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**Basic Fighter Manoeuvres
Theory package V1.1**

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Months of preparation, one of those few opportunities, and the judgment of a split second are what makes some pilots an ace, while others think back on what they could have done.
Colonel Gregory 'Pappy' Boyington, USMC

This document is the part of the Operational Conversion series, designed to teach regular Squadron pilots how to improve their skills. The Basic Fighter Manoeuvres package is the starting point for all pilots learning how to dogfight. It takes them through the terms and techniques required to fight and win against another aircraft in the 1v1 Within Visual Range (WVR) arena.





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1 LESSON ONE - THE GEOMETRY OF AIR COMBAT

1.1 INTRODUCTION

In order to become a great fighter pilot, you must perform great Basic Fighter Manoeuvres (BFM). To do this a fighter pilot must understand his positional relationship to the target from three perspectives: positional geometry, attack geometry and the weapons envelope. BFM is designed to teach basic offensive and defensive manoeuvres flown by one aircraft against a single opponent. It covers the basics of 3D manoeuvring with emphasis on spatial relationships and control of airspeed, which is a fancy way of saying that the manoeuvres are intended to keep your opponent out in front of you or, if he is behind you, the manoeuvres are meant to deny him a firing opportunity, or even better, make him overshoot and become defensive. BFM is 1v1 manoeuvring to a desired result.

1.2 POSITIONAL GEOMETRY

Angle-off, range and aspect angle are terms used in BFM discussions to describe the relative advantage or disadvantage that one aircraft has to another.

ANGLE-OFF

Angle-Off is the difference, measured in degrees, between your heading and the bandit's, see Figure 1. This angle provides information about the relative fuselage alignment between the pilot's jet and the bandit's. For example, if the Angle-Off between you and a bandit were 0° , you would be on a parallel heading with the bandit, and the two fuselages would be aligned. If the angle-off were 90° , your fuselage would be perpendicular to the bandit. Angle Off is also known as HCA (Heading Crossing Angle). This is the basic, root form of other, more specific geometry's (Angle Off Tail - AOT, and Angle Off Nose - AON).

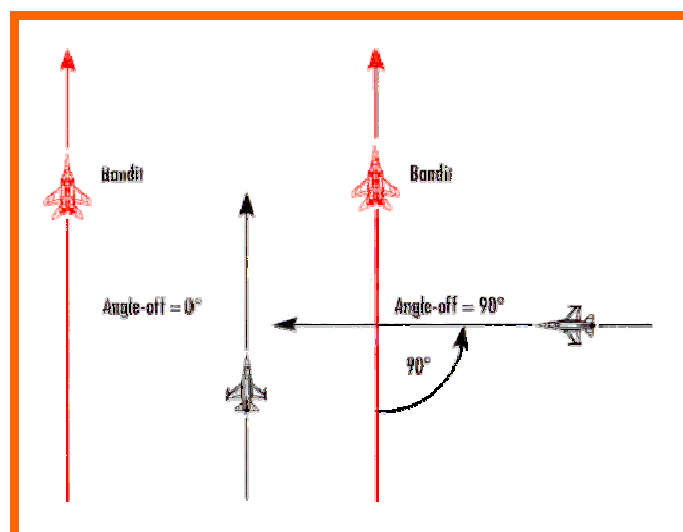


Figure 1 - Angle Off

RANGE

Range is the distance between your jet and the bandit (Figure 2). In most HUDs, range is measured in feet, out to one nautical mile (6,000 feet). Outside one nautical mile, range is measured in miles and tenths of miles. For example, a range to the target of 9,000 feet would be displayed as 1.5 nautical miles.

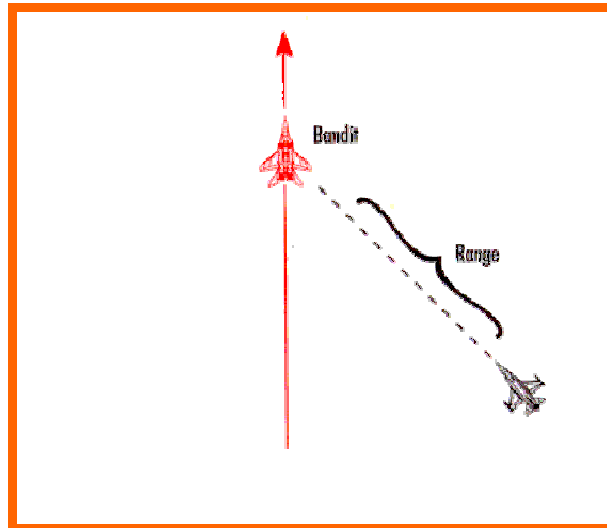


Figure 2 - Range

ASPECT ANGLE

Aspect angle is the number of degrees measured from the tail of a target to your aircraft (Figure 3). Aspect angle is important because it indicates how far away your aircraft is from the target's 6 o'clock position. Aspect angle has NOTHING to do with your heading. Note that the aspect angle stays the same, regardless of which way your aircraft is heading. Aspect angle is determined from the tail of the opposing aircraft. The tail, 6 o'clock position, is 0° . The nose of the Bandit is 180° . If you are on the right side of the bandit, that is right aspect. If you are on the left side, this is left aspect. Aspect angle is important because, if you know the aspect angle and range to the target, you then know his lateral displacement or turning room from the target-and lateral displacement is important in BFM.

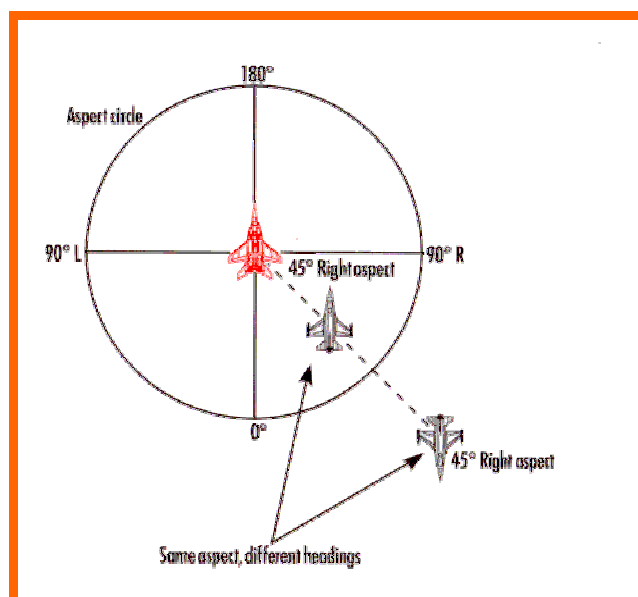


Figure 3 - Aspect Angle

1.3 ATTACK GEOMETRY

Attack Geometry describes your Offensive aircraft's flight path to its target. Very simply, if you are pointing behind your target aircraft, you are in "Lag Pursuit". If you are "Nose On" the target, you are in "Pure Pursuit". And if your nose is pointing in front of the target, you are in "Lead Pursuit", see Figure 4.

LAG PURSUIT

Lag Pursuit is primarily used for approaching the target. It can also be used when a bandit pulls out of plane; that is, when the bandit pulls out of the same plane of flight, or motion, as the attacking aircraft. To fly Lag Pursuit for any extended length of time, you must be able to out turn the target. You must have the ability to out-turn the bandit in order to fly lag pursuit for any length of time. The reason? In order to shoot a missile or the gun at the enemy, you must pull your nose out of lag. If the bandit can turn at a higher rate, he can keep your nose stuck in lag and keep you from shooting him.

PURE PURSUIT

Pure Pursuit is exactly what it sounds like. You keep your nose on the target and fly straight at him. Flying a pure pursuit course all the way into the bandit will lead to an overshoot. For this reason, you should only point at the bandit when you are going to shoot. Use Pure Pursuit for missile shots.

LEAD PURSUIT

Lead pursuit is used to close on the bandit and is also used for gun shots. Flying a lead pursuit course is the fastest way to get to the bandit because you cut him off in the sky. The problem with establishing a lead pursuit course too early is that you will overshoot the bandit when you get in close unless you have a significant turn rate advantage. If you are fighting a similar aircraft, such as the MiG-29, you will not normally be able to stay in lead and will be forced into an overshoot. It is important, however, to establish lead pursuit at the proper time in the fight because it is the only way that you can get into the gun envelope. You may find yourself going from Lag to Lead to Lag to Lead, several times over in some dogfights. This is not desirable. You want to pull your nose on the bandit and shoot him, get it over and done with. This sort of manoeuvring also bleeds speed at a higher rate, which is not a good idea. If you find yourself evenly matched, you may have no choice but to "dance" for a while to line up a good kill shot.

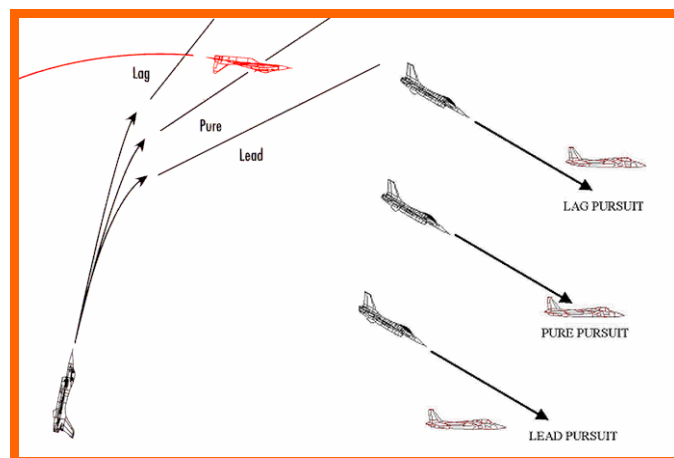


Figure 4 - Pursuit Courses

DETERMINING THE PURSUIT COURSE

There are two positions that the bandit can be in, "In Plane" and "Out of Plane" (Figure 5).

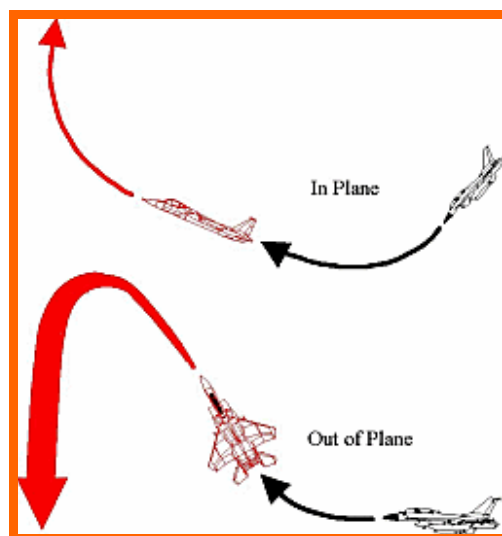


Figure 5 - In and Out of Plane Manoeuvres

In Plane

"In Plane" is where the attacker and the defender are both in the same plane of motion. If the bandit is "In Plane" with your aircraft, the Velocity Vector will determine the pursuit course you are taking (Figure 6).

The Velocity Vector is the direction your aircraft is travelling. For the sake of explanation, this can be determined by the nose of the aircraft. It represents the direction of travel of your aircraft. The Flight Path Marker on your HUD will indicate your Velocity Vector. The velocity vector, for the sake of our discussion, is the nose of the aircraft and represents the direction that your jet travels through the air at any given time. From the cockpit, the velocity vector is depicted by the flight path marker.

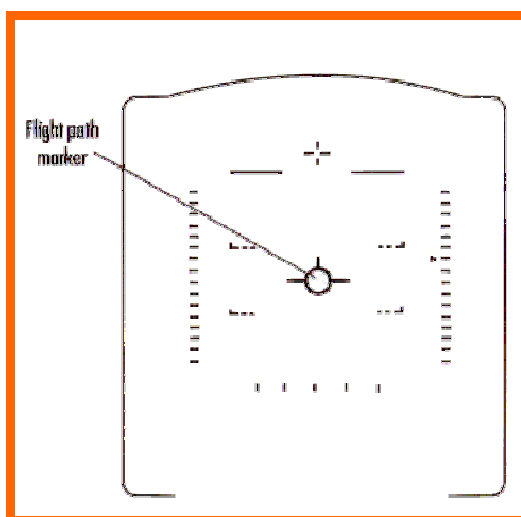


Figure 6 - The Flight Path Marker (FPM)

Out of Plane

If the defender and attacker are not in the same plane of motion, then you are "Out of Plane". To determine the pursuit course during "Out of Plane" manoeuvres, use your "Lift Vector" which is simply a vector pointing out of the top of the aircraft. This is the direction the aircraft moves at high G's. You position your Lift Vector by rolling the jet so that the Lift Vector points in the direction you want to go. The nose of the aircraft will track towards the Lift Vector.

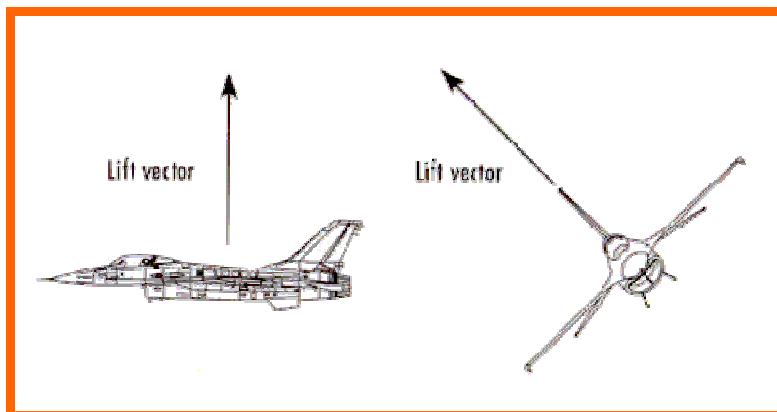


Figure 7 - The Lift Vector

When the attacker pulls out of plane with a bandit, he is, by definition, flying lag pursuit. As he pulls back into a bandit, he may be flying lag, pure or lead pursuit, depending on the geometry of the fight. (The image below does not show a recommended manoeuvre but rather illustrates the effect of out-of-plane manoeuvring on the pursuit course.)

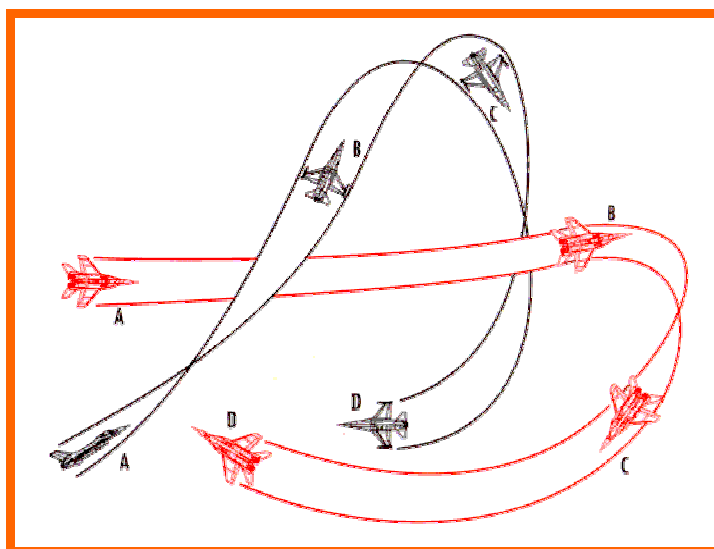


Figure 8 - Out of Plane Manoeuvring

In this image, the F-16 immediately goes to lag pursuit when he pulls his nose out of plane in position B. At the top of this manoeuvre, he initiates a pull back down into the defender at position C. In this position, the F-16 is in pure pursuit. Notice at position D, when the F-16 enters the MiG-29's plane-of-motion, his nose is on the Fulcrum and he is again flying a pure pursuit course.

Where you position the nose of the aircraft is very important when a pilot attacks the bandit. The use of attack pursuit geometry will be explained later on in detail, and we will talk in specific terms about where to place the jet in relationship to the bandit. For now, just make sure you understand what each of the pursuit courses are and what they do for you.

1.4 THE WEAPONS ENVELOPE

The Weapons Envelope is often overlooked as a fundamental and listed in other areas of BFM instruction but if you don't know and understand the Weapons Envelope and how it affects your choice of manoeuvres, you will not be able to make good choices for the next move you should make.

The Weapons Envelope is the area in which your missiles or gun can be effective. It takes into account the weapons maximum and minimum range, weapons capabilities, Aspect Angle, Speed, Angle Off, Relative Headings... Basically, the Weapons Envelope is determined by every possible variable imaginable. The basic shape of a Weapons Envelope is that of an egg shaped doughnut that you impose over the bandit.

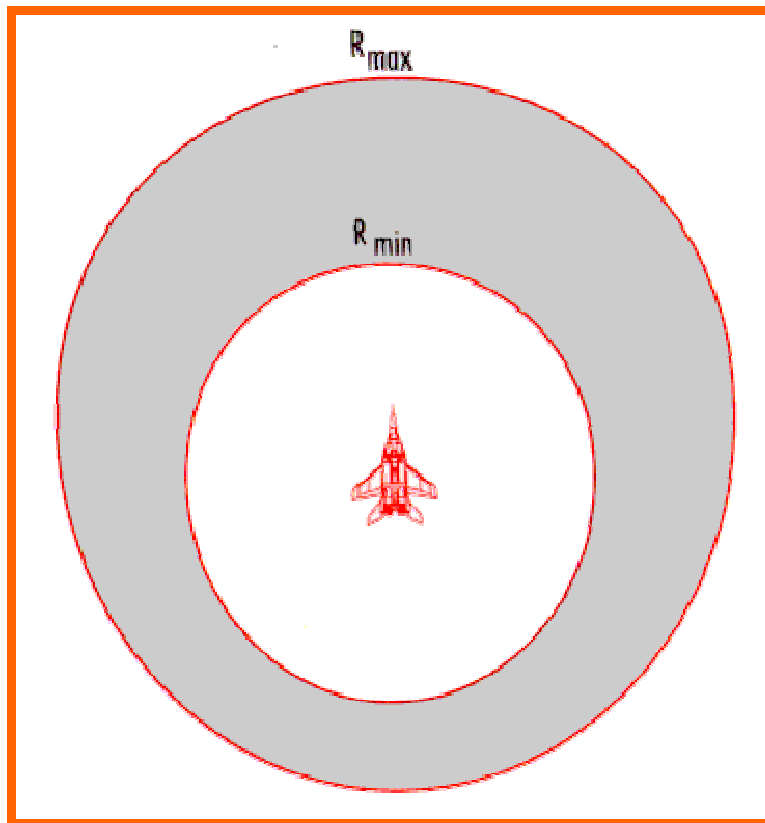


Figure 9- All Aspect Missile Weapons Envelope

RMAX is the maximum effective range and RMIN is the minimum effective range of a particular weapon. Figure 9 is an example of a weapons envelope of an All Aspect missile. A Rear Aspect missile would not have the front lobe of the "egg". As you can see, the effective operating range to the front of the bandit is much larger than the rear area. More of the area is in front of the bandit than behind him because a missile fired at high aspect on a bandit (that is, from in front), has a greater effective range than a missile fired at low-aspect (from behind).

If you shoot a missile head-on at a bandit, the mere fact that the bandit is flying towards you will help the missile reach its target. The missile may actually fly a shorter distance to hit the bandit head-on than if it were fired at the bandit's six. However, the range at which you first launch the missile will be greater, and this is what is important. The farther away you can launch a missile on the bandit and still have that missile be effective, the better. Always strive to get maximum performance out of your weapons. Another way to increase a missile's effective range is to launch at a significantly higher altitude than the bandit. This will give your missile a reserve of potential energy that it can convert into kinetic energy.

As a target pulls G's, the weapons envelope shifts. Generally, the limits of R_{max} and R_{min} in front of the aircraft both move out in the direction of the turn, while R_{max} and R_{min} behind the aircraft move in on the belly side of turn. Figure 10 shows a target in a 5 G turn. The important point to remember is that a bandit that is in fear of dying will turn into you at high G. When this happens, R_{min} expands outward from the target at a rapid rate, and within seconds you may be inside minimum range for a missile shot.

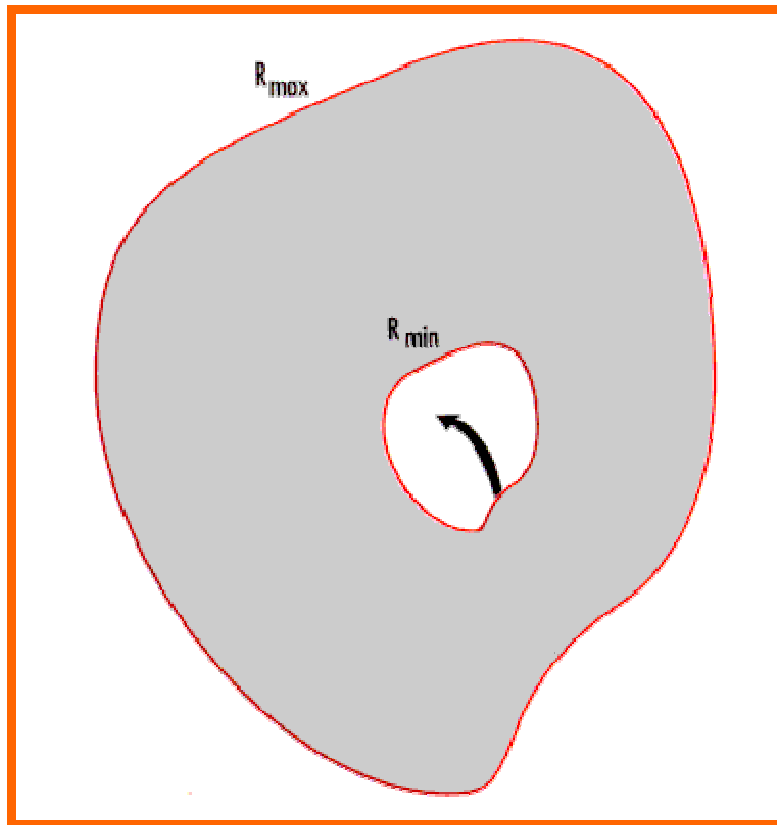


Figure 10 - Weapons Envelope for a Bandit in a 5g Left Hand Turn

The gun is different from missiles in that it has no minimum range and you are close enough to minimize the effect of the bandit's movement for R_{MAX} range, so the "egg" becomes more rounded. You can have your nose half way up the targets tailpipe and still shoot guns but the problem here is that you may end up killing yourself as pieces of your opponent start coming off and hitting your aircraft, so beware just how close you get before you take the shot.



LESSON 2 - OFFENSIVE BFM

2.1 INTRODUCTION

The ultimate goal of offensive BFM is to kill the bandit in the minimum amount of time. In order to accomplish this goal, the fighter pilot must understand basic offensive maneuvering. It is helpful to think of offensive BFM as a series of fluid rolls, turns and accelerations. Some of the maneuvers in offensive BFM have names, but the modern day fighter pilot thinks in terms of driving his jet into the control position from an offensive setup, rather than in terms of executing a series of named "moves" to counter the bandit's defensive maneuvering. The sustained maneuverability of a modern fighter has made a "move-counter-move" discussion of offensive BFM obsolete.

You need to keep your manoeuvres smooth and graceful. Sudden jerks, quick directional changes, and basic rough handling of the aircraft will cause loss of energy, speed and attitude (both of the aircraft and your mental attitude when all your fancy moves makes you a wallowing, low speed pig, ripe for the kill by your opponent).

It may seem obvious, but the primary reason that you need offensive BFM techniques is to counter a bandit's turn. When you are behind a bandit who is flying straight and level, it is a simple matter to control your airspeed with the throttle and fly around behind him. When the bandit turns, however, things change dramatically. A turning bandit will immediately create BFM problems.

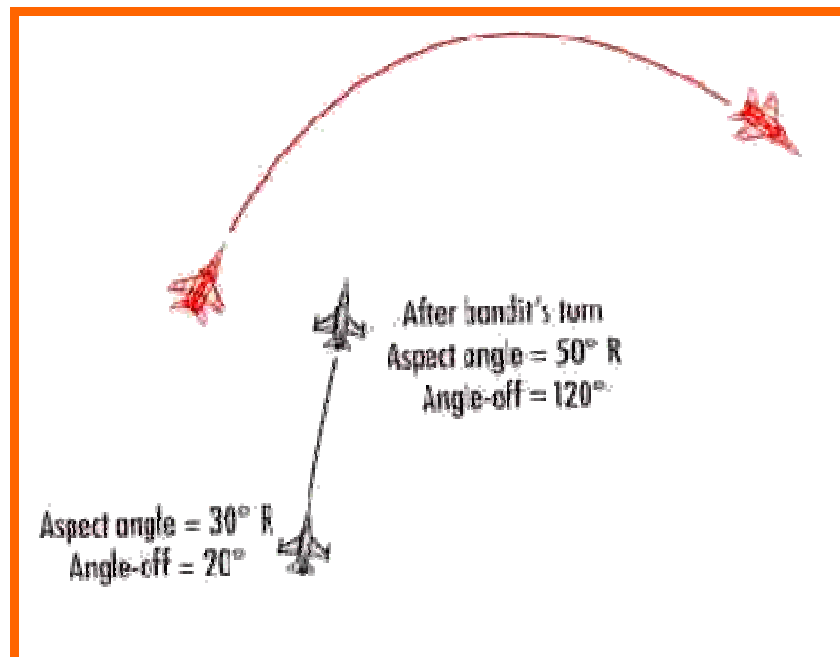


Figure 11 - Bandit Creates BFM Problems by Turning

In order to stay in weapons parameters and in control of the bandit, you must stay at his 6 o'clock. To do this, you must maintain control of angle-off, range and aspect angle. Remember these terms defined the angular relationship between two aircraft. Figure 11 shows how a bandit's turn will change the angular relationship between the offensive and defensive fighter. To control the "angles" and stay at 6 o'clock, the offensive fighter must also turn his jet (this is also known as "flying to the elbow").

Figure 12 shows why an immediate turn by the offensive fighter will not work. If the offensive fighter goes into a turn to match the defensive fighter, he will just end up out in front because the centre of there turn circles are offset.

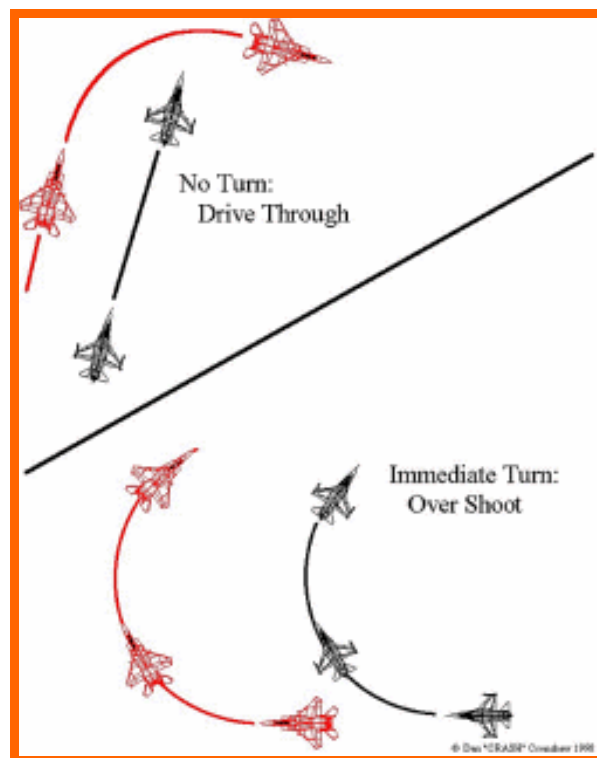


Figure 12 – An Immediate Turn Creates an Overshoot

An immediate turn will not work, and driving straight will not work. A turn of some sort is the solution to solving the BFM problems of angle-off, aspect angle and range caused by the bandit's defensive turn. The problem is twofold-how to turn and when to turn. Let's look first at the mechanics of turns.

2.2 BFM AND TURNS

BFM has a lot to do with turns. Turn performance is the ability of an aircraft to change the direction of its motion in flight. This direction is defined by the velocity vector, which may be visualized as an arrow pointing in the direction of aircraft motion. It is important to understand several concepts about turns in order to be successful at BFM. These include the concepts of positional energy, turn radius, turn rate, corner velocity, vertical turns, instantaneous and sustained performance.

ENERGY

There are two types of energy in air combat manoeuvring: kinetic and potential. Kinetic energy is directly related to the speed or velocity that the aircraft is travelling. Potential energy is "stored" energy available for use. This does not mean stored like in batteries. Potential energy is directly proportional to the altitude of the aircraft. At high altitude, the aircraft has a HIGH potential energy, while at low altitude, the potential energy is LOW.

The easiest way to explain this is to visualise a jet at 30,000 feet. This pilot has the option to put the jet into a dive, thus increasing his airspeed. The higher he is flying, the more speed he can generate in a dive. An aircraft at low altitude of 5,000 feet has much less room to increase speed in a dive. Always remember: you can trade altitude (potential energy) for speed.

Likewise you can trade speed for potential energy. If you have one, you have the ability to gain the other when you need it. You can also trade energy for nose position but remember, manoeuvring costs energy, and will cause your aircraft to slow down and lose energy. The higher the G pulled in a manoeuvre, the more "costly" to your energy level it is. The only consolation to this is that the bandit is working under the same laws of physics and has the same problems to overcome.

TURN RADIUS AND TURN RATE

The first two characteristics of turns are turn radius and turn rate. Turn radius is simply a measure of how tight your jet is turning. If you are looking down on the aircraft as it turns, the turn radius is the distance from the centre of your turn circle to the aircraft, measured in feet (Figure 13).

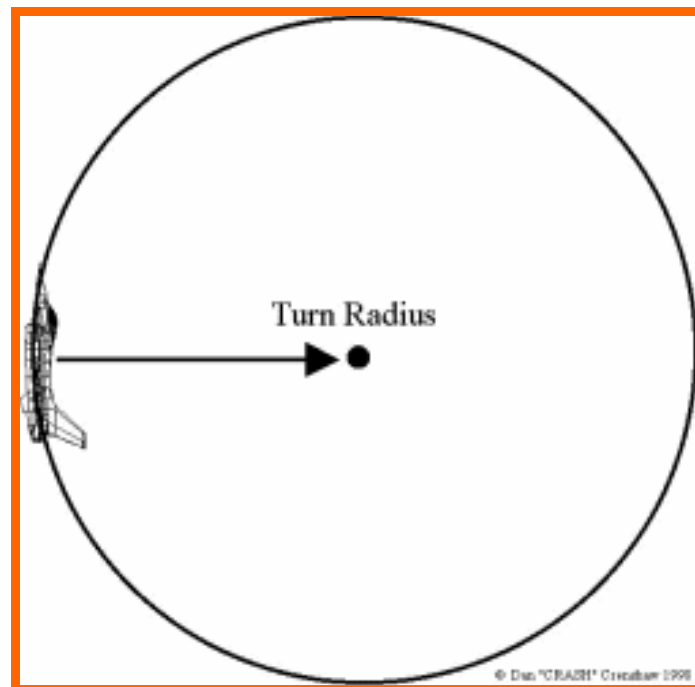


Figure 13 - Turn Radius

While the actual math for calculation of turn radius is not important, it is critical to understand that turn radius increases exponentially with velocity, or speed. A 500 knot turn at 9 G's will not be twice the size of a 250 knot turn at 9 G's, but roughly 4 times the size. **Just remember that airspeed has a much greater effect on turn radius than does G force effect.**

Turn rate is the second important factor for turning the jet. Turn rate indicates how fast the aircraft moves around the turn radius or circle we just talked about. It is also described as how fast an aircraft can change its nose position. Turn rate is measured in degrees per second and is dependant upon G's and Velocity. To really over simplify this, if the velocity remains constant, the higher the G's the faster the turn rate. Inversely, if the G remains constant, the lower the velocity, the faster the turn rate.

RULES OF THUMB to remember (see also Figure 14 below):

Turn radius is minimized by high G at slow speed

Turn rate is maximized by high G at slow speed.

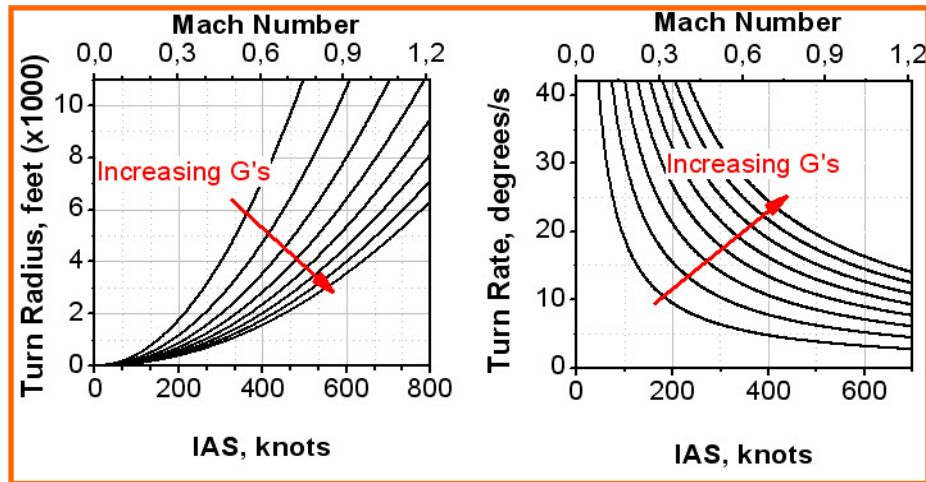


Figure 14 - Turn radius & Turn Rate Dependence on a/c Speed & Load Factor

CORNER VELOCITY

You may think that slowing down to minimum airspeed and pulling as hard as you can is the best course of action in order to achieve a high turn rate. Not so. There is a relationship between airspeed and G's. At lower airspeeds, you have less G available or, in other words, you can't pull as many G's as you get slow. Less lift is produced by the wings of an aircraft at slower speeds, and as a result, there is less force available to turn the aircraft. Conversely, if you get going really fast (above Mach 1, for example), you also lose G availability.

For every fighter, there is an optimum airspeed for achieving the highest turn rate. The airspeed where the jet has the quickest turn rate with the smallest turn radius is called corner velocity. In simple terms, corner velocity is the slowest an aircraft go while still being able to pull maximum G. In most modern fighters, it is between 400 to 500 KCAS. In a combat configuration, the F-16 has a corner velocity of between 340-430 KCAS or 0.65 Mach as shown in Figure 15.

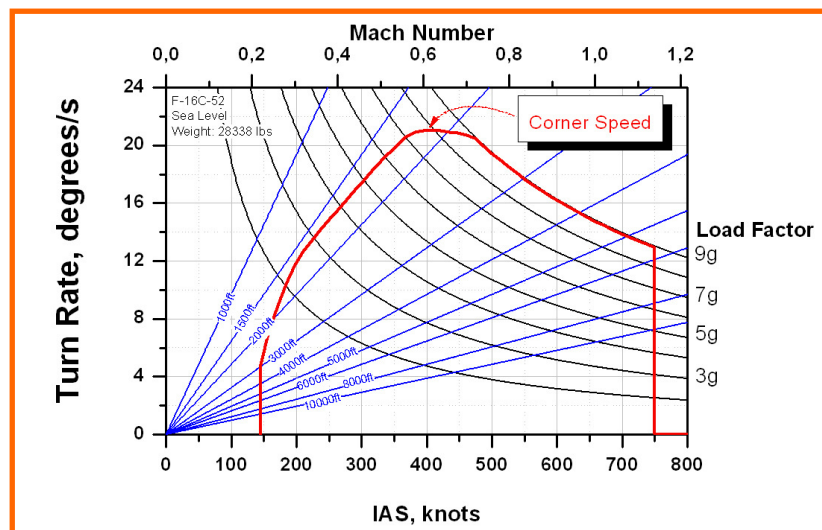


Figure 15 - F-16C-52 Turn performance at sea level with 100% fuel and combat configuration (2XAIM-9M, 2XAIM-120B and ALQ-131).

A corner velocity of 408 knots (IAS) , i.e. Mach 0.62 gives a maximum turn rate of 21.1 degrees per second, which corresponds to pulling about 8g at this speed. Sustained through 360 degrees, it takes the F-16 17 seconds to complete a full circle.

The airspeed of a jet can be controlled by the pilot in the following four ways:

- Throttle position
- Drag devices
- Nose position in relation to the horizon
- Aircraft G

Throttle position controls how much slow, cold air you turn into fast, hot gas. Drag devices refer primarily to speed brakes. Nose position in relation to the horizon also affects airspeed. For example, a nose-low position will increase your airspeed because of the effect of gravity.

Finally, G force causes airspeed to bleed off. Remember the brief discussion earlier about exchanging energy for position. No modern fighter flying at medium altitude can stay at corner velocity while pulling max G's for long. In a Cat I configuration, the F-16 can only sustain it's maximum turn rate (staying horizontal) below 10,000 ft. Above this height you must lower the nose or reduces the G otherwise you will quickly bleed off speed to below Mach 0.65.

As you pull G's, you will get slower. It is important, however, to start manoeuvring close to corner velocity because the first turn you make is usually the most important in the fight. Blow it and allow the bandit on your 6, the fight could end very fast and with an outcome you would rather not talk about. Use all your tools to achieve corner velocity, and you could be on the bandits 6, in control of the fight, and in a very good position to add a tally to your kill sheet.

Fighter pilots should think in terms of both turn rate and turn radius. A fighter with a superior turn rate can out manoeuvre a fighter that has a poor turn rate but a tighter turn radius. Fighter pilots have a simple two-word saying: "Rate kills." What this means is that the ability to move (or rate) your nose is the primary means of employing weapons (which is what offensive BFM is all about). A bandit may have a tight turn circle, but if you can rate your nose on him and shoot, the fight is over. The flaming wreckage will no longer cause you BFM problems.

VERTICAL TURNS

There are two key factors for you to consider in a dogfight; the bandit and the ground. Both can kill you. However, the ground can also help you. If you pull the nose of a fighter straight across the horizon, gravity will have no effect on your turn performance. When you pull the nose up or down, however, gravity becomes a player and the gravitational pull of the earth can actually allow you to pull a faster turn rate and tighter Turn Radius than a turn that has you parallel to the ground.

Gravity affects airspeed, as already mentioned. Gravity also affects G availability. To understand how an aircraft turns, you must understand that there are two factors that determine the rate and radius of a fighter's turn. The first is the G being felt and read out on the G meter in the cockpit. The second is the pull of gravity. Radial G is a term used by fighter pilots to describe the effective G that determines a fighter's turn.

Figure 16 shows this concept by depicting a fighter doing a loop. The cockpit G (the G felt by the pilot) is a constant 5 G's. You will notice that when an aircraft is straight and level and trying to pull in the vertical, the effective G or radial G is only 4. Gravity is subtracted from cockpit G so that the jet is pulling only 4 radial Gs. When the fighter is pulling 5 G's in the cockpit in the pure vertical (90° point) either straight up or straight down, gravity has no effect, so radial G is equal to cockpit G. When the fighter is inverted and pulling straight down at 5 G's, gravity adds 1 G to your effective or radial G. The fighter, in effect, is turning at 6 G's

at this point. Radial G then is simply a term that describes the effective or turning G created by combining the positive or negative influence of gravity with cockpit G.

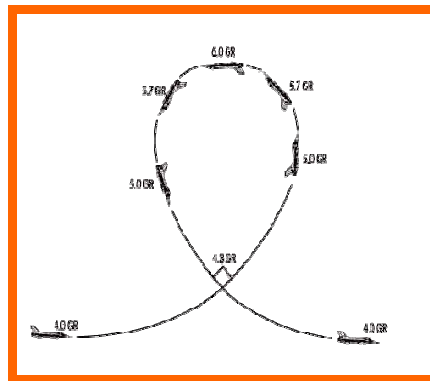


Figure 16 - Radial G in the Loop

What Figure 16 shows is that cockpit G is not equal to radial or turning G when manoeuvring in the vertical. Remember that 2' per second is a significant turning advantage. The extra G you can get by placing your nose below the horizon when you turn can give you at least 2' per second turn advantage. Most of the time, 1 GR equates to 3°-4° per second.

The concept of radial G can be seen in Figure 17. Here both fighters are pulling the same cockpit G. Notice that the fighter with his lift vector below the horizon is turning tighter. What is not so obvious in this figure is that the fighter turning toward the ground is also moving or rotating the nose faster.

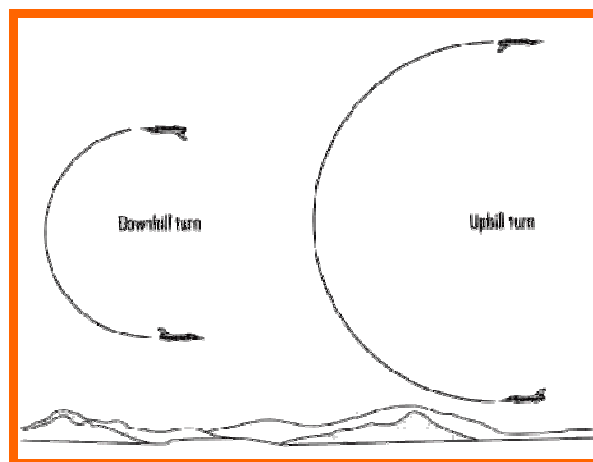


Figure 17 - Uphill vs Downhill Turn

2.3 TURN CIRCLE

When a bandit starts to evade and turns, he creates a Turn Circle (TC). To effectively attack him without becoming the prey yourself, you must get "inside" his TC (Figure 18).

TC has two basic definitions:

"The path a fighter flies through the sky when it turns" and "The area you must position yourself for Offensive BFM to be effective."

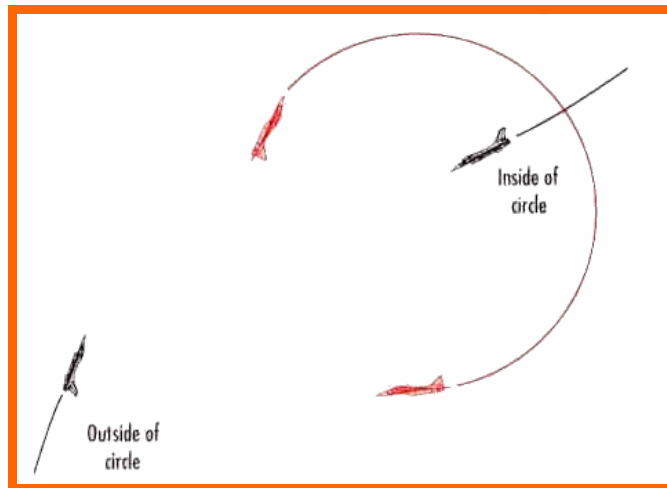


Figure 18 - Inside or Outside the Turn Circle?

Starting offensive BFM manoeuvres outside of the TC allows the bandit to continue his turn and cut off any Turning Room you may have been able to get and meet you close to head-on and possibly take control of the fight. Turning Room is the offset and distance between you and the bandit and can be Vertical, Horizontal or a combination of the two.

Figure 19 shows how an offset manoeuvre outside of the TC has resulted in a head-on pass, negating the attacker's initial advantage.



Figure 19 – Offset Manoeuvre Outside of the TC Leads to a Head On Pass

Going Vertical while outside the TC to acquire Turning Room will usually put you into a very compromising position and should be avoided. It gives the bandit enough turning room to get his nose around on you and when you pass at high aspect, the bandit will be nose high while you will be nose low. He gets the first use of gravity to increase his radial G as you pass and will probably get behind you, see Figure 20.

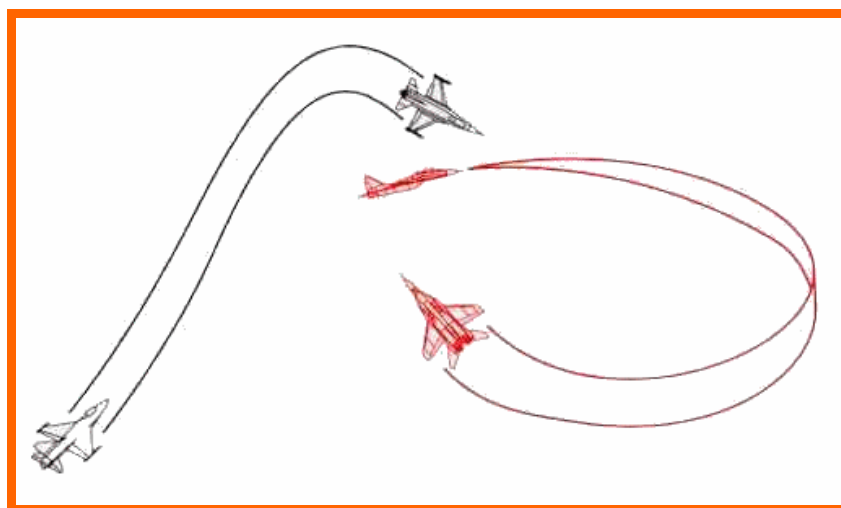


Figure 20 – A High Yo-Yo Outside the TC Leads to a Head on Pass

The bottom line is: any manoeuvres you make outside of the TC will create turning room for the bandit, which is likely to result in a head on pass and subsequent turning fight. You need to get into the bandit's TC as fast as possible and the best way to do this is normally to go pure or even lead pursuit, but watch out the overshoot and getting into the bandit's WEZ.

How do you know when you are in or out of the Turn Circle? To make your decisions on when to turn and what type of turn to do, you really need to know this. Watch the bandit's turn rate. If the bandit's present turn rate will force his nose on you or even close to you, you are outside the bandit's turn circle and you are not in an offensive fight-you are in a head-on BFM fight. If he cannot get his nose around and point it at you, you are inside the Turn Circle.

For modern fighters at high G, you are normally outside the bandit's turn circle at ranges outside 2 nm. At 1 nm, you are normally inside the bandit's turn circle, and between these ranges, you are in a transition zone. These ranges, of course, do not really matter to a fighter pilot. When you start behind a bandit, you simply fight what you see.

As the bandit turns, you predict where he is going and manoeuvre based on this prediction. For example, if the bandit is only pulling 4 G's, then at 2 nm you are still inside his turn circle. Figure 21 shows the difference between starting at 2 nm from a 4 G target and starting at 2 nm from a 7 G target. Most fighter pilots will not pull only 4 G's when they are in danger of dying. Still, you fight what you see.

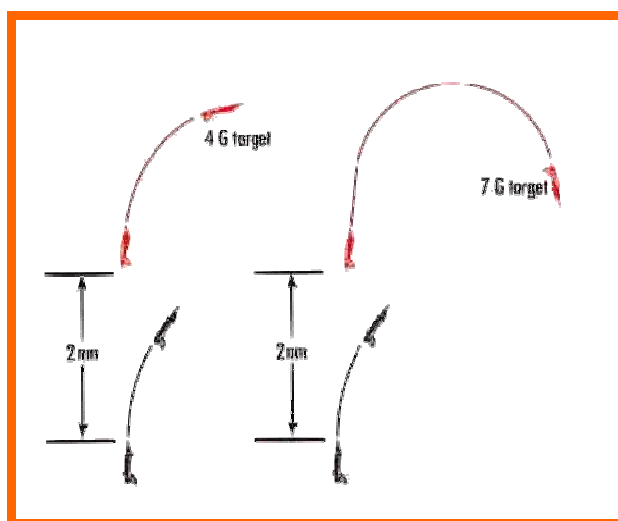


Figure 21 - Example of a 4G and 7G Manoeuvring Target

2.4 SUSTAINED VERSUS INSTANTANEOUS TURN PERFORMANCE

Maximum performance turns may be classified as one of two types: instantaneous or sustained. Instantaneous refers to the aircraft's maximum turn capabilities at any given moment under the existing flight conditions (e.g. speed and altitude). A particular capability may last for only an instant before flight conditions change, resulting in a change in instantaneous-turn capability. Sustained turns are those which the aircraft is able to maintain for an extended length of time under a given set of flight conditions.

Turns at the corner speed are normally not sustainable because high G-load will increase drag and slow aircraft, in return this will reduce the maximum G obtainable. Conversely, a lower G-load produces less drag. Eventually we will reach a point where thrust will be sufficient to overcome the drag being produced. This will allow us to maintain the current G-load and speed. In this situation we have reached the sustainable turn performance.

In general, an aircraft with small, highly loaded wing may have superior instantaneous turn performance, but poor sustained turn performance: it reacts quickly to control input, but its ability to sustain a tight turn is limited. A classic example is the F-104 Starfighter, which has a very small wing and high wing loading. An F-16 with full fuel tanks using full afterburner is just able to hold the corner speed at lower altitudes. The black art of the air combat includes that split-second decision about when to use the instantaneous or the sustained turn performance.

2.5 GOING OFFENSIVE

The entire reason we are doing all of this is to get the bandit into your "Kill Zone" and end the fight as fast as possible. The longer the fight goes on, the better the odds are that the bandit will get into a position to take a shot at you so if you have a shot take it NOW! Do not wait for a better chance, or until you can get close enough to use guns instead of missiles. To die with a full wing of missiles because you thought, "I might need them later in the mission" is just stupid.

As you approach the rear of a bandit, you have a very short period of time before his Defensive BFM will put your missiles out of parameters. The harder the defending target turns, the less time you will have before you are forced into a decision on your next move ... and then it may be too late, so I'll say it once again, if you have the shot, take it.

So, your missile shot missed or you missed the chance before the bandit saw you and you now pull into an attacking rear aspect position. The bandit sees you and starts Defensive BFM ... your move. At this point, you are committing the next stage of the fight to guns (or a rear quarter heater shot if you're lucky). When do you start your turn to maintain your advantage – to "Stay in Control" of the fight?

The point you want to begin your turn will be approximately the same place the bandit started his: this is known as the "Entry Window" (Figure 22). This window will be to the inside of the bandits turn circle (remember you do not want to start an Offensive BFM manoeuvre outside of the bandits turn circle). Once you enter the window, begin your high G pull into the bandit.

Other ways to estimate the Entry Window would be Chaff and Flare possibly dropped by the bandit as he started his turn, or when the bandit is about 30° off of your nose. Or maybe a bit of debris from your near miss missile shot. Watch for any signs that may help you, but do not focus on where you should turn at the expense of not paying attention to what the bandit is doing.

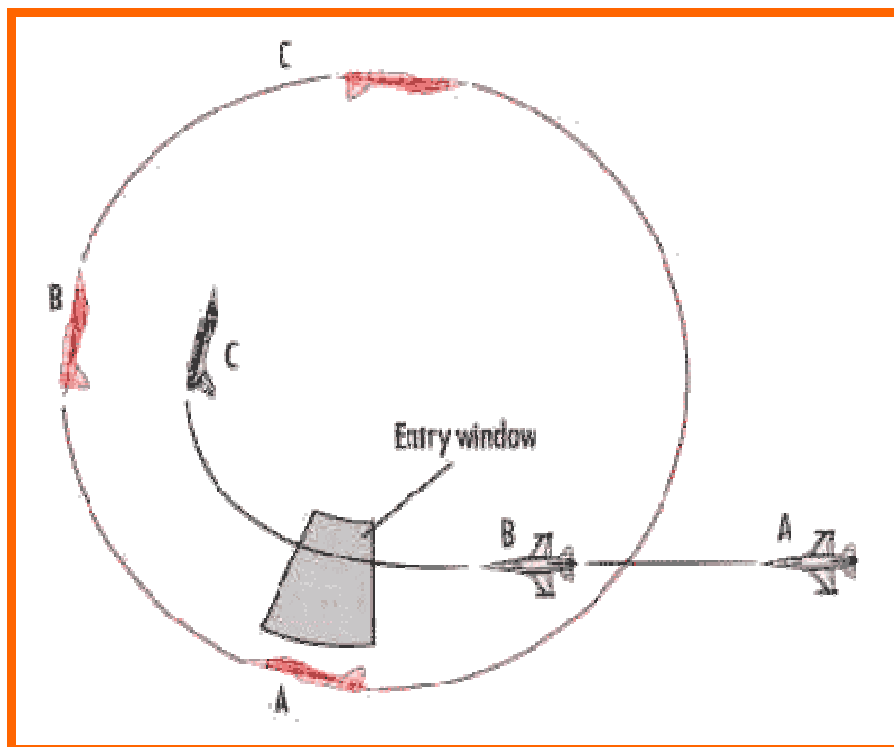


Figure 22 - The Entry Window

As you approach the Entry Window you want to be at Corner Velocity. If you enter too fast or too slow, you will be forced into a Lag Pursuit where you will probably not be able to pull your nose into Lead Pursuit for a gun shot. You must be at your best turn rate, which is Corner Velocity, to have the control and the option to pull your nose around fast enough to take a shot when you want to.

Okay you have determined the Entry Window, and you have it at Corner Velocity ... everything is going great so far. The next step is to pull 7 to 8 G's into the bandit. As you come around the corner, keep your nose in lag. If you see the nose of your jet approaching pure pursuit, ease up on the G. Hold this lag pursuit course until you get within 3,000 feet of the bandit. At this range, go to lead pursuit and get ready for a gun shot. Watch your speed during this period so you do not bleed off or pick up too much speed so you keep at Corner Velocity.

When you arrive inside 3,000 feet on the bandit with your nose in pure or lead pursuit, your throttle controls your overtake. Note this. In close to the bandit, with your angle-off less than 45° and your nose in pure or lead pursuit, the position of your throttle controls your closure. When you get saddled up for a gun shot, you must match airspeed with the target. In most cases, this will require constant movement of the throttle. In addition to banging the throttle off both stops, you may have to manoeuvre out of plane to control your airspeed. If a throttle reduction and the speed brakes don't slow you down enough, roll the jet to orient your lift vector out of the bandit's plane-of-motion and pull. Hold this lag pursuit pull for about two seconds; then ease off the G and watch the bandit. When he starts to move forward on your canopy, it is time to pull back into him. Pull your lift vector out in front of the bandit as you pull down.

2.5 GUN SHOT PROCEDURES

You're inside 3,000 feet on the bandit with your nose in lead. How do you take a gun shot? The gun in most fighters is actually a cannon. The F-16, for example, has an M-61A1 20mm cannon, which is common to almost every U.S. fighter. The M-61A1 shoots High Explosive Incendiary (HEI) rounds at the rate of 100 per second. At the proper range, the gun is like a giant buzz saw. In order to carve up the enemy, however, you must understand the fundamentals of taking a gun shot. To hit a target with the gun, you must meet the following conditions:

- You must be in range. This range varies, depending on aspect, but it is usually about 2,500 feet at low aspect angles and about 4,000 feet at high aspect.
- You must have your nose in lead pursuit. The bullets fired by the gun are unguided projectiles that take time to get to the target. For most gunshots, the bullet time-of-flight (TOF) is .5 to 1.5 seconds. If you point directly at the target and fire, the bullets will pass behind the target. If the bullet moved at the speed of light, you could point right at a turning target and score a hit. Since the bullet is considerably slower, you must pull lead. This lead may not be very pronounced, however, at close range.
- You must be in the bandit's plane of motion. When an aircraft turns, it carves a circle in the sky that creates a plane. In order for you to hit the target with the gun, you must be turning in the same plane as your target. For example, if the target is flying a loop and creating a vertically oriented plane of motion, you have to be flying a loop in the same plane as the target.

USING THE GUN SIGHT

The gun sight of choice on the F-16 is called EEGS. EEGS (pronounced as it is spelled) stands for Enhanced Envelope Gun Sight (Figure 23). The EEGS funnel allows the pilot to match the wingspan of the target with the width of the funnel to determine the proper firing range. The other important gun aiming cue in the HUD is the gun cross. The gun cross represents the departure line of the bullets. You can consider the gun cross as the gun barrel. Bullets pass straight out the gun cross.

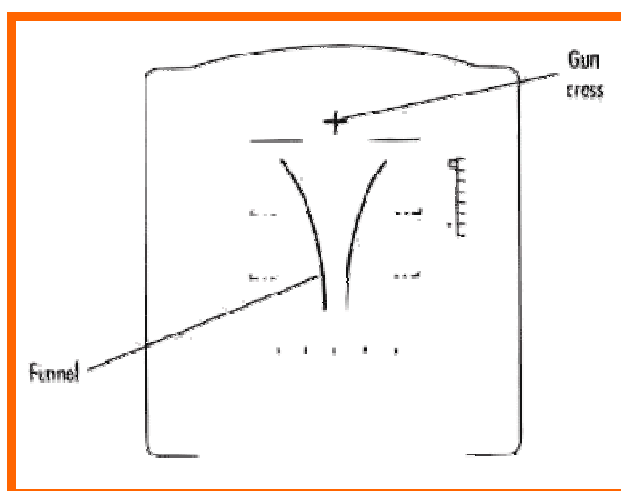


Figure 23 - The EEGS Gunsight

So, how do you use the funnel? The gun in the F-16 is boresighted to 6 mils. This means that the gun is adjusted to fire a burst that will put 80% of the rounds inside a 6-foot diameter circle at 1,000 feet. This is a tight pattern. You can have either a highly concentrated burst

that completely misses the target or a very lethal burst that vaporizes the target. It just depends on the quality of your gun sight (and your ability to aim it.)

Air-to-air situations are always dynamic, and targets under attack will normally jink violently to stay alive. Since the sight (and your reactions) are not instantaneous, it is likely you may achieve a highly accurate miss; that is, a tight burst that finds only empty air. The sight was lined up and stable, but you missed. How could this happen? The sight was lying because the target was jinking faster than the sight could react. The way to overcome this problem is to strive for an inaccurate hit. You do this by using the EEGS funnel to fire a burst while moving the target through the area of uncertainty. The EEGS funnel gives you a perfect solution when the wingtips of the target match the width of the funnel. If the target is jinking, however, this "perfect solution" may be in error. Here is how to use the gun cross / funnel combination to kill the bandit:

- Place the gun cross out in front of the target. Picture the target with a long pilot boom sticking out the nose. The gun cross should be placed on this extended pilot boom. If the target changes his plane-of-motion, then fly to place the gun cross on the new position of this imaginary pole sticking out of the nose of the target.
- Next, over lead the target by making the wingspan of the target extend past the funnel. This will place your bullet stream in front of the target's nose.
- Fire the gun while easing up on the G. This will move the target from the bottom of the funnel to the top. Cease fire when the target's wings are inside the funnel.
- Make a slight jink out of the bandit's plane-of-motion so, when he blows up, you don't suck a body part down your intake.

This technique uses the gun cross and the EEGS funnel to place the bullet stream in front of the bandit. When you ease up on the G, the target should fly through your bullets. Figure 24 shows how to make this shot.

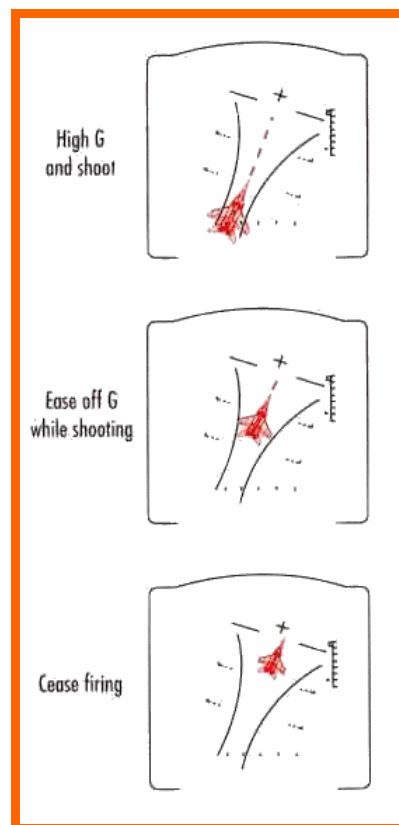


Figure 24 - Using the EEGS Funnel



LESSON THREE - DEFENSIVE BFM

3.1 INTRODUCTION

The call comes over the radio, "I've been hit!". You execute a Wingman Padlock only to see "2" rolling into a spiralling dive, flames and smoke belching from the aircraft. You think to yourself, "Where did that come from" as you frantically do a search for bandits ... you spot him. The MiG that just took out "2" is moving into position on your "6" to take his next ATOLL shot ... at you.

Welcome to Defensive BFM. You are in the worst position a fighter pilot can be in ... on the defensive. In Offensive BFM we learned the basic offensive manoeuvres to get into and stay in control long enough to take a "Killing" shot. In this lesson, we will learn what to do to keep the bandit out of the "Kill Zone". If that fails, what to do to avoid getting hit by the "Killing" shot.

When you think of Defensive BFM, think of High G, difficult manoeuvres that are executed while straining your neck to watch what the bandit behind you is doing. There is no magic move ... you can't "Just hit the brakes and he'll fly right by" like Tom Cruise did. To avoid getting killed by the bandit, you're going to have to work pretty damn hard. As in Offensive BFM, you want to keep your movements smooth and fluid, no sudden manoeuvres.

Keep in mind, if you fly perfect Defensive BFM and the bandit flies perfect Offensive BFM ... "you're going to lose". What you want to do is cause BFM problems for the bandit and force him to make a mistake. If he does not, all you can do is make him work for the kill and force him to close to gun parameters, then you must work to defeat his gun shot.

3.2 DETECTION

Most kills are on a target that had no idea he was about to get hit. Before you can execute Defensive BFM, you need to know there is a threat. There are 3 primary methods:

RADAR



Radar is the best way to detect an attack because it has good range (usually 40nm or more) and allows you to track a targets movement. If you get a bandit on Radar, you can usually keep him there and know what he is doing. The problem is, Radar has a limited scan area. You can not always pick up a bandit and have a rather large blind area to deal with.

TWS



Your Threat Warning System (TWS) will react if Radar is looking at you. It will pick up airborne as well as ground threats but it does not detect IR targeting devices or other threats not using Radar, so again there are limitations.

VISUAL



Your eyeballs are probably the best detection device ever. Regardless of how you first detect the bandit, when you get WVR you are going to have to get tally to fight him effectively.

3.3 DEFENDING AGAINST A MISSILE

Whether you see an attacking bandit or not, you must stick to a fundamental rule of air combat: "Fight the most immediate threat". Ignoring this rule is probably the most common mistake pilots make. The missile lock klaxon is going off in your cockpit ... you know you have a missile inbound, but if you hold this line just a couple more seconds, you can kill this bandit you are tracking. STOP! If you have someone or something shooting at you, get out of its way before you even think about attacking a target.

How do you evade a missile? There are several techniques, some of which are better and more reliable than others are. They all use the same basic root principal ... "Fight Missiles with Aspect". What this means is you want to give the missile the most difficult guidance solutions possible by making it manoeuvre. The first thing you want to do is put the missile on your 3/9 line and "Beam" it.

Your 3/9 line is the imaginary line that goes across your aircraft from left to right. If you look down at the top of your aircraft, and imagine it sitting on a clock face nose pointing to 12 o'clock, you will be able to visualize the "3/9" line. Most missiles fly in Lead Pursuit to increase their range, so by putting the missile on your 3/9 line you will cause it to pull maximum lead. As you do this, drop chaff and flares. This may confuse the missile as it tries to create guidance calculations. Do not try and let the missile close in and expect to pull a high G turn to force the missile to over shoot you.

Missiles are designed to explode if they over shoot so your attempt to pull around the missile will bring you close enough to it that on explosion, you will take damage. You need to judge timing for a break away from the missile as you drop chaff/flares. Near the end of the missile's flight (after the motor has burned out) you want to pull a high G turn causing the missile to try and pull a turn with you as this forces it to use up energy and slow down until it can no longer keep up with you. The chaff/flares may confuse the missile as it tries to track you and it may lock onto that leaving you a get away. Don't wait too long or, once again, you will be in the blast radius of the missile.

3.4 CREATING BFM PROBLEMS FOR THE BANDIT

The first BFM manoeuvre, in a fight is the most important. There are two reasons for that. Pete Bonanni makes an excellent point in "Art of the Kill", when you pull that first high G manoeuvre, not only are you creating BFM problems for the bandit to resolve, you are making a clear statement that "I am going to stay alive. If you are going to kill me ... you're going to have to work hard for it." (Pete said it with a little more flamboyance ... "It's you and me for all the wine and women in the world".) A mid or low level G turn is almost a surrender ... at this point you might as well just fly straight and level and let him shoot you.

The other reason is to create BFM problems. You need to get to corner velocity. If you are not there yet, start your manoeuvre anyway and try to get there. Slowing down is easy, cut the throttle – pull your G's and make your speed. Speeding up is not so easy and is a very good argument for cruising at or above corner velocity. Pull your turn and put your velocity vector on the bandit. If you do not, you will create additional turning room for the bandit when you are trying to take it away. Figure 25 shows a defending aircraft creating turning room for his attacker.

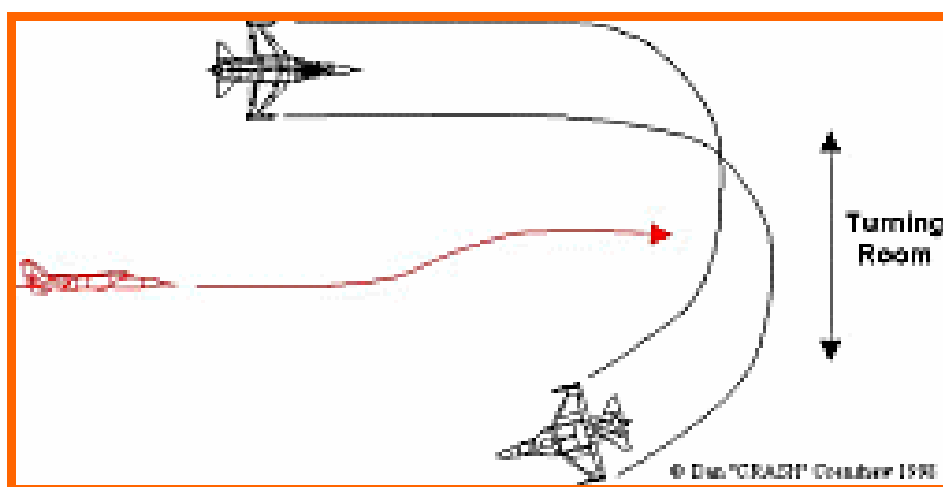


Figure 25 - Defender Creating Turning Room

3.5 BANDIT IS OUTSIDE YOUR TURN CIRCLE

You want to begin your BFM turn as soon as possible. If you spot the bandit early enough and can begin your BFM while he is still out side of your Turn Circle, you can turn a defensive position into at least a Head On Pass, or even an offensive position.

So there is no missile and you have a bandit on your six, you begin Defensive BFM. How do you know what to do next? How do you know what you are doing is working? If your turn is moving the bandit away from your 6 o'clock position and up towards your 3/9 line, it is working. You want to get the bandit forward of your 3/9 line. If you start your turn while the bandit is outside your turn circle, and you put your lift vector on him and execute the turn correctly, you should force the bandit in front of your 3/9 line. Here is where it gets a little tricky.

If the bandit pulls a Lead Pursuit while you are executing the turn that is forcing him in front of your 3/9 line, he will get the opportunity for a gun shot as he over shoots. Watch out for this. If he starts to pull Lead Pursuit the best way to defend for this is to quickly pull out of plane. At this point, you have to judge when to make your "jink" out of plane. Don't wait too long, if you're too late ... your dead, if your too early, you just need to "jink" again. Better too early that too late.

3.6 BANDIT IS INSIDE YOUR TURN CIRCLE

If the bandit is inside your turn circle when you begin BFM, there is a much different scenario that plays out. First you need to determine how serious the pilot behind you is. If he intends to get in on your 6 and take a shot at you, he will have to fly Lag Pursuit to get to your entry window. If he pulls into a Lag Pursuit, he wants to party and you better be ready. Figure 26 shows a well executed Lag Pursuit entry.

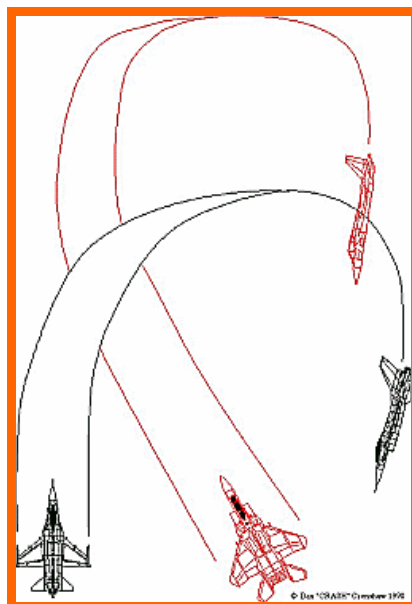


Figure 26 - Lag Entry

Your best shot here is to pull a high G turn at Corner Velocity. At this point it is imperative you are at Corner Velocity. You want to keep his nose in Lag. Your best chance for survival is to keep turning hard and see if he can get around on you for a shot. If he can, get ready for Guns Defence. There is also the school of thought that you should unload and extend (release the G and accelerate for distance). The problem here is that the bandit will quickly get deep into your 6 o'clock and probably take a missile shot at you.

Now you can not count on the bandit to do everything you want him to. He may try to trick you into making a mistake as well. He may try to go vertical. Keep pulling hard and put your Lift Vector on him. As you start to climb, watch him. If he pulls down, back into a Lag Pursuit as you climb, you got a hot shot on your hands and he will quickly move in for a gun shot. But if he continues going up, keep your pull and follow him. You should be able to hang onto enough speed to be able to pull your nose around on him and take a shot (most likely a snapshot, but a shot never the less) as shown in Figure 27 below.



Figure 27 - Keeping Lift Vector on the Bandit

Now you have probably gotten into a "Scissors" fight. Better than having him on your 6, now the odds are much more even. A "Scissors" is when you and the bandit are in a Line Abreast or side by side situation. Both planes pull towards each other as they try to bleed speed and thus, get behind the opponent. The fighter that can slow his aircraft the fastest usually wins this one. Use every trick you know to do this, airbrakes, flaps, barrel rolls. Not recommended but if the fight gets slow enough, throw out your gear ... just get behind him. Figure 28 shows the Scissors.

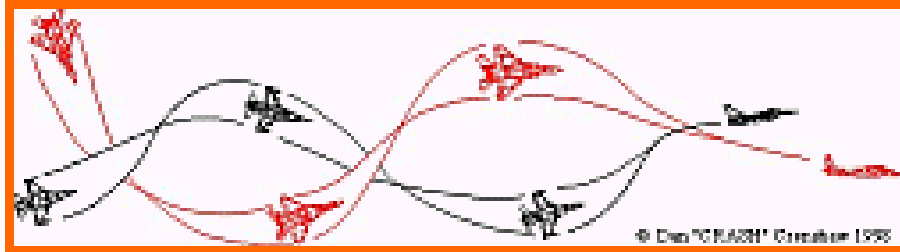


Figure 28 - The Scissors

Then again, the bandit may try a Lead Pursuit immediately. He may overshoot you, but still get a snapshot. The trick here is to pull for all that you are worth. Be at Corner Velocity ... any faster or slower and he will be able to keep behind you. And pull G's till it hurts (or in this case, until the screen goes black).

A quick side note about how many G's to pull. If you start to blackout you may get a tunnelling effect but as long as the screen isn't completely black, keep pulling. It isn't a matter of maintaining awareness at this point, it is about survival. Situational awareness is important, but if you unload G's to lessen the blackout effect, the other guy is going pull his nose on you and shoot. When it says HIGH G anywhere in these lessons, it really means HIGH G's.

The last thing that the bandit may try this close is a Pure Pursuit. If the bandit has his nose on you and has not launched a missile, you have just met your next Kill Tally. He is manoeuvring in HUD BFM ... he is always looking through the HUD. At close range, it will lead to an overshoot and suddenly you will find yourself on his 6 ... now you can go back and try stuff you learned in Lesson 2. You are in control and on his 6.

3.7 OVERTSHOTS

We have talked about overshoots in several places now. Let's describe what an overshoot is and why it is important to you as a defensive aircraft. There are two basic types of overshoot, the Flight Path Overshoot and the 3/9 Line overshoot. Figure 29 shows a Flight Path Overshoot.

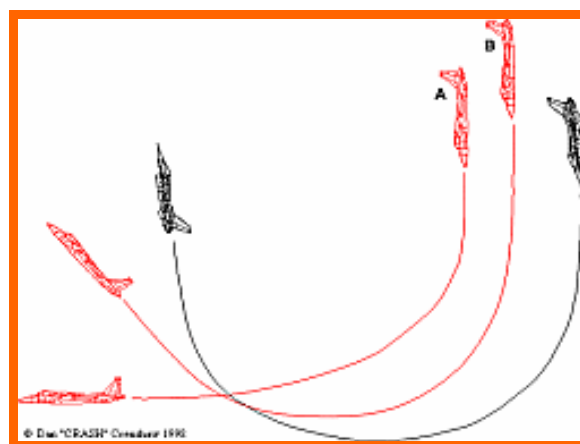


Figure 29 - A Flight Path Overshoot

A Flight path overshoot can be a minor error for the attacker, or a fatal error. If the path causes a minor overshoot as aircraft A in the figure, this will usually mean very little to you as a defender, and very little stress to the attacker. An excessive overshoot, however, like aircraft B, could easily give the defender the opportunity to reverse his turn and cause a line abreast situation (which would result in a Scissors) or even on the attackers six, turning the tables.

A 3/9 Line overshoot, as shown below, puts the attacker in front of the defending aircraft. A quick reversal by the defender and the hunter becomes the hunted.

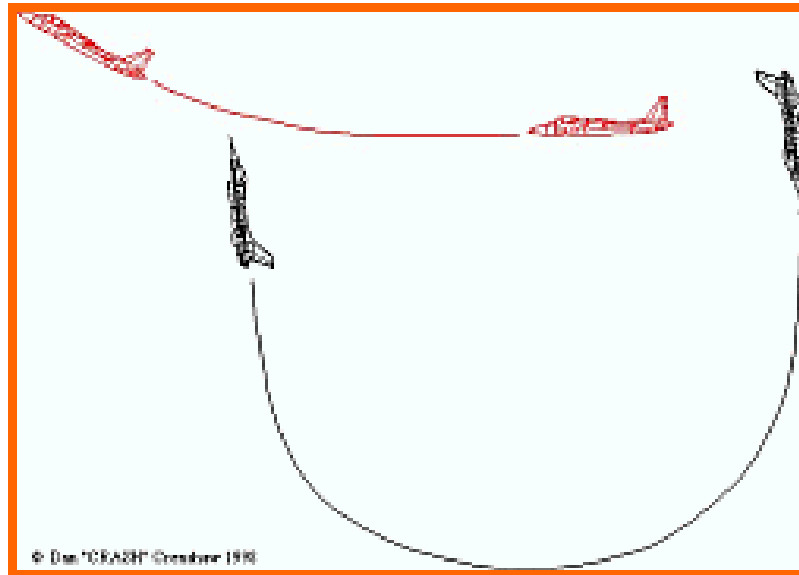


Figure 30 - A 3/9 Line Overshoot

When the bandit overshoots, you have 2 basic ways to reverse your turn. If the bandit is going to overshoot with a high line of sight rate (he is going to pass you very quickly), you will probably want to do an "Unloaded Reversal". You need to release the G load on your aircraft (ease off on the stick), roll your aircraft so that your lift vector is on the bandit and then pull maximum G at him. Only use this method if you are sure he will overshoot. This move will not force an overshoot, but it will get your nose on the bandit quickly when he does.

The other type of reversal is the "Loaded Reversal". Use this move to force an impending overshoot into an overshoot. This is simply maintaining the G's on your aircraft as you roll your lift vector onto him. Pull for all your worth at maximum G. The figure shows a Loaded Reversal.

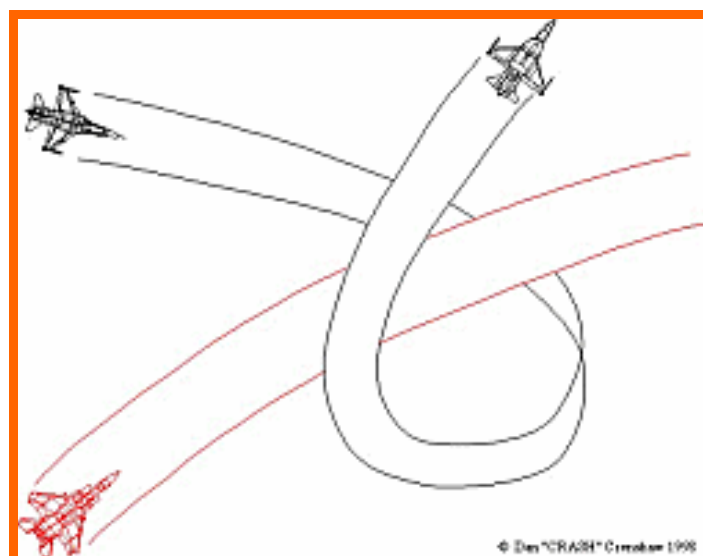


Figure 31 - A Loaded Reversal

There is one issue you must consider in a Loaded Reversal. If the bandit doesn't over shoot, you will have him clawing at your underwear; do a quick check to make sure you know where the EJECTION handle is. You will have almost no airspeed after this manoeuvre, so if he stays behind you, you will have no manoeuvring ability.

This brings us to the Rules for Reversal. 3 quick thoughts to consider before you decide to reverse on this guy as he over shoots.

1. When in doubt if the bandit will over shoot, don't reverse.
2. Best results are when you reverse when the bandit is within your turn circle with a high line of sight.
3. Do not reverse if the bandit is outside your turn circle. He has way to much room and time to correct.

3.8 GUNS DEFENCE

Now you are down to the wire. He has closed in range for a gun shot. You need to know the two types of gun shots and what to do.

SNAPSHOT

A Snapshot is when a bandit is passing you at a high line of site rate. To defend against this type of attack you need to break out of plane. The tough part is to decide when to make the break. Early is better than late ... so watch him closely.

TRACKING SHOT

This is where the bandit has maintained control, is on your 6 and tracking you for the kill. This will require multiple "jinks" out of plane. These "jinks" must be rather severe, a 70° or more break is what we are talking about here. Do not lose sight of the bandit, once he begins to line up again you need to "jink" again. Make the "jinks" random in direction, sudden, and severe.

THE SNAKE

The Snake is a form of Jink. Here's how you execute the manoeuvre: when you see the bandit pulling his nose into lead, you unload rapidly, roll 180°, and reverse your direction of turn. Hold this course and make the bandit pull his nose back into lead, unload again and roll 180° to reverse your turn again. This time, reduce power to bait him into an overshoot. Repeat until you see the bandit overshoots then get back into full burner, set your wings level with the horizon and pull max G. This will help him fly out in front of your 3/9 line then reverse and you are in control. Remember the manoeuvre is not a magic move, if the bandit is skilled he will probably gun you, snake or no snake.

3.9 CONCLUSION

This concludes the basics of Defensive BFM. In a nutshell, you need to pull hard with your lift vector on the bandit. Watch him to see if he makes any errors, if he does, jump on the opportunity to turn the tables. If you fly perfect BFM, and the bandit does as well, you will end up defending against his guns attack (not really a consolation prize, but better than already being shot down).

Above all, if you are in a defensive mode, never give up. Do whatever it takes to cause as many problems or the attacker as you can. If he is going to kill you, make him work harder than he ever has before for a kill. Of course, the best Defensive BFM is not to let him on your 6 in the first place.



LESSON 4 – HEAD ON BFM

4.1 INTRODUCTION

Head On or neutral BFM, the most difficult of BFM situations. Your aircraft is "nose on" to the bandit, and he is "nose on" to you. When used as a Competition set up, you are generally required to make a clean first pass, no shots fired and once the 3/9 line is cleared, "FIGHTS ON!"

For this purpose, a lead turn is excellent. Both combatants are at an equal advantage/disadvantage and this sort of fight requires more manoeuvring, tactics, skill and luck than any other BFM.

But in a WAR chivalry is dead. There will be no clean first past. Odds are, the yokel heading at you will start spraying you with bullets the second you are in range.

You have many decisions to make rather early on in Head On BFM. Do you commit to a Turning Fight? Do you opt for a "blow through" and extension and run away? If you commit to the Turning fight, do you go for a two circle fight or a single circle fight? All of this must be decided before you even enter the fray and in a Head On fight, closure speeds can easily exceed 1000 KIAS, so you don't have a lot of time to decide.

There are several factors that can help you make this decision. We need to remember that a Turning Fight, or Knife Fight, eats up time and energy. Time is critical, since if you get tied up, the longer you are in the fight, the more time there is for one of your playmate's friends to show up and sucker punch you. Energy is obviously needed for manoeuvring.

There are many reasons to "blow through" and leave a fight. There are also as many reasons to stay and fight. This lesson will give you some basic guidelines to help you lay out a strategy for a fight. The first thing you will need to know and remember is the "Escape Window"

4.2 ESCAPE WINDOW

A fighter pilots job is to enter a fight, shoot down the enemy and live to be able to do it again. A priority when entering a fight is to be aware of your position in relationship to your "escape window". What is an escape window? An escape window is a loose representation of your ability to extract yourself from an engagement. It is called a window because it can open or close in varying degrees depending on the current situation, position and energy level of your aircraft.

If you sneak up on a bandit that has no clue you are there, your escape window is enormous. You have the ability to leave the fight at anytime you want, you have complete control. The window is wide open. But if the tables are turned and a bandit sneaks up on you, the window is closed. Any attempt you make to leave the fight will most likely end in you getting shot down. In between these two extremes the window can fluctuate in size. The smaller the window, the less your chance of getting out of a fight alive. In any manoeuvring fight, the window will close completely at some point. You are then committed to stay in the fight to the conclusion.

In the figure below, the attackers escape window is open. The bandit can not turn and get a shot on the attacker as he passes through the fight.

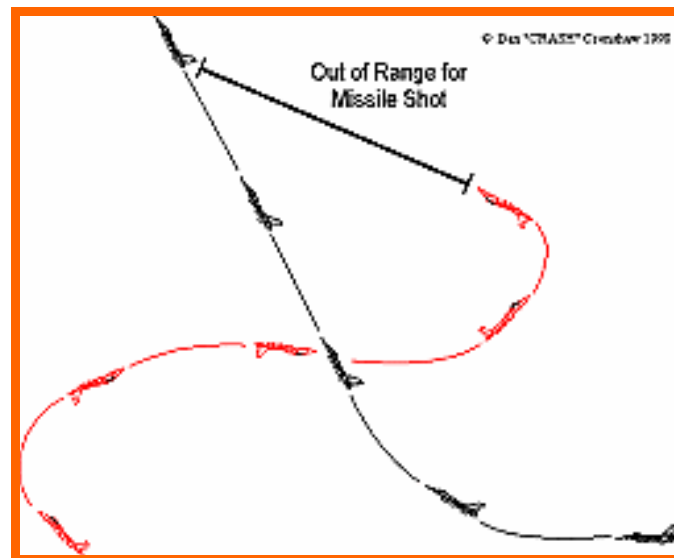


Figure 32 - Open Escape Window

If the attacker turns to roll out of the fight, the bandit can not reverse his turn fast enough to engage. If the attacker "Blows Through" and extends, by the time the bandit can come around to engage, the attacker is out of range.

In the figure below, the window is closed. An attempt to leave the fight will give the bandit the opportunity to turn and engage the attacker. The attacker has tried to leave the fight, and the bandit has reversed his turn and lined up on the attackers 6.

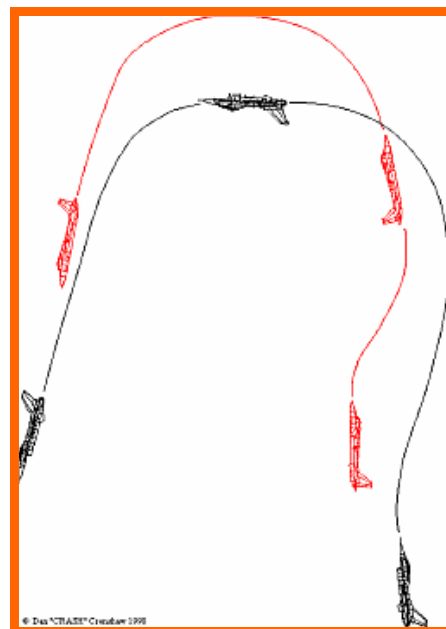


Figure 33 - Closed Escape Window

If the attacker reverses to leave the fight, the bandit has plenty of time to turn and engage from a 6 o'clock position. Any attempt to "Blow Through" will probably cause an overshoot, or allow the bandit ample time to reverse and engage.

The figure below shows a classic "Lufbery". In this fight neither aircraft can leave, both windows are closed. The first one to try and leave will get shot.

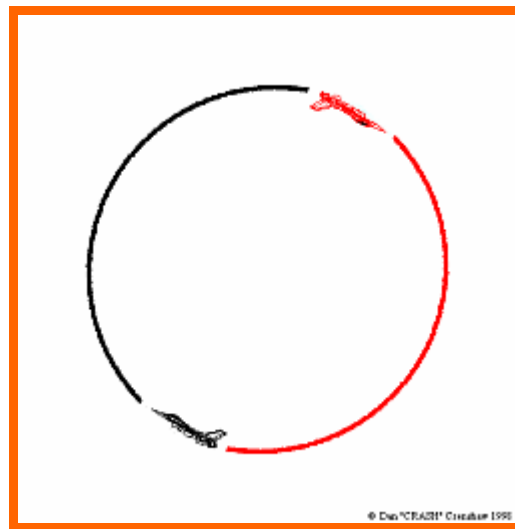


Figure 34 - The Lufbery

While it is important to know where your escape window is, if you intend to be successful and shoot down bandits, you will have to close your escape window. Knowing where your escape window is will prevent you from trying to leave a fight that has a closed escape window.

Should I stay, or should I go?

Providing you both see each other, there are three main factors that affect an escape window:

- a. Range: The range between you and the bandit. The greater the range, the more open the window
- b. Energy: Energy relative to your opponent. The greater your energy in relationship to the bandit, the more open your window.
- c. Angle-Off: The greater your angle-off, the more open your window. (A head on pass is the best advantage here).

All of these factors combine or cancel each other out to figure the size of your escape window.

Should you decide to stay, you need to decide when to make your move. Remember, you have decided to stay and fight, so FIGHT TO WIN! To go aggressive, you have really only one option before the merge. Lead Turn. Any other manoeuvre is not going to put you on the offensive and will probably put you on the defensive pretty quick.

4.3 LEAD TURN

A Lead Turn is when you try to decrease the angle-off prior to the merge, or passing the bandits 3/9 line. Lead Turns are a critical and highly important part of BFM and can be used almost anywhere. This is most frequently used in a HEAD ON Pass. Lead Turns are the most efficient way to BFM and are so potent that, if you Lead Turn and your opponent does not, you will win.

How exactly do you execute a Lead Turn? Looking at it from a HEAD ON aspect: As you approach your opponent, you will have a relatively low line of site rate on your bandit. Remember line of site rate is how fast the bandit is moving across your field of view.

In a HEAD ON, the bandit is almost stationary, almost no line of site rate at all. However as you close with the bandit, he will start to slowly move towards the rear of your aircraft. You will be able to watch him move from the centre or near centre of your HUD to the edge and then out of it and aft on your canopy. As this happens, the line of site rate increases.

In a HEAD ON Pass, closure speeds can easily meet or exceed 1000 knots. Your closure speed, velocity of closure, is VC. This is the sum of your speed and that of your opponent. In a HEAD ON Pass, it is pure addition. If you are going 500 knots and your opponent is going 500 knots, your VC is 1000 knots. When your 3/9 line is even with his 3/9 line, your VC will rapidly change from 1000 knots to negative 1000 knots. It is at this point, when your 3/9 lines are even, that you want to start your Lead Turn.

You can not wait until this point is reached to begin your turn. If you do, you are too late in executing your turn. You must remember, the further back the bandit moves on your canopy, the faster his line of site rate will increase. Before you know it, he will be blasting past you, and if he is smart, will be making his own Lead Turn. You need to anticipate when to begin your turn.

The best place to begin your turn is where the line of site rate begins to increase very rapidly. This happens usually around 30° off of your nose in a good turning aircraft (some slower turning aircraft may have to start sooner than this). As you practice this, you will begin to notice when this happens and can then pick a reference point in your cockpit to use as a "start your Lead Turn here" indicator.

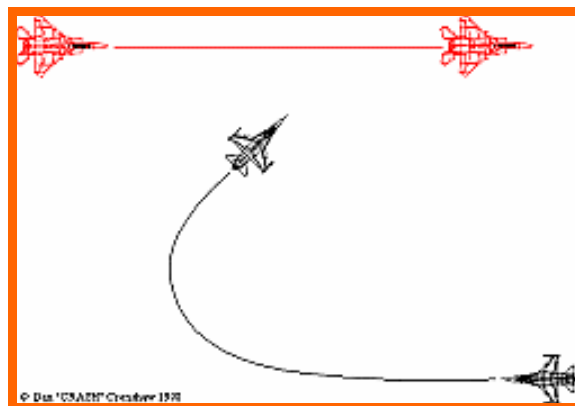


Figure 35 - The Lead Turn

The figure below shows, from a cockpit view, approximately where you would begin a Lead Turn.



Figure 36 - Picture at Start of Lead Turn

Now we have a pretty good idea when to begin the turn, what about the turn? Well, we are back to the CRASH SCHOOL of BFM ... Pull as many G's as you can. Pull for all your worth. When you make a Lead Turn, you are committing yourself to the fight. You have closed your escape window and the only way to open it again is kill your opponent (There may be a few other ways if the bandit really makes a mistake, but odds are you will not get that lucky).

Lead Turns do not have to be executed in HEAD ON. They can be used from any aspect and angle-off. You must be able to predict the bandit's flight path and take great care not to fly out in front of the bandit when you pull your turn.

If you Lead Turn and your opponent does not, you will win. Likewise, if he Lead Turns and you do not, he will win. In similar aircraft fights, a Lead Turn will not give you the advantage if you both execute them, but if you both do a Lead Turn, he will not get the advantage either.

In aircraft with distinctive handling differences, a Lead Turn vs. Lead Turn will gain you the advantage if your aircraft is the better of the two. If you are in an F-16 and entering a fight with a MIG-29, you will more than likely gain an advantage in the Lead Turn fight. If you are in an F-14 and fighting the same MIG-29 ... I truly hope you have planned a high speed "blow though" and acceleration, or have your hand poised on the "seat popper".

If you ever find yourself "Nose High" while the bandit is closing "Nose Low", you're either very lucky or very good. (Remember, Nose High and Nose Low refers to aircraft nose position relative to the horizon). You are in a prime spot to pull a high G Lead Turn going high and getting help from the Radial G effect discussed in previous lessons. If you pull a Lead Turn here, you can quickly gain the 3/9 line advantage, get behind your bandit and score a kill. The figure shows a Nose High/Low Pass Lead Turn and a subsequent Vertical Lead Turn.



Figure 37 - Vertical Lead Turn

VARIATIONS ON A THEME

As much fun as it is to dogfight - the longer you are in a fight, the more the chances are that you will make a mistake and end up losing (or get jumped by your playmates friends). So the idea is to manoeuvre into a position to get a good kill shot. First thought is All Aspect Missiles. There are a few different variations, most common are All Aspect Heat Seekers (AIM-9M/X) and the ASRAAM, All Aspect Short Range Air to Air Missile.

Thought number 2 ... guns. Problem here is you need to manoeuvre to aim your guns and sacrifice setting up for good BFM. And remember, if your bullets can hit him in a HEAD ON Pass ... his can hit you too. It is therefore best to avoid flying HEAD ON into a bandit. Always break to one side or the other to get some separation to set up for BFM. Even if you intend to extend and run, keep off centre to avoid giving him an easy shot.

You may even get a "Face Shot" with an All Aspect missile as you close with the bandit. But again, he may have this same opportunity. If you have the chance, and the equipment to take a HEAD ON Missile shot, do it. It should put your opponent on the defensive, take you out of a HEAD ON fight as he evades pending doom, and give you the advantage.

4.4 FIGHT GEOMETREY: ONE & TWO CIRCLE FIGHTS

The figure below shows the difference between a one circle and a two circle fight. By looking at the figure, you can easily see why they are called what they are. If you and your opponent both use a Lead Turn, you are going to end up in a two circle fight.

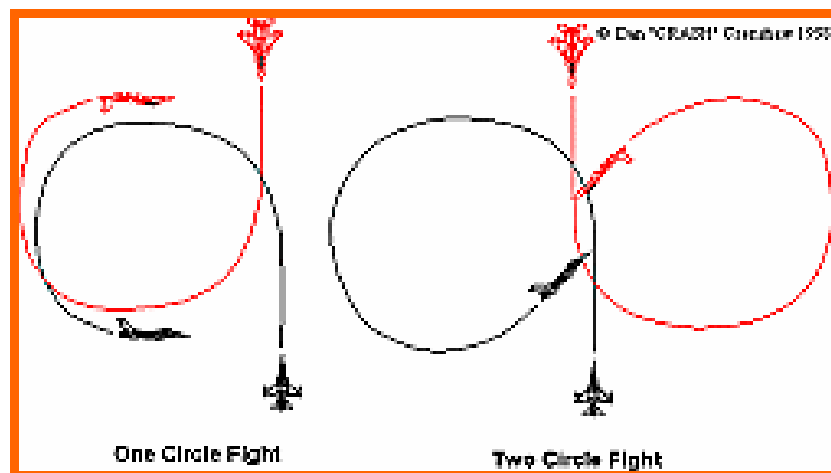


Figure 38 - One and Two Circle Fights

If one of the fighters turns away from the other, you will be in a one circle fight. Most fighters will turn into each other to get the most use of their available turning room. If a fighter turns AWAY from the Lead Turning bandit, he has given himself less turning room to work with while actually GIVING his opponent more turning room. Thus handing him the advantage.

What is the worst that can happen if you turn away from the bandit? You can GIVE your opponent the advantage and get yourself shot down. The figure below demonstrates one way this can happen. Fighter A turns away from fighter B.

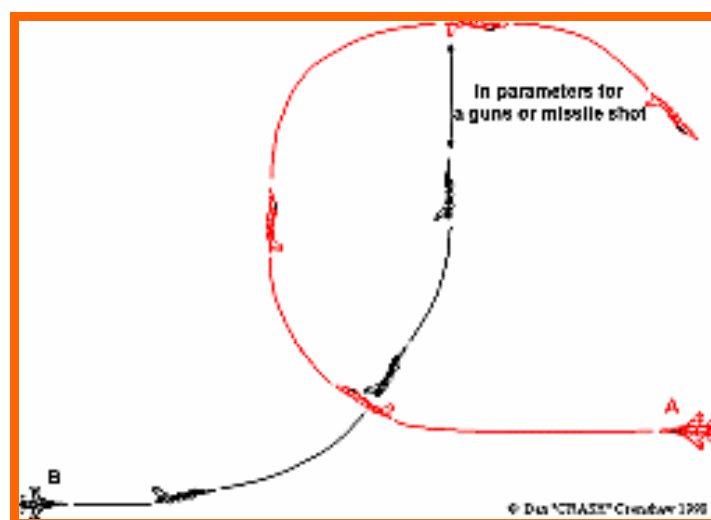


Figure 39 - Giving Your Opponent the Advantage

So why would you turn away from the bandit? There is a reason you may attempt this. In a two circle fight, a fighter may get the opportunity to fire an All Aspect Short Range RADAR or IR Missile if he can get his nose around fast enough. In a One Circle fight, you are most likely

too tight for an accurate missile shot (missiles take a little bit of time to lock and start their tracking). So if you do not have All Aspect capability and you think your opponent does, this may be an option to stay alive.

The last rule of the circle fight ...once you have started your turn, DO NOT REVERSE IT! If you want a two circle fight, but the bandit turns away, do not try to reverse. Continue with your turn. If you try a reverse, you will give away energy, time, and angles while you reverse your turn. You will also more than likely lose sight of the bandit during this move.

4.5 OPTIONS AT THE PASS

If you are going to stay and fight, it is unlikely you are going to go for a Head On guns shot. So you need to decide exactly what type of turn to execute with the Lead Turn. There are 3 basic options you can use:

- Turn Nose Low
- Turn Level
- Go up into the Vertical

These are not the only types of turns you can use. There are other manoeuvres that can be done, but anything other the three listed will probably result in you getting shot down.

NOSE-LOW

When you pull a Nose Low Lead Turn, or Slice, you are using Gravity to help you turn faster. The RADIAL G effect will pull your nose around faster than the other Lead Turn options here. When you do a Nose Low Slice, you pull High G's with your nose pointing 10 to 15 degrees down to take advantage of the RADIAL G. The figure shows a Nose Low Slice.

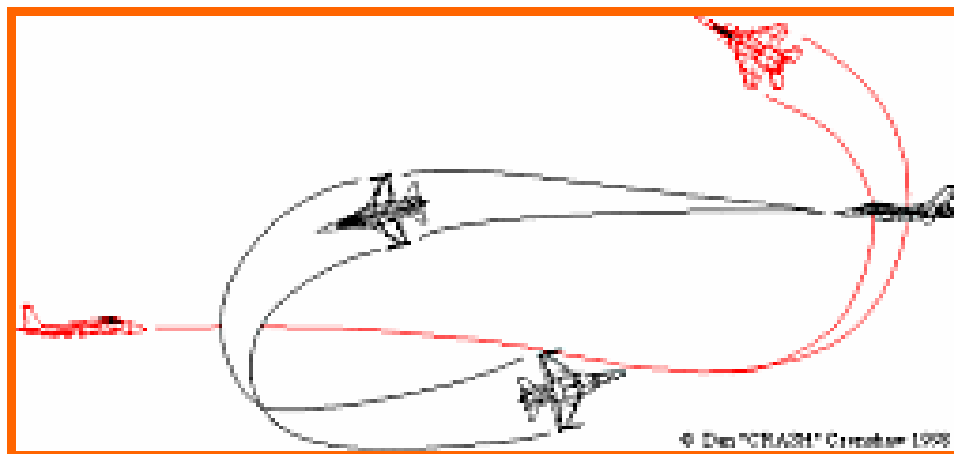


Figure 40 - Nose Low Slice

There is a qualifier here. This manoeuvre will more than likely, if executed correctly, put the bandit out of sight for a very short period of time. Now we talked about "Lose Sight, Lose Fight", so you are thinking this is probably not the best manoeuvre to initiate. Well, from a technical standpoint yes. However ... you should only lose sight for a VERY brief time. The bandit should reappear quickly approaching your 12 o'clock, a bit above the horizon, as you come around a full 180°.

If you are attempting to execute this manoeuvre, you are in a fast turning aircraft that can pull High G's. If this is not the case, you have already made your first mistake by staying in the fight.

LEVEL TURN

Basically the same manoeuvre as the Nose Low Slice with its own pros and cons. In a level Lead Turn, you should be able to maintain a visual on the bandit, but will slow your airspeed down much more than a Nose Low Slice.

VERTICAL

Going Vertical is not usually your best option. A few cases do exist where it may be a good idea. If the sun is overhead, you may be able to lose yourself in it. The bandit may lose sight of you, "Lose Sight, Lose Fight" works both ways. This may also help in the event of a Heat Seeker Missile shot.

If the sun is NOT above you ... you are a marked man. Hot afterburner against a cold blue or grey sky, makes a nice signature for an IR missile. If the bandit does lose sight of you, you can then set yourself up for a better shot while he flounders around looking for you. (If you see S-turns and rocking wings, he is trying to look behind himself to find out where you are. He will more than likely not be pulling towards you either.)

You will also have a lot of plane form to look at of your bandit while you do this. Problem you will have is speed loss is HIGH! As you begin your Vertical move, you will be at a disadvantage since you must fight gravity to pull up (RADIAL G again), remember that you will gain the advantage of the RADIAL G as you come over the top. If the bandit manages to get a tally on you while you are doing this, you can bet he will be making moves on you. Best bet is that unless you are positive you can get lost in the sun, going vertical is a big gamble at best.

A rule of thumb here is if you plan to go vertical, get some speed built up. Not corner velocity. Once you pull up, you will bleed speed so fast, that you will hit CV pretty quick anyway. Start wings level for maximum lift, get some high speed and pull hard.

As you get to the pure vertical, find your little pal and put your lift vector on him and pull into him. You may have to pivot or rotate your aircraft to do this (if not, he really is daft and deserves to be shot down). The odds are the bandit has had a tally on you for a little while and has made moves of his own.

What this means is the YOU are the wrong end of a Nose Low/Nose High merge like we discussed earlier. (See why I said you should not go vertical unless you are SURE you can get lost in the sun?) He will probably start a Lead Turn into you. You need to counter this with a Lead Turn of your own. Once you are able to continue around in the level, put your lift vector on him and pull into him.

Your other option here would be to continue the vertical fight. If you pull over the top and realize you have been spotted, go vertical again. You will not have the luxury of getting a lot of speed built up again. Accelerate until you are passing the bandit and pull up again. As you get to the pure vertical, look for your playmate and rotate and put your lift vector on him again and pull into him.

Do not hesitate on this vertical pull, if you do the bandit will be able to convert and get on your 6. Watch your opponent. You may have to try this vertical move again. When he is no longer pulling his nose up into you, you have the advantage. Then you have altitude that you can trade for speed and your opponent is out of energy. You now have the turning room and the energy advantage.

I am only talking about a full vertical climb and turn here. An oblique vertical turn will not give you enough turning room. The figure below shows the difference in turning room offered between a full vertical turn and an oblique vertical turn. The full vertical turn is on the left, while the oblique vertical turn is on the right.

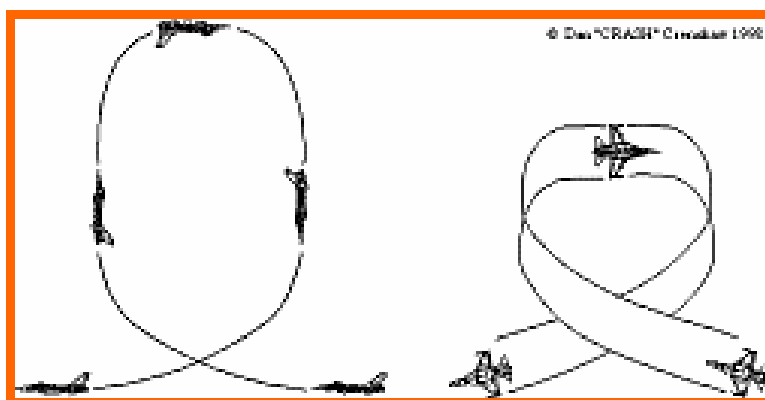


Figure 41 - Vertical and Oblique Turn

4.6 CONCLUSION

HEAD ON BFM is the most manoeuvre intensive type of fight you can get into. And as a result, you will not win this fight. Manoeuvre intensive fights are lost because of mistakes. The more manoeuvring required in a fight, the higher the chances of a mistake. You must make deliberate and calculated moves. Watch your opponent and work to counter his moves while putting yourself in a position that puts and/or keeps him on the defensive. Obviously to do this, you must keep him in site. "Lose Sight, Lose Fight" is not just a cute cliché, it is very real.

The basic manoeuvres described here can get you behind your opponent. Depending on how successful you have been, you can go back to the chapter on Offensive BFM or if you weren't so smooth, Defensive BFM.

You also need to make sure you keep your air speed up in the area of corner velocity, pull high G's (not wimpy little mid-level G's), keep your Lift Vector on the bandit, Lead Turn ... you must do all of these things CORRECTLY to have a chance to win.

The most important decision you must make in HEAD ON BFM is whether or not to stay and fight. If your opponent is in a superior handling aircraft, extend! Keep your Escape Window open. Run away! The F-14 vs. MIG-29 example from earlier is a prime example for "putting the hammer down" and "blowing through" the fight ... hit MACH 2 and run like hell. Do not wait and decide at the last minute you will stay and fight, or after you have started a Lead Turn that you may want to extend and run instead.

Summary

Reading and practicing these lessons, in conjunction with the ACM, BVR, A2A tactics and Air Threat Analysis packages will give you all the information you need to be successful in the A2A environment. Practicing these skills on a regular basis will improve your communications, mutual support and SA and, as an element or flight, you will be able to dominate the skies against all comers.

Credits

Thanks go to Bill "Tasty12" Castello for his articles that the lessons were primarily taken from. You can view them here:

<http://www.combatsim.com/htm/jan99/ACM-pt1a.htm>

and to Warren "Big Red" Hudson for his article that includes training setups. You can view it here:

<http://www.combatsim.com/review.php?id=475>

The "Art of the Kill" by Pete Bonanni was also used extensively in writing these Lessons.