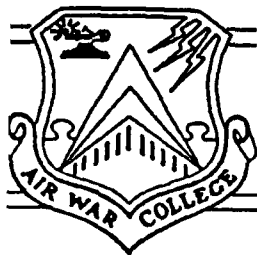


AD-A258 351



2



AIR WAR COLLEGE

Research Report

UNITED STATES AIR FORCE GROUND LAUNCHED CRUISE MISSILES:

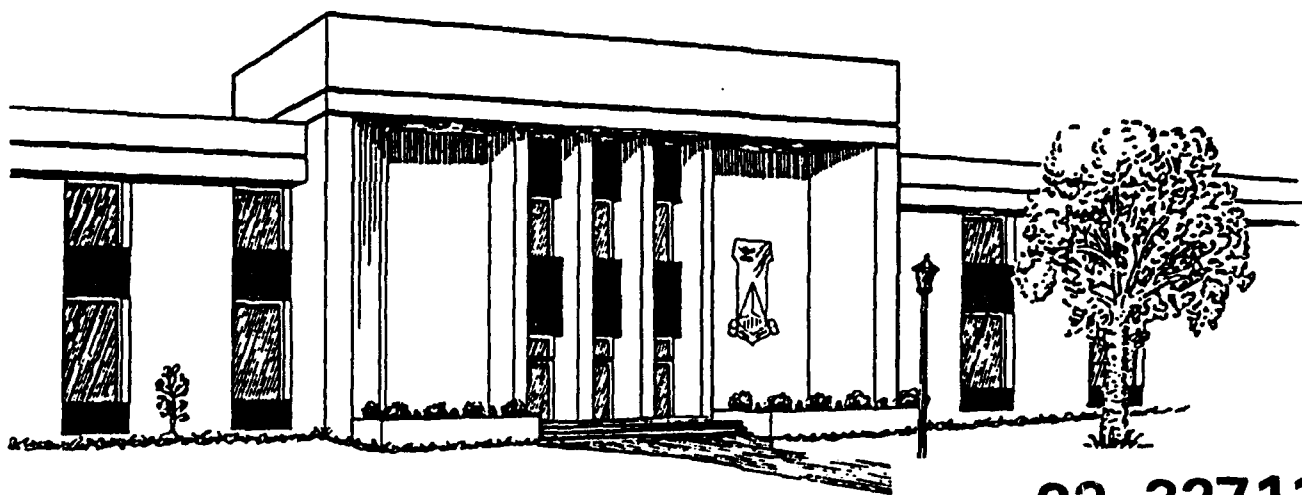
A STUDY IN TECHNOLOGY, CONCEPTS, AND DETERRENCE

AIR FORCE HISTORICAL FOUNDATION AWARD

RANDALL L. LANNING

LIEUTENANT COLONEL, USAF

1992



92 12 23 06 8

92-32711



Air University
United States Air Force
Maxwell Air Force Base, Alabama

Approved For Public
Release: Distribution Unlimited

AIR WAR COLLEGE

AIR UNIVERSITY

**"UNITED STATES AIR FORCE GROUND LAUNCHED CRUISE MISSILES:
A STUDY IN TECHNOLOGY, CONCEPTS, AND DETERRENCE"**

by

Randall L. Lanning
Lt Colonel, USAF

A RESEARCH PAPER SUBMITTED TO THE FACULTY
IN
FULFILLMENT OF THE CURRICULUM
REQUIREMENT

Advisor: Col James H. Slagle

MAXWELL AIR FORCE BASE, ALABAMA

15 April 1992

DISCLAIMER

This study represents the views of the author and does not necessarily reflect the official opinion of the Air War College or the Department of the Air Force. In accordance with Air Force Regulation 110-8, it is not copyrighted but is the property of the United States government.

Loan copies of this document may be obtained through the interlibrary loan desk of the Air University Library, Maxwell Air Force Base, Alabama 36112-5564 (telephone (205) 953-7223 or DSN 493-7223).

Accession For	
NTIS CRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution /	
Availability Codes	
Dist	Avail and/or Special
A-1	

RECEIVED 1'

ABSTRACT

**TITLE: "United States Air Force Ground Launched Cruise Missiles:
A Study in Technology, Concepts and Deterrence"**

AUTHOR: Randall L. Lanning, Lieutenant Colonel, USAF

Although generally neglected by historians, USAF Ground Launched Cruise Missiles (GLCM) have made important contributions to US national security. The paper begins with a brief description of the German V-1, the first true operational GLCM. The balance of the paper traces the lineage of the three tactical, theater-based GLCMs that served with the US Air Force: The Martin TM-61 "Matador," the Martin TM-76 "Mace," and the General Dynamics BGM-109G "Gryphon." Areas for a comparison and contrast assessment of these systems include the strategic setting, technological description (missile and support equipment), concepts of operation, operational history, phase out, and contributions to deterrence. Appendices, maps, figures, and photographs support the main body. The paper concludes that the first two systems (TM-61 and TM-76) possessed neither the technological sophistication nor sound concept of operations to make them truly effective weapons. Both deficiencies were rectified in the BGM-109G system. However, with conclusion of the Intermediate Range Nuclear Forces Treaty in December, 1987, this class of missiles will probably never be deployed again. Arms control initiatives removed them just when technology and sound operating concepts enabled the GLCM to be a potent deterrent.

BIOGRAPHICAL SKETCH

Lieutenant Colonel Randall L. Lanning (M.A., European History, Central Missouri State University) retains a long term interest in military history with an emphasis on weapons technology. This interest was focused on cruise missiles when he was assigned to the Initial Operational Test and Evaluation Team for the BGM-109G Ground Launched Cruise Missile (GLCM) in August, 1980. In December, 1982, he was sent to RAF Greenham Common UK as part of the initial cadre of the first operational unit, the 501st Tactical Missile Wing (TMW). While working in the Operations Plans Division, he was instrumental in the development of the first unit-level GLCM war plan and Emergency Actions File, the plan for transitioning the wing from peace to war.

In July, 1985, he was sent to the Directorate of GLCM Operations at Headquarters, United States Air Forces, Europe (USAFE). During his tenure, he was the USAFE GLCM operations point of contact for the beddown of the 303rd TMW at RAF Molesworth UK, the USAFE GLCM war plan, and the Intermediate Range Nuclear Forces Treaty, signed in December, 1987.

In 1988, he was transferred to the Air Staff where he served as the political-military affairs officer for the UK and Scandinavia, and in 1989, became Political-Military Advisor to the Deputy Under Secretary of the Air Force for International Affairs.

Lt Col Lanning has earned the command missile badge, with time in the GLCM and the Minuteman II weapon systems. He is a 1992 graduate of the Air War College.

TABLE OF CONTENTS

DISCLAIMER.....ii
ABSTRACT.....iii
BIOGRAPHICAL SKETCH.....iv
INTRODUCTION.....1
OVERVIEW.....1
PROLOGUE: The Legacy of the V-1.....2
Cruise Missile Lessons Learned from the V-1 Program.....4

Chapter

I. THE STRATEGIC SETTING.....6
II. THE MARTIN TM-61 "MATADOR".....9
Development.....9
Technical Description.....10
 Designations.....10
 The TM-61A Missile.....11
 The TM-61C Missile.....13
 Support Equipment.....14
Concept of Operations.....15
Operational History.....17
Phase Out.....17
Contributions to Deterrence.....17
III. THE MARTIN TM-76 "MACE".....19
Technical Description.....19
 Designations.....19
 The TM-76A Missile.....19
 The TM-76B Missile.....22
 Support Equipment.....22
Concept of Operations.....24
 "Mace A" Dispersal.....24
 "Mace A" Rapid Fire Multiple Launch (RFML).....25
 "Mace B" Hardened Shelters.....26
Operational History.....26
Phase Out.....26
 The "Mace A" Drone Program.....27
Contributions to Deterrence.....27
An End for Cruise Missiles?.....28
IV. AN INTERLUDE WITHOUT GROUND LAUNCHED CRUISE MISSILES.....30
The Strategic Setting.....30
Technological Improvements.....33
 Guidance.....33
 Engine.....34
 Miniaturization.....34
 Construction and Materials.....34

TABLE OF CONTENTS
(Cont.)

Chapter

V. THE GENERAL DYNAMICS BGM-109G "GRYPHON".....	35
Technical Description.....	35
The Missile.....	35
Support Equipment: The Transporter-Erector-Launcher.....	36
Support Equipment: The Launch Control Center.....	36
Support Equipment: TEL and LCC Common Features.....	37
Concept of Operations.....	37
Main Operating Base.....	37
Dispersal.....	38
Operational History.....	39
Phase Out.....	40
Contributions to Deterrence.....	40
POSTSCRIPT.....	42
Conclusions.....	42
Technology.....	42
Concept of Operations.....	43

Appendix

A. SPECIFICATION: Martin "Matador".....	45
B. TM-61 LAUNCH ACTIVITIES.....	46
C. ORGANIZATIONAL LINEAGE.....	47
D. SPECIFICATION: Martin "Mace".....	52
E. SPECIFICATION: General Dynamics "Gryphon".....	53
F. "GRYPHON" FLIGHT COMPOSITION (Typical).....	54

Map

1. GERMAN TM-61 AND TM-76 BASES.....	55
2. SOUTH KOREAN TM-61C BASES.....	56
3. TM-76B BASES ON OKINAWA.....	57
4. BGM-109G BASES IN USAFE.....	58

Figure

1. MARTIN TM-61 "MATADOR".....	59
2. TYPICAL MSQ FLIGHT PATH.....	60
3. TYPICAL SHANICLE FLIGHT PATTERN.....	61
4. MARTIN TM-76A "MACE".....	62
5. MARTIN TM-76B "MACE".....	63
6. "MACE" TERACRUZER AND TRANSLAUNCHER.....	64
7. GROUND LAUNCHED CRUISE MISSILE - BGM-109G.....	65
8. BGM-109G TEL AND LCC.....	66

TABLE OF CONTENTS
(Cont.)

tograph

1. TM-61 MISSILE LAUNCH.....	67
2. TM-61 ZERO-LENGTH LAUNCHER.....	68
3. TM-61 ASSEMBLY PROCEDURES - WARHEAD MATING.....	69
4. TM-61 ASSEMBLY PROCEDURES - RATO LOADING.....	70
5. TM-76A MOUNTED ON TRANSLAUNCHER.....	71
6. MM-1 PRIME MOVER FOR THE TM-76A.....	72
7. RAPID FIRE MULTIPLE LAUNCH FACILITY.....	73
8. TM-76B LAUNCH FROM HARDENED SHELTER.....	74
LIST OF REFERENCES.....	75
GLOSSARY.....	78

UNITED STATES AIR FORCE GROUND LAUNCHED CRUISE MISSILES:

A STUDY IN TECHNOLOGY, CONCEPTS, AND DETERRENCE

Introduction

Science fiction writers in the early 20th Century must have been infatuated with the idea of unmanned airborne "robot" bombers that could fly to distant targets and rain a devastating payload upon helpless populations. The Second World War saw this concept become reality, albeit in rudimentary form. Today, when the average citizen thinks about unmanned delivery systems, the ballistic missile comes to mind first. But the winged, air breathing cruise missile, which preceded ballistic missiles, has made both technological and deterrent contributions to US security. Even today, cruise missiles have generally been neglected by historians.

Overview

The purpose of this paper is to trace the lineage of three tactical, theater-based Ground Launched Cruise Missiles (GLCM): the Martin TM-61 "Matador," the Martin TM-76 "Mace," and the General Dynamics BGM-109G "Gryphon." Following a prologue introduction to the first operational GLCM, the German V-1, each system will be discussed in terms of the strategic setting, technology, concept of operations, operational history, phase out, and contributions to deterrence. This study will show that technology and operating concepts were unable to blend effectively in the two earlier systems. Although the BGM-109G integrated high technology and sound operating concepts, the Intermediate Range Nuclear Force (INF) Treaty (signed December, 1987) eliminated this class of missiles. Conclusions from this work will provide a detailed contrast and comparison.

PROLOGUE

The Legacy of the V-1

The German V-1 was the first "guided" (by gyro autopilot) missile to be used in large numbers, and will be remembered as one of the most destructive and unique weapon systems in history. First flown in December, 1942, it was known by several designations (see Appendix 41). Technically, it was known as the Feisler Fi-103, but the most common terms were V-1 (V for Vergeltungswaffe or vengeance weapon), and simply "Buzz Bomb" and "Doodlebug." Regardless of designation, the V-1 caused far more damage than its well known predecessor, the V-2 ballistic missile.

The V-1 was essentially an unmanned aircraft (17 foot wingspan and 26 foot length), powered by an Argus 109-014 pulsejet engine. It carried a 1,876 pound (lb) warhead nearly 150 miles at a speed of 400 miles per hour (mph) (11:46). Since the pulsejet engine needed a minimum speed of 200 mph to engage, launch was effected using a 180 foot ramp and catapult to rapidly gain speed. In addition, 1600 were air launched by HE-111H mother aircraft to further extend the range. Regardless of launch mode, after 100 miles of flight, a small propeller in the nose armed the warhead. A standard gyro autopilot was used as guidance, and terminal dive was initiated by fuel starvation. Londoners therefore knew that as long as they heard the distinctive pulsejet, they were safe.

Of the nearly 30,000 V-1s produced, Flak Regiment 155 launched 1,922 against London. A total of 2,419 actually hit the city, killing 6,184 people and injuring another 17,981 (33:60). Later in the war, continental targets were also hit, with 7,400 V-1s

ted against Antwerp, Netherlands and Liege, Belgium (33:60).

The British used a four-tiered defense system against the V-1s. The first line of defense was bombing the launch sites (88 launch sites by December, 1943) and the factories where the V-1s were built. Roughly 67% of those V-1s actually launched were destroyed by the remaining defenses. Allied fighters were used to intercept the V-1s, but due to the missile's speed, few were able to catch it. The British Supermarine "Spitfire" XIV, the "Tempest" V, and DeHavilland "Mosquito" together with the American P-51 "Mustang" were the prime interceptors. The Gloster "Gloster" I, Britain's first operational jet, was also used on intercept missions. Gunfire was often used, but the jet exhaust from the V-1 could cause damage to the interceptor. An alternate method was to ease up along side the V-1, slipping a wing under the missile's wing, and flipping it over to throw off the gyro pilot. This method, though unconventional, was less dangerous, and required more flying skill. The last two lines of defense were anti-aircraft guns and barrage balloons. However, neither was as effective as bombing and aerial interception.

Following the war, both the US Army Air Corps/Air Force and the Navy experimented with the V-1 under the designations JB-2 "Loon" respectively. The Navy saw potential for launching V-1 missiles from submarines, and 64 such tests were conducted (3). A total of 1,385 JB-2/"Loons" were delivered, but interests in advanced cruise missiles ("Matador" and "Regulus" respectively) by both Services precluded widescale procurement and employment.

The Missile Lessons Learned from the V-1 Program

The V-1 proved that the cruise missile could be a useful, effective weapon. An Allied study after World War II concluded V-1 production/operating cost-to-inflicted damage ratio in dollars was 1:3 (33:61). The system had some distinct, inherent stages. It was a relatively inexpensive weapon that did not require use of strategic materials and could be used in mass. It was a true "pilot saver" that could be launched in all types of weather, day or night. Once airborne, the missile was difficult to spot and attack because of its relatively small size, high speed, and low altitude flight path. The V-1 also had few parts that were critically vulnerable to attack.

Like all weapon systems, the V-1 also had some distinct characteristics. For the most part, it was launched from fixed (and therefore vulnerable) launch sites. Unlike the V-2, V-1 ground launchers were never mobile, or even movable. Once aloft, the missile flew a predictable flight path with a constant course and speed. Knowing this, the Allies could effectively plan accordingly. Finally, the missile had extremely poor accuracy, which severely limited its effectiveness as a precision bombardment weapon. Its primary impact therefore was one of psychological warfare (terror). A parallel can be drawn between the V-1 in World War II and the Iraqi "Scud-B" during Operation DESERT STORM in that regard.

After the war, further work on cruise missiles was curtailed for three primary reasons. First, because of Allied defenses against the V-1, postwar opinion regarding cruise missiles tended

to downplay their effectiveness. It was assessed that these early cruise missiles were too vulnerable to countermeasures. Second, with rapid demobilization after the Second World War, funding was not readily available for in-depth development. The Martin "Matador" discussed in Chapter 2, was one of the few cruise missile systems to escape cancellation during the postwar period.

Finally, with the Air Force's proud tradition of manned aircraft, there was probably an understandable resistance by senior Air Force leaders to deploy a pilotless or remote control weapon. From the earliest days of combat aviation, there has been a justifiable reliance on "the man in the cockpit." While the cruise missile offers the military planner flexibility and many other advantages, its use and cost have been a concern of Air Force leaders because it removes the human element from immediate combat.

In summary, the V-1 proved to be a remarkable technical achievement. The balance sheet showed that it was a cost effective weapon for the Germans; it had to be in the later war years. It was advanced technically, economically, and tactically. This assessment set the stage for development of the Air Force's first surface-to-surface guided missile, the Martin TM-61 "Matador."

CHAPTER I

THE STRATEGIC SETTING

At the end of the Second World War, the common ties that held the Grand Alliance together dissipated rapidly. The Soviet Union under Josef Stalin remained fearful of foreign invasion and came to depend on the Eastern European buffer to ensure their national security. While working with Stalin was acceptable to President Roosevelt during the war years, President Truman viewed Soviet adventures in Eastern Europe as attempts to expand Communism. In 1947, when Communist inroads appeared likely in Greece and Turkey, the President established the Truman Doctrine. This policy stated that the United States would support any non-Communist government attempting to resist subjugation by the Soviets. Relations between the US and USSR were further distanced when the Soviets declined assistance under the Marshal Plan of 1948. The Berlin blockade and formation of NATO in 1948 and 1949 respectively lead to further entrenchment on both sides. When Mao Tse Tung seized power in China in 1949 and North Korea attacked the South in 1950, President Truman's "Containment" strategy was expanded to the global realm. Throughout this period (1945-1953), the United States had a virtual monopoly on atomic weapons, although we did not have many of them. The first Soviet atomic bomb was exploded in 1949. President Truman's strategy of "Containment" restored the balance of power in Europe and set the tone for future relations between the US and Soviet Union.

When President Eisenhower assumed office in 1953, he realized that containing Communism would be a very expensive venture over

the "long haul." Given that the US had clear nuclear superiority, then Secretary of State John Foster Dulles announced the nuclear strategy called "Massive Retaliation" in January, 1954. This policy stated that the United States would retaliate at times and places, and with means of our own choosing. "Massive Retaliation" exemplified "brinkmanship," in that the Soviets would have to carefully calculate how aggressive they could be without bringing a massive nuclear strike down upon themselves. It also took the initiative away from the Soviets, an advantage they had enjoyed under the previous "Containment" strategy. US military response to Soviet aggression would no longer necessarily be limited to the immediate conflict area.

Concurrently, President Eisenhower advocated five major tenants of his "New Look" umbrella defense strategy, which embraced "Massive Retaliation:"

- The United States would never start a war.
- US military forces would be used to deter conflict.
- Modern (nuclear) weapons would be employed.
- Alliances would be an integral part of US defense strategy.
- US national security depended on both military and economic capability.

It is interesting to note that these five concepts have essentially endured to this day. President Eisenhower's last point on economic capability was key. He planned to use overwhelming US nuclear superiority as a less expensive alternative deterrent to conventional forces. These non-nuclear forces would continue to play a "tripwire" role overseas to signal Soviet aggression.

Clearly, nuclear superiority from 1953 to 1961 allowed "Massive Retaliation" to succeed. Even so, "Flexible Retaliation" may have been a more appropriate term, because there were few scenarios (attack on the US or Western Europe) where the US would have massively retaliated. Although the US was comfortably secure in its nuclear superiority during this period, the launch of the world's first artificial satellite, Sputnik, by the Soviets in October, 1957, contributed to fears of a possible missile and bomber gap. We know now this was only a perceived threat.

By 1954, the Korean War was over and the Soviets had tested their first thermonuclear bomb. Although the surface-to-surface missile (SSM) was not used in Korea, great interest remained in targeting Soviet and Chinese military forces, rather than cities (counterforce rather than countervalue targeting). Defense planners recommended development of an entire family of missiles to support these objectives in the immediate postwar period. Examples include the Army's "Redstone", the Navy's "Regulus I and II," and the Air Force's "Snark" and "Matador" (4:27). These missiles together with a modern bomber force offered diverse capabilities for US planners against enemy theater forces, as well as their industrial bases. Even so, the missile had not been fully accepted into strategic force planning due to the new technology involved and the varied opinions of V-1 effectiveness during the Second World War.

CHAPTER II

THE MARTIN TM-61 "MATADOR"

Development

Although funds were limited after World War Two, the success achieved by the Germans with their V-1 spurred similar cruise missile development in the United States. As noted above, the American versions of the V-1 (JB-2 and "Loon") lead directly to development of the first US-designed cruise missiles, the Navy's "Regulus I" and the Air Force's "Matador." The Army was essentially uninvolved with these types of programs due to a ruling issued by Secretary of Defense Charles F. Wilson on 26 Nov 56. His guidance stated that Army weapons used for tactical support would be limited to a range of 200 miles (23:112).

In 1946, the Glenn L. Martin Company was awarded \$1.8 million to begin development on what was then known as the SSM (presumably for surface-to-surface missile) (7:1850). With this contract, the Air Force expressed a need for unmanned "pilotless bombers" to supplement conventional aircraft. Planners saw cruise missiles as an effective means to deliver a heavy offensive load at reasonable cost, since the vehicle could be built for a one way trip, and avoid designs that needed to accommodate landing stress (17:205). The Air Force requirement called for a "pilotless bomber" with a range between 175 and 200 miles at speeds in the 600 miles per hour (mph) range (33:108). The missile was to be ground launched, although air delivery was studied. The first XSSM flight occurred on 19 Jan 49. Concurrently with 10 dynamically similar models, Martin built 15 XSSM experimental missiles from readily available

components, modified as necessary to get a missile into the air as quickly as possible. The aerodynamic shape of the missile was, in fact, similar to that of the Martin XB-51, a three-engined, two-place bomber that never entered production (8:300). Testing of these XSSM's continued at Holloman AFB, New Mexico, throughout 1949 and 1950. During design and test flights, the XSSM program survived several defense cuts, until the outbreak of the Korean conflict in June, 1950. Experiences during the Korean conflict emphasized the need for a tactical cruise missile for bombardment at medium and long ranges, and SSM development proceeded with top priority. During this time, another key element that made the SSM attractive to the Air Force was Martin's zero-length launcher (ZEL). The ZEL allowed launch from a towed trailer using a rocket assisted take off (RATO) booster, eliminating the need for the long catapult rails associated with ground launch of the V-1. This ZEL, sustainer engine, and RATO combination accelerated the SSM from 0 to 200 mph in less than two seconds, allowing for takeoff in a very short distance (14:5).

The SSM evolved into the B-61 (the "B" designation retained due to its role as a pilotless bomber) to become the first operational US surface-to-surface missile, with deployments beginning in March, 1954 in Germany. It was the first cruise missile since the V-1 to enter service.

Technical Description

Designations

The "Matador" went through several designations throughout its operational life. As noted above, it was known as the XSSM,

and then the SSM during testing. Upon initial deployment, it was known as the B-61 until June, 1955 when it was redesignated TM-61 (Tactical Missile). The TM-61 was developed in three versions, models A, B, and C. The TM-61A and C remained "Matador" and are discussed below in this chapter. The TM-61B was such a dramatic departure from the TM-61A, that it was given an entirely new designation, the TM-76 "Mace," discussed in the next chapter. In 1963, the "Matador" was again redesignated as MGM-1, though by that time it was completely phased out of operational service.

The TM-61A Missile

Appendix A contains the specification for the TM-61 missile. Figure and Photograph 1 provide illustrations. The SSM closely resembled the TM-61; the major difference was in wing location. The SSM had a mid-body wing, while the TM-61 featured a shoulder-mounted wing.

The TM-61 was in the truest sense of the word a pilotless airplane. Composed of all-metal sandwich construction, its airframe was designed for one flight, and therefore more lightly stressed than a manned aircraft. The inner layer was light alloy with a honeycomb metal foil filler under a thick metal outer skin, bonded together with a thermo-setting resin (8:302). The wings, fin, and tailplane were solid except for control runs and a flux-gate compass in the port wingtip.

The TM-61 series had the capability to carry either a conventional or nuclear warhead. The nuclear warhead used was the Mark 5, America's first lightweight nuclear weapon. Its fissionable material was kept separate from the weapon in a capsule,

and inserted before launch. Providing a yield of 40 to 50 kilotons, its nuclear punch was not a significant improvement over the bombs dropped on Japan at the close of World War II (10:82). An airburst weapon only, it was designed for high altitude internal carriage, and most effective against soft targets. Other carriers of this weapon included the B-29, B-36, B-45, B-47, B-50, B-52, and "Regulus I" cruise missile.

The sustainer powerplant was the Allison J-33 A-37 centrifugal turbojet engine, the same used for both the P-80 and T-33. Although rather unspectacular in performance, it was very reliable. This was a "short life" version of the engine, designed for only 10 hours of operation (33:109).

The RATO booster weighed 2000 lbs, 700 of which was picric nitrate solid rocket fuel. Upon ignition, the RATO unit produced up to 57,000 lbs of thrust for 2.3 seconds, rapidly accelerating the missile to a speed of 200 mph (8:303). The booster was attached only by a screw jack on the launcher and forward facing open hooks on the missile. It was held in place by thrust, and when the booster burnt out, it simply fell off.

Upon launch, the ground controller had to take control of the missile immediately after booster separation. At this time, the missile automatically transitioned to level flight at booster separation. Its flight path included four phases: launch, climb, cruise, and terminal dive to burst altitude (28:1), under continual ground radio control.

The guidance used in the TM-61A employed technology derived from World War II and Korea all weather bombing systems used to

direct fighter-bomber strikes on enemy targets at night or in overcast conditions. It was a manually controlled ground radio command guidance system known as MARC (Manual Airborne Radio Control). It used an AN/MSQ-1 mobile ground radar set and an AN/APW-11A airborne radar assembly (12:129). This system was line-of-sight only, and required ground based radio operators to be posted on remote mountain tops between the missile launch point and the target. For German-based units, the 601st Tactical Control Wing performed this function. These operators were really remote pilots, who acquired the TM-61A immediately after launch and guided it to the assigned target. Remote commands included course changes, warhead arming, and terminal dive. These commands were manually "beeped" to the autopilot and warhead using the APW-11 transponder in the missile. Because this guidance was line-of-sight, it had inherent drawbacks. It limited the range to approximately 200 miles, even though the fuel capacity permitted a longer flight (up to 650 miles). It also had an increased vulnerability to air interception and was subject to jamming. The ground radio direction sites were themselves vulnerable to attack and destruction (14:6). Figure 2 illustrates the MARC concept.

The TM-61C Missile

For all practical purposes, the TM-61A and TM-61C were externally identical. Internally, the only major difference was the guidance system used. As noted above, the MARC system had limitations. These were partially rectified by the SHANICLE (Short Range Navigation Vehicle) system introduced in the TM-61C. This

stem, similar to LORAN, employed four ground based transmitters beacons to create a hyperbolic grid - two (master and slave) controlling the range, and two for azimuth - along which the missile would fly (10:145). A hyperbolic grid system involves the creation of a grid pattern of radio waves by the four radio transmitters, each located in a different location. Unlike radar which is limited to line-of-site, a radio grid may be broadcast for several hundred miles. The missile could be programmed in advance to follow a certain sequence of augmented and diminished radio impulses directly to the target without the necessity for manual control by a human operator, as required by MSQ (30:1-1-18). Figure 3 illustrates this concept. SHANICLE in the TM-61C afforded both greater range and less vulnerability to jamming. The line-of-sight requirement was gone, and controllers could guide more than one missile at a time. The TM-61C could be guided by either the SHANICLE or ARC systems, and with the latter, achieved a true all weather capability (20:108).

As the most advanced version of the "Matador," the TM-61C was assessed to have the following reliability figures (15:1):
Launch: 95%, In Flight: 75%, Overall: 71%, Circular Error Probable (CEP): 2700 feet. CEP is the radius of a circle, with the target as center, in which at least 50% of warheads launched will impact.

Support Equipment

A total of 28 vehicles of various types were required to support the TM-61 system (33:112). Equipment included the launcher, transporter, special purpose check out and targeting equipment, remote guidance and tracking equipment, and ground handling and

servicing equipment (28:1).

The ZEL (Photograph 2) was the most important piece of support equipment. This launcher allowed the TM-61 to become airborne without any takeoff run. It held the missile at three points and elevated it to 17 degrees in preparation for launch. It carried its own motor generator, blower, hydraulic pump, and wing racks, and was pulled by a standard Army 5 ton prime mover. In preparation for launch, it was steadied by three hydraulic jacks. Although the concept of operations called for the use of a separate transporter (which also served as assembly rig), the ZEL could be used as a transporter in an emergency (34:15). This need for a separate transporter and launcher highlighted the potential benefit of combining the two. A Coles 20 ton, 39 foot mobile crane was used to move missile components from the transporter to the launcher (34:15).

Of note, the TM-61 was the first Air Force weapons system to have its own supply depot deployed overseas. This eventually became a detachment of the Warner Robins Air Materiel Area at Columbus AB, using contracted civilian workers (26:20).

Concept of Operations

Although described as a mobile missile system, the TM-61 may be better described as "movable" due to the extensive amount of support equipment required. Even so, all equipment needed for launching the TM-61 was on wheels and operations could be conducted from an area with pierced steel planking in "a corner of a farmer's field" (5:21). Therefore perhaps the the best term to describe "Matador's" concept of operations is "extremely limited

persal."

Prior to dispersal, TM-61 components were tested and the line was run up. Missile components were stored on their transporters fully fueled and combat ready except for the nose cone, wings, and RATO unit (8:303).

In advanced states of readiness, the missile and its support vehicles would deploy to the field. Each flight would deploy five vehicles equidistant from the main base and each other (12:152). In route, the missile was carried in four parts: fuselage, wings, nose, head, and booster (10:145). Upon arrival at the launch site, it took ten men 90 minutes to prepare the missile for takeoff. A breakdown of these tasks may be found at Appendix B. Photographs and 4 illustrate this work in progress.

Each TM-61 squadron had three flights. There were 100 vehicles per squadron, fifty of which were powered. Therefore one-third of the 169 men assigned were drivers of some sort. Three support vans accompanied the convoy, providing rations for up to 10 days of dispersed operations. Each squadron had six ZEL launchers, and was capable of launching 20 missiles in a 9 hour period (12:31). By 1958, this number had increased to eight launchers per squadron, with six on nuclear alert in each squadron (20:107).

For testing and training, the missiles were never fired from their operational sites, but countdowns were practiced regularly and included assembly, testing, and engine start. The RATO unit was never fired. However, European theater operational test launches were conducted from an Air Force site 17 miles east of Wheelus Bay, Libya, which extended far into the Libyan Desert.

To give ground controllers practice at operational units, specially instrumented T-33s would overfly the site at time of simulated launch and respond to visual and audio commands generated by the MARC or SHANICLE controllers on the ground (8:301). These aircraft flew daily training schedules, sometimes performing two or three missile runs per flight.

Operational History

The TM-61 entered service in 1951 as the first operational guided missile in the Air Force inventory (27:9). Subsequent operational deployments to both Europe and the Pacific are summarized in Appendix C, Organizational Lineage.

Phase Out

Despite improvements with the SHANICLE guidance system, navigation and accuracy problems with the TM-61 persisted, never being completely solved. Phase out of the TM-61A was complete in 1957, and the TM-61C was gone by 1962. The improved TM-61B, long in development, was to replace both systems as the TM-76A.

Contributions to Deterrence

The TM-61 gave the United States Air Forces in Europe (USAFE) tremendously enhanced nuclear capability. With this missile, USAFE could strike enemy targets that were too heavily defended by manned aircraft in all types of weather, day or night. Advertised as a mobile missile (though it was really only movable), it was not restricted to airfields. Except for the SM-62 "Snark," it remained the longest range missile in the Air Force inventory, until replaced by "Mace." According to the 701st Tactical Missile

(TMW) TM-61C Operations Handbook, the mission of these missiles

to:

aid in the establishment of air superiority.

operate when weather conditions restrict manned aircraft.

operate when maximum effort with reduced reaction time is

required.

destroy heavily defended targets which could result in prohibitive

losses by manned aircraft (30:1-1-4).

The system's technology could also be applied to new missile development. As a result of its introduction, the Air Force maintains its lead in missile handling and guidance expertise.

Major General Robert M. Lee, Commander of 12th Air Force, summarized "Matador's" contribution to deterrence well: "The introduction of these units will enable us to launch attacks on any type of target in all types of weather" (5:21).

CHAPTER III

THE MARTIN TM-76 "MACE"

Technical Description

Designations

As noted in the previous chapter, the "Mace" originally began as an advanced version of the "Matador," the TM-61B. Due to extended development, the TM-61B was not deployed as such, but was redesignated TM-76A or "Mace A." A second variant of "Mace" was the TM-76B. Both are discussed below. By the end of 1963, designations for the TM-76A and B were changed to MGM-13B and CGM-13C respectively. In March, 1964 designations were again changed to MGM-13A ("Mace A") and CGM-13B ("Mace B"). Drone versions of "Mace A" were known as MQM-13A (20:107). To summarize, the following designations applied:

- "Mace A" = TM-61B = TM-76A = MGM-13B = MGM-13A = MQM-13A
- "Mace B" = TM-76B = CGM-13C = CGM-13B

On a humorous note, the original nickname for the missile was to be "Mighty Mace," but it was so often misquoted as "Mickey Mouse" that the name was shorted simply to "Mace" (14:5).

The TM-76A Missile

The TM-76A was the third USAF GLCM to enter service, following the TM-61 "Matador" and SM-62 "Snark" (an intercontinental cruise missile beyond the scope of this paper). Development of the TM-61B ended in 1957, when it was determined there were enough differences (from the TM-61A) to warrant a completely new designation (10:148). With its "Matador" lineage, the TM-76 could trace its ancestry back to the V-1. The TM-76 was virtually identical to the TM-61

from the mid-fuselage back. Although six feet shorter than those on "Matador," the wings were also very similar, incorporating the same "finger fan" spoilers on the upper surface (14:6). However, rather than remaining completely detached, the TM-76 wings could be folded along the fuselage sides, much like that of a World War Two carrier aircraft.

The main difference between the two missiles was the forward fuselage area, 5 feet longer in "Mace." In this section, additional fuel could be carried to accommodate longer flights and lower altitudes. A more powerful warhead was carried: the Mark 28 fusion bomb. With a yield in the high kiloton and low megaton range, this warhead packed 40 times the nuclear punch of the Mark 5 in "Matador" (10:148). This same warhead could also be carried by "Hound Dog," the B-47, B-52, B-66, and F-105.

The biggest difference between the TM-76 and the earlier TM-61 was the guidance system. "Mace A" used a system called ATRAN (Automatic Terrain Recognition and Navigation). It incorporated a large DPS-1 radar dish in the nose that would search for key topographical and geographical landmarks along its preprogrammed flight path. ATRAN's memory stored this information on 35 millimeter film strips in the missile. At two nautical mile intervals, ATRAN would search the terrain below for key landmarks and compare readings with the filmstrips stored in the guidance set. These intervals were known as "lock boxes," and overlapped to an extent, similar to the "trip-tic" concept used by The American Automobile Association for long journeys. This system could be used to program the missile to avoid known defensive

areas, take evasive maneuvers, and change flight altitudes (10:149). After launch, it was completely independent, and could not be recalled. Although a tremendous advance over the TM-61C SHANICLE system, ATRAN had significant drawbacks. It limited the missile's range, as it could fly farther than the map matching system could be programmed. ATRAN proved to be highly susceptible to jamming and could not be used over water. Even so, since ATRAN did not require a preplanned, firm launch point, it could be fired from various locations, and therefore a mobile concept of operations for "Mace A" was adopted. This however traded prelaunch survivability for target accuracy.

The new TM-76A nose section was completed with the addition of an autopilot, avionics cooling equipment, and a radar altimeter. The changes collectively produced a missile with greater range, firepower, and accuracy than the earlier TM-61. However, the cost per missile was much higher: \$250,000 for "Mace" compared to \$60,000 for "Matador" (27:111).

The booster and sustainer engine were also more powerful to accommodate "Mace A's" increased weight. See Appendix D for complete specifications and Figure 4 and Photograph 5 for illustrations. The Allison J-33A-4-1 produced 5,200 pounds of thrust and the booster produced 97,000 pounds of thrust. This \$15,000 short life engine, also used in the P-80, T-33, and F-84, allowed standard jet aircraft mechanics to work on "Mace." A Headquarters, Tactical Air Command spokesman was quoted as saying, "The Martin Mace is the least complex missile in our inventory today" (7:1814).

The TM-76B Missile

As noted above, although the ATRAN guidance system was an improvement over that of the TM-61, it retained inherent limitations. Development of the "Mace B" was focused on an improved, inertial only guidance system. Inertial guidance is a form of "memory navigation." The geographic position of both the launch point and the target must be known and set into the system prior to launch. The missile then "knows" the exact distance to be traveled. Once launched, the missile is aware of exactly how far it has traveled. It then subtracts this distance from the "remembered" total distance and knows precisely how far it is to the target. This process is constantly repeated until the distance to the target is zero at which point the TM-76B is put into a dive or simply explodes in an airburst. Although externally identical to "Mace A," the TM-76B replaced ATRAN with the self contained AChiever inertial guidance system produced by the AC Sparkplug Company. This improvement afforded greater range for the missile (twice that of "Mace A") and allowed for overwater flights. This change also affected both its deployment location and concept of operations. Since "Mace B" was inertial guidance only, it required a fixed launch point, eliminating mobility. It also was the logical candidate for Pacific deployment due to the large amounts of water and distances involved in theater. Figure 5 depicts "Mace B."

Support Equipment

Only "Mace A" had unique support equipment, since it was the only version to be used in a mobile configuration. Goodyear

Aircraft designed its complete ground support equipment set.

This standardization drastically reduced the number of vehicles required for launch down to three (33:112).

All three vehicles (launcher and two support vehicles) used the Military Model One (MM-1) "Teracruz" built by the Four Wheel Drive Corporation of Clintonville, Wisconsin. Figure and Photograph 6 illustrate this vehicle. It was designed solely for the "Mace A" system, and the Air Force bought 189 of them at a cost of \$39,366 each. All were delivered by mid-1959. This prime mover was 30 feet long and 9½ feet tall, over and above the 18 foot ground clearance needed to accommodate the tires. The engine was an eight cylinder Continental engine, offering a speed of up to 25 mph. It used unique "Tera" or "Pillow" tires that were each 3½ feet high and wide. With low tire pressure, they offered excellent mobility. Since these tires could be inflated or deflated using the engine's compressor, leaks were tolerated and flats were infrequent (14:13).

The MM-1 was essentially a mini-flatbed truck designed to carry various equipment packs used for ordinance, assembly and checkout, and launch (16:415). These packages included the Transporter-Launcher (Translauncher), crane, storage pack, fuel pack, nose and booster pack, fifth wheel, test pack, van pack, and power pack (25:34). Figure 6 shows the configuration of the main vehicle: MM-1 with fuel and power packs, fifth wheel, and Translauncher.

The Translauncher used four "Tera Tires" that were detached prior to launch. This trailer is also used as a platform for

assembly, servicing and checkout.

Concept of Operations

"Mace A" Dispersal

Using the support equipment above, the TM-76A was officially classed as mobile, but the expense of truly mobile operations was prohibitive, so the term "movable" was considered more appropriate, just as it was for the TM-61 series (20:108). In advanced states of readiness, the TM-76A was transported to dispersed locations carried on the Translauncher with its wings folded. Missiles were deployed individually to remote locations where they were assembled, checked out and launched by a nine man crew. Upon arrival, only the booster and nose/warhead section needed to be attached and the wings unfolded, quite a change from the procedures for the TM-61 described in Appendix B. The missile also had wide weather parameters for firing: up to a 50 mph headwind, 25 mph tail or side wind, temperatures from -50 to 103 degrees Fahrenheit, and less than 5000 feet above sea level (23:164). Even though streamlined prelaunch setup procedures and wide launch parameters afforded a much faster attack response, a "hitch free" countdown took 43 minutes, much too long for satisfactory prelaunch survivability (10:148). In addition, dispersal movements were severely hampered by the fragile nature of the missile's vacuum tubes, the narrow German road system, and Weapons System Safety Rule restrictions. Consequently, the TM-76A retained this dispersal concept of operations for only about 18 months after fielding (14:7).

Headquarters, Pacific Air Forces observers noted the following additional limitations of "Mace A" dispersal (23:120):

A strong possibility that the dispersed launch sites were already known to the enemy, and could be taken out before missile launch.

Camouflage would not be very useful due to the smoke, dust, and noise caused by engine run up and booster ignition.

Sites could be detected by enemy photo reconnaissance.

Electronic radiation generated from the equipment could lead to discovery.

"Mace A" Rapid Fire Multiple Launch (RFML)

After dispersal was abandoned as a viable concept for "Mace A" units, the RFML concept was adopted in October, 1961. Each affected tactical missile group (TMG) established three launch complexes on the main operating base in fixed, unhardened locations. As illustrated in Photograph 7, each of these complexes had two launch sites with four missiles per flight. Launch control was effected from a 10 X 18 foot hardened block house at each site. The alert crew consisted of one officer and three enlisted men (24:20). Four of these missiles were continually elevated, on alert and were to be launched within 12 minutes. Those remaining would be fired every 90 seconds thereafter (31:2). In summary, each TMG had 36 TM-76As, with 12 in maintenance and the remaining 24 on alert.

This concept was also flawed in that the unprotected missiles were extremely vulnerable to attack. Even though they remained on the base, and could be launched rapidly, their positions were known and had no protection from direct attack.

"Mace B" Hardened Shelters

The TM-76B with inertial guidance used the most effective concept of operations, hardened shelters, at both Bitburg in Germany and on Okinawa in the Pacific. These shelters were built to withstand conventional attacks only, and deemed the best protection for these missiles. At Bitburg for example there were two "Mace B" sites. Each site had two hardened complexes with four launchers each, for a total of 16 missiles on Quick Reaction Alert (QRA). The complexes were completely self sustaining, providing their own power, water, and sewage. A seven man launch crew worked behind two five ton blast doors (26:20). Photograph 8 depicts a "Mace B" launch from a hardened site.

Operational History

Appendix C contains the operational history of the "Mace A and B" in Europe, and the "Mace B" in Japan (Okinawa). As a footnote to Appendix C, the decision to base nuclear weapons in Japan (Okinawa) was a calculated risk that could have caused international political repercussions. However, no serious problems developed (18:18).

Phase Out

In 1965, Secretary of Defense Robert McNamara put the Army's "Pershing I" on QRA, believing it could replace "Mace" due to a dramatically reduced launch time. It appears range was not considered, given "Pershing's" range was only half that of "Mace A" and only a quarter of "Mace B" (10:149).

The last "Mace Bs" left Bitburg AB by Fall of 1969, leaving only the 498 TMG on Okinawa. They were retired in 1971 in

preparation for Japan retaking custody of the island on 15 May, 1972.

The "Mace A" Drone Program

The "Mace A" did soldier on in a drone program administered by the Tactical Air Warfare Center (TAWC) at Eglin AFB, Florida. The TM-76A proved to be a realistic target for testing Air Force weapons. Aircraft from the 4756 Air Defense Wing at Tyndall AFB and the 33rd Tactical Fighter Wing at Eglin AFB used the old missiles for gun and missile target practice. In one incident, F-4s failed to down a "Mace A" using both 20 millimeter cannon gunfire and "Sidewinder" missiles, despite several direct hits. The missile continued south and actually overflew Cuba, crashing only when out of fuel.

Major General Andrew J. Evans Jr., Commander of TAWC at the time, said, "The realistic conditions which we can create through the use of of these "Mace" drones have enabled us to test and deploy many new air-to-air weapons systems to Southeast Asia. The knowledge we gain through these tests enables us to accurately predict how the weapons and tactics will perform under combat conditions (26:22).

Contributions To Deterrence

"Mace" was built to compliment tactical fighter bombers in counter air and air interdiction roles. With it, the Air Force was given a much improved all weather, day or night interdiction capability. It remained the only medium range tactical missile in the Air Force inventory. After launch, the system had a high probability of penetration, capable of flying under radar defenses

in any conditions. As the least complicated missile in the Air Force inventory, it was relatively inexpensive, and was most reliable. (16:414-415). In a 1960 Budget Hearing Statement prepared by Martin, "Mace" was described as a weapon system that "is inexpensive, it is available, it is versatile, and it is capable of fulfilling a requirement for a quick reacting, all-weather strike weapons system in both the Pacific and NATO areas."

In the Pacific, "Mace B" was deployed to act as a deterrent force to be used prior to the arrival of TAC's Composite Air Striking Force. It was an effective replacement for the "Matador," whose range was too short (13:214). With "Mace B," key Chinese industrial complexes such as Chunking, Hankow, Shanghi, and Beijing could be targeted. There was no other significant force in theater that offered this capability (18:18).

An End For Cruise Missiles?

In March, 1969, The Airman called "Mace" the "last surface -to-surface nonballistic missile in the Air Force inventory" (26:19). Throughout the lifetime of the TM-61/TM-76 systems, missile guidance proved to be the major technological stumbling block. Both the guidance and the manpower intensive nature of these systems impacted the concepts of operation. Some of the more notable deficiencies in these missiles included (33:112):

- Generally poor design features.
- Inadequate testing.
- Poor inflight reliability (survivability) and CEP.
- Questionable control over long distances.
- Nonstandardized development procedures (ad hoc adaptations).

- Unacceptable operational performance, needing many modifications.
- Limited mobility.

In general, "Mace" and "Matador" could not offer the desired capabilities of mobility, high speed, and extreme accuracy. These characteristics ran counter to missiles of this type, and the technology was not available to make them a reality. With the advent of ballistic missiles, many believed GLCMs were obsolete. In fact, retirement of these systems signaled only the end of our first major historical period of cruise missiles.

CHAPTER IV

AN INTERLUDE WITHOUT GROUND LAUNCHED CRUISE MISSILES

"Mace" was finally retired from operational service by 71. The next generation of GLCM would reach initial operational capability in December of 1983, leaving just over a decade without fielded missile in this class. The international environment and technological advances during this interim period merit brief examination to serve as a transition from early cruise missiles to the current generation.

The Strategic Setting

Both "Mace" and "Matador" served in their heyday during President Eisenhower's era of "Massive Retaliation," discussed in Chapter I. "Mace" soldiered on throughout the 1960's during a change in our defense strategy known as "Flexible Response," advocated by Secretary of Defense Robert McNamara and supported by both Presidents Kennedy and Johnson. Military spending was focused on conventional forces and an ability to combat Communist aggression at all levels of conflict, with new attention towards the Third World. The Vietnam War was a direct outgrowth of this strategy. Nuclear forces remained important during this period, but from 1965 onward, the Soviets reached rough nuclear parity with the US.

When President Nixon assumed office in 1969, his top priority was to withdraw with honor from Vietnam. He did this through the Nixon Doctrine's three pillars, which stated the following:

The US will honor our existing treaty commitments.

The US will retain a "nuclear shield" for self protection and at of selected allies.

The US will assist other nations in lower forms of aggression, t the primary burden for defense will rest with the nation directly fected.

Nuclear strategy reflected a US-Soviet parity in "Realistic terrence," where superiority was no longer the goal. The Nixon ministration was also responsible for opening the door to China, tente with the Soviets, and arms control agreements such as LT I, concluded in 1973. After President Nixon's resignation, esident Ford generally retained these policies.

In the aftermath of Watergate, President Carter assumed fice in 1977 on a moral and human rights platform. His nuclear rategy, known as the "Counterveiling Strategy" reflected nuclear fficiency. The premise was a response "in kind," to a Soviet clear attack, but not necessarily at the same levels. It also ployed a counterforce, or military, targeting policy.

The signals sent by President Carter and his nuclear policies re mixed in Europe. Some felt his perceived indecisiveness s causing a nuclear imbalance in Europe, particularly with ployment of the Soviet SS-20 Intermediate Range Ballistic Missile.

response, President Carter agreed to field 572 new nuclear ssiles (464 GLCMs and 108 "Pershing II") in Europe as part of "dual track" decision. This decision was based on the condition at the deployment was to be made concurrently with arms control itiations to withdraw or eliminate these missiles. Massive tinuclear protests were also a factor in seeking an arms control

reement. NATO unanimously approved this dual track decision December, 1979 (33:201). These missiles were not an increase the number of weapons, just modernization of the existing force; older systems would be retired (10:151). In a January, 1979 meeting, the nations agreed to host the missiles: The United Kingdom (first), Italy (first to agree to host), Germany, Belgium, and the Netherlands. However, it must be remembered that Germany was already host to US Army "Pershing I" missiles, and for political reasons, preferred that another continental NATO ally agree first host cruise missiles. Although Italy did volunteer first, the basing selection was Comiso, on the island of Sicily (off the continent). In any event, GLCM was attractive to the NATO allies as it offered a highly survivable, cost effective nuclear system that could free up dual capable aircraft for conventional missions. For the US, the deployment offered significant political advantages for the US in that it was highly visible and demonstrated US resolve and commitment (33:201-202).

Although the US Army was to operate the "Pershing II," the Army had little or no interest in GLCM due to manpower required (33:204). So, in the tradition of "Mace/Matador" and Secretary of Defense's 1956 ruling on the 200 mile range limit for Army support weapons, the Air Force became operators for the GLCM.

President Carter's confidence in emerging cruise missile technology was reflected in his decision to arm the existing 2nd Air Force with Air Launched Cruise Missiles (ALCM) rather than to deploy the B-1A (which he canceled). The administration based its decision on both cost savings and military effectiveness.

(33:177). Cruise missile technology had made great strides since "Mace," and it is important to understand the most important improvements before discussing the BGM-109G in detail.

Technological Improvements

From a technological standpoint, "Matador" and "Mace" will be remembered as large, unreliable, and generally inaccurate. After their development, there were several new cruise missile designs studied, but only three noteworthy examples were actually deployed. Two were air launched: the AGM-28 "Hound Dog" nuclear standoff missile and the GAM-72 "Quail" decoy missile. The third was a surface-to-air "pilotless interceptor," the CIM-10 "Bomarc".

Improvements that made the BGM-109G, the entire "Tomahawk" family, and Boeing AGM-86 ALCM possible fall into four categories:

Guidance

The McDonnell Douglas Aircraft Company developed a system known as Terrain Contour Matching (TERCOM), a highly advanced version of the ATRAN system associated with "Mace A." TERCOM employs a series of map cells (or squares) that range from 3200 feet per side on the larger maps, down to 100 feet per side on the smallest maps. Like ATRAN, TERCOM compares overflown terrain with the maps stored in memory and makes course adjustments accordingly (33:136). Since TERCOM missions are planned in advance, this system can also be used to avoid known defenses. The missile's flight path is governed primarily by inertial guidance with periodic TERCOM updates. This system also improved post launch survivability by affording the capability to fly at extremely low altitudes. As the missile approaches its target, the maps become progressively

smaller. Landfall maps are the largest, midcourse are the medium sized maps, and terminal area maps are the smallest. Accuracy was dramatically improved due to the very narrow error parameters associated with the small terminal area TERCOM maps.

Engine

Both the AGM-86 and BGM-109 series use the Williams International F-107 turbofan engine. This fuel efficient, high performance sustainer powerplant can achieve high subsonic speeds and has proven highly reliable. The fuel used was also an improvement to give the missile required range.

Minaturization

The technical ability to substantially reduce the size of the guidance set, warhead, and engine increases post launch survivability. The small overall size of modern cruise missiles presents an extremely small radar cross section to the enemy.

Construction and Materials

New manufacturing processes and materials reduced both weight and production costs, but neither was as prominent an improvement as the others discussed above.

CHAPTER V

THE GENERAL DYNAMICS BGM-109G "GRYPHON"

Technical Description

The Missile

The BGM-109G (Boosted Guided Missile) externally resembles the General Dynamics family of "Tomahawk" cruise missiles. Figure 7 illustrates the missile with the wings and four tail fins fully extended. In storage, the main wings are retracted inside the fuselage and the tail fins are folded over. The missile in this configuration with solid rocket booster attached is placed in a canister for transport and protection. The missile in its canister is known as an All-Up-Round (AUR). The AUR is loaded on the Transporter-Erector-Launcher (TEL) to serve as a launch tube for the missile.

Internally, the missile is powered by the Williams International F-107-WR-102 turbofan engine, producing 600 pounds of thrust (10:150). The guidance system is provided by McDonnell Douglas, and consists of inertial guidance and updates using the TERCOM system described in the previous chapter. The warhead used is the W-84, unique to this weapon system. ~~Unclassified~~ sources indicate a yield of 80 kilotons (10:150). See Appendix E for full missile specifications.

Launch of the BGM-109G could be effected in any direction. Upon booster ignition, the missile burst through the forward end of the AUR, which was made of material resembling thick aluminum foil. Shortly after takeoff, the tail fins deploy first to provide roll stability, followed several seconds later by the main wings.

During the transition from boost phase to cruise flight, the booster burns out and drops off as the sustainer engine engages. The missile flies first to the Initial Timing Control Point (ITCP). This is the point in airspace where the mission actually begins. To get to its target, the missile uses its inertial guidance and TERCOM. As noted in Chapter IV, TERCOM uses three types of "maps," landfall, enroute, and terminal area. Each is progressively smaller, so navigation margins are reduced as the missile nears its target.

Support Equipment: The Transporter-Erector-Launcher (TEL)

The TEL is the first of two units required to launch the BGM-109G. It is 56 feet long and 8 feet wide, with a weight of 80,000 pounds (10:151). Each TEL carries four AURs in a strongback assembly that elevates to 45 degrees in preparation for launch. As the strongback assembly elevates, protective covers for the launch tubes at the rear begin to open. When the strongback is fully elevated, these covers are fully open.

Support Equipment: The Launch Control Center (LCC)

The LCC is the second unit required for launch of the BGM-109G. The main shelter houses the two launch control officers and provides protection from small arms fire. It also contains the weapons control system and High, Very High, and Ultra High Frequency radios. Entry into the LCC is through an armored door on the right side of the shelter, but an escape hatch in the floor is also provided. The environmental control system is located in an aft equipment box that also provides for chemical, biological and radioactive protection.

Support Equipment: TEL and LCC Common Features

The TEL and LCC had several features in common. The trailer used was standard Government Furnished Equipment. The same four-wheeled frame was used for both units. The forward equipment box, though not identical, was similar for both in that it housed an MEP-404A turbine generator for power. Both the TEL and LCC used the same prime mover - the eight-wheel drive M.A.N. (Maschinenfabrik Augsburg-Nuremberg) tractor made in West Germany. This same prime mover was also used for the Army's "Pershing II" missile system. Finally, TELs and LCCs were connected for command and control by finger-thin fiber optic cables. Figure 8 shows both the TEL and LCC.

Concept of Operations

The basic operating unit for the BGM-109G was the flight. Each flight consisted of four TELs and two LCCs. Since each TEL carried four missiles (in AUR configuration), one flight could launch 16 missiles. Although only one LCC was required for launch, a second was provided for redundancy. The flights operated in two modes, on the main operating base and dispersed.

Main Operating Base

Day to day during peacetime, BGM-109G flights were stored in Ready Storage Shelters (RSS), one flight per shelter. These shelters were located in a secure GLCM Alert and Maintenance Area (GAMA). The RSS was little more than a heavily protected garage for six vehicles (two LCCs and four TELs), with drawbridge type doors that opened at each end. One RSS in the GAMA had built in living quarters for a launch crew to perform Quick Reaction

Alert (QRA). The wing alternate command post was located adjacent to the QRA crew area to take advantage of the hardened protection against conventional attack afforded by this facility. If needed, the QRA crew had the capability to launch their missiles from the GAMA by pulling the TELs out of the shelters for execution. Commercial power was used in lieu of the MEP-404 generators on the vehicles.

Dispersal

A key attribute of the BGM-109G was its high survivability through mobility. In advanced states of readiness, during the transition from peace to war, flights would leave the GAMA, marshal with their dispersal support vehicles, and depart the main operating base. The complete dispersal flight composition is found at Appendix F. Normally, the flight traveled in two cells, with two TELs and one LCC in each. This gave each cell an independent launch capability. In the event launch crews in the LCCs received an emergency action message directing employment of one or more missiles during this "road march," each cell would proceed to the nearest preselected enroute launch point, hastily emplace, and execute launch.

Upon arrival at a preselected and surveyed dispersal site (that was never used in peacetime), a more orderly defensive position and emplacement was possible, to include camouflage netting over the lowered TELs and LCCs. Continual security and alert duty was performed. Each flight remained dependent on the main operating base for resupply and other logistical support, but could act as an independent unit in the event the base was destroyed. The

flight was programmed to relocate to new dispersal sites periodically until all missiles were expended or directed to return to the main operating base. Training for this dispersal mission was the most rigorous and challenging aspect of peacetime operations. This training was conducted at selected field training ranges in the host country, which were obtained through bilateral negotiations.

Operational History

Initial plans for Intermediate Nuclear Forces modernization called for the deployment of 464 BGM-109Gs (29 flights) and 108 "Pershing IIs." All 108 Army "Pershing IIs" were deployed in Germany at Neu Ulm and Schwabish Gemund. Five nations agreed to host the BGM-109G: The United Kingdom, Italy, Germany, Belgium, and The Netherlands. Although the first unit to reach initial operational capability was in the UK (501st TMW), Italy was the first of the five to agree to host cruise missiles. Deployment was frozen on 9 Dec 87 at 304 missiles (19 flights), when President Reagan and President Gorbachev concluded the INF Treaty in Washington. Appendix C shows the individual Air Force units, their locations, and planned/actual deployments of the BGM-109G.

When GLCM was in development, initial plans were made for a possible deployment to the Pacific in Korea. Although one advance planner was assigned to Headquarters, Pacific Air Forces, all plans of this nature were canceled early in the process.

The 868th Tactical Missile Training Group at Davis-Monthan AFB AZ served as Tactical Air Command's "schoolhouse" for personnel assigned to GLCM prior to transfer overseas. Here personnel were

trained in GLCM unique ground combat skills prior to reporting to their operational units in theater.

Phase Out

The INF Treaty was ratified in June, 1988 by the US Senate. Under the provisions of the treaty, all GLCMs and their launchers were to be destroyed within three years (June, 1991), except for several as static display museum pieces. This has been completed. Warheads and LCCs were not restricted by the treaty provisions. In addition, former GLCM bases are subject to inspection for up to 13 years from the time the INF Treaty entered into force. All bases remain within this inspection window to this date.

Contributions to Deterrence

The deep commitment of the US and NATO Allies to the GLCM (and "Pershing II") deployments were instrumental in bringing the Soviets to the negotiating table. With the INF Treaty, this class of missiles/nuclear weapons has been eliminated. This treaty was the first in arms control efforts to have built in verification and inspection provisions. It also became the framework for even broader arms control initiatives such as the Strategic Arms Limitation Treaty (START) and Conventional Forces in Europe (CFE) Treaty.

While the BGM-109G was deployed, it provided a highly mobile, and therefore survivable nuclear deterrent capability, attained through a sound concept of operations. These missiles allowed theater commanders more flexibility and were able to free up more dual capable aircraft for conventional missions. While US Air Force crews manned GLCM LCCs, these (and "Pershing II") missiles

were placed under NATO command and control. It was also an extremely cost effective deterrent, since the missiles were never fired, or even "run up" as in the case of the old "Matador." Concurrently, it capitalized on the significant breakthroughs associated with modern cruise missile technology. Finally, it sent an extremely strong and visible political signal to our allies and adversaries alike. Its deployment in five NATO nations bolstered Alliance solidarity, despite growing antinuclear movement in the mid and late 1980s.

POSTSCRIPT

Conclusions

The overview to this work indicated that neither the TM-61 nor TM-76 weapon systems incorporated the proper technology and concepts of operation to make them truly effective weapon systems. Although the BGM-109G incorporated both, it has now been retired as a result of arms control agreements. This final section will compare and contrast the key areas. For purposes of this comparison, the "Matador" and "Mace" (M/M) will be considered as one.

Technology

- Size: M/M were in the truest sense of the word pilotless airplanes. Their size was that of a small jet, and their engines were short life versions of those used in contemporary fighters and trainers. Nuclear warheads of the period were also bulky. Although launched from a zero-length launcher, their size tied with a predictable flight plan threatened post launch survivability. Technological improvements in the BGM-109G in warhead, engine, and guidance set size allowed the missile to be built much smaller and consequently present a greatly reduced radar cross section.

- Components: Partially due to size, "some assembly required" definitely hindered the M/M concept of operations. Assembly of major components prior to launch extended launch preparation time to what would be unacceptable levels today. The components themselves were relatively fragile, which hindered reliability. Their size hindered mobility. The BGM-109G was completely self contained in its All-Up-Round configuration. No component assembly

was required, and even during routine base level maintenance, the missile would never have to be completely removed from its canister.

- Guidance: The M/M navigation systems were the single greatest limitation to success. Though innovative, they were generally categorized as unreliable, inaccurate, range-limiting, and subject to jamming. The superb TERCOM system in the BGM-109G eliminated all these problems.

- Support Equipment: Technology also hindered the effectiveness of M/M support equipment. The number of support vehicles required to effect launch ranged from 28 in the TM-61 to only two in the BGM-109G. Of note, the unique "Teracruz" prime mover with its palletized mission cargo was an innovative improvement used in the TM-76A system.

Concept of Operations

- Unmanned Aspects: As noted earlier in this work, senior Air Force leaders have been traditionally concerned primarily with manned aircraft. As an understandable side effect, GLCMs have historically received only secondary importance. Despite the many advantages offered by cruise missiles, they drew both manpower and money away from Air Force "bread and butter" - the manned aircraft. Consequently the ingrained resistance to these systems must be frankly realized when studying their role in US Air Force service.

- Doctrine: The Air Force never developed any consistent GLCM doctrine. A comparison of V-1, M/M, and BGM-109G operations shows only the most rudimentary similarity. Technology again was largely

responsible. There were significant technological "leaps" between each system. Serious prelaunch survivability concerns inherent in the V-1 concept of operations effectively ruled out application of M/M. Changes and improvements in M/M give the distinct impression of adaptation and innovation rather than concerted research and development. While assigned as an operations planner for the GM-109G, this author knows of no attempt to review M/M concepts or possible application to "Gryphon."

Mobility: Mobility was not a consideration for the V-1 and only goal for M/M. Technological limitations gave only a "movable" capability to these systems, and with it only marginal improvements in prelaunch survivability. The BGM-109G was the only true mobile GLCM and its high prelaunch survivability was a key aspect of its deterrent value.

This comparison has shown that GLCM technology and concepts were inseparably intertwined and mutually influential towards contributing to nuclear deterrence. It appears we will never see missiles of this type deployed again; they accomplished their mission. But it is important to record and assess their historical significance and their roles in US national security. This point was unintentionally driven home during research on this work, when the author contacted General Dynamics concerning information about the BGM-109G. The return mail included only a photograph with a short note that read in part, "Sorry, but this (the photo) is all we have left in our files. I couldn't even locate a brochure."

APPENDIX A

SPECIFICATION: Martin "Matador"

Designations: XB-61, B-61, TM-61A/C, MGM-1.

Dimensions:

- Length: 39 ft 7 in
- Wing Span: 27 ft 9 in
- Diameter: 4 ft 6 in

Weight: 12,000 pounds

Performance:

- Speed: Mach 0.9 (650 mph); over Mach 1 in terminal dive
- Range: 700 miles
- Ceiling: 35,000 feet
- CEP: best 2700 feet

Propulsion:

- Sustainer: One Allison J33-A-37 Turbojet producing 4600 pounds thrust
- Booster: One Aerojet General solid fuel rocket motor producing 55,000 pounds of thrust for two seconds

Guidance:

- "Matador A": Radar directed radio command guidance system (MARC/MSQ)
- "Matador C": MSQ and SHANICLE

Warhead: Conventional or single W-5 fission nuclear warhead of 40 to 50 kiloton yield

Prime Contractor: Martin Aircraft (now Martin Marietta)

Number of Missiles: 1200 total produced

- 100 "Matador A" deployed to Europe
- ? "Matador A" deployed to Formosa
- 150 "Matador C" deployed to Europe
- 60 "Matador C" deployed to South Korea

Key Milestones:

- "Matador" project initiated in August, 1945
- First USAF TM-61A launched in March, 1953
- First USAF TM-61C launched in January, 1956

Source: Reference 10, page 148.

APPENDIX B

TM-61 LAUNCH ACTIVITIES

Training launches for the "Matador" involved transfer to the zero-length launcher, assembly, and testing in order to be ready for firing within 90 minutes. Although operational launches would differ somewhat in both time and procedures, the major tasks involved are described below:

- Launch (L)-90 (min): Protective tarpaulins are removed and wings are lowered from their transporter stowage.
- L-80: Cradle is attached to the fuselage. Fuselage transported to the zero-length launcher (Photograph 2) by mobile crane.
- L-70: Wings are lowered into position on the fuselage and servos, ground supply feeds are connected.
- L-60: Nosecone/warhead is brought from the armory on a special trolley and winched up the launching ramp into position. Guidance equipment is set and checked. See Photograph 3 for an illustration of this procedure.
- L-40: The booster is hooked into place and final checkout begins. See Photograph 4 for an illustration of this procedure.
- L-05: The pad is cleared and the missile is raised to its launch angle of 17 degrees.
- L-03: Automatic engine start; power increases from 10% to 25%, then to 60%.
- L-01: Sustainer engine to 100% power.
- Launch: Booster ignites; remaining umbilicals pull free. See Photograph 1, depicting a TM-61 launch.

Source: Reference 8, pages 304-305.

Photographs courtesy of the USAF Museum, Wright-Patterson AFB, Ohio.

APPENDIX C

ORGANIZATIONAL LINEAGE

Sources: References 10, pages 144-50, and 20, pages 107-109.

MARTIN SSM/B-61/TM-61/MGM-1 "MATADOR"

TESTING

4802nd Guided Missile Squadron formed at Patrick AFB, Florida for research and development purposes; became the:

6555th Guided Missile Wing (later moved to Cape Canaveral, Florida with operational testing at Holloman AFB, New Mexico).

- 1st Pilotless Bomber Squadron (PBS) (light) formed 1 Oct 51 at Patrick AFB.
- 2nd PBS (light) formed 10 Jan 52.

"MATADOR A" EUROPEAN DEPLOYMENT

Headquarters, United States Air Forces, Europe.

- Headquarters, 12th Air Force.
 - 36th Tactical Fighter Wing (logistic support and operational control) beginning 14 Mar 55.
 - 1st PBS (TAC) deployed to Bitburg AB GE with 50 missiles, arriving 20 Mar 54. This unit was redesignated the 1st Tactical Missile Squadron (TMS) in Jun 55 concurrent with the missile's redesignation as TM-61A.
 - 50th Tactical Fighter Wing (logistic support and operational control) beginning 14 Mar 55.
 - 2nd PBS (TAC) deployed to Hahn AB GE with 50 missiles, arriving 1 Oct 54. This unit was redesignated the 69th TMS in Jun 55 concurrent with the missile's redesignation as TM-61A.
 - Both squadrons were brought under the 7382 Guided Missile Group, formed at Hahn AB on 1 Feb 56, for logistic support and operational control, relieving the 36th and 50th TFWs.

(Note: "Matador A" completely phased out of Europe by May, 1957.)

"MATADOR A" PACIFIC DEPLOYMENT

- The 17th TMS on Taiwan (Formosa) was the first TM-61A missile unit deploy in Asia. Numbers deployed, operating locations, and operational history for this unit are unknown.

"MATADOR C" EUROPEAN DEPLOYMENT

Headquarters, United States Air Forces, Europe.

- Headquarters, 12th Air Force.

-- 701st Tactical Missile Wing (TMW); unit redesignated 38th TMW on 18 Jun 58, based at Hahn AB.

--- 585th Tactical Missile Group (TMG) at Bitburg AB GE, formed 15 Sep 56.

---- 1st TMS and supporting squadrons equipped with "Matador C" by Feb 57.

--- 586th TMG at Hahn AB.

---- 69th TMS and supporting squadrons equipped with "Matador C" by Feb 57.

--- 587th TMW at Sembach AB GE.

---- 11th TMS and supporting squadrons deployed with 50 "Matador C" missiles from the outset; unit formed 1 Jul 56, arriving in Europe during 1957.

In Jun 58, the following squadron redesignations occurred:

- The 1st TMS at Bitburg became the 71st TMS.
- The 69th TMS at Hahn became the 405th TMS.
- The 11th TMS at Sembach became the 822nd TMS.

(Note: "Matador C" completely phased out of Europe by 1 Apr 60.)

"MATADOR C" PACIFIC DEPLOYMENT

- 314th Air Division, Osan AB, Korea.

-- 58th TMG (588th TMG until 1 Oct 58), Osan AB, with 60 missiles in 1958.

--- Flight 1 (20 missiles), Osan AB.

--- Flight 2 (20 missiles), Kimpo Airport (Seoul).

--- Flight 3 (20 missiles), Chinchon Ni.

(Note 1: "Matador C" completely phased out of S. Korea by 1962.)

(Note 2: Reference Map 2 for S. Korean TM-61C bases.)

ORGANIZATIONAL LINEAGE (Cont.)

MARTIN TM-61B/TM-76/MGM-13/CGM-13 "MACE"

"MACE A" EUROPEAN DEPLOYMENT

Headquarters, 12th Air Force.

- 38 TMW.

-- 585th TMG.

--- The 71st TMS at Bitburg AB GE would never receive "Mace A." They were ordered to retain the "Matador C" due to delays in replacing all-weather aircraft capability with the F-105. This unit would transition directly to "Mace B."

-- 586th TMG.

--- The 405th TMS at Hahn AB GE with 50 missiles.

-- 587 TMG.

--- The 822nd TMS at Sembach AB GE with 50 missiles.

- By September, 1962, three additional 38th TMW squadrons were added to the existing force, with 50 missiles each, bringing the total to 250 "Mace A" missiles.

-- The 89th TMS at Hahn AB GE.

-- The 823rd and 887th TMS' at Sembach AB GE.

(Note: "Mace A" completely phased out of Europe by Sept, 1966.)

"MACE A" PACIFIC DEPLOYMENT - None.

"MACE B" EUROPEAN DEPLOYMENT

Headquarters, 12th Air Force.

- 38th TMW.

-- By September 1965, 50 "Mace B" missiles and their hardened launchers were deployed to the 71 TMS, Bitburg AB GE.

(Note 1: "Mace B" completely phased out of Europe by 1 May, 1969.)

(Note 2: Reference Map 1 for German TM-61 and TM-76 bases.)

"MACE B" PACIFIC DEPLOYMENT

Headquarters, Fifth Air Force.

- 313th Air Division, Kadena AB, Japan.

-- 498th TMG (591st TMG prior designation) activated on
8 Feb 61 and deployed to Okinawa, Japan with 60 missiles.

--- 873 TMS, Bishagawa Billeting Annex.

---- Bolo Point Auxiliary Airfield (two tactical
missile flights - 20 missiles).

---- Motobu Quarry (one TMF - 10 missiles).

---- Motobu Army Airfield (one TMF - 10 missiles).

---- Camp Hansen Easely Range (two TMF - 20
missiles).

(Note 1: "Mace B" completely phased out of Japan during 1970-71.)

(Note 2: Reference Map 3 for TM-76B operating locations on
Okinawa.)

ORGANIZATIONAL LINEAGE (Cont.)

GENERAL DYNAMICS BGM-109G "GRYPHON"

Headquarters, United States Air Forces in Europe

- Headquarters, Third Air Force, RAF Mildenhall UK
 - Wing 1: 501st TMW, RAF Greenham Common UK
 - IOC: Dec 83
 - Number flights projected/deployed: 6/6
 - Number missiles projected/deployed: 96/96
 - Wing 5: 303rd (ex-550th) TMW, RAF Molesworth UK
 - IOC: Dec 87
 - Number flights projected/deployed: 4/1
 - Number missiles projected/deployed: 64/16
- Headquarters, 16th Air Force, Torrejon AB SP
 - Wing 2: 487th TMW, Comiso AS IT (Sicily)
 - IOC: Mar 84
 - Number flights projected/deployed: 7/7
 - Number missiles projected/deployed: 112/112
- Headquarters, 17th Air Force, Sembach AB GE
 - Wing 3: 485th TMW, Florennes AB BE
 - IOC: Mar 85
 - Number flights projected/deployed: 3/1
 - Number missiles projected/deployed: 48/16
 - Wing 4: 38th TMW, Wueschheim AS GE
 - IOC: Mar 86
 - Number flights projected/deployed: 6/4
 - Number missiles projected/deployed: 96/64
 - Wing 6: 486th TMW. Woensdrecht AB NL
 - IOC: N/A
 - Number flights projected/deployed: 3/0
 - Number missiles projected/deployed: 48/0

TOTALS

	<u>Projected</u>	<u>Deployed</u>
Flights	29	19
Missiles	464	288

(Note: Reference Map 4 for BGM-109G operating locations.)

APPENDIX D

SPECIFICATION: Martin "Mace"

Designations: TM-61B, TM-76A/B, MGM-13A/B, MQM-13B (target drone)

Dimensions:

- Length: 44 feet 2 inches
- Wing Span: 22 feet 1 inches
- Diameter: 4 feet 6 inches

Weight: 13,000 pounds

Performance:

- Speed: Mach 2.8
- Range:
 - "Mace A": 800 miles
 - "Mace B": 1500 miles
- Ceiling: Over 40,000 feet

Propulsion:

- Sustainer: One Allison J33-A-41 turbojet engine producing 5,200 pounds of thrust
- Booster: One Thiokol solid rocket motor producing 50,000 pounds of thrust

Guidance:

- "Mace A": Goodyear Automatic Terrain Recognition and Navigation (ATRAN) system
- "Mace B": AC Spark Plug "ACHiever" inertial guidance system

Warhead: One conventional or W-28 fusion nuclear warhead of 2 megaton yield

Prime Contractor: Martin Aircraft (now Martin Marietta)

Number of Missiles: Over 1000 produced

- 250 "Mace A" deployed to Europe
- 50 "Mace B" deployed to Europe
- 60 "Mace B" deployed to Okinawa, Japan

Key Development Dates:

- First YTM-76A flown on 12 Oct 55.
- Production began in May, 1958.
- First TM-76A deployed in April, 1959.
- First TM-76B deployed in September, 1961.

Source: Reference 10, page 148.

APPENDIX E

SPECIFICATION: General Dynamics "GRYPHON"

Designation: BGM-109G (Boosted Guided Missile)

Dimensions:

- Length: 18 feet 2 inches; with booster, 20 feet 6 inches
- Wing span: 8 feet 7 inches (wings extended)
- Diameter: 1 foot 9 inches

Weights:

- Missile alone: 2,650 pounds
- Missile with booster: 3,200 pounds

Performance:

- Speed: Approximately 500 mph
- Range: 1500 miles
- Ceiling: 10 to 500 feet
- Warhead CEP: 100 feet

Propulsion:

- Sustainer: One Williams International F-107-WR-102 turbofan producing 600 pounds of thrust
- Booster: One solid fuel rocket motor producing 7000 pounds of thrust

Guidance: Inertial system with McDonnell Douglas Terrain Contour Matching (TERCOM) updates at selected intervals

Warhead: One W-84 fusion warhead of 80 kilotons yield

Prime Contractor: General Dynamics

Number of Missiles:

- 464 planned for deployment in Europe
- 288 actually deployed in five European countries

Source: Reference 10, page 150.

APPENDIX F

"GRYPHON" FLIGHT COMPOSITION (Typical)

Personnel: 70

- Flight Commander (1)
- Assistant Flight Commander (1)
- Launch Control Officers (4) (two per LCC)
- Maintenance personnel (19) (all enlisted)
- Security Police (44)
 - At UK bases, 1/3 of security police were RAF Regiment
 - At Comiso, 1/3 of security police were Italian Carabinieri
- Medic (1)

Vehicles: 19

- Transporter Erector Launchers (TEL) (4)
 - Four missiles in All-Up-Round configuration per TEL
- Launch Control Center (LCC) (2)
- Wrecker (1)
- Security Police vehicles (10)
- Supply vehicles (5)

Notes:

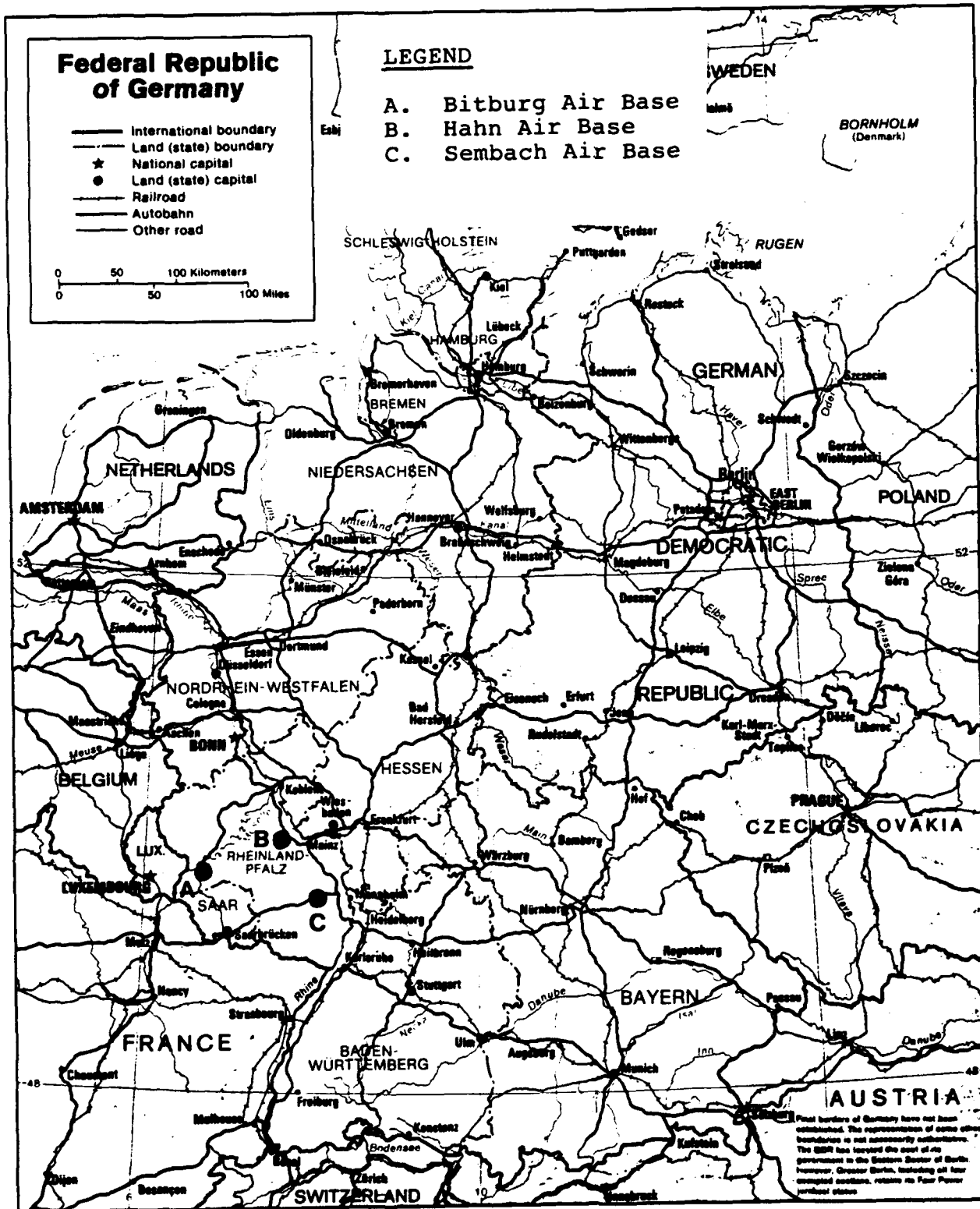
Normally GLCM convoys traveled in two cells. Each cell had two TELs and one LCC, so each retained an independent launch capability.

TELs, LCCs, and the Wrecker used the German M.A.N (Maschinenfabrick Augsburg - Nuremburg) prime mover. The US Army's "Pershing II" used the same prime mover.

Several security and supply vehicles towed water buffaloes or cargo trailers.

MAP 1

GERMAN TM-61 AND TM-76 BASES



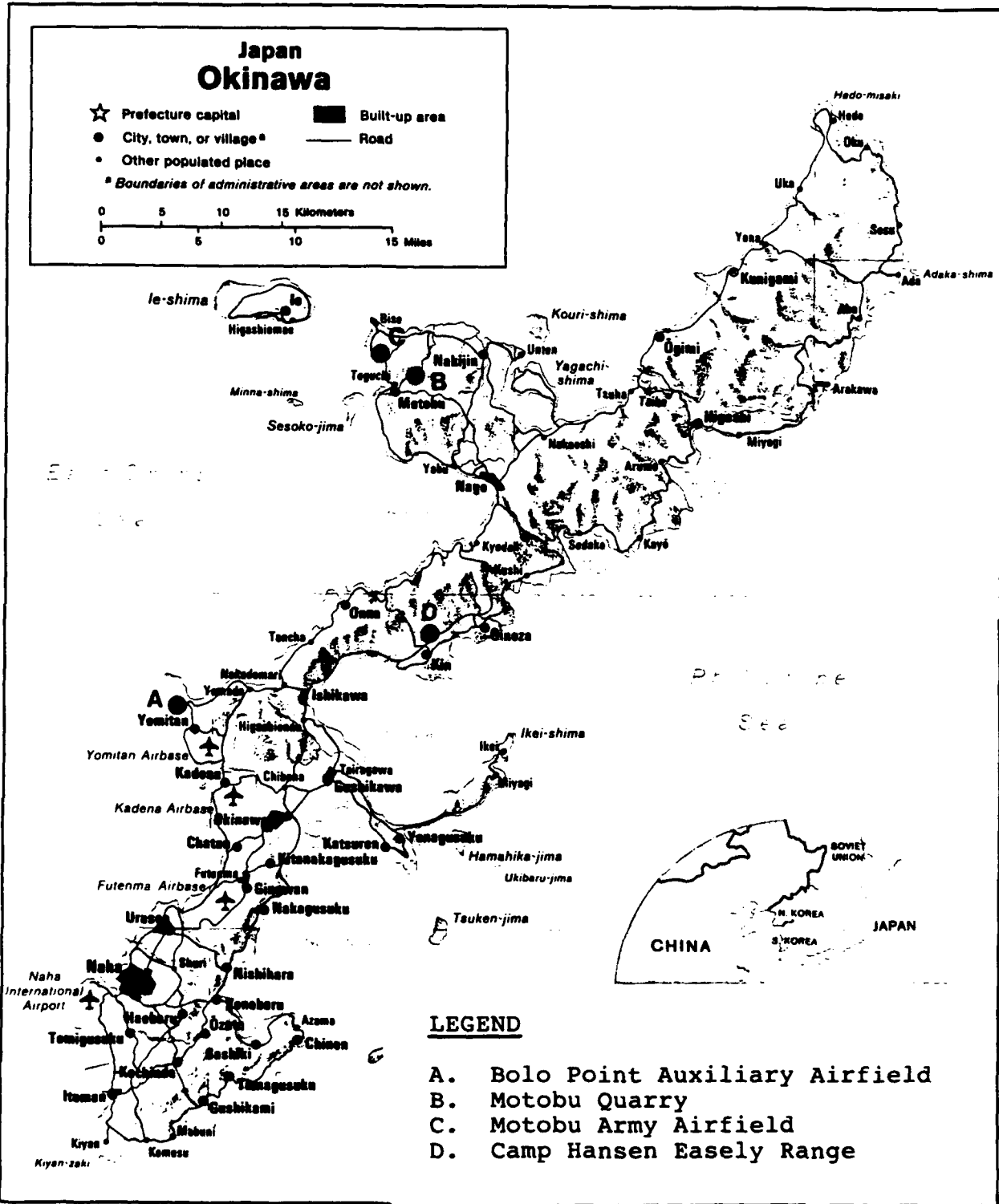
MAP 2

SOUTH KOREAN TM-61C BASES



MAP 3

TM-76B BASES ON OKINAWA

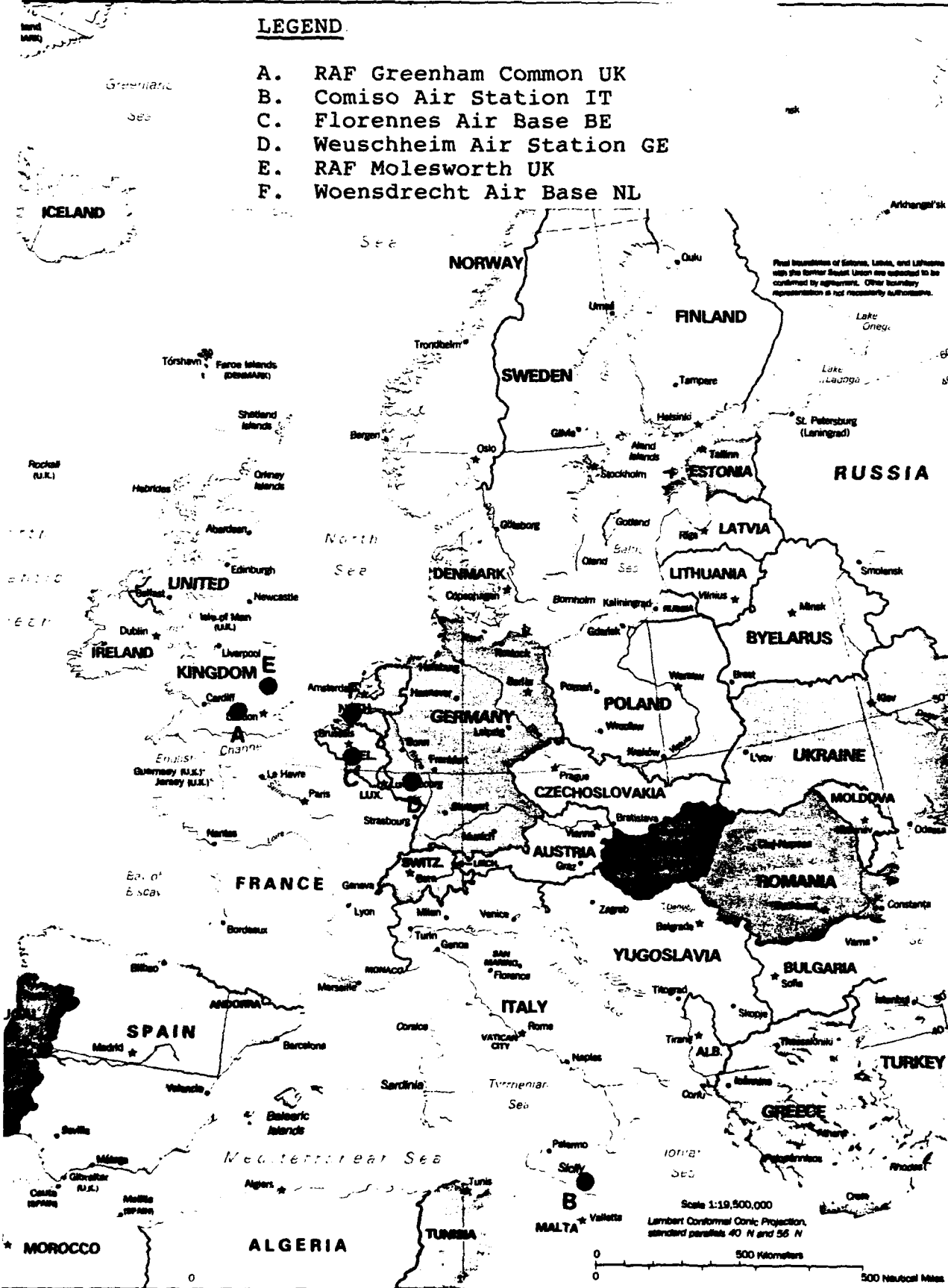


MAP 4

BGM-109G BASES IN USAFE

LEGEND

- A. RAF Greenham Common UK
- B. Comiso Air Station IT
- C. Florennes Air Base BE
- D. Weuschheim Air Station GE
- E. RAF Molesworth UK
- F. Woensdrecht Air Base NL



801970 (801266) 2-92

FIGURE 1
 MARTIN TM-61 "MATADOR"

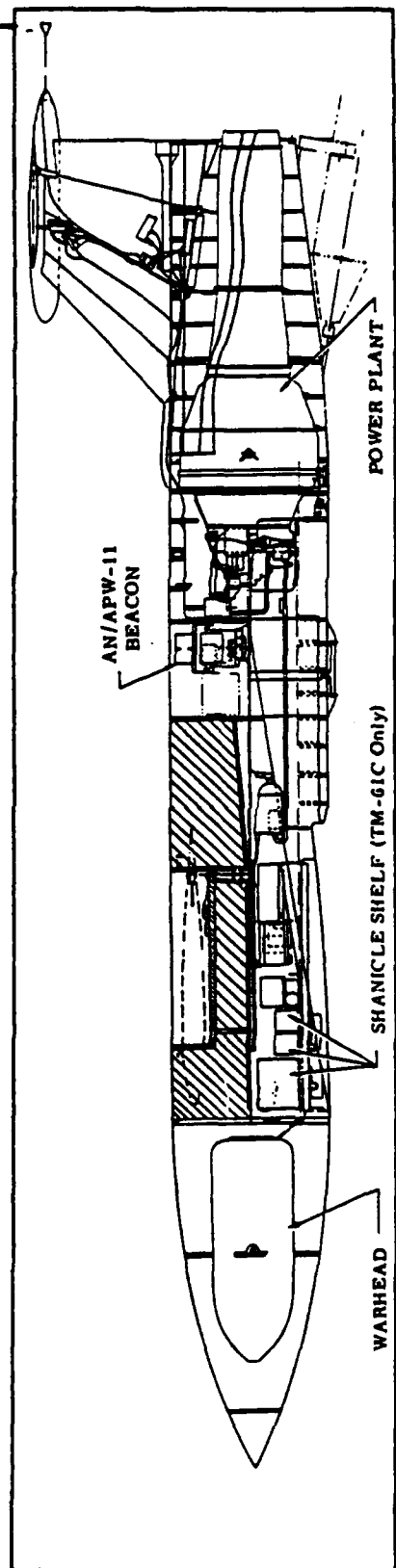
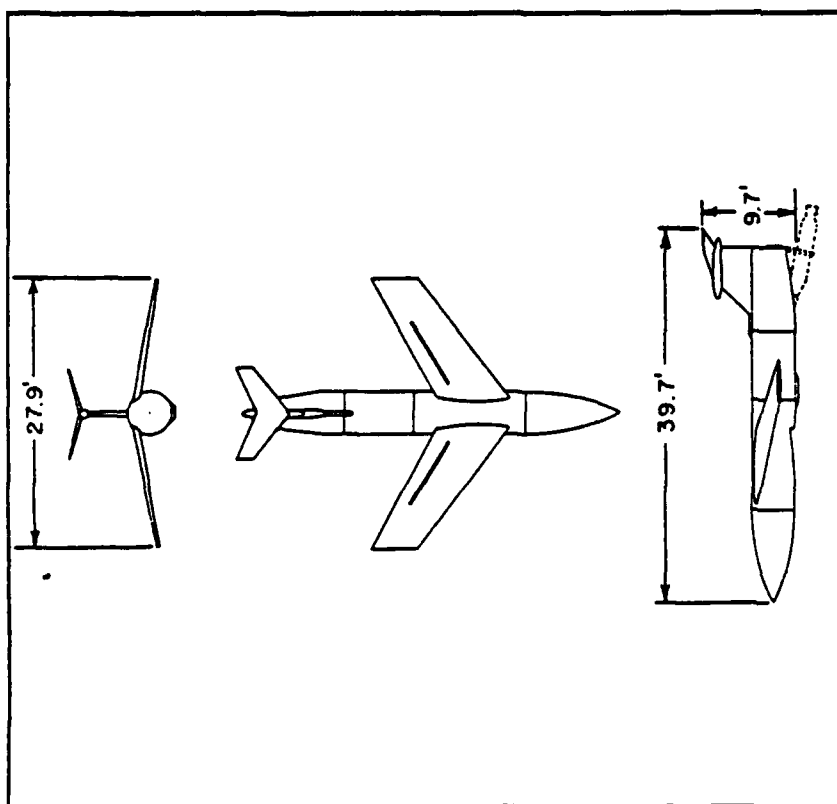
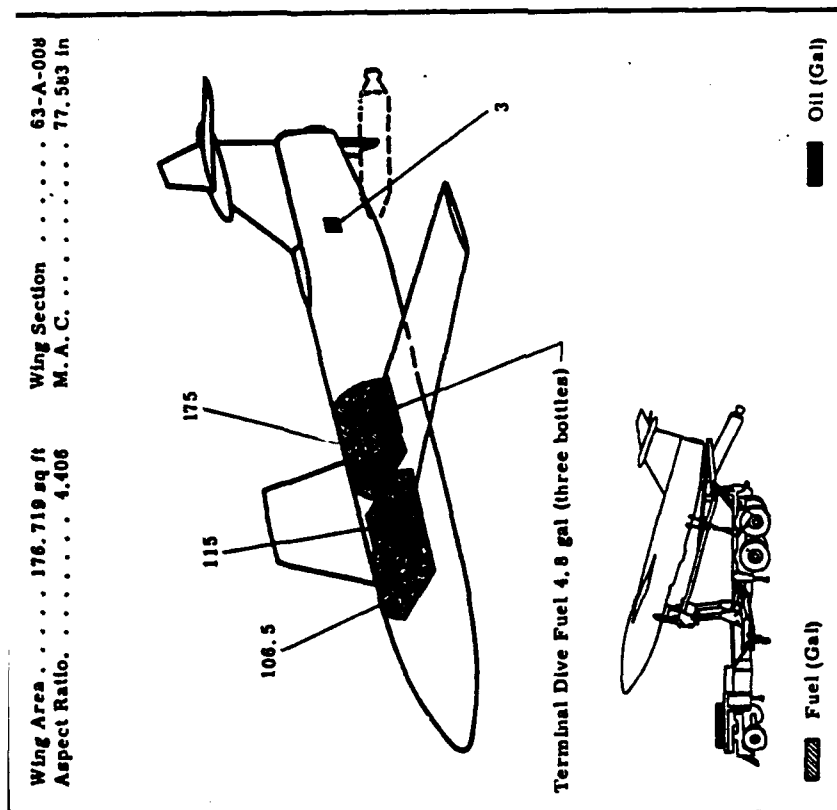
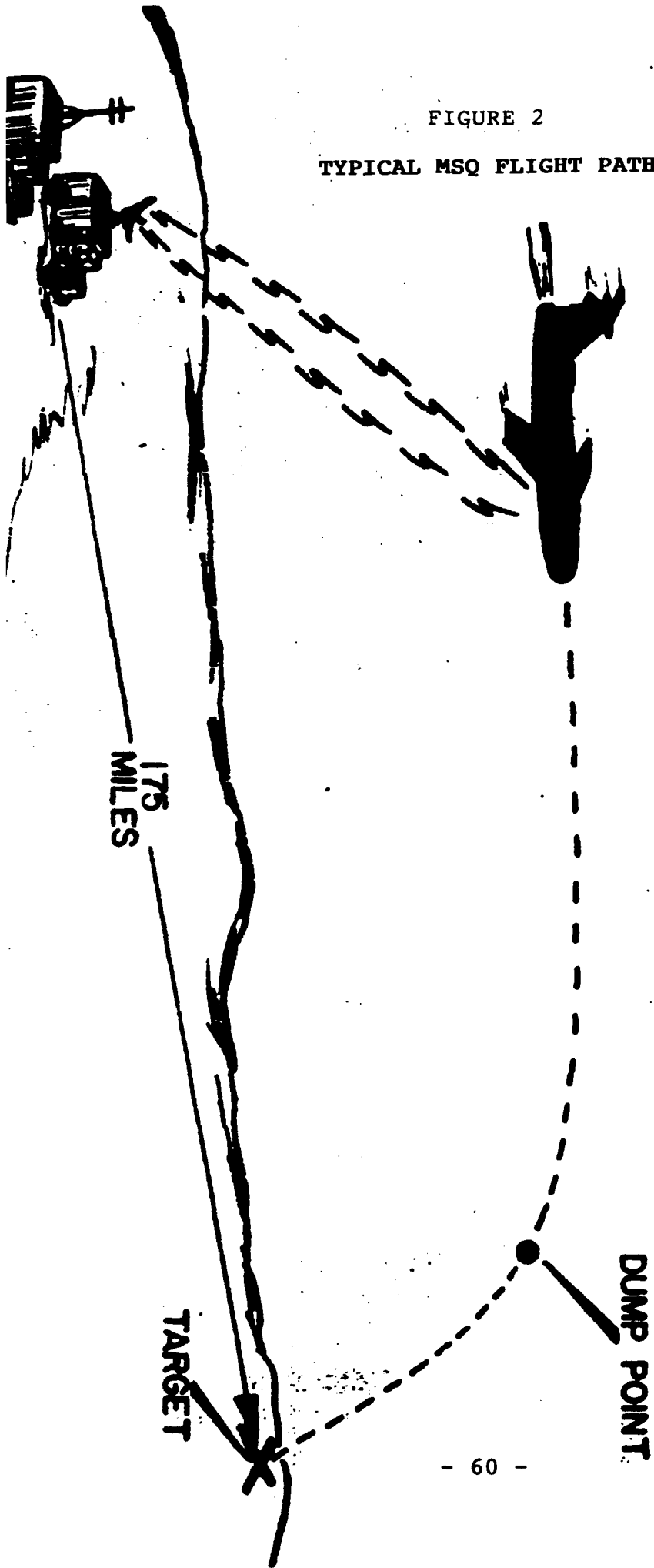


FIGURE 2

TYPICAL MSQ FLIGHT PATH



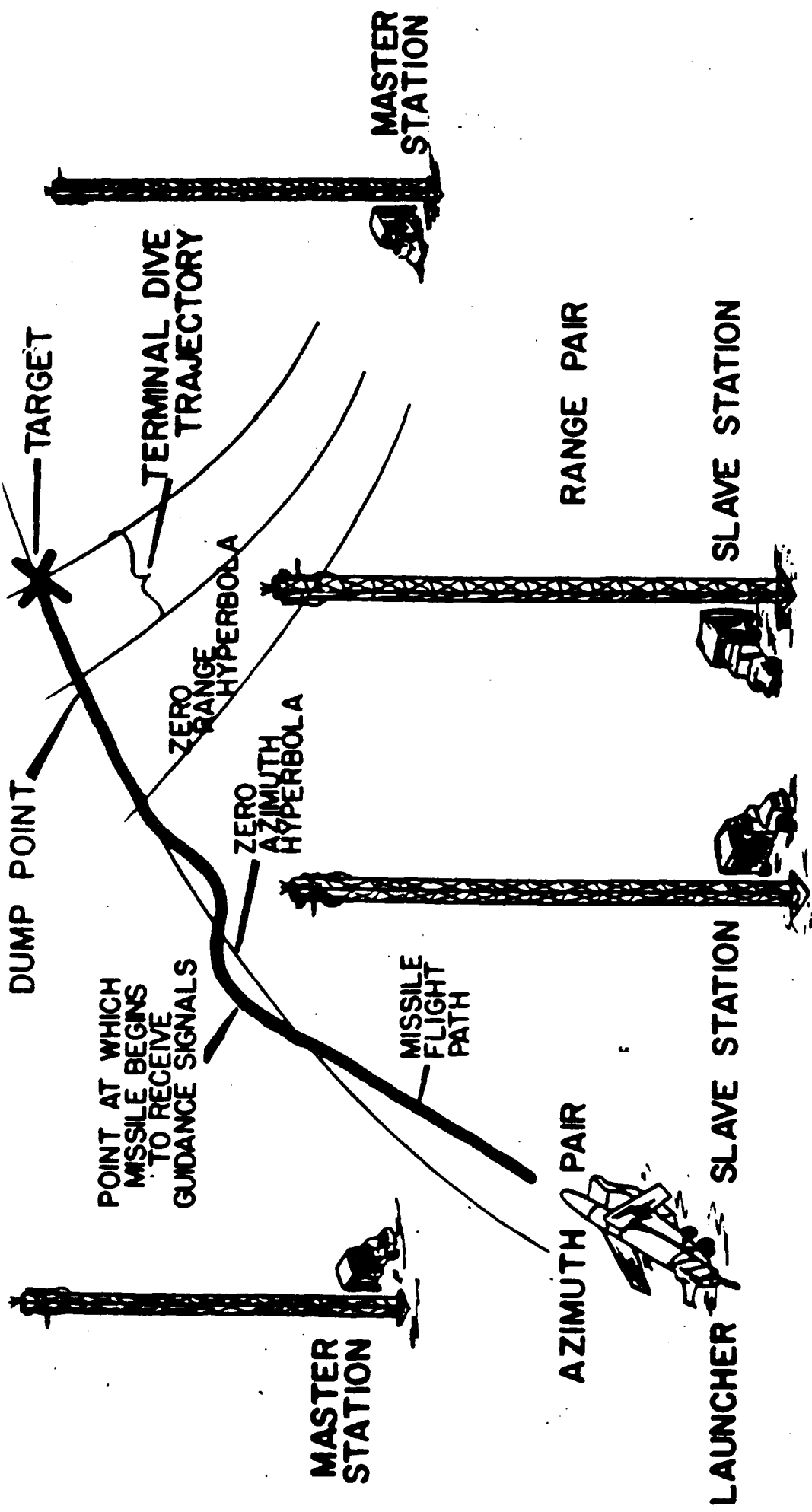


FIGURE 3

TYPICAL SHANGLE FLIGHT PATTERN

FIGURE 4

MARTIN TM-76A "MACE"

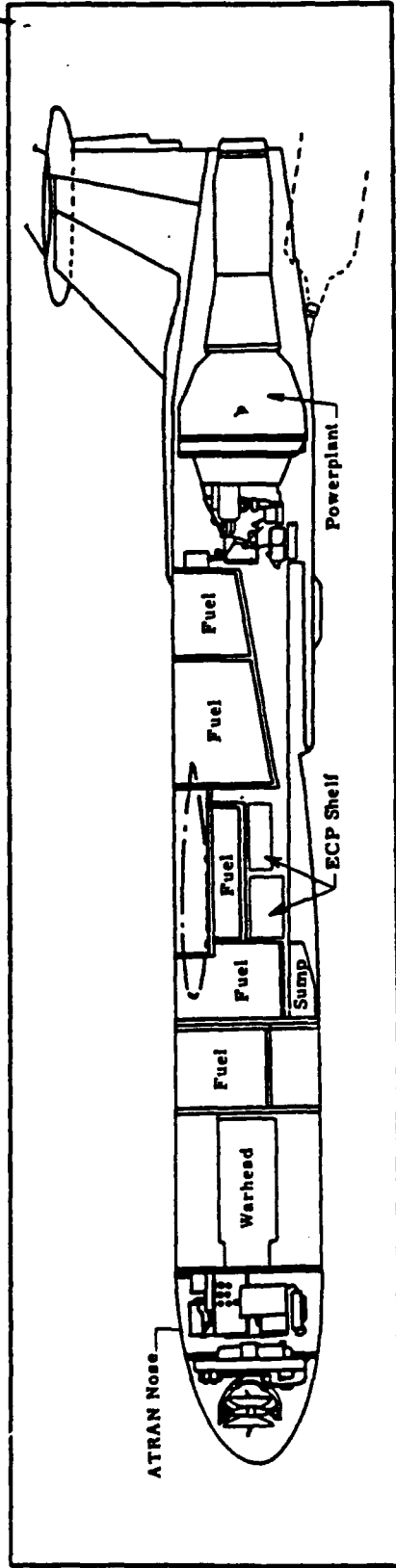
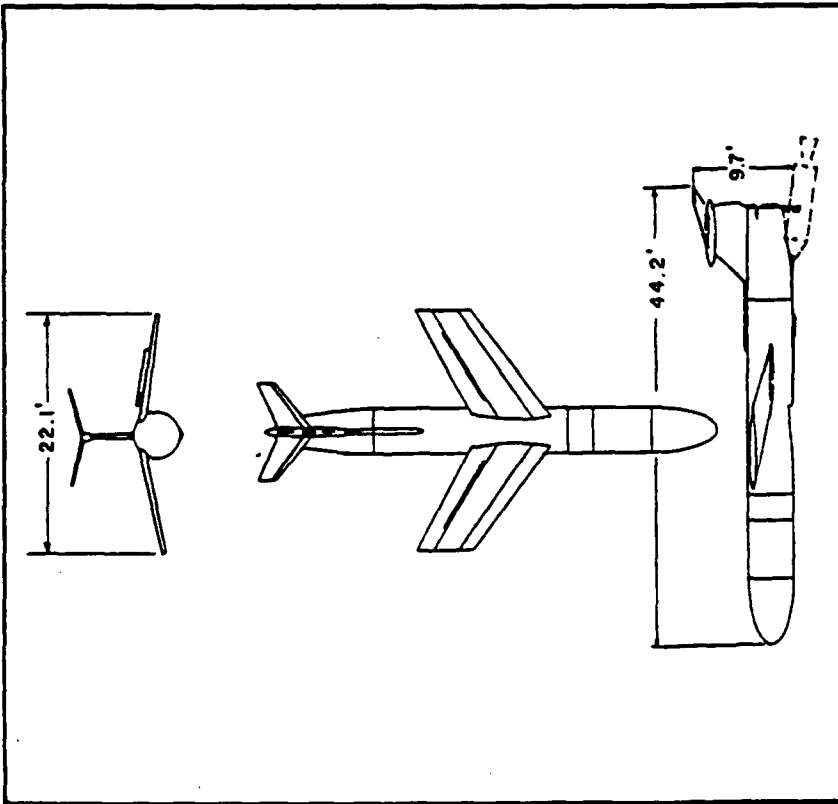
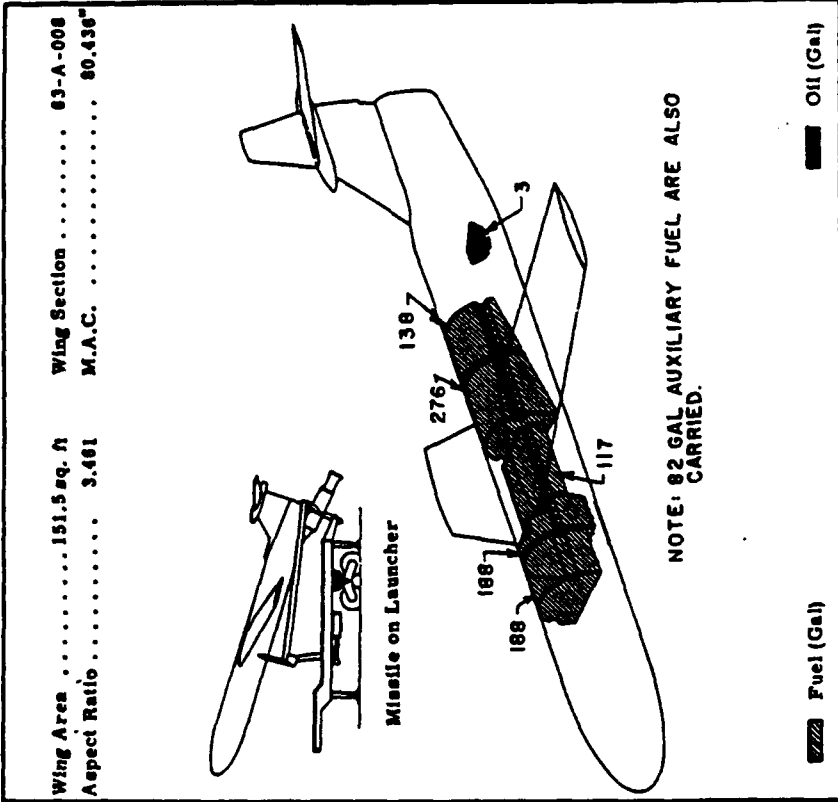


FIGURE 5

MARTIN TM-76B "MACE"

Wing Area 151.5 sq ft Wing Section 63-A-008
 Aspect Ratio 3.461 MAC 80.426"

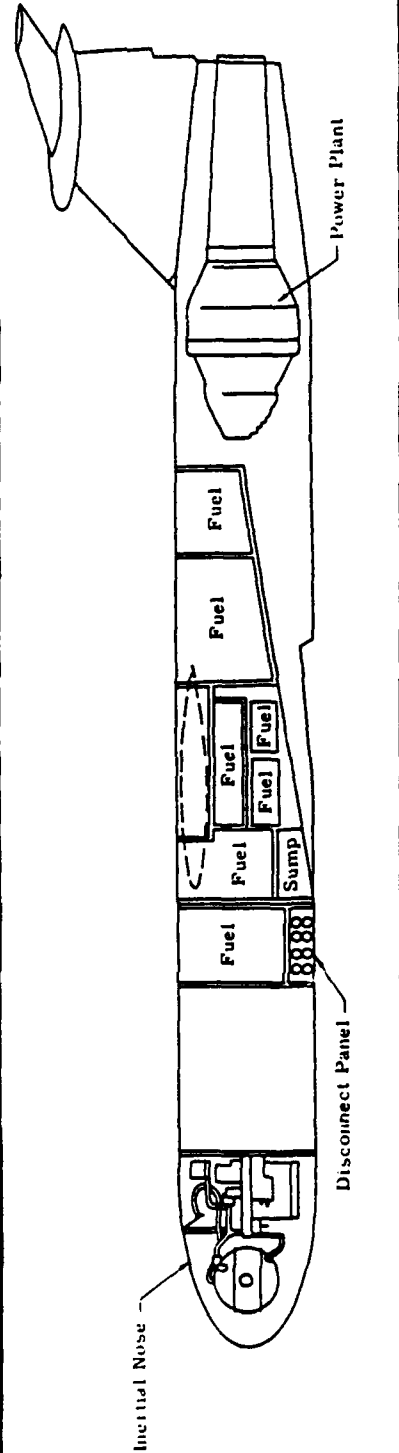
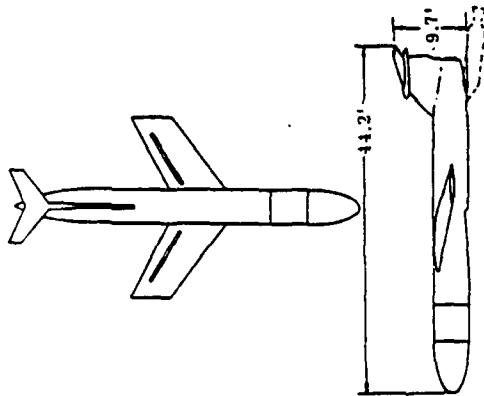
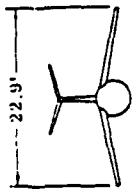
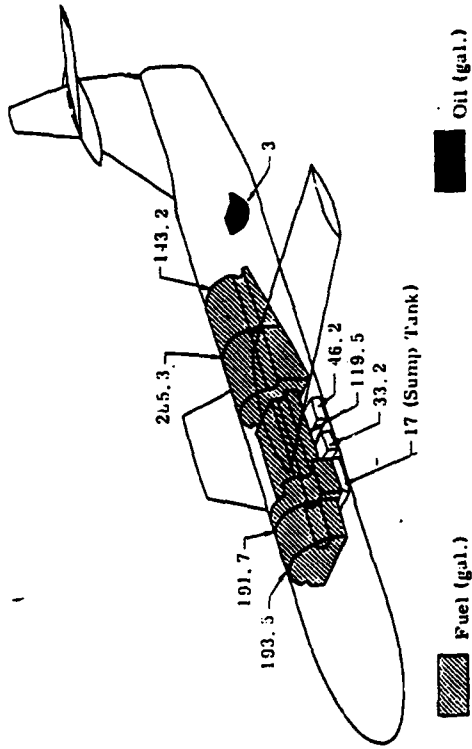


FIGURE 6

"MACE A" TERACRUZER AND TRANSLAUNCHER

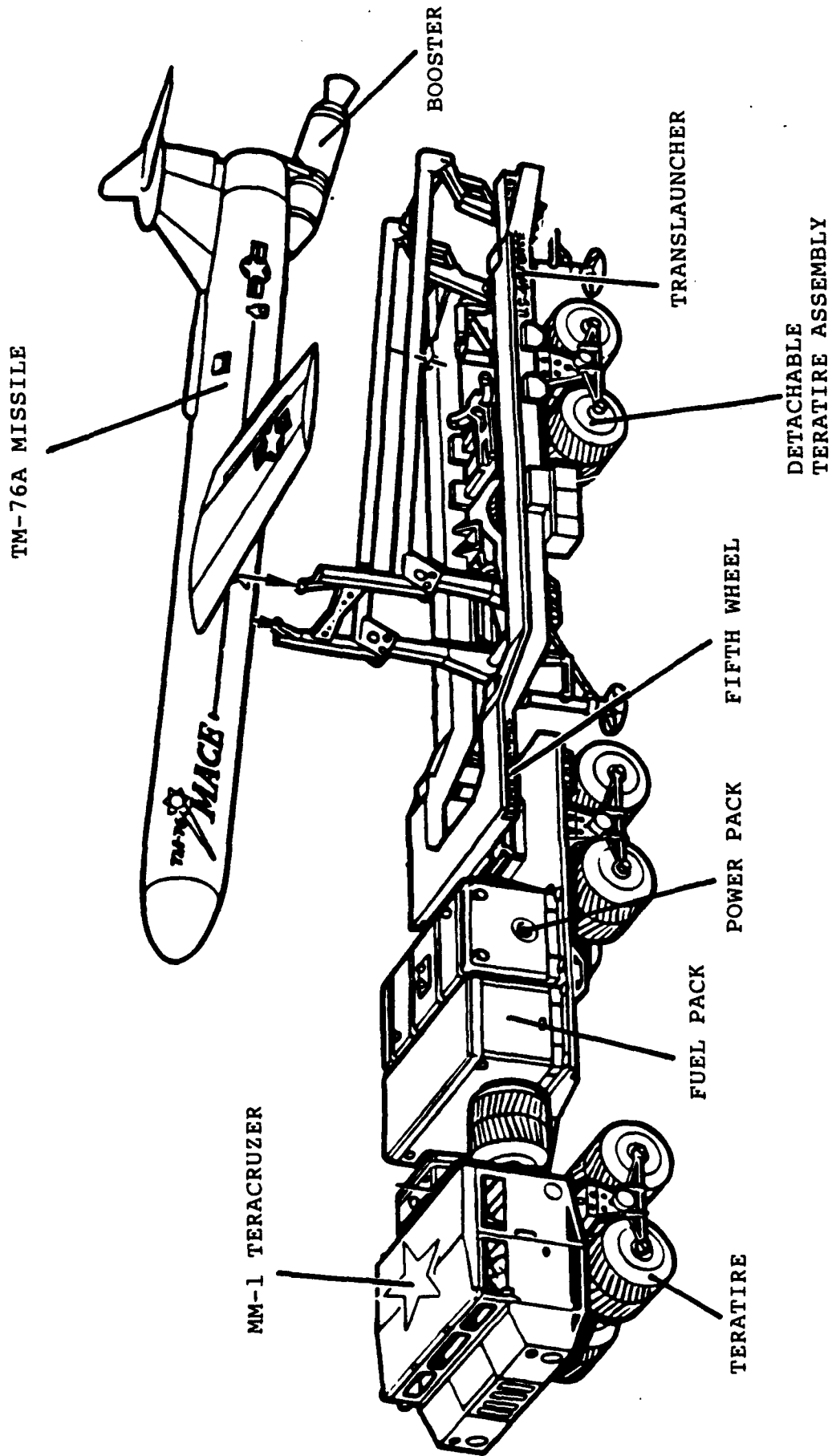
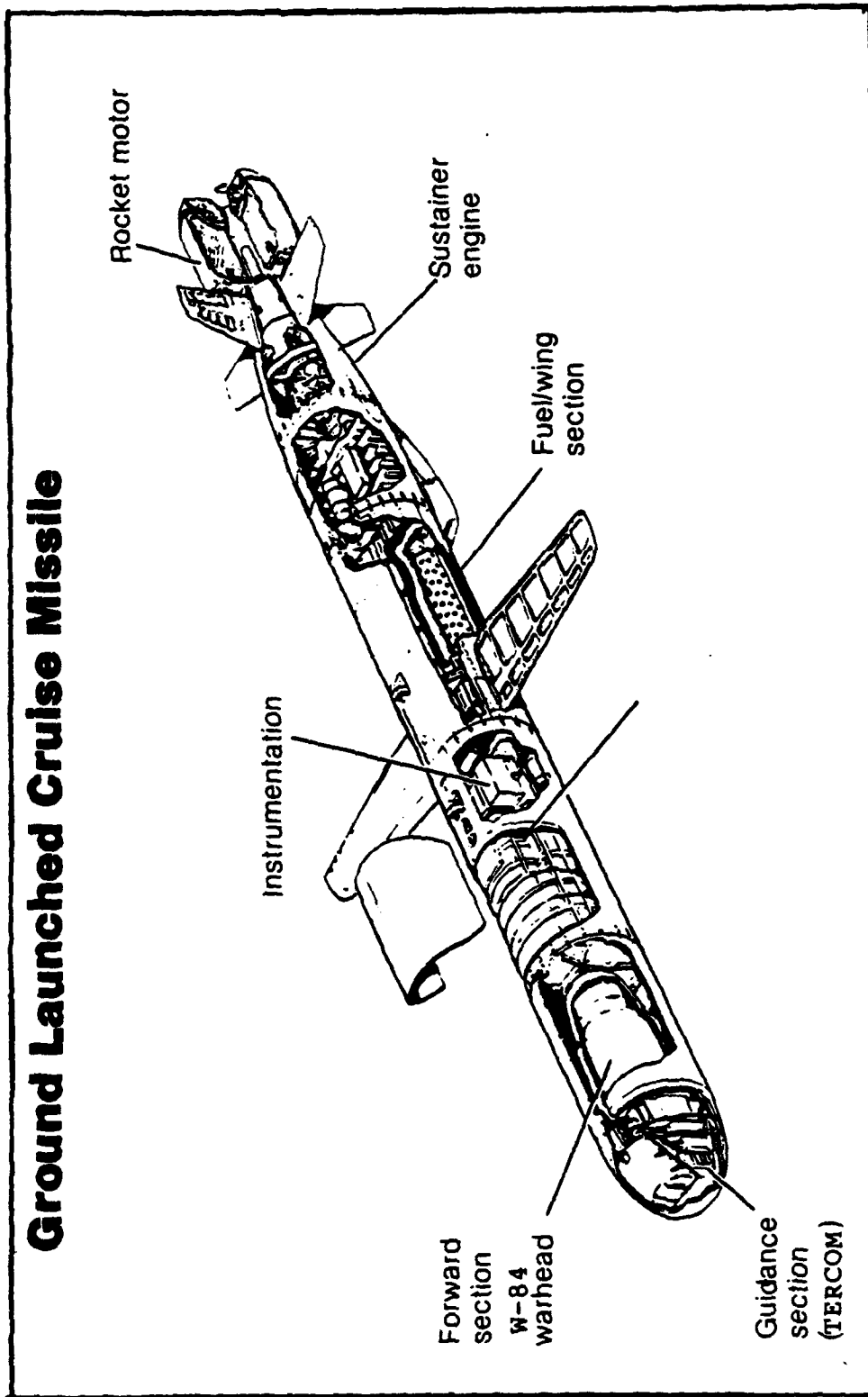


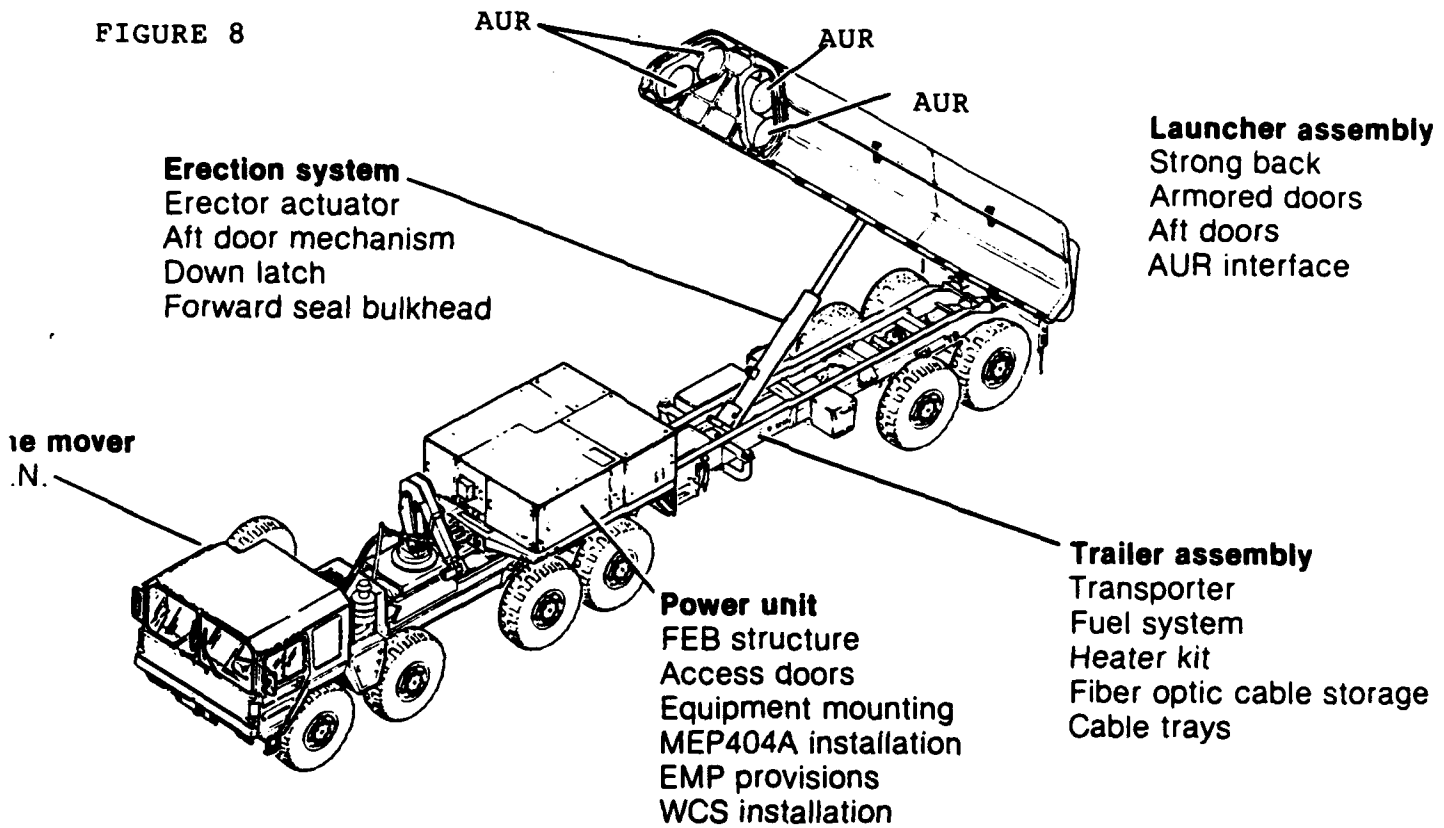
FIGURE 7

GROUND LAUNCHED CRUISE MISSILE - BGM-109G

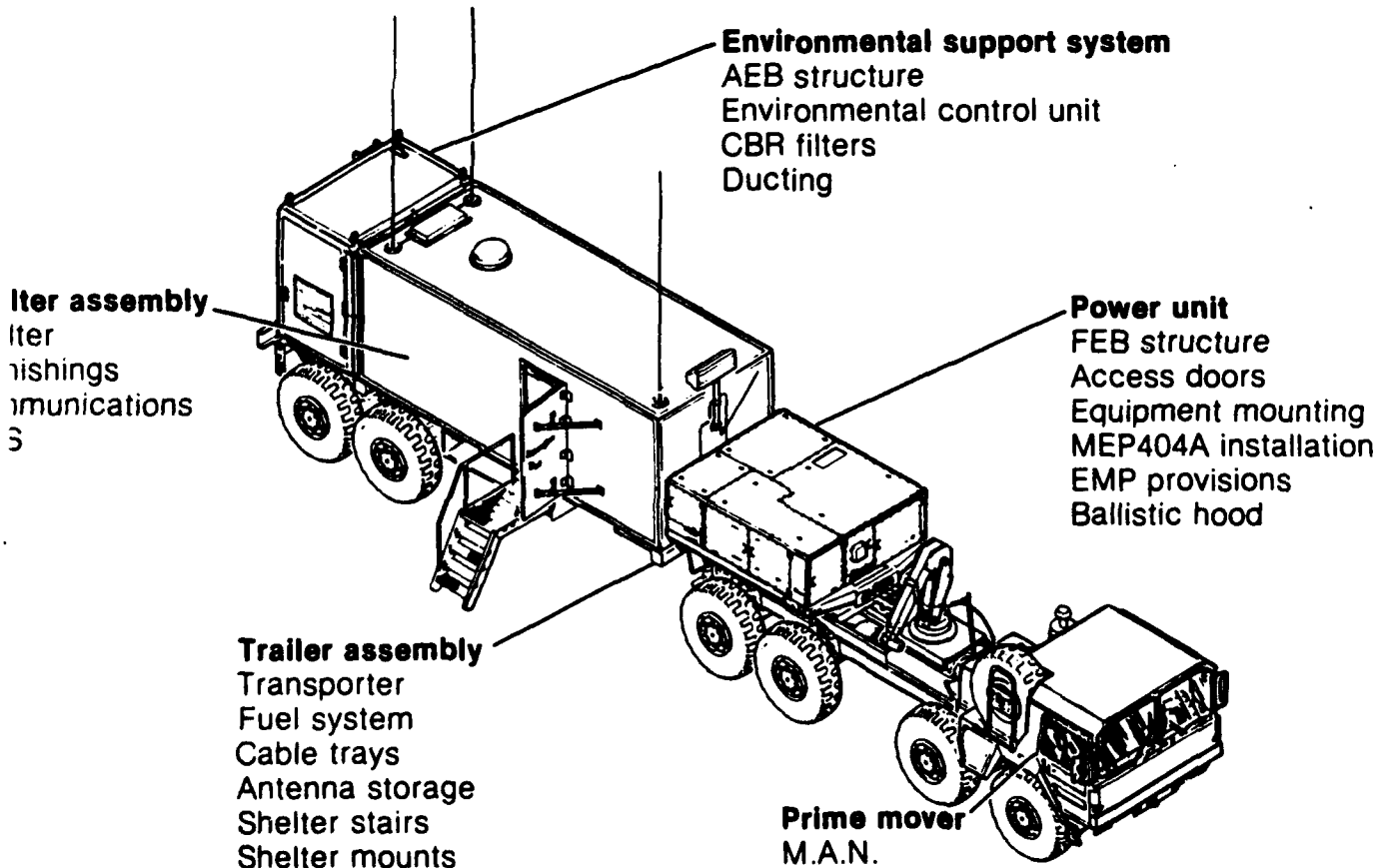


Transporter-Erector-Launcher (TEL)

FIGURE 8



Launch Control Center (LCC)



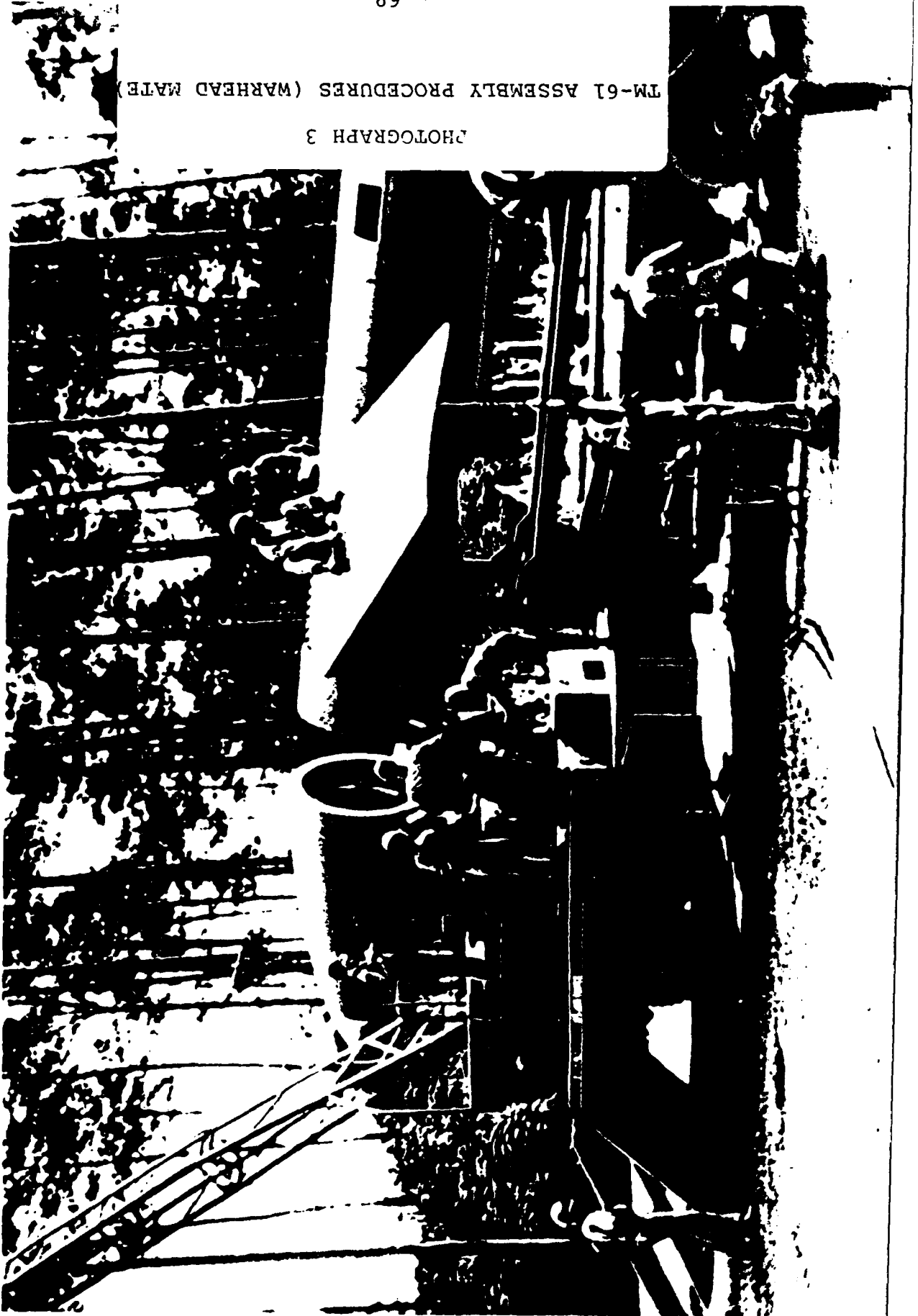
TM-61 MISSILE LAUNCH

PHOTOGRAPH 1



TM-61 ASSEMBLY PROCEDURES (WARHEAD MATE)

PHOTOGRAPH 3



TM-61 ZERO-LENGTH LAUNCHER

PHOTOGRAPH 2



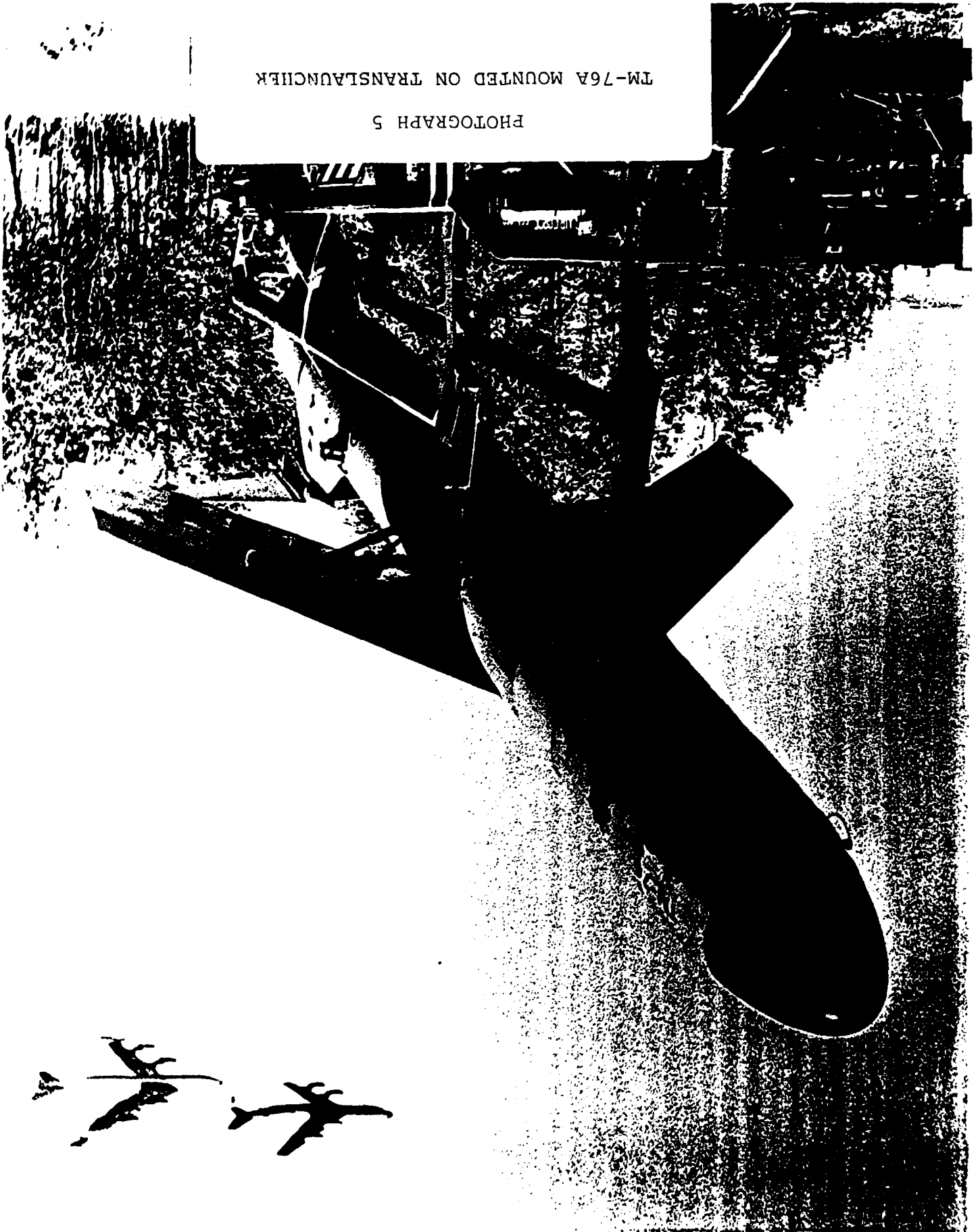
TM-61 ASSEMBLY PROCEDURES (RATO LOADING)

PHOTOGRAPH 4



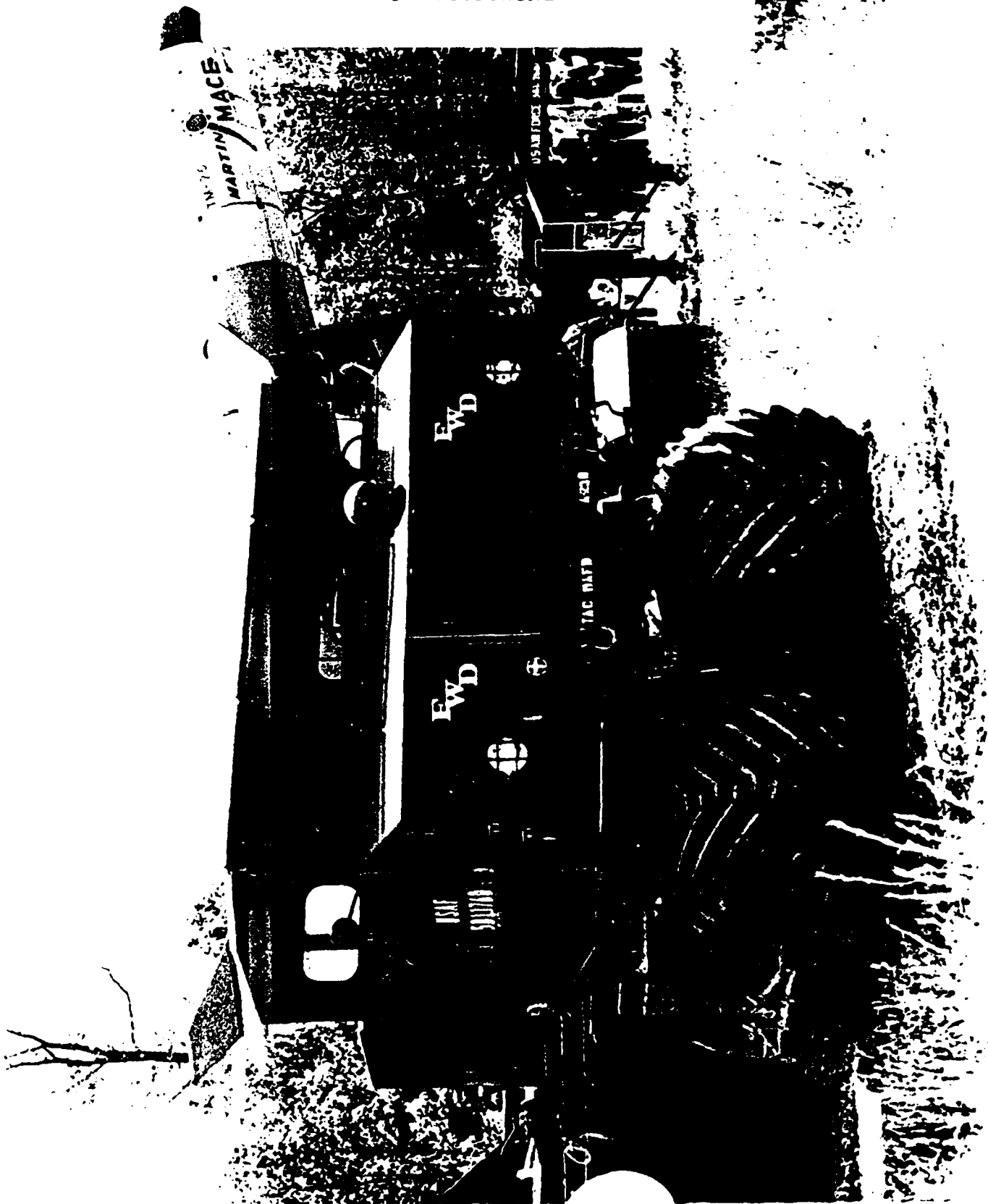
TM-76A MOUNTED ON TRANSLAUNCHER

PHOTOGRAPH 5



MM-1 PRIME MOVER FOR THE TM-76A

PHOTOGRAPH 6



RAPID FIRE MULTIPLE LAUNCH FACILITY

PHOTOGRAPH 7



20/1/74 CE 11/1/74 48



MACE: Tactical surface-to-surface guided missile
fired from a hardened site.

PHOTOGRAPH 8

TM-76B LAUNCH FROM HARDENED SHELTER

LIST OF REFERENCES

1. MSgt Gary R. Akin, "Evolution and Development of Cruise Missiles," Air Power History, Vol. 38, No. 2, Summer, 1991, pp. 43:48, Air Force Historical Foundation: 1991.
2. Dr. David Baker, PhD., The Rocket, The History and Development of Rocket and Missile Technology, London: New Cavendish Books, 1978.
3. Dr. James A. Bell, PhD., "The Mighty Mace," The Airman, August, 1961, pp. 18-19.
4. Robert Berman and Bill Gunston, Rockets and Missiles of World War III, London, New York, Sydney, and Toronto: Hamlyn (Bison Books Corp.), 1983.
5. Ronald Farquhar, "Matadors in Germany," Royal Air Force Flying Review, August, 1954, pp. 20-21.
6. Fifth Air Force History, 1 Jan through 30 Jun 58, Document No. 5FCAG12070.
7. Bernard Fitzsimons, Editor, Weapons and Warfare, The Illustrated Encyclopedia of 20th Century, Vol. 17, New York: Columbia House, 1969.
8. John Fricker, "The U.S.A.F.'s Operational Guided-missile," The Aeroplane, August 26, 1955, pp. 300-306.
9. Kenneth Gatland, "Martin Mace - Missile with the Knockout Punch," Royal Air Force Flying Review, Vol XIV, No. 1, October, 1958, pp. 43-45.
10. James Norris Gibson, The History of the US Nuclear Arsenal, Greenwich CT: Brompton Books, 1989.
11. Bill Gunston, Rockets and Missiles, London: Salamander Books, 1979.
12. History of USAFE, 1 Jan through 30 Jun 1957, Vol I, Narrative, 15 Nov 57.
13. Oliver, L. Hobson, Historical Division, Office of Information Services, History of the Pacific Air Forces, 1 Jul 58 - 31 Dec 58.
14. Fred Horky and Dr. Griffin T. Murphy, "Mace/Teracruzer, Part 1," International Plastic Modelers Society Quarterly, Vol. 21, No. 3, Spring, 1986, pp. 5-17, IPMS/USA: 1986.

LIST OF REFERENCES
(Continued)

15. HQ TAC/TOOT-TL, TM-61C Operations Summary, 10 Oct 60.
16. Daniel W. Jenkins, Maj Gen, USAF, "The Mace Missile," Ordnance, November-December, 1959. pp. 414-415.
17. Lloyd S. Jones, U.S. Bombers: 1928 to 1980s, Fourth Edition, Fallbrook, CA: Aero Publishers, 1984.
18. Frank G. McGuire, "Mace B Bases Readied on Okinawa," Rockets and Missiles, March 13, 1961, p. 18.
19. Missilier, the 701st TMW's Magazine, Vol I, No. 2, March, 1958.
20. Dr. Walter S. Moody, PhD, Historian, HQUSAFE Office of History, "Air Force Posture in NATO's Central Region, 1947-1976," USAF Historical Monograph, 17 May 78.
21. Stan Morse, Managing Editor, War Machine, Vol. 1, Issue 2, "Surface to Surface Missiles," London: Orbis Publications, 1983.
22. Stan Morse, Managing Editor, War Machine, Vol. 8, Issue 85, "Early Strategic Missiles," London: Orbis Publications, 1985.
23. Wayne G. Peterson, Command Historian, The Mace - Matador Guided Missile Program in the 313 AD, 26 May 59.
24. Carroll S. Shershun, Capt, USAF, "Who Needs Glamour?," The Airman, August, 1963, pp. 20-23.
25. L.W. Schopp and C.E. Fordham, Goodyear Aircraft Corp., Akron, Ohio, "GSE Design Criteria," Astronautics, December, 1958, pp. 34-35, 78.
26. TAWC Information Office, Eglin AFB, FL, and Robert P. Everett, Capt, USAF, "Old Maces Die Hard," and "Old Missile On the Firing Line," (respectively) The Airman, March, 1969, pp. 18-23.
27. Michael J. H. Taylor, Missiles, Warbirds Illustrated No. 12, London, Melbourne, and Harrisburg PA: Arms and Armor Press, 1983.
28. Bernard J. Termena M.A., Historian, Air Materiel Command, History of the Mace and Matador Guided Missiles, 1951 - 1957, Historical Study No. 317, Vol I.

LIST OF REFERENCES
(Continued)

29. Jack L. Thatcher, 2nd Lt, USAF, Historical Officer, "History of the 701st TMW, 1 Jan 58 - 15 Jun 58."
30. TM-61C Missile Operations Handbook, undated, published by the 701st TMW.
31. TM-76A Training Plan, Document No. TODO-30021, 9 Mar 61.
32. Stanley Ulanoff, The Illustrated Guide to US Missiles and Rockets, Garden City, NY: Doubleday and Co., 1959.
33. Kenneth P. Werrell, The Evolution of the Cruise Missile, Maxwell AFB AL: Air University Press, 1985.
34. "Zero Length Launcher," Ordnance, January - February 1955, p. 15.

GLOSSARY

AB	Air Base
ALCM	Air Launched Cruise Missile
ATRAN	Automatic Terrain Recognition & Navigation
AUR	All-Up-Round (BGM-109G)
BGM	Boosted Guided Missile (as in BGM-109G)
CEP	Circular Error Probable (warhead accuracy)
CFE	Conventional Forces in Europe (Treaty)
GAMA	GLCM Alert & Maintenance Area (BGM-109G)
GLCM	Ground Launched Cruise Missile
INF	Intermediate Range Nuclear Forces (Treaty)
IOC	Initial Operational Capability
ITCP	Initial Timing Control Point (BGM-109G)
LBS	Abbreviation for Pounds
LCC	Launch Control Center (BGM-109G)
MARC/MSQ	Manual Airborne Radio Control (TM-61A)
MM-1	Military Model One ("Mace" Teracruzer)
MPH	Miles Per Hour
PBS	Pilotless Bomber Squadron
QRA	Quick Reaction Alert
RATO	Rocket Assisted Take Off (booster)
RFML	Rapid Fire Multiple Launch (TM-76A)
RSS	Ready Storage Structure (BGM-109G)
SHANICLE	Short Range Navigation Vehicle (TM-61C)
SSM	Surface-to-Surface Missile
START	Strategic Arms Reduction Talks

GLOSSARY

(Cont.)

TAC	Tactical Air Command
TAWC	Tactical Air Warfare Center (Eglin AFB)
TEL	Transporter-Erector-Launcher (BGM-109G)
TERCOM	Terrain Contour Matching (BGM-109G)
TM	Tactical Missile (as in TM-61 & TM-76)
TMG	Tactical Missile Group
TMS	Tactical Missile Squadron
TMW	Tactical Missile Wing
USAF	United States Air Force
USAFE	United States Air Forces in Europe
Vergeltungswaffe	German for "Vengeance Weapon" (V-1)
ZEL	Zero Length Launcher (TM-61)