15 Oct 2006

Weapons Delivery Manual

Strike Fighters: Project 1
Wings Over Vietnam
Wings Over Europe

Rob "Bunyap" McCray
bunyap@tularosa.net
www.bunyap2w1.com

Contributors

Like the Weapons Pack, this manual is a community project. Feel free to submit any information or material for any section of the manual.

The following people have contributed to sections of this manual:

“Streakeagle”
“Mk2”
“Deacon211”
“USAFMTL”
“Zerocino”
“Kout”

Introduction

This manual is a companion to the Strike Fighters: Project 1 Weapons Pack and contains information on the weapons and equipment included with the pack. In addition to weapon descriptions, you will find procedures for employing the weapons in Strike Fighters: Project 1.

Two sections dealing with mission planning and mission execution are also included as a primer on techniques to use when delivering the various weapons. All information presented draws heavily on 60's and 70's era USAF manuals.

You will notice that some sections are more complete than others. This manual is very much a work in progress and, considering the number of weapons and amount of information to be covered, will never be fully complete.

All "in action" screenshots were taken from the sim by community members and all weapon models shown are those included with the Weapons Pack. The artwork you see throughout this manual is from the Cold War era flight manuals where much of the information presented here originated.

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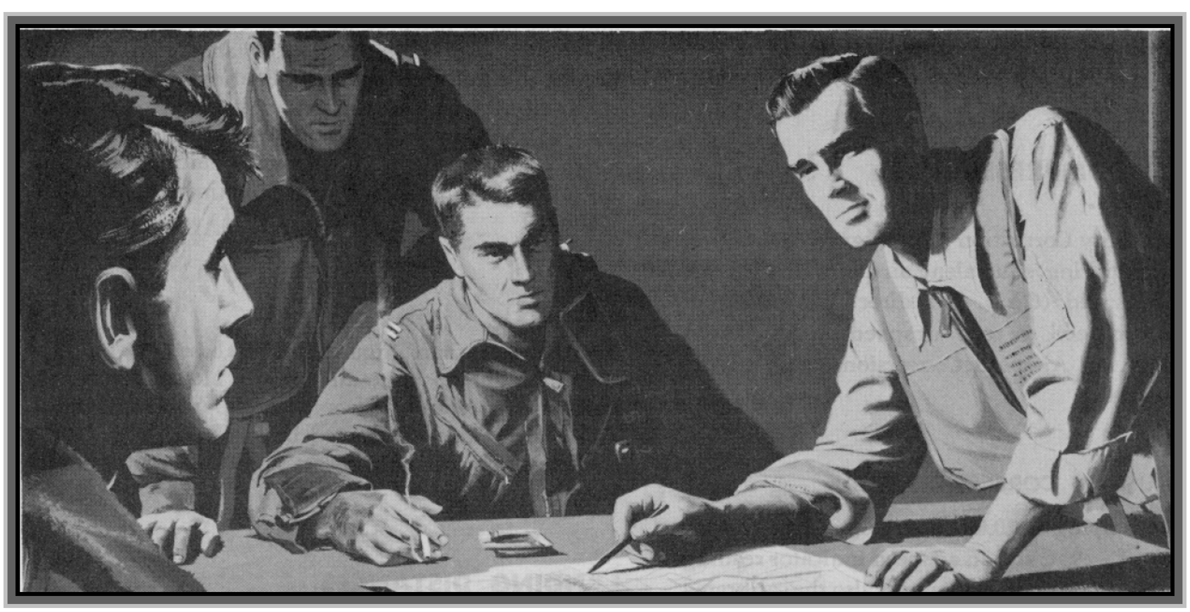


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Section 1

Weapons Familiarization

Bomb Type Munitions
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BOMB TYPE MUNITIONS.

Bombs are generally categorized according to the ratio of explosive weight to total weight. Categories include general purpose (GP), demolition, fragmentation, and penetration.

GP Bombs.

The explosive weight equals approximately 50 percent of the total weight. These bombs normally weigh from 250 to 2,000 pounds and produce blast and fragmentation. GP bombs can be used against a variety of targets. Since the body case is approximately one-half-inch thick, the casing creates a fragmentation effect at the moment of detonation. Also, since the explosive filler constitutes approximately 50 percent of the total weight, considerable damage from the blast effect can be expected at the target. In addition to these effects, a mining effect can be gained through the use of delayed-action fuzes. GP bombs can be made into a semi-armor piercing bomb by retaining the original nose closure plug and installing only a tail fuze. This configuration will penetrate medium hard targets. The bomb was given the designation GP because of its versatility. Examples of this type are the MK 82 and 84 series bombs.

Navy A-4F loaded with SUU-30 dispensers and AGM-45s over Haiphong Harbor.

Demolition Bombs.

The explosive weight equals approximately 65 to 80 percent of the total weight. These bombs have a relatively thin-walled casing to maximize blast effects while penetration and fragmentation effects are limited.

Fragmentation Bombs.

As the name implies, these bombs are intended to disperse and project high-velocity fragments. The fragments are the principle damage mechanism of the weapons, with blast effects being a secondary consideration. The charge to total weight ratio varies from 10 to 20 percent. GP bombs produce a relatively good fragmentation effect. CBU munitions are primarily fragmentation weapons.

MiG-21s take off in formation over North Vietnam.

Penetration Bombs.

These bombs are designed to penetrate and explode inside a hard target such as a concrete bunker. They are built with heavy cases and are aerodynamically designed to counter break-up. The explosive charge is approximately 25 to 30 percent of the total weight. The BLU-109/B is a good example of a penetrating munition.

BOMB EFFECTS.

The destructive effect of a high-explosive bomb is due primarily to the detonation of the high-explosive filler. The chemical reaction which takes place upon initiation of the explosive train is the fundamental action required to attach and defeat a specified target. Generally, the explosive train is used to achieve one of five basic effects in the target area. These are blast, fragmentation, cratering, armor penetration and incendiary.

Blast.

The blast effect is caused by the tremendous overpressures generated by the detonation of a high explosive. Complete detonation of high explosives can generate pressures up to 700 tons per square inch and temperatures in the range of 3,000 to 4,500°C prior to bomb case fragmentation. Approximately half of the total energy generated will be used in swelling the bomb casing to 1.5 times its normal size prior to the fragmenting and then imparting velocity to those fragments. The remainder of this energy is expended in compression of the air surrounding the bomb and is responsible for the blast effect. This effect is most desirable for attacking industrial complexes or habitable structures with the intention of blowing down walls, collapsing roofs, destroying or damaging machinery, etc. The effect of blast on personnel is confined to a relatively short distance (110 feet from a 2,000 pound bomb). Blast is maximized by using a GP bomb with a fuzing system that will produce a surface burst with little or no confinement of the overpressures generated. The shock wave is a compression wave in which the pressure rises from atmospheric to a peak overpressure in a fraction of a microsecond. It is followed by a much slower (hundredths of a second) decline to subatmospheric pressure and then returns to normal. This subatmospheric portion is called the negative or suction phase. For a fixed weight of explosive, the peak pressure decreases with distance from the explosion. At a fixed distance from the explosion, the peak pressure increases as the weight of explosive is increased. The face of the target that is turned toward a detonation will be subjected to a peak overpressure two or more times greater than the face that is oriented at 90° to the shock front. The overpressure on the facing side is called side-on pressure. Face-on pressure causes the most damage.

Hard Target Penetration.

Target penetration is a function of the weapon’s velocity, impact angle, and angle-of attack at impact. Impact angle is the angle between the weapon’s velocity vector and the target plane. The best penetration is achieved when the impact angle is 90 degrees. Angle-of-attack is the angle between the weapon’s velocity vector and the longitudinal axis of the weapon. The best penetration is achieved when the angle-of-attack is 0 degrees. Penetration values are given in vertical feet, and do not represent the weapon path except for the case of a 90 degree impact angle on a horizontal target. Figure 1-163 illustrates impact angle and angle-of-attack. The GBU-28A/B guidance algorithms are designed to maximize the impact angle and minimize impact angle of attack. These are discussed further below.

Fragmentation.

The size of bomb fragments depends on the thickness of the case, the case material, the explosive and the ratio of explosive weight to case weight. In weapons where fragment size is not predetermined, such as GP bombs, the fragments vary widely in size and weight. In weapons where fragmentation is the desired effect, casing are designed to produce uniform fragment size calculated to optimize the effectiveness of the weapon against particular types of targets. Fragments of a bomb case can achieve velocities from 3,000 to 11,000 fps depending on the type of bomb, (for example GP bomb fragments have velocities of 5,000 to 9,000 fps). Fragmentation is effective against troops, vehicles, aircraft and other soft targets. The fragmentation generated from the detonation of a high-explosive bomb has greater effective range than blast, usually up to approximately 3,000 feet regardless of bomb size. The fragmentation effect can be maximized by using a bomb specifically designed for this effect, or by using a GP bomb with an airburst functioning fuze. Most fragments (called side spray) are dispersed perpendicular to the longitudinal axis of the bomb. The direction of fragment projections is determined by the shape of the casing, location of the fuze, impact angle, and terminal velocity of the weapon.

A Sepecat Jaguar releases BL755 Cluster Bombs.

Cratering.

With conventional aircraft-delivered bombs, the cratering effect is normally achieved by using a GP bomb with a delayed fuzing system. This system allows bomb penetration before the explosion occurs and permits the formation of a larger crater as a result. This effect is most desirable in interdiction of supply routes and area denial operations. It also finds application in attacks on multiple-storied buildings. Rather than functioning the bomb instantaneously on impact with the roof of a building, the delayed fuzing will allow the bomb to penetrate and use the confinement of the building walls to increase the destructive effect of the bomb.

Care must be exercised when employing GP bombs against hard targets. If the bomb impact angle is less than 40 degrees it will likely ricochet; if the velocity is too great, it will deflagrate (rapid burning). Both factors are interdependent.

Armor Penetration.

Shaped-charge weapons shape the explosive fill with a resultant hollow cavity in the explosive that can be any shape. The hollow cavity causes the gaseous products formed from the explosion to focus the energy of the detonation, creating an intense localized force in the direction of the hollow section. The addition of a liner, which is common in the conical-shaped-charge weapons, causes the formation of a jet of energy, which is very effective in penetrating armor. This jet is extremely energetic, moves at extremely high velocity, and actually pushes the armor material aside. There is an ideal distance that the weapon must detonate from the target surface to achieve maximum penetration, which is called the standoff distance.

Incendiary.

Fire is effective in interrupting operations of enemy personnel and in damaging supplies stored in the open. Although a relatively small firebomb can provide a spectacular display, it often does less damage than indicated. Conventional incendiaries which started great fires during World War II had little penetrating capability. Munitions have now been developed with full fragmentation and penetrating capabilities coupled with reactive incendiary devices. These improved incendiaries are highly effective against fuel and other flammable targets.

MISSILE TYPES.

A missile maybe either guided or unguided. Unguided missiles follow the natural laws of motion to establish a ballistic trajectory. Guided missiles may either home to the target, or follow on a nonhoming course. Nonhoming guided missiles are either inertially guided or preprogrammed. Homing missiles may be active, semiactive, or passive. An active missile carries the radiation source on board the missile. Radiation from the missile is emitted, strikes the target, and is reflected back to the missile. The missile then is self-guided on this reflected radiation. A passive missile uses radiation originated by the target or by some source not a part of the overall weapon system. Typically, this radiation is in the infrared (IR) region (Sidewinder) or the visible region (EO Maverick), but may also occur in the microwave region (HARM). A semiactive missile has a combination of active and passive characteristics. A source of radiation is part of the system but is not carried in the missile. The source (usually at the launch point) radiates energy to the target, from which the energy is reflected back to the missile. The missile senses the reflected radiation and homes to it.

A USMC F-4B on hits targets over Vietnam.

TYPES OF GUIDANCE.

Guidance is the means by which a missile steers to, or is steered to a target. By guiding after launch, the effect of prelaunch aiming errors and target maneuvers can be compensated. Postlaunch guidance can be done in a number of ways. Some of the prominent types of guidance are discussed in the following paragraphs.

LEAD PURSUIT.

The launch aircraft directs its velocity vector at an angle from the target so that missiles or projectiles launched from any point on the course will impact on the target if within the range of the weapon. Lead pursuit is flown by the launch aircraft in conjunction with the missile trajectory.

DEVIATED PURSUIT.

The missile tracks the target and produces guidance commands to establish a fixed lead angle (X). When the fixed lead angle is zero, deviated pursuit becomes pure pursuit. Random errors and unwanted bias lines often result in a deviated pursuit course. Also, quite often the launch aircraft flies a deviated pursuit course.

PURE COLLISION.

Pure collision is a straight line course flown by a launch aircraft or weapon such that it will collide with the target.

LEAD COLLISION.

Lead collision is a straight line course flown by a launch aircraft such that it will achieve a single given firing position. The time of flight (TOF) of the weapon is a constant.

COMMAND GUIDANCE.

The launch aircraft tracks the target with one radar and tracks the missile with a second radar. A computer on the launch aircraft determines if the missile is on the proper trajectory to intercept the target. If it is not, steering commands are generated by the computer and transmitted to the missile.

BEAM RIDER.

The launch aircraft tracks the target with a V -shaped beam. The missile flies at the bottom of the V. If the missile moves out of the bottom of the V, sensing circuits in the missile cause the missile to return to the correct position. As long as the launch aircraft continues to track the target, and the missile continues to ride the radar beam, the missile will intercept the target.

PROPORTIONAL NAVIGATION.

This is a course flown such that the lead angle is changed at a rate proportional to the angular rate ($\Delta\lambda$) of the line of sight (LOS) to the target.

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Section 2

Air to Surface Munitions

General Purpose Bombs
Cluster Bombs and Dispensers
Napalm and Incendiary Bombs
Special Purpose Bombs
Practice Bombs
Rockets and Launchers
Gun Pods
EO Guided Bombs
Laser Guided Bombs
IR and EO Guided Missiles
Radar Guided Missiles
Anti-Radiation Missiles

General Purpose Bombs

GP bombs are all cylindrical in shape and are equipped with conical fins or retarders for external high-speed carriage. They are adapted for both nose and tail fuzes to insure reliability and to cause the desired effects, which may be blast, cratering, or fragmentation.

AN-M66A1 2,000 pound GP Bomb.

The bomb body contains the high explosive, charging well, and suspension lugs. Other parts added to make a complete munition are adapter boosters, fin assembly, arming wires, and fuzes.

Charging Well.

GP bombs are constructed with a charging well connected to the nose and tail fuze wells. The charging well, located just aft of the forward suspension lug, is usually closed with a threaded plug that must be removed for installation of braided steel arming cables or lanyards used with the fuze, munition, and live unit (FMU) fuzes. The steel cables or lanyards are threaded through the conduits inside the bomb and extend out of the top of the charging well for attachment to the aircraft solenoids.

Suspension Lugs.

Bombs weighing less than 2,000 pounds are equipped with two-point 14-inch suspension lugs. The MK 84, which is in the 2,000-pound class and above, is equipped with two-point 30-inch suspension lugs.

Adapter Boosters.

Nose and tail adapter boosters are required when mechanical fuzes are installed in bombs. The typical adapter consists of an adapter bushing and booster charge assembled in a cylindrical metal casing. There are various models of adapter-boosters and exact design will vary slightly. The bushing has external threads for installation in the bomb fuze well and internal threads to accommodate the fuze. The body consists of a fuze seat liner, a booster charge of two perforated tetryl pellets, two felt spacer disks, and inert filler. The body is enclosed within a metal casing. A protector plug, in the form of a metal tube closed at one end, extends through the perforations in the booster charge and closes the casing at the booster end.

Conical Fin Assembly.

The purpose of the conical fin assembly is to help stabilize the bomb in flight. Fins are made of light metal and may be easily bent. Spot welds and other joints may be damaged. A bent fin may ruin the bomb’s ballistic trajectory.

Mechanical Fuzing.

Arming wires and lanyards are installed on bomb-type munitions to allow the pilot to release an armed bomb or a safe bomb. Arming wires are used with mechanical fuzes and arming lanyards are used with FMU series fuzes.

Arming wires and lanyards are rigged to provide the highest possible probability that the munition will arm as desired. Prior to uploading the bomb on the suspension equipment, arming wires are attached to the bomb suspension lugs. One end of the nose arming wire is secured to the aft suspension lug. The other end is inserted through a swivel and link then through the front suspension lug. The tail fuze arming wire is attached to the front suspension lug, inserted through a swivel and link, then through the aft suspension lug. The bomb is now ready for uploading onto the appropriate suspension equipment. Once uploaded, the free ends of the arming wires are then attached or threaded through safety devices in the fuze, thus maintaining the fuze in a safe (unarmed) condition. A copper beryllium Fahnstock clip is placed over the ends of the arming wires to prevent accidental slippage prior to release. The arming wire passes through the round ring of the swivel and link. These are inserted into the proper arming solenoids.

Release.

If the weapon is released armed, the energized solenoid will hold the swivel and link assembly and cause the metal clips to be stripped off the arming wire, allowing it to pull from the fuze, which then arms. If the munition is configured with an FMU-type fuze, the solenoid will normally hold the swivel and link assembly. This causes a sharp pull on the lanyard or cable which then activates the FMU fuze.

Safe.

If the bomb is released in the safe condition, the arming wire swivel loops are released from the arming solenoids, the arming wires remain in the fuze safety devices, and the fuzes cannot arm. Without fuze operation, the bomb will usually be a dud. Low-order detonations may result from very high impact shock. A low-order detonation results when the high explosive is incompletely exploded. A high-order detonation results when all components of a high-explosive train decompose as planned. With an FMU-fuzed munition, the swivel loop is also released with the bomb and the fuze is not activated.

Explosive Fillers.

The primary high-explosive filler used in the GP bombs is Tritonal, but there are a relatively small number of bombs in the inventory filled with H-6.

Knowledge of what type of explosive is used in bombs can be important. H-6 is more sensitive to impact than Tritonal. A test was conducted with MK 84 bombs fitted with inert fuzes to compare Tritonal and H-6 filled bombs. Seventy-five percent of the H-6 bombs exploded on impact (impact velocity 1,030 fps). The Tritonal filled bombs all survived (1,040 fps). This has several important implications for employment of Tritonal and H-6 bombs.

Tritonal is much less impact sensitive than is H-6. Because of this, Tritonal-loaded GP bombs provide significantly improved penetration and survivability.

Some bombs will be marked Tritonal or H-6 somewhere on the bomb body. If the bomb is not marked, the type of explosive can be determined by requesting the information from explosive personnel or supply.

MK 82 LD, MK 83 LD, MK 84 LDGP Bombs.

The MK 82 (500-pound class), MK 83 (1,000 pound class), and MK 84 (2,000-pound class) low-drag, general-purpose (LDGP) bombs are similar in construction and vary only in size and weight. The bombs have a streamlined cylindrical body with a tapered aft section to which a conical fin assembly is attached. The conical fin assembly will accept the ATU-35 series drive.

The MK 82 Mod 2 version has an exterior thermal coating, an improved interior lining and a new base sealing compound to make it more resistant to cookoff in an open fire. The MK 82 Mod 2 can be recognized by a bumpy exterior surface and two yellow stripes around the bomb body.

The MK 83 LD is equipped with the MK 83 conical-type fin. The total weight of the MK 83 is 985 pounds, and it contains 416 pounds of Tritonal or H-6 high-explosive filler.

The MK 83 Mod 5 has an exterior thermal protective similar to the MK 82 Mod 2 coating.

The MK 84 LD is equipped with the MK 84 conical-type fin. The total weight of the MK 84 is 1,972 pounds, and it contains 945 pounds of Tritonal or H-6 high-explosive filler.

AV-8A loaded with Mk 82 GP Bombs.

The MK 82 (500-pound class) Snakeye I; a high-drag, general-purpose (HDGP) bomb, is a MK 82 GP bomb that is modified by attaching a MK 15 series retarding tail assembly. This configuration allows for low level releases and steeper impact angles. The four MK 15 retarding fins are linked to a sliding collar so all four fins must open at the same time.

In the LD configuration, the retarder fins are held closed by a retaining band. The retaining band is under 40 pounds of tension provided by leaf springs under the retarder fins. After release from the aircraft, the fin release wire/lanyard is fully extracted from the weapon, releasing the retaining band. At this time the leaf springs force the retarder fins into the airstream. Airloads complete the opening of the fins, extending them approximately perpendicular to the airstream to provide maximum drag and stability. The MK 82 Snakeye can be released in either the HD configuration (retarding fins open after release) or in the LD configuration (retarding fins remain closed). The release configuration is determined by arming wire/ lanyard routing and may be cockpit selectable.

The MK 15 Mod 3A and Mod 4 tail assemblies are restricted to a maximum of 500 knots calibrated airspeed (KCAS). When released HD, the MK 15 Mod 3 is restricted to a maximum of 400 KCAS. HD deliveries (Mod 3A and Mod 4) below 450 KCAS may, and below 400 KCAS will, cause the fins to partially open. This results in the bomb impacting long and, depending on fuzing, may increase the chance of self fragmentation. HD deliveries above 5,000 feet above ground level (AGL) may, and above 10,000 feet AGL will, cause bomb impact errors up to hundreds of yards, due to the inherent mil dispersion of this weapon.

MK 82 Air Inflatable Retarder (AIR) HDGP Bomb.

The MK 82 (500-pound class) AIR is a MK 82 bomb that is modified by attaching a BSU-49/B AIR tail assembly. The AIR provides a high-speed, low-altitude delivery capability by use of bomb retardation. This increases bomb trail and reduces the danger of the aircraft being hit by weapon fragments. The probability of bomb ricochet is reduced by increase impact angles.

The BSU-49/B AIR tail assembly consists of a LD stabilizer canister unit, the ballute (combination of balloon and parachute), and the retarder release lanyard assembly. The stabilizer canister unit acts as a container for the ballute and provides aerodynamic stability during carriage and LD delivery. Four ballute attachment straps connect the ballute to an attachment plate near the center of the stabilizer unit. The aft end of this stabilizer assembly is held in place by a latch assembly until release.

Forward of the attachment plate is a door for insertion of the ATU-35 series arming drive. The entire canister is connected to the bomb. The ballute assembly is made from high strength, low-porosity nylon fabric and is approximately 8 inches in circumference at the point it enters the stabilizer canister. Ram air inflation is accomplished through four air inlet ports toward the aft end of the ballute.

The retarder release lanyard assembly, located between two fins along the top side of the stabilizer canister, consists of a lanyard held in place by an adjustable retracting spring. The lanyard connects the arming solenoid to the latch assembly holding the baseplate onto the canister. As the bomb is ejected from the suspension rack, the lanyard pulls the safety latch pin, and the baseplate is forced into the airstream by compressed springs. Airloads continue to pull on the baseplate, withdrawing the ballute until airflow through the ram air inlets inflate it to full size. During this process, the lanyard cable pulls on the swivel and loop assembly, shearing it. The lanyard is retained by the bomb, preventing damage to the aircraft.

The MK 82 AIR release is cockpit selectable in either the HD configuration (ballute inflated) or in the LD configuration (ballute not inflated) provided arming wire/lanyard routing is accomplished during loading for these options. The BSU-49/B contains a lanyard to which a M-904 nose fuze may be wired, thus enabling nose fuze arming only when the BSU-49/B inflates (positive high drag arming).

The BSU-49/B AIR assembly provides the capability to deliver HD MK 82s at airspeeds from 200 to 700 KCAS, depending on type of aircraft and fuzing. LD deliveries should be limited to a maximum of 600 KCAS as testing has found excessive dispersion caused by ballistic instability at delivery speeds above 600 KCAS.

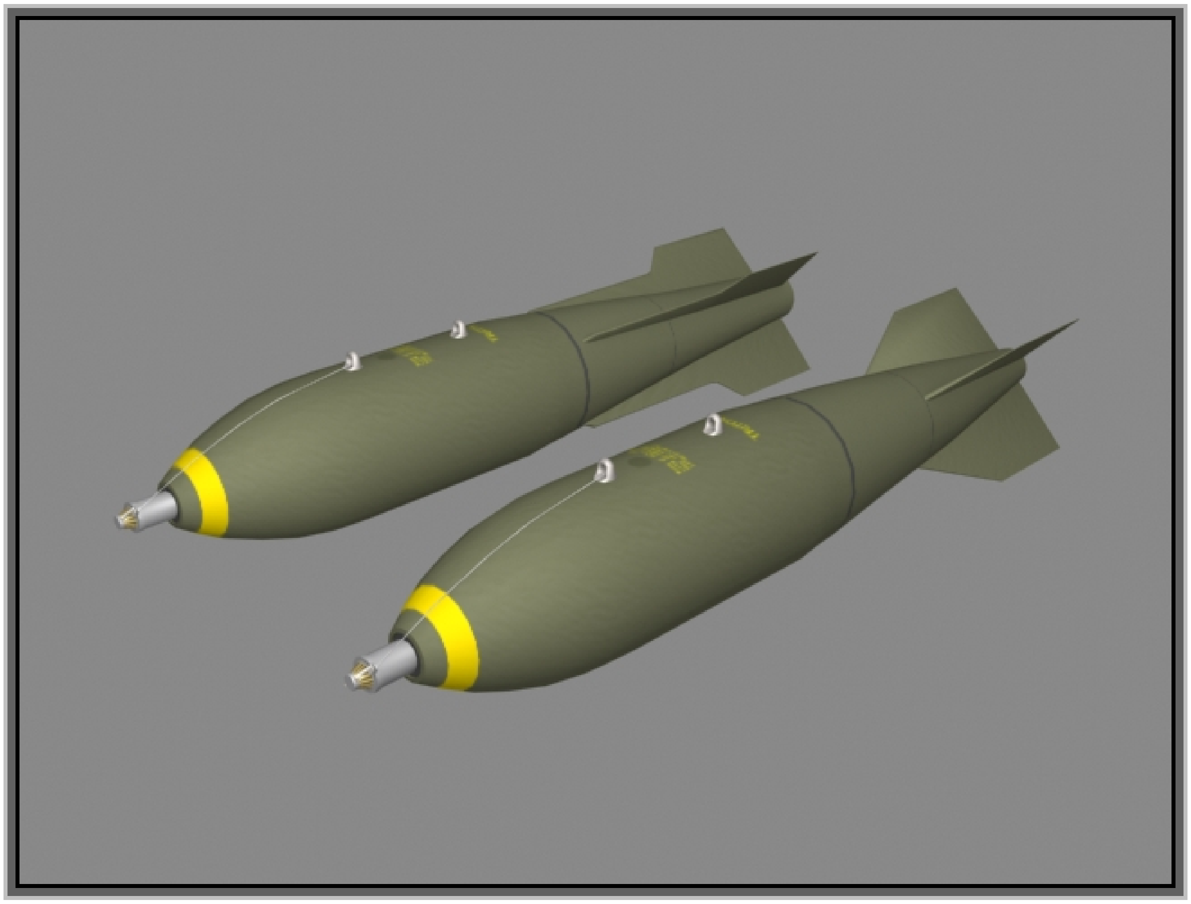
MK 84 Air Inflatable Retarder (AIR) HDGP Bomb.

The MK 84 (2,000-pound class) AIR is a MK 84 bomb that is modified by attaching a BSU-50/B AIR tail assembly. The BSU-50/B assembly is similar to the BSU-49B AIR assembly and consists of a LD stabilizer canister unit, a ballute, and the retarder release lanyard assembly. BSU-50/B operation is identical to BSU-49/B operation with the exception it lacks the positive high drag arming feature. The release configuration is determined by arming wire/lanyard routing and may be cockpit selectable.

The BSU-50/B AIR assembly provides the capability to deliver the MK 84 at airspeeds to 700 KCAS. Decelerating forces to initiate fuze arming determine minimum release airspeeds. The minimum airspeeds are significantly higher than those required to arm the BSU-49/B. The BSU-50/B is only 12 percent larger than the BSU-49/B, but the MK 84 is four times heavier than the MK 82. This increase in weapon mass, coupled with a very small increase in ballute size, forces a higher delivery airspeed for proper g forces sensed by the fuze. Minimum release airspeeds for HD employment of the MK 84 AIR are:
FMU-54A/B Fuze - 550 KCAS
FMU-139A/B Fuze - 450 KCAS

M117 GP Bomb.

The M117 (750-pound class) LDGP bomb has a cylindrical metal body with an ogival nose and a tapered aft section to which a MAU-103B or MAU-103AB fin assembly is attached. The MAU-103/B differs from the MAU-103AB only in size and material. Both fin assemblies will accept the ATU-35 series drive. Bombs marked M117A1E 1 or M117A3 contain 386 pounds of Tritonal explosive filler whereas those marked M117A1E2 contain 386 pounds of Minol II explosive filler.



M117 GP Bombs

M117R (Retarded) GP Bomb.

The M117R (750-pound class) bomb consists of an M117 bomb body with a BSU-93/B, MAU-91A/B or MAU-91B/B retarding tail assembly. The fin assembly replaces the conical fin and provides for a high- or low-drag employment. The HD or LD configuration is determined by arming wire/lanyard routing and may be cockpit selectable.

The fin assembly consists of four extendable drag plates attached to the bomb body by a flange and support tube. In the LD configuration, the drag plates are held closed by a release band. In the HD configuration, the release band latch is pulled by the lanyard attached to the arming solenoid and allows the drag plates to deploy. The drag plates are snapped open by a leaf spring under each plate and by the airstream. The drag plates stop approximately perpendicular to the airstream to provide maximum drag area and stability.

227 kg (500 lb) GP BOMBS (Mk 1/2)

The current UK in-service 227 kg (500 lb) bomb was developed by Royal Ordnance from Second World War type bombs. Main design changes since that period are

improvements to aerodynamic shape and tail units to allow for the performance of modern aircraft when flying at low altitudes and carrying out high-speed maneuvers. There is also the incorporation of both single and twin NATO standard suspension systems, up-to-date fuzing systems and modern explosives. Two versions of the 227 kg bomb are produced, the Mk 1 with an HE filling of RWA 4, and the Mk 2 which is filled with Torpex.
The RWA 4 filling was chosen because of its suitability for high-temperature flight conditions.

F-4C loaded with six M117 GP Bombs.

Both versions of the bomb are designed to be fitted with either the standard ballistic No 116 tail unit or the No 118 retarding tail unit.

The UK 227 kg (500 lb) bomb has a streamlined body constructed from forged seamless steel, a pointed nose and a bolt-on conical tail assembly with four stabilising fins. The bomb can be fitted with the British single suspension lug or the standard NATO 356 mm spaced suspension lugs. Both Mk 1 and 2 bombs can be fitted with either the standard Type No 116 ballistic tail unit or the Type No 118 retard tail unit. The Type No 116 tail unit is 0.96 m long, has a tailspan of 0.46 m and weighs 18.6 kg. The Type No 118 retarding tail unit is also 0.96 m long, but has a tailspan of 0.43 m and weighs 54 kg (further details of the No 118 can be found under a separate entry). The overall length of the Mk 1 bomb with either tail unit is 2.0 m long, it has a body diameter of 330 mm and depending on tail unit weighs 260.6 kg or 296 kg with a 97 kg high explosive filling of RWA 4. The Mk 2 has the same measurements but with an explosive filling of Torpex weighs 259.6 kg or 295 kg. The bomb is said to be of the medium capacity (MC) type. This means that the explosive filling is between 40 and 60 per cent of total bomb weight. The bomb design allows the use of several different types of nose and/or tail fuzing, including the latest electronic MultiFunction Bomb Fuze (MFBF) No 960 developed by

THORN EMI and the FEU-80 used on the 454 kg bombs. Type 951 fuzes are used in the retarded mode, and FEU-80 fuzes for free-fall mode. The MFBF fuze can be used in all modes.

454 kg (1,000 lb) GP BOMBS (Mks 10/13/18/20/22)

The current range of in-service 454 kg (1,000 lb) bombs was developed by Royal Ordnance (now owned by BAE Systems) from Second World War type bombs. The major changes which have been introduced since that period are improvements to aerodynamic shape and tail units to allow for the performance of modern aircraft when flying at low altitudes and carrying out high-speed manoeuvres.

Other improvements include the incorporation of up-to-date fuzing systems, modern explosives and the provision for both single and twin NATO standard suspension systems to cater for all carriage conditions. Altogether some 17 Marks of this bomb have been developed and produced, including: Mk 6, 7, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20 and 22. However, the current range of bombs in UK service comprises the Mk 10, 13, 18 and 20 and the recently developed Mk 22. The Mk 13 is fitted with RWA 4 explosive as opposed to the Torpex HE used in the other Marks. The RWA 4 filling was introduced to provide a stable explosive to combat kinetic heating conditions as a result of low-level high-speed flight. The Mk 20 is similar to the Mk 18 but has been specifically designed to crater aircraft runways and roads. It is fitted internally with a thermal liner to protect the explosive filling against high-temperature flight conditions. All versions of the bomb can be fitted with either the standard ballistic Nos 107 and 114 tail units or the No 117 retarding tail unit.

Description.

The UK 454 kg (1,000 lb) bombs have streamlined bodies constructed from forged seamless steel, pointed noses and a bolt-on conical tail assembly with four stabilising fins. The bombs can be fitted with the British single suspension lug or the standard NATO 356 mm spaced suspension lugs. Because of the various combinations of tail units and Marks of bomb, their specifications are given separately.

All Marks of bomb can be fitted with either the standard Type No 107 or No 114 ballistic tail units or the Type No 117 retard tail unit. The Type No 107 is 1.03 m long, has a tailspan of 0.58 m and weighs 22 kg. The Type No 114 is 1.0 m long, has a tailspan of 0.58 m and weighs 27 kg. The Type No 117 retarding tail unit is 1.04 m long, has a tailspan of 0.58 m and weighs 70 kg. All four Marks of bomb without tail units fitted, are 1.26 m long and have a maximum body diameter of 420 mm.

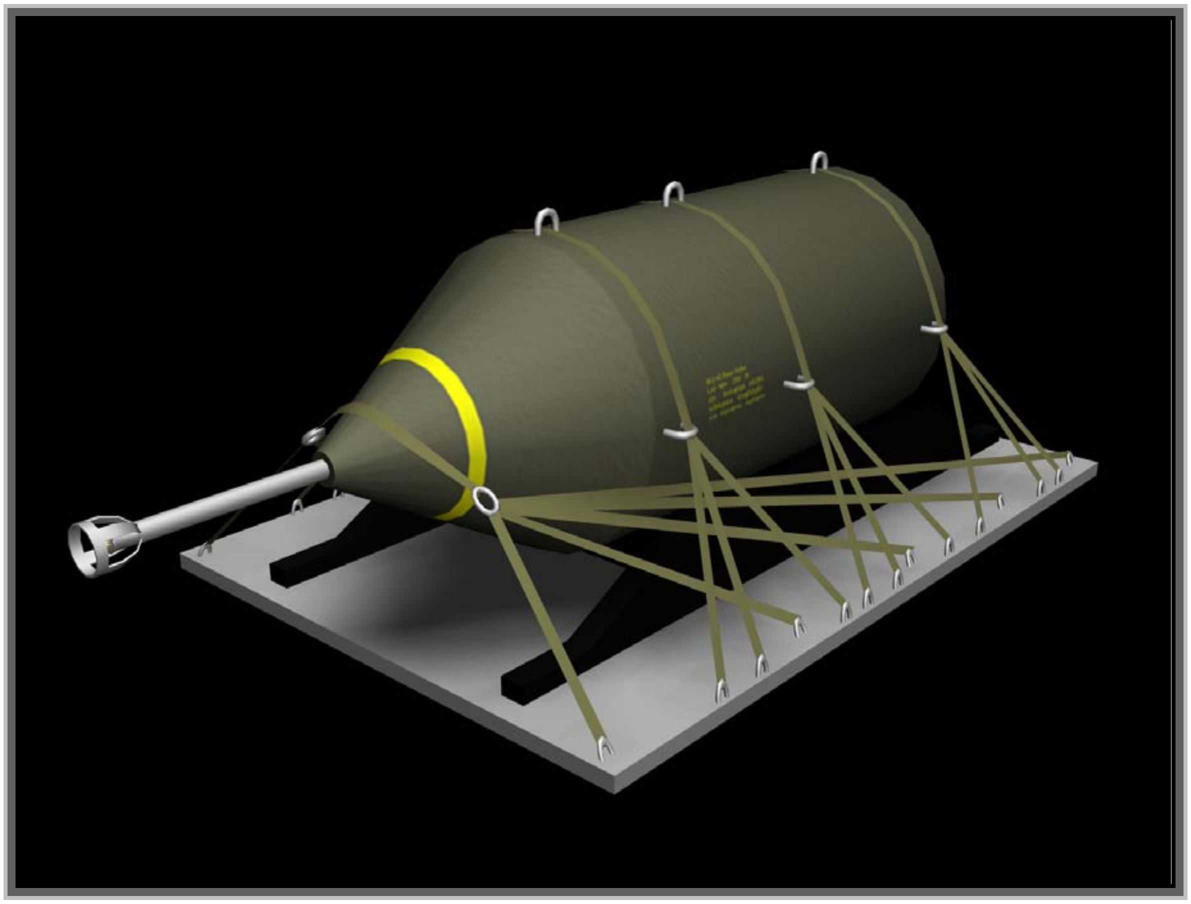
British 500 and 1,000 pound general purpose bombs.

For practice and training there is a variety of bombs available, including a 14 kg practice bomb, a 316 kg practice bomb, and a Mk 22 practice bomb that is fully representative of the live Mk 20 bomb.

The Mk 10 body weighs 405 kg with approximately 180 kg of Torpex HE. The Mk 13 body weighs 412 kg with approximately 180 kg of RWA 4 HE. The Mk 18 body also weighs 412 kg with approximately 184 kg of Torpex HE. The Mk 20 body weighs 410 kg with approximately 184 kg of Torpex HE. The bomb design allows the use of several different types of nose and/or tail fuzing including the No 947, 951, 952, FEU-80 and the electronic MultiFunction Bomb Fuze (MFBF) No 960 developed by THORN EMI. For high-speed low-level delivery the 454 kg bomb would typically be used with a Type 117 tail unit and the MFBF. In the free-fall delivery mode a Type 114 tail unit is used with the FEU-80 fuze. The Mk 13, 18 and 20 bombs can be converted into LGBs by the fitment of tail unit No 120 Paveway II Guided Bomb Unit (GBU) No 16.

BLU-82.

The BLU-82/B bomb is a 15,000-pound, slurry-filled weapon mounted on a wooden cradle intended primarily for internal carriage and delivery by cargo-type aircraft. The bomb has a conical nose and a cylindrical body closed by a standard tank pressure head at the aft end. The forward end of the bomb body includes a fuze and booster well for installation of M904E2 fuze, BBU-23/B auxiliary booster, T45E7/M148 adapter booster, and M1 fuze extender. The nose fuze well is closed during shipment and storage by a steel plug. The fuze mounting structure on aft end of bomb is an inverted cone with a fuze and booster well for installation of M905 fuze, BBU-23/B auxiliary booster, T46E4/M147 adapter booster, and fuze drive assembly. The filled weight of the bomb is 15,000 pounds. The explosive charge (DBA-22M Gelled Slurry Explosive-GSX) weighs 12,600 pounds. The weight of a filled bomb and its cradle is 15,400 pounds.



BLU-82

During slowdown checklist, the load master releases the left-handed cargo locks. At 20 seconds before release, the co-pilot remotely deploys the extraction chute. At the release signal, the bomb and cradle are extracted from the aircraft. As the bomb clears the ramp, the static line connector contacts a stop on the static line anchor cable on the aircraft. As the bomb separates from the cradle and platform, a lanyard attached to the left-hand nose collar clevis withdraws the arming wire from the M904 nose fuze, allowing the vane to rotate and begin arming sequence. Once the bomb is free of the platform, the platform and bomb cradle are pulled away from the bomb by the extraction chute. As the platform and bomb cradle separate from the bomb, the mechanical shaft lock which is secured to a tie-down ring on the platform by means of a lanyard is withdrawn, unlocking the motor drive shaft; at the same time the shaft lock is withdrawn, the deployment line of the weapon stabilization parachute is pulled by a lanyard attached to a platform tie-down ring. As the weapon stabilization parachute deploys, a lanyard attached to the parachute deployment bag withdraws an arming wire through the tail fuze drive assembly pullout switch allowing the fuze drive assembly to run, beginning the arming cycle.

MirageIIIE loaded with two BL 4 GP Bombs and AS-30 Guided Missile.

BLU-109/B Penetrator Bomb.

The BLU-109/B (2,000-pound class) Penetrator Bomb is a special purpose bomb designed to be used on hardened targets with delayed fuzing allowing penetration and destruction at desired times. The BLU-109 bomb case is made from modified 4340 alloy steel. A conduit (charging tube) connects the fuze well to arming well. The BLU-109/B bombs uses FMU-143 series fuzes and FZU-32B/B initiator. The BLU-109/B bomb is loaded with 80/20 tritonal explosive (80 percent TNT and 20 percent aluminum powder). A Stores Away Pad (SAP) is bolted to the upper surface of the bomb to provide a contact surface for a stores away switch.

Cluster Bombs and Dispensers

Cluster bombs are dispensers loaded with submunitions and released as a free-fall unit. Dispensers that remain attached to the aircraft dispense the submunition by ejection through the bottom of the dispenser. Dispensers released as free-fall units are designed with three longitudinal sections. The clamshells blow apart at a predetermined time after release, or at a given altitude, and the submunitions inside are released. The submunitions are bomblets or mines designed for use against such targets as light material, personnel, or armor.

Sepecat Jaguar loaded with BL755 Cluster Bombs.

SUU-64/B, -65/B, -66/B Tactical Munitions Dispensers.

Sequence of Events.

After release, the bomb falls away from the aircraft and pulls the fin lanyard which releases the extendable fins. When the primary arming wire is pulled, the battery in the integral timer fuze starts the timer. When the option wire is also pulled, the same battery provides power to the FZU-39/B and tells the integral timer fuze to wait for a proximity signal. When either the preselected time has expired (pull primary wire) or the proximity sensor sees the preselected HOF (pull primary and option wires), the integral timer fuze detonates the explosive bolt, This allows the fin cant mechanism to rotate the fins 56°.

The fin cant imparts spin on the TMD and the integral timer fuze fires the ALSC when it senses the preselected spin rate. The ALSC cuts the TMD in three equal longitudinal pieces and the bomblets are radially dispensed.

CBU-87/B Cluster Bomb Combined Effects Munitions (CEM).

The CBU-87/B Combined Effects Munition (CEM) consists of a SUU-65B TMD, 202 BLU-97B bomblets and an optional FZU-39/B proximity sensor. Of the six ground selectable spin rates, only two are used with CEM; setting 3 (1000 RPM) and setting 5 (2000 RPM). The BLU-97B case is made of scored steel designed to fragment into approximately 300 performed 30-grain fragments for defeating light armor and personnel. It contains a forward-firing, shaped-charge liner for defeating armor, and a zirconium ring for incendiary capability. An Air Inflatable Decelerator (AID) or Ram Air Decelerator (RAD) that provides drag, orientation and flight stability for the bomblet is held encased by a cap called a spyder.

F-4F loaded with BLG-66 Cluster Bombs and BAP 100 Anti-runway Bombs

When the BLU-97B is released into the airstream from the SUU-65 dispenser and attains a minimum airspeed of 175 KCAS or greater, the airflow releases the spyder which pulls the cup assembly rearward, exposing the AID/RAD to the airstream. As the AID/RAD is inflated by ram air, it orients and stabilizes the BLU97B for proper target impact by despinning the submunition and reducing the descent rate to approximately 125 fps. The AID/RAD transmits the air-induced loads to a shaft in the fuze which arms the submunition. 6.5 g deceleration is required to arm the fuze. Total arming time after deployment requires approximately 1.0 seconds. Release of the spyder also allows a standoff tube to deploy forward. When the BLU-97B impacts the target, the standoff tube is driven rearward to detonate the submunition. In the event the BLU-97B impacts the target at an angle that does not drive back the stand-off tube, a secondary omnidirectional piezo electric firing system will detonate the submunition.

The CBU-87A/B is identical to the CBU-87/B except the weapon includes an installed FZU-39/B.

The CBU-87B/B consists of a SUU-65B TMD, 202 BLU-97A/B submunitions and a FZU-39B proximity sensor. The BLU-97A/B is identical to the BLU-97/B except for the secondary firing mechanisms. The BLU-97A/B has an omnidirectional all mechanical secondary detonator firing mechanism vice the BLU-97/B piezo electric firing system. The CBU-87B/B does not experience the same number of airbursts as demonstrated by the CBU-87B, AB and has no limitation on its delivery envelope.

The CBU-87C/B differs from the CBU-87B/B in that its proximity sensor is the FZU-39(D-4)/B.

Mk44 “Lazy Dog” Dispenser.

CBU-89 Cluster Bomb (GATOR).

The CBU-89/B GATOR consists of a SUU-64/B TMD, a KMU-466/B electronics assembly, 72 BLU-91/B antitank mines (AT), 22 BLU-92/B antipersonnel mines (AP) and an optional FZU-39/B proximity sensor.

The CBU-89A/B differs in that the FZU-39/B is installed during manufacture and the munition is delivered as an all-up round.

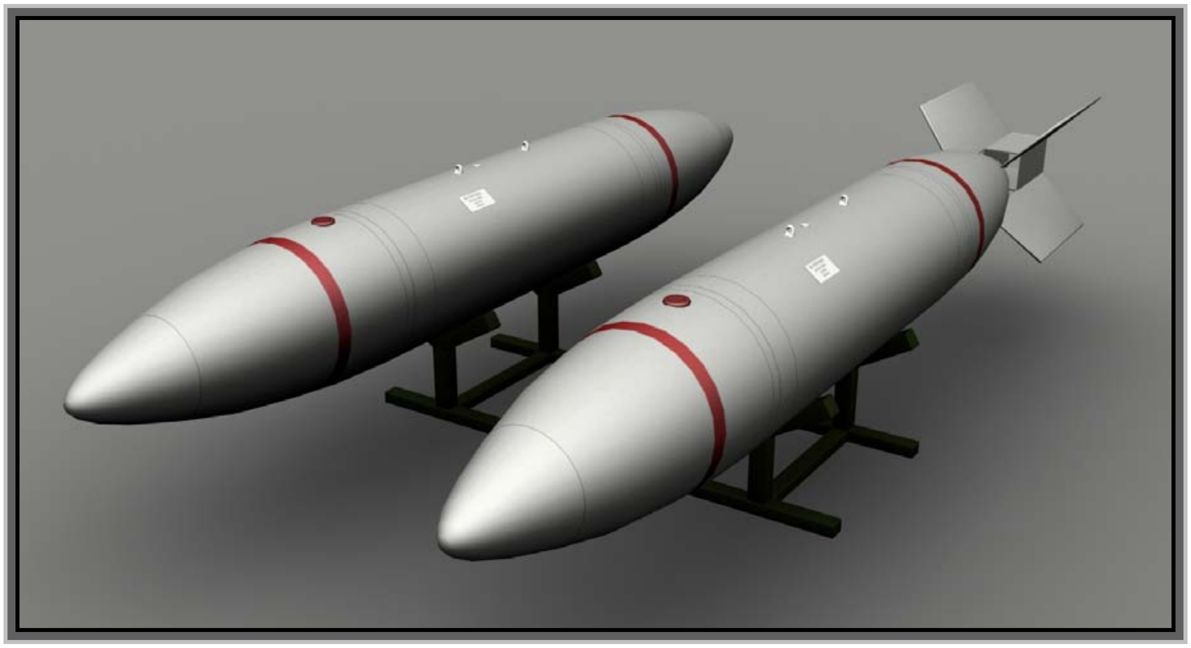
Mine arming begins when the TMD opens and requires two minutes to complete. After the mine is armed, mine detonation is initiated by target detection, mine disturbance, low battery voltage and self-destruct timeout. The submunitions are programmed with one of three self-destruct settings which are ground selectable on the selfdestruct switch located on the TMD.

The anti-tank mine is a magnetic sensing submunition. Its bi-directional, mass-focused, self-forging warhead is effective against tanks and armored vehicles. Detonation occurs when the magnetic sensor detects a target or the mine is disturbed. If no target is detected prior to expiration of the preset self-destruct time, the mine will detonate. If mine battery voltage drops below acceptable level, the mine will detonate.

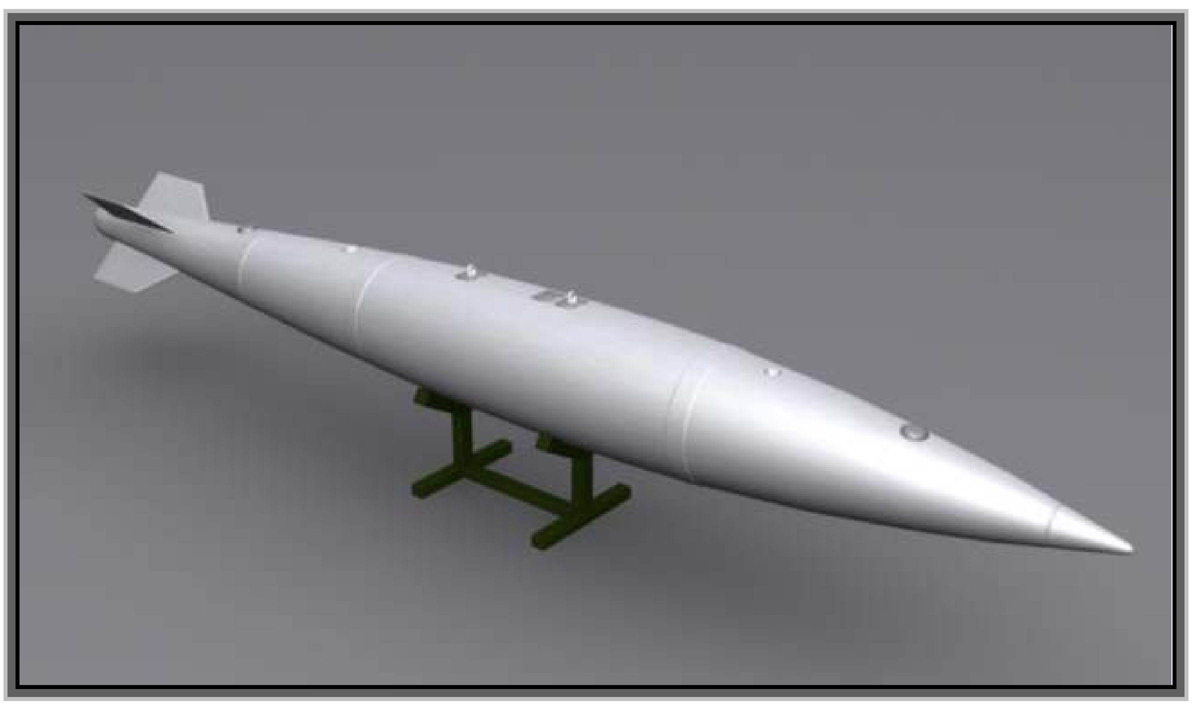
The BLU-92/B antipersonnel mine closely resembles the BLU-91/B in appearance and function. The BLU-92/ B is a fragmenting case warhead triggered by tripwires. The BLU-92/B contains eight tripwires and tripwire sensors, four per face.

Maximum tripwire deployment length is 40 feet. The four upward-facing tripwires deploy at mine arming. Mine arming is otherwise similar to the BLU-91/B arming process. Detonation occurs when a target actuates the tripwires or when the mine is disturbed. If no target is detected prior to expiration of the preset self-destruct time, the mine will detonate. If mine battery voltage drops below acceptable level, the mine will detonate.

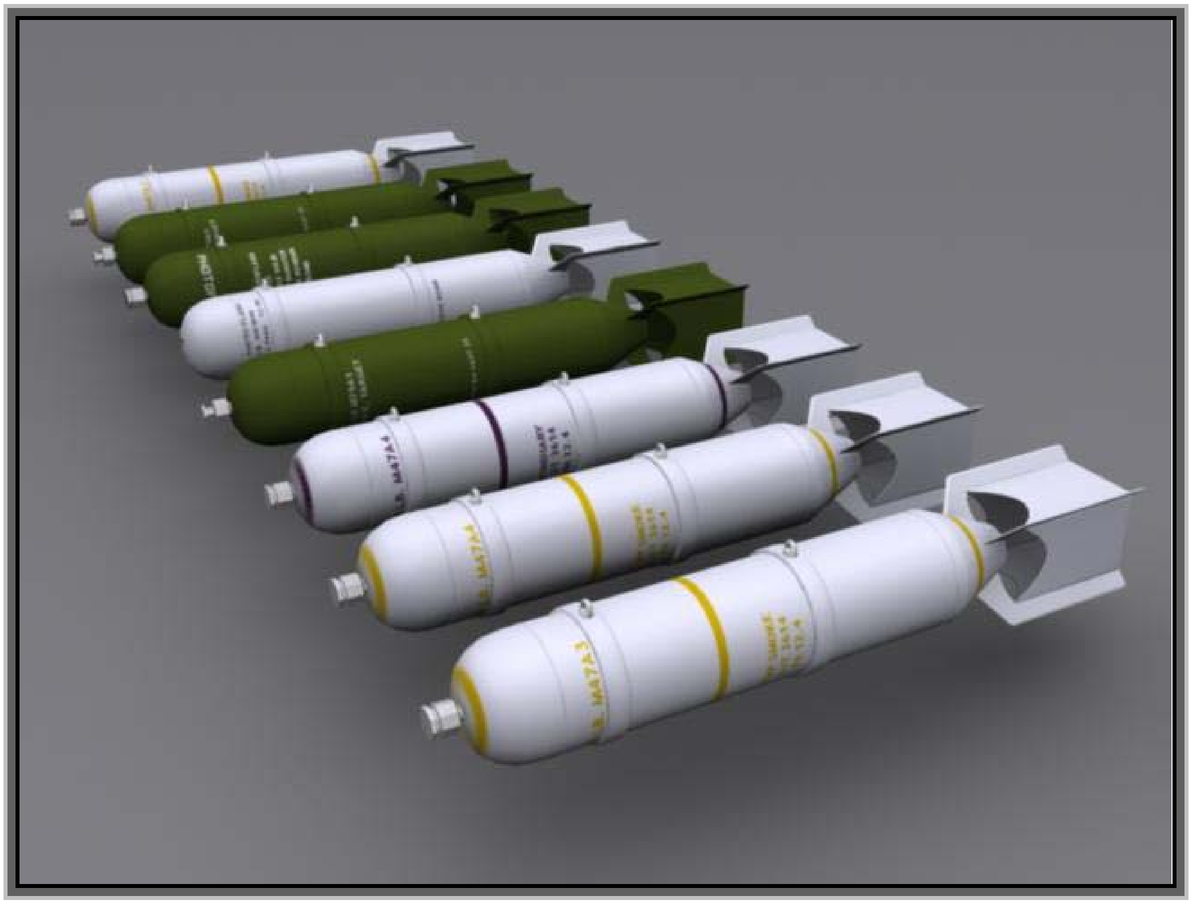
Napalm and Incendiary Bombs



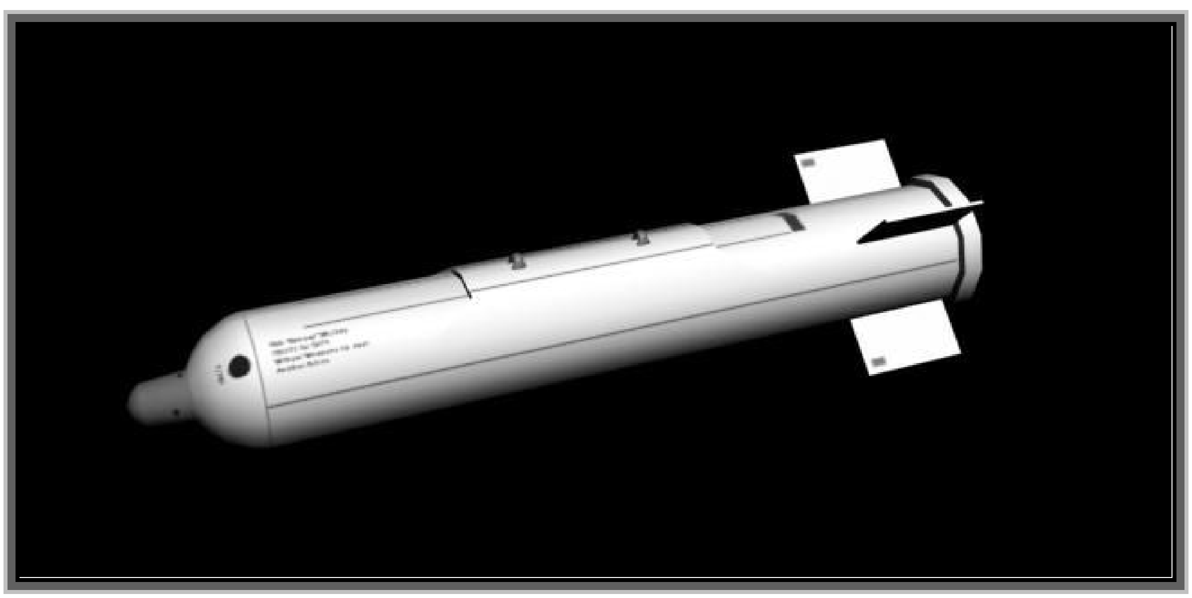
BLU-1 Fire Bomb



Mk 79 Fire Bomb



AN-M47 series Incendiary Bombs



CBU-55 FAE

A-10A loaded with two CBU-72 FAE

Special Purpose Bombs

M129E1 AND E2 LEAFLET BOMBS AND MJU-1 CHAFF BOMB.

The M129E1 and E2 are leaflet bombs designed for use in delivery and distribution of leaflet type material.

When these bomb bodies are filled with chaff, they are called MJU-1 chaff bombs. The bomb has a cylindrical body with an ogival nose and a tapered aft section. It is constructed of fiberglass and has an external configuration similar to the M117 GP bomb. The bomb body is split longitudinally into two sections which are held together by four latches on each side. A steel reinforcing plate below the suspension lugs is added for forced ejection from the aircraft. The fuze well, which is located in the nose of the bomb body, will accommodate a mechanical time fuze designed for airburst operation. Tail fuzes are not used or provided for in the M129E1, E2 bombs. The fin (M148) consists of an elongated fiberglass cone about 20 inches long and four streamlined blades assembled perpendicular to the cone.

Other components include an arming wire, an adapter-booster assembly, and a detonating cord (PRIMACORD). The arming wire is threaded through the fuze safety device, thus keeping the fuze in a safe condition until release. The adapter-booster accommodates the fuze and retains the detonating cord in the proper position. The detonating cord is used to effect separation of the two bomb body sections.

Operation of the bomb occurs at a predetermined number of seconds after release. Functioning of the fuze causes the booster to ignite and detonate the 12-foot-long detonating cord. The detonating cord is inserted through the adapter-booster and longitudinally around the entire bomb. Detonation of the detonating cord separates the two body sections, detaches the fins, and allows the leaflets to be released and scattered. If the nose fuze fails to function, the bomb will disintegrate upon impact.

SUU-76C/B (PDU-5/B) LEAFLET BOMB.

The SUU-76C/B (PDU-5/ B) leaflet bomb consist of a MK 7 Mod 3 Bomb dispenser with a 0.125 inch thick aluminum skin cargo section. Externally attached to the dispenser are two nose fairings, a tail fin assembly, fuze arming and option wires, a fin release wire (all with extractors), two suspension lugs, and a MK339 mechanical time fuze. A fuze cover assembly is attached to nose fairings for fuze protection during shipping, handling, and storage. Upper nose fairing has two observation windows, one for viewing safe/arm indicator and one for observing fuze time setting dials. Two access holes are in the lower nose fairing for changing fuze primary/option times. The tail cone assembly consist of a conical body with four spring loaded fins held in a folded position by means of a fin band assembly. Fuze arming and fin release wires are placed in conduits and are attached to aircraft bomb rack by relocatable extractor assemblies. Two suspension lugs installed in dispenser cargo section are used to attach dispenser to aircraft bomb rack.

When the SUU-76C/B (PDU-5/B) leaflet bomb is released from aircraft, fuze arming and fin release wire extractors pull respective wires sufficiently to arm the MK 339 fuze and release the fins. The positive armed fin release wire extractor frees the fin release band allowing fins to snap open by spring force and stabilizing the falling bomb. After arming wire has been pulled a sufficient distance to arm the MK 339 fuze, the extractor wire breaks to prevent damage to aircraft/aircraft bomb rack and allows bomb to retain arming wire. Fin release wire is also retained by bomb in this manner. Simultaneously fuze arming wire releases fuze impeller band and timer starting pin. Fuze impeller then rotates in airstream and must have sufficient airspeed to rotate greater than 5400 RPM to arm MK 339 fuze. After preset delay interval (depending on required fuze time selected), fuze initiates linear shaped cutting charge, secured inside dispenser skin. The shape charge separated the dispenser into from front to back to disperse the load (leaflets).

BLU-52/B Chemical Bomb.

Practice Bombs

BDU-33.

The BDU-33 is a 24-pound practice bomb, designed for aircrew training in weapons delivery techniques. The teardrop-shaped body is cast metal with a cavity running lengthwise through the center. A conical fin is attached to the bomb body and has a hollow tube that serves as an extension of the bomb signal cavity. A single-suspension lug is installed.

BDU-33B/B.

From nose to tail, the signal cavity of an assembled BDU-33B/B bomb contains an MK 1 Mod 0 firing pin assembly, MK 4 Mod 3 or MK 4 Mod 4 signal cartridge, inertia tube, and cotter pin. The BDU-33B/B also has a safety (cotter) pin installed between the signal cartridge and the firing pin assembly. Once the safety pin is removed, it cannot be reinstalled in the bomb until the bomb is disassembled. Impact of the bomb drives the signal cartridge, aided by the inertia tube, against the firing pin assembly and detonates the cartridge. The cartridge expels smoke and a flash from the tail of the bomb, permitting visual observation of bombing accuracy. Instead of the signal cartridge, a CXU-3 spotting charge can be used in the bomb to produce cold white smoke. The safety clip on the CXU-3 can be reinstalled without disassembly of the bomb.
BDU-33D/B.

The BDU-33D/B differs from the BDU-33B/B in that the BDU-33D/B spotting charge has been relocated from the tail to the nose of the bomb. The spotting charge relocation results in a new firing pin on the nose of the bomb which utilizes a safety block to prevent the firing pin from being moved during handling operations. The safety block is held in place by a cotter pin or a safety pin. The safety block may be reinstalled after removal without disassembling the bomb.

BDU-50/B, A/B.

The BDU-50/B, A/B practice bombs are used to simulate the parent MK 82 GP bomb.

The BDU-50/B, A/B is factory filled with inert material and does not have internal plumbing or fuze wells.

The BDU-50/B is capable only of being configured with the standard MK 82 bomb tail fins and assemblies. The BDU-50A/B has been modified so that it will accept all current GBU applications.

BDU-56/B, A/B.

The BDU-56/B, A/B practice bombs are used to simulate the parent MK 84 GP bomb. he BDU-56/B, A/B is factory filled with inert material and does not have internal plumbing or fuze wells.

The BDU-56/B is capable only of being configured with the standard MK 84 bomb tail fins and assemblies. The BDU-56A/B has been modified so that it will accept all current GBU applications.

Rockets and Launchers

2.75-Inch Folding Fin Aircraft Rocket (FFAR)

The 2.75-inch FFAR uses MK 4 and MK 40 rocket motors and is fired from LAU-3, LAU-60, LAU-68 and LAU131 series launchers and SUU-20 dispensers. The motor tube is made of aluminum, weighs 11.4 pounds, and is 39.4 inches long. Both motors include an igniter, propellant grain, stabilizing rod, and nozzle and fin assembly.

The rocket is ignited by aircraft electrical power. When a firing impulse is applied to the igniter contact disk, electric current passes through the igniter circuit and ignites the squib, which ignites the main igniter charge. The salt-covered stabilizing rod prevents unstable burning and reduces flash and after-burning of the propellant grain.

Gas pressure from the burning igniter charge ruptures the igniter case, and burning particles of the igniter charge ignite the propellant charge. Burning propellant blows or burns away the nozzle seals and fin retainer and provides propulsion gases from the rocket. After the rocket leaves the launcher, gas pressure on a piston and crosshead in the nozzle and fin assembly forces the fins open. The opened fins stabilize the rocket in flight.

The MK 40 rocket motor uses scarfed nozzles that impart a spin to the rocket for additional stabilization while in flight. A rocket equipped with the MK 40 motor is designated a low-spin FFAR.

2.75 inch FFAR rockets.

2.75-Inch Wrap-Around Fin Aircraft Rocket (WAFAR)

The 2.75-inch WAFAR consists of the MK 66 rocket motor and various combinations of warheads and fuses. The MK 66 rocket motor is an improvement over previous MK 4 and MK 40 rocket motors in that is provides 36 percent increased thrust resulting in a 40 percent increase in range. The wrap-around fins provide increased stability in flight which increases accuracy both for fixed wing and rotary wing aircraft. It is compatible with the LAU-131 rocket launcher. The MK 66 rocket motor is 42 inches long and weighs 14 pounds. It consists of a motor tube, igniter, stabilizing rod assembly, charge support assembly, propellant grain, and nozzle fin assembly). The aluminum motor tube is threaded at one end to accept the warhead and grooved at the other end to provide the means for nozzle attachment. Spin is imparted to the rocket by the nozzle and flight stability is provided by the wrap-around fins which open and lock in place after the rocket exits the tube. Combustion is initiated by the igniter using current supplied by the launcher. The charge support assembly immobilizes the propellant grain to prevent gas circulation. The motor is propelled to the target by the forces resulting from combustion which are aided and stabilized by the stabilizing rod assembly. Rocket motor burn time is a nominal 1.1 seconds.

2.75-Inch Rocket Warheads

MK 1 Warhead (HE)

The MK 1 HE warhead has a steel case and an HE charge of 1.4 pounds of HBX-1, and uses the MK 176, MK 1.78, or M427 fuze. With the MK 178 fuze installed, the warhead weighs 6.5 pounds. The primary effects of the MK 1 warhead are blast and fragmentation.

MK 5 Warhead (HEAT)

The MK 5 warhead is similar in external configuration to the MK 1 warhead. The filler is 0.92 pound of Composition B in the form of a shaped charge. A booster pellet is located at the base of the shaped charge. With the MK 181 fuze installed, the warhead weighs 6.6 pounds. The warhead is intended for use against tanks and armor.

When the MK 5 warhead impacts and the fuze functions, a shaped-charge booster in the fuze projects a shock wave through the cone and flash tube of the warhead to the warhead booster pellet. The warhead booster pellet detonates and ignites the warhead shaped charge, which is designed to focus all the energy from the detonation into a narrow, high-velocity jet. Pressures up to 25,000 psi are produced on the point of impact. Depth of penetration is a function of target density. Since all energy is directed forward, there is little appreciable lateral blast effect from the MK 5 warhead.

M151 Warhead (PMI)

The M151 warhead has a pearlite malleable iron (PMI) case filled with 2.32 pounds of Composition B4 and uses the M427/M423 fuze. With the M427/M423 installed, the warhead weighs 9.6 pounds.

The primary effect of the M151 warhead is fragmentation.

M156 Warhead (WP)

The M156 is a target-marking white phosphorous (WP) warhead. The external appearance of the M156 is identical to that of the M151 HE warhead. Because of this similarity in appearance, markings must be carefully observed and maintained. With the M427 fuze installed, the warhead weighs 11 pounds, and contains 0.125 pound of Composition B4 and 2.3 pounds of WP.

When the warhead impacts and the fuze functions, the fuze booster initiates the warhead burster charge. The burst charge ruptures the warhead case and scatters the phosphorus, which ignites spontaneously to provide; dense smoke. Incendiary effect is minor.

M257 Standoff Illuminating Flare

The M257 provides standoff capability during night operations when/where target illumination is required. The flare warhead is cylindrical in shape containing four main sections: integral fuze, drogue parachute, main parachute, and illuminant. The M257's integral fuze arms by motor forward thrust (a minimum of 17 Gs). Just after motor burnout, the fuze functions and ignites a nine-second delay. Ignition of first expulsion charge separates spent motor deploying drogue parachute, which decelerates flare and ignites a two-second delay. A second expulsion charge separates drogue chute, freeing pilot parachute to assist deployment of main parachute. Opening force of main chute ignites flare. Flare now descends at a rate of 13 feet per second on main chute with a light output of one million candle-power, burning for about two minutes.

M274 Smoke Signature Practice Warhead

The M274 warhead is a modified version of the WTU-1/B cast iron, inert, practice warhead. The modification consists of the addition of a sealed S&A and smoke cartridge, nose cap, firing pin, retainer ring, and blow plugs. Functioning of the 2.75-inch rocket with an M274 warhead begins when the firing circuit switch is closed. Current passes through the launcher firing contact to the igniter in the rocket motor. This current generates the heat necessary to initiate the igniter charge, which ignites the propellant, pressurizes the chamber and exhaust through the nozzle, providing the unequal forces required for rocket thrust. The thrust of the nozzle exhaust blows off the fin retainer and releases the fins. Upon clearing the launcher, the fins are opened by the force of the fin actuating piston pushing on the heels of the fins. The fins are held by the crosshead of the piston at an angle of 45 degrees with the axis of the motor tube.

The acceleration of the rocket motor causes the S&A device to arm. Upon ground impact, the nose cap collapses and drives the firing pin into the primer, resulting in initiation of the smoke charge, which provides the visible signature.

M278 Illuminating Warhead

The M278 illuminating warhead consists of an ignition system, flare, main parachute, drogue parachute assembly and an integral fuze and delay assembly. The warhead is enclosed in an aluminum case.

The rocket with M278 illuminating warhead is fired with standard 2.75-inch motor MK66 to attain elevation between 2000 and 4000 feet at 3000 meters down-range. Upon rocket launch, the M422 fuze arms upon acceleration (17 Gs approximately required).

After 1.0 second (at motor burnout), the fuze functions initiating delay train. After nine seconds, delay ignites first expulsion charge in fuze assembly. Gas pressure forces pusher plate forward, shears pin, separates motor and adapter section from remainder of warhead. Rocket velocity is now approximately 800 fps.

The deflector plate, attached by cable to motor adapter, is extended into airstream, deflects path of motor and adapter. Pusher plate, attached to drogue chute, deploys drogue. Rocket warhead velocity then decreases to approximately 200 fps during next two seconds.

Upon deployment of drogue chute, the gas generator is activated by pull on lanyard attached to drogue. After two seconds, the gas generator functions the second expulsion charge located in retainer block of drogue housing. Gas pressure forces pusher plate forward, shearing pins and separating drogue housing from main chute insert and candle assembly.

The pusher plate is attached by a thread-line to the pilot chute. The pilot chute is deployed, and, in turn, pulls bag off main chute. The main chute now deploys the steel cable which is attached to the main chute shroud lines on one end and in turn, pulls a lanyard attached to candle igniter assembly.

The pull on the lanyard rotates a bellcrank, releasing the firing pin. The firing pin fires a rifle primer, which fires boron pellets.

5 inch HVAR Rockets.

The boron pellets ignite a propellant wafer. Propellant ignites the candle. Ignition gases pressurize nose cap, blowing it free. The candle, suspended from the main chute is now burning. During the first 15 seconds, the igniter housing is burned away. The candle descends at 13 fps, burns for 180 seconds with a light maximum output of 1000 candlepower in the visible spectrum.

WDU-4A/A Warhead (Flechette)

The WDU-4A/A antipersonnel flechette warhead weighs 9.1 pound and contains 5.5 grams of explosive. The warhead contains 2,200 20-grain flechettes. The warhead has a base only fuze, ejecting charge, piston, and aerodynamic nose cone, and contains red dye marker to provide visual identification of warhead functioning. The warhead is used on MK4 and MK40 rocket motors.

The fuze is installed during assembly and is an integral part of the warhead. At launch acceleration forces arm the fuze. At 1.6 seconds after launch, an airburst, initiated by deceleration forces, allows the spring loaded firing pin to ignite the ejecting charge. The ejecting charge generates gas pressure against the pusher plate, which transmits the pressure through the flechettes to the shear pins on the nose cone. The shear pins break, the nose cone is ejected, and the flechettes follow the nose cone. The flechettes are packed alternating fore and aft. Aerodynamic force causes the tail-forward flechettes to tumble and streamline after ejection. This weather vaning causes dispersion.
Slant range at launch is the critical factor in determining slant range at warhead function. Slant range at function must be known to determine dispersion and weapon effectiveness. Refer to aircraft ballistic tables to determine optimum launch conditions.

MK 61 Warhead (TP)

The MK 61 TP warhead has an inert, solid iron head and simulates the ballistic characteristics of the MK 1 warhead. It has the same appearance as the MK 1 warhead. The MK 61 weighs 6.5 pounds.

WTU-1/B Warhead (TP)

WTU-1/B TP warhead is an inert, one-piece cast warhead that simulates the ballistic characteristics of the M151 warhead. The WTU-1/B weighs 9.4 pounds.

LAU-3A, A/A, B/A, -60/A Rocket Launcher.

The LAU-3/A, A/A, B/A, -60/A rocket launcher can carry and launch nineteen 2.75 inch folding fin aircraft rockets (FFAR). The flight configuration consists of the loaded centersection ssembly with streamlined fairings installed and locked onto the ends. When the launcher is fired, the front fairing is hattered by rocket impact, and the tip of the rear fairing is shattered by rocket blast. The frangible fairings are made of treated paper and shatter readily after rocket impact and blast.

Approximately 11 inches of the base of the rear fairing will remain on the adapter to channel rocket debris away from the undersurface of the wing. The launcher center section is constructed of 19 paper tubes clustered together and is wrapped with a thin aluminum outer skin.

Detent devices within the tubes restrain the rockets against normal flight loads and provide electrical contact to ignite the rockets. Contact fingers on the aft bulkhead provide a ground to complete the circuit through the rockets. Two receptacles on top of the center section provide the connection to the aircraft rocket-firing circuitry. The receptacles are wired in parallel; therefore, only one of them is connected to the aircraft.

A shorting pin is inserted in the left side of the LAU-3/A, A/A, B/A launcher as a ground safety device which is removed prior to flight. The LAU-60/A contains a breaker switch on the top of the launcher behind the aft electrical receptacle. Electrical power for the rocket ignition system supplied to the launcher is 28 volts direct current (dc). The intervalometer, located within the launcher, converts the aircraft firing voltage into a ripple-fire pulse with a 10-millisecond delay interval which will ripple-fire the rockets in pairs until the launcher is empty. The launcher should completely fire-out in approximately 0.1 second. MER and TER switches must be positioned on rocket to provide the ripple-fire sequence.

The CBU position would cause the high voltage to burn out the wire-type intervalometer at a rate that will produce a near salvofire effect, and the rockets will collide upon leaving the launcher.

Several intervalometers are available for use with the LAU-3/A; some are reusable. A burnout type unit supports the ripple-fire mode only. The reusable type supports both the ripple- and single-fire modes and includes a reset switch to select the firing modes. In a singles mode, two rockets are fired with each fire pulse.

LAU-68A/A, B/A Rocket Launcher.

The LAU-68A/A, B/A rocket launcher can carry and launch seven 2.75 inch FFARs. The LAU68A/A, B/A versions are basically the same as the LAU-3/A, only smaller. The descriptions of construction and operation of the LAU-3/A apply to the LAU-68A/A, B/A versions with the following exceptions:

1. The LAU-68A/A has a 26-pin electrical receptacle forward and a 5-pin electrical receptacle aft. The LAU-68B/A has a 5-pin electrical receptacle forward and aft.
2. The tail fairings of the LAU-68A/A, B/A versions are constructed of metal and shaped like a funnel, with a hole on the aft end. During rocket launching, the tail fairing functions to channel rocket debris away from the underside of the aircraft wing. Not using the rear fairing may damage the wing during firing.
3. The launchers utilize a reusable electromechanical intervalometer to route the fire pulse to the different rocket tubes. A single/ ripple switch and an intervalometer control, which must be positioned during aircraft loading, are located on the aft end of the launcher. With the single/ripple switch in single, one tube is fired with each fire pulse received by the launcher; with the switch in ripple, all tubes are fired in sequential, order with a 60-millisecond interval between tube firings. The intervalometer control has a load position for, ground safety, an arm position, and firing positions 1 through 7.

The interface of the LAU-68 intervalometer and ripple/pairs mode causes system anomalies. When the launcher is mounted on a TER9/A, these anomalies may cause hung rockets. In this case, if a ripple mode is desired, select ripple on the LAU-68 single/ripple, switch and use the aircraft single mode.

LAU-131/A Rocket Launcher.

The LAU-131/A rocket launcher is similar in characteristics to the LAU-68B/A. The LAU-131/A has the capability to use both Folding Fin Aircraft Rockets WAR) and Wrap-around Fin Aircraft Rockets (WAFAR). The launcher consists of the center section with streamlining fairings installed and locked onto the forward and aft ends. The front fairing is constructed so that upon, rocket firing, the fairing shatters. The aft fairing is constructed to funnel rocket debris away from the aircraft. Detents within the tubes restrain the rockets against normal flight loads and the contact spring (MK 66 motor)/contact arm (MK 4 and MK 40 motors) provide electrical contact to ignite the rockets. The rockets are grounded through the detent retainer to complete the electrical firing circuit. Two electrical receptacles are located on the top of the center section to receive power from the aircraft. The receptacles are wired in parallel. The firing of the 7 rockets is controlled by an electromechanical intervalometer. The intervalometer will fire either one rocket in the Single mode, or in Ripple mode will fire each rocket with a 40 millisecond (60 millisecond if modified with a LAU-68 intervalometer) interval between pulses. The firing circuit of the launcher is safed by a shorting pin installed into the launcher side. The launcher is connected electrically to the aircraft armament system by a cable and is attached to the bomb rack by suspension lugs spaced 14 inches apart.

Harrier GR.3 loaded with BL755 Cluster Bombs and SNEB Rocket Pods.

Gun Pods

F-4E loaded with three SUU-23/A Gun Pods.

F-4M loaded with SUU-23A/A Gun Pod.

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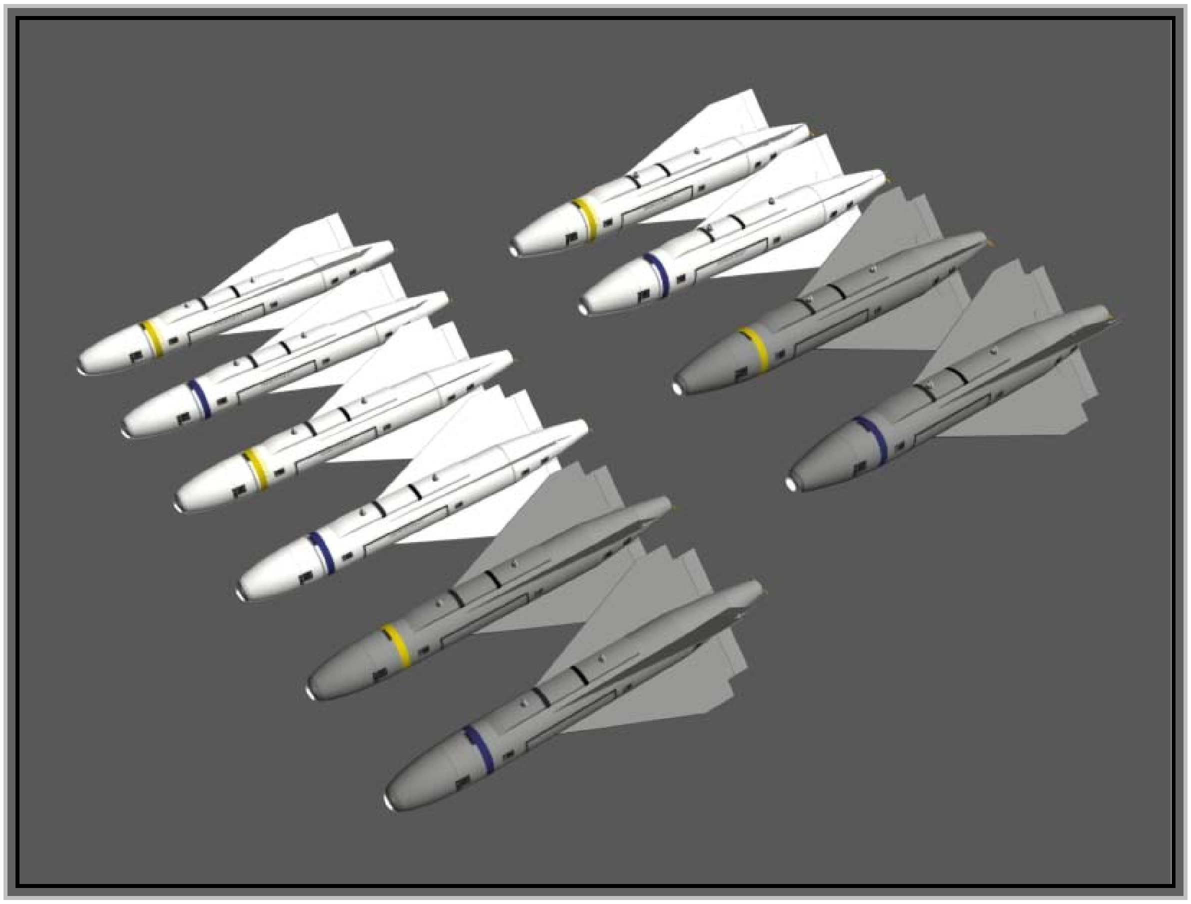
EO Guided Bombs

Walleye I and II.



The AGM-62 WALLEYE is a guided glide bomb designed to be delivered on a surface target from an attack aircraft. It is used primarily against targets such as fuel tanks, tunnels, bridges, radar sites, port facilities, and ammunition depots. The weapon system consists of the weapon, the attack aircraft, the AN/AWW-9B data link pod, and the OK-293/AWW control group. The WALLEYE is unique in that it has no propulsion section and must rely on its ability to glide to the target after release from the aircraft.
There are three basic series of the WALLEYE weapon.

The original WALLEYE I Extended Range Data Link (ERDL) utilizes a tone data link system while the newer version utilizes the differential phase shift keyed digital data link, designed to prevent signal jamming. The WALLEYE II and WALLEYE II ERDL are greater in diameter, length, and weight than the WALLEYE I ERDL weapons. The AGM- 62 designation for Walleye nomenclature is not in wide use.

China Lake designed and developed the first precision-guided anti-surface weapon, the Walleye (AGM-62) TV-guided glide bomb. In January 1963 a Walleye television glide bomb, released from a YA-4B, made a direct impact on its target at the Naval Ordnance Test Station, China Lake in the first demonstration of its automatic homing feature. A contract for production of the Walleye television homing glide bomb was issued to the Martin Marietta Corporation in January 1966. An outgrowth of in-house China Lake technology efforts, Walleye was fielded in 1967 and proved its unsurpassed accuracy in combat.

Originally developed by the Navy, the Air Force began Walleye combat tests in Vietnam during August 1967 that achieved excellent results in good visibility against targets that gave a strong contrast and were lightly defended. Later Walleye operations in more demanding conditions were less successful. It continued to be used in Southeast Asia, but due to its operating restrictions, cost, and the appearance of laser-guided bombs (LGB), comprised only a small fraction (6 percent) of the total number of PGMs employed in Vietnam.

F-4E loaded with two WalleyeI EO Guided Bombs.

The ERDL weapon provides distinct advantages over the standard WALLEYE. With the ERDL version, the added data link permits the weapon to continue to send a video target display from launch of the weapon until target impact. The data link further allows the controlling aircraft to control the weapon in flight and to either retarget or redefine the target aim point. The controlling aircraft can be the launching aircraft or a second aircraft equipped with a data link pod (AN/AWW-9B).

The 1427-1435 MHz band is used for proficiency training using various guided weapon systems. The weapon systems and supporting data links that operate in this band include the AWW-13 Advanced Data Link, used in the Walleye and SLAM. The current Navy inventory includes approximately 200 Walleye and 800 SLAM weapon systems. The loss of this band for missile command operations would render Navy systems more susceptible to jamming and will impair their terminal guidance. Compounding the problem are developmental weapons, such as the Joint Standoff Weapon Unitary (JSOW Unitary), that will use the AWW-13. The AWW-13 requires spectrum for both command and video functions.

Electro-optical [EO] sensors such as used on Walleye depend on both light and optical contrast for target searching and identification. This obviates their use at night and in significantly adverse weather or visual conditions where the line of sight to a target was obscured. The requirement for visual contrast between the target and its immediate surroundings imposed problems during Desert Storm. For Walleye delivery, F/A-18 pilots reported that a target was sometimes indistinguishable from its own shadow. This made it difficult to reliably designate the actual target, rather than its shadow, for a true weapon hit. The low-light conditions at dawn and dusk often provided insufficient light for the required degree of optical contrast. A "haze penetrator" version of Walleye used low-light optics to see through daytime haze and at dawn and dusk, permitting use in some of the conditions in which other optical systems were limited.

In 1963, the Naval Ordnance Test Station (NOTS, later Naval Weapons Center NWC) at China Lake began the development of an unpowered television-guided glide bomb, to be named *Walleye*. Although it had no propulsion system, it was designated as AGM-62A in the newly created missile and rocket designation system. AGM-62 was actually the first new designation allocated in this series, as all lower numbers were used up for redesignations of existing missiles. *Walleye* was to provide the pilots of strike aircraft with a fire-and-forget high-precision air-to-ground weapon, i.e. the aircraft should be able to turn away as soon as the weapon was launched. The only guided tactical air-to-ground missile available at the time, the AGM-12 *Bullpup*, required the pilot of the attacking aircraft to manually guide the missile all the way to the target. After an industry-wide competition for a missile design for the NOTS TV-guidance system in 1964/65, Martin received a production contract for *Walleye* in January 1966. In 1967, *Walleye* entered service with the U.S. Navy. In that year the USAF also ordered its first batch of *Walleyes*, but Air Force use of this weapon was very limited.

The *Walleye* was a glide bomb controlled by four large wings with trailing-edge control surfaces. In the nose it had a TV camera, which transmitted its image to a screen in the launching aircraft. When the pilot had acquired a target on this image, he "locked" the image and released the weapon. The guidance system then continually matched the current TV image with the locked one, and corrected the course of the missile to compensate any deviations. Power for the TV and other systems was provided by a ram-air turbine driven by a small propeller in the missile's tail. The TV-guidance system proved to be quite successful when used against targets which stood out clearly against the background, but capability to remain locked on low-contrast targets was decidedly unsatisfactory. The relatively light-weight 374 kg (825 lb) MK 58 linear shaped-charge warhead also meant, that only a direct hit was really effective. The maximum range of the glide bomb depended of course heavily on launch altitude, but minimum range for all *Walleye* versions is generally given as 1.8 km (1 nm).

By the time the production contract was awarded in 1966, the Navy had second thoughts about designating an unpowered glide weapon in the guided missile series, and dropped the AGM-62 designator. Instead, the initial production *Walleye* was known as **Guided Weapon, MK 1 MOD 0**. Later *Walleye* variants received higher MARK and MOD numbers. The *Walleye* **MK 2** was an inert training variant of the tactical weapon. The **MK 3** *Walleye ER* (Extended Range) was a version with slightly larger wings for extended glide range, and **MK 4** was another training missile (possibly of ER configuration). To evaluate the results of captive-carry training flights, the MOD 1, 4, 6, and 7 versions of the MK 4 had a video-recorder to record the TV camera image for post-flight analysis.

The small warhead of the original *Walleye* was useless against many hardened or large high value targets, like bridges and powerplants. Therefore the NWC developed a significantly enlarged version, initially known as "Fat Albert", but officially designated Guided Weapon **MK 5** *Walleye II* (the small-warhead versions were renamed *Walleye I*). The *Walleye II* had a larger body with a 900 kg (2000 lb) MK 87 linear shaped-charge warhead, and much larger fins for further extended glide range. The seeker of the MK 5 used a smaller optical "gate" for increased accuracy, but this required even better contrast for a successful lock-on. The *Walleye II* was built by Hughes under subcontract to Martin Marietta. After operational evaluation in 1973, it was introduced in U.S. Navy service in January 1974 in the MK 5 MOD 4 variant.

The designation **MK 6** referred to a nuclear version of the *Walleye II,* armed with a low-yield (625 T) W-72 fission warhead. The W-72s were rebuilt low-yield W-54 warheads taken from retired weapons. Although the W-72 was stockpiled, it's possible that no *Walleye* missiles were ever completed as all-up nuclear rounds. The W-72 warhead was removed from the nuclear stockpile in 1979.

The next major step in the evolution of *Walleye* was the ERDL (Extended Range Data Link) modification. One drawback of the *Walleye*'s guidance system was the requirement to lock the seeker onto the target before launch, meaning that the attack aircraft had to come relatively close to a potentially heavily defended target. The ERDL system equipped the *Walleye* with a two-way datalink, and the launch aircraft were equipped with an AN/AWW-9 (later AN/AWW-13) underwing data-link pod. The pilot could now launch the *Walleye* out of visual range of the target, turn away, watch the bomb's TV camera image, which was transmitted via the data-link, and lock-on to the target at any convenient moment. It was even possible to control the weapon from a different aircraft than that which launched the *Walleye*, and because of the limited number of data-link pods available, it was actually standard practice for one pod-equipped aircraft to guide *Walleyes* dropped by several attack aircraft (not simultaneously, though). To use the beyond-visual-range capability to full effect, ERDL *Walleyes* were usually dropped from high altitude which led to glide ranges of up to 60000 m (65000 yd) for the *Walleye II*. The *Walleye II ERDL* also had slightly larger wings than the standard *Walleye II*. The initial production variants in 1975 were the **MK 21** *Walleye I ERDL* and **MK 23** *Walleye II ERDL*. These versions used a MK 46 guidance section and a MK 159 control section. The **MK 22** was a *Walleye I ERDL* variant, which replaced these components with MK 53 and MK 165 guidance and control sections, respectively. I haven't found any reference to a *Walleye* MK 24, but it seems plausible that this nomenclature was reserved for a *Walleye II ERDL* variant with the MK 22's components. Production of the ERDL *Walleyes* ended in 1976, but in the late 1970s, around 1400 *Walleye I*s and 2400 *Walleye II*s were converted to ERDL variants. The *Walleye ERDL Trainer* **MK 27** was an inert training missile for both ERDL variants (MODs 3,4,5 were of *Walleye II* configuration) and was used for ground handling and captive-carry flight training.

In the 1980s, the data-link equipment was upgraded, leading to the interim *Walleye ERDL* Phase I and the final *Walleye ERDL* Phase II configurations. The Phase II configuration is also known as ERDL/DPSK (Digital Phase-Shift Keying). I don't know exact details of this upgrade, but it was most probably a reliability and anti-jamming improvement for the data-link. The initial ERDL Phase II models were the **MK 29** *Walleye I ERDL/DPSK* and the **MK 30** *Walleye II ERDL/DPSK*, respectively. These variants used MK 64 guidance and MK 187 control sections, while the later **MK 34** and **MK 37** *Walleye I/II ERDL/DPSK* models had MK 71 guidance sections instead. The **MK 38** was a special ERDL/DPSK inert training model for use with data-link equipped F/A-18 *Hornet* aircraft.

There were many other MARKs and MODs of the *Walleye* glide-bomb, which differed by having different types and versions of components (warhead, warhead section, guidance section, control section) or simply used different frequencies for the data-link (which had to be pre-selected from multiple options for the original ERDL models). A typical example is the MK 29 series, which used all possible combinations of two guidance sections (MK 64 MOD 0 and MOD 1), five control sections (MK 187 MODs 0 through 4), and two sets of warhead sections (MK 98 MOD 0/2 and MOD 1/3), to create the initial 2x5x2=20 MODs of the MK 29 weapon. MK 29 MODs 20 and up used a different guidance section (MK 65 MOD 0/1).
I don't know the details of most of the MK/MOD variations, but the following two tables are provided to give a complete cross reference to all *Walleye* Guided Weapon MK/MOD designations known to me.

Gradual phase-out of the *Walleye* began in the late 1980s, but in Operation Desert Storm in 1991, it was again used in combat. After the war ended, the Navy quickly retired the A-7E *Corsair*, the main launch platform for *Walleye*, and the missile was subsequently removed from active service in the mid-1990s. A total of about 5000 *Walleye* glide bombs of all types were built by Martin Marietta and Hughes.

LASER-GUIDED BOMBS

PAVEWAY Series.

Paveway Laser-Guided Bombs (LGB) are maneuverable, free-fall weapons that guide to a spot of laser energy reflected off of the target. The LGB is delivered like a normal GP warhead and the semi-active guidance corrects for many of the normal errors inherent in any delivery system. Laser designation for the weapon is provided by an airborne or ground laser designator.

The LGB consists of a laser guidance kit that attaches to the nose and tail of standard GP, Blast or Penetrator warheads. The GBU-10 is a kit attached to the MK 84 or BLU-109 warhead. The GBU-12 is a kit attached to a MK 82 warhead. LGB's are not active until after release and require no modifications or electrical interface with the delivery aircraft.

The laser guidance kit consists of two major components that are attached to the warhead:

A common Computer Control Group (CCG) that attaches to the nose of all warheads, e.g., the CCG is common to all LGB's of a particular class or generation of the weapon.

A warhead specific Air Foil Group (AFG) that consists of a tail mounted wing assembly.

Computer Control Group.

The CCG consists of an aerodynamically shaped seeker, a computer section and control section. The seeker detects laser energy reflected off of the target and converts this energy to electrical signals. The computer processes and decodes these signals and develops appropriate guidance commands that are sent to the control section. The control section develops the mechanical power necessary to actuate the control fins or canards that guide the weapon.

Seeker.

The seeker consists of a laser detector, suitable optics and electronic processing circuitry that determines the angular displacement of the target from the seeker package's boresight alignment. This seeker package is aerodynamically shaped and gimbal mounted on the nose of the CCG. The gimbal allows the seeker to streamline with the relative wind, effectively aiming the seeker's boresight along the weapon's flight path. Thus, the target return develops a signal in the seeker dependent upon the angle between the weapon's flight path and the target's location. The weapon then maneuvers to align its flight path with the target by steering the weapon to zeroize the angle between the flight path and the target's location.

The seeker’s laser detector element is divided into four electrically distinct quadrants and is mounted perpendicularly to the seeker heads aerodynamic axis.

CF-18A loaded with six GBU-12 Laser Guided Bombs.

Optics in front of the detector project the laser return on one or more of the four quadrants. This energy develops an electrical signal that is processed to give a guidance command to center the return on the detector’s four quadrants, boresighting the target. For instance, if the laser return falls on the upper right quadrant, the bomb’s electronics produce a down and left guidance command. The initial guidance commands can usually center the laser return on the center of the detector in three to five seconds. Essentially, the target is said to be boresighted when the slightly defocused spot hits the center of all four quadrants and no further guidance commands are generated. For a brief period of time, the bomb falls ballistically until one or two of the quadrants receive more laser energy than the others and an appropriate canard deflection is generated to re-center the spot. Control deflections are commanded only when the spot is off boresight. Gravity and wind effects plus boresight overshoots combine to produce a hunting action around boresight that is on-off by nature. This on-off type of guidance signal produced by the seeker, generates flight characteristics that are further accentuated by the all-or-nothing control fin deflection system. This combination of an on-off type seeker and a hard-over displacement of control fins produces a type of guidance called "bangzerobang" or "bang-bang" guidance.

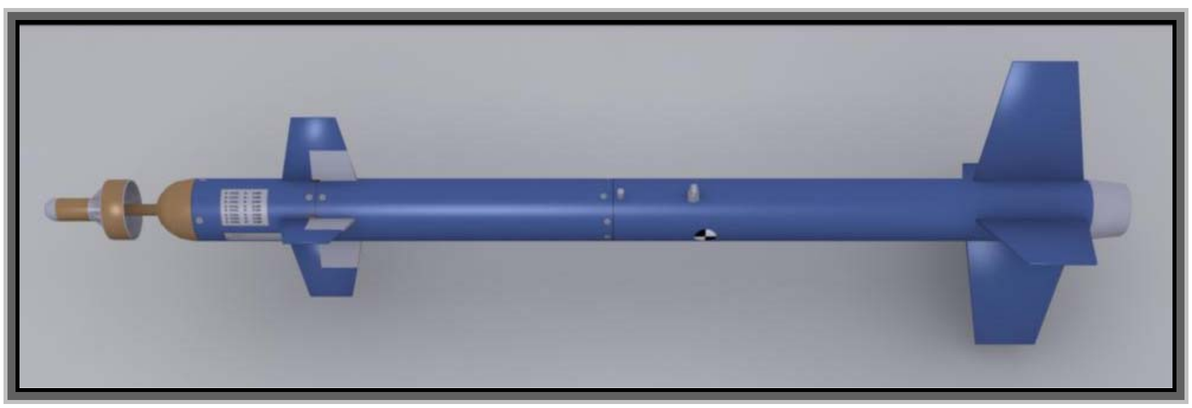
Computer Section.

The computer section contains circuitry that processes electrical signals from the detector and develops the directional command signals for the control fins. Coding options include capabilities to decode pulse repetition frequency (PRF) and pulse interval modulation (PIM) coding schemes.

Control Section.

The control section contains the power sources for the CCG. A thermal battery provides electrical power for the seeker, computer and the solenoid valves that control the canard actuators. The battery is initiated by a battery firing device (BFD) connected by an arming lanyard to the bomb rack. PW II thermal battery life is 55 seconds.

The power source for the control fins is a gas grain generator that develops a high-pressure, hot-gas supply to the four cylinders and pistons that move the canard actuator shafts. The MAU-169H/B and MAU-209/B use a cold nitrogen gas to drive the canard actuator shaft pistons. The gas is routed to the pistons through a manifold assembly containing the four control solenoids that regulate gas flow out of each cylinder.



BDU-57 Laser Guided Training Round.

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At high velocity, control fin deflection is constrained only by air-loads. At lower velocities, fin deflection is constrained by the mechanical limits of the actuator pistons. When a control valve is closed, the pressure build up in the cylinder forces the actuator piston towards the air-load or mechanical limit of the system. Depending on the air-loads on the control fins, as a general rule-of-thumb, it takes approximately 0.3 seconds for the fin to move to its limit position. For large corrections, the fin will move to its limit position and stay there until boresight is achieved or the weapon's rotation produces a change in the instantaneous vector towards boresight. Full fin deflection and large overshoots through the boresight-to-target line-of-sight (LOS) are common during the transition phase. In addition, a very detrimental case occurs during low, terminal-angle deliveries where prolonged full fin deflection is necessary to fly-up-to and stay near the boresight LOS.

When the laser return is boresighted or no laser return is detected, the four control valves are commanded open, control fins streamline to the relative wind, and the weapon falls ballistically. The fins streamline very quickly (<0.1 seconds) after the control valve is opened.

The merits of the bang-bang system are extreme simplicity and reliability. The disadvantage is the rapid loss of weapon accuracy as the weapon's energy and airspeed is decreased.

Control Fins (Canards).

Guidance control fins, or canards, are attached to each quadrant of the control section. Opposing canards are attached to either end of the two actuator shafts and operate in unison. The fin-pairs generate the up/down or left/right directional changes necessary to keep the weapon's flight path on the target. In addition, the weapon is not roll stabilized and may rotate randomly about its longitudinal axis. These factors, together with the bang-bang guidance and the random, off-boresight corrections give the PW II it's unique guidance characteristics.

Airfoil Group Components.

The AFG is a shipset that consists of the canards, the wing assembly and the other mechanical devices necessary to marry a CCG to a particular warhead.

Paveway II weapons have a tail assembly with four folding wings that spring deploy after release. Wing deployment is activated by a lanyard attached to the bomb-rack's sway brace or positive arming post. After release, shock absorbers in the wing deployment mechanism restrict opening speed for safe aircraft separation.

EO and IR Guided Missiles

AGM-65 MAVERICK MISSILE

The Maverick is a rocket propelled air-to-ground missile. It is a launch-and-leave munition, relying on automatic self-guidance.

Various modes of guidance are used in the Maverick series. The Air Force has procured six models: the Electro-Optical (EO) AGM-65A, B, H, and K, and the infrared (IR) AGM-65D and G/G2.

The AGM-65A, B, D and H models use a 125-pound, shaped charge warhead optimized for use against armored vehicles, bunkers, boats, radar vans and small hard targets. The AGM-65G/G2 and K use a 300-pound kinetic energy penetrator, blast/fragmentation warhead that is effective against unusually shaped targets such as hangars, bridges, ships and small tactical targets such as tanks and bunkers.

The A/A37A Training Guided Missile (TGM) and Captive Air Training Missile (CATM)-65K are used to train aircrews in AGM-65 employment and can be carried on either the LAU-88 or LAU-117 series launchers. The AGM-65A, B, D and H models are carried on and launched from the LAU-88 or LAU-117 series launchers. The AGM-65G/G2 and K are carried on and launched only from the LAU-117 series, due to missile weight constraints on the missile shear pin.

Components

Guidance Control Section.

The nose of all Maverick missile variants has a dome-shaped window that is protected by a clear, translucent, frangible glass dome cover. The dome cover is shattered by activation of a pyrotechnic squib and piston, as the missile is selected for launch. Immediately behind the dome is a seeker unit surrounded by a ring-shaped gyro mounted on a two-axis gimbal structure. The seeker is positioned by push rods connected from the gyro to two electrical torquer motors.

The guidance control section also contains the electronic circuits which operate the seeker unit, track the target, and generate missile steering commands. The autopilot combines these steering commands with gyro-sensed yaw, roll, pitch, and lateral acceleration rates. From this information, the autopilot computes course corrections to steer the missile on a collision path to the target.

Center Aft Section.

The Maverick missile is propelled by a 104-pound solid propellant rocket motor. The boost-sustain type motor consists of a case, liner, and blast tube. The boost phase produces approximately 10,000 pounds thrust and lasts approximately 0.5 second; the sustain phase produces approximately 2,000 pounds thrust for approximately 3.5 second. After rocket motor burnout, the remainder of the missile flight is unpowered.

Rocket motor ignition is accomplished through an igniter cable on the aft end of the missile. Before takeoff, the ground crew attaches the igniter cable to the receptacle on the launcher.

The missile uses aircraft electrical power until the missile has started to launch. When the launch command is received, the missile thermal battery is activated and reaches rated voltage in approximately 0.5 second. As the missile begins to travel forward along the launcher rail, the umbilical plug in the aft end of the missile separates from the launcher-mounted receptacle.

At this point, the missile battery assumes the electrical load of the missile. The battery will continue to supply adequate power for a minimum of 105 seconds.

AGM-65A and AGM-65B (EO) Maverick Missiles.

The AGM-65A and AGM-65B are TV-guided models of the Maverick missile family. Both models contain a shaped charge warhead and an analog EO, centroid-type tracker. Targets must be visually acquired and missile video acquisition must be accomplished prior to launch. Both models are guided autonomously, providing a launch-and-leave capability.

The AGM-65A has a 5 degree field of view (FOV). The AGM-65B has an improved guidance unit and a magnified target image (2.5 degree FOV) that permits the target video acquisition and launch at greater ranges than the AGM-65A missile. Other portions of the B model missile are the same as the AGM-65A.

AGM-65A fired from an A-10A.

AGM-65D and AGM-65G/G2 (IR) Maverick Missiles.

The guidance control section is significantly different from EO Mavericks. The guidance unit uses an IR seeker that converts IR energy into electrical signals. The signals are then converted by a digital computer into a TV video image from which the aircrew is able to identify and lock onto objects within the seeker FOV.

The AGM-65D utilizes a centroid mode of targeting similar to the AGM-65A and B. In addition to the centroid mode, the AGM-65G/G2 can also operate in a forced correlate mode of operation for aimpoint selection of large targets or a shiptrack mode optimized for ship targets. The digital computer also allows the missile to make logical decisions prior to, during and after launch, decreasing aircrew workload and enhancing missile performance.

A-10A loaded with six AGM-65Ds on LAU-88 launchers.

A dual FOV capability was added to provide selection of wide (3 degrees) FOV (WFOV) for target acquisition and narrow (1.5 degrees) FOV (NFOV) for improved target identification and increased launch range. The IR seeker expands the missile launch environment to include night and degraded visual conditions.

AGM-65H and AGM-65K (CCD) Maverick Missiles.

The AGM-65H and AGM-65K are digital TV-guided models of the Maverick air-to-ground missile family. Both models use a solid state, digital, charge coupled device (CCD) TV camera as the seeker.

The AGM-65H and AGM-65K GCS is manufactured to a common standard from the older AGM-65A or AGM-65B GCS, using core IR circuit cards, the new CCD camera, specialized video processing cards and redesigned master interconnect board. An AGM-65H is created when the CCD GCS is mated to a lightweight, shaped-charge (125-pound) warhead CAS. The AGM-65K is comprised of the CCD GCS mated to a heavyweight, penetrating (300-pound), blast/fragmentation warhead CAS. Selectable wide and narrow fields of view are retained as in the AGM-65D and G/G2 models.

Targets must be visually acquired and missile video acquisition must be accomplished prior to launch. Both models retain lock-on before launch, autonomous guidance, providing a launch-and-leave capability. All the tracking and guidance algorithms from the AGM-65G2 are retained with the exception of minor differences in the G-bias profile.

AGM-65K fired from an F-4E.

Maverick Training Devices

The Maverick TGM/CATM are captive training devices designed to train aircrews in the use of the AGM-65A, B, D, G/G2, H, and K missiles. They provide realistic training in system operation, target acquisition and tactics. The TGM/CATM can be configured as a TGM-65A, D, G, or CATM-65K.

Because of the similarity of the operational and training systems, only the differences will be discussed. In most respects the TGM/CATM is physically identical to the live missile. The differences are: the external control surfaces are not present, the warhead has been replaced by a signal processing unit and the rocket motor and the hydraulic actuation system have been replaced by a film recorder, AVTR and/or ballast.

The TGM/CATM can be suspended from any LAU-88 or LAU-117 launcher. The TGM/CATM is completely inert because it contains no warhead, rocket motor, hydraulic actuation system, or battery. Electrical control is provided by the launcher electrical assembly. The inflight switch positions are the same for the TGM/CATM as for the live missile.

The TGM/CATM provides the same cockpit control response as the operational AGM-65 missile, except it does not launch. Launch is simulated by blanking the cockpit video display 1 second after depressing the pickle button. When the weapons release button is depressed to simulate launch, the TGM/CATM performs an orderly shutdown, which takes approximately 1 second.

A 4450th TG A-7D strikes a target on the Bombing Range terrain.

Radar Guided Missiles

AGM-84 HARPOON MISSILE

The Harpoon missile is an all weather, anti-ship attack weapon. The weapon system uses mid-course guidance with a radar seeker to attack surface ships. Its low-level, sea-skimming cruise trajectory, active radar guidance and warhead design assure high survivability and effectiveness. The missile is capable of launch from low and high altitudes (above 20,000 ft.), with engine start before launch or after launch, depending on the aircraft altitude and mach number at separation.

No data link from the launching platform is required by the missile after launch. The tactical missile has a low-level trajectory, active guidance, counter-counter measures capability and contact detonated high explosive blast type warhead to ensure high kill probability.

When the target comes within the search area of the active seeker, the high resolution system detects and locks - on the target. After target acquisition, the missile-flies at sea skim altitude to target except for the AGM-84A-1 missile that has a terminal pop-up maneuver just prior to target impact. The AGM-84D-1 tactical air launch missile has extended range due to using JP-10 fuel in lieu of JP-5 fuel and selectable search priority.
Once targeting information is obtained and sent to the Harpoon missile, it is fired. Once fired, the missile flies to the target location, turns on its seeker, locates the target and

strikes it without further action from the firing platform. This allows the firing platform to engage other threats instead of concentrating on one at a time.

An appropriately configured HARPOON can be launched from an AERO-65 bomb rack, AERO-7/A bomb rack, MK 6 canister, MK 7 shock resistant canister, MK 12 thickwall canister, MK 112 ASROC launcher, MK 8 and MK 116 TARTAR launcher, or submarine torpedo tube launcher.

F/A-18As firing AGM-84 Harpoon missiles.

The *Guidance Section* consists of an active radar seeker and radome, Missile Guidance Unit (MGU), radar altimeter and antennas, and power converter. The MGU consists of a three-axis attitude reference assembly (ARA) and a digital computer/power supply (DC/PS). Prior to launch, the DC/PS is initialized with data by the Command Launch System. After launch, the DC/PS uses the missile acceleration data from the ARA and altitude data from the radar altimeter to maintain the missile on the programmed flight profile. After seeker target acquisition, the DC/PS uses seeker data to guide the missile to the target.

The *Warhead Section* consists of a target-penetrating, load-carrying steel structure containing 215 pounds of high explosive (DESTEX) and a safe-and-arm/contact fuze assembly. The safe-and-arm/contact fuze assembly ensures the warhead will not explode until after the missile is launched. It is designed to explode the warhead after impacting the target. The warhead section can be replaced by an exercise section which transmits missile performance data for collection and analysis.

An F-4J loaded with two AGM-84A.

The *Sustainer Section* consists of a fuel tank with JP-10 fuel, air inlet duct, and a jet engine. This provides the thrust to power the missile during sustained flight. The Sustainer Section has four fixed fins which provide lift.

The *Control Section* consists of four electromechanical actuators which use signals from the Guidance Section to turn four fins which control missile motion.

The Harpoon missile was developed in the early 1970s. Numerous upgrades have kept it at the forefront of missile capabilities, including the Block 1 introduced in 1978, and the Block 1B introduced in 1981. Today, the latest variant developed in 1982 called Block 1C is deployed by the United States military (Navy and Air Force) as well as US allies. New developments are constantly being evaluated. Although originally planned to be in use until 2015, there is no plan to develop a replacement by the USN. There are continuing, extensive efforts (testing and analysis) to ensure no detrimental effects of missile aging. With budget constraints projected into the future, Harpoon will be employed past 2015.

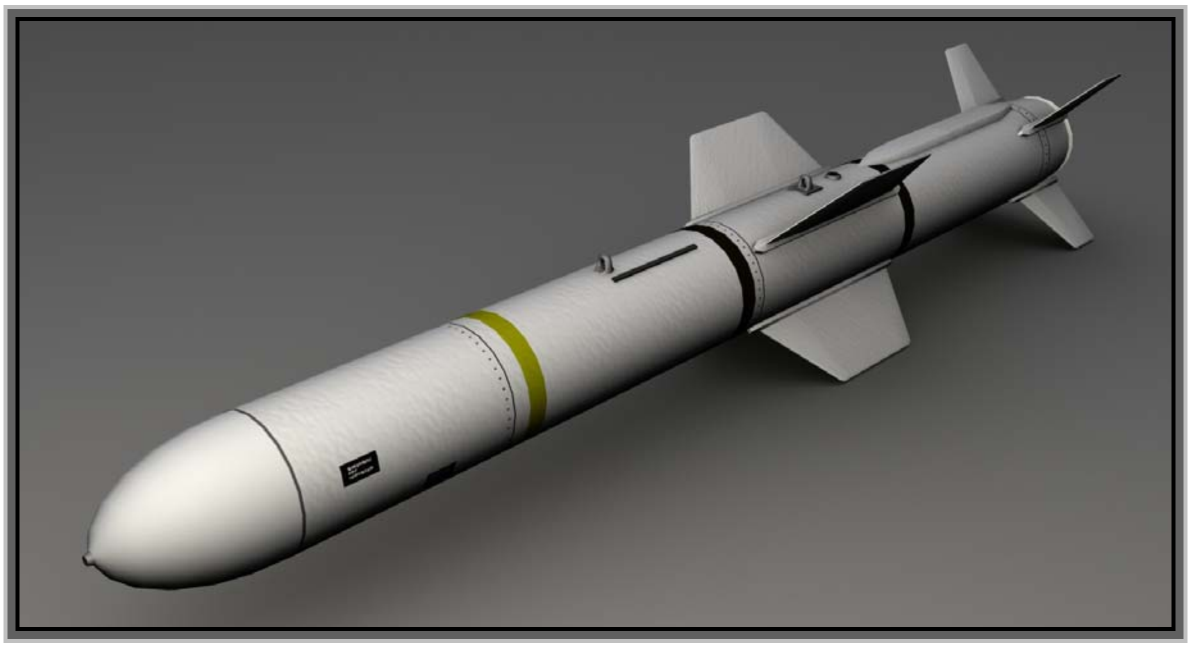
The **AGM-84D Harpoon** is an all-weather, over-the-horizon, anti-ship missile system produced by Boeing [formerly McDonnell Douglas]. The Harpoon’s active radar guidance, warhead design, and low-level, sea-skimming cruise trajectory assure high survivability and effectiveness. The missile is capable of being launched from surface ships, submarines, or (without the booster) from aircraft. The AGM-84D was first introduced in 1977, and in 1979 an air-launched version was deployed on the Navy’s P-3 Orion aircraft. Originally developed for the Navy to serve as its basic anti-ship missile for fleetwide use, the AGM-84D also has been adapted for use on the Air Force’s B-52G bombers, which can carry from eight to 12 of the missiles.

An F-4J destroys a Cargo Ship on the Korea terrain.

The **AGM-84D Harpoon Block 1D** (with a larger fuel tank and reattack capability) was developed in 1991. With the reduced threat because of the break-up of the Soviet Union, this upgrade was shelved and never produced.

The **AGM-84E Harpoon/SLAM [Stand-Off Land Attack Missile] Block 1E** is an intermediate range weapon system designed to provide day, night and adverse weather precision strike capability against high value land targets and ships in port. In the late

1980s, a land-attack missile was needed. Rather than design one from scratch, the US Navy took everything from Harpoon except the guidance and seeker sections, added a Global Positioning System receiver, a Walleye optical guidance system, and a Maverick data-link to create the Stand-off Land Attack Missile (SLAM). The AGM-84E uses an inertial navigation system with GPS, infrared terminal guidance, and is fitted with a Tomahawk warhead for better penetration. SLAM can be launched from land-based or aircraft carrier-based F/A-18 Hornet aircraft. It was employed successfully in Operation Desert Storm and UN relief operations in Bosnia prior to Operation Joint Endeavor.



AGM-84D Harpoon

AGM-86 (CONVENTIONAL ALCM)

The AGM-86 is a conventionally modified AGM-86B Air Launch Cruise Missile (ALCM).

The Conventional ALCM (CALCM) is a winged, turbofan powered, subsonic, inertially guided long-range cruise missile. GPS provides continuous updates to the inertial navigation element (INE) for highly accurate enroute and terminal navigation. The CALCM does not use Terrain Contour Matching (TERCOM) map updates. The modification installs high explosive (HE) in place of the existing warhead area and portions of two fuel tanks. Blast is equivalent to a MK-84, 2000 pound class general purpose bomb. The warhead is detonated by the missile INE or by impact sensors.

Mission Description.

The AGM-86 is an all-weather system that provides a quick reaction, world-wide capability to accurately attack a wide variety of targets. B-52s can employ the AGM-86 from standoff distances beyond the range of SAMs and AAA. A B-52H can carry a total of 20 missiles -- eight internally on the common strategic rotary launcher (CSRL), and six externally on each of two underwing missile pylons. USSTRATCOM Det 1 plans the AGM-86 mission.

Missile Physical Description.

The AGM-86 consists of the missile guidance and control system, missile flight control system, missile environmental control system, missile propulsion and fuel system, and missile arming system.

Missile Guidance and Control System .

The navigation/guidance system consists of the inertial navigation element (INE), global positioning system (GPS), radar altimeter element (RAE), air data element (ADE), and flight control element (FCE).

The INE provides receives data from the B-52 Offensive Avionics System (OAS) before launch and inputs from the GPS, RAE, ADE, and FCE after launch. The INE provides control of all missile functions including navigation, guidance, autopilot, event sequencing, and warhead arming and fuzing. The aircraft environmental system cools the INE during captive flight and the missile environmental system cools the INE after launch.

The GPS receiver is installed in the missile to aid the INE in navigation. At missile power application the GPS receiver turns on and begins searching for GPS satellites after launch. The GPS may not be able to track the satellites until after launch due to wing shielding from the B-52. The GPS provides position and velocity inputs to the INE after the GPS begins tracking the satellites. The operator cannot monitor the status of the GPS receiver.

The missile uses a radar altimeter for terrain following inputs only. The CALCM does not use the ALCM terrain contour matching system. The air data element measures pitot pressure and static pressure, and provides this information to the INE.

Missile Flight Control System.

The flight control system consists of flight control system electronics, the rate and acceleration sensors, and two eleven servos to maintain controlled flight.

Missile Environmental Control System.

The missile environmental control system maintains temperatures within the missile and components. Prior to launch, cooling is provided for the inertial navigation element electronics by conditioned air from the aircraft.

Missile Propulsion and Fuel System.

An F107 WR 100 twin spool, turbofan engine is the propulsion source for the missile. After launch, a start cartridge starts the missile engine. The missile fuel system is a sealed three tank system using JP-10 as the missile fuel. The engine provides low pressure bleed air for the missile environmental control system and fuel tank pressurization.

Missile Arming System.

The warhead arming device provides the control and monitor interface for the missile warhead. The warhead arming device provides OAS monitor and control of the warhead prearm and safe circuits; however, the aircrew does not arm the arm/disarm switch; the INE accomplishes this function after launch. The warhead arming device processes missile generated warhead enabling, arming, and fuzing signals after launch. After the arm/disarm switch becomes armed, a time delay within the warhead interface unit (WIU) prevents the warhead fuzes from becoming enabled for 35 seconds. After this delay, the circuit is closed which will allow the fuze triggering signal to be sent from the WIU to the two warhead fuzes located on the underside of the conventional warhead. The AGM-86C uses two FMU-139 A/B fuzes.

An impact fuze provides both an alternate as well as backup fuzing to the air vehicle computer unit to control inertial fuzing. The impact fuze is located in the nose of the missile and consists of three sensors connected to the warhead device. Fuzing signal occurs when the missile contacts the ground. The fuze signal is generated in the warhead arming device and routed through the WIU to two warhead fuzes on the bottom side of the missile underneath the warhead.

AGM-86C Missile (CALCM C).

There are two versions of the AGM-86C missile, Block 0A and Block 1A missile.

The Block 0A missile has 2000 pound class warhead. The Block 1A missile has a 3000 pound class warhead. The AGM-86C have the GRIU/P GPS receiver and computer co-processor that supplements the computer in the INE. Additionally, the AGM-86C missiles are outfitted with a GPS Anti-jam system.

AGM-86D Missile (CALCM D).

The AGM-86D missile has a 1000 pound class penetrator warhead. The AGM-86D also has the GRIU/P GPS receiver and computer co-processor that supplements the computer in the INE. Additionally, the missiles are outfitted with a GPS Anti-jam system.

Command Guided Missiles

AGM-12 Bullpup

The Bullpup was developed in the 1950s by Martin Marietta, now Lockheed Martin, to a US Navy requirement. The missile first entered service in 1959 and there were five versions produced. The Bullpup A, designated AGM-12A and -12B, was built around a standard 250 lb bomb. This smaller missile was finally upgraded to the AGM-12E, and fitted with an anti-personnel fragmentation warhead. The Bullpup B, designated AGM-12C and -12D, was built around a 1,000 lb bomb, with some AGM-12D missiles having a nuclear warhead.

F-4M loaded with AGM-12C Bullpup missiles.

The smaller Bullpup A missile has four small delta control fins at the nose, with four clipped-tip delta-wings aft. The missile is 3.2 m long, has a body diameter of 305 mm and a wing span of 0.94 m. The missile weighs 258 kg. The larger Bullpup B missile has four small delta control fins at the nose, with four clipped and raked delta-wings aft. AGM-12C and -12D are 4.14 m long, have a body diameter of 450 mm and a wing span of 1.22 m. These missiles weigh 812 kg. Guidance for both Bullpup A and B types is by radio-command, with the operator centring his sight on the target and either manually tracking flares at the rear of the missile, or using an automatic IR tracker (AN/ASW 22). The missiles all have liquid-propellant motors. Several types of warhead were used by the five versions of Bullpup, but basically the missiles were built around standard 250 lb and 1,000 lb GP bombs. AGM-12D had an optional nuclear warhead, the 15 kT yield W 45, but this was taken out of service in the mid-1970s.

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Anti-Radiation Missiles

AGM-45 SHRIKE

The AGM-45 Shrike was the first dedicated air-to-surface ARM (Anti-Radiation Missile, sometimes also called Anti-Radar Missile) of the U.S. armed forces. It was used in very large numbers by the USAF and the U.S. Navy, until being replaced by the AGM-88.

Development of the Shrike began at the NWC (Naval Weapons Center) in 1958 under the designation ASM-N-10. The missile was intended to counter the threat of the then new Soviet S-75 surface-to-air missile system (known to the NATO as SA-2 Guideline) by homing on the emissions of the SA-2's "Fan Song" guidance radar. The ASM-N-10 was based on the airframe of the AAM-N-6/AIM-7C Sparrow III missile, but had a larger warhead, smaller rocket motor, and smaller tail fins. In June 1963, the ASM-N-10 was redesignated as AGM-45A, and large-scale production of the initial AGM-45A-1 model for the USAF and the U.S. Navy began at Texas Instruments and Sperry Rand/Univac. It entered service with the Navy in 1965.

AGM-45B fired from an F-4E.

The AGM-45A was used in combat by many different types of tactical aircraft in South East Asia, including the A-4, A-6, A-7, F-4, and F-105G. It was powered by a Rocketdyne MK 39 solid-fuel rocket motor (or Aerojet MK 53 MOD 1 in some missiles), and was controlled in flight by its forward cruciform wings. It could use three different blast-fragmentation warheads, the 67.5 kg (149 lb) MK 5 MOD 0 and MK 86 MOD 0, and the 66.6 kg (147 lb) WAU-8/B, and employed a dual-mode (proximity and impact) fuze. The **ATM-45A** was a training round with the motor and seeker of the AGM-45A, but with an inert warhead section.

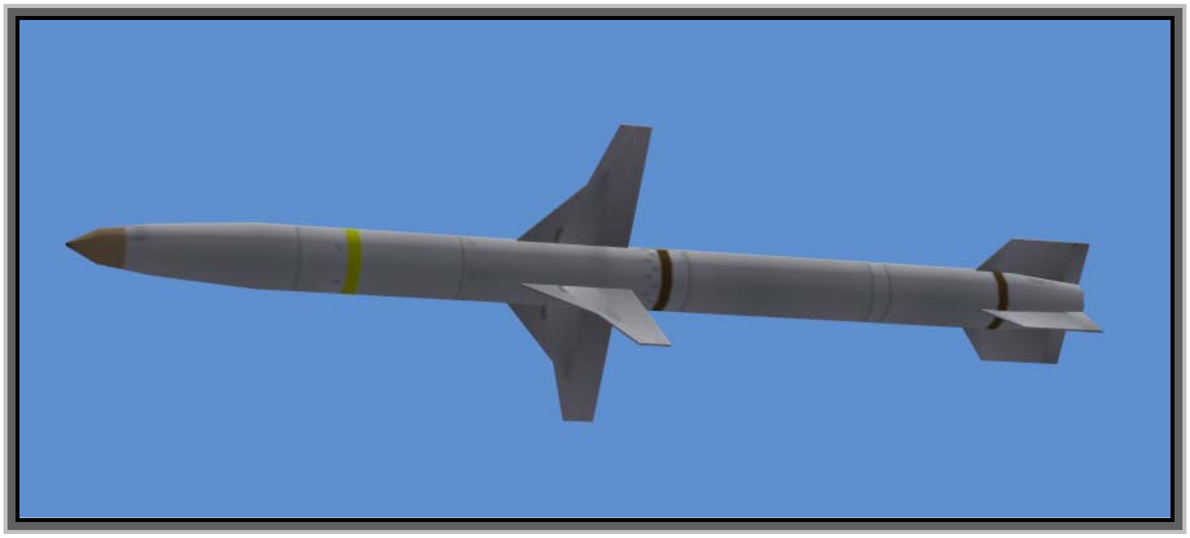
The original mode of operation was to send the *Shrike* on a lofted trajectory (for maximum range) towards a suspected SAM site. As soon as the missile had passed its peak altitude and started to come down, its seeker would detect the site's radar emission and home on it. Although it was used at least with some success in the Vietnam conflict, the AGM-45 had a number of serious operational drawbacks. Most importantly, the seeker was tuned to a fixed frequency range, so whenever the enemy deployed a new radar operating on a different frequency, a new seeker variant for *Shrike* had to be developed. The led to a long line of sub-variants of the AGM-45 (tabulated below), and of course meant that the mission planners had to know in advance which types of threat radars would be encountered. A second problem was that the seeker was not gimballed and had a fixed and rather limited field of view, so that the *Shrike* had to be aligned almost perfectly towards the radar emitter to detect it. The third limitation of the AGM-45 was its lack of any kind of on-board target memory. When the SAM site shut its radar down (because *Shrike*-equipped attackers approached), any missiles already fired would lose lock, and go ballistic. However, the *Shrike* could be considered semi-successful in that case, because without a radar, the SAMs wouldn't guide either.

The AGM-45A-2 had a seeker tuned to a different frequency band and introduced a white phosphorus target marker in the warhead to mark the impact point. The AGM-45A-3 (as well as all later variants) employed angle gating to prioritize the target. Field modification of the guidance unit enabled the *Shrike* to be used in line-of-sight attacks. The attack aircraft could dive straight towards the SAM site with an activated AGM-45, which would be fired automatically as soon as the seeker picked up a radar emission. The designation **AGM-45B** applied to *Shrike* missiles with modified warhead and motor, introduced in the early 1970s. The AGM-45B used an Aerojet MK 78 dual-thrust (boost/sustain) solid rocket, which significantly increased the maximum range (high-altitude lofted trajectory) from 16 km (10 miles) to 40 km (25 miles). The warhead was either a MK 5 MOD 1, MK 86 MOD 1, or WAU-9/B. The **ATM-45B** was the inert training variant of the AGM-45B.

The *Shrike* was also exported to several countries, and some used it operationally, including Isreal against Egyptian SA-2 *Guideline* and SA-3 *Goa* SAM sites. When production ended in 1982, about 18500 AGM-45 missiles of all variants had been built. In U.S. service, the AGM-45 was gradually replaced by the much more versatile (but also more expensive) AGM-88 *HARM* (High-Speed Anti-Radiation Missile), and the last *Shrikes* were withdrawn from U.S. inventory in 1992.

AGM-88 HIGH-SPEED ANTIRADIATION MISSILE (HARM)

The AGM-88 is a supersonic, air-to-ground missile. The missile body consists of four sections: the guidance section provides guidance and control digital information; the control section provides appropriate electrically driven wing torques, using commands from the guidance section; the warhead is a directed fragmentation warhead using the variable change-to-metal ratio concept; the rocket motor provides the thrust for the missile by the burning of reduced smoke propellant.



The guidance section contains an electronically erasable programmable read-only memory (EEPROM) board. This memory board gives the user the added capability of reprogramming the missile's mission in the field by reprogramming the guidance section's software. The missile is designed to be loaded and launched from an aircraft externally mounted LAU-118 launcher.

The AGM-88 HARM (high-speed anti-radiation missile) is a supersonic air-to-surface tactical missile designed to seek and destroy enemy radar-equipped air defense systems. The AGM-88 can detect, attack, and destroy a target with minimum aircrew input.

Guidance is provided through reception of signals emitted from a ground-based threat radar. It has the capability of discriminating a single target from a number of emitters in the environment. The proportional guidance system that homes in on enemy radar emissions has a fixed antenna and seeker head in the missile nose. A smokeless, solid-propellant, dual-thrust rocket motor propels the missile. The Navy and Marine Corps F/A-18 and EA-6B have the capability to employ the AGM-88. With the retirement of the F-4, the F-16C is the only aircraft in the current Air Force inventory to use the AGM-88. The B version has an improved guidance section which incorporates an improved tactical software and electronically reprogrammable memory.

The AGM-88 missile was approved for full production by the Defense Systems Acquisition Review Council in March 1983. The Air Force equipped the F-4G Wild Weasel with the AGM-88 to increase the F-4G's lethality in electronic combat. The missile worked with the APR-47 radar attack and warning system on the aircraft. The missile is operationally deployed throughout the Air Force and in full production as a joint US Air Force-US Navy project. HARM continues to prove its value against continuously emitting threat radar. Over 80 missiles were fired from USN/USMC aircraft both during and post Desert Fox.

The AGM-88A/B HARM is an evolution of anti-radiation missile weapon systems, SHRIKE and STANDARD ARM. HARM incorporates the more desirable features of each while providing additional capabilities that enhance operational effectiveness. Although generally similar in appearance and mission to the AGM-45 Shrike, produced more than 25 years prior to the AGM-88, the AGM-88 HARM is several feet longer than an AGM-45, has a slightly-enlarged diameter a foot back from the nose, and has a slightly greater diameter overall. The AGM-45 also has an RF window/slot on the side, not present on the AGM-88.

The system consists of the guided missile, LAU-118(V)1/A launcher, launch aircraft, and HARM peculiar avionics. The weapon system has the capability of detecting, acquiring, displaying, and selecting a radiating threat and launching a missile or missiles. The HARM Missile receives target parameters from the launch aircraft prior to launch. The HARM Missile uses these parameters and relevant attitude data to process incoming RF energy to acquire and guide the HARM Missile to the desired target. The HARM missile has a terminal homing capability that provides a launch and leave capability for the launch aircraft. Additional unique features include the high speed, low smoke, rocket motor and seeker sensitivity that enable the missile to easily attack sidelobes and backlobes of an emitter.

Components

Guidance Section.

Several modifications have been made to the HARM Guidance section through hardware modifications and software upgrades.

The AGM-88A was the first version of the missile to be produced. It incorporated a fuzable-link memory that required the guidance section to be returned to the manufacturer to change the Tactical software. The AGM-88B missile was developed in the mid 1980s and incorporated an electronically reprogrammable memory that allowed changing the missile software in the field. The AGM-88C missile is the latest version and incorporates several new design features and is also reprogrammable in the field.

Block I software was the original Tactical software used with the AGM-88A missile. Block II software provided guidance and fuzing improvements and was used in both

AGM-88A missiles and AGM-88B missiles. In 1990 Block III software was installed in AGM-88B missiles to counter the capabilities of the advanced threats. All AGM-88C missiles contained Block IV software which is currently the latest version.

AGM-88 HARM fired from an F-16C.

Warhead Section.

The warhead section is designed to inflict sufficient damage on the target antenna and waveguide system to force an inoperative condition. It also ensures complete destruction of the HARM Missile guidance section.. The AGM-88A, and AGM-88B warhead section contains 25,000 pre-formed steel fragments, an explosive charge, a fuze, and a fuze booster. The AGM-88C utilizes an improved warhead section containing 12,845 tungsten fragments and an improved explosive charge which provides greater overall lethality. Control Section. The control section of the HARM Missile is located aft of the warhead section. The control section contains wing actuators to steer the missile on a desired trajectory, missile captive and free flight electrical power supply equipment, attitude reference equipment, and the missile target detection device. An umbilical connector mounted on top of the control section provides electrical interface between the launch aircraft and the missile.

Rocket Motor Section.

Thrust for the HARM Missile is developed by a dual thrust rocket motor utilizing a low smoke propellant. The section contains a manually operated safety-arming device, igniter, propellant grain, and a fixed nozzle. External components on the rocket motor section consist of fittings for the fins, launch lugs, and a detent rib.

Wings.

The wings direct the course of the HARM Missile in flight by internally controlled actuators within the control section. Four wings are required per missile.

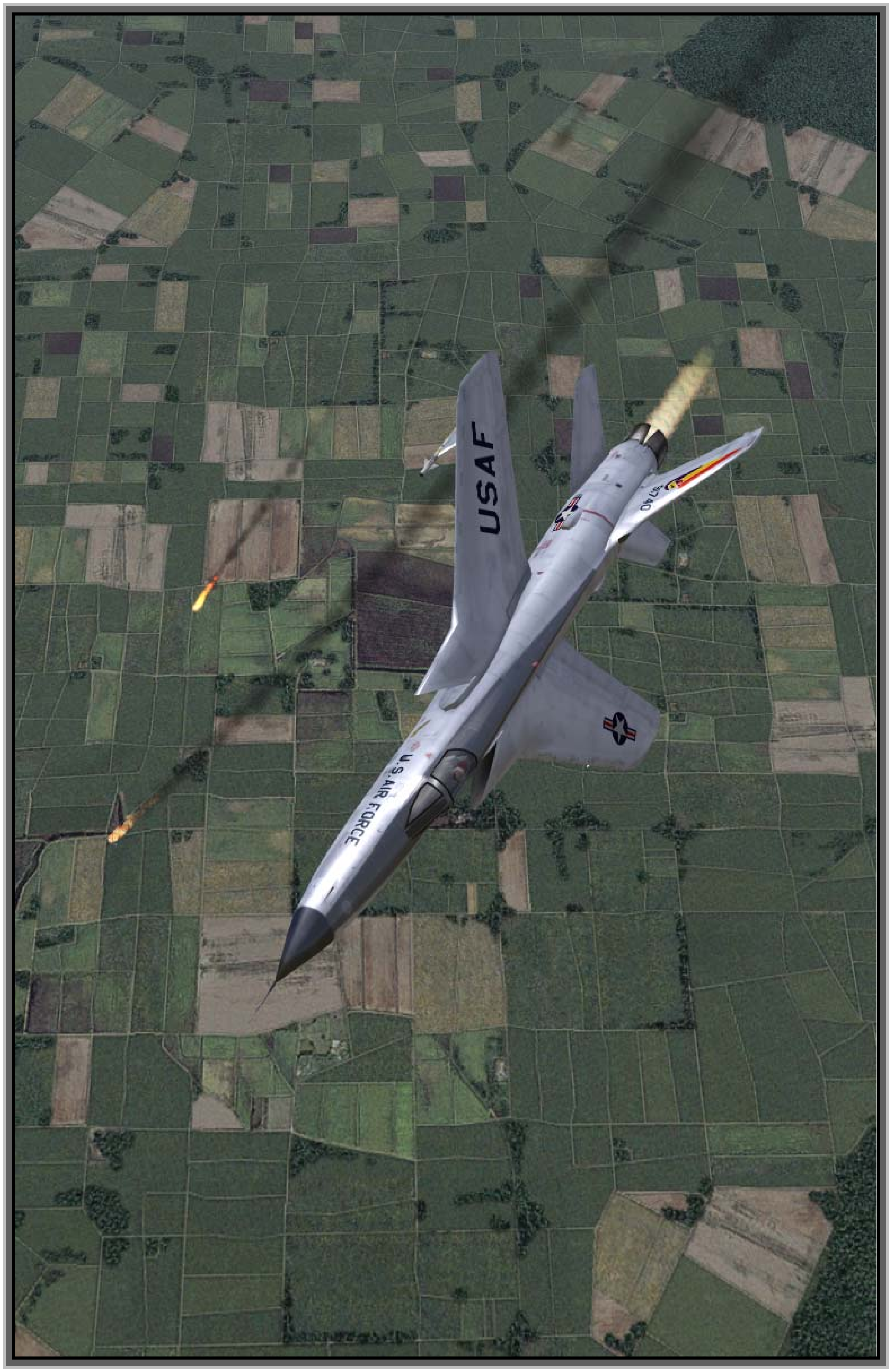
Fins.

The BSU-60/B and BSU-60A/B fins are identical type fins except for a redesigned locking mechanism. They are interchangeable as sets. The fins provide aerodynamic stability of the HARM Missile during flight.

Section 3

Air to Air Missiles

Semi-Active Radar Guided Missiles
Active Radar Guided Missiles
IR Guided (Hear Seeking) Missiles


USAF
U.S. AIR FORCE

Semi-Active Radar Guided Missiles

AIM-7 SPARROW MISSILE

DESCRIPTION.

The AIM-7 is a supersonic, air-to-air guided missile. The missile can intercept and destroy targets in adverse weather conditions. The AIM-7 is a semiactive missile which is guided on either continuous wave (CW) or pulse doppler (PD) radio frequency (RF) energy radiated by the launching aircraft and reflected by the target. The missile is guided, controlled, and detonated by the target seeker and flight control sections. The warhead is of blast fragment design which expands upon detonation of its explosive charge to produce target destruction. The solid propellant rocket motor provides the thrust (boostsustain).

AIR FRAME.

Four major sections comprise the AIM-7 Sparrow missile: the guidance section (radome and target seeker); the control section (autopilot and wings); the warhead; and the rocket motor. The sections of the missile are coupled together and locked into position by screws. Four delta-shaped wings are plugged into the wing hub sockets. Four tail fins are attached to the rocket dovetail pad. A wiring harness provides the electrical connection between the target seeker and control section, and a waveguide provides an RF connection from the rear antenna to the target seeker. The missile is attached to the launcher by a set of hooks on the rocket motor and one lug on the flight control section. An umbilical cable and a rocket motor fire connector provide an electrical interface between missile and launcher. A safe and arming device on the rocket motor permits manual arming of the motor after installation.

GUIDANCE SECTION.

The radome forms the nosepiece of the missile and covers the seeker head assembly. It forms an important part of the external contour of the missile and is a vital link in the electromagnetic path of RF energy reflected from the target to the missile front antenna. The AIM-7 has an ogive shape which provides optimum balance between aerodynamic drag and electromagnetic requirements. The ogive shape is flared into a cylindrical aft section, allowing for antenna size and minimizing RF interference at antenna gimbal limit angles.

The AIM-7M Sparrow target seeker receives and compares the radar energy acquired directly from the target illuminator on the launch aircraft and radar energy reflected by the target. The guidance system uses range rate, LOS and LOS rate information to produce guidance signals for the autopilot. The target seeker consists of electronic modules packaged around the hydraulic system for the missile antenna gimbals. The antenna gimbal system provides antenna pitch and yaw motion about the missile body axis.

CONTROL SECTION.

The control section consists of the autopilot and the hydraulic control group. The functions of the control section are to process angular error information and provide wing control signals to guide the missile and to stabilize the missile in pitch, yaw and roll. The launching aircraft supplies the control section with attitude control voltages (English bias), which provide the missile with course correction commands used prior to target acquisition. The launching aircraft supplies a roll command signal which aids the missile in establishing a normal postlaunch flight attitude (umbilical up).

The wing hub assembly consists of the steel midsection shell and the internal hub block. The hub block acts as a structural stiffener and functions as a foundation and support for the components required for wing operation. The assembly mounts contain the hydraulic accumulator, the valve manifold, wing servo valves, wing locks, four sets of double linear actuators and wing socket assemblies. All four wings are actuated in pitch and yaw, while two of the wings also control roll rate. A maximum of ±22 degrees of rotary motion is available in each wing. Before activation, wing motion is restrained by spring-loaded locks to ±0.25 degree deflection. The hydraulic control group reacts to the signals from the autopilot to control the flightpath of the missile. The accumulator supplies the hydraulic power necessary to move the wings as required by the flight command signals from the autopilot.

WARHEAD SECTION.

The AIM-7 has a blast fragmentation warhead designed to be more effective against very small targets. The blast fragmentation warhead produces a spherical pattern rather than a ring.

The safe and arm device is mounted at the forward end of the central axis of the warhead. The basic function of the safe and arm device is to maintain the warhead in an unarmed condition until the missile has intentionally been launched and has traveled a safe distance from the launching aircraft. After the missile reaches a safe distance, the safe and arm device arms the warhead so that upon receipt of a firing pulse from the guidance section, the warhead will be detonated.

ROCKET MOTOR SECTION.

The AIM-7M rocket motors are solid propellant motors providing thrust (boost-sustain) for the missile. The motor is attached to the aft end of the control section and consists of three major subassemblies: a case propellant grain, a safe and arm igniter assembly, and a nozzle weather seal assembly. The motor case consists of a cylindrical tube section with an integral forward dome and an aft boattail section. The boattail incorporates four fin support brackets (dovetails) and an antenna mount.

The safe and arm igniter assembly is a manually operated mechanism that can be locked in either the safe or armed position. The initiator gases are contained within the free volume of the device when the safe and arm igniter assembly is in the safe position. The safe and arm igniter assembly is attached to the rocket motor case and requires a separate arming tool to actuate the mechanism. A red streamer is attached to the handle of the arming tool to visually indicate that the igniter is in the safe position. The arming tool is removed after the igniter is armed. The igniter contains a main charge and a booster charge. When the rocket motor ignition is commanded, the gases exhaust through the perforated aft end of the case. The booster charge is ignited with redundant single-bridgewires by electric heating.

The rear antenna is a structural waveguide used to receive the RF energy emitted by the launching aircraft and conduct it to the target seeker. The rear antenna waveguide is constructed in two sections.

MISSILE OPERATION.

The AIM-7 homes on radar energy reflected from the target. Therefore, the target must be illuminated throughout the missiles time of flight (TOF). The AIM-7 is compatible with pulse doppler (PD) or continuous wave (CW) illumination. The AIM-7 determines target velocity information by comparing the frequency of a reference signal from the illumination (received by the missile rear antenna) to the doppler-shifted radar return from the target (received by the front antenna). In the primary air-to-air mode, the missile determines the proper target by its unique doppler shift prior to launch.

If two targets with similar doppler shifts are present in the AIM-7's (or any doppler tracking missile) front antenna beam width, the missile has a good chance of tracking the return with the larger signal strength. This fact can be a problem if the target doppler is the same as the doppler of the ground return. This is a missile problem and is true regardless of the type of illumination used.

The missile determines range information by computing the change in range from the closing velocity and time, then applying that change to the known range at launch. Range information is important because the missile inhibits fuzing until inside a certain range to help avoid early fuzing.

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Active Radar Guided Missiles

AIM-120 SERIES AMRAAM MISSILE

The AIM-120 Series missile is an all weather, beyond-visual-range, radar guided air-to-air missile with launch and leave capability. The missile permits launch and maneuver by launching aircraft at ranges in excess of the AIM-7. It has rail and/or ejection launch capability. The missile guidance section system incorporates four guidance modes: (a) an active radar with home-on jam during any phase of flight; (b) command update at long range plus active terminal; (c) inertial plus active terminal if command update is not available; and (d) active terminal with no reliance on aircraft fire control systems at ranges within seeker acquisition range. It is propelled by a solid fuel, reduced smoke rocket motor.
The AIM-120A missile is not reprogrammable and requires a hardware change to upgrade the software. The software version is identified by an alpha charter on the guidance section. Lots 1-3 missiles do not have TIVS harness covers and are used by the AF only. The AIM-120B missiles are reprogrammable through the missile umbilical. The AIM-120C missiles are reprogrammable and have a compressed carriage configuration. These missile designs are upgraded using the block upgrade concept. Missile configurations are identified as AIM-120C, C-4 (incorporates new warhead), C-5 (incorporates plus 5 rocket motor and shortened control section), and C-6 (incorporated QTTD).

The AMRAAM missile consists of the following items: guidance section, armament section, propulsion section, control section or shortened control section (SCAS) on C-5 and C-6 missiles, wings, fins, buffer connector, wiring harness, harness cover, boattail, rectifier filter, and data link receiver. The wings, fins and buffer connector are detachable items which are not installed until preparation for attachment to aircraft. The harness cover on later versions contains a Thermally Initiated Venting System (TIVS) which is a device designed to be activated in a fire to weaken the rocket motor case and vent the rocket motor if ignited.

GUIDANCE SECTION.

The guidance section includes the hardware and software necessary to perform the functions of acquisition and track, navigation, data link processing, and section secondary power. The guidance section contains: seeker/servo electronics, transmitter/electrical conversion unit (ECU), electronics unit, inertial reference unit (IRU), and Quad/ target detection device (Q/TDD). The TDD antennas are mounted in the aft portion of the guidance section and are covered with a glass wrap. Alpha codes located after section part numbers define software of section for AIM-120A missiles. AIM-120B, C guidance sections are reprogrammable and do not have alpha codes.

SEEKER/SERVO ELECTRONICS.

The seeker/servo electronics subassembly contains: main antenna, guard band antenna, RF processor, inner and outer gimbals, azimuth and elevation rate gyros, azimuth and elevation torque motors, and servo electronics. The seeker/servo electronics subassembly processes RF information.

TRANSMITTER/ELECTRICAL CONVERSION UNIT (ECU).

The transmitter/ECU consists of the transmitter, ECU, and two thermal batteries to provide primary power.

CF-188 loaded with AIM-120s and AIM-9s.

ELECTRONICS UNIT (EU).

The EU processes information for guidance to target and processes target information. The EU consists of a housing interconnect assembly containing eight electronic chassis. The eight chassis vary depending upon guidance section configuration but generally include the following assemblies: remote terminal (RT), program memory (PM), launch sequencer (LS), input/output (I/O), AMRAAM data processor (ADP), filter processor (FP), range correlator/IF receiver (RC /IFR), and frequency reference unit (FRU). For AIM-120B and AIM-120C missiles, the guidance sections (WGU-41/B and WGU-44/B, respectively) replaced the PM chassis with a desiccant canister to further reduce the amount of moisture in the guidance section. The PM function was relocated on another chassis for these guidance sections. In addition, certain GS configurations replaced the FP, I/O, and ADP chassis with a corresponding three card FIA (FP-I/O-ADP) set of chassis (the FIA itself and two ballast chassis).

INERTIAL REFERENCE UNIT (IRU).

The IRU provides a reference for the navigation of the missile. It measures acceleration in three physical axes along with three-axis angular rates. It is the source of all navigational guidance input. There are three printed wiring boards (PWB) and a sensor cluster. Each PWB is mounted in its own frame with its own connector. The sensors are mounted on a cluster block which is an integral part of the housing.

TARGET DETECTION DEVICE (TDD).

The TDD is used to sense the approach of the target during the final moments of missile flight. It consists of four antenna subassemblies contained within the skin of the guidance section, an RF processing assembly (RF head), and three digital circuit cards (video processor). The QTDD is an AIM-120C-6 enhancement to the TDD function.

ARMAMENT SECTION.

The armament section consists of the warhead, booster and safety, arming and fuzing device (SAF). The warhead is initiated by the output of a SAF device containing parallel (redundant) detonators and explosive leads. This output initiates the booster. Functioning of the booster initiates the primary warhead explosive load which in turn propels steel fragments, (square fragments WDU-33/B and diamond shaped fragments WDU-41/B) outward at a high velocity.

WARHEAD.

The warhead contains the primary explosive load. The primary kill mechanisms of the warhead are fragments. The warhead is coated with an epoxy coating beneath missile top coat of paint. The epoxy coating acts as a thermal barrier during flight.

The SAF is located directly behind and attached to the missile warhead. In the safe position, each of the rotor leads (one in each of five rotors) are locked mechanically out of line with the stationary detonators (and the leads) by approximately 72 degrees. The detonator bridge wires are electrically open on both the positive and return sides. To arm the SAF three functions must occur: a setback weight must be unlocked; a minimum acceleration level must be met; and a minimum elapsed time is required to allow the rotor leads to align.

The booster is part of the detonation chain. When initiated by the SAF it initiates warhead detonation.

PROPULSION SECTION.

The propulsion section consists of an airframe structure with an integral rocket motor, blast tube, exit cone and Arm/Fire device (AFD) for rocket motor ignition. Wing sockets and wing restraints are located on them propulsion section for wing installation. A visual indicator (light tube) is provided for safe/arm status of the AFD. The propulsion section is located between the armament and control sections. The WPU-6/B is used on AIM-120A, AIM-120B, AIM-120C and AIM-120C-4. The WPU-16B rocket motor used on C-

5 and C-6 missiles and has an additional 5 inches of propellant and a 5 inch shorter blast tube.

Arn/Fire Device (AFD).

The AFD is an electromechanical device that provides ground and captive flight protection against accidental rocket motor ignition. Arming the AFD occurs as part of the launch cycle. The source of the AFD enable signal is missile battery power switched on by the launch sequencer which is controlled by the data processor. Removal of power from the AFD rotary solenoid returns the AFD to the safe position.

CONTROL SECTION.

The control section consists of four independently controlled electromechanical servo actuators, four aluminum-lithium batteries (WCU-11/B, WCU-23/B) (two batteries WCU-28/B) and fuselage structure which is part of the airframe. Each actuator consists of a brushless DC integral 4 pole motor and infinite resolution potentiometer directly coupled to the output shaft. A gas generator is also contained in the section which is squib activated to provide pressure to unlock the fin output shafts. Electronics are also provided for motor control and attachment points for fin installation are provided. The control section is the aft section behind the propulsion section a skirt attached to end of the section and is referred to as the boattail. A data link receiver is also attached to the aft end of the control section for reception of target update information.

The control electronics receives three signals (pitch, yaw, and roll) from the guidance section. It converts these signals into four control signals for driving the servoactuators. It also controls the amount of current delivered to the servoactuators.

The actuator batteries provide control section primary power and consist of four identical cylindrical thermal batteries (WCU-11/B, WCU-23/B) (two batteries WCU-28/B). Each battery provides a nominal -135 V output at an average 1-ampere load.

CATM-120.

The CATM-120 is a Captive Air Training Missile and is also used as a load trainer. The training missiles are inert missiles that duplicate weight, center of gravity, and external characteristics of the missile.

The CATM is externally identical to the tactical missile except for markings. The similarity includes AFD indicator, detachable wings and fins, and a tactical missile umbilical. The CATM contains no electronics or internal electrical connections to the umbilical connector. A bridge wire is installed on the umbilical connector to return a Missile Present signal to the aircraft. The CATM has dummy warhead, propulsion, and control sections. The CATM-120B is similar to the CATM-120A except for the "blunt" nose radome which is two inches shorter. The CATM-120C, which has "clipped" wings and fins, simulates an AIM- 120C missile.

IR Guided (Heat Seeking) Missiles

AIM-9 SIDEWINDER MISSILE

The AIM-9M Sidewinder missile is a supersonic air-to-air intercept missile. It is a passive missile that guides on infrared (IR) radiation generated by a target. Because no guidance is required after launch, the pilot may take evasive action immediately after the missile is launched. The AIM-9 missile consists of four external sections: GCS, warhead, fuze, and missile body (rocket motor). The AIM-9 missile interfaces with the aircraft through the umbilical cable. The missile has three basic phases of operation; captive flight, launch, and free flight. Power is supplied from the launcher during captive flight. The power is switched to the missile contained thermal batteries during the launch phase and during free flight.

GUIDANCE AND CONTROL SECTION.

The AIM-9M seeker receives IR energy emitted by a heat source and converts this energy into an electrical signal which is used to navigate the missile. The IR detector is cooled to improve its sensitivity to IR energy. This cooling is with cryogenic gas in AIM-9M missiles. An electrical signal is generated and sent to the GCS so that proper guidance to the target can be maintained. The GCS provides commands to keep the seeker looking at the target and to steer the missile via the canards. Canard movement is accomplished by connected servo-pistons which move up and down within their respective cylinders. The AIM-9 flies a proportional navigation course to the target.

The GCS consists of three major assemblies; an IR seeker assembly for detecting the target, an electronic assembly for converting the detected target information to tracking and guidance command signals, and a hot gas servo assembly (consisting of a gas generator, manifold, pistons, rocker arms, electrical solenoids, and a thermal battery) where electrical guidance commands are converted to mechanical movement of the control fins.

The GCS also contains an inertia switch and capacitor; if the missile strikes the target, the inertia switch actuates and discharges the capacitor which feeds a firing pulse to the Safing and Arming (S-A) device to initiate warhead detonation. The umbilical cable is part of the GCS but is sheared off at missile launch.

AIM-9B fired from an F-100D Super Sabre.

COOLANT TANK.

The coolant pressure tank, TMU-72/B or TMU-72A/B provides high pressure argon/nitrogen gas to the GCS Refrigerated Detector Unit (RDU) for cooling as long as the missile is attached to the aircraft. Once the missile leaves the aircraft, power is lost to the coolant valve and the tank is no longer used. A small reservoir in the GCS supplies coolant for approximately one minute while the missile is in flight. This is ample time for the missile to reach the target. Either argon or nitrogen may be used as coolant. The coolant pressure tank is capable of storing 4.92 cu. ft. (0.4 pounds) of argon gas (or nitrogen) at a maximum pressure of 5,000 pounds per square inch. A fully charged coolant tank will provide approximately 9.0 hours of continuous cooling when filled with argon gas and approximately 5.5 hours of continuous cooling when filled with nitrogen gas. Sustained cooling rates of both argon and nitrogen are less per hour than initial cool down rates. Coolant usage varies due to temperature, flight time and type of sortie. The cumulative effect of greater demand for argon during initial cool down and the number of cool down cycles have a large impact on bottle duration.

SAFETY-ARMING DEVICE.

The Safety-Arming (S-A) Device Mk 13 Mod 2 is an electro-mechanical device that causes initiation of the warhead. The S-A device is 7.1 inches long, 1.5 inches in diameter and weighs 1.4 pounds. It contains 0.0039 pounds of high explosive (CH-6). At launch, the S-A device launch-latch is electrically unlocked. Missile acceleration of at least 6g causes a setback weight to move into the enabled position. Continued acceleration causes eccentrically weighted rotors to rotate. When the rotors have traveled through their full movement, the explosive train is complete. On target intercept, an electrical signal from the TD initiates the S-A device explosive train; warhead booster ignition and warhead detonation follows.

WARHEAD.

The warhead WDU-17/B is an Annular Blast Fragmentation (ABF) warhead consisting of a case assembly, two booster plates, transfer tube assembly, high explosive, and fragmentation rods. The warhead weighs 20.8 pounds total including 7.9 pounds of PBXN-3 explosive, is 13.5 inches long, and 5.0 inches in diameter. The S-A device explosive output is transferred through the transfer tube assembly to the booster plates. The initiation is then transferred through the explosive-loaded channels of the booster plates to the booster pellets at each end of the warhead. Detonation of the booster pellets sets off the high explosive (PBXN-3) causing warhead detonation.

ROCKET MOTOR.

The rocket motor is a solid propellant, high thrust motor that comprises the aft end of the missile. The propellant is cast into the tube and case bonded to the tube wall. The propellant igniter train consists of a main charge, booster charge, and a Mk 5 squib. The igniter is held in place by a nonpropulsive head closure that blows out upon accidental ignition, making the rocket motor nonpropulsive if the warhead is not attached.

. The rocket motor features a nonremovable safe-arm selector handle that is used to mechanically ARM or SAFE the rocket motor on the ground.

The rocket motors are 70 inches long, weigh 99 pounds (without wings) 123 pounds (with wings), and have a propellant weight of 60 pounds. The rocket motor electrically and mechanically interfaces with the launcher. The mechanical interface is by means of a forward, center, and aft hanger. When the missile is loaded on the launcher, two striker points within the launcher are in contact with the two contact buttons on the forward hanger. When the firing circuit is activated, the firing voltage is sent through the aft contact button and fires the initiator on the S-A assembly. The initiator ignites the rocket motor propellant grain, thrust is developed, and the missile is launched.

WINGS.

Four identical wings, Mk 1 Mod 1/2 provide aerodynamic lift and stability during flight. The wings are attached to wing ribs located at the aft end of the rocket motor. The wings weigh 24 pounds (4 wings) and have a span of 25.2 inches (with rolleron caged). Each wing has a rolleron assembly that provides pitch, yaw, and roll stabilization during free flight.

The wing rolleron wheel is designed so the passing airstream causes it to spin at a very high speed, thus acting as a gyroscope to help stabilize the missile during flight. The entire rolleron assembly is held in line with the longitudinal axis of the missile during captive flight by a caging device. When the missile is fired, the rolleron is uncaged by acceleration and is free to move about the longitudinal axis throughout flight. An oil-filled damper at the forward end of the rolleron assembly is provided to smooth rolleron operation and prevent flutter.

FINS.

Four identical fins, BSU-32/B, located on the GCS, provide a lift force on the airframe proportional to the input signal from the seeker, missile velocity, and altitude. The fins are electrically controlled and pneumatically operated by a servo system located in the aft part of the GCS.

Section 4

Special Equipment

Targeting Pods
ECM Pods

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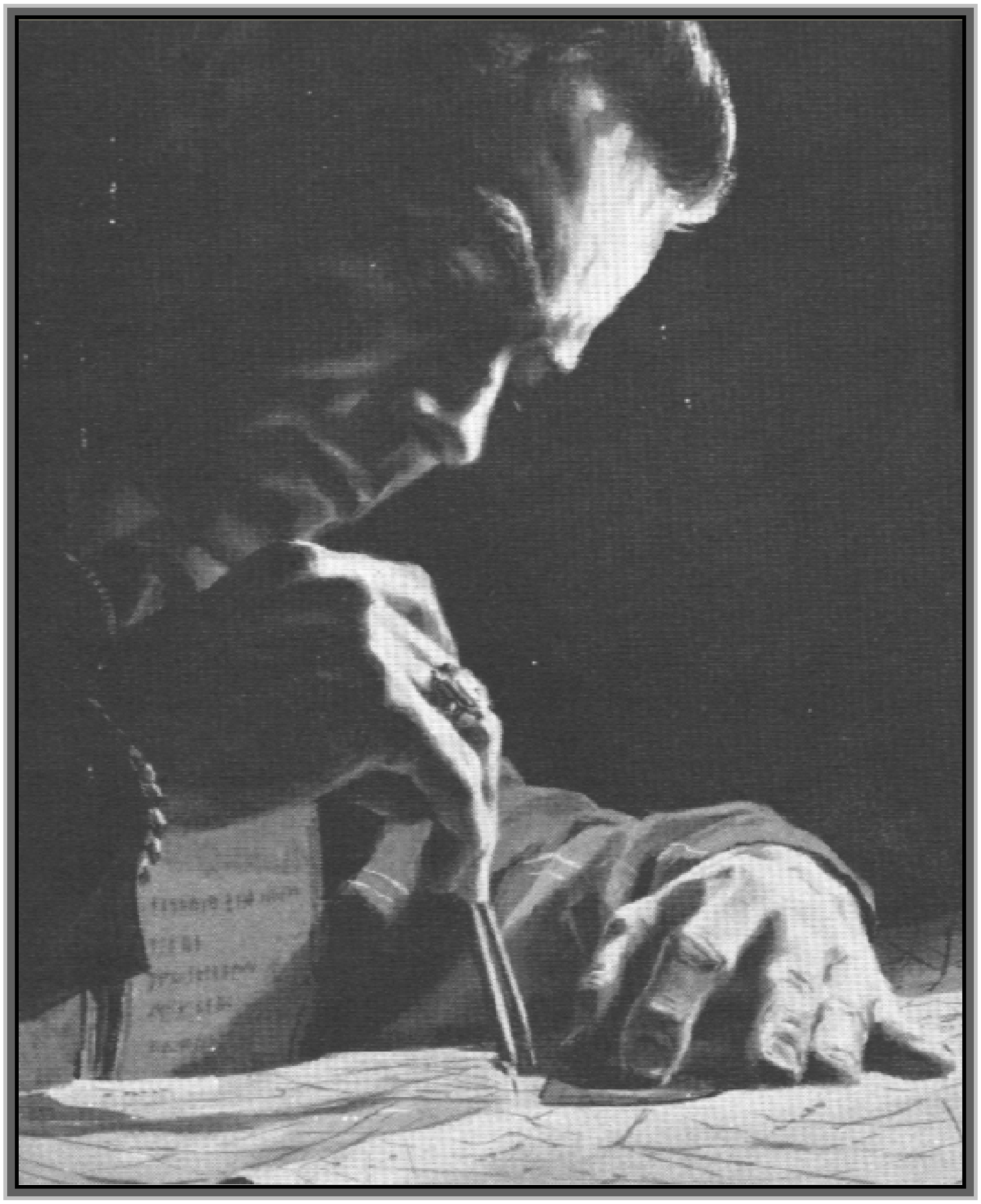
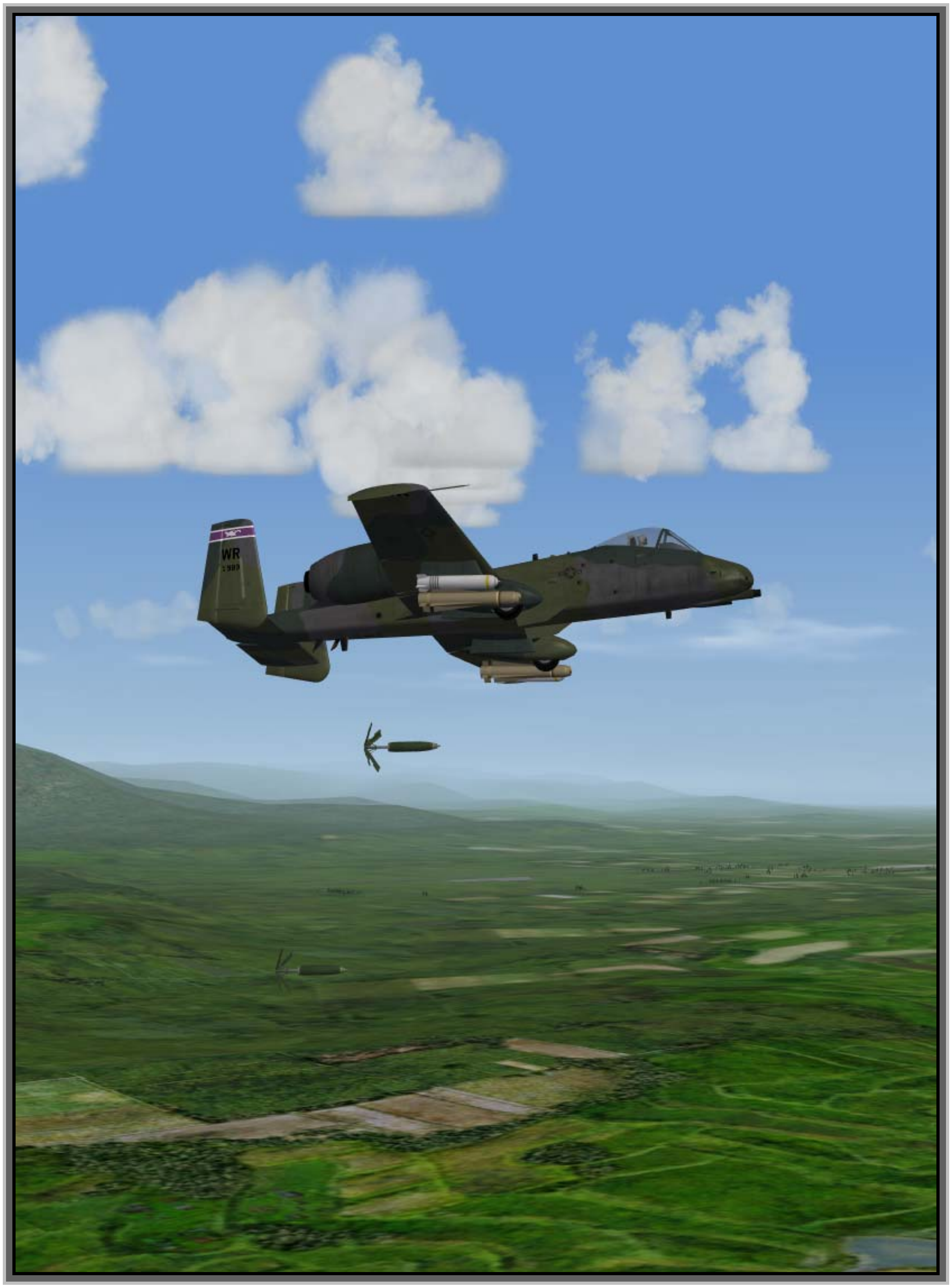
Section 5

Mission Planning

Pre-Mission Planning
Planning Your Attack The Scientific Way
Safe Separation/Safe Escape

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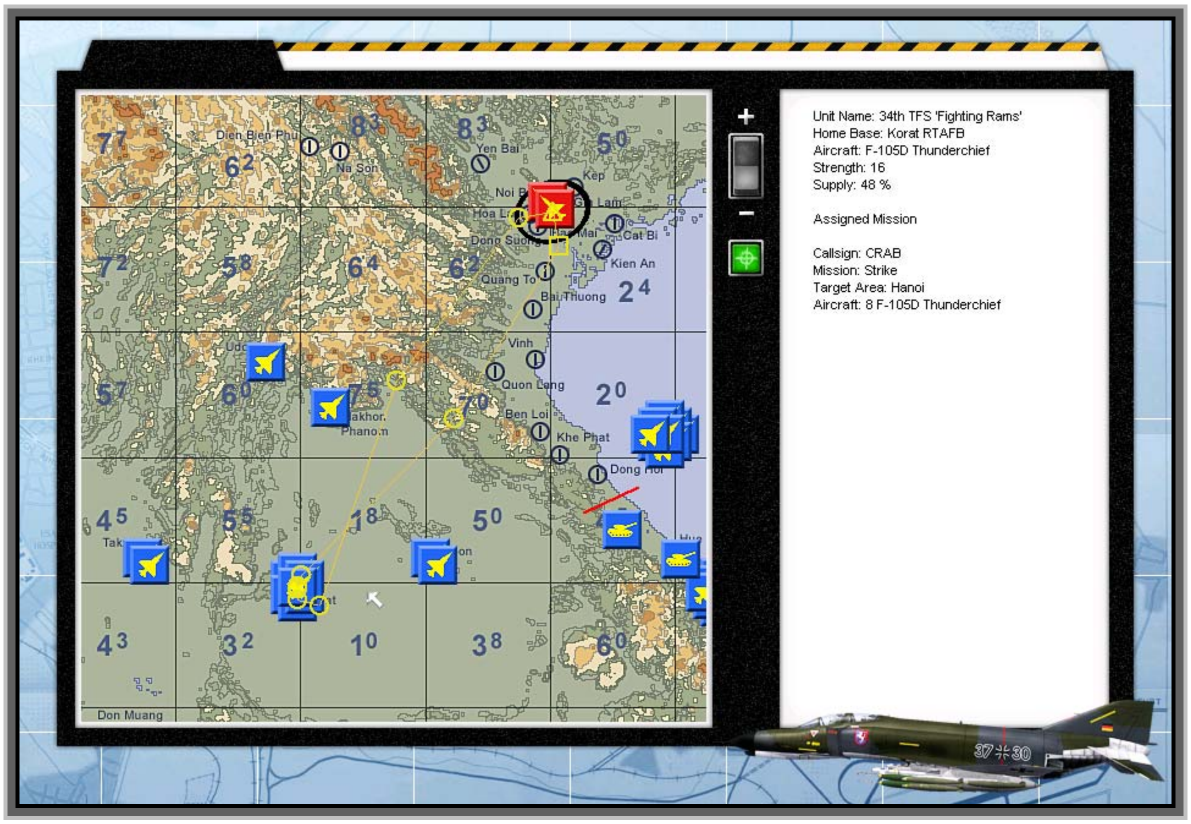
Pre-Mission Planning

Before starting the mission you should have a plan in place for how you are going to get there, what you are going to do when you get there, and how you are going to get back. Several tools are at your disposal for use when developing a plan. I will walk you through planning of a strike mission on the Vietnam terrain as an example of some things that can be done.

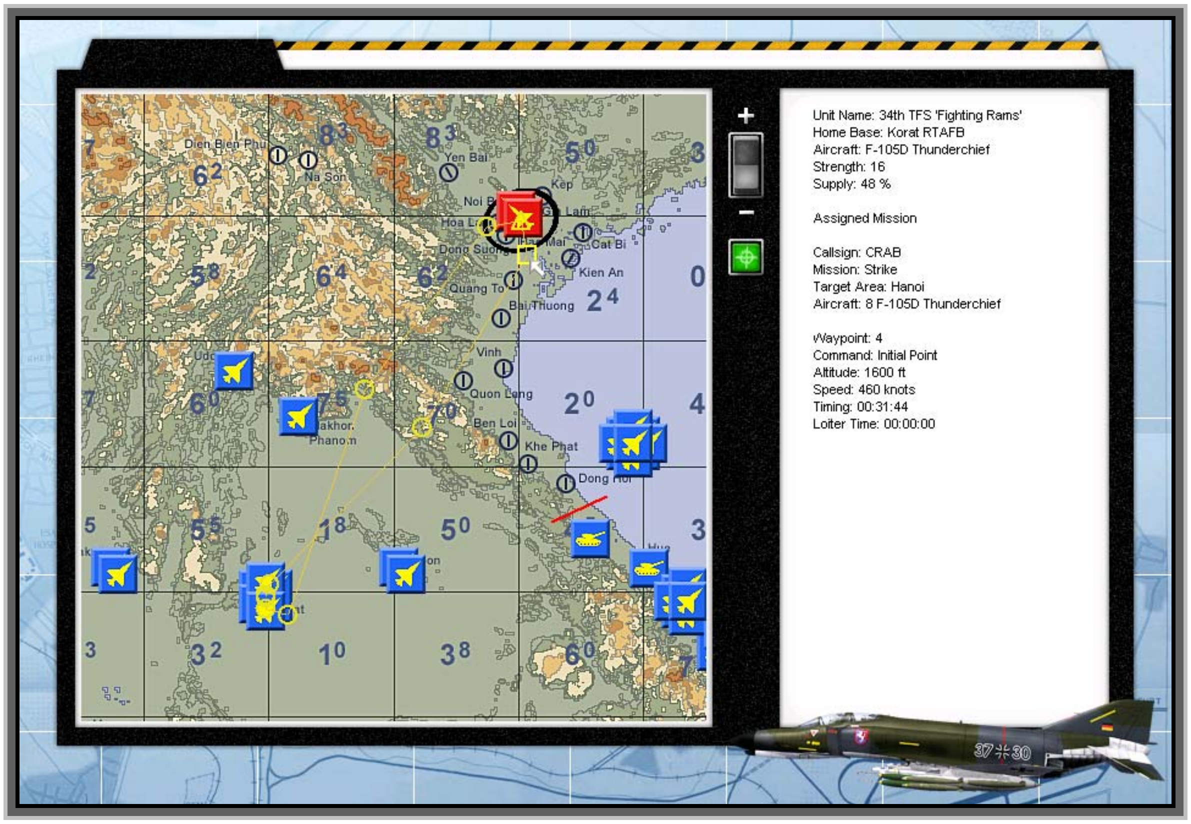
The most valuable tool at your disposal is the planning map. Here, you can see that you are Crab flight, 8 F-105D flying out of Korat RTAFB. Your mission is a Strike in the Hanoi area.



Enemy aircraft expected to be in the area are in red and friendly aircraft are in blue.

The route selected for your flight is shown in yellow. The altitude, airspeed, and time into the mission you pass each waypoint is displayed when the cursor is placed over the waypoint.

Here, you can see the cursor placed over waypoint 4. You are scheduled to arrive there at 1,600 feet, 460 KCAS, and 31 minutes, 44 seconds after take-off.



Waypoints can be moved by clicking and dragging the waypoint on the map. The waypoint can be placed at any point on the map with the resulting change in timing displayed to the right. Waypoints that are time and location dependant such as the takeoff point, marshal point, and target can not be moved.

Moving the waypoints can be very beneficial because the initial placement of points on the map does not take into account what you will be overflying or from what direction it is best to approach the target from.

In general, you want to pick a route that will avoid overflying enemy airfields or anywhere with air defenses in place.

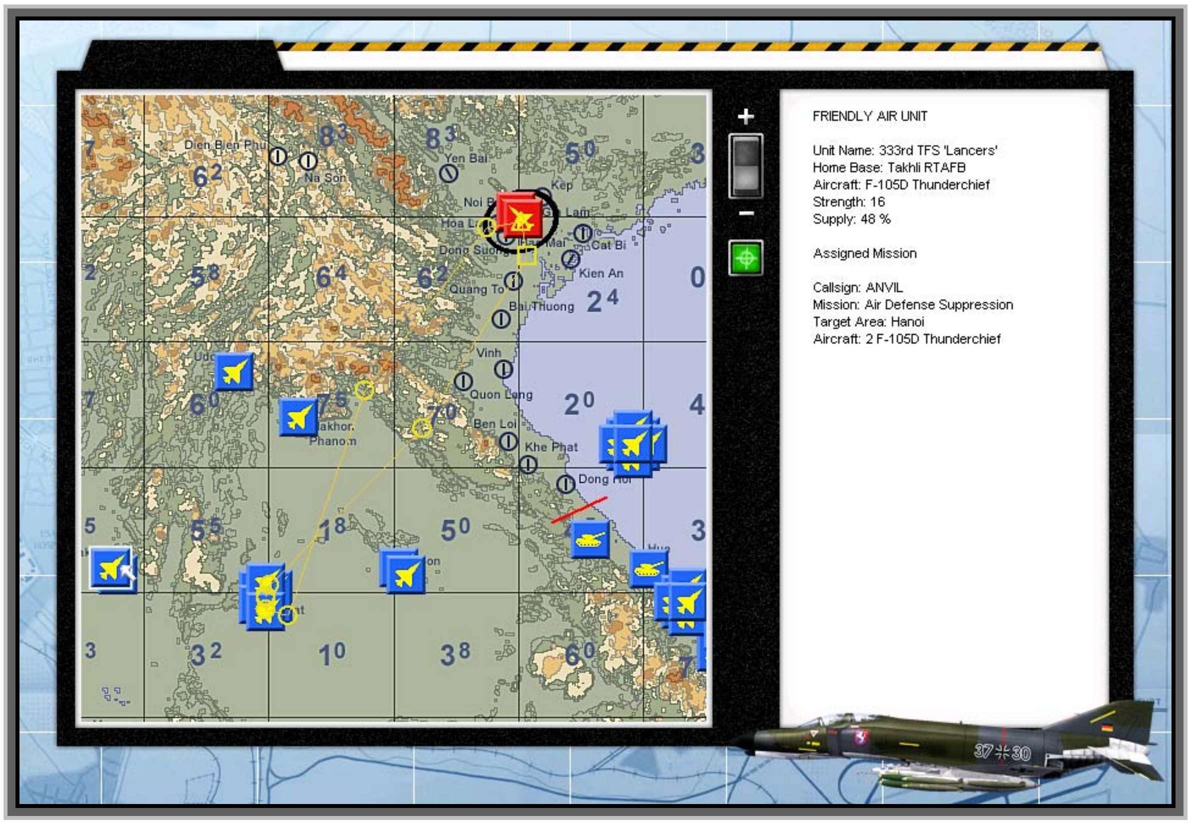
Your strike package.

Not all friendly aircraft shown on the planning map will be assigned to your strike package.

Most strike packages consist of four flights. There is your flight, an Air Defense Suppression escort, an Air to Air escort, and a Recon flight.

There is no sure fire way to tell which aircraft are assigned to your package yet but you can get a good idea by highlighting friendly aircraft icons and looking for aircraft with the same target area.

Here, you can see that Anvil flight is assigned an Air Defense Suppression mission in the Hanoi area. This means that Anvil flight will likely be one of the flights in your package.



Make a note of their callsigns once you identify the flights. This will be hard to figure out once the mission starts.

Your escorts will fly the same basic route as your flight. If you arrive at waypoint 3, the Marshall Point, on time your escorts will be very close to you at that point.

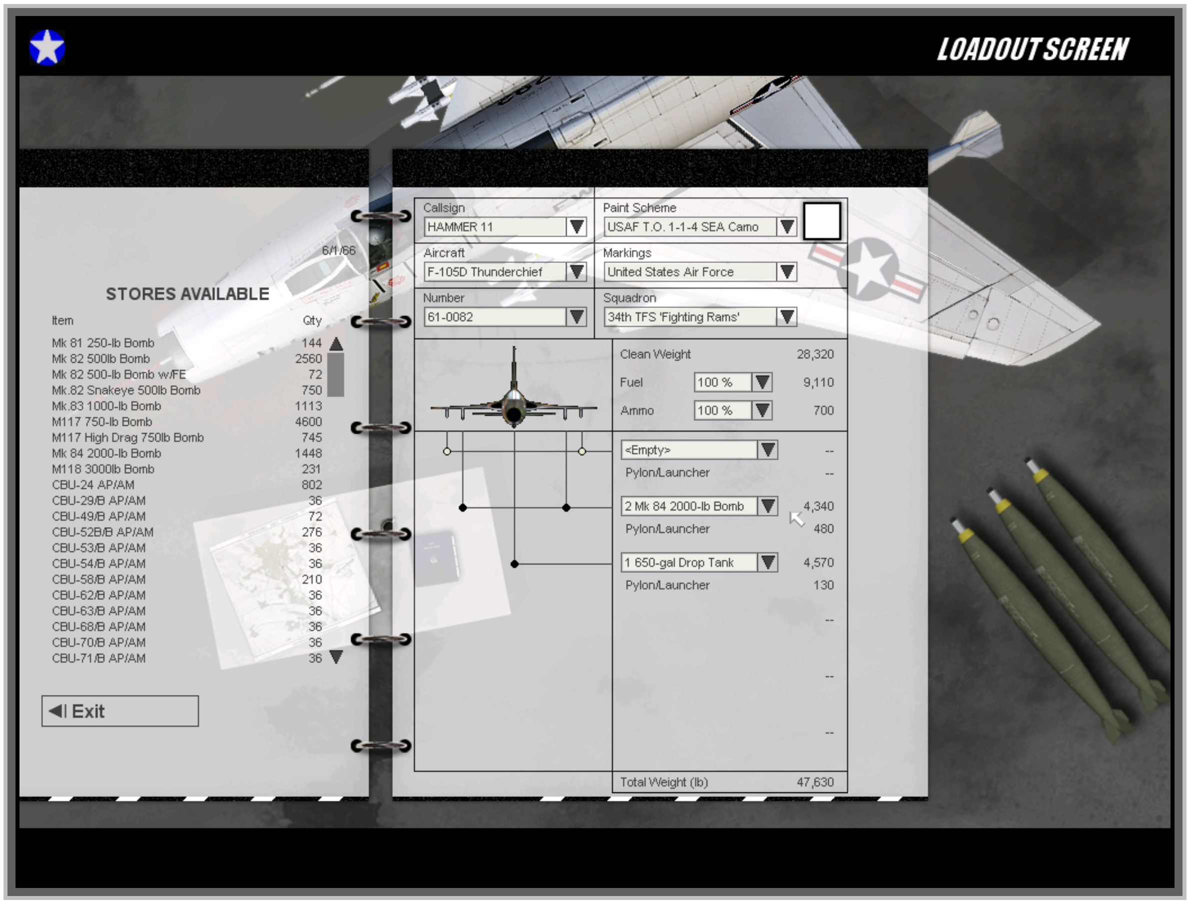
The times you arrive at the IP and target are critical because of the timing built into the escorts. If you arrive too early or too late the escorts will be too far away to provide any protection. Arriving at the IP exactly on time will place the Air to Air escort a couple minutes ahead and the Air Defense Suppression escort about 30 seconds ahead of your flight, right where they need to be to do the most good. The Recon flight will fly over the target about 5-10 minutes after you leave.

The target and how to take it out.

After you have a good idea of what kind of support you will have, it is time to think about what the target is and what kind of firepower it will take to destroy it. (Actually, there is no set order to do any of this in.) Section 2 of this manual addresses specific munitions, their effects, and what they are used for. Use this information when choosing loadouts for your flight.

You can see that our target is the Paul Doumer Bridge. Several different weapons would work well against this target. General purpose bombs would work well here just as they would against most targets. Precision guided munitions such as the AGM-12 Bullpup, Walleye, or GBU-10 would also work well.

To keep it interesting we will use two Mk-84 2,000 lb general purpose bombs.



Some things to consider when choosing your loadout are fuel load, aircraft weight, and the amount of drag your stores produce. One 650 gallon fuel tank on the centerline station should give enough fuel to make it to Hanoi and back. In reality, this would require a mid-air refueling but the terrain is scaled down to make missions without refueling possible.

You can see that the total weight of the aircraft with this load is 47,630 pounds. Be careful not to overload the aircraft. It the weight gets too high, you may not be able to take off before running out of runway.

Also, too many weapons can add a lot of drag to the aircraft. This can be bad for a number of reasons. The more drag you have on the aircraft, the more fuel you use and the lower your top speed. In general, only take enough weapons to do the job.

Choosing your flight members.

The number of aircraft in you flight and who flies them can be changed at the flight roster screen.

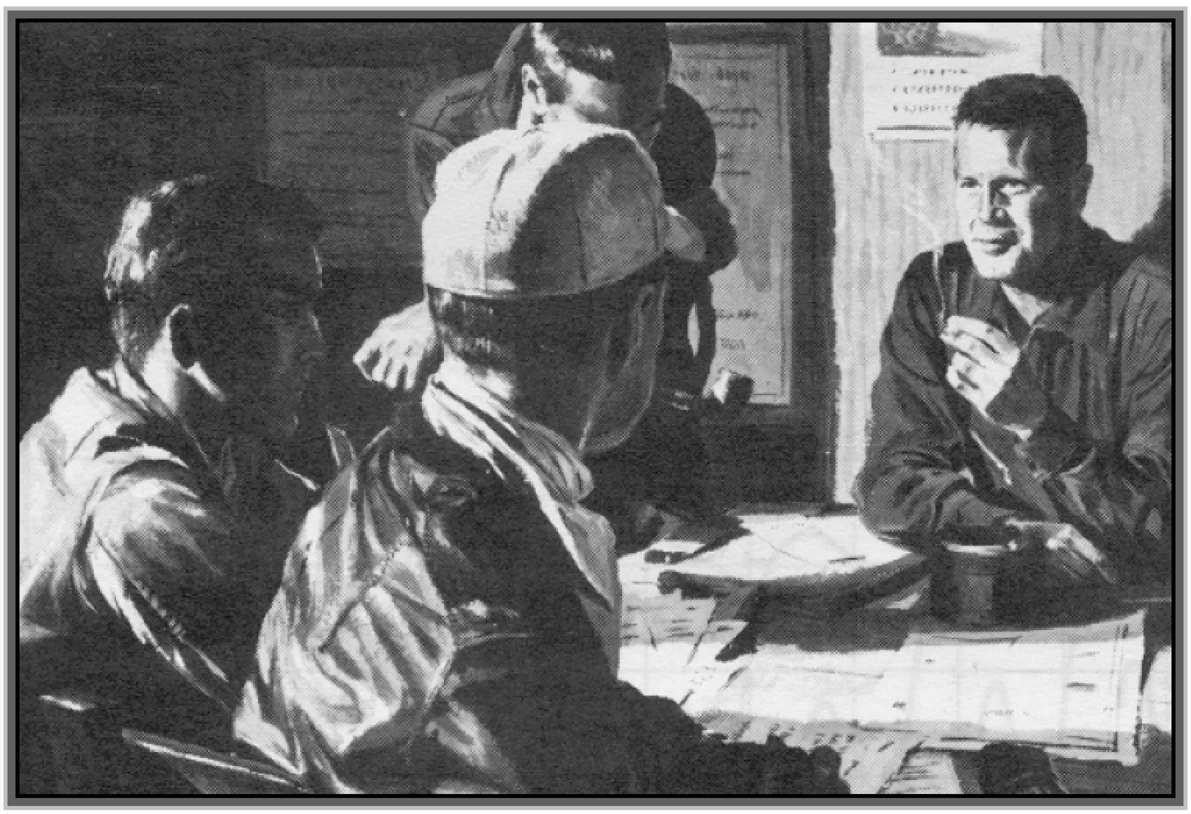
Pilot	Combat Missions	Kills A/A	Kills A/G	SKL	EXP	MRL	CND	Status	Aircraft Assigned
2Lt Rob McCray	6	0	1	---	---	---	---	Active	HAMMER 1-1
Maj Thomas Holcombe	10	0	0	68	100	73	97	Active	HAMMER 2-1
Capt Sidney Clark	0	0	0	74	100	100	82	Active	HAMMER 1-3
Capt Max Craig	0	0	0	66	100	79	97	Active	
1Lt Lee Kjer	8	0	0	68	100	100	97	Active	HAMMER 2-3
1Lt Ron Lodge	8	0	0	45	100	100	87	Active	
1Lt Ronald McKee	0	0	0	42	100	88	85	Active	
1Lt Harry Cherry	0	0	0	68	100	100	98	Active	HAMMER 2-2
2Lt Richard Logeman	5	0	0	25	96	80	90	Active	
2Lt Albert Hardgrave	1	0	0	71	92	78	84	Active	HAMMER 2-4
2Lt Stuart Tibbett	0	0	0	41	91	81	83	Active	
2Lt Edward Moss	0	0	0	40	91	100	85	Active	
2Lt Theodore Kjer	0	0	0	50	91	100	96	Active	HAMMER 1-4
2Lt Alan Wilbur	0	0	0	92	91	100	95	Active	
2Lt Alan Couch	0	0	0	39	91	100	85	Active	
2Lt Ed Boyer	3	0	0	78	94	91	93	Active	HAMMER 1-2

Pilots in your squadron are displayed here along with skill ratings. You can choose flight members by clicking their name on the screen. Generally, you want your best pilots flying as flight or element leads. A good pilot on your wing doesn't hurt either.

Planning Your Attack The Scientific Way

This is an advanced presentation of the techniques used to put bombs on target adapted from Air Force T.O. 1-1M-34, the Aircrew Weapons Delivery Manual.

Modern avionics perform most of the functions described here for us. However, an understanding of what the problems involved with bombing are and how they can be solved mathematically can lead to a better understanding of what is going on and improve performance.



Bombing Geometry.

In dive deliveries, the bomb is released manually from a fixed dive angle; approach to the target is at a preplanned airspeed and altitude. After release, the bomb is accelerated downward by gravity and slowed by aerodynamic drag. These factors cause the bomb to travel along a curved path and to impact the ground some distance short of the intersection of the aircraft's extended flightpath and the ground.

The geometry of a manual dive bombing problem is illustrated in Figure 3 through Figure 5. The ballistic tables for free-fall munitions give sight depression from flightpath (SDFP) in mils.

SDFP is predicated on four factors: gravity, drag, ejection forces that provide aircraft/bomb separation, and parallax. Gravity, drag, and ejection forces are used for a given dive angle, altitude, and airspeed. Using trigonometry, the SDFP can be calculated with bomb range, release altitude, and dive angle.

The following parameters are defined:

NOTE
Level bombing is a specific case of dive bombing where the dive angle is zero. Therefore, by using a dive angle equal to zero, this discussion applies equally to dive and level bombing.

r - Denotes parameters at weapon release
Yr - Release altitude, feet above ground level (AGL)
BR - Bomb range, feet
θ - Dive angle, degrees (measured below horizontal)
φr - SDFP at release
Sr - Slant range from release point to target, feet
αr - Zero sight line angle of attack (AOA) at release
D - Total sight depression set in the HUD/sight for weapon release
i - Denotes initial parameters (rollout)
AOD - Aim off distance, feet
Yi - Rollout altitude, feet
IPP - Initial pipper placement, mils
αi - Zero sightline (ZSL) AOA at rollout
Φi - Target depression from flightpath at rollout
S - Sightline from the pilot’s eye to target, at rollout
C - Horizontal range from target at rollout

Using these parameters, SDFP at release (φr) is calculated as follows:

The angle δr is the sum of dive angle and SDFP.
Therefore φr=!δi-θ
The tangent of δr equals Yr divided by BR.

This yields a SDFP predicted on gravity, drag, and ejection force. Parallax is caused by the distance from the bomb to the pilot's eye, and will cause a small change in SDFP. For any dive angle, the horizontal (Ph) and vertical (Pv) components of parallax can be found in Figure 2.

HORIZONTAL/VERTICAL PARALLAX CORRECTIONS

DIVE ANGLE (DEG)	A/OA-10	F-15	F-16
HORIZONTAL PARALLAX CORRECTIONS (P_h FEET)			
0	17.5	21	17.3
5	18.0	21.4	17.6
10	18.3	21.6	17.7
15	18.5	21.6	17.7
20	18.5	21.4	17.6
25	18.4	21.1	17.3
30	18.2	20.7	16.9
35	17.8	20.1	16.4
40	17.3	19.3	15.7
45	16.6	18.4	14.9
50	15.8	17.3	14.0
55	15.0	16.1	13.0
60	13.9	14.8	11.9
VERTICAL PARALLAX CORRECTIONS (P_v FEET)			
0	6.0	5.0	3.8
5	4.5	3.2	2.3
10	2.9	1.3	0.7
15	1.3	-0.1	-0.8
20	-0.3	-2.5	-2.3
25	-2.0	-4.3	-3.9
30	-3.6	-6.2	-5.4
35	-5.1	-7.9	-6.8
40	-6.7	-9.7	-8.2
45	-8.1	-11.3	-9.5
50	-9.6	-12.9	-10.8
55	-10.9	-14.3	-12.0
60	-12.2	-15.7	-13.1

FORMULA:

$P_h = P_h\,(x)\cos\theta = P_v\,(y)\sin\theta$

$P_v = P_v\,(x)\cos\theta = P_h\,(y)\sin\theta$

x = horizontal parallax correction for θ.

y = vertical parallax correction for θ.

Figure 2

Release altitude corrected for parallax (Yrp) is:
Yrp = Yr + Pv, (Figure 2)

Bomb range corrected for parallax (BRp) is:
BRp = BR - Ph, (Figure 2)

θ is normally expressed in degrees and φ in mils. The ratio 17.45 mils/degree is used to convert mils to degrees.

Therefore, SDFP (expressed in mils) predicted on gravity, drag, ejection forces, and parallax is:

$$\text{SDFP}\,(\phi_r) = 17.45\left[\tan^{-1}\left(\frac{Y_e}{Br_p}\right) - \theta\right]$$

SDFP is not the total sight setting. The aircraft has some AOA that must be considered when calculating total sight depression. In dive bombing, the zero sight line is used as a reference (when zero mils is set into the HUD/sight). The zero sight line angle of attack (ZSL AOA) is a function of release KCAS, aircraft gross weight, and dive angle.

The total sight depression (or sight setting) is the sum of SDFP and ZSL AOA at release:
$D = \varphi r + \alpha r$

For the planned combination of dive angle, altitude, and airspeed, this sight setting will define the proper release point. Any variation in any parameter will nullify this relationship, and the sight setting will be in error (it will not define the proper bomb range).

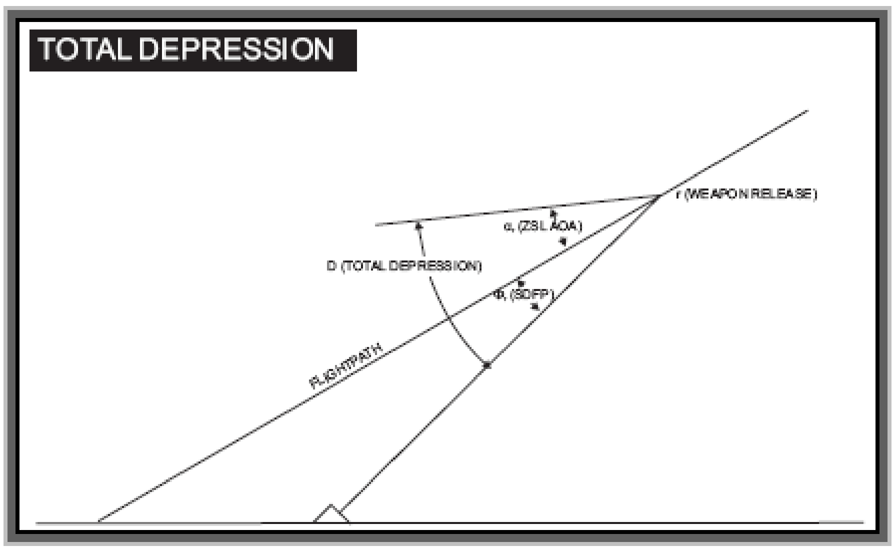


Figure 3

Several other relationships exist that are useful in solving the dive bombing problem.

The AOD is the distance from the target to the point where the theoretical extension of the aircraft flightpath intersects the ground. This intersecting point is called the aim off point (AOP). In order to arrive at the proper point in space, as defined by the sight setting, the aircraft must be flown along the flightpath ending at the AOP, as depicted in Figure 5. If the AOP can be visualized on the ground, the aircraft can be flown toward the AOP with the proper dive angle to intercept the preplanned flightpath.
Normally the AOP is difficult to visualize; therefore, another method can be used to point the aircraft flightpath toward the AOP.

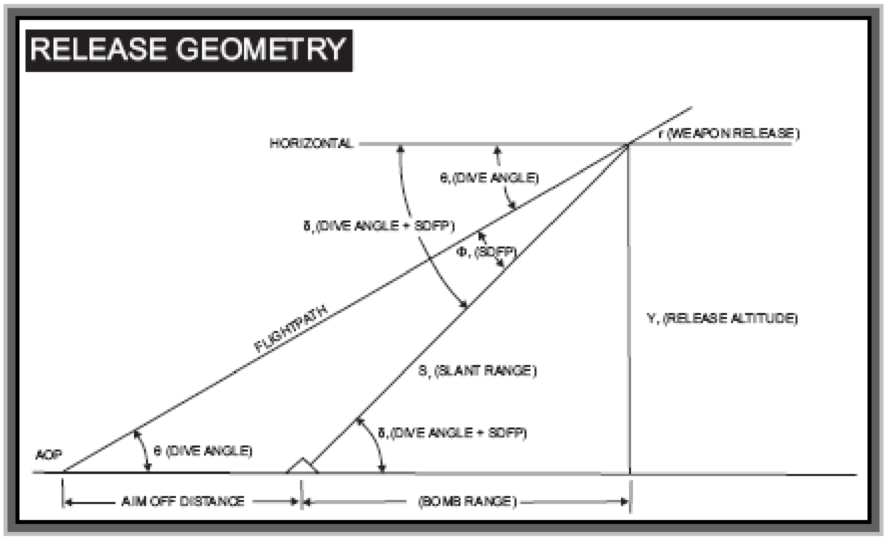


Figure 4

The aircraft flightpath can be pointed toward the AOP using the geometric relationships depicted in Figure 5. If rollout is achieved at the preplanned point and the pipper is positioned the proper distance short of the target at rollout, the flightpath will necessarily be the proper distance (AOD) past the target. This IPP is measured in mils short of the target, and can be computed as follows:

IPP = D - αi – φi

The ZSL AOA at rollout is a function or rollout KCAS, gross weight, and dive angle. Just as φr subtends the AOD at release altitude (Figure 5), φi subtends the AOD at rollout altitude and is computed in the same manner as φr.

$$\phi_i = \tan^{-1}\left(\frac{Y_i}{C}\right) - \theta$$

$$IPP = D - \alpha_i - \phi_i$$

$$IPP = D - \alpha_i - \phi_i - \tan^{-1}\left(\frac{Y_i}{C}\right) + \theta$$

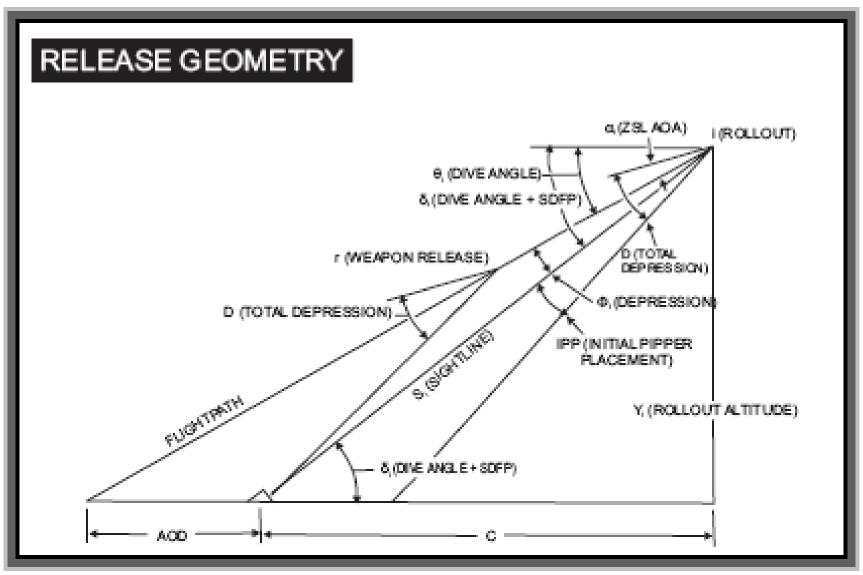
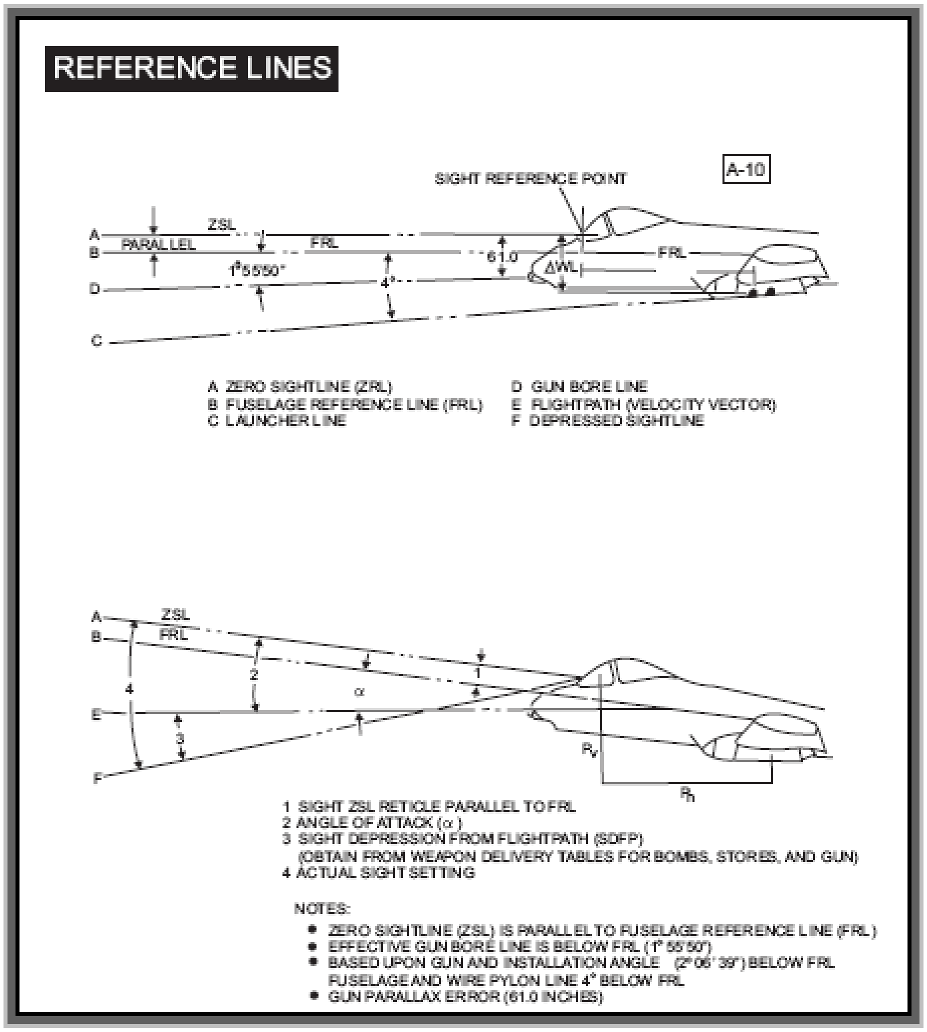


Figure 5



A-10 Reference Lines

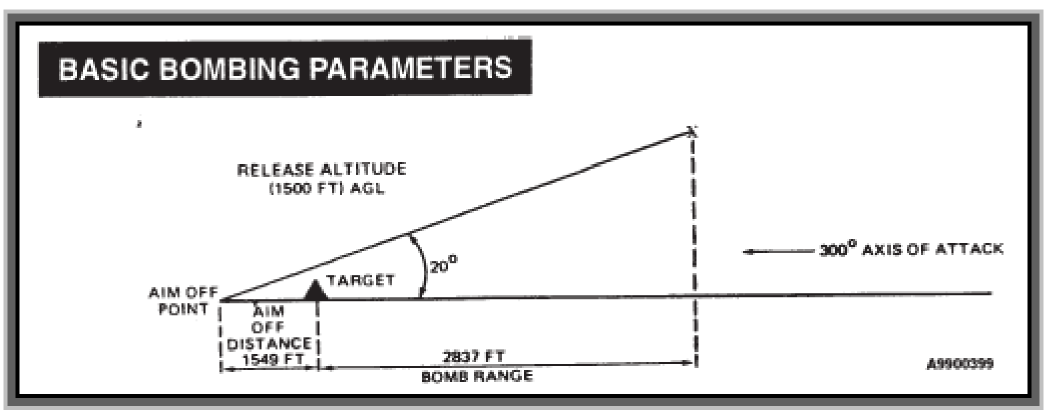
Popup Attack Planning.

Popup planning is best approached by starting at the target and working backwards to the initial point (IP).

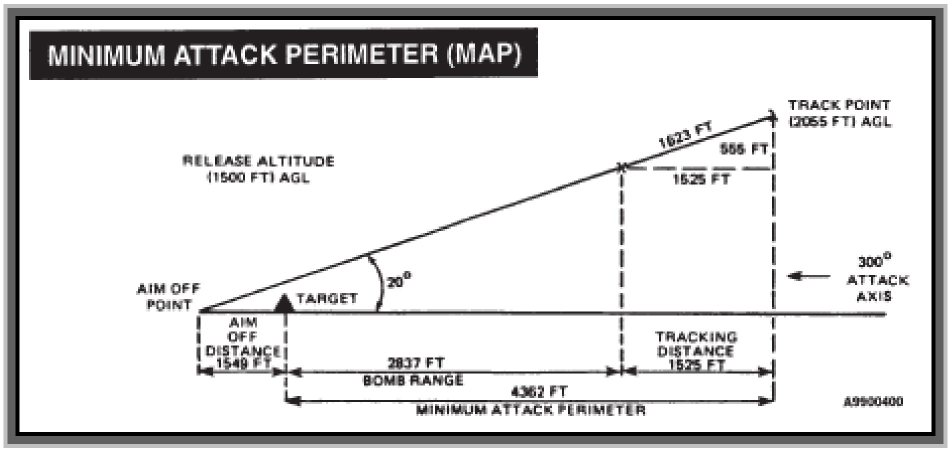
A sample problem follows to demonstrate popup attack planning. Vertical and horizontal depictions of the problems are recommended to aid in visualizing and understanding the maneuver.

Example:
Aircraft - A-10A
Weapon - MK 82 LDGP
Release airspeed - 320 KTAS
Release altitude - 1,500 feet AGL
Dive angle - 20 degrees
Tracking time - 3 seconds
Bomb range - 2,837 feet
Aim off distance - 1,549 feet
Axis of attack - 300 degrees

1. Depict the basic bombing problem to include target, axis of attack, dive angle, release altitude, bomb range (BR), and AOD.



2. Convert tracking time to distance covered across the ground. Adding this distance to the BR gives a point over the ground at which tracking is initiated, i.e., the minimum attack perimeter (MAP).

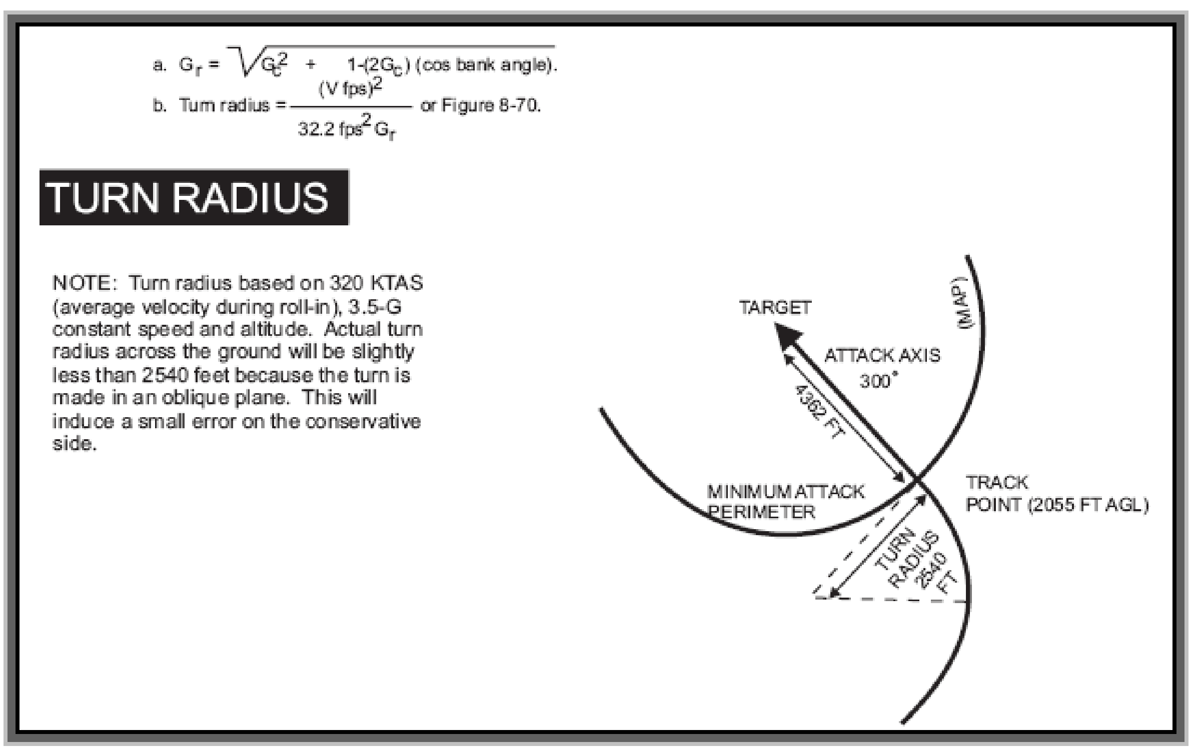


a. Computations:

Average velocity = 320 KTAS x 1.69 = 541 fps
Tracking time = 3 sec
Tracking distance = 541 fps x 3 sec = 1,623 feet
Tracking distance across the ground - cosine 20° x 1,623 = 0.93969 x 1,623 = 1,525 feet

b. The MAP in the problem is 4,362 feet from the target. To track toward the target for 3 seconds and then pickle at 1,500 feet AGL, you must arrive at a point 4,362 feet from the target with the flightpath on the AOD.

3. From the track point, draw in the turn radius toward the IP.



4. From the IP, draw a line tangent to the roll-in arc. The point of tangency is the roll-in point.

5. Compute the climb angle, APEX altitude, pulldown altitude, pullup point (PUP), and run-in angle off:

Climb angle = dive angle + 5° (for 5° through 15° deliveries)

= dive angle + 10° (for 200 and higher angle deliveries)

APEX altitude = track point altitude + (dive angle x 50),
(dive angle x 9) A-10 only

For A-10: Pulldown altitude = track point altitude = (dive angle x 10)

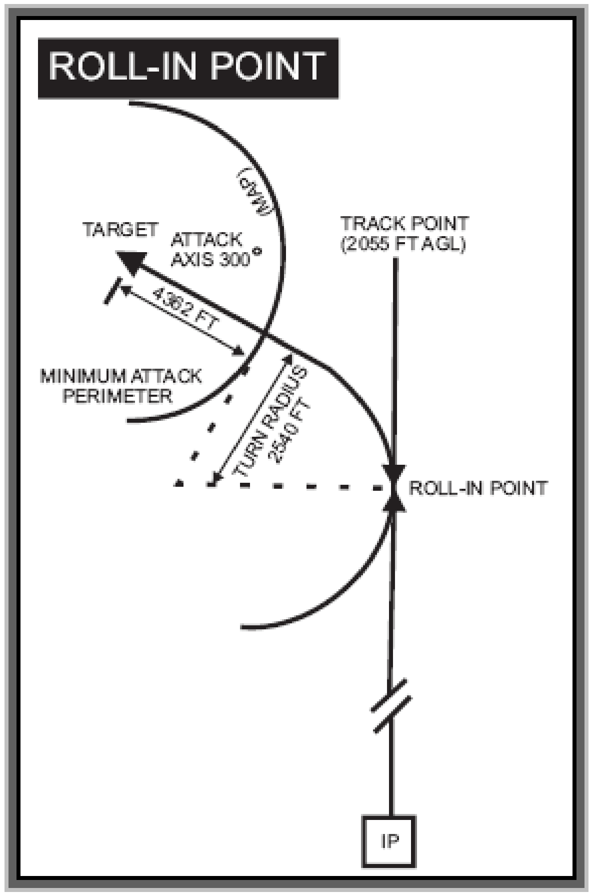
(for 20° and higher angle deliveries)
= track point altitude (for 5° through 15° deliveries)

For others:
Pulldown altitude = APEX altitude - (climb angle x 50) for a 3 to 3.5-g roll-in

Pulldown altitude = APEX altitude - (climb angle x 37.5) for a 4.5 to 5-g roll-in

$$\text{PUP to pulldown point} = \frac{\text{pulldown altitude}}{\tan(\text{climb angle})}\ \text{A-10, or}\ \frac{\text{APEX alt} \times 60}{(\text{climb angle})}\text{, others}$$

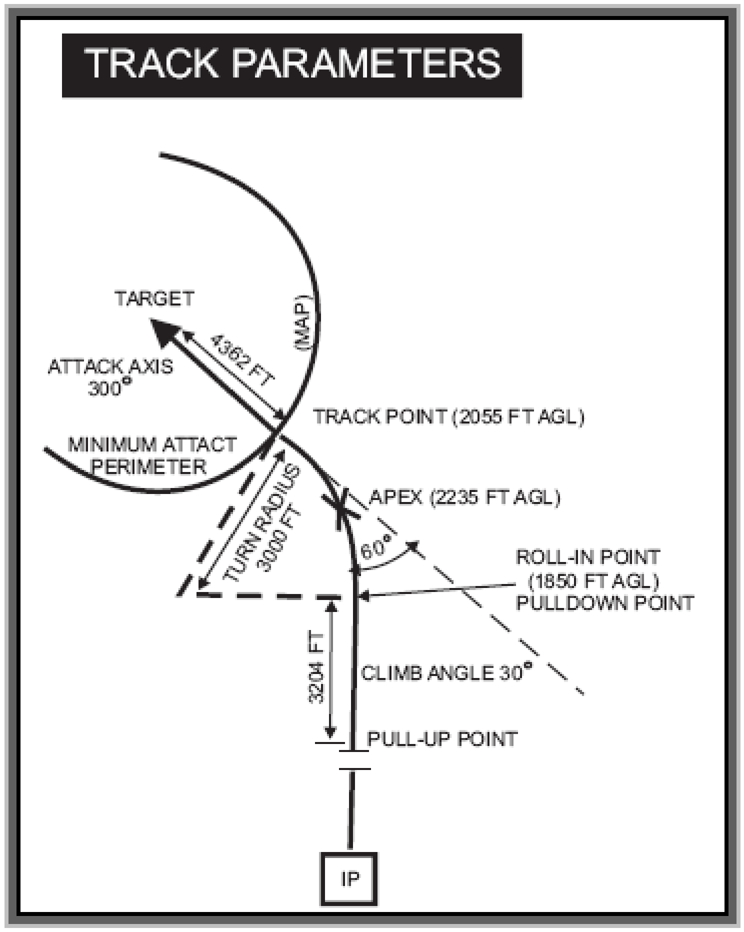
Optimum angle-off = 2 x climb angle



6. In this problem):

Climb angle = dive angle + 10°
= 20° + 10°
= 30°

APEX altitude = track point altitude + (9 x dive angle)
= 2,055 + (9 x 20)
= 2,055 + 180
= 2,235 feet



Pulldown altitude = track point altitude - (10 x dive angle)
= 2,055 - (10 x 20)
= 2,055 - 200
= 1,855 feet

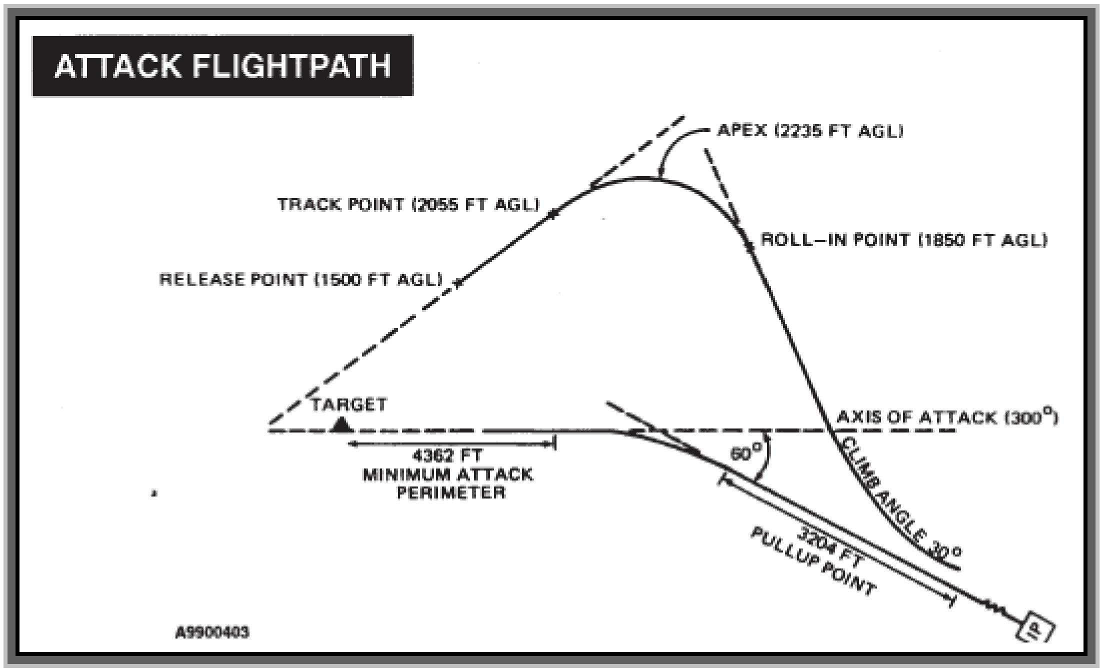
$$PUP = \frac{\text{pulldown altitude}}{\tan(\text{climb angle})}$$

$$= \frac{1{,}850 \text{ feet}}{\tan 30} = \frac{1{,}850 \text{ feet}}{0.57735}$$

= 3,204 feet drawn from pulldown point

Optimum angle-off = 2 x climb angle
=2x30°
= 60°

7. Add those figures to the depiction, then construct a three-dimensional drawing of the attack and label points along the flightpath.



Direct Pop Planning.

Direct pops are performed differently from angle off popups. The aircraft is flown directly at the target and at a precomputed range a loaded pullup to a predetermined climb angle is initiated. At the computed roll-in altitude, an unloaded 180 degree roll-in is initiated to inverted flight. A loaded pulldown is then performed to the desired dive angle. An unloaded 180 degree rollout is then performed. (Some lead may be required in initiating the rollout in order to arrive at the desired dive angle.) If executed properly, the target should now be in the HUD field of view and a normal diving delivery can be completed.

Direct pop planning is quite a bit different from angle off popup planning. The formulas used are not so much rules of thumb as they are basic trigonometry. This makes the whole approach to direct pop planning much different from angle off popup planning. It is still best approached by starting at the target and working backwards.

Aircraft - F-15 E
Weapons - 12 x MK-82 AIR (HD)
Release airspeed - 540 KTAS

Release altitude - 700 ft AGL
Dive angle - 10 DEGREES
Track time - 5 SECONDS
Track airspeed - 525 KTAS
Bomb range (1st bomb) - 2132 FEET
Pattern length - 550 FEET
Aim off distance - 1570 FEET
Run-in airspeed - 540 KTAS
Run-in altitude - 100 ft AGL
Pullup g - 4g (cockpit g)
Pulldown g - 4g (cockpit g)

Assumptions:
- 120 degree per second roll rate, i.e. 1.5 second roll
- G buildup takes 2 seconds
- Pulldown KTAS = Climb KTAS = Run-in KTAS (conservative simplification)

1. First, the apex altitude is calculated.

APEX ALTITUDE =
TRACK ALTITUDE + ALTITUDE LOST DURING ROLLOUT + ALTITUDE LOST DURING PULLDOWN

TRACK ALTITUDE =
RELEASE ALTITUDE + ALTITUDE LOST DURING TRACK

ALTITUDE LOST DURING TRACK =
[RELEASE KTAS + TRACK KTAS]/2 x 1.69 x SIN (DIVE ANGLE) x TRACK TIME

ALTITUDE LOST DURING ROLLOUT =

TRACK KTAS x 1.69 x SIN (DIVE ANGLE) x ROLLOUT TIME

ALTITUDE LOST DURING PULLDOWN =

$$\frac{[\text{PULLDOWN KTAS} \times 1.69]^2}{[\text{PULLDOWN G} + 1] \times 32.2} \times [1 - \text{COS (DIVE ANGLE)}]$$

ALTITUDE LOST DURING TRACK =
[540+525]/2 x 1.69 x SIN 10 x 5 = 781 ft

TRACK ALTITUDE =
700 + 781 = 1481 ft

ALTITUDE LOST DURING ROLLOUT =
525 x 1.69 x SIN 10 x 1.5 = 231 ft

ALTITUDE LOST DURING PULLDOWN =

$$\frac{[540 \times 1.69]^2}{[4 + 1] \times 32.2} \times [1 - \text{COS } 10] = 79 \text{ ft}$$

APEX ALTITUDE =
1481 + 231 + 79 = 1791 ft AGL

2. Next, pulldown altitude is computed. Pulldown altitude is the altitude at which the loaded pulldown, from inverted flight, is initiated. (If the 180 degree unloaded roll is completed in the computed time, pulldown altitude is not used. In this case, the pulldown would be initiated at the completion of the roll.)

PULLDOWN ALTITUDE =
APEX ALTITUDE GAINED DURING PULLDOWN - ALTITUDE GAINED DURING - G BUILDUP

ALTITUDE GAINED DURING PULLDOWN =

$$\frac{[\text{PULLDOWN KTAS} \times 1.69]^2}{[\text{PULLDOWN G} + 1] \times 32.2} \times [1 - \text{COS (CLIMB ANGLE)}]$$

ALTITUDE GAINED DURING G BUILDUP =
CLIMB KTAS x 1.69 x SIN (CLIMB ANGLE) x G BUILDUP TIME

CLIMB ANGLE =
DIVE ANGLE + 5 (for 5 through 15 degree deliveries)
DIVE ANGLE + 10 (for 20 degree and higher deliveries)

CLIMB ANGLE =
10 + 5 = 15 DEGREES

ALTITUDE GAINED DURING PULLDOWN =

$$\frac{[540 \times 1.69]^2}{[4 + 1] \times 32.2} \times 1 - \text{COS } 10 = 176 \text{ ft}$$

ALTITUDE GAINED DURING BUILDUP =
540 x 1.69 x SIN 15 x 2 = 472 ft

PULLDOWN ALTITUDE =
1791 - 176 - 472 = 1143 ft

3. From pulldown altitude, the roll-in altitude can be computed. Roll-in altitude is the altitude where the unloaded 180 degree roll is initiated.

ROLLIN ALTITUDE =
PULLDOWN ALTITUDE - ALTITUDE GAINED DURING ROLLIN

ALTITUDE GAINED DURING ROLLIN =
CLIMB KTAS x 1.69 x SIN (CLIMB ANGLE) x ROLLIN TIME

ALTITUDE LOST DURING ROLLOUT =
540 x 1.69 x SIN 15 x 1.5 = 354 ft

ROLLIN ALTITUDE =
1143 - 354 = 789 ft

4. The Minimum Attack Perimeter (MAP) is computed the same as in an angle off pop.

MAP =
BOMB RANGE (1st bomb) + PATTERN LENGTH/2 + TRACK DISTANCE

TRACK DISTANCE =
[RELEASE KTAS + TRACK KTAS]/2 x 1.69 x COS (DIVE ANGLE) x TRACK TIME

TRACK DISTANCE =
[540+525]/2 x 1.69 x COS 10 x 5 = 4431 ft

MAP =
2132 + 550/2 + 4431 = 6838 ft

5. Backing up from the MAP, the distance covered during the 180 degree pullout from inverted flight is computed.

ROLLOUT DISTANCE =
TRACK KTAS x 1.69 x COS (DIVE ANGLE) x ROLLOUT TIME

ROLLOUT DISTANCE =

525 x 1.69 x COS 10 x 1.5 = 1311 ft

6. Next, the horizontal distance covered during pulldown is computed.

PULLDOWN DISTANCE =

$$\frac{[\text{PULLDOWN KTAS} \times 1.69]^2}{[\text{PULLDOWN G} + 1] \times 32.2} \times [\text{SIN (CLIMB ANGLE)}] + \text{SIN (DIVE ANGLE)}$$

PULLDOWN DISTANCE =

$$\frac{[540 \times 1.69]^2}{[4 + 1] \times 32.2} \times [\text{SIN } 15 + \text{SIN } 10] = 2237 \text{ ft}$$

7. Now, the pulldown g delay must be taken into account.

PULLDOWN G DELAY =
CLIMB KTAS x 1.69 x COS (CLIMB ANGLE) x G BUILDUP TIME

PULLDOWN G DELAY =
540 x 1.69 x COS 15 x 2 = 1763 ft

8. Climb distance is now computed.

CLIMB DISTANCE =
ALTITUDE GAINED DURING CLIMB / TAN (CLIMB ANGLE)

ALTITUDE GAINED DURING CLIMB =
PULLDOWN ALTITUDE - RUNIN ALTITUDE - ALTITUDE GAINED DURING PULLUP

ALTITUDE GAINED DURING PULLUP =

$$\frac{[540 \times 1.69]^2}{[4 - 1] \times 32.2} \times [1 - \text{COS } 15] = 294 \text{ ft}$$

ALTITUDE GAINED DURING CLIMB =
1142 - 100 - 294 = 748 ft

CLIMB DISTANCE

$$\frac{748}{\text{TAN } 15} = 2792$$

9. Now the horizontal distance covered during the pullup to the desired climb angle is computed.

PULLUP DISTANCE =

$$\frac{[\text{RUNIN KTAS} \times 1.69]^2}{[\text{PULLUP G} + 1] \times 32.2} \times \text{SIN (CLIMB ANGLE)}$$

PULLUP DISTANCE =

$$\frac{[540 \times 1.69]^2}{[4-1] \times 32.2} \times \text{SIN } 15 = 2231 \text{ ft}$$

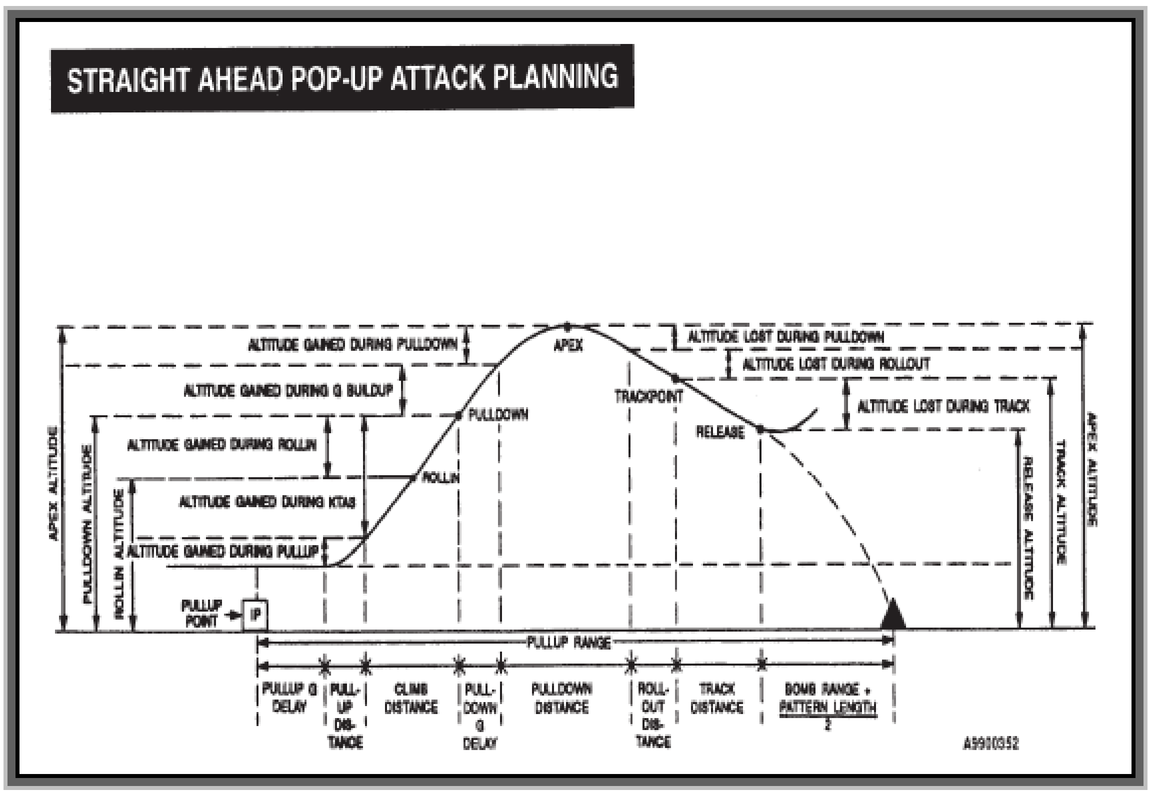
10. Next, the pullup g delay must be taken into account.

PULLUP G DELAY =
RUNIN KTAS x 1.69 x G BUILDUP TIME

PULLUP G DELAY =
540 x 1.69 x 2 = 1825 ft

11. Finally the pullup distance from the target is computed.

PULLUP DISTANCE FROM TARGET =
MAP + ROLLOUT DISTANCE + PULLDOWN DISTANCE + PULLDOWN G DELAY CLIMB



DISTANCE + PULLUP DISTANCE + PULLUP G DELAY

NOTE
For dive toss type deliveries, add aimoff distance to the above.

PULLUP RANGE (NM) =
PULLUP DISTANCE FROM TARGET / 6076

PULLUP DISTANCE FROM TARGET
6838 + 1311 + 2237 + 1763 + 2792 + 2231 + 1825 = 18,997 ft

PULLUP RANGE (NM) =

$$\frac{18{,}997}{6076} = 3.13 \text{ NM}$$

PULLUP DISTANCE FROM TARGET FOR DIVE TOSS =
18,997 + 1570 = 20,567 ft
PULLUP RANGE FOR DIVE TOSS =

$$\frac{18{,}997}{6076} = 3.13 \text{ NM}$$

Safe Separation/Safe Escape

This section is dedicated to safe escape and safe separation criteria, aspects of mission planning not mentioned very often in discussions of flight simulations.

Picture yourself doing this. You drop down to 200 feet at five miles from the target and push the throttle up to the stop. At 3 miles you have the target in sight. You select a Mk-84 Slick. At half a mile from the target AAA lights up but you press on towards the target at 200 feet. As the target slips below your aircraft you pickle off your bombs, turn, and watch the target explode.

Great job right? Well… not quite. There were a couple problems. First, you were too close to the bombs when they detonated. The same forces and fragments that took out the target just took you out as well. Second, the fuze that detonates the bomb did not have time to arm before impact. The bomb would have been a dud.

The following covers how it is planned in the real world. You'll probably be surprised.

Safe Escape.

Safe escape is ensured by selecting a release altitude that provides the delivery aircraft with acceptable protection from weapon fragments when the detonation is at the preplanned point. To meet safe escape criteria, the release altitude must be high enough that the probability of the aircraft being hit by the weapon's fragments is less than or equal to 1/1,000 ($P \leq 0.001$) per pass, when the weapon detonates as planned. This release altitude is called the Safe Escape Minimum Release Altitude (MRA).

An F-4B loaded with GBU-12 LGBs over Korea.

Safe escape must be considered whenever the delivery aircraft will penetrate the vertical or horizontal limits of maximum fragment travel during the maximum time of flight of those fragments. Figure 1, Maximum Bomb/Rocket Fragment Travel Chart, provides the vertical and horizontal limits of maximum fragment travel for munitions. Data in Figure 1 are provided for Sea Level and 5,000 feet target density altitudes.

MAXIMUM BOMB/ROCKET FRAGMENT TRAVEL CHART

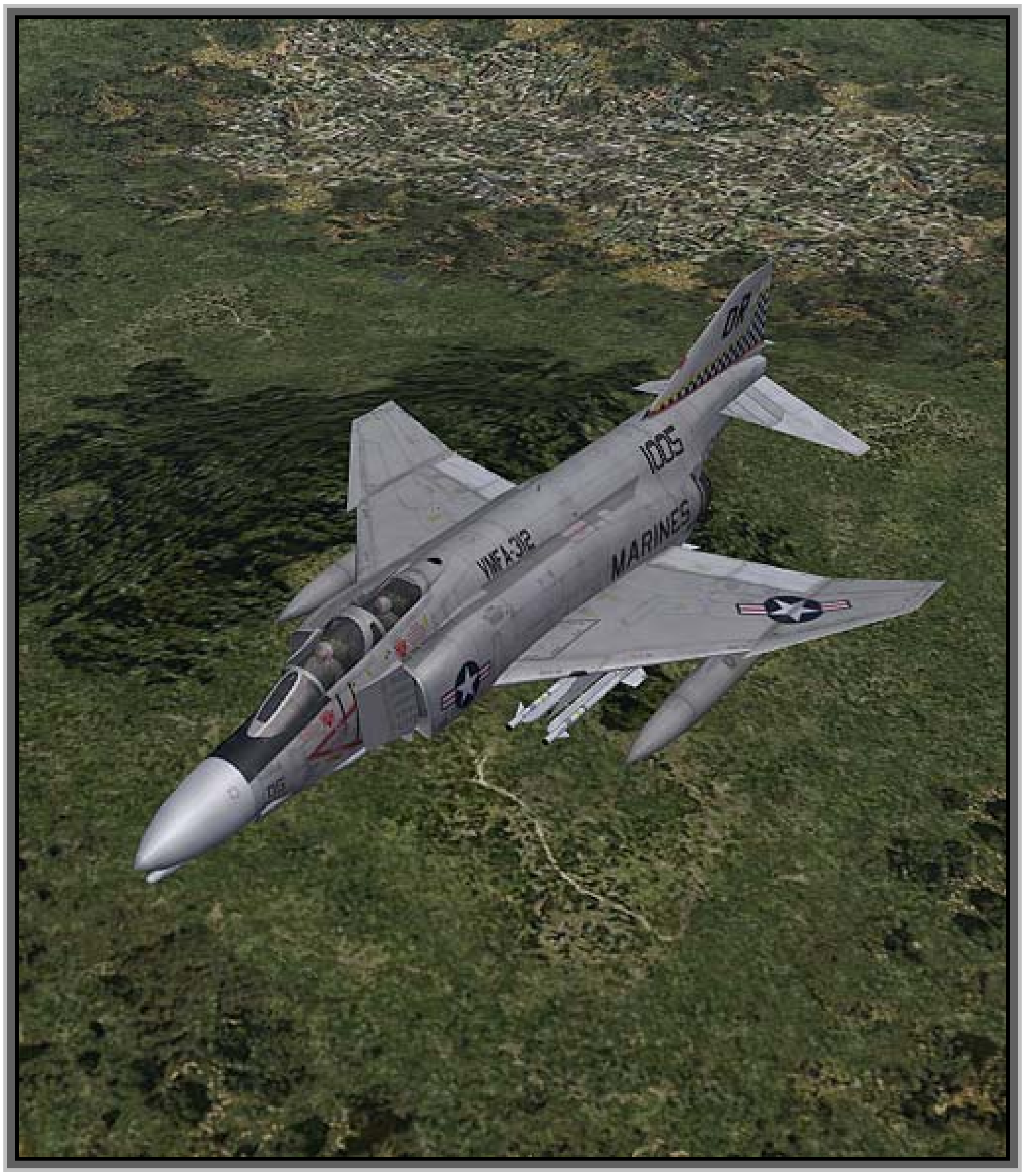
MAXIMUM BOMB FRAGMENT TRAVEL	ALTITUDE (FEET) TDA		HORIZONTAL RANGE (FEET) TDA		TIME OF FLIGHT (SECONDS) TDA	
	SEA LEVEL	5000 FEET	SEA LEVEL	5000 FEET	SEA LEVEL	5000 FEET
UNITARY WARHEADS						
MK 82 ALL TYPES	2225	2535	2600	2965	25.3	27.0
MK 83 ALL TYPES	2424	2769	2807	3205	26.7	29.3
MK 84 ALL TYPES	2855	3265	3295	3760	28.9	30.9
M117 ALL TYPES	2790	3160	3395	3850	27.6	29.2
BLU-109 ALL TYPES	3590	4080	4295	4880	31.5	33.4
BLU-110 ALL TYPES	MK-83 with PBNX-109 Fill - NO DATA AVAILABLE					
BLU-111 ALL TYPES	MK-82 with PBNX-109 Fill - NO DATA AVAILABLE					
BLU-113 ALL TYPES	4630	5235	5700	6450	35.1	37.3
BLU-117 ALL TYPES	MK-84 with PBNX-109 Fill - NO DATA AVAILABLE					
AGM-65G	FRAG TRAVEL - JMEM					
AGM-65H	FRAG TRAVEL - JMEM					
AGM-65K	FRAG TRAVEL - JMEM					
INTACT CANISTERS						
CBU-87/B, A/B, B/B, C/B	1980	2250	2360	2685	23.6	25.1
CUB-89/B, A/B	2400	2735	2805	3195	26.3	28.0
CBU-103	1980	2250	2360	2685	23.6	25.1
CBU-104	2400	2735	2805	3195	26.3	28.0
CBU-105	2760	3150	3225	3675	28.2	30.0
CBU-107	NOT A FRAGMENTATION WARHEAD - NOT APPLICABLE					
CLUSTER SUBMUNITIONS						
BLU-91/B (CBU-89, -104)	NOT A FRAGMENTATION WARHEAD - NOT APPLICABLE					
BLU-92/B (CBU-89)						
BLU-97/B, A/B (CBU-87, -103)	545	620	635	725	12.8	13.7
BLU-108/B, B/B (CBU-105)	NOT A FRAGMENTATION WARHEAD - NOT APPLICABLE					

MAXIMUM ROCKET FRAGMENT TRAVEL							
MUNITION	IMPACT ANGLE (DEGREES)	ALTITUDE (FEET) TDA		HORIZONTAL RANGE (FEET) TDA		TIME OF FLIGHT (SECONDS) TDA	
		SEA LEVEL	5000 FEET	SEA LEVEL	5000 FEET	SEA LEVEL	5000 FEET
MK-1	5	1030	1170	1430	1630	17.1	18.1
	10	1015	1150	1425	1630	16.9	17.9
	20	985	1110	1425	1620	16.5	17.5
	30	930	1045	1410	1610	16.0	17.0
Mk5	5	1190	1360	1620	1850	18.5	19.5
	10	1175	1340	1620	1845	18.3	19.4
	20	1140	1300	1615	1840	18.0	19.1
	30	1110	1265	1600	1825	17.7	18.8
MK-151	5	1010	1145	1335	1515	17.1	18.2
	10	1000	1135	1330	1515	17.0	18.1
	20	990	1110	1325	1510	16.9	17.8
	30	965	1085	1300	1500	16.6	17.6
WDU-4A/A		NOT A FRAGMENTATION WARHEAD - NOT APPLICABLE					

Figure 1

Safe Separation.

Safe separation is ensured by selecting a fuze arm time setting that provides the delivery aircraft acceptable protection from early weapon detonation (early burst). To meet safe separation criteria, the selected fuze setting must be high enough that if the weapon detonates at the earliest possible fuze arming time (i.e. Fuze arm setting + inherent delays - negative fuze tolerance) the probability of the aircraft being hit by weapons fragments is less than or equal to 1/1,000 ($P \leq 0.001$) per pass.



A USMC F-4B over Vietnam

Formation Deconfliction.

Attacks by multiple aircraft must not only consider safe escape/safe separation for the releasing aircraft, but must also take action to reduce the probability of fragmentation damage to other aircraft in the formation. This formation deconfliction can occur in simultaneous or sequential attacks as discussed in the following paragraphs.

Simultaneous attacks occur when multiple aircraft release munitions while flying in formation. For simultaneous formation deliveries on the same target or area, when time, altitude or horizontal deconfliction will not be achieved, wingmen must be in close (fingertip) formation. In this type of delivery, the safe escape minimum release altitude provides fragment protection.

The Maximum Bomb/Rocket Fragment Travel Chart, Figure 1, is used to determine fragment deconfliction between multiple aircraft attacks. The maximum altitude and maximum horizontal range anticipated for the worst case fragment of the bomb case, and the time from detonation until all bomb case fragments have settled to the ground represent an envelope. For all weapons employment involving sequential deliveries on the same target or on separate targets in the same area, mission planning must ensure that either time, altitude, or horizontal fragment deconfliction is achieved as discussed below.

Time Deconfliction for Sequential Attacks.

When using time deconfliction, subsequent aircraft should not enter the horizontal or vertical limits of the fragmentation cylinder until expiration of the time of flight for the preceding aircraft's weapon fragments. Time separation between aircraft (using similar delivery profiles) is equal to the fragmentation time of flight, plus preceding munition time of fall, plus the time to fly the distance between weapon actual range (AR) and maximum fragment travel horizontal range of the preceding fragments.

This formula can be represented as:

$$TA = TOFF + TOFW + (RF - AR)/GS$$

TA: Time Between Aircraft (sec.)
TOFF: Maximum Fragment Travel, Time of Flight (sec.)
TOFW: Weapon Time of Fall (sec.)
AR: Weapon Ground Actual Range (i.e. downrange distance from release to weapon impact) (ft.)
RF: Maximum Fragment Travel, Horizontal Range (ft.)
GS: Aircraft Ground Speed (ft./sec.)

This equation is relative to the time the preceding aircraft releases the munition. The difference between the horizontal range of the fragmentation cylinder and subsequent aircraft's weapon ground range accounts for the aircraft's position relative to the fragmentation cylinder at weapon's release. Depending on weapon configuration and delivery parameters, weapon release may occur either inside or outside the fragmentation cylinder.

The subsequent aircraft's time to release at preceding aircraft's weapon detonation can be used to verify time deconfliction outside the fragmentation cylinder. Now, the subsequent aircraft is no longer concerned with weapon time of fall for the preceding aircraft, but rather time until reaching the fragmentation cylinder from the preceding aircraft. Similar to the previous formula, time at detonation (TD) can be represented as:

TD = TOFF + (RF -AR)/GS

This assures that as long as the preceding aircraft's detonation occurs no later than TD, the fragmentation cylinder will not be penetrated during fragmentation time of fall. Both these situations are valid for same Desired Mean Point of Impact (DMPI) release, and for single or ripple releases. In case of offset axis attack (different axis for each aircraft) the ripple/interval time must be accounted for since the first weapon may not be the closest to subsequent aircraft run-in line. If offset exceeds 90 degrees, adding the weapon interval/ripple (sec.) accounts for worst case offset between aircraft.

An F-111 loaded with M117 GP Bombs.

Altitude Deconfliction for Sequential Attacks.

When altitude deconfliction is used, subsequent aircraft must recover above the maximum altitude for the fragment envelope for the preceding attacker's munitions. For example, the maximum fragment travel (altitude) is 3265 ft for a MK-84 delivery at a 5,000-foot target density altitude (See Figure 1). So the subsequent aircraft must recover above 3265 ft. at a minimum.

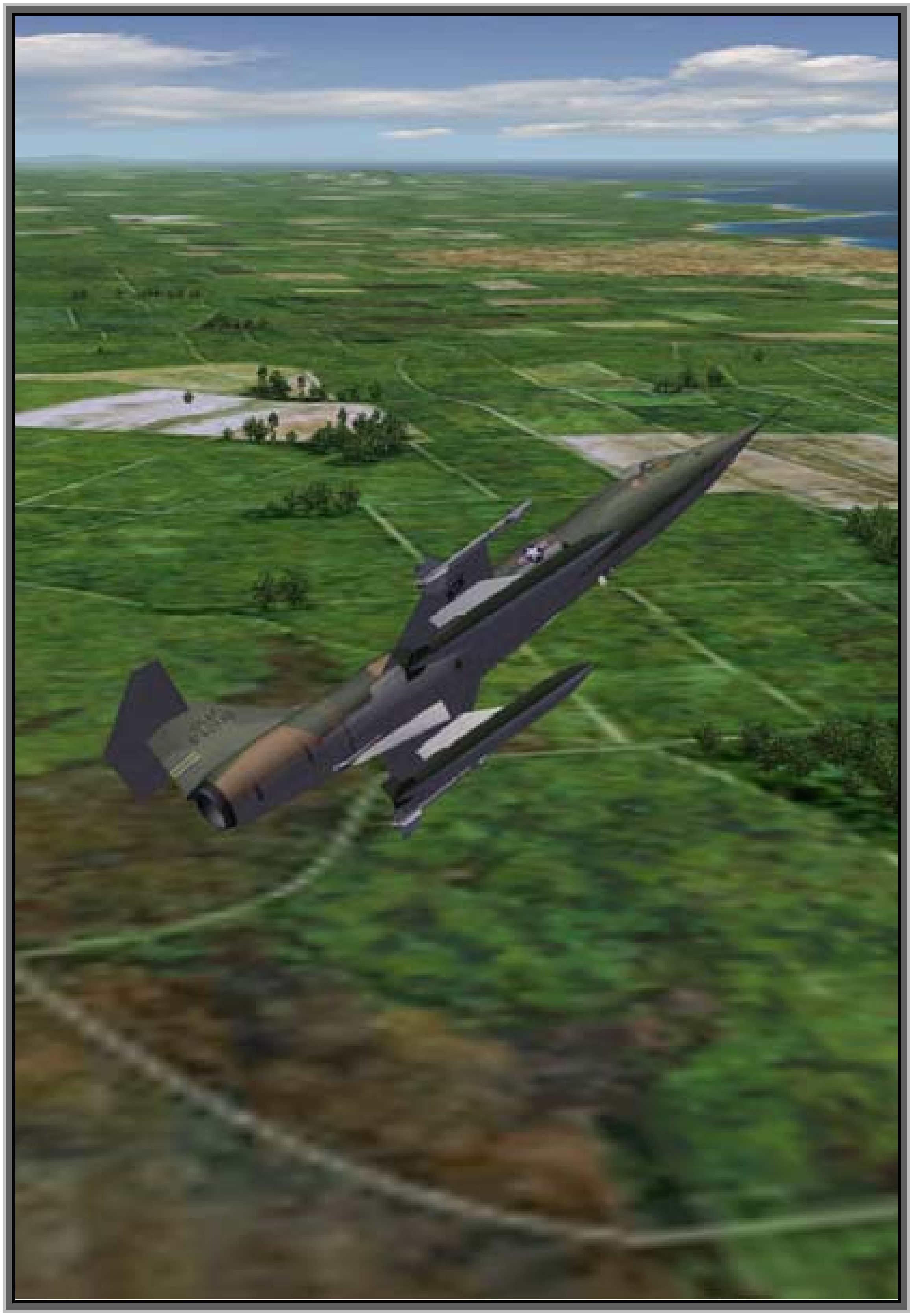
Horizontal Deconfliction for Sequential Attacks.

When using horizontal deconfliction, subsequent aircraft must remain outside the maximum horizontal range of the fragment envelope for the preceding attacker's munitions. For example, from Figure 1, a lateral separation of 2,600 feet provides deconfliction from a MK-82 released at Sea Level.

For CBU munitions, the horizontal deconfliction must be equal to or greater than the larger of the following:

1. The maximum horizontal range of the fragment envelope of the intact cluster (available in Figure 1).

2. The sum of CBU pattern half-width (radius) and maximum horizontal range of the fragment envelope for the submunition.



Section 6

Mission Execution

Navigation and Time Management
Ground Mapping Radar Scope Interpretation
Weapon Delivery Considerations
Intercept Considerations
The Strike Fighters Fire Control System
F-4 Radar Guide
AGM-65 Maverick Employment
Walleye I/II Employment
LGB Employment
AGM-84 Harpoon Employment
AGM-45 Shrike Employment
Red Air Intercept
Notes on Mission Survival
Air-to-Air Tips for New Pilots
Notes on Tactics

Sepecat Jaguar dispensing flares over the Falklands.

Navigation and Time Management

Getting from one place to another can be half the fun in flight simulations. Getting to the right place at the right time ensures that your flight fits correctly into the greater scheme of things. Arrive too early or too late and you will not have any support from escorts because they are ahead of or behind you.

In Strike Fighters, the really hard stuff is done for you. All you need to do is select the waypoint and fly towards it. There is really no way to get lost. The only thing not done for you is ensuring you arrive at the waypoint on time.

This section will show you how to do that using the information provided by the aircraft's instruments and one simple tool.

F-4Es enroute to the target over Germany.

There are three basic instruments you use when flying from one place to another in Strike Fighters. They are the Altimeter, Airspeed Indicator, and Horizontal Situation Indicator (HSI).

Altimeter.

The altimeter is an instrument used to measure the altitude of an object above a fixed level. The altimeter found in most aircraft works by measuring the air pressure from a static port in the airplane. Air pressure decreases with an increase of altitude — about one millibar (0.03 inches of mercury) per 27 feet (8.23 m) close to sea level.

Airspeed Indicator.

The airspeed indicator is an instrument used in an aircraft to display the aircraft's airspeed, typically in knots indicated airspeed (KIAS).

Some aircraft have an additional indicator that displays True Airspeed (TAS). This will make your job a lot easier as you will see below.

Horizontal Situation Indicator (HSI).

The HSI is an instrument that displays course and distance to a selected point. There are other functions, but course and distance is all you need to worry about for now.

Some aircraft have a compass and distance indicator instead of the HSI. For our purposes, the two are interchangeable.

Airspeed Definitions.

It is important when navigating to use an airspeed corrected for altitude and other factors. Making calculations based on what is displayed on the airspeed indicator can lead to errors.

Indicated Airspeed (IAS).

IAS is the uncorrected reading taken from the face of the indicator. It is the airspeed that the instrument shows on the dial.

Calibrated Airspeed (CAS).

CAS is basic airspeed corrected for pitot-static error or attitude of the aircraft. The pitot-static system of a moving aircraft will have some error. Minor errors will be found in the pitot section of the system. The major difficulty is encountered in the static pressure section. As the flight attitude of the aircraft changes, the pressure at the static inlets changes. This is caused by the airstream striking the inlet at an angle. Different types and locations of installations cause different errors. It is immaterial whether the status source is located in the pitot-static head or at some flush mounting on the aircraft. This error will be essentially the same for all aircraft of the same model, and a correction can be computed

Equivalent Airspeed (EAS).

EAS is CAS corrected for compressibility. Compressibility becomes noticeable when the airspeed is great enough to create an impact pressure which causes the air molecules to be compressed within the impact chamber of the pitot tube. The amount of the compression is directly proportionate to the impact pressure. As the air is compressed, it causes the dynamic pressure to be greater than it should be. Therefore, the correction is a negative value. The correction for compressibility error can be determined by referring to the performance data section of the aircraft flight manual or by using the F-correction factor on the DR computer.

True Airspeed (TAS).

TAS is equivalent airspeed that has been corrected for air density error.

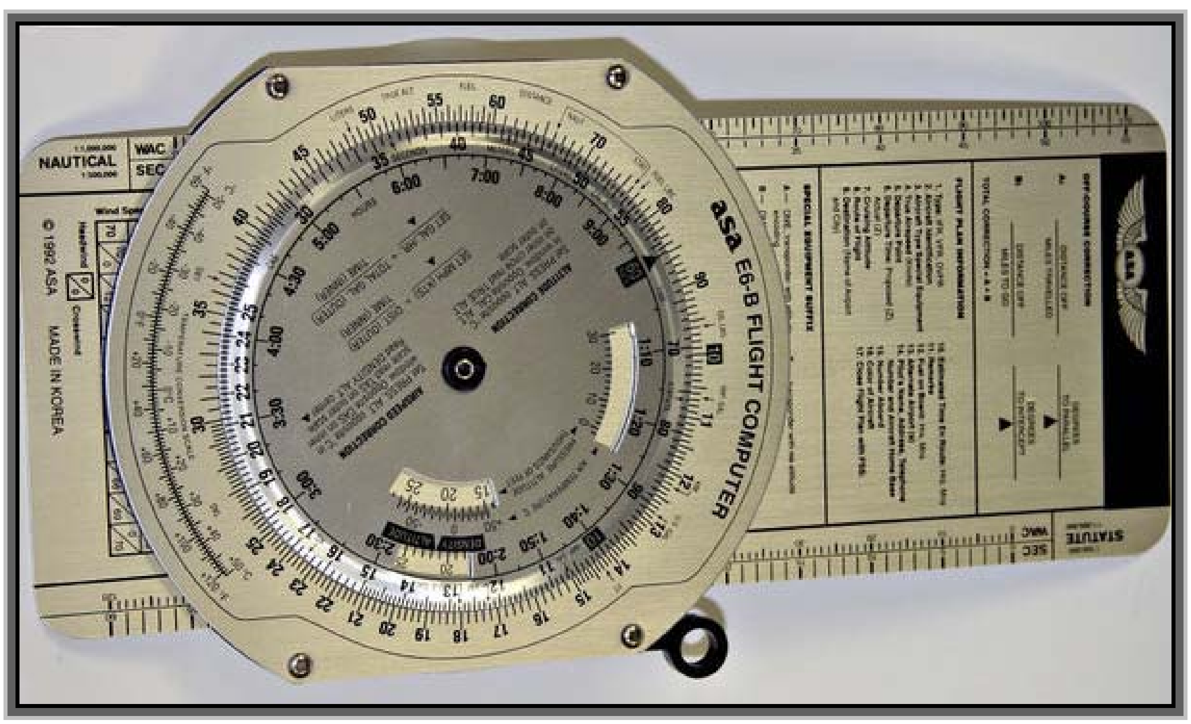
By correcting EAS, the navigator compensates for air density error and computes an accurate value of TAS. The TAS increases with altitude when the IAS remains constant. When the TAS remains constant, the IAS decreases with altitude.

You could take it a step farther and calculate ground speed based on wind strength and direction but for now, TAS will get us close enough.

Computing True Airspeed:

If your aircraft has a TAS indicator you are all set. The calculations have been made for you. If not, TAS can be computed as a function of IAS and altitude.

One of the easiest ways to do this is with a tool called the Dead Reckoning (DR) Computer, or E6B. These can be found at any aviation store. If you're on a budget a .pdf version is included that you can print out and assemble. Look for the E6B-Computer.pdf in the Weapons Delivery Manual Folder of the Weapons Pack and print it out.



The computer described here is simply a combination of two devices: a circular slide rule for the solution of arithmetical problems, and a specially designed instrument for the graphical solution of the wind problem.

The slide rule is a standard device for the mechanical solution of various arithmetical problems. Slide rules operate on the basis of logarithms. Slide rules are either straight or circular; the one on the DR computer is circular.

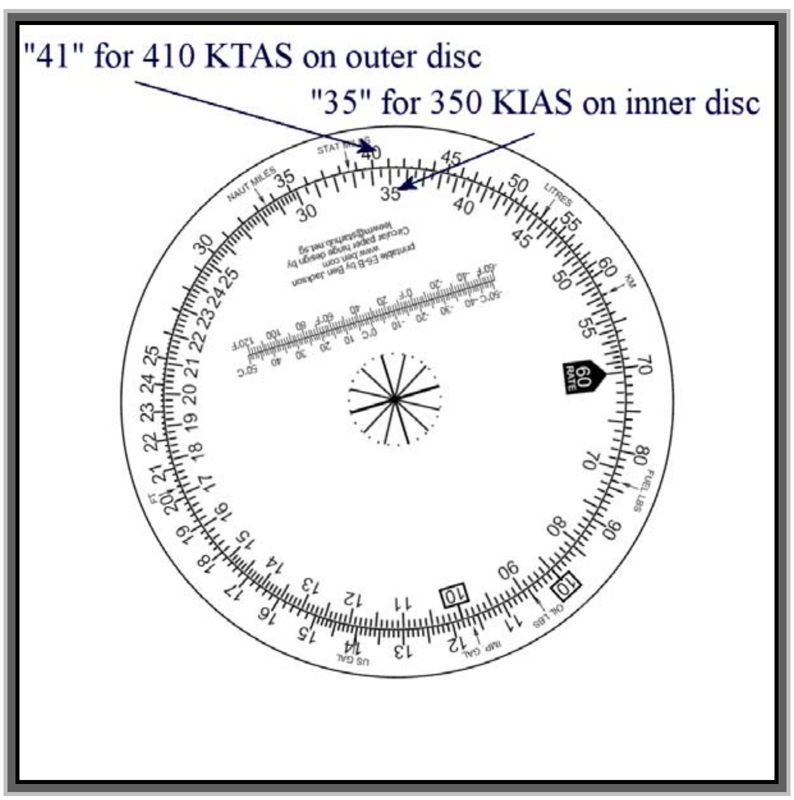
Here is an example problem for finding True Airspeed:

Altitude – 10,000 feet
Temperature – 0 Deg Celsius (I don't think this is modeled in the simulation so I just go with 0 degrees all the time.)
IAS – 350 Knots Indicated Airspeed.

1. Rotate the disc until 0deg Celsius is located directly over 10,000 feet.
(The printable computer does not have this feature.)

2. Refer to the scale on the inner disc and find "35" which represents 350 KIAS.

3. Look directly over 35 on the inner disc and find that it lines up with "41" on the outer disc.



Your True Airspeed is 410 Knots.

Computing your ETA at a waypoint.

Now that you have your True Airspeed you can calculate how long it will take to arrive at a waypoint.

We will assume for now that our airspeed is 522 KTAS.

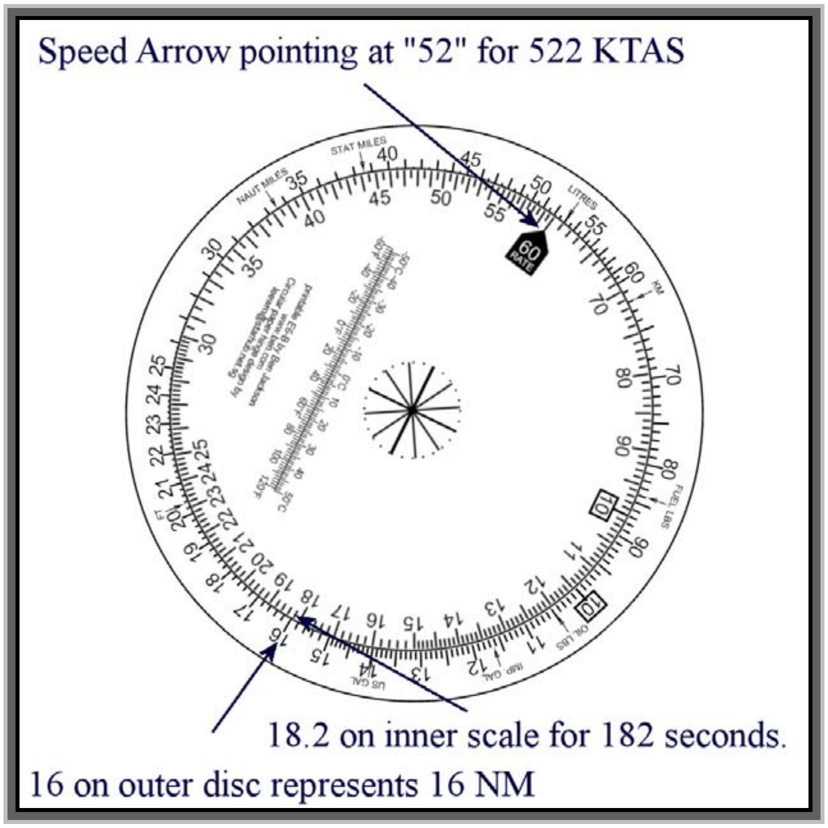
We will also assume that we are 16 miles from the waypoint.

Again, we can use the DR Computer to make the calculation.

1. Rotate the inner disc until the speed index (arrow) is pointing at “52” on the outer disc which represents 520 Knots.

2. Move clockwise on the outer disc until you find “16” which represents 16 miles.

3. Look directly below 16 and find that it is lines up at 18.2 on the scale.



It will take 182 seconds (3 minutes, 2 seconds) to reach the waypoint.

Computing the speed required to reach a waypoint at a certain time.

The time your flight is scheduled to arrive at a waypoint can be seen on the planning map before the mission starts. See "Pre-Mission Planning" in section 5 for a description of where to find this.

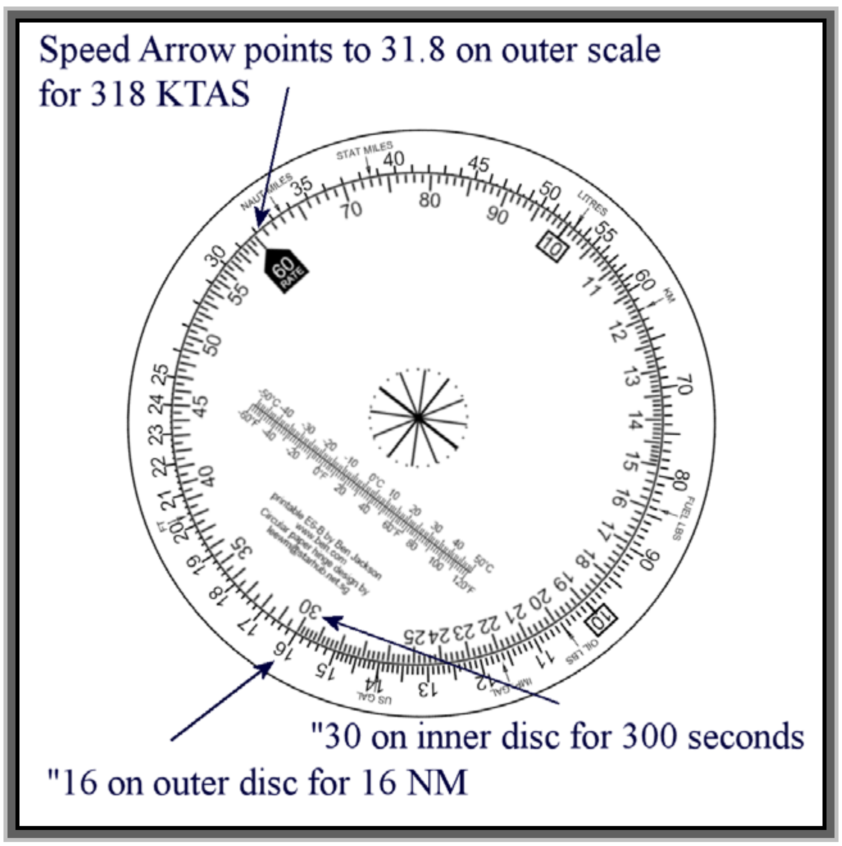
If you know what time you need to arrive at a waypoint and how far away from that point you are, you have enough information to compute an airspeed that will place you there on time.

Using the example above, let's assume that you are scheduled to arrive at the waypoint 30 minutes into the mission. You are now 16 miles away, and 25 minutes into the mission. What airspeed do you need to arrive on time?

Again, we can use the DR Computer.

1. You need to be there in exactly 5 minutes, or 300 seconds so position "30" on the inner disc directly under "16" (for 16 miles) on the outer scale.

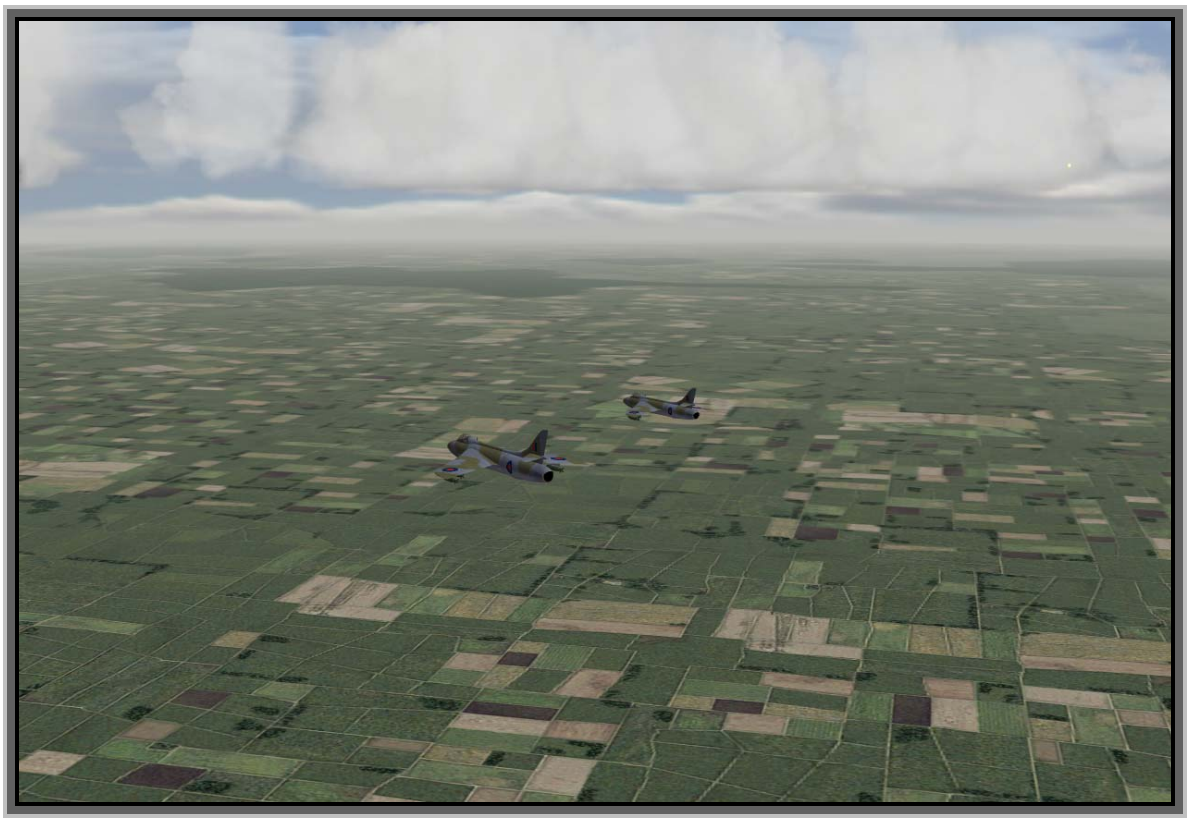
2. The speed index "arrow" is pointing at "31.8" on the outer disc.



The airspeed you need to fly at to reach the waypoint on time is 318 KTAS.

Once you have these three calculations down, true airspeed from indicated airspeed, ETA at a waypoint, and speed required to reach a waypoint at a specific time, you will have all the information you need to fly a successful mission from the navigation standpoint.

There are literally hundreds of other tutorials for these procedures on the internet that go into far more detail than I do here. Adding a little navigation to your missions can keep from getting bored on the way to the target and help with mission performance by ensuring you are in the right position to receive help from your escorts.



Hawker Hunters leaving the target area over Germany.

Ground Mapping Radar Scope Interpretation

The ground mapping radar in Strike Fighters has almost all of the functionality of the real thing. Its primary purpose is as an aid to navigation. This section discusses what you will see on the radar scope and how it can be interpreted.

For additional information on the ground mapping radar and displays see the section called “The Strike Fighters Fire Control System” below.

Basics.

The ground mapping radar display (PPI) presents a map-like picture of the terrain below and around the aircraft. Just as map reading skill is largely dependent upon the ability to correlate what is seen on the ground with the symbols on the chart, so the art of scope presentation analysis is largely dependent upon the ability to correlate what is seen on the scope with the chart symbols. Application of the concept of radar reflection and an understanding of how received signals are displayed on the PPI are prerequisites to scope interpretation. Furthermore, knowledge of these factors applied in reverse enables the navigator to predict the probable radarscope appearance of any area.

A typical ground mapping radar display.

Factors Affecting Reflection.

A target's ability to reflect energy is based on the target's composition, size, and the radar beam's angle of reflection. The range of the target from the aircraft is definitive in the quantity of returned energy. The range of a target produces an inverse effect on the target's radar cross-section. And there will be some atmospheric attenuation of the pulse proportional to the distance that the energy must travel. Generally, all four factors contribute to the displayed return. A single factor can, in some cases, either prevent a target from reflecting sufficient energy for detection or cause a disproportionate excess of reflected energy to be received and displayed.

The following are general rules of radarscope interpretation:

The greatest return potential exists when the radar beam forms a horizontal right angle with the frontal portion of the reflector.

Radar return potential is roughly proportional to the target size and the reflective properties (density) of the target.

Radar return potential is greatest within the zone of the greatest radiation pattern of the antenna.

Radar return potential decreases as altitude increases because the vertical reflection angle becomes more and more removed from the optimum. (There are many exceptions to this general rule since there are many structures that may present better reflection from roof surfaces than from frontal surfaces or in the case of weather.)

Radar return potential decreases as range increases because of the greater beam width at long ranges and because of atmospheric attenuation.

NOTE: All of the factors affecting reflection must be considered to determine the radar return potential.

Typical Radar Returns:

Returns From Land.

All land surfaces present minute irregular parts of the total surface for reflection of the radar beam; thus, there is usually a certain amount of radar return from all land areas. The amount of return varies considerably according to the nature of the land surface scanned.

This variance is caused by the difference in reflecting materials of which the land area is composed and the texture of the land surface. These are the primary factors governing the total radar return from specific land areas.

Flat Land.

A certain amount of any surface, however flat in the overall view, is irregular enough to reflect the radar beam. Surfaces which are apparently flat are actually textured and may cause returns on the scope. Ordinary soil absorbs some of the radar energy and, thus, the return that emanates from this type of surface is not strong. Irregularly textured land areas present more surface to the radar beam than flat land and, thus, causes more return. The returns from irregularly textured land areas are most intense when the radar beam scans the ridges or similar features at a right angle. This effect is particularly helpful in detecting riverbeds, gullies, or other sharp breaks in the surface height. At times, in desolate areas that are flat, these occasional surface changes are apparent where it would not have appeared in more irregular topography. Such returns provide recognizable targets in otherwise sparse circumstances. In other cases, especially at low-level over broken terrain, this effect could complicate scope interpretation.

Hills and Mountains.

Hills and mountains will normally give more radar returns than flat land because the radar beam is more nearly perpendicular to the sides of these features. The typical return is a bright return from the near side of the feature and an area of no return on the far side. The area of no return, called a mountain shadow, exists because the radar beam cannot penetrate the mountain and its LOS transmission does not allow it to intercept targets behind the mountain.

The shadow area will vary in size, depending upon the height of the aircraft with respect to the mountain. As an aircraft approaches a mountain, the shadow area becomes smaller at higher altitudes. Furthermore, the shape of the shadow area and the brightness of the return from the peak will vary as the aircraft's position changes. As the aircraft closes on the mountainous area, shadows may disappear completely as the beam covers the entire surface area. At this point, a great deal of energy is reflected back at the antenna and recognizable features in that area will be rare.

Recognition of mountain shadow is important because any target in the area behind the mountain cannot be seen on the scope. In areas with isolated high peaks or mountain ridges, contour navigation may be possible because the returns from such features assume an almost three-dimensional appearance. This allows specific peaks to be identified.

In more rugged mountainous areas, however, there may be so many mountains with resulting return and shadow areas that contour navigation is almost impossible. But these mountainous areas are composed of patches of mountains or hills, each having different relative sizes and shapes and relative positions from other patches. By observing these relationships on a chart, general aircraft positioning is feasible.

Coastlines and Riverbanks.

The contrast between water and land is very sharp, so that the configuration of coasts and lakes are seen with map-like clarity in most cases. When the radar beam scans the banks of a river, lake, or larger body of water, there is little or no return from the water surface itself, but there is usually a return from the adjoining land. The more rugged the bank or coastline, the more returns will be experienced. In cases where there are wide, smooth mud flats or sandy beaches, the exact definition of the coastline will require careful tuning.

Since both mountains and lakes present a dark area on the scope, it is sometimes easy to mistake a mountain shadow for a lake. This is particularly true when navigating in mountainous areas that also contain lakes.

One difference between returns from mountain areas and lakes is that returns from mountains are bright on the near side and dark on the far side, while returns from lakes are of more uniform brightness all around the edges. Another characteristic of mountain returns is that the no-show area changes its shape and position quite rapidly as the aircraft moves; returns from lakes change inconsequentially.

Cultural Returns.

The overall size and shape of the radar return from any given city can usually be determined with a fair degree of accuracy by referring to a current map of the area. However, the brightness of one cultural area as compared to another may vary greatly and this variance can hardly be forecasted by reference to the navigation chart. In general, due to the collection of dense materials therein, urban and suburban areas generate strong returns, although the industrial and commercial centers of the cities produce a much greater brightness than the outlying residential areas.

Many isolated or small groups of structures create radar returns. The size and brightness of the radar returns these features produce are dependent on their construction. If these structures are not plotted on the navigation charts, they are of no navigational value. However, some of them give very strong returns, such as large concrete dams, steel bridges, etc.; and, if any are plotted on the chart and can be properly identified, they can provide valuable navigational assistance.

Terrain Avoidance Radar.

Terrain avoidance radar gives the aircrew an all-weather, low-level capability. As mentioned earlier, interpreting mountain shadows on a normal radarscope can be confusing. There is no time for indecision at low altitudes and at high speeds. Terrain avoidance increases safety and eliminates confusion by displaying only those vertical obstructions that project above a selected clearance plane.

Plan Display.

The plan display is a sector scan presentation that indicates the range and direction of obstructions projecting above a selected clearance plane. The clearance plane can be manually set at any level from 3,000 feet below the aircraft up to the level of the aircraft. Only those peaks projecting above the clearance plane are displayed; all other returns are inconsequential and are eliminated. The sector scan presentation limits the returns to those ahead of the aircraft. The vertical line represents the ground track of the aircraft and ranges are determined by range marks.

Low-Level Navigation

The main reasons for conducting low-level operations are to gain the element of surprise, to avoid detection or interception, and to minimize the effect of enemy defenses.

Operations such as personnel drops and aerial resupply missions demand a low-level capability. The problem of performing accurate navigation at low altitudes differs considerably from that at higher altitudes. Low-level navigation requires comprehensive flight planning, accurate dead reckoning (DR), and extensive use of all available aids. You must work very rapidly to obtain and interpret in-flight observations. In general, low altitude flying affects the navigation problem because of reduced radar and visual range, potential adverse weather situations, and the need for reactive decision making. In addition, the normal mechanics of navigation such as writing, computing, and plotting are made difficult or impossible by turbulence encountered at low altitudes.

Planning the Mission

The key to successful low-level navigation is careful and comprehensive planning accomplished prior to the flight. Every minute spent in flight planning helps to ensure the low-level mission will be successful.

Route Determination.

Carefully select the route with emphasis upon navigational checkpoints, safety of flight, and possible threats. Turn points should be over or close to identifiable points, such as those that provide good land-water contrast or give good radar definition at maximum range.

Directness.

To conserve time and fuel, the route should be as direct as possible. A direct route also minimizes the time spent within range of enemy defenses such as surface-to-air missiles or air-to-air interceptors.

Radius of Turn.

Compute radius of turns for all turn points since the aircraft must roll out on course (unless flying point to point). Remember that flying faster or slower than flight planned airspeed will change your turn radius.

Altitude.

Terrain elevation, both along the intended flight path and adjacent to it, is an extremely important factor when planning mission altitudes. Normal altitudes for low-level combat missions are between 100 and 500 feet above ground level.

Airspeed.

Normally, low-level missions are flight planned for airspeeds that make mental DR computations simple. These are 240 knots (4 NM per minute), 300 knots (5 NM per minute), 360 knots (6 NM per minute), etc. While it is important to maintain a constant GS for accurate DR, you may have to vary the GS to control the time of arrival at turn points and over the target.

Fuel Planning.

Fuel consumption is a major consideration in low-level planning. Aircraft consume more fuel at low altitude than they do at high altitude. Since combat sorties leave very small fuel tolerances for recovery, carefully plan all phases to conserve fuel. The navigator usually assists the pilot by closely monitoring fuel quantities. The fuel consumption problem is further complicated by the variable load requirements for specific missions.

Threats.

Plot any known threats and their tactical ranges. Avoid threats to the maximum extent possible by flying around them. If unable to avoid threats, use terrain masking to reduce the effective range. If it's impossible to avoid the threat, request threat suppression or reevaluate the mission.

Weather Planning.

On combat missions, there is no designated minimum ceiling and visibility condition for low-level flight. The wind velocities encountered at low altitude over land are generally light. However, because of surface friction, particularly in rugged terrain, these winds tend to be very volatile.

Because of this inconsistency and for reasons of simplicity, low-level flight planning is normally based on no-wind conditions.

In planning low-level missions over water, spin a wind corrected flight plan for greatest accuracy. Overwater navigation depends entirely on DR and computer and/or GPS systems because of the absence of checkpoints with which to establish fixes and to make course corrections.

Chart Selection.

One of several charts may be appropriate for low altitude navigation. One chart designed for low-level use is the Operational Navigation Chart (ONC). The 1:1,000,000 scale permits identification of all visual and radar significant features and the chart has good cultural and relief portrayal. For increased detail or slower speed aircraft, the Tactical Pilotage Chart (TPC) (1:500,000) or a Joint Operations Graphic (JOG) (1:250,000) may be used.

It is possible to mix navigation charts. The en route portion of the low-level mission can be plotted on an ONC, while the TPC or JOG may be used for the target area or for specific identification of checkpoints. If available, aerial photos are very useful for route study.

Annotate items of importance to navigation (turn points, descent points, high terrain, emergency airfields, etc.) on the chart. Label preplanned fixes with planned radar range and bearing information. In all cases, the annotations should be neat and compact for quick reference. Time is critical at high speed and low altitude, so minimize the time you spend interpreting your chart in flight.

Planned Pacing.

Choose suitable topographic or cultural returns for in-flight fixing and determine a pacing schedule to accommodate these fixes. Plan the entire mission before takeoff. What you accomplish in the air is merely a follow-through of what you have previously flight planned. Because navigation demands flexibility, planning a pacing schedule involves two separate steps. First, complete a premission plan based on expected in-flight conditions. Then, construct an alternate plan in case the unexpected happens. For example, a 120-NM navigation leg, flown at 360, knots might accommodate three radar fixes. This plan becomes the primary pacing schedule for the leg. A secondary pacing plan might consider an unforeseen increase in GS and it would incorporate only two fixes. These apply to visual navigation as well as radar, but the fixes are generally closer together in visual navigation.

Radar Prediction.

Radarscope interpretation can be preplanned for low-level flights. Note significant returns, such as land-water contrast, unique terrain features, and towns. The time of year is also important since radar returns during the winter may not appear the same as in other seasons of the year.

At low altitude, the appearance of a radar return changes rapidly as the aircraft approaches or passes over the return. Often, the best identifying features of a checkpoint cannot be distinguished by radar at low altitude. Because of this reduced radar range, the navigator should use DR procedures to verify and identify radar returns.

No-return areas like lakes and rivers are better for radar prediction and navigation because they furnish more accurate fixes than do towns or similar type returns. Constantly fine-tune your tilt and gain settings; they are critical at low altitude. Use radar navigation in conjunction with an INS or GPS at lowlevel for best effect.

Visual Prediction.

In addition to the problems mentioned in radar prediction, other problems are encountered with forecasting map-reading fixes. Weather effects, such as precipitation, smoke, haze, or blowing dust, may obscure features intended for fixing. Visual navigation is especially difficult when looking into the sun, particularly in hazy conditions. Avoid using cultural features for checkpoints because they contain people and perhaps enemy forces, and during conflict should be avoided.

Course Control

Maintaining Track.

To meet controlled times of arrival and to avoid terrain hazards, attempt to fly the low-level flight exactly as planned. Every low-level navigation leg is planned within a flight corridor for safety-of-flight reasons. There are several ways to maintain course, each of which has advantages and limitations. Some of the methods are described here.

Correction to a Point on Centerline.

When radar is an available aid, use the manual cursor to correct back to centerline. Locate a suitable target on centerline and determine the intercept return to centerline. The intercept correction (degrees of heading change) is an arbitrary determination based primarily on the distance of the target from the aircraft. The closer the target is, the larger the correction will be. However, heading corrections should normally not exceed 45°. Move the manual cursor to the desired intercept angle on the side of the scope opposite the target from 360° and turn the aircraft an equal number of degrees toward the radar return. When the target falls under the repositioned manual cursor, the aircraft has returned to centerline and the heading correction should be taken out.

Example: Aircraft 3 NM right of course, target found 15 NM down course, 45° intercept. Move manual cursor 45° right (045 bearing), turn aircraft 45° left (3l5° heading). When target is under repositioned cursor, the aircraft has returned to centerline and heading correction should be taken out.

30° Intercept Method.

The 30° intercept method can be used when no target is available on course line but the relative aircraft position left or right of course is known. The steps involved to intercept course are:

Parallel course.
Determine the distance the aircraft is left or right of course and double the distance. Determine the time needed to fly the doubled distance by using current GS. Turn 30° in the direction back to centerline. When time has elapsed, turn to desired magnetic course (MC) and kill the drift.

EXAMPLE: Aircraft 3 NM right, GS 360 knots, magnetic heading (MH) 270°. Turn to 240° and hold correction for 1 minute. After 1 minute has elapsed, return to MH 270°.

Off-Course Correction Tables.

Off-course corrections can also be determined by using the table shown in Figure 1. Enter from the top of the table with the miles-off-course, go vertically to the line representing miles flown, and read the correction to intercept. You must be paralleling course to use this table.

Correction to Intercept Course.

The graph shown in Figure 2 is used when it is necessary to intercept course rather than converge at the turn point. To use this graph, the entering arguments are NM off course and GS. The table can be used for fixed alterations of 15°, 30°, or 45°. Enter the graph on the left with NM off course; go horizontally across the chart to the line representing GS. Then, go vertically to the top or bottom (depending on the desired degrees to alter) to read the time required to intercept course. After altering the indicated time has elapsed, correct back to the original heading to maintain desired course.

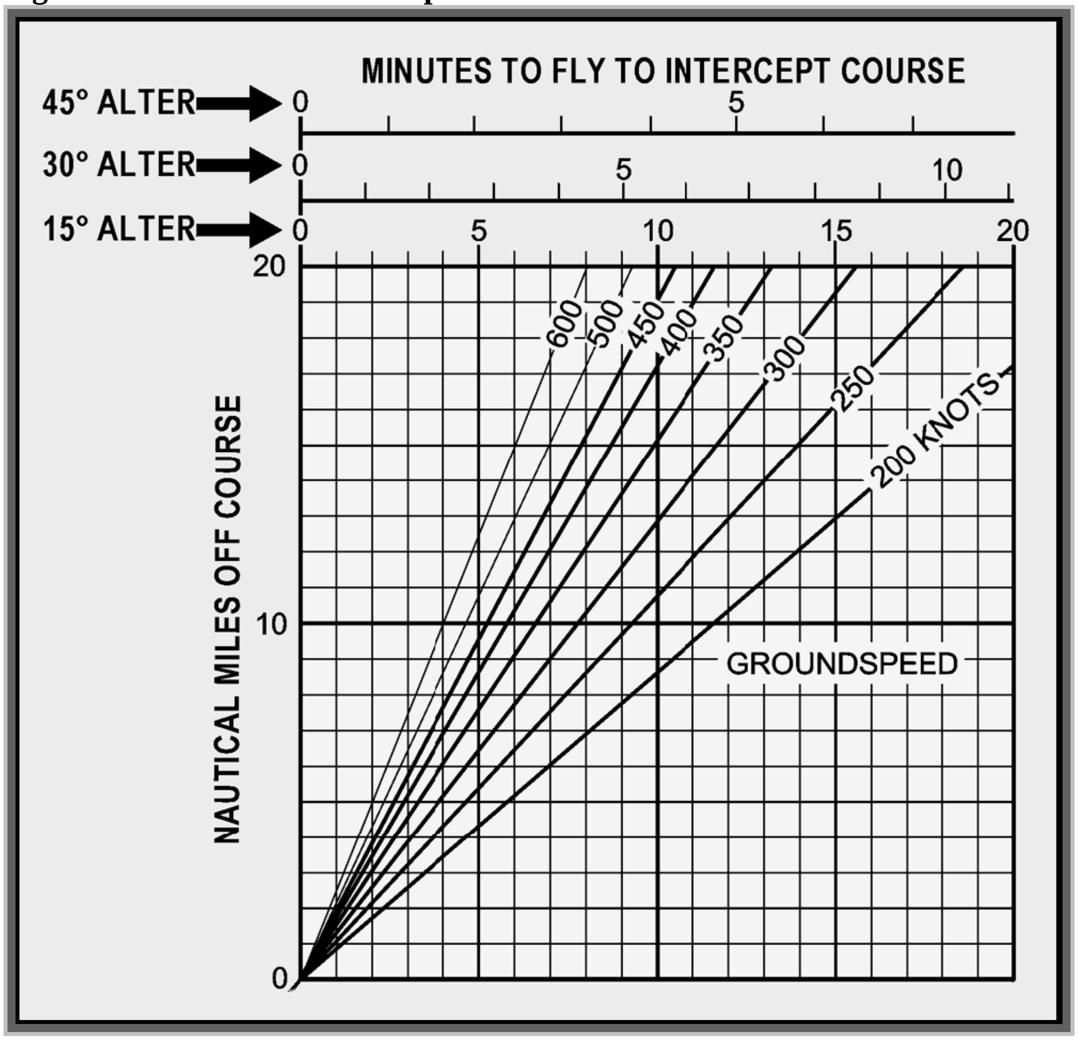
Sixty-to-One Correction.

One degree of latitude, measured along a meridian, is equal to 60 NM and 1 minute of arc is equal to 1 NM. If you're 60 NM from the next turn point, 1 NM off course and paralleling course (drift killed); a 1° turn toward centerline will put the aircraft over the turn point. Most of the time you will be less than 60 NM from the turn point; therefore, divide 60 by the distance to go to the next turn point, then multiply by the number of NM off course. For example, if 30 NM from the turn point and 3 NM left of course, take 60/30 X 3 to get a 6° required correction. Apply the 6° to the desired MC and kill the drift for a good heading to correct back to the turn point.

Figure 1. Off-Course Correction Table.

Miles	Miles Off Course										
	1	2	3	4	5	6	7	8	9	10	15
To Fly	Correction In Degrees To Intercept Course										
2	30	60	--	--	--	--	--	--	--	--	--
4	15	30	45	60	--	--	--	--	--	--	--
6	10	20	30	40	50	60	--	--	--	--	--
8	8	15	23	30	38	45	53	60	--	--	--
10	6	12	18	24	30	36	42	48	54	60	--
12	5	10	15	20	25	30	35	40	45	50	--
14	4	9	13	17	21	26	30	34	39	43	--
16	4	8	11	15	19	23	26	30	34	38	56
18	3	7	10	13	17	20	23	27	30	33	50
20	3	6	9	12	15	18	21	24	27	30	45
22	3	5	8	11	14	16	19	22	25	27	41
24	3	5	8	10	13	15	18	20	23	25	38
26	2	5	7	9	12	14	16	18	21	23	35
28	2	4	6	9	11	13	15	17	19	21	32
30	2	4	6	8	10	12	14	16	18	20	30
32	2	4	6	8	9	11	13	15	17	19	28
34	2	4	5	7	9	11	12	14	16	18	26
36	2	3	5	7	8	10	12	13	15	17	25
38	2	3	5	6	8	9	11	13	14	16	24
40	2	3	5	6	8	9	11	12	14	15	23
42	1	3	4	6	7	9	10	11	13	14	21
44	1	3	4	5	7	8	10	11	12	14	20
46	1	3	4	5	7	8	9	11	12	13	20
48	1	3	4	5	6	8	9	10	11	13	19
50	1	2	4	5	6	7	8	10	11	12	18

Figure 2. Correction to Intercept Course.



Ten, Twenty, or Thirty Degree Correction Technique.

This course correction technique is used when 3 NM or less off course. It uses 10°, 20°, or 30° heading corrections back to centerline, depending on your distance off course. Begin by paralleling course. Second, determine the distance left or right of course. Third, multiply the number of NM off course by 10 to determine the number of degrees to turn toward centerline. Fourth, hold the correction for 6 NM of travel (example, 300 knots GS 1:12, 360 knots GS 1 minute). At the end of the time, turn back to MC and kill the drift.

Time Control

Positive time control of aircraft flying low-level missions is imperative. Each sortie is assigned a specific time to arrive at each designated turn point and over the target zone. Failure to meet your ETA precisely can result in aborted missions or two aircraft occupying the same airspace simultaneously (very bad). Annotate route legs on the chart with a series of small time ticks drawn across the leg. Space these time ticks 1 minute apart according to forecast GS; for example, 6 NM apart for a planned GS of 360 knots. Time ticks begin at the low-level entry (starting) point and continue through the entire route to the target. With these time ticks, you can check the time over each tick and keep a running account of whether the aircraft is ahead of or behind the required time schedule.

Methods of Time Control.

If you need to change GS, use an established method to make this change accurately and quickly. Six methods are presented in the following paragraphs. These are not the only accepted methods but are some of the easier methods to use. As with most time corrections, these methods are based on flight planned GS.

Proportional Method.

The proportional method can be used either high or low-level. Begin by determining the number of seconds early or late. Next, increase or decrease flight planned GS by that increment (20 seconds = 20 knots). Hold this correction for the following length of time: flight planned GS/60 minutes (360 knots/60 = 6 minutes).

EXAMPLE: You are 30 seconds late and your flight planned GS is 420 knots. Increase flight planned GS (420 knots) by 30 knots (450 knots) and hold it for 7 minutes.

Total Time and/or Total Distance.

This method is normally used at high-level but also applies to low-level. Check the distance to your next checkpoint and compare current Zulu time with desired Zulu time at the next checkpoint. This will give you a time and distance to go. Set up a ratio on the MB- 4 computer by putting the desired time to go over the distance to go and look above the rate index for the required GS.

EXAMPLE: Current Zulu time is 1100:00 and distance to go is 140 NM. Desired ETA at the next checkpoint is 1120:00. You must fly 140 NM in 20 minutes or 420 knots GS (140 NM/20 minutes = 420 knots GS/rate index).

Turn Point Method.

During mission planning, a correction factor can be calculated for each low-level leg. This is done by multiplying each low-level leg time by the appropriate coefficient (Figure 17.3). The correction factor calculated for each leg equals the number of seconds gained or lost for each 10 knots of speed change from flight planned GS over the entire leg.

EXAMPLE: Leg time is 7 minutes, 42 seconds. Flight planned GS is 420 knots. Coefficient extracted from Figure 3 is 1.5. Multiply leg time by coefficient factor (7:42 x 1.5) to equal approximate correction factor of 12. You are 36 seconds late at your last turn point (based on Zulu time). You will gain 12 seconds over the length of the low-level leg for each 10 knots increase in flight planned GS. Therefore, an increase in flight planned GS of 30 knots to 450 knots will gain 36 seconds if 450 knots is held for the entire leg.

Figure 3. Coefficient Table.

Planned GS	Coefficient
180-240	3.0
240-360	2.0
360-600	1.5

Six Minutes Out Method.

To use this method, determine the distance remaining to a checkpoint 6 minutes prior to the time required over the turn point. Multiply this distance by 10 to get required GS to fly to turn point, starting 6 minutes out.

EXAMPLE: Required time at checkpoint is 1413:27. Six minutes before (1407:27) you are 38.5 NM from the turn point. A GS of 385 knots at 1407:27 will put you at the checkpoint on time.

Ten Percent Method.

Determine the amount of time to gain or lose. Adjust your GS to 10 percent above (if late) or below (if early) of the flight-planned GS (10% x 300 knots = 30 knots). The rule states that holding the 10 percent increase or decrease of flight-planned GS for 10 minutes will gain or lose 1 minute. This also means that one can gain or lose 6 seconds for every minute the adjustment is maintained. To apply this method, determine the 10-percent factor during mission planning.

EXAMPLE: In flight, you determine you are 35 seconds late. Your flight-planned GS is 300 knots. You should increase your GS by 30 knots (to 330 knots) and hold it for 6 minutes. This will make up 36 seconds.

Incremental Method.

To determine the increment, you must find your miles per minute (300 knots = 5 miles per minute). Multiply that by 10 to obtain the increment (5 X 10 = 50 knots). Determine time ahead or behind in seconds. Divide this time by 10 to obtain the number of minutes to hold the correction. The rule of thumb states that if the increment is held for 1 minute, you will gain or lose 10 seconds.

EXAMPLE: You are 90 seconds late and your flight-planned GS is 300 knots. The increment is 50 knots. Increase flight-planned GS (300 knots) by 50 knots (350 knots) and hold it for 9 minutes.

NOTE: Remember that most methods are based on flight-planned GS. Apply the correction to the flightplanned GS, not the current GS.

Summary.

The most important phase of the low-level mission is flight planning. If the mission is planned well and there is good crew coordination, mission success is greatly enhanced. Consequently, you should (1) know what aids will be available, (2) be familiar with all phases of the particular mission and study them until a clear mental picture of the flight emerges and finally, (3) maintain good, reliable in-flight DR procedures. If you do all this, the low-level mission will be greatly simplified. If not, the chances of success are greatly reduced.

Weapon Delivery Considerations

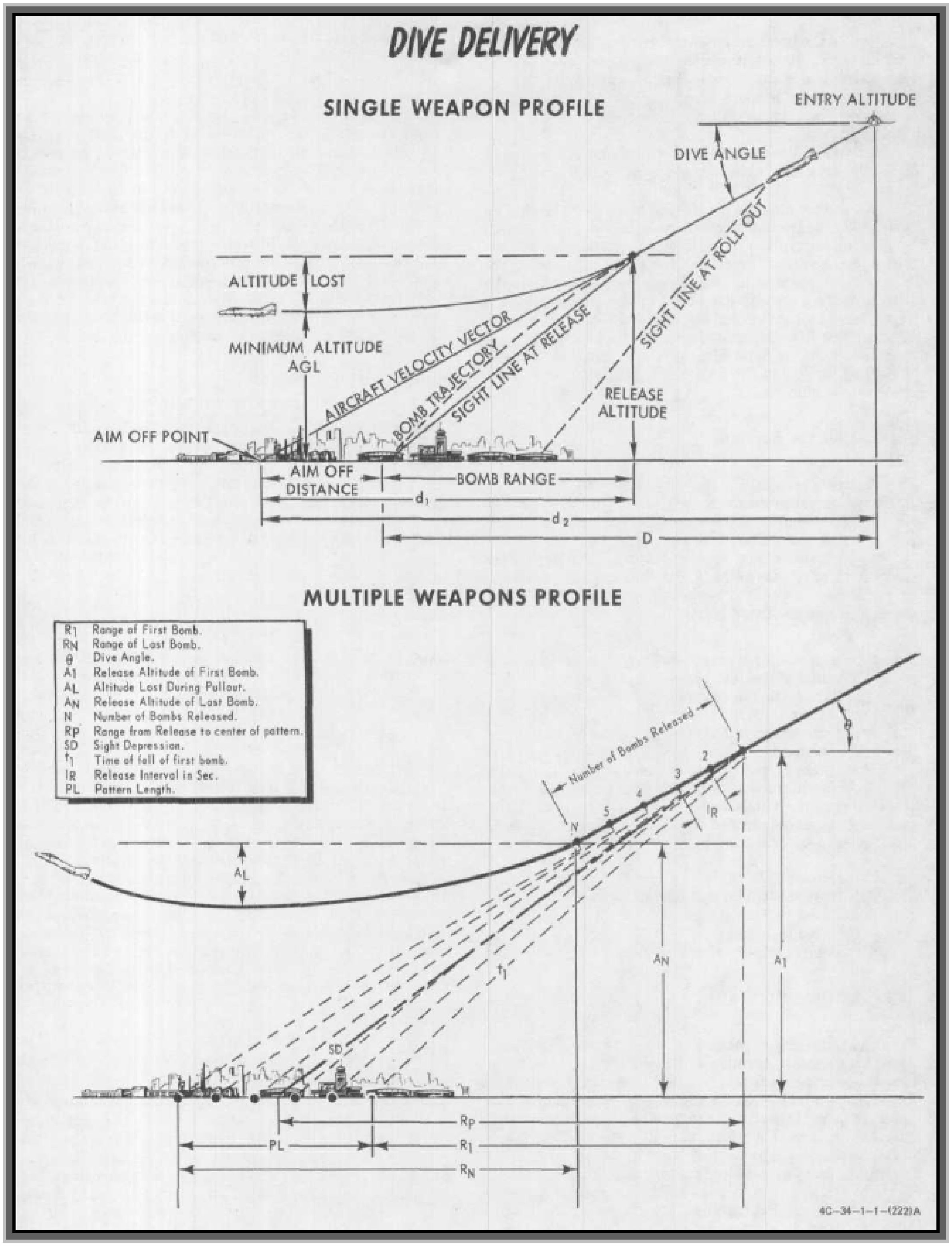
This portion of the manual discusses the various air-to-ground delivery maneuvers used to deliver ordnance.

Visual Dive Bombing

The avionics and ballistics data provided in this manual supports the basic dive, level, and the loft delivery flight path. The dive and level release maneuvers may be used in most any strike situation against targets of opportunity or preplanned targets of known location. The loft maneuver is used only against targets of known location, and enroute IP's and run-in headings must be accurately determined. This discussion considers no one specific munition, but simply describes the delivery maneuver with respect to a munition type and the aircraft avionics.

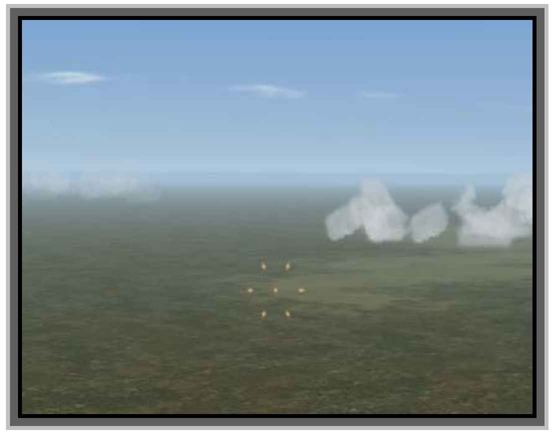
BOMB MUNITIONS.

A typical dive delivery profile is shown below. The upper profile demonstrates delivery parameters for a single weapon release. The lower profile, which is simply an extended case of the upper, shows parameters for a multiple weapon release at consistent intervals. Although some of the release parameters for the two profiles are quite different, the flying involved is essentially the same.


DIVE DELIVERY
SINGLE WEAPON PROFILE
ENTRY ALTITUDE
DIVE ANGLE
SIGHT LINE AT ROLL OUT
ALTITUDE LOST
MINIMUM ALTITUDE AGL
AIRCRAFT VELOCITY VECTOR
BOMB TRAJECTORY
SIGHT LINE AT RELEASE
RELEASE ALTITUDE
AIM OFF POINT
AIM OFF DISTANCE
BOMB RANGE
d1
d2
D
MULTIPLE WEAPONS PROFILE
R1 Range of First Bomb.
RN Range of Last Bomb.
θ Dive Angle.
A1 Release Altitude of First Bomb.
AL Altitude Lost During Pullout.
AN Release Altitude of Last Bomb.
N Number of Bombs Released.
RP Range from Release to center of pattern.
SD Sight Depression.
t1 Time of fall of first bomb.
IR Release Interval in Sec.
PL Pattern Length.
Number of Bombs Released
N
5
4
3
2
1
θ
IR
AL
AN
A1
t1
SD
RP
PL
R1
RN
4G-34-1-1-(222)A

The optical sight is the primary aiming device for the dive weapon release. The ballistics data provides sight depression values (at the release point) for given dive angles, release altitudes, and release velocities for the specific munition shape. The table sight depression value is given with respect to aircraft flight path.

On some aircraft, the sight will not be visible when set to low settings. One trick to use, is “blinking” the cockpit on and off using the . key on the number pad. You can then pick a point under the sight glass where the sight would be to use as a reference.



In the accompanying screenshots, I planned to bomb the target from 1,500 feet above ground level, 500 KCAS, and in a 20 degree dive. I’m using inert Mk 82s with a spotting charge. The target elevation is 1,500 feet so to bomb from 1,500 feet above the ground, I must release at 3,000 feet above sea level.

The sight setting for this combination is 99 mils.

For now, the sight must be set to the desired setting prior to flight. This can be done by opening the aircraft’s xxxx_cockpit.ini file and adjusting the “DefaultDepression=” setting as seen here.

[GunsightFront]
HasGunsight=TRUE
GunsightMilSize=50
GunsightName=F-100d_sight.tga
LeadComputing=TRUE
MinLeadRange=182.88
MaxLeadRange=1828.8
DefaultLeadRange=300
MaxDepression=250
DefaultDepression=99

Tables showing proper sight settings for a given airspeed and dive angle may be found in Section 7 of this manual.

Other aircraft equipment used in dive bombing is the airspeed indicator to establish release speed, the altimeter to establish release height, and the attitude indicator as a dive angle reference.

The attitude indicators that come with most aircraft are not accurate and can not be used for dive bombing.

Corrected indicators for the default aircraft are included with the Weapons Pack aircraft data.

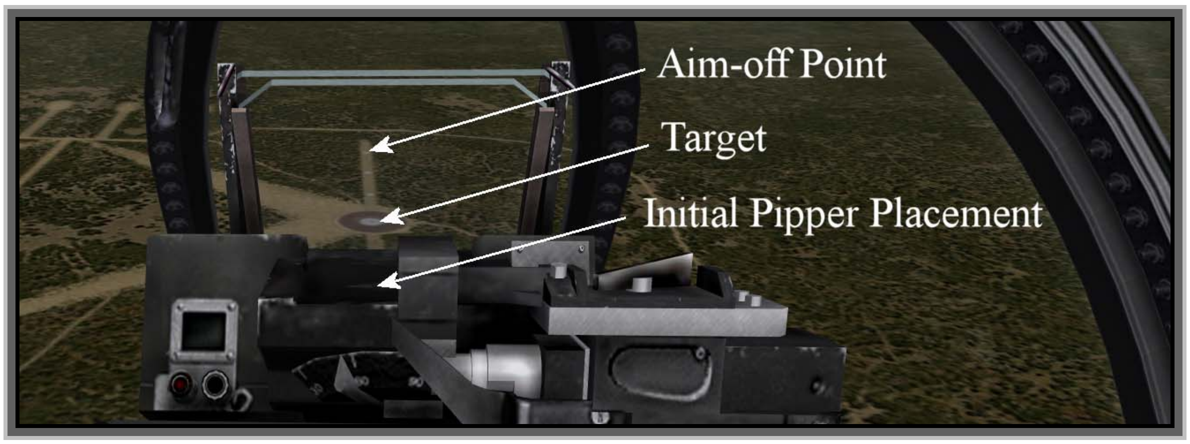
Before the bomb run, neutral rudder trim should be accomplished at or near the planned delivery speed.

Establishing the roll-in point is the most important phase of a dive bomb pass. This point establishes the ease with which the pilot will achieve the release conditions. For a given entry altitude, the desired dive angle can be achieved with reasonable accuracy by beginning the roll-in at the correct horizontal range from the target. This position may be estimated using the pilot's experience or the pilot may attempt to locate a landmark/IP at the appropriate distance (D) from the target (see the above figure):

D = d2 - (d1 - Bomb Range)

where d2 and d1 are horizontal ranges for the entry altitude and release altitude respectively.

At roll out, the aircraft velocity vector (dive angle flight path) should be established on the aim-off point beyond the target a distance (the Aim-off Distance) equal to (d1 - Bomb Range). The depressed sightline (pipper) at roll out will be short of the target and as the dive continues, the pipper will track toward the target.



Hence, as the pipper reaches the target, release velocity and altitude requirements should be met and the pilot applies the release signal. The wings must be level and normal acceleration (for that dive angle) must be maintained until the bomb (or last bomb) is released. If the dive angle is initially observed to be in error, the pilot may lead or delay release by a few mils in an effort to compensate.

Immediately following release, the pilot initiates recovery from the dive and takes any required evasive action.

Several factors must be considered when determining an indicated release altitude: altitude loss during pullout, minimum aircraft ground clearance, altimeter lag, altimeter position error, and target elevation. See “Planning Your Attack the Scientific Way” in section 5 for additional information.

Ripple Release Bombing.

The factors previously stated also apply to a ripple or multiple weapons release mode. The weapons are released along a planned ground track to impact on an area target. For a diving maneuver, the weapon spread for a given release interval setting is a function of the horizontal component of release velocity, the dive angle, the change in release altitude between bombs.

A “Ripple Release Planner” is included in the Weapon Deliver Manual folder of the Weapons Pack. Calculations regarding ripple release pattern lengths and intervalometer settings can be made there.

Additional considerations are listed below:

a. Safe escape and dive recovery must be based on the release altitude of the last bomb.
b. The sight setting or bomb range is computed to place the center of the impact pattern on target.
c. Wind correction is based on the time-of-fall of the first bomb released.
d. During the ripple release, a straight line flight path should be maintained; the pipper will pass beyond the target during the ripple release. If a straight line flight path is not observed prior to and during the ripple release, the following adverse conditions can be expected:

(1) Increased dive angle.
(2) Increased altitude lost during recovery.
(3) Reduced pattern length,
(4) Reduced G-loading.
(5) Possible bomb-to-aircraft collision.

High/Low Drag Bombs.

As far as the flying is concerned, there are no particular differences between the dive delivery of high and low drag bombs. Low drag weapons, however, essentially maintain the airplane release velocity and depending on the release maneuver, may impact close to a point directly under the delivery airplane. Therefore, careful consideration must be given to tables that provide bomb fragmentation data and minimum release altitude information to ensure that adequate escape conditions exist, especially in low altitude, low angle dive bombing.

The high drag weapon on the other hand decelerates rapidly allowing the delivery aircraft considerable trail distance at impact. This in turn safe escape and fuze data tables are provided for both weapons so that the aircrew may compensate for the limited regions of operation.

For both high and low drag bombs, wind can be compensated for by releasing with the pipper on the upwind aimpoint, or the crabbing method may be used by releasing with the pipper long/short of a line that passes through the target and is perpendicular to the aircraft ground track.

Due to the small bomb trail distance of low drag bombs, a crosswind is almost totally corrected for by crabbing the airplane so that the ground track is over the target. For high drag bombs, the airplane ground track must be offset upwind to compensate for the large bomb trail distance.

FIRE BOMB DELIVERY.

Ballistic tables are provided for the dive delivery of both finned and unfinned fire bombs. The only added consideration here is that the sight depression values in the tables are for a hit on target. If it is necessary to get impact short of the target, the distance must be estimated or the depression value may be recomputed (decreased) using the sight depression charts.

DO NOT fly through Fire Bomb smoke within 20 seconds of burst as a compressor stall or flameout could occur.

ROCKET LAUNCH.

The launching of 2.75 inch rocket munitions requires the same considerations with respect to flying the launch dive angle, launch altitude and velocity. Mil depression values are provided as a function of these parameters for several gross weights. Escape considerations, however, must include the fact that the launch aircraft is flying toward the rocket impact/frag area, with the possibility of secondary target explosions. The escape data provided for 2.75 inch rockets does not consider terrain avoidance or secondary explosions. Normally, fuze arming data is not a consideration in rocket ordnance deliveries, except when the WDU-4/A Flechette warhead is aboard.

GUN FIRING.

Firing parameters of speed, dive angle and angle of attack (as compared to other weapons) have negligible effect on projectile accuracy; slant range from target is the most important factor.

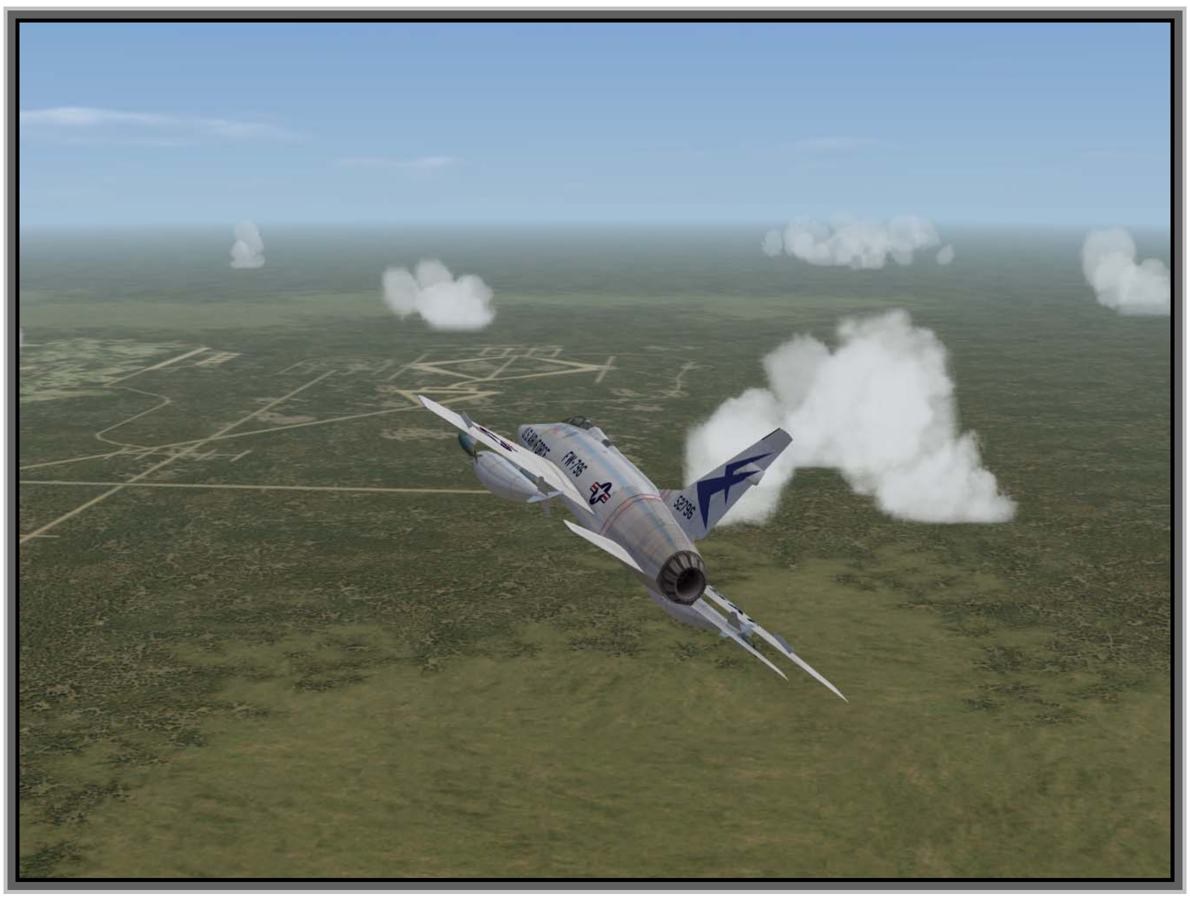
Depending on the type of target, the pilot has the prerogative of firing by one of two ways and the flying involved is slightly different for each. For an area target, for example, the pilot may walk the projectiles along an impact corridor. The dive angle is held constant and firing commences as the pipper reaches the leading edge of the target area and ceases at the desired point. The flying and the optical picture is essentially the same as the rocket or multiple bomb delivery.

This procedure is unacceptable for pinpoint targets since most of the rounds would be totally ineffective. If the pilot fires a 1.0 to 2-second burst, for example, the aircraft distance from target (during the burst) closes at rates of 600 to 800 feet per second. The result is that the burst commences at or slightly outside of the given sight depression range, and terminates at a distance inside the given depression range. The actual sight depression range set into the sight is valid essentially for one point in space, and for one round fired at that point. Therefore, the tendency of the pipper (and the rounds fired) to move through and beyond the target during the burst must be reversed.

One way to accomplish this is to fly the airplane so that the pipper comes to a point above and nearly tangent to the upper edge of the target. At the estimated initial firing range, allow the pipper to move downward at a smooth rate and commence firing as the pipper initially moves into the target image. Cease firing when the pipper moves below and tangent to the lower edge of the target, and immediately initiate the recovery maneuver.

The net result is that the pilot is inducing a very slight change (increase) in dive angle throughout the burst duration. There are of course, variations to the procedure which can be applied to suit the individual and his methods of tracking a target. The pilot must exercise caution and avoid target fixation since procedures such as these require more concentration.

Safe escape considerations when firing the 20mm gun must include terrain avoidance, ricochet, and target explosions.

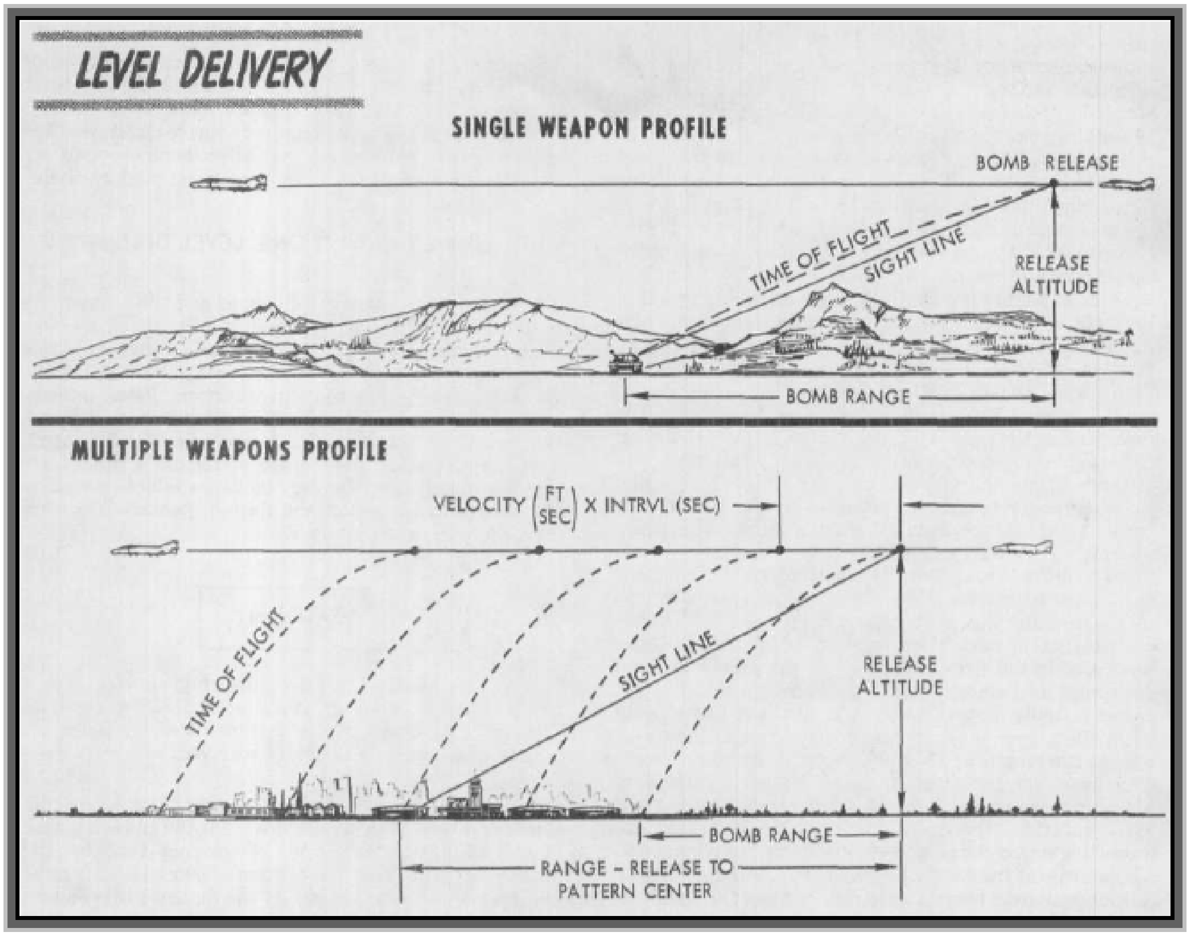


Level Delivery

The level delivery is simply an extension or a special case of low angle dive bombing where the dive angle is zero. The delivery serves well in situations where the aircrew wishes to release close to the target and at the lower delivery altitudes. The pilot may release weapons for a single point target, or release multiple weapons at a planned interval to cover an area target.

Gun and rocket munitions are normally not used during a level delivery unless the target has adequate vertical definition.

The approach to the target is performed at a constant altitude with wings level, and at a stabilized airspeed.



After bomb release, the aircraft may continue the approach course and speed or perform the required evasive maneuver. The most sensitive parameters that affect bombing accuracy are the release altitude above target and pitch attitude.

HIGH/LOW DRAG WEAPONS, LEVEL DELIVERY.

The high drag versions of GP bombs and CBU dispensers and the fire bomb weapons afford the best low altitude/close-in release capabilities. Some of these munitions can be delivered at altitudes of 50 and 100 feet. However, when weapon and fuze functioning time periods, terrain avoidance, or frag envelope data must be observed, the release altitudes must be increased accordingly.

Therefore a rather wide range of release altitudes are provided in the level delivery ballistics tables, especially for stores such as leaflet and flare dispensers.
For missions involving a given number of high drag weapons released in train, the pattern length is a function of the number of weapons released, the interval setting and the aircraft velocity. The sight depression values are based on the distance between an impact point in the center of the pattern and the release point of the first weapon. This distributes the pattern evenly along the desired target area.

During low level deliveries with aircraft in trail, DO NOT fly over or near the target area within 20 seconds of detonation. Aircraft damage can result from flying debris.

During low altitude level training missions, at least 20-seconds spacing between aircraft must be observed when inert or sand filled bombs are released. Observing the 20-second spacing prevents a bomb-to-aircraft collision in the event a bomb releases low drag and ricochets into the air after impact.

The level delivery of low drag bombs that are fuzed to detonate at impact normally involves the release of only a single weapon. The minimum release altitudes can be as low as 500 feet, provided a climbing military power escape maneuver is flown immediately after release. The escape tables list those weapons that are frag-critical and show the minimal release altitudes and required escape conditions for each. If release altitudes are increased as the level escape tables show, multiple low drag weapons can be released at set intervals using a level escape.

Bombing with CCIP

The CCIP, or Computer Calculated Impact Point, provides a visual display of the projected weapon impact point on the HUD. A bomb fall line is provided as an aid to lining up the CCIP pipper with the target. A common technique is to place the bomb fall line over the target and “walk” the pipper onto the target. When the pipper is directly over the target, release the weapon.

The solution is usable for both dive and level deliveries. Since the solution is based on automatic weapon ballistics, complete freedom to maneuver is available prior to release. However, a stable bombing pass will give best results.

Ninety-nine percent of the techniques used for visual dive bombing with a fixed reticule carry over to bombing with CCIP. The only difference is that the projected impact point is displayed. This means that corrections to the release point for being too shallow in the dive, too fast, or at the wrong altitude are performed for you. Otherwise, the procedures and techniques are identical.

Intercept Considerations

The following comments are intended as aids and are not to be considered mandatory. Portions of this information are qualitative in nature, and should be considered for guideline purposes.

The pilot should plan the intercept as far ahead as possible. From all available information, the problem should be assessed and a mental picture of the tactical situation constructed. Throughout the intercept, the pilot should be comparing what is happening with what should be happening. In so doing, the pilot can determine when something is going wrong and take timely corrective action.

In general, the performance of the radar has an overriding influence on system effectiveness. Probability of kill is greatly enhanced when radar detection and lock-on can be achieved. In order to achieve radar detection and lock-on with high probability, the radar presentation must be free or nearly free of ground reflections. In general, this means that the aircraft must be placed at or below the target altitude for targets below about 5000 feet. This requirement relaxes as target altitude increases until a target at 30,000 feet can be detected from maximum attainable level flight altitude. There are no overriding radar influences on direction of approach to target (nose or tail).

With radar guided missiles, frontal attacks are more effective than tail or beam attacks. If the interceptor can be placed at or below the target in forward hemisphere attack, optimum kill probability is attained for any altitude target. For a forward hemisphere look-down situation (target below 5000 feet with interceptor above), the missile seeker is not degraded, but lock-on by the radar is more difficult. Rear hemisphere attacks have generally lower probability of success since in this case missile seeker capability is generally poor at very low interceptor and target altitudes and improves as interceptor altitude increases, until approximately 20,000 feet where only slight degradation exists. The placement of interceptor below targets for radar lock-on holds for rear hemisphere as well as front, radar lock-on prior to launch is extremely important for missile success.

The technique employed depends on the type control under which the interceptor is operating. The accuracy of target heading, altitude and speed determine how the attack is to be conducted.

LOW LEVEL INTERCEPT

For purposes of discussion:

a. Low altitude intercept operation over water consists of searching for and tracking targets below 1000 feet.
b. Low altitude over land is considered to exist when the ground return precludes normal operating techniques.

When operating in this environment, the pilot should strive to be at least co-altitude and preferably below the target, as an antenna look down angle makes detection more difficult and lock-on less stable. A head-on reciprocal heading intercept at low level can be converted to a forward quarter which lends itself to a re-attack without breaking lock with the conversion being initiated as late as 10-15 miles.

The Strike Fighters Fire Control System

The primary purpose of the Fire Control System (FCS) is to perform necessary guidance and control function to launch a missile against an airborne target. The FCS is capable of airborne radar search, automatic range and angle tracking, ground mapping, and terrain avoidance functions.

All FCS functions differ slightly from aircraft to aircraft.

Operating Controls and Indicators

The operating controls for the FCS are located on the keyboard and consist of the Insert, Home, Page Up, Page Down, End, and Delete keys. These controls can be mapped to any key or button.

Radar Power.

The radar starts the mission powered down. You must turn the radar on in order to use it during the mission. You can cycle the radar on and off using the <**Ctrl - Page Up>** key combination.

Radar Modes.

There are four basic radar modes to choose from: search, boresight, ground map, and terrain avoidance. You may cycle through available modes using the <**Page Up>** key.

Radar Range.

Radar range may be cycled using the <**Page Down>** key. The ranges available will differ based on the aircraft and mode selected.

Target Cycle.

You may cycle between targets displayed using the <**Home>** key. This only functions in the Search radar mode.

Target Lock.

You may command the FCS to lock a target using the <**Insert>** key. This only functions if you are in the Search radar mode and have selected a target using the <**Home>** key.

In Range Indicator.

On some aircraft, an In Range Indicator illuminates when the target is between the maximum and minimum range of the selected weapon.

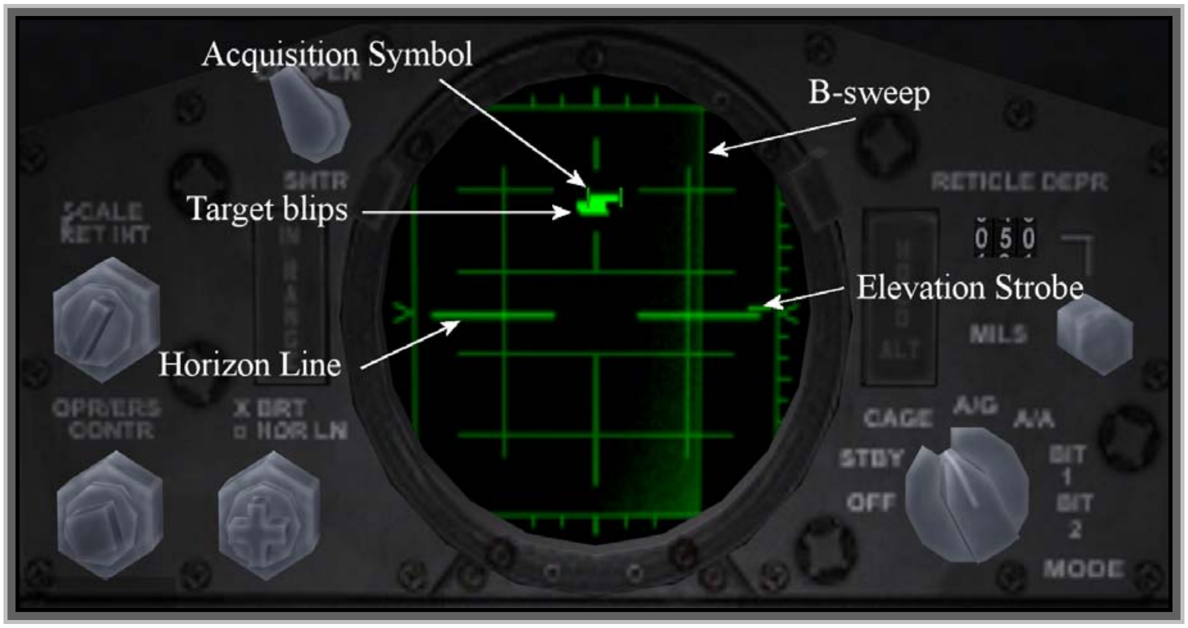
Break Indicator.

On some aircraft, this illuminates when the target is below the minimum range of the selected weapon. This may also be displayed as an X on the Radar Display.

Radar Displays

Search Display.

While in the search radar mode, the display consists of a B-Sweep, a horizon line, acquisition symbol, and an elevation strobe.



B-Sweep.

The B-Sweep is a thin vertical line with the side to side position representing antenna azimuth and range along the line representing display range. In short, this shows you where your radar is pointing. Targets are displayed as blips of light on the B-Sweep at their respective range and azimuth bearings.

Horizon Line.

The horizon line duplicates the information presented on a standard aircraft gyro artificial horizon line. The horizon line is a straight line with the center third blanked. With zero roll and climb angles the horizon line is horizontal on the display. Climb or dive angles up to 90 degrees move the horizon line up or down (maximum pitch displacement of scope is 55°) and roll signals tilt to display aircraft attitude.

Elevation Strobe.

The elevation strobe is a horizontal line on the right edge of the scope. The vertical position of the elevation strobe during search and track operation indicates antenna elevation angle with respect to the centerline of the aircraft.

Acquisition Symbol.

The acquisition symbol is a pair of parallel vertical bars about one eighth or one quarter of an inch long and about one quarter of an inch apart. The symbol is used to select a target for tracking. Azimuth position indicates the position to which the antenna will slew when the **Insert** key is pressed. Vertical position is used to select desired target range.

Boresight Display.

When the boresight radar mode is selected, the antenna is positioned 2° below the fuselage reference line and 0° in azimuth. The antenna is not drift stabilized; the B-sweep remains centered on the scope regardless of aircraft drift.

In boresight mode, the auto-acquisition of the target is possible. The target must be within the B-sweep to obtain a lock-on. The radar beam is 4.7° or approximately 82 mils in diameter. Therefore, when the target is within 41 mils of the pipper, the target should be in the B-sweep.

When the target enters the B-sweep, the radar system will lock on and provide full angle and range tracking. The track display appears on the scope.

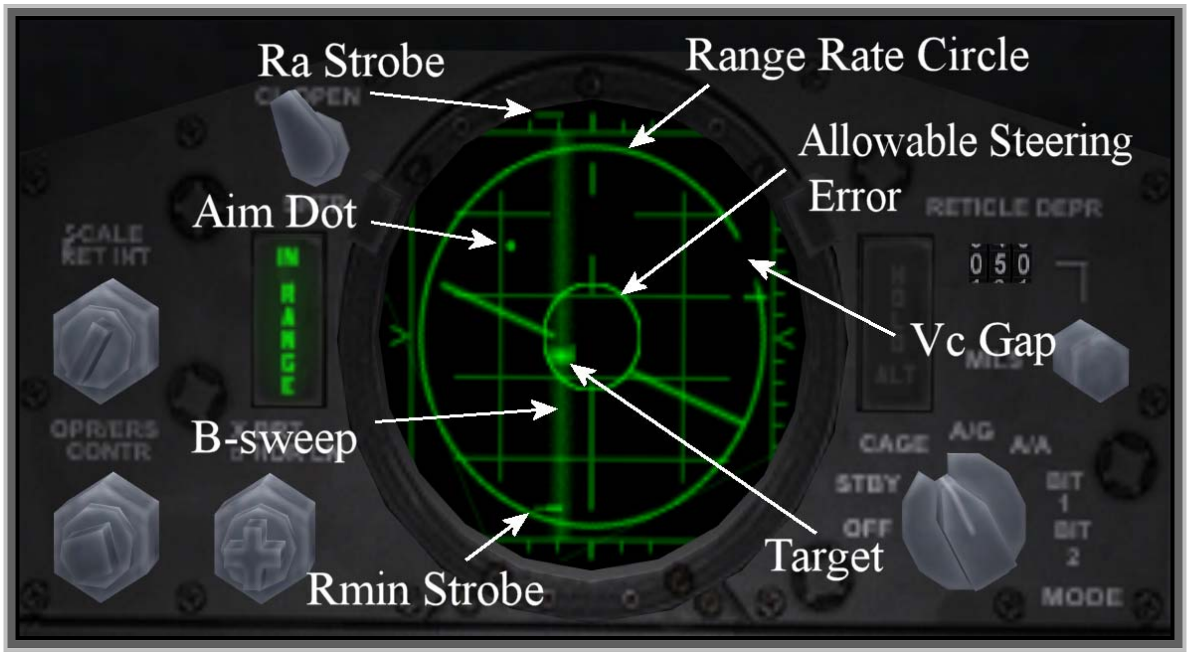
Acquisition Display.

The acquisition display is obtained by locking a target with the **Insert** key. The search display symbols remain and a range strobe appears. When the key is pressed, the antenna slews to the azimuth position of the acquisition symbol, thereby illuminating the desired target.

The radar locks onto the target and the track display appears.

Track Display.

In track operation the acquisition symbol is removed and the Ra and Rmin strobes replace the acquisition symbol. These strobes are presented at the immediate left of the B-sweep.



At lockon, the horizon line, B-sweep, elevation strobe, and range strobe are unchanged and the following symbols appear:

Range rate circle
Allowable Steering Error circle
Aim dot
Ra and Rmin Strobes
Range Rate Circle.

The range rate circle is displayed on the scope as a fixed diameter circle that contains a small gap or blanked portion. The only function of this circle is to provide a medium on which the Vc gap can be displayed.

Vc Gap.

The blanked portion of the circle is the Vc gap. The clock position of the Vc gap indicates either the opening or the closing velocity between the target and the aircraft, with clockwise positions indicating closing velocity and counterclockwise positions indicating opening velocity.

The approximate position of the counterclockwise edge of the Vc gap relative to the opening or closing velocity is as follows:

Gap Position

10:30 o'clock	450 knots opening
11:00 o'clock	300 knots opening
12:00 o'clock	0 knots
1:00 o'clock	300 knots closing
2:00 o'clock	600 knots closing
3:00 o'clock	900 knots closing
4:00 o'clock	1200 knots closing
5:00 o'clock	1500 knots closing
6:00 o'clock	1800 knots closing
7:00 o'clock	2100 knots closing
8:00 o'clock	2400 knots closing
9:00 o'clock	2700 knots closing

Allowable Steering Error.

The allowable steering error is determined by the maximum heading error at which the missile can be launched and still achieve a miss distance of less than 25 feet in 90% of the cases computed. It is compared to the actual lead angle error to operate an interlock in the missile firing circuits. The allowable steering error is presented on the scopes as a circle.

The aim dot, positioned by the lead angle error, must be maintained inside the circle for the interlock to be closed.

The deflection of the aim dot from the center of the display indicates an aircraft steering error from the desired course. During an attack the aircraft should be flown to keep the dot within the ASE circle. Missiles fired with the dot outside the circle will not guide to the target.

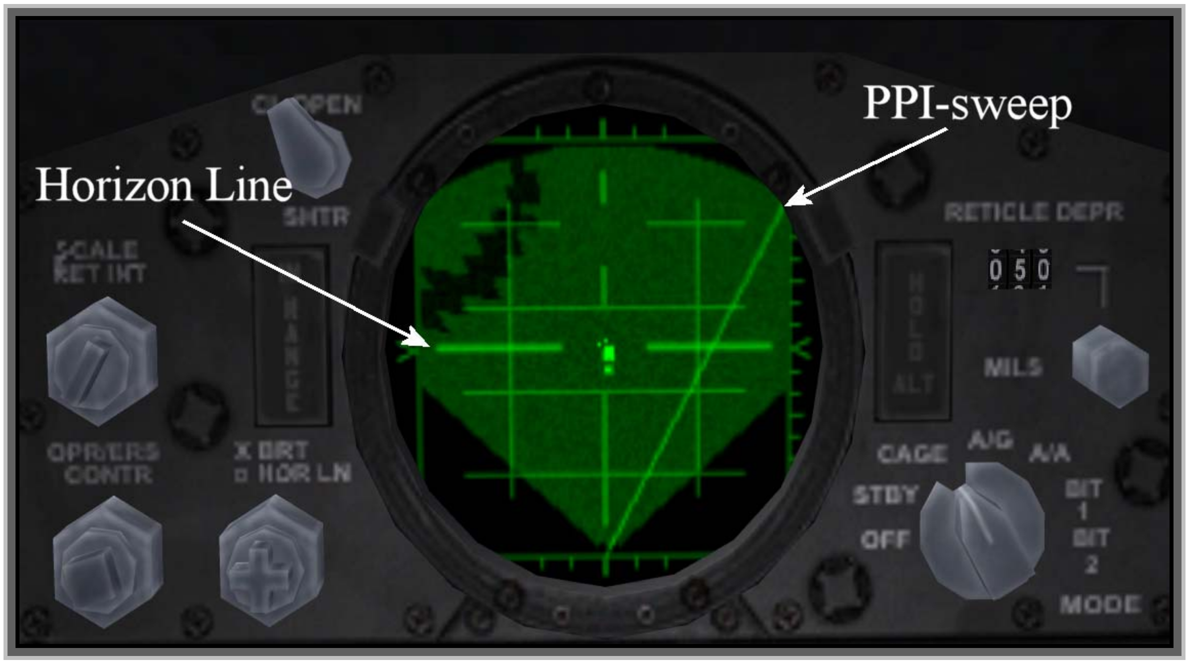
Breakaway Display

When the computed range reaches Rmin, the track display disappears and the break X is displayed.

The appearance of the break X warns that the minimum range has been reached and that a maneuver should be performed to break away from the attack.

Ground Map Display.

The ground mapping mode is used as a navigation aid and means to estimate range to a target. The display consists of a PPI-sweep and horizon line.



The PPI-sweep maintains its origin at the bottom of the scope and traces in a 120 degree arc across the face of the scope. The target range may be interpolated along the length of the sweep line. For example, with the range set to 10 miles, a target halfway along the PPI-sweep is 5 miles from your position.

A horizon line is present as an additional attitude reference.

Terrain Avoidance Display.

The Terrain Avoidance Display shows any obstacle that lies ahead parallel to the aircraft's current flight path with a clearance plane elevation fixed at 500 feet below. If an object appears in the scope, climbing until it disappears will avoid it.

F-4 Radar Guide

By Streakeagle

Using radar and radar homing missiles like the AIM-7 Sparrow on Hard settings seems too hard for many people. With a little review of the way radar works and what the display indications mean, it really isn't that difficult.

A basic summary:

1. Use Search Mode to detect a target on your display (vary the range scale using the <PAGE DOWN> key if necessary).

2. Use the <HOME> key to move the cursor to the target.

3. Use the <INSERT> key to lock on.

4. Center the steering dot in the ASE circle.

5. Launch when "IN RANGE".

6. Maintain target lock on until missile hits, or missile will miss.

Note: Once you have locked on, you can use <CTRL><R> to visually acquire the target, which also identifies the type of aircraft (an unrealistically accurate form of IFF). Then use either <F4> to padlock the target from within the cockpit, <SHIFT><F8> to padlock the target from an external player-to-target view, or <F8> to see the target up close.

Alternatively, steps 1 through 3 can be bypassed when engaging targets held visually: Select Boresight Mode and hold your gunsight exactly on the target until a lock on occurs. Then continue with step 4.

The idea behind radar in the 1960s was that radio energy could be used to search for contacts by rapidly sweeping an antenna from side to side while transmitting radio energy pulses and receiving "echoes" from targets hit by those pulses. The antenna has a "beam", which is the pattern or shape of the radio transmission. Ideally, this beam is very narrow since it determines the elevation and azimuth resolution. The radar display graphs the azimuth (bearing) of the antenna versus the time (range) of the echoes. In the case of the F-4 radar as portrayed in SFP1 and WOV, the elevation of the antenna alternates between a look up and a look down angle. Each elevation angle is referred to as a bar. The F-4 radar's search pattern in SFP1 and WOV is a 2-bar scan.

The F-4 has radar azimuth limits of +/- 60 degrees, which means it can see targets in a 120 degree cone centered on its nose.

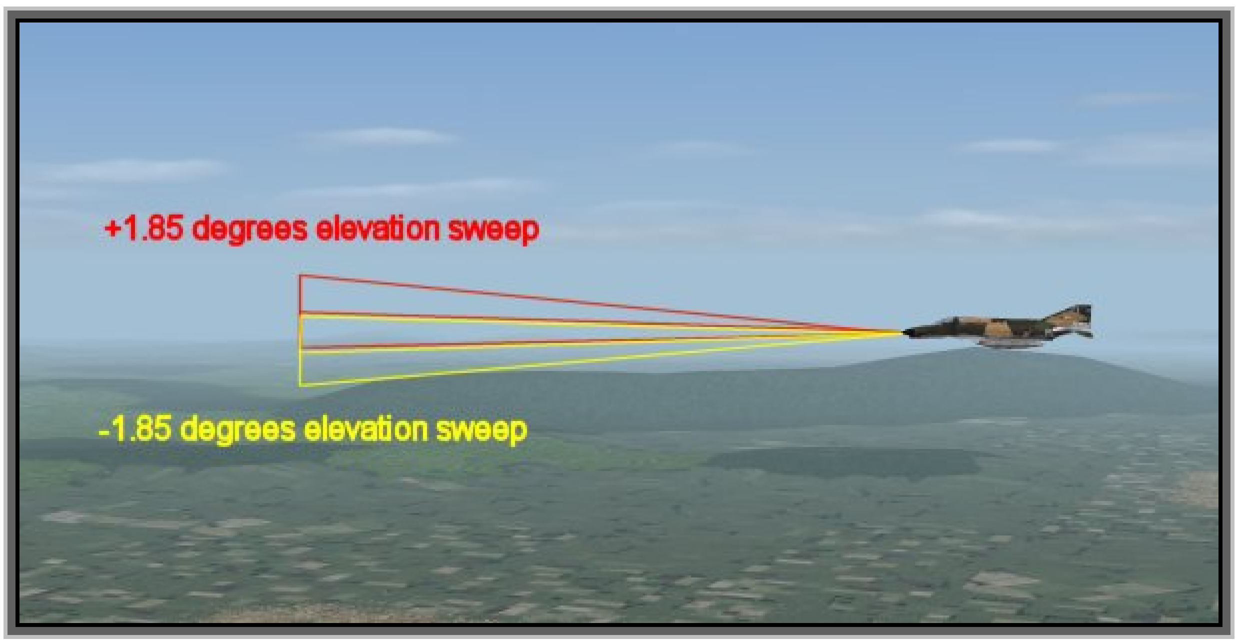
Illustration of horizontal azimuth sweep pattern:

The 120 degree horizontal search cone is quite large, but not every target will be covered by it. There are four ways to get a target into your search sweep:

1. Arbitrarily change course by +/- 120 degrees to cover a full 360 degrees. In reality, you should know what is behind you, so check turns of +/- 60 degrees are probably adequate.
2. Point your nose at RWR contacts.
3. Steer to the targets in the verbal reports from the ground controller.
4. Use the <M> key to bring up the map to see where to turn your nose to acquire targets known to ground control.

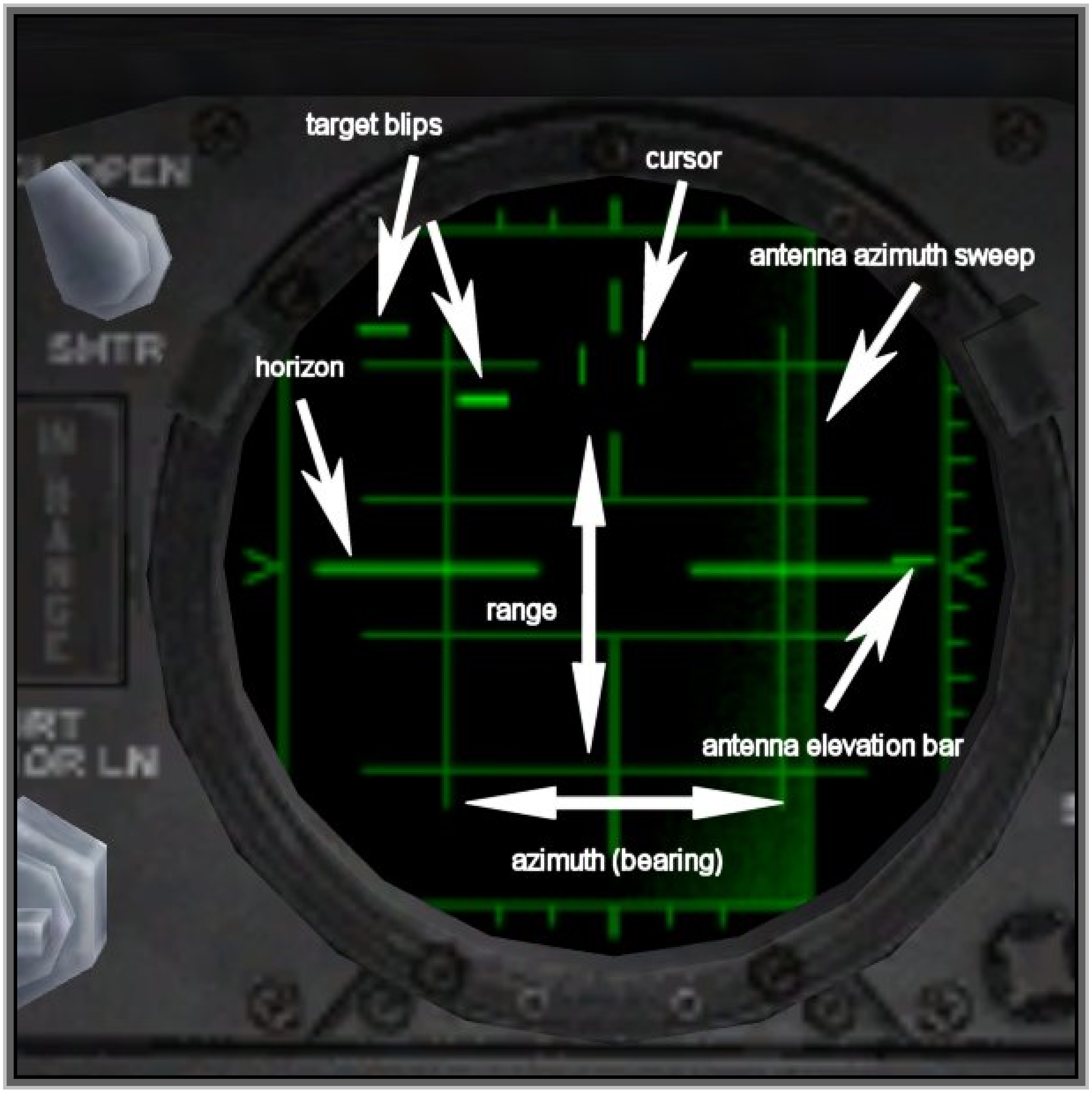
The F-4 has radar elevation limits of +/- 60 degrees, but does not scan over that entire range. It merely permits the radar to continue a full horizontal sweep when banked 90 degrees. The vertical search is constrained to two elevation bars at +/- 1.875 degrees. The radar beam is 6.7 degrees wide and the two elevation bars overlap providing about 10 degrees of vertical coverage.

Illustration of 2-bar vertical sweep pattern:



While this was outstanding for its day, it is easy to see that targets might be above or below the 10 degrees of vertical search. The F-4 must periodically pitch its nose up or down to get more vertical coverage. Of course, the F-4 does not have look-down radar. If the nose is pointed down too much, the radar will be cluttered heavily with ground returns. In reality, the F-4 had major problems trying to use the radar and Sparrow missiles at low altitudes or against targets flying at much lower altitudes. The game is not quite so picky, but a target can try flying very low and using ground clutter to break lock ons and/or decoy Sparrows.

Here is a typical search display from an F-4 radar in SFP1 with two targets:



Once you have found a target on your search display, you have the option to acquire/track/lock on to the target. This means the radar stops sweeping rapidly and instead tries to keep the antenna pointed at the target at all times. This provides very accurate information on a single target, which is needed to launch and guide radar guided missiles such as the AIM-7 Sparrow. Tracking a single target does not permit searching for more targets.

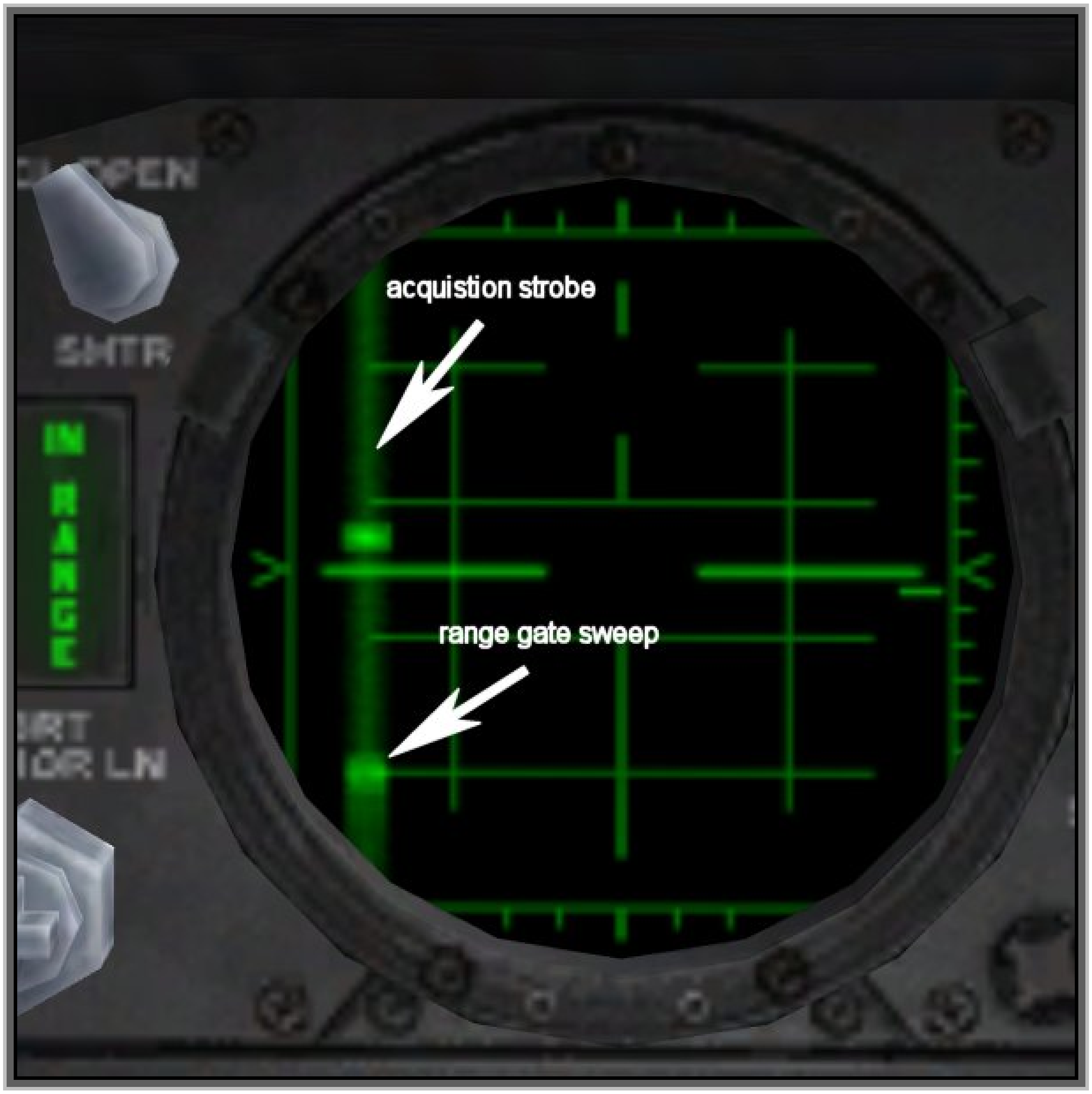
The F-4 radar has a cursor that allows you to choose which target you want to acquire.

Press the <HOME> key to move the cursor. If the cursor is not on the desired target, then continue pressing the <HOME> key until the cursor is on the desired target.

Here is what happens if you push the <HOME> key while a target is displayed (the cursor moves to the target):

Once the cursor is in the desired position, simply press the <INSERT> key to track/acquire/lock on to the target. The sweeping strobe stops on the bearing of the contact, all other targets disappear from the display, and a range gate sweep moves up the strobe until it finds the target's range. At that point, lock on has been achieved.

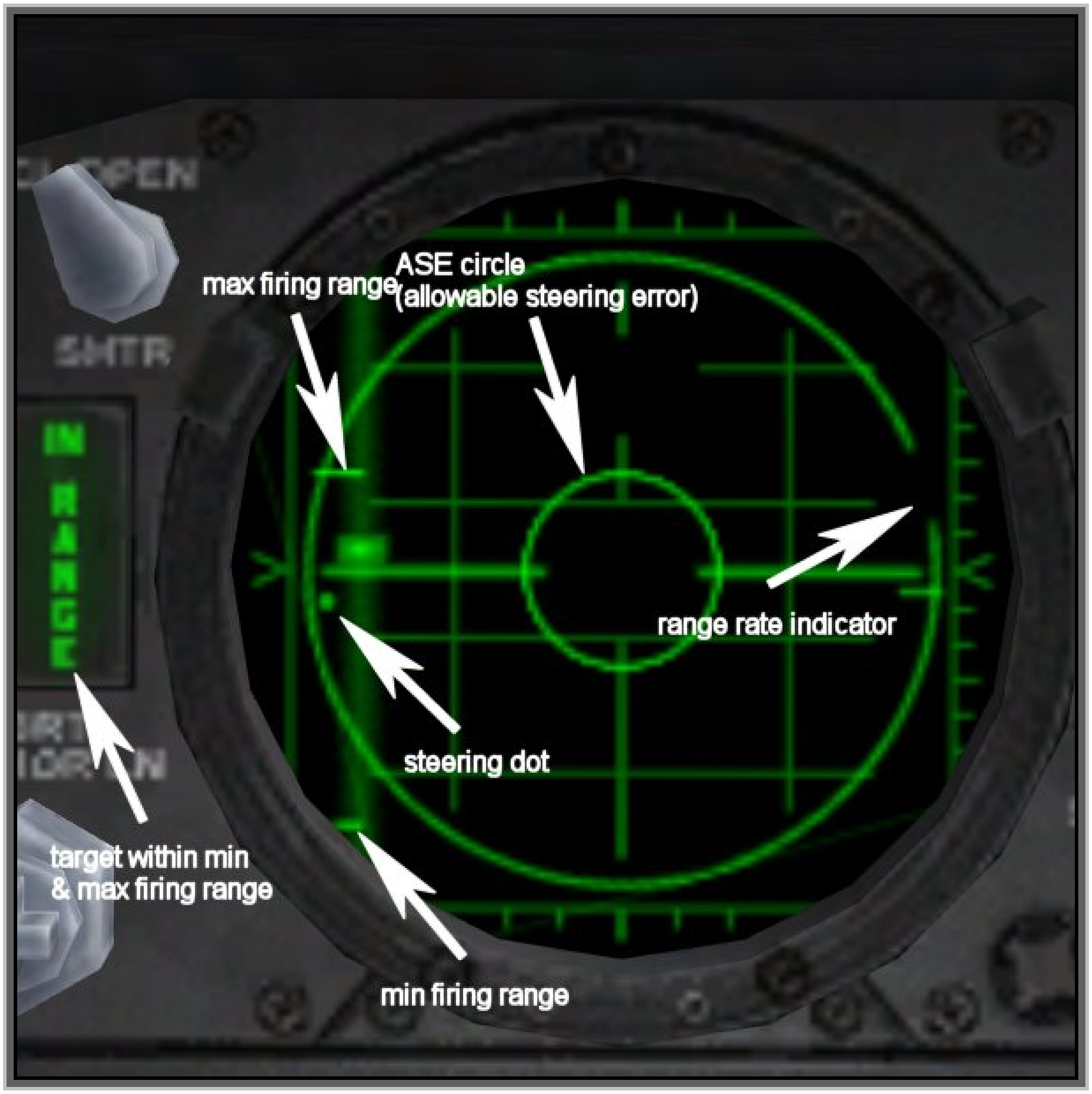
Here is what happens if you push the <INSERT> key while the cursor is on a target (the radar enters acquisition mode):



If you successfully lock on, the radar displays additional information: closure rate using a rotating ring, allowable steering error, steering dot, and the min and max ranges of the selected weapon. There is even an IN RANGE light to let you know when the target is within firing range parameters.

The notch in the range rate circle rotates to indicate closure rate. If the notch is at 12 o'clock (top of the circle), then there is no closure. As the notch moves clockwise from 12 to 3 to 6 to 9, it indicates an increase in the closure speed. As the notch moves counter-clockwise from 12 to 9, it indicates that the target is opening rather than closing. In other words, the target is moving away from the radar.

Here is what the display looks like while locked on:



Sparrows have two primary launch requirements:

1. Locked on to the target.

2. Target between Min and Max range limits.

But just because you are able to launch a Sparrow, doesn't mean it has a chance of hitting. Other launch requirements that should be considered include:

1. Launching aircraft should not be maneuvering violently.

2. Steering dot should be within the ASE circle.

3. ASE circle changes size with range. In general, the larger the circle, the better the chance to hit. Try to hold fire until the circle is close to its maximum size.

4. Aspect of the target can render Sparrow shots impossible. The AIM-7 likes direct head-on shots form long distances and rear quarter shots from short distances. Crossing shots at the targets front quarter and beam may prove difficult, if not impossible to hit.

5. Launching aircraft should have as high a speed as practical since the missile can maneuver better, fly longer range, and impact sooner if it has more energy at the moment of launch.

Here is what the F-4 radar display looks like when close to optimum firing conditions (the ASE circle is very large and the steering dot is almost centered in the circle):

If you get too close to fire an AIM-7 Sparrow, the radar displays a big "X" (the phrase "too close for missiles, switching to guns" should come to mind):

AGM-65 Maverick Employment

Strike Fighters Maverick Displays.

AGM-65A Video Display.

The AGM-65A seeker 5-degree FOV is presented on the cockpit video display as shown here.

AGM-65A Video Display

A set of crosshairs that span the entire display is presented. The intersection of the crosshairs is open to represent the tracking gate which has a minimum size or 1.8 mils (milliradians) high by 1.4 mils wide. The crosshair gap expands to accommodate the target size. A solid lock-on is achieved when the crosshairs become steady and centered on the target.

Before missile launch, the seeker must be pointing within 15 degrees of the missile centerline in order to maintain successful track during transient forces encountered during launch.

AGM-65B Video Display.

The seeker of the AGM-65B has a 2.5-degree FOV and a 0.9-mil-high by 0.7-mil-wide tracking gate.

AGM-65B Video Display

A larger vidicon lens is used to double the apparent size of the target. The cockpit video display also presents a magnified image, and the symbology for the tracking gate is a rectangular arrangement of four small squares (background gates).

A small crosshair, called a pointing cross, shows seeker position relative to the missile centerline. Before missile launch, the seeker must be aimed within 10 degrees of the missile centerline in order to maintain successful track during transient launch forces.

A-10A cockpit view showing AGM-65B Video with pointing cross.

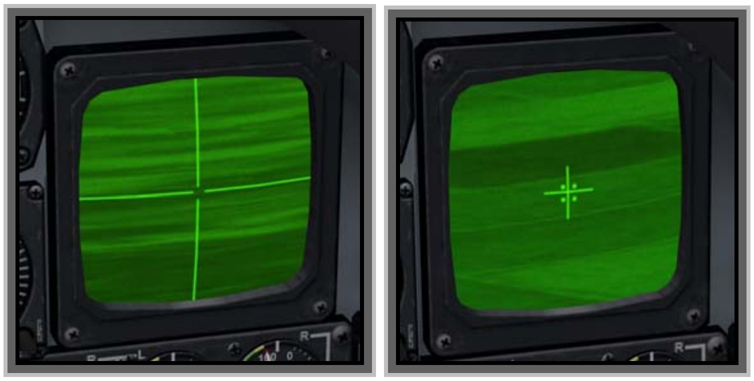
AGM-65D, G/G2, H and K Video Display.

For now, these use the AGM-65B video display.

Maverick Employment.

Once the target area is reached, the AGM-65 can be selected by cycling through weapons with the \ key.

The AGM-65 video will be displayed initially with the crosshairs pointed down the boresight of the missile.

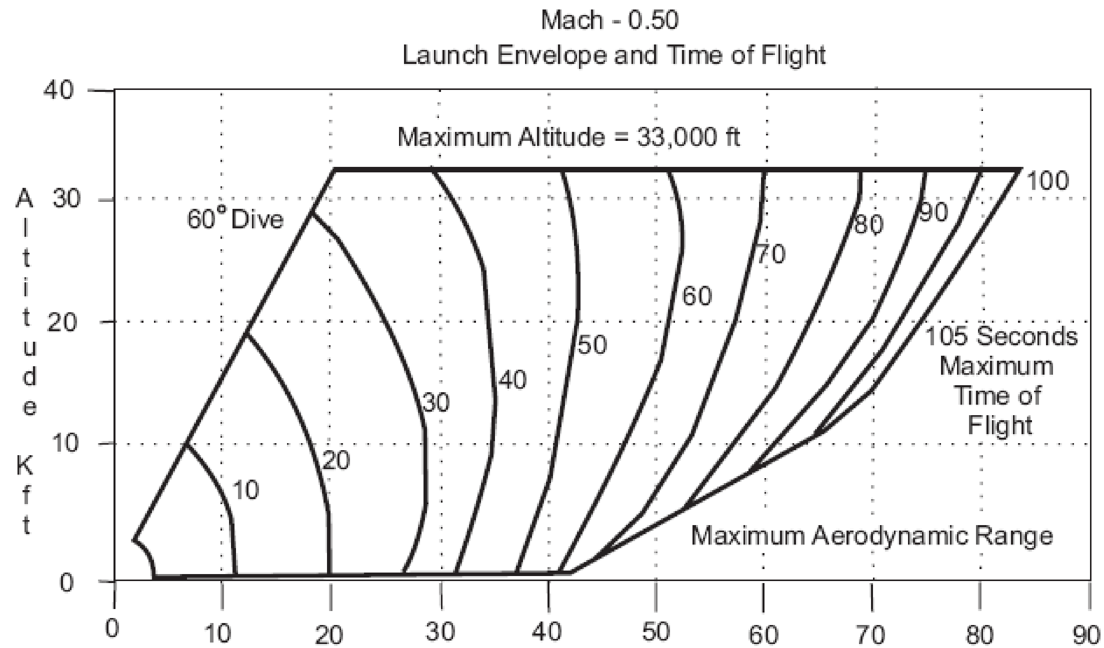


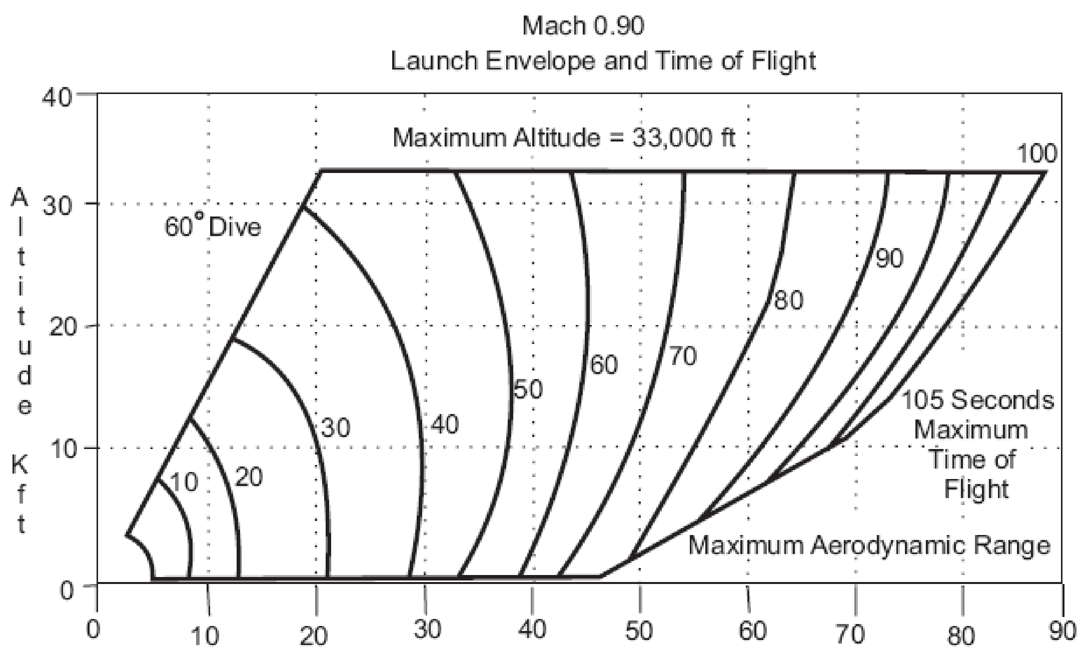
AGM-65A and B Video Display with no target.

The AGM-65 in Strike Fighters operates in a missile slave mode. Selecting a target with the E key automatically slews the missile seeker onto that target. A lock is achieved automatically and the missile may be fired when the target is in the crosshairs.

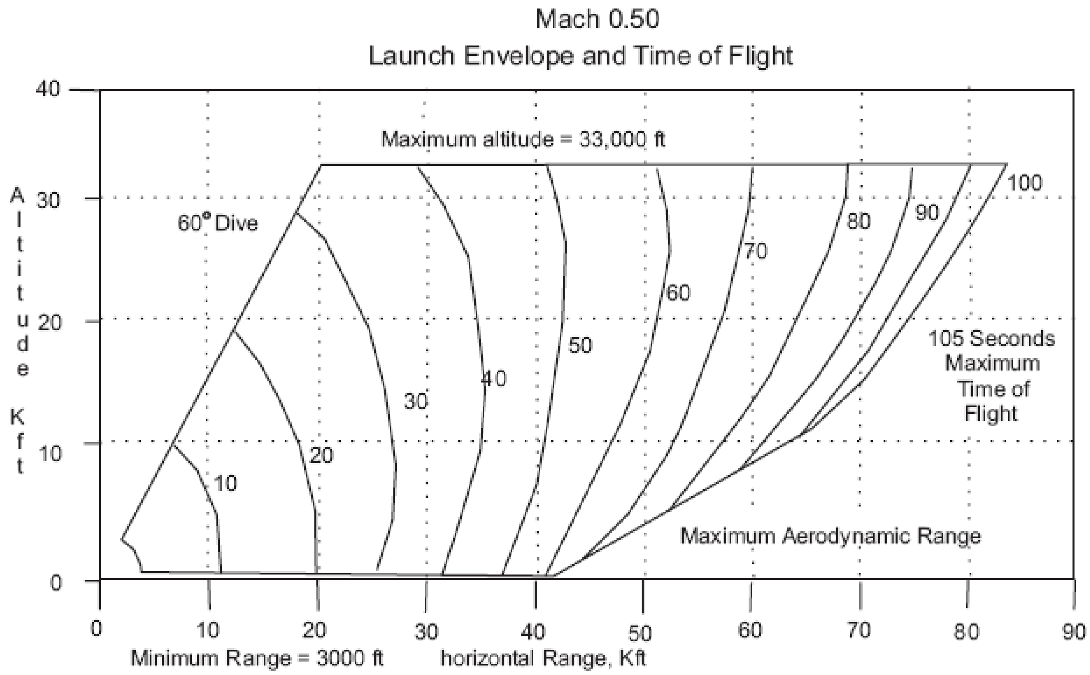
AGM-65A and B Video Display with target locked.

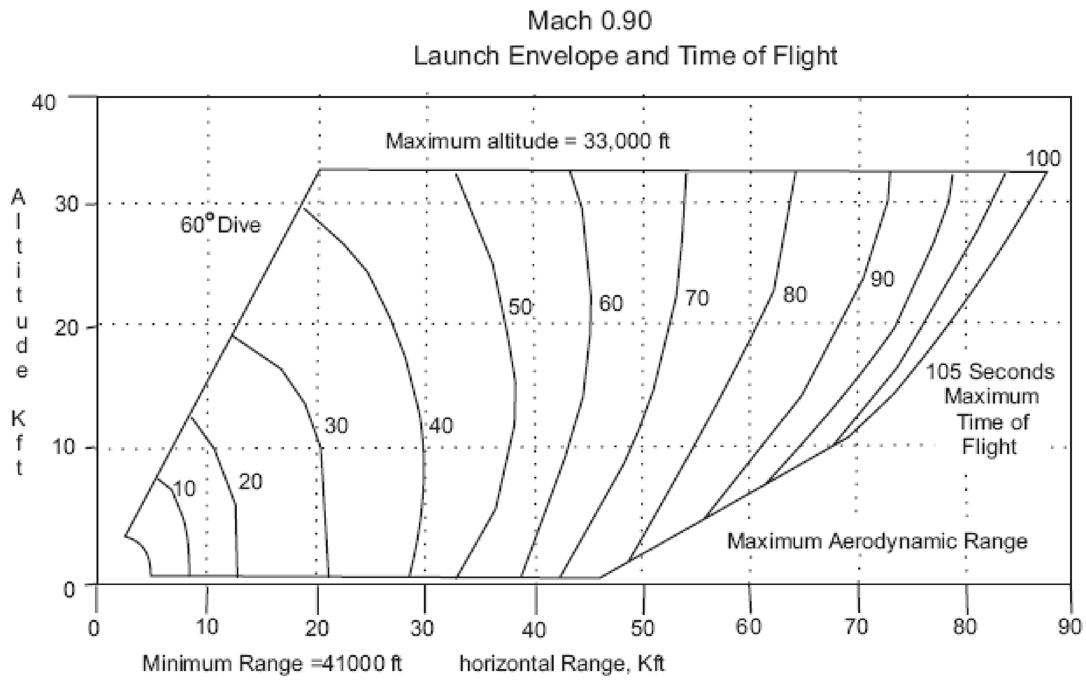
In all cases, you must ensure the target is in range before launching the missile. Use the following tables to determine maximum range for the missile you are using.



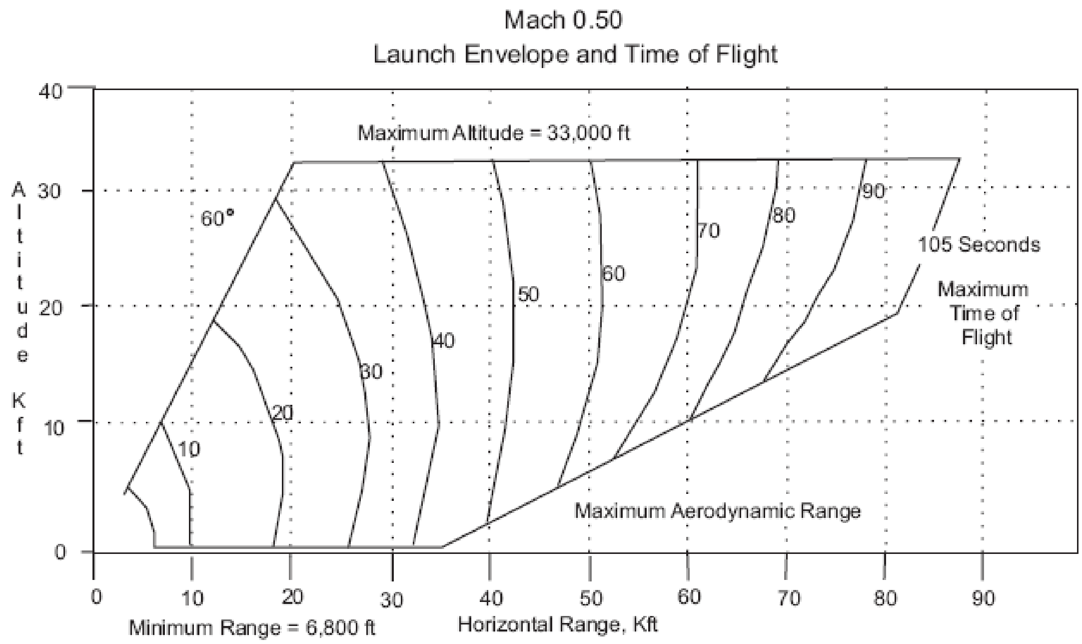


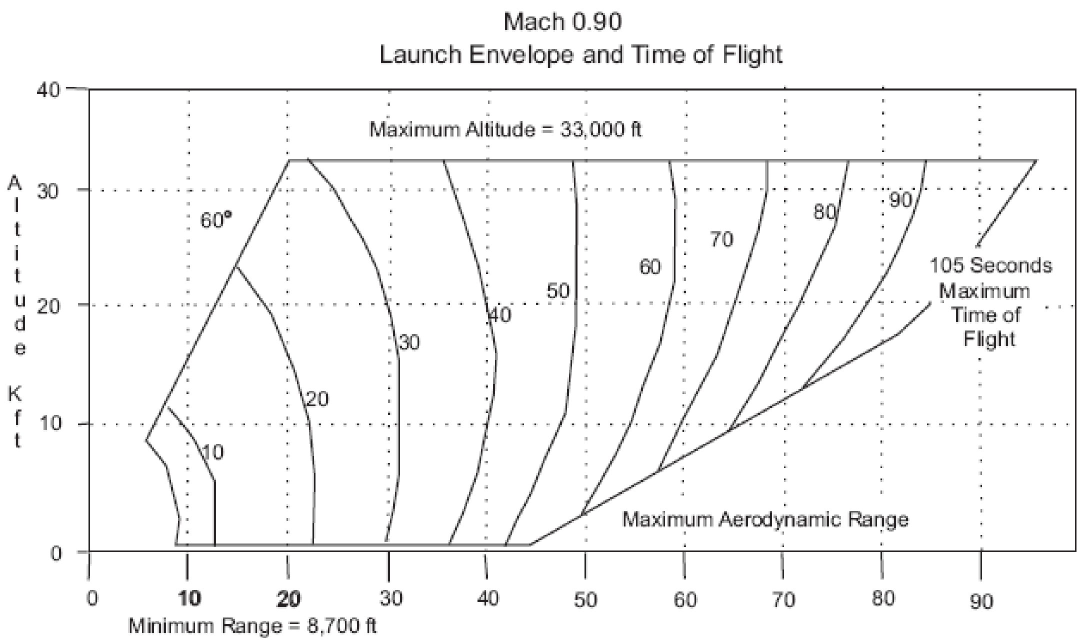
AGM-65A and AGM-65B Missile Launch Envelopes.



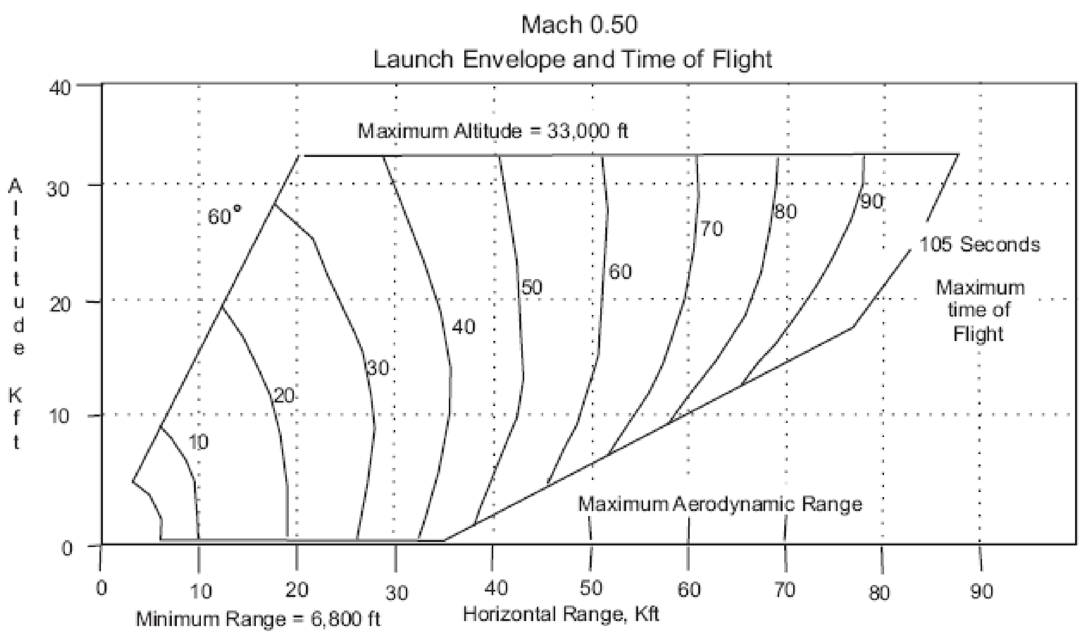


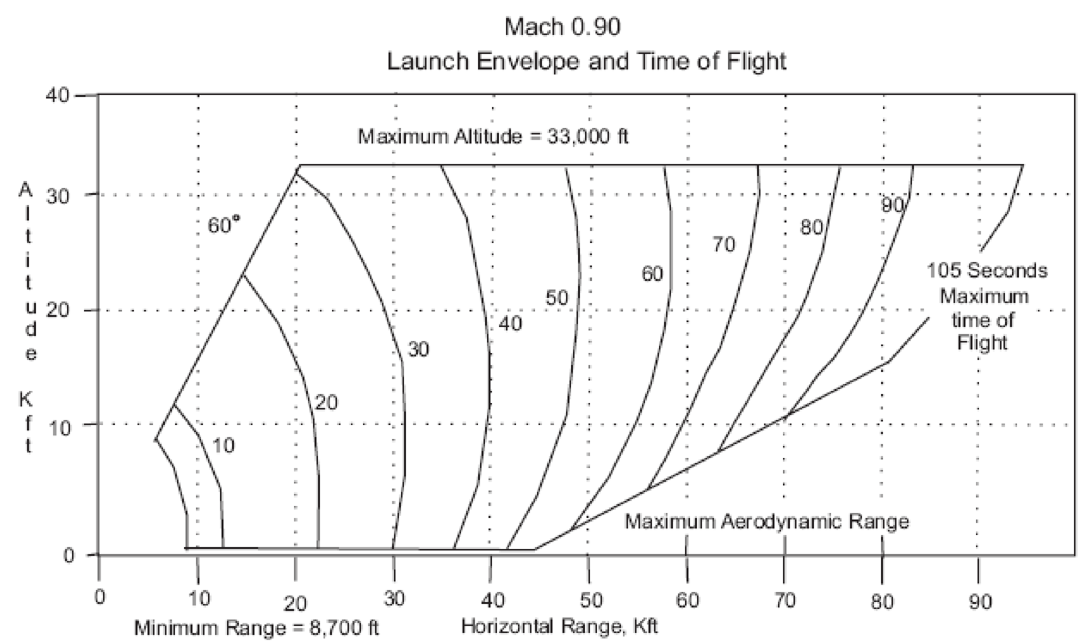
AGM-65D Missile Launch Envelopes.



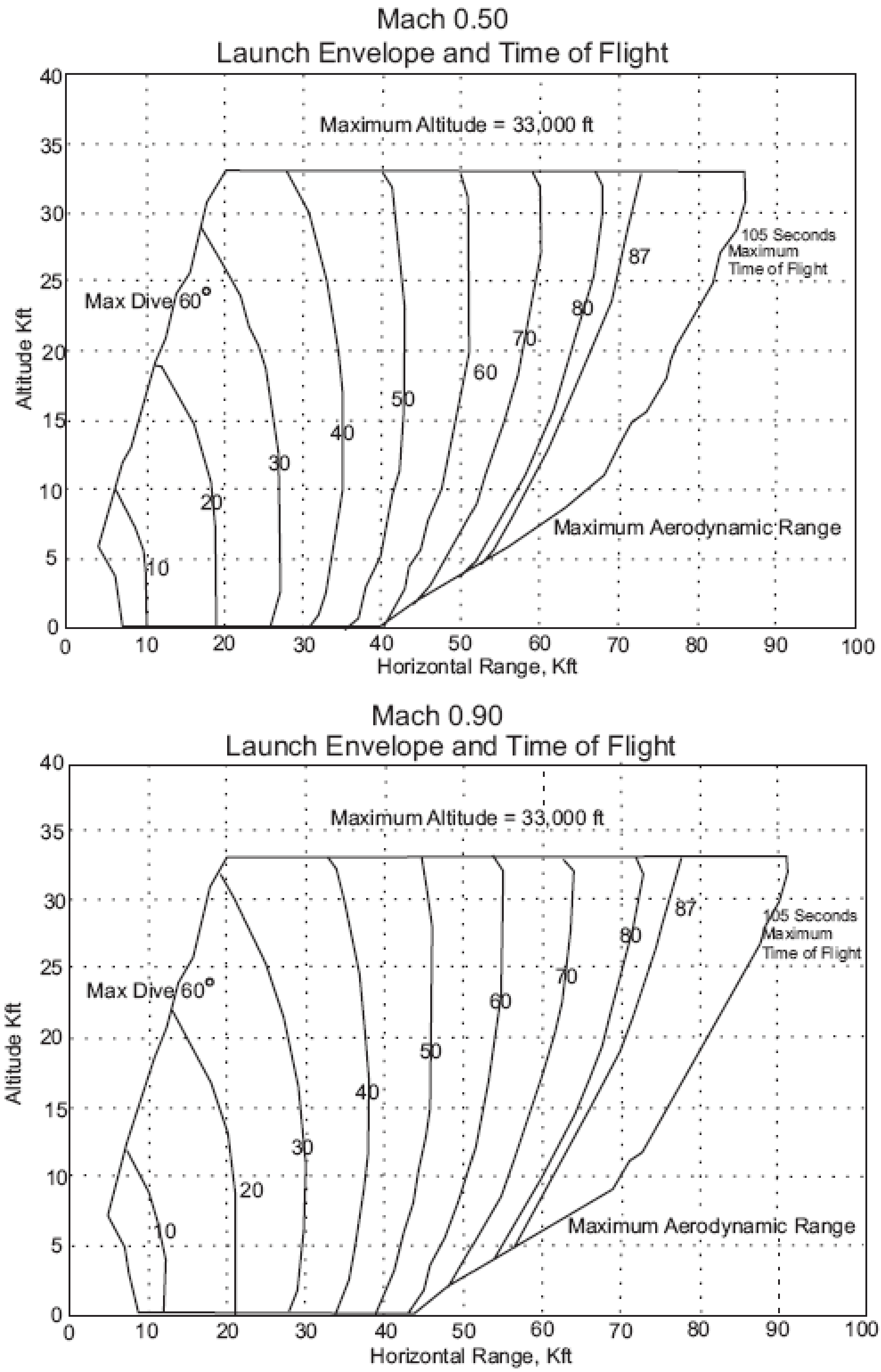


AGM-65G Missile Launch Envelopes.

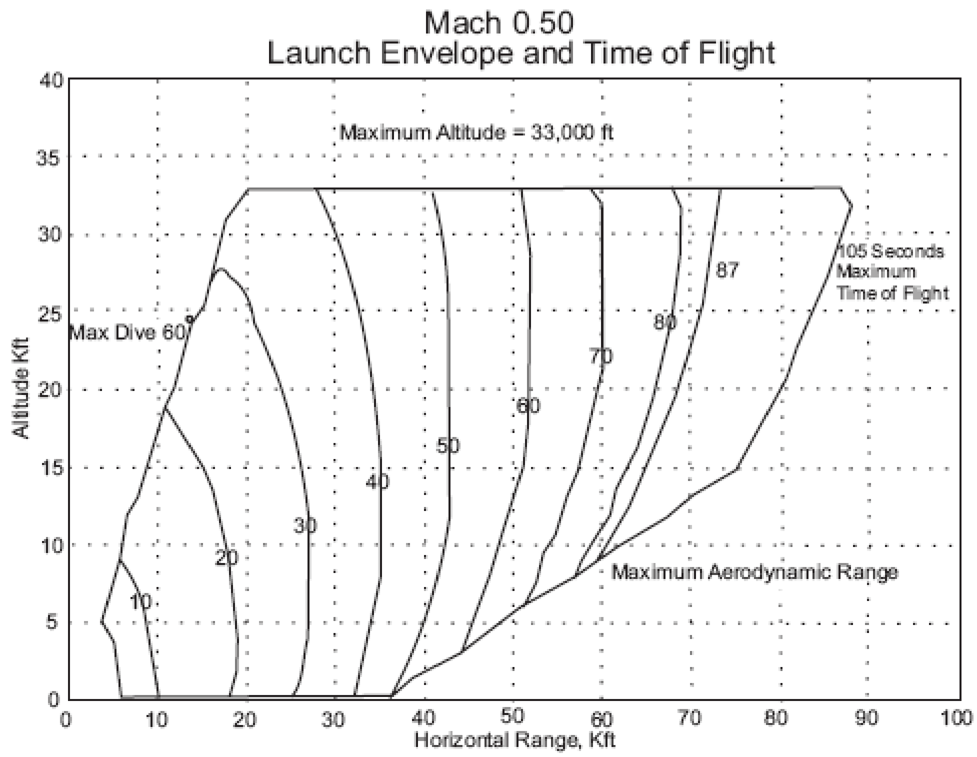


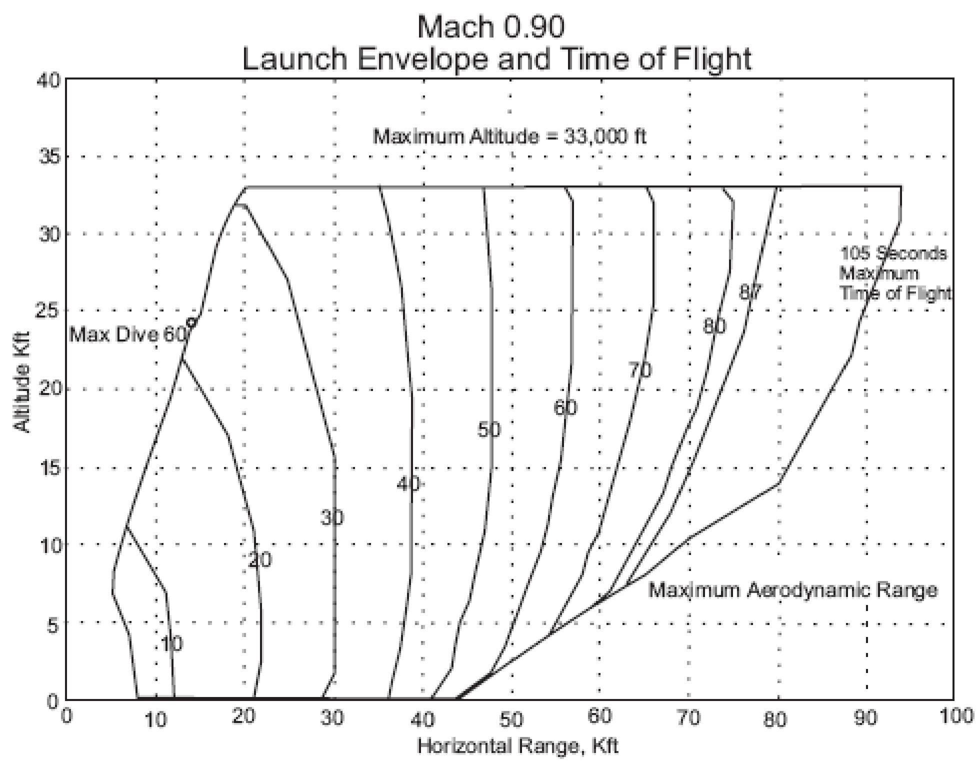


AGM-65G2 Missile Launch Envelope.



AGM-65H Missile Launch Envelopes.





AGM-65K Missile Launch Envelopes.

The AGM-65 missile should not be launched under conditions which exceed the following limits:

- Launch speed: Maximum, mach 1.2

- Maximum gimbal offset angle: AGM-65A, 15 degrees; AGM-65B, 10 degrees; AGM-65D/G, 10 degrees; AGM-65H/K, 10 degrees.

- Maximum dive angle: 60 degrees.

- Maximum bank angle: 30 degrees.

- Maximum roll rate: 30 degrees per second

- At targets with speeds exceeding 74 feet per second (50 miles per hour) perpendicular to the missile flight path.

An F-4E overflies the target on the Bombing Range terrain.

There is a slight delay between the moment you depress the weapon release switch and rocket motor ignition. After the missile is fired, it will guide to the target automatically. You may select other targets by pressing the E key again.

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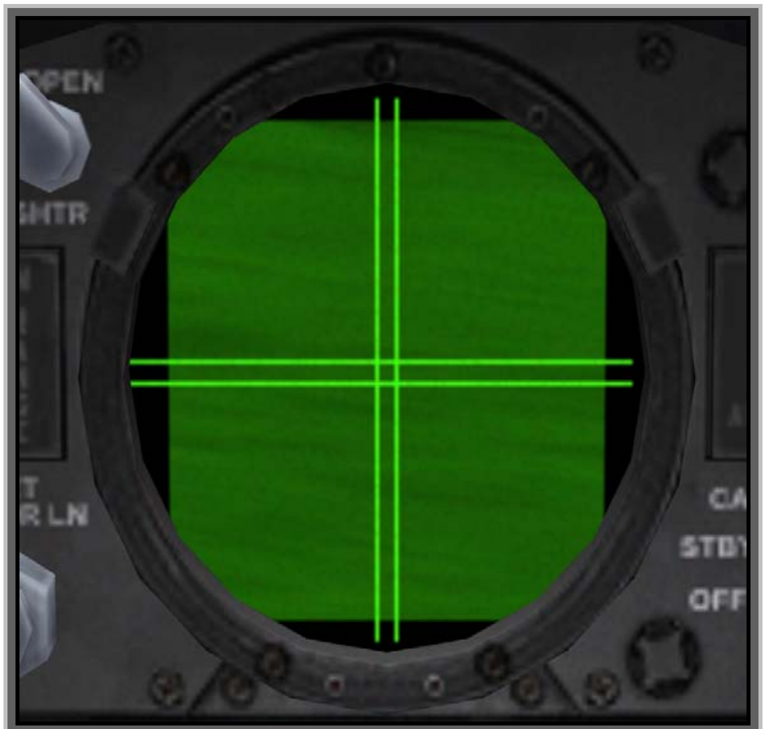
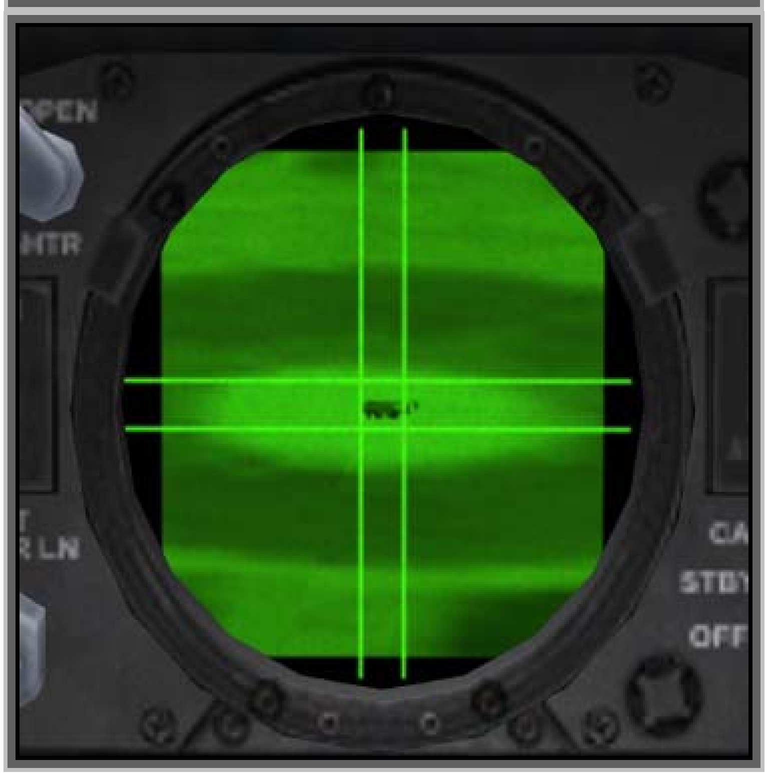
Walleye I/II Employment





LGB Employment

Flight Path Characteristics.

The flight path characteristics of a PW II would ideally approximate the flight path of a similar unguided free fall weapon, using only small corrections over the entire weapon time-of-flight (TOF) to achieve required accuracy. Ideally, weapon delivery system inaccuracies, winds, weapon dispersion and a host of other factors would be fully compensated for on each delivery. Several flight control characteristics of the PW II can significantly degrade its performance when delivery parameters and laser designation tactics cause end-game trajectories of less than 35 degrees. The following explanation of typical PW II flight paths discuss various effects upon end-game performance and expected accuracy.

General Characteristics.

The PW II flight path from release to impact can be divided into three phases of flight. The phases of flight are: ballistic, transitional and the terminal phase (Figure 1-135). The ballistic phase of flight occurs between release and the point where laser acquisition takes place. During this period, the weapons ballistic characteristics are very close to the parent warhead's characteristics for any delivery mode (dive, level, and loft/toss).

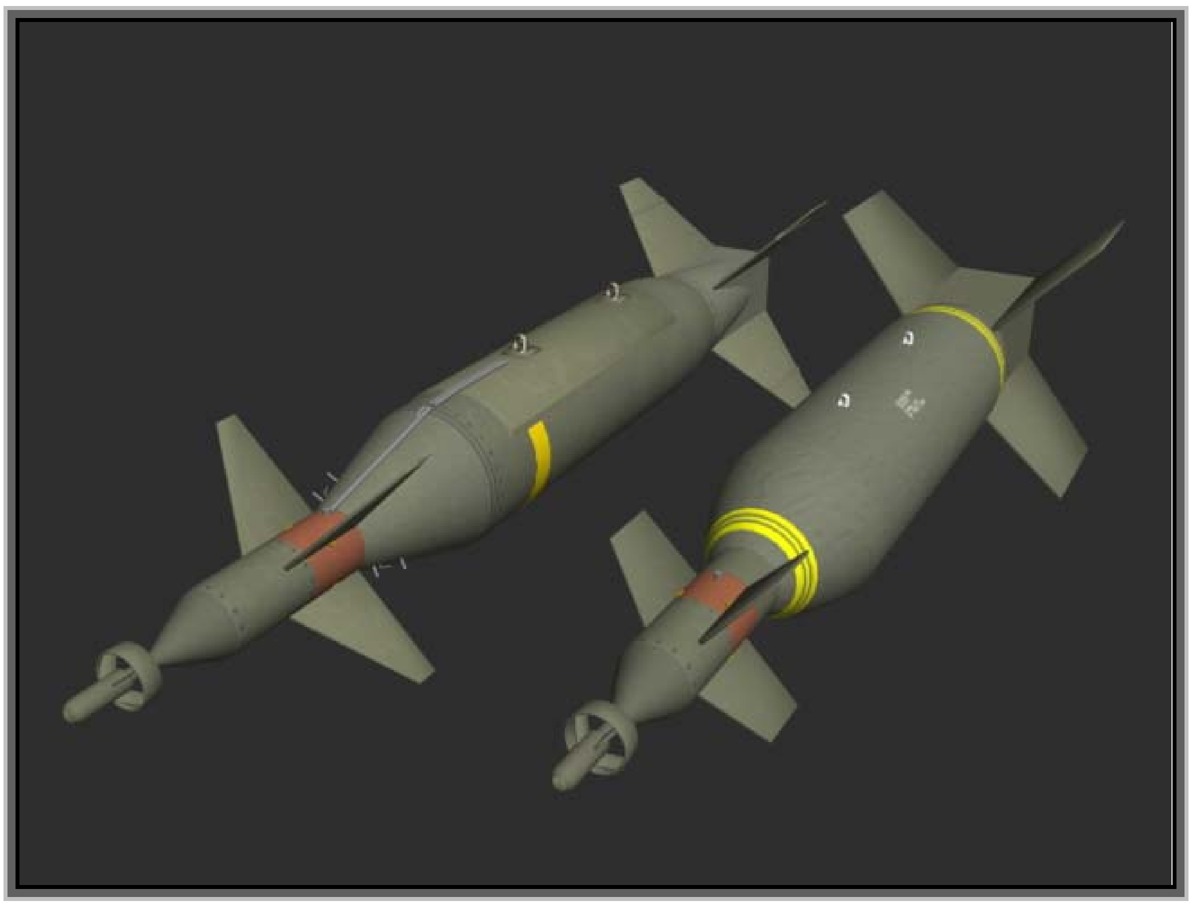
The transitional phase of flight occurs between laser acquisition and the point where the target becomes boresighted on the seekers four quadrant detector. This period is characterized by relatively long periods of full fin deflection as the computer attempts to correct off-axis errors, typically exceeding one degree. The transitional period for weapons employed in the heart of the envelope may last from three to five seconds. The transitional period for weapons employed near the front edge or toward the rear of the envelope may last until impact and result in lower accuracy.

F-4E carrying GBU-2 and GBU-11 Laser Guided Bombs.

The terminal (end-game) phase of flight occurs when the weapon operates in the boresight mode and the target return is maintained within approximately one degree of the seeker's center. PW II flight characteristics during this phase are characterized by an oscillation about the instantaneous weapon-to-target LOS. The oscillation is somewhat random due to the guidance sequence inherent with the bang-bang system. Starting from the boresight position, the target return is centered on the detector and no guidance commands are issued causing the weapon to fall ballistically as the canards are streamlined.

Eventually, one or two of the detector quadrants receives more laser energy than the other quadrants and a command to re-center the return is issued by the computer. This command starts the appropriate set of canards to the hard-over position to re-center the target on the detector. As the target is re-centered on the detector, the guidance command is stopped, the canards streamline, and the weapon again falls ballistically. This action continues as the weapon nears the target and the one degree limit of the boresight cone becomes physically smaller and smaller. This constant deflection of one or both canard pairs causes the weapon to constantly maneuver. This maneuvering requires energy. When delivered well within its envelope, the weapon usually has sufficient energy to offset the constant maneuvering. When the weapon is delivered at the rear edge of its envelope, the usual result is a rapid decay in energy and poor performance.

The amount of energy decay is closely related to the end-game impact angle. If the impact angle is greater than 35 degrees, energy reserve is usually large enough to preserve maneuver capability as the weapon approaches the target. In fact, as the terminal angle is increased above 35 degrees, the weapon will accelerate end-game. This results in improved accuracy because maneuver potential increases as the weapon approaches the target.



GBU-2 and GBU-11 Laser Guided Bombs.

If the impact angle is less than 35 degrees, the energy used to stay on or near the LOS increases. As the glide path approaches zero (level flight), energy loss may become excessive causing total loss of maneuver potential. In all cases, maneuver capability decays rather than improves as the weapon approached the target. Low or slow deliveries have a marked decrease in accuracy even when launched with perfect delivery parameters. In fact, during low or slow employment, the envelope size has decreased markedly or does not exist.

Envelope size increases slightly at higher speeds and decreases rapidly at lower speed. The 35 degree impact rule is important enough to divide the PW II's guided flight characteristics into two regions. Both the high, terminal-delivery and low, terminal-delivery regions will be discussed separately as if there are two separate weapons involved.

High, Terminal-Deliveries.

High terminal angle deliveries are defined as any delivery where the impact angle is 35 degrees or greater. This angle can be achieved by medium altitude level deliveries above 10,000 feet AGL, high angle dive deliveries of 30 degrees or greater, or loft/toss deliveries above 25 degrees release angle. The total-trajectory scenario for this type of delivery is described above under General Characteristics. A ballistic phase, followed by a transitional phase that ends in a terminal phase where the weapon oscillates very slightly about the weapon-to-target LOS. These deviations are normally within 3 to 5 feet of the instantaneous LOS.

High-Angle, Dive-Bomb Delivery.

High-angle, dive-bomb deliveries of 30 degrees or greater impart excellent energy to the weapon when released at typical combat airspeeds. In fact, this is the set of delivery parameters for which the weapon was designed. The weapon will gradually ccelerate/decelerate to its terminal velocity of approximately 0.95 Mach if acquisition is delayed. With a constant designation, acquisition normally occurs shortly after weapon turn-on. The transition phase begins with a large correction to boresight maneuver. Energy loss in this phase may induce airspeed reductions of over 100 KTAS. As boresight is achieved, the terminal glide path to the target is soon established and a slightly sagging approach, due to gravity, is flown to the target.

The initial approach angle of this terminal glide path almost wholly determines the overall impact accuracy of the delivery.

Generally, the steeper this angle is above 35 degrees, the better. Glide paths above 35 degrees cause a gradual acceleration during the terminal phase and those below 35 degrees cause a deceleration. The end result is that the steeper the angle, the higher the weapon's speed and maneuverability approaching the target. This, in turn, decreases the deviation around the instantaneous LOS during the weapon's constant hunt for boresight.

Conversely, shallower angle (below 35 degrees) produce ever decreasing airspeeds as the target is approached and larger deviations around the LOS.

Dive angles of 45 degrees or greater, at release altitudes over 10,000 feet AGL produce excellent acceleration down the terminal glide path with a resulting calibrated airspeed at impact. These effects produce very low deviations around the LOS at impact with commensurate very high accuracies. In addition, as the glide path angle is increased, gravity sag of the LOS is reduced to negligible proportions and impacts are more generally centered around the aimpoint rather than being biased to the 6 o'clock position.

Medium to High Altitude, Level Deliveries.

Level deliveries at altitudes greater than 10,000 feet AGL, at 500 KTAS or greater, generally result in a terminal flight path angle greater than 35 degrees or where the higher release compensates for the shallower impact angle produced by release speeds of 550 to 650 KTAS.

As the delivery altitude is increased, the impact angle increases with the attendant increase in airspeed and therefore increased accuracy at impact. Deliveries of this sort have essentially the same terminal characteristics as the high angle dive bomb delivery explained previously. The higher, the faster and the closer to the front edge of the envelope, the better!

High-Angle, Loft/Toss Deliveries.

Loft/toss deliveries of 30 degrees or greater generally result in impact angles greater than 35 degrees. However, the impact velocity is generally about 50 to 100 knots less than the run-in speed. This speed differential assumes a ballistic phase from the optimum release point to the point where laser acquisition occurs shortly after weapon apogee. Weapon velocity at this point has decreased steadily due to the climb from the release point. A further decrease in velocity is experienced during the transition phase and little is regained during the relatively short terminal phase.

Attempts to increase impact velocity and possibly accuracy by changing the ballistic phase are usually doomed to failure. Increasing the loft angle does not increase impact velocity appreciably. Moving the release point around is risky in that the weapon's envelope barely covers the release dispersion of most delivery systems. Therefore, the only practical way to increase the impact velocity of the PW II in the loft/toss mode is to use a faster run-in and not by changing the ballistic portion of the flight.

If loft/toss delivery must be used, only deliveries of 30 degrees or greater will give a reasonable chance of success.

Low, Terminal-Angle Deliveries.

Low terminal-angle deliveries are defined as any delivery where the impact angle is less than 35 degrees. Deliveries producing this type of terminal angle are generally confined to low-altitude, level launches at less than 10,000 feet, loft/toss deliveries below 30 degree and low-angle, dive deliveries.

The total trajectory scenario for this type of delivery is generally as described above under General Characteristics. The ballistic phase and transitional phase may or may not end in a terminal phase. The transitional phase in this type of delivery may last until impact due to a combination of minimum range constraints and gravity effects that prevent boresight from ever being achieved. If a true boresighted terminal phase is achieved, it is characterized by a significant sag below the original LOS due to gravity effects that prevent the weapon from ever attaining a position on or above the preceding LOS after each correction.

Trajectory Sag.

Low-terminal angle deliveries are generally characterized by a sagging end-game trajectory that causes a preponderance of impacts at the 6 o'clock position. This trajectory sag is caused by several effects that combine to accentuate the less desirable flight characteristics of the simple guidance scheme used in the PW II. The major effects to be discussed in no significant order are gravity effects and energy bleed off. Gravity effects are the main contributor to the trajectory sag that influence all PW II deliveries. However, as the terminal glide angle becomes shallower, gravity influences are magnified by the bang-bang guidance used by the PW II. These effects cause the weapon to spend more time beneath the desire LOS as it attempts to climb and re-establish boresight. When boresight is achieved and the canards re-center, the weapon is almost immediately pulled below the established flight path by gravity. This effect causes the weapon to spend more of its time below the desired flight path rather than oscillating above and below the desired flight path as described in High, Terminal-Angle Deliveries. In addition, the weapon spends more of its time fighting gravity (with fully deflected canards) resulting in an even greater dissipation of energy.

These factors of gravity and the bang-bang guidance system act in concert to produce a trajectory that sags below the original boresight LOS. In addition, the sag becomes more pronounced as energy reserves are depleted and maneuverability decays during the end game trajectory which causes a greater sag that in turn induces even greater sag.

Trajectory sag effects not only produce consistent short bombs, they also reflect back to actual delivery process. The aircrew is forced to use a portion of the weapon's envelope that may be smaller than the aircraft's release computer capability, study of envelopes edge data may confirm that an envelope does not exist or is only tens of feet in diameter.

Increasing Low, Terminal-Angle Delivery Effectiveness.

The best way to deliver the PW II is to choose a delivery that will produce an impact angle of over 35 degrees. However, when forced to use a lower angle delivery, consider the following:

Increase Release Airspeed. Increasing the weapon release speed to the highest speed obtainable or to the highest certification limits is one of the best methods to increase its probability.

Elevate Spot Height. Raising the laser's aimpoint to a point as high as possible on the target face will also increase hit probability. Very significant gains in hit probability are possible when increasing the spot height above six feet. Since the weapon spends more of its flight time below the LOS as the terminal glide path is decreased, raising the spot will capture more impacts on the target face.

Delay Designation. Delayed designation is a technique that was developed to allow low angle loft/toss deliveries to reach apogee before laser acquisition. The intent was to increase the weapon's terminal glide path angle slightly in order to counteract some of the trajectory sag prevalent in this arena. In addition, the shorter guidance time (versus continuous designation) used less energy which resulted in higher impact velocities.

Several factors work against the use of delayed designation and must be well understood prior to attempting this technique.

When used with low angle lofts of 30 degrees or less, the envelope is extremely small or non-existent and a poor hit probability is already assured.

Additional Delivery Considerations.

Predicted PW II performance is based upon accurate weapon release at a preplanned airspeed, dive angle, altitude and horizontal ground range from the target. Deviations from any of the preplanned parameters will nearly always result in decreased weapon accuracy.

Energy, Airspeed and Maneuverability.

The PW II should be considered as essentially a free fall weapon with a limited controlability that is used to correct minor delivery deviations. Comparisons of the PW II to a high speed glider are not truly valid since most gliders do not use bang-bang guidance or a lag pursuit guidance law. However, if the glider concept helps one's understanding, realize that this glider must have a launch point that ideally would produce at least a 35 degree glide slope.

In addition, it must be launched at a speed and altitude that will ensure some maneuverability down this glide slope. In other words, a release point should be selected so that the weapon will have an energy state at release that will allow the final glide slope to be flown so that enough maneuverability remains at impact to achieve an accurate CEP.

The energy state of the weapon at release is a combination of the kinetic energy (speed) and the potential energy (altitude). The greater the energy state at release, the greater the performance of the PW II! Combat CEPs of less than 15 feet can be expected when the weapon is released at dive angles of 30 degrees or better at altitudes over 10,000 feet AGL and combat speeds of >500 KTAS. Level flight releases above 10,000 feet AGL and > 500 KTAS produce the same results. This together with other flight characteristics of the PW II produce the three distinct types of terminal flight paths discussed previously. The ideal flight path is where excess kinetic and potential energy is available and the calibrated airspeed increases as the target is approached.

Here, the envelope is usually very large and excellent accuracy is obtained on a routine basis. A less desirable release produces a terminal flight path near 35 degrees. Here, calibrated airspeed remains relatively constant during the terminal phase and potential energy is just adequate to supply maneuver capability. Deliveries in this area produce good accuracy when high release speeds (above 500 KTAS) are utilized. Envelope size permits routine deliveries by proficient aircrews. The third possibility involves deliveries where the terminal angle is less than 35 degrees. In this case, potential energy is inadequate to maneuver capability and calibrated airspeed decreases as the target is approached. Maneuver capability in this region depends almost entirely upon the kinetic energy obtained at release. Envelope size shrinks rapidly in this area and gravity sag becomes a factor.

Field experience has shown that a 2-g maneuver capability will provide a reasonable minimum approach speed to provide a 30 foot CEP. This rule-of-thumb is only true if the terminal approach angle is > 30 degrees. The bottom line from this data is that PW II weapons must get to the target with at least 360 KCAS for the GBU-12 and at least 440 KCAS for the GBU-10. These speeds will achieve only barely acceptable results and should be used as absolute minimums.

Suppose a GBU-12 is delivered from a 550 KTAS (or KCAS at sea level, etc.) 25 degree loft/toss. At apogee, the weapon has slowed to about 420 KCAS and shortly thereafter acquisition will occur and 30 KCAS is lost in the transition maneuver.

Approximately ten seconds of terminal guidance on the resulting 24 degree glide slope reduces the airspeed by a further 25 knots. This example shows how a reasonable launch velocity of 550 KTAS results in an impact velocity of 365 KCAS when everything is optimized. Although 52 percent of the weapons will impact within 30 feet of the target, the majority will impact at 6 o’clock.

In the same example, being 20 knots slow at release will increase the automated launch angle several degrees. This will in turn increase the transition maneuver loss from 30 KCAS to 50 KCAS after acquisition, there will be little change in terminal glidepath angle so the terminal speed decay will still be about 25 knots. The end result is that the maneuver capability near impact has decreased from about 2-g's to 1.5-g's and gravity sag becomes the predominating factor. In this case, the center of impacts shifts rapidly to the 6 o'clock position and outside of the 30 foot circle.

Spot Motion and Jitter.

Every designator has inherent stabilization characteristics which cause spot motion and jitter. Spot motion usually results from operator inputs to the laser steering controls and abrupt aircraft maneuvers that overtax the slewing capabilities of the designators aiming drive motors. Jitter is inherent in all laser designators and is caused by minute vibrations within the designator drive mechanism and optical bench. These vibrations cause a change in the laser position on a pulse to pulse basis.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AGM-84 Harpoon Employment

The AGM-84 is a fire and forget weapon that does not require further action from the pilot after launch. Targets may be selected using the E key. The AGM-84A thru D do not have a land attack capability so limit targets to shipping only.

Maximum launch range is between 120 and 140 KM. The aircraft's air to ground radar can be helpful when locating targets and can be used to estimate range.

F/A-18A loaded with four AGM-84A Harpoon missiles.

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AGM-45 Shrike Employment

The AGM-45 is not fired at a specific target, but is “lofted” into the general area and homes in on any radar transmitting at the time. This may sound overly simplified, but it is really how the system worked.

The best tool for aiming the AGM-45 in Strike Fighters is the RWR. The RWR, shown here at the top right, gives a relative bearing to any active radar site.

Cockpit of the F-4E showing the air to ground radar and RWR.

For best results, fire the missile when the radar site is at the 12 o’clock position and within 10 miles. Missile range may be extended to 25 miles by firing in a gentle climb. Be careful when you do that, however, as the missile may overshoot the target.

One interesting feature of the AGM-45B is the white phosphorus smoke left by the warhead. This allows visual identification of the target after the missile has taken out the radar. The AGM-45A does not have this feature.

Radar site marked with WP from an AGM-45B.

Anti-radiation missiles have an unparalleled ability to home in on enemy emitters and disrupt or destroy the elements of an integrated air defense system (IADS). However, they are not classic precision-guided weapons, such as laser-guided munitions. On the contrary, ARMs cannot be steered and under certain conditions may not guide on the target that they were originally fired. Also, they do not have the ability to discern friend from foe. Therefore, the precision detection capability of the launching platform and its human operator in the loop are key elements ensuring weapon effectiveness and the prevention of fratricide. The translation of what the launching aircraft sees to what the ARM sees is paramount.

Several unique factors effect ARM employment. Most significant are the ambiguities in the radar frequency spectrum which cause friendly, enemy, and neutral radar emissions to appear similar. Ambiguities make accurate platform targeting and missile guidance difficult. These ambiguities will continue to worsen as the frequency spectrum becomes more dense and overcrowded. A limited amount of frequencies is suitable for radar operations, and as newer systems evolve, more emitters will overlap. In some instances, high target area activity in a dense emitter environment may cause cockpit task saturation and decrease targeting efficiency. Now previously defined enemy emitters from the Soviet era cannot be exclusively classified as such. Potential partners in multinational combined operations may employ such systems, causing use of the same weapon system on both sides of a conflict. For example, in Desert Storm, coalition forces and Iraq both used the SA-6 and Hawk weapon systems. As systems intermingle during changing world political conditions, it will become increasingly difficult to detect friendly, enemy, and neutral radar emitters.

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Red Air Intercept

By Mk2

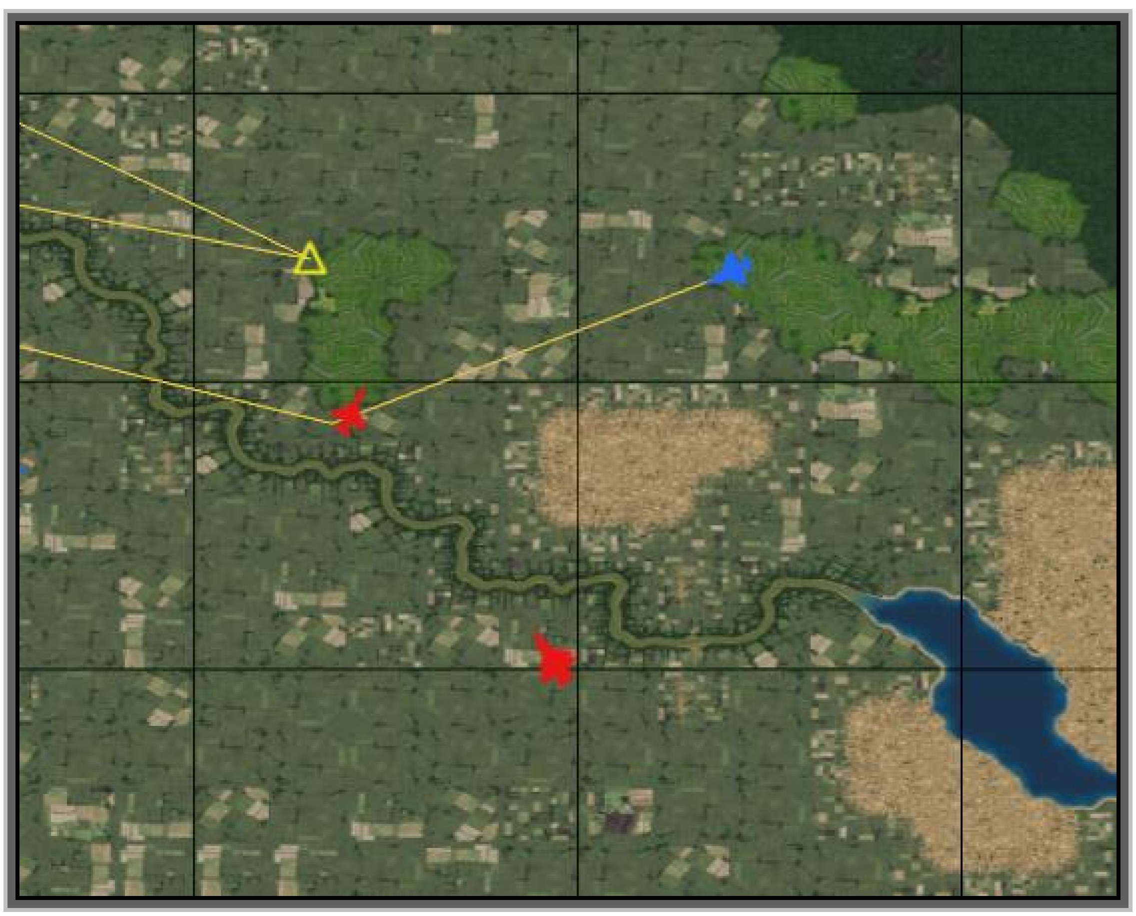
Ok here is a step by step look on how to successfully intercept an incoming raid by US forces if you are flying for the VPAF. I have read a few times that surviving as a VPAF pilot is almost impossible in this game. I fly on all HARD settings.

I used a Mig-21MF from the 1/921st regiment in the up and coming Aces over North Vietnam Campaign.

I will include tips at the end of the presentation but will focus on the most important thing which is the intercept itself.

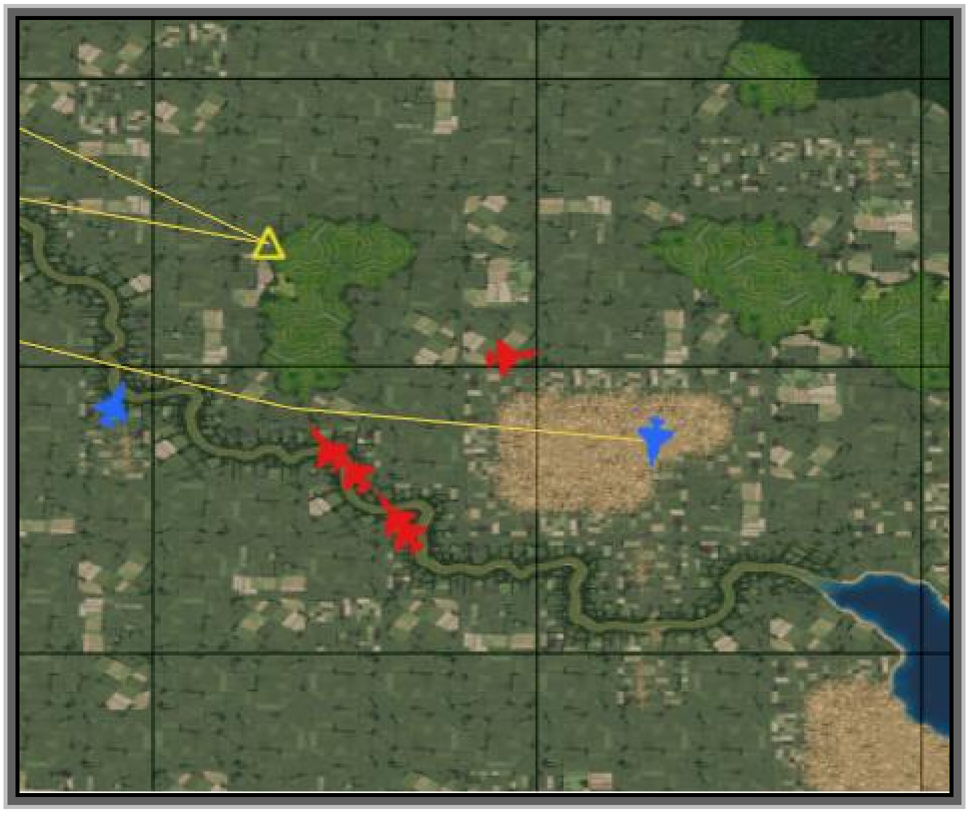
You must I repeat you must use the map liberally. For anyone who thinks this is unfair I point out, that it is included in the game as a situational awareness tool and the GCI of the VPAF (Ground Control Intercept) was historically phenomenal.

I have successfully taken off and I am on the way to the intercept. Ground control makes me aware that they have bandits on their radar. I check the map and see the following:

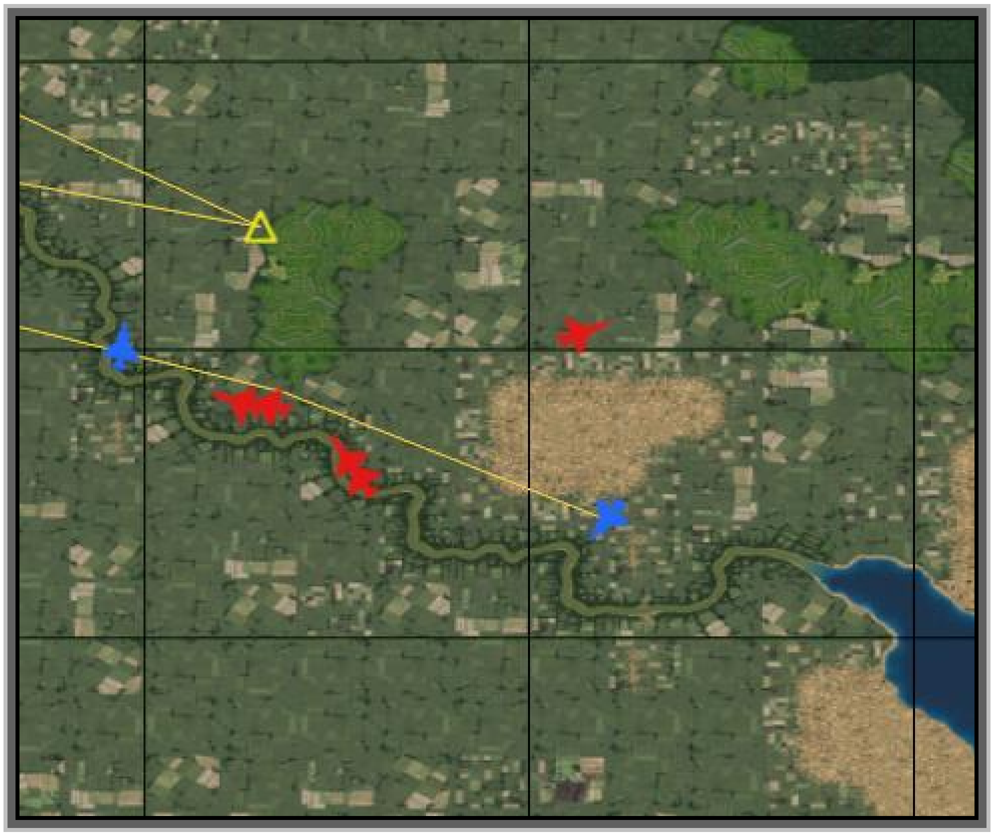


There is an incoming raid, most likely the first aircraft are fighter escort sent in to clear the way.

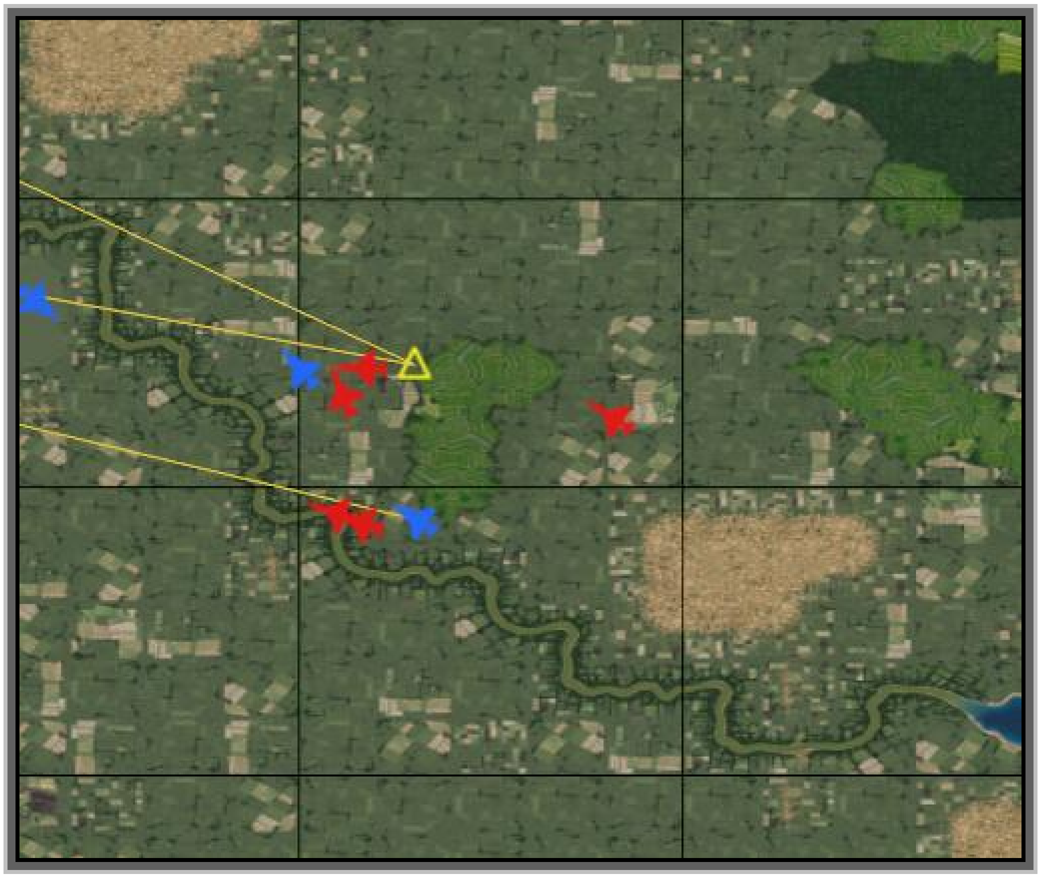
I am flying from the cockpit of course (if not I would crash) but momentarily check the map for positioning. Here I make a hard left and accelerate using afterburner. The escorts GCI has spotted me as well and they turn to meet me.



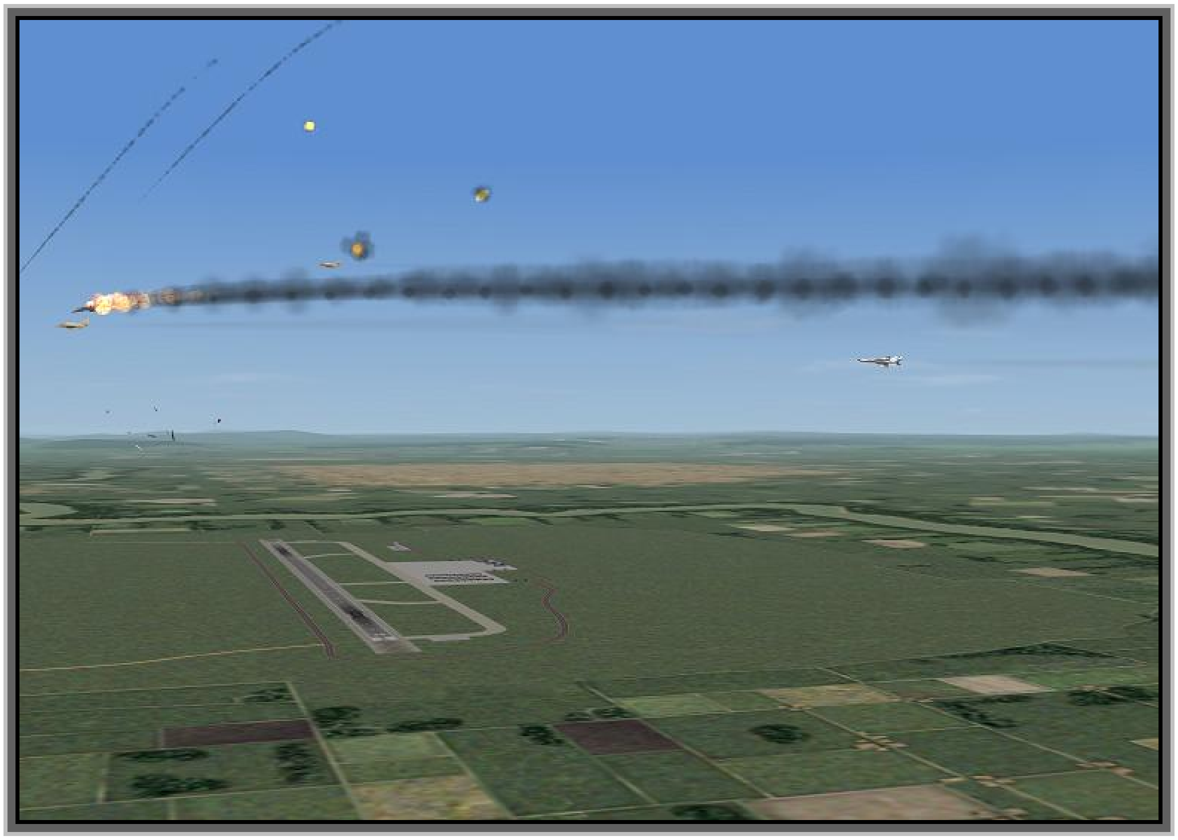
I continue to accelerate and drop a bit to gain even more energy. I have now successfully separated myself from the escorts and the hunt begins.



The intercept has gone very well and I used my eyes to spot flak burst and locate the enemy flight visually. I also hit the T key so that I may now orientate myself properly (what planes are we attacking) and so that I may use the pad lock key to close in on my target.



Here the first A-4 erupts from an Atoll missile.

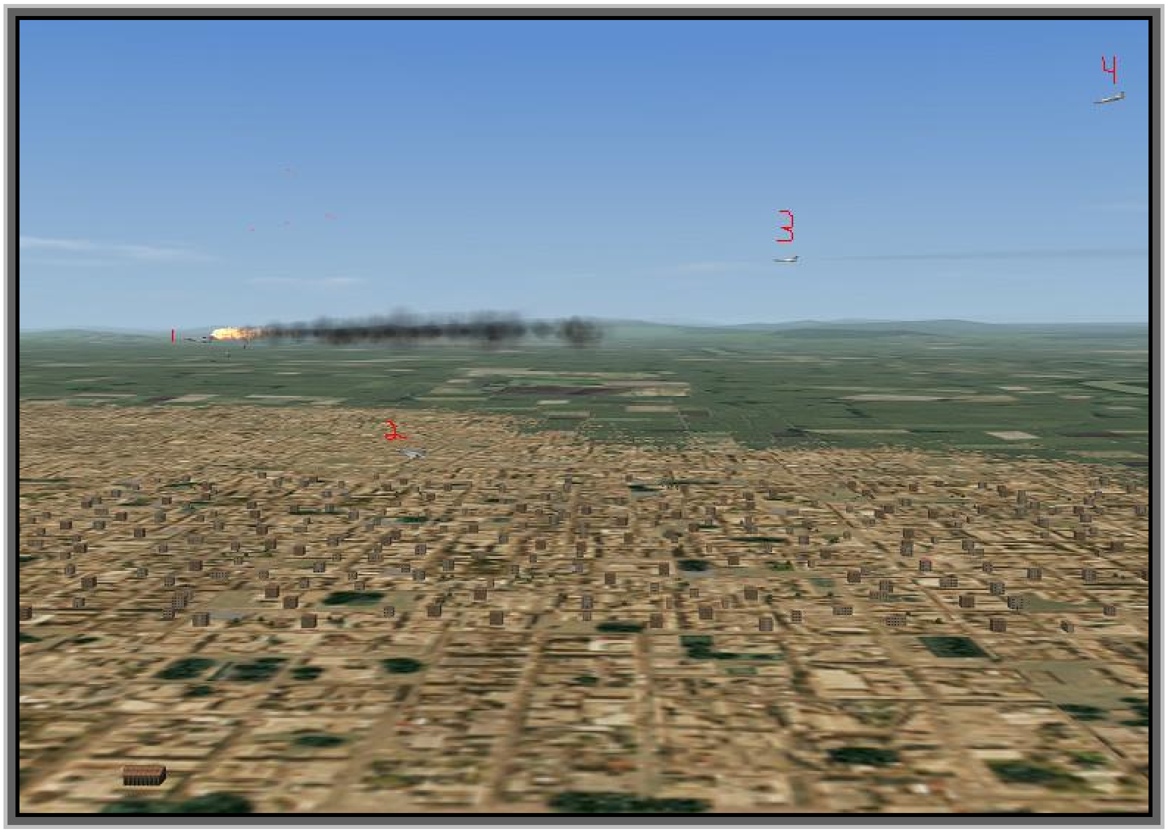


The second A-4 erupts from another Atoll, I have not slowed down a bit and I maintain full energy as I accelerate past the flight.

DO NOT EVER LOSE ENERGY ON THE INTERCEPT that is fatal.

If you can not set up properly and your speed is too great, well then too bad, live to fight another day, blast past the enemy flight and don’t look back, do not turn, do not slow down, head for home, the intercept is blown. That was not the case this time. Notice how we have maintained flight integrity. All flight members are still together. Try to not hit “engage air” to soon, as the other members might go “Rambo” on you and head for another flight. The only time you let them loose is when all bets are off and the enemy fighters have successfully gotten in your way. If this happens, YOU MUST deal with the enemy fighters.

I have numbered the flight members in the picture below.



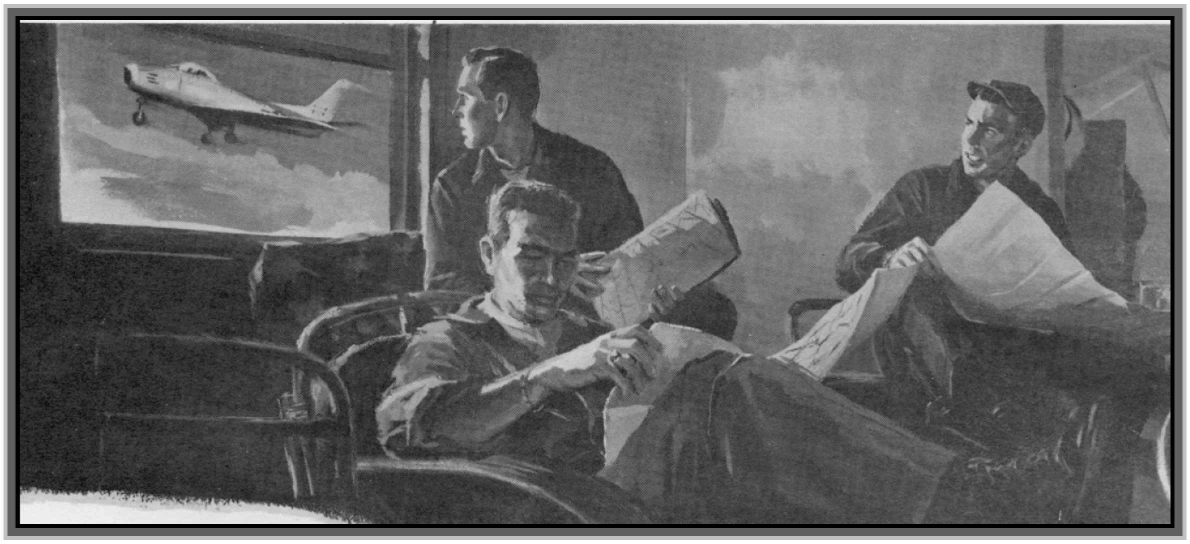
One last point to drive home. Once you have the "mission is a success" signal (or failure) or for that matter you blew the intercept, calmly send everyone home. Light afterburner and get as low as you can possibly go. I have avoided and survived Sparrow and AIM missile shots at the end of an intercept by getting low. Also you draw the enemy over your own AAA and SAMs.

So now I got home, the entire flight intact, avoided the dreaded Phantom Js that were lurking. Got two of the enemy (ground fire got a third and helped with the mission being successful) and completed a successful intercept.

Flying with a Mig-21 in the late war environment is tough but with discipline you can be successful.

Notes on Mission Survival

By Deacon211



I think the big overarching thing to remember about flying combat sims is survivability. Not that there will never be a time that you should take risks, but your reward must always be worth that risk.

So: Should you jettison your tanks/bombs if you get targeted? If speed or maneuverability is an issue, always. Obviously, you would want to keep your tanks in particular for as long as possible ‘cause gas is good. But all it does is make a bigger fireball if you're dragging them around trying to evade a SAM. No sim I know of really properly simulates this, but a jet with tanks/bombs/pods hanging off it really handles like a pig. Mission accomplishment is important of course (it’s why you’re out there), but there are definitely times when you gotta’ shell your load so you can survive to kill bad guys another day. One fault of many sims is that they provide such a thick air defense environment, that every mission has MiGs, SAMs, and AAA coming out the wazoo. In RL, you may see MiGs once every 3 or 4 missions (or, as was pointed out to me recently by a Viet Nam F-4 driver, even more seldom than that). Or perhaps your escort is taking care of them for you. Instead of dodging 30 SAMs every mission, you may only have one, or perhaps none, targeted on you during the course of any single mission. But that would make it boring wouldn't it? The unfortunate downside of this enhanced defense though, is that you are virtually forced to fight to the target every mission lest you never get a bomb off. Just keep in mind that a wise pilot knows when to hold ‘em…and when to fold ‘em.

In the same vein then, if every truck park is defended like Moscow, it would be wise to keep in mind the old adage:

"One pass, haul ass, expend all!"

An aircraft TACMAN once noted that 75% of ground attack aircraft shot down were done so on a reattack. So hanging around the target area, especially if you are ingressing low, (which BTW should only be done for high threat environments [fighters/high end SAMs]), is generally a bad idea. If the defenders weren't aware of your presence before, they certainly are now and are doubtlessly cheesed off that your first bomb accidentally hit the beer tent! Even if you are truly low to medium threat (light AAA, MANPADs), you still gotta make the call if the target's value warrants trolling around the area and repeatedly dipping your nose into the threat envelope. In any case, once the lead starts flying, you aren't increasing your chances of surviving the day any by hanging around. In the end, always keep in mind that it takes alot of destroyed trucks to equal the cost of one Phantom, so one for one is not a very good exchange rate.

In regard to Positive aircraft ID, it is very tough to simulate properly in a sim since RL PID criteria is hard to simulate. Did GCI watch where the bogey took off from? Do they know that there are simply no other friendly flights in the area? Are they picking up telltale electronic emissions of a bandit? When VID is/was necessary, RIOs would sometimes carry binoculars to help in the task of identifying the bogey. In the Tomcat, they have a big honking TV system for just that purpose and all modern fighters have some sort of IFF or NCTR to help. In the absence of any advanced systems, an eyeball/shooter maneuver is very effective:

http://www.combataircraft.com/tactics/offensive_split.asp

But even this maneuver is hard to simulate in most sims since we always seem to be flying with the bottom of the class, AI wise, as wingmen. Therefore, I tend to accept a certain amount of "cheating" to make up the difference in most sims. If you really want to do the VID thing without counting on your wingman, just make a high speed blow through to ID the bogey then reset at 30 mi or so and pitch back to take a BVR shot providing there aren't friendlies in the immediate area.

This point is critical! Do not fire at a bandit if you have a potential friendly/unknown aircraft in the missile's field of view. If you do fire into a furball, whether you have the bandit IDed or not, you can probably expect to get a good ass kicking in the ready room by the guys you inadvertently shot at. Extreme care is always taken to ensure missiles reach ONLY their intended target and there's no way to guarantee that unless there isn't another airplane in the missile's FOV.

In short, if you really want to fly sims like you would in real life, play as if this is the only life you've got and all the other cockpits have your best friends in them.

Air-to-Air Tips for New Pilots

By Mk2

These are random tips directed at new players for getting more shoot downs.

How can you actually score more kills?
It’s all in learning how the weapons work

I fly with the following settings:

Flight: hard

Weapons: hard

Ammo Usage: hard

Everything else including enemy skill on Normal. So let’s do those settings first.

Next step:

Get familiar with the “T” key. This targets your next enemy in visual range. It places a rectangular red box over the target (using the above settings). This is great if you have bad eye sight like I do as you will be able to pick up the red box when otherwise you would miss the target against the background or down low in the weeds etc.

Now lets move on to weapons selection. Arm the weapon you want, lets talk about the radar guided missiles first. Turn on the Radar. You can set it to search and hit the corresponding key to change range (I find this useless unless I am trying to pop something with an AIM-54 from very far away) usually I set it to bore sight as I am within 10 miles when I run into the enemy. If you are on boresight and you keep your nose pointed at the enemy (hopefully by now you have hit T key and placed a rectangular box around him) a yellow diamond will appear. At this point, if you are in the envelope where you can fire the missile, you do so. If you are turning….you have to wait for a cleaner shot, one that will allow the weapon to guide. Once you fire, you must keep your nose on the enemy to maintain lock.

The IR missiles are a bit different. I found that the growl it makes when it is locked is real weak. I always miss it when wingmen are screaming and the afterburner is on, so I tweaked my own file. This file really GROWLS loud and there is no mistaking when you have a lock. I find that different weapons require different angles. When I fire an early model Atolls for example, I like to be slightly above or below the plane and I have to fire it almost when I am at his 6 o'clock and he is not moving much, it has a real small launch window. The modern IR missiles require you to lead a bit (to help the missile out) depending which way the target is leaning.

So let's recap:

Get your settings the way you like them but I find the above to be the best for new players who want realism but flexibility to learn how to play.

Familiarize yourself with the "T" key.

Familiarize yourself with switching Radar to "Bore sight" mode.

Familiarize yourself with switching from weapon to weapon.

Ok this is the most important one. When you go to the control section to set all these keys up, find the command that is defaulted to F4 on your keyboard, it is your padlock target. I set it up on my joystick. When I click it my eyes go right to the target and I can keep a visual on him while I am turning and burning. If I need to orientate myself again, I click on it again to look forward. In a dogfight I usually go back and forth, back and forth. This will take your head out of the cockpit and keep it where it belongs, in the fight.

Also, when you are a point blank range, switch to guns. Make sure the command is on your joystick, so you can get to it quickly.

Notes on Tactics

By USAFMTL

Here are some of the tactics I use for multiple flights. i.e. flight of 8 planes or more.

Air to Ground Tactics:

On a ground attack mission, I send my wingman in with me after the primary target. My other 2 planes I have them loaded up for A2A and have them provide cover for us. The 2nd flight I send to attack all ground targets. They keep the SAM's and the AAA busy while the wingman and I go in after the target.

In a CAS situation, load up your wing man well. Lots of CBU's then play FAC for him. After he has expended his ordinance have him cover you then you go in and clean up. If you have another flight have them loaded for A2A and have them provide MIGCAP for you. Mind you if you are in an A-10 do not do this with your second flight, have them go after TOO (targets of opportunity) MiGs show up....BUG OUT!

Rule of thumb, and I stress this (coming from real world pilots), you only make one pass at the target, expend all your ordinance and bug out. Use your pre planned egress routes if you miss you miss, so what. Get to your rally point recall your flight, go home. Better to be a live pilot then a dead hero.

A2A Missions

Keep your wingman with you as much as you can. Then send the rest to break them up....CRY HAVOC AND BRING FORTH THE DOGS OF WAR...is how I fly A2A missions.

#1 Fly aggressive - just watch your six! Target fixation will kill you. :cuss:

#2 Watch your six and you buddies six. Getting a MiG off your buddy’s tail is more important than scoring for yourself.

#3 Know when to run. 20 Mig17's vs. 4 F-4's = **NO GOOD** use your speed, extend and escape. He who fights and runs away will live to fight another day.

#4 Know your plane. You aren’t going to out turn a Mig-17 in an F-4. Use your speed, boom and zoom. Or the long arm of the law rule....if you can kill him from 20 miles away, then do it. If you get into a knife fight just because you are just looking for it...be prepared to ride the silk elevator. Be smart...

Bomber Intercept

Bombers are a pain in the ass especially with a sting in its tail. If you can take them out BVR then do so with extreme prejudice. However if you are in a early jet and have guns/rockets or AIM-9B's you need to think about what you are doing. Use the AIM-9B but remember it’s temperamental and you may get into range of its tail gun before it decides to lock. Not good.

Taking them head on works but you have to be quick because your close in speeds can be up to 900 kts. You do not have time to line up and think; you have enough time to get a few rounds off then break. Always break low and away to the left or right to avoid breaking low and behind only to get your ass shot up by the tail gun.

Finally, bombers en mass are trouble and I would only recommend this tactic for the experienced. Break them up and separate them into ones and twos. Without the mutual protection of each other, they can be picked off one by one (in addition to their bombs runs are now hosed) I take a tactic from the brave British airmen during the Battle of Britain. They would dive through a formation of He-111's, it is crazy but nothing will break up a formation faster. Timing is everything in that tactic. Another plus side to that is if you have an over zealous escort chasing you and he forgets rule #1 of my previous thread on A2A tactics, well he can end flying into one of his own bombers. See a 2 fer and you didn’t even fire a shot.

F-4E Intercept Procedures

By Zerocinco

Note: The missions described here may be flown on the Bombing Range terrain available here: [Bombing Range Terrain]

When one intercepts another aircraft, he uses certain techniques that bring him into attack or identification position rapidly. Since this must be conducted at night and in weather, all the information must be passed to the pilot or radar intercept officer through the scope.

You should learn to intercept entirely on the scope without visual reference. Sometimes you really do not know where you are in a map view but the techniques here are designed to get you into the other aircraft's six o'clock no matter whatever else is going on.

THE SCOPE.

At first, this is a little mysterious.

In the above figure, you have locked onto an aircraft. The bars spaced left and right of center are degrees of azimuth. Your target is about 40-degrees left of the nose. At 60-degrees, the radar will break lock since that is as far as the radar antenna will slew in any direction. In other words, the intercept is done keeping the aircraft in front of you at all times. Exactly where you keep the target is the important part.

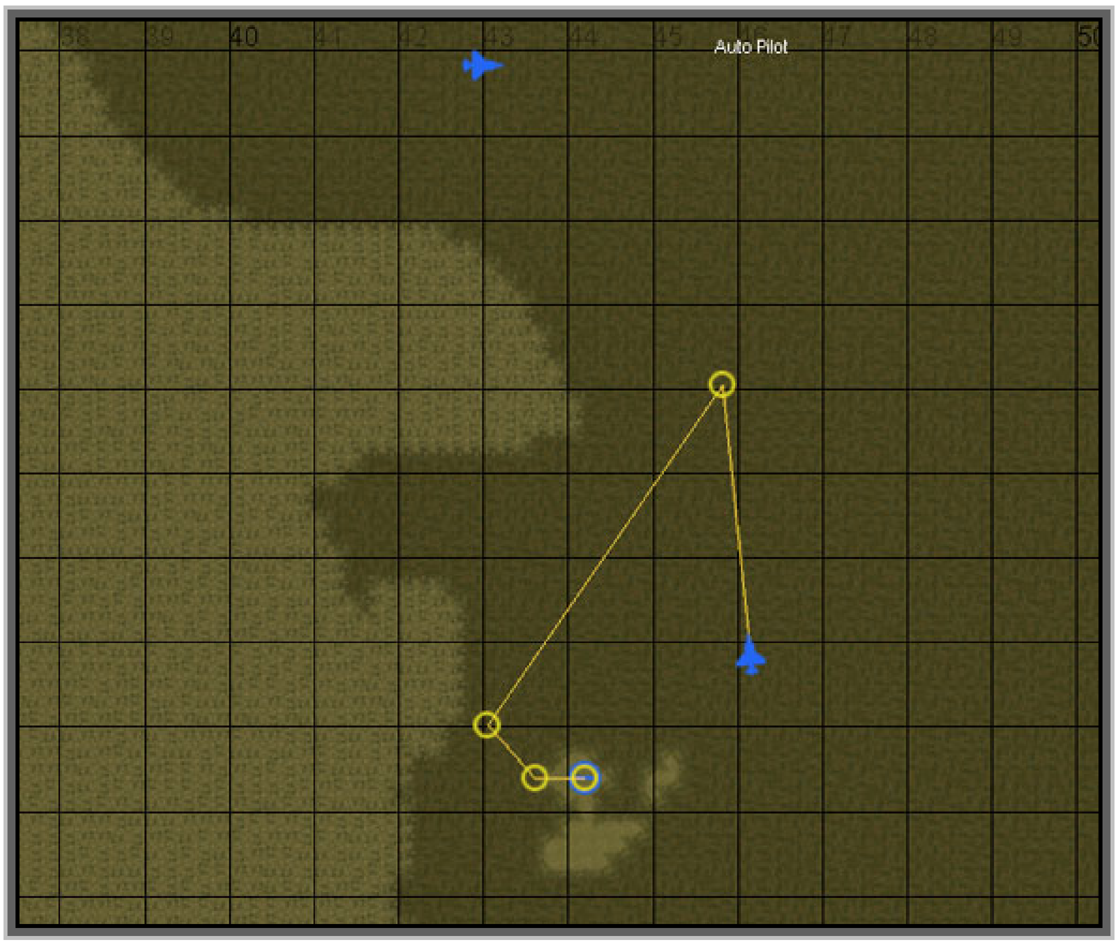
The horizontal lines measure distance out from you. Zero is at the bottom. Since this is the 50-mile scope (the farthest you can acquire lock) our target is about 38 NM away from you. If this were the 25 or 10 mile scopes, he would be 19 and 7 respectively. Therefore, each line is 20% of the selected scope's distance.

On the left are the minimum and maximum ranges for the Sparrow missile IF IT IS SELECTED. These numbers are based upon many variables and can change rapidly. Here, at this instant, you can fire at 22-miles or the max range of the missile (13.7), whichever is least. Fire when the target is in the middle of the range parameters.

This blurred mark is the Steering Dot. If you maneuver the aircraft to put that dot in the middle of the center circle, the computer will guide you to a lead-pursuit position as used in aircraft identification intercepts…slightly low and behind. On crossing intercepts, you can often just center the dot and it will put you at 6 o'clock. Head-on is another story.

The bar on the right shows the relative orientation of the target. This one is slightly low.

FOUR INTERCEPT MISSIONS



RANGE INTERCEPT L2R: You will intercept a Firebee drone crossing left to right. The target is flying at 271 knots at 16386 feet. He will stay on an easterly course.

NOTE: The waypoints only point you in the general direction. Use Wing Leveler instead of Autopilot to keep it steady. Climb to his altitude, set your throttles around 35 to 40% and the let the radar find him. Then lock on.

The previous map and the figure above are the same aircraft. He is initially 20 degrees left at about 45 miles. The system is acquiring lock.

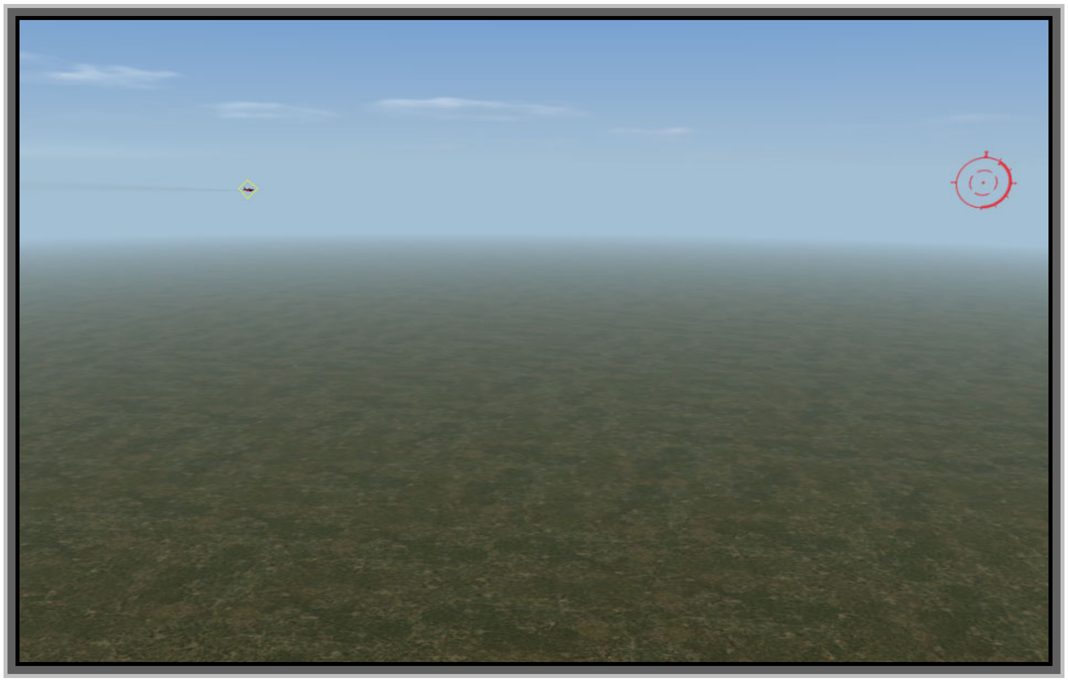
The scope is telling you that he’s 20 degrees left, now at 32 NM, slightly low and closing at a good clip…about 300 knots.

Now is where you do the intercept. You know you are closing but can you converge on the same spot? A good practice is to turn to put him 40-degrees off your nose. (Remember: The system will break lock at 60-degrees.)

Once he is there, you watch to see what happens. If he starts to drift inward, you are converging but he is getting ahead of you. If he is drifting slowly outward, you are going to pass ahead of him and therefore not converge.

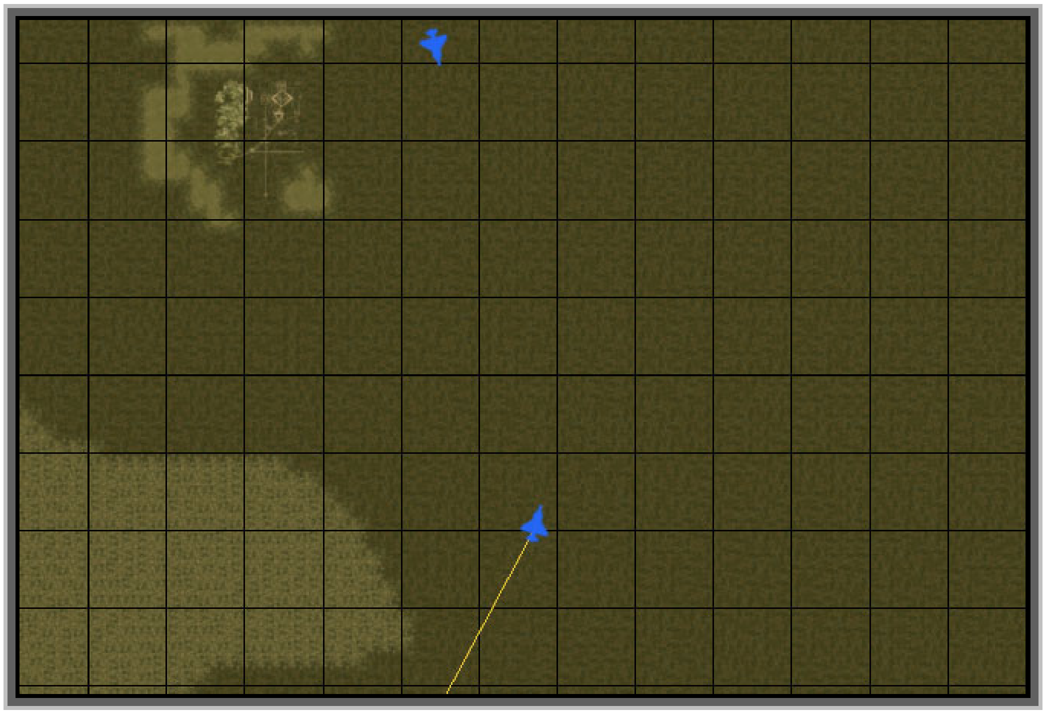
In either case, you would turn to try to keep him at 40-degrees off the nose…for now.

Keep in mind, the Steering Dot. At any time *on this intercept* you can center it and it will take you into his 6 o’clock. Center too soon and you will have a long tail chase. Center too late and you will overshoot and be at this twelve o’clock instead.



Here’s how this one came out.

RANGE INTERCEPT FQTR. The second intercept is staged with the drone heading on a southerly heading and the fighter on a northerly heading. Note the higher closure rate.



If you were to turn to offset the target at 40-degrees, it will begin to drift outward rapidly. A rapid divergence requires that you put him on your nose and keep him there.

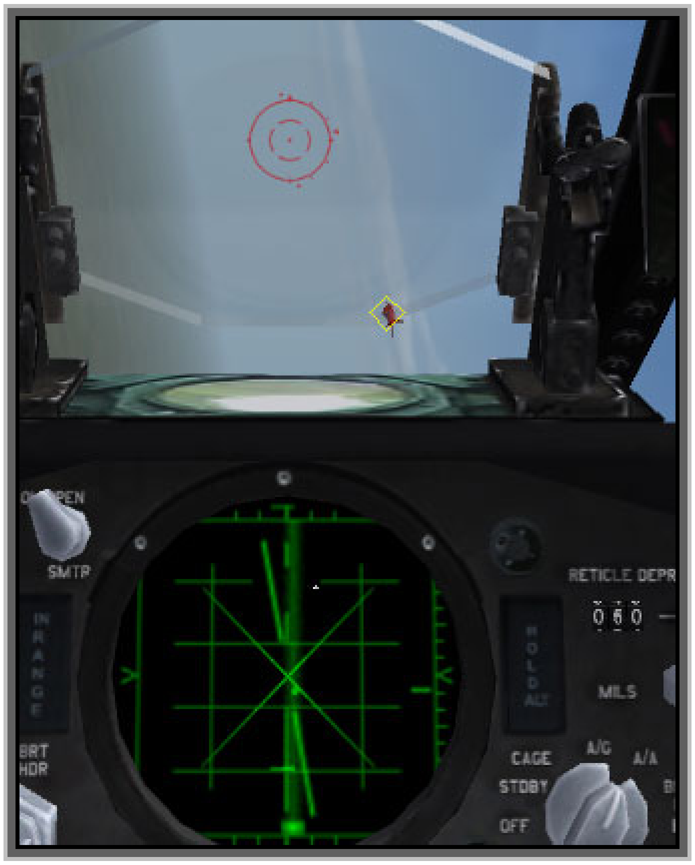
Center the dot and allow the target to close on you.

Obviously, if you keep him there you will fly into his face. At a point determined by rate of closure and your mach number, you will offset to one side, wait but not let him exceed 60-degrees off of boresight, then center the dot and hang on. The computer will bring you right around behind him more gently than you would imagine…perfect for a Fox Two.

In the next picture, you are head-to-head with the target in the 25-mile scope. When you select the 10-mile scope the center circle enlarges. That is the attack scope.

When you are within 10 miles, you must make a decision when to offset and then to swing back into him. Check your Mach number. At .9 Mach, an F-4 needs 9 miles to do a 180 in a less-than-steep bank turn…and in weather you won't want to horse it around.

Flying at .9 Mach and visual, take half that. At 4 or 5 miles, turn. If he is on one side of the center line, turn that direction. Watch his azimuth! At 2, turn back to center the dot.



There he is.

RANGE INTERCEPT FQTR. The third intercept is a rear-quarter shot. You can tell it's a tailchase by the closure rate. These are pretty boring but a good lesson. If you center the dot too early, this is where you end up. All that power won't do you any good. If you are 30 miles behind with a 100-knot advantage, you have twenty minutes of high fuel burn to sit through. The game is generous on fuel and speed. In reality, the tanks are not supersonic so you would jettison your fuel just before burning it at a horrendous rate.

Center the dot and hit the afterburner. And, finally, there he is.

This is a successful intercept but check the fuel. You started at 1200 pounds!

RANGE INTERCEPT MANEUVER. The last intercept is at night. This one is from right to left but if you waste too much time, he will begin to maneuver.

This is not a difficult intercept but it is here to show you that now you can catch anyone in any weather by following a few rules of thumb.

1- At lock, check his closure rate for a clue to his relative heading.

2- Turn to the shortest way to put him 40-degress off your nose.

3- Watch which way he drifts…if at all.

4- If he is moving inward, he is getting there first and you will end up chasing him.

5- If he is moving outward, you are going to cut across his nose.

6- In either 4 or 5 miles, continue to adjust to keep him at 40-degrees to cut him off.

7- If he is diverging rapidly, turn to put him on your nose and keep him there until it is time to swing in behind him.

Air Combat Maneuvering

The following article was originally published in September 1962 Fighter Weapons Review.

Although present tactical commitments tend to relegate aerial tactics to secondary importance, it must be ever present in the fighter pilot's mind that he must be proficient in aerial combat maneuvering (ACM).

Tactical offense and defense are so dependent on split-second timing, as well as the combat situation, that it is difficult to fully comprehend a discussion of these when studying them for the first time. It will take hours of practice in the aircraft and careful study on your part to become proficient in fighter tactics. To become expert is a full-time job.

Given an opportunity to engage the enemy, it may well be that the difference between those who become aces and those who are shot down will lie not only in the ability to handle the aircraft, but also in a complete visualization of the fighter tactics concept.

This article is designed to give the fighter pilot a basic concept of ACM. They are designed primarily for the F-100 but can be applied to almost any present day fighter.

BASIC TACTICS

The fundamentals for fighter versus fighter tactics are very important to understand. Here the pilot picks up the building blocks on which must be based all the rest of his maneuvering. If he is limited in application of these fundamentals, this will also affect the rest of his training. It is imperative then that the pilot concentrates in order to fully understand and appreciate these fundamentals.

We have included the following elements in this section:

1. How to Perform a Hard Turn.
2. How to Perform a Break.
3. How to Recognize and Correct for Adverse Yaw.
4. How to Recognize Favorable Yaw above Mach 1.
5. How to Obtain the Best Results from your Afterburner.

One can easily see that item 3 and 5 might not apply to every aircraft, but the rest can be included in maneuvering nearly every present day fighter. The approach may also appear to be defensive in nature. However, we feel this is necessary since any offensive action is directly dependent on the precise maneuver the defender chooses to execute. If the defender's knowledge is limited in scope, the attacker's corresponding maneuvers will reflect this limitation.

Therefore, to fully understand what the attacker may have to do, we analyze the defender's possibilities. The hard turn and break are considered basic maneuvers.

The difference between the two lies in applications. The hard turn is gradually and steadily increased to maximum performance to keep the attacker at high enough an angle-off to prevent a tracking solution. At the same time it is an attempt to gain an overshoot for lateral separation. The break accomplishes the same purpose, but maximum performance must be reached instantly as the attacker is within firing range.

Now why not use a break for every situation? Because a break, if done correctly, diminishes air speed very rapidly. This reduces future maneuvering potential and can possibly prevent a pilot from achieving an advantageous position if the turn has to be prolonged for too long a time. If a break is attempted in a situation demanding a hard turn, the turn would be extended for too long a time, and the airspeed loss would be great.

Therefore, even though the defender frustrated the immediate attack, he will have placed himself in a more vulnerable situation. An understanding of adverse and favorable yaw is necessary in the F-100 because they have a strong influence on the turning rate of the aircraft. Adverse yaw is the tendency of the aircraft to yaw or roll away from the intended turn. This influence is present in the subsonic range, but is especially noticeable at lower indicated speed ranges when a high relative G condition is present. Favorable yaw is the tendency of the aircraft to yaw in the direction of the intended turn.

We recommend that the pilot pay particular attention to these items in the manual, as they will exert a tremendous influence on how well he can fly in a tactical maneuvering situation.

The afterburner is nothing more than an additional throttle increment. However, there are times and places where the after burner is effective. Since it is essentially a ramjet mounted tandem to a turbojet engine, its efficiency - like a ram-air jet – multiplies enormously as the speed increases. Therefore, the afterburner is most effective in low-G conditions.

With the aircraft in a high angle of attack, the resultant drag is extremely high; therefore, the afterburner, if used, is in its least effective speed range and provides poor acceleration characteristics.

How to Perform a Hard Turn.

1. Estimate the range of the attacking aircraft.
2. Make a hard turn if the attacker is at a range greater than 2,500 feet. This is a planned maneuver in which you are trying to achieve lateral separation.
3. Do not make an instantaneous maximum performance turn. This will kill off your airspeed very rapidly and will reduce your future maneuvering potential.
4. Play the turn to maintain your attacker at a high enough angle-off to force him out of your turn radius.
5. Increase rate of turn steadily but quickly to maximum performance. The F-100, in many cases, requires extreme rudder control to obtain maximum performance.

How to Perform a Break.

1. Estimate range and angle-off of the attacking aircraft.
2. Call a break only if the attacker is closer than 2,500 feet and at a low angle-off in a tracking curve. This is an emergency maneuver designed to ruin your attacker's tracking solution.
3. Make an instantaneous maximum performance turn into the attack.
4. Use hard rudder momentarily (top or bottom) if necessary to change flight path and get out of the impact area. This is necessary, if the attacker has already opened fire, to make his tracking more difficult and to prevent presenting a plan view as a target.

How to Recognize and Correct for Adverse Yaw.

1. Notice the tendency of the F-100 for the nose to move in a direction opposite the turn. The F-100 is designed with large inboard ailerons to aid control through all flight conditions. In a turn, the low wing aileron is deflected up and the high wing aileron is deflected down. This condition imposes a greater amount of drag upon the high wing or in the direction opposite the turn. This will be more noticeable at airspeeds below 250 knots in a high-G condition; however, it occurs at all subsonic speeds.

2. Add rudder, as necessary, in the direction of the turn to counteract this condition. Rudder pressures should be increased as the rate of turn increases because of a steady increase in adverse yaw.
3. Do not add aileron in the direction of the turn. This will produce additional adverse yaw.
4. Neutralize aileron control and continue the turn. This will reduce the adverse yaw component and result in a maximum performance turn.
5. Do not arbitrarily use full rudder and opposite aileron to achieve a maximum performance turn. This may inadvertently place your aircraft in an uncontrollable condition.

How to Recognize Favorable Yaw above Mach 1.

1. Notice the tendency in the F-100 for the nose to move in the direction of the turn. This occurs at speeds above Mach 1. Due to the formation in the shock wave upon the wings, a favorable yaw is induced when ailerons are deflected for a turn.
2. Do not use extreme rudder pressures. Excessive rudder may cause an uncontrollable rate of turn. It may become necessary to use slight opposite rudder pressure to perform a coordinated turn.

How to Obtain the Best Results from your Afterburner.

1. Anticipate the need for afterburner and try to use it before your airspeed dissipates and your angle of attack or G-load becomes too high. Because of a very rapid increase in angle of attack below 250 knots at lower altitudes, or below Mach 0.8 at high altitude, you will not gain optimum afterburner efficiency.
2. Do not use afterburner in a low-speed, nose-high condition. You will be at such a high angle of attack that your aircraft will be on or near the low side of the power curve. In this situation, the afterburner will not increase your acceleration appreciably.
3. Use the afterburner to gain acceleration in a nose-low, low-speed, low-G condition. (See lowspeed yo-yo.) Since you have a reduced angle of attack, you will obtain good acceleration characteristics. (See How to Maneuver for Airspeed and Lateral Separation.)
4. Use afterburner in short bursts or as necessary to maintain a high position on an opponent. (See high-speed yo-yo.)
5. Do not use afterburner if a surprise attack can be completed with normal engine power. The afterburner will leave a short smoke trail prior to ignition. This may compromise any surprise by advertising your position.

TACTICS INVOLVING A HIGH RATE OF CLOSURE

When a high-speed attack is made against aircraft, the defender will maneuver generally as outlined in basic tactics and specifically as stated in "How Defend Against a High Side Attack." The purpose of the resulting turn or break is an attempt to force the attacker into an overshoot condition and destroy his tracking solution. Furthermore, it is the first step in an attempt to attain offensive capability. All you need to know is how to make use of this overshoot or lateral separation. The scissors maneuver will provide just that.

It forces the attacker, with his higher airspeed, into an ever-increasing higher angle-off until he is forced completely out front and onto the defensive. The only prerequisite for this maneuver is a definite overshoot and enough lateral separation to prevent the attacker from sliding into the 6 o'clock position when the reversal is attempted.

It is not hard to see, if you are on the attack with overtaking speed, that being caught in a scissors-type maneuver could be disastrous. How, then, is the attacker going to prevent such a catastrophe? Simple.

Instead of overshooting the attacker, he will yo-yo high the moment he realizes he cannot stay inside the defender's turn. This will position the attacker at 6 o'clock high and still in an offensive position. However, the defender still has a few alternatives. If the attacker yo-yo's too far behind or too high, the defender can use the maneuver for airspeed and lateral separation in an attempt to seek more favorable position. If the attacker yo-yo's are high and maintains very little nose-tail separation, the defender can pull up into the attack by using the defense against a yo-yo. Of course this can be carried on and on by having the attacker use the proper procedures in the yo-yo if a defender pulls up into the attack.

In a head-on attack both individuals begin with the same potential. The objective here is not one of turning the aircraft the tightest to achieve a favorable position. Instead, it is to use your airspeed to turn in a 3-dimensional sense, instead of losing it and reducing maneuvering potential by turning in a level plane. The individual who knows the procedures required to trade airspeed for altitude (and vice versa), correct throttle technique, etc., will find himself gaining more turn and advantage, without the tremendous loss of airspeed and altitude usually associated with this maneuver.

How to Defend Against a High Side Attack.

1. Make an immediate nose-high 180° turn (lazy-eight type) and attempt to maneuver into a head-on pass if the attacker is at a range beyond 6,000 feet.
2. Begin a planned level turn into the attack if the attacker is inside 6,000-foot range. This will cause the attacker to increase G loading to continue tracking and position him further inside your turn at a higher angle-off. This will force the attacker into a nose-low overshoot situation.
3. Pull the nose up hard and begin a turn reversal as the attacker passes behind your tail.

4. Continue the hard turn reversal and attempt a scissors if the attacker overshoots. You should not make a turn reversal until a positive overshoot is accomplished.

How to Perform a Scissors Maneuver.

1. Increase your rate of turn into the attack until the attacker overshoots or moves outside your turn radius.
2. Reduce throttle and/or use the speed brake initially if necessary to increase the attacker’s closure rate. The higher the rate of closure, the faster the attacker will be forced outside your radius of turn. Remember, speed brakes may advertise your subsequent maneuvers.
3. Pull the nose up hard and execute a turn reversal as the attacker passes your tail. The decision on when to reverse your turn will depend upon how rapidly the attacker is sliding to the outside of the turn and how far behind he is as he slides through your flight path. A good rule of thumb --rapid turn overshoot, early reversal, slow turn overshoot, late reversal. However, a reverse too early will be to the attacker's advantage.
4. Retract speed brake and advance power to gain and hold a high position behind the attacker.
5. Hold the nose up and slow your aircraft (without reducing power) as necessary to place you at your attacker's 6 o'clock position. Maximum attainable power reduces the stalling speed of your aircraft to the lowest possible increment. Therefore, the pilot able to reduce his airspeed most rapidly, as well as to the lowest increment, will end up with an advantage over his opponent.
6. Repeat a hard turn reversal each time your opponent slides through your flight path and to the outside of your turn.
7. Use rudder to obtain maximum performance on each turn reversal. If the initial reversal is misjudged and an extremely slow speed scissors results, rudder must be used smoothly or a snap or stall will occur.
8. Use speed brake to S down to 6 o'clock position or perform a top quarter roll-off to prevent over-running if you obtain a position above and behind your opponent.
9. Attempt to place yourself in phase with your opponent if you find yourself below and behind or under him. This forces your opponent into a visual disadvantage with the subsequent possibility that he may mismaneuver and help you to obtain offensive potential.

How to Make a High Speed Attack.

1. Stalk your target in an attempt to complete the attack at close range and in the 6 o'clock position.
2. Keep the aircraft you are attacking in sight. One glance away and you may not see him again.
3. Depress the gunsight electrical cage button and hold the sight reticle image on the reflector glass in a high G condition.
4. Position the gunsight reticle ahead of your target.
5. Check that your fuselage is pointing in the same relative direction as the target's fuselage. This will help prevent an overshoot.

6. Close on the target and get a radar lock-on.
7. Release the electrical cage button and place the pipper on the target within the 2,500-foot range.
8. Begin to track the target as you close range and slow your aircraft to enable you to track smoothly. You may use the speed brake, abrupt elevator movement, or hard rudder to help slow down; but, remember to maintain enough airspeed to give you an advantage in case you should miss the attack. However, too much airspeed may allow the defender to dive away, i.e., if the attacker is forced to zoom or yo-yo off in order to prevent an overshoot, the defender may use the maneuver for airspeed in order to gain separation.
9. Make a positive identification (ID) of the target. You should ID him as an enemy before you squeeze the trigger. If you are unsure, you are out of range and should not fire.
10. Check range dial and open fire within 2,000 feet. A 1/2-second burst will normally insure a kill if the pipper is held on the target while firing. For film assessing purposes, this is 16 frames of tracking time.
11. Maintain some closing speed and continue tracking the target. You should slow down to approximately a 50-knot closing speed to enable you to fire a lethal burst; however, all airspeed advantage should not be sacrificed.
12. Use afterburner if all closure is lost during any part of the attack.
13. Zoom or yo-yo off target if you are able to stay inside your opponent's turn radius.

How to Perform a High Speed Yo-Yo.

1. Attempt to track the target as you close range.
2. Roll away from the turn and pull the nose up hard when you can no longer hold the pipper on the target. (This will prevent overshoot, loss of offensive, and subsequent defensive scissor.) When the pipper begins to slide behind the target, you are no longer in the target's turning radius, and you must break off to prevent overshooting. This maneuver should be started before reaching 2,000 feet or it will be difficult to maintain an advantage. If it becomes impossible to maintain parallel fuselage direction with the target, your angle-off will be too high to complete an attack and you must yo-yo off your target.
3. Slide high and to the rear of your opponent. You are now trading airspeed for altitude in order to prevent an overshoot on your opponent with the subsequent possibility of being caught in a scissors.
4. Push the throttle into afterburner range and gain a higher rate of climb, increase your turn capability, maintain a high airspeed, and gain a decisive altitude advantage. Use of the afterburner after initial pull-up will be determined by the target's evasive action and your rate of closure.
5. Do not use afterburner if it becomes apparent that your yo-yo apex will provide too much altitude separation. If your altitude separation is too great, your opponent may spiral or dive away and reduce your offensive potential.
6. Roll in on the target for another pass. Proper use of the speed brake and afterburner will help cut your turn radius and speed your entry into the target's radius of turn. Rudder control must be used to obtain a maximum performance turn-in.
7. Do not lose your airspeed advantage until the kill is assured.

8. Perform this maneuver as many times as necessary until you are able to maneuver into a firing range and position. Misjudgement is the original cause for an overshoot, and any well executed yo-yo maneuver should not require more than two pull-ups and subsequent attacks to insure a kill.
9. Use caution to prevent a nose-low attitude when attempting to slide down toward your opponent's 6 o'clock position. It is difficult to recover from a steep nose-down attitude and this may force you into a defensive situation if your opponent reverses up into the attack. Use the following procedures if this should occur:
a. Roll one-quarter turn away from your opponent's line of flight the instant your opponent begins pull-up and you recognize a steep nose-low attitude as you approach tracking range.
b. Keep your opponent in sight and at the same time maintain nose-tail separation. (If you fail to take immediate action, your opponent will gain an advantage and a dive for airspeed and lateral separation is recommended.)
c. Begin a smooth pull-up without "burbling" the aircraft as you reach your opponent's original altitude. You will have a greater airspeed at that level than your opponent. This will allow you to maintain an airspeed or altitude advantage.
d. Continue the pull-up and maneuver toward your opponent's 6 o'clock position as you gain advantage.
e. Continue maneuvering until you achieve a firing position. (Refer to sections concerning scissors and yo-yo maneuvers.)

How to Defend Against a Yo-Yo.

1. Play the attack in an attempt to force an overshoot. Your opponent will probably counter with a yo-yo maneuver in order to maintain his offensive advantage.
2. Determine whether or not the attacker is going high and to the rear. If the attacker has an extremely high rate of closure, he will be forced into extreme altitude separation. Use the maneuver for airspeed as a defense. If the attacker slides high and maintains very little nose-tail separation, follow the procedures as outlined below:
a. Maintain a level to slight nose-down turn, relaxing Gs as your opponent slides high. This will allow you to maintain airspeed for future maneuvering potential. Your opponent will probably not be able to recognize the decreased G loading.
b. Wait until your opponent has committed himself to a nose-low attack.
c. Make a hard rolling reversal up into the attack. This will force your opponent into a high angle, nose-low attack below and forward of your line of flight. This is caused by a rapid change in relative airspeeds - your opponent's airspeed increasing and your airspeed decreasing.
d. Maintain a nose-high attitude if your opponent attempts to pull-up with you, and use speed brakes and power as necessary to slide into his 6 o'clock position.
e. Use hard rudder and maximum attainable power to turn behind your opponent if he dives away.

How to Maneuver after a Head-On Attack.

1. Make a coordinated rolling pull-up and a descending turn back down into the attack to crease your turn back down into the attack. This decreases your turn radius after passing your opponent. This closely parallels the first half of a lazy-eight maneuver and will allow you to cut off in the turn in both climbing and descending attitudes. If your opponent makes a level turn, his turn radius will be larger than yours, and you will gain some advantage by maneuvering toward his 6 o'clock position.
2. Use afterburner as you begin your pull-up to minimize airspeed loss.
3. Do not attempt to hold maximum G-loading or burble the aircraft, as this will nullify the advantages of this maneuver.
4. Use the afterburner throughout the descending part of the turn until a pull-up is begun. If afterburner is used during the pull-up, it will act in the direction of gravitational force and will impose an apparent higher wing loading and increase your radius of turn at pull-up.
5. Shut off afterburner, begin easing the noseup, and maintain a slight nose low attitude as you approach the target from the front quarter.
6. Initiate a rolling pull-up as you pass the target and move throttle outboard to afterburner range as your nose passes through the horizon. This will prevent your opponent from obtaining separation.
7. Continue making dives and climbs; until you are inside your opponent's turn radius.


USAF

The Air Tactics Problem

MAJOR FREDERICK C. "BOOTS" BLESSE
OPERATIONS OFFICER
3596TH FLYING TRAINING SQUADRON, NELLIS AFB, NEVADA

(This article is reprinted from January Issue, No 1, 1954,
***Fighter Gunnery News Letter**.)*

The Air Tactics problem since World War II had continued to sink into a position of relative unimportance until the air war in Korea brought it again to life. Any F-86 pilot who fought the Mig-15 in F-86A's and E's knows that it was pilot aggressiveness and superior aircraft that brought us victories in Korea - not necessarily a superior aircraft.

These pilots learned the hard way, the difference good Air Tactics can make, and, in doing so, ran up an eight-to-one kill ratio over an aircraft that was at least as good as the one they were flying.

Although I served in Fighter outfits for seven years in P-47's, F-80's and F-86's, it took an air to air tour in Korea for me to realize fully that air to air gunnery is only about 10 or 15 percent of the overall problem of destroying an enemy aircraft. The problem breaks down into three distinct phases:

(1) That of positioning oneself at an angle off where a shot can be taken (85%).
(2) That of adjusting the pipper on the enemy aircraft (10%).
(3) That of actually firing and adjusting the burst so as to obtain a lethal pattern (5%).

Much has been done to promote phase (2) and phase (3), but phase (1), the real meat of the problem, and the simplest and least expensive for Tactical Units to work on, continues to be looked down upon as an unnecessary part of Fighter Training. It may be unnecessary but, if I were headed for combat and had to choose between 75:00 of gunnery and a good solid 40:00 of air to air tactics, I would by far prefer to go into combat without having ever fired my guns than to venture forth without a thorough knowledge of how to utilize properly a four ship flight in combat. Let's look for a moment at some of the major considerations.

Proper Tactical Operation of a four-ship flight in combat is the result of highly specialized training of four individuals working as a team. Each member of this team must perform his job thoroughly if the team is to perform its primary function of destroying enemy aircraft in the air. Let us consider the contributions of wingman, element leader and flight leader. In an attempt to realize fully the importance of each, then knowing want it is we wish them to accomplish, we can record some information that may help each better perform his own particular phase.

First, the Wingman:
The wingman must hold a position on his leader while patrolling that allows him to do two things:

(1) Cover the rear of the flight.
(2) Assume an offensive position on his leader quickly.

He must have a mastery of his aircraft and already have developed the ability to dogfight and look around at the same time. Approximately 75-80% of the defensive observation must be accomplished by the wingman if the leader is to be effective offensively. It takes a cool, determined, reliable, skillful pilot to fly wing on a good flight commander.

The element leader in this type operation is invaluable to the flight commander. He must take a position on the lead element that affords him an advantage on any aircraft trying to attack the element. His primary purpose is to cause the attacker of the lead element to break off, thus allowing the lead element that period of time necessary for the destruction of the aircraft he is attacking. The element obviously performs other defensive and offensive functions but, with the four-ship flight on the offensive, it must be kept in mind that the primary function of the element is that of allowing the lead element to complete successfully any attack begun. Any split of elements before this function has been performed should not be condoned. A good element leader may perform as indicated several times on the same mission, or only once before a physical split of the elements is necessary. The tactical situation will determine when this split is to made. Either element may be the lead element, depending on experience level in the flight, direction of attack, position of enemy aircraft, and who sees the enemy first. If time permits, however, the lead element should be directed until visual contact is made, thus allowing the flight to begin the fight with the element properly positioned and with each man performing the job for which he is best trained.

The flight leader's duty is obvious. He must maneuver his element into the firing position on enemy aircraft without unduly jeopardizing other members of the flight. The word "unduly" can and will be interpreted differently by all flight commanders. Some, because of their ability, may attack twice or three times their number with no more risk involved than another flight commander attacking a single element. A good flight commander must have a complete mastery of his aircraft and must be an accomplished navigator and instrument pilot. He must be able to think alone, possessing that essential ability of being able to assess a combat situation quickly and accurately. He must be aggressive or all his other capabilities are wasted. He must know the capabilities of enemy aircraft to be encountered in relation to the performance of his own aircraft.

These, then, are the qualities that make good wingmen, element leaders and flight leaders along with the primary functions of those positions.

Here are a few pitfalls to avoid in attempting to make your flight or yourself tactically effective:

(1) Look around and live! The flight leader is engaged about 80% of the time offensively and must be able to depend on his wingman to supply those necessary eyes to the rear.

(2) Don't play Russian Roulette. When you are told to break, do it.

(3) Avoid staring at contrails. There are a dozen enemy aircraft around for every one you see.

(4) Divide the enemy and conquer. It is very difficult even for the best pilots to work mutual support tactics in high speed jet aircraft. If you can split the tactical formation of the enemy, more often than not his mutual support efforts against you will be ineffective.

(5) Your best defense is a good attack. If you can put him on the defensive, your defense will take care of itself. When in doubt, attack.

(6) Keep your airspeed up while cruising. If enemy aircraft are in the area, don't be satisfied with anything less than about 94% of your power.

(7) Play on the team - no individualists. If you are flying wing, be the best wingman in the squadron and you'll soon be flying element or lead. Do your part of the teamwork to the best of your ability and your flight will be the one that consistently comes back with the kills.

(8) Shut up on the radio. If what you have to say does not concern everyone on the mission, get your flight over on another channel.

(9) Keep the enemy in sight; once you spot him, you must watch him constantly. Take your eyes from him for one second and you'll become one of many who "had him cold" and let him slip away.

(10) Guts will do for skill, but not consistently. Know what you have to do and know how to do it or you'll soon find someone else will have your flight.

(11) If you have an enemy aircraft in front of you, assume there is one behind also. More often than not, there is.

(12) Don't shoot unless you're positive it's an enemy aircraft. If you can't tell from where you are, the odds are you should still be maneuvering with him instead of trying to fire. Remember this: When it is time to fire, you'll know whether or not it's an enemy.

(13) Watch the sun - the enemy has good pilots; and if he's smart, that's where he'll come from.

(14) Be a good flight leader. Find out what maximum power your slowest member can pull, then give him 3% especially when engaging the enemy. A little judgement can make up for that 3% and you will find that having your flight together when the fight starts will increase your chances tremendously.

(15) Don't underestimate the enemy. Assume every enemy aircraft you see is being flown by the enemy's best pilot.

(16) When in doubt, trade airspeed for altitude.

(17) Know the "Big Three". Be familiar with glide characteristics, air start procedures and fuel consumption at altitude and at idle R.P.M. If you are attacked on the way home, you may need all three to make it safely.

(18) Don't slow down to get a kill unless you have your element high and fast above you for top cover.

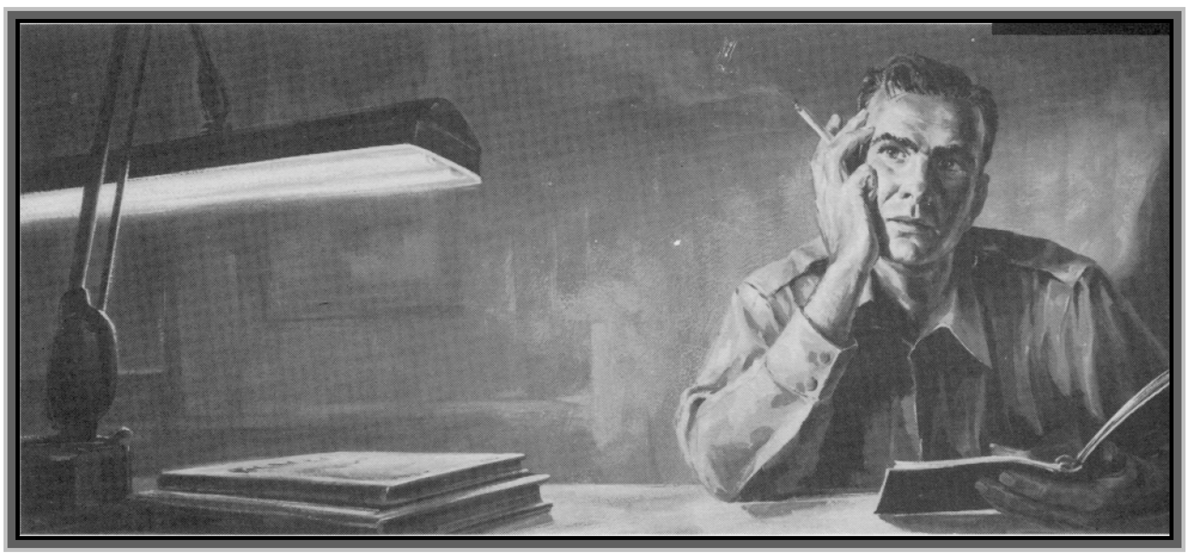
(19) Have one "last ditch" maneuver; practice it frequently. If you get one at six o'clock and he is at your airspeed, you'll need it.

(20) One last word before you set out to become the next Jet Ace…… No Guts, No Glory. If you are going to shoot him down, you have to get in there and mix it up with him. If he's damn good, you are immediately going to be confronted with a problem we sincerely hope you will have solved during your training missions.

Section 7

Supplemental Data

Sight Setting Tables



Sight Setting Tables

Mk 82 Low Drag

AIRCRAFT GROSS WEIGHT - 48000 LBS

RELEASE VELOCITY - 450 KCAS

TARGET DENSITY ALTITUDE - FEET

DIVE ANG DEG	RELEASE ALT FT AGL	0 SS	0 XW	0 TF	2000 SS	2000 XW	2000 TF	4000 SS	4000 XW	4000 TF	6000 SS	6000 XW	6000 TF
10	1000	133	8	4.7	130	8	4.6	126	8	4.6	102	8	4.5
	1500	163	11	6.3	159	11	6.2	154	10	6.2	150	10	6.1
	2000	189	13	7.7	184	13	7.6	178	13	7.5	173	13	7.5
	3000	231	17	10.1	224	17	10.0	218	17	9.9	212	17	9.8
20	1500	121	8	4.4	117	7	4.4	114	7	4.3	109	7	4.2
	2000	141	9	5.6	137	9	5.5	133	9	5.4	128	9	5.3
	3000	175	13	7.7	170	13	7.6	164	13	7.5	159	12	7.3
	4000	203	16	9.5	197	16	9.4	191	16	9.2	185	15	9.1
30	2500	121	9	5.3	117	9	5.2	114	9	5.1	110	8	5.0
	3000	134	10	6.1	129	10	6.0	125	10	5.9	121	10	5.8
	4000	156	13	7.7	151	13	7.6	146	13	7.5	142	12	7.3
	5000	176	16	9.2	170	15	9.0	164	15	8.9	159	15	8.8
45	4000	105	10	6.1	101	10	6.0	98	10	5.9	94	10	5.7
	5000	118	12	7.3	114	12	7.2	110	12	7.1	106	12	6.9
	6000	130	14	8.5	125	14	8.4	121	14	8.2	117	14	8.1
	7000	140	16	9.6	135	16	9.5	131	16	9.3	127	15	9.2

RELEASE VELOCITY - 500 KCAS

DIVE ANG DEG	RELEASE ALT FT AGL	0 SS	0 XW	0 TF	2000 SS	2000 XW	2000 TF	4000 SS	4000 XW	4000 TF	6000 SS	6000 XW	6000 TF
10	1000	111	8	4.5	108	7	4.4	105	7	4.4	102	7	4.3
	1500	138	10	6.0	134	10	6.0	130	10	5.9	126	10	5.8
	2000	161	13	7.4	156	12	7.3	152	12	7.3	147	12	7.2
	3000	199	17	9.8	193	16	9.7	188	16	9.6	182	16	9.5
20	1500	99	7	4.1	96	7	4.1	93	7	4.0	90	7	3.9
	2000	117	9	5.3	113	9	5.2	109	9	5.1	106	8	5.0
	3000	147	12	7.3	144	12	7.2	138	12	7.1	133	12	7.0
	4000	172	15	9.0	167	15	8.9	162	15	8.8	157	15	8.7
30	2500	100	8	4.9	96	8	4.8	93	8	4.7	90	8	4.6
	3000	111	10	5.7	107	10	5.6	103	9	5.5	100	9	5.4
	4000	130	12	7.2	126	12	7.1	122	12	7.0	118	12	6.9
	5000	148	15	8.7	143	14	8.5	139	14	8.4	135	14	8.3
45	4000	86	10	5.6	84	9	5.5	71	9	5.4	78	9	5.3
	5000	98	12	6.8	95	11	6.7	92	11	6.6	89	11	6.5
	6000	109	13	8.0	105	13	7.8	102	13	7.7	99	13	7.6
	7000	119	15	9.0	115	15	8.9	111	15	8.8	108	15	8.7

* SS - SIGHT SETTING (INCLUDES PARALLAX AND ANGLE-OF-ATTACK)
XW - OFFSET (FT/KT) OF WIND
TF - BOMB TIME OF FLIGHT - SEC

Mk 82 High Drag

AIRCRAFT GROSS WEIGHT - 48000 LBS

RELEASE VELOCITY - 450 KCAS

TARGET DENSITY ALTITUDE - FEET

RELEASE DIVE ANG DEG	ALT FT AGL	0 SS	0 XW	0 TF	2000 SS	2000 XW	2000 TF	4000 SS	4000 XW	4000 TF	6000 SS	6000 XW	6000 TF
10	500	125	6	3.7	121	6	3.6	115	6	3.5	111	6	3.4
	700	164	9	5.1	157	8	5.0	150	8	4.9	143	8	4.8
	1000	221	12	7.0	211	12	6.9	202	11	6.7	192	11	6.6
20	1000	144	8	4.7	136	8	4.6	130	7	4.4	123	7	4.2
	1200	171	10	5.8	162	9	5.6	154	9	5.4	146	9	5.2
	1500	214	12	7.3	202	12	7.1	191	12	6.9	181	11	6.7

RELEASE VELOCITY - 500 KCAS

RELEASE DIVE ANG DEG	ALT FT AGL	0 SS	0 XW	0 TF	2000 SS	2000 XW	2000 TF	4000 SS	4000 XW	4000 TF	6000 SS	6000 XW	6000 TF
10	500	105	6	3.5	100	6	3.4	96	6	3.4	92	6	3.3
	700	141	8	5.0	134	8	4.8	128	8	4.7	122	8	4.6
	1000	195	12	6.9	186	11	6.7	177	11	6.6	168	11	6.5
20	1000	120	8	4.5	113	7	4.3	107	7	4.1	102	7	4.0
	1200	146	9	5.5	137	9	5.3	129	9	5.1	122	8	5.0
	1500	186	12	7.1	175	12	6.8	164	11	6.6	155	11	6.4

* SS - SIGHT SETTING (INCLUDES PARALLAX AND ANGLE-OF-ATTACK)
XW - OFFSET (FT/KT) OF WIND
TF - BOMB TIME OF FLIGHT - SEC

BLU-1 Fire Bomb (unfinned)

AIRCRAFT GROSS WEIGHT - 48000 LBS

RELEASE VELOCITY - 450 KCAS

RELEASE DIVE ANG DEG	RELEASE ALT FT AGL	0 SS	0 XW	0 TF	2000 SS	2000 XW	2000 TF	4000 SS	4000 XW	4000 TF	6000 SS	6000 XW	6000 TF
10	400	97	4	2.6	95	4	2.5	92	4	2.5	90	4	2.5
	600	122	6	3.7	118	6	3.6	115	6	3.6	112	6	3.6
	800	145	8	4.7	141	8	4.7	138	8	4.6	134	8	4.6
	1000	167	10	5.7	163	10	5.6	159	9	5.6	155	9	5.5
	1500	219	13	7.8	214	13	7.8	209	13	7.7	204	13	7.7
	2000	266	17	9.8	260	16	9.7	255	16	9.7	250	16	9.6

TARGET DENSITY ALTITUDE - FEET

RELEASE VELOCITY - 500 KCAS

RELEASE DIVE ANG DEG	RELEASE ALT FT AGL	0 SS	0 XW	0 TF	2000 SS	2000 XW	2000 TF	4000 SS	4000 XW	4000 TF	6000 SS	6000 XW	6000 TF
10	400	80	4	2.4	78	4	2.4	76	4	2.4	74	4	2.3
	600	101	6	3.5	99	6	3.5	96	6	3.4	93	6	3.4
	800	123	8	4.5	119	8	4.5	116	8	4.4	113	7	4.4
	1000	143	9	5.5	140	9	5.4	136	9	5.4	133	9	5.4
	1500	192	13	7.7	187	13	7.6	183	13	7.6	179	13	7.5
	2000	236	16	9.6	231	16	9.6	226	16	9.5	221	16	9.5

* SS - SIGHT SETTING (INCLUDES PARALLAX AND ANGLE-OF-ATTACK)
XW - OFFSET (FT/KT) OF WIND
TF - BOMB TIME OF FLIGHT - SEC

Mk 20 Rockeye II

FUZE FUNCTION TIME - 1.2 SEC
AIRCRAFT GROSS WEIGHT - 48000 LBS

RELEASE VELOCITY - 450 KCAS
TARGET DENSITY ALTITUDE - FEET

RELEASE DIVE ANG DEG	ALT FT AGL	0 SS	0 XW	0 TF	2000 SS	2000 XW	2000 TF	4000 SS	4000 XW	4000 TF	6000 SS	6000 XW	6000 TF
10	600	120	7	3.9	117	7	3.9	114	6	3.8	111	6	3.8
	800	150	9	5.2	146	9	5.2	142	9	5.1	139	9	5.1
	1000	180	11	6.4	176	11	6.4	172	11	6.3	168	11	6.3

RELEASE VELOCITY - 500 KCAS

RELEASE DIVE ANG DEG	ALT FT AGL	0 SS	0 XW	0 TF	2000 SS	2000 XW	2000 TF	4000 SS	4000 XW	4000 TF	6000 SS	6000 XW	6000 TF
10	600	100	6	3.7	97	6	3.7	94	6	3.6	91	6	3.6
	800	127	9	5.0	124	8	5.0	120	8	4.9	117	8	4.9
	1000	156	11	6.3	152	11	6.2	148	10	6.2	144	10	6.1

FUZE FUNCTION TIME - 4.0 SEC
RELEASE VELOCITY - 450 KCAS

RELEASE DIVE ANG DEG	ALT FT AGL	0 SS	0 XW	0 TF	2000 SS	2000 XW	2000 TF	4000 SS	4000 XW	4000 TF	6000 SS	6000 XW	6000 TF
20	2500	186	15	8.6	181	14	8.5	176	14	8.4	170	14	8.3
	3000	223	18	10.7	217	18	10.6	211	18	10.5	205	18	10.4
30	3000	153	13	7.7	148	13	7.6	143	13	7.4	138	12	7.3
	3500	179	16	9.5	174	16	9.4	168	16	9.2	162	15	9.0
45	4500	138	16	9.4	133	16	9.2	128	15	9.0	123	15	8.8
	5000	157	19	11.1	151	18	10.8	146	18	10.6	140	18	10.4

RELEASE VELOCITY - 500 KCAS

RELEASE DIVE ANG DEG	ALT FT AGL	0 SS	0 XW	0 TF	2000 SS	2000 XW	2000 TF	4000 SS	4000 XW	4000 TF	6000 SS	6000 XW	6000 TF
20	2500	157	14	8.1	152	14	8.0	147	13	7.9	142	13	7.7
	3000	191	17	10.3	185	17	10.1	179	17	10.0	173	17	9.9
30	3000	126	12	7.1	122	12	6.9	117	11	6.8	113	11	6.6
	3500	150	15	8.9	144	15	8.7	139	14	8.5	134	14	8.3
45	4500	114	15	8.6	109	14	8.3	104	14	8.1	100	13	7.9
	5000	130	17	10.2	125	17	9.9	120	16	9.7	115	16	9.4

* SS - SIGHT SETTING (INCLUDES PARALLAX AND ANGLE-OF-ATTACK)
XW - OFFSET (FT/KT) OF WIND
TF - BOMB TIME OF FLIGHT - SEC