is the primary volume. Volumes II through VII contain detailed information on specific areas within the overall ACR program.

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13. ABSTRACT (Maximum 200 words)

The Advanced Combat Rifle (ACR) program was a technology base program that investigated current rifle technologies to increase combat effectiveness over the current M16A2 rifle system. Four different and unique ACR candidate systems successfully demonstrated various rifle technologies including caseless and plastic cased ammunition, small caliber flechette projectiles, high cyclic rate gun mechanisms, and optic sights. The ACR program has significantly advanced the state-of-the-art in rifle technology and will form the basis of any future individual weapon requirements. This report documents the entire ACR program from the initial caseless contracts through the completion of the field experiment in 1990. The report documents the programmatic aspects and decisions made during the program and concentrates on the technology investigation efforts. It discusses the planning efforts related to the field experiment and presents general results of the experiment as they relate to the overall program. The details of the field experiment and analysis of the results are documented in separate reports published by the appropriate government organizations.

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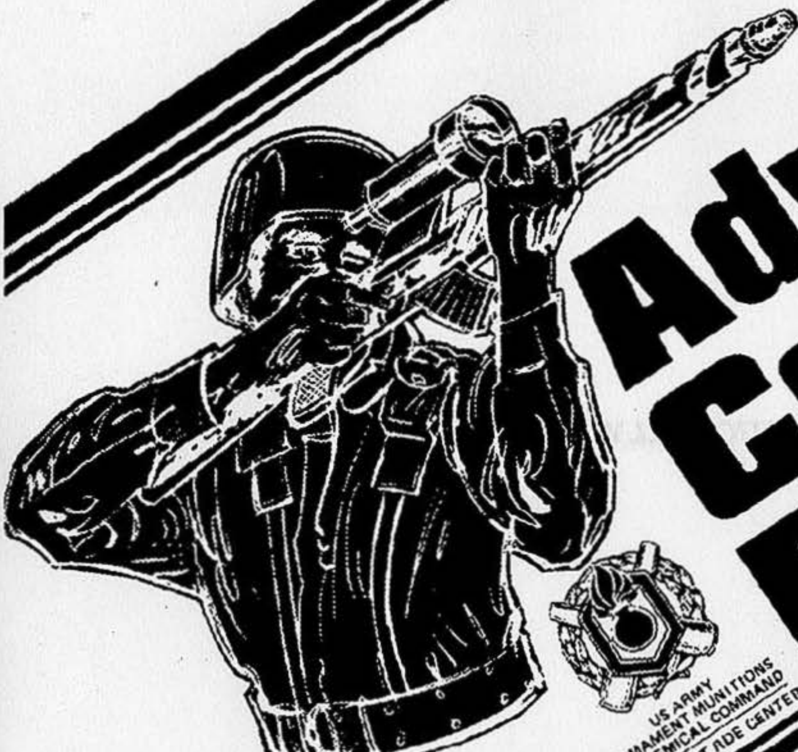
Advanced Combat Rifle



US ARMY ARMAMENT MUNITIONS & CHEMICAL COMMAND
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VOLUME I
PROGRAM SUMMARY

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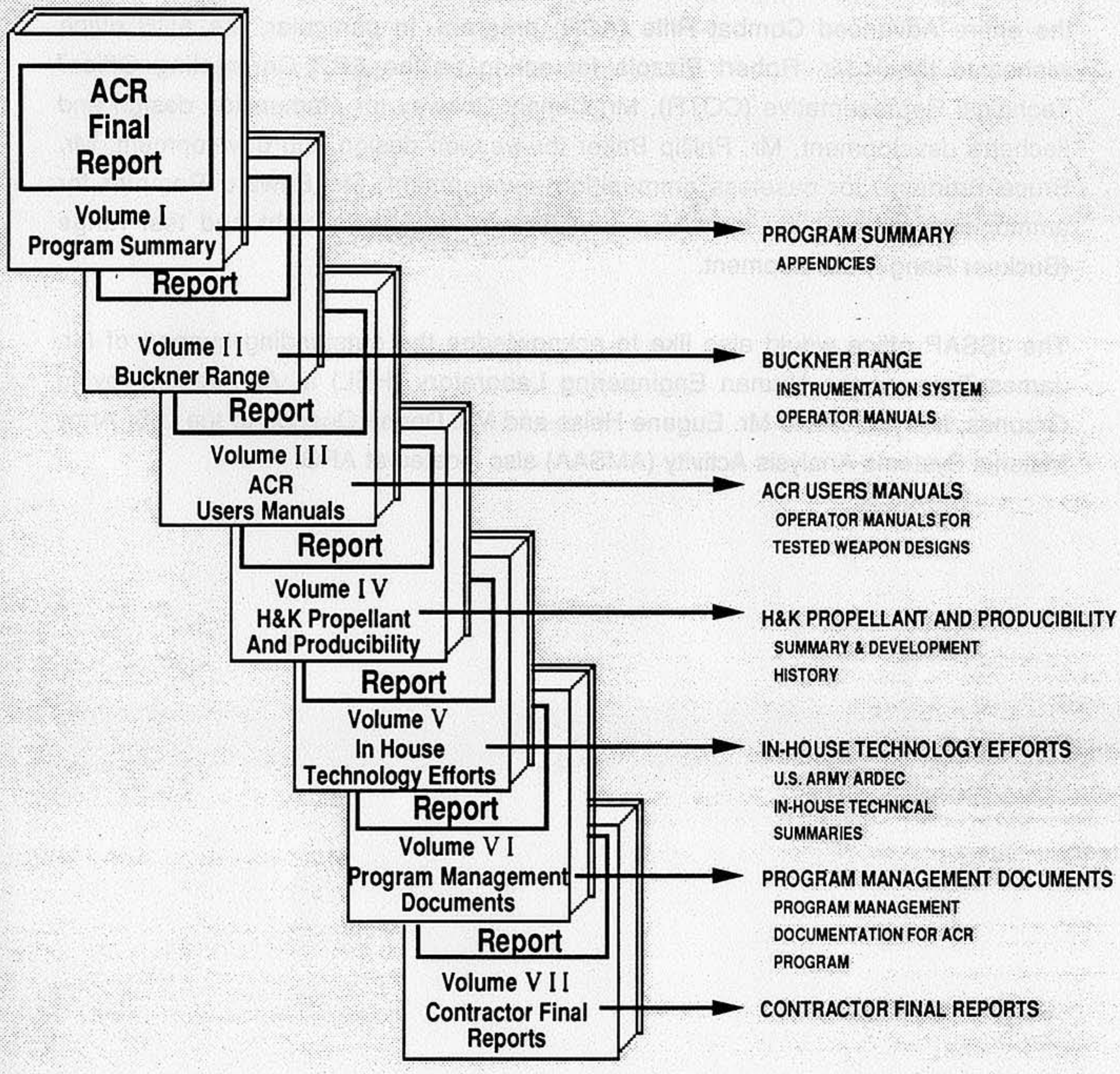
GUIDE TO ACR FINAL REPORT

The ACR final report documents all aspects of the ACR program. It was prepared in a multi-volume format to permit separation of the major components within the total program. All volumes are published in an unclassified format. The entire report consists of the following volumes:



Volume I is the primary volume of this report. It summarizes all information necessary to become familiar with and understand the ACR program. Volume I highlights background information and summarizes the weapon systems, engineering and safety tests, and field experiment. It also provides general test results and conclusions. Volumes II - VII contain detailed information on specific areas within the overall ACR program by subject matter.

ACKNOWLEDGMENTS

The Joint Service Small Arms Program (JSSAP) office wishes to acknowledge the outstanding technical support provided by ARDEC's in-house personnel throughout the entire Advanced Combat Rifle (ACR) program. In particular, the ACR office wishes to thank Mr. Robert Pizzola for acting as the ACR Contracting Officer Technical Representative (COTR), Mr. Dennis Conway for ammunition design and flechette development, Mr. Phillip Baker for weapon design and development, Mr. Bruce Brodman for caseless ammunition development, Mr. Edward Rempfer for ammunition producibility, and Mr. John Edwards for optic sight and test range (Buckner Range) development.

The JSSAP office would also like to acknowledge the outstanding support of Mr. James Torre of the Human Engineering Laboratory (HEL) at Aberdeen Proving Grounds, Maryland, and Mr. Eugene Heiss and Ms. Donna Querido of the U.S. Army Material Systems Analysis Activity (AMSAA) also located at APG.

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Advanced Combat Rifle Program

1.0 INTRODUCTION.

In April 1980 the United States Congress House Armed Services Committee requested that the Joint Service Small Arms Program (JSSAP) office conduct a study of the current combat rifle. This study concluded that the current rifle, the M16A1, met all the U.S. Armed Forces needs but possible improvements to it should be investigated. A series of improvements have since led to the M16A2 and M16A3 rifles. For the long term, the study concluded that the technology base should be developed to support a significant improvement in capability. Revolutionary improvements in capability were envisioned to be well beyond the year 2000, leaving the opportunity for a significantly improved combat rifle in the mid-1990 time frame. A technology base effort was initiated.

Concurrent with initiation of the technology base efforts, the Honorable James Ambrose, then Under Secretary of the Army, saw the need to do something for the individual soldier. Through his encouragement and direction, the Advanced Combat Rifle (ACR) program was established. The ACR Operational and Organizational Plan (O&O) was approved in January 1985 and the program received his personal approval in February of the same year.

The ACR effort caused weapon concepts to be developed under contract and prototype hardware to be produced and evaluated with troops in a field experiment. The program remained a technology base activity. The program was concluded upon completion of the field experiment in 1990. The program has significantly advanced the state-of-the-art in rifle technology and will form the basis of any future individual weapon requirement.

1.1 Description of Systems. Concepts were developed under contract to improve the soldier's hit performance in combat. Under the stress of combat where there are multiple targets, moving targets, and targets that are mostly obscured and exposed for short amounts of time, the soldier's performance is degraded. When the soldier does engage these targets, he does so hurriedly and with large aiming errors. The weapon concepts were developed to fire more than one projectile per trigger pull. The dispersion of this burst of projectiles was controlled to compensate for the soldier's aiming error.

The following is a brief description of the weapon systems taken to the field experiment. A synopsis of system characteristics is given in Figure 3.1 on page 9.

AAI Corporation -	5.56 mm serial launch salvo rifle, reciprocating bolt action, firing brass cased flechette ammunition.
Colt's Manufacturing Co. -	5.56 mm serial launch salvo rifle, reciprocating bolt action, firing brass cased duplex ball ammunition.
Heckler & Koch -	4.92 mm serial launch salvo rifle, rotating chamber action, firing caseless ball ammunition.
Steyr-Mannlicher -	5.56 mm serial launch salvo rifle, rising chamber action, firing telescoped plastic cased flechette ammunition.

1.2 Program Goals and Objectives. As outlined in the ACR O&O Plan (see Appendix A), the ACR will be the initial development within the small arms family. It will be the primary weapon for the individual soldier. Primary target will be the individual threat soldier protected by body armor at ranges out to 600 meters. It must offer enhancement in hit probability of at least 100 percent at combat ranges over the baseline performance of the M16A2 rifle when measured under realistic battlefield conditions. At extended ranges, the improvement required will be considerably greater than 100 percent. The weapon will be expected to enable the rifleman to detect targets at ranges greater than 400 meters in offensive action and at least 1000 meters during conduct of the defense. Acquisition and engagement of the target is expected to occur at 400 meters during offense and 600 meters during defense.

2.0 BACKGROUND.

An analysis of current small arms (e.g. hand held individual weapons) considers the man/machine interface to be a significant factor affecting system performance. While most systems offer excellent accuracy, the soldier's ability to hit targets depends on his situation. Figure 2.1 is a graph showing the probability of hitting a kneeling man size target as a function of range. The top curve labeled "M16A2 Capability" represents the capability of the weapon system in a fixed mount. The hit probability is decreased at the longer ranges due to the round to round dispersion of the ammunition which is about .275 mils. The second curve labeled "M16A2 Training" represents an aiming error of 1 mil and is representative of a training standard. It is the performance achieved in the Army record fire program. Marksmanship and zeroing performance is better than this and represents an aiming error of about .5 mils. The soldiers performance in an operational environment however, is worse than the training standard. Where targets are obscured, mostly moving and exposed for short amounts of time, studies have shown performance to be significantly worse. The bottom curve labeled "M16A2 Stressed" is derived from a large data base of tests involving moving and short time of exposure targets. AMSAA reviewed this data and used the worst third of the data to represent the expected soldier's performance in a stressed environment. This does not represent actual combat stress, but was used as the basis for the ACR program.

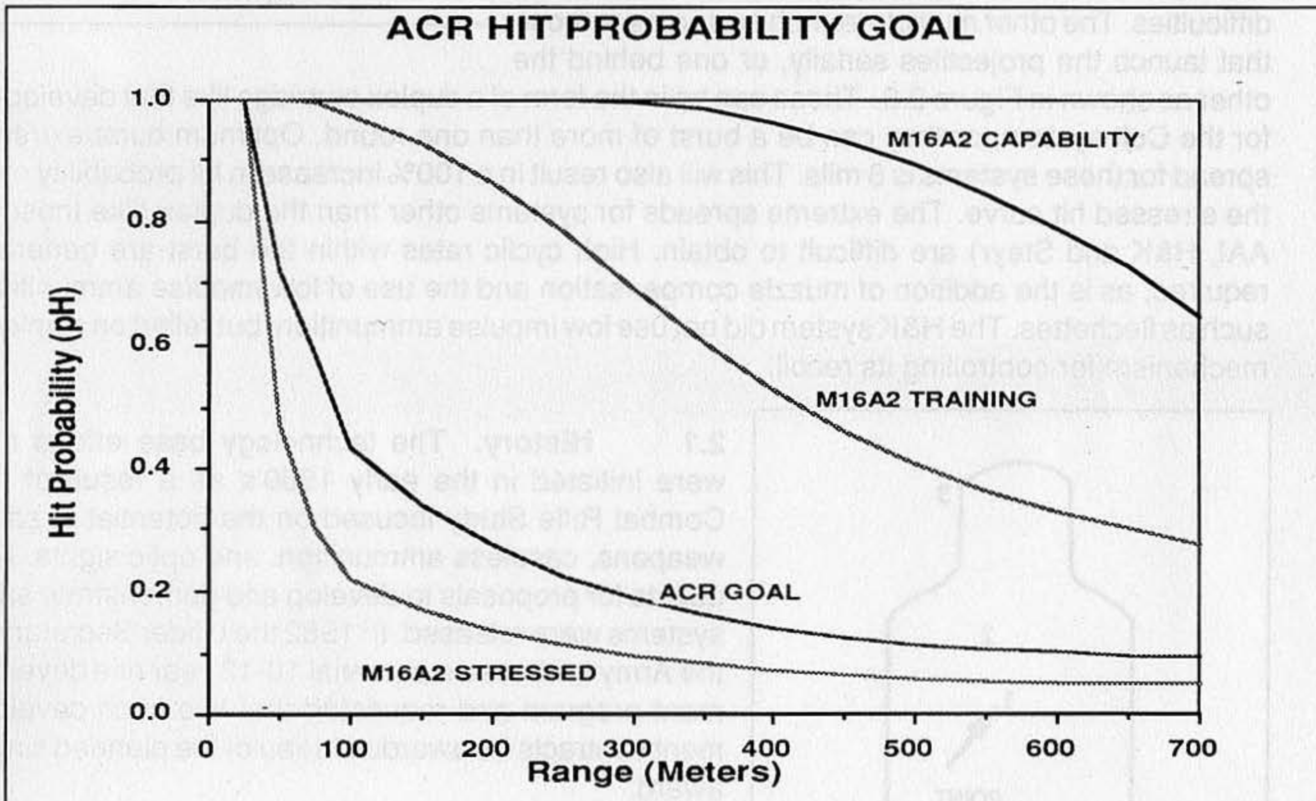
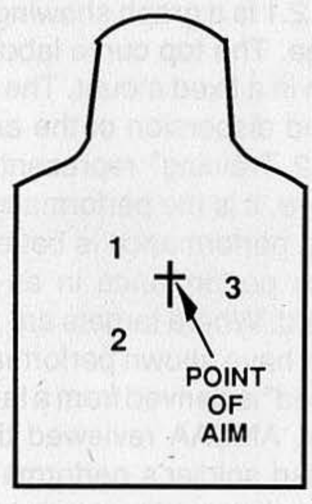


Figure 2.1

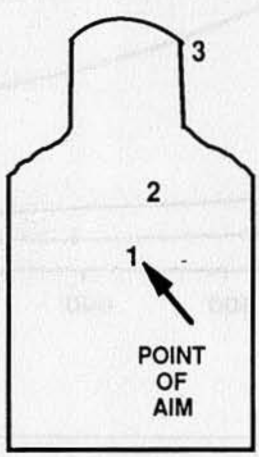
At very close ranges of 0-100 meters aiming errors were assumed to range from 8-10 mils. These targets are exposed for very short amounts of time and are hurriedly engaged, often by pointed fire rather than aimed fire. At ranges of 300-400 meters the aiming errors drop to about 3 mils, and at extended ranges from 500-600 meters aiming errors of 1-2 mils were expected.

The technical challenge in the design of an ACR concept was to compensate for or reduce these large aiming errors, and thus significantly improve combat effectiveness. Analysis has shown that for these aiming errors, if a salvo of three projectiles is fired at a target the probability of at least one hitting the target could be increased on the order of 100%. There are two types of salvo launches. A true salvo system launches multiple projectiles at one time. The projectiles are distributed about the aim point as shown in Figure 2.2. A burst extreme spread of 6 mils is optimal for this system for the aiming errors assumed. McDonnell Douglas was developing a true salvo system of this type launching multiple flechettes for each round fired. This system was not taken into the field experiment due to technical difficulties. The other multiple launch systems are those that launch the projectiles serially, or one behind the other as shown in Figure 2.3. These can be in the form of a duplex cartridge like that developed for the Colt system, or they can be a burst of more than one round. Optimum burst extreme spread for these systems is 8 mils. This will also result in a 100% increase in hit probability over the stressed hit curve. The extreme spreads for systems other than the duplex (like those of AAI, H&K and Steyr) are difficult to obtain. High cyclic rates within the burst are generally required, as is the addition of muzzle compensation and the use of low impulse ammunition, such as flechettes. The H&K system did not use low impulse ammunition, but relied on a unique mechanism for controlling its recoil.



SALVO FIRE BURST PATTERN

Figure 2.2



SERIALLY FIRED BURST PATTERN

Figure 2.3

2.1 History. The technology base efforts that were initiated in the early 1980's as a result of the Combat Rifle Study focused on the potential of salvo weapons, caseless ammunition, and optic sights. Requests for proposals to develop and demonstrate such systems were released. In 1982 the Under Secretary of the Army endorsed a potential 10-12 year rifle development program and requested that two such development contracts be awarded in lieu of the planned single award.

In Sept 1982 contracts were awarded to AAI Corporation and Heckler and Koch, Inc. The AAI effort was later terminated due to technical difficulties encountered. A summary of these and all contract efforts can be found in Appendix B of this report.

During the next few years the Under Secretary continued to press for an accelerated program with additional industry involvement. In 1984 the ACR program evolved. The Operational and Organizational Plan was staffed and approved in January 1985. A program strategy was approved by the Under Secretary in February 1985. This strategy called for additional industry involvement and the demonstration of potential technology in a field experiment with troops. The thrust of the program direction from Mr. Ambrose was to challenge industry based on the need defined in the O&O Plan, to focus on current technology, and to demonstrate this technology to the user as a "stake in the ground" to form the basis of a possible requirements document. The approved acquisition strategy was one of the first in the "ASAP" Accelerated Acquisition Process which planned four years to production from the generation of a requirement document.

In 1984-1985 industry conferences were held at ARDEC and Ft. Benning to detail the needs and goals of the program. Shortly thereafter, contracts were competitively awarded to AAI, ARES, Colt, McDonnell Douglas, and Steyr. These contracts came to be known as the industry alternative efforts. These efforts called for the development and fabrication of the proposed rifle systems for evaluation in government tests. The contracts were phased with no commitment on the part of the government to proceed into the next phase. The phase I effort required the development of a test fixture that would demonstrate the potential of the system. Phase II was the development and testing of one weapon system, while the final phase III effort called for the production of hardware for testing. The ongoing H&K contract was modified to include a hardware production phase to bring it into line with the other contracts. The ARES and McDonnell Douglas contracts were terminated at the end of their phase II effort due to lack of maturity of their systems. A complete chronology outline of the ACR program is provided on the following pages.

2.2 OGA Support. The delivered weapon systems were evaluated by several government agencies both with and without contractor support.

Combat System Test Activity (CSTA): Initial evaluation of the weapons' function and safety was conducted as well as several engineering tests to assess the maturity of the systems.

Test and Evaluation Command (TECOM): Provided the safety release to allow the firing of the weapons by troops. Safety release was based on CSTA testing.

Ballistic Research Laboratory (BRL): Tested all the ACR concepts against tissue simulant gelatin to assess the lethal characteristics of the projectiles. Tests provided information for the calculation of the indices of probability of incapacitation given a hit; the projectile lethality.

TEXCOM Infantry Board (INFBD) : The INFBD conducted the actual field experiment or troop test at Ft. Benning.

Army Material System Analysis Activity (AMSAA): AMSAA performed the data analysis of the test results from the INFBD, CSTA and BRL tests.

These efforts are discussed in detail in the remainder of this report.

ACR Program Chronology

1980 • JSSAP tasked by Congress to conduct Combat Rifle Study (CRS) to address:

- Deficiencies of M16A1 rifle
- Replacement candidates for M16A1 rifle
- Requirements for a new combat rifle

1981 • Results of CRS:

- Established stated service need for significantly/revolutionary improved rifle
- Near Term - Retain product improvement over M16A1
- Long Term - Develop technology base for ACR

1982 • Under Secretary Army (USA) endorses rifle development program for 10-12 year technology approach

• Two competitive contracts awarded to AAI and Heckler & Koch to pursue the following technologies:

- Caseless
- Salvo
- Optics

• M16A2 Rifle Type Classified in November

1983 • USA requests acceleration of program and directs user to set performance goals and become more involved

1984 • USA calls for vigorous program to acquire a significantly improved successor to the M16 rifle

• TRADOC tasked to define requirements

• Emphasis placed on technology currently available

• USA direction results in formulation of industry alternative strategy

• ACR Industry Conference Briefing; USAIS Ft. Benning, GA

• Accelerated program approved by Army Materiel Command (AMC)

• ACR Operational and Organizational (O&O) Plan drafted

1985
- O&O Plan approved by Training and Doctrine Command (TRADOC) in January
- USA approves ACR program and field experiment
- AMSAA/BRL study concludes that the best way to improve rifle performance in near term is to fire multiple projectiles per trigger pull with a (controlled) salvo pattern of dispersion
- Industry briefed on new alternative rifle program in May
- RFP released in September

1986
- Industry Alternative Program awarded Phase I contracts to:
    - AAI Corporation
    - ARES Inc.
    - Colt's Manufacturing Company
    - Mc Donnell Douglas Helicopter Company (MDHC)
    - Steyr-Mannlicher
    - Heckler & Koch (modification)

1987
- MDHC & ARES efforts were terminated due to hardware immaturity
- Test Integration Working Group (TIWG) chartered to design and plan ACR test program
- Range instrument requirements identified

1988
- Test and Evaluation Master Plan (TEMP) drafted
- HEL Salvo Stress Test conducted
- Field experiment test design complete
- Range instrumentation requirements initiated

1990
- Buckner Range completed
- Hardware delivered
- Safety and Engineering Tests conducted
- ACR field experiment conducted
- Lethality Test conducted

1991
- AMSAA analysis conducted
- ACR Final Report prepared

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3.0 ACR CANDIDATES - WEAPON SUMMARIES.

3.1 General. The ACR prototype weapon systems tested in the ACR field experiment were developed under contract by AAI, Colt, H&K, and Steyr. The ACR concept concentrated on developing a weapon system based upon available technologies in the areas of weapon, ammunition, and sight design. A synopsis of the weapon systems' characteristics is given below in Figure 3.1.

SYSTEM CHARACTERISTICS

	AAI	Colt	H&K	Steyr	M16A2 Standard
Weapon Length (inches)	40.00	40.625 extended 36.75 retracted	29.53	30.12	39.63
Weapon Mechanism	reciprocating bolt	reciprocating bolt	rotating chamber	rising chamber	reciprocating bolt
Weight (lbs.)*	9.39	10.30	9.15 (optic only)	8.53	8.80
Sights	iron or 4x optic	iron or 3.5x optic	multi pwr optic 1.0x & 3.5x	iron or multi pwr optic 1.5x & 3.5x	iron only
Magazine Capacity (rounds)	30	30	45	24	30
Modes of Fire	semi-automatic 3 round salvo burst	semi-automatic automatic	semi-automatic automatic 3 round salvo burst	semi-automatic 3 round salvo burst	3 round burst
Caliber (mm)	5.56	5.56	4.92	5.56	5.56
Cartridge	brass cased flechette	duplex & M855 ball	caseless ball	plastic cased flechette	M855 ball
Muzzle Device	muzzle compensator	muzzle brake compensator	none	flash suppressor	flash suppressor
Chamber Pressure (PSI)	55,000	50,750-M855 50,000-duplex	56,000	60,000	50,750
Muzzle Velocity (ft./sec.)	4,600	3,110-M855 2,900-duplex	3,000	4,900	3,110
Barrel Twist (inches)	1:85	1:7	1:6	1:100	1:7

** Weight includes iron and optic sights and loaded magazine of ammunition.*

Figure 3.1

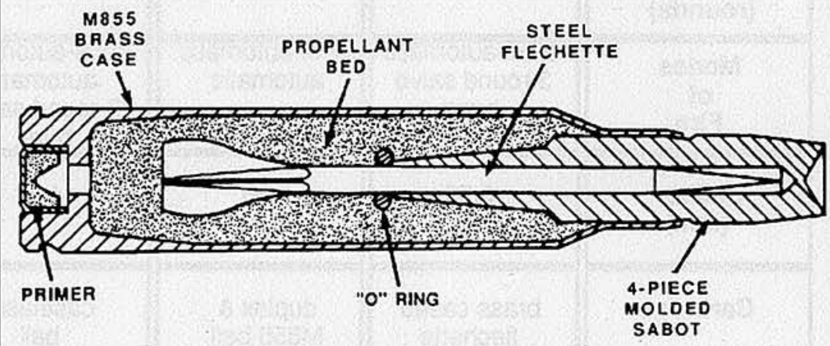
3.2 AAI.

3.2.1 Weapon. The AAI ACR (see Figure 3.2) is a gas operated, air-cooled, magazine fed flechette firing rifle. It has the capability to fire either a single shot semi-automatically, or a high cyclic three round salvo burst using a thirty round magazine. The AAI ACR is a modification to the previously developed serial bullet rifle. It fires from the closed bolt position and utilizes a muzzle device that reduces barrel climb in the three round burst mode. The rifle uses either an interchangeable iron or optic sight.

AAI ACR

Figure 3.2

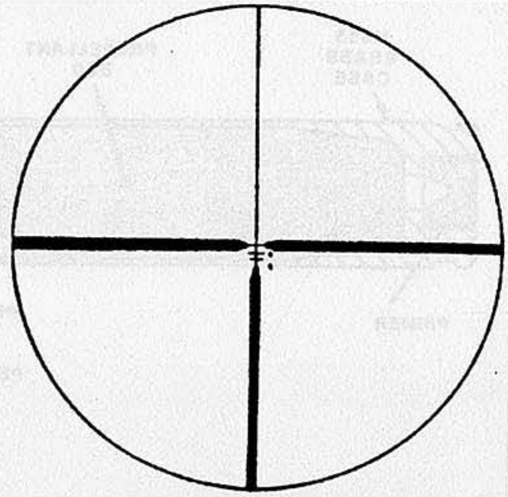
3.2.2 Ammunition. The AAI ammunition (see Figure 3.3) consists of a 10.2 grain steel flechette using the standard M855 brass case. The projectile package includes the flechette projectile, a four segment sabot, and an "O-ring" used to hold the sabot segments together. The sabot segments separate from the flechette after muzzle exit allowing the flechette to continue its aerodynamic flight downrange towards the target. The light weight projectile and high muzzle velocity allows for a relatively flat trajectory over long ranges.



AAI FLECHETTE AMMUNITION

Figure 3.3

3.2.3 Sight. The AAI ACR uses either an iron or four power (4X) optic sight. A quick release lever allows the changeover without the need to rezero the weapon. The optic sight has a tritium powered reticle (see Figure 3.4) for ease of use in reduced light level situations. The optic sight also incorporates aiming point stadia lines for 400, 500, and 600 meter ranges. Along the top of the rifle is a long aiming surface to assist in quick fire engagements.



AAI RETICLE PATTERN

Figure 3.4

3.3 Colt.

3.3.1 Weapon. The Colt ACR (see Figure 3.5) is a human engineered derivative of the current M16A2 rifle. It uses the same operating mechanism used in the standard M16A2 and fires the standard 5.56mm M855 NATO round interchangeably with a newly developed duplex ammunition. It can fire either in the semi-automatic or full-automatic mode using a standard M16A1 trigger mechanism. The rifle incorporates a newly designed handguard which consists of a heat resistant inner shield, air cooling vent holes, and a front end restricting ring. It offers a telescoping buttstock to custom fit the individual shooter. The rifle also has a muzzle break compensator (MBC) and a new oil/spring hydraulic buffer to reduce recoil of the weapon. This weapon also has interchangeable iron and optic sights.

COLT ACR

Figure 3.5

3.3.2 Ammunition. The Colt ACR fires either the NATO standard M855 round or a newly developed 5.56mm duplex ammunition (see Figure 3.6). It is envisioned that this system would remain a two ammunition type family: one ammunition for short range (duplex) and a second for long range (M855). The duplex ammunition consists of two similar projectiles positioned nose to tail in the same cartridge case, in which the leading projectile will proceed to the weapon's aimpoint while the trailing projectile will have some random dispersion around the aimpoint. This concept should improve the probability of at least one projectile hit for each round fired. The standard M855 round contains a single 62 grain projectile, while the duplex's front and rear projectiles weigh 35 and 33 grains, respectively.

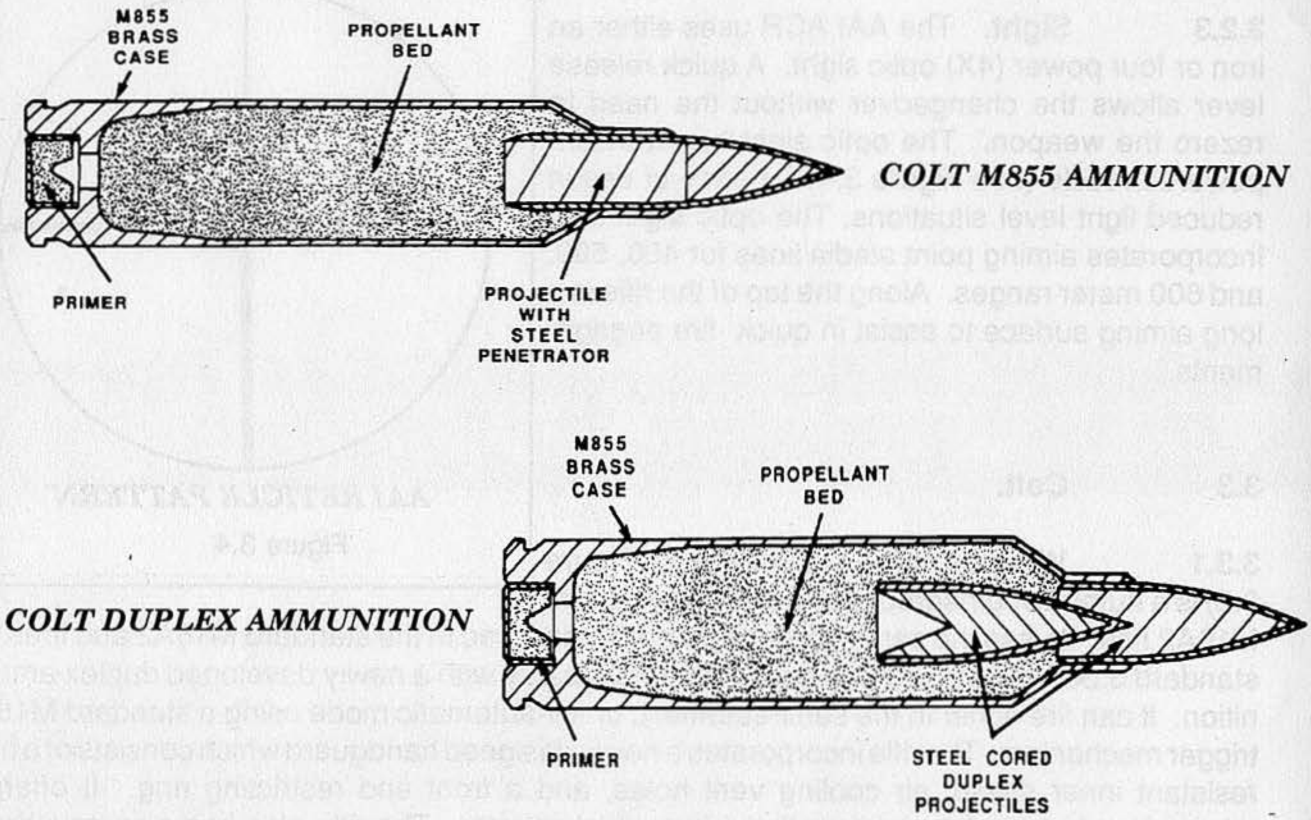
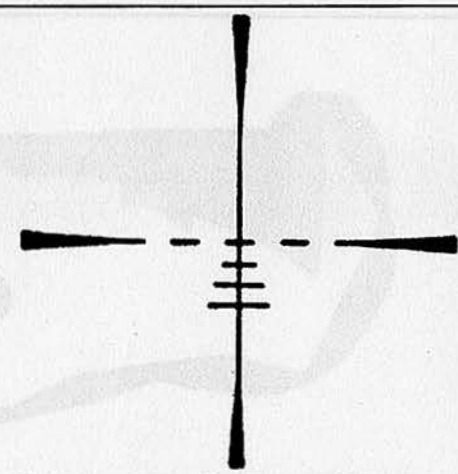


Figure 3.6

3.3.3 Sight. The Colt ACR uses either a detachable iron sight or a 3.5 power optic sight. The iron sight includes the carrying handle and a flip-type aperture for both short and long range targets. The optic sight is equipped with a self-powered illuminating reticle pattern (see Figure 3.7) for periods of reduced light. The rifle also has an aiming/pointing rib on its upper surface for quick target engagements.



COLT RETICLE PATTERN

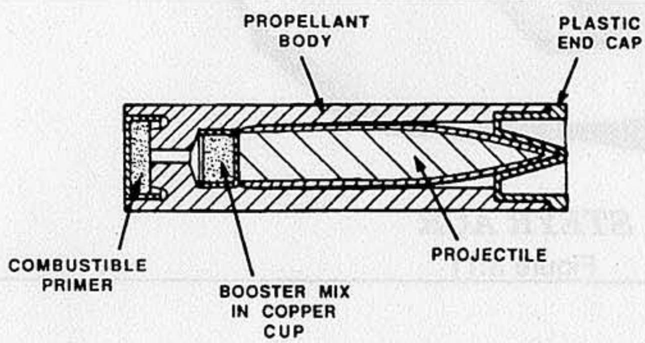
Figure 3.7

3.4 Heckler & Koch (H&K).

3.4.1 Weapon. The H&K ACR (see Figure 3.8) is a gas operated bullpup rifle firing caseless ammunition. The weapon operates using a rotating chamber mechanism and is charged with a rotary cocking device located on the side of the weapon. It can fire either semi-automatic, fully-automatic, or a three round salvo burst using a forty-five round magazine. Its caseless ammunition eliminates the need for an extraction cycle during firing allowing its salvo burst to be fired at over 2,000 rounds a minute. Its operating mechanism is unique in that the recoil of the weapon is delayed until after the round(s) have left the muzzle. The H&K ACR only offers the use of a day optic.

H&K ACR

Figure 3.8

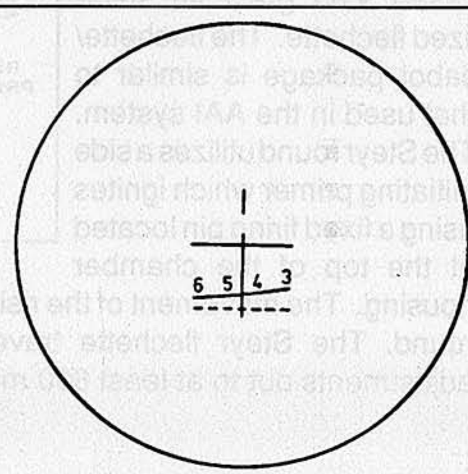


H&K CASELESS AMMUNITION

Figure 3.9

3.4.2 Ammunition. The ammunition is fully telescoped 4.92mm caseless ball ammunition (see Figure 3.9). This square cross section round consists of the nitramine based solid propellant body, a single 51 grain bullet projectile, primer, booster and plastic end cap. All ammunition components are consumed during firing except for the plastic end cap and copper booster cup which exit the muzzle upon firing. This round also has a variety of coatings to provide additional waterproofing, low friction surfaces, and heat resistance.

3.4.3 Sight. The H&K ACR uses a multi-powered (1.0X or 3.5X) optic sight which is integrated into the rifle's carrying handle. There is no backup iron sight on this weapon. The magnification is adjusted by turning a ring located on the eyepiece which also has settings for 400, 500, and 600 meters. The optic's reticle pattern (see Figure 3.10) offers a stadia line pattern that can be used to estimate distances beyond 300 meters. The magazine, which is located atop the weapon along the barrel, serves a secondary purpose of providing a pointing aid to the shooter for rapid engagement scenarios.



H&K RETICLE PATTERN

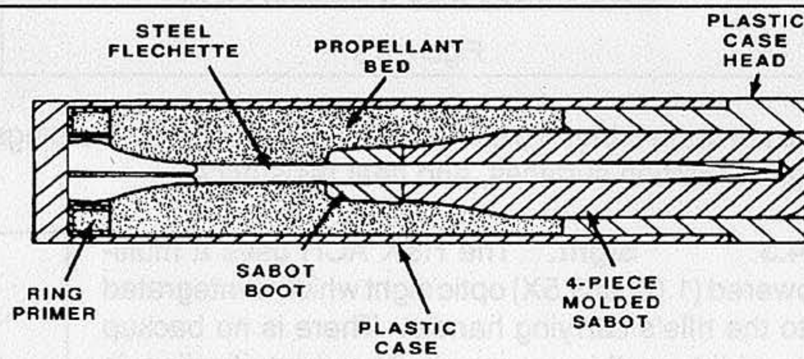
Figure 3.10

3.5 Steyr.

3.5.1 Weapon. The Steyr ACR (see Figure 3.11) concept is a novel bullpup style weapon featuring a rising chamber mechanism and a side initiating plastic cased round. The weapon can fire either a single shot or a three round high cyclic salvo burst. The weapon system and mechanism is very simple. It fires a flechette projectile from a twenty-four round transparent magazine. The Steyr ACR fires from the open bolt position in which a live round enters the chamber only after the trigger has been pulled. This characteristic greatly reduces the concern for ammunition cook-off. The iron sight is removable and interchangeable with the preferred day optic.

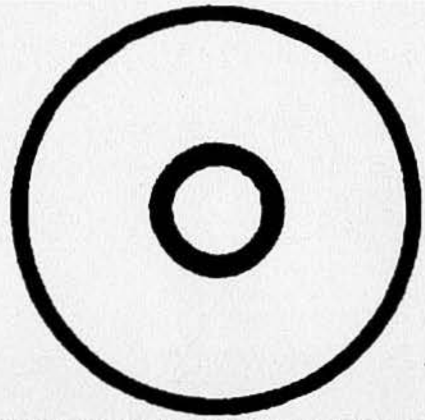
STEYR ACR
Figure 3.11

3.5.2 Ammunition. The Steyr ACR ammunition (see Figure 3.12) consists of a fully telescoped plastic cased 9.85 grain fin stabilized flechette. The flechette/ sabot package is similar to that used in the AAI system. The Steyr round utilizes a side initiating primer which ignites using a fixed firing pin located at the top of the chamber housing. The movement of the rising chamber creates the impact energy required to ignite the round. The Steyr flechette travels at a very high velocity which requires no elevation adjustments out to at least 600 meters.



STEYR FLECHETTE AMMUNITION
Figure 3.12

3.5.3 Sight. The Steyr ACR uses either an iron peep sight or a multi-powered optic sight. All windage and elevation adjustments are made on the front sight post while using the iron sights. The optic incorporates a multi-powered (1.5X or 3.5X) magnification capability that can be adjusted with a simple twist of the eyepiece. The optic uses a ring reticle pattern (see Figure 3.13) in which the shooter simply places the target inside the ring and fires. There is also a long shotgun style rib/carrying handle along the top surface of the rifle to aid as a pointing device in rapid target engagements.



STEYR RETICLE PATTERN
Figure 3.13

3.6 Summary. A detailed system description and in-depth contract summary is included in Appendix B of this volume. The weapon system's operator and maintenance manuals are included in Volume III of this report. Contractor final reports are in Volume VII.

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4.0 ENGINEERING TESTS.

4.1 Background. Prior to the ACR field experiment in 1990, safety and engineering tests were conducted at Aberdeen Proving Grounds (APG), Maryland, to assess the various ACR concepts. The U.S. Army Test and Evaluation Command (TECOM) issued an ACR safety release which was required to allow military personnel to participate in the field experiment. This safety release assigned specific limitations on each ACR concept based upon test information. The U.S. Army's Combat System Test Activity (CSTA) was responsible for conducting all ACR safety and engineering tests, while the Ballistic Research Laboratory (BRL) conducted live fire projectile lethality testing.

4.2 Safety and Engineering Tests - CSTA.

4.2.1 Objective. The objective of testing conducted by CSTA was to determine whether the ACR candidates were safe for military personnel to operate and to demonstrate their technical performance. All live firing was conducted by the Light Weapons System Division of CSTA's Armament System Directorate at APG. The test program at CSTA was designed in a three phase effort. Phase I was the safety qualification phase in which those tests required to issue a limited safety release would be performed first. The next two phases consisted of the ammunition and weapon technical feasibility tests. These tests were conducted to demonstrate the technical performance characteristics of the various ACR concepts. The testing was designed by CSTA in consultation with the ACR Test Integration Working Group (TIWG) and in conjunction with the Independent Evaluation Plan (IEP) prepared by the U.S. Army Material Systems Analysis Activity (AMSAA).

4.2.2 Description of Tests Performed. The safety qualification testing of the ACR candidates included weapon inspection, reliability, cook-off, toxic fumes, system signature and projectile hazard subtests. The ammunition feasibility test plan examined thermal shock, waterproofness, salt-fog, penetration, exterior ballistics and chemical compatibility. The weapon phase of this testing evaluated accuracy/dispersion characteristics, extreme temperature performance (high and low temperature), accessory compatibility and an engineering study. A human factors summary was conducted to determine the human engineering characteristics of the ACR candidate weapon systems. The Human Engineering Laboratory (HEL) at APG provided support and assistance to CSTA regarding the human factors engineering aspects of the ACRs. Due to funding limitations and the engineering status of the ACR prototype hardware, the original test schedule was modified to include only those tests required and/or considered of significant importance to the program.

4.2.3 Summary Results. The result of the CSTA safety qualification testing was a recommendation to TECOM for a limited safety release so that these prototype weapons could be fired by military personnel in the 1990 field experiment. The safety release was continuously updated as testing at CSTA continued. Several amendments to the TECOM safety release were issued throughout the field experiment. General restriction outlined in the safety release included: weapon handling, hearing protection, weapon/ammunition compatibility, and maximum round limitations. There were also specific restrictions placed on each of the ACR candidates which included: firing limits without cooling (cook-off concern), ammunition and weapon safety characteristics, and system specific maintenance and safety procedures. The most critical element concerning the various safety release amendments involved the Steyr ACR system. Safety concerns involving ruptured buttstocks caused the Steyr system to be temporarily removed from testing and very stringent maintenance requirements to be placed on the contractor to allow the Steyr ACR to be further tested in the field experiment.

A complete detailed description and summary of testing and test results can be found in CSTA report #USACSTA 7103, TECOM Project No. 2-WE-600-ACR-001, "Final Report: Technical Feasibility Test of Advanced Combat Rifle Candidates," 1992.

4.3 Projectile Lethality Testing - BRL.

4.3.1 Objective. The objective of the BRL testing was to estimate, assess and test the lethality capabilities of the various ACR projectiles. BRL was responsible for deriving the probabilities of incapacitation given a hit on the target, P(I/H), for the prototype ammunition. By combining the P(I/H) estimates with the hit probabilities generated in the ACR field experiment, an estimate of the incapacitation capability of each prototype can be derived. Live fire testing was conducted on each of the ACR projectiles using standard BRL gelatin test procedures.

4.3.2 Description of Tests Performed. BRL was tasked to establish initial P(I/H) values for the various ACR projectiles (bullets and flechettes) while they were still in the developmental stage. These initial estimates were based on ballistic performance estimates (velocity vs. range, yaw cycle, etc.) and projectile design characteristics (mass, diameter, length, nose length, and center of gravity). Pretest P(I/H) estimates were established using a mathematical model for the bullets and empirical testing for the flechette projectile

The ACR projectile tests were conducted at velocities simulating ranges of muzzle, 100, 300 and 500 meters using downloaded cartridges. Penetration/time measurements of the projectile in the gelatin targets were obtained using high speed film, allowing BRL to empirically determine the projectile's kinetic energy deposit on the target. Throughout testing, BRL used 20% gelatin blocks (15cm x 15cm x 38cm) having an internal temperature of 10 degrees C.

A limited number of tests were conducted using 10% gelatin blocks having an internal temperature of 4 degrees C. Although this configuration is not the standard used in weapons effects assessments, it has been used by personnel at the U.S. Army Letterman Institute of Research to describe wound profiles for penetrating projectiles. This testing was conducted to assess the accuracy of statements made by the Letterman Institute regarding ACR flechette lethality.

4.3.3 Summary and Results. Flechette lethality has been a controversial issue throughout the entire ACR Program. Previous flechette studies have shown that flechettes generally exhibit two kinds of behavior in tissue and gelatin. A critical velocity exists for flechettes regarding lethality. Flechettes impacting a target at velocities less than this value tend to penetrate the target media in a stable, nondeforming, non-tumbling mode. At striking velocities greater than this value, flechettes tend to deform and tumble in both gelatin and tissue targets. Both the AAI and Steyr flechettes remained above this critical velocity to ranges beyond 600 meters. The Steyr flechette, however, did exhibit different types of behavior for another reason. The current design iteration of the Steyr weapon required that the flechette be shortened by 0.10 inches to fit in the cartridge case. This change to the projectile, while not significantly reducing weight, reduced the overturning moment sufficiently that the projectile deformation in the soft target could no longer be assured. This shortcoming could be corrected by using a full length flechette in the next rifle design. The testing performed to examine penetration in the 10% and 20% gelatin revealed no significant differences in flechette performance in the two simulant formulations. In both formulations, the ACR flechette tumbled and deformed as predicted. When the flechettes tumble, they exhibit lethality characteristics similar to bullets.

A complete detailed description and summary of testing and test results can be found in BRL Report, "P(I/H) Estimates for Advanced Combat Rifle Ammunition Candidates," March 1992 (expected publish date). This report is classified CONFIDENTIAL.

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5.0 ACR FIELD EXPERIMENT.

5.1 Test Integration Working Group (TIWG). The ACR TIWG was formally chartered to provide for the coordination and planning of testing under the ACR program. Of principle concern was the design, conduct and evaluation of a joint user/developer field experiment to appraise potential ACR technologies. The issues to be tested and the test methodology was developed by the TIWG. The TIWG consisted of the ARDEC Development Project Officer (DPO) as the non-voting chairman,with principle voting representatives of the Army (Infantry School), Navy (Naval Weapon Support Center), Air Force (Office of Security Police), Marine Corps (Marine Corps Development and Education Center), and the Army Material System Analysis Activity (AMSAA). The TIWG was supported by many other non-voting members.

5.1.1 Test Design Plan (TDP). The TEXCOM Infantry Board, based upon the TIWG's test design requirements, prepared the ACR Test Design Plan, the Detailed Test Plan and executed the field experiment as a customer test for the TIWG. The TIWG also determined that the Infantry Board report would only provide the results of the test and no data analysis. A complete data analysis would be done by AMSAA under a sperate report.

5.1.2 Related Actions. The TIWG also formulated a Data Authentication Group consisting of the various evaluation agencies to review the raw data to determine the validity of the data to be evaluated, and to agree as a community on the information to be placed in the data base.

In December 1987, the Navy withdrew their support for the ACR program, and announced that they would no longer participate in the planned test or attend future TIWG meetings. Some time later, after playing a major role in the TIWG and the design of the test, the Marine Corps also withdrew from participation in the ACR program and planned participation in the ACR field experiment.

In response to a request by the Air Force and the Deputy Under Secretary of the Army for Operations Research, it was agreed to determine the interface of female firers with the ACR concepts, but only as a subtest to the field experiment. This was based on prior studies that showed that the performance of women was statistically different than that of men.

5.1.3 Independent Evaluation Plan.

5.1.3.1 Purpose. The Independent Evaluation Plan (IEP) identifies the testing issues, data requirements and procedures used by the U.S. Army Materiel Systems Analysis Activity (AMSAA) to evaluate the results of the field experiment and engineering tests. This plan also includes test firer/weapon matrices and target presentation scenarios which form the basis of the Test Design Plan (TDP) developed by the U.S. Army Infantry Board for the field experiment.

5.1.3.2 Issues for Evaluation. The major issues to be evaluated in the field experiment have been divided into two groups. These groups include critical and investigative issues. The critical issues contained in this document for the continuation of a candidate weapon system pertain to mission performance and safety. Other design issues, although essential in the fully developed system, will not be considered critical for this stage of testing. These investigative issues include: training, other mission performance issues, reliability and maintainability, human factors and position disclosing effects. The IEP is published in the Infantry Board's ACR TDP, "Customer Test of Advanced Combat Rifle (ACR)," TRADOC Project #89-0000752, USAIB Project #3839, June 1989.

5.2 Buckner Range.

5.2.1 Introduction. Buckner Range was converted into a unique highly instrumented live fire test facility to compare the performance of four ACR concepts against the U.S. military's standard M16A2 rifle. Target location and firer behavior have been designed to stress the shooter and replicate aiming errors experienced in combat. Unisys Corp., of Huntsville, AL, designed and installed the Fort Benning, GA, range to meet the requirements outlined by the TIWG. The two lanes of equipment and instrumentation are run independently by a computer controlled test system consisting of instrumented fixed and moving target mechanisms. Range control data acquisition hardware and software are used for the acquisition, storage, processing and display of firing data from user programmable scenarios. The computer system collects such data as target hits, time of all events, target miss locations and even soldier heart rates. Hit sensitive targets, both stationary and moving, are emplaced in the natural terrain from 25 to 600 meters. The down range target systems provide time information on target presentation and hits. At the firing position, a return fire simulator can be programmed to come on to simulate returning enemy small arms fire. An audible hit indicator can also be activated to indicate each time a target is hit. Heart rate sensors are integrated into the computer system and provided at the firing point to monitor each shooter throughout the test.

5.2.2 Miss Distance Indicator (MDI). Unique to Buckner Range is the MDI instrumentation that is located at 14 of the 35 targets out to 300 meters. This capability also applies to five moving targets. The unique features of this system are the accuracy, large detection window size, and the ability to detect small high velocity projectiles like flechettes. The MDI system, using curved rods, sense the shock waves from the supersonic projectiles. The computer system uses this information to calculate the location where the projectiles penetrated the air space around the target.

5.2.3 Lane Control and Data Acquisition System (LCDAS). All equipment and instrumentation is controlled by the Lane Control and Data Acquisition System (LCDAS) from the control tower. The two LCDASs, one per lane, can be programmed to operate independently in either an automatic or manual mode. In addition to being able to program target presentations and exposure times, the LCDAS provides flexibility to pause scenarios for necessary range delays, such as weapon stoppage or safety concerns.

5.2.4 Summary. A list highligting specific characteristics and specifications of Buckner Range is provided in Figure 5.1. Volume II of this report is devoted entirely to providing additional information on Buckner Range.

EVENTS TO BE MEASURED, RECORDED OR CONTROLLED

- Weapon firing.
- Target hits and misses.
- Location of target hits and misses (for misses within 15 feet).
- Firer heart rate.
- Pop-up target up/down position and operational status.
- Moving target up/down position, location and operational status.
- Return fire simulation.
- Computer operator signals.

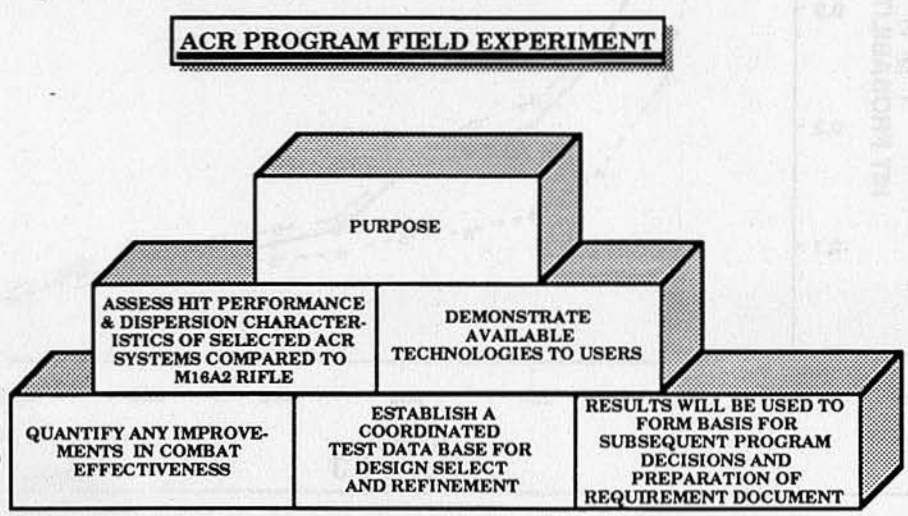
RANGE SPECIFICATIONS

- Number of firing lanes: 2.
- Stationary pop-up targets per lane: three at 25, 50, 75, 100, 150, 225, 300, 400, 500 and 600 meters.
- Moving targets per lane: one at 75; two at 150, and two at 225 meters.
- Data timing resolution: 1.0 milliseconds.
- Moving target speeds:
  - -- 6 feet per second (to simulate walking target).
  - -- 12 feet per second (to simulate running target).
- Target size: half-man size (man crouching).
- MDI maximum window size: 15-foot radius from center of target.
- MDI accuracy (Difference between where projectile actually penetrates target area and where MDI records where the projectile penetrated):
  - -- Minimum (window center): 1/2 inch.
  - -- Maximum (window extreme): 10 inches.

Figure 5.1

5.3 Test Rationale and Design.

5.3.1 Purpose. The purpose of the field experiment was to assess the hit performance and dispersion characteristics of selected ACR weapon systems when compared to those characteristics of the M16A2 rifle. The test was to demonstrate the available technologies to the users, quantify any improvements in combat effectiveness, and establish a coordinated test data base for design and refinement.



5.3.2 Test Rationale. A disproportionately large number of rounds are fired from small arms compared to the number of casualties produced by bullets. The reason for this is two fold, first small arms fire is used against area targets to suppress the enemy presence. Second, small arms fire, when aimed, is directed against targets that are moving, exposed for short periods of time, and take advantage of cover. Thus, the shooter is rushed, is often not in a stable firing position, and is concerned for his welfare. All of these factors result in high aiming errors and low hit probabilities (see Figure 5.2).

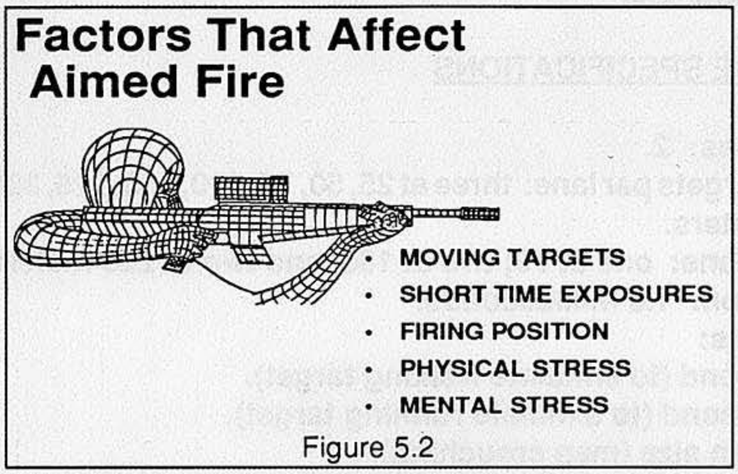


Figure 5.2

Field studies such as Salvo I and II, SPIW (XM19) Day Defense Test, and the CDEC XM19 test all concluded that low momentum systems firing multiple projectiles per trigger pull could compensate for the high aiming errors and increase hit probabilities.

The ACR concepts fire multiple projectiles per trigger pull. Multiple projectiles were fired from a single cartridge and from serially fired cartridges at a single trigger pull. In both cases small dispersions, approximately one half the aim error, are required. Figure 5.3 presents the increase in hit probability that can be expected over the M16A2 stressed from a serially fired system concept (8 mil extreme spread) and a salvo (simultaneously) fired system concept (5 mil extreme spread) for very high aiming errors. Optical sights were used to improve accuracies at longer ranges and at low light level conditions.

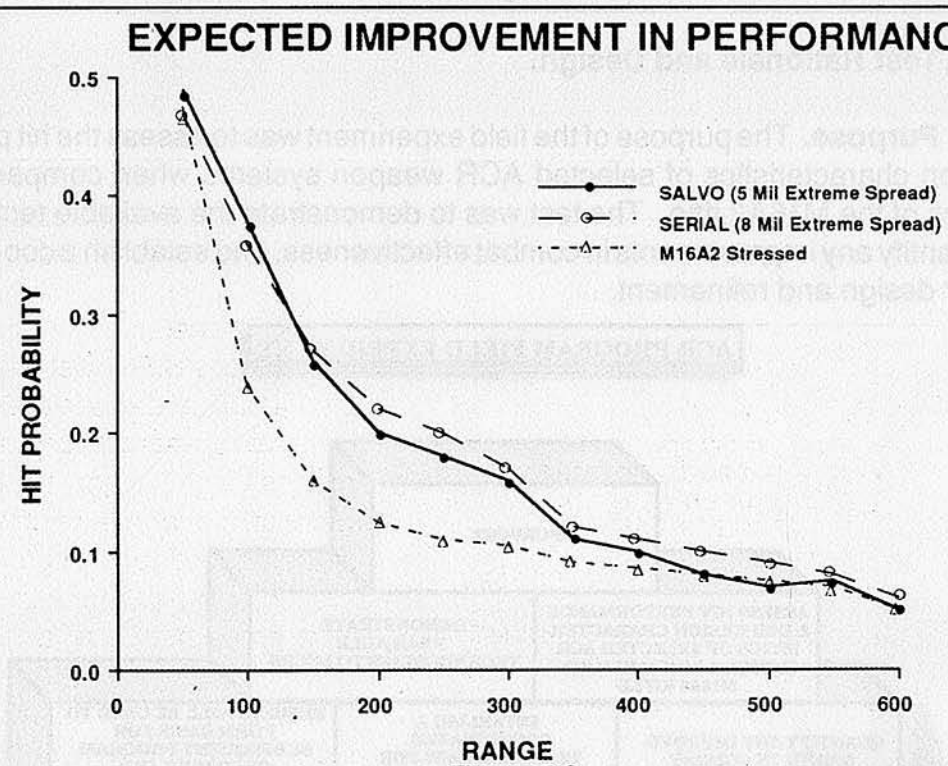


Figure 5.3

The ACR field test has been designed to compare these competing design concepts under expected conditions of use for aimed fire. Three scenarios have been generated in order to manipulate the predominant variables which effect aimed rifle fire (see Figure 5.4). These variables are target characteristics, target behaviors, and firing stability (e.g. position). Target range has been varied from 25-600 meters, exposure times for stationary targets have been varied from 1.5 to 10 seconds (depending on range) and for moving targets exposure times of 3 and 5 seconds. The moving targets operated at speeds of 6 ft/sec and 12 ft/sec to simulate a walking and running man, respectively. Additionally, multiple targets for selected times and ranges will be presented to act as a forcing function. Three firing positions were chosen, standing (the least stable), prone unsupported (moderately stable) and foxhole supported (the most stable).

The predominant design characteristics thought to contribute to hit probability, mode of fire and sighting system, will be examined for each concept. Most concepts provide two modes of fire and two sighting systems, resulting in four test combinations. Each of these will be tested in order to discern their contribution to hit probability. As many of these combinations as possible have been tested within the resources of the program.

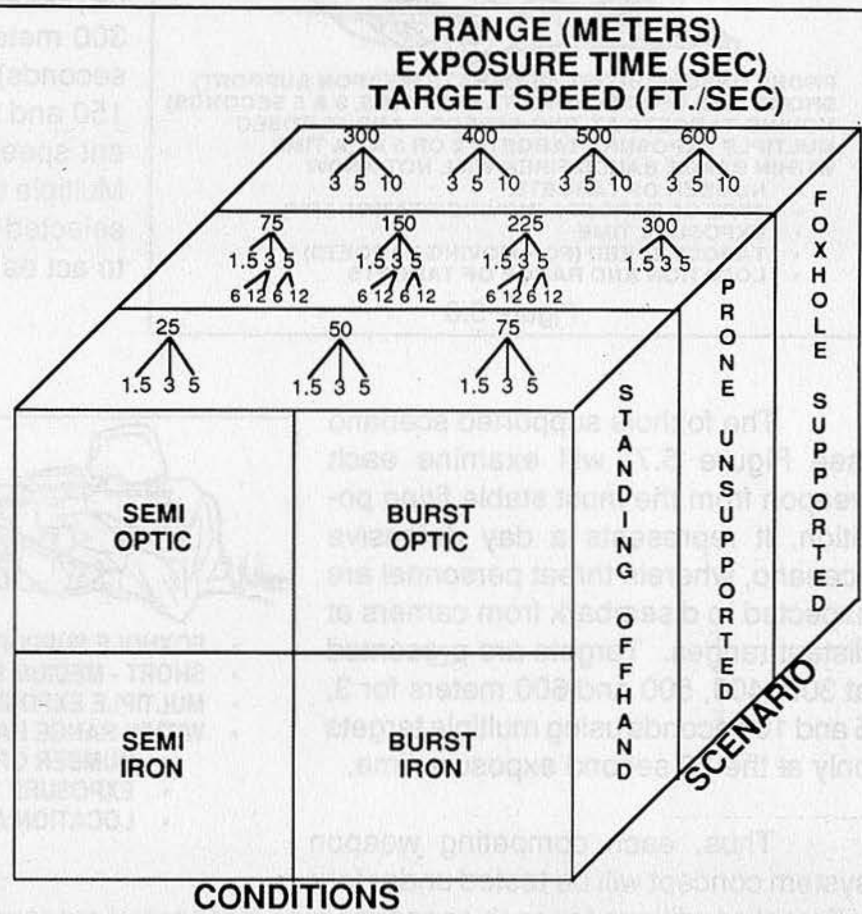


Figure 5.4

Short Range
25 to 75 M

- STANDING (LEAST WEAPON SUPPORT)
- QUICK FIRE/POINT FIRE TECHNIQUE
- RAPIDLY APPEARING SHORT EXPOSURE TARGETS (1.5, 3 & 5 SECONDS)
- WIDE ENGAGEMENT ANGLE
- MULTIPLE EXPOSURE TARGETS 2 OR 3 AT A TIME
- WITHIN RANGE BAND FIRER WILL NOT KNOW
    - NUMBER OF TARGETS
    - EXPOSURE TIME
    - TARGET RANGE OR LOCATION

Figure 5.5

The standing offhand scenario (see Figure 5.5) was designed to examine the concepts in the quick fire role wherein targets are presented at short ranges for short exposure times over a wide target angle engaged from the standing position. High aiming errors are expected because the target exposure times are short and multiple targets are presented for selected times. It has been shown that aiming error increases exponentially with decreasing target exposure time. Targets exposed for periods shorter than 2 seconds will force gunners to point the weapon and not use their sights, while targets exposed for longer than 4 seconds do not further reduce aiming error. The multiple targets will act as a forcing function to further ensure high stress and aim error.

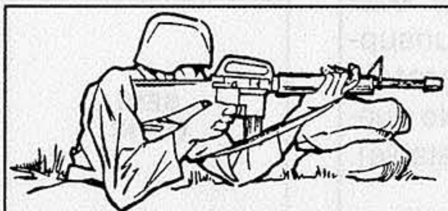
Intermediate Range
75 to 300M

- PRONE UNSUPPORTED (MODERATE WEAPON SUPPORT)
- SHORT TIME OF EXPOSURE TARGETS (1.5, 3 & 5 SECONDS)
- MOVING TARGETS AT TWO SPEEDS 6 AND 12 FT/SEC
- MULTIPLE EXPOSURE TARGETS 2 OR 3 AT A TIME
- WITHIN RANGE BANDS FIRER WILL NOT KNOW
  - NUMBER OF TARGETS
  - TYPE OF TARGETS (MOVING/STATIONARY)
  - EXPOSURE TIME
  - TARGET SPEED (FOR MOVING TARGETS)
  - LOCATION AND RANGE OF TARGETS

Figure 5.6

The prone unsupported scenario (see Figure 5.6) was selected to examine a more stable firing position. Targets will be presented at intermediate ranges (75-300 meters) for varying times (1.5, 3, 5 seconds) along with moving targets (75, 150 and 225 meters) operating at different speeds (6 and 12 feet per second). Multiple targets will also be presented for selected exposure times (3, 5 seconds) to act as a task induced stressor.

The foxhole supported scenario (see Figure 5.7) will examine each weapon from the most stable firing position. It represents a day defensive scenario, wherein threat personnel are expected to disembark from carriers at distant ranges. Targets are presented at 300, 400, 500 and 600 meters for 3, 5 and 10 seconds using multiple targets only at the 10 second exposure time.



Long Range
300 to 600M

- FOXHOLE SUPPORTED (MOST WEAPON SUPPORT)
- SHORT - MEDIUM EXPOSURE TIMES (3, 5 & 10 SEC)
- MULTIPLE EXPOSURE TARGETS TWO AT A TIME
- WITHIN RANGE BAND FIRER WILL NOT KNOW
  - NUMBER OF TARGETS
  - EXPOSURE TIME
  - LOCATION AND RANGE OF TARGET

Figure 5.7

Thus, each competing weapon system concept will be tested under four different conditions for each scenario using a repeated measures design with all subjects firing each weapon condition scenario combination. A three factor within subjects repeated measures MANOVA will be used for analyses. Post-hoc contrasts such as the Turkey HSD will be used following the MANOVA.

The primary dependent measures will be:

a. $\dfrac{\text{number of targets hit}}{\text{targets exposed}}$

b. $\dfrac{\text{number of hits}}{\text{trigger pull}}$

c. $\dfrac{\text{number of hits}}{\text{first trigger pull}}$

d. $\dfrac{\text{number of hits}}{\text{projectile fired}}$

e. time to first hit

f. time to fire

g. $\dfrac{\text{number of casualties}}{\text{combat load (trigger pulls)}}$

Number of trigger pulls will be based on available magazines which in turn will be based on total system weight, magazine volume, and magazine configuration (bulkiness).

An additional analysis will include cumulative percent targets hit as a function of time.

Other dependent measures of interest will be aim error as a function of: target range (apparent size), exposure time, firing position, and multiple targets; but most importantly aim error occurring when firing single projectiles per trigger pull will be compared with aim error occurring when firing multiple projectiles per trigger pull.

Inducing high aiming errors is a vital part of the field test. The task induced stressors will be random presentations of short target exposures at different ranges against targets that are moving or stationary. In addition, competition between units and physical exercise will be used.

The aim error as a function of exercise will show how aim error changes as a function of time which in turn will be related to distance run and physiological variables such as breathing rate, heart rate, and muscle tremor.

The ACR field test will include as many independent variables and their parameter values that are thought to be present in combat producing high aiming errors.

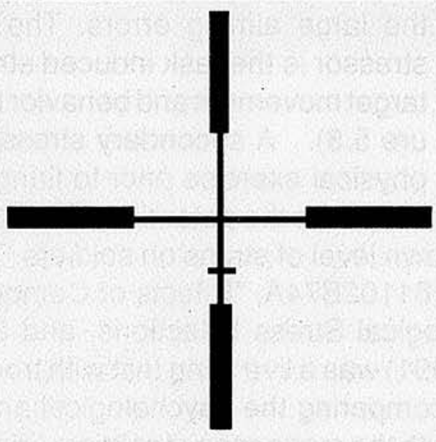
5.3.3 HEL Salvo Stress Test. This test funded under the ACR program was conducted as part of the planing for the stress in the ACR field experiment. Stress in the shooter is the reason for poor hit performance in combat. Although combat stress cannot be replicated in a test, other stressors were used in the field experiment to generate the large aiming errors. The primary stressor is the task induced stressor of target movement and behavior (see Figure 5.8). A secondary stressor is the physical exercise prior to firing the target scenario. The purpose of the Salvo Stress Test was to assess the potential of peer pressure and competition as a methodology for producing a known level of stress on soldiers. The test, documented in the HEL report (HEL Project No. 1L161102B74A, "Effects of Competition of Mode of Fire on Physiological Responses, Psychological Stress Reactions, and Shooting Performance", Technical Memorandum 11-91, July 1991) was a live firing test with troops. The stress created during competition was assessed by comparing the psychological and physiological responses of the soldiers firing competitively with the responses of soldiers firing during noncompetitive control conditions, and with responses obtained from subjects in other stress protocols. Psychological reactions were measured by a battery of instruments. Physiological reactions were determined by measuring several stress related hormones in multiple blood samples and by monitoring heart rate. This experiment documented that competition can be used to reliably produce a moderate level of stress.

Figure 5.8

5.4 Field Experiment.

5.4.1 Weapon Systems. Characteristics of the weapon systems tested in the field experiment are shown in Figure 3.1 on page 9. In addition to the five systems shown on the chart, two additional systems were included in the tests. These two systems were modifications to the standard M16A2. One was equipped with a 4.0 power optic sight mounted on the carrying handle (see Figure 5.9 and 5.10), and the other was equipped with a 4.0 power optics sight with a rifle muzzle stabilizer and modified to fire in the automatic fire mode. Duplex ammunition was also fired from the M16A2 weapon systems.

M16A2 (with Optic)
Figure 5.9



M16A2 OPTIC RETICLE PATTERN
Figure 5.10

5.4.2 Characteristics Tested. The characteristics tested in the field experiment as well as the Measures Of Effectiveness (MOE) are given in Figure 5.11 on the following page.

5.4.3 Test Players and Equipment.

5.4.3.1 Test Firers. The U.S. Army and U.S. Air Force each provided eighteen male and five female test firers to participate in the field experiment.

5.4.3.2 Weapon System Instructors. The U.S. Air Force provided five primary and three alternate instructors, while the U.S. Army provided one chief instructor, five primary instructors, and two alternate instructors.

CHARACTERISTIC	MEASURE OF EFFECTIVENESS (MOE)
Training	Instances noted during training when test firer performance of tasks indicated inadequate training
Ease of zero	Mean number of rounds to zero Time to zero
Dispersion firing	Burst and Automatic Fire mode: Extreme spread, extreme horizontal spread, & extreme vertical spread of each burst Semi-automatic Fire mode: Extreme spread, extreme horizontal spread, & extreme vertical spread of each five-round group
Hit performance	Target hits/trigger pulls Target hits/rounds fired Targets hit/trigger pulls Targets hit/rounds fired Targets hit/targets exposed Mean miss distance
Response times	Response times were the mean times to first target hit for single target exposures; mean times to first target hit for two target exposures; & mean times to first, second & third target hits for three target exposures
Zero retention	Percent of times zero was retained
Reliability	Mean rounds between failures
Maintainability	Mean time required to perform operator maintenance Mean time required to perform contractor maintenance
Human Factors	Number & nature of human factors problems noted by test firers Preference ranking by test firers
Safety	Number & severity of safety hazards noted
Compatibility	Number & nature of problems concerning compatibility with safety glasses & Kevlar helmet
Position disclosing effects	Position disclosing effects of test & control systems (flash, dust, smoke, & noise)

Figure 5.11

5.4.3.3 Weapons and Ammunition. ARDEC provided the following weapons and ammunition for the test:

A. Weapons:

1. Fifteen ACR test weapons: AAI, Colt, Heckler and Koch, and Steyr.
2. Fifteen standard M16A2.
3. Ten rifle optic sights to be used with the standard M16A2.
4. Ten M16A2 rifles modified to fire automatic and equipped with muzzle stabilizers.

B. Ammunition: Approximate Quantity:

1. AAI — 90,000 Flechette rounds
2. Colt — 53,000 Duplex rounds & 10,000 M855 rounds
3. Heckler & Koch — 75,000 Caseless rounds
4. Steyr — 90,000 Flechette rounds
5. M16A2 with Optic — 52,000 M855 rounds
6. M16A2 with Optic & Muzzle Stabilizer — 52,000 Duplex rounds
7. Standard M16A2 — 188,000 M855 rounds

5.4.4 Test Events & Conditions. The test was conducted in three phases. Phase I and II consisted of one week of pretest training and five three week test rotations for male firers. The five rotations allowed for each subject to be assigned each of the four ACR candidates as well as the M16A2. Each test rotation consisted of one week of test training and two weeks of test firing. Phase I and II were identical, except phase I involved the first half of the firers and phase II involved the second half. Phase III consisted of five rotations of two days each for female firers. The first day consisted of training and the second day consisted of hit performance firing.

5.4.4.1 Training. From 17 through 28 July 1989, the weapon contractors trained U.S. Army and U.S. Air Force instructors and INFBD test directorate personnel at Ft. Benning, GA, on the ACR test weapon system. A two day refresher training took place during the first week in January 1990 prior to the start of the ACR field experiment. This refresher training involved the ACR contractors reviewing details and procedures with the instructors on the ACR candidates. After completion of training, these military instructors organized into integrated training teams and instructed the male test firers during pretest training and test training (Phases I and II) and instructed the female firers during 1 day of test training (Phase III).

5.4.4.2 Test Events for Phases I and II (Male Firers).

5.4.4.2.1 Zeroing. Prior to beginning test firing each day, the male test firers zeroed their assigned weapon's iron or optic sight, as appropriate. Zeroing was conducted under existing daylight and weather conditions.

5.4.4.2.2 Dispersion Firing. Following the zero exercise, the male test firers participated in a non-stressed, untimed, dispersion firing exercise which was conducted under existing daylight and weather conditions. All dispersion firing was conducted on MDI equipped targets on Buckner Range.

5.4.4.2.3 Hit Performance Firing. After completing the dispersion firing exercise, the male test firers participated in a stressed, timed, hit performance exercise conducted under existing daylight and weather conditions. The male test firers engaged both single and multiple stationary E-type silhouette target exposures and single moving E-type silhouette target exposures at ranges of 25 to 600 meters. Targets in the short range (25-75 meters) were engaged from the standing unsupported position, while targets exposures in the intermediate range (75-300 meters) and the long range (300-600 meters) were engaged from the prone unsupported and foxhole supported positions, respectively. All hit performance firing was conducted on Buckner Range. The test firers fired target scenarios in four basic conditions (semi-automatic/iron sight, semi-automatic/optic sight, burst/iron sight, and burst/optic sight). The male test firers were stressed using physical exercise, simulated return fire, short target exposures, multiple targets, and moving targets (target speeds were 6 and 12 feet per second). To monitor effects on the heart rate of the test firers, each test firer wore a heart-rate monitor during firing. Personal competition was also used as a stress factor.

5.4.4.2.4 Zero Retention. Following dispersion and hit performance firing each day, the male test firers fired a live fire zero retention exercise, under existing daylight and weather conditions, with that weapon system's iron or optic sight (as appropriate) and checked for zero retention. The test firers fired two three-round shot groups to check for zero retention. If the zero was not retained, the mechanical corrections necessary to return the system to zero, and the number of rounds required were recorded. If a weapon system did not fire any test events during a scheduled firing day, that system did not conduct a zero retention exercise at the end of the day, but fired a zero confirmation exercise the next morning prior to beginning firing the test events. If the zero was not confirmed, the firer again zeroed his weapon system.

5.4.4.2.5 Position Disclosing. A position disclosing effects exercise was conducted only by the male test firers during the phase II hit performance firing events. Remotely operated audiovisual recorders were placed downrange and to the flanks of the live firing to record the flash, dust, smoke, and noise effects of the test systems.

5.4.4.2.6 Reliability, Maintainability, Human Factors, Safety, and Compatibility. Test data regarding reliability, maintainability, human factors, safety and compatibility were collected throughout the conduct of the test for the male test firers through the use of questionnaires, interviews, and observations by test directorate personnel.

5.4.4.3 Test Events for Phase III (Female Firers).

5.4.4.3.1 Hit Performance Firing. The female firers participated in a stressed and timed hit performance exercise conducted under existing daylight and weather conditions. The female test firers engaged both single and multiple stationary, E-type silhouette target exposures at ranges from 25 to 300 meters from the foxhole supported firing position. All hit performance firing was conducted at Buckner Range. The female test firers were also physically stressed prior to conducting hit performance firing. All weapons were zeroed prior to test firing. During phase III, this zeroing data was not collected and/or analyzed because of the limited training time on each weapon system.

5.4.4.3.2 Reliability, Maintainability, Human Factors, Safety and Compatibility. Test data for female test firers regarding reliability, maintainability, human factors, safety and compatibility were collected in the same manner as for phases I and II.

5.4.5 Firing Controls and Range Reliability. All test firers fired all firing events while wearing Battle Dress Uniform (BDU), load-bearing equipment, and Kevlar helmet. Because the weapon systems were prototypes, test firers were required to wear safety glasses when firing. All test firers fired all firing events in accordance with a randomized sequence of events so that any learning effects were minimized and controlled for all systems. Testers closely controlled all events throughout the entire field experiment. The target layout sequence of test events, and test control procedure were explained to all test firers to aid in insuring the accurate collection of data. The test range personnel used live ammunition to check range instrumentation reliability each day prior to testing.

5.4.6 **Results.** A complete description of the ACR field experiment is documented in the TEXCOM Infantry Board's (INFBD) Final Report, "Customer Test of the Advanced Combat Rifle (ACR)," November 1990. The report summarizes all the activities conducted on the ACR field experiment under TRADOC Project # 89-0000752 and TEXCOM INFBD Project # 3837. No statistical comparisons or analysis on the performance of the various weapon systems was made in this report. A complete analysis was conducted by AMSAA as described in section 6.0 of this report.

6.0 AMSAA ANALYSIS.

6.1 Results of the Field Experiment. The detailed results of the field experiment are contained in the Infantry Board Test Report. An analysis of the results was conducted by AMSAA and is documented in AMSAA report, "Independent Evaluation Report No. 5-91 of the Advanced Combat Rifle", August 1991. This report contains classified information. The results discussed here are extracted from the AMSAA report.

6.2 Record Fire. Each gunner received one week of training with the M16A2 rifle and then fired the standard Army record fire course. This course consists of forty (40) targets located from 50 to 300 meters. One round was fired at each target from the prone position using semiautomatic and iron sights. The score is the total number of targets hit. The gunners are classified according to the following scores.

Minimum Classification Score

Expert 36
Sharpshooter 32
Marksman 23

Initial qualification scores of the gunners (see Figure 6.1) show that the performance of the test gunners was well above basic trainee scores and scores needed to qualify on the M16. Phase I gunners also performed better than phase II gunners in the record fire course. For this reason in the data analysis, the phase I and II results will be treated separately.

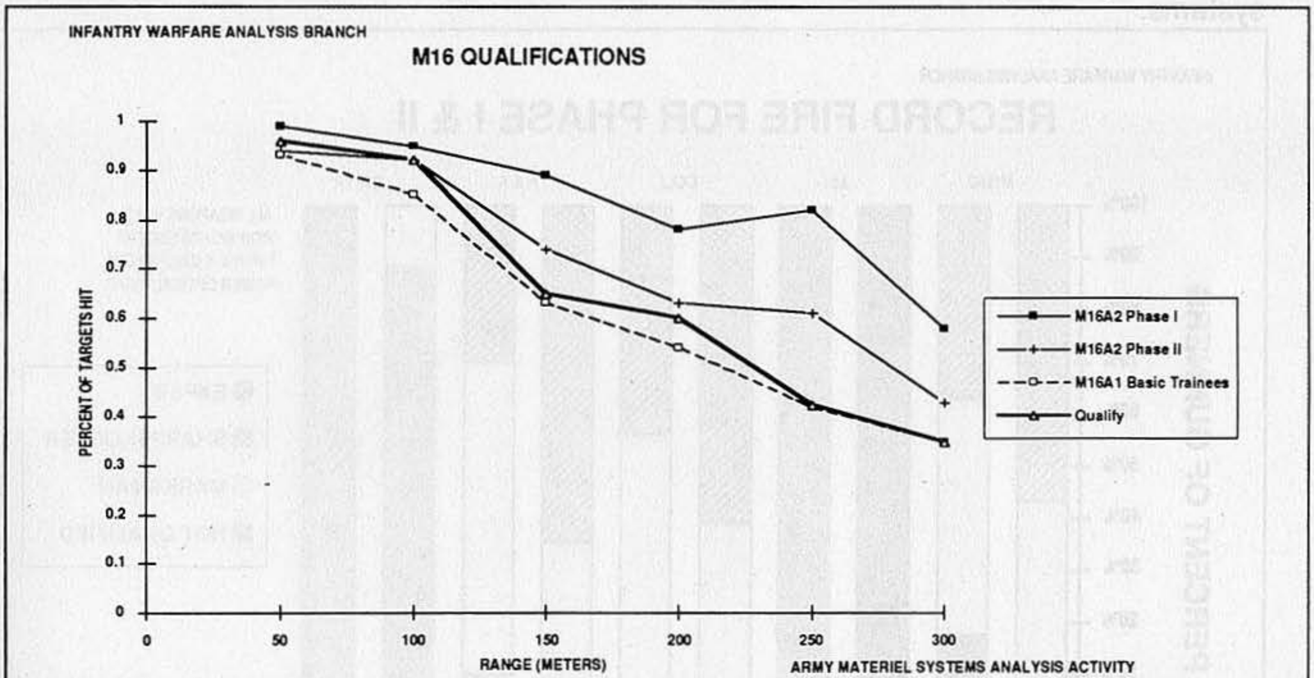


Figure 6.1

The operational field test was conducted using the standing (unsupported), prone (unsupported) and foxhole (supported) firing positions while engaging hit sensitive standard E-type silhouette targets located from 25 to 600 meters. Limited test resources did not allow for the testing of each firing position at each range. Therefore, the ranges of engagement were divided into three range bands. Targets in the short range band (25-75 meters) were fired in the standing position, intermediate range band (75-300 meters) in the prone position, and the long range band (300-600 meters) in the foxhole position. Another limitation was that not all weapon conditions could be fired in each range band. The selection of weapon conditions fired in each range band, was based on recommendations from the contractors and decisions of the TIWG. With these restrictions, a repeated measures test design plan was developed. This plan was statistically designed and controlled for order position, carry-over effects, learning, stress and time of day. This test design plan provided that:

- Each gunner fired each weapon condition.

- Once a gunner was assigned a weapon, all weapon conditions of that weapon were fired before the gunner was assigned another weapon.

Following one week of training on the test weapons the gunners fired the record fire course again with the test weapons prior to proceeding into the stressed hit probability test on Buckner Range. The results of the record fire tests for phase I and II can be seen in Figure 6.2. It can be seen that with the two flechette firing guns (AAI and Steyr) that almost all of the gunners failed to hit sufficient targets to be considered qualified. This is due to the fact that the round to round dispersion of the flechette projectiles was more than two times that of the bulleted systems.

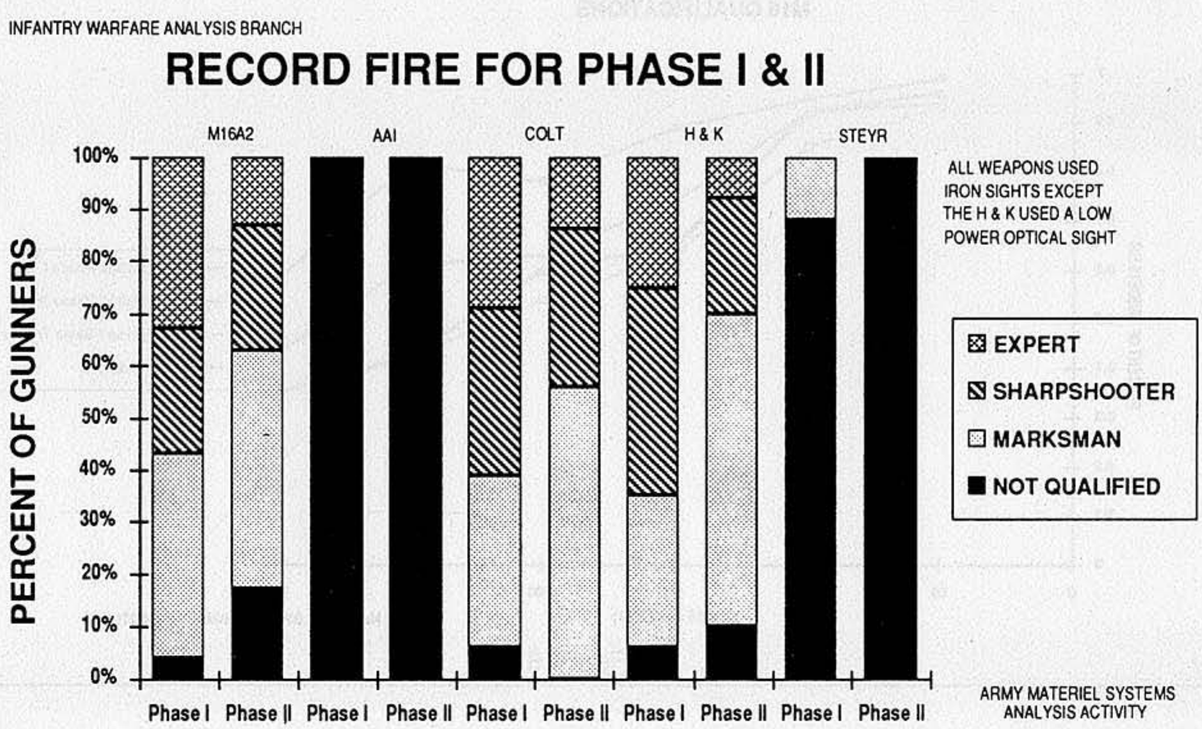


Figure 6.2

6.3 Hit Performance. The primary measure of effectiveness (MOE) used to represent hit probability is the percent of targets hit on the first trigger pull. These values, averaged over the target exposure time, stationary and moving targets and the range bands are shown in figures 6.3 through 6.5. The statistical analysis of the hit performance was conducted using the procedure for a three factor experiment with repeated measures. The standard weapon system is the M16A2 firing semiautomatic using iron sights.

6.3.1 Short Range Band. There were no statistical differences in the hit performance of the weapons tested in the ACR test for the short range band, at the 0.1 level of significance for a two-tailed test. Thus, no pairwise comparisons of weapon systems can be made statistically. Figure 6.3 shows that the hit performance of the flechette weapons (AAI and Steyr) fired on semiautomatic and using iron sights, have a lower point estimate of the hit performance than the standard. However, these differences were not of such a magnitude that statistically significant differences could be detected with the sample size of the ACR test.

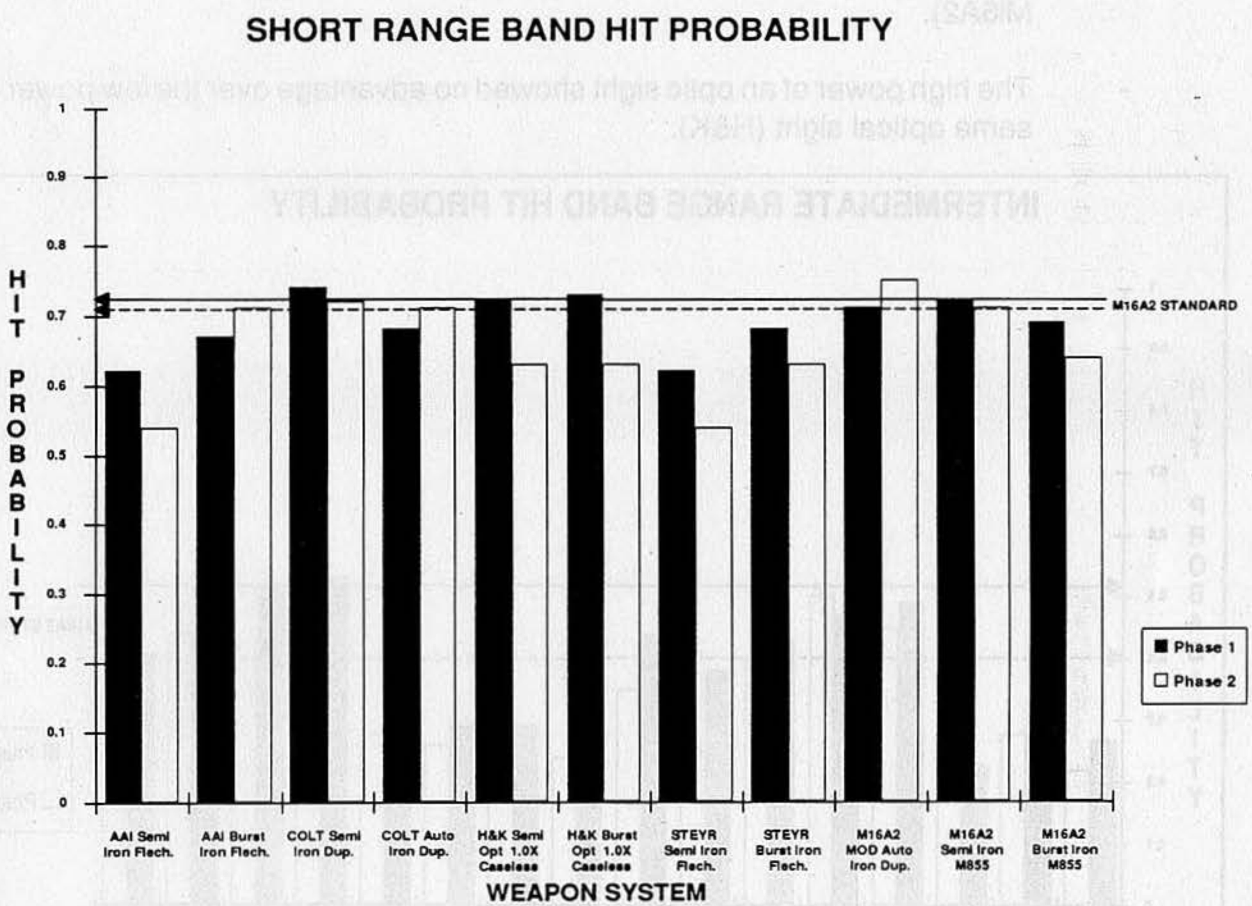


Figure 6.3

6.3.2 Intermediate Range Band. Significant differences among the candidates were detected for the intermediate range band. Therefore, pairwise comparisons could be made. The criterion for determining that a weapon system/firing condition is better or worse than another weapon system/firing condition is that a statistically significant difference in the comparison for both phase I and phase II exists. The conclusions based on the comparisons, shown in Figure 6.4 are:

- The flechette weapons (AAI and Steyr) were worse than the standard for all weapon conditions.
- The H&K firing semiautomatically and using low power optical sight was worse than the standard.
- The M16A2 fired automatic using iron sights was worse than the standard.
- All other weapon systems were not significantly different from the standard.

Pair wise comparisons within a weapon system lead to the conclusions:

- Optical sights did not show any advantage over iron sights (AAI, Colt, Steyr and Ml6A2).
- The high power of an optic sight showed no advantage over the low power of the same optical sight (H&K).

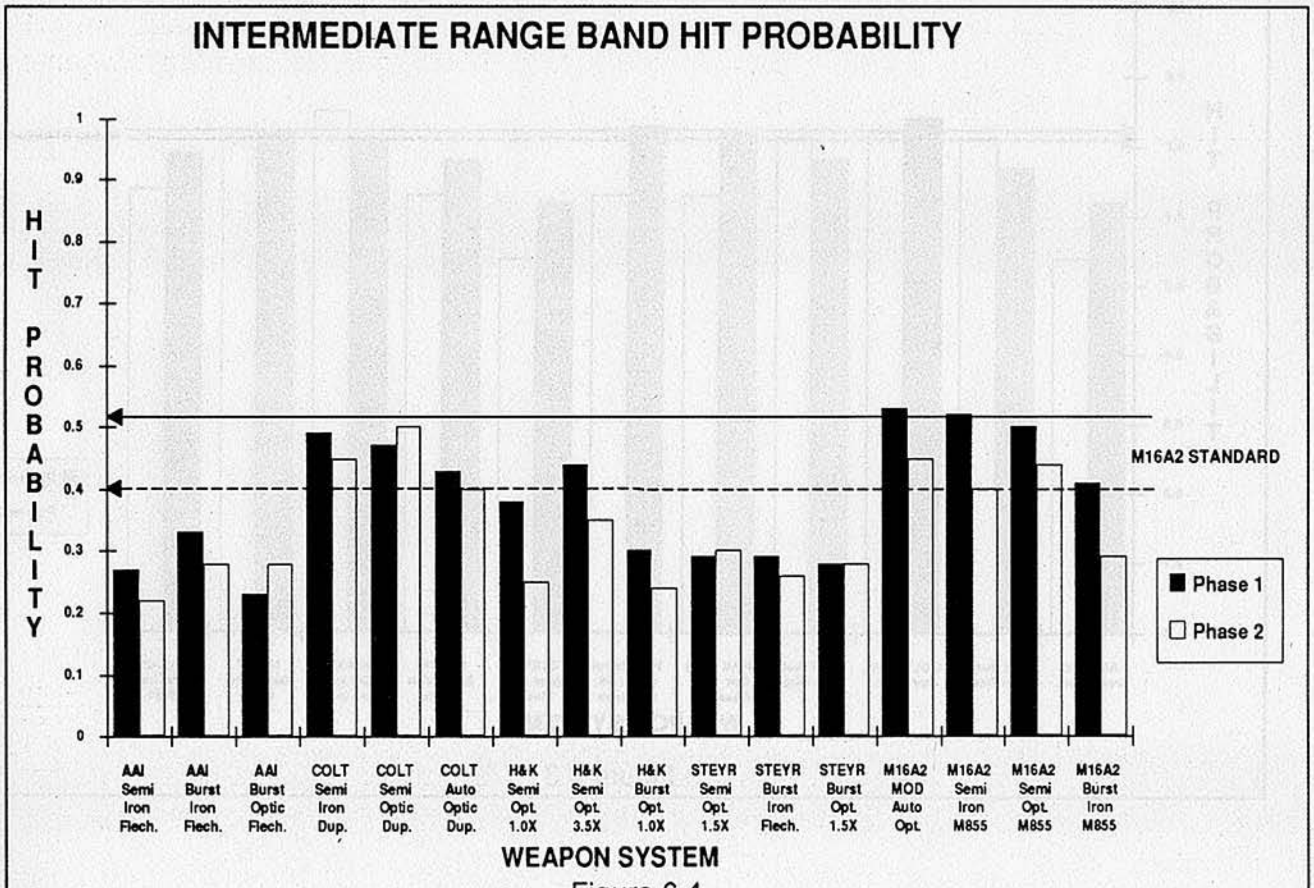


Figure 6.4

- Except for the M16A2, there were no statistically significant differences between semiautomatic and automatic fire (AAI, Colt, H&K and Steyr). Both modes of fire were equally effective. In the case of the MI6A2, semiautomatic fire is superior to three-round burst fire.

6.3.3 Long Range Band. There was a statistically significant difference among the weapon systems, at the 0.1 level, for the long range band. Thus pairwise comparisons could be made. The conclusions from these comparisons shown in Figure 6.5 are:

- The flechette weapon systems (AAI and Steyr) and the H&K were statistically worse than the standard for all firing conditions.

- The Colt firing duplex ammunition semiautomatically using the optical sight was worse than the standard.

- The Colt firing duplex ammunition semiautomatically using the optical sight was worse than the Colt firing M855 ammunition using the optical sight.

- The M16A2 firing three-round bursts using the iron sight was worse than the standard. There were no statistically significant differences between semiautomatic and three-round burst fire for the AAI, H&K and Steyr weapon systems (all using optical sights).

- There were no statistically significant differences comparing the Colt firing M855 ammunition semiautomatically using the optical sight, modified M16A2 firing duplex ammunition semiautomatically using the optical sight, and the M16A2 firing M855 ammunition semiautomatically using the optical sight when compared to the standard.

LONG RANGE BAND HIT PROBABILITY

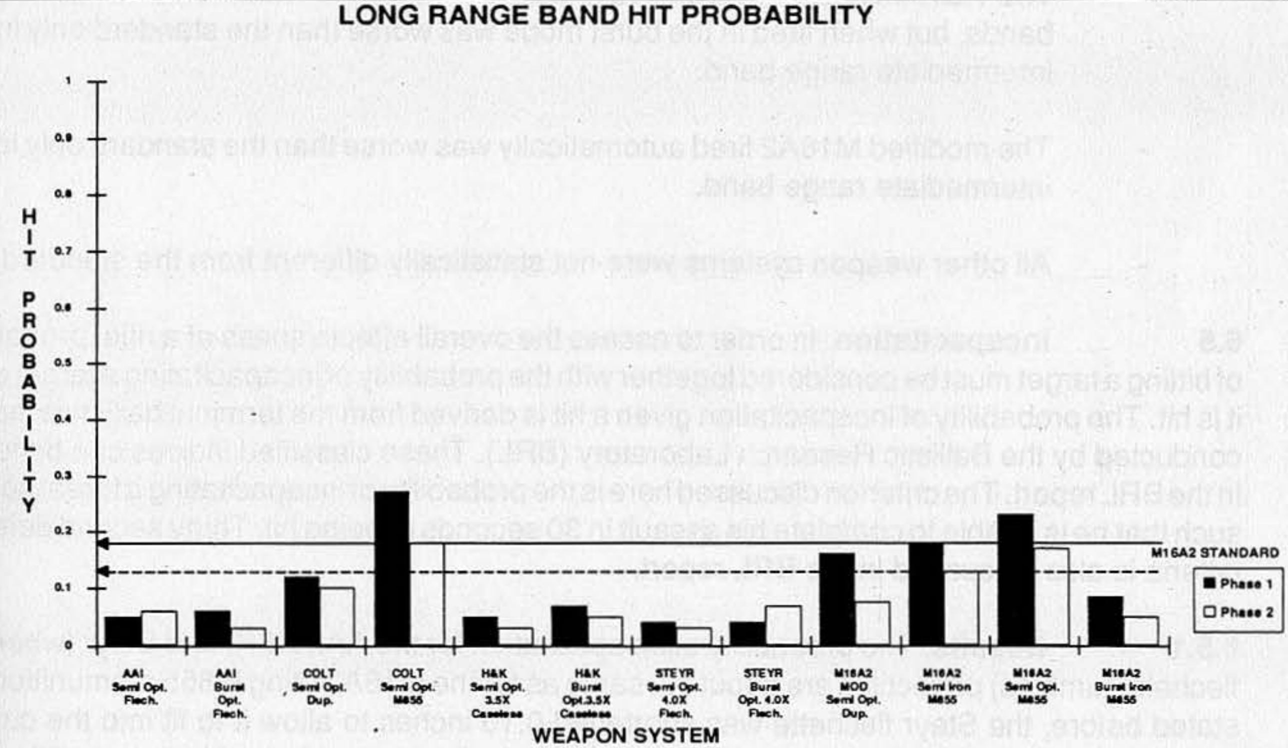


Figure 6.5

6.4 Female Gunners Phase III. The test plan for phase III was the same used in phase I and II except for the following.

- Ten gunners used (five Army, five Air Force).
- Only short and intermediate range bands used.
- No moving targets used.
- Only iron sights used (except for H&K where low power optic was used).
- All firing was from a foxhole supported position.

6.4.1 Test Procedure. The test procedure for phase III was the same as for the major portion of the tests performed in phases I & II. However, phase III consisted only of two day rotations; one day for training and a second day for testing. The female firer test was a very limited test in scope and resources.

6.4.2 Record Fire. The results of the record fire tests were similar to those of the male firers where no gunners qualified with the flechette weapons. In addition, 80% of the females failed to qualify with the H&K weapon. This is most likely due to the limited training time with the weapon.

6.4.3 Hit Performance. Except for the changes noted above, the test and the resulting data were the same type as that of phases I & II. Statistical differences were seen between the weapons at both the short and intermediate range bands. The results of these comparisons are as follows:

- The flechette weapons (AAI and Steyr) were statistically worse than the standard for both the short and intermediate range bands.

- The H&K fired semiautomatically was worse then the standard at both range bands, but when fired in the burst mode was worse than the standard only in the intermediate range band.

- The modified M16A2 fired automatically was worse than the standard only in the intermediate range band.

- All other weapon systems were not statistically different from the standard.

6.5 Incapacitation. In order to assess the overall effectiveness of a rifle, probability of hitting a target must be considered together with the probability of incapacitating a target once it is hit. The probability of incapacitation given a hit is derived from the terminal ballistics testing conducted by the Ballistic Research Laboratory (BRL). These classified indices can be found in the BRL report. The criterion discussed here is the probability of incapacitating a threat soldier such that he is unable to complete his assault in 30 seconds of being hit. Thirty second defense criteria is also discussed in the BRL report.

6.5.1 Results. The probability of incapacitation for the AAI, H&K, and Steyr (when the flechette tumbles) projectiles are about the same as for the M16A2 firing M855 ammunition. As stated before, the Steyr flechette was shortened 0.10 inches to allow it to fit into the current weapon design iteration. In this shortened condition, the flechette only tumbled some of the time upon target impact. When it does not tumble, it is significantly less lethal. The full length AAI flechette did not exhibit this behavior. The Colt duplex projectile incapacitation probability is quickly degraded with increasing range. This is primarily due to the bullets' light mass and high drag resulting in less energy delivered to the target at the longer ranges.

As seen in the discussion on hit probability, no system had a higher probability of hitting the target than the M16A2 based on the MOE of targets hit per first trigger pull. However,some of the systems, particularly the Colt and the modified M16A2, firing duplex, showed more target hits per trigger pull. The probability of incapacitating a target given multiple hits is greater than for a single hit. Various assumptions can be made on the effects of multiple hits on a target. It can be assumed that the second hit is independent of the first, however the second hit can only incapacitate a portion of the target that was not hit by the previous hit. These assumptions are discussed in more detail in the AMSAA report.

The statistical analysis of probability of incapacitating the target on the first trigger pull showed that significant differences existed between weapons for all three range bands. The conclusions relative to incapaitation which could be made from the pairwise comparisons include:

- Duplex ammunition fired automatically from the Colt and modified M16A2 was better than the standard in the short range band.

- Duplex ammunition fired automatically from the modified M16A2 was better than the standard in the intermediate range band.

- The Colt using duplex ammunition with the optical sight sight was worse than the standard in the long range band.

- The H&K weapon (both semi-automatic and burst) was worse than the standard for the low power optic in the intermediate range band and the high power optic in the long range band.

- The flechette weapons (AAI and Steyr) fired semi-automatically were worse than the standard in all three range bands.

- The flechette weapons (AAI and Steyr) were worse than the standard for all weapon conditions in the long range band.

- The modified M16A2 fired automatically was worse than the standard in the long range band.

Conclusions based on point estimate values relative to incapacitation are:

- At 25 meters all weapons fired automatically/burst had higher values than the standard.

- Out through 50 meters, all weapons fired automatically/burst, except the Steyr, had higher values than the standard.

- Out through 75 meters, all weapons fired automatically/burst, except for Steyr and H&K, had equal to or higher values than the standard.

- Out through 150 meters, the Colt and the modified M16A2 firing duplex ammunition had higher values than the standard for all weapon conditions fired.

- Out through 300 meters, the modified M16A2 firing duplex ammunition had an equal to or higher value than the standard.

7.0 PROGRAM OMBUDSMAN.

7.1 Wetzel International. As stated in the background section of this report, this program was highly visible with senior Army management. The program was formulated and approved by the Under Secretary of the Army and contract direction provided by the Commander of the Army Material Command (AMC). Another directive from the Commander AMC was the hiring of an ombudsman or individual respected in the community to observe and assess the planning and conduct of the field experiment. LTG (R) Wetzel, from Wetzel International (WI), was hired for this purpose. LTG Wetzel attended most of the TIWG meetings, and witnessed the instructor training and field experiment. The following was extracted from his report:

> Wetzel International, Inc. (WI) served as an independent contractor with the mission to provide an independent evaluation of the planning and the conduct of the ACR field experiment through limited (part time) observation and involvement. The purpose of the field experiment was to compare hit performance and dispersion characteristics of six candidate systems (four ACR conncepts and two M16A2 varients) and the M16A2. In the opinion of the WI team this purpose was accomplished. Sufficient valid data was collected to address the following issues: hit performance, dispersion, training, zero retention, response times, reliability and maintainability, and human factors. ARDEC is to be commended for its test planning. Army and Air Force NCO instructions and TEXCOM Infantry Board data collectors performed admirably and were appreciated by each weapon system contractor. To appreciate the complexity of the field experiment one must understand the planning of this experiment. Unlike an ordinary experiment where all candidate systems were designed to a set of specifications providing an experiment which would then be equally applicable to each candidate, the ACR experiment had to be designed to test the characteristics of each system, yet be fair to all candidates. Each candidate had unique safety considerations, unique ammunition, unique maintenance, unique training, and even unique zero requirements. Buckner Range was designed and constructed specifically for this test. The purpose of the ACR test, in the opinion of Wetzel International, was accomplished by the field experiment.

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8.0 CONCLUSIONS.

As a technology base program, the ACR program is considered to be a success. Although the desired hit probabilities were not achieved, significant advances in the state-of-the-art in rifle technology have been made. New gun mechanisms have been designed and proven, and the feasibility for reduced combat load through the use of lightweight plastic case and caseless ammunition has been demonstrated. All rifle systems performed well in the stressed environment of the field experiment. The baseline performance of the M16A2 rifle was better than anticipated in terms of hit probability. This experiment for the first time has established a statistically valid data base on rifle performance in an operational environment. The hit performance predictions prior to this experiment were based on a conglomeration of test results collected under differing conditions, with less sophisticated instrumentation. Prior estimates of M16A2 rifle performance were shown at the beginning of this report. The new estimate of hit performance for the M16A2 is shown in Figure 8.1. This graph is a smooth curve estimate based upon the results of the ACR field experiment. This data base will be used to replace the estimates of rifle hit capability currently being used in the joint munition evaluation methodology handbook.

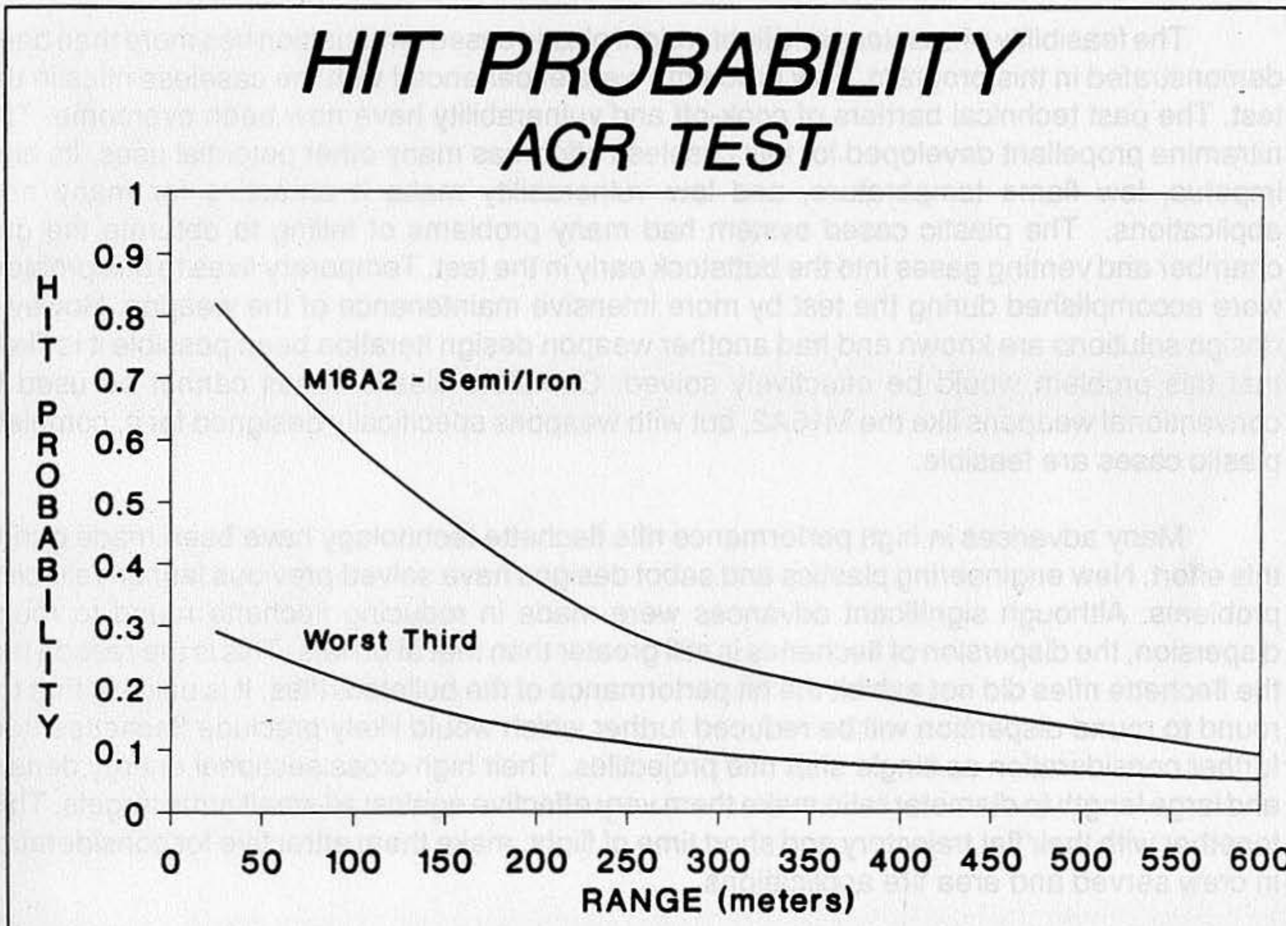

Figure 8.1

No rifles showed an increase in probability of hit over the M16A2 rifle under the stressed conditions of the test. This is primarily because the soldiers performed better than expected; meaning their aiming errors were smaller than anticipated. Therefore, the salvo burst sizes were too large to effectively increase the probability of at least one projectile hitting the target. Another contributing factor is that the burst size actually obtained from the weapons was somewhat greater than that originally requested. The aiming errors assumed from the past tests were based on calculations of targets hit over targets engaged with the data collected on less sensitive and less reliable instrumentation. The instrumentation on Buckner Range not only allowed for more accurate data to be collected in an operational setting, but for the first time allowed for aiming errors to be measured directly from the miss distance information.

The stressors used in this test to replicate aiming errors expected in combat were the task induced stressors of target behavior and movement. Additional factors of physical exercise prior to firing a scenario also helped to further stress the shooter. Peer pressure and competition was used to motivate the troops during the extended duration of the test. It is unlikely that additional stressors, short of actual combat, could have been used in this test. The aiming errors generated in this test are considered to be an accurate reflection of current weapon system performance. This data base will remain the basis against which all individual weapons will be assessed well into the future.

The feasibility of caseless and light weight plastic cased ammunition has more than been demonstrated in this program. Few problems were experienced with the caseless rifles in the test. The past technical barriers of cook-off and vulnerability have now been overcome. The nitramine propellant developed for this caseless effort has many other potential uses. Its high impetus, low flame temperature, and low vulnerability make it attractive for many new applications. The plastic cased system had many problems of failing to obturate the gun chamber and venting gases into the buttstock early in the test. Temporary fixes to this problem were accomplished during the test by more intensive maintenance of the weapon. However design solutions are known and had another weapon design iteration been possible it is likely that this problem would be effectively solved. Complete plastic cases cannot be used in conventional weapons like the M16A2, but with weapons specifically designed for it, complete plastic cases are feasible.

Many advances in high performance rifle flechette technology have been made during this effort. New engineering plastics and sabot designs have solved previous launch reliability problems. Although significant advances were made in reducing flechette round to round dispersion, the dispersion of flechettes is still greater than that of bullets. This is the reason that the flechette rifles did not exhibit the hit performance of the bulleted rifles. It is unlikely that the round to round dispersion will be reduced further which would likely preclude flechettes from further consideration as single shot rifle projectiles. Their high cross sectional energy density and large length to diameter ratio make them very effective against all small arms targets. This, together with their flat trajectory and short time of flight, make them attractive for consideration in crew served and area fire applications.

Salvo rifles can be effective in increasing hit probability under conditions of large aiming errors. However, with the size of the aiming errors experienced in this test, a significantly smaller burst size would be required than those produced by the rifles in this program. It is unlikely that sufficiently small burst sizes could be obtained and controlled to effectively improve performance with the aiming errors now known to exist.

The instrumentation of Buckner Range at Ft. Benning has resulted in a one-of-a-kind capability. This facility is not only unique because of its operational setting, and state-of-the-art computer control, but also because of the advances made in its instrumentation. The miss distance instrumentation (MDI) developed for this range is more accurate than any other currently available, with larger detection window sizes. The equipment is also more sensitive to be able to measure low shock wave projectiles like flechettes. It is also the only known range to incorporate this same MDI equipment on moving targets. The successful instrumentation of Buckner Range is an additional technical accomplishment of this program.

The technology gains made under this program have opened the possibility of utilizing new weapon concepts to meet future needs and requirements. These technology gains as well as the development of a statistically sound data base have significantly advanced the state-of-the-art in rifle and individual weapon technology which was the primary goal of this effort.

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9.0 ACR REFERENCE REPORTS.

The following is a list of other important reports relating to the ACR program. These reports have already been published and are available through the Defense Technical Information Center (DTIC) or through the appropriate publishing organization.

"Technical Feasibility Test of Advanced Combat Rifle Candidates - Final Report," CSTA Report No. USACSTA 7103, TECOM Project No. 2-WE-600-ACR-001, Light Weapons Systems Division, Armament Systems Directorate, Combat Systems Test Activity (CSTA), Aberdeen Proving Ground, MD 21005-5055, 1992.

"P(I/H) Estimates for the Advanced Combat Rifle Ammunition Candidates (U)," Integrated Battlefield Assessment Branch, U.S. Army Ballistic Research Laboratory (BRL), Aberdeen Proving Ground, MD 21005-5066, March 1992, CONFIDENTIAL.

"Customer Test of Advanced Combat Rifle (ACR) - Test Design Plan," TRADOC Project No. 89-0000752, USAIB Project No. 3837, Small Arms Test Division, United States Army Infantry Board (USAIB), Fort Benning, Georgia 31905-5800, June 1989.

"Effects of Competition and Mode of Fire on Physiological Responses, Psychological Stress Reactions, and Shooting Performance," U.S. Army Human Engineering Laboratory (HEL), Aberdeen Proving Ground, MD 21005-5001, July 1991.

"Customer Test of Advanced Combat Rifle (ACR) - Final Report," TRADOC Project No. 89-0000752, USAIB Project No. 3837, Small Arms Test Division, United States Army Infantry Board (USAIB), Fort Benning, Georgia 31905-5800, November 1990.

"Independent Evaluation Report No. 5-91 of the Advanced Combat Rifle (U)," Infantry Warfare Analysis Branch, U.S. Army Material Systems Analysis Activity (AMSAA), Aberdeen Proving Ground, MD 21005-5071, August 1991, CONFIDENTIAL.

"5.56mm Flechette Component and Cartridge Producibility", Report No. ARCCD-CR-9103, Advanced Development Engineering Center (ADEC) Automation, Folcroft, PA 19032, March 1991.

"Small Arms Technology Assessment, Individual Infantryman's Weapon, Volume I: Rifles, Volume I: Appendices, Volume II: Grenade Launchers (U)," U.S. Army Laboratory Command (LABCOM), Adelphi, MD 20783-1145, March 1990, CONFIDENTIAL.

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APPENDIX A

ACR OPERATIONAL AND ORGANIZATIONAL (O&O) PLAN

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APPENDIX A

1.0 ACR OPERATIONAL AND ORGANIZATIONAL (O&O) PLAN.

1.1 Purpose. The purpose of the O&O Plan is to explain and document in detail the soldiers need for an Advanced Combat Rifle (ACR) which would be the focal point for a family of advanced small arms systems. The overall goal of the ACR program would be to enhance the individual soldiers battlefield effectiveness. By definition, an O&O Plan describes how a system will be used on the battlefield, its interface with other systems, and the type and number of systems per unit. Inasmuch as an Operational Requirements Document has not been prepared for the ACR, the ACR program and development contracts have been governed by the technical characteristics outlined in the O&O Plan.

1.2 History. The need for a new family of small arms with higher hit probabilities was identified in the 1984 TRADOC Battlefield Development Plan (BDP), and through analysis which indicated that hit probabilities are severely degraded by soldiers during periods of combat stress. The O&O Plan for the ACR was approved by TRADOC in January of 1985.

TRADOC's goal was the development of an ACR with a 100 percent improvement over the baseline performance of the M16A2 rifle at combat ranges, and greater than 100 percent improvement at extended ranges. Additional required features include:

1. Enabling the rifleman to detect targets at ranges greater than 400 meters in offensive action and at least 1,000 meters during conduct of the defense.
2. An ACR fire control system that would maintain its effectiveness under all battlefield conditions.
3. An improved launch signature that would improve passive security and thus reduce stress.
4. Training and logistical commonality with additional small arms systems.

The ACR will serve as the baseline system for a new generation of small arms which may include:

(1.) Advanced Close Support Weapon (ACSW) - The ACSW would replace the current light support weapons (M60 machine gun and M249 squad automatic weapon). Key design features would include high sustained rates of fire without barrel changes, high single shot hit probability for long range point target engagements, common module design with the ACR to ease logistical burdens, light weight and capable of preset precision aiming without an additional stable platform such as a tripod.

(2) Advanced Grenade System (AGS) - The AGS would replace the current M203 40mm grenade launcher. Key design features include the capability of being mounted on the ACR, provide greater lethality and hit probability against light armor threats, improved antipersonnel lethality, and the ability to cover dead space. Addition desired features include the development of smaller, lighter, and more lethal ammunition which would increase rates of fire and improve accuracy over current launch mechanisms.

1.3 Organizational Plan. It is envisioned that the ACR would be deployed throughout the U.S. Army with the entire family of advanced weapons being utilized primarily by combat forces. The Basis of Issue Plan (BOIP) for the weapon systems would be based on a one-for-one replacement of similar type weapons currently being used.

1.4 Additional Considerations.

Personnel - The introduction of the ACR would not increase manpower in the force structure, and would not generate any new MOS for employment or maintenance.

Training - Initial training resources and associated hardware will be established to train operators and maintenance personnel for support and operation of the equipment into the inventory. It is envisioned that high technology stress simulation devices/simulators will be developed to support innovative marksmanship training techniques.

Logistics - The maintenance concept for the system would be consistent with current support organizations, concept of operations, and repair level policies. Maximum utilization will be made of existing TO&E tools, TMDE, and other support equipment. The LSA/LSAP process would be used to determine and define support transportability requirements and personnel tasks and skills for the operation, maintenance and support of the system.

1.5 Annexes. The ACR O&O Plan includes an annex entitled, "Advanced Combat Rifle (ACR) Operational Mode Summary/Mission Profile (OMS / MP)." This annex summarizes through the use of tables, the wartime and peacetime operational mode summaries and mission profiles. The approved ACR O&O Plan is included in this appendix.

2 9 JAN 1985

DEPARTMENT OF THE ARMY
HEADQUARTERS UNITED STATES ARMY TRAINING AND DOCTRINE COMMAND
FORT MONROE, VIRGINIA 23651

REPLY TO
ATTENTION OF:

ATCD-ML

SUBJECT: Operational and Organization Plan (O&O Plan) for the Advanced Combat Rifle

Commander
US Army Infantry Center
ATTN: ATSH-CD
Fort Benning, GA 31905

1. Subject O&O Plan (Encl 1) has been approved by the TRADOC Commander and is forwarded for publication and distribution.

2. The point of contact at this headquarters is CPT Mills, AUTOVON 680-4415.

1 Encl
as

CARL H. McNAIR, JR.
Major General, GS
Deputy Chief of Staff
for Combat Developments

CF:

HQDA (DAMO-FDD/DAMA-WSM)
COMMANDER
AMC (AMCDE-SG)
USACAC (ATZL-CAI-I)
ARDC (AMSMC-CO(D))

OPERATIONAL AND ORGANIZATIONAL (O&O) PLAN
FOR THE
ADVANCED COMBAT RIFLE (ACR)

I. PURPOSE. A need exists for an Advanced Combat Rifle (ACR) which will significantly enhance the individual soldier's battlefield effectiveness. It is anticipated that the ACR will serve as the baseline system for a new generation of small arms.

A. DEFICIENCIES: The TRADOC Battlefield Development Plan (BDP) 1984, identifies Inadequate Small Arms Capability as deficiency number 90. Driving factors behind this deficiency are as follows:

1. M16A1 lacks effectiveness at extended range and ruggedness.

2. Manportable small arms are degraded by obscurants.

3. Weapons and ammunition are excessively heavy.

4. Sniper rifles problems render them incompatible with TO&E combat units (See Close Combat Mission Area Analysis (CCMAA), Dec 83, Vol IV, App C for complete analysis).

5. Platoon small arms ammunition is not interchangeable.

B. The need for an improved rifle was derived from a detailed analysis of current small arms available to the combat rifleman and those in advanced development. This review considered the man/machine interface, and integrated support requirements associated with the following small arms systems:

M16A1 Rifle
M16A2 Rifle
Enhanced M16A2 Rifle
XM4 Carbine
Firing Port Weapon
Squad Automatic Weapon
M60 Machine Gun
M203 Grenade Launcher
M3 Submachine Gun
.45 Caliber Pistol
9mm Personal Defense Weapon
M21 Sniper Rifle

C. While the above systems offer excellent gun accuracy, historical and interaction analysis over a period of 25 years has indicated that a common problem with all small arms systems is the degradation in hit probabilities which soldiers experience when placed in an operational environment which exposes them to combat stress. The amount of combat stress which a soldier experiences is highly dependent on individual differences and the specific employment scenario. While the stress factor cannot be quantified, it nevertheless is manifested by gunner aiming error. Best estimates of aiming error induced by stress range from 8-10 mils at very close combat ranges of 0-100 meters, 2-3 mils at combat ranges of 300-400 meters, and a low of 1-2 mils at extended ranges from 500-1000 meters. The technical challenge in the design of a new combat rifle is to compensate for or reduce the large aiming errors associated with the man/machine system under battlefield conditions, and thus significantly improve combat effectiveness.

D. Current systems and those in development are based on adaptations of commercially available small arms. Each system requires unique training and logistical support. There is little interchangeability of parts and marksmanship skills are not readily transferred from one system to another. Numerous different types of ammunition are required within a single combat unit. All current small arms were designed for day use only, without regard to the combat soldier's operational requirements to conduct continuous operations. Current night vision aids are heavy, provide limited capabilities, and do not provide satisfactory interface with the small arms system they are designed to assist.

E. An advanced individual weapon system is needed to provide significantly greater combat effectiveness under stressed conditions. It must alleviate current deficiencies, maintain effectiveness under all environmental and visibility conditions, and greatly reduce the training and logistical burdens of combat units. The system must be operable by the individual soldier in an NBC environment while wearing the full range of protective garments to include MOPP4 and ballistic eye protection.

II. THREAT/DEFICIENCY.

A. Combat riflemen could be employed throughout the world in any level of conflict. Threat forces can be expected to range from the most sophisticated and highly trained military and paramilitary elements of the USSR and Warsaw Pact, to relatively untrained and ill-equipped insurgency forces. Soviet doctrine emphasizes high speed, continuous mechanized operations. Continuing improvements in weapons systems, electronic warfare, and chemical, biological, and nuclear systems, can be expected to enhance the combat capabilities of the threat. Soviet research with respect to Directed Energy Warfare will directly affect the combat rifle system. The development of an advanced individual weapon must incorporate appropriate countermeasures to protect against this emerging threat. The primary threat to the combat rifle system will be the indirect fragmentation from artillery, combat vehicles, and missile systems. At close combat ranges (within 1000 meters) the direct fire threat from small arms will commence and amplify as ranges close between combatants.

B. While the likelihood of employment is considerably higher for the low intensity conflict spectrum, high intensity conflict presents the greatest overall threat. Our combat units must be prepared to engage in any type of conflict anywhere in the world at short notice. Insufficient resources and training and logistical constraints, preclude the optimization of a small arms system for any specific employment scenario. The deficiencies listed in paragraph I A jeopardize the success of our forces in all scenarios. An advanced combat rifle will provide each combat soldier with a weapon system which will greatly enhance his individual contribution to overall force effectiveness under the stressed conditions inherent in any close combat scenario. The performance goal of the system is to achieve 100 percent improvement in effectiveness over the current combat rifle primarily through increased hit probabilities under battlefield conditions.

III. OPERATIONAL PLAN.

A. Emerging doctrinal concepts require that combat soldiers possess the capability to fight continuously, in all types of terrain, climate, and warfare situations. Technological advances will provide the force with an enhanced ability to acquire long range targets and significantly greater effectiveness of major weapons at long range. Increased emphasis will be placed on the logistical constraints associated with small unit independent operations. At close combat ranges (within 1000 meters), the combat soldier's primary weapon will continue to be the individual small arms system with which he is equipped. The new family of small arms should contain as many multipurpose weapons as possible to reduce the overall inventory of small arms.

B. Advanced Combat Rifle (ACR). The ACR will be the initial development within the small arms family. It will be the primary weapon for the individual soldier. Primary target will be the individual threat soldier protected by body armor at ranges out to 600 meters. It must offer enhancement in hit probability of at least 100 percent at combat ranges over the baseline performance of the M16A2 rifle when measured under realistic battlefield conditions. At extended ranges, the improvement required will be considerably greater than 100 percent. The weapon will be expected to enable the rifleman to detect targets at ranges greater than 400 meters in offensive action and at least 1000 meters during conduct of the defense. Acquisition and engagement of the target is expected to occur at 400 meters during offense and 600 meters during defense. The ACR fire control system must maintain its effectiveness under all battlefield conditions. The launch signature of this system should be minimized to improve passive security and thus reduce stress. An Operational Mode Summary/Mission Profile for the ACR is attached at Annex A.

C. The design of the ACR must consider future Army requirements for additional small arms systems to insure training and logistical commonality. Other components of an overall small arms family, currently being considered in the tech base may include:

1. Advanced Close Support Weapon (ACSW). The ACSW should be capable of engaging area targets with high sustained rates of fire without barrel changes. The ACSW should have a very high single shot hit probability for long range engagement against point targets. The ACSW should be a common module design with the ACR to ease logistical burdens. The weapon's terminal effects must be derived from the same consumable product which is utilized in the ACR. An additional kill mechanism is desired which would improve penetration of such targets as building walls, bunkers, and light armor. The system should be capable of preset precision aiming without the necessity of an additional stable platform such as a tripod. The overall weight of the system to include ammunition load must be considerably less than the current light support weapons (M60 machinegun and Squad Automatic Weapon) which it will replace.

2. Advanced Personal Defense Weapon (APDW). An additional APDW configuration of the ACR may be required for combat soldiers whose primary mission is as a vehicle crewman, crew served gunner, or unit leader. The APDW must be compact and lightweight so as not to interfere with the soldier's primary duties. The configuration must be optimized to permit rapid engagements at close ranges (within 200 meters) with wide dispersion patterns to compensate for the large aiming errors inherent in such high stress scenarios. The APDW is envisioned as a replacement for carbines, submachineguns, firing port weapons, and pistols in combat units. The requirement for the APDW will be refined based on the prototype design of the ACR.

3. Advanced Grenade System (AGS). The AGS may be required for employment in the role currently filled by the M203. It should be capable of being mounted on the ACR. It should provide greater lethality and greatly enhanced hit probability against light armor threats at ranges in excess of the Soviet manportable light antitank weapon (currently RPG 16). It must also possess improved antipersonnel lethality and the ability to cover dead space more accurately than the M203 grenade launcher. Prime consideration should be to the development of smaller, lighter, and more lethal ammunition which can be employed from a lightweight weapon system with increased rates of fire and improved accuracy over current launch mechanisms.

IV. ORGANIZATIONAL PLAN.

A. The Advanced Combat Rifle will be deployed throughout the US Army. The entire family of small arms will be utilized by combat forces in the forward areas while selected types of weapons will be used in service support units. Allocation of the entire family is envisioned to such units as:

1. Infantry.

2. Armor/Cavalry.

3. Cannon Artillery.

4. Special Operations Forces.

5. Combat Engineers.

6. Air Defense.

7. Military Police.

8. Forward Support Elements.

B. The BOIP for the weapons systems will be based on a one-for-one replacement of similar type weapons currently being used or under development.

V. PERSONNEL IMPACT. The introduction of the Advanced Combat Rifle will not increase manpower in the force structure, and will not generate any new MOS for employment or maintenance of the weapons. The possibility exists that personnel requirements could decrease in logistics/maintenance units through enhanced RAM-D characteristics and use of common module design. There will be no special personnel skills required for the operation of the system. Soldiers of combat, combat support, and combat service support (of all grades) will be able to effectively fire and maintain their weapon system after appropriate training.

VI. TRAINING CONCEPT.

A. The materiel developer, in conjunction with the TRADOC proponent, will be responsible for training development efforts for the weapons systems. Initial training sources and associated hardware requirements will be established to train operators and maintenance personnel for support of operational test and evaluation and introduction of the equipment into the operational inventory. All training devices required to support the weapons will be developed by the materiel developer. It is envisioned that high technology stress simulation devices/simulators will be developed to support innovative marksmanship training techniques. Appropriate DA technical manuals will be provided by the materiel developer.

B. All training products developed as part of this system's training subsystem will be designed/developed IAW TRADOC Reg 350-7, A Systems Approach to Training.

C. USAIS will conduct a complete review of Army rifle marksmanship training at the training base and unit level. The purpose of this study will be to improve combat performance of the rifleman through innovative training techniques. This study will consider the impact of all systems. Results will be used as the basis for changes to current programs of instruction and modifications to existing range facilities to support both institutional and unit training need.

VII. LOGISTICAL IMPACT. The maintenance concept for the system will be consistent with current support organization, concept of operation and repair level policies. Maximum utilization will be made of existing TO&E tools, TMDE, and other support equipment and/or presently approved emerging TMDE or support equipment to minimize proliferation. Specific examples of materiel that must be developed in conjunction with each system are: (1) blank firing attachments; (2) ammunition pouches/bandoleers; (3) special tools; (4) storage racks (designed and available at fielding); and (5) need for laser eye protection for individual soldiers. The LSA/LSAP process will be used to determine and define support transportability requirements and personnel tasks and skills for the operation, maintenance and support of the system. The final system support package will be tested in conjunction with the user Operational Test II.

VIII. FUNDING*.

ADVANCED COMBAT RIFLE
(Dollars in Millions)

	85	86	87	88	89	90	91	92	93	94	95	96	TOTAL
RDTE	5.1	12.1	10.7	5.3	4.6	3.9	1.3	1.3	1.1	.4	.4	.4	46.6
MMT	.3	6.0	9.2	6.3	1.5	1.0	.7	--	--	--	--	--	25.0
OMNIBUS	2.9	7.0	9.0	3.1	1.0	--	--	--	--	--	--	--	23.0
FACILITY				25.0	114.0	6.0							145.0
PROVE-OUT							20.0	30.0					50.0

UNIT COST (FY85 CONSTANT DOLLARS): 750.
TOTAL PROCUREMENT (FORCE PACKAGE II) 1122.4M

* Funding profiles for the ACSW, APDW, and AGS cannot be developed until concepts are more clearly defined. The O&O plan will be revised to include this information at the earliest practical time.

ANNEX A

ADVANCED COMBAT RIFLE (ACR)

OPERATIONAL MODE SUMMARY/MISSION PROFILE (OMS/MP)

1. Wartime.

a. Operational Mode Summary (OMS). The Advanced Combat Rifle (ACR) will be the primary weapon for the individual soldier. The ACR will have operational application for world-wide geographic areas. The weapon is expected to enable the rifleman to detect targets at ranges greater than 400 meters in offensive actions and at least 1000 meters during conduct of the defense. Acquisition and engagement of targets is expected to occur at 400 meters during offense and 600 meters (suppression) during defense. The wartime OMS is shown in Table 1-1. Each of the figures indicated in the Op-Mode Summary (offense and defense) is derived from the mission profile, the O&O for the weapon system, and military experience. The format for the Op-Mode summaries is taken directly from the RAM Rationale Report Handbook, 1 October 1984. NOTE: The Alert Time is that time from notification to actual mission start time.

Table 1-1. Wartime ACR OMS.

MISSION	(a) OT	(b) OT+AT	(c) CT	(d) PERCENT MISSIONS	(a)x(d)=(e) AVERAGE OT	(b)x(d)=(f) AVERAGE OT+AT	(c)x(d)=(g) AVERAGE CT
Offense	16.25	19.00	20.00	57.5%	9.343	10.925	11.500
Defense	7.17	7.97	9.00	42.5%	3.048	3.388	3.825
TOTAL	not required			100%	12.391	14.313	15.325

OT - operating time (hours)
AT - alert time (hours)
CT - calendar time (hours)

b. Mission Profile (MP). The engagement tasks in each of the mission areas are shown in Tables 1-2 and 1-3. The wartime missions for the ACR, Offense and Defense, each consist of six mission tasks. The life unit is one hour and the duration of time considered is 24 hours. The numbers of occurrences are derived from the O&O and practical military experience. It is important to note that both the "operating time per task" and "total operating time" are in seconds.

Table 1-2. ACR Offensive MP.

OFFENSE TASKS	NUMBER OF OCCURRENCES	OPERATING TIME FOR EACH TASK	TOTAL OPERATING TIME
Search/Surveillance	2	28800 (sec)	57600.00 (sec)
Target Detection	50	1 (sec)	50.00 (sec)
Target Acquisition	25	3 (sec)	75.00 (sec)
Identify	25	5 (sec)	125.00 (sec)
Fire/Burst	200	3 (sec)	600.00 (sec)
Fire/Semi	50	1 (sec)	50.00 (sec)
TOTAL	XX	XX	16.25 (hrs)

Table 1-3. ACR Defensive MP.

DEFENSE TASKS	NUMBER OF OCCURRENCES	OPERATING TIME FOR EACH TASK	TOTAL OPERATING TIME
Search/Surveillance	3	7200 (sec)	21600.00 (sec)
Target Detection	400	1 (sec)	400.00 (sec)
Target Acquisition	350	2 (sec)	700.00 (sec)
Identify	350	4 (sec)	1400.00 (sec)
Fire/Burst	150	3 (sec)	450.00 (sec)
Fire/Semi	300	1 (sec)	300.00 (sec)
TOTAL	XX	XX	7.17 (hrs)

2. Peacetime.

a. Operational Mode Summary (OMS). The peacetime missions of the ACR are shown in Table 2-1. As indicated, the peacetime missions are training missions.

Table 2-1. ACR Peacetime OMS.

MISSION	(a) OT	(b) OT+AT	(c) CT	(d) PERCENT MISSIONS	(a)x(d)=(e) AVERAGE OT	(b)x(d)=(f) AVERAGE OT+AT	(c)x(d)=(g) AVERAGE CT
Quali-fication	12.00	14.00	20.00	08%	0.960	1.200	1.600
FTX	120.00	216.00	230.00	45%	54.000	97.200	103.500
ARTEP	120.00	216.00	230.00	45%	54.000	97.200	103.500
CALFEX	3.00	4.00	10.00	02%	0.060	0.080	0.200
TOTAL	not required			100%	109.020	195.680	208.800

OT - operating time (hours)
AT - alert time (hours)
CT - calendar time (hours)

b. Mission Profile. The tasks to support the training missions are shown in Tables 2-2, 2-3, 2-4, and 2-5.

Table 2-2. ACR Qualification Mission Profile.

TASKS	NUMBER OF OCCURRENCES	OPERATING TIME FOR EACH TASK	TOTAL OPERATING TIME
Field/Fire	2	3600 (sec)	7200.00 (sec)
Record/Fire	2	3600 (sec)	7200.00 (sec)
Night/Fire	2	3600 (sec)	7200.00 (sec)
Auto/Fire	2	3600 (sec)	7200.00 (sec)
Night/Sight	2	3600 (sec)	7200.00 (sec)
Prep/Marksmanship	2	3600 (sec)	7200.00 (sec)
TOTAL	XX	XX	12.00 (hrs)

Table 2-3. ACR Field Training Exercise Mission Profile.

TASKS	NUMBER OF OCCURRENCES	OPERATING TIME FOR EACH TASK	TOTAL OPERATING TIME
Movement to Contact	3	43200 (sec)	129600.00 (sec)
Defend	3	28800 (sec)	86400.00 (sec)
Attack	3	28800 (sec)	86400.00 (sec)
Hasty/Attack	3	14400 (sec)	43200.00 (sec)
Night/Attack	3	28800 (sec)	86400.00 (sec)
TOTAL	XX	XX	120.00 (hrs)

Table 2-4. ACR Army Training and Evaluation Program Mission Profile.

TASKS	NUMBER OF OCCURRENCES	OPERATING TIME FOR EACH TASK	TOTAL OPERATING TIME
Movement to Contact	3	43200 (sec)	129600.00 (sec)
Defend	3	28800 (sec)	86400.00 (sec)
Attack	3	28800 (sec)	86400.00 (sec)
Hasty/Attack	3	14400 (sec)	43200.00 (sec)
Night/Attack	3	28800 (sec)	86400.00 (sec)
TOTAL	XX	XX	120.00 (hrs)

Table 2-5. ACR Combined Arms Live Firing Exercise Mission Profile.

TASKS	NUMBER OF OCCURRENCES	OPERATING TIME FOR EACH TASK	TOTAL OPERATING TIME
Provide Overwatch	1	3600 (sec)	3600.00 (sec)
Engage/Target	1	3600 (sec)	3600.00 (sec)
Search/Surveillance	1	3600 (sec)	3600.00 (sec)
TOTAL	XX	XX	3.00 (hrs)

3. Environmental Conditions. The environmental conditions for both wartime and peacetime are listed in Table 3-1. These indicate that the majority of the forces will be stationed in a basic environment and will travel cross-country the majority of the time.

Table 3-1. ACR Environment for Both Wartime and Peacetime Conditions.

CLIMATIC DESIGN TYPES (AR 70-38)	% FORCE
Hot	20
Basic	60
Cold	15
Severe	5

MOVEMENT TERRAIN
10% Primary Road
35% Secondary Road
55% Cross-Country

APPENDIX B

ACR CONTRACTOR ACTIVITY SYNOPSIS

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APPENDIX B

1.0 ACR CONTRACTOR ACTIVITY SYNOPSIS.

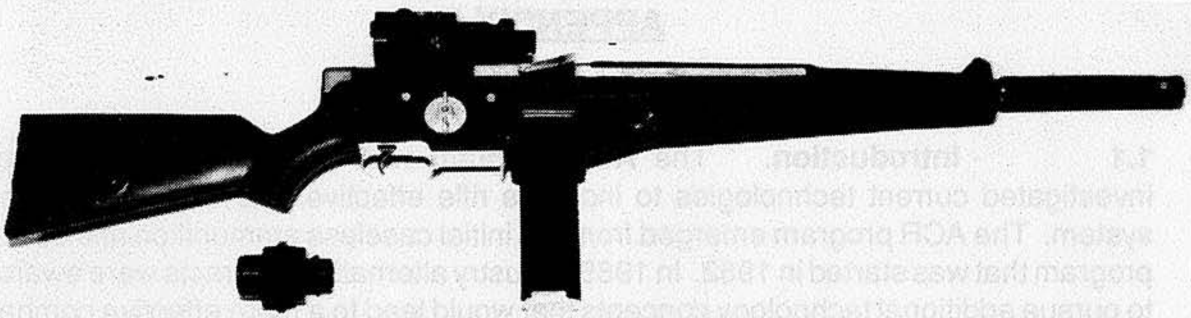
1.1 Introduction. The ACR program was a technology base program that investigated current technologies to increase rifle effectiveness over the current M16 rifle system. The ACR program emerged from the initial caseless ammunition rifle system (CARS) program that was started in 1982. In 1985, industry alternative contracts were awarded in order to pursue additional technology concepts that would lead to a more effective combat rifle. This appendix to Volume I of the ACR Final Report gives detailed information and highlights key aspects of each of the contracts involved in the ACR program. The ACR operator and maintenance weapon manuals are contained in Volume III of this report, while the contractors' final scientific reports are located in Volume VII.

1.2 Caseless Efforts. There were two original awards for the development of a caseless weapon system made prior to the Advanced Combat Rifle Program's elevation to program status. These contracts were awarded to the AAI Corporation of Hunt Valley, MD, as well as Heckler and Koch (H&K) Inc., located in Sterling, VA. The purpose of both contracts was to develop demonstrator hardware incorporating caseless ammunition, an optic sight, and the salvo weapon concept. A key to the effort was to develop a solution to the two traditional and historically encountered technological barriers of a caseless gun system; cook-off and round vulnerability to an incoming projectile.

1.2.1 AAI: Caseless Weapon Contract #DAAK10-82-C-0331.

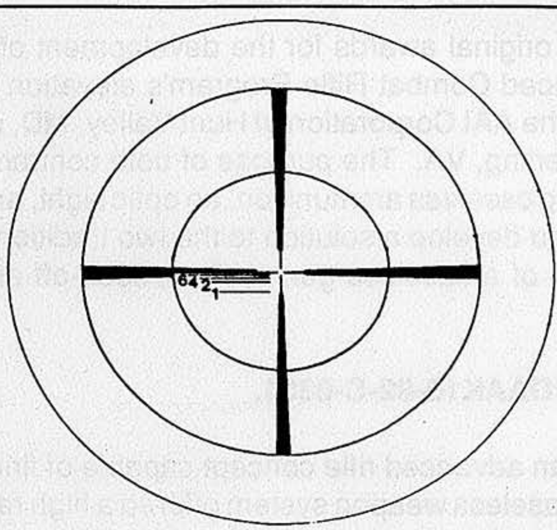
1.2.1.1 Background. AAI was developing an advanced rifle concept capable of firing molded propellant caseless ammunition. The AAI caseless weapon system offered a high rate burst capability along with improved fire control through the use of an advanced reflex sight with a detachable three power scope. The AAI contractual development effort was terminated because of AAI's inability to fabricate a round of ammunition which would withstand gun feeding forces. Under the other caseless contract, H&K worked with Dynamit Nobel, AG (DNAG) of Nuremberg, West Germany to successfully develop a caseless ammunition propellant that solved these problems. However, this information could not be divulged to AAI because it was protected under license agreement. An in-house effort to investigate the combination of the AAI weapon concept with the H&K/DNAG propellant was cancelled due to lack of funds.

1.2.1.2 Weapon. The firing mechanism of the AAI caseless weapon (see Figure B1) utilized a reciprocating bolt actuated by a direct propellant gas driven firing pin/bolt carrier. The mechanism was housed in a full length stock configuration, but could have also been modified into a compact bullpup configuration with no sacrifice in performance. The weapon contained a modular trigger mechanism that provided the user with three selectable modes of fire: semi-automatic from a closed bolt, high cyclic three round salvo burst (1600-1800 rpm), or full automatic (700 rpm) from an open bolt. A muzzle break provided compensation to minimize muzzle climb during burst and automatic fire. This rifle used a single power (1X) optic sight (see Figure B2) along with a three power (3X) detachable telescope for special purpose or long range engagements and incorporated a back-up iron sight. Windage and elevation adjustment knobs were also incorporated into the optic.



AAI CASELESS WEAPON

Figure B1



AAI (Caseless) RETICLE PATTERN

Figure B2

The mechanism was firing pin driven in that pressure from the burning propellant caused the firing pin to slide rearward. After about an inch of travel, the firing pin unlocks (rotates) the bolt and draws it rearward to the buffer. The bolt recoils from the buffer, strips the next round, is locked by the firing pin, which then ignites the round to begin the cycle again. The bolt and firing pin seals were of the same basic design; rings of triangular cross-section placed point up - point down - point up. Under gun pressures, these rings sealed to both the bolt outer diameter and the housing around the bolt. For the firing pin, the seal was between the bolt central firing pin hole on the bolt inner diameter and the firing pin itself. Even though there were not a great number of rounds fired using this arrangement of seals, this design had survived, intact, far longer than their predecessor designs and held the promise of being good enough for a weapon. The weapon was otherwise conventional.

AAI had conducted computer modelling of the firing of caseless rounds which showed that the normally expected point of cook-off initiation was from the bolt face. Restated, the bolt face got hotter faster than any other part in contact with the round. The solution was to put a strip of copper along the length of the bolt to lead heat away and place a refractory metal on the bolt face to retard erosion. Next, the chamber was wrapped within an aluminum block to act as a heat sink for the chamber. This proved to be effective in concert with the improved bolt and firing pin seals. The operating principle was heat transfer from the burning propellant body to the chamber wall; through the chamber wall into the aluminum block; with discontinued firing after there was no longer sufficient heat transfer driving force between chamber and heat sink. The hope was that this condition would occur only after sufficient rounds had been fired to represent a complete mission for an infantryman.

1.2.1.3 Ammunition. The ammunition shape was that of a right circular cylinder with the projectile protruding from one end and the primer inserted in the other. The projectiles were totally conventional in which the round could accommodate almost any bullet. AAI was developing a dual cartridge concept for the ACR caseless ammunition system. A single 28 grain 4.32mm subcaliber saboted projectile round was developed for low impulse controlled burst fire, while a heavy 70 grain steel tipped 5.56mm round would be used for long range penetration. The round body was comprised of compressed standard nitrocellulose propellant with an acetone/collodion binder. The idea was sound, but the reduction to practice was faulty. AAI had subcontracted the fabrication of test rounds to Hercules, Inc., Kenvil, NJ. As industry had not been involved with such fabrication methods for many years, the expertise to do so had been lost. Hercules simply could not supply AAI with rounds strong enough to withstand gun feeding forces at the high cyclic rates required for this salvo weapon; therefore, all extended testing was hampered by stoppages. Since this weapon was designed with no broken round extraction mechanism, the number and quality of tests was minimal. The concept was and is feasible; only lack of money prevented its further development.

There were numerous firing tests conducted with the faulty ammunition. Unfortunately, there was never an opportunity to actually obtain an accurate cook-off level because a broken round would create a weapon stoppage, destroying the cook-off test. There were, however, a number of partial test results developed. On multiple occasions, 45 to 55 rounds were fired and no cook-off of the next chambered round occurred. The best result, obtained only once, was 75 rounds fired without a cook-off. To understand the significance of this data, it must be understood that the best prior historical performance was 11 rounds fired without a cook-off. Clearly, the AAI system, by never experiencing a cook-off, had accomplished and demonstrated something of value. The problem was to get a round with sufficient physical strength to be used in the gun.

Vulnerability tests on the AAI caseless rounds were conducted. There were no shrapnel after effects as a result from an incoming armor penetrating round and/or conventional ammunition. There was however, a severe fire which propagated until all rounds were consumed. The fire was severe enough and fast burning enough to state that the infantryman would have no real chance to divest himself of his ammunition in the event he survived the incoming round. For rounds in storage such as a field magazine, the fire would most likely result in total destruction of ammunition stored. There is a solution to this problem. It lies with packaging technology to prevent and retard the propagation of fire once one round has been initiated.

1.2.1.4 Summary. The Government engineering team involved with this contractual effort remain convinced that the theoretical solution, the heat sink, developed by AAI was a valid and workable concept, potentially leading to a weapon mechanism of greatly reduced complexity as compared with the H&K developmental weapon. For future purposes, the melding of the AAI mechanism with the highly superior H&K propellant might conceivably result in a weapon superior to both candidates. (See the following section on the H&K caseless effort; also refer to the summaries in Volumes IV and VII of this report for additional information involving caseless ammunition development.)

1.2.2 Heckler and Koch: Caseless Weapon Contract #DAAK10-82-C-0332.

1.2.2.1 Background. The second contract awarded during this period of time was to Heckler and Koch (H&K), GmbH of Oberndorf am Neckar, West Germany through their wholly owned subsidiary in Sterling, VA. H&K had formed a "consortium" with Dynamit Nobel, AG (DNAG) located in Nuremberg, West Germany. H&K was the weapon designer and manufacturer, while DNAG developed and produced the caseless ammunition. The two companies formed a firm named GHGS to be a management overseer in Germany.

A complication with this contractual effort was the fact that Germany was, at the time, totally committed to replacement of their worn out supply of G-3 (7.62 mm) assault rifles with the caseless weapon, termed G-11 in Germany. The same technology development was in fact funded by both Germany and the U.S. under the ACR program. From a technical viewpoint, it was virtually impossible to separate what work was being funded by which nation.

H&K along with DNAG had managed to conduct a cook-off test where 100 rounds were fired at an average cyclic rate of 85 shots per minute. The 101st round did not cook-off when allowed to remain chambered for thirty minutes. Near the point in time when this technical milestone was achieved, the ACR program was initiated and the H&K contract was modified to a wider ranging development program culminating in the delivery of weapons and ammunition for troop testing. All of this was to be done under an accelerated acquisition schedule. The requirement to accelerate the program caused the newly formed Advanced Combat Rifle (ACR) program office to modify the existing contract with H&K, rather than take the more time consuming route of terminating the existing contract and making a new award. Contractually, with the factors mentioned above to aggravate the situation, this contract was extremely difficult to manage and control.

From a contract perspective, the major errors made involving this contract included the following: (1) failure to re-write a new contract to accommodate the altered requirements, (2) the acceptance of an unwieldy, multi-layered contractor management organization, (3) acceptance of the use of a wholly owned subsidiary as the "prime" contractor, and (4) failure to station a government technical manager on site in the contractor's facility in Germany.

1.2.2.2 Weapon. The H&K weapon system (see Figure B3) is a revolutionary caseless mechanism with semi-auto, salvo three round burst, and full automatic modes of fire. Because the chamber is radially reciprocating, rocking back and forth 90 degrees between the load and fire positions, a number of novel weapon mechanism innovations had to be developed and integrated into this weapon system.

H&K ACR
Figure B3

The original U.S. funded effort employed a "shouldered" round with a ring mid-chamber for the round to seat against. The chamber was rotary and the round was inserted form either end. The resulting seating ring was therefore a thin ring and became a hot spot, the most likely point to initiate cook-off. A chamber redesign of major proportion ensued. The projectile was telescoped into the round body and the mid-chamber ring was eliminated. While the round could still be fed from either end, the design was to have the chamber radially reciprocate so that the round was always fed from the same end. This modification dictated an entirely new interior ballistic sequence, or method of function. The first problem was to get the chamber sealed to the housing in which it sat. The projectile then had to be induced to enter the forcing cone of the barrel so that total sealing was accomplished, and then the projectile could be accelerated down bore. A booster pellet was added to the interior of the round to assist in accomplishing this process. After primer ignition, the booster pellet, seated immediately in front of the primer, ignited and accelerated the projectile out of the still intact round body and into the forcing cone. This process initiated the sealing of the chamber and propellant ignition.

A free volume area had to be added to the breech block. This was accomplished by drilling two holes into the breech block at about 45 degrees up and 45 degrees down from the central chamber hole, the barrel centerline. This free expansion volume smoothed the pressure time curve and was a key to accuracy of the projectile. Simultaneously, the chamber had been redesigned with a split. As the gas pressure increased, the gases entered the split and forced the two pieces of the chamber to move away from each other, contact the housing, and seal the chamber to the housing.

Many variations of the chamber design were tested. The variants differed from the split being located near one end so that the smaller piece was, in essence, an end cap; to having a split at either end or two end caps; to finally, having the split at the center of the chamber. Many other variables were being tested at the same time that the optimum chamber design was determined. This occurred many years after the "shouldered" cartridge was eliminated from contention.

The H&K caseless weapon had been under development in Germany for a period of time prior to U.S. involvement. Originally, it is believed that the design departed from more standard linearly reciprocating mechanisms due to the difficulties envisioned with the extraction cycle for duds, misfires, broken rounds, etc. There was no simple, reliable method envisioned to remove a round or fragments if that were necessary. The rotary chamber, conversely, did offer a method whereby this extraction might take place reliably. This lead to the advent of the rotary chamber in the H&K design. This chamber must rotate accurately and precisely at extremely high rates to accomplish its intended purpose. In the salvo mode of fire, the chamber must accept a round, rotate exactly ninety degrees to be in line with the barrel, fire the round and obturate the mechanism to seal the chamber, then counter-rotate exactly ninety degrees again to be in the loading position at over 2,000 times a minute. The weapon has long ago demonstrated its ability to perform just as described.

For extraction of a round, whole or broken, the firer must turn a crank on the side of the weapon. When this is done, the chamber rotates into the vertical position (loading position), and the next round pushes the old round or its fragments out of the chamber and through a hole in the bottom of the housing which has a cover that opens momentarily at just the correct time.

Continued rotation of the handle will load a new round into the chamber for firing. An incomplete rotation of the cocking lever will result in a misfire when the trigger is pulled because the primer is not adjacent to the firing pin. To clear the weapon, one must retract the magazine partially (or totally) and repeat the misfire/dud removal cycle. Then, instead of the next round pushing out the prior round, an extractor pushes the round out through the bottom port. While this system works reliably, the mechanism to accomplish all of these activities is very complex.

As the mechanism is so very complex, H&K has decided that the soldier will not normally open the plastic housing of the weapon except for cleaning. During cleaning, the weapon is broken down into major sub-assemblies but not fully disassembled. The plastic housing is sealed from the environment, but the chamber is not totally sealed from the rest of the mechanism. The chamber does not fully obturate until the internal pressure has built to some hundreds of psi (400-500). Until full obturation occurs, there is a gas path from the chamber to the interior of the plastic housing. There is also a corresponding spark path. Couple this information with the fact that propellant is never totally burned and both carbon monoxide and hydrogen gases are normal by-products of propellant combustion, and it becomes intuitive that eventually, an explosive mixture will accumulate within the housing. Pressure relief valves can keep the pressure prior to ignition at about 0.25 psi gauge, but after spark initiation of the explosive gas mixture, no relief valve will act quickly enough to vent the burning gases. There is absolutely nothing which can be done to prevent the generation of these by-product gases. Any attempt to introduce air to keep the concentration below the lower explosive limits will also allow the passage of water. Therefore, H&K has elected to re-design the housing to withstand these recurring initiations. Additionally, an opening in the housing with a one-way pressure relief valve has been fitted with a wire mesh covering to prevent burns after a gas initiation has occurred. These design features undoubtedly perform as intended, but the basic sealed design has forced these further complications to an already complex weapon.

The H&K ACR incorporates a unique buffering system, termed the internal operating floating system (IOFS). This hydraulic unit allows the entire recoiling mass (breech and barrel assembly) to recoil differing distances depending on the mode of fire selected. There is the minimum recoil in semi auto, limited recoil in the relatively slow (600 spm) full auto mode, and the maximum recoil while firing the three round salvo burst. Adequate testing has been done to prove that, in the salvo mode, each recoil force peak is substantially reduced relative to the M16 rifle. While firing in this mode, the buffer does not reach its rearmost point of travel until after the third projectile has exited the muzzle.

The weapon mechanism has been designed to be bi-laterally symmetric so that as the weapon heats and expands, there are no bending or twisting moments.

Another major innovation is the rotating firing pin. It is far more difficult to design a long-lasting, high pressure seal for an item such as an axially translating firing pin than it is to design a long-lasting, reliable circumferential seal around a turning shaft. In the latter case, the technology is well known and readily applied to a gun. The H&K primer is of the stab type, incorporating glass chips to act as anvils within the mix. The firing pin itself is no longer restricted to being a "pin" to obtain the needed indentation energy, but may be a more substantial part, tipped with a refractory metal alloy such as tungsten carbide, which would have a major effect on "pin" life. Such is the case with the rack and pinion rotary firing pin in the H&K design.

The optics selected by H&K were designed by Swarovski Optik of Innsbruck, Austria. It is a multi-powered optic offering settings of either 1 or 3.5 magnification. A distance adjustment knob located at the rear of the optic, allows the magnification to be easily changed from one setting to the other. Single power magnification is used for short range targets out to 300 meters, while 3.5 power is recommended for longer range engagements. A stadia line pattern is incorporated into the optic to assist in range estimation beyond 300 meters. Calibration settings for 300, 400, 500 and 600 meters adjust the reticle pattern to the desired range. While H&K was encouraged to develop a removable sight, they declined because their plastic housing, with no metal backing, would likely not permit zero retention. The daytime optic is built into the weapon's carrying handle.

The magazine is a single row forty-five round capacity unit. The square "rounds" of ammunition are loaded back-to-back, nose down, into the magazine. The magazine is situated above and in line with the barrel and has a short white line on top to aid the shooter in point fire engagements. This magazine is quite long and likely to interfere with a maneuvering soldier, so H&K has also designed and developed a half-length, 25 round magazine. This shorter magazine was not tested in the ACR field experiment.

The weapon is charged using a rotary cocking lever located on the side of the weapon. After pulling the trigger, the primer ignites the booster and the projectile begins to move forward. The propellant body then begins to burn. The build up of pressure forces the two unequal parts of the chamber outward until each piece encounters the massive breech cylinder housing. The chamber ends are curved to match the radius of the breech cylinder in which the chamber sits. This surface is used to properly seal the chamber and contain the gun gases. The breech cylinder rotates inside of the body of the main housing. This cylinder has a cam plate (control disk) attached to it which is driven by a series of levers. This is the basic source of the weapon's complication. Regardless, the mechanism has been highly reliable, with minimum weapon related stoppages or other form of malfunction traceable to the weapon mechanism. The majority of the malfunctions/stoppages experienced in the field experiment were ammunition related.

1.2.2.3 Ammunition. H&K's caseless ammunition (see Figure 3.9) is square in cross section with an indentation at the front end to permit front end identification without direct vision. The round consists of propellant body, bullet projectile, plastic end cap, primer and booster.

The projectile is a gilding metal clad, steel penetrator, lead wire backed unit of 4.92mm diameter. Another version, without penetrator, was supplied for the ACR field trials. This projectile appears to be nothing out of the ordinary; however, it is a high precision part which requires close tolerances in order to perform properly. A major portion of the ballistic cycle calls for the bullet to enter the forcing cone, stop momentarily, and then proceed down bore. To do this reproducibly requires high projectile precision. With such high tolerance parts required, the cost of manufacture is necessarily higher than for similar, more conventional projectiles.

The plastic end cap is one of two non-combustible parts. The purpose of the end cap is to hold the projectile within the body of the round in line with the barrel, and to provide a heat resistant barrier between the combustible round body and the hot face of the barrel breech to delay the onset of cook-off. It further serves to prevent dirt and water from collecting in the bullet cavity. The end cap is pre-scored to facilitate projectile penetration. After firing, the plastic proceeds down bore, usually in pieces, and does not represent a significant hazard to friendly troops.

The round body is comprised of a true high ignition temperature propellant relative to standard nitrocellulose propellants. The basic composition is a nitramine named "Her Majesty's Explosive", HMX, with an energetic binder, a small percentage of fiber for strength, and an induced porosity. Details of this round of ammunition can be found in Volume IV of this report. The historic objections to caseless ammunition have been with vulnerability and cook-off. A videotape is available which shows the effects of incoming armor piercing rounds impacting various points on a magazine of live H&K caseless rounds. To summarize that tape, it may be said that there are no initiations from a round striking any part of the caseless round except for the primer being directly hit. When any part of the round is hit without initiation, the only result is broken rounds. When the primer is directly hit, a slow fire results. By slow, it is meant that the magazine may be removed, dropped, and will continue to burn until the rounds are consumed. Aside from a gun mechanism which is now very dirty, there are no adverse effects on the weapon. Firing of a dirty gun was accomplished, so that it is known that the weapon functions normally before cleaning. As for cook-off, the results are not yet fully documented. In March 1986, a cook-off test was conducted which showed resistance to cook-off to 100 rounds fired at rates of both 85 and 325 shots per minute (spm). Since then, the previously mentioned need to obtain a reproducible interior ballistic cycle, accomplished by establishing a uniform T4 time at a lengthy 5 msec, resulted in a four-fold increase in time to projectile muzzle exit, and the time for burning propellant gases to transfer heat to the chamber was also increased four-fold. The cook-off level dropped to 1/4, or 25 rounds. Continued work has re-established a cook-off performance level of 100 shots fired at 85 spm without cook-off of the 101st round. For the safety certification, the Combat Systems Test Agency (CSTA) did cook-off testing at 35 spm, the estimated cyclic rate to be tested in the field experiment, and determined a cook-off level of greater than 135 shots fired without cook-off. The weapon was to be restricted to 135 rounds (three magazines) before cooling during the field trials.

The drive train booster is a compacted pellet in a thin wall copper cup, the second non-combustible component of the round. This copper cup is partially consumed, leaves no detectable residue in the barrel, and provides no significant hazard to friendly troops. The cup is oriented with the opening toward the rear with the base of the cup at the rear of the bullet. In addition to igniting the round body, this booster orientation causes the bullet to move forward into the forcing cone at the earliest possible stage of the internal ballistic cycle; thus causing the projectile to seal the chamber and give uniform pressure generation.

The primer is a pellet consolidated into a cup formed of the same composition material as the round body. As stated before, the mix is of the stab type, incorporating ground glass to act as an anvil.

The finished rounds receive a variety of exterior coatings to serve multiple purposes: a teflon coating to prohibit round to round sticking, especially when hot; a coating to enhance cook-off resistance; and various additives for other purposes.

The H&K round is completely waterproof, with or without exterior coatings. The round is extremely hard, but not friable; and is very hard to break. The basic constituent of the propellant is a polymorph of HMX not normally considered to be an end product here in the United States. Therefore, it is not easily obtained except from the Holsten A.A.P. modified

Bachmann process. Production at Holsten is occupied for other items, so the production allocations for Holsten must be altered to produce this material in CONUS. This is primarily a cost problem. Other constituents of the H&K round are extremely hazardous to synthesize and alternative materials will not be easily or cheaply substituted. This round is, and will continue to be expensive to produce. See Volume IV of this report for detailed information on the H&K round.

1.2.2.4 Summary. In conclusion, the H&K ACR is a revolutionary radially reciprocating caseless ammunition rifle. The weapon incorporates a variety of novel technologies. The most important is probably the unique IOFS with hydraulic buffer, which allows the third round of a high rate salvo burst to leave the muzzle before the shooter can feel the recoil impulse. Virtually every other innovation was developed to compensate for the rotary chamber's unique requirements. The feasibility of a caseless ammunition rifle system has been successfully demonstrated with this effort.

1.3 Industry Alternative Efforts. At the same time the Under Secretary of the Army (USA), the Honorable Mr. James Ambrose, approved a restructured program to include the field trials, he also directed the incorporation of greater industry involvement. USA Ambrose was familiar with in-house R&D programs conducted routinely by the major defense contractors, and was convinced that the government unnecessarily restricted contractor efforts. His guidance was for ARDEC to award contracts which were virtually unrestricted. Industry was to develop the best rifle system possible, without the time and cost expenditure to meet nuisance requirements routinely imposed by government bureaucrats.

A contract solicitation resembling a performance requirement was prepared for dissemination world-wide. There were eight timely responses to that solicitation; five of which were at least minimally acceptable. Each of the five concepts were to receive a contract for a breadboard demonstrator effort. The three most successful breadboard demonstrators were to be awarded a follow-on contract phase. The solicitation specifically prohibited a caseless concept on the basis that the government was convinced that technological solution was already adequately represented with the ongoing H&K effort. In accordance with the milestones imposed by the new program, this led to a six month initial effort to demonstrate a breadboard system concept. Contracts were awarded to AAI Corporation in Hunt Valley, MD (non-caseless); ARES, Inc. in Port Clinton, OH; Colt's Manufacturing Company, Inc. in Hartford, CT; McDonnell-Douglas Helicopter Company (MDHC) in Mesa, AZ; and Steyr-Mannlicher GmbH, of Steyr, Austria. The contracts were termed the industry alternatives because they were concepts from industry as an alternative to the original government caseless efforts. The H&K contract was modified to continue along with these other concepts.

All five contractors failed to have a system demonstrator model available on time, so the government redefined a breadboard and sought full funding for all contractual efforts to continue. The funds were made available and there was to now be a down-select after the second contract phase. The second phase, originally of one year duration, was extended to 18 months and later, to twenty one months. There was pressure from higher authority to continue with all five contractors, but funding was not coming easily and two concepts were deemed to be beyond the ability of the contractors to successfully complete in a timely fashion.

Therefore, after a red team was formed and a final attempt to successfully demonstrate their concepts was deemed unsuccessful, the ARES and MDHC contracts were terminated. Ultimately, AAI, Colt, H&K and Steyr proceeded into hardware fabrication for the field trials. The end product was to be twenty weapons and about 100,000 rounds of ammunition. A separate contract modification was awarded for field experiment maintenance support.

1.3.1 AAI: Industry Alternative Contract #DAAA21-86-C-0365.

1.3.1.1 Background. Contractually, the problem with the AAI contract was that it was originally underestimated by AAI. This led to numerous, low value cost growths. As might be expected, every time there was a change to the requirements of any kind, major or minor, there had to be a cost bearing contract modification.

AAI was also the repository of the equipment necessary to produce the flechettes needed for both their contract and the Steyr-Mannlicher contract (and the MDHC contract). The production of flechettes was a cost, time and quality problem throughout the entire development effort. As the AAI concept had the flechettes strongly crimped into a brass case, there was not a need, with their concept, for extremely straight flechettes. However, with the competing Steyr concept, the quality of flechettes needed to be higher with respect to straightness and concentricity because the crimp from the plastic case was not nearly as strong. Looking at performance, the flechette round was not ever made to be as accurate as a standard bulleted round. There is some controversy as to whether the flechette round is inherently less accurate and whether any amount of future development effort would result in equal accuracy to a standard bulleted round. The pace of technology today is such that it is unlikely that further development work on small caliber flechettes will be funded for rifles. However, flechettes still offer significant potential for bursting munitions and crew served weapons.

1.3.1.2 Weapon. The AAI weapon (see Figure B4) is a 5.56mm modified version of the previously developed Serial Bullet Rifle (SBR) using a reciprocating bolt mechanism. The major modification is to incorporate an "entrapped gas" operating system. Gun gases enter a cylinder, drive a piston to power the system, and prevent any leakage of propellant gases and residues into the other mechanism parts. This action should reduce the cleaning frequency and incidences of fouling-related stoppages.

The weapon has two modes of fire; semi automatic and three round salvo burst at a cyclic rate of 1800 shots per minute. A removable 4X optic with lighted reticle was also used on ACR field trial configured weapons. As the trajectory of the flechette round launched at 4600 ft/sec is fairly flat, the optic had horizontal lines in the internal lighted reticle to compensate for projectile drop between 300 and 600 meters.

There is a long sight rib section on the upper surface to aid the soldier in unaimed fire situations.

The basic SBR design is a well-proven, mature design which performed in a reliable fashion during the FY90 Advanced Combat Rifle (ACR) field trials.

AAI ACR with Iron Sight
Figure B4

1.3.1.3 Ammunition. The AAI round (see Figure 3.3) uses the standard 5.56mm M855 brass case with M41 primer. The projectile is a 10.2 grain sub-caliber flechette. The sabot is a liquid crystal polymeric compound (plastic), which is designed in four segments held together by a neoprene "O" ring at the rearmost point of the sabot segments. The sabot segments, when assembled together with the flechette and "O" ring produce a package of 5.56mm diameter. The sabot is designed to have a chamfer on the nose to prevent "stubbing" of the round during feeding. Behind the approximately 1/4 inch long chamfer, a full diameter bourrelet section begins. Near the mid-point of the bourrelet is a molded crimp groove into which the neck of the brass case is rolled, giving a "shot start", or minimum pressure build up before movement of the projectile assembly can begin. Aft the approximately 1/2 inch long bourrelet, there is a radius and a 3/8 inch long ramp down in diameter to a thin section where the "O" ring sits.

The propellant of choice is a modified blend of WC662, produced by Olin Corporation. After the last batch of WC662 was exhausted, Olin supplied a batch identified as WC670-17, supposedly identical with WC662, which performed equally as well with a lesser charge weight. The ballistic performance to be expected from either of these propellants is approximately as given below:

charge weight............22 to 23 grains
velocity.......................4600 ft/sec.
pressure.....................55 to 61 Kpsi
accuracy....................0.8 to 1.5 mils

The weights of the various AAI round components are given as follows:

brass case.. 95 grains
primer... 4 grains
flechette... 10 grains
sabot,boot... 11 grains
propellant... 23 grains

TOTAL...143 grains
An M855 round weighs approximately 185 grains.

There are no technical barriers envisioned in the correction of deficiencies which are known or anticipated with the weapon; however, the ammunition does suffer from being heavy as compared to the caseless or plastic cased ammunition.

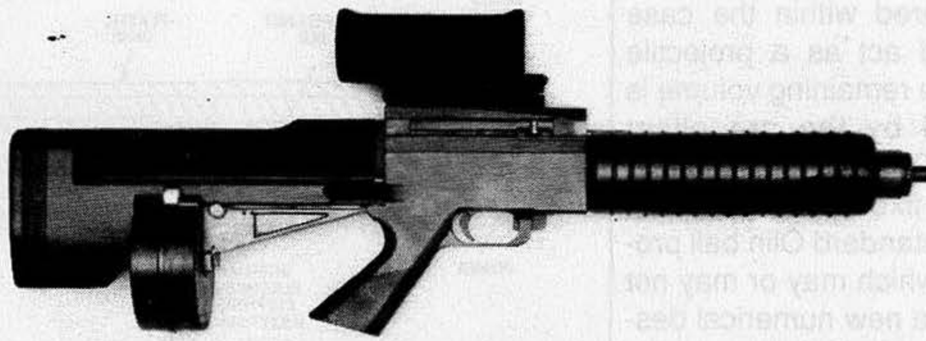
The non-existence of a blank fire round is a minor deficiency which may readily be solved. However, the non-existence of a tracer flechette round presents a more serious problem. It is believed that there is a reasonable solution, but the development of such a round will not be accomplished either quickly or easily. The most likely route to a successful tracer flechette development might be to intentionally sacrifice lethality of the tracer round in favor of a longer trace burn time on a matching trajectory. A substantial amount of work would be required to verify the assumption that the trade off is feasible. Other, more standard approaches will suffer from relatively shorter burn times, lower daylight visibilities, and potentially high manufacturing costs.

1.3.1.4 Summary. In summary, the AAI ACR is regarded to consist of a relatively mature weapon of known reliability characteristics coupled with a slightly lighter, high launch reliability, flatter trajectory, brass cased, sub-caliber flechette round.

1.3.2 ARES: Industry Alternative Contract #DAAA21-86-C-0363.

1.3.2.1 Background. ARES was one of the two contractors terminated prior to the ACR field trials. Contractually, there were no problems with the ARES contract. This effort was adequately funded throughout its existence. During the proposal evaluation phase, this had been the highest rated concept proposal. The ARES proposal was complete, covering every aspect of the planned development. Unfortunately, there were apparently subtle conceptual problems which prevented the concept from being acceptably demonstrated in a timely fashion. The key to Government action to later terminate this contract effort was not that there were insurmountable problems, but that there was too great a risk that the problems would not be solved in a timely fashion. There was also the sure knowledge of insufficient funding to support all of the industry alternative contracts into the field experiment phase. The basic nature of the problem was that the weapon concept called for plastic cases for reduced weight. Being plastic, with insufficient stiffness relative to brass, the round tended to compress under the bolt forces resulting in misfires. Attempts to solve this problem, which was not apparent as a critical conceptual defect until very near the time of the demonstration, were determined to be insufficiently effective to warrant the risk of a failed development if the contractor were allowed to proceed further into the hardware production phase.

1.3.2.2 Weapon. The ARES ACR (see Figure B5) is a bull-pup design incorporating a novel rising chamber mechanism. The weapon fires from the quasi-open bolt. With an exception being after the last round in the magazine has been fired, there is always a round in the rising chamber block, even when the weapon is out of battery. This feature could possibly represent a major deficiency, especially in an overheated weapon where a cook-off might occur. Admittedly, with a plastic cased, telescoped projectile and a chamber which is not constantly in contact with the hot barrel, there is a greatly reduced opportunity for a cook-off to occur. However this possibility still exists.



ARES ACR

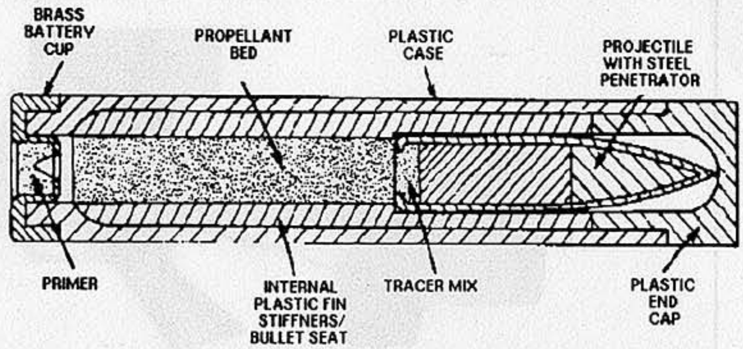
Figure B5

A demonstration was held at the end of the Phase I effort during which all participants who had fired the weapon stated that it was exceptionally easily controlled. This is partially a testimonial to the efficiency of the ARES muzzle device. However, the ammunition at that time was low in both velocity and pressure. While no actual analysis has been done and none of the observers fired single shot accuracy for record, there is some indication that the rising chamber mechanism does not provide the normal "jerk" to the weapon. This movement, traditionally caused by the bolt slamming home in open bolt mechanisms, tends to decrease the ability to accurately fire in the semi-auto mode. The minimization of muzzle movement by bolt closure would be totally unrelated to the fact that the ammunition was not at full ballistic performance at the time of the test.

The ARES 60 round drum magazine offers the soldier almost a doubling of firepower between reloads, but the trade-offs include a bulky magazine which might interfere with the shooter in certain positions and a somewhat higher degree of magazine complexity, cost, and malfunction opportunity. The original magazine design had a gun driven plastic tape, which was objectionable in that it trailed and might catch on bushes or other objects. ARES changed the design to a gun driven linked belt. This eliminates the plastic tape, but the tradeoff is in the cost of the ammunition. The most likely result would be that the magazines are not field reloadable; but are throw-aways. Again, there is a cost impact to this design.

The primary feature of this system resides not in the hardware, but in the proposed method of weapon employment; that is, the "closed loop fire control" tactic. The basis of this tactic is that the shooter employs the visual feedback offered by a visible tracer stream to alter the aim point of his weapon, thereby improving his probability of hit performance. This weapon is lightweight and easily controlled. The projectile impulse is the minimal required to assure lethal effects out to ranges where most targets are found. It is unfortunate that the ARES system could not be assessed in the field experiment. Unlike the other concepts, the ARES "closed loop" fire control approach could not be modeled to predict performance.

1.3.2.3 Ammunition. ARES ACR ammunition (see Figure B6) is 100% traced. The projectile is fully telescoped within a plastic case of GTX-910 material, with a brass battery cup and primer. There is a plastic end cap which is ultrasonically welded to the case body for waterproofing and anti-tampering purposes. The plastic case has internal fins to serve the dual purposes of keeping the projectile centered within the case body and act as a projectile seat. The remaining volume is occupied by the propellant charge. The propellant has not yet been fixed, but it will be a blend of standard Olin ball propellants which may or may not be given a new numerical designation by Olin. The case head, made of the same GTX-910, is pre-scored for projectile exit.



ARES AMMUNITION
Figure B6

The projectile itself is 5mm and has a 45 grain total weight. It has a steel penetrator, backed by consolidated lead wire and two grains of pyrotechnic mix. The projectile in encased in a gliding copper jacket. The tracer burns out between 300 and 400 meters.

The ammunition has a limited effective range and does not currently meet the criterion of dual use in both the ACR and a follow-on light machine gun. Aside from the knowledge that a round acts differently following burn out of its tracer mix, it is not known how this round performs at the longer ranges of interest.

The ARES round, at 111 grains, weighs 60% of the 185 grain M855. This may be regarded to be a major combat load improvement for the individual soldier.

1.3.2.4 Summary. In summary, the ARES ACR, had it continued in development, was to have an unproven tactical use and the potential for a failure with a live round chambered in the out-of-battery position. This is considered to represent a greater than negligible safety hazard to the shooter. The closed loop fire control tactic proposed by ARES could not demonstrated.

1.3.3 Colt: Industry Alternative Contract #DAAA21-86-C-0367.

1.3.3.1 Background. The Colt ACR contract proceeded through development with no significant problems. The effort was adequately funded throughout the entire program. Specific design characteristics used in the Colt ACR have been incorporated into the newly developed M16A3 rifle.

1.3.3.2 Weapon. The Colt ACR (see Figure B7) is a modified M16A2 with a muzzle brake compensator (MBC), telescoping buttstock, and a much "cleaner" upper surface that should enhance weapon pointability. The upper receiver also includes a rail making the mounting of an optic sight far more acceptable than on top of the current carrying handle. A new oil/spring hydraulic buffer has been designed for this weapon. The remaining Colt weapon design efforts have been in the area of human engineering. Contractor testing has shown a major decrease (in the area of 40%) in recoil attributable to the MBC as compared to the current M16A2.

COLT ACR with Iron Sight
Figure B7

1.3.3.3 **Ammunition**. The Colt system was designed to use any round of ammunition which may be used in the M16 rifle. However, the contractor proposes the use of a two ammunition family for the ACR; a newly developed duplex round for short range engagements and the NATO standard M855 ammunition for longer ranges (see Figure 3.6). The AMSAA analysis done at the end of phase I efforts under the ACR contractual program gave Colt a projected improvement in probability of incapacitation relative to the M16A2 only because of the use of duplex ammunition. When using M855 ammunition, there was no performance improvement projected with the Colt ACR relative to the M16A2.

The concept of duplex ammunition is not new; in fact, there is a type classified 7.62mm duplex round. The Olin Corporation used this predecessor round to develop the 5.56mm duplex round. The duplex ammunition places two bullets, nose-to-tail, in the same cartridge case. The theory behind the duplex round is that the lead projectile will travel to the aimpoint, while the trailing bullet will have a dispersion around this aimpoint. This ammunition should greatly increase the probability of at least one projectile hit. The weight of the front bullet is 35 grains, while the rear bullet weighs 33 grains. Both are copper jacketed steel penetrators. The dispersion between the two projectiles is approximately 1.0 mils. The duplex round offers no weight reduction to the overburdened soldier and is, in fact, slightly heavier than the standard M855 round. However, the soldier carrying duplex ammunition will have twice as many bullets than the soldier carrying the same amount of M855 ammunition.

During routine testing with duplex ammunition during contractor development tests, there was a gun incident which resulted in a blown-up weapon with no personnel injury. There was a major investigation into the cause of the incident. It was determined that, with duplex ammunition, if the rear projectile is permitted to migrate in the direction of the primer, the trailing projectile may become lodged in the bore. When the next round is fired, a similar incident may occur.

A production test series was conducted and it was determined that with a 108% to 110% compressed charge, there was sufficient propellant compression to prevent migration of the trail bullet. For the purposes of creating a margin of error, the charge was to be 112% (min.) to 116% (max.) for all future duplex production. To ensure that there was no migration, rounds were loaded and put through a vibration test common for shipping and X-rayed thereafter. The X-ray photographs clearly proved the success of the solution, but for safety reasons, the duplex rounds were all X-rayed. In production, this would only be necessary on a sample basis as opposed to a 100% X-ray test. The significance of this, is that the X-ray test procedure is very expensive and time consuming.

Before drawing any conclusions on the Colt ACR, the baseline M16A2 weapon system must be briefly discussed. A muzzle device has been designed by Naval Ordnance Station, Crane, IN. This device replaces the current flash suppressor and may be easily substituted on the M16A2. Such M16A2 configurations have been recently tested in a salvo stress test conducted by the Human Engineering Laboratory (HEL) at APG, MD. Duplex ammunition was designed to fit the same chamber configuration as the M16A2, and is immediately usable therein. Relative to the Colt ACR, the M16A2 does not have a clean upper sighting surface, nor is the mounting of an optical sight on the handle any better than an expedient action at best. In addition to the Colt system, an M16A2 rifle with the Crane muzzle device firing duplex ammunition was evaluated in the field experiment.

1.3.3.4 Summary. In conclusion, the Colt ACR is a muzzle compensated, human engineered variation of the M16A2. In consideration of the fact that the great majority of any improvements to be accrued with the Colt ACR are attributed to the use of duplex ammunition fired with an integrated muzzle device.

1.3.4 McDonell Douglas: Industry Alternative Contract #DAAA21-86-C-0366.

1.3.4.1 Background. McDonnell Douglas Helicopter Company (MDHC) was the second contractor concept terminated for inability to demonstrate the system in a timely fashion. Unlike ARES, this concept was further behind in development status with numerous inherent problems that became obvious during the course of development. The concept was designed around a flat cylindrical case which could use a single projectile or multiple projectiles for the desired salvo effect. A true salvo system. The system had objectionably high recoil and was the sole system which was intended for use in the semi- automatic mode of fire only. At the time of the demonstration, it became abundantly clear to all persons involved that this concept was simply not ready to enter the program production phase. The contract was well funded for the original intent, but when the contractor met with early failures, the system concept was altered, and financial difficulties began. While this lockless concept has been successfully demonstrated as a light machine gun, it was not adequately proven in the assault rifle version and the effort was terminated.

1.3.4.2 Weapon . The MDHC ACR (see Figure B8) is a recoil operated .338 caliber weapon based on the "lockless" principle. This mechanism was previously demonstrated in a small caliber light machine gun developed in the 1970s. The barrel and breech are produced from a single piece of material where the breech is separated from the barrel by a mortise slot. This slot acts as the chamber of the gun. A sleeve slides over this mortise slot to seal the chamber and is retracted to permit feeding of the next round. During the course of feeding, the new "live" round ejects the prior round; either an expended round or a misfire. A muzzle device is incorporated into this rifle to help reduce recoil.

McDONNELL DOUGLAS ACR

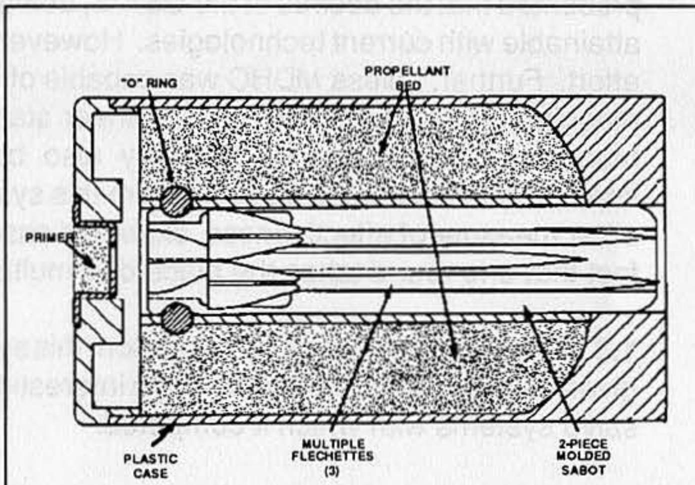
Figure B8

The optic is a removable 4X telescope. It may be replaced with any other optic or by back-up iron sights.

The magazine has a capacity of ten rounds, protrudes from the weapon side like a handle, and is positioned immediately under the chamber. Ejection for this reason is upward. The weapon is long, has a shotgun-type sight rib and should point quite well in quick fire situations.

This entire effort represents a change from the system developed by MDHC in the first phase of their ACR contract. As such, this design was not fabricated for the first time until the end of May 1988. It was insufficiently mature for the purposes of demonstration in the field trials.

1.3.4.3 Ammunition. The MDHC ammunition (see Figure B9) is a "chiclet" shaped rectangular solid. The projectile package sits in the center of the longest dimension directly in front of the primer. The case is plastic and the inserted primer is of standard brass construction. Propellant is charged into the cavity on either side of the projectile package and gases from the burning propellant are vented into the central cavity by means of ports, which are exposed as the sabot passes by. The round is extremely inefficient, requiring a charge weight of 90 grains of propellant to launch a projectile weight of 70 grains. The original projectile package under development was multiple bullets (duplex and triplex), similar to the Colt duplex round. The recoil impulse from this massive projectile package was unacceptably high. MDHC then chose to totally reorient their effort to a multiple flechette projectile package consisting of either three, four, or five flechettes. The final configuration before contract termination was that of three flechette projectiles.



McDONNELL DOUGLAS AMMUNITION

Figure B9

The sabot material is a liquid crystal polymeric type as in the AAI and Steyr sabots. It's weight is roughly 30 grains. Temporarily, the material of the case itself is nylon; an unacceptable material in later stages of development. The case is designed to fail along its four longer edges because the case is not fully supported and pressures must be approximately equalized both within and around the case to prevent the reeds from deforming. The reeds are the remaining web of material after the chamber volume is mortised from the barrel/breech block. This intentional case failure and the added volume which must be pressurized around the case are the cause of the aforementioned inefficiency in round design.

The approximate ballistic performance of this ammunition is 4700 ft/sec launch velocity at 35000 to 37000 psi. The projectiles are the same flechettes discussed in other sections of this report and are provided to MDHC as GFM. The total weights of this round are 191 grains for the three flechette version and 201 grains for four flechettes. Each round is slightly heavier than an M855 round, but launches a multiplicity of projectiles. On the unproven assumption that a single MDHC round is equally as effective as three or four M855 rounds, this design might represent a very substantial weight savings to the soldier, especially at shorter ranges where both systems will be firing multiple projectiles at any given target.

The greatest technical barrier for MDHC to overcome in their terminated development effort was the basic immaturity of their system. The switch from a multiple bullet approach to a multiple flechette approach had cost MDHC a substantial amount of time. This created a real concern very early after the switch was made involving their ability to overcome the expected developmental difficulties in sufficient time to enter the field demonstration with a system developed enough to be worthy of testing. Remaining identified problems included launch reliability and dispersion. The multiple flechette approach has the inherent problem that, in past similar efforts, none of the flechettes go to the point of aim. This is not a problem where the aim error is high; but in the relatively low aim error in longer range engagements, this system would likely exhibit extremely poor hit probability performance. There is a valid argument to be presented that the desires of the USAIS, being high hit probabilities at long ranges, may not be attainable with current technologies. However, it was still the goal of the contract development effort. Further, unless MDHC was capable of reducing their dispersion to the general order of magnitude between 5 and 10 mils linear standard deviation, the intermediate range performance of this system would likely also be poor. Assuming that the hit performance improvements could be obtained from this system, then it would perform extremely well in the other measure of effectiveness, expected casualties per combat load. This is based upon the fact that one round takes the place of a multiplicity of rounds in any other system.

1.3.4.4 Summary. In conclusion, this system was well behind in development status, but given success might have offered an interesting and valuable alternative to the serial launched salvo systems with which it competed.

1.3.5 Steyr-Mannlicher: Industry Alternative Contract #DAAA21-86-C-0364.

1.3.5.1 Background. The Steyr system was similar to the ARES system in that it fired using a rising chamber mechanism. However, the Steyr ACR fired a single flechette from a plastic case using a radial ring primer. Initiation of the ring primer was from the side of the case near the base. The problem of insufficient case stiffness and misfires as a result of this feature never arose.

In Steyr's system, the flechette package was crimped by the plastic case head of the round. This was simply not as strong as the compression applied by a roll-crimped brass case as in the AAI system. Accordingly, the flechette package left the mouth of the case at a much earlier point along the pressure-time curve, with the result that round-to-round accuracy suffered when compared to the AAI round. As mentioned earlier, flechette accuracy has not been at the same level as bullets even under the best of circumstances. With this system, flechette dispersion was, at best, twice as wide as the standard bulleted system and often wider than that. This deficiency became noticeable at the longer ranges.

Further, the system was at the lowest point of prior development relative to all other contenders at the time of contract award. The weapon experienced difficulties during the safety certification testing and even into the first phase of the field test itself. These problems were solved during the test, but there was enough trouble that there was consideration given to concept termination at the very late testing phase. There was resistance to this action because of the extreme simplicity of the system and the highly cooperative attitude of the contractor personnel.

In terms of the contract, the aforementioned attitude of contractor personnel made the management of the effort simple and easy. It should be mentioned that Steyr was represented in the United States by Gun South, Inc. of Trussville, AL. The concept was adequately funded and there were no contractual problems.

1.3.5.2 Weapon. The Steyr ACR weapon (see Figure B10) bears a remarkable resemblance to the ARES weapon insofar as the basic mechanism type is concerned. Both are rising chamber mechanisms. Where the ARES gun was a quasi-open bolt with a live round normally

STEYR ACR with Iron Sight

Figure B10

in the chamber in the out-of-battery condition, the Steyr gun is a true open bolt mechanism in that there is a spent case normally in the chamber in the out-of-battery condition. A live round only enters the chamber after the trigger has been pulled.

The Steyr weapon is unusually simple in comparison to all other ACR candidate systems. There are a total of 87 different parts, 97 total parts, and some lesser number of indivisible sub-assemblies. The 97 total parts are broken down as follows:

Barrel	4
System Housing	27
Trigger Group	24
Receiver Group	29
Magazine Group	4
Stock Group	9

Aside from the novelty embodied in the basic rising chamber mechanism, there are a number of other innovations which lead to a simple weapon. The first is the gas system, which has the gas "piston", actually a hollow cylinder, mounted annularly to the barrel so that the barrel's outside diameter acts as the inside surface of the gas system, and the "piston" inside diameter acts as the outside surface of the gas system. The weapon slide is welded to the outside of the gas piston. After the projectile passes the gas port, the piston moves rearward, with the attached slide. The slide, a flat strip on either side of the barrel, acts on a pin protruding through tabs on the underside of the chamber. In rearward motion, the pin and chamber are forced down by a cam to the load position, cocking the spring which drives the chamber upward. After the gas piston contacts the buffer, the recoiling mass moves forward, pushing the chamber pin out of the lower detent position, driving the chamber up into the firing position. As the chamber is rising, the slide continues to move forward to its uncocked rest position. When the slide is in its most rearward position, a projection from the slide is positioned immediately behind the topmost round in the magazine. As the slide moves forward, this round is stripped directly into the chamber; at the same time ejecting the spent round from the chamber forward and downward to a port in the plastic stock of the weapon. As the chamber approaches top dead center, a fixed firing pin mounted in the top of the housing protrudes through a hole in the top of the chamber where it impacts the plastic case above the ring-shaped primer to ignite the round.

To allow direct feed of rounds from the magazine into the chamber, the plastic magazine has a transition zone where the round stacking goes from two staggered rows to a single row. This adds undesirable height to the magazine. To keep the magazine protrusion from being lower than the shield around the trigger/pistol grip, the round capacity of the magazine was reduced to 24 instead of 30 rounds. This will have an adverse effect on expected casualties per combat load because of the reduced magazine capacity. Steyr also has a high capacity, drum-type magazine design which was not fabricated for the ACR field trials.

The small number of parts and simple design allow for quick and easy disassembly with no tools. There has been forethought given to such things as making pins interchangeable and large enough to be easy to grasp and hard to lose. By removal of the rear plastic stock, the soldier can pull a quick disconnect sleeve and remove the barrel with a quarter turn. From this point, the gas piston return spring is free to be removed, the misfire ejector may be removed, and the mechanism is easily broken into several sub-assemblies. Springs are easily compressed by hand while pins need only finger pressure to remove or are easily pushed out with the sling pin

The weapon has been designed from its conception with eventual manufacture in mind. Numerous design changes have already been implemented strictly for manufacturing purposes. The result is that the projected cost to manufacture is approximately $375 - $400; less than the current cost of the M16A2.

The weapon profile resembles that of the Austrian Universal Gun (AUG). The AUG is also developed and manufactured by Steyr in Austria. It is a bull pup configuration with the magazine behind the trigger group and a longer barrel than the M16 rifle. The front hand grip has a cavity around the muzzle to permit the use of finned muzzle launched ordnance without modification. The mounting of a grenade launcher is unaffected, but the mounting of the current M-9 will require a minor modification.

The Steyr optic is a switchable 1.5X to 3.5X telescopic sight. It incorporates the Steyr ring reticle, which based on earlier testing, Steyr believes strongly assists untrained shooters. The concept is to put the ring around your target and pull the trigger. There are no sighting corrections incorporated in the reticle of the Steyr sight, because at a launch velocity approaching 1500 meters/sec, there is a flat enough trajectory to require no range compensation out to 600 meters. The optic may be removed and a conventional iron sight quickly installed.

1.3.5.3 Ammunition. The Steyr round (see Figure 3.12) is a fully telescoped, plastic cased flechette round based almost 100% on the ARDEC designed flechette/sabot package. The flechette provided as GFM was shortened slightly by Steyr to allow it to fit in the available case/chamber design. The flechette projectile weighs 9.85 grains while the entire projectile package weighs about 22 grains. The low impulse of this round permits the salvo cyclic rate to be fired at about 1200 spm. The very low weight of the flechette/sabot/boot projectile package permits the fully telescoped plastic case to function reliably. Larger launch weights require metallic case reinforcing as in the ARES design while much larger weights, as with a 62 grain M855 projectile, would require a virtually all metallic case according to early Steyr tests.

The round consists of four parts; case body, case head, ring primer, and projectile package. The projectile package is in itself an assembly of a single flechette, four segment sabot, and a boot to hold it all together. The case body is a right circular cylinder open at one end only. The ring shaped primer is pushed down to the bottom of the case body. The projectile package is inserted into the case head and, after propellant loading, is assembled with the charged case body. Materials used for the case have been polypropylene and polyamid-12. Both offer long term storage resistance to propellant. Using polypropylene, the total round weight is 4.5 grams; while with polyamid-12, it is 5.0 grams. In either situation, it is weight competitive with the 5.0 gram H&K caseless round.

The propellant used is produced by the Olin Corporation and is a variation of WC662 or off-the-shelf WC296. The favored propellant is WC296, which yields somewhat lower velocities and pressures; 1470 meters/sec at 4500 bars with WC296; as opposed to 1500 meters/sec at 5000 bars with WC662.

All flechettes used by Steyr to date have been GFM. Steyr has been dissatisfied with the quality of these flechettes and, for that reason, was investigating a different manufacturing process for this part. Their test analyses seem to indicate that if the flechettes were extremely tightly controlled with respect to straightness, fin-to-body concentricity, and shaft diameter that a major performance improvement would result. The basic contentions that Steyr makes about the quality and the expected performance gains of a more precise part are not wholly concurred in by ARDEC.

The Steyr round, like their weapon, is both simple and cheap to produce. Of all ACR candidates, this is the least costly ammunition round. It is expected to cost about 40% of an M855 round when in full production.

Round-to-round dispersion performance is generally 1.0 mils and the range is from a best performance of 0.5 mils to a worst performance of 1.75 mils. This seems to be the case regardless of ammunition configuration. The primer orientation of primer opening facing rearward has had an effect on reducing the standard deviation of velocity and pressure, but minimal effect on dispersion. With primer reversed, facing rearward, the velocity standard deviation is about 5 m/sec with an approximate 125 bar pressure standard deviation. With primer facing the mouth as is normal, standard deviations are roughly doubled. Both levels of performance are good. Weapon system function is unaffected.

An inherent drawback to the Steyr system lies in sabot hazard to friendly troops. This is a safety concern that exists in the AAI system as well.

A second deficiency to the system lies in the fact that the weapon is very short. According to the HEL, shorter weapons simply do not point as well as longer weapons. Even though the weapon has an uncluttered top sighting rib, it may not point as easily as a longer weapon.

A third deficiency common to all flechette firing rifles is their lack of accuracy relative to bulleted approaches. As stated earlier, the accuracy performance of the weapon at this time is about 1.0 mils linear standard deviation. This contrasts to bulleted weapons on the order of 0.25 mils. The performance improvements projected by Steyr for high precision flechettes and a muzzle device to eliminate muzzle effects from gas back- flow are now only projections.

A further deficiency discussed under the AAI ACR is the current non- existence of a tracer round and blank fire round. As with AAI, the blank is not a problem while the tracer situation was discussed in the AAI section.

1.3.5.4 Summary. In conclusion, the Steyr ACR represents the simplest weapon, the simplest round, and the most cost effective approach of any of the ACR contenders. Its greatest current deficiency is its poor round to round dispersion characteristics.

1.4 Baseline Weapon System - M16A2 Rifle.

1.4.1 Background. The M16 rifle system is not in the same class as the other weapon systems described previously in this section. This weapon is distinguished from the other ACR candidates in that it is a fully proven and fielded weapon system which may well be the finest assault rifle in the world today. It has a firing history of billions of rounds and, through the years, has been exhaustively product improved. The government is currently developing the M16A3 rifle to incorporate an optic as the primary fire control. There are no known deficiencies to the weapon with respect to its intended application. The "problem" with the M16 is that the future desired capabilities of the soldier's individual weapon have changed, are still changing, and will continue to change until a new individual weapon is fielded and undoubtedly thereafter.

1.4.2 Weapon. The M16A2 (see Figure B11) is an improved version of the earlier M16A1 rifle, and is the standard weapon of the individual soldier. It is a magazine fed, gas operated 5.56 mm assault rifle that fires in the semi-automatic or three round burst mode. The three round burst mode is simply a three round counter incorporated into the automatic firing mode to reduce unnecessary

M16A2
Figure B11

ammunition expenditure. The cyclic rate of the burst is about 800 spm. Weapon weights are approximately 7.5 lbs without sling and loaded magazine, and 8.75 lbs with sling and loaded 30 round magazine. The weapon has a flash suppressor which permits the use of 22 mm (launch tube diameter) muzzle launched ordnance. This flash suppressor helps control muzzle climb and reduces muzzle flash when firing at night. The M16A2 has a sophisticated rear iron sight which can be adjusted for both wind and elevation corrections. A brass deflector is also incorporated into this version to protect left-handed shooters from spent case ejection. The weapon shoulders well and points reasonably well. "Deficiencies" are that there is no good way in which to rapidly and cheaply mount a optical device on the standard weapon configuration. The handle mounting option is so poor as to be a non-option. Another system problem is the use of metal magazines. Metal, when deformed, stays deformed and if the magazine lips are damaged, the result can easily be a series of feeding malfunctions. These problems are admittedly minor and it is reiterated that the weapon has no known inherent problems with respect to its assigned mission.

To obtain the controlled burst dispersion characteristic of a "salvo" burst, three things are required: low impulse ammunition, a high cyclic rate, and a muzzle device which compensates and attenuates recoil effects. The current M16 system has none of these features. The three round burst from the M16 has no greater hit probability than the semi-automatic mode in the M16 as there is negligible contribution to increased hit performance coming from the second and third rounds of the burst. While the weapon is sufficiently accurate for military purposes, the inability to use the weapon to compensate for high aiming errors when the soldier is stressed, as in combat, is seen to be the major deficiency of this weapon and the primary underlying justification for the ACR program development effort. An extremely important but secondary characteristic of the M16 weapon system which figured heavily in the establishment of the ACR program to replace the M16 is the ammunition weight. The standard brass cased round weighs 12.5 grams while two ACR competitors have 5.0 gram or lighter ammunition.

1.4.3 Ammunition. The family of 5.56mm NATO ammunition is well known. The newest possible addition may be duplex ammunition as described in the Colt ACR section (see Figure 3.6).

APPENDIX C

PROGRAM PLANNING DOCUMENTS

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APPENDIX C

1.0 PROGRAM PLANNING DOCUMENTS.

1.1 ACR Test and Evaluation Master Plan (TEMP).

1.1.1 Purpose. The ACR TEMP relates the program objectives of the ACR to materiel performance. It is used at all levels to manage test and evaluation (T&E) and is a required milestone document.

1.1.2 History. The ACR TEMP, dated December 1988, evolved out of the need for an Advanced Combat Rifle (ACR) as detailed in the approved Operational and Organization (O&O) Plan for the ACR, dated January 29, 1985. The ACR will be the initial development within an advanced small arms family.

1.1.3 Organization. The TEMP is based on the previous DOD guidance on test and evaluation (DOD 5000.3) in the following five key areas: System Details, Program Summary, Technical Test & Evaluation (TT&E) Outline, User Test & Evaluation (UT&E) Outline, and Test & Evaluation Resources Summary.

1.1.3.1 System Details. Summarizes the required technical and operational characteristics of the ACR as found in the O&O Plan.

1.1.3.2 Program Summary. Specifies the ACR management responsibilities and specifies that the program will be controlled by a Developmental Project Officer (DPO) and supporting Project Office located within the Joint Service Small Arms Program (JSSAP) Office at ARDEC. Additionally this section organizes the formation of the Test Integration Working Group (TIWG) whose purpose is to effectively manage the many T&E requirements. Another important portion of this section is the structure and contract summary paragraphs. These paragraphs address how the program is to be executed within the Army Streamlined Acquisition Process (ASAP) and what contract efforts are planned for this program.

1.1.3.3 Technical Test and Evaluation (TT&E) Outline. Outlines the critical technical issues that must be addressed. These issues include:

1. What are the comparative hit and incapacitation probabilities and response times of test fires when engaging with the ACR concepts and M16A2 rifle under stressed conditions?
2. What are the multiple launch projectile dispersions for the ACR candidate weapon systems?
3. What safety hazards, if any, are associated with the use of the ACR concepts?

This section additionally summarizes TT&E to date and future TT&E.

1.1.3.4 User Test and Evaluation (UT&E) Outline. This section is used to crosswalk critical operational issues and criteria to specific user test and evaluation objectives. It details the method, manner, and tasks to be tested which are used to evaluate the mission performance of the ACR weapon system with respect to the evaluation issues as defined by the user.

1.1.3.5 Test and Evaluation Resources Summary. This section represents a summary of T&E resources required by specific tests planned through the life-cycle of the ACR program (e.g. contractor tests, field experiments, and concept evaluation program (CEP)).

1.2 ACR System MANPRINT Management Plan (SMMP).

1.2.1 Purpose. The purpose of this plan is to outline MANPRINT issues and concerns which should be monitored during the ACR's development and acquisition cycle.

1.2.2 History. The SMMP was developed after the approval of the ACR O&O Plan and reflects system deficiencies and MANPRINT requirements stated by the O&O Plan. The U.S. Army Infantry School (USAIS) will be the user proponent lead agency for MANPRINT in the ACR acquisition process.

1.2.3 Scope. The SMMP addresses the overall MANPRINT Strategy for the ACR by detailing specific objectives and concerns.

1.2.4 MANPRINT Strategy Objectives. The ACR MANPRINT Strategy centers around six specific areas which are summarized as follows:

1. Manpower - Ensure that the system has minimal impact upon manpower requirements for employment and maintenance.
2. Personnel - Ensure that the system can be fielded without the requirement for additional MOS or increases in overall skill levels.
3. Training - Ensure that the current level of marksmanship training and range/support resources will be adequate to enable the soldier to meet ACR performance requirements.
4. Human Factors Engineering - Ensure that the system is user friendly.
5. System Safety - Analyze new technology designs to eliminate system safety risks, or reduce them to an acceptable level.
6. Health Hazards - Eliminate health hazard risks or reduce them to an acceptable level.

It is the overall goal of the MANPRINT Strategy to ensure that MANPRINT issues are incorporated into program documents so as to avoid the MANPRINT shortcomings of the current M16A1 and M16A2 systems.

1.2.5 Supporting Documentation. The remainder of the SMMP is devoted to MANPRINT supporting documentation which outlines and summarizes the MANPRINT task descriptions, key questions to be resolved in the six major objective areas, and points of contact for MANPRINT/ACR coordination.

1.3 ACR Integrated Logistic Support (ILS) Plan.

1.3.1 Purpose. The integrated logistics support plan for the ACR provides the transition from research and development to readiness. The objective of the plan is to design supportability into the equipment. Supportability includes all the items required to keep the mission equipment ready after it is fielded (e.g. repair parts, operator's and maintenance manuals, and training development). The ILS Plan for the ACR was prepared by the Integrated Logistic Support Manager (ILSM) at HQ AMCCOM, Rock Island in coordination with the ACR office at ARDEC.

1.3.2 Organization. The ACR ILS Plan is divided into three main categories:

1. System Description and Application - Details the need for and goals of an ACR and describes the several concepts/technologies being explored.
2. Logistic Management - Lists the ILS management team members, program milestones, planned production schedule, program status and applicable references.
3. Plans, Goals, and Strategy - Highlights the operational and organizational (O&O) plan, the acquisition strategy, the logistic support analysis (LSA) strategy, and the test and evaluation master plan (TEMP).

1.3.3 ILS Elements Plan. This portion of the ILS Plan provides an overview of the major areas associated with ILS. These areas include design influence, maintenance plan, manpower and personnel, supply support, support equipment and TMDE, training and training devices, computer resources support, packaging, handling, and storage, transportation and transportability, facilities, standardization and interoperability, MANPRINT, logistic resource funds, and material fielding plan.

1.4 ACR Production Readiness Master Plan (PRMP).

1.4.1 Purpose. The ACR program's PRMP is designed to describe the system producibility and production program strategy, along with associated accomplishments and risks. The PRMP is required by AR 70-1, AR 70-72, and AMC-R 70-66 and will be updated prior to each milestone decision review.

1.4.2 History. During the Proof of Principle (POP) phase for the selection of the best ACR technical approach four technologies were in contention. The ACR concepts under evaluation were developed by AAI, Colt, H&K and Steyr.

1.4.3 Program Strategy for Manufacturing.

1.4.3.1 Purpose. The ACR program strategy incorporates early involvement by the system designers and manufacturing planners to ensure system producibility and to accomplish all planning necessary to ensure production readiness.

Specific acquisition strategy objectives include:

1. Obtain competition throughout the ACR program.
2. Ensure that guidance technology selection is based on a hardware POP evaluation.
3. Consider should-cost goals and objectives to reduce cost and efforts by reduction of non-value-added requirements wherever possible.

4. Ensure implementation of Total Quality Management (TQM) by requiring the FSED contractors to submit a program plan with their proposal.
5. Achieve the status of two independent qualified sources for system production by end of FSED.
6. Facilitize a government owned facility to meet the mobilization requirement for ammunition.
7. Use cost/schedule control criteria, design to cost, and management reviews to identify and combat cost overruns.
8. Use design-in growth potential to meet requirements of the evolving threat.

1.4.3.2 Functional Effort Integration. This section provides an overview of the following strategies that must be integrated into the PRMP:

1. Producibility Engineering and Planning (PEP).
2. Value Engineering (VE) Program Strategy.
3. Manufacturing Technology (MANTECH) Program Strategy.
4. Industrial Preparedness Planning (IPP) Program Strategy.
5. Corrosion Prevention and Control (CPC) Program Strategy.
6. Configuration Management (CM) Program Strategy.
7. Total Quality Management (TQM) Program Strategy.
8. Technical Data Package (TDP) Program Strategy.
9. Production Testing Strategy Overview.

1.4.3.3 Transition Plan. The government's transition plan includes the utilization of the PRMP and the contractor's Producibility Program Plan and Production Plan.

1.4.3.4 Program Status and Risk Assessment. This section describes the programs status, future milestones, and risk assessments based on technical, cost, and schedule analysis.

1.5 Small Arms Master Plan (SAMP).

1.5.1 Purpose. The Small Arms Master Plan (SAMP) identifies and outlines Army goals and desired characteristics for small arms through the near term into the 21st century. The SAMP is not a requirements document but a vehicle developed by TRADOC and AMC to stimulate small arms technology. The SAMP's objective is to develop the optimum type and mix of small arms and munitions on the future battlefield in the most cost effective manner.

1.5.2 History. The cornerstone of the SAMP, dated 1 September 1989, is the U.S. Army Infantry School's "Small Arms Strategy 1995," 22 March 1986. This strategy focused on small arms development and fielding in two areas: near term, and future.

Near Term - This area is represented by the ongoing fielding of new weapons such as: MK19 Mod 3 Grenade Machine Gun, M249 Squad Automatic Weapon (SAW), M16A2 Rifle, M24 Sniper Weapon System (SWS), M4 Carbine and the M9 pistol.

Far Term - This area focuses on the development of an objective family of small arms (OFSA) that incorporates leap ahead technology to insure 100 percent and above increases in hit probabilities. The objective family of small arms is viewed as a three-member family consisting of an individual combat weapon, a crew-served weapon system, and a personal defense weapon. The centerpiece of the objective family is the individual combat weapon. It is expected that this objective individual combat weapon (OICW) would be developed first and the other two members of the family would follow based on the experience gained from that development.

1.5.3 Methodology. The SAMP has been structured in accordance with 8 steps of combat development methodology:

1. Identify and state the problem.
2. Analyze and project current/future threat capabilities.
3. Review available technology.
4. Develop a concept based on mission, threat and technology.
5. Draft an Operational and Organizational (O&O) Plan.
6. Conduct analysis and testing to validate concept.
7. Determine the systems programmatics.
8. Draft the concept formulation package.

1.5.4 Development Strategy.

Technology Base Blueprint - The emphasis of the small arms technology base is to provide a technology build (hardware and/or analysis) to allow for a system decision. The five technology base activity areas are: current rifle technology, bursting munitions, modular fire control, advanced crew served weapon, and leap ahead technology.

1.5.5 SAMP Transition. The transition plan for the SAMP consists of two phases. The first phase takes place from 1986 through the late 1990's with fielding of near term weapons. The second phase of transition begins with the fielding of the objective family of small arms beginning in the late 1990's with the objective individual combat weapon. The exact date for the fielding of the remaining systems depends greatly upon the maturity of the technologies that are selected for the weapons, and the availability of RDT&E/production funds.

1.5.6 Program Planning Documents. The ACR program planning documents, with the exception of the SAMP, are included in Volume VII of this report.

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