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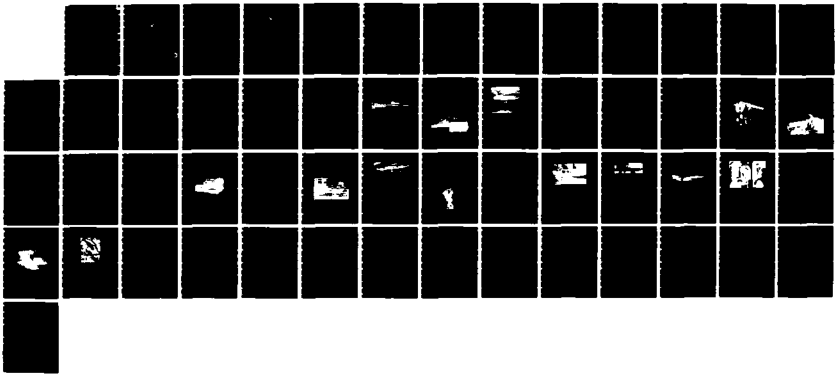

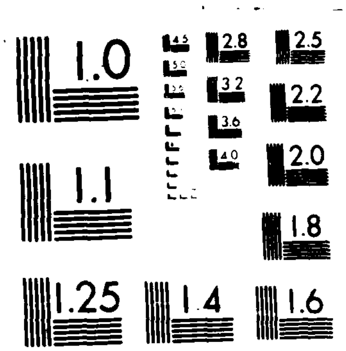

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STUDENT REPORT

THE HISTORY OF THE AERIAL GATLING GUN

MAJOR DENNIS C. CAREL 87-0415

"insights into tomorrow"

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This historical analysis traces the history of the Gatling gun as an aerial weapon. The end of World War II is the starting point for the analysis, and the focus is the development of the weapon for U.S. Air Force fighter aircraft. Chapter One examines some of the aerial combat lessons of World War II, from both Allied and German perspectives, thereby establishing a need for the weapon. The remaining three chapters look at development of the weapon, weapon deployment up through 1986, and the future beyond 1986, respectively.

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PREFACE

During the Civil War, Union inventors attempted to support the war effort by creating revolutionary multifiring mechanisms for the Army. In 1862, Dr. Richard Gatling received a patent for one such mechanism. (8:7,13) The December 1862 edition of Eclectic Magazine of Foreign Literature, Science and Art described Dr. Gatling's gun in the following manner:

> "The construction is exceedingly simple. Six rifle-barrels, of the size and caliber of the Springfield and Enfield regulation rifle, are placed in a circular frame of solid iron, in which are also placed the locks and springs which produce the explosion. The regulation cartridge of fifty-eight one-hundredths caliber is loaded into a cast-steel chamber some three inches long and capped. These chambers, to the number of fifty, are placed in a hopper, from whence they fall, one by one, into cavities prepared for them at the rear of the barrel in the same iron frame. A rotary motion is imparted by a crank, attached to a mitered gearing in the breech, and the fifty charges are discharged in sixteen seconds, or at the rate of one hundred and ninety to two hundred per minute. Several hundred chambers are attached to each gun, and as the attendants can load them as fast as they are fired, thousands of shots can be made without any necessity of intermission. The recoil is entirely overcome, the point of the barrel does not fly up, and each shot is effective at more than ordinary Enfield rifle range." (8:18)

The U.S. Army adopted the Gatling gun in 1866 and declared it obsolete in 1911. (22:88;8:156)

CONTINUED

In 1956, some 200 newsmen and other observers visited Palmdale, California to witness the first public flight of the Lockheed F-104 Starfighter--the world's fastest warplane at that time. (18:361) Upon close examination of a static F-104, newsmen discovered a curious bulge on the port side of the fuselage. "That must be the machine gun," was a remark heard by one reporter. In fact, the bulge was the gun bay for the "still secret 20mm cannon that pours out shells at the rate of 7000 rounds per minute." (18:362) The cannon, produced by General Electric and called the Vulcan, was the first gun designed specifically for supersonic aircraft. (17:19) Ironically, the Vulcan also represented an application of an 84 year old principle; the Vulcan was the world's first aerial Gatling gun. (10:28) Today, the three newest fighter and attack aircraft in the U.S. Air Force inventory, the F-15, F-16 and A-10, are all armed with Gatling guns derived from Dr. Gatling's original design.

Therefore, the purpose of this paper is to examine why and how the Gatling gun rose from the ashes of obsolescence to its position today as standard armament on front-line U.S. Air Force aircraft. The end of World War II is the starting point for this historical analysis, and the focus is the development of Gatling guns for U.S. Air Force fighter

CONTINUED

aircraft. Background information necessary to assess the need for the aerial Gatling gun is presented in Chapter One. Chapter Two is an outline of the development of the original aerial Gatling gun. Chapter Three contains a discussion of the deployment of the weapon beginning with the F-104 and concluding with the A-10. The impact of the Viet Nam War on Gatling gun employment and various Viet Nam inspired Gatling gun modifications are also discussed in Chapter Three. Chapter Four deals with the future of aerial Gatling guns and also contains the conclusion of the paper.

ABOUT THE AUTHOR

Major Dennis C. Carel graduated from the U.S. Air Force Academy in 1974 and attended Undergraduate Pilot Training at Columbus AFB, Ms. He graduated from UPT in 1975 and remained at Columbus AFB as a T-38 Instructor Pilot. In 1979, he transitioned to the F-4 and served consecutive operational tours with the 3TFS at Clark AB, R.P., the 497TFS at Taegu AB, ROK, and the 81TFS at Spangdahlem AB, Ge. Major Carel is a graduate of the USAF Fighter Weapons Instructor Course.

Additionally, Major Carel earned a Masters Degree in Systems Management from the University of Southern California and is a graduate of Squadron Officers School. Major Carel is currently a member of Air Command and Staff College class of 1987.

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GLOSSARY

AFAC—Air Force Armament Center
AFAL—Air Force Armament Laboratory
AIM—Air Intercept Missile
ATF—Advanced Tactical Fighter

CHAG—Compact Hi-Performance Aerial Gun

HE—High Explosive

in.—inch

lbs.—pounds

max—maximum
min—minimum
mm—millimeter
MRBF—Mean Rounds Between Failure

r.p.m.—rounds per minute

SEA—Southeast Asia

TFW—Tactical Fighter Wing

U.S.—United States
USAAF—United States Army Air Force
USAF—United States Air Force

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EXECUTIVE SUMMARY

REPORT NUMBER 87-0415

AUTHOR(S) MAJOR DENNIS C. CAREL, USAF

TITLE THE HISTORY OF THE AERIAL GATLING GUN

I. Background: In 1862, Dr. Richard Gatling received a patent for the world's first machine gun. His weapon used multiple barrels and an external power source to achieve rates of fire as high as 200 rounds per minute. The Gatling gun saw action during the American Civil War. The U.S. Army adopted it in 1866 and declared it obsolete in 1911.

In 1946, U.S. Army Ordnance awarded a contract to General Electric Corporation to develop a high rate of fire Gatling type weapon for use on fighter aircraft. The resulting weapon, the M-61, 20mm Vulcan Aircraft Gun, became operational in 1956.

II. Statement: Since 1956, the M-61A1, an improved version of the M-61, has become the most widely used free world fighter aircraft gun in history. It is carried by both frontline USAF fighters, the F-15 and F-16, as well as the aging F-4E. In addition, Gatling type weapons are used throughout the entire spectrum of air warfare. For example, AC-130 gunships carry both 20mm and 7.62mm Gatling guns, as do many Army helicopter gunships. Probably the best known variation of Gatling gun technology is the 30mm, GAU-8/A Avenger carried on the A-10.

CONTINUED

III. Objective: The purpose of this paper is to examine why and how the Gatling gun rose from the ashes of obsolescence to its position today as standard armament on frontline U.S. Air Force fighter/attack aircraft. The end of World War II is the starting point for this historical analysis. The focus is the development of Gatling guns for U.S. Air Force fighter aircraft.

IV. Conclusion: The Gatling gun became an aerial weapon because, after World War II, there existed a need for a reliable, relatively light weight, high rate of fire aerial gun. Dr. Gatling's original weapon design of multiple barrels and an external power source made his Nineteenth Century invention adaptable to Twentieth Century applications.

Chapter One

ASSESSING THE NEED

The genesis of the aerial Gatling gun can be traced to the end of World War II when U.S. ordnance experts recognized the need for a high rate of fire aerial gun to equip future military aircraft. This realization, coupled with the lessons of World War II, resulted in the improvement of the Browning .50 caliber machine gun. It also resulted in two advanced design guns, the M-39, a 20mm cannon, and the Vulcan cannon, a 20mm Gatling gun. Of the latter weapons, the M-39 became operational first and saw limited action in the Korean War. This chapter will use the lessons of World War II and the USAF experience in Korea to illustrate the need for a high rate of fire aerial gun.

WORLD WAR II LESSONS

Aerial guns in use during World War II were essentially ground weapons adapted for use on aircraft. In fact, USAAF fighter aircraft predominantly carried World War I vintage Browning M-2, gas operated, .50 caliber machine guns. (23:288;38:1) The specifications of the M-2 follow:

Weight of gun	61 lbs.
Overall length	56.25 in.
Operation	Recoil
Cooling	Air
Rate of Fire	750-850 r.p.m.

TABLE 1. Browning M-2 Specifications (38:1)

During World War II, all USAAF fighters carried multiple M-2 weapons and, therefore, packed sufficient firepower to destroy enemy fighter aircraft. The M-2's inability to fire an explosive round did not pose a significant problem as fighter aircraft generally had thin skins and contained flammable aviation fuel. Consequently, a P-47, carrying eight .50 caliber guns, had a high probability of hit because its total rate of fire was 6000-6800 rounds per minute (r.p.m.). This, in turn, yielded a corresponding high probability of kill.

Even though the M-2 performed well in World War II, gun experts realized that its shortcomings would limit its future effectiveness. The USAAF had compensated for the M-2's major limitation, a low rate of fire, by employing multiple guns on fighter aircraft. However, aircraft developments late in World War II sealed the fate of the M-2.

Germany's introduction at war's end of the Me-262, their first operational jet fighter, meant that future aerial combat would feature high performance aircraft. Time available for lethal gun shots would be measured in split seconds. High rates of fire would be necessary to guarantee sufficient bullets in the air for a lethal shot. [NOTE:

Muzzle velocity may also impact the probability of hit. However, the Germans found that, within certain limits, the number of shots required for a hit and the muzzle velocity involved were independent. (15:44)] The World War II practice of carrying more guns would not be feasible because of the aircraft performance penalty associated with the extra weight.

The initial solution to the problem came in the form of the M-3, an improved M-2 with a fifty per cent increase in firepower. The specifications of the M-3 follow:

Weight of gun	64.60 lbs.
Overall length	57.20 ins.
Operation	Recoil
Cooling	Air
Rate of fire	1150-1250 r.p.m.

TABLE 2. Browning M-3 Specifications (38:4)

The Browning M-3 illustrates how the lessons of World War II influenced the thinking of U.S. gun experts. Since it retained the .50 caliber size of the M-2, probably because of the M-2's success in World War II, its increase in firepower derived solely from the increase in the rate of fire. By opting for a faster .50 caliber gun, the U.S. had adopted an easy, inefficient solution to the problem posed by future fighters. The M-3 could put more bullets in the air, but each bullet possessed no more killing power than those of the M-2. The U.S. needed a large caliber, high rate of fire aerial gun, not another ground weapon modified for aerial use. Ironically, the Germans, spurred by their World War II lessons, would provide a start for U.S. aerial gun development.

The German aerial combat experiences during World War II illustrate the relationship of caliber to firepower. Their problem in aerial combat differed from that of the Allies because their targets included both thick-skinned B-17 bombers and Allied fighters. In that environment, a high probability of hit does not equate to a corresponding high probability of kill unless the bullet is of sufficient size to do damage. German experience showed that it took 50-100 hits with 12.7mm (.50 in.) projectiles to down a B-17. By way of comparison, they obtained similar results from only 18-20 hits with 20mm high explosive (HE) projectiles, or four hits with 30mm HE projectiles. (15:44) Not surprisingly, the Germans believed that the problem resolved itself into developing an aerial gun of the largest caliber within the weight constraints of the aircraft. They considered 30mm adequate for air-to-air work and, consequently, built several 30mm guns. Among these was the Mauser MG-213C, which had a rate of fire of 1500 r.p.m. (15:45) U.S. forces later captured an MG-213C intact and U.S. gun experts eagerly exploited the weapon. (16:37)

The exploitation of the MG-213C, coupled with events which took place in the U.S. Army Ordnance's Small Arms Branch in 1945 (these events will be discussed in Chapter Two), mark the beginning of U.S. efforts to build a high rate of fire aerial gun suitable for jet combat. The key year in U.S. aerial gun development is 1946, because

U.S. Army Ordnance awarded two contracts for advanced technology gun research and development. The development of a high rate of fire aerial cannon was the goal of both contracts. [NOTE: Weapons of 20mm size or greater are considered cannon and can fire explosive rounds; smaller weapons are machine guns.] One contract, awarded to Armor Research Foundation of Illinois Institute of Technology, called for the development of an MG-213C type weapon. (16:37) General Electric Corporation received the other contract which directed the development of a Gatling principle type machine gun. (18:364) In spite of these efforts, the USAF failed to field a new weapon prior to its 1951 entry into the Korean War. At that time, its hottest fighter, the F-86, still carried six M-3, .50 caliber machine guns. (20:4)

Korean War Experience

During the Korean War, the Communist forces used Russian-built Mig-15 jet fighters which presented USAF fighter pilots with all the problems associated with jet aerial combat. The problems were higher speeds, relatively non-volatile fuel and aircraft with stressed skins to withstand the rigors of high speed flight. (20:4;23:258) The stressed aircraft skin, coupled with the non-volatile fuel, appeared to make the .50 caliber machine gun, and its non-explosive rounds, obsolete. Consequently, the USAF needed an aerial cannon, just as the Germans needed one in World War II.

Ironically, the F-86 enjoyed a 10-1 kill ratio during the Korean War. The USAF leadership, however, realized that the reasons for the success lay with superior aircrew training and an excellent fire control system on the F-86, rather than superior firepower. (14:14) The M-3, in fact, was obsolete. In jet combat, with all things being equal, its high rate of fire could not compensate for its small size. In spite of USAF success in Korea, pressure to field an aerial cannon increased. The 20mm M-39 (FIGURE 1) resulted from that pressure. (9:21)

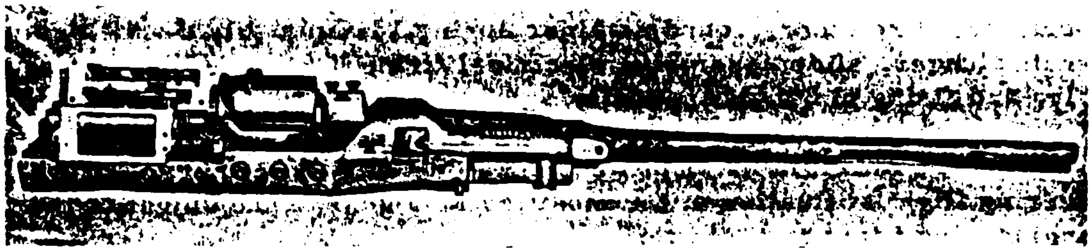

FIGURE 1. M-39 20mm Cannon (Air Force Photo)

The M-39 descended from the exploited MG-213C. Produced by Ford Motor Company, it achieved high rates of fire by using one barrel and a five-chamber revolving breech. (23:258) The M-39 specifications follow:

Weight of gun	180 lbs.
Overall length	72 in.
Operation	Recoil
Cooling	Air
Rate of fire	1700 r.p.m.

TABLE 3. M-39 Specifications (18:361,363)

Compared to the M-3, the M-39 represented a quantum leap in killing power. Several F-86F aircraft, fitted with four M-39's each, deployed to Korea late during the war and demonstrated this fact. (FIGURE 2) In a short period of time, these modified F-86 aircraft destroyed six Mig-15 aircraft, damaged twelve others and claimed three more probable kills. (9:21;18:363) These successes proved the value of the large caliber, high rate of fire aerial gun. The M-39 had been a breakthrough in gun technology. Because it represented the state of the art, it is not surprising that the F-100 Super Sabre (FIGURE 3) came off the assembly line in 1954 armed with four M-39's. (5:115,133) However, as the next chapter will show, the M-39 would be no match for General Electric's Gatling gun.

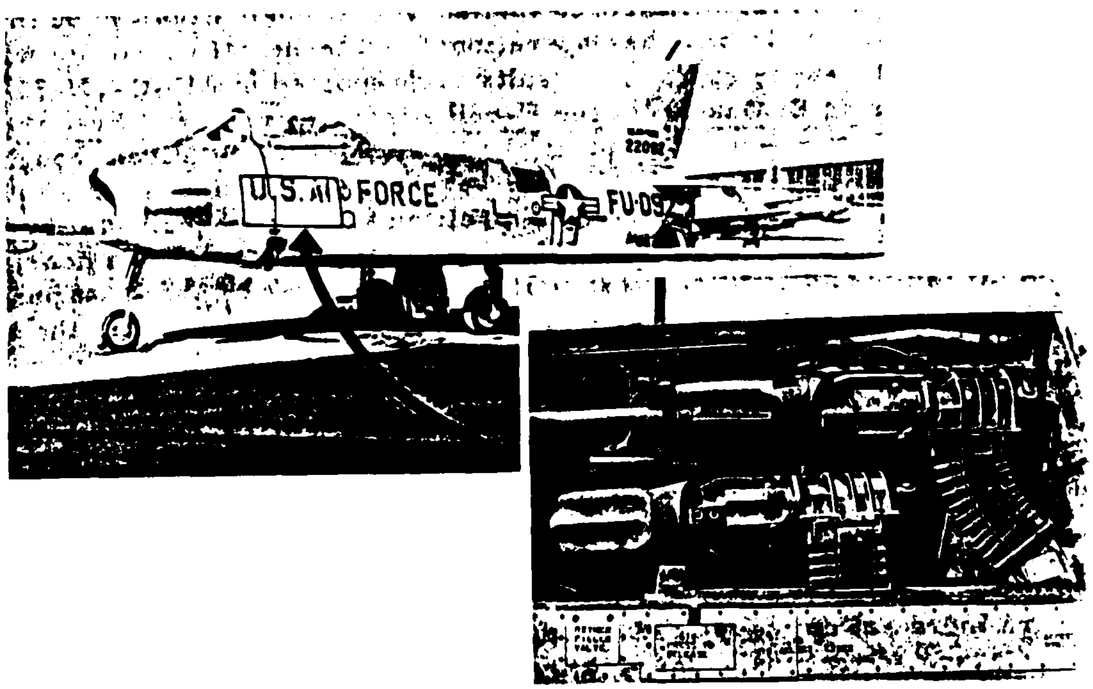

FIGURE 2. F-86 Aircraft With M-39 Installed. (Air Force Photo)

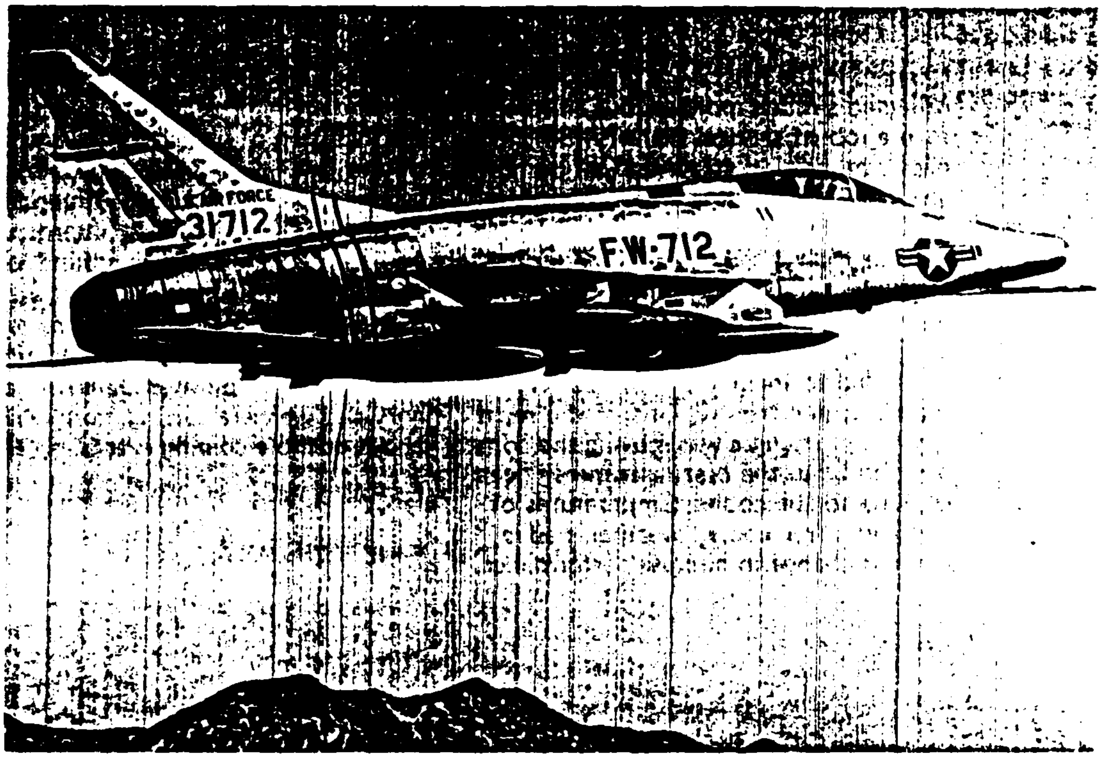

FIGURE 3. F-100 Super Sabre (Air Force Photo)

CHAPTER TWO

DEVELOPMENT OF THE VULCAN

As stated in Chapter One, 1946 became a key year for U.S. aerial gun development when the USAF initiated development contracts for the M-39 and the Vulcan cannon. The M-39 proved the value of the 20mm cannon in aerial combat and signaled the end of the Browning .50 caliber machine gun era. Although not declared operational until 1956, the Vulcan cannon quickly made the M-39 obsolete. This chapter will detail the development of the Vulcan cannon from the idea stage through its testing and development and then compare the two weapons. The comparison will show that the Vulcan is a superior weapon to the M-39 because of the strength of Dr. Gatling's original design.

THE IDEA TAKES SHAPE

Col. Rene R. Studler's U.S. Army Ordnance Research and Development Service, Small Arms Branch, put forth the idea for the aerial Gatling gun in 1946. No one in the office claimed sole credit for the idea, but it probably stemmed from the fact that Dr. Gatling had received a patent in 1893 for an electric motor attached to his gun. He generated a rate of fire of 3000 r.p.m., but dismissed the idea as having little utility. (10:29;23:1092) Nevertheless, after studying all machine gun patents, the Small Arms Branch decided that the Gatling system offered the greatest potential for a modern aircraft gun. The reasons for the assessment were the tremendous rate of fire possible and the reliability of a design incorporating an externally powered cluster of barrels. (8:156) The use of multiple barrels reduced the erosion and heat generation associated with high cyclic-rate guns. They also permitted cooler, more reliable operation with minimum chance of overheated ammunition exploding prematurely and wrecking the gun. (8:156;17:19)

Based on these preliminary findings, Johnson Automatics, Inc. of Providence R.I. received a feasibility study contract. Col. Melvin M. Johnson, inventor of the Johnson Semi-automatic Rifle and the Johnson Light Machine Gun, headed the firm. He attached an electric motor to an 1883 vintage, ten barrel, 45/70 Gatling gun. By firing an electrically timed fifty round burst, he attained a firing rate of 5800 r.p.m. Colonel Johnson submitted his feasibility report in 1946 with recommendations for the adaptation of a power driven Gatling system for aircraft use. (8:157)

In June 1946, General Electric received a contract to build an aerial Gatling gun. The undertaking became known as "Project Vulcan"; Vulcan is the Roman mythological god of fire and metalworking. Preliminary design specifications of the Vulcan gun included the following requirements:

Caliber	.60
Number of barrels	5-10
Barrel length	60 in.
Overall gun length	80 in.
Total weight	100 lbs/barrel(max)
Rate of fire	1000 r.p.m./barrel(min)

TABLE 4. Preliminary Vulcan Specifications (18:364;8:157)

The first design of the test gun had five, sixty inch barrels grouped in a circle and fastened at the breech end to a single member. It had an additional support two feet forward of the breech end. Completed and fired by April 1949, this model achieved a rate of fire, in short bursts, of 2500 r.p.m. By June 1950, improvements in the gun brought the firing rate to 5000 r.p.m. and by September 1950 to 6000 r.p.m. (18:364;8:157)

TEST AND DEVELOPMENT

Development continued and, by mid-1952, several models of the gun existed. The .60 caliber gun received a designation of T-45A (FIGURE 4) with improved models designated T-45B and T-45C. (28:1) When the T-45C later changed to a 20mm weapon, its designation became the T-171C. (28:1;18:364) [NOTE: A 27mm gun, T-150, also existed for a short period of time, but General Electric subsequently dropped the design. (18:364)] The T-45A had a steady state rate of fire of 4000 r.p.m. and weighed 435 pounds. The rate of fire of the T-45C was 4600 r.p.m. and it weighed 365 pounds. (28:1) The Air Force ordered twenty-seven of the model C guns for testing with delivery starting in

August 1952. (18:364;28:1) General Electric built the first twelve model C guns as .60 caliber weapons, so the Air Force received twelve .60 caliber T-45C and fifteen 20mm T-171C weapons for testing. Later, the Air Force redesignated the T-45C/T-171C weapons as T-45E1/T-171E1, and testing began on both weapons. Eventually the Air Force modified all T-45 weapons to T-171 weapons because they performed better and 20mm ammunition stacked better than .60 caliber ammunition. (28:1)

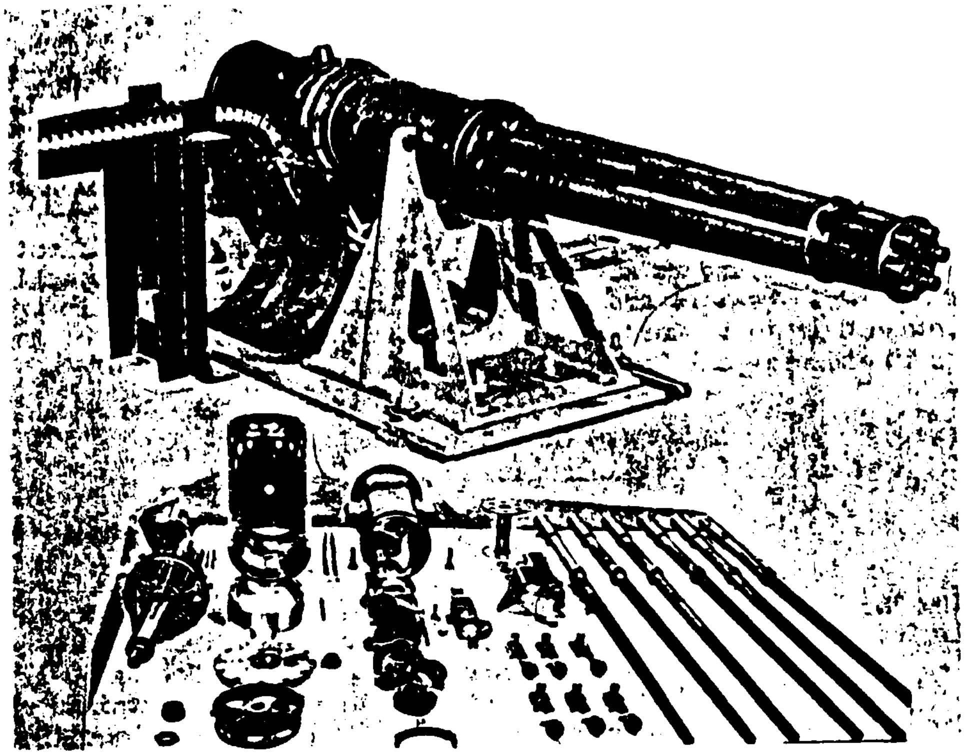

FIGURE 4. T-45 Model A Gun (Air Force Photo)

The Air Force Armament Center (AFAC), under the auspices of "Project Gun-Val", tested the T-45E1/T-171E1 gun. (29:1) Testing centered around evaluating the parts life of the weapon and the effects of extreme cold and high altitude on its operation. AFAC also evaluated the installation/compatability of the weapon with the F-94B and the A-5 gun turret on the B-47.

Generally speaking, the T-171E1 lived up to expectations and performed well in the testing. Modifications occurred throughout the testing process and the T-171E1 eventually became the T-171E3. (FIGURE 5) Major modifications included the following:

1. A lightweight barrel design reduced the weight of the T-171E2 to 265 pounds. More rigid construction reduced dispersion in the T-171E3 but increased the weight to 295 pounds. (29:1)

2. Maximum rate of fire (D rate) increased from 4600 r.p.m. for the T-171E1 to 6000 r.p.m. for the T-171E2 and T-171E3. (29:2)

3. The T-171E3 system incorporated a rotary drum ammunition feed system. (31:1)

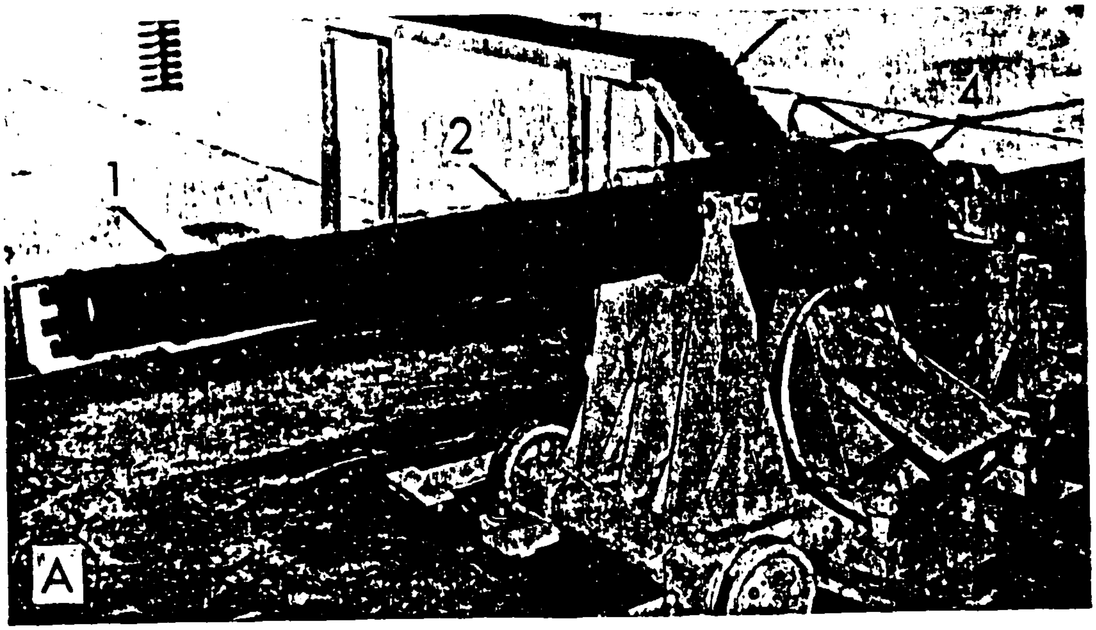

FIGURE 5. T-171E3 Weapon Without Drum Feed System
(Air Force Photo)

COMPARISON OF THE VULCAN AND M-39

The result of the testing and modification process was a weapon technologically superior to the M-39 in many respects. However, the technology which allowed the T-171 to outperform the M-39 did not derive solely from new materials or construction methods. Instead, the basic gun design, originally patented by Dr. Gatling, gave the T-171 its technological edge. A technological edge so great, in fact, that Gen. Bruce K. Holloway, Vice Chief of Staff, USAF, later wrote that "The Vulcan 'Gatling' gun is an order-of-magnitude improvement over our early Korean War 20mm aircraft cannon..." (13:460) Two areas, rate of fire versus total gun weight and weapon reliability/barrel life, are the best examples of this edge.

The M-39's 1700 r.p.m. with a weight of 180 pounds represented an improvement over the Browning M-3, especially when one considers the killing power of 20mm compared to .50 caliber. Both the M-39 and the M-3 maintained relatively low weights by being gas operated--gun gases operated the gun mechanisms. The T-171, in contrast, required an external power source (electric or hydraulic motor) to operate its mechanism. Hence, the external power source added weight to the total system and the T-171 weighed 295 pounds. Even though this represented a roughly seventy-five per cent weight increase over the M-39, the T-171 generated a rate of fire four times that of the M-39. Therefore, it took four M-39s, weighing a total of 680 pounds, to equal the firepower of one T-171. The reason is that a single mechanism fed all the barrels, just as in Dr. Gatling's original gun. (10:28) Also, because the gun had an external power source, "dud" rounds did not cause the gun to stop. This allowed the firing of each round to be independent of the previously fired round—another feature of the original Gatling gun which made the T-171 a superior weapon. (10:28) During testing, the M-39 experienced a stoppage rate of 1.1 per 1000 rounds fired (27:iii). In contrast, the T-171E3 experienced a rate of .1 per 1000 rounds fired. (29:1)

Weapon reliability/barrel life is the other area where the T-171 enjoyed an edge over the M-39. Gun reliability in high cyclic guns is often reduced by barrel erosion and excess heat. Both are by-products of high rate of fire weapons, and both have the effect of shortening barrel life and gun parts life. For example, when the M-39-armed F-86F aircraft deployed to Korea, barrel replacement occurred after 200-300 rounds. (25:138) Later testing of a Ford-modified M-39 established service life of the weapon to be in excess of 4000 rounds fired. (27:iii) Even though test weapons are fired in short bursts and combat weapons are fired as required, the Ford-modified M-39 demonstrated a greater reliability than the Korean War model. Therefore, increasing gun parts life and barrel life increases gun reliability. The T-171 solved both problems.

First, the constant stop and start of a gas operated gun has an increasingly destructive effect on gun parts. A Gatling gun, because of its constant rotation, does not have the same destructive effect. (10:28) The T-171, with its six barrels, also solved the problem of gun barrel erosion. Each barrel had a lower per-barrel rate of fire than the total output of the weapon. The result is reduced heat generation with a corollary effect of less barrel erosion and longer life. (10:28)

For the record, the T-171E1 had an established gun life of 40,425 rounds. The weapon received no major maintenance until after 10,000 rounds had been fired. Likewise, a stoppage attributable to the gun did not occur until after 35,000 rounds had been fired. (26:2) While these numbers are impressive, it should be noted that the test weapon fired bursts of only 150 rounds (approximately 1.5-2.0 seconds) in length. Testing of the T-171E3 three years later resulted in a somewhat more realistic assessment of the expected life of the weapon. After firing 214,379 rounds at C rate (4000 r.p.m.), all parts exhibited a minimum life of 6000 rounds. (25:iii)

In 1956, the U.S. Air Force and Army standardized the T-171 gun as the M-61, 20mm Vulcan Aircraft Gun, and ordered it into production. Subsequent improvements resulted in a redesignation as the M-61A1. (FIGURE 6) The M-61A1 specifications follow; the service life is particularly noteworthy:

Weight of gun	255 lbs.
Overall length	72 in.
Number of barrels	6
Operation	External power
Cooling	Air
Rate of fire	Up to 7200 r.p.m.
Service Life	100,000 MRBF

TABLE 5. M-61A1 Vulcan Specifications (8:159;40:--)

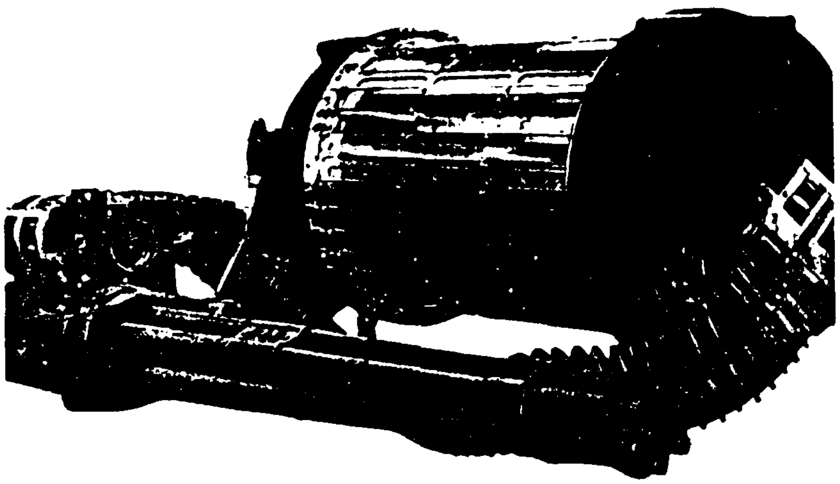

FIGURE 6. M-61A1 Vulcan With Rotary Drum Linkless Feed System (Air Force Photo)

CHAPTER 3

DEPLOYING THE VULCAN

Chapters One and Two have shown that U.S. aerial combat lessons of World War II and Korea drove the development of the Vulcan. However, the initial aircraft to receive the weapon performed primarily air-to-ground missions. Ironically, the lessons of another war, the Viet Nam War, would finally force the Vulcan into an air superiority fighter and expand the applications of the Gatling gun itself. This chapter will outline the initial deployment of the Vulcan Gatling gun, the lessons of the Viet Nam War, the eventual use of the Gatling gun in the air combat arena and the alternate applications of the Gatling gun as a result of the Viet Nam lessons. A discussion of post-Viet Nam Gatling employment culminating with today's ultimate anti-armor weapon, the 30mm, GAU-8/A Avenger carried by the A-10, will conclude the chapter.

INITIAL DEPLOYMENT

The Vulcan had been designed with the supersonic fighters in mind, and the F-104 (FIGURE 7) and F-105 (FIGURE 8) had been designated as recipients. Even though the weapon performed reasonably well in testing, it ran into problems when it mated with, and ground fired in, the F-104A mockup (30:--) and F-105B mockup. (32:--) Consequently, the Air Force accepted operational models of both jets without the weapon installed. The F-104A, accepted by the Air Force in January 1956, did not have a Vulcan cannon. The F-104C, accepted in October of the same year, did have the weapon. The Air Force later retrofitted the F-104A's. (5:183,188-189) Likewise, the F-105B, accepted by the Air Force on 27 May 1958, did not contain a gun. However, the F-105D, accepted on 28 December 1960, and the later F-105F, contained the M-61A1, 20mm Gatling gun. (5:205)

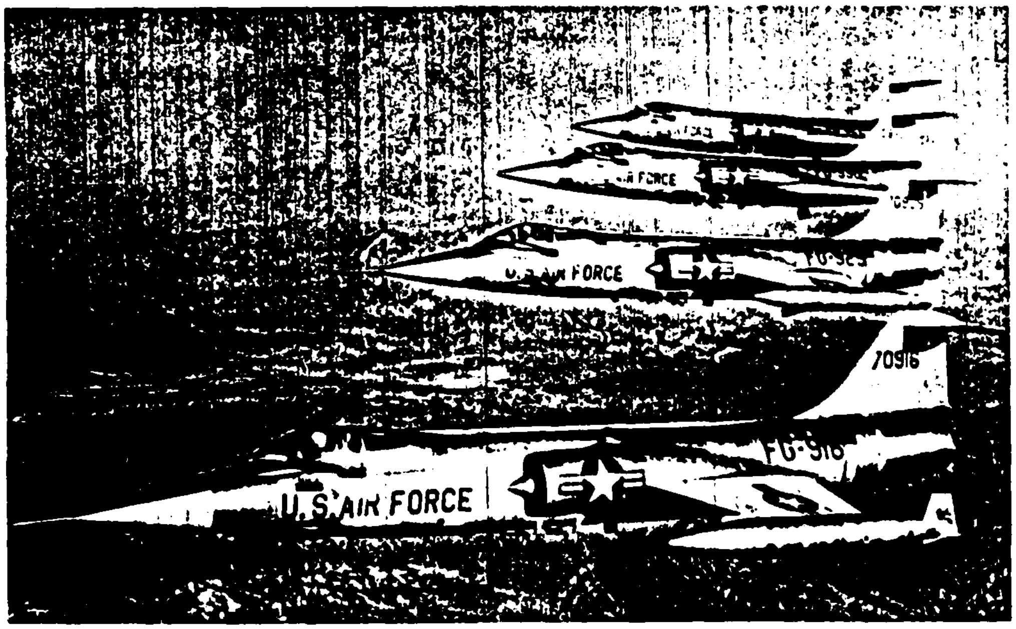

FIGURE 7. F-104 Starfighters (Air Force Photo)

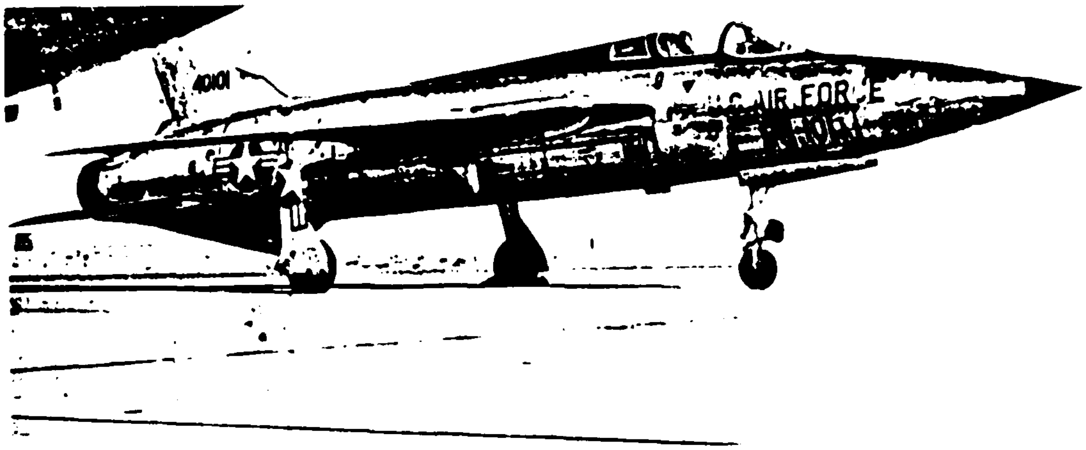

FIGURE 8. F-105 Thunderchief (Air Force Photo)

Ironically, the Vulcan, which had been conceived and built as a result of aerial combat experiences in World War II, finally reached operational status in the F-104C. Its purpose being to augment the F-104's ground attack capabilities. (6:28) Similarly, the next aircraft to receive the Vulcan, the F-105, possessed a primary nuclear strike role. (5:191) In fact, the Vulcan would not be deployed in an air superiority fighter until 1967, when it became an integral part of the armament suite of the F-4E. (5:277) In the interim, it would find itself used in the A-7, a Navy/Air Force ground attack jet, (7:641) and the F-111, an aircraft initially postulated to have an air defense capability but ultimately employed exclusively in a strike role. (5:224) The Vulcan also found its way into the air as defense for the B-58 and the B-52H. (8:161)

The lack of the Vulcan, or any internal gun, in the weapon suite of the F-101, F-102, F-106 and the early F-4 models did not result from poor performance by the Vulcan. It resulted, rather, from a change in tactical thought within the Air Force. [NOTE: The Air Force later retrofitted the F-106 with a M-61A1 Gatling gun in the early 1970's. (5:219)] Advances in technology had made air-to-air missiles the weapons of the future for interceptor aircraft. Missiles could be controlled in flight, could travel greater distances than bullets without risking aircraft or aircrews, and were more accurate than guns. (19:42) For these reasons, the Air Force cancelled all aerial gun and rocket development in 1957 in favor of missile development. (11:383) As a result, the F-4C, the Air Force's newest fighter, deployed to Southeast Asia (SEA) in 1965 inadequately armed for the war it would face.

"HOKAY, YANKEE AIR PIRATE, DRAW!!!"

(SOURCE: USAF Fighter Weapons Review, Summer 1978)

SOUTHEAST ASIA EXPERIENCE

Air-to-air missiles of that time functioned at longer ranges, but they had three very critical weaknesses. First, enemy pilots could outmaneuver visually acquired missiles. (19:43) Secondly, an alert enemy pilot could maneuver his cannon armed aircraft inside the minimum firing range of the missile rendering it ineffective. (19:43) Lastly, enemy aircraft flying at low altitude provided radar clutter and alternate heat sources to radar missiles and heat missiles, respectively.

The 366 Tactical Fighter Wing (TFW) highlighted the latter two weaknesses on 5 May 1967 by informing Seventh Air Force (7AF) that "This wing has lost [a] minimum [of] seven kills in the past ten days because of a lack of kill capability below 2000´ altitude and inside 2500´ range." (34:1) The problem stemmed from "new MIG tactics which use ground clutter to mask our missile capability." (34:1) The SUU-16 gun pod, a Vulcan cannon that could be carried on the weapons pylons of an F-4 aircraft, became the solution to the problem. (FIGURE 9) The 366 TFW described the SUU-16 gun pod as "the only air weapon than can be employed against very low altitude aircraft." (34:1) On 14 May 1967, two members of the 366 TFW became the first crew to down a Mig with the SUU-16. (34:5)

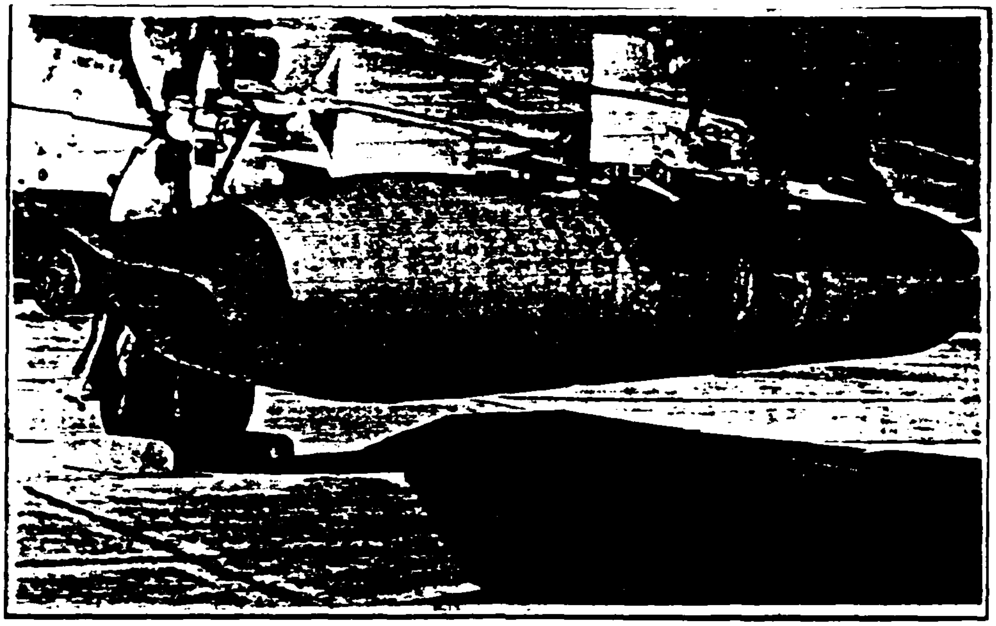

FIGURE 9. SUU-16 Gun Pod (Air Force Photo)

Even though the SUU-16 performed well, there existed room for improvement. Because they are carried externally and not built into the airframe, gun pods add aerodynamic drag to the aircraft. Aerodynamic drag decreases aircraft performance. The ram air turbine (RAT) that powered the SUU-16 accentuated this problem because it extended into the airstream. The SUU-23 (FIGURE 10) solved the problem of the SUU-16 because it used the XM-130 self-powered version of a standard M-61A1 20mm gun. The XM-130 used a combination of aircraft electrical power and a gun gas drive for power instead of a RAT. (41:8,10)

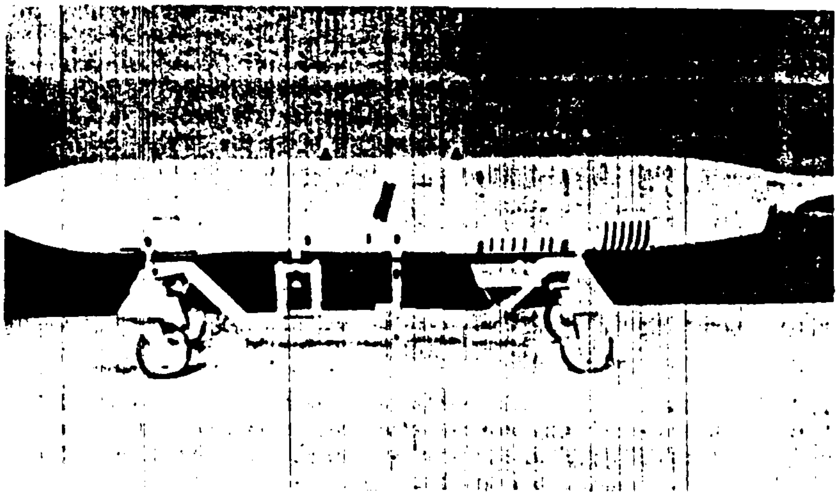

FIGURE 10. SUU-23 Gun Pod (Air Force Photo)

The success of the 20mm gun pods, coupled with the ability of Mig pilots to neutralize the effectiveness of air-to-air missiles, provided support to advocates of a gun-armed air superiority fighter. As a result, on 3 October 1967, the Vulcan cannon-armed F-4E (FIGURE 11) entered operational service. (5:279) The marriage of the F-4E and the Vulcan is significant because it represents the first employment of an aerial Gatling gun as a primary air-to-air weapon. The F-4E/Vulcan combination provided pilots with an expanded aerial fighting capability. Lt. General Thomas P. Gerrity, Deputy Chief of Staff, Systems and Logistics Headquarters, detailed the significance of this new weapon system in a statement before the Ninetieth Congress' Committee on Armed Services.

"The F-4E...has an internal M-61 20mm Gatling gun in the nose of the aircraft,...This version with the internal gun [F-4E] is eagerly awaited by our tactical forces because of the advantage it will provide in air-to-air engagements. When visual identification of the enemy is required our fighters, armed only with air-to-air missiles, are often too close to attack after positive identification is made. Having an internal gun will allow pressing the attack at close range while a position advantage still exists, rather than requiring further maneuvering to get in a position suitable to utilize missiles." (41:948)

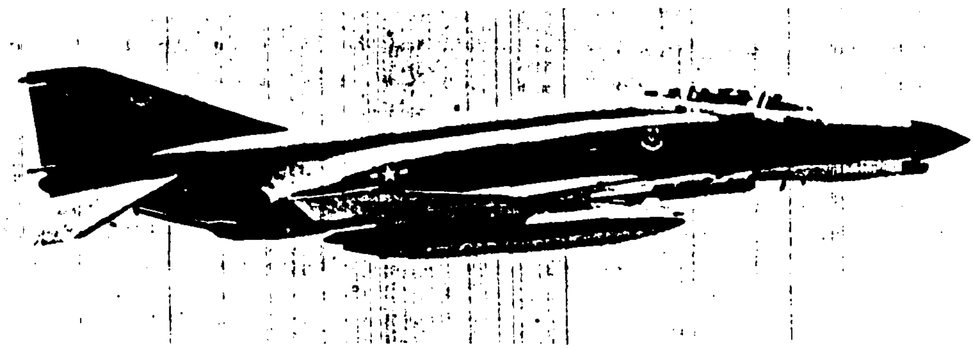

FIGURE 11. F-4E Phantom II (Air Force Photo)

Besides reinforcing the value of the cannon in aerial combat, the war in Southeast Asia also showed that there existed a need for flexible and versatile aircraft weapons with extreme firepower. (21:--) The 20mm gun pods provide good examples. Besides being carried as air-to-air weapons by the F-4, 20mm gun pods also saw action on the F-100 augmenting its close air support role. (21:315) These gun pods, however, had limited applications because of their weight; the SUU-16 weighed approximately 1600 pounds. (8:161) The GAU-2/A, a lightweight, 7.62mm Gatling gun developed by General Electric in 1963, became the primary weapon in situations where the heavyweight Vulcan was unsuitable. (FIGURE 12)

FIGURE 12. GAU-2 7.62mm Gatling gun (Air Force Photo)

General Electric designed the GAU-2/A (or M134) Aircraft Machine Gun (Minigun) as a fast-firing, lightweight armament package for helicopters and other light aircraft. It made use of proven M-61 Vulcan design principles, fired a 7.62mm North Atlantic Treaty Organization (NATO) standard round at up to 6000 r.p.m., weighed approximately fifty-two pounds (without ammunition) and had a design life of 100,000 rounds. (33:--;8:162,163) The GAU-2/A, and the newer GAU-2B/A, have been used in at least twenty-five aircraft and helicopter weapon subsystems. (7:1092) The following examples typify the versatility of this Gatling system:

(1) The Bell AH-1 Huey Cobra (attack helicopter) carried various combinations of GAU-2B/A miniguns and grenade launchers in its chin turret. (7:1310)

(2) The AC-47 gunship carried three GAU-2B/A guns giving it a capability of firing 18,000 r.p.m. (1:30) A follow-on gunship, the AC-130 Spectre, carried up to four GAU-2B/A and four M-61 Vulcan cannon. (1:139)

(3) Aircraft which could not carry an internal GAU-2/A carried the SUU-11/A gun pod. This pod utilized the minigun with a linkless feed system similar to the M-61A1 and a self-contained battery powered electric motor drive. It weighed 250 pounds and had an ammunition capacity of 1500 rounds. (8:163)

The GAU-2/A is not the only example of modifications to the original Vulcan design inspired during the Viet Nam War period. By making changes in the feeder, housing, bolts and barrels, it is possible to make a new gun which fulfills another need in battle. For example, helicopter gunships in Viet Nam used a three barrel 20mm Gatling gun, the M197, capable of firing 3000 r.p.m. (7:1106;8:132) The demonstrated versatility and adaptability of the Vulcan system guaranteed the Gatling gun's place on all USAF fighters procured since the F-4E.

POST SOUTHEAST ASIA

Since the war in Viet Nam, three fighter/attack aircraft have been purchased by the USAF--the F-15, F-16 and A-10. All three carry a

Gatling gun. In the case of the F-15 and F-16, it is a 20mm Vulcan. (3:410,451) [NOTE: The Air Force did attempt to arm the F-15 with a Philco-Ford 25mm Gatling gun, the GAU-7, which fired caseless ammunition. (7:1092) Philco-Ford later abandoned the project because they could not perfect the caseless ammunition. (19:44)] The A-10 carries the 30mm, GAU-8 Avenger. (3:398) (FIGURES 13 and 14)

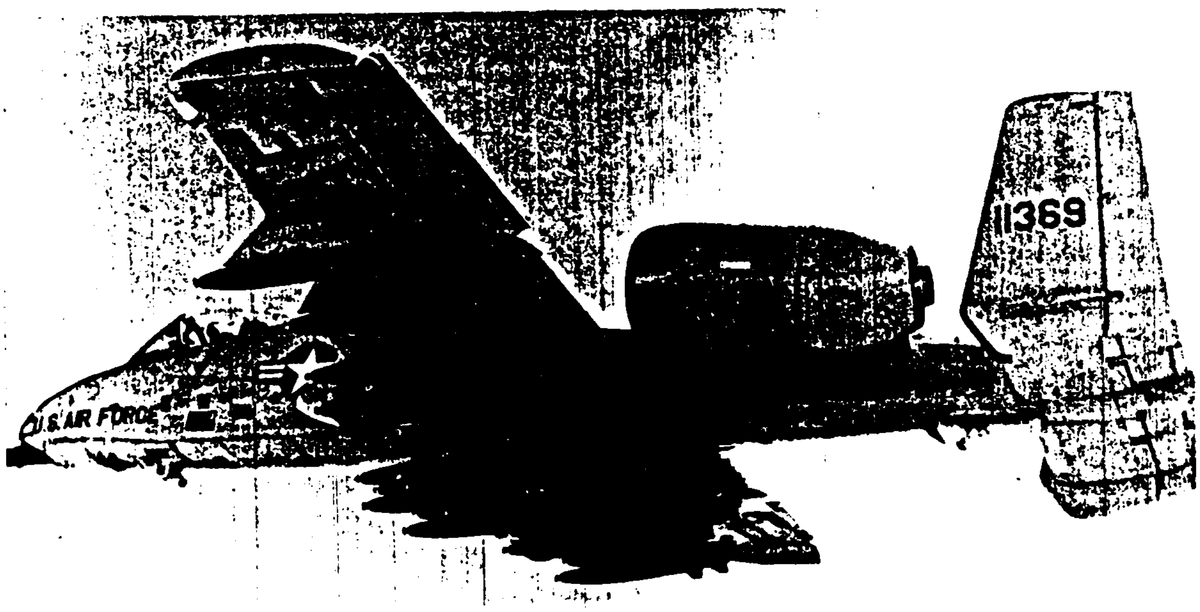

FIGURE 13. A-10 Thunderbolt II [Note GAU-8 protruding from nose of aircraft.] (Air Force Photo)

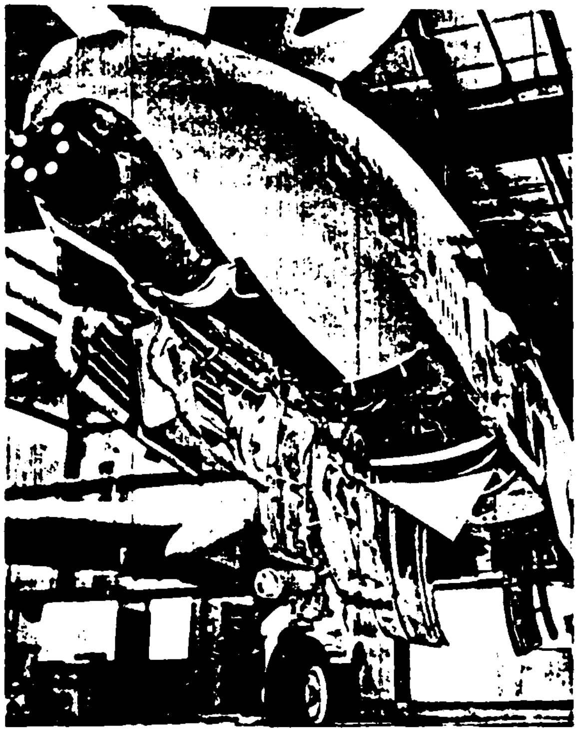

FIGURE 14. GAU-8 Installation in A-10 (Air Force Photo)

The GAU-8 concept began in 1968. The Air Force Armament Laboratory (AFAL) at Eglin AFB, Florida instituted a design study of a gun system to operate in close air support against a complete array of targets, including tanks. They determined that anything less than a high velocity, 30mm projectile showed low probability of defeating armored targets at standoff ranges. (24:132) [NOTE: The U.S. learned the same lesson during World War II. (11:388)] AFAL then established a requirement for a high-performance, 30mm gun system capable of firing 4000 r.p.m. Such a large caliber, high rate of fire weapon would yield a high probability of kill on a single gun pass (single attack). (24:132) In January 1969, General Electric undertook trade-off studies and selected a seven barrel, scaled-up version of the Vulcan Gatling gun.

The gun that General Electric completed in November 1970 is impressive. It has the following specifications:

Weight of gun	1650 lbs.
Length of gun	113.5 in.
Reliability	22000 MRBF
Rate of fire	Up to 4200 r.p.m.

TABLE 6. GAU-8/A Specifications (7:203;4:423)

The GAU-8/A's performance is equally impressive. Lethality tests of the weapon against U.S. and Soviet armor found that, "It is apparent...that a GAU-8/A APIT [Armor Piercing Incendiary Tracer] projectile hit can result in severe damage to a Soviet T-62 tank a remarkably high percentage of the time." (39:13) The GAU-8/A system proved so successful that General Electric built a four barrel version of the weapon, GAU-13/A, and marketed it to the USAF in a gun pod, GPU-5/A. (4:425) The GPU-5/A allows older aircraft, like the F-4, to employ a state of the art GAU-8/A-type weapon. Chapter Four will look beyond the GAU-8/A and GPU-5/A and explore the future of high technology Gatling guns on future fighters.

CHAPTER 4

BEYOND 1986

The previous chapters have outlined the history of the aerial Gatling gun from 1946 to the present. Common threads throughout have been the impacts of the lessons of war (World War II, Korea and Viet Nam) and the consistent success enjoyed by the Vulcan and its variants. Not surprisingly, this chapter will deal with the future of aerial Gatling guns by showing possible areas of improvement and summarizing current efforts to develop new Gatling guns. Future applications of Gatling guns beyond the F-15, F-16 and A-10 are unknown; however, the conclusion will address the issue of a Gatling gun in the armament suite of the Advanced Tactical Fighter (ATF).

FUTURE DEVELOPMENTS

Before postulating on future developments of the Gatling gun, one must first determine if there is a place for guns on the fighters of the future. Examination of this issue reveals that air-to-air missile technology has improved dramatically in recent years. However, the missiles themselves are very expensive ($70,000 in the case of the AIM-9, double that for an AIM-7). (2:26) It is conceivable that budget constraints may dictate reliance on cheaper forms of aircraft armament such as aerial guns. Additionally, once the missiles are fired, a combat aircraft without a gun is defenseless. Therefore, in light of these facts, it appears that indeed there is a place for guns on the fighters of the future.

Based on the above assertion that guns are part of the armament suite of the future fighters, it is safe to say that an M-61-type Gatling gun will be included. So far, high technology replacements, using liquid propellants and caseless ammunitions, have failed to provide a replacement. (2:26) Armed with this information, it is now possible to look at the future of Gatling guns.

Future improvements in aerial guns will focus on improving the probability of kill of a single burst of gunfire. The main parameters affecting probability of kill are rate of fire, muzzle velocity, caliber of the weapon, and accuracy. (12:38) In examining these factors, two of them, muzzle velocity and accuracy, are not so much dependent on gun technology as they are ammunition and fire control developments. Likewise, optimum caliber is dependent on the desired destructive effects and so tends to be a function of ammunition (i.e., What kind of explosive mechanism can be put into a 20mm round? 30mm round? etc.) The last factor affecting probability of kill is rate of fire. However, it appears that automatic cannon (Gatling guns included) already reach the upper limits of technically feasible rates of fire. (12:38) This does not mean that there is no room for improvement in Gatling guns. On the contrary, it means that gun improvements will focus on efficiency and weight.

The current M-61 and GAU-8 systems provide an example of how weight saving translates to increased efficiency. In the current 20mm M-61 system, only nineteen per cent of the total system weight is in the projectiles which reach the target. In contrast, thirty-two per cent of the GAU-8 total system weight reaches the target. (11:311) A potential for improvement exists in future gun systems, especially in light of improved materials and production methods. These new construction techniques will also allow the use of newer, high performance ammunition. This is a necessity because higher muzzle velocities associated with such ammunition make higher demands on gun barrels. (12:38) To summarize, the Gatling gun of the future should be able to effectively kill the target and still maintain a low total system weight.

The Air Force realized this and began its search for a lightweight gun in the mid-1970's. The Air Force Armament Laboratory initiated several studies to develop an Advanced Technology Gun intended for fighter use in air-to-air combat. (36:1) The Gatling gun, along with several other gun types, became a candidate.

In 1976, the Air Force awarded study contracts to several companies to establish a technology base for a new aerial gun. They called the gun of the future the Compact Hi-Performance Aerial Gun (CHAG). (37:1) Several companies, including General Electric and Hughes, entered the sweepstakes with their versions of a lightweight Gatling gun. (37:1;35:1) The General Electric version took the form of a three barrel, 30mm weapon based on the design of the XM-188, a lightweight gun built for an attack helicopter prototype. It fired GAU-8 ammunition at a rate of 2000 r.p.m. and weighed approximately 120 pounds without ammunition. (7:1106;37:—) The Hughes version had similar characteristics. (35:3)

Both designs proved feasible. However, whether or not a CHAG-type weapon is adopted for future Air Force use is dependent upon other technology. Granted, the Gatling gun is the current state of the art in aerial guns, but the gun is only one part of the total system. Technological improvements in fire control systems or ammunition could make the Gatling gun more formidable, or mark the end of the Gatling gun era by creating an attractive replacement. Just how far technology has to advance to replace the Gatling gun is difficult to estimate, but in the medium term, the Gatling gun will not be supplanted. (12:39)

CONCLUSION

As stated in the introduction, this paper examined how and why the Gatling gun rose from apparent obsolescence to its place today as the standard armament on front-line USAF fighters. Analysis of the weapon's history uncovers two factors responsible for its longevity.

The first of these factors is that Dr. Gatling's original concept was sound, and more importantly, adaptable. Adaptability is critical because it allowed the weapon to grow with technology. Even though the electric-driven Gatling idea failed to gain support in 1893, the demonstration later convinced Col. Studler's Small Arms Branch that Dr.

Gatling's Nineteenth Century idea would prove successful in the Twentieth Century. Project Vulcan became a reality because of the adaptability of the Gatling principle.

The history of the Gatling gun also shows that, in the realm of weapons, war is the mother of invention. Dr. Gatling attempted to shorten the American Civil War with his original gun, and the resurrection of the Gatling gun resulted from lessons learned in the skies over Europe during World War II. Re-introduction of the aerial gun as an integral part of a fighter aircraft's armament, gun pods, and the development of various caliber Gatling guns are all outgrowths of lessons learned in Viet Nam.

The future employment of a Gatling gun in the armament suite of new fighters is uncertain because technological improvements in other areas may vault another gun type to pre-eminence. However, the recent announcement of contractors for the ATF means that an armament decision on the ATF armament package will be forthcoming. If the past record of the aerial Gatling gun is any indication, it will be on the ATF. According to General Electric Corporation, the M-61A1 Vulcan is the most widely used free world fighter aircraft gun in history. The GAU-8/A, a weapon capable of killing a Soviet T-62 main battle tank, derives from the M-61A1. The ATF, and other future fighters, can benefit from this proven technology.

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