

RT-13
Air-to-Air Reference Text

Originally Published by 35TTS Air-to-Air Flight, George AFB, CA
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LIST OF SYMBOLS AND ABBREVIATIONS

A	Acceleration
AA	Aspect Angle
AAA	Anti-Aircraft Artillery
ACM	Air Combat Maneuvering
ACT	Air Combat Tactical
AFSC	Air Force Specialty Code
AGL	Above Ground Level
AI	Airborne Interceptor
AMRAAM	Advanced Medium-Range Air-to-Air Missile
AOA	Angle of Attack
APX	On-Board IFF Interrogation Equipment
BFM	Basic Fighter Maneuvers
BIT	Built-in Test
BRA	Bearing, Range, and Altitude
BVR	Beyond Visual Range
C_D	Coefficient of Drag
C_L	Coefficient of Lift
CAP	Combat Air Patrol
CE	Chemical Energy
CND	Could Not Duplicate
D	Drag
E_s	Specific energy
E_t	Total Energy
ECM	Electronic Countermeasures
FL	Flight Level
Ft	Feet
FWR	*Fighter Weapons Review*
g	Acceleration Due to Gravity (g = 32.2 ft/sec^2 or 9.8 m/s^2)
G	Acceleration in Units of g
GCI	Ground-Controlled Intercept
G_g	Acceleration Due to Gravity in Units of g (G_g = 1)
G_r	Radial Acceleration in Units of g
GIB	Guy in Back; WSO
GS	Ground Speed
H	Height
HCA	Heading Crossing Angle
HEI	High Explosive Incendiary
HUD	Heads-Up Display
ID	Identify
IFF	Identify Friend or Foe
IMC	Instrument Meteorological Conditions
INS	Inertial Navigation System
IP	Instructor Pilot
IR	Infrared
IRMD	Infrared Missile Defense
K	Conversion Factor from Radians to Degrees (K = 57.3 deg/rad)
KCAS	Knots Calibrated Airspeed
KE	Kinetic Energy
KIAS	Knots Indicated Airspeed
KIO	Knock It Off
KTAS	Knots True Airspeed
L	Lift
Lbs	Pounds
LCOS	Lead Computing Optical Sight
LES	Leading Edge Slats
LOS	Line of Sight
LRBFM	Long-Range Basic Fighter Maneuvers
m	Mass
mm	Millimeter
MSL	Mean Sea Level
N	Load Factor (Gs due to lift)
NM	Nautical Miles
OOP	Out of Plane
ORI	Operational Readiness Inspection
P_k	Probability of Kill
P_s	Specific Excess Power
PE	Potential Energy
POW	Prisoner of War
Q	Dynamic Pressure
R	Radius
RAPCON	Radar Approach Control
ROE	Rules of Engagement
R/T	Receiver/Transmitter
RTB	Return to Base
RWR	Radar Warning Receiver
S	Surface Area
SA	Situational Awareness
SAC	Strategic Air Command
SAM	Surface to Air Missile
Sec	Seconds
SRBFM	Short-Range Basic Fighter Maneuvers
T	Thrust
TAS	True Airspeed
TFW	Tactical Fighter Wing
TOF	Time of Flight
TOT	Time Over Target
UHF	Ultra-High Frequency
USN	United States Navy
V	Velocity
V_C	Closure Velocity
VID	Visual Identification
VMC	Visual Meteorological Conditions
VVI	Vertical Velocity Indicator
W	Weight
WSO	Weapons System Officer
ρ	Air Density (Greek letter *rho*)
ω	Turn Rate (Greek letter *omega*)

CHAPTER 1
INTRODUCTION TO AIR-TO-AIR

INTRODUCTION

In every conflict since WWI, aircraft have been used to destroy other aircraft. The aircraft, weapons, and arenas have changed, but basic concepts and basic maneuvering remain the same. Even though technological advances in fighter airspeeds, closure rates, and weapon slant ranges have expanded the air-to-air arena, the aircrew must still analyze their own skills, aircraft, and weapons, and weigh them against the adversary for maximum effectiveness. The tactics discussed in class assume that the enemy's aircraft are being flown by a competent, well-trained aircrew. If the enemy proves to be incompetent, we may press the attack more aggressively.

THE MISSION

Operational doctrine with regard to tactical air operations may be found in various manuals. These manuals describe the various roles in which tactical air forces can be employed. One of these is "the attainment of air supremacy by destruction or neutralization of enemy aerospace forces, surface-to-air defense systems, air command control structure, and defense of friendly forces and installations from air attack."

To enable friendly tactical air forces to conduct any type of tactical air operations, air supremacy (complete control of the skies), or at least temporary, local air superiority must be achieved. In air-to-air combat, of course, we attempt to destroy or neutralize enemy aircraft while airborne.

The importance of this task cannot be underestimated. From USAF doctrine: "....because both air and surface operations are significantly impaired in the face of effective enemy air opposition, the outcome of counter air operations exercises a direct influence on all other operations. Therefore, counter air operations may demand the highest priority of all air operations whenever enemy air power presents a significant threat." To negate enemy air power, five different types of air-to-air missions are generally identified:

Fighter Sweeps

A fighter sweep consists of sending flights of aircraft into disputed airspace to drive enemy aircraft from the skies. A classic example of a fighter sweep is the January 1967 flight of F-4s, led by Col Olds, which impersonated F-105s and accounted for 7 MIG kills.

Screens

Screens are normally used to restrict enemy air movement. During conditions when an enemy attack on friendly forces is likely, air defense may be enhanced by positioning a screen of airborne tactical fighters between the threat and friendly forces. (Screens are called BARCAPs by the Navy.)

Combat Air Patrol

Air patrol can be conducted over an objective, a friendly air or surface force, a critical combat zone, or along a corridor. CAP differs from screens which are imposed between the threat and the area or force being defended, whereas a CAP is positioned over or near the area or force being protected.

Air Escort

Air escort is employed to prevent enemy air action from disrupting friendly air operations. Escort aircraft may be tasked to defend strike, airmobile, reconnaissance, airlift, or air rescue operations.

Air Intercept Mission

When hostile offensive air action is a threat, air interception of enemy and unidentified aircraft is a vital task. Tactical units are charged with air defense and intercept responsibility or air alert when a threat is imminent.

PREPARATION

Professional fighter pilots do not just take off, climb out, engage, win, let down, and land in casual victory. Their every action is designed to make them winners in the aerial combat arena.

Some of these habit patterns may help you as well.

Personal Equipment

The first basic action we should consider begins with a look at some "tools of the trade" - your personal equipment. The proper fit of helmet and G-suit may not win an aerial battle, but it can keep us from losing one.

Start at the top with the helmet. If you don't already have a lightweight, form-fitted helmet, get one as soon as possible. This helmet is fitted in a 1-G environment, but in the air, under G loads, the foam filling can compress, leaving the helmet loose on your head. If you ever have to hold or readjust your helmet during high-G transition maneuvers, have the helmet refitted. This may prevent loss of a Tally-Ho under high-G conditions. A properly adjusted nape strap and chin strap will contribute to minimizing helmet slippage during high-G conditions. Whether the visor is worn up or down is a matter of personal preference based on weather and visibility conditions. If you wear it down make sure it is spotless. A smudge on your visor that covers, delays, or just confuses a tally at a critical moment can cost you your life.

NOTE

Another item to consider is your hair. If your hair hangs down on your forehead and momentarily blocks your vision, it could cost a Tally-Ho. Either get it cut or rotate your skull cap aft as your put it on to avoid encountering this problem.

Oxygen Mask

Working downward, the next piece of gear which is attached to the helmet is the oxygen mask. Make sure it is fitted properly. A mask that is too large will be difficult to see over, reducing downward visibility, and will also place the mike too far from the lips. When you smile, the mask should smile with you, thus preventing that rubber muzzle from slipping down over your mouth, making it difficult to call "Fox-2" or "Tracking".

Anti-G-Suit

Our next subject is the anti-G-suit. A loose G-suit will lower your maximum G tolerance. The calf and ankle area left carelessly unzipped will mean you can't sustain that 6-G turn long enough to track your opponent. Have life support technicians refit your G-suit regularly; strings tend to stretch with wear. The G-suit should function like a squeegee applying supporting pressure first in the lower legs. To accomplish this, your G-suit should fit comfortably snug in the legs. The waist portion should fit just snugly enough when not inflated to keep it from slipping down on your hips. You should be able to get one hand comfortably between you and the G-suit. If the suit is tight in the waist when not inflated, it will act like a tourniquet and trap blood in your body when it is inflated. Also, make sure any items stowed in your G-suit pockets will not come out under negative-G. Insure the side comfort zippers are zipped up - they provide 1 to 1½ G of extra tolerance.

The Cockpit

Now that we have considered our body, let's look at the environment within which we work -- the cockpit. Beginning from the top, start with the canopy. It should be clean and free of specks, flies, and water spots. Constantly beating your head against the canopy while breaking into a paint fleck can induce permanent brain damage.

Inside the cockpit, the next step is to get rid of any loose and extraneous objects. Take only those items into the cockpit which are necessary for that flight. Reduce your checklists and publications to the minimum size needed for an air-to-air mission (for example, you probably won't need that portion of the dash 34 checklist which tells how to drop bombs). Leave the gun camera dust cover with the crew chief and make sure the film magazine is securely fastened in the gun camera.

All objects which are necessary for the flight must be secured in the cockpit. It can be very distracting during a zero or negative-G maneuver to suddenly have the approach plate plastered over your visor, blocking the view of a pursued or pursuing bandit. In the same vein, before opening the canopies at the end of an air-to-air mission, inventory all items and check the top of the ejection seat area. Several inadvertent ejections have occurred when the canopy was opened on the ground and a foreign object, like a checklist, was forced into the ejection seat mechanism.

Strapping In

Speaking of the ejection seat, there are several techniques of strapping into the seat which are optimum for the air combat arena. The lap belt should be very tight, and should be re-tightened in

flight prior to entering the working area. This will enable you to remain in the seat during zero- and negative-G maneuvering. On the other hand, the survival kit straps should be slightly loose to enable your torso to twist around in the seat for optimum six o'clock coverage; however, too loose and you risk man-seat-chute entanglement on ejection.

The seat height itself should be adjusted so that while sitting erect the top of your helmet is just below the top of the canopy. On the ground you should be able to fully deflect the rudder pedals with a slight bend remaining at the knees. Set a fairly high throttle friction setting to prevent unintentional throttle creep. Finally, consider the internal cockpit mirrors. Their purpose is to extend six o'clock coverage by a few degrees, so they should be adjusted to cover an area you would not otherwise be able to see.

Radar Boot

Backseaters need to insure the radar boot is in a position where they can see the entire scope face. These details may seem trivial, but individually or collectively, they could determine the outcome of an air battle.

EFFECTS OF G FORCES

As you will see in this course, maneuvering the aircraft in the air combat arena requires that you function under physical and mental stress in a high G environment. You must be aware of how G forces hinder your ability to effectively see, communicate and most important, think.

Probably all of us have experienced tunnel vision, grey out, and black out, but even prior to these effects G forces can insidiously affect your performance. Your visual acuity is degraded when operating at more than one G. You can padlock on a bogey but lose sight due to a 4- or 5-G turn into him. This occurs because blood has been diverted from the eyes. In a similar manner, our ability to think and talk is affected. In some cases, it might be necessary to use a lower sustained G-loading to enable us to see, think, and talk with greater clarity. To effectively manage G forces, we need to anticipate them and their associated problems and use an aggressive anti-G straining maneuver as required to control blood pooling in the lower extremities.

NOTE

Remember to close the glottis (windpipe valve), when doing the anti-G straining maneuver. Tense all the muscles in your body while straining, and hold for two to four seconds. Try to exhale and inhale to fill your lungs again as quickly as possible, so as to minimize the time that you are not straining.

VISUAL LOOKOUT

Have your ever noticed that some people have an amazing ability to see aircraft at long distances in the air? Certainly some of this ability is due to being blessed with good set of eyes, but some is also due to the use of proper visual techniques which enhance their ability. The most important factor in determining the tactical advantage in an air battle is who gets the first tally.

Focusing the eye

The threshold of visual detection for fighter aircraft can vary from zero to twenty miles, depending on aircraft aspect and size, altitude, weather, and sun position. In order to approach these limits of detection, the eyes must be focused to infinity. This can be accomplished by focusing on an object such as cloud, or ground, which is at least 3-5 miles away. This will give a depth of field, or area of sharp focus, of less than one mile to infinity.

Remember, every time you look inside the cockpit, the eyes refocus to 1-2 feet, and must be refocused before efficient visual search can be accomplished. It is relative motion against the background, or drift, which attracts the eye's attention first. To see this drift you must focus on a thirty or forty degree sector of the sky and hold it for three to four seconds. Once detection is accomplished, it may be impossible to take your eyes off the other aircraft without losing visual contact.

Early detection

To ensure the highest probability of a visual pickup, all flight members should be looking in a different area. This is one of the advantages of a two-seat fighter. There are numerous items which will assist you in gaining/maintaining a tally. These include contrails, smoke trails, silhouettes against atmospheric haze, puffs of smoke from engines or venting fuel, shadows on ground or clouds, as well as relative movement against the background. All these can be used to facilitate the earliest possible detection of a bandit. Remember, 80% of all fighter pilots shot down by

enemy aircraft never saw the attacker. CHECK SIX!

COMMUNICATIONS

Timely, descriptive, and directive communications are required to effectively employ fighter aircraft in the air-to-air arena. A study of aerial engagements in previous conflicts shows that ineffective verbal communications were often directly or indirectly responsible for losses, while good communications played a significant part on many successful missions. Radio transmissions are essential and must be clear and concise.

Think of UHF radio transmission time as a valuable resource which should be used when needed and conserved when not needed. When making transmissions, use of the complete call sign is a must. Know the Operational Brevity Code (see Appendix B). Standardized calls assist in conserving UHF transmission time, but they must convey the same meaning to all members of the flight. During the tactics block, your instructor will cover many of these calls in detail.

Additionally, every flight member must be able to make these calls. The time lag to relay information from the WSO to the pilot so he can make the UHF call is unacceptable in the time critical ACM environment, particularly when the safety of another flight member is at stake. To relay visual acquisition information to other flight members, a standard format is used. The format used depends on whether you are offensive or defensive.

Defensive

When your wingman or flight lead is under attack, the critical task is to get him maneuvering to rotate his vulnerable cone away from the threat and position his eyeballs in the correct direction. The format we use consists of three words, or three parts:

1. Flight call sign, "CHETA FLIGHT..", (or, if appropriate, the individual's call sign.)

2. "BREAK", "HARD", or "GUNS BREAK", depending on slant range and severity of the threat.

3. The direction of the threat, i.e., ("LEFT, RIGHT, or HIGH-LEFT"), referenced to the aircraft under attack.

Now you should get off the UHF, for four to five seconds, to allow a response. If your element mate has a tally, no additional UHF is required. If his response is "No-Joy", only then would you add more descriptive and directive commentary as necessary, (Bandit Position/Range).

An example of the above might be:

"DAGGER, HARD LEFT"

"DAGGER 2, NOJOY"

"DAGGER 2, BREAK LOW LEFT, BANDIT NOW LEFT EIGHT, ONE MILE"

Offensive

Here the critical task is to communicate with your flight lead or wingman. The format we use is:

1. *Your* call sign (who has sighted the bogey?)

2. Say what you see, and your intentions. If you have a tally, and plan or wish to engage, simply say "...engaged...". If your flight lead is already engaged, "...tally..." is sufficient. If you have a radar contact you want to run against, use "...committed...", if already committed, "..contact.." or "..flash..", as appropriate, would suffice.

3. Where is the bandit? If tally, use clock position, elevation, and slant range in nautical miles. If your call is off the radar, or GCI, then magnetic bearing, range, altitude, and target aspect are important. Target aspect can be broken down into "head-on", (or "hot"), "left/right forward", "left/right beam", "left/right aft" or "dragger"

4. Additional remarks (type aircraft/numbers/ formation).

An example of the above might be:

"CHEVY 2, ENGAGED, LEFT ELEVEN, TWO MILES, 2-SHIP, IN TRAIL."

NOTE

As flight lead, you do not need anyone's permission to engage (as a wingman does) and, if you are in parameters to shoot, one option to the above call is to simply do just that. "CHEVY ONE FOX ONE LEFT ELEVEN.....etc."

PSYCHOLOGICAL FACTORS

Although participants in an air battle are isolated from one another and totally enclosed by their

cockpits, psychological factors play a large part in determining the outcome of an air battle.

Flight Discipline

Every flight member must be familiar with, capable of, and willing to perform every task assigned him. At times, individualism must be suppressed for the benefit of the flight. Some examples are strict adherence to briefed separation and bingo fuels, and visual lookout of assigned portions of the sky during tactical formation.

Aggressiveness

This is a must for a fighter aircrew. However, this quality must be distinguished from foolhardiness. Aggressiveness means the crew is willing to take the calculated risk when the odds are favorable. Foolhardiness means pursuing unfavorable situations when tactical urgency is not required. This often leads to a "no-win" situation. If you do not presently possess this valuable trait start working on it right now. It is essential for success in air combat.

Pride

In self, crew, flight, squadron. Pride can be used by flight leaders to push individuals to higher levels of performance. The crew who is called once over the UHF for being out of position, for example, will probably work harder during the rest of the flight. However, if they neglect visual lookout in favor of maintaining precise formation position, then pride has worked in a negative way to the disadvantage of the entire flight. You must use every measure of effort to pursue the development of individual pride.

Pride is the single most important motivator of excellence. When it comes to ideas, flight leads and the "heavies" don't have a corner on the market. They are (or should be) still learning too.

Confidence

In aircraft, self, crew. Confidence is best gained through proper, realistic training. Confidence, pride, aggressiveness, and discipline are all closely intertwined.

The Enemy

Within one or two turns in a one-on-one situation, it is possible to assess your opponent's skill and, perhaps more important, his aggressiveness. Is he merely attempting to avoid losing or is he vigorously pressing in for the kill?

Intimidation

Inspire fear and uncertainty in the enemy. By being aggressive and showing him you mean to gain a victory, you may obtain a psychological edge. Make him react to you and get out of your way in head-on situations. Against an unskilled or inexperienced adversary, "cheap shots", or firing for effect may be an effective way of inspiring fear and uncertainty, but be careful not to waste ordnance only to inspire contempt for your own abilities if he knows you are firing out of parameters.

PROFICIENCY AND CREW COORDINATION

The key is for each crew member to demand discipline, maturity, and excellence during every minute of training. As a general rule: If it's easy, you should be doing something harder. During your training, you should be tasked close to your individual level of competence, but not beyond. To improve proficiency, you must be practicing what you are not yet proficient at! Be demanding and critical of yourself; if you think you make no mistakes, it's because you aren't smart enough to recognize them!

One of the overriding factors which will determine the outcome of an air battle is not only the proficiency level of each crew member in the F-4, but the quality of the teamwork employed by the two people. It is no accident that in today's lightweight fighter environment, the F-4 continues to illustrate its excellent aerial capability. The extra set of eyes and the reduced individual work load in the complex air combat arena are a major factor in its superior capability. Several articles have been written in the USAF Fighter Weapons Review which highlight the importance of these factors. Four of these articles are included in Appendix A.

CHAPTER 2
AERODYNAMICS AND TURN PERFORMANCE

As fighter aircrews, we must be able to extract the maximum from our weapon systems. A thorough knowledge of the forces which affect turn rate and radius and how aircraft characteristics affect maneuverability can have a large bearing on the outcome of an aerial engagement. The stakes are too high to risk coming out in second place. In this chapter we will discuss how some aerodynamic concepts affect air combat and how to extract the best performance from the F-4 in aerial combat.

RADIAL AND TOTAL G

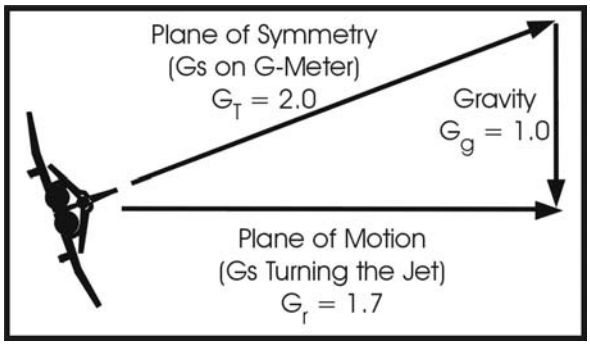


Figure 2-1. Radial and Total G in a Horizontal Turn.

Turning capability is produced by excess lift or G. Take an aircraft in straight and level flight where weight is countered by lift. Increase G (lift) in wings-level flight and the aircraft climbs (turns in the vertical). Increasing the bank with increased G will cause the aircraft to begin turning in the horizontal.

The G force we feel on our bodies during these turns is total or aircraft G and is read on the cockpit G meter. However, that is not the G that turns us since we are also affected by the force of gravity. Depending on the direction of the total G force, gravity may be helping or hurting our turn performance. The vector sum of the load factor (N, the Gs on your G-meter) and gravity (G_g) produces the effective turning force, G radial (G_r), depicted in Figure 2-1.

When the lift vector of your aircraft is pointed above the horizon, gravity is reducing your radial G and turning performance. When the lift vector is pointed below the horizon, gravity improves your turning performance. This effect can be illustrated by imagining an aircraft in a constant airspeed (KTAS) loop-type maneuver, holding a constant aircraft G (i.e., constant N). This produces an "egg" shaped flight path which shows gravity's effect on turning performance. The maneuver is illustrated in Figure 2-2 for an aircraft at 500 KTAS and 4 Gs (N). Note the large difference in radial G at the various points on the egg.

In actual flight, the aircraft would decelerate during the climb (thrust minus gravity) and accelerate during the dive (thrust plus gravity) which tends to accentuate the "egg" shaped maneuver even more. For a normal transition phase loop maneuver, the turn radius and rate at the bottom of the loop with 500 KCAS and N = 5 would be 7,200 feet radius and 7.7° per second rate; while at the top with 200 KCAS and N = 1.2 it would be 2,900 feet radius and 9.9° per second rate.

Many new fighter pilots have difficulty with air-to-air because they don't understand the third dimension. They were born and raised in a flat, two-dimensional world. Consequently, the vertical element of three-dimensional space is an unnatural factor. Although correct use of the vertical component of maneuvering is sometimes difficult to grasp, it is essential to successful aerial combat.

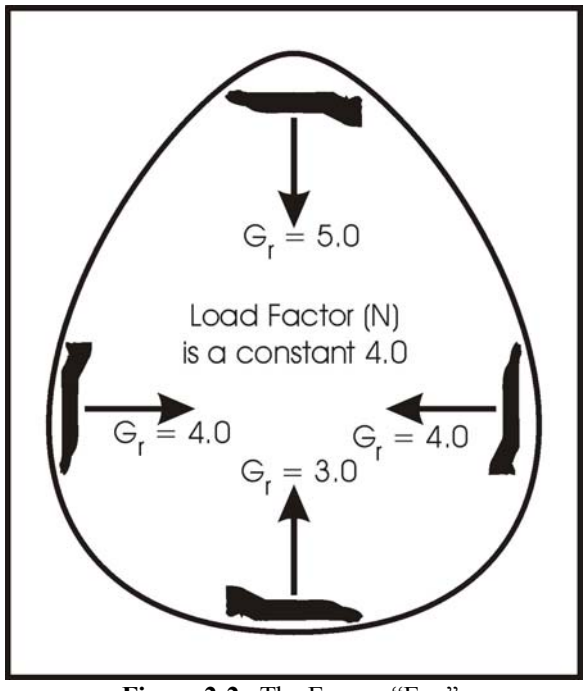


Figure 2-2. The Energy "Egg"

TURN PERFORMANCE

Two basic parameters determine the turn capability of an aircraft, turn rate and turn radius.

Turn Rate

Turn rate, ω, is measured in degrees per second and is solely dependent on aircraft true airspeed and radial G as shown in the formula below.

$$\omega = \frac{G_r \ x \ g \ x \ K}{V} = \frac{1845 \ x \ G_r}{V} \quad or \quad \omega \propto \frac{G_r}{V}$$

where

ω	=	Turn rate (deg/sec)
G_r	=	Aircraft radial G
g	=	32.2 ft/sec²
K	=	57.3 deg/radian
V	=	TAS in ft/sec

How do we use this formula? The relationship we need to know is common sense. Hold the same velocity while increasing G and turn rate will increase. Hold a constant G while increasing velocity and turn rate will decrease.

Turn Radius

Turn radius (R) is measured in feet and, as with rate, is solely dependent on aircraft true airspeed and radial G as shown in the formula below:

$$R = \frac{V^2}{g \ x \ G_r} = \frac{V^2}{32.2 \ x \ G_r} \quad or \quad R \propto \frac{V^2}{G_r}$$

where:

R	=	Turn radius (feet)
G_r	=	Aircraft radial G
g	=	32.2 ft/sec²
V	=	TAS in ft/sec

Again, we need to note that if we hold the same velocity while increasing the radial G, turn radius will decrease and if we hold the same radial G while increasing the velocity, the turn radius will increase. Note that velocity is squared in this equation. A small increase in airspeed results in a significant increase in turn radius.

Overall Turn Performance.

Bringing this all together, we can relate our overall turn performance to aircraft true airspeed and radial G. However, we rarely think in terms of radial G when flying the aircraft, but rather, we are aware of the total G and the position of our lift vector above or below the horizon. So, given a constant total G to hold, our best overall turn performance (quickest rate and smallest radius) would be achieved when inverted and slow enough to achieve the desired total G on the aircraft, like the top of a loop. While our poorest overall turn performance (slowest rate and largest radius) would be achieved when wings level and very fast, like the bottom of a loop.

Also, think about the formula in comparing two types of aircraft. If both aircraft are at the same TAS and G_r their turn rate and radii will be the same. Therefore, a 747 and an F-104 at 300 KTAS and 2 Gs will have the same turn performance. The thing that will determine the real air-to-air turn performance is an aircrafts ability to pull more Gs than the other at equal airspeeds.

V-N DIAGRAM

From the performance section of the Dash One (Appendix, Part 9), we can gain an appreciation for our aircraft's ability to produce lift (pull Gs) at various airspeeds by referencing a V-N diagram. One for 5000 MSL is shown in Figure 2-3. These diagrams illustrate charts of G vs. airspeed. It is called a V-N diagram because engineers refer to aircraft G as Normal Load Factor and symbolize it with the letter N. From these diagrams, we can obtain considerable information pertaining to our aircraft's performance capabilities.

1. Maximum allowable airspeed (Q/Placard limit).
2. Maximum allowable (Placard) G limit.
3. Stall airspeed at a particular G.
4. G load for a particular AOA and airspeed.

However, there are a number of limitations to the V-N diagram. First, note that it is only for one altitude. Other charts are given in the Dash One for certain other altitude (e.g., 30,000 or 40,000 ft MSL) and we have to interpolate between them if we are operating at an altitude other than those charts (i.e., 10,000 feet MSL). Also, note that the diagram is for a clean configuration at only 37,500 lbs (about 3 - 4,000 lbs of fuel) so the structural limit would be lower and the stall airspeeds faster for a change in aircraft configuration and weight.

Another misleading catch on the chart is that the aerodynamic limit (stall) is for 30 units AOA rather

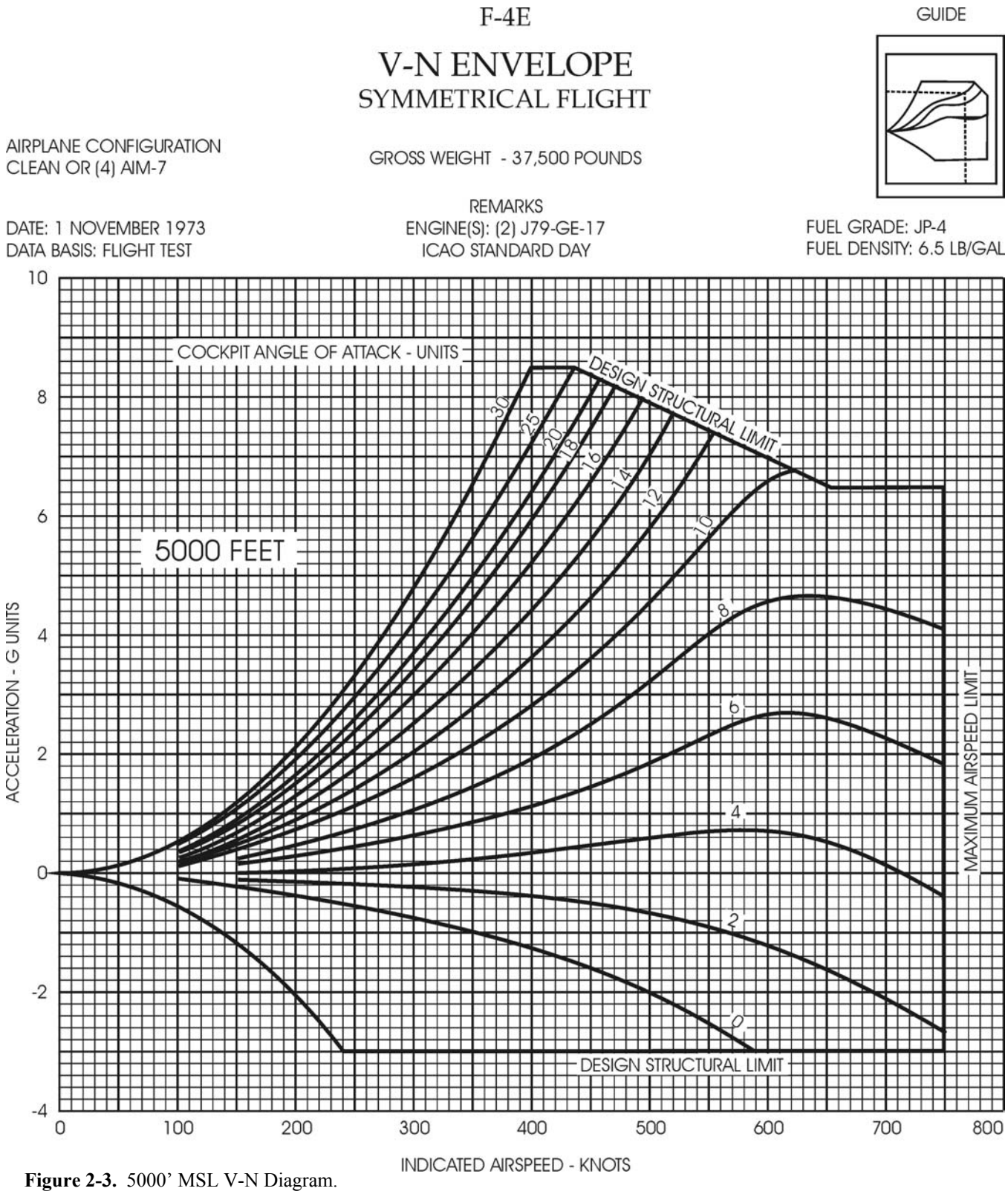


Figure 2-3. 5000’ MSL V-N Diagram.

than our normal maximum allowable AOA. Additionally, a major limitation to the chart is that it only applies for the instant in time that you apply the controls on the aircraft. It doesn't say what happens to the aircraft after a G load is established. But, we will get into this area more in Chapter 3, Energy Maneuverability. So the V-N diagram is a useful tool, but it must be understood completely to avoid its pitfalls.

Corner velocity

Let's put our aircraft at the maximum airspeed with maximum allowable G (750 KCAS and 6½ Gs) and compare the turn rate and radius as the aircraft slows down but maintains the maximum allowable G/AOA. A graph of the maximum allowable G, turn rate, and turn radius for an F-4E at 30 units AOA is shown in Figure 2-4.

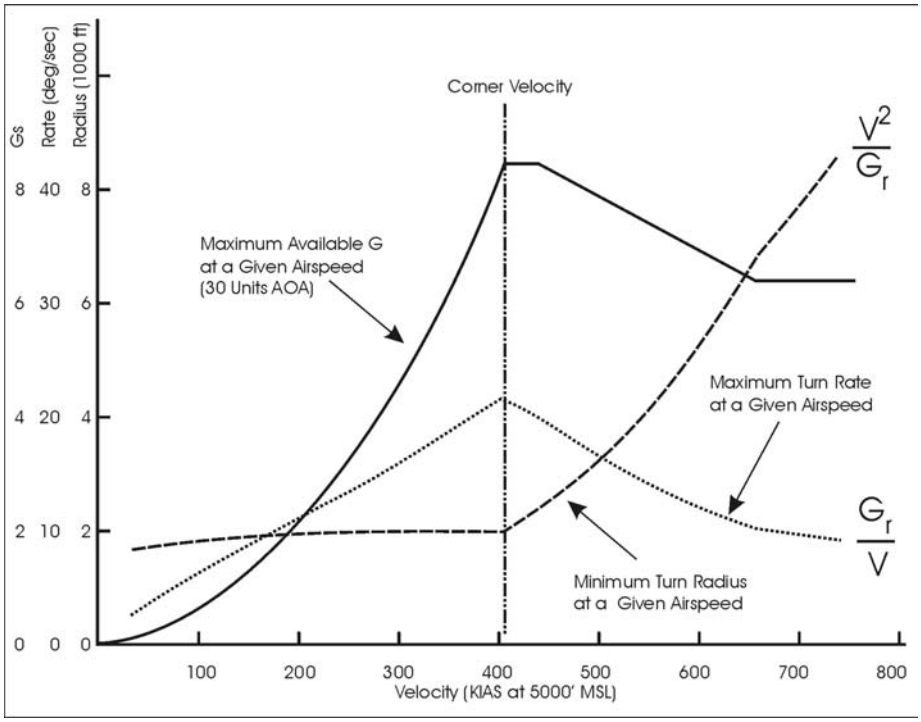


Figure 2-4. G Available, Turn Rate, and Turn Radius vs. Airspeed.

Notice that as we slow down, turn radius initially decreases then remains almost constant after the maximum AOA limit is reached. Turn rate, however, first increases, peaks out, then decreases again. For the mathematically inclined, a look at the formulae in the preceding section tells why. But, it is obvious there is an airspeed at which our turn performance is maximized. This airspeed is called Corner Velocity.

Corner velocity is that airspeed where we can generate the greatest turn rate and the tightest turn circle for our configuration and gross weight. As you can see from Figure 2-4, this occurs at the slowest airspeed at which we can generate maximum allowable G. (On Figure 2-3 corner velocity is about 400 KCAS at 8½ Gs and 30 units AOA). Note that when talking about corner velocities, the maximum allowable G does not have to be the design structural limit. It may be simply a training limit like 5 Gs and 25 units, (where the corner velocity is 330 KCAS).

ANGLE OF ATTACK

When we want to turn the F-4, we talk about specific angles of attack to produce various types of turns.

Acceleration

You should recall from Flight Characteristics class that when we want to gain energy, we need to minimize the drag and maximize the thrust. Aerodynamically this occurs in the 3-5 unit AOA regime as shown in Figure 2-5. In actuality, of course, we are primarily interested in gaining airspeed. The effect of flight path pitch attitude on your rate of acceleration is much larger than the effect from small changes in AOA.

Maximum Performance Turns

Figure 2-5 also dramatically points out the penalty you pay for flying in the maximum allowable AOA regime, (maximum allowable AOA for the F-4E LES is 25 units.) Drag is so high in this regime that we will be continuously bleeding off airspeed towards a stall. Although you achieve the highest possible instantaneous turn rate here, it literally only lasts for a split second.

Optimum turns

An optimum AOA turn is at 12-14 units AOA in the F-4E LES. A graphical depiction of the ratio of C_L

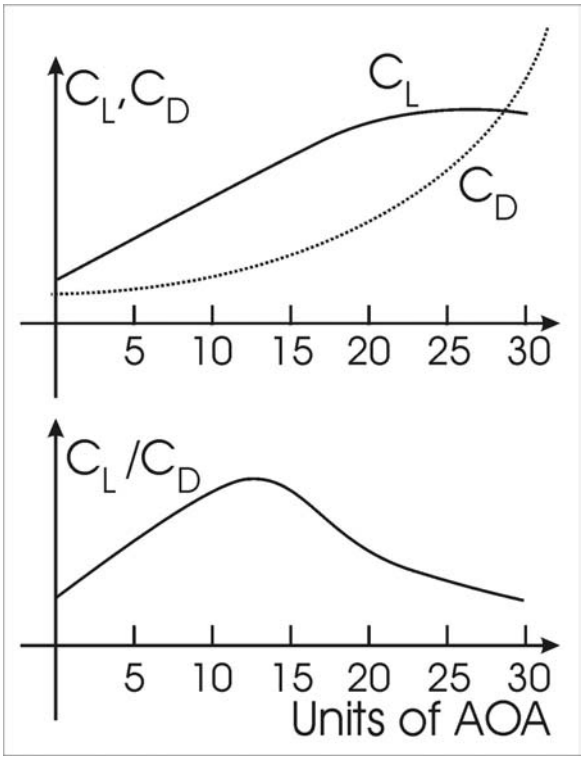


Figure 2-5. Lift and Drag Coefficients vs AOA.

to C_D, as shown in Figure 2-5, emphasizes the importance of the optimum turn as the AOA regime where we can get the best tradeoff between turning performance (related to lift) and airspeed control (related to drag). In actuality, the aircraft G in an optimum turn and a maximum turn approach each other at high airspeeds due to the structural limit as shown in Table 2-1.

We obviously can't limit ourselves by only flying at 3 to 5, 12 to14, or 23 to 25 units AOA. But we should be extremely aware of the advantages gained by operating as close as possible to the optimum AOA regime and the heavy disadvantage in airspeed bleed-off as the AOA approaches maximum. Even the transition phase of flying uses the optimum turn where, for a loop, once below about 470 KCAS, an optimum AOA should be used to continue the pull up and over the top since we are trying to get over the top with more than 200 KCAS (maximize tradeoff of turn and airspeed preservation). In the air-to-air environment, we would prefer to use optimum turns as much as possible while using BFM (Chapter 7) to make up the difference in reduced turn performance, and save that maximum AOA turn to defeat a missile shot or to get the nose out in front of the enemy for that last chance "snap shot."

Airspeed KIAS	Optimum Turns 12-14 Units	Max AOA Turns 23-24 Units
350	3.2 Gs	5.6 Gs
450	5.4 Gs	7.0 Gs*
550	6.5 Gs*	6.5 Gs*
650	6.5 Gs*	6.5 Gs*
* Design structural G-limit at 20,000 MSL and 37,500 lbs gross weight (about 4,000 lbs fuel remaining)		

Table 2-1. Optimum and Maximum Turns Compared.

AIRCRAFT COMPARISON

Over the years, many ways of comparing the relative performance capabilities of different aircraft have been devised. Although each is useful, an understanding of their limitations is required to prevent drawing incorrect conclusions, especially with today's third generation aircraft.

Wing Loading

One of the many ways to compare aircraft is through wing loading, where:

$$Wing\ Loading = \frac{Gross\ Weight}{Surface\ Area}\ (lbs / ft^2)$$

For example, the F-4 has a wing loading of about 78. When comparing two aircraft, the lower wing loaded aircraft will generally have the better turning performance at slow airspeeds. The F-4 has a higher wing loading than the T-38 but a lower one that the F-104.

While wing loading is a valid point of comparison, it is only one of many factors that should be considered when comparing the maneuvering abilities of two aircraft. Most recently designed aircraft, in fact, generate so much lift from other things besides the wing (high lift devices, the fuselage, fore-body strakes, etc.), that the term *effective wing loading* has been coined to take into consideration these other contributions to lift.

Thrust-to-Weight Ratio

A way to compare the acceleration capabilities of aircraft is Thrust-to-Weight ratio where:

$$Thrust - to - weight = \frac{Total\ Thrust}{Gross\ Weight}$$

The ratio of an aircraft's engine thrust to its gross weight gives us a rough way of comparing their acceleration capabilities. The F-4 has about a 0.8

ratio, meaning its thrust is about 80% of its combat weight. The F-15 has a better than 1.0 ratio—or more thrust than weight. The aircraft with the higher thrust-to-weight ratio will probably out accelerate or climb the other aircraft. However, acceleration also depends on aircraft drag. The F-15, for example, has a higher thrust-to-weight ratio than an F-111, but because of its high lift wing and bubble canopy, its acceleration capabilities do not reflect its greater thrust-to-weight.

Afterburner Efficiency

Like lift on a wing, the amount of thrust produced by a jet engine is proportional to the amount of air flowing through it. Recalling the formula for lift from Flight Characteristics,

$$L = \tfrac{1}{2} C_L \rho V^2 S ,$$

where

	L	=	lift
	C_L	=	coefficient of lift
	ρ	=	air density
	V	=	aircraft TAS
and	S	=	wing surface area,

can give us some insight to this air mass flow. Part of this equation represents this mass flow. Engineers call it dynamic pressure (Q) and it is mathematically described as:

$$Q = \tfrac{1}{2} \rho V^2 .$$

As usual, we can't use the formula in the cockpit; but understanding Q and its dependence on flight conditions is important. In particular, we are interested in areas that define the extremities of Q's values. Such as, at low altitude and high airspeed, Q would be very high and thus the engine will produce lots of thrust. However, as the altitude is increased and/or the airspeed decreased, Q and thrust would be reduced.

The F-4 engine, for example, produces about twice as much thrust in full afterburner than at Mil power when near Mach 1 airspeed; but at zero airspeed it only produces 50% more thrust than at Mil power. In addition to all that, the thrust produced in full afterburner at 10,000 ft MSL is only about half that produced in full afterburner at sea level.

Handling Qualities

The F-4 has several aircraft handling peculiarities we must discuss.

Transonic Dig-in

As an aircraft slows from supersonic to subsonic speed, the aerodynamic center shifts forward significantly. In the F-4E LES aircraft, this occurs relatively slowly and usually does not present any problem unless slat extension occurs at the same time. In that case, there is a possibility for a 2-3 G increase in the G load. Extreme care should be used in this area since it not only can cause an aircraft overstress but a departure from controlled flight.

Dihedral Effect

Roll produced from yaw is called the dihedral effect. At high AOA, application of rudder causes a yaw in that direction and, due to wing sweep, produces more lift on the opposite wing. This unequal lift causes a roll in the direction of yaw.

Adverse Yaw

Attempting to roll the F-4 with ailerons while above 20 units AOA produces a sideslip (yaw) opposite the intended direction of roll. This is caused by the down aileron and the ineffectiveness of the spoiler in this regime of flight. The yaw produced an opposite dihedral effect which at a minimum inhibits the intended roll and could cause a roll opposite the intended direction. The slats on the F-4E minimize the effects of adverse yaw. However, above 20 units AOA, the rudder is more effective and must be coordinated with ailerons to achieve smooth, controllable high roll rates.

ACM RULES OF THUMB

Several practical applications can be derived from the preceding areas of discussion:

Acceleration

Fastest airspeed increase/acceleration occurs in full afterburner, with the nose below the horizon, and at 3-5 units AOA. Afterburner efficiency increases with higher airspeed and lower altitude. At very low airspeed (250 KCAS or lower) and the situation allows (altitude, weather, and enemy) initially use a steeper nose low attitude to accelerate faster. Approaching 350 KCAS use an optimum pull (3-4 Gs) to raise the nose up nearer the horizon as you continue the acceleration.

Optimum Turns

The tradeoff of lift and drag (turn and airspeed control) is an optimum turn at 12-14 units AOA.

Maximum Turns

To maximize turn performance (increase turn rate and decrease turn radius):

1. Keep airspeed near corner velocity as much as possible.
2. Keep the nose below the horizon to minimize airspeed bleed-off and remain closer to corner.

Drag Penalty

Always remember that in addition to achieving maximum turn performance, a maximum allowable AOA turn (23-25 units AOA in the F-4E LES), causes an enormous airspeed bleed-off. Above this AOA, airspeed bleed-off increases even further, and the aircraft begins to lose directional control/stability. For this reason, the advantages of being at corner velocity can only be realized for one or two seconds.

Afterburner Lift

At 18 units AOA and above 350 KCAS, full afterburner adds an additional ½ G to the total G produced by lift.

Fuel Flow

F-4 fuel consumption in full afterburner is about 1,500 lbs/minute or 1,000 lbs/360° of turn.

Jettison Tanks

In a combat situation, jettison external fuel tanks to reduce parasite drag.

EDITOR'S NOTE ON THE "ENERGY EGG"

The "energy egg" (Figure 2-2) is one of the most commonly misused diagrams in all of fighter instruction. While concisely incorporating the major concepts of how radial G, load factor, and climb angle are related, it gives the impression that the flight path of a constant speed, constant G loop is actually egg-shaped. This is not the case, as is clearly shown in Figure 2-6 where airspeed and G are held constant (the same assumptions as in the standard energy egg description). In the more realistic scenario where thrust and G are held constant, the non-egg-shaped flight path is even more apparent (Figure 2-7).

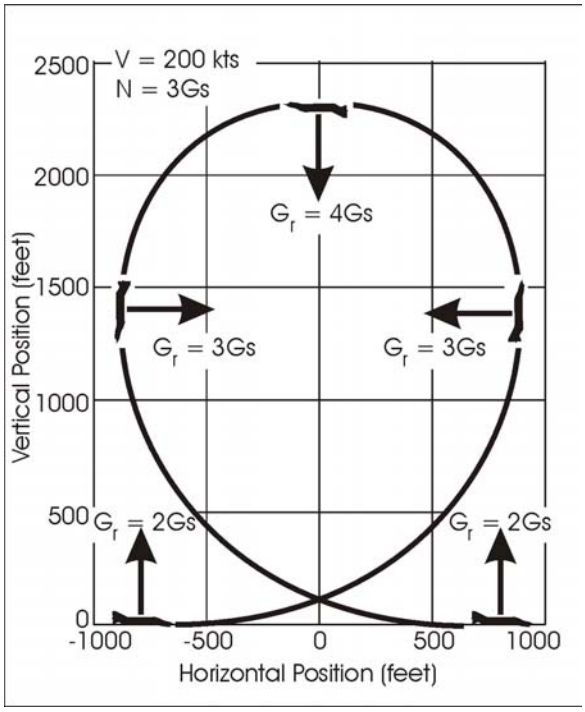


Figure 2-6. The Actual "Energy Egg" Flight Path for Constant Airspeed and Load Factor. Data from generic aircraft computer simulation.

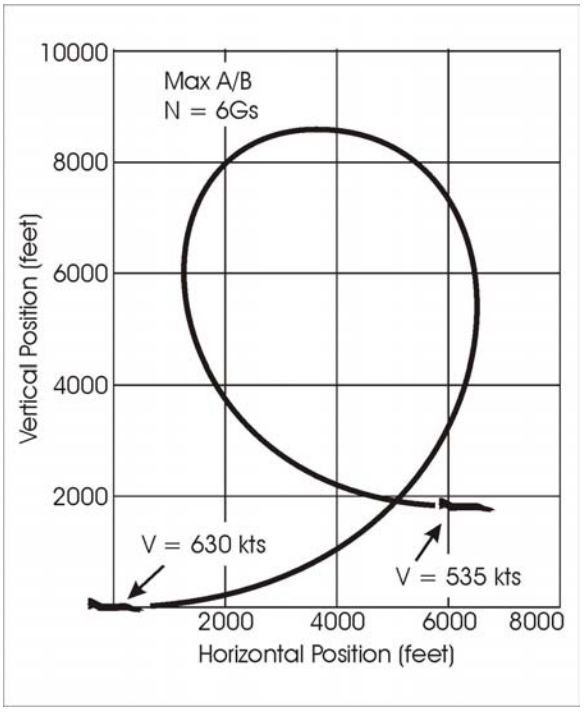


Figure 2-7. The Actual "Energy Egg" Flight Path for Constant Thrust and Load Factor. Data from computer simulation using F-4E flight parameters.

CHAPTER 3
ENERGY MANEUVERABILITY

INTRODUCTION

Victory in aerial combat usually goes to the aviator who flies and fights smarter. To fly and fight smart, we must emphasize our relative strengths while exploiting the enemy's relative weaknesses. As discussed in the previous chapters, a number of factors can be evaluated in determining strengths and weaknesses. Although today's high technology air-to-air missiles are becoming more and more important, maneuverability is still the foundation of any fighter's strength. Maneuverability can be described as the ability to change the direction and/or magnitude of your velocity vector. While this description describes what maneuverability is, it says little about how to optimize it in the various regions of the aerial combat arena, (the aircraft operating envelope, Figure 3-1). In the late 1950s, in an attempt to better answer these questions, the theory of energy maneuverability was conceived.

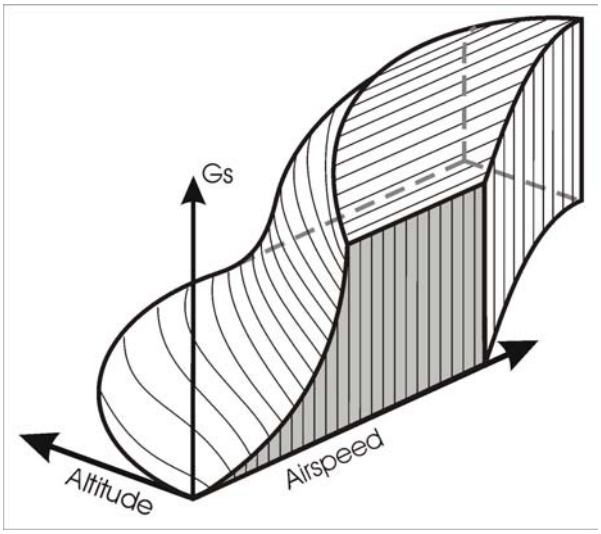


Figure 3-1. Example Performance Envelope. The shaded region is the sea-level V-N diagram, with Gs on the vertical axis and airspeed on the horizontal axis.

History

Even before the 1950s, aviators traditionally recognized the importance of energy by attempting to always enter a fight with more altitude and airspeed than their opponents. If equally proficient crews, in identical aircraft, began a hassle, the one who enters the fight from a higher altitude and/or airspeed would probably win. Thus, the early studies of energy were largely the result of trial and error in engagements. Even the follow-on war stories didn't give the novice aviator much solid information to start on and he usually had to go through the long trial and error process to learn it. This method of learning was finally replaced by actual flight tests and official technical sources, like the Dash-One. From these, a number of specific data points (discussed in Chapter 2), were established:

1. Thrust-to-weight ratio.
2. Wing loading (effective wing loading)
3. Combat and service ceiling
4. Maximum achievable rate of climb
5. Stall airspeed
6. Corner velocity
7. Maximum G limit
8. Maximum airspeed

This method also produced many charts, (such as the V-N diagram in Chapter 2). Some of these could not only depict the performance of one aircraft, they could be used to compare two aircraft with each other. This data, however, had one deficiency. It gave no indication of what was happening to the aircraft during the period of a sustained maneuver (e.g., airspeed loss at high AOA). Some method was needed to measure the ability of an aircraft to gain, maintain, or decrease altitude, airspeed, and/or G during an extended time period. The advent of the energy maneuverability concept presented a method of providing this information through the principle of energy change over time.

BASIC CONCEPTS

The concept of energy maneuverability was developed in an attempt to better describe an aircraft's maneuverability by using specific power as a basis to relate these changes (i.e., energy change per unit of time).

Maneuverability

This is defined as the aircraft's ability to change the magnitude and/or direction of its velocity vector.

Energy

The ability to do work and overcome resistance. In flying, it produces velocity and lift by overcoming gravity and drag.

Chemical Energy (CE)

The energy in fuel. This is converted to heat and thrust by the engines.

Kinetic Energy (KE)

The energy a body has due to its motion (i.e. velocity). $KE = \frac{1}{2} mV^2$

Potential Energy (PE).

The energy a body has due to its height (i.e. altitude). Potential energy is height, (H), times the aircraft weight. $PE = mgH$

Total Energy (E_t)

The sum of a body's kinetic and potential energy. To the fighter pilot, total energy is altitude and airspeed.

$$E_t = KE + PE = \frac{1}{2} mV^2 + mgH$$

where: m = aircraft mass
V = velocity (TAS) in ft/sec
g = 32.2 ft/sec²
H = aircraft altitude in (ft)

Total energy includes mass, so it is not an accurate indicator of maneuverability. (The C-5A has the most total energy!) It is *energy per pound of aircraft weight*, or Specific Energy (E_s), which indicates an aircraft's capability to maneuver.

Specific Energy (E_s)

Weight (mass times g) can be mathematically eliminated from the equation to give us specific energy:

$$E_s = \frac{E_t}{w} = \frac{V^2}{2g} + H\ (feet).$$

E_s refers to an energy level or state and can be thought of as the height an aircraft could theoretically attain (zero thrust and zero drag) if all of its kinetic energy was converted to potential energy (i.e., altitude).

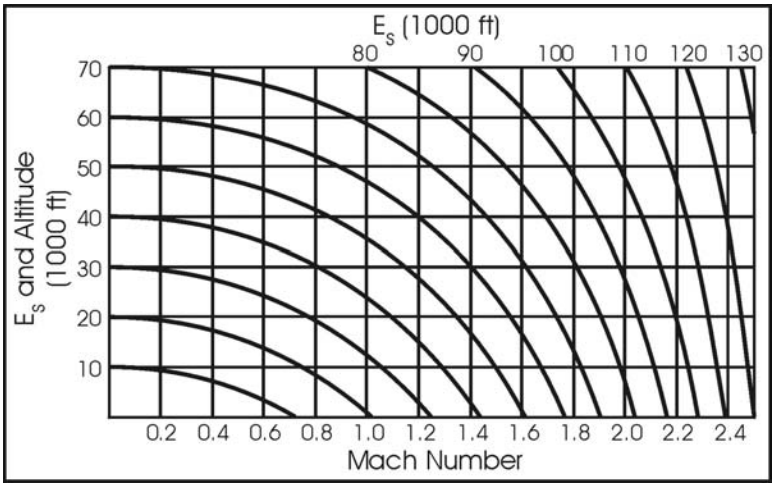


Figure 3-2. Specific Energy Curves.

A series of curves can be plotted on a chart that depicts varying combinations of Mach number and altitude as shown in Figure 3-2. Each curve represents a constant E_s value as determined by the combination of altitude and airspeed. At zero airspeed, the energy is purely potential (i.e., altitude). As you move to the right and down along a curve, airspeed increases and altitude decreases until, at zero altitude, the energy is purely kinetic (i.e., airspeed).

Energy Rate Diagram

At this point, we can go one step further by superimposing an aircraft's 1-G operating envelope on the chart as shown in Figure 3-3. The left edge of the envelope is the aerodynamic limit and establishes the stall speed for any specific altitude. The top of the envelope is the maximum altitude/ceiling where thrust equals drag. The right side may either be the placard airspeed limit as determined by temperature or structural limits, or for thrust limited aircraft, the speed where thrust equals drag. An aircraft can operate outside this envelope only temporarily. It will be unable to establish a steady-state situation there and will soon slip back inside the envelope.

NOTE

The maximum sustainable energy level is about 100,000 feet. This energy is at Mach 2.05 at about 45,000 feet MSL. As mentioned above, the fighter who enters the engagement with the most energy will, generally, have a maneuvering advantage. But since our objective is *sustained*

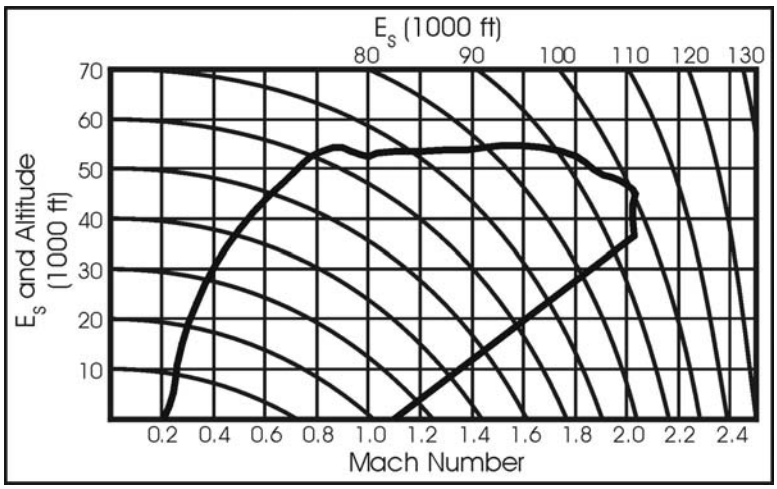


Figure 3-3. 1-G Operating Envelope.

maneuvering and not simply instantaneous capability, in actuality how well that energy is managed becomes a more important factor.

Specific Power (P_s)

By looking at the power of an aircraft, we can now gain an understanding of what happens to an aircraft over the time period of a climb, acceleration, or turn. Power is defined as the rate of change of energy with respect to time. Since we are more interested in using the information to compare aircraft with different gross weights we are once again more concerned with specific power or the rate of change of specific energy with respect to time. Specific power is a measure of the combined engine/airframe output at a specified airspeed, altitude, and G-loading, and can be experimentally determined from flight tests and the following formula.

$$P_s = \frac{V(T-D)}{W}$$

where:

V	=	TAS in ft/sec
T	=	thrust (pounds)
D	=	drag (pounds)
W	=	weight (pounds)

This formula has been used for many years in flight test programs to determine the best climb schedules and range profiles, but because of the immense job of calculating all the possible P_s values within a flight envelope, it was not used for anything other than flight tests. With the modern computer it became possible to develop diagrams which relate P_s for any altitude, airspeed and G-loading that can be established for a specific thrust setting, gross weight, and configuration. Constant P_s contour lines are then established in the aircraft's performance envelope for the specific flight condition as shown in Figure 3-4.

This chart is called an energy rate diagram and emphatically points out that P_s is in fact a measure of an aircraft's sustained maneuverability. For any combination of altitude, airspeed, and G-loading, a P_s may be determined that will incorporate drag, excess thrust, wing loading, and other aerodynamic considerations to tell us what is happening to the aircraft's energy.

Although P_s data originally came from the flight test equation, it is also equivalent to the rate of change of total energy, (E_t). Total energy can change as a result of a change in true airspeed, or by a change in altitude, as the following derivation shows.

This alternate formula for P_s, talking about rates of acceleration, and rates of climb, is of course much more interesting to us as fighter pilots than the thrust, drag and weight terms in the flight test equation. We will come back to this formula later, when we try to analyze exactly how much P_s equates to a significant climb rate or acceleration advantage.

Without looking at the specific values of P_s for the present, let's look at what happens to total aircraft energy (E_t), when P_s is positive, negative, or zero.

Positive

When P_s is positive (+), it means that the pilot can either climb, accelerate, increase G, or any combination of the three by some amount while avoiding a subsequent reduction in airspeed, altitude, or G. The pilot has complete choice in the matter and simply does whichever he chooses. But, overall, his energy level should increase.

Negative

When P_s is negative (-), the pilot must either descend, decelerate, reduce G, increase thrust, or a combination of the four. Again, the pilot has complete choice in the matter and simply sacrifices whichever he chooses. But, overall, his energy level should decrease. An example of this is when we get outside the performance envelope of the aircraft and are unable to sustain the flight conditions.

Zero

When P_s is zero (0), the pilot is either operating on the boundary of the flight envelope (i.e., cannot go any slower, higher, or faster), or he has established a flight condition (i.e., altitude, airspeed, G-loading, and thrust setting) where he can just maintain level flight without losing airspeed. Overall, the energy level will remain the same

ENERGY RATE DIAGRAMS.

The specific power contours of an energy rate diagram provide an excellent method to measure the ability of an aircraft to change its energy level (altitude and airspeed) at any point in the flight envelope. These contours become even more important when we look at an aircraft attempting to sustain more than 1-G. But, before moving on to those diagrams, let's look at the 1-G diagram a little closer to discuss what kind of information can be determined from it.

Before interpreting any diagram though, always read the heading first. We have to realize that an aircraft at other than the conditions started in the heading will not have the exact characteristics presented in the diagram and must be adjusted for by reference to other diagrams. Also, it should be noted that the thrust is always in full afterburner in the diagrams

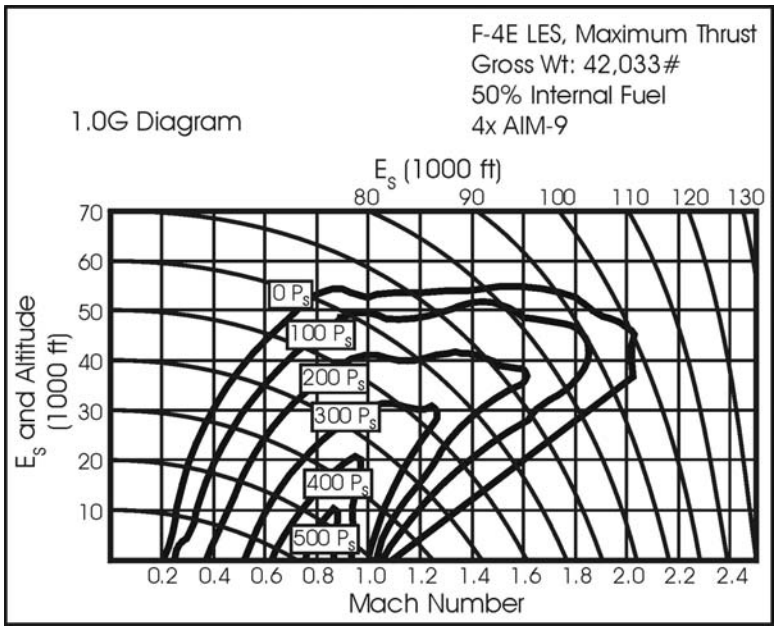


Figure 3-4. Energy Rate Diagram.

1-G Chart

Figure 3-4 is the 1-G Energy Rate diagram. The gross weight and configuration are shown on the charts. The G-loading is shown in the upper left hand corner. A number of points around the perimeter of the envelope can be of interest for use in the normal aircraft operation.

1. Stall speed/Mach number.
2. Maximum attainable altitude.
3. Maximum attainable energy level.
4. Maximum Mach number for any altitude.
5. Maximum attainable rate of climb at any given altitude and Mach number.

Now, let's recall the P_s formula and look more specifically at what a set P_s value means to us in the cockpit. We can also get a formula for specific power by differentiating the specific energy equation:

$$P_s = \frac{dE_s}{dt} = \frac{V\ x\ A}{g} + \frac{dH}{dt}\ (ft/\sec)$$

where:

V	=	Velocity
A	=	Acceleration
g	=	32.2 ft/sec²
$\frac{dH}{dt}$	=	Rate of climb

Constant TAS Climb

We will assume that we are going to climb out at 1-G and full afterburner. Since we are going to accomplish a constant TAS climb, the change in velocity will be zero; so, the first term in the equation will also be zero because "A" will equal zero.

$$P_s = \frac{V\ x\ 0}{g} + \frac{dH}{dt}$$

$$P_s = 0 + \frac{dH}{dt}$$

100 P_s

Now, let's look at what a P_s of +100 ft/sec means in a climb.

$$P_s = \frac{dH}{dt} = 100\,ft/\sec$$

We don't have a feet-per-second gauge in the cockpit; but, if we multiply that number by sixty, we will have 6,000 feet per minute which can be read on the VVI gauge.

Greater P_s

Now we know what a +100 P_s factor means in climb rate. For higher P_s, the climb rate will simply be a multiple of the +100 P_s figure (e.g., +300 P_s = 3 x 6,000 feet/minute = 18,000 feet/minute). So, reading the P_s at sea level and 0.9 Mach, the chart says we can climb in excess of 36,000 feet/minute (6 x 6,000) in a 0.9 Mach climb. Note that as we climb, the P_s values decrease. Passing 5,000 feet MSL, we would only be generating 33,000 feet/minute climb rate. This would continue to decrease until the P_s is zero, (about 49,000 feet MSL), where the aircraft would stop climbing. Also note that this is theoretical—in the real world, fuel weight would be reduced during the climb causing slightly better performance. It does, however, give some impressive numbers for the F-4.

Level Acceleration

Again, we look at the P_s formula. Assuming a level altitude, 1-G, full afterburner acceleration, the change in altitude will be zero so the second term in the equation will be zero.

$$P_s = \frac{V\ x\ A}{g} + 0\ (ft/\sec)$$

Solving this equation for A, the acceleration,

$$A = \frac{g\ x\ P_s}{V}\ (ft/\sec^2)$$

We can see the acceleration is not as simple as the climb rate where it was a constant with P_s throughout the envelope. The acceleration is affected by the velocity as well as the P_s value. But, first let's look at a midrange example of velocity and then later examine the trends as we change the velocity.

Mach 0.8 (880 ft/sec)

First let's analyze what 100 P_s means in rate of acceleration:

$$A = \frac{g\ x\ 100\,ft/\sec}{880\,ft/\sec} = 3.66\,ft/\sec^2 = 2.2\,knots/\sec$$

Now we know what a +100 P_s factor means in 1-G acceleration at 0.8 Mach. For higher values of P_s *at 0.8 Mach*, the acceleration rate will simply be a multiple of the +100 P_s figure (e.g., at 5,000 feet MSL and 0.8 Mach, +500 P_s means a 13 knots/second acceleration rate).

Mach 0.5 (558 ft/sec)

Here the rate of change in velocity for +100 P_s would be slightly different:

$$A = \frac{g\ x\ 100\,ft/\sec}{558\,ft/\sec} = 5.78\,ft/\sec^2 = 3.4\,knots/\sec$$

Mach 1.1 (1210 ft/sec)

At the other end of the Mach scale, the acceleration rate from 100 P_s at 1.1 Mach would be:

$$A = \frac{g\ x\ 100\,ft/\sec}{1210\,ft/\sec} = 2.66\,ft/\sec^2 = 1.6\,knots/\sec$$

These numbers might lead us to believe we accelerate better at the slower airspeeds. A closer look at the 1-G acceleration chart tells why this is not so. As we accelerate, the P_s values increase due to the engine's increased thrust at higher velocities. At 0.9 Mach, the 900 P_s there will give us 22 knots/second, much more than the 8 knots/sec which 220 P_s at 0.4 Mach will produce. P_s values peak out slightly past 0.9 Mach, then drop off rapidly due to the transonic drag, so our best acceleration is going to be where the highest P_s values are. For right now, we should remember that a +100 P_s value means about 2 to 3 knots/sec rate of change in velocity. Although in real combat we should accelerate nose low to trade altitude for airspeed, these level-flight, 1-G numbers give us a rough idea of the F-4's capabilities, particularly when we are comparing our acceleration against that of another aircraft.

Rutowski Profile

P_s contours also tell us the best path for gaining energy in minimum time. This path is called the Rutowski Climb Profile (Figure 3-5), and is determined by joining the points where the P_s and E_s contours are tangent to one another (e.g., at 25,000 feet MSL and 1.00 Mach, 40,000 feet E_s and + 300 feet/second P_s are tangent). To fly it, accelerate unloaded until reaching any portion of the profile. After intercepting the path, proceed along it until the desired energy level is achieved. To move along a given E_s contour, the pilot need only unload to zero G and hold that until reaching

the appropriate Mach number. However, aircraft cannot turn square corners so the following rules of thumb have been developed to enable a pilot to find and move along the best energy gain path.

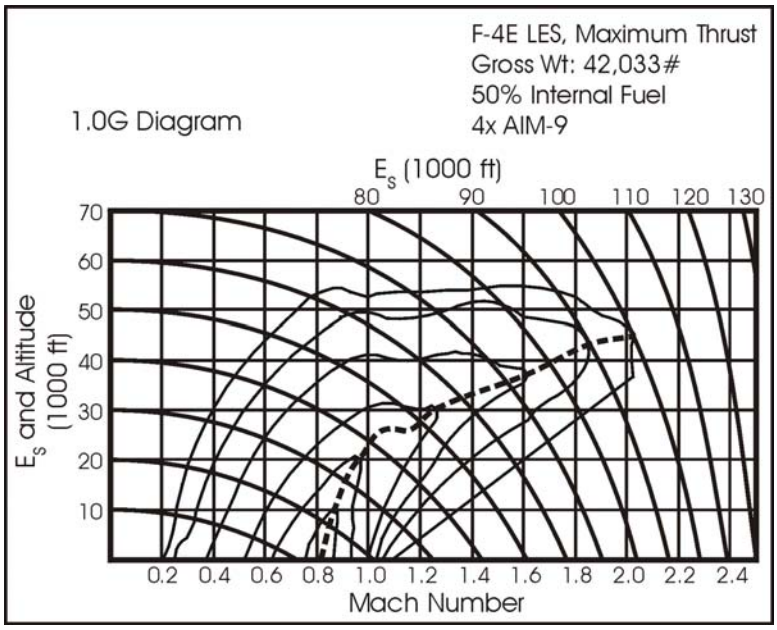


Figure 3-5. The Rutowski Profile.

1. If initially subsonic (cruise or takeoff), accelerate to 0.87 Mach then use an optimum pull to establish a constant 0.92 Mach climb.

2. At FL 200, push over at 3-8 units AOA (peaking out in altitude at about FL 280) to establish and hold a ten-degree dive while accelerating.

3. At 1.2 Mach, use an optimum pull to establish a five-degree climb and hold 580 KCAS.

4. Hold 580 KCAS until the desired energy level is achieved. This will give us 1.9 Mach at FL 420.

5. When flying the subsonic portion of the profile it is preferable to be slightly slow rather than slightly fast due to the increased drag in the transonic area above 0.92 Mach. Conversely when supersonic never allow the airspeed to drop below the desired calibrated airspeed. Try to remain slightly fast since P_s drops off rapidly with any reduction in airspeed.

Higher G Charts.

P_s diagrams of more than 1-G may also be plotted. From these diagrams, it is possible to determine an aircraft's capability to sustain a given G at any altitude and Mach. Some of the P_s contours in these diagrams contain negative values. When operating in these areas, the aircraft must give up energy in some form to maintain the constant turning situation. Otherwise the turning performance must be reduced to sustain the energy level and this means going to another diagram for the new G-loading.

In some instances, the G force in a level turn will reduce the airspeed until the maximum AOA is reached (i.e., stall airspeed at that altitude and G) when altitude reduction will be required in addition to the airspeed bleed-off. In others, altitude may be traded until the aircraft is operating under positive/zero P_s values where the situation can now be sustained.

Notice that as the negative values get larger, a condition will be reached where the aircraft must both descend and decelerate due to the large amount of energy loss. As an example, a minus (-) 800 P_s requires a descent rate of 48,000 feet/minute to sustain airspeed. That descent rate equates to 0.8 Mach going straight down (90 degree dive). Figure 3-6 shows the 3-G and 5-G energy rate diagrams for the F-4E. As with the 1-G diagram, a number of points of interest can be found on the diagrams, but, in general, we should primarily be interested in:

1. Maximum altitude we can sustain the specified G loading, (i.e., the peak of the zero P_s contour). For example, a 4-G turn can be sustained at 17,000 feet MSL at 0.9 Mach.

2. Required VVI to sustain a constant G and Mach. For example, to sustain 5-G and 0.8 Mach at FL 200, we must descend at the rate of 12,000 feet/minute.

3. Required/available Mach number change to sustain a constant G and altitude. As an example, to sustain 5-G and FL 300 at 1.0 Mach, an initial airspeed bleed-off rate of 20 knots/second will occur. This figure will of course change rapidly as airspeed decays and puts you at a different point in the flight envelope.

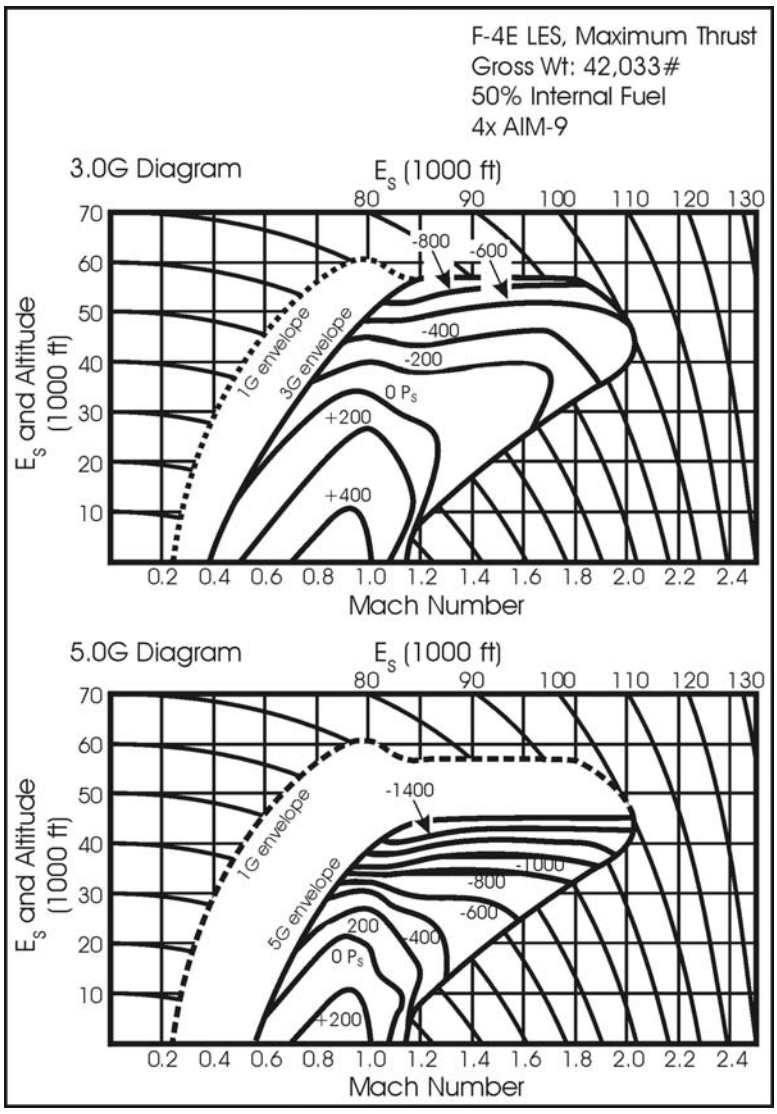


Figure 3-6. 3- and 5-G Energy Rate Diagrams.

OVERLAY COMPARISONS

A comparison of two aircraft was originally available only by placing two comparative energy rate diagrams side by side. This proved to be quite time-consuming so the difference diagram was introduced to readily point out the areas where energy rate advantages and or disadvantages existed. Figure 3-7 shows an F-4E versus T-38 energy rate difference diagram for 1-G flight. By convention, *the aircraft read first in the heading* (i.e. on the left side) *always has the advantage when the Delta P_s values* (i.e., energy rate differences) *are positive* and the aircraft on the right has the advantage in the negative Delta P_s value areas. The operating envelopes of both aircraft are also presented. However, care should be used in relating to the P_s advantage value since it does not tell us what our aircrafts actual P_s is. As an example, the T-38 may have a P_s value of -1200 while we have a -1100 value. This will give us a +100 P_s advantage; but we will both be losing energy at great rates. We will just be slowing down or falling out of the sky at a slightly slower rate. This point would be quite apparent in the 3-G and 5-G Energy Rate Difference diagrams.

An energy rate difference of 100 P_s could be considered an energy advantage. However, our past look at what 100 P_s really means to us (e.g. 2-3 knots per second of acceleration) should tend to push that figure up a little -- particularly during the beginning stages of learning energy management. During this stage, crew capabilities can easily make up for or lose that Delta P_s. So, a Delta P_s value of 200 to 300 is needed before considering that your aircraft has an energy advantage to be exploited.

MANEUVER DIAGRAMS

For a number of reasons it was decided that there was a need to look at our aircraft's performance capabilities from a different aspect than constant AOA/G with variations in altitude and Mach number. Besides simply needing a better method to illustrate the data, it can easily be seen that only the bottom one-quarter of the energy rate diagrams was really of primary concern for a maneuvering engagement.

V-N Diagram

Originally, the P_s values were simply put into a V-N diagram as the new method of presenting the aircrafts maneuvering capability. As shown in Figure 3-8, this presented the aircraft's performance envelope at a constant altitude, varying G and Mach number.

Rate-Radius Diagram

As fighter pilots though, we are interested in turn rate and radius when engaged in an air battle. Thus, the Rate/Radius Diagrams were devised to illustrate all the appropriate data on one diagram as shown in Figure 3-9. The Rate/Radius Diagram is like a V-N diagram with turn rate on

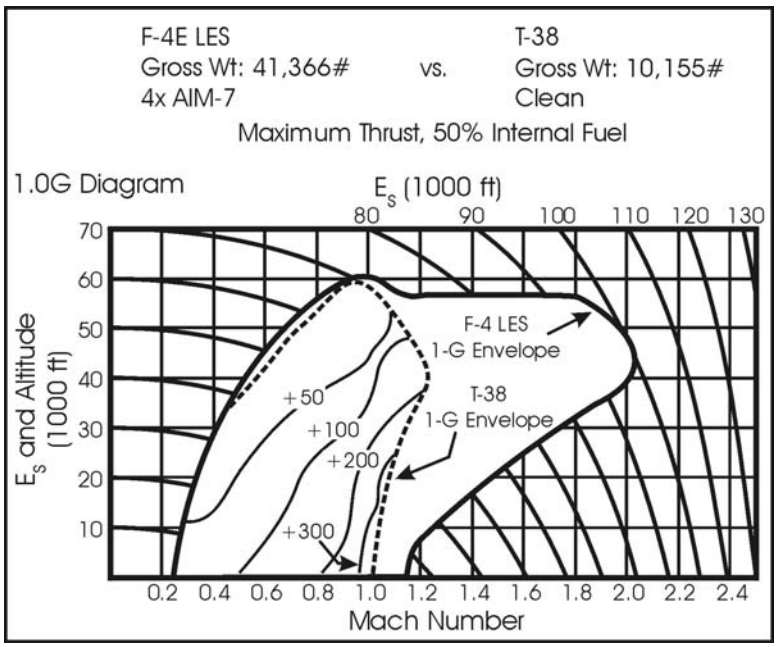


Figure 3-7. F-4E vs. T-38 Energy Rate Overlay Diagram.

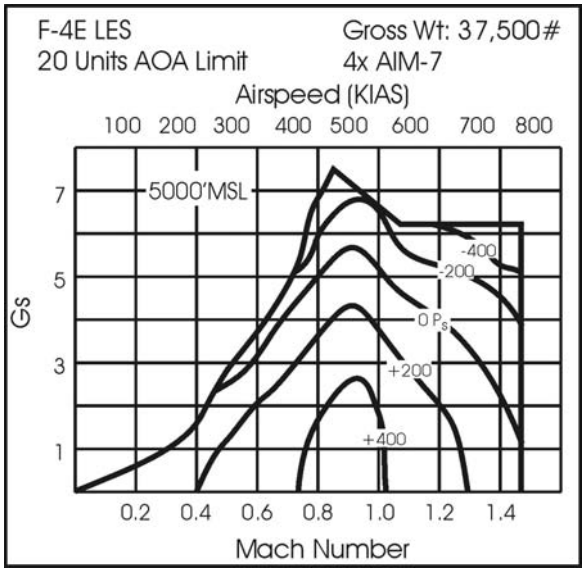


Figure 3-8. F-4E Maneuver Diagram.

the vertical axis instead of G. Figure 3-9 is for an F-4E at 5,000 feet MSL. These diagrams show at a glance the entire level flight performance envelope of an aircraft with the representative altitudes of 5,000, 15,000, and 25,000 feet MSL. Although *these diagrams only consider turning in the horizontal plane*, they are extremely useful for learning how to manage energy.

Description

Basically, the Rate/Radius Diagram is three diagrams in one. At the top is the heading which specifies altitude, weight, thrust, and configuration. Along the bottom axis is Mach number; the turn rate in degrees per second is along the vertical axis. Because the diagram is for a constant altitude we can also plot calibrated airspeed (KCAS) along the top. Additionally, since we are now plotting turn rate along the vertical axis the lines of constant G are now curved, from high left on the chart to low right. Lines of constant turn radius radiate from the lower left corner of the chart. Finally, the aircraft operating envelope, with P_s lines, is overlaid.

Differences

The operating envelope in Figure 3-9 looks considerably different than it did on the energy diagrams. The left side is still the Maximum AOA or aerodynamic limit and the right side is still the maximum airspeed, (determined by placard limit). But the top right boundary of the envelope now represents the aircraft's placard G limit, and is curved from high left to low right along the lines of constant G.

Interpretation

There are several important regions or points on the Rate-Radius Diagrams. The best maneuver for a situation depends on the relative energy levels (i.e. airspeed and altitude) of two aircraft as well as whether turn rate or energy is more important.

Although the rate-radius does not indicate AOA, a quick look at the AOAs inside the turn envelope may give us an idea of how to control our energy rates during an engagement. This is shown in Figure 3-10. Note where the three general ACM AOA regimes lie within the envelope (3 to 5, 12 to 14, and 23 to 25 units for the F-4E). However, the left boundary of the performance envelope will always be the maximum allowable AOA limit for the specific aircraft of the diagram. For a more practical look at the performance data, let's look at the F-4E Rate-Radius diagram—Figure 3-9. If turning is critical and altitude or airspeed losses can be allowed, maneuvering at maximum AOA/G produces the best turn performance. The quickest and tightest turn for that altitude can be achieved at corner velocity. This point is readily

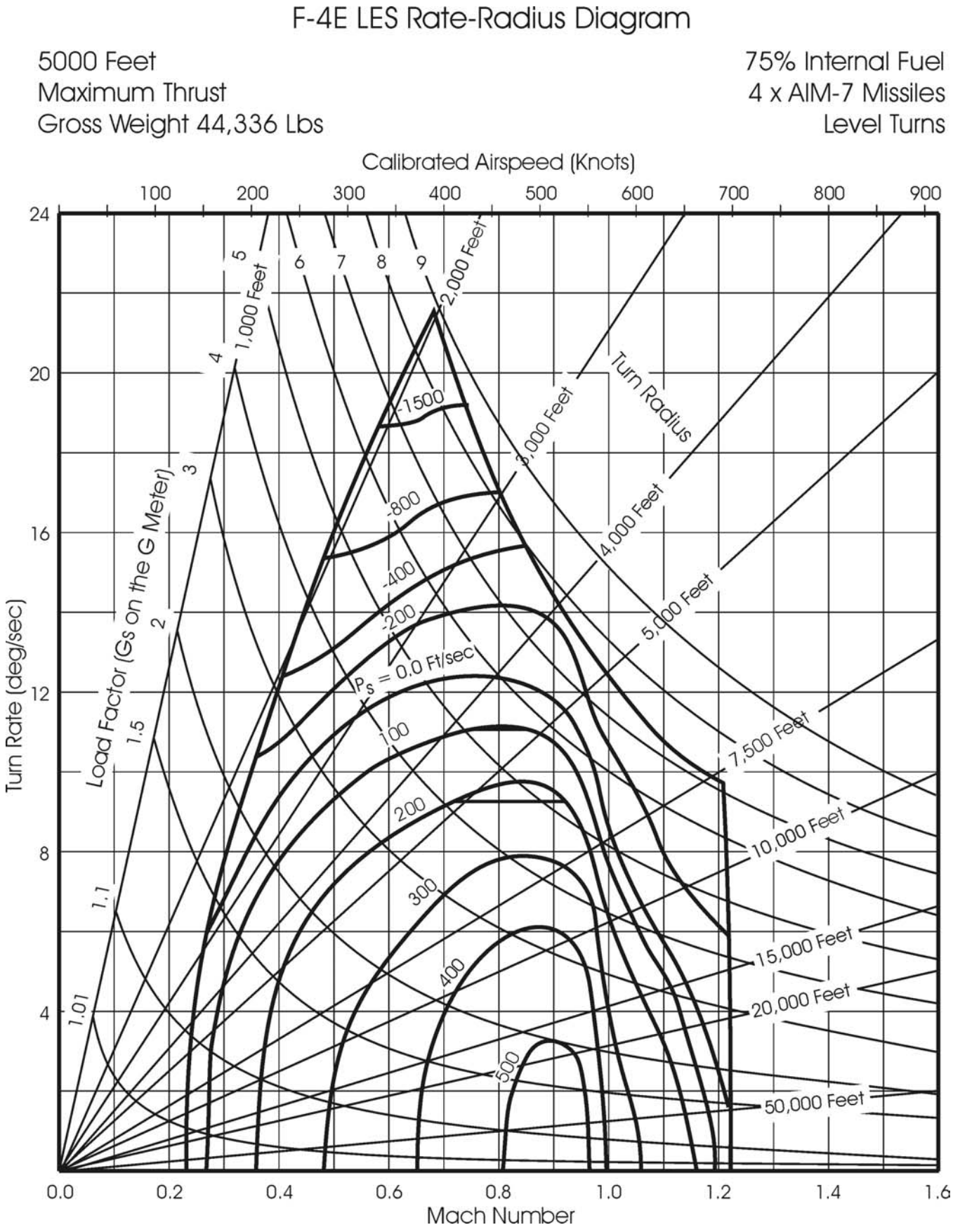


Figure 3-9. 5000' MSL Rate-Radius Diagram (The Spaghetti Chart).

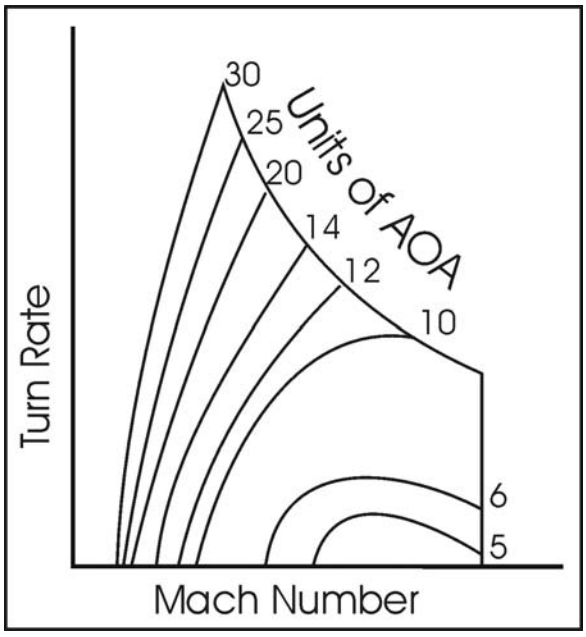


Figure 3-10. Lines of Constant Angle of Attack.

apparent as the velocity where the performance envelope peaks out (e.g., 400 KCAS and 8 Gs produce about an 19 deg/sec rate and 2,200 foot radius). However, also note that for a level turn the airspeed will bleed off at about 40 kts/sec.

If gaining energy for a tactical energy advantage is important, only minimal turning should be done and at least maximum P_s Mach should be maintained. This regime is where the P_s contours apex (i.e., about 0.9 Mach at 5,000 feet MSL). There are, of course, compromises between the two extremes of maximum turn and maximum energy. If the energy level of the aircraft is satisfactorily high, maneuver where the sustained turn rate is highest. This point occurs at the peak of the zero (0) P_s contour (i.e., 0.75 Mach and 5½ Gs).

There is, however, an entire spectrum of maneuverability between the absolute quickest turn and the maximum energy gain. One can be traded for the other. The best tradeoff of both can be gained in an optimum turn. It all depends on the desired effects. It should be emphasized that the diagrams are good for only one altitude. True optimum maneuverability and energy management should consider variable altitude in conjunction with variations in airspeed and G.

ENERGY

Observing the correlation of energy with maneuverability it follows that tactical fighter maneuverability is directly related to the amount of energy possessed. But possibly even more important is that the follow-on maneuverability will depend on how well that energy is managed. It is critical that the fighter pilot understand the options available to or required of him in various P_s regions.

Positive P_s

With positive P_s you can increase altitude and/or airspeed with a constant G, increase airspeed and/or G with a constant altitude, increase all three, or reduce thrust and maintain altitude, airspeed and G.

Zero P_s

This means an aircraft can maintain a constant altitude, airspeed and G with the present thrust.

Negative P_s

Here you must give up something. You may reduce G for a constant altitude and airspeed, lose altitude to hold a constant airspeed and G, or lose airspeed for a constant G and altitude.

SUMMARY

For the best maneuverability, the fighter pilot must know when and how to move to a higher or lower energy level and how to best conserve his internal energy (i.e., fuel) when locked in an air-to-air encounter. Although the old cliché that "P_s doesn't kill -- only 20mm does", is undoubtedly true, the fighter pilot who arms himself with a comprehensive knowledge of the concept of energy maneuverability, becomes thoroughly proficient in the performance of his aircraft, and knows something about the performance of his adversary, has a much greater likelihood of finding himself in position to deliver ordnance rather than receive it!!

CHAPTER 5
PRINCIPLES OF BFM

INTRODUCTION

BFM is what you use to maneuver your aircraft to the position you want, with the desired airspeed and nose attitude. In bombing or ground attack this may be relative to a fixed ground target. In aerial combat it will be relative to an adversary who is also maneuvering. But it should be remembered that the first thing you must learn about BFM is how to maneuver the aircraft.

Any BFM reflects a combination of three basic actions—roll, turn, and acceleration. BFM is a blending of these three basic maneuvers. In air-to-air your objective is to gain an energy advantage, a positional advantage, or (hopefully) both. You may want to maneuver to employ ordnance or avoid someone else's. Especially today, weapons capabilities have a significant effect on the BFM we choose. Some of today's high technology air-to-air missiles require little more than turning to point your nose near your adversary. Nevertheless, for many reasons it is critical that you understand and become proficient in traditional, classic BFM. That is our objective in the academic as well as the flight phase of this course.

In spite of what the syllabus seems to imply in its grading procedures, BFMs are not exact maneuvers that are flown to specific conclusions but are complementary combinations of maneuvers that blend one into the other. These combinations are based upon a continual reassessment of the tactical situation. First, the attacker observes where the bandit is and what he is doing. During this observation he assesses the bandit's energy state (maneuvering potential) as well as his own. From this, he predicts where the fight will progress, and based on that prediction, selects the most appropriate weapon and maneuvers himself into ordnance parameters. The entire process of observation, prediction, maneuver and counter-maneuver, is continual until either a kill or a separation has been achieved.

GEOMETRY

In order to successfully execute BFM, you must understand the geometric relationship between you and the target and how it affects your ability to employ weapons. The spatial relationship of two aircraft can be analyzed from four perspectives: positional geometry and target line of sight (LOS) movement, turn circle, attack geometry, and the weapons envelope.

Positional Geometry

When discussing one aircraft's position relative to another, range, aspect angle, and angle-off (heading crossing angle) are used to describe the angular relationships (Figure 5-1).

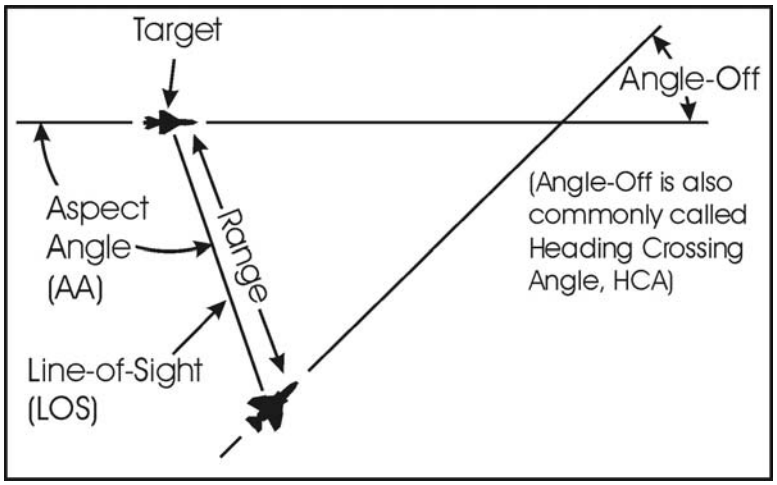


Figure 5-1. BFM Geometrical Relationships.

Range

Range is the distance between the two aircraft.

Aspect Angle

Aspect angle is used to describe your relative position from the target *without regard to your heading*. Strictly speaking, aspect angle is defined as the angle measured between *your* LOS to the target and *the target's* extended tail line or longitudinal axis. Your own heading is irrelevant!

Angle-Off

Angle-off is defined as the angle between the longitudinal axis of the

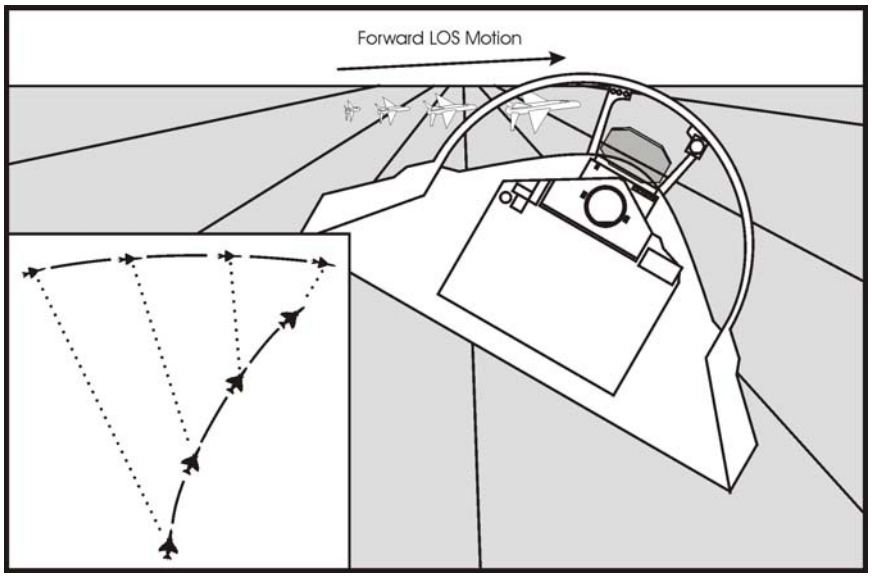


Figure 5-2. Forward LOS Motion.

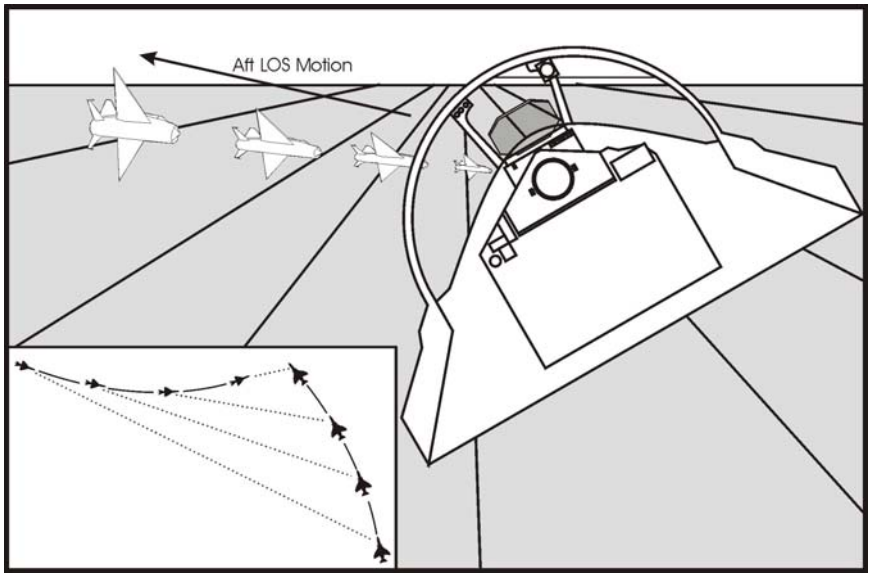


Figure 5-3. Aft LOS Motion.

attacker and the longitudinal axis of the defender. It is the degree of fuselage alignment (a better description might be misalignment) of the two aircraft. Whenever you point at the defender, aspect angle and angle-off are the same.

LOS Rate

Target LOS motion is the direction and rate at which the target appears to move against an "infinite backdrop", or, if you are not turning, on your canopy. This is the overriding factor determining which aircraft has a positional advantage. Regardless of actual angle-off/aspect, or range, if the target appears to move towards your nose, you have the advantage. If the target moves aft, toward your six o'clock, the he has the advantage (Figures 5-2 and 5-3).

Turn Circle

The turn circle is defined by how large your turn radius is. Turn radius varies with the intensity of the turn and with your true airspeed. There is a wide range of airspeeds, from stall speed up to corner velocity, throughout which turn radius, and therefore the size of your turn circle, is relatively constant.

Outside the Turn Circle

As the attacker, you cannot turn to decrease the angle-off, nor can you prevent the defender from generating aspect angle, until you reach the defender's turn circle. An earlier turn would merely effect an "in place" turn (Figure 5-4). How much aspect angle is generated depends on the defender's turn intensity and how long it takes you to close to the defender's turn circle.

Inside the Turn Circle

At the turn circle, you can negate some or all of the aspect and angle-off being generated by using your turn capability. As an example, say the defender can generate 15°/second and you can generate 20°/second. Prior to the defender's turn circle, for you to use your 20°/second would only put you in front of him. Once inside his turn circle, you can use 20°/second, and by doing so you will align fuselages at a rate of 5°/second. If the capabilities were reversed, the defender could create angles at the rate of 5°/second.

PURSUIT COURSES

There are three available attack pursuit courses: lead, lag, and pure. Your nose position relative to the target determines which type of pursuit courses is being flown (Figure 5-5).

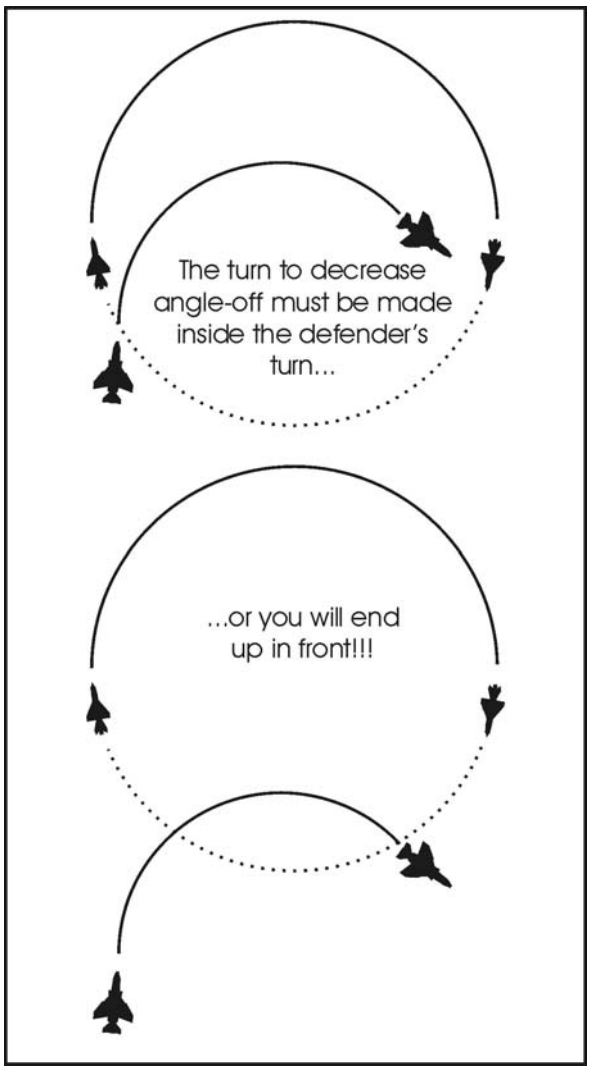


Figure 5-4. The Turn Circle.

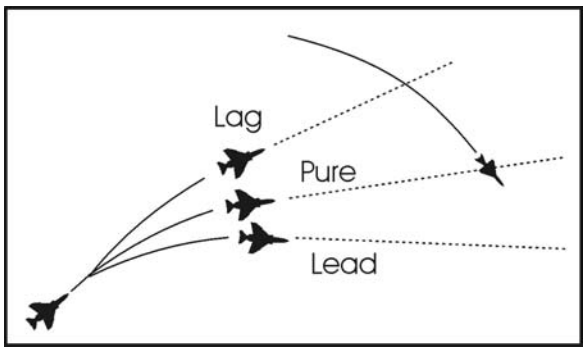


Figure 5-5. Pursuit Courses.

Lead Pursuit

Lead pursuit generates the most closure. It gets you to the defender's turn circle faster than any other pursuit curve because you are literally "rejoining" on the defender. This minimizes the time in which your adversary can generate aspect angle which you will have to solve in the end game. The practical limit to lead is the collision course (where the defender's LOS movement slows to zero or begins to move aft).

Outside the Turn Circle

Lead outside the defender's turn circle also allows you to select how far behind the defender you will be when you get inside his turn circle. Depending on the starting conditions, you will be forced to go from lead (30 to 40°) to less lead (5 to 20°) and back to lead (30 to 35°) as you approach the defender's turn circle, to position yourself in the AIM-9P cone between 4,000 and 6,000 feet behind.

At the Turn Circle

If you are still behind the defender's 3/9 line at the turn circle, lead will allow you to use your turn capability to gain/maintain fuselage alignment or at least minimize the increase in angle-off.

Closure

Lead allows you to control or generate closure. At low aspects, 30° of lead equates to 50 to 75 knots of pure geometry overtake.

Inside the Turn Circle

Lead inside the turn circle also allows you choose your final range behind the defender without jeopardy of being trapped in lag, as well as establishing lead for guns. You will go through a process of lead to less lead from the turn circle on in. At approximately 3,500 to 3,000 feet, you will go from 30 to 45° of lead to 15 or so to prevent losing sight of the defender as he comes into plane; this is not normally a good move. This process of lead to less lead also allows you to rejoin 1,000 to 2,000 feet behind your adversary (15 to 20° of lead) instead of on his wing (30° of lead).

Pure Pursuit

Pointing at a bandit allows you to obtain boresight lock-ons and to employ AIM-9s. It is also comfortable for the novice, who can see that by pointing at the bandit he will not fly out in front. Pure pursuit does solve angle-off and aspect if

the defender is not turning (Figure 5-6A). However, if the defender is turning, (Figure 5-6B), angle-off and aspect will build as long as you remain nose-on. It will take more and more G to maintain pure pursuit as range decreases. You maintain the capability to regain lead until the target's LOS rate across the sky exceeds your maximum rate of turn. In other words, you can pull lead again until you run out of turn rate. At this point you are trapped in lag.

NOTE

Depending on end-game geometry, the bandit's energy state relative to you, and the amount of G he is pulling, you may be able to pure pursuit all the way to a collision.

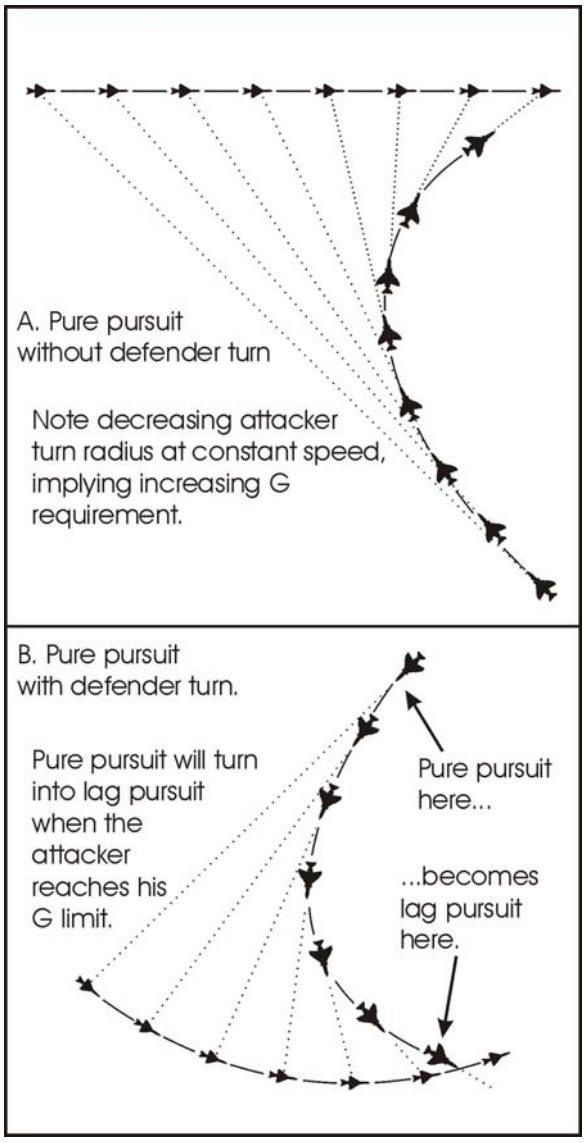


Figure 5-6. Pure Pursuit.

Lag Pursuit

Using lag with a large airspeed advantage, you may be able to drive to a bandit's blind cone, i.e., decrease aspect. If the defender is turning, however, he will be generating angle-off. To stay behind him requires that you be able to turn as well as he can. If not, you may find yourself lagged to his 12 o'clock. As with pure pursuit, you maintain the ability to pull lead until that point where the defender's LOS rate exceeds your maximum available turn rate. From this point on, you will go further in lag.

VULNERABLE CONE

The vulnerable cone of a defender is defined using range, aspect, angle-off, and pursuit course to approximate the weapon's envelope of the specific type of ordnance employed. BFM is used to decrease range, aspect, and angle-off, until an attacker is within the vulnerable cone for the ordnance he plans to employ.

TURNING ROOM

In order to discuss how BFM can solve range, aspect, and angle-off, a concept called turning room is used. The turning room available to you is your perpendicular distance from an extension of the defender's longitudinal axis or straight-line extension of his flight path.

Turning Bandit

The bandit's turn direction (into or away from the attacker) will affect how much turning room will become available. When inside the bandit's turn radius, you must have a turn rate and radius capability that will allow you to "make the corner" the bandit presents. The disadvantage of turning room inside the bandit's turn is that it frequently requires high energy bleed off rates to make the corner. When outside the defender's turn, part of your geometry problem is being solved, since the bandit is rotating his vulnerable cone towards you. Unfortunately, this only occurs when the bandit is unaware of your presence or is forced to respond to another attacker (Figure 5-7).

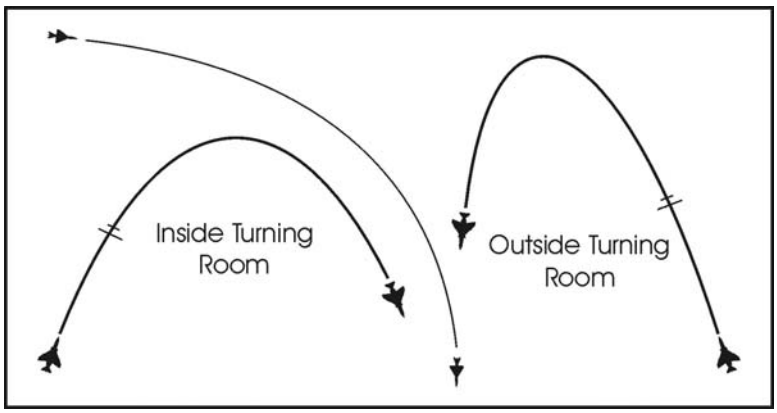


Figure 5-7. Turning Room.

Out-of-Plane Turning Room

If the bandit is in a vertical turn this turning room may be located in horizontal plane. More commonly, the bandit is in a horizontal turn, and turning room will be available either above or below his plane of turn. Energy can be gained while going low to gain turning room from below.

If you elect to go for turning room from above the bandit, you must have enough airspeed to gain this turning room above him and retain sufficient energy to continue your attack. The key is to have the energy to use the tuning room available.

If you do not have the energy to use the turning room, then deny the bandit the use of it. Turning room required is based on an aircraft's turn performance; therefore, a more maneuverable airplane will not require as much turning room as a less maneuverable one.

Remember, the defender can deny out-of-plane turning room by putting his lift vector on you and pulling until he is nose-on. His success or failure depends upon his energy level relative to you, and the slant range when he begins his turn.

MECHANICS OF BFM

This section will examine the three basic principles of BFM: roll, turn, and acceleration.

Roll

Roll allows you to position your lift vector, thus determining the plane of motion in which you will turn. At high speed and low angle of attack, the F-4 has a very high roll rate capability. However, as the airspeed slows and AOA builds, roll performance begins to degrade. At slow speed, in order to roll effectively, the AOA must be reduced prior to initiating the roll. Is should also be noted that the slower the airspeed, the longer it will take to reduce AOA. This factor becomes very important in slow-speed lift vector positioning such as might be required to defeat a gunshot.

Roll can position the bandit so you can maintain a tally. This is especially useful with an aft-quadrant bandit where a simple roll to maintain line of sight is preferable to energy depleting "kick outs".

Turn

Your turn capability is crucial to your ability to maneuver. Turn is measured by turn rate and radius. Turn rate increases from slow speed up to 420 KCAS (corner velocity), which is where turn rate is the highest (Figure 5-8). Turn radius at maximum AOA/G is relatively constant over an airspeed range of 200 to 420 KCAS. Above 420

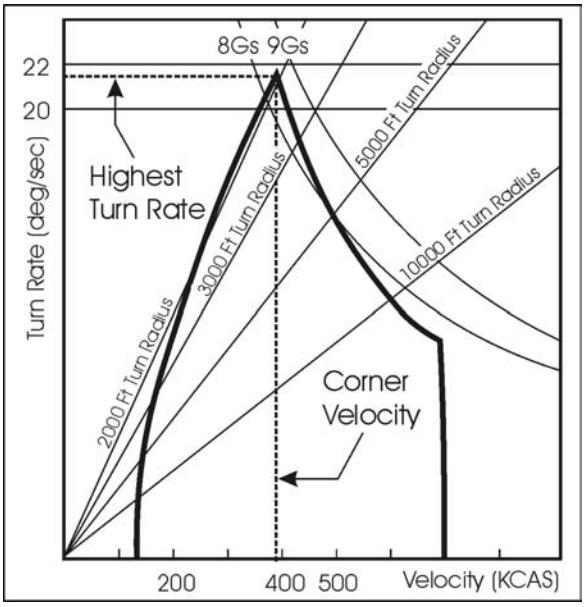


Figure 5-8. Corner Velocity on a Maneuver Diagram.

KCAS, turn radius begins to increase dramatically. The F-4 turns better with afterburner because it allows you to sustain airspeed and thereby sustain a higher turn rate. Additionally, the F-4 engines are canted down which adds a small amount of lift.

Turn Radius

Radius defines the size of an aircraft's turn or its "turning circle". The significance of turning circle

to the fighter pilot is that it defines how much turning room is required for offensive or defensive BFM.

Offensively

Sustained operations in the same plane against a defender with a smaller turn circle are not possible without inviting an overshoot/reversal situation (Figure 5-9).

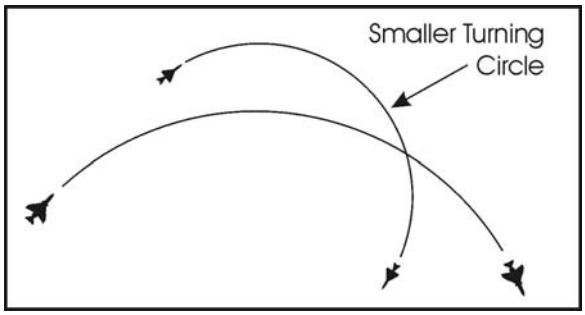


Figure 5-9. Effect of Turn Radius.

Defensively

Defensively, a defender wants to tighten his turning circle as much as possible. This is because a superior turning aircraft cannot use his better in-plane turn ability until he is inside a defender's turning circle.

Turn Rate

Rate is needed to employ weapons or to defeat attacks. Your turn rate must exceed a target's LOS rate to establish lead for a gunshot. To track him, your turn rate must match his LOS rate. Rate also allows you to decrease angle-off or minimize the angle-off your adversary can create. When on the defense at short range, you can use rate to increase the angle-off. At longer ranges where an attacker cannot turn for fear of turning in front of you, rate also increases the aspect angle, limiting an adversary's weapons employment options and shortening the amount of time he has to make them. Finally, rate helps defeat air-to-air missiles. A good turn rate allows us to put missiles on the beam faster, where they have problems with both guidance and fuzing.

Acceleration

The primary factor affecting acceleration is aircraft pitch attitude. Get the nose pointed downhill. Do not concentrate so much on 3-8 units that you allow your nose to get buried, (lower than 25-30°). If you bury your nose, the high G dive recovery may negate the positive effects of the airspeed you have gained. Also, a bandit you are separating from may be able to arc and close during a high G dive recovery.

Other factors affecting acceleration are altitude and airspeed. The lower the density altitude, the more effective the acceleration will be because of increased thrust. Acceleration is a trade off between thrust and drag. Thrust increases at a greater rate than parasite drag with velocity increases over the speed range of 100 to 450 KIAS (or 0.95 Mach, whichever comes first) due to the ram air effects on the engine. Above 450 KIAS, acceleration rates decreases as drag becomes dominant (both parasite drag and compressibility drag). As a rule of thumb, the best acceleration rates occur in the speed range 350 to 450 KIAS.

LEAD TURNS

Before discussing individual BFM, an examination of the concept of lead turns is in order. A lead turn is an attempt to decrease angle-off prior to passing the opponent's 3/9 line. The classic lead turn is accomplished by offsetting your flight path one turn diameter to one side or the other of your adversary's predicted flight path, and initiating a turn to arrive at that point in space with reduced angle-off and behind your opponent (Figure 5-10).

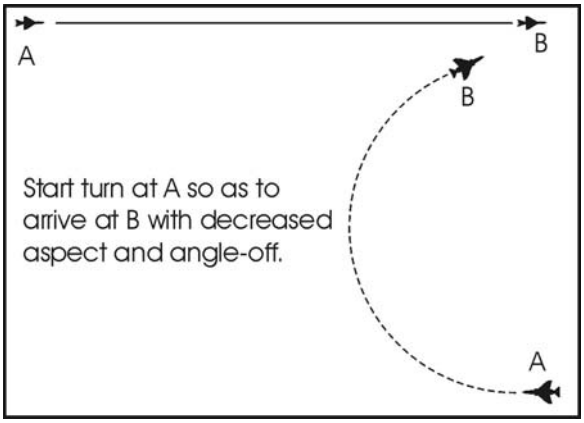


Figure 5-10. Lead Turns.

Start Early

To arrive within range to employ weapons, you must start the lead turn prior to passing your adversary's 3/9 line. The more turning room available, the lower the G loading you will require to complete the maneuver. Conversely, if the maneuver is initiated in close with little or no offset a high-G turn may be required. The up

range distance at which a lead turn is initiated will govern the rollout range at the target's six. Lead turns against a target that maneuvers prior to passing your 3/9 line will not produce a dead six position, but should still result in some turn advantage.

Counters to a Lead Turn

The obvious counter to a lead turn is to remove the offset prior to the lead point. To do this, simply point your nose at your adversary.

Against aircraft with equal or inferior turn performance, if you start a lead turn at the proper range, you will automatically counter any turn your opponent attempts (Figure 5-11).

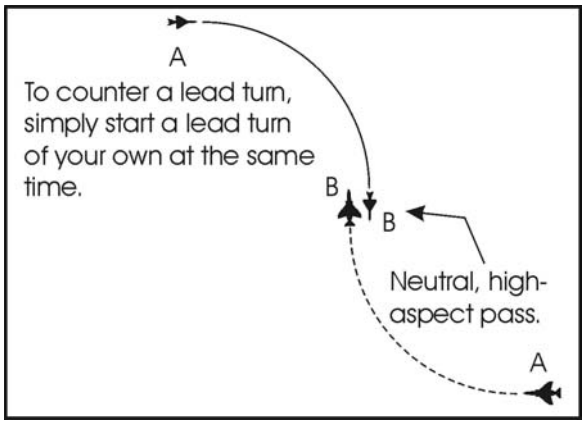


Figure 5-11. Mutual Lead Turns.

If engaged defensively by lower wing-loaded aircraft, you should fly head-on at your opponent (in training, honor the minimum range bubble!), eliminating all offset and denying him any chance for a lead turn. It is important to start the turn to point at your opponent prior to arriving inside his turning circle, which is the point where he will begin his lead turn. If you wait until the bandit has already started turning against you, the fight will quickly develop into a lagging contest that will be won by the superior turning aircraft (Figure 5-12).

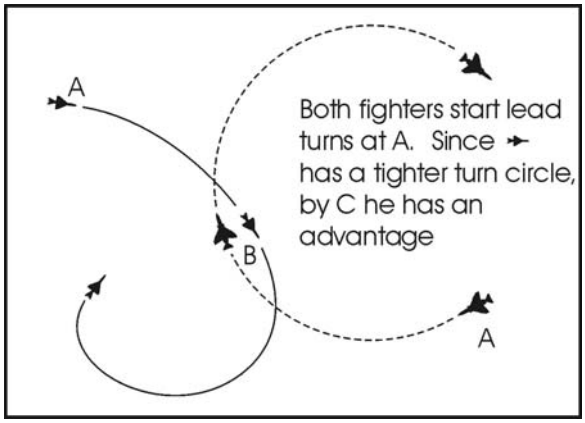


Figure 5-12. Lagging Contest.

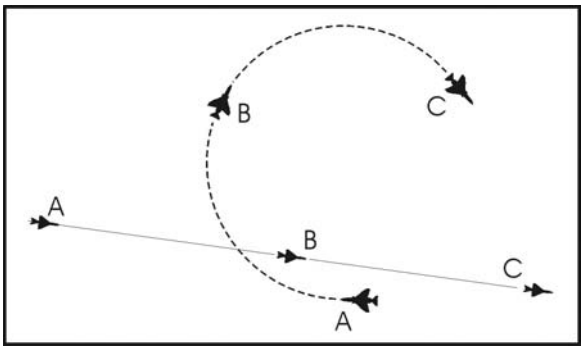


Figure 5-13. Early Lead Turn.

Tactical Considerations

Lead turns are efficient BFM, so use them whenever possible. Remember, though, that it tends to anchor you in a turning fight, so be sure the energy you expend during your turn will gain the advantage needed to kill. As an example, always lead turn during your initial entry into a fight, when the bandit doesn't see you yet.

Lead turns may be attempted without turning room simply by initiating a turn prior to passing your opponent's 3/9 line. If your opponent continues on his present course, you will roll out with decreased angle-off, but you will still have an aspect angle problem (Figure 5-13). However, the defender can easily counter by pulling away from the direction in which you are turning and continue to build angle-off (Figure 5-14). If you initiate the turn outside the defender's turning circle, he can slow his forward vector (throttles, speed brakes, out-of-plane), and force you to fly in front of him (Figure 5-15).

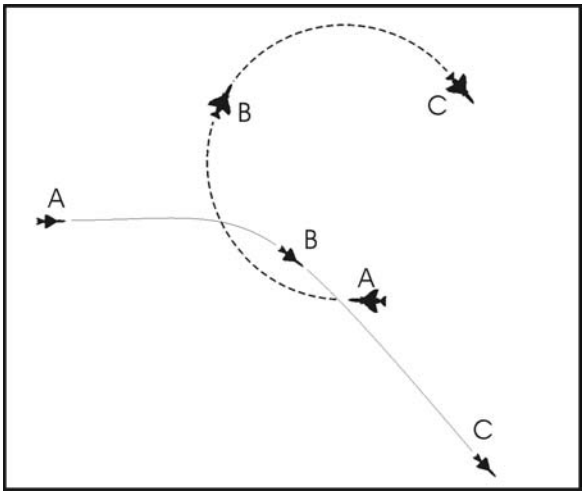


Figure 5-14. Early Lead Turn with Defender Counter.

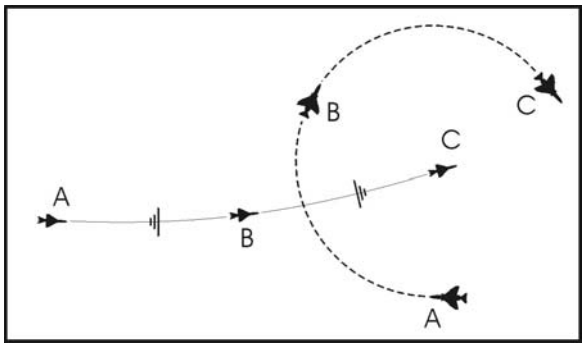


Figure 5-15. Very Early Lead Turn with Defender Counter.

Lead turns can be accomplished in any plane but are more advantageous in the pure vertical because of the reduced opportunity for the bandit to acquire you. A lead turn down or split "S" is useful because it preserves airspeed and energy. A lead turn up is tactically advantageous because it allows visual contact with the target while placing you in the defender's blind cone.

If you achieve offset above your adversary, but you cannot commit to a nose-low slice, lead turn in the horizontal. This is done by pulling to a lead point in a plane above the bandit's flight path. Although not as efficient (there is still an aspect problem to be solved) as a turn done in-plane with the bandit, it preserves nose position (the vertical HCA between you and the defender) and prevents a vertical overshoot should the bandit attempt to counter the lead turn by pulling up and into you.

VERTICAL TURNING

The concept of vertical turning (using the "egg"), is important in the F-4, (Figure 5-16). Through the use of optimum or energy conserving turns in the bottom portion of a vertical turn and high turn rates at the upper portion of the vertical turn you can sustain a high average turn rate over time. During the pull-up, high-airspeed/lower AOA turns are made in order to minimize airspeed bleed-off and offset the effects of gravity. Once positioned on top, transition to a slower airspeed and higher AOA turn so you can realize the full benefit of the additional G being generated by gravity. High AOA turns should be used in the bottom half of the egg only to defeat a gun or missile shot, or if the turn will gain nose/tail separation by forcing a vertical overshoot and allow a reversal of roles. Offensively, only use maximum performance if the turn will allow you to position your nose so to shoot and kill your opponent.

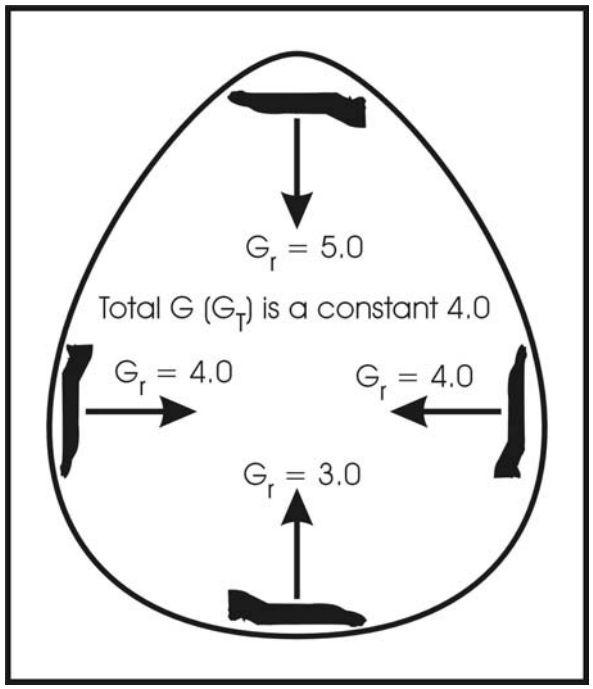


Figure 5-16. "The Egg."

ENERGY VS. POSITION

Energy is the potential to maneuver. However, like most things, too much energy can be a dangerous thing. Excessive speed can lead to severely degraded turn performance, minimum time in weapons parameters, and reduced station time. The factor to consider is how much energy you need and how much you are willing to expend for a given positional advantage.

Tactical Considerations

BFM allows the achievement of weapons parameters with minimum energy expenditure in as little time as possible. This concept of energy efficient maneuvering is important because in a tactical situation, it will dictate how much BFM should be employed in a given engagement. How much time can the F-4 pilot afford on one attack with regard to the entire tactical environment? How much energy or future maneuvering potential should be expended for a given positional advantage? Will that position be sufficient for the kill or will it just prolong the engagement? All these questions must be asked and evaluated to determine the trade off for given situation.

Obviously, high energy bleed-off for position is justified to achieve firing parameters against a Flogger attacking the home 'drome, while the

same P_s expenditure may be unwise in an outnumbered sweep vs. sweep scenario deep in enemy airspace.

Energy Is Relative

Energy must be measured in relation to your adversary. It is not just relative airspeed. Although other tactical considerations may often make 200 KIAS an undesirable airspeed, being at 200 KIAS 10,000 feet above an opponent is a position of advantage. Maintaining an energy advantage is a necessity against lower wing-loaded aircraft. This can mean co-speed well above him, or co-altitude with 100 KIAS greater airspeed. No matter what your relative position, being co-speed and co-altitude with lower wing-loaded adversary is a deadly mistake.

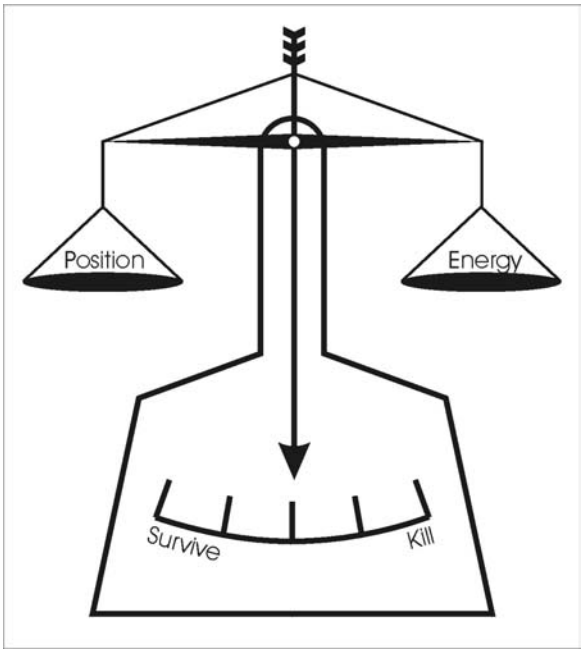


Figure 5-17. Energy vs. Position.

Balance

Energy and position must continually be kept in balance. BFM is the tool used to achieve this balance—trading energy for position or altitude, and using position to employ ordnance, while always remaining cognizant of the need for survival.

CHAPTER 7
OFFENSIVE BFM

INTRODUCTION

Offensive BFMs can be divided into two generic classes of maneuvers -- long range and short range BFM. Slant range is often used to distinguish between the two, but there are other distinctions which are equally important.

Slant Range

One approach is to use the defender's turn circle as a slant range cutoff between long and short range BFMs. Outside his turn circle, you cannot use your turn rate to solve aspect and angle-off problems without risk of turning in front of your adversary. Instead you must use large "turning room" and "lead turn" type maneuvers, until you are inside his turn circle. Once inside his turn circle, you are increasingly able to use turn rate to solve aspect and angle-off problems.

Bandit Tally-Ho

Another important distinction has to do with whether your adversary sees you. If he does (and is free to react to you), then he will probably turn hard into you, and long range, large turn circle maneuvers will not be possible. You will be forced into a near neutral, high-aspect pass. Only if the bandit remains unaware of you will you be able to perform the long range BFMs we are about to discuss.

LONG-RANGE BFM (LRBFM)

The first set of maneuvers we will examine are those used from when we first acquire a tally-ho at long range, to when we close within weapons parameters. Your adversary may be flying straight and level, in a turn into, or away from you. Whatever he is doing, if he does not see you, you have an opportunity to sneak up behind him and kill him. That's what long range BFM is all about. The maneuvers we fly to accomplish this are called *entries*.

Tactical considerations

What you will do when you first see your opponent depends on many factors. In today's high-tech warfare with forward aspect radar and infrared missiles, you may not want to use long range BFM at all!! Just centering the dot, and letting Raytheon do the BFM for us may be our best option. Deliberately closing inside the visual maneuvering arena with third generation aircraft which clearly outperform the F-4 is not smart. That is not to say that it won't ever become necessary, but if the long gray telephone pole can do the work for you, let it have the kill! Next, the rules of engagement (ROE) may require visual identification (VID) prior to expending ordnance. This will have a major impact on your tactical game plan. Finally, whether or not your adversary has a tally on you will significantly determine what you do when you first see him.

Does He Have a Tally-Ho?

This is the critical question. If the answer is no, keeping him from getting that tally must be your major concern as you execute your long range BFM. In air to air warfare, sight is life. If your target does not see you, and remains unaware of your presence as you close inside of weapons parameters, his airframe performance, radar/systems and ordnance capabilities become irrelevant. On the other hand, if he sees you while you are still three miles away, a competent pilot in almost any aircraft can survive indefinitely. The objective of long range BFM is to get from far away from your adversary, to a position from which you can kill him, without being seen.

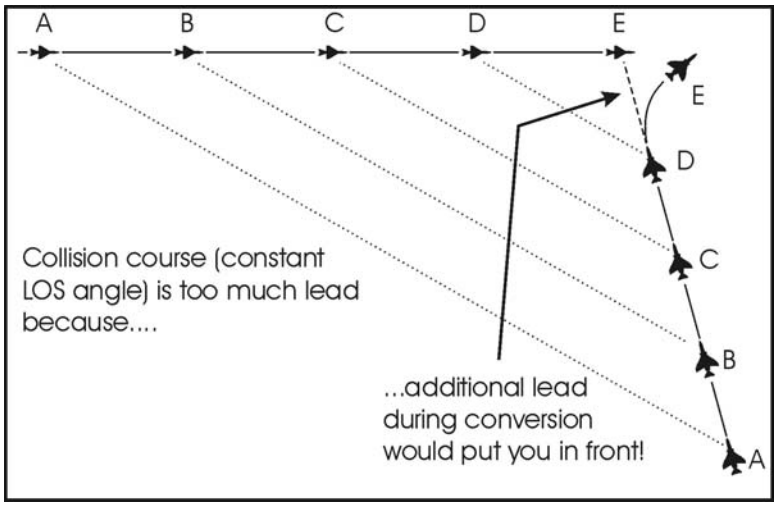


Figure 7-1. Collision Course, Too Much Lead.

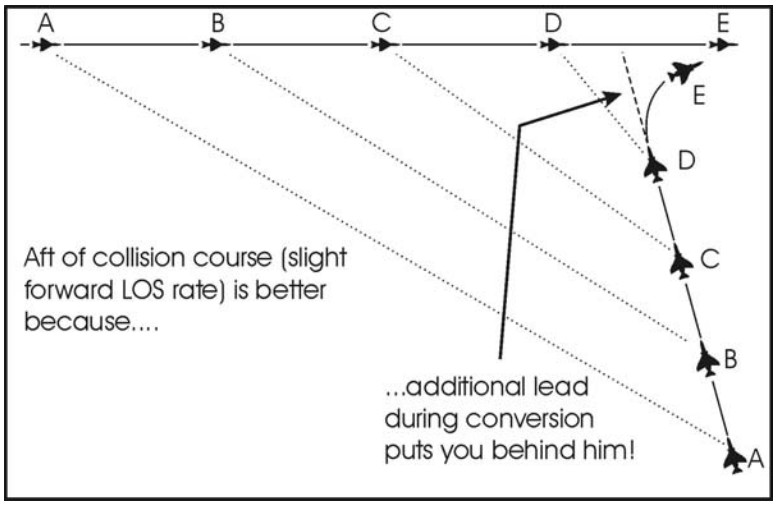


Figure 7-2. Aft of Collision Course, Slight Forward Motion.

Fly to His Blind Cone

In the F-4, of course, you do not need to fly to his six o'clock to shoot, but that is a better place from which to shoot than from in front of him. Pilots generally spend more time looking out the front than out the back so he is more likely to see you there. Secondly, he can't shoot back when you are behind him. Last, overtake when head-on minimizes shot opportunities. Behind someone, you have a wider choice of ordnance, and launch opportunities last longer. So, in general, if your opponent seems not to see you, you are better off trying to fly to his six o'clock.

After LRBFM

If done correctly, and successfully, there will be no need for short range BFM, your adversary will be dead. If not done correctly, you will arrive behind him with too much or too little overtake, or with too much angle-off, and you will need to use short range BFM to consummate the kill. If he sees you, and turns hard into you, you will need to employ short range BFM to solve the aspect angle problem this will cause you. Short range BFM, (SRBFM), will be discussed in the second part of this chapter.

Objectives

What are the objectives of long range BFM? First, we must close with the bandit. In this respect, it is similar to a join-up. Unlike a join-up, however, it is critical that we do it unseen. Finally, once in weapons range at his six o'clock, we must point at the target to employ ordnance and kill.

Mechanics of LRBFM

Entries can be broken down into two phases; first, the closing phase, where we close with the bandit, reducing the range and aspect angle; and second, the conversion phase, where we reduce the angle-off to point at him from his six o'clock.

Closing Phase

To close with another aircraft, we fly the collision course as in a single turn conversion or cutoff attack. If all we were interested in was closing, we could do this just as air-to-air missiles do. We could just turn until the target's Line of Sight (LOS) rate in the sky slowed to zero—and we would be on the collision course. We would close with—and collide with—him. This would reduce the range in the minimum time. It does little good, however, to be at the target's six o'clock, if we arrive there with 135° angle-off. To stay there, we must have our fuselages aligned. To employ ordnance, we must turn and point at him. On the collision course, that additional lead we would be pulling in order to turn to match his heading would roll us out in front of him.

Slightly aft of collision course

So, the collision course is too much lead for this maneuver (Figure 7-1). The right amount of lead is the collision course for a point some distance behind him. How far behind depends on how much we will have to turn to align headings once we get there, i.e. on the angle-off. Outside of four to five miles the LOS drift rate will be almost stopped. In closer, approaching the point where it is time to start the conversion, we should begin to see the target LOS drifting towards our nose. On a flight path which would "collide" with a point five thousand feet behind the target, the target must drift forward and cross in front of you, (Figure 7-2). It must be emphasized that initially, this is still lead.

Almost at once, just from watching the LOS motion, you can turn and put your jet on the collision course. If the target is drifting to the left slightly, you must turn left. If he were drifting to the right, you would turn right. Turn until LOS drift has almost stopped. If you are outside of five miles, turn until it has stopped. This puts you on or just aft of the collision course and minimizes the time to intercept. As you close inside of four to five miles, you want to see more LOS drift towards your nose.

NOTE

Where you must put the bandit on your canopy to "zero out the drift" can also tell you another piece of valuable information - his aspect angle. If he ends up between 30° and 45° off the left of the nose, just outside the canopy bow, then aspect angle is somewhere near the beam (90°), with a left to right pass. The closer to your nose he ends up, the further away from the beam he is, although the LOS itself cannot tell you whether he is head-on or dragging away from you.

Out-of-Plane

Before you make this turn, you must decide whether to attempt your entry from above or from below. If you perform the entry co-altitude with your adversary, you are right on his horizon line. Remember, he is probably clearing for you just as you should be clearing for him. Performing an entry co-altitude increases the probability that he will see you. Once that happens, he will turn to point at you and the maneuvers we are discussing in this section will no longer be possible.

The sooner you establish and maintain the necessary altitude separation, the more likely you are to remain unobserved. So, in this turn you should establish the pitch attitude necessary to gain this vertical turning room. At the same time you are making this horizontal and vertical turn, you must select full afterburner, call the tally and declare your intentions to your flight lead/wingman. These three actions should all come simultaneously, and we call them the "Three T's"; Turn, Talk, and Throttle.

High or Low?

Initially, the most important consideration in this choice should probably be where you are relative to him when you first see him. If you are already below him, to climb above would require that you cross his horizon. If you are close enough to see him, and you put your aircraft on his horizon, he will probably see you! Unless the terrain, the weather, or his altitude make it malapropos to stay where you are you should remain there. But all other things being equal, there are some definite advantages of entries from below vice from above the bandit's altitude (Table 7-1). Typical low and high entries are shown in Figures 7-3 and 7-4.

Table 7-1. LRBFM Entry Options

	Advantages	Disadvantages
From Below:	Remain unseen	Timing harder
	High Speed	Bandit can counter
	Defensive capability	Less total energy
	Less vulnerable cone	
	Radar and visual lookup	
From Above:	Easier	Bandit lookup
	Harder to counter	Slower
	More energy	More vulnerable

Bandit Tally-Ho

Over most terrain, your adversary is much less likely to see you if you perform your entry from below. Visibility downwards is generally poor -- especially so in MiG-series jets. Most pilots do

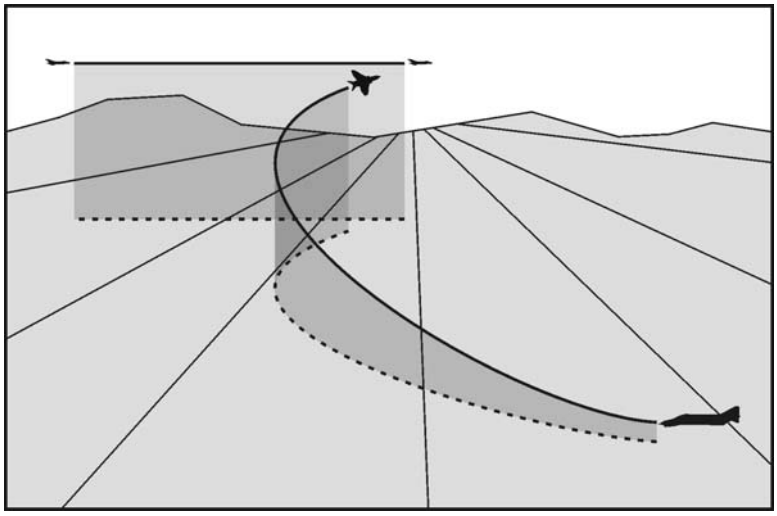


Figure 7-3. Entry from Below.

not clear enough in the vertical in either direction; those who do generally clear more above than below them. This factor, if it denies the bandit a tally on you, makes all the other disadvantages irrelevant. But entries from below also have another advantage.

Less Vulnerable

When you are low, you are less vulnerable to other bandits. There are several reasons for this. First, you will be closer to the ground, in the radar and infrared ground clutter. It will be more difficult to find you, and more difficult to maintain contact with you. Also, your airspeed should be higher. High true airspeed makes intercept and conversion to your six o'clock more difficult and reduces a bandit's chances of completing his intercept within weapons parameters. Finally, high calibrated airspeed shrinks your vulnerable cone, and increases your defensive capability if and when you detect an attack.

Difficulty

Entries from below are harder to execute because the closure is higher. Timing becomes more critical and harder to judge. From above, you are generally slower and it is easier to adjust for errors in timing. Secondly, if the bandit sees you while you are still below and in front of him, he can easily turn down into you and deny you the entry. When you are above, even if he sees you he may not have the energy to turn up and into you to defeat the entry. Last, when you enter an engagement from high to low, you'll generally end up with more airspeed and energy than when coming from low.

Execution

There are some differences in execution of entries from above, as opposed to entries from below,

From Below

For an entry from below you need to adjust your flight path so that you are aimed slightly aft of a collision course. If at the tally-ho the bandit has an aft LOS rate, you must correct this while also establishing vertical separation (Figure 7-5). Over-bank as you pull in the direction of his LOS rate (Figure 7-6) so that when you roll out with the proper amount of lead you are already going downhill (Figure 7-7). How nose low you get depends on how far away you are and how much vertical turning room you need. At high aspect, you will have to turn 180° in the final conversion. From low to high, this will require ten to twelve thousand feet. If your final conversion turn ends up being purely vertical, (an Immelmann), then this is also the altitude split required to perform the entry. Oblique turns, or if the angle-off is less than 180°, will require less vertical turning room. But keep in mind that if you only get enough turning room for a 90° turn, and the bandit unexpectedly changes what he is doing and ends up head-on to you, you won't have enough. Too much turning room can be easily adjusted for by easing off during the conversion. The reverse is not so easy.

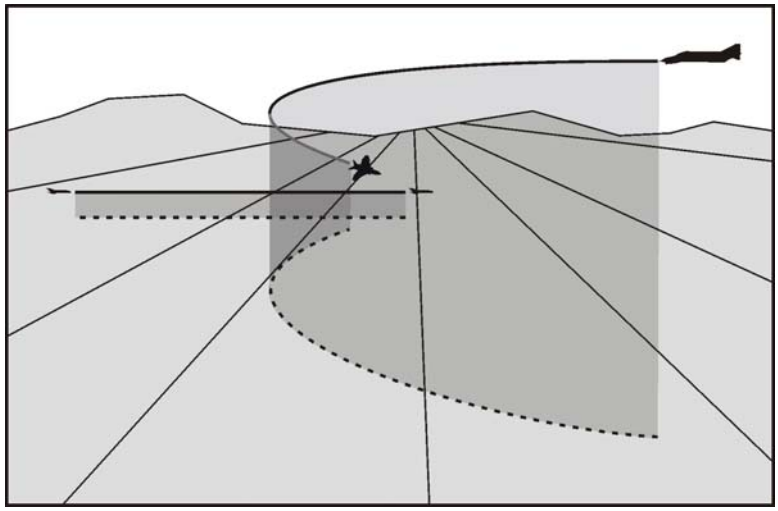


Figure 7-4. Entry from Above.

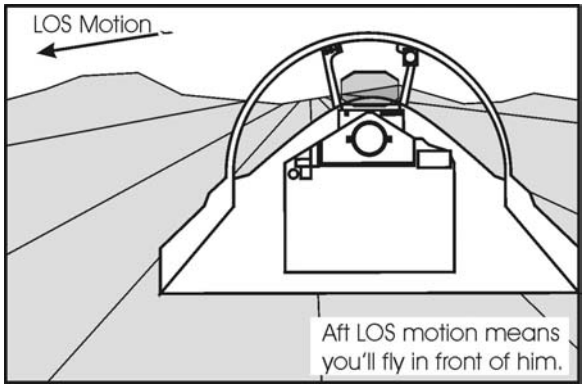


Figure 7-5. Tally-Ho!!

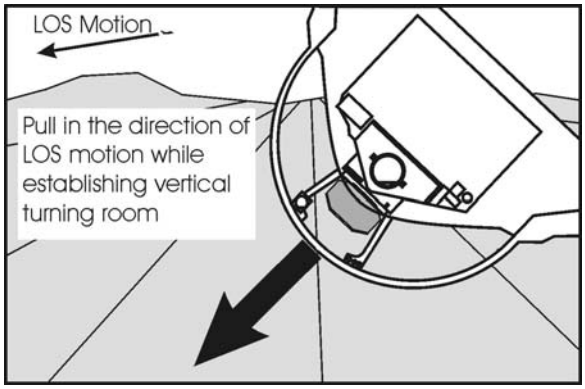


Figure 7-6. Initial Turn to Intercept.

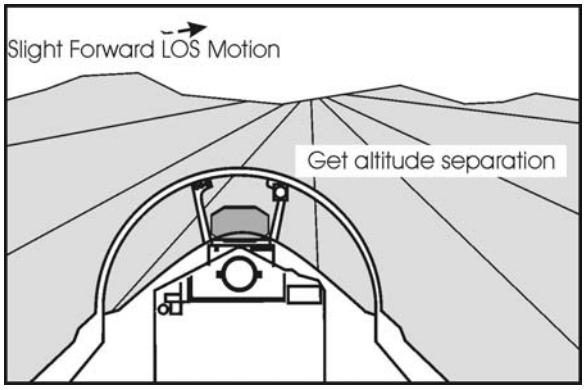


Figure 7-7. Slight Forward LOS Motion.

From above.

For an entry from above, eight to ten thousand feet of turning room is required. Again, the sooner you begin climbing, the less pitch up will be required. Do not, however, begin any climb for vertical turning room with less than 450 KIAS. With less than 450 KIAS, first perform an acceleration maneuver. If only slightly above the bandit, and he is still unaware of you, the dilemma is whether you should allow yourself to descend below his altitude during this acceleration. Unless you are sure he cannot see you (he is turning belly up away from you), then the answer is a resounding no. Gaining airspeed is less significant than denying the bandit the tally.

Vertical LOS Rate

As you are attempting to build turning room above or below him, you must also watch his vertical LOS rate, to ensure that he is not taking it away.

Recognition

If the bandit started 5° above the horizon, then as you descend that elevation angle should increase. The bandit should appear to rise further above the horizon (Figure 7-8). If this does not happen, if he remains the same apparent distance from the horizon, or, if he gets closer to it, then he is also descending, perhaps faster than you are, and you are not building turning room at all.

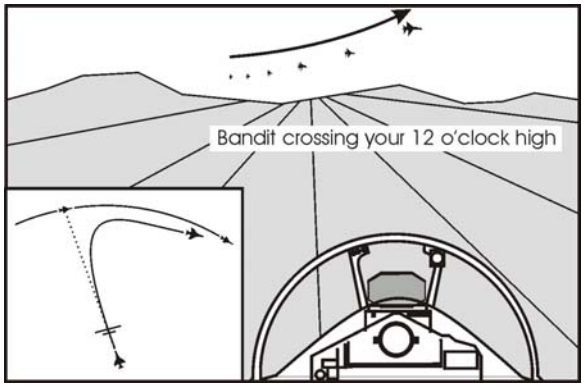


Figure 7-8. Upward LOS Motion Says You Are Gaining Vertical Turning Room.

Solution

What you should do in this situation depends on whether or not, in your judgment, the bandit has you in sight. If, by his maneuvering, you feel he is reacting to you, then you must be careful not to keep attempting to gain turning room inside the range where you can still point at him. If you did, he can start to lead turn you, and when you pass he may have a slight advantage. When inside of about three miles, and you suspect that the bandit sees you, you should turn to point at him, and treat the situation as a high aspect neutral engagement, which we will discuss later.

If, in spite of the fact that he is thwarting your attempt to get turning room, you still feel that he is unaware of your presence, then you may still have the option of changing from low to high or, much harder, from high to low. Keep your nose pointed in front of him, with the proper lead, and

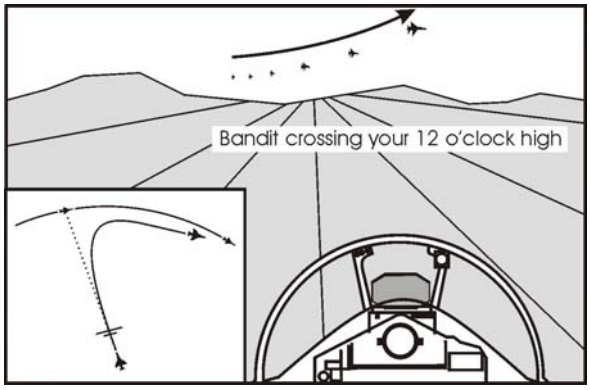


Figure 7-9. Medium Angle-Off Entry From Below.

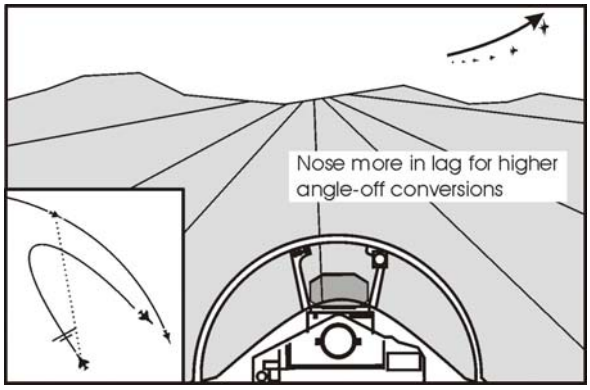


Figure 7-10. High Angle-Off Entry From Below.

pull the nose up, or back down, to go in the opposite direction he is going in.

How Much Vertical?

There are several visual cues for recognizing when you have enough vertical separation. The most useful is the elevation of the LOS. How far above or below the horizon is the bandit? The ten thousand feet of turning room you need should put him 20° high/low at five miles slant range, and about 30° at three miles. If you get inside of three miles without enough turning room, it's too late to get more. For entries from above, this 30° will be below the horizon, and is difficult to judge. Keep in mind that it is his position relative to the horizon and not relative to your nose which is critical. In most high entries your nose will already be up 20° to 30° when evaluating this and the bandit would then be 50-60° below the nose.

Monitor Lead/Lag as You Close.

As you close, adjust your heading so that the target's LOS motion drifts slowly towards your nose. How much drift, and where he should end up relative to your nose, depends on the angle-off you will have to solve during the final conversion turn. If you will only have to turn 90-135° at the end, then, as you begin your conversion, the target should be crossing your nose at about two miles slant range, between 30° and 40° above or below the horizon, (Figure 7-9). For a higher angle-off situation, 160-180°, the target should be allowed to cross your nose, and get 30-40° on the other side (nose in lag) at about two and a half to three miles slant range, (Figure 7-10). This lag is in fact additional turning room in the horizontal, which will make our conversion easier. What will happen if you don't have the right amount of lead/lag at these slant ranges, and at this point how can you correct for this?

Too Much Lead

If you have too much lead, then as you turn in the conversion you will turn in lead of the collision course and roll out in front of the bandit. This is the worst error. Early recognition allows you to fix this by simply pulling the nose to lag or less lead, prior to starting the conversion. This will increase the angle-off and adds to the turning room required. In addition, if you are approaching the slant range to start the conversion, fixing this problem may delay you enough to cause a late conversion. This will flush you outside and past the bandit's flight path, or increase your roll out range at the bandit's six o'clock.

Not Enough Lead

Conversely, if the bandit crosses your nose or rotates his nose through your position while you are too far away to begin the conversion, simply re-establish lead. Again, it is the target's LOS motion against the background which you should use to evaluate this. This turn will also reduce the angle-off problem and make your conversion easier.

Inside/Outside?

Once on the correct course, with the necessary turning room, you must continue to evaluate what the bandit is doing. His level of maneuvering will determine what the conversion phase of your entry will look like. Until you get to the point where it is time to use the turning room you have established and convert to his six o'clock, you must maintain your lead and the vertical turning room. If the bandit is straight and level, then very little adjustment will be necessary to remain on the correct course. A turning bandit, on the other hand, may change the geometry as you are closing. This may require you to adjust how you complete the final conversion turn. The key factor to consider is whether the bandit is turning hard

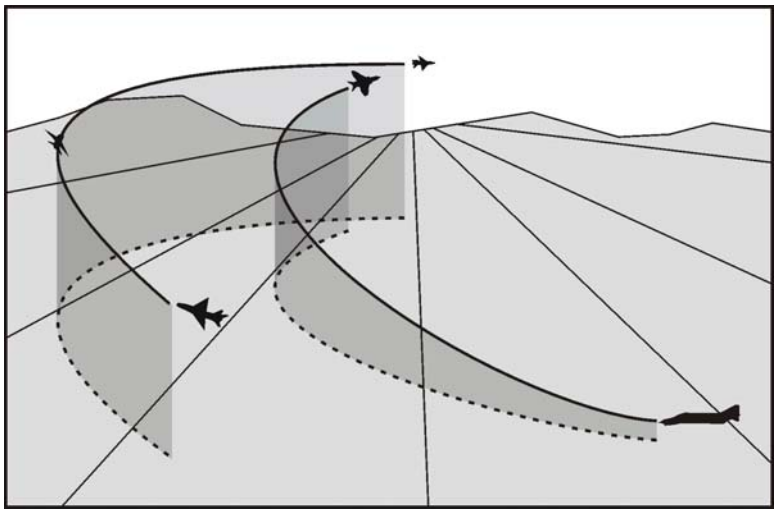


Figure 7-11. Inside Entry From Below

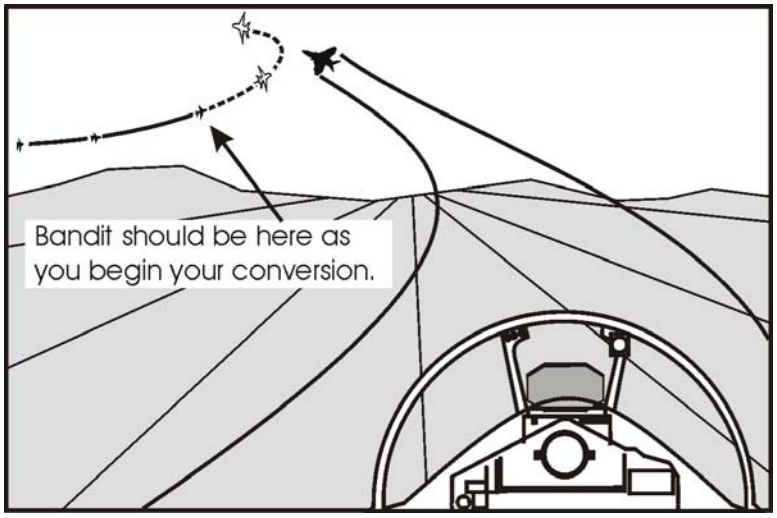


Figure 7-12. Outside (Belly) Entry From Below.

enough to bring his nose through you prior to your completing the conversion.

If the bandit will not turn far enough to bring his nose through you during the entry the final part of the conversion will be inside the bandit's turn. We call this an "inside" entry (Figure 7-11), and it is most common against a low-G or non-maneuvering bandit. If he will go nose on during the conversion, then you will end up outside his turn circle during the final phase. We call this an "outside" or "belly" entry (Figure 7-12).

It is important to understand that you have little control over this. It is the bandit who determines whether your entry will be inside, or outside. If you attempt to get "outside" of a low-G bandit's turn, (by pulling too much lead), you will fly out in front of him. Conversely, trying to get "inside" of a high-G turn circle can be impossible. Secondly, if you are sufficiently displaced in the vertical, it doesn't matter very much! You will have the right amount of vertical turning room to make the entry. For belly entries, however, there are some differences (discussed in the next section), in the visual cues you must be aware of during the conversion.

Conversion Phase

The purpose of the conversion is to solve the angle-off part of the problem and align fuselages at the bandit's six o'clock.

Airspeed

Begin a conversion from low to high with no less than 550 KIAS to insure combat airspeed when you roll out behind the bandit. When your training area is cleared supersonic, get even more: 600 to 625 KIAS is not excessive. You don't want to roll out behind the bandit with 350 KIAS or less. When converting from high to low, start down with about 400-425 KIAS. Monitor your airspeed carefully as you descend, and adjust power and "G" as necessary to control closure and turn radius. If you need to ease off on the back stick, you may need to pull your power back to prevent accelerating excessively.

When to Begin

The first problem is deciding when to start the conversion. The right time to begin it is when you are the required turning room away from him. There are some visual cues which are common to all entries, and some which are specific to particular situations.

Bandit Elevation

A common factor is the elevation of the target LOS. In almost all types of entries the target elevation when it is time to start the conversion will be between 25° to 35° above or below the horizon. Another useful cue is the speed of the bandit's vertical LOS motion. How fast is he drifting up or down (away from the horizon)?

At long range the bandit will move away from the horizon slowly. When you reach the right place to start the conversion, this vertical LOS motion should begin to accelerate. This is because you are approaching the point where if you continued

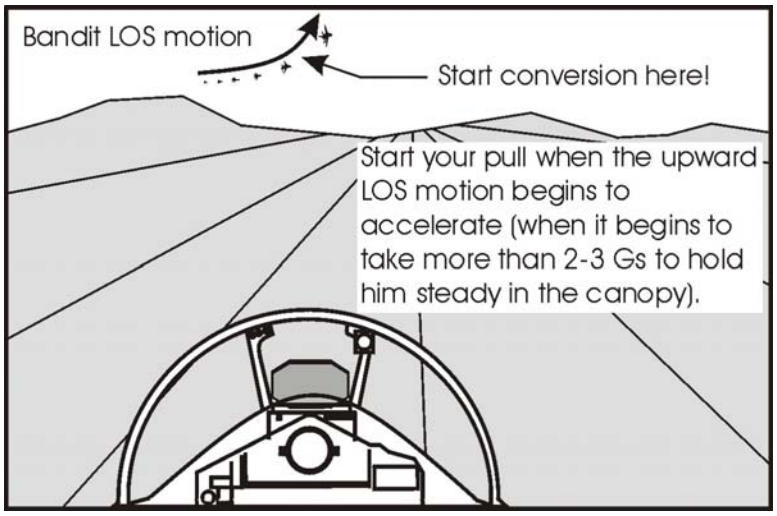


Figure 7-13. When Vertical LOS Motion Begins to Accelerate.

on your current course you would soon fly under (or over) him. This acceleration in vertical LOS rate is a very accurate cue that it is time to begin the conversion (Figure 7-13). For entries from below, one method of using this cue is to attempt to hold the bandit 30° high on the canopy and then begin your conversion when the G required to do this begins to increase.

90° To Go

Another technique is to imagine the position you should be in with 90° left to go to his heading. At this point in the conversion you should be about seven to nine thousand feet away from the bandit, pointed slightly in lead, and above or below him by at least 45°. Your lift vector should at this point be lined up with his fuselage, pointed towards where he is going, as you pull your nose to his heading (Figure 7-14). Imagine this position and start your conversion with this as your goal.

Belly/Outside Entries

For a belly entry, when you begin your conversion you should still be looking at the top of his aircraft. This may be hard to picture, but, if you wait until the bandit has already turned his nose through you, you will almost certainly be late. The aspect angle you should see as you start the conversion is somewhere between 90° and 135°. The bandit at this time should be no more than 25° from your nose (Figure 7-12).

Conversions from Above.

The cues to begin a conversion from above are similar to those from below, but there are several minor differences. Just aft of the collision course is still a good rule of thumb, but if you are beginning your climb for turning room high late, or close to the bandit, the steep climb angle this requires will slow your forward motion and cause you to pass further behind the bandit than you might have planned. He will then cross under your nose too soon and too far away from you. So, when a late or very steep climb is needed, your initial heading during the first part of the maneuver should be more in lead. Just the opposite happens in the downhill conversion. There is a natural tendency to gain airspeed, which can cause you to overshoot. This is especially dangerous against a slow bandit. Because of this problem, it is recommended that you shoot for a position further at six o'clock, (more forward LOS motion), when you perform conversions from above.

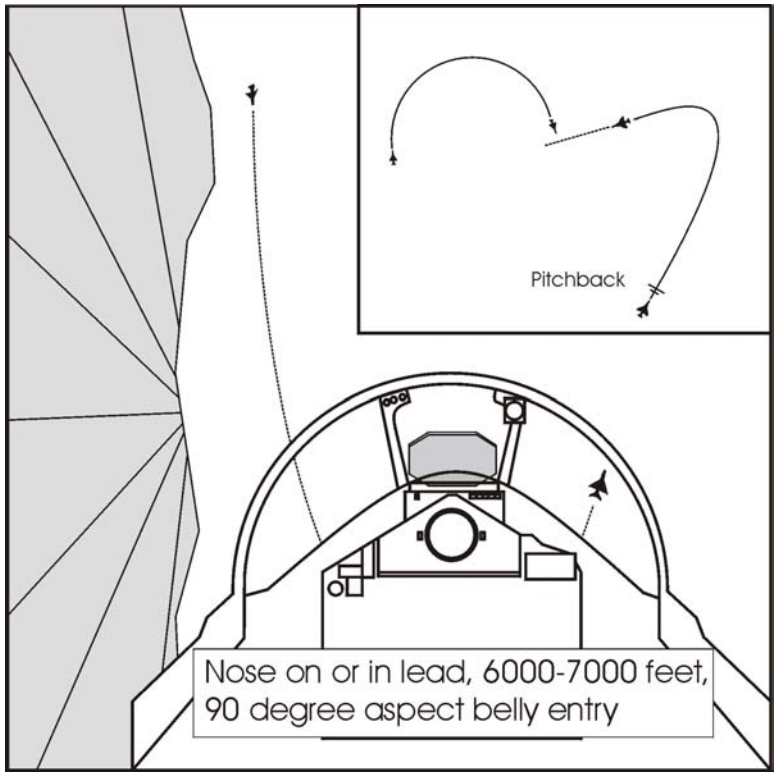


Figure 7-14. Halfway Through the Conversion.

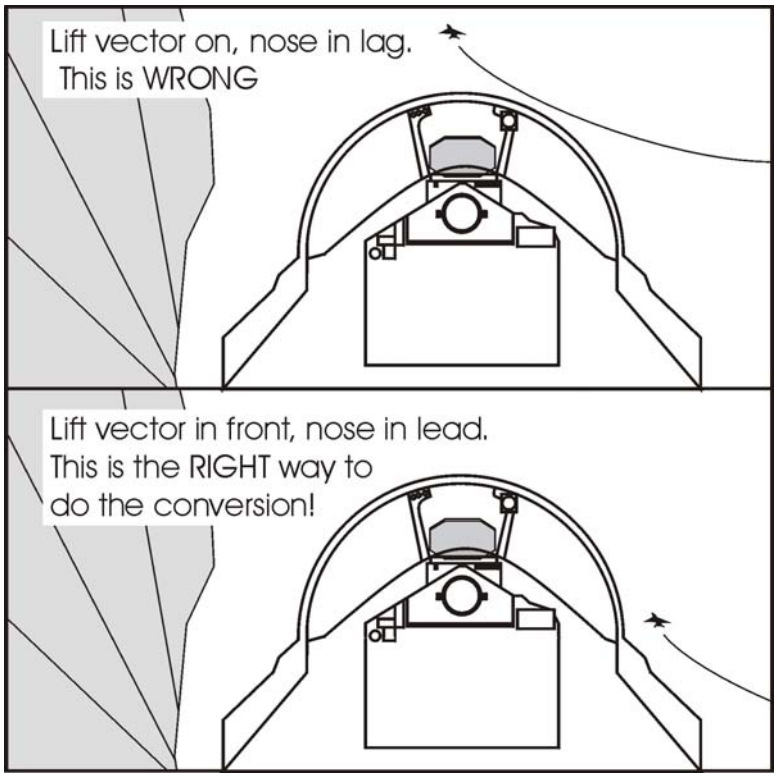


Figure 7-15. Lift Vector and Nose in *Lead* during conversion.

Maintaining Tally

When using turning room above the bandit, the angle-off just prior to beginning the conversion has a significant effect on the geometry and warrants some discussion.

Medium Angle-Off

When the angle-off is between 80° and 135° you will still have your nose on or slightly in lead when it is time to begin the conversion (Figure 7-9). You must have the nose well in lead as you climb. If inside of three miles, attempt to align the fuselages prior to or as you begin to pitch up. When it is time to start the conversion, you will have been maintaining the tally by looking opposite the direction you must turn to make the conversion. In an entry from below, this is no problem. From above, the roll to position your lift vector will momentarily cross the bandit under the radome. Therefore, in this situation, especially against a small, hard to see bandit, roll into the bandit 230°-270°, bringing the tally from one edge of the radome, across the top of the canopy to the other edge of the radome and then initiating the conversion. This roll must be unloaded, since a loaded roll will turn you opposite the direction you want to be going in, increasing the angle-off, the turning room required, and final roll out slant range.

High Angle-Off

When the angle-off is greater than 135° you will have to turn 180° or more during the conversion. You need a full turn diameter of turning room. If you begin your climb inside of three miles start up with your nose slightly behind the bandit to give yourself some horizontal turning room as well as vertical. Think of trying to fly towards the center of the bandit's turning circle. If you have established the turning room farther away, the bandit will cross under your nose before it is time to begin the conversion. As in the medium aspect case, it is critical that you maintain the tally as this happens.

Lift Vector Control

In the conversion, you control roll out range and angle-off by varying aircraft G and the position of your lift vector relative to the bandit's flight path. By rolling to orient your lift vector more or less in the direction of the bandit's direction of motion, you will control angle-off and final roll out slant range.

A common student error during long range BFM is to put the lift vector on or behind the bandit instead of well in lead. You must put your lift vector in front of the bandit—where he will be, not where he is now. (Figure 7-15). Aligning the lift vector in the bandit's direction of motion reduces angle-off, and takes you where the bandit will be instead of where he is now. It is LOS motion that should tell you whether you have too much or too little lead during the conversion. Adjust your lift vector to control the LOS motion, until you roll out at his six o'clock.

Fixing Too Much Lead

If you recognize that you have too much or too little lead before you begin the conversion, simply turn to re-establish the proper amount of lead before beginning the pull. But what if you don't recognize the problem until you are already in the pull (Figure 7-16)? If the bandit's forward LOS motion begins to slow, or, much worse, begins to track aft, you must ease off on the G or roll your lift vector away from lead until the bandit begins to track forward again. Rolling away from lift vector in lead will result in a more vertical turn. Unless you began with considerably more turning room

than you needed, this will cause a vertical overshoot (Figure 7-17).

Vertical Overshoot from Above

If you are performing an entry from below, it will be a vertical overshoot at the bandit's high six o'clock. This is not a bad place to be. If you are performing an entry from high, on the other hand, this will be a nose low, vertical overshoot below the bandit, at his low six o'clock. If he sees you, he can put you in front of him by pulling up into the vertical. So if this problem occurs during an entry from above, rather than over-banking and overshooting below the bandit, ease off on the G and overshoot laterally. Float to the other side of the bandit's flight path. This will make the conversion flatter -- less vertical (Figure 7-18). This will cause you to overshoot laterally, above or at the bandit's altitude. You will now have an aspect angle problem, but at least the bandit will not be able to reverse on you.

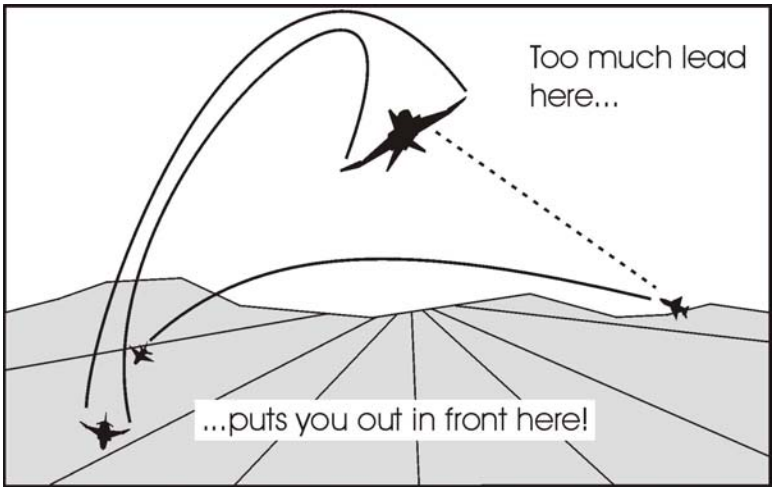


Figure 7-16. Too Much Lead Puts You Out In Front.

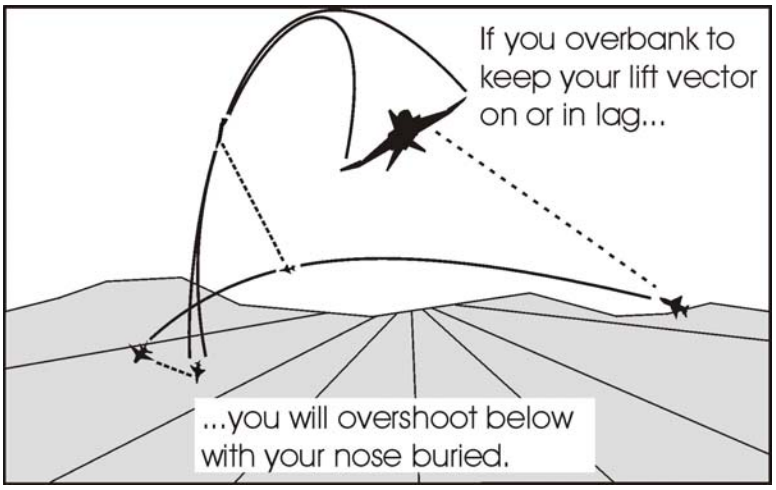


Figure 7-17. Over bank Causes Nose Low Vertical Overshoots.

If your entry was from high and inside the bandit's turn, this overshoot will put you outside the bandit's turn circle with a view of his belly side. If he continues to turn away from you, the aspect problem goes away. If the entry was from high and outside, this overshoot will put you inside the turn with an increasing aspect angle problem. In this situation, it is critical not to give up your lead!! You will be pulling into the bandit as you finish this maneuver and the natural tendency will be to keep pulling all the way to nose on. Don't. When you have turned into the bandit enough to ensure that you will pass behind him (remember LOS rate) roll out and start thinking lead! Your options are either a snapshot or some kind of short range BFM (Figure 7-19).

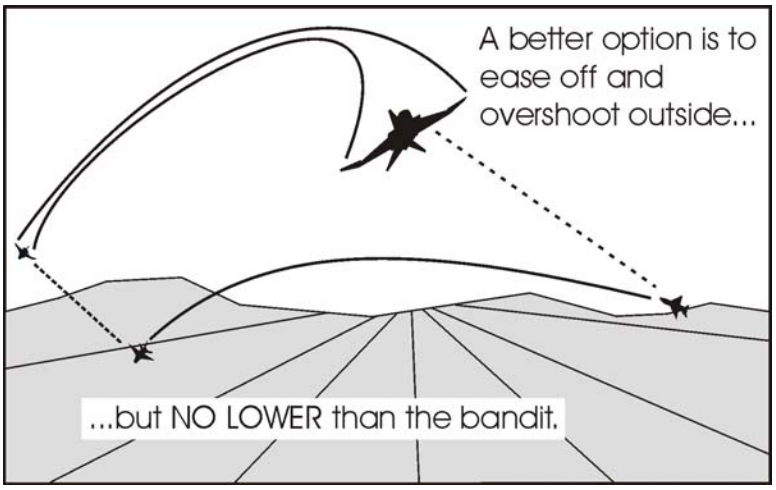


Figure 7-18. Ease Off—Overshoot Laterally.

SHORT RANGE BFM (SRBFM)

Long range BFM should get you to a position of decreased aspect, angle-off and slant range, with controllable overtake roughly equivalent to AIM-9 parameters. Short range offensive BFMs are those maneuvers used to remain in this position, and/or to close further into the gun envelope.

There are two basic classes of problems that short range BFMs solve, velocity closure and aspect angle. Four to five maneuvers are used in combination to solve them.

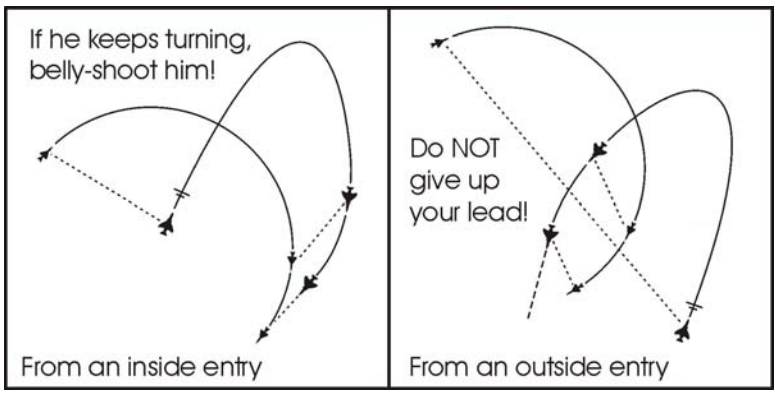


Figure 7-19. After an Overshoot.

Velocity Closure Problems

You may have too much or not enough closure.

Not Enough Closure

If the bandit is opening the range and you want to close, perform an acceleration maneuver or low-yo-yo (Figure 7-20). Select full afterburner as you turn with the aircraft nose low, well in lead. You should turn almost to the collision course. Use the target's LOS motion against the background to gauge the proper amount of lead. Getting the

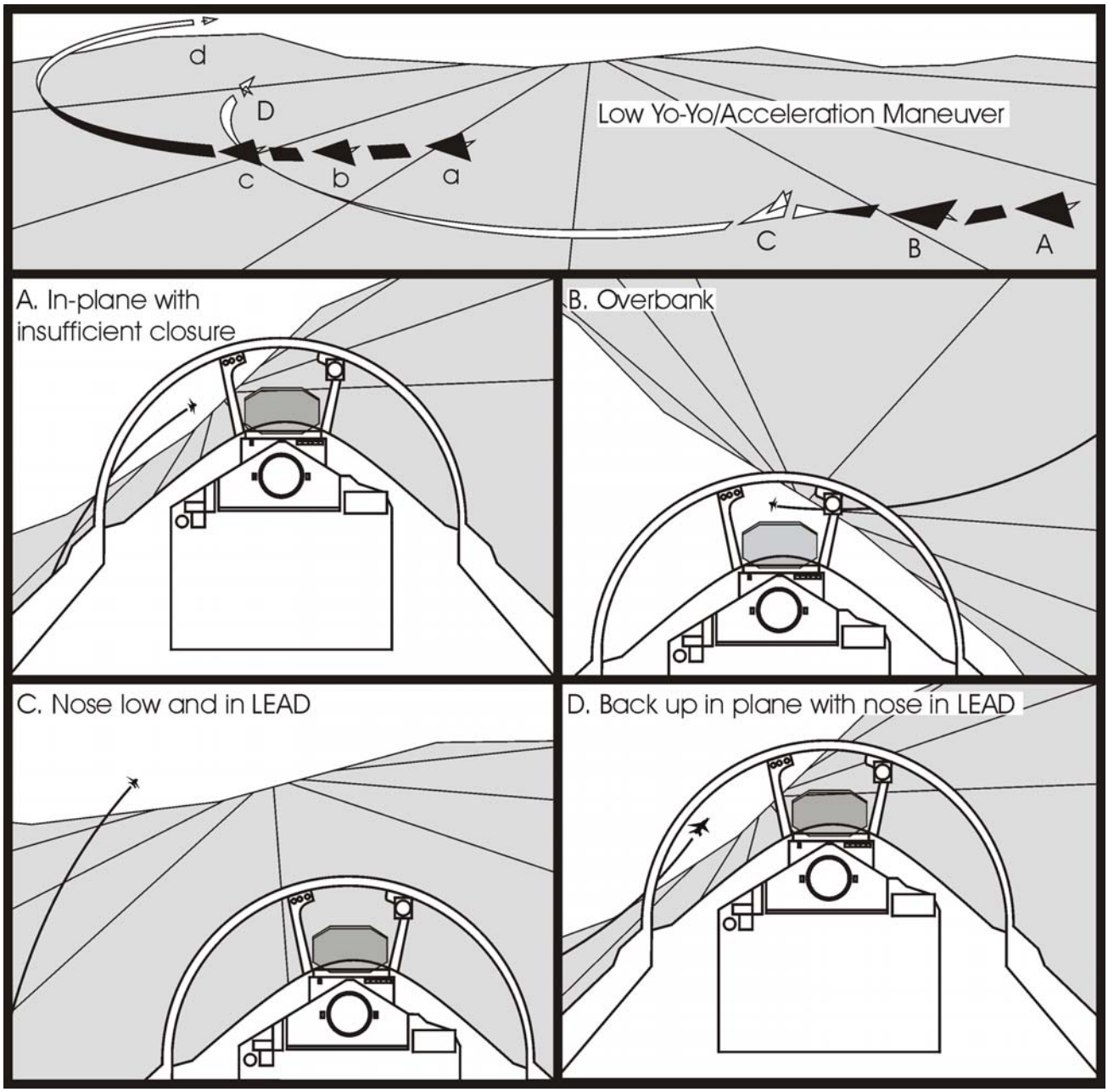


Figure 7-20. Acceleration Maneuver or Low Yo-Yo.

nose below the horizon may require that you over-bank in the turn. Remember that your objective here is not to gain energy but airspeed, and the fastest way to gain knots is to go downhill. Once your nose is established with the proper amount of lead and below the horizon, unload to 3-5 units AOA to maximize your acceleration. (Going downhill, however, is the most critical factor.)

Never let the nose fall below about 25° nose low trying to maintain 3-5 units, since at high speed it takes a long time to bring it back up again. If the bandit is turning as we do this, watch his LOS track and begin to pull back up into him when this LOS begins to track upward and aft again. Your nose should always remain in lead during this maneuver. Against a turning bandit, your lift vector should also be pointed out in front of him when you begin to pull back up into the plane of his turn. It can be helpful to think of the last part of this maneuver as a rejoin which is tilted slightly away from level, as the relative positions and amount of lead required are very similar. The nose should NEVER go to lag during an acceleration maneuver or low yo-yo!

Too Much Closure

It is easy to build a large airspeed advantage against a slow adversary, especially when performing an entry from well above him. Airspeed and closure rates must be monitored continuously to ensure that we can safely control the V_c and remain behind the bandit's three/nine o'clock (Figure 7-21). Simply recognizing closure is not enough. Closure can also be due to aspect/angle-off, and this problem is very different and requires different solutions. Always be aware of the bandit's aspect angle, (what does his jet look like?). This tells you whether closure is due to velocity or aspect angle.

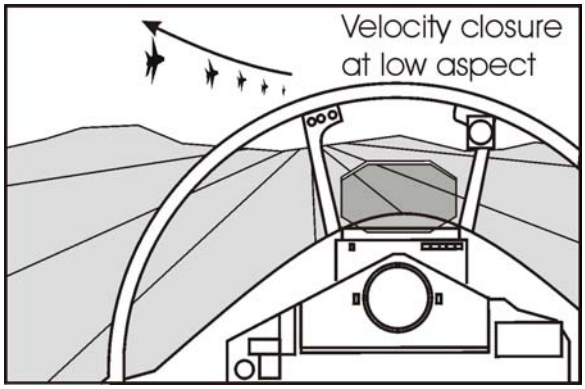


Figure 7-21. Excessive Closure.

Slow Down?

Throttle modulation is the first possible solution to this problem. If excessive overtake is due to airspeed at low angle-off, come out of afterburner and use the speed brakes as required. Slow down to control the closure. However, be careful of slowing down too much behind a lower wing-loaded adversary. Being co-airspeed at 200 KIAS at a MIG-29's six o'clock might not be as tremendous an advantage as it initially seems. A better idea is to use that airspeed to reposition in the vertical well above him. If you must slow down to 200 KIAS to stay behind him, do it 6000 feet above him, where he is not a threat and you may be able to maintain the energy advantage you have.

Hi Yo-Yo (Figure 7-23)

If the closure is too severe to be handled solely by throttle reduction, slow down your velocity vector towards the bandit by momentarily rotating it away from his direction of motion. After reducing power and extending the speed brakes, rotate your lift vector away from his direction of motion in the shortest direction towards the vertical. Use the rudders to roll while maintaining G on the jet. How far you roll out of the bandit's plane of turn depends on how much closure you have to solve and how late you recognized the problem.

Visual Cues

Use the same LOS rate cues—target motion against the background, to determine when you have controlled the closure satisfactorily (Figure 7-22). Once the closure is under control, rotate the lift vector back into lead and pull back in-plane with the bandit.

Too Much Out-of-Plane

A common mistake in the execution of high yo-

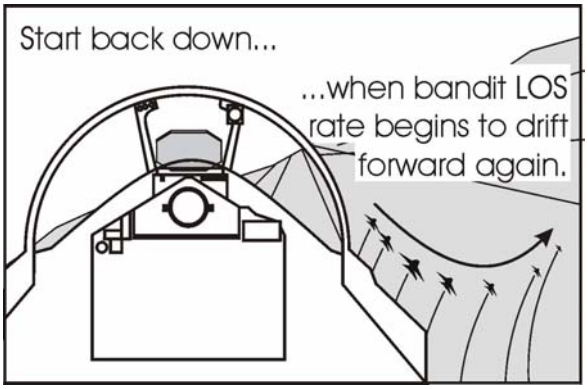


Figure 7-22. When to Start Back Down.

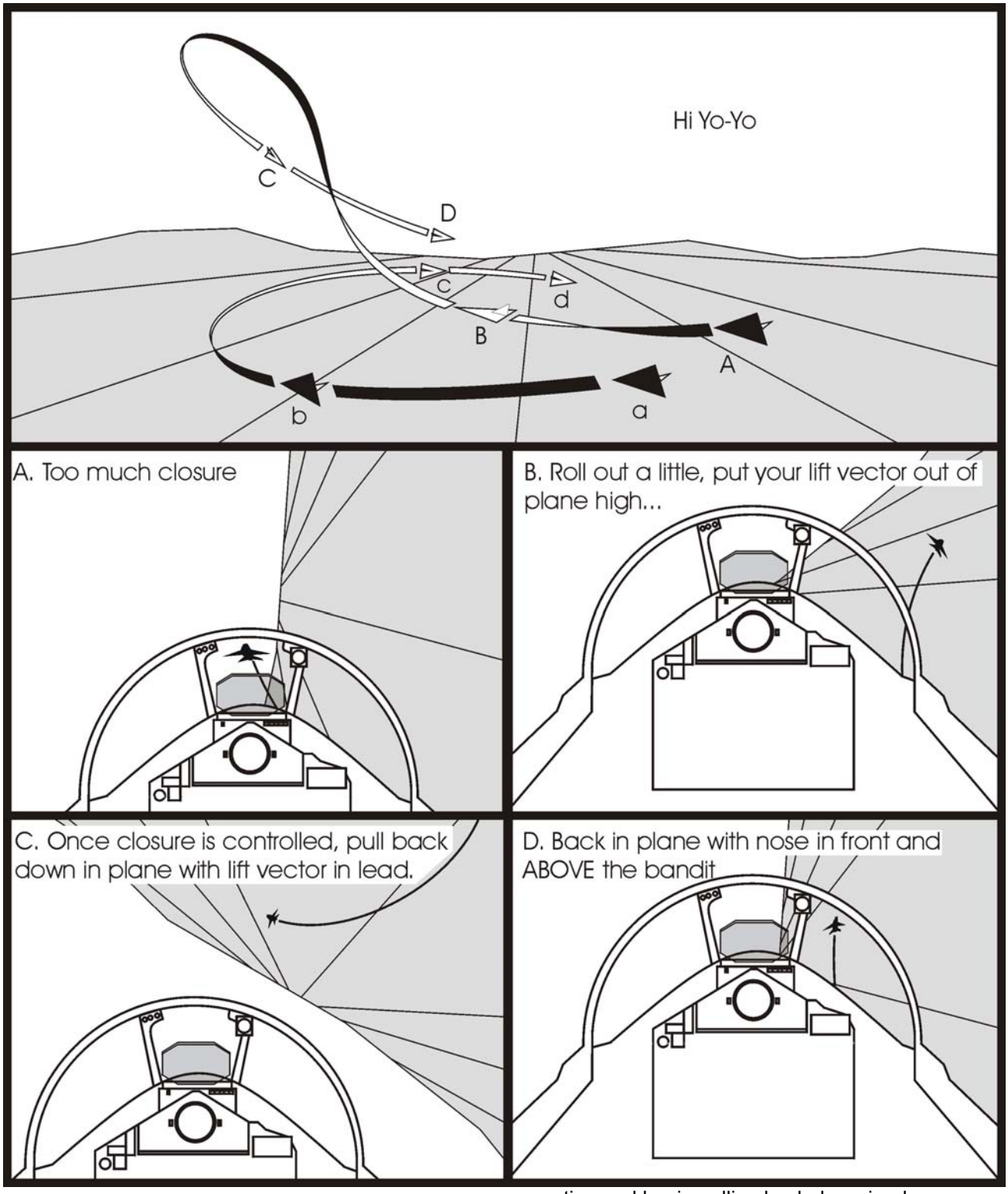


Figure 7-23. High Yo-Yo.

yos is to pull too far out-of-plane and allow the bandit to extend away from you. Prevent this error by carefully monitoring the bandit's LOS motion and begin pulling back down in-plane slightly before the LOS motion starts to drift forward away from you. Another approach is to do several smaller maneuvers rather than one large one. Should you make this error and see

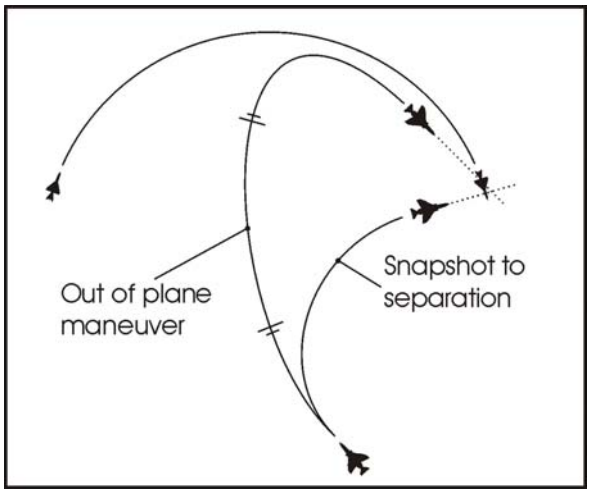


Figure 7-24. Solutions to Aspect Angle Problems.

the bandit opening the slant range again, immediately reselect afterburner and pull back down nose low, in lead, and execute a low yo-yo or acceleration maneuver.

Aspect Angle Problems

If the bandit sees you prior to arriving inside his turn circle, he will probably turn hard into you, causing you an aspect angle problem. The aspect angle will cause high closure rates, but it is important to recognize that your problem is not the closure but the aspect angle.

Recognition

How do you recognize this problem? Anytime you see more than 45° of aspect angle, you have this problem. Most jets are near 45° aspect when their wingspan and their length appear to be the same apparent size. Another cue is the rate at which the aspect appears to be changing. Anytime you see rapid change in the amount of wing surface which is visible, you are about to have a major aspect angle problem.

Solutions

You have two options in this situation (Figure 7-24). You may attempt to solve the aspect problem by using out-of-plane turning room, or you may remain in-plane with lead, and attempt a high angle snapshot to a separation or vertical reposition.

Out-of-Plane Maneuver

The first option, using out-of-plane turning room to solve the aspect and angle-off problem, looks much like an exaggerated high yo-yo. It is not the same maneuver, however, in that it is the aspect angle and not the closure which is our problem. Since this is a turning room problem, the solution is to establish turning room out of the plane of the bandit's turn, with the right amount of lead/lag in his direction of motion, and then lead turn back down to his high six o'clock.

Slant Range

The further away from the bandit you are with this problem, the more aspect he can generate before you arrive inside his turn circle. You will then have more angle-off and need more out-of-plane turning room. Outside of two miles, this is almost long range BFM and looks very much like an entry from above. If the bandit has tally and is reacting to you, however, you must have an energy advantage to perform this maneuver. Only then can you gain turning room that he cannot pull up and take away from you.

When to Start up

The sooner you begin to generate the turning room, the less pitch attitude will be required. With sufficient airspeed, 450 KIAS minimum, begin climbing above the bandit. For a medium aspect problem, (45-90°), three to four thousand feet out-of-plane should be enough. For higher aspect problems, (greater than 130°), you will need five to seven thousand feet out-of-plane.

Power

Do not let the closure you are experiencing fool you into reducing power. This closure is due to the aspect angle, and unless you are clearly much faster than the bandit, the power should remain in full afterburner during the maneuver.

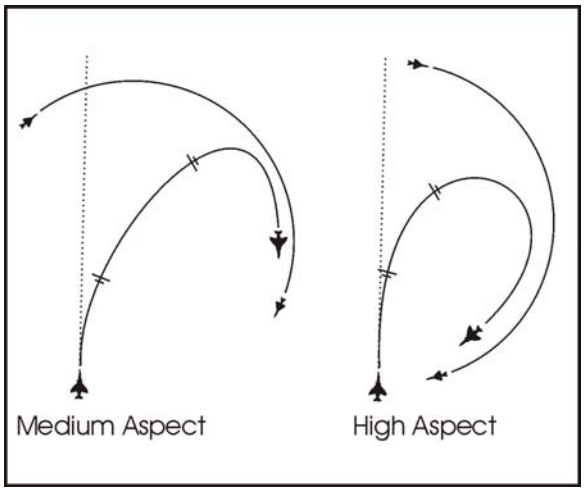


Figure 7-25. How Much Lead?

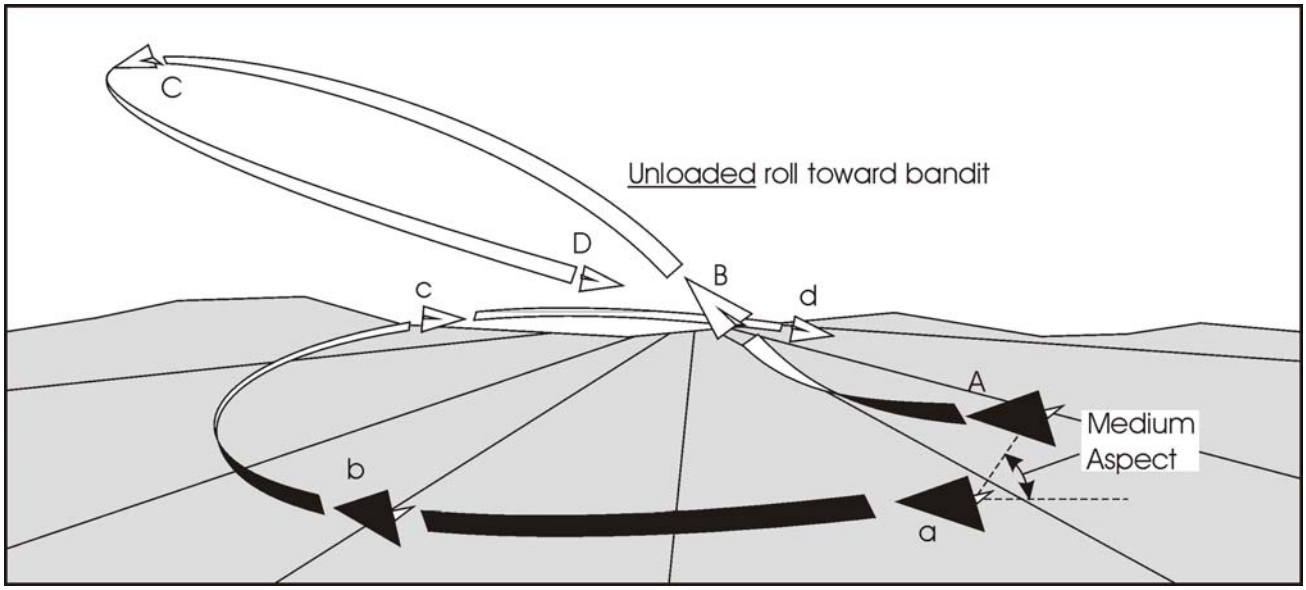


Figure 7-26. Lag Roll.

How Much Lead?

Where you place your nose laterally as you establish turning room depends on the slant range, angle-off, and severity of the bandit's turn. Inside the turn circle your nose should be in lag (Figure 7-25). These maneuvers are called lag rolls and quarter plane maneuvers.

Lag Roll (Figure 7-26)

If your nose is in lead inside the bandit's turn circle and you have more than 45° aspect, execute a lag roll. Pull up for turning room and roll, unloaded, into the bandit as he turns under your nose. Before you would cross his high six o'clock, set your lift vector in lead and pull back down in-plane again. This maneuver is effective only when you can out-rate the bandit. If not, you will end up stuck in lag. The more out-of-plane turning room you can get, the more effective the lag roll will become.

Quarter Plane (Figure 7-27)

If an out-of-plane maneuver is done at close range to prevent an overshoot, nose position becomes critical. At low to medium angle-off, there is a significant possibility of a three/nine line overshoot. The maneuver is called a quarter plane because you must roll 90° from the bandit's direction of motion, a quarter of a full 360° roll, and pull for his high six o'clock. In cases where your lead is excessive a "three/eighths plane" maneuver, where you roll 135° away, may be required to ensure that you remain behind the bandit's three/nine line (Figure 7-28).

NOTE

When the bandit's plane of turn is not level, you should always roll in the shortest direction to the pure vertical. When the bandit's plane is more than 45° nose high, however, rolling 90° will put your nose below his. This will give him the positional advantage and cause you to move out in front and lose three/nine line advantage. In this case, you must roll no farther than the point where your nose is lower than his, even if that is less than 90° (Figure 7-29).

Outside the Bandit's Turn Circle

When further away from the bandit, and you perceive an aspect angle problem exists (or is developing), attempt to point towards the center of his turn circle as you establish turning room. At medium aspect, this will be lead. At higher aspect, you should be somewhat in lag. Watch the bandit's LOS drift. He should be drifting forward at a rate which will cause him to cross under your nose at 5-6,000 feet slant range. The greater the aspect angle or the harder the bandit is turning, the less lead you should have. Since you may need to turn 180° or more when you come back down in-plane, a combination of lateral and vertical turning room is advantageous. This means your nose should be behind the bandit as you climb out-of-plane.

Starting Back Down

There is another difference between the quarter plane and the high yo-yo done for velocity closure. In the latter case, you can do a series of smaller maneuvers, or start back down early, and still solve some of the closure problem. With an

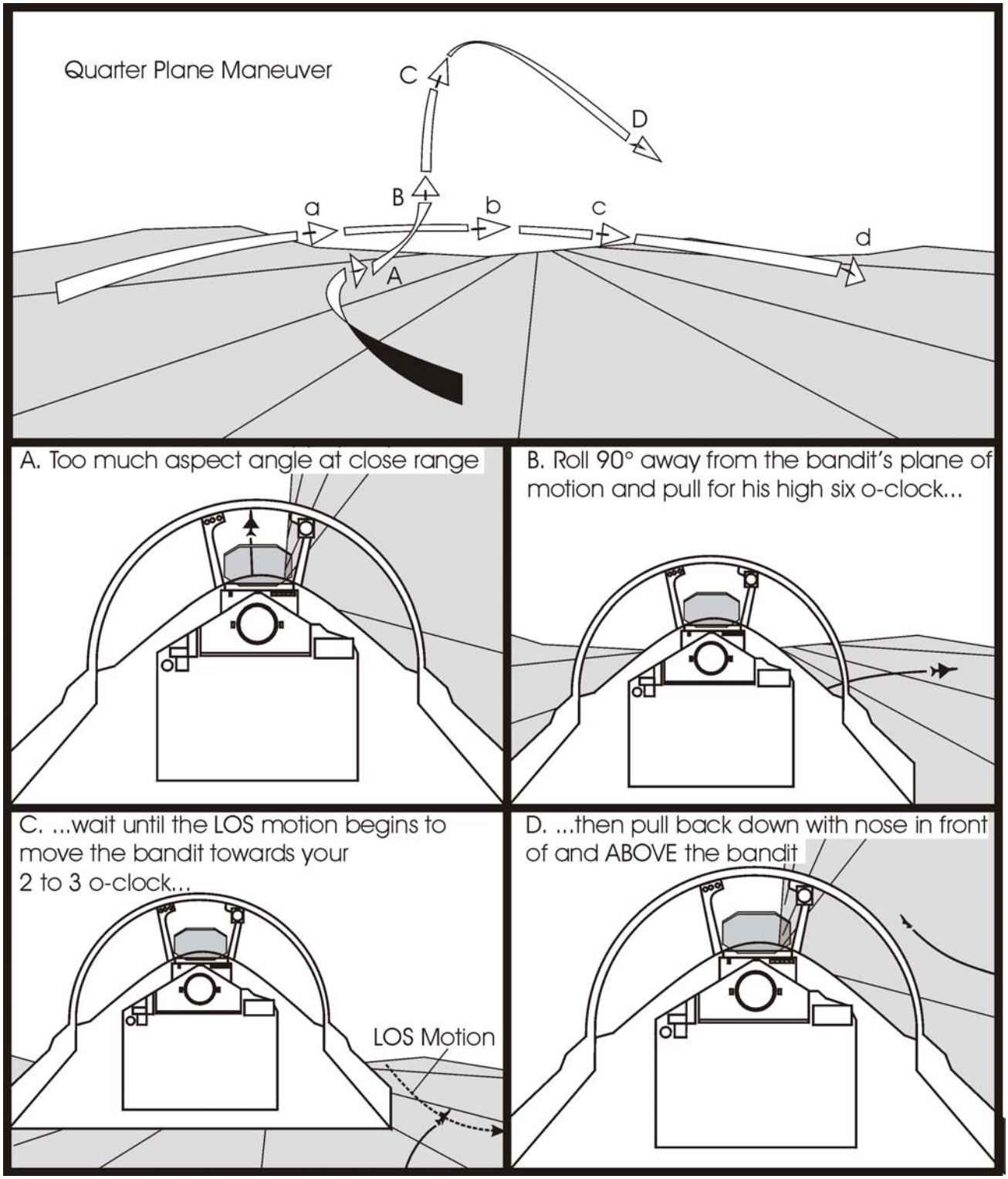


Figure 7-27. Quarter Plane Maneuver.

aspect angle problem, on the other hand, starting back down too soon, before the problem has been solved, is completely ineffective. As long as the aspect continues to build, you must remain out-of-plane above the bandit. If timed correctly, you will not be coming back in-plane, but directly above the edge of the bandit's turn circle. There are several useful techniques for gauging when to start back down from this maneuver.

Remember, regardless of what other cues may be telling you, if you are still looking at the top of the

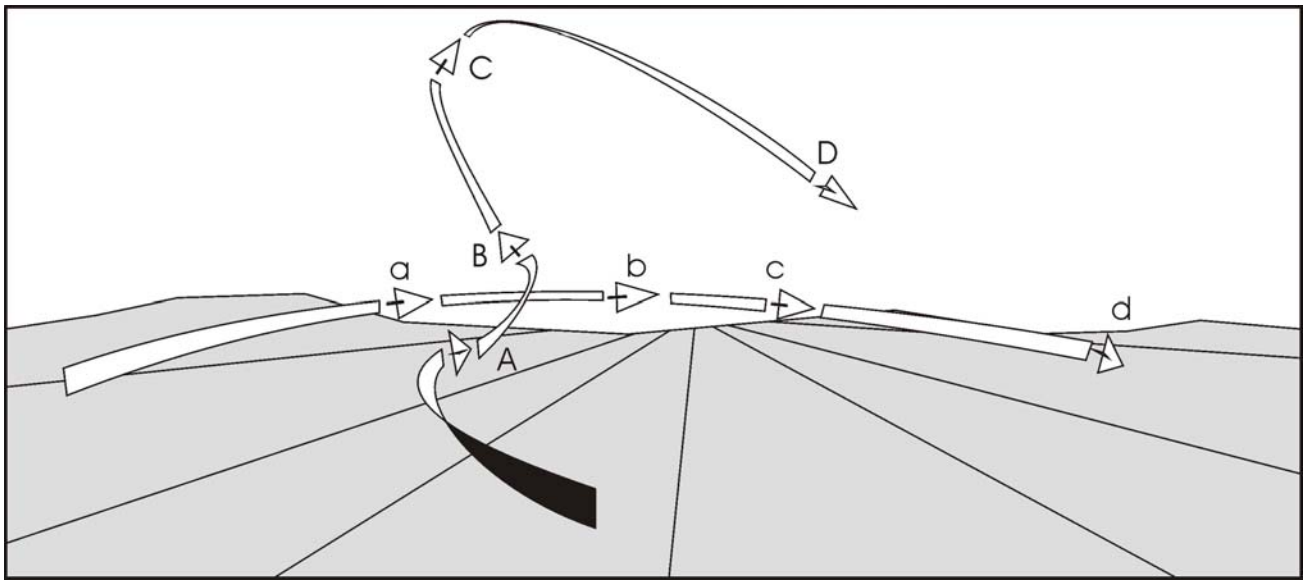


Figure 7-28. "Three-Eighths" Plane Maneuver.

wing, with 45° or more aspect angle, you should not be in-plane or starting to come back in-plane again (Figure 7-31).

Decreasing Aspect Angle

One technique is to wait almost until the aspect angle starts to decrease, then start back down again. While you are outside the bandit's turn circle, the aspect will continue to build as the bandit turns into you. The closer you get to the center of his turn circle, the slower it will increase, until it's rate of increase stops, as you get to the turn circle center, after which the aspect will begin decreasing again. Just prior to when it stops is the right time to start back down.

One Turn Radius Away

Another useful technique is to start back down when you imagine yourself one turn radius away from the bandit's flight path. This will put you directly at the bandit's high six o'clock with zero degrees aspect.

Target LOS Motion

Last, the target's LOS motion is a very accurate cue. Initially, it will be tracking slightly in the direction of the bandit's true airspeed vector, but mostly down due to your climb above him (Figure 7-30). As you fly over to the point where you would cross his high six o'clock, the lateral LOS motion in his direction of travel will accelerate rapidly as he moves from your 1 o'clock to your

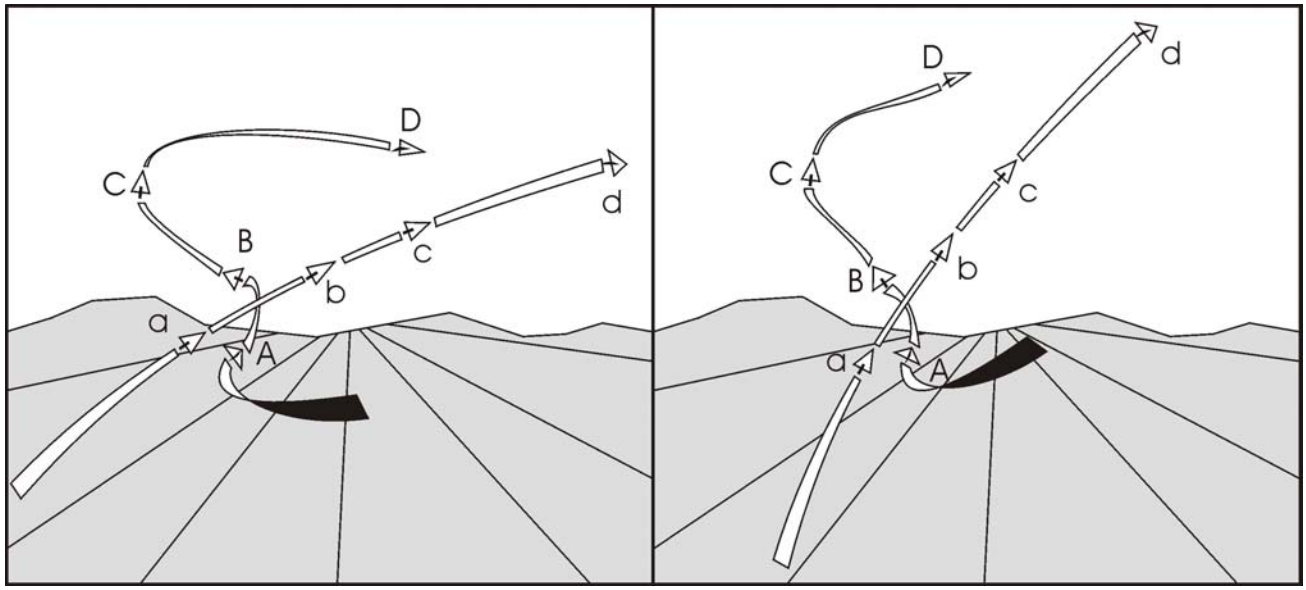


Figure 7-29. Bandit Turning in the Oblique.

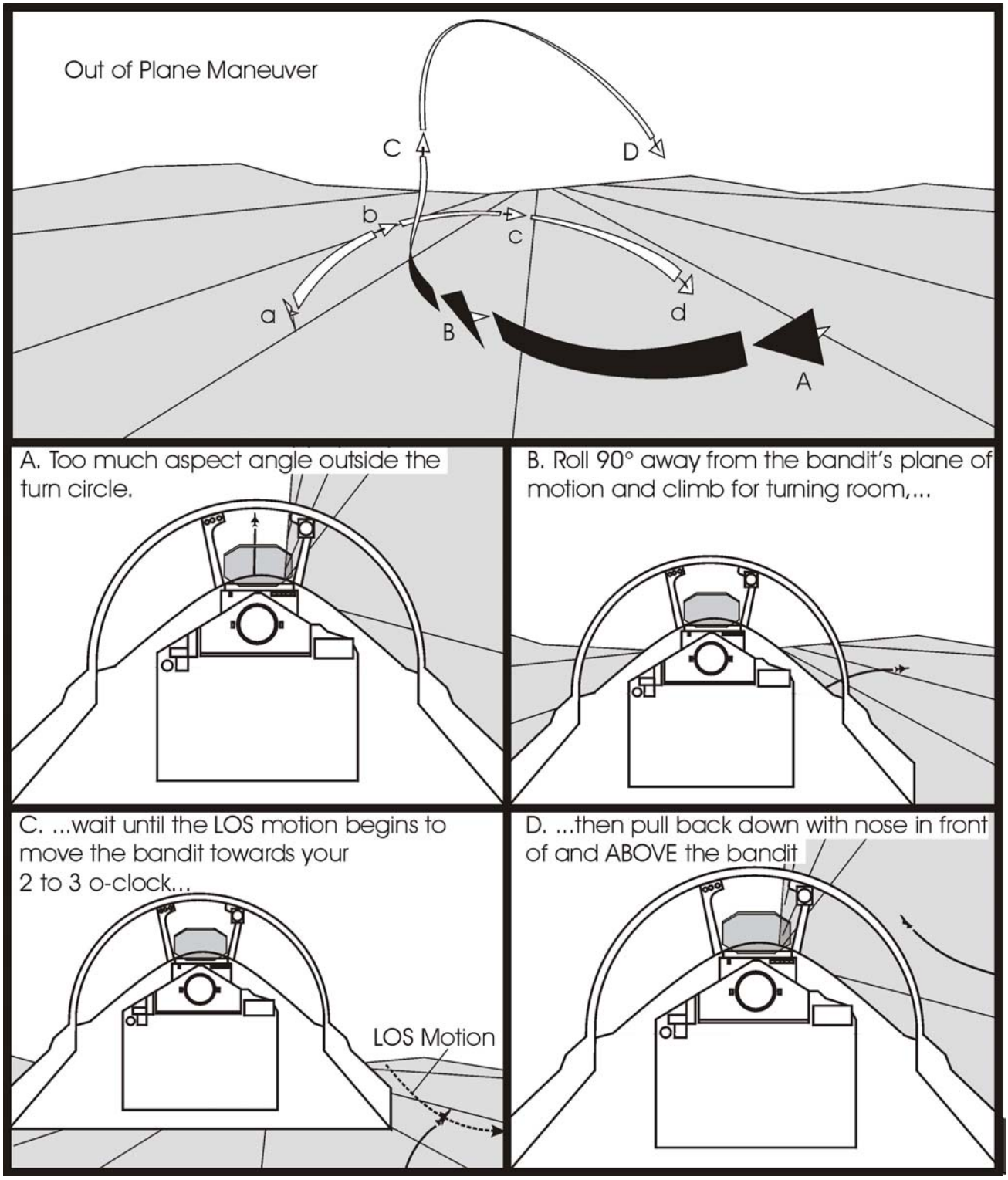


Figure 7-30. Out-of-Plane (OOP) Maneuver.

2:30 to 3 o'clock (assuming a right turn). As the lateral LOS motion begins to accelerate, start back down again.

Errors Coming Back Down Again

There are two major errors when coming back down after an out-of-plane maneuver.

Lift Vector in Lead

The most common error is pulling back down with your lift vector on the bandit instead of in lead.

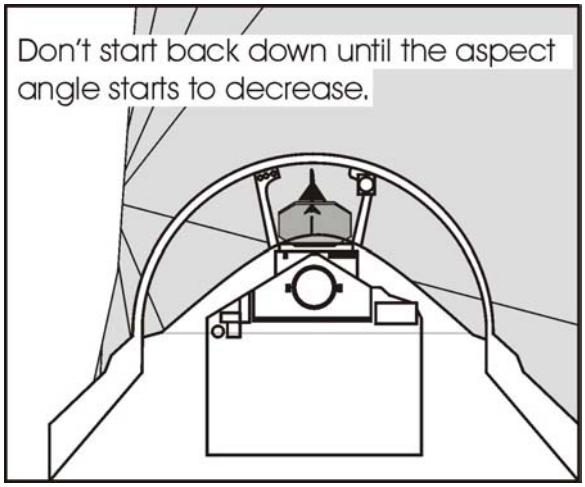


Figure 7-31. Starting Back In Plane Too Soon.

Align your lift vector in the bandit's direction of motion. This will cause you to fly to where the bandit is going and not to where he is now (Figure 7-30D).

Nose Position

The second error is allowing your nose position to drop lower than the bandit's. It is natural to try to point at the bandit to take the Fox II. If you do that from a position at the bandit's high six o'clock, your nose will be considerably lower than his and he can overshoot you below and in front of him by starting a maximum performance break up and into you (Figure 7-32). When coming back down after an out-of-plane maneuver, never let your nose get lower than the bandit's. Be pointed in lead in the vertical as well as in the horizontal. Now, if the bandit starts a pull up and into you, you will already have lead established which you can use to slide right into a 2,000 foot gunshot.

Snapshots

Snapshots, and gun employment techniques, are discussed extensively in Chapter 4.

SRBFM Rules of Thumb

The short range offensive BFMs in this section are designed primarily to help you stay behind an adversary until you can expend ordnance and kill him. They can be summarized in the following rules of thumb:

NEVER Point!

DO NOT STAY NOSE ON IN-PLANE, unless you are at low aspect angle and in range to expend ordnance.

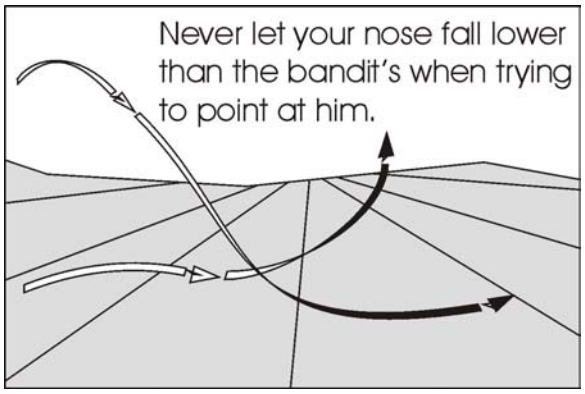


Figure 7-32. Vertical Overshoot.

LEAD!

If you are in-plane, or are coming back in-plane, be establishing lead. If out-of-plane pulling back in-plane, align your lift vector in the bandit's direction of motion, in front of, and not on, the bandit.

SHOOT!

Finally, maneuver to shoot. If there isn't a shot opportunity, make one. If one can't be made, separate before the bandit makes one for himself.

HIGH-ASPECT BFM

If the bandit has the first tally or if he acquires a tally before you close inside of about three miles, with a hard turn he can meet you with very high aspect angle. If you do not have a sufficient energy advantage to gain and use turning room above him, you may be forced into a high aspect, high speed head-on pass. As discussed in the first part of long range BFM, it is critical that you be able to recognize when the bandit has a tally and is reacting to you. If there is any doubt, cease all attempts to gain turning room before you close inside about three miles. Inside three miles, it becomes increasingly difficult to point at the bandit and take away the turning room you have unintentionally given him.

Prior to the Pass

As stated in long range BFM, you should in general attempt to gain turning room high if you are above or low if you are below the bandit's horizon line. However, all other things being equal, being underneath him at the merge has some significant advantages.

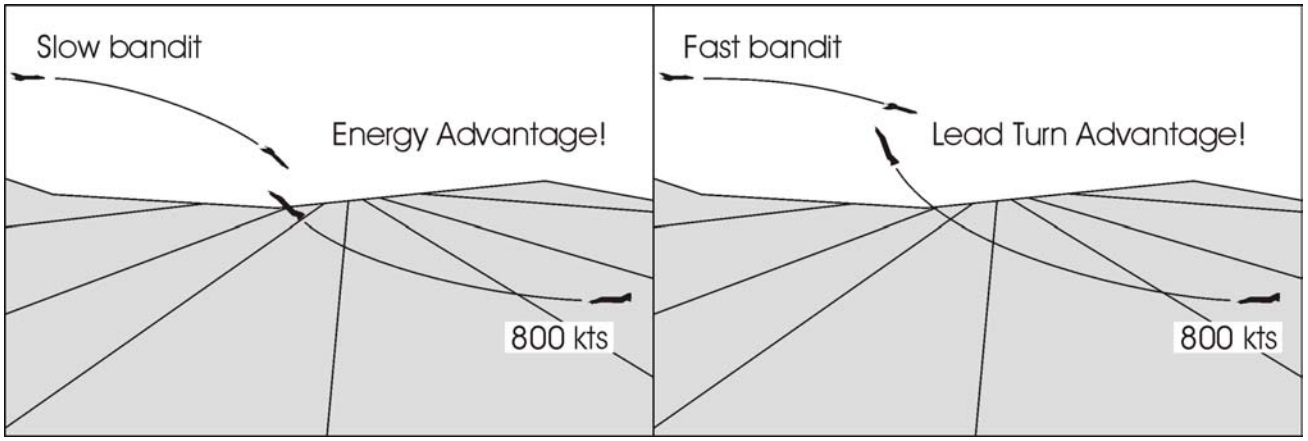


Figure 7-33. Lead Turn From Below.

Turning Room High or Low?

In today's tactical environment, where most aircraft have some forward aspect capable ordnance, being above the bandit prior to the first pass has a serious disadvantage. This is another argument for starting low in the radar and infrared ground clutter.

Stay and Fight?

If your intention is to stay and fight, then being below just prior to the merge is a significant advantage. You can accelerate through the Mach and lead turn the bandit from below. In order to counter your lead turn by lead turning you, he must be subsonic, at best. Imagine initiating a split-S at Mach 1.2! This means that you will either have a lead turn advantage or an energy and a positional advantage after the merge (Figure 7-33).

Run

If your intention is to run (are you running short of fuel, ordnance or SA?), then it is generally better to start above, and be headed downhill at the merge. Be above him just prior to the first pass and start a supersonic lead turn to point nose low at him. After the pass, just keep going. Even a Flogger will be some time catching you.

Early Lead Turn

If you try to lead turn from high, it is important that you start down into the bandit early enough to control the pitch attitude at the pass. If you wait too long, to where you must pull severely nose low to point at the bandit, he can arc you in the vertical during your subsequent dive recovery. If you don't pull all the way to nose-on, you allow him to use whatever turning room you have not taken away and at the pass he will have acquired some angular/positional advantage as a result.

At the Pass

No matter how you arrange the first pass, if you both fly your jets well, you should pass with close to 180° angle-off, with minimum separation. In combat, here is where you set the tone of the engagement. Remember you are fighting the man, not the Machine.

Head-on Guns

Don't forget the gun! If you are directly head-on, or with the nose in front of him, squeeze off a 50-60 round burst. Seeing HEI coming out of the nose of your jet might significantly damage his confidence; you might even kill him and save yourself a lot of work. On the other hand, you ought to be ready if he tries the same thing on you.

The "Bubble"

Second, in wartime, pass him with the absolute minimum lateral separation. Again, if he's trying to get out of your way, and when you pass close aboard you physically shake his jet with a 3-4 G supersonic shock wave, you have set the psychological tone of the fight in your favor.

Training Rules

In peacetime of course, we must honor and follow the training rules. Most of these are designed to help prevent midair collisions, and head-on passes are one of the places where the potential for that is very, very high. Head-on gunshots, (where the angle-off exceeds 135°), are absolutely prohibited during peacetime training. Secondly, for all formal syllabus training, we must remain at all times a minimum of 1,000 feet slant range away from all other aircraft engaged in air-to-air training. So, on this initial head-on pass,

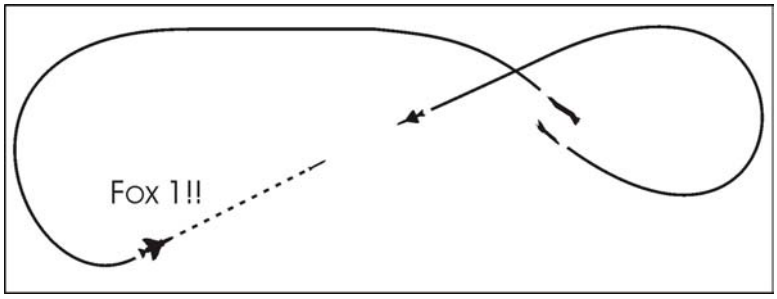


Figure 7-34. High-Speed AIM-7 Fight.

make sure you start off headed at least 1,000 feet away, and delay any lead turns until you are sure that you will not close inside 1,000 feet during the lead turn.

After the Pass

As stated above, your relative pitch attitudes have much to do with your options at the pass. Especially in the F-4, however, consider the tactical situation carefully before you choose to stay and fight. Most current fighter aircraft have superior maneuverability, thrust to weight, radar and ordnance capabilities. If your adversary has already demonstrated he has a tally and some skill at air to air by countering your attempt to gain turning room, then perhaps you should extend straight through and look for someone who is not so gifted. But, let's assume your decision is to stay and fight.

Maintain Tally!

It is critical that you maintain the tally after the pass. This is not so easy. A check turn into the bandit, either laterally or vertically, will almost always be required to regain the tally after a head-on pass. Use the upper mirror in the front cockpit and outside the rear cockpit if available to help regain the tally.

AIM-7 Fight

One option, not to be used against aircraft with all aspect ordnance, is to extend straight through for two to three miles and then turn around, level or nose low in the vertical (Figure 7-34). The idea is to attempt to get far enough away so that when you turn around you will still be outside minimum head-on AIM-7 range. There are two disadvantages to this. First is the difficulty of maintaining a tally at the slant range you will have just prior to starting your 180° turn, as well as maintaining it during the high G turn. Secondly, the whole time you are in the turn, the bandit, if he is chasing you, will be relatively unloaded with you on his nose. If he is all aspect capable as well, you will get shot in the turn long before you get pointed at him.

Vertical Pitch

Another option is to go into a vertical pitch (Figure 7-35), attempting to reposition above the bandit so that the next time you pass you will have some amount of turning room above him with which to lead turn. In order for this to be effective against a well flown bandit, you must have a significant energy advantage at the pass. Controlling the pass so that you are climbing and the bandit is descending also increases your chances of making this work. With an energy advantage, start an optimum pull into the vertical. Reacquire the tally as soon as possible at deep six o'clock, over the rudder. Once tally at deep six, observe what the bandit is doing.

Bandit Running

If he is running straight ahead, you must slow to corner and transition to a slice to chase him as quickly as possible.

Bandit Turning

If he is turning level, or uphill less than in the pure vertical, continue your pull until you are pure vertical, then roll to orient the lift vector in the direction the bandit is headed under you (Figure 7-35). The idea is to attempt to fly directly over where he will be after 270° of turn, so that you can lead turn him from above. This roll can be disorienting, and maintaining tally can be difficult, so do it slowly and carefully. Should you pass each other close to level, and he also begins a pure vertical pull, then whoever has the most energy will out-zoom the other and gain some

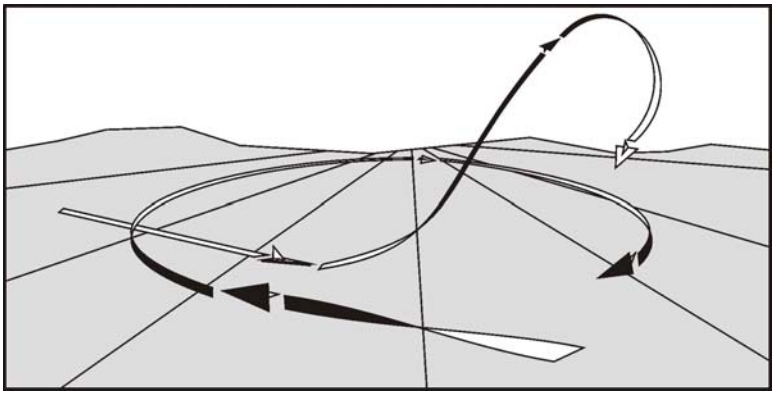


Figure 7-35. Vertical Fight.

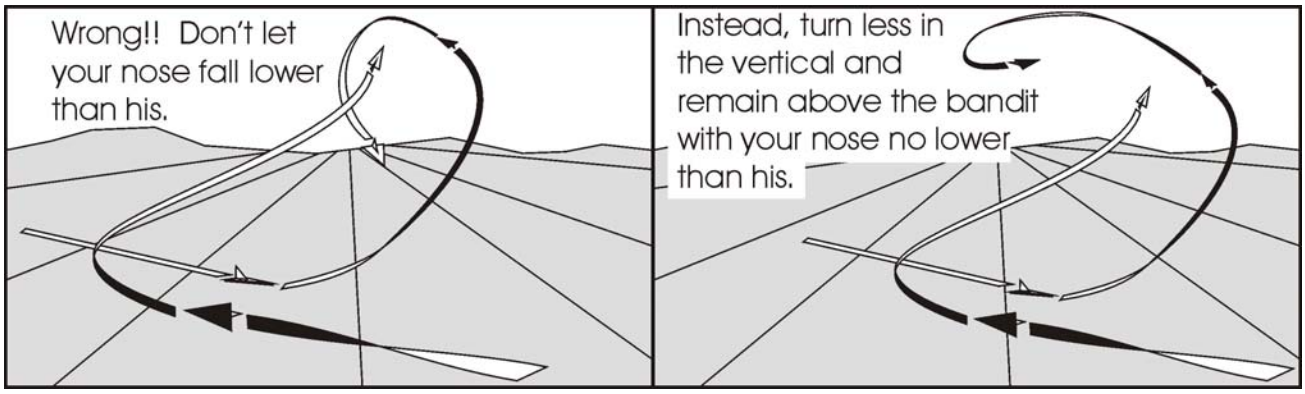


Figure 7-36. How to Use Insufficient Turning Room.

altitude advantage. You must judge, in the climb, who has the most energy. You will be two, perhaps three miles away from one another in this climb, and only the bandit position (above/below the horizon), and the LOS rate (drifting up/down) will tell you who has more energy.

You Out-Zoom the Bandit

If you have more energy, you will be able to out-zoom the bandit, but to do so you must keep climbing until you see that this is assured. Do not pull away from the pure vertical to point at him while he is still climbing. You will give up the altitude advantage you might have gained, and he will end up above you.

If you pass above him with some altitude advantage, how you use this altitude advantage is very important. Unless you have enough altitude to do a complete split-S and not descend below him, do not lead turn him in the pure vertical. He will pull up into you and overshoot you below and in front of him. Instead (Figure 7-36), tilt the plane of your lead turn in the horizontal, away from him, so that you will roll out offset to one side behind him, but at his altitude or higher. You may have an aspect angle problem, but at least you will be behind his three/nine line with a positional advantage.

He Out-Zooms You

If he has the energy advantage and out-zooms you, you can either pull to his low six o'clock and attempt to extend away underneath him, or pull to point at him and shoot something at him to get him to pull back down into the missile earlier than he would have otherwise.

Level Turn

Last, you can go into a level turn either into or away from the bandit. This option is useful when at low altitude and you cannot use the vertical due to weather or some other factor. If the bandit turns the same way as you do, you end up in what the navy calls a two-circle fight. If the bandit turns opposite to you, we call it a one-circle fight.

Two-Circle Fight

A two-circle fight, (Figure 7-37), has an advantage for the F-4 in that when we come nose on again we will be further away from the bandit, possibly outside the minimum range for the AIM-7. But if the bandit has all aspect ordnance, we are also outside his min range, and min range for all aspect IR missiles is less than that for radar missiles. Also, with our pulse radars, weapons employment head-on at low altitude and close range is a difficult problem. Finally, against a small bandit, maintaining a tally at three to four miles may be impossible

One-Circle Fight

Arranging for a one-circle fight (Figure 7-38) may

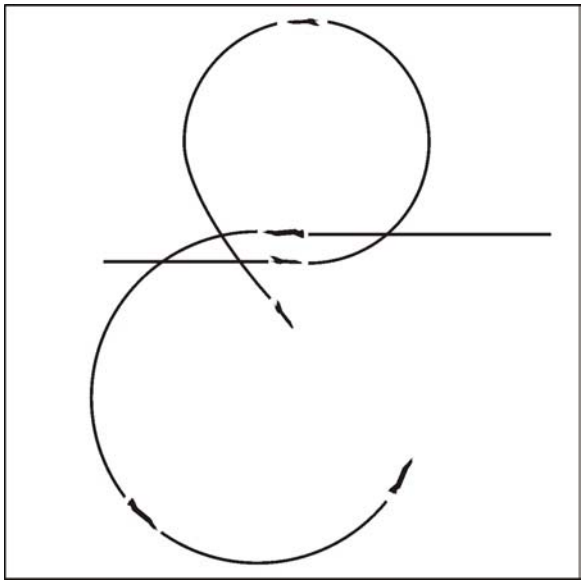


Figure 7-37. Two-Circle Fight.

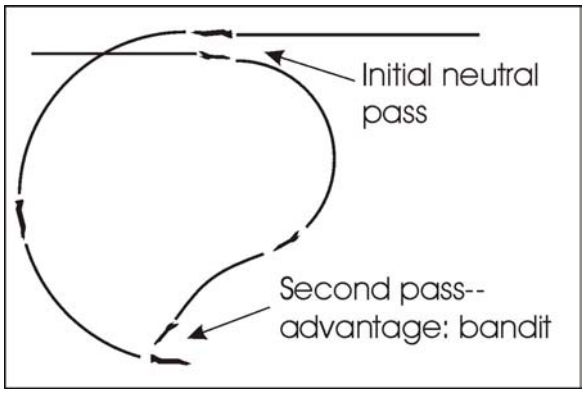


Figure 7-38. One-Circle Fight.

not be easy. To make the fight one-circle requires that you turn away from the bandit at the pass. You give up the tally, and whatever lateral separation existed at the pass now becomes turning room for the bandit. But now we will remain within two NM of the bandit, hopefully denying him the use of his forward aspect ordnance. Secondly, we will be better able to maintain tally. The one-circle fight is stupid against a more maneuverable bandit, however; for each time around the circle, he will be a little closer to your vulnerable cone. Use this only against higher wing loaded, less maneuverable jets.

SUMMARY

Historically, more than 85% of those aircraft who have been shot down never saw their adversary. Of the remainder, most were tally just prior to or after ordnance had been expended. Only a very small percentage of these air to air engagements started in a neutral or near neutral situation. This should teach us two lessons. First, you must always be checking six! And second, if the bandit you are attacking sees you, at a minimum, it will take you a lot of time, fuel and attention to kill him, if you even can. So, when you meet someone at high aspect who obviously sees you, and has some skill at BFM, the question you should ask yourself is whether this particular bandit is worth all that effort?

CHAPTER 8
DEFENSIVE AND NEUTRAL BFM

INTRODUCTION

The primary objective of defensive BFM is to survive. You may kill hundreds in the aerial arena, but you can only die once! First of all, it is critical that you be able to recognize when you are defensive. The second most important factor is psychological. You must fight harder to survive than you ever do on the offense. It is borne out by history that many pilots either simply give up too soon, or panic and die under adverse circumstances.

Who Is Defensive?

Although skill, energy level, airframe and ordnance capabilities etc, all affect the outcome of a fight, what we mean by "recognizing when you are defensive" is, "Who is about to shoot whom?". This can be determined by the inertial (against the background) LOS movement of your adversary, (see Figure 5-2 and Figure 5-3 on Page 28) If your adversary is moving aft against the background, then you will fly in front of him, and he is about to shoot you! Do not confuse relative LOS movement (movement on the canopy), with this "inertial" LOS movement. Although they are the same when you are straight and level, when you are maneuvering this relative motion in the canopy (due primarily to the change in aircraft attitude), means something distinctly different. It is possible (in a defensive break turn, for example) that a bandit may initially move forward on the canopy, even as he is moving aft against the background. This forward canopy motion is due to your turning; the bandit's aft motion against the background tells you he will pass behind you. You are defensive.

Never Give Up

Fight hard -- the longer you can stay alive, the better the chance your adversary will elect to look for someone else who is not so tenacious.

GENERAL RULES OF THUMB

There are two general rules of thumb for defensive BFM. Never lose the tally is the first. The second rule concerns defensive turns.

Tally

Ninety percent of the air-to-air kills throughout history have been unobserved. Of the other ten percent, more than half of them did not acquire the tally until after ordnance had been expended. The lesson is obvious. You cannot fight someone you do not see. You cannot defeat a missile if you do not know you have been shot at. Disciplined visual lookout and situational awareness of what is going on around you are critical. Another problem we have in the F-4 is losing the tally during the engagement. Fighting a small aircraft at extended range with our aft visibility limitations, can make it extremely difficult to maintain the tally. There are techniques to help with this—use them. With today's high technology weapons, the old saying is truer than it ever was: "Lose sight, lose the fight!"

DEFENSIVE TURNS

When you first acquire an attacking bandit, you must evaluate whether he is a threat to you. If not, one option may be to accelerate (extend) away from him. Many factors must enter into this decision. Today's air-to-air weapons have extended ranges at most altitudes -- ranges greater than our typical tally-ho range. You may, on the other hand, have intelligence information about what ordnance is available. If you trust it, information like this can make this judgment easier. Another important factor is AGL and MSL altitude. Low AGL altitude shrinks weapons envelopes due to radar and IR clutter problems. Low MSL altitudes shrink missile kinematic capability. The tendency to incorrectly estimate slant range can also cause problems. Deciding that a bandit is out of range when he has already launched a missile will kill you. On the other hand, turning into an out of range bandit generates closure which immediately gives him a launch opportunity. Finally, if you do decide to run,

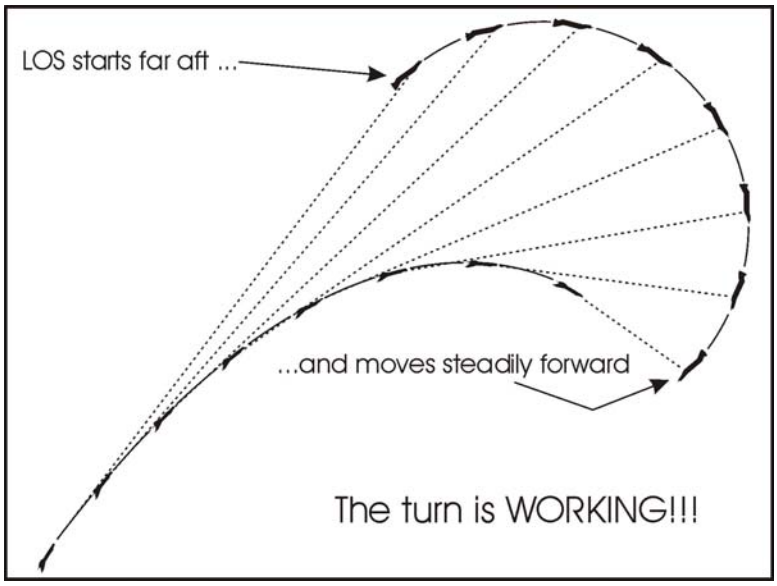


Figure 8-1. The Turn Is Working.

maintain the tally and keep looking for missiles. Even smokeless motors flash at launch, and produce a faint trail during motor burn in flight.

Increase Aspect Angle

If you decide the bandit is a threat to you, should you turn into him? The key factor here is whether the turn will "work"—will it produce the desired results? What do we want from a defensive turn? For a bandit behind our three/nine line, we want to increase the aspect angle he sees. This does several good things for us.

Up to 90°

First, higher aspect angle, up to 90°, increases LOS rates for the bandit, as well as for any missiles he might launch. Higher LOS rates increase minimum launch ranges due to the high missile turn rate required to establish the proper lead, as well as the limited ability of the missile seeker head to follow you (called gyro tracking rate). In addition, near-beam aspects means large lead angle requirements for missile collision course. This can cause seeker-head gimbal limit problems.

Past 90°

Increased aspect past the beam further increases the minimum launch range, due to the increased closure. This increased minimum range combined with the closure high aspect causes minimizes the time during which an attacker can employ ordnance. A break turn into an attacker very near his maximum launch range in your stern, can put you head-on with him inside his minimum head-on launch range.

Separation Potential

Finally, assuming the bandit does not turn in front of you, higher aspect angles mean higher angle-off at the merge. The higher the angle-off is at the merge, the greater your potential to safely separate from the fight.

Canopy Motion

So, if it is aspect angle we want from our defensive turn, how can tell if we are getting it? This is where "motion in the canopy" is the determining factor. If the bandit is moving forward in the canopy, his aspect angle is increasing (Figure 8-1).

Outside of Your Turn Circle

If the bandit is more than about 9,000 feet away from us (at medium altitude), you can increase the aspect no matter what he might be doing, (Figure 8-2). If you decide to react to a bandit at long range behind you, it is better to turn into him initially, and increase the aspect as much as you can before he closes inside your turn circle.

Inside Your Turn Circle

At closer range your ability to increase aspect by turning into an attacker depends on his current

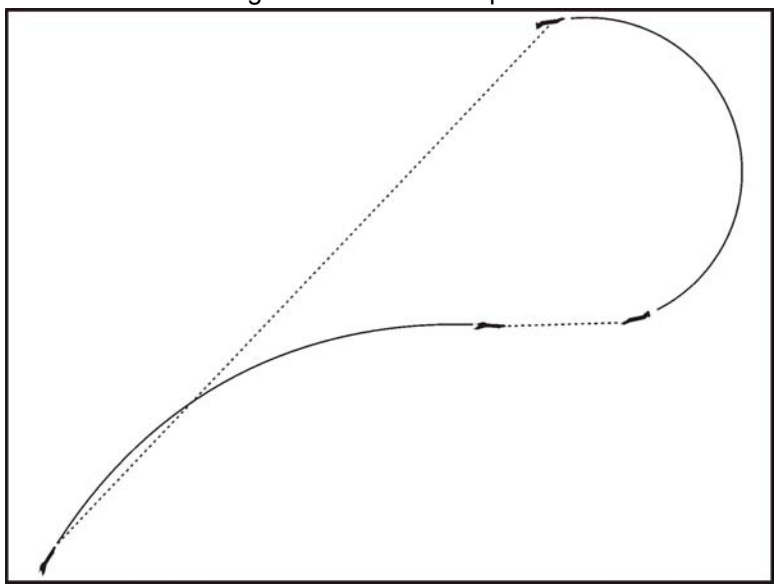


Figure 8-2. Outside Your Turn Circle.

aspect and on how much lead he has. Turning into a bandit who is 5,000 feet at three o'clock, with his nose 30° in lead, will march him further towards your nose. The same turn against someone 5,000 feet at five o'clock with nose well in lag will have a completely different effect.

How to Tell

It is easy to judge this. Simply turn into him, lift vector on, and see if he moves forward. This gives us our second "Rule of Thumb" for defensive BFM—if he's moving forward in the canopy, the turn is "working", so keep turning.

How to Perform a Defensive Turn

Should the turn be any different for a bandit at 2 NM than for one at 5,000 feet? How about a defensive turn against a missile in the air?

Lift Vector ON!

With two exceptions, all defensive turns should be at maximum performance, with your lift vector on the threat.

Maximize Aspect Angle

Lift vector on maximizes the increase in aspect angle. Any lift devoted to turning in a direction away from the bandit (or the missile), is wasted lift. The higher the initial aspect the more important this is. For a bandit very close to six o'clock (zero aspect), on the other hand, any direction is equally effective. So in this case you should turn downhill as much as AGL altitude allows in order to preserve airspeed.

Bandit Well Above

The first exception to this is when the bandit is well above you. Unless you begin at high airspeed, a "lift vector on" turn will result in a nose high, low airspeed situation where you may get guns tracked. Here your best option is to turn into, but slightly below the bandit, keeping your lift vector as high as possible without excessive airspeed bleed-off. A general rule of thumb is to try not to slow down below 300-350 KIAS trying to turn into a bandit above you.

Guns Threat

The second exception is obvious but critical -- when the bandit is inside gun range with his nose in lead. It is safe to assume that all current fighters are gun equipped. Lift vector on will fly you directly through the stream of bullets. You must get "out-of-plane" above or below the extension of his nose. That may only require that you roll your lift vector 30º away from the direction he is coming from. The closer your lift vector is to him the greater a problem you give him for follow on maneuvering, but the easier it is for him to "get in-plane" for the shot. If you die from this shot, follow on maneuvering becomes academic.

How Hard Should You Turn?

Turn rate is what causes the aspect angle problem we want to give the bandit. The harder we turn the greater the problem we give him. But nothing is free. The price we pay for this maximum performance turn is energy. The question is—is it worth it?

Close Range

Inside our turn circle, a turn at less than maximum performance may not increase the bandit's aspect at all, and may allow him to arc at low angle-off right into a tracking gunshot opportunity. If you need to make a defensive turn at close range, turn as hard as possible.

Further Away

Outside our turn circle, the harder you turn the more aspect and angle-off you will create before the bandit closes inside your turn circle. The choice here is between:

Break Turn

A maximum performance turn which will produce higher aspect and angle-off and all of the benefits associated with that, and a reduced airspeed and energy level, or…

Hard Turn

A less-than-maximum-performance turn which will result in a higher energy level, but less aspect and angle-off. This author (and the editor) believes the aspect and angle-off are more important than the energy. Air-to-air "experts" have yet to resolve this, however, so feel free to make up your own mind.

How Far Should You Turn?

This depends on whether you are fighting the aircraft or a missile. To fight an aircraft, the higher the aspect the better. Meeting him head-on gives us better separation potential, and minimizes his weapons launch window more than meeting him with 135° aspect would. But today's air-to-air missiles, once launched, often have the highest P_k when in the forward aspect. Their major limitations, in general, occur on or near the beam.

Missile defense

An in-depth discussion, being classified, must of course be left to the classroom. However, you must understand the limitations of air-to-air missiles on the beam to be able to defeat them. In general the quicker you get to the beam, the better off you are. High airspeed and lookdown for the missile helps too, so as you are putting the missile on the beam, head down hill, to minimize airspeed loss and maximize background clutter.

Shot in the Face

What about a missile launched from in front of your three/nine line? To turn to put it on your three/nine line means turning away from the missile -- and from the bandit that launched it. But your first objective must be to defeat the missile. If it kills you, performing the best BFM in the world against the launch aircraft is meaningless.

When targeted by an air-to-air missile from the front quarter, the determining factor is the slant range. If you can be positive the missile is more than three to four miles away, you have time to turn to the beam, downhill and away from the missile, and still reacquire tally prior to missile intercept. In this case this is your best course of action (Figure 8-3). Take this action with good radar SA on bandit slant range, and when RWR tells you that you are targeted.

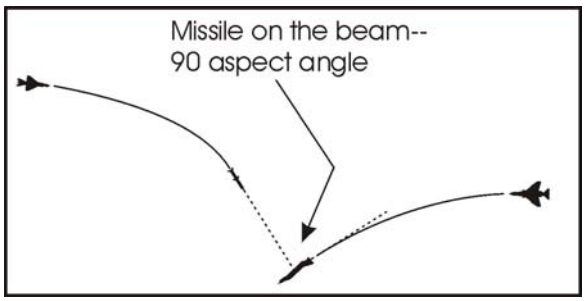


Figure 8-3. High-Aspect Missile Defense.

If you visually observe an aircraft shoot at you from the front quarter, chances are there is insufficient time to get the missile to the beam. Immediately put the stick in your lap and pull as hard as possible, in whatever direction the lift vector is positioned when you acquire the tally. The objective is to create as much G as you can, as quickly as you can. Missile TOFs from the front quarter are so short that in general there will not be sufficient time to roll the wings to a better position, apply G and move the jet prior to missile intercept. If after applying the G the missile is still in front of you, begin rolling slowly into it without unloading to create a "multiple plane" problem for it to solve.

Power

You must understand the effect airspeed has on turn performance. A 550 KIAS, 7 G turn is not a maximum performance turn. A slower aircraft can close and solve angles by arcing inside your turn radius. To be effective, a defensive turn must end up near or below corner velocity. When well above corner, you must reduce the power. This may mean military power or it may mean idle and speed brakes. Depending on pitch attitude, re-engage the afterburner 50-100 knots above corner to minimize airspeed bleed-off below corner.

IRMD

This classified topic is for classroom discussion and will be addressed there.

DEFENSIVE COUNTERS

For a bandit outside your turn circle, a defensive turn will always increase his aspect and angle-off problem. No matter what maneuver a bandit attempts, meeting him head-on minimizes the threat he presents to you. Once he is inside your turn circle, however, the situation changes. Now even a break turn may not increase his aspect angle (when he is at low aspect and angle-off, for example). Under these circumstances, we must think of our defensive BFMs as counters to his offensive BFMs.

Attacker Nose-On Turn

When nose on, he is not a gun threat, and he has an angle-off problem equal to his aspect. By turning into him you prevent him from decreasing the angle-off, and perhaps keep him from establishing lead. In addition, at close range, turning into a pure pursuit bandit will cause a longitudinal (six/twelve o'clock) axis overshoot.

Nose in Lead

What you should do against a nose in lead bandit depends on his range and overtake.

Inside Gun Range

Inside gun range, with his nose in lead, the bandit has already satisfied two of the three requirements for an effective gunshot. Your primary concern must be in preventing him from

satisfying the third—getting in-plane. A defensive turn, lift vector on, solves this problem for him! You must get him out of plane, immediately, and keep him there. The best way to do this depends on how long your adversary will remain in the guns envelope.

Guns Jink

When an attacker is in a position of low aspect with controllable overtake he can remain there for more than one shot opportunity. Your situation is very serious. To survive an attempted gunshot you must remain out-of-plane while causing a BFM problem which will allow you to separate or gain the offensive.

Above 250 KIAS, your best move is a high G/AOA rolling maneuver that will force maximum plane change for the gun attack, while continuing to generate an aspect and angle-off problem for the bandit.

Below 250 KIAS, the best initial roll direction is down, to generate a sufficient turn rate to defeat the attack. After 180 to 270° of roll, assess the situation before continuing the defense. If the attacker continues to press for guns, he will be nose-low at your five or seven o'clock position and a vertical pull may force a 3/9 line overshoot. If the bandit quarter planes to control overtake and nose/tail separation, an extension for energy may be possible. Remember, this extension may quickly drive you into the heart of his Aphid or Alamo envelope, so a tally is essential for follow-on defensive reactions.

Below 200 KIAS, any gun defense will be severely hampered by the F-4's inability to roll and turn effectively. The best plan is not to allow airspeed to slow to this regime while in a defensive posture (HA!). If forced there, you must initiate what we call a guns-jink.

While maintaining tally, break out-of-plane, either above or below the bandit. Hold this break turn until the bandit begins to slide back to your high six o'clock. Before he reestablishes himself in your plane of symmetry, unload, roll your lift vector away from him by at least 45 to 60°, and re-establish the G in a different plane. As you continue this sequence of break turn, unloaded roll, turn again, you should be working your way downhill. This will help preserve your airspeed and available G while you get down to low altitude where the F-4 flies better.

Maintaining a tally is difficult during the maneuver but it is a must. If you do lose sight, do not just keep a steady G on, in the same plane, for more than three to four seconds. That would present the bandit with a stable platform to shoot at—just what most LCOSs are optimized for. A successful jink-out may drive you right into heat missile parameters since no attempt is made during the maneuver to generate a 3/9 line exchange. In any case, you must remember that when the attacker's nose is well off, or he is out of guns range or is repositioning, he is no longer a guns threat and a gun defense is not the most appropriate move.

Guns Break

If the bandit will be in guns range for only a short time, (High angle-off or high V_c), then your guns defense can be shorter, and is called a guns break. Again, you must concentrate on getting "out of plane". If the bandit is coming from medium or high aspect, then prepare for the guns break by rolling slightly early to position your lift vector away from the direction he and his bullets are coming from. The higher the angle-off, the more out-of-plane you should roll. Initiate the guns break just before he would open fire. If he is unloaded, (lift vector not aligned with your fuselage), then this is just before you would be looking straight down his gun barrels. If he is loaded up (attempting to lower the LOS rate by pulling in-plane G), then the point is just a second earlier than that. In all cases, if you wait until he is pointed at you, or in lag, you have waited too long! Roll to position your lift vector above or below him, and pull away from the direction the bullets will be coming from. Remember that if you are slow, you must unload to generate the roll rate necessary to break out-of-plane. If you can at least roll to get your wings in the attacker's plane, you will minimize your silhouette and increase your chances of survival.

Follow-Up Intentions

Your follow-on intentions also determine how you change planes. As someone closes to gun range, they also approach your 3/9 line. If you can defeat the gun attack, you may then be able to challenge for 3/9 line advantage. The best way to do this is to slow your forward velocity vector and create a severe closure problem for the attacker. To do this, the nose should be rotated up. Remember, however, first defeat the gun attack by breaking out-of-plane effectively. You may have to go down in order to generate sufficient turn rate, even at the expense of a counteroffensive opportunity.

Errors in Guns Defense

There are several major errors that are made during any gun defense. The first is losing tally. To avoid doing this, note the opponent's position when you initiate the first plane change and predict where he will go during your defensive maneuver. Another error is attempting to roll at high AOA. A rapid plane change is essential and a slow roll rate may be deadly. The aircraft AOA should be reduced first to achieve the quickest roll rate, unless the defense is initiated at sufficient airspeed (above 250 KIAS) to guarantee an acceptable roll and turn rate. To survive a gun attack will take skill and patience; the fighter pilot must remember this. The most critical error is giving up and settling into a constant plane turn.

Outside Gun Range

Closure significantly affects what "gun range" really is. With low overtake the average aircraft 20-30 mm gun system can be effective out to 3000 feet. At the higher overtake normally associated with medium to high aspect gunshots guns can be effective out to 4500-5000 feet, although gun sights are not as yet reliable at these types of shots. If a bandit is still outside of guns range and is arcing you, with his nose in lead, then what you should do depends on how much closure he has.

Stagnated or Opening V_c

If a bandit with his nose in lead appears to have little or no overtake, i.e., getting bigger slowly and staying in the same relative place on the canopy, you may be able to stagnate the attacker by extending away from him. This is the classic case of arcing. The attacker is using geometry to get closer and may actually be at an airspeed disadvantage.

It is not uncommon for a 250-knot attacker to gun a 450-knot defender because he insists on turning to allow the attacker to rejoin. Extending away from him, downhill (keeping him in sight near the aft visibility limits), may allow you to open the range sufficiently to separate. In addition it allows you to gain airspeed you may need if he shoots something else at you. Maintain tally, and if he comes nose-on, turn and move him out of your vulnerable cone. You must continue to defend yourself and be prepared to react if the situation changes, i.e., the attacker gains overtake by out-accelerating you. You must keep the bandit in sight during this maneuver. If you lose sight for just that one second during which he fires an Aphid at you, you will discover it only after it impacts your jet.

With Closure

If the bandit is closing on you, then you should break turn into him. Attempt to get inside his minimum missile launch range, before he launches at you. Since he already has closure, extending simply offers him more time to employ his weapons at a lower aspect. Remember that your turn will bring him quickly within guns range, so you must be ready to do the appropriate guns defense as he transitions through the gun envelope.

Nose Off in the Vertical (BFM)

If the bandit goes nose off in the vertical inside your turn circle and you cannot out-zoom him, you should extend away to open the range and gain energy. Remember, however, the first rule from defensive turns. If your defensive turn is bringing him forward on the canopy, then you are making his aspect angle problem bigger. This is an easy to use, accurate visual cue telling you that he is outside your turn circle, and you should keep turning.

Nose in Lag

The most obvious reason for this attack profile is to allow the bandit to use excess energy to drive to your blind cone, then slow his aircraft down and turn hard to point and shoot at you unobserved, (Figure 8-4).

Maintain Tally!

To counter this, you should turn hard to rotate your vulnerable cone and maintain a tally with the

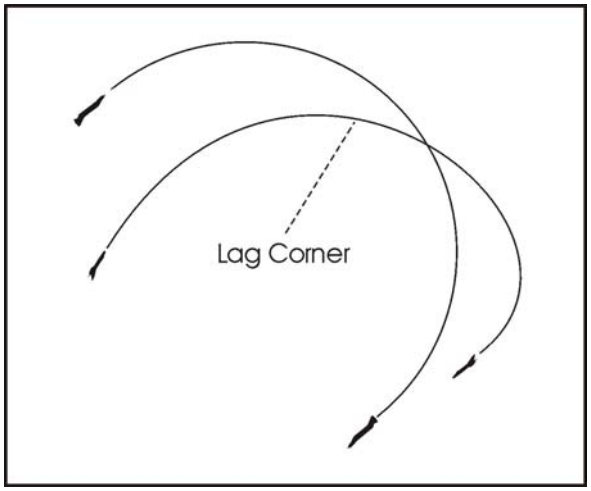


Figure 8-4. Lag Corner.

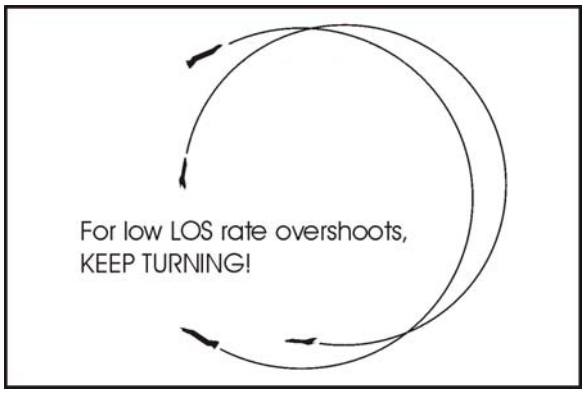


Figure 8-5. Low LOS Rate Overshoot.

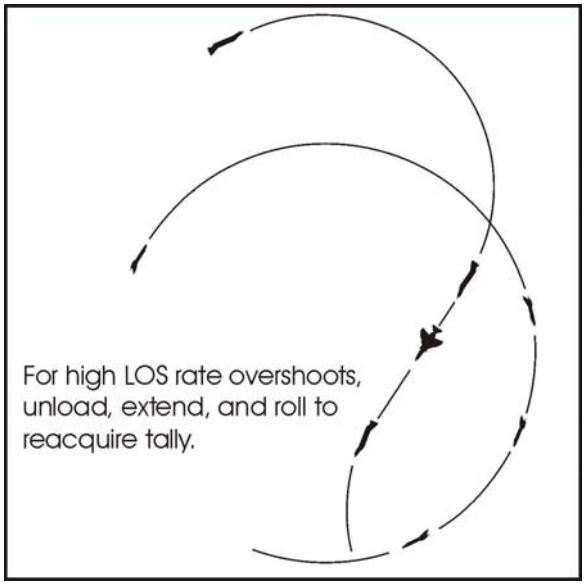


Figure 8-6. High LOS Rate Overshoot.

bandit. The further back the bandit is, the more effective your turn to rotate the blind area away from the attacker will be. Once you have increased the aspect to the point that you can maintain a tally, you should extend or ease off while the bandit is slowing to turn. As the bandit comes nose on, you must assess his range and overtake and react with a hard turn or a continued extension.

Low LOS Rate Across Six O'Clock (Figure 8-5)

If the angle-off is low, or the bandit is outside 4000 feet, then his motion towards your six o'clock will be slow, in spite of your hard turn. You must keep turning, as hard as possible, even if he momentarily drifts into your blind cone. If you attempted to reverse, or unload to reacquire tally on the other side, there is a strong possibility that the bandit will roll out in your blind cone nose on and shoot unobserved.

Hi LOS Rate Across Six O'Clock (Figure 8-6)

If the bandit is at close range at high aspect, then his relative LOS rate (in the canopy), will be high. The visual cue you should be watching for is that you will be unable to turn hard enough to keep him inside your turn. As a decision point, this LOS rate must be rapid enough so to ensure that you will be able to roll out and find the bandit already on the other side of your blind cone. If you can safely make this judgment, then unload, roll the other way for tally, and extend downhill straight ahead.

Overshoots

Fighter pilots use the word "overshoot", to describe several different situations, ranging in significance from minor to life-threatening. Any time a bandit is presented with an angular problem that he cannot solve inside your flight path, he will overshoot. There are three different types of overshoot geometry, (Figure 8-7).

Flight Path Overshoot

A flight path overshoot is often confused with a longitudinal (six/twelve o'clock) overshoot, so make sure which one someone is talking about when they say "flight path". If they really mean the flight path, then they are of course talking about your smoke trail or jet wash. Overshooting this is not significant. (The attacker is still inside your turn, visible out the top of the canopy.) The confusion occurs because in debriefs, the defender leaves a line on the board where he has been, and it is an easy reference to use for overshoots.

If an adversary overshoots your flight path, it is essential that you continue to turn in the same direction to reacquire the tally to prevent offering

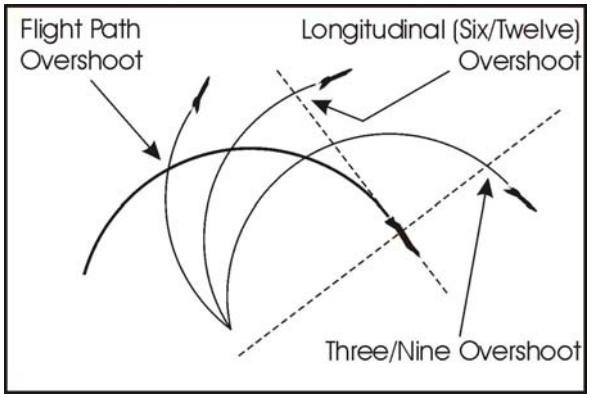


Figure 8-7. Types of Overshoots.

the attacker a low aspect, low angle-off shot. This turn needs to be your best possible turn. The key to recognizing this type of overshoot is your adversary's relative (in the canopy) LOS movement towards your six o'clock. If this movement is slow, then, if you foolishly unloaded, he will probably be able to point at you from your dead six o'clock, where you cannot see him at all.

Longitudinal Overshoot

Now the bandit has crossed your six/twelve o'clock line—the straight line extension of your fuselage. This overshoot is significant because now a continued turn in the same direction is turning away from him, belly up. The more to your belly side that he flies, the longer you must turn away just to get him back inside the turn again. When a bandit overshoots longitudinally, with a high LOS rate, you should unload, and roll the other way for tally ho, as you extend downhill away from him (see *Maintain Tally* on page 66). A longitudinal overshoot can be recognized by a much higher LOS rate towards your six o'clock. Your options are now determined by three aspects of the overshoot: range, angle-off, and the attacker's closure.

Low LOS Rate

If the overshoot occurs far at six, treat it like a low LOS rate nose-in-lag defense. Keep turning until you have reacquired tally inside your turn. The farther back in range the overshoot occurs, the less likely role reversal will be. If you cannot reverse and gain the 3/9 line advantage, then you should roll wings level, reacquire the TALLY, and extend. The higher the aspect of the attack, the higher the angle-off will be at the overshoot. The higher the angle-off, the more pronounced the overshoot will be. The final factor is the closure of the attacker. Obviously, this is related to the angle-off. The more closure the attacker has at the overshoot, the farther across the longitudinal axis he will go.

High LOS Rate, Close Range

High angle-off and close range enhances the overshoot, but angle-off near 90° will result in the bandit ending up aft of your 3/9 line and going away from you. In this case, a nose-high reversal would leave you slow and outside your weapon's parameters (Figure 8-8).

Three/Nine Overshoot.

Continue to turn hard until the overshoot is assured. If it is apparent a longitudinal axis overshoot will occur, as the bandit crosses your six, reduce AOA, roll wings level, and reacquire the tally while assessing the situation. You are now in Short Range Neutral BFM, discussed in the next section.

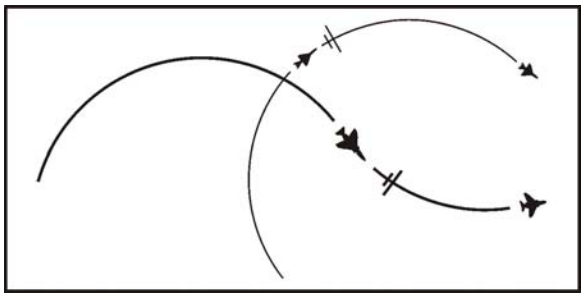


Figure 8-8. High LOS Rate Longitudinal Overshoot.

Early Reversal

If it is **certain** that the bandit will overshoot, an early move to gain the 3/9 line advantage may be initiated. If there is sufficient airspeed to allow a high roll rate while maintaining AOA, a high G, rolling reversal should be executed by continuing to turn into the bandit and applying a combination of top rudder and aileron. The advantage of this reversal technique is that it continues to force maximum angular problems on the attacker while initiating counteroffensive maneuvering. The penalty, however, for an incorrect assessment is much greater if the bandit makes a vertical move to maintain positional advantage. You may find yourself nose high, slowed down, and too low on energy for the follow-on defense. If in doubt, turn until the bandit overshoots, unload, roll, and assess the situation.

SHORT-RANGE NEUTRAL BFM

If you misjudge your overtake during offensive BFM, perform an entry with too much lead, or overshoot an attacking MiG with an aggressive break turn, you may find yourself close to a neutral situation at close (inside 4,000 feet) slant range. This situation also commonly occurs after overshooting from an unsuccessful medium aspect snap shot. From such a position a fight often goes into the vertical, fighting for three/nine line, and a flat scissors, a rolling scissors, or a separation may develop.

Recognition

First comes the critical task of evaluating who is winning. Inertial LOS motion and relative energy levels are the two factors which determine who has the advantage in this type of situation.



Figure 8-9. He Is Winning!

LOS Motion

This is the overriding factor in determining who has the instantaneous positional advantage (Figures 5-2 and 5-3). If your adversary is moving forward against the background, he will pass in front of you, potentially through your gun bore line, and you have the advantage—at least for the moment! If on the other hand he is drifting aft, you will cross in front of his guns and you are on the defensive (Figure 8-9).

Energy

Relative energy levels determine who has the long term advantage. The aircraft with the most energy, flown properly, has the potential long term advantage. Judging relative energy levels can be difficult at range but in close it is relatively easy.

Options

You basically have two choices in this situation. You can attempt to gain or regain the offensive (scissors) or you can attempt to separate.

Scissors or Separate?

Your choice here depends not only on who has the advantage, but on how well the bandit flies his jet.

Energy and Positional Advantage

If you have a positional and an energy advantage, try to maintain it by staying aft of the bandit's three/nine line. Initiate this scissors by pulling for his high six o'clock.

Energy and Positional Disadvantage

If you do not have a positional or an energy advantage, then you should attempt to separate or at least to extend. Reversing and/or attempting to out-zoom someone with an energy and positional advantage will result in you being trapped at low airspeed, nose high, in a cloud of HEI.

Energy Advantage Only

If you have more energy than your adversary, but he has the positional advantage, set the wings and pull for his high six o'clock. The closer to the pure vertical your lift vector is, the faster you will be stopping your forward motion and the higher above the bandit you will get. The idea is to stop your forward motion relative to the bandit, until he begins to march forward again. An in-plane turn into him, in this situation, before you have regained the positional advantage, is a common and deadly error. If he is still marching aft against the background, turning into him just causes you to fly across his nose, in front of his guns. As the Israelis say, "This is stupid!"

Positional Advantage Only

In the reverse of this situation, you have a positional advantage but the bandit has more energy than you. This is common after you force a high energy attacker into a longitudinal axis overshoot. What you should do here depends on whether the bandit makes the error discussed in the preceding paragraph.

If the bandit overshoots and continues turning lift vector on, then roll to lift vector in lead and pull to control the forward LOS motion and the range at which he crosses in front of you. If his forward LOS motion is severe enough, this may actually require that you turn away from him, in a lead turn, while he is still aft of your three/nine line on the other side! Once he has passed you, this lead turn may require 35 to 40° of lead and may feel uncomfortable. Never lose the tally under the radome inside 5,000 feet. Remember that as long as the bandit's LOS motion against the background is forward, towards your nose, you will pass behind him. Make sure you are in-plane and turn the gun on early!

If the bandit has read the last few paragraphs, he will of course not do this. He will instead pull up in the vertical, for your high six o'clock. In this situation, since you momentarily have a positional advantage there will be a strong temptation to go up with him. This would be a mistake, for the same reasons as discussed above. Unless you can use your positional advantage to get a high P_k shot very quickly, you will end up slow and nose high below and in front of him. So, when you recognize by his vertical move that the bandit

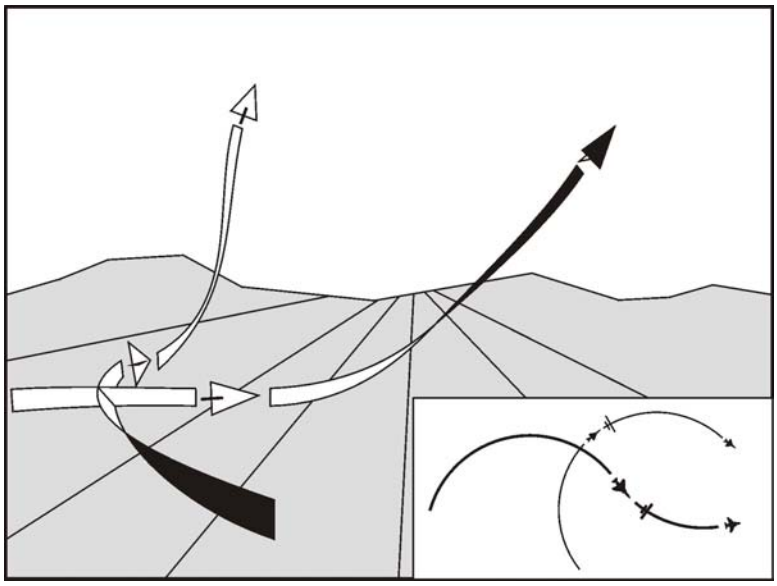


Figure 8-10. Start of a Scissors.

is flying his jet well, you should extend and attempt to separate.

Scissors

There are in general two types of scissors, the flat scissors and the rolling scissors.

Flat Scissors

A flat scissors can occur when you overshoot level and in-plane with the bandit (Figure 8-10). Pull for the bandit's high six o'clock, to slow your forward motion. The key is to out-rate the bandit in the initial pull. The less lateral separation you have, the closer to the pure vertical you should be pulling. Imagine putting the lift vector on a point in the sky 1,000 feet behind, and 3,000 feet above him. Do not turn into him to decrease the lateral separation unless and until you have a definite positional advantage. Any bank away from the pure vertical is lift taken away from pulling nose up, and in a close contest he will get his nose higher, slow his forward motion more, and you will march out in front. This will be apparent to you by the bandit's aft LOS motion against the background.

Power

Unless well above corner, the power should remain in full afterburner during a scissors. The most likely ordnance to be employed in a flat scissors is the gun and the best opportunity to employ it is early in the scissors when there is still adequate nose/tail separation and crossing angles are still high enough to make a separation effective. Remember, a flat scissors is primarily a slow speed vertical flying contest and will be won by the aircraft which is more maneuverable at slow speed/high AOA. If the outcome is in doubt, the best move is to separate early before losing the positional advantage.

Errors

There are two main errors in flat scissors. The first is not pulling enough in the vertical and giving up nose position. The pilot is not pulling towards the bandit's high six and allows too much lateral separation to develop. The second common mistake is not controlling bank angle at slow speed and losing nose position.

Rolling Scissors

A rolling scissors can develop after a vertical overshoot or from a horizontal overshoot with an altitude differential. One way a rolling scissors can develop is after a quarter plane, or entry from high, when you allow your nose to get too low, too close to the bandit. If he recognizes this and pulls up and into you, he will cause a vertical overshoot which will spit you out in front of his three/nine line. As you overshoot below and in front of the him, you will be continuing to pull up and into him, as he reverses his nose-up pull to pull back down to your six o'clock, reversing the positions again. This would be a pure vertical scissors. More often there is a lateral component as well, as both players pull slightly out of the plane of each other's guns, causing the maneuver to be a series of continuous rolls rather than pure vertical pull-ups and pull-downs.

Lift Vector Placement

This is the most difficult concept to understand in a rolling scissors. The natural place to pull towards is the bandit's six o'clock. However, even as you begin moving towards that position, he will have moved laterally. As a result, you will be rolling and continually "catching up" and will never get a shot opportunity. What you must force yourself to do is align your lift vector in the direction he is drifting. As in most BFM this will cause you to pull towards where he is going and reduce the angle-off. It will also reduce the LOS rate which you must match to track him if and when you do get a shot opportunity.

Maneuverability

In a continuous rolling scissors, the fighter with the better maneuverability and nose authority will win. Separations from a rolling scissors will generally be more graceful than from a flat scissors if done early and properly. The best time to initiate one is during the roll down when the bandit is pulling up.

Errors

The same mistakes are made as in the flat scissors with one exception. When coming back down again, never allow your nose to get lower than the bandit's. As much as possible, keep your lift vector aligned in the same direction as the bandit's.

Extensions

The goal of any extension is to separate beyond the adversary's weapons envelope. This range should be at least 12,000 feet and often puts the typical threat aircraft near the aft limits of visual acquisition.

Altitude and Attitude

All extensions should be nose low, to increase airspeed as rapidly as possible, and to descend into the low altitude arena where weapons envelopes shrink and pilot, aircraft radar, and missiles must deal with radar, optical and infrared clutter. Although extensions will be discussed in depth in the next chapter, there are two points worth mentioning here as well.

G-Loading

First of all, always extend at 1 G or less. Holding 2 to 4 Gs in 70 to 80° of bank prevents the jet from accelerating and allows the bandit to arc you. If you cannot discipline yourself to unload, solve both problems by rolling out to less than 30° of bank during your extensions.

Ineffective Extension

The second most common error during extensions is to begin a defensive turn back into the bandit before he has pointed his nose at you. By turning into him while he is still pointed in lead, you allow him to arc, with lead, right into the tracking guns envelope. Obviously, if he shoots a missile at you from off-boresight, you must defend against the missile. But as long as he has not fired something at you, wait, no matter how difficult it may seem, until he is pointed nose on, before breaking into him again.

Separations

Separations, as a follow up move after employing the gun, were discussed at the end of Chapter 7. The same principles apply in any separation. The most important consideration in a close in slow speed situation like a scissors is to attempt the separation while you still have the positional (LOS) advantage. Once the bandit is behind you, he will be lead turning and attempting to gun you, each time you pass, and separating will become much more difficult.

INTERCOCKPIT DEFENSIVE COMMENTARY

These directive calls assume the rear cockpit has a tally-ho and the front cockpit is no-joy. Effective crew coordination in the air combat arena is essential for survival. If it takes three to four seconds for the WSO to recognize that he is about to be gunned, think about what to say and effectively communicate it to the guy driving the jet, chances are the intercom will be debris before it gets used again.

HARD LEFT/RIGHT

Used to direct a defensive turn when the bandit is at range and no ordnance is as yet observed. The use of the word hard is not indicative of any intent to turn at a reduced G or AOA. In fact, you should turn as hard as possible while the bandit is far enough away that you can still increase his aspect angle problem.

BREAK LEFT/RIGHT/UP

Used to direct a defensive turn when the bandit is much closer or when a missile is in flight. Energy conservation is not a factor. Infrared Missile Defense, (IRMD), procedures should be implemented immediately. Minimum turn radius and maximum turn rate is required. These conditions are best achieved at or near corner velocity. If well above corner (500+ KIAS), apply your limit G, drag power even further, and use speed brakes as required to slow down. Approaching corner, reapply power and get the boards up. If called below corner, apply maximum obtainable AOA consistent with G limitation. In both cases, this is a single plane maneuver into the attacker or the launched missile.

SET YOUR WINGS

Normally used when a bandit overshoot has occurred and the defender chooses not to immediately attempt a reversal. Immediately relax AOA to roll quickly with aileron at least far enough to check the bandit's position and reaction. This is not a loaded, high AOA rolling-type maneuver. After the roll, expect a follow- up call such as EXTEND or PULL.

REVERSE LEFT/RIGHT

Normally used when a bandit three/nine line overshoot is in progress and the defender chooses to execute a reversal to attempt to stay and fight. Since the defender needs to decrease the attacker's nose-tail separation, it is critical that you beat the attacker into the vertical. Set your wings level and begin a maximum performance pull into the vertical, while looking over the opposite shoulder for the tally.

PULL

This call will normally follow a SET THE WINGS or a REVERSE call. With the wings set, a pull toward the pure vertical will slow or stop horizontal movement and can generate nose-tail separation with subsequent nose position advantage. Pull at optimum AOA limit until bandit's aft motion against the background has slowed or begun to move forward. Now pull back into lead for guns. Be prepared to gracefully separate if your gun jams.

GUNS BREAK LEFT/ RIGHT/UP/DOWN

This call is used to direct a last-ditch defense against a gun attack. Pitch and power control is identical to that used in a missile break. However, a successful guns defense must occur out of the plane of the attack. Remember, roll performance is poor at very high AOA, therefore, the rolling moment must be introduced before reaching excessive AOA. DO NOT maintain your G for more than 3-4 seconds without changing the plane of your turn.

JINKOUT

This call is used to direct a guns defense while gaining energy and possible separation. Jinkouts are applications of rolls, turns, and acceleration which move the aircraft (not just the controls and control surfaces) out-of-plane and prevent the attacker from achieving a stabilized guns solution. Apply pitch and roll control and each time hold them just long enough to establish a new flight path. This is a multi-plane, three-dimensional maneuver. Maintain maximum power. Use caution for G overshoots during the jinkout as you accelerate past corner velocity. One of the most important ingredients of a successful jinkout is maintaining tally-ho.

EXTEND

Used to gain energy or separation when not immediately threatened. Pull the nose below the horizon, select maximum power and unload to 3 to 8 units. The result should be a descending, straight line unloaded acceleration maneuver. Rolls can be made at 3 to 8 units to maintain tally and/or set the lift vector for future maneuvering.

KICK HIM OUT LEFT/RIGHT

Used to maintain tally on the bandit during an extension. At the call generate a hard turn of fifteen to twenty degrees in the direction called. Expect a HARDER or EXTEND call to follow. Maintain maximum power and expect a series of kickouts and extensions if the bandit pursues.

KICK HIM ACROSS THE TAIL

Used to maintain tally during an extension if we want to position the attacker on the opposite side or the bandit is close to or moving towards our blind cone. Performed the same as a kickout. This call often occurs as we depart the fight during a role exchange in ACM. Expect a HARDER or EXTEND call to follow.

PITCHBACK LEFT/RIGHT

Used to direct a nose high course reversal from high calibrated airspeed. The intent is to exchange excess airspeed for altitude, thereby turning more efficiently and exercising energy management. At maximum power, pull nose high at approximately 6 ½ Gs (not to exceed configuration G limits) and pull to simultaneously change heading, reduce airspeed and gain altitude. Maneuver may resemble a chandelle, Immelmann, or half Cuban-eight. Rollout airspeed will vary based on how the maneuver is accomplished. Generally, it is a good idea to terminate with a good tactical minimum of 400+ KCAS.

SLICEBACK LEFT/RIGHT

Used to direct a nose low course reversal from low or medium airspeed. The intent is to exchange altitude for instantaneous and sustained maneuvering capability, thereby exchanging energy for turn performance. Roll to position the lift vector below the horizon and pull to simultaneously change heading, while increasing or maintaining airspeed. May be done at any power or AOA, but generally maximum power and AOA to maintain 400 KCAS or greater. Depending on situation, may be followed by HARDER, EASE OFF, or ROLLOUT.

HARD TO SIX

A maximum performance cross turn maneuver used to maintain tally and rotate your vulnerable cone away from bandit at your 6 o'clock. Each aircraft in the element should maintain/increase their altitude split during the cross turn to achieve turning room for continued maneuvering.

APPENDIX A
FIGHTER WEAPONS REVIEW ARTICLES

Although some of the material in the following *FWR* reprints is dated, there is still much of value here, especially for the F-4 driver.

BRIDGING THE GAP BETWEEN CONTACT AND TALLY-HO

Lieutenant Colonel Larry Keith
USAF Fighter Weapons Review
Winter 1976

How many times have you entered an ACM or ACT engagement as a team member of fluid two with only a visual and no tally? Or, how many times have you entered an engagement with a visual and a tally but no idea of how to progress successfully to get the quick kill? More times than not, the next step from either one of these situations is a shot by the bandit and it's usually on you. And, more times than not, the basic reason for the shot on you was because you were behind your leader in a predictable, trailing-type turn. Does that sound familiar?

What other situations have we been in that lead to the same results? How about running in on a tactical intercept and, because of blocked or misunderstood Bullseye or GCI calls, we weren't certain as to the geometry of the setup, or we were on the wrong side at the last minute to perform a lag hook? This last situation usually leads to out delaying the turn too long or turning in front of our partner. Either way, we lose visual (with no tally) and are out of the fight from the start.

Is there anything we can do to eliminate or minimize any one, or all, of the above situations a high percentage of the time? I believe so, and I have had a degree of success in the last three years using the methods I'm about to suggest.

To keep this article within the tradition of the *Fighter Weapons Review* standards, let's include some figures and numbers so we can have a common point of departure for future discussions.

Figure A1-1 depicts desired maneuvering cones once our partner starts his maneuvering to ID the bogey(s) or engage. Also, we want to try to maintain our energy level within ±200 knots of our partner. Note the 20-degree cone behind our partner. We want to stay out of it if at all possible.

Now, let's generalize for a little bit before we get into specifics. First—as the engagement becomes imminent, concentrate on maintaining your visual and clearing your partner's six o'clock area from high, level, and low. This will aid you immeasurably in spotting your partner's first move, which is what our initial maneuvering is keyed on. Second—attempt to stay out of your partner's plane of motion as much as possible. Third—attempt to predict where your partner is going. This will probably lead your eyes to the bogey(s). Fourth—if time and radio permit, keep your partner informed as to your position from him. This aids him in clearing your six as the fight progresses.

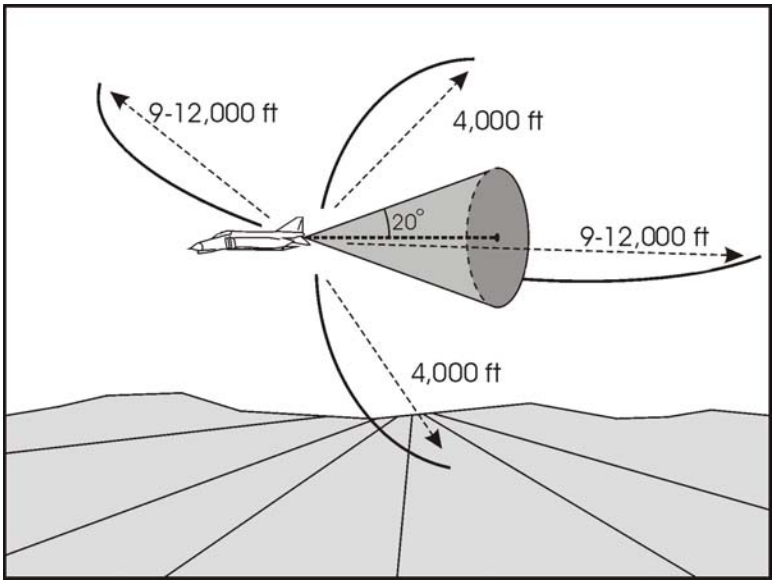


Figure A1-1. Maneuvering Cones.

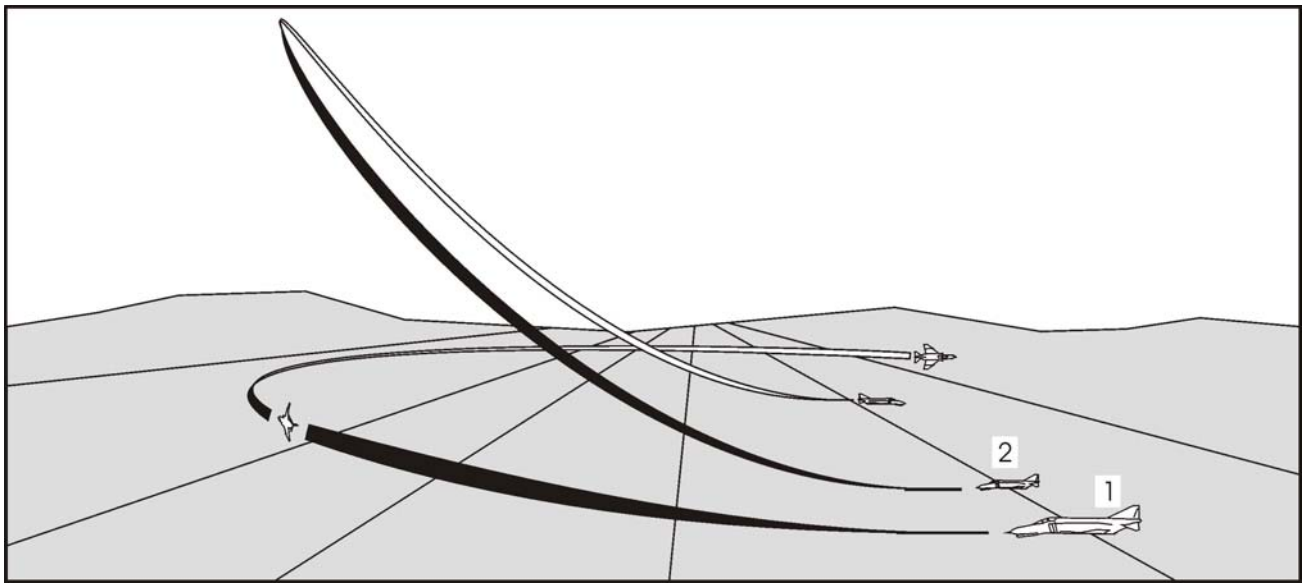


Figure A1-2. Level (±20º) Turn Into You.

To further define the ballpark, we are not talking about patrol type-turns. That is a separate subject. What we are talking about here is engaged or preparatory to engagement-type maneuvering. This means our initial reaction will be in the 5 to 6 G area and out reaction is initiated instantaneously when we notice a hard move by our partner's aircraft. With this in mind, let's set up some "what if" initial conditions.

Initial Condition. We are line-abreast and level to slightly high on our partner. He has called for burners (or he starts to rapidly accelerate away from us and we have a visual—no tally—and are uncertain just where the bogey is coming from. Shortly after we get our energy level up to a comfortable engagement speed, our partner starts a relatively level hard turn away from us. If altitude permits, over bank him 30 to 45 degrees in a hard nose low turn to attempt to cut him off on the far side of his turn. Once you have your nose pointed in the right direction, unload as much as possible and accelerate across the circle to cross you partner's flight path at or near the 90-degree point. If altitude does not permit going below him, then under bank the same amount, pull in the vertical until approaching corner velocity, then over bank back to nose low, accelerate, and cut him off on the other side.

If he turns less than 180 degrees, your nose low over bank move will have you initially out-accelerating him, which should allow you to get back along the wing line or line-abreast quickly. Remember, your initial energy levels were fairly close and his level hard turn depleted some of his energy so that you should be able to close on him. With your initial under bank nose high to over bank nose low position, you will have altitude, plus a more nose low attitude to aid you in accelerating to close back into position. If you gain a tally and your partner continues to press the attack, then maneuver as the pre-briefed game plan and mutual responsibilities called for. If you gain a tally and your partner is bugging out on divergent flight path, go with your partner. Nine times out of ten, if he elects to go, and you stay and turn with the bogey, he is definitely out of the fight and you are on your own in a one vs. one situation at best. This usually leads to your getting slow, and absorbing one or more shots before the engagement is called off. This does not mean passing up and opportunity for a quick shot as you egress the area.

Our next initial condition remains the same, only this time out partner starts a hard level turn into us (Figure A1-2). Our initial move is to pull into the vertical in an attempt to stay inside of our partner's flight path, then execute an unloaded roll into him, to keep him in sight, and set your wings on a flight path to cut him off on the other side of the circle. Pull in that direction until you are through the vertical and can unload to accelerate toward his wing line in a rapid cutoff-type maneuver. During this maneuvering, keep checking your partner's six and twelve o'clock areas in an attempt to gain a tally on the bogey(s). Once the tally has been gained, continue to split-plane maneuver off of your partner until you gain a tally or separate.

If, during the pull into the vertical, you can't stay inside of your partner's flight path, then roll away

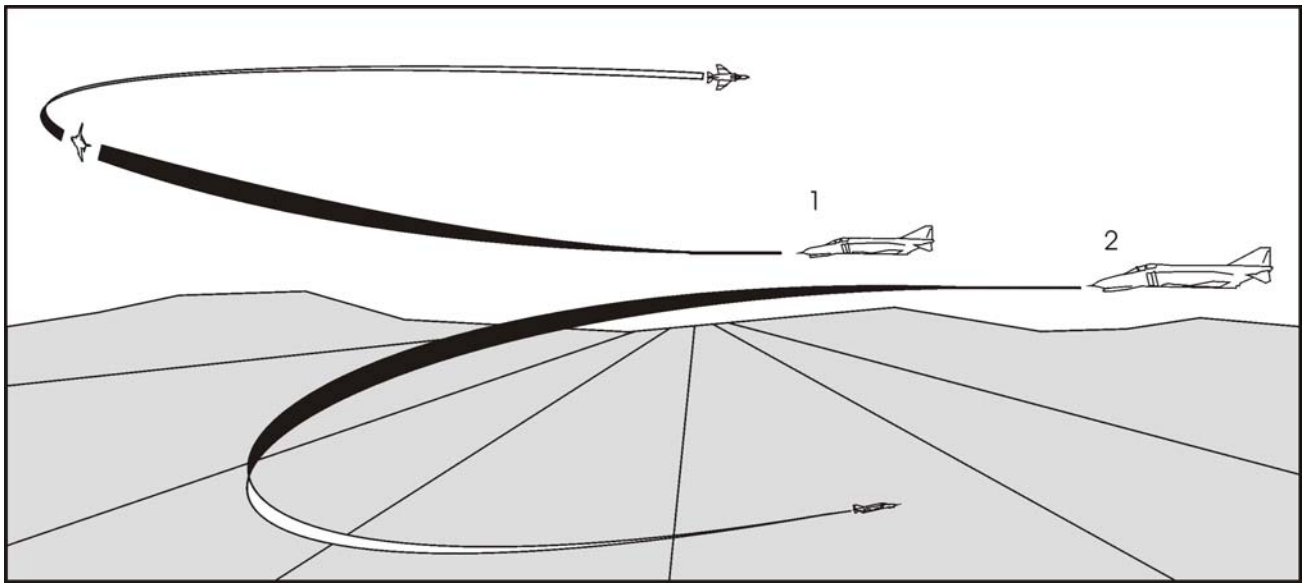


Figure A1-3. Behind the Wing Line.

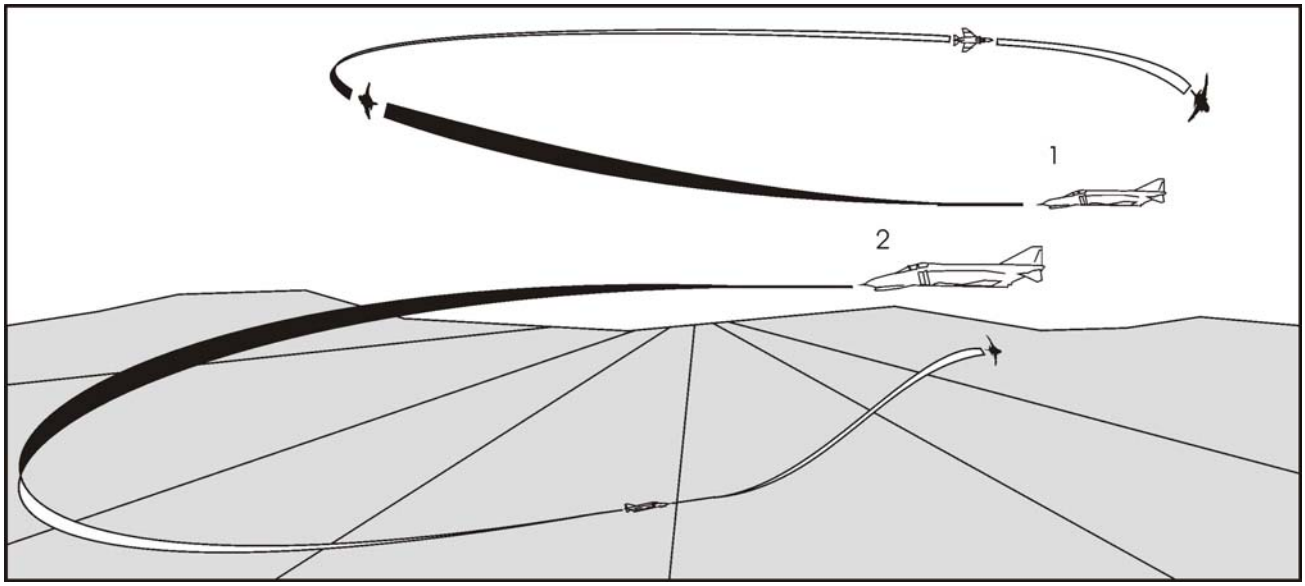


Figure A1-4. Ahead of the Wing line (Turn Away)

from him in a 135º slice turn, pulling through underneath until you can unload to cut him off on the far side of his turn. Execute the rolling slice as you lose sight of your partner going behind you. Regain your visual by initially looking out of the top of you canopy, as far back as you can see. If no visual is gained by the time your nose is pointed down, then switch your search to the opposite side of the canopy from which you rolled; i.e., if you rolled to the right, then search on your left. If your partner stays engaged, then you should be able to come into the fight from below, out of his plane, and have a high probability of picking up the bogey and continuing the game plan. On the other hand, if your partner decides to only turn 80 to 100º and leave the area, then you will be at his high four or eight o'clock position, ready to accelerate for a line-abreast egress.

The roll away from your partner will work anytime he executes a hard turn into you within ±20º of level. If his turn goes beyond those limits, then you will need to roll into him in order for the projected geometry to work. A roll into your partner will be required if your initial 5 to 6 G pull to the vertical puts you inside of his projected flight path. In this latter case you should not lose sight of your partner.

Any time your partner pulls hard into the vertical, either up or down, and either into or away from

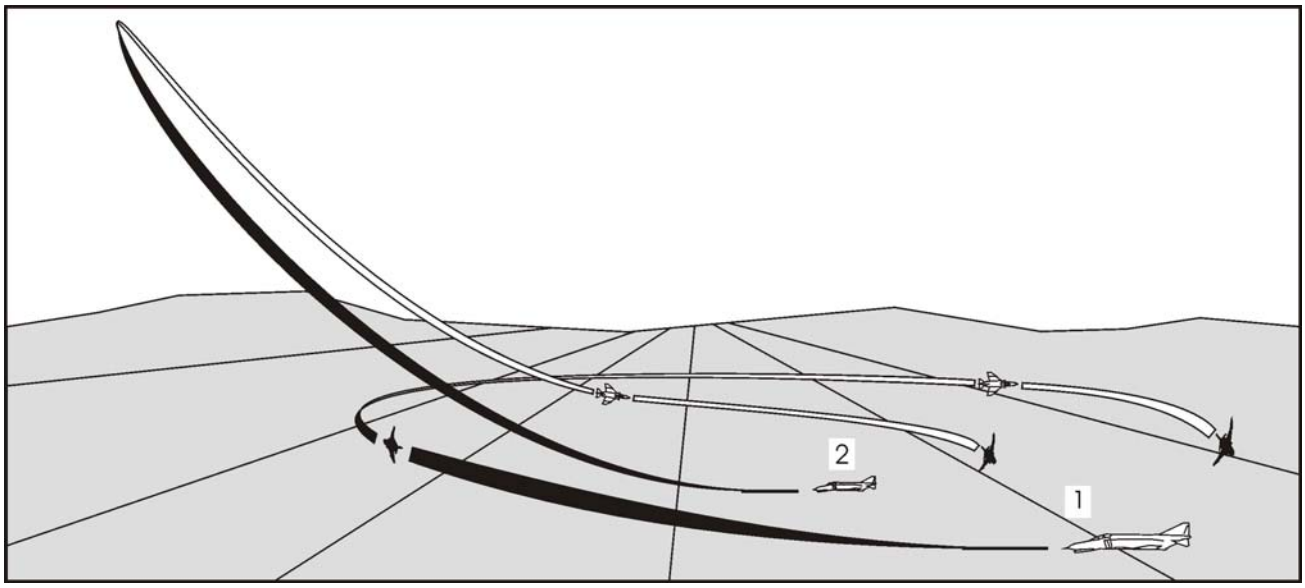


Figure A1-5. Ahead of the Wing Line (Turn Into).

you, you should be able to roll or turn toward him and set up your split-plane maneuvering. The key is to get out of his plane as soon as possible.

Now let's change out initial conditions a little. Assume that we are deployed or just lagging, 6-9000 feet out and well behind our partner's wing line when he starts his hard maneuvering. In this case, turn hard to set up a cutoff, then unload as much as possible to close to the split-plane envelope, as described above, and continue split-planing until you can move for a kill or separate with your partner (Figure A1-3).

Being behind the wing line initially is the easiest maneuvering position. Conversely, being ahead of the wing line forces a wide division of responsibility fore and aft of your wing line, as well as being a difficult position from which to maneuver.

Finally, we will consider the problems caused be being ahead of the wing line, and understand that the further ahead you are, the harder it is going to be to recover.

If your partner turns away from you, immediately go into a slice in the same direction. If you are no more than about 10º ahead, you should be able to enter the fight at about the 270º point from where your partner started. This should set up for further split- plane or supporting fighter maneuvering to the kill (Figure A1-4).

If you are more than approximately 10º ahead of your partner and he starts a hard turn into or away from you, then perform a pitchback-type turn in the same direction that he turns. This will aggravate the split and set you up to leave with him if he elects to bugout at 80 to 100º of turn (visual, but with some distance to close), or have you set up to continue split-plane maneuvering on your partner. In both cases, discontinue the pitchback as your airspeed approaches corner velocity and convert to a slice turn to preserve your energy (Figure A1-5)

If you are 10º or less ahead of your partner and he turns into you, whether it be up, level, or down, the slice turn in the same direction and plan on entering the fight at 270º from where your partner started.

For those of you who are still with me at this point, you might ask the logical question, "How do we find time and sorties to train our people?" My answer to this is as follows.

During our BFM training, after we have mastered the delayed 90º and 180º turns, we can plan and brief one of the conditions on each succeeding BFM sortie. Example: we need a 90º left turn to get squared away in our training area. Plan and brief a hard 270º fight turn from one of the above initial conditions. This allows the wingman to practice his initial move to get into the split-plane maneuvering arena. This is just one way, and I'm sure with a little imagination and planning, you can find other suitable times and methods to practice and train with these maneuvers. Some key points to remember:

1. Plan and brief thoroughly before each sortie.

2. Make sure your energy states are compatible before beginning the maneuvers.

3. Don't forget everything you've learned about needing and getting turning room to successfully complete BFM maneuvers.

4. And, above all, keep your Mach up and check six!

INSTINCTS OF THE FIGHTER PILOT

Captain John Jumper
USAF Fighter Weapons Review
Winter 1976

(Editor's note: this particular Capt. Jumper became USAF Chief of Staff in 2002.)

Those of us who were pumped through the training pipeline into Southeast Asia have an excellent base on which to contrast requirements of that period with those of today and tomorrow.

On a scale of one to ten, a new guy through the pipeline probably entered on a level of two. Usually there was a training period which provided some theater indoctrination and progression to flight leader. The wide array of mission demands allowed commanders to exercise some prerogatives as to who flew what type of mission. By the eight-to-ten-month point, the average guy's combat capability had usually peaked out.

For most of that conflict, our combat capability in the air-to-surface environment was necessarily tailored to the threat from AAA and SA-2. Thus, our tactics, ECM, and weapons systems evolved to enhance our capability from medium altitude. While air-to-air tactics advanced significantly during this period, air-to-surface tactics generally emphasized mass and concentration of force. The unique requirements of that environment were not conducive to tactical development in the area of surprise and flexibility.

Contrast this to the environment for which we are training now. Entry level requirements for the next conflict will probably peg the needle on our old one- to-ten scale. Gone are the resources to indoctrinate crews in the course of battle, and the flexibility to progress less experienced crews through less demanding combat missions. One can conclude that the demands of our next engagement will in all probability exceed the level of training expertise developed from combat experience in Southeast Asia.

A perceptive fighter pilot once said that when the demands of the dynamic battle arena transcend the scope of the training environment or platitudes of the briefing room, it is the fighter pilot's instinct which sustains the greater need.

The instincts to which our profound friend was referring are those qualities which allow us to respond to the demands of dynamic and unpredictable situation. In that dynamic environment we must be able to exercise, to the limit of our own capability, the inherent flexibility of our fighter aircraft.

Again we hear the skeptic: "What the hell are you guys talking about? Instincts, flexibility, dynamic environments - give me something I can put a fork into. I can't grade a guy on instincts and flexibility." True enough. So, let's bring this discussion back to sea level. There are two basic qualities that are fundamental to the complete development of an individual's capabilities. These are discipline and awareness. Discipline comes in many forms. All of us can remember being glued to some gruff IP's wing, squeezing a bubble out of the top of the stick with a vice-like grip, sweating bullets, and being totally oblivious to anything in the universe beyond the relationship of light in the star. This type of chin in, shoulders back discipline is, of course, basic to those skills which must become second nature.

The next level of discipline was acquired when, as wingmen, we were assigned responsibilities commensurate with some mission-oriented goal. Under the precepts by which most of us were taught, this was a very perplexing transition. We were given visual and radar lookout responsibilities but were told, "All I want to hear out of you is two, roger, or mayday." In many cases the wingman was never given the opportunity to develop beyond the bounds of basic disciplines.

In today's environment the responsibilities assigned to a wingman are very nearly equal to those of his leader. With less plentiful resources and a greater threat, comes the need to employ maneuverable formations and a trend toward the basic two-ship fighting element. Each assigned responsibility within the two-ship is crucial. The disciplines involved with coordination of cockpit-oriented duties and responsibilities outside the

cockpit are essential to survival and target destruction.

Let us reflect on the development of these qualities, specifically for the F-4. Notice the impact of higher order disciplines and awareness on the crew concept: Coordination of duties in and out of the cockpit, reading flight paths, mutual support, etc. Although free use of the term "fighter pilot" has been evident throughout this text, a great portion of the implied responsibilities falls to the fighter pilot occupying the rear cockpit. Where does the WSO stand in the front seat-oriented training environment of today? What opportunities does he have to develop his own tactical skills, and how do the attitudes of front and backseat combine to develop combat capability?

Throughout the history of the F-4 in the Air Force, conflict has shrouded the role of those who occupy the rear cockpit. They have been conceded stick time, or control of the radio, and generally patronized to identify with the role of the front-seater. An honest evaluation of the problem would reveal that present training offers little in the way of training beyond basic equipment operation. Those qualities of discipline and awareness unique to the rear cockpit, and vital to effective employment, are often left for the WSO to learn for himself. If we accept the time-honored precept that the words "fighter pilot" are synonymous with attitude and not an AFSC, it follows that attitude is the requirement for combat capability, regardless of which chair is being discussed.

In the pages that follow, we will see that the tactical situations which require the highest degree of WSO capability are also the most critical for combat capability.

Finally we must address the combination of discipline and awareness. They grow simultaneously through simple, self-initiated challenges practiced daily. Disciplines such as switchology (practice quick transition from AIM- 7 to AIM-9/gun or maverick to air-to-air) and precise visual patterns go hand-in-hand with awareness built by daily employment of tactical formations, radio silent turns, etc. The WSO participates by learning techniques to efficiently coordinate radar and visual search responsibilities, stab-out radar lock, and so forth. Some of these exercises and techniques are detailed on later sections. WSOs develop those instinctive, instantaneous actions and reactions, and brief efficient crew coordination techniques which are basic to survival and target destruction in the multi-bogey/target, high- threat environment.

THE GIB AND THE F-4

Captain Bob Pratt
USAF Fighter Weapons Review
Summer 1977

The F-4 is a two-seat fighter aircraft that has proven itself in just about every imaginable tactical situation. It has performed the role of the Striker, Protector, MiG Killer, Forward Air Controller, Wild Weasel, and even Loran Pathfinder for SAC's B-52's. It is truly a fighter aircraft. In my mind, the guys who fly it are, by definition, "Fighter Pilots". When discussing the "guy-in-the-back" and his job, this concept of all of us being Fighter Pilots (even if you don't wear aviator wings) will not be forgotten by me. I'm a GIB and a Fighter Pilot - proud of both.

In the 18th TFW, the job handled by the GIB can be categorized into three main areas: general responsibilities, responsibilities in an air-to-ground environment, and responsibilities in the air-to-air arena. Throughout all of these, there are two guys in the aircraft: one who manipulates the Machine and one who assists in any way he can. With this in mind, let's discuss each area separately.

GENERAL RESPONSIBILITIES

For all of us Fighter Pilots, the one-to-two hours we actually spend airborne on each mission certainly don't represent all we really do. Most days are very long: We spend a lot of time on additional duties, squadron meetings, projects, flight preparation, and hopefully, study. I say hopefully, because I know that too often there doesn't seem to be any time left. But mental preparation is absolutely necessary when it comes to actual flying. Both guys have to know their Machines, the tactical options, the ordnance available, and how to integrate these to achieve success. Without the "know-how", you're not going to RTB every time you take off; that is a fact. The point is: to be a truly good GIB requires hours and hours of self-motivated study. Why not start now instead of waiting for the eve of a war? You may be too late by then.

With or without study, we all find ourselves scheduled to fly, usually on a fairly regular basis. Having been scheduled, it's now your responsibility as the GIB to coordinate for a smooth briefing and challenging mission. You do this by insuring that the weather forecast is obtained, charts, and Forms 70 are prepared, flight plans are filed, and a myriad of other tasks are completed. Finally, and this is the biggie, you should seek out your AC or the flight lead if you're not lead GIB, and ask, "What can I do to add to the planning and the briefing?" Too many times I've heard GIBs unassertively waddle through a very dry, unorganized, delta sierra briefing that, to me, obviously originated with zero planning and little knowledge. This is unacceptable for a Fighter Pilot; just ask any flight lead. What I'm saying is really very simple. First, you must seek out (and sometimes fight for) the responsibility you want, study and plan for it, and then stand up with the authority that comes from knowing you're prepared and deliver it to your fellow Fighter Pilots. You won't always have it all together, but at least you're functioning. With a little practice, you'll be controlling your own destiny.

OK, we made it through the briefing and now it's time to go to the Machine. Before you ever get "wheels in the well", you have to know the "N.S." status of your war Machine and its systems. This means BIT Checks. If you don't have them memorized, you don't know your job. If you don't understand them then you've already busted the big ORI in the sky; namely, combat. Just like your buddy in the front seat who does flight control check, you have to do yours with the same degree of professionalism. After all, you're a Fighter Pilot too!

Once airborne, the general responsibilities of a GIB revolve around the premise: one guy flies; the other assists. Even if you're not lead GIB, you should be providing navigation info to your driver. If you don't believe me, try flying a couple of legs of a route and instruct your AC not to tell you anything about position; then see how you feel. At the same time, try doing all the channel changes on the UHF yourself. It's no fun and it's not being part of a team. One guy flies and the other assists, and that means anticipating what's about to happen before it happens. If you're behind the aircraft for an entire flight, you haven't properly prepared to fly.

There are other general anticipation occurrences that become shared responsibilities between AC and GIB; e.g., what about flight assistance? Even though your AC bites the accident board bullet for stalling out in the final turn, you may bite a bigger bullet and make you wife a thousandaire - posthumously!! This goes hand-in-hand with situational awareness; e.g., RAPCON vectors you to 240º and your AC turns to 140º. Are you going to sit there and wait for him or RAPCON to figure out the mistake? I hope not.

All of these responsibilities, if accepted and responded to, will make that smooth, efficient briefing into a smooth, productive flight. But, the Fighter Pilot's job is not done yet. If a system malfunction was noted during preflight or inflight, then it's your responsibility to perform postflight checks on these systems. How many WCS technicians think we're a bunch of dummies because of all the CND write-ups we produce? Also, how many of you know your WCS technicians? We can save them a lot of work and ourselves a lot of pride by re-accomplishing faulty BITs. Reconfirm the discrepancy before you shut down the aircraft. The previous problem could have been a cold radar system or just water in the system somewhere. Some of our eccentric radar sets have the habit of repairing themselves inflight. If you have a N.S. write-up, then how about spending a little time writing a legible account of the discrepancy? If you don't, then your buddies get attacked with the same bird you had with the same discrepancy. Believe it or not, your flight still isn't over until you've completed a thorough debriefing. Every GIB worth his salt should ask, "What can I add?" when the flight is regrouped in the briefing room. We often jokingly refer to our Wing as a "Tactical Training Wing", but in reality, it's no joke at all. Even if we were placed in combat tomorrow, we would still be training. More can be learned during a debriefing than in any other phase of flying if the participants will only participate -that means ACs and GIBs alike. Remember, we're both Fighter Pilots.

RESPONSIBILITIES IN THE AIR-TO-GROUND ENVIRONMENT

I've spent a lot of time talking in a general sense about the GIB's responsibilities. They all hold true for the specific tactical situations of air-to-ground or air-to-air combat. However, in a tactical situation, many of the responsibilities already mentioned become extremely critical; hence, more demanding tasks arise for the GIB. To some of you, "air-to-mud" may sound like the other squadron's job, or, "That doesn't apply to me". But, once into combat or even in some training situations, you may find yourself thrust into an air-to-ground role. This may be in the form of Pave Spike, Maverick, SCAR, Wild Weasel, etc., etc. While considering the following points, I ask that you apply the general responsibilities already discussed. Think of these before you "cross the fence".

In terms of navigation, air-to-ground dedicated flights are presented with some additional requirements. Often a TOT is assigned, due to total force integration. This makes the lead crew responsible for keeping ahead of their timing objective. It's also incumbent upon all other crews in the strike flight to provide help to the lead crew, should he experience navigational difficulties. (There have been embarrassing instances of a strike force commander leading a 16-ship strike force, plus Weasel support, plus MiG CAP into the wrong Pack Six target during the Viet Nam War). These navigational errors cost lives in times of combat.

As the GIB, you must insure that the TOT is met - or face the consequences of conflicting times on target and/or loss of integrated defensive aids such as MiG CAP, Wild Weasel, Stand-Off Jamming, etc. At first glance, this additional requirement may seem insignificant to many. After all, "it's easy to make a TOT". But, combine with the specified TOT the requirement to be at 50 to 100 feet AGL (avoiding enemy defenses), 420+ on the airspeed—and the job of "time keeper" suddenly becomes difficult. You must also act as a "talking map" to aid your AC. He cannot look down at a map while flying this low and fast. Add to this the confusion and apprehension experienced when ground fire is observed or reported, and you've progressed from "sheer boredom" to the other end of the spectrum: Pure Hell. Can you hack it?

In the target area, the GIB must again be assisting. If you haven't learned how to get winds off the BDHI and INS, then you should. It may preclude another trip over the same target area. If you can't tell what 45º (or 35º, 15º, or 10º is in a dive bomb pass, then it's time to learn. On-the-spot analysis can make or break your whole day. If you've never looked outside while charging down the chute, then you should. That 3/8 undercast you see may not be clouds at all, but instead—AAA airbursts. If you've never had to take an aircraft away from a totally disoriented AC

at night while being shot at, then you're luckier than I - or are you? All I can say is, "Have it together", no matter what the mission is- no matter what the threat. That's what's expected of every Fighter Pilot.

RESPONSIBILITIES IN THE AIR-TO-AIR ENVIRONMENT

Generally speaking, air-to-air combat isn't that much different from the air-to-ground arena. An axiom that applies to both is revealed in a single word: participate. The GIB who strives for knowledge then plans, then acts, will be rewarded with success.

Any aircrew sent aloft on an air-to-air sortie has been chartered with an objective: "Protect the Force—Kill the MiGs". Step one in achieving this goal is to understand the enemy. That means "hit the books". You must know your Machine versus his, tactics versus his, your armament versus his, etc. When engaging the enemy, you must be first with a tally. For our sophisticated systems this means to me that you must have the first contact. How well you do this depends on your knowledge of the F-4's total fire control system and how well you can employ it. Hopefully, you will have many aids such as GCI-initiated bandit calls or even GCI close-control; but you'll never have a better aid than that already with you: your eyes, ears, and brain. Program them; exercise them; and use them.

Now that you've located the enemy, where are you in relation to him. Formulate a plan for approaching him in the most advantageous way. You must employ your tactics as unpredictably as possible, to place your aircraft at a point in space where the AC can bring ordnance to bear upon the enemy. This requires that you, the GIB, be totally up-to-speed on intercept geometry, current tactics, your ordnance limitations, and that you be proficient in communications with your AC and other flight members. At the same time, you must be checking six and insure that switchology is correct for the ordnance employed.

Once visually engaged, your primary job again is assistance. This will include telling your AC where #2 is, achieving a bore-sight lock-on because auto-acquisition doesn't work (indicated in the BITs), monitoring fuel consumption, monitoring navigation, and anticipating a combat separation. With the separation, your job has not yet ended. You must continue to check you own (and the flight's) six o'clock. If you ever wanted responsibility, you have it now! Only you can see the 5 to 7 o'clock area— this is the most vulnerable. Uncage your eyeballs and look around. Longevity is a beautiful thing. To beat the enemy, you have to see him first. Don't forget the old adage: "Lose sight, lose fight".

SUMMARY

Any time a Fighter Pilot starts talking about responsibilities, he invariably comes up with a long list of perishable items, and I've certainly done that. For what it's worth, this hasn't been intended as sermon or a warning. You GIBs have, and are getting more each day, your stuff together. This is good because it means that fewer of you will perish or become POWs on our next encounter. It's no pretty thing to watch you friend go down in combat - that privilege should be reserved for the enemy.

If you have the desire to be a good GIB and Fighter Pilot, you have to be a professional; you have to want to be a professional. You belong to the best—an operational fighter squadron. There is no greater organization in the Air Force, and you have to work to stay there. Have pride in yourself and your job. Become involved in the mission. Without involvement, there can be no professionalism.

A professional is being one of the finest. All else is rubbish. This is an acquired attitude and one willed to us by our predecessors. It comprises not only what I've mentioned, but an entire way of life. It requires infinite dedication. For some of us, this profession is a means—for others, an end. Whatever your motives, it's one of your choosing. Although this may sound trite, a fighter squadron cannot function as a unit without professionalism.

In closing, I want to recapitulate in few short statements my feelings on what make a good GIB. You must:

(1) Be prepared—know your job

(2) Anticipate

(3) Participate

REMEMBER WHAT YOU ARE: A "FIGHTER PILOT"!!

THE ENEMY IS A MAN WHO.....

Captain Nelson (Ed) Cobliegh
USAF Fighter Weapons Review
Fall 1976

"The enemy is a man who will try to kill you before you see him." That statement is as true now as it was in 1918. That enemy now has more ways to accomplish his sinister task than he did in the days of a Mauser firing through the airscrew. in this article, written originally for the Royal Air Force, I will try to increase your knowledge on how to see that man before he sees you. I'll use as my sample aircraft the Anglo-French Jaguar, but the techniques are valid for the crew of any aerospace vehicle.

The limited maneuvering potential of a heavily-laden Jaguar against a airborne threat requires that the threat be sighted visually at long range if the Jaguar and its pilot are to survive. We will consider the VMC case first, as it is under these conditions that visual search techniques are the most vital. Most clear-air-mass interceptors must position themselves in their intended target's rear hemisphere to deliver their ordnance. If the interceptor is sighted at a sufficiently long range, even a fully-laden Jaguar can turn enough to spoil the interceptor's attack geometry and place the enemy pilot outside his ordnance parameters. Even if the fighter first appears in Jaguar's six o'clock, an early sighting may allow the Jaguar pilot to turn and/or extend the range to outside the lethal. Avoidance of surface-to-air missiles (SAMs) also depends on early visual pickup of the airborne missile. The Jaguar pilot must watch the missile's flight long enough to determine its characteristics and plan a maneuver that will defeat the missile in its terminal guidance stage. To do this, the Jaguar pilot must see the missile at long range. Early visual sighting of airborne threats, missile or manned, is not dependant on a special knack or freak eyesight, but is a technique that can be learned and polished with the application of knowledge and with constant practice.

VISUAL SEARCH TECHNIQUES

An aeroplane seen at long range appears not as an identifiable shape but rather as a dark dot, moving against the background. It is this motion of the dot against the background that most often alerts the eye that there is something there. For this relative motion to be apparent, the eye's gaze must be fixed. An airman's most common mistake is to constantly scan the whole area. This is an almost sure way not to see the relative motion of a tiny speck but only to recognize a threat when it takes a familiar shape, that of an aeroplane or missile.

Instead of constantly scanning, divide the area to be searched up into sectors, about 30º each. Fix your gaze in that sector for a second or two. Investigate any movement in that sector, then move on to the adjacent sector.

If left to themselves, your eyes will focus themselves on a point about 6 to 20 feet outside your cockpit, definitely too late to acquire a threat! Focus on something in each sector searched at about the maximum range you expect to acquire a threat, about 3 to 7 NM, then search that sector. Each change of sector can require a re-focus. This problem is minimal when looking at the ground as a background; it is acute when looking at the sky. When the sky is an all-over deep blue, the lack of focus problem is at its worst. This is what baseball players call a "high sky". Focus on the ground at an appropriate range, then move your gaze up to the sector of sky to be searched. If clouds are present, focus on one, then move to the blue. Do not look in the cockpit and then attempt to search the sky; your eyes will still be focused at the distance of the instrument panel.

If your kite has two bodies in it, divide the area to be searched. Each bloke should then scan his area of responsibility. The areas should overlap somewhat to avoid blind spots. Once a threat is seen, the chap with the contact should use a standard bogey call (left or right, clock position, elevation, range, and remarks) to put the other man's eyes on the bogey. In extreme circumstances the chap sighted can take control of the aeroplane and point the pitot probe at the bogey. In formation, also divide up the area to be searched between wingmen, but with rather more overlap between air machines. There are as many search schemes as there are searchers; just ensure that yours gives complete coverage. When making bogey call on the R/T to another kite, use the clock code relative to the chap you're calling. Tell him where to look from his aeroplane, not yours.

A common mistake is to look too high at too long a range. Scanning 45 degrees at 7 miles would place a bogey 30,000 feet above you. If an interceptor spots you at low level from FL300, it just isn't your day.

USE OF EQUIPMENT

Not only must you look in the proper manner, you must use your equipment to best advantage. If you need glasses wear them; you can always remove them for publicity photos. Make sure your glasses are clean. If either is scratched, replace it. If cockpit fogging is recurring problem, waxes are available that will prevent your glasses or visor from misting.

Insure that your helmet fits correctly. No part of the helmet should be visible from inside. Sometimes the structure intrudes on your vision at 12 o'clock high or at the temples. Your friendly safety equipment man and his trusty file can usually cure this. Also, make sure that the helmet fits securely. You don't want it slipping around on your guard during a fast head swivel so that you're looking into your earphone. Keep your shoulder harness unlocked so you can lean forward to turn around, check six o'clock, or look over the canopy sill. If it won't stay locked, some jocks have been known to jam a plastic window wedge or door stop into the go-forward lever to hold out in the unlocked position. The jocks also secure their wedge with string to prevent it getting lost in the cockpit and to yank (excuse the expression) on in the event of a need to lock the harness. This technique, while strictly illegal, is simple, effective, and safe.

Hair hanging in your eyes can constitute both an irritant and an obstruction. It is almost impossible to stow loose strands without removing your helmet. So get a haircut. Besides, your commander will love it.

Seat height adjustment is a compromise between visibility over the canopy sill and visibility directly overhead. You should be able to tilt your head back to look above. The highest seat position that allows this is usually the best. To be able to tilt your head back, particularly under G, some neck muscle exercise at the base gym will help. The back arch maneuver, rolling you bean from side to side, is very effective for strengthening the check-six muscles. Whether at six o'clock or not, once a speck that may be a threat is seen, never take your eyes from it for any reason. Identify it before looking elsewhere. This is called being "padlocked". To keep track of a bogey, and look around, take your eyes from the bogey when it is near some feature that will guide your eye back to it, like a cloud or ground feature. Also note the bogey's movement. To re-acquire the bogey, find the feature or cloud, then look in the direction of the bogey's last movement. If the bogey passes behind some cockpit obstruction such as a canopy post or compass, resist the temptation to focus on the obstruction lest re-acquisition of the bogey be difficult. Likewise, don't read the HUD if the bogey passes in front of the sight glass; re-focusing will then be a problem. If you have trouble focusing at long ranges, try squinting. Squinting compresses the eyeball, changing its focal length and making long-range targets come into focus.

Insist that the hood and windscreen be spotless. You don't want to destroy maneuvering energy turning into a squashed bug. If your hood is covered with a zillion tiny scratches, called "crazing", have your friendly flight line mechanic polish it. Sometimes a tube of toothpaste and a soft rag works wonders. Note to USAF: Use this procedure with caution; some types of canopy (hood) don't take kindly to toothpaste.

If you prefer to wear sunglasses to reduce sun glare and use a clear visor, be advised of the polarizing effect of some sunglasses. Bausch and Lomb "Ray-Ban" glasses seem to produce the most pronounced effect. The polarizing effect of the glasses and the refractory effects of sections of the windscreen can wipe your vision right out. Under the certain lighting conditions such as flying toward a low sun, it may be impossible to see through any section of windscreen composed of two flat parallel surfaces, such as the flat portion directly at 12 o'clock. Under these circumstances, it appears that the windscreen is covered with a rainbow-colored oil. To test your sunglasses, look at the rear window of a Volkswagen in strong sunlight. If a regular pattern of spots appears, you can expect to have your airborne vision degraded under certain lighting conditions.

Conditions in the cockpit also affect your vision. Make sure your rearview mirrors are adjusted properly. Aim them so that some patterns of your aircraft is visible in the mirror for use as a gauge to judge the bogey's size and bearing. The mirrors should cover from five to seven o'clock level to slightly high. If they won't stay in alignment, have the ground crew tighten them. Also, don't store maps on the glare shield; their bright colors break the camouflage pattern of the

aircraft and can reflect onto the inside surface of the windscreen.

WHAT TO LOOK FOR

Now that we know how to look, let us examine some techniques for spotting other aircraft. The easiest bogy to see is the one on the horizon. Look for a dark speck there. Sometimes a smoke trail will be visible. The smoke from a Phantom can be seen 20 to 30 miles under certain lighting conditions. When the reheats are lit, most aircraft erase their smoke, so beware of a smoke trail that suddenly terminates. This means someone has seen something; that "something" might be you. Be advised that you usually only see a smoke trail when you are looking nearby down on it, i.e., when the bogey's track is either toward or away from you. Some interceptors leave a large puff of grey smoke when reheat is selected. At time this can take the form of a short, thick contrail and is a dead giveaway of a bogey's presence.

A low sun, especially in atmospheric haze, makes their smoke trails stand out very well as silhouettes on the horizon. As they said in WW I, "Watch out for the Hun in the sun." To check the area of the sun itself, place your extended thumb over the orb of the sun, then look there (at the sky, not your thumb, twit), don't look into the sun without shielding it as you won't see anything for a few seconds, unable to search properly anywhere at all.

To see a low level target, the interceptor pilot must be below, at, or slightly above the target's altitude. If he is far above, your camouflage is more effective, also, you appear smaller. If he is able to look up to spot you, you aren't low enough. This leaves the area level to slightly high for your maximum search. If the interceptor is above you he can be spotted against the horizon. You can accentuate this by flying tactically down valleys. This may force the interceptor to skylight himself over a ridgeline to get you.

To spot a fighter below you—heaven forbid it should happen—look for movement against the background or a bit of color that does not belong. Non-camouflaged aircraft are easy to spot this way. Once you have padlocked on a bogey, you may still lose sight as he changes his aspect to you. A Starfighter is invisible head-on. The disappearance of a previously seen speck may mean that he has seen you and has pointed his nose toward you.

Many a cowboy has prevented a bushwacking by spotting the sun glint of a rifle barrel in the dry gulch ahead. You may do the same. A glint seen against the sky means that something is definitely there, but, the range may be too far to see the aeroplane itself. A glint seen against the ground is usually sunlight on water, ground fire, or an Indian's rifle barrel.

"Keep your head on a swivel!" This statement is heard so often as to be passé, but it is the most important thing you can do. As we've seen, most lethal ordnance comes from the rear hemisphere—you must check six o'clock. The poor rearward visibility from the Jaguar produces a blind cone at six necessitating that you move the aircraft to effectively see back down your flight path. Small turns, producing a weaving flight path ease your task. A route planned to eliminate long, straight legs and to include frequent, hard turns also protects your six. But however you do it keep on a swivel. Studies and statistics have shown that over 80% of all fighter pilots on both sides in all wars who have been bagged, never see the fighter who gets them. Visual acuity is like sex; the more practice you get, the better you perform. Practice spotting bogeys all the time, no matter what the mission.

ON THE OFFENSIVE

Now we've worked the problem from the viewpoint of the hunted, let's examine the task of the hunter which is more fun anyway. Use of the Jaguar in the air-to-air role demands the addition of some slightly different techniques to sight the target. Practically, you will need to be above the expected flight path of the intended target. Looking down, you will often spot the target's shadow before you see the aircraft itself; this is most likely over the desert, ocean, or other light colored background. To spot the future victim, scan from the shadow toward the sun. The lower the aircraft is, the closer it will be to its shadow. A re-heated target will be easier to see from six o'clock, particularly against a dark background or under low light levels. A re-heat light may mean that your attack has been detected and that the target intends to run.

Under conditions of high humidity, wingtip vortices are generated by high angles of attack at high TAS; while these are probably too indistinct and transitory to be an aid to visual acquisition, they can provide instantaneous indication that a target is turning hard and can provide clues as to the turn radius.

With smoke and/or haze present, remember the saying about the sun and the Huns therein. Your visibility down-sun can be much greater than up-sun. This is even more pronounced when the sun is low on the horizon. Try to be up-sun from the target's expected position and above or directly in the sun from the target's viewpoint. If you are below a low sun on a hazy day, you run the risk of skylighting yourself, especially if your kite is producing a smoke trail. Within hazy clouds, it is possible to follow a smoke trail and intercept its owner if:

(1) You are on the target's exact track and heading when entering IMC.

(2) You are slightly below the target's altitude.

(3) You are in thin stratiform clouds.

(4) You can devote 110% of your attention to following the smoke trail.

(5) The target is a large smokey, non-maneuvering aircraft.

(6) You are fearless.

Now that we're all aces in spotting aeroplanes, we must not forget that aircraft aren't the only objects airborne, must we?

SAMs

Surface-to-air missiles (SAMs) pose a different sort of sighting problem than aircraft. They usually are smaller than aircraft but may be easier to spot. When the missile is launched, a cloud of smoke is usually produced and the missile's booster motor usually leaves smoke trails—this is the time to spot the missile. The rocket exhaust may stir up a cloud of dust, particularly on dry terrain; that makes the launch even easier to see. If there is no dust because the launch site is foliated, the white or grey rocket plume may contrast well against the green. The booster rocket trails a flame that is also highly visible. Once the booster burns out, the smoke and flame will diminish, and guidance will begin. Solid fuel sustained engines emit a smoke trail that varies with the type of missile. It will range from a thick white that is highly visible to a thin grey that is harder to see.

The rocket flame itself will still be visible after booster burn-out, though smaller. Liquid fuel missiles emit very little smoke or flame and can be difficult to spot. Observe the missile's flight path along the smoke trail.

If it is straight or climbing vertically, it probably is not guided and can be disregarded (it says here). If the flight path turns, is "snaky", "wiggly" or corkscrew-shaped, the missile is being guided. A guided SAM attempts to fly a lead pursuit course, holding the target at a constant look angle. This means that the SAM's relative position to the target will not appreciably change; it will remain at about the same spot on the canopy. If you see a smoke trail or brilliant spot of light that remains at the same place on your canopy, prepare to take evasive action. Remember, as most missiles are smaller than their intended victims, your range to the missile will be harder to estimate.

Heat-seeking missiles also fly a lead pursuit course, but these will probably be sighted at such short range that avoidance action is always strongly advised. Air-to-air missiles almost always leave a thick, white trail that is easy to spot. (Editor's note: no longer true!!!) Even after missile motor burnout, the coasting missile leaves a thin, blue or white signature. If you see one at six o'clock—break! Due to the closer rates involved, you have time to spot the smoke trail quite near your aircraft and still break successfully. An air-to-air missile fired head-on is more of a challenge. It will probably be fired at long range and initially leave a straight, thick trail. As the missile fins unlock and guidance begins, the trail will curve. If you see a trail in your front quarter, probably slightly high, that has short, straight segment followed by hook toward your route of flight, look out! This is the sort of challenge most blokes can do without.

AAA

Anti-aircraft artillery (AAA) fire is also a challenge to spot. There are three regions where AAA fire can be spotted: At the gun barrel, in flight, and the airburst. Most guns produce a visible flash. Small-bore rapid fire flashes look like twinkling sparklers on the ground, the intensity of which varies from type-to-type. This is easiest to spot when the gun barrel is pointed directly at you. Larger guns make larger, slower-rate flashes that can often be seen from the side. As most AAA sites are heavily camouflaged, the muzzle twinkles or flashes are often the only aid to visual identification of the site itself. Some guns produce a thin puff of blue-grey smoke but this is usually too light to see, quickly disperses, and is not a reliable AAA site marker. The bullet stream may or may not contain tracer rounds. Radar-armed guns tend not to use tracers, while small and medium-bore pieces that are visually-laid

almost always shoot a certain percentage (10 to 25%) of tracers. As the tracer element is in the aft end of the shell, tracers are easiest to see when they are going away from you, which is when you need to see them least. Big-bore tracers can be seen from the side and, under low light levels, head-on. In the daytime you probably won't see the tracers until it is too late to avoid that particular burst. However, by watching the tracers, it will be obvious whether or not you need to take evasive action to foil the next burst. It is difficult to follow the tracers back to their source due to their ignition delay (if any) and their rate of movement, but it is possible if the lighting is dim and the burst is well aimed. At dawn, dusk, or night, if you are flying directly at the gun, you can get the visual sensation that you are flying down a tunnel, the walls of which are made up of tracers. You may be hesitant to turn in fear of hitting the "wall". Break yourself of this habit as what you are flying in is not a hollow tunnel, but a solid stream. For every tracer round that you see, there are many other non-tracers you don't see. Better yet, break yourself of the habit of flying directly at guns.

Tracers often look like flying golf balls, colored red, yellow, or white (for whatever that's worth). The airbursts of AAA are a tip-off of the gunner's accuracy. Small automatic weapons produce no airburst. Medium size guns don't use proximity fuzes, so the airburst represents the maximum range. If the burst is between you and the gun, you are out of range of that gun. The bursts themselves look like cotton balls and range in color from white through grey to black. Large bursts may mark radar fuzes; note if the altitude of the bursts changes as you change your height.

NIGHT FLYING

By now some chap is no doubt asking, "What about night flying?" What about night flying, indeed?

The techniques for visual acquisition of threats change radically at night, mainly because it is dark. Adding to the problem is the difficulty of proving or disproving night vision techniques, i.e., "I didn't see any thing I didn't see."

Due to the low ambient light levels, different parts of your eyes are used at night and notice must be taken of this fact. Light-sensitive cells on your retina, called "rods", provide night vision. Rods function slightly different from the "cones" that your eyes use in bright light. The rods contain much higher percentages of "visual purple" (sounds like a rock group), the chemical that reacts with light to trigger nerve impulses. Visual purple is extremely sensitive to a lack of oxygen; this is what causes grey-out under "G" loading. Also, the rods are blind to colors, especially red. This is why all cats are grey at night. With this in mind, let's see how to improve night vision.

Anything that causes a lack of oxygen in the blood will degrade night vision. Altitude is the chief culprit. With air mix selected on the regulator, any altitude at all reduces the amount of oxygen available to the visual purple. This effect is unnoticeable in the daytime but significant at night. Some researchers have found that a cabin altitude of 8,000' with air mix selected, can degrade you night vision by 20%. So, use 100% at night. The duration of Jaguar missions offers no threat of oxygen poisoning. Just remember to clear your ears frequently after landing to purge dissolved oxygen in the inner ear. Also, cockpit fumes, a heavy smoking habit, or a hangover, can cause degradation of your night vision due to mild histozoic hypoxia (oxygen deficiency). Therefore, no smoking before a night sortie. Attempts to artificially increase the quantity of visual purple are probably ineffective. The massive doses of vitamin A (50,000 units or more) taken by some night owls are usually a waste of time and come under the heading of self-medication, which is a no-no. A balanced diet with lots of yellow veggies like carrots or squash (yum-yum) will provide vitamin A. If, on the other hand, you survive solely on fish and chips, better see the doc about some vitamins.

Strong light can render your rods insensitive. A day spent on strong light, as on the beach or ski slopes, without sunglasses, can wipe out your night vision for as long as a week. So, when night flying is unavoidable, keep your shades on outside.

Acquiring night vision can take one-half hour after your eyes enter the dark and the sensitivity can be ruined by one bright light. So, stay in the dark for at least an hour before takeoff. Sometimes it is not possible to black out operations, so consider wearing red goggles until strap-in. Motorcycle goggles with red lenses will do. These will get you some laughs in the crew-room, but the mates will wrap up when you see the target and they don't. An alternative if extensive night flying is anticipated, is to change all the squadron light bulbs to red. If no red bulbs are available, red cellophane over tube fixtures and red nail

polish (the shade is unimportant) on light bulbs works well.

There's no sense in acquiring night vision in the crew-room and losing it on the pan. Floodlights should be off unless needed for servicing the kites. If the hardstand is lighted, red goggles should be worn. For the same reason, don't shine your taxi light in some other bloke's cockpit and don't watch your wingman's re-heat plume when he rolls. Protect your vision in the cockpit. Start with your cockpit lighting set at a dim, but comfortable, setting. As your eyes night-adapt, turn the lights down as far as possible. Turn all non-essential lights off. Cockpit lighting can bug you in two ways: by affecting your night vision and by obstructing your view as it reflects on the inside of the canopy. While doing serious night work, it is possible to mount the wander lamp so it shines, with red light and a low level set, on the attitude indicator and flight instruments turning all other lights off. This allows a totally blacked out cockpit. Some cockpit lights can't be dimmed sufficiently or at all. A possible solution is to tape over offending lights. Paper tape, such as masking tape, will dim the lights such that they can still be seen. For completely useless lights, black cloth tape will eliminate their shine. As a rule, the darker the cockpit, the more you'll see outside. Dim the HUD as much as practicable, and turn off the other light on the windscreen such as the E2B compass and "G" meter.

Acquiring sight of threats is both easier and harder ar night. AAA muzzle flashes and airbursts are much easier to see. Tracers can usually be seen at all aspects to the bullet path. AAA is so easy to see that the tendency is to overreact. Use the intercept principle - if it's motionless on the canopy, watch out. Otherwise, relax and enjoy the fireworks. Something not to be enjoyed are other aircraft; they will be invisible unless in re-heat. Sometimes it is possible to judge an aeroplane's aspect by the perceived shape of the re-heat, but be careful of making predictions on apparent motion. Only one thing is certain: If the light is stationary on the canopy, the threat is either headed directly for you (bad) or directly away (good). Missiles are a mixture of good and bad. During the booster phase they will be very visible, with yellow-white flame trails. After missile motor burn-out, they will be invisible, except from the missile's six o'clock. During the coast phase, a missile will have to be negated by ECM or superb sense of timing.

CONCLUSION

As a parting shot, let me say that there is no substitute for practice. The USAF Weapons School some years back flew in a joint exercise with the USN Fighter Weapons School (TOPGUN) and a USN F-8 Crusader unit. The Crusader pilots consistently acquired bogeys at longer ranges than did the USAF Phantom drivers. Was it some special diet the anchor clankers had been eating? No, just constant practice during years spent specializing in the air-to-air role.

The reverse side of the coin is shown by airline pilots, who evidently never look out the window. This is proven by the example they constantly set by running those big mothers into things - like the ground, each other, etc.

By constant practice, applying the techniques listed above, plus others of your own you can:

(1) Increase your combat effectiveness, which, after all, is the bottom line.

(2) Amaze your friends and/or wingman with your eyesight.

(3) Be the hunter, not the hunted.

(4) Keep from being hit by a missile, bullet, or an airliner.

GOOD LUCK AND GOOD HUNTING, CHAPS.

APPENDIX B
OPERATIONAL BREVITY CODES

The following is a list of operational brevity codes for use during combat and daily training flights. They are intended to provide a common set of terms to allow aircrews to communicate the maximum amount of information in the minimum amount of valuable radio transmission time. Needless to say, the more you practice using these terms in day-to-day training flights, the more familiar and comfortable you will be with them when you need them in combat.

Use of the terms listed below is dependent on the following assumptions:

1. This list is not all inclusive.

2. Some words are informative, while others are directive.

3. When a flight lead makes a directive call, the wingman must respond.

4. When a wingman makes a directive call, it is in fact a request, and the flight lead must approve the request before the wingman takes that action.

Code words are organized below by mission type and phase of flight.

GENERAL TERMS

Anchor: Orbit about specified point; also, tanker ground track.

Angels: Thousands of feet.

Alpha check: Request for bearing and range to specified point.

Bandit: Known enemy aircraft.

Bogey: Radar contact with unidentified aircraft.

Chicks: Friendly fighter aircraft.

Stranger: Visual contact with non-participating aircraft.

Tally (number): Visual sighting of enemy (hostile) aircraft.

No Joy: No visual contact with any hostile aircraft; opposite of *tally*.

Visual: Visual contact with friendly aircraft, normally the other members of your flight.

Blind: No visual contact with friendly aircraft, normally the other member of your flight; opposite of *visual*.

Posit: Short for position; question as to where someone or something is, response would be location relative to some common reference point, (other aircraft, georef, etc.)

Bulls-eye: Established reference point from which the position of an aircraft can be determined

Spike (__ o'clock): RWR indication of AI threat, normally followed by clock position.

Mud (__ o'clock): RWR indication of surface-to-air threat, normally followed by clock position.

Padlock: Tally, and cannot take eyes away from bandit due to risk of losing tally.

Gadget: Radar or emitter equipment.

Parrot: IFF transponder.

Bent/Sick: Identified system or equipment is inoperative/degraded.

Joker: Pre-briefed fuel state above *bingo*; significance depends on flight lead; normally used to begin a separation or bug-out.

Bingo: Fuel state where you must begin RTB to arrive home with safe fuel.

Fence (check): The boundary between hostile and friendly ground forces; preparing the aircraft systems for combat.

Knock-it-off: Safety of flight item; some condition requires that the tactical scenario and/or engagement stop. All participants should cease maneuvering, climb up out of low altitude environment (if applicable), and acknowledge the KIO.

Terminate: Term used to direct the routine conclusion of tactical scenario or engagement. All participants must acknowledge.

Check: Directive to examine reference item; no response is required if status is normal.

Squawk ( ): Operate IFF as directed.

ELEMENT MANEUVERS

Cross Turn: A 180º turn reversal by a flight where aircraft turn into each other.

Shackle: A single weave; one crossing of flight paths.

Weave: Continuous crossing of flight paths.

GCI INTERCEPT TERMINOLOGY

With GCI Controller

Bogey Dope: Request for target information.

Broadcast: Type of GCI control where target information is not directed at individual flights or aircraft.

Close Control: Type of GCI control where target information is provided reference to individual aircraft or flights.

Commit(ted): Intent to engage/intercept; weapons controller continues to provide target info.

ID: Directive to identify target.

Merge: Informative that fighters and bandits have merged.

Midnight: Due to loss of GCI systems, only advisory control is available.

Picture: Request to GCI for overall real-time tactical situation.

Playtime: How long can aircraft stay on station.

Judy: Aircrew will take control of intercept. Requires either radar or visual contact with target.

Skip It: Veto fighter commit; followed by further instructions.

Snap (direction): Turn immediately to indicated heading.

Saunter: Fly at best endurance.

Shadow: Follow indicated target.

Threat (Direction): Informative that untargeted bogey is within 10 NM of friendly.

Target Information

Numbers/Formations

Few: Two to four aircraft.

Many: Five or more aircraft.

Group: Radar contacts within 3 NM of each other.

Gorilla: Large force of undetermined numbers and formation.

Box: Groups of aircraft/contacts in box or offset box formation

Champagne: A formation of three distinct groups of aircraft with two groups in front and one group behind.

Element: Two aircraft.

Echelon (Left/Right): Group or formation with wingman displaced 45º back from the leader.

Ladder: Three or more groups in trail.

Line Abreast: Two groups/formations side by side.

Package: Geographically isolated group of targets.

Stinger: Formation with a single aircraft in trail.

Trail: Formation with two or more aircraft following one another.

Trailer: The last aircraft in a formation.

Vic: Three groups or contacts with one in front and the other two following behind side by side.

Wall: Three or more groups/contacts line abreast/side by side.

Wedge: Formation of two or more aircraft with one in front and the others laterally displaced on either side behind the leader's wing line.

Target Altitude/Speed

Weeds: Indicates target(s) very close to the surface.

Very Low: Target is below 300 AGL.

Low: Indicates target(s) below 5,000 feet AGL

Medium: Indicates target(s) between 5,000 AGL and 25,000 MSL

High: Target(s) between 25,000 MSL and 40,000 MSL.

Very High: Target(s) above 40,000 MSL.

Slow: Target Ground Speed (GS) less than 300 kts.

Fast: Target GS above 600 kts (Mach 1 or better).

Target aspect

All these terms will normally be followed by the target's magnetic heading or cardinal direction.

Head: Target with stable aspect greater than 160º.

Flank(er): Target with stable aspect between 120 and 150º.

Beam(er): Target with stable aspect between 70 and 110º.

Drag(er): Target with stable aspect less than 60º.

Shooter: That aircraft primarily responsible to expend ordnance.

Hook (Left/Right): An intercept where both fighters will terminate on the same side of the bandit.

Bracket (Left/Right): Intercept where two fighters will terminate on opposite sides of the bandit. Also used to describe brackets in the vertical.

Deploy: Directive to flight members to assume pre-briefed formation positions.

Crank (Direction): F-Pole maneuver; implies illuminating target at radar gimbal limits.

Post-hole: A rapidly descending spiral.

Pump: Directive to perform a pre-briefed sequential maneuver to stop relative forward motion while maintaining SA on the threat.

INTERFLIGHT TERMS

Acquisition

Most of the following calls will be followed by a position report, to include magnetic bearing, range, and altitude (BRA), or simply clock position if that is all that is available.

Contact: Radar contact.

Paint: APX information

Flash: Another term used for an APX hit.

Locked: Indicates on-board radar is locked to the target.

Broke Lock: Obvious.

Faded: Radar contact lost.

Reno: Breaking out individual radar returns in a formation; normally followed by number of aircraft and type formation.

Sort(ed): Indicates which aircraft in a formation you will target (lock on and shoot).

Hot: Indicates intercept geometry will take you in front of target.

Cold: Intercept geometry will take you behind the target.

Execution Phase

Eyeball: That aircraft with primary responsibility for identifying the target. In scenarios where fighters are cleared to shoot BVR, this term has no significance.

ENGAGEMENT TERMINOLOGY

Sequential Attack

Engaged: Maneuvering with the intent to kill. Assumes tally.

Supporting: Indicates responsibility for maintaining flight path deconfliction and clearing engaged fighter's six o'clock; assumes visual.

Clear(ed): Approval for requested action; also short for "your six is clear"

In (Direction): Commencing attack from the indicated direction; High/low, North/south, etc.

Off (Direction): Terminating attack and extending away from the fight in the indicated direction.

Separate (Direction): Directive to leave the fight in the indicated direction. No information about intent to reengage.

Bug-out (Direction): Directive to permanently leave the fight in indicated direction.

Press: Informative to engaged fighter that supporting fighter has a visual and is in or approaching a position from which he can attack the bandit.

Lag: Informative to engaged fighter that supporting fighter is far from any position from which he can attack the bandit.

Defensive ACM

Break (Direction): Indicates bandit is in a highly threatening position outside gun range, or that a missile is observed.

Hard (Direction): Indicates bandit is in a less threatening position, and that no missile is observed.

Guns Break (Direction): Bandit is a guns threat.

Extend (Direction): Bandit is out of range at six o'clock to the indicated direction.

Switch: Indicates attacker has changed from one target to another.

Sandwich: Situation when an aircraft or element finds itself between opposing aircraft elements.

SHOT CALLS

Apex/Alamo: Training term; simulates launch of enemy all aspect radar guided missile.

Aphid/Archer: Training term; simulates launch of enemy all aspect infrared guided missile.

Fox One: Simulated/actual launch of radar-guided missile.

Fox Two: Simulated/actual launch of Infrared guided missile.

Fox Three: Simulated/actual launch of AMRAAM/Phoenix.

Guns…Guns: A gunshot satisfying tracking criteria.

Snapshot: A gunshot satisfying snapshot criteria.

Kill: Indicates kill criteria have been satisfied.