Tactical Employment; Beyond Visual Range Combat

v57TTP 3-1.BVR, Revision 5, 13 April 2020
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OTHER PUBLICATIONS IN SERIES

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(SOON) v57TTP 3-1.Su-27, Tactical Employment; Su-27S/J-11A (U)

OTHER RESOURCES

This YouTube playlist will contain supplementary tutorial videos:
https://www.youtube.com/watch?v=3FpBu4815tk&list=PLYP4wOve-qgbYXWEGwDLAYbKB8au-bYyT

SOURCES REFERENCED

NATOPS P-825 All Weather Intercept (AWI)
F-16 Korean AF BEM
F-16 Combat Aircraft Fundamentals
NATOPS P-820 Radar Theory
Fighter Combat, Tactics And Maneuvering

Special Thanks To…

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SECTION 1 -- FUNDAMENTALS AND 1v1 BVR COMBAT

BVR TERMINOLOGY

Before we take a look at BVR tactics, we must familiarize ourselves with the terms and definitions frequently used and referenced in BVR combat tactics. Proper understanding of these terms is essential to learning how to excel at BVR combat. All definitions will be boldface.

Geometry Basics

In air combat, understanding the relative and absolute geometry of you and the bandit is immensely helpful to combat effectiveness

Properly describing the positional geometry of an aerial engagement is critical to both BFM and BVR combat. There are 3 main positional terms:

Antenna Train Angle (ATA): The number of degrees the defender is off the boresight of the attacker.
Target Aspect (TA): The ATA for the bandit.
Aspect Angle (AA): The angle measured from the tail of the target to the position of the attacker. AA+TA = 180°.
Slant Range: The range between the fighters in 3D space.
Heading Cross Angle HCA: The angle formed by the intersection of the bandit and fighter flight paths.
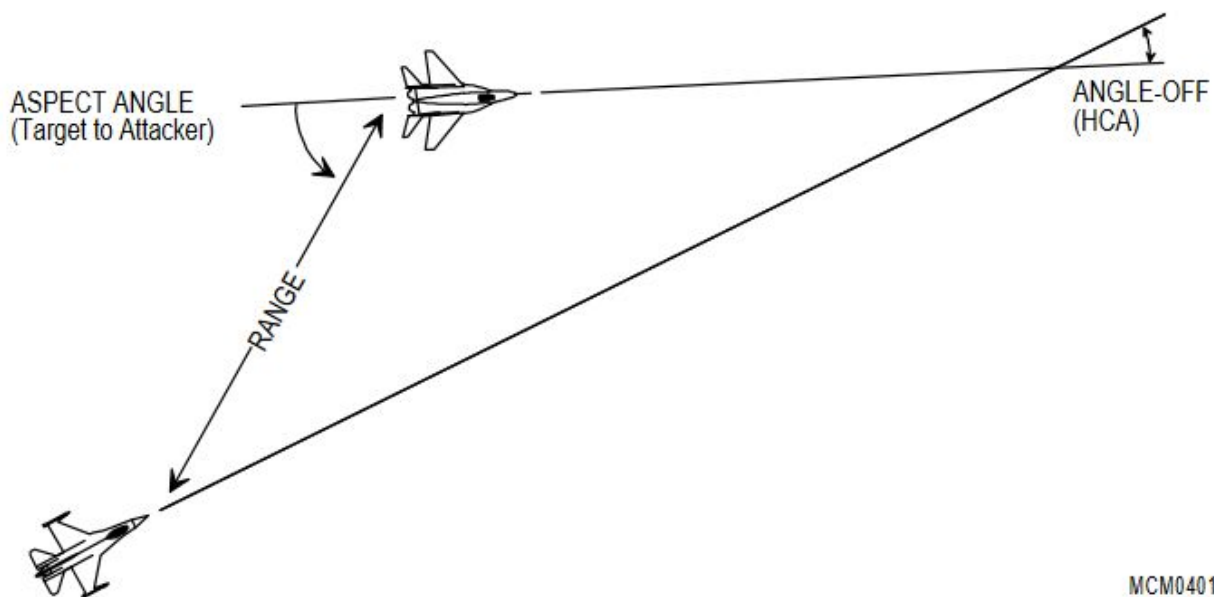
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Aspect is typically divided into 4 zones: hot, flank, beam, and drag:
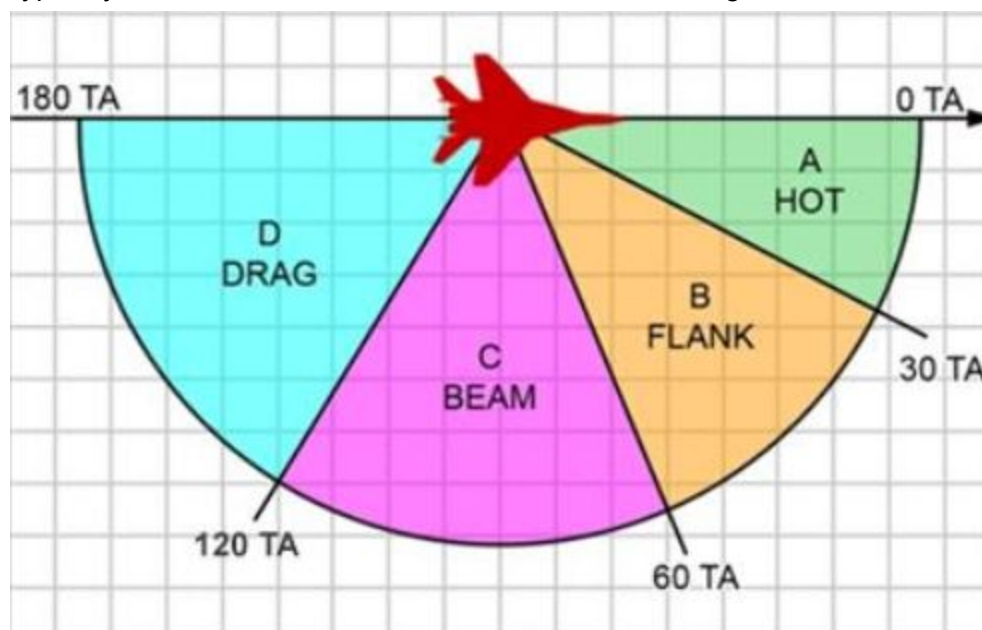
Pursuit Curve. There are three available attack pursuit courses: lead, lag and pure.
The attacker's nose position determines the pursuit course being flown.
With his nose pointed in front of the defender (such as in the case of a gunshot), he is in **lead pursuit.**
If he points behind the defender, he is in **lag pursuit.**
 If he points at his adversary, he is in **pure pursuit.**
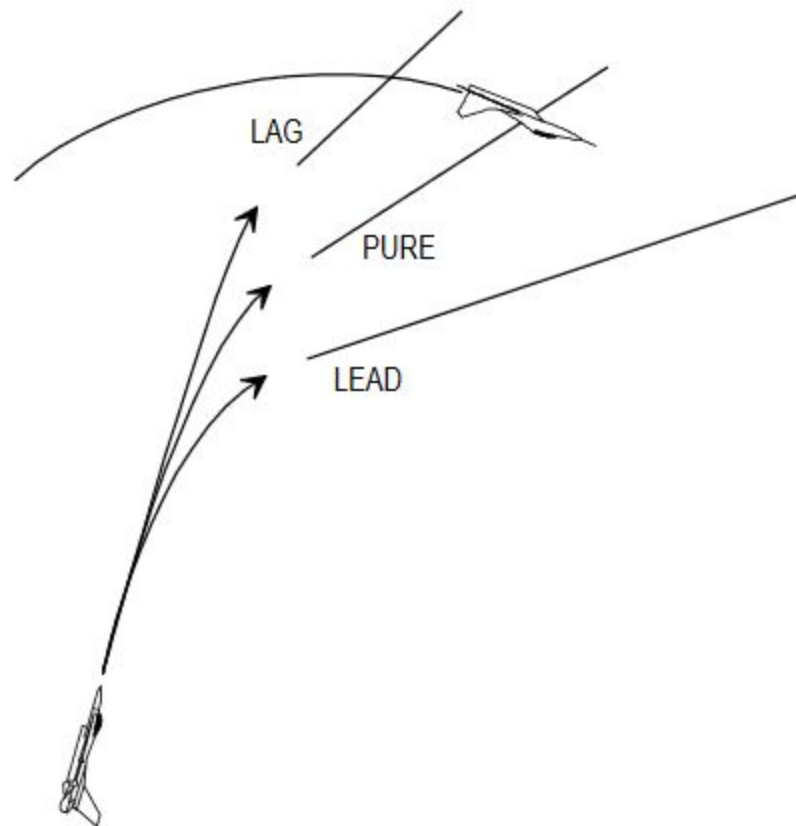
BVR TACTICAL CONSIDERATIONS

BVR Priorities

Prioritizing is critical in BVR. Without a way of prioritizing (and therefore reacting to) the information you are receiving, you will find yourself constantly making tactically incorrect decisions. Although there is never any one way to prioritize in all situations, we can still give a good overview of the typical priorities when flying alone (these will be expanded further in two-ship tactics discussion). Please note that these steps are not totally separate and unrelated, they have some overlap. For example, better SA allows you to have more info on the incoming missile, and better defend it.

   (1) Defending any missiles that have or could be launched
   (2) Gaining Situational Awareness (SA)
   (3) Maneuvering for effective weapons employment

Defending any missiles that have or could be launched: In BVR, your first priority is to defend any weapons that are either in the air, or likely to be launched. Defending in DCS must be anticipation based, with many aircraft capable of TWS launches of ARH missiles. For longer range launches, defending is quite simple, and can be performed with little consideration, allowing for the accomplishment of the other steps. Closer in, however, missile defense is a lot more involved and complicated, and may require you to temporarily sacrifice mental focus on gaining SA and weapons employment. Remember, if you need to focus purely on defense (which happens a lot when you are less experienced), don't be afraid to do it. That extra SA won't do you much good while you are hanging from your chute. Better to be defensive than dead. As you gain experience, confidence, and proficiency, you will better be able to multitask, but don't be afraid to go pure defensive when needed. Remember, prioritize on fighting what poses the greatest threat to you *at that moment*(such as an incoming missile, or the nearest bandit)*.*

Gaining Situational Awareness (SA): After defending, the next priority is gaining and maintaining SA. SA is crucial to all three steps. SA isn't simply knowing the physical position of the bandits, although it is a critical part. SA encompasses much more than position. SA includes things such as threat type and capabilities, expected skill level, and predicting where he will be. Thus, gaining more SA is critical in BVR. Please note that SA is NOT what your instruments tell you, it's the mental interpretation of this information into an image, or picture of the situation. SA can be lost, as SA requires concentration and effort to obtain. Defensive maneuvers such as the drag do drain SA, but as mentioned above, better to be defensive with low SA than to get hit by a missile trying to gain SA. So although SA is critical to defense, you must know when gaining new SA is secondary to defending. More info on SA will be in a paragraph later.

Maneuvering for effective weapons employment: After you have been cleared of defensive duties, and have enough SA, you can then begin to focus on employing weapons. One mistake made by newer players is prioritizing weapons employment over defensive duties and SA; although weapons employment is needed to shoot people, you can't shoot people if your lack of defense and SA have already got you shot down.

Situational Awareness

As mentioned above, situational awareness is key to BVR combat. Although acquiring new information is important to SA, prioritizing and filtering it is just as important. You can't possibly have SA on every event going on, You need to have a mental "threat range" where outside of this you only remember basic information (bearing) on detected threats. This range will be lower the newer you are; a good starting range is 30nm/60km (note that this is threat-specific; on a cold war server with IR threats this could drop to under 10nm. Altitude also affects this; at higher altitudes you may need to make this range a bit bigger, and vice versa for lower altitudes). Inside this threat range, you need to keep track of the bearing, altitude, aspect (hot/beam/cold).

Keeping track of this can be difficult, which is why practicing on less-crowded servers is better when you are new(er). Remember, use all the sensors you can for SA. Don't be fixated on the radar, or SA page. Those are important for BVR, but the RWR is one often under-used tool BVR. It can tell you whether a bandit is aware of you or not, and how he is using his radar against you. Learn it's symbology, it's worth it.

Lastly, never forget to use your eyes. Although BVR does use a lot of radar work, keeping visual SA on your surroundings immensely helps. In addition to the missile smoke trails and aircraft contrails, you can perform "contact flying", which is flying maneuvers (such as a notch) relative to terrain features. This is only possible if you have SA on the surrounding terrain, and at least his azimuth. Plus, terrain SA allows you to much better deal with "cockroaches" (the Flankers that think flying in the valleys is tactically smart :)). Remember, the only way to truly improve SA is lots of practice, and getting shot down, and seeing why you got shot down, so you don't make the same mistake again. Tacview is an excellent tool for this.

Overview of Air-to-Air Missiles

Guidance: Missile defense requires a basic understanding of how missiles work, specifically kinematically, and with their guidance. Missiles have varying kinematic performance based on their launch conditions. Missiles launched at higher speeds have a greater range than those at lower speeds, because of the extra kinetic energy given to the missile. Altitude works similarly; missiles at higher altitudes have greater range than those at lower altitude, for two reasons:

1. At high altitudes the air is thin, reducing drag, and allowing faster speeds, and lower bleed rates
2. Missiles at high altitude also have a lot of extra potential energy, and for targets below the missile, the missile can convert this kinetic energy into potential energy

As a general rule missiles at high altitudes (over 30kft) can have around triple the range of the same missile launched at sea level.

Gravity also has an effect on missiles. Missiles that have to climb uphill have reduced range compared to those travelling downhill. As a general rule, however, drag is a much more significant factor than gravity; therefore, at medium altitude, you do not climb to force the missile to climb as well; you dive to drag it into dense air.

Missiles also have to guide their way to the target, and the most common form of guidance is Proportional Navigation. Quoted from Wikipedia,

Proportional navigation (also known as **PN** or **Pro-Nav**) is a guidance law (analogous to proportional control) used in some form or another by most homing air target missiles. It is based on the fact that two vehicles are on a collision course when their direct Line-of-Sight does not change direction as the range closes. PN dictates that the missile velocity vector should rotate at a rate proportional to the rotation rate of the line of sight (Line-Of-Sight rate or LOS-rate), and in the same direction.

All DCS missiles fall under two categories: Constant PN, or Variable PN. Constant PN missiles have a constant PN factor(the number that determines how "aggressively" it turns), and use the same Gs close in as they do at longer ranges. An example is the R-27 series missiles, the Super 530D, and all the IR missiles. Variable PN missiles have varying PN factors, based on

range, so the missile is not wasting all its energy at long range pulling high Gs(almost pure pursuit in some cases), but waits until closer. The AIM-7/120 and SD-10/PL-12 are the main examples. Constant PN missiles bleed much more energy intercepting targets cranking at longer ranges; For variable PN missiles, changing direction while cranking essentially gives the missile higher closure, and with a variable PN, not much energy is bled to keep up, since its not trying to pull full lead.

　　　　Missiles are also susceptible to high LOS (Line of sight, how fast the target is moving across the seeker) rates, generated by a near beam aspect angle, and close ranges. These conditions give the missile the biggest angular problem to solve for How effectively a missile can cope with this circumstance determines how small of a Rmin it has.

Types of missiles:
　　　　Infrared: Infrared (IR) missiles guide on the targets heat source. They are fire and
　　　　forget, needing no support from the launching aircraft.
　　　　Semi-Active Radar Homing: Semi-Active Radar Homing (SARH) missiles guide on a
　　　　Continuous Wave (CW) signal from the launching aircrafts radar. They need support for
　　　　the entire TOF. (Note that SARH missiles technically can re-acquire, provided it is not
　　　　too long of a delay before restoring lock, and if the bandit did not use chaff)
　　　　Active Radar Homing: Active Radar Homing (ARH) missiles have a miniature onboard
　　　　radar that allows them to track the target autonomously. However, most seeker ranges
　　　　are under 10-15mi (in DCS, all ARH missile seekers range are 7.5mi). From launch until
　　　　the time the missile seeker is in range, a datalink from the launcher guides the missile to
　　　　the target. If datalink is lost, most ARH missiles will assume the target maintained its last
　　　　known course, and go active at the last estimated range.

Launch Denial: Although many of these maneuvers are specifically designed to defend against missiles that have already been launched, you must remember that it is always best to deny him the launch capability in the first place.

Anticipation and Situational Awareness in Missile Defense: Many people think that missile defense is based on mastering specific maneuvers. In reality, missile defense is mainly based on situational awareness, and anticipation. With so many Fox 3 carriers capable of TWS launches, anticipation is key. The first and most important rule of missile defense can be stated here: **Assume all aircrafts within Rmax have launched at you in the absence of evidence that they have not.** Refer to DAWSTTP 3-1.Threat Guide for specific threat info, but as a general rule, this is ~10mi ASL, and ~25mi at altitude (over 25k). How to defend is outlined in this diagram. Always assume he has launched at least one shot in every possible Pk category that you could be in range for.

Rmax

Launchers Perspective --Employment

This is the low Pk shot zone. Do not take shots at this range unless the target has no SA, or no RWR, etc. If the bandit cranks the missile is defeated.

Targets Perspective -- Defending

This is the low Pk shot zone. Shots at this range can be defeated by cranking.

Crank-Through Range/Rdef

This is the medium Pk shot zone. This is a good zone to take initial BVR shots at. He will have to drop his lock before reaching MAR to defend. If the bandit turns cold assume the missile to be defeated.

This is the medium Pk shot zone. These shots can be defeated by beaming near the top of the zone, and by running away at the bottom of the zone. The MAR is the closest you can wait to go fully defensive. Notching is a less-preferable option.

MAR

This is the high Pk shot zone. This is the optimal endgame BVR shot. He will have to commit to the notch to defend your MRM. The only way he can reliably trash the missile here is either notching, or LOS jinking. If he notches, condiser the shot defeated.

This is the high Pk shot zone. Against radar missiles notching is the best option here. You cannot outrun his missiles. Depending on the missile engagement geometry LOS jinking may also be an option.

RWR Interpretation: The RWR is programmed to issue a missile launch warning to the pilot, by sounding a launch warning audio tone. To understand how this works, we need to discuss how the radar and missiles work. Note that for specific symbology, refer to the aircraft manual.

In RWS and TWS modes, the radar scans the sky in a regular fashion. The radar antenna is not focused on any particular target. The target RWR will sound the regular search tone whenever the radar beam "paints" it. When a bandit locks you from RWS, it switches to STT mode. STT focuses the pulses of radiation on the target being tracked. This intensification of energy will show up as a hard lock on the RWR, and the hard lock tone will sound. Normal radar transmission is in discrete pulses. This is the case for pulse and pulse doppler radars, regardless of radar modes (RWS, TWS, or STT).

When many SARH missiles are launched, the radar will switch modes to support the missile. Many older SARH missiles do not guide on the discrete STT pulses, they need a Continuous Wave (CW) radio signals. This further increase in energy is detectable, and shows up as a SARH missile launch. When an ARH missile is launched in STT, it technically should not give a CW warning, as the missile needs datalink, not CW. Nevertheless, in DCS it does give a CW warning.

General Missile Evasion

Regardless of missile type, there are a few basic missile evasion maneuvers. You need to remember that when evading missiles, kinetic energy (speed) is king, provided you are running away. Potential energy (altitude) is simply not helpful. This doesn't mean you dump all your altitude to defend if you don't need to; Outside MAR, a slice/level turn to tail aspect with minimal altitude loss will defeat the missile, and the altitude will help you when re-committing. But never hesitate to drop altitude if you need to.

The Drag: The drag is probably the easiest maneuver to perform; its simply running away from the missile/launching aircraft. Before going further, we need to define MAR.

Minimum Abort Range (MAR): The minimum abort range is an important concept in BVR combat. MAR is the closest range you can kinematically defeat a FLO (First Launch Opportunity, usually Rmax for radar missiles) shot from a bandit by dragging, and remain out of his stern WEZ. Note that MAR assumes that you were HOT/FLANK on the target when he launched the missile, and stayed that way before you began dragging.

If you are outside of a missile's MAR, you will be guaranteed to defeat it. When you drag, just remember, do it fast. Full burner, and if needed dropping extra stores(fuel tanks, bombs, etc). If you do it right, even if your plane is inferior in speed, you can still out drag a superior aircraft until he runs out of fuel/is engaged by another friendly if you have a sufficient range cushion (around 5-10 mi past MAR is good). You almost always want to drop some altitude while dragging, so you can convert some of that altitude into airspeed. You do not want to drop too much altitude, or he will have a decisive speed advantage.

Launch Range, anywhere between
Rmax and MAR IAW Shot Intent

NLT MAR

MAR, and oustide of rear aspect WEZ;
Bandit must begin evasive manuvering

Execution: At medium-high altitudes, it is typically commenced with a split-S or a sliceback (essentially a split S, but only banking 135 instead of 180 deg before turning). At lower altitudes, or any time an altitude loss is undesirable, a level turn may be used.

The Crank: The Crank is one of the most simple, yet effective and useful BVR maneuvers. The Crank is the main maneuvers to increase your A/F-Pole (more on these two later). The Crank

involves putting a radar contact near the edge of the gimbal limit, while still maintaining lock. Since you are not flying directly at the target, your closure rate is reduced, and any missile he has in flight will have to cover a greater distance. The range between you and the enemy closes slower as well. Cranking has two main tactical applications: 1), Using it before he fires to minimize his WEZ, and 2), using it when a missile is in the air to increase the F-Pole of your missile.

       F-Pole: The separation between the launch aircraft and the target at missile endgame/impact. A video illustrating is is below: https://youtu.be/7f4wKQgPeQU

       For maximum crank ranges (Rdef) vs specific missiles, see DAWSTTP 3-1.Threat Guide. Video Example. A visual illustration is below.
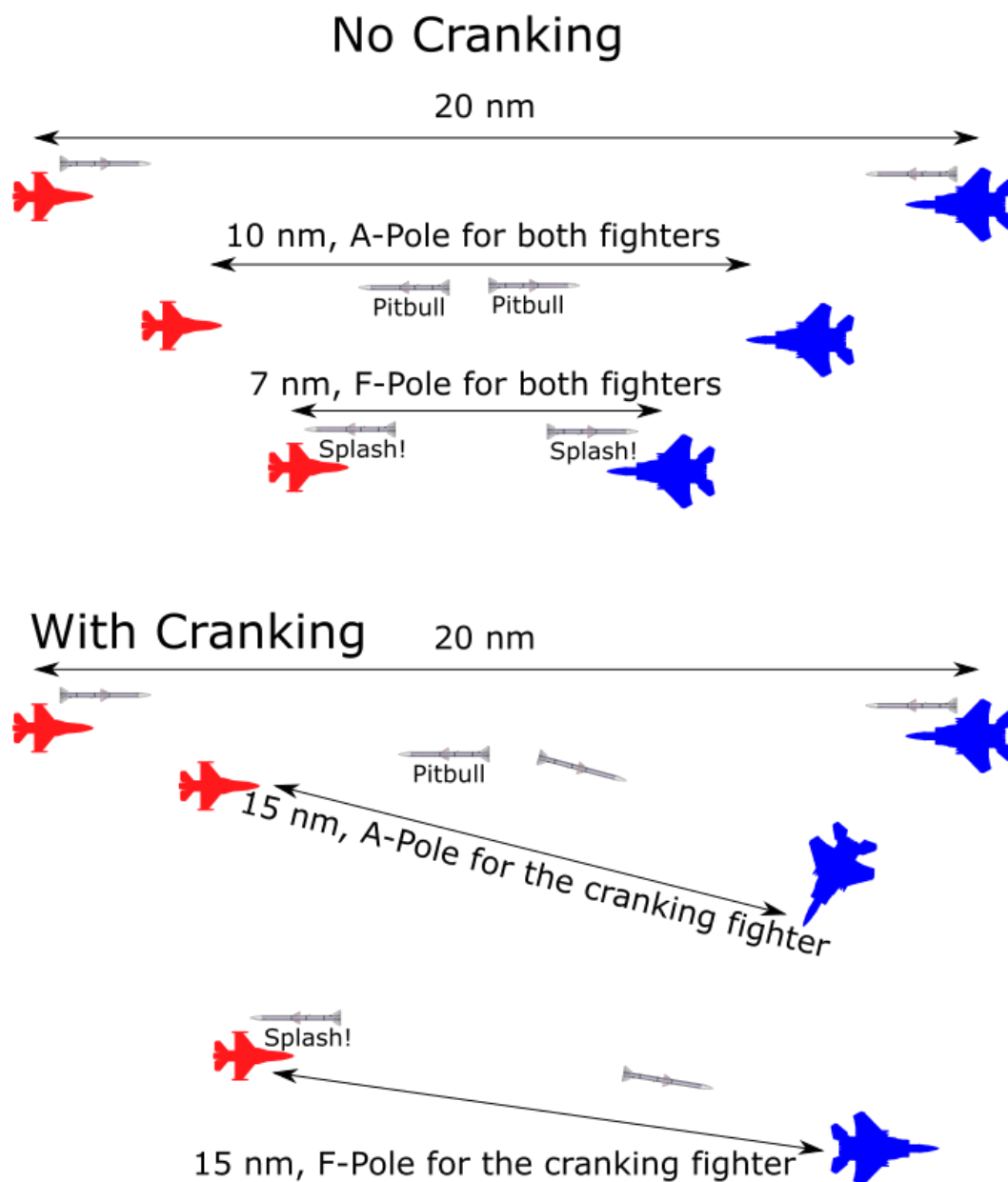
Execution: To execute a crank, perform a hard level or descending turn to the radar gimbal limits. Often, a dive is used as well, in order to pull the bandit missiles into denser air. One common misconception is that cranking requires you to turn from one side to the other, and that simply is not true. If you turn in and switch sides, you are *increasing* your closure to the target, and decreasing your F-Pole. Unless you are sure his missile is out of energy, NEVER turn in until you are preparing to fire again. Choose a side to crank, and stay there. As a rule, crank away from the bandits flight path.

The Beam: Beaming involves putting a missile on your 3-9 line in order to force the missile to pull the most lead, bleed the most energy turning, and fly a further distance, as in the crank. It also gives it a LOS problem at close ranges. The minimum range this works is the Beam Through Range (BTR). See DAWSTTP 3-1.Threat Guide for the BTR against various missiles.
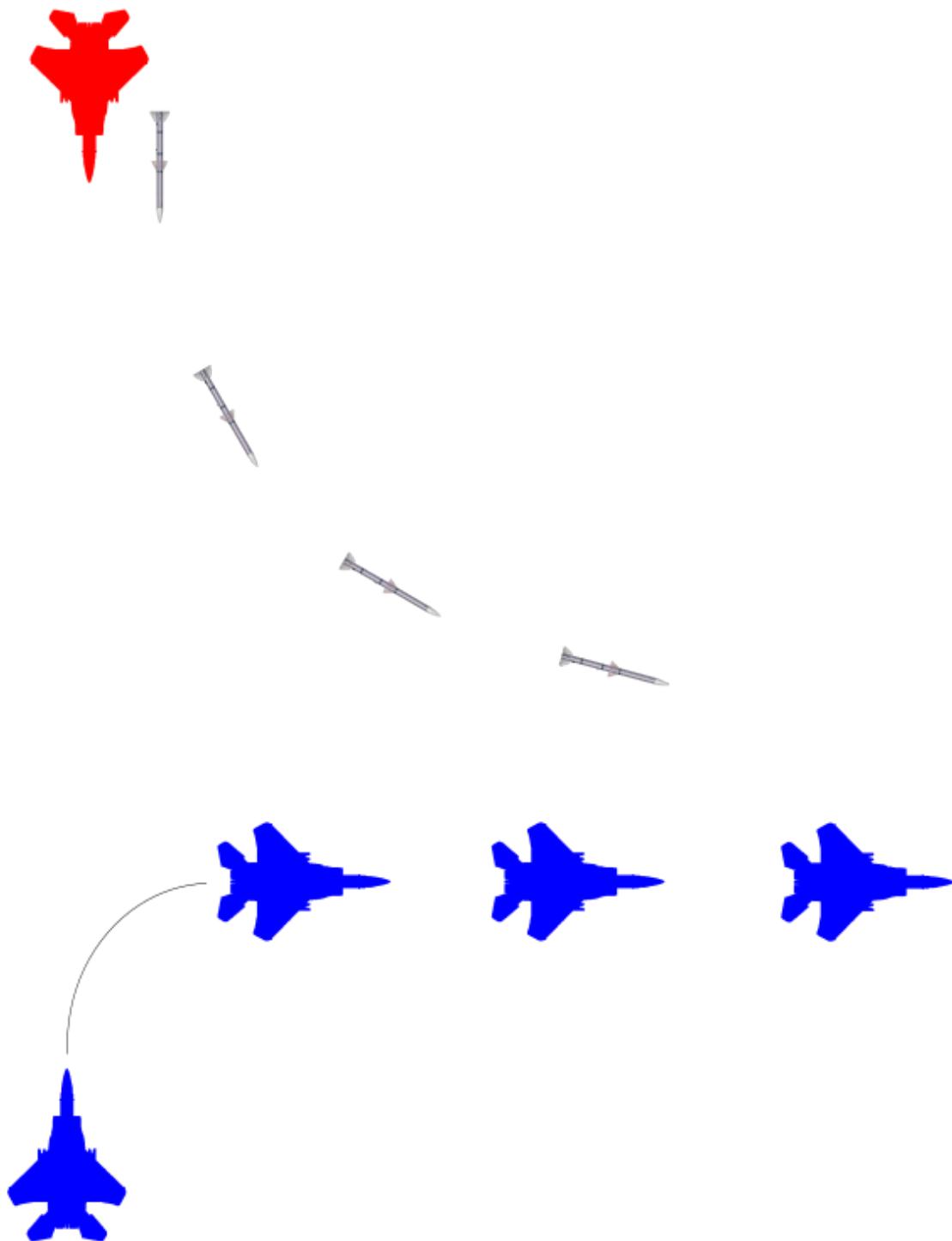
Execution: Like with a crank, a hard level descending turn will be used, except all the way to the beam. Diving can also be used with a beam, like with a crank.

Terrain: Putting terrain between you and the missile is a *very* effective method of defeating it. However, finding the terrain, and being positioned at the right spot can be hard to replicate consistently. Thus, this is not a recommended tactic to rely on. If you see the opportunity, however, use it! Another terrain related defense maneuver involves diving towards the ground at a steep angle and pulling up at the last minute. Under certain engagement geometries, this will cause the missile to crash, as it will try to lead you, unaware of the terrain.

LOS Jinking: All missiles have limits to LOS (Line of sight, how fast the target is moving across the seeker) rate. The LOS rate is highest either in the front quarter at close ranges, or in the beam, depending on the circumstance. Refer to DAWSTTP 3-1.Threat Guide for the LOS rate limits for specific threats. Higher speeds and turn rates generate the most LOS, so keep your speed up if attempting to out-LOS a missile. Under most conditions, you will execute the maneuver when the missile is within 1-3nm. of you. For threat-specific procedures refer to DAWSTTP 3-1.Threat Guide.

> **Execution:** Unlike the above mentioned evasion maneuvers, there is not one way to LOS jink missiles, it is very situational. As a general rule, however, LOS jinks fall under two categories: In-plane and out-of-plane. In-plane LOS jinks are either directly into or away from the missile. Most that are near/at/in Rmin are away from the missile, while most that are outside are into the missile. For defense near Rmin, a level/descending break away from the missile will spoof it. If well outside Rmin, you need the missile to be at least 60deg off your nose, and in lead pursuit (little to no LOS drift). When the missile is between 2 and 3mi from you, break into it with a max-rate turn at. You must keep at least M 0.9 at all times. Keep up the turn until you nose heading has clearly passed through the launching aircraft. Note that some missiles are much easier to jink than others, see DAWSTTP 3-1.Threat Guide for threat-specific advice.

Radar Missile Defense (RMD)

In addition to that presented above, there are a few radar-missile specific evasion tactics, divided into SARH (Semi Active Radar Homing) and ARH(Active Radar Homing) tactics:

SARH Evasion: As SARH missiles need the launcher to keep a lock for the entire TOF, any method of breaking the lock will defeat a SARH missile. One way to do this is the doppler notch.

> **The Doppler Notch:** The Doppler Notch is a maneuver that specifically exploits the Pulse-Doppler(PD) radars used on most modern aircraft and missiles. Essentially, Pulse Doppler radars filter radar returns that have near-zero closing velocity(such as terrain), therefore allowing "look-down shoot-down" capabilities. However, this leaves open the exploit of the "Notch", which involves flying with near zero closure. The most efficient way to notch is being at 90º aspect to the target, whether in the vertical or horizontal. Speed plays a major factor in how effective you notch, particularly against missiles. Slow

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speeds mean a much greater tolerance for deviation from 90º (good for more inaccurate RWRs like the SPO-15), but is means lower overall energy for maneuvering. Fast notching does the exact opposite. How fast/slow you go will all be dependent on the tactical situation, and the capabilities(specifically kinematic) of your aircraft. Note that you must be at a lower altitude than the target (in DCS this isn't fully implemented in all aircraft yet). Example Video. Illustrated below:
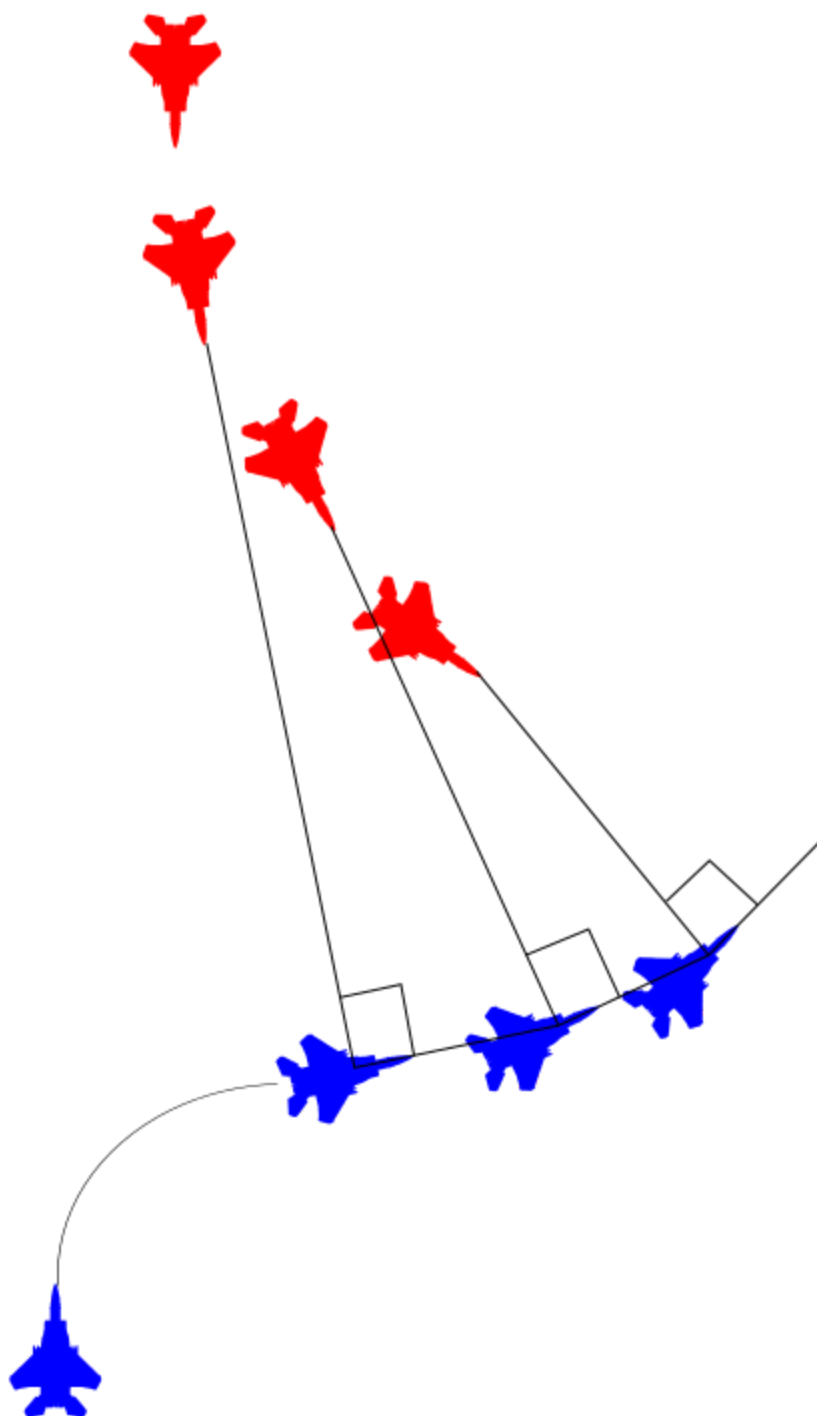
Note that the notch does not just have to be used to defend against missiles in the air; it can be used to deny him a radar track on you outside of firing range, and severely reduce his SA. These tactics, combined with altitude changes during the notch, may allow you to "close the gap" to WVR unnoticed, or at least until the effective range of your weapons.

Execution: Executing the notch with the needed accuracy can be challenging at first. Fortunately, there are techniques that can help ensure that you enter and maintain the notch as quickly and efficiently as possible. Although the RWR is an excellent tool for maintaining/adjusting the notch as needed, it isn't quite as helpful in entering the notch, as the blindspot will cause the spike to disappear during the turn. You could fly in the general beam direction, then use the RWR to fine tune, but its far faster to enter correctly in the first place. One way of entering the notch is through heading. By adding/subtracting 90deg from the bandits heading, you can arrive in the notch with quite a bit of precision. A simple way to do this is to either add 100deg, then subtract 10deg, or subtract 100deg, and add 10deg to the bandits heading.

Another method is contact flying, which is using terrain landmarks to notch. It is useful because (a), by paying attention to where the bandit was, you can visually notch at BVR ranges by using terrain and cockpit references, and (b), by paying attention to the terrain that is 90deg from you (provided you are aimed at the bandit when doing this), you can quickly notch without even looking at your RWR.

Using cockpit references will work to notch SARH missiles, as long as you have visual on the bandit (or are contact flying). Refer to aircraft-specific instruction on cockpit references.

Missile Defeat Cues: When a missile is defeated by a notch there are several cues to look for when at closer ranges. First, see if the missile is staying on the same place on the canopy. If it is not drifting, it is guiding and on a collision course. If it is drifting in any direction, it is not guiding. Also, see if it reacts to a sudden change in pitch. If it follows, it is guiding. If it still flies straight it is not guiding. A video illustrating this is below:

Chaff: Chaff are strips of aluminum(yup, essentially aluminum foil…) designed to reflect radio waves, and create a large radar signature. Chaff technically works against SARH missiles at all aspects; however, effectiveness is maximized in the beam/notch. See DAWSTTP 3-1.Threat Guide for effectiveness of chaff against specific missiles. Finally, remember that chaff is *not* needed to break an SARH lock. However, dropping a few chaff *will* stop the missile from re-acquiring you if you re-enter from a notch.

ARH Evasion: Unlike SARH evasion, you are trying to break the missile lock, rather than the launching plane (after pitbull). When you break the lock, the missile will stop guiding towards you, and fly straight ahead and turn on its seeker.

Notching: Notching works against ARH missiles; however, due to the high closure speeds involved, and the close ranges, the intercept geometry changes much faster than for a SARH missile, as its the missiles you are notching, not the launching AC like in SARH. Chaff is a must for notching ARH missiles. Overall, its much less effective than it is against SARH missiles, but it is definitely a viable tactic in DCS. As with SARH missiles, it is an effective launch denial tactic as well.

Execution: As you are trying to notch the missile not the launcher, purely using headings may not work, as the missile heading will normally deviate slightly from the bandit heading. Nevertheless, the above mentioned techniques will still help for establishing an initial notch.

As a last-ditch effort at closer ranges, an S-turn + chaff may defeat the missile. When doing this, break to the notch, but intentionally overshoot by 5-15deg. Then reverse the turn, and intentionally overshoot, etc, all while dumping chaff as frequently as possible. This will present a perfect notch to the missile several times, and hopefully it goes after the chaff on one of them.

One thing to note: Once you have initially leveled out from the hard turn into the notch, you should not pitch in immediately. You should wait 2-3 seconds to ensure that the missile did not lose track but then reacquire. If there is no RWR warning after 2-3 seconds, pitch in.

Chaff: In DCS chaff works the same against SARH and ARH with one exception: SARH missiles that get decoyed can *not* re-acquire, while ARH missiles can. Also, as a general rule, ARH missiles are more chaff-resistant than SARH missiles, so using chaff outside the notch really does not work like it does against some SARH missiles. When you do use it, however, spam it. If you died with chaff still on the jet you did something wrong.

Infra-Red Missile Defense (IRMD)

IR Evasion: Infrared missiles guide onto a targets heat source. As such, they cannot be notched. And unless its a rear aspect only missile, or at long ranges, the missile can track a target in idle throttle easily. Therefore, the only method of escaping NEZ IR missiles is flares.

Flares: Flares are hot pieces of burning metal that are hotter than your engine exhaust, and are designed to fool the missile into choosing it instead of you. They are ONLY effective against IR missiles, they have no effect against radar missiles! And ALWAYS reduce to at least MIL, and preferably IDLE power when launched on. **DO NOT USE AFTERBURNER WHEN EVADING IR MISSILES.** In order to further reduce your IR signature, break turn into the missile and attempt to put your nose on it, and give it the lowest IR signature possible. When the missile appears to be defeated, make a slight turn away so it does not reacquire you. At close ranges, sub 1-2nm, pre-flaring(flaring as soon or before he is in WEZ rather than when he fires) will significantly decrease the Pk of the missile. As a rule, the closer your nose is to the target, the less amount flares are needed. Shots from behind your 3-9 line will require significantly more flares than those in front. Note that flares have a maximum range, as at long enough ranges the aircraft will still be in the seeker FoV at flare burnout.

Missile Defeat Cues: When the missile is guiding, it will stabilize in one spot on the canopy or slowly move forward as it zeros out its own LOS rate and guides to impact.
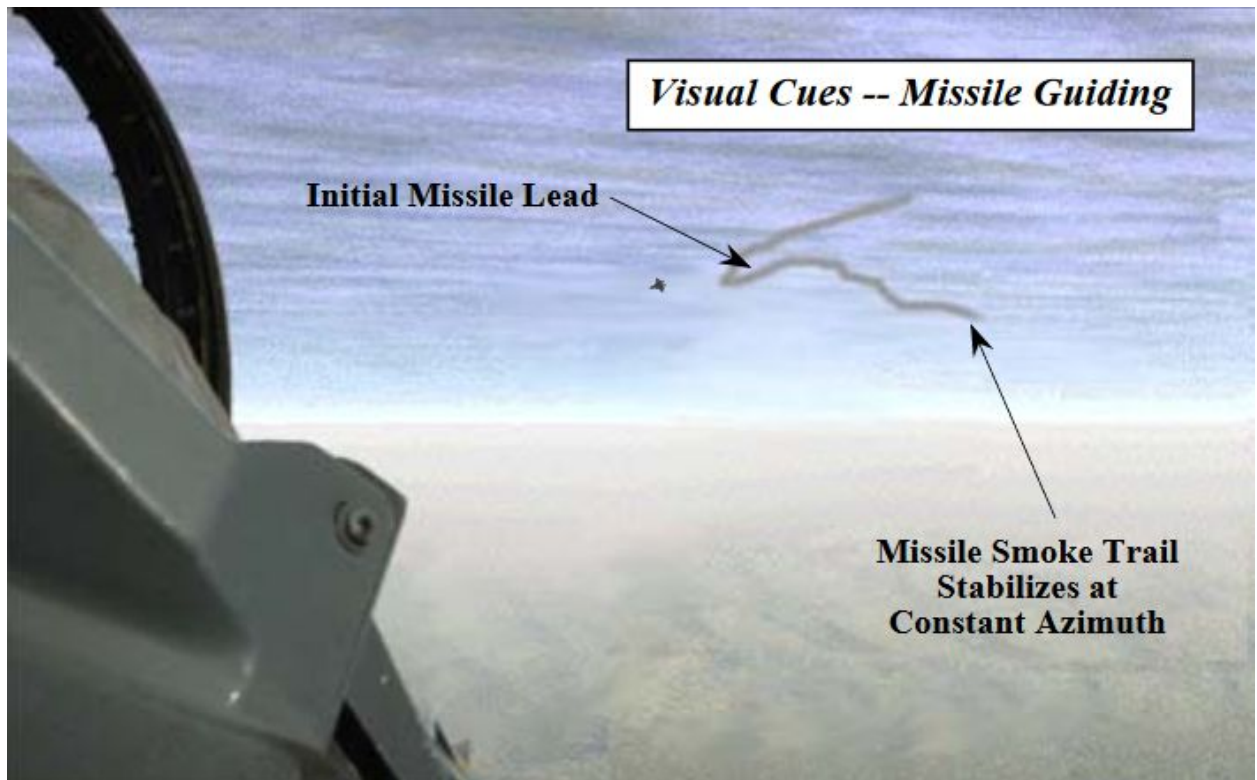
A decoyed missile will make a clear move aft(relative to the horizon) as it guides to the flares behind you. It may not appear to move aft much on your canopy at first. However, as range decreases, it will appear to rapidly move aft on your canopy.
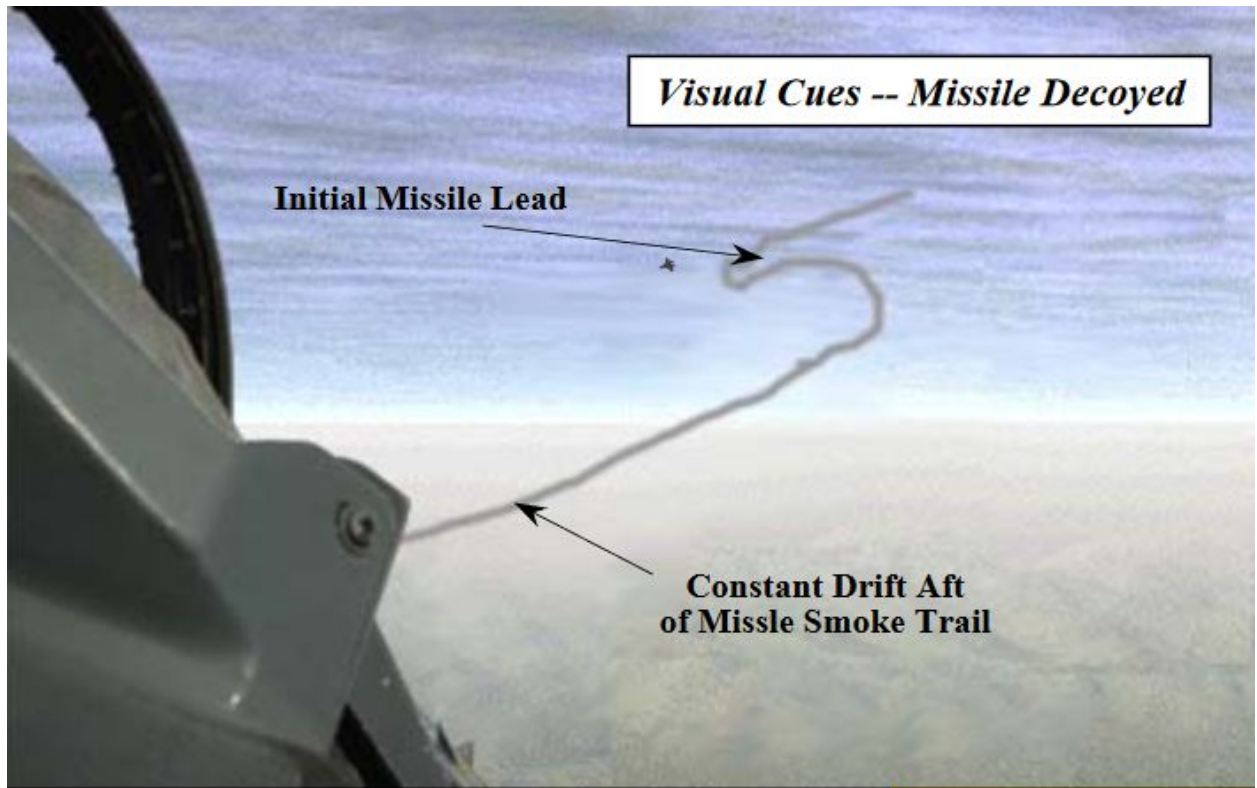
Missile Employment Fundamentals

Now that you understand how to defend against missiles, you need to understand how to employ them.

What's with all the poles?: If you have done research on BVR missile employment, you have likely run into the many "poles", such as the F-Pole, A-Pole, etc, and they can be quite confusing at times. Fortunately, they actually are quite simple. Poles represent a range to a target aircraft that is of significance to BVR combat.

> **F-Pole:** The separation between the launch aircraft and the target at missile endgame/impact. A video illustrating is is below: https://youtu.be/7f4wKQgPeQU
> **A-Pole:** The distance from the launching aircraft to the target when an ARH missile begins active guidance.
> **E-Pole:** The range from a threat aircraft that an abort maneuver must be accomplished to kinematically defeat any missile the bandit could have launched or is launching. More commonly referred to as MAR.

Weapons Employment Zone (WEZ): The Weapons Employment Zone, or WEZ, is a three dimensional volume of space around a hostile aircraft into which the fighter must fly in order to have a chance to successfully employ its weapons. WEZs are often depicted in a 2-dimensional, top-down or side view. The WEZ is largest with 0 TA, at high airspeed and high

altitude, and is smallest in the rear quarter at low altitude and low airspeed. Missiles like altitude, airspeed, and closure to achieve maximum kinematics. An illustration of WEZ vs aspect is below:
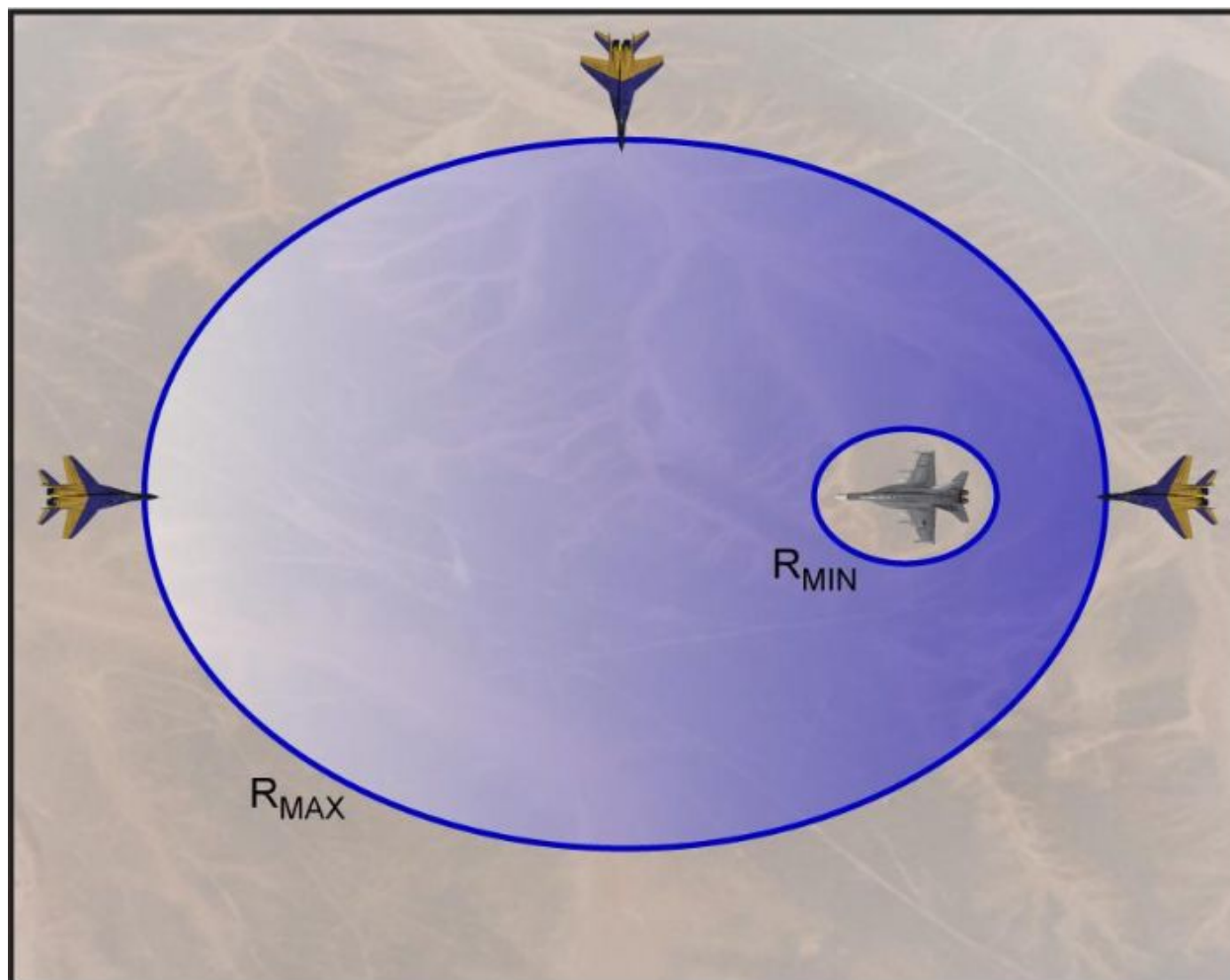
An illustration of WEZ vs altitude is below:
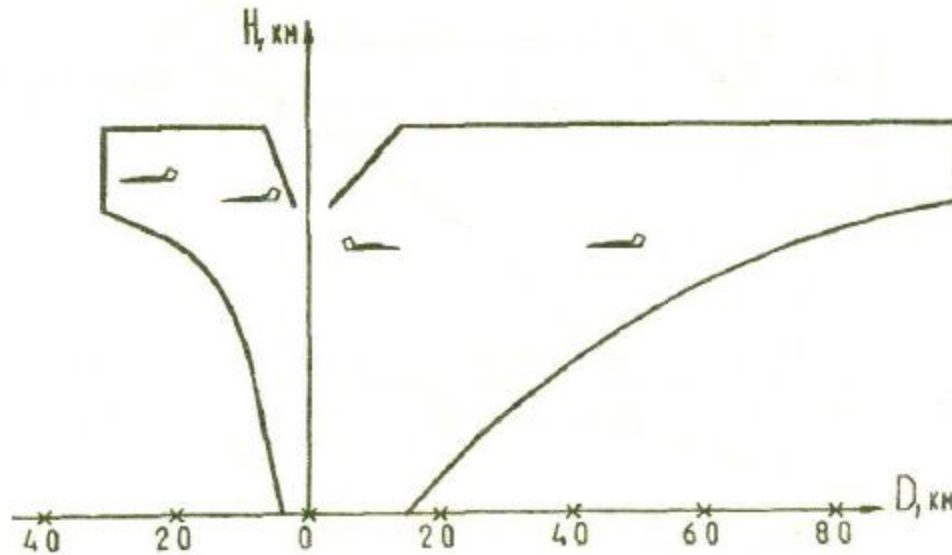
The WEZ can also be expressed in angular terms. For example, the R-73 in DCS has a gimbal limit of 75°. This compares to the AIM-9M, with a gimbal limit of only 45°. Even though they have similar ranges, their gimbal limits, and thus WVR/dogfight WEZs, are very different.

The DLZ: The Dynamic Launch Zone(DLZ) is a set of at least 3 constantly calculated (hence the name, Dynamic) ranges representing specific points in the WEZ. The aircraft avionics usually displays them on the HUD/Radar display. Most DLZs have at least 3 ranges: Range Maximum, or Rmax(sometimes known as Rpi, Range of Probable Intercept), Range Turn and Run, abbreviated as Rtr, and Range Minimum, Rmin. Here is a page from the F-15C manual illustrating their appearance on the VSD(Vertical Situation Display):

Target heading		Rpi
Target TAS knots		Current range
Target aspect angle		Rtr
Target altitude 29 900 FT		Rmin
Target		Range to target
Steering dot		Pre-launch Time to missile intercept
ASE circle		
NCTR		

Display readout: 400 20L 76 ... 40 ... 29-9 ... 824 > ... STT ... G 423 ... Su17 ... M26SEC ... 095 24
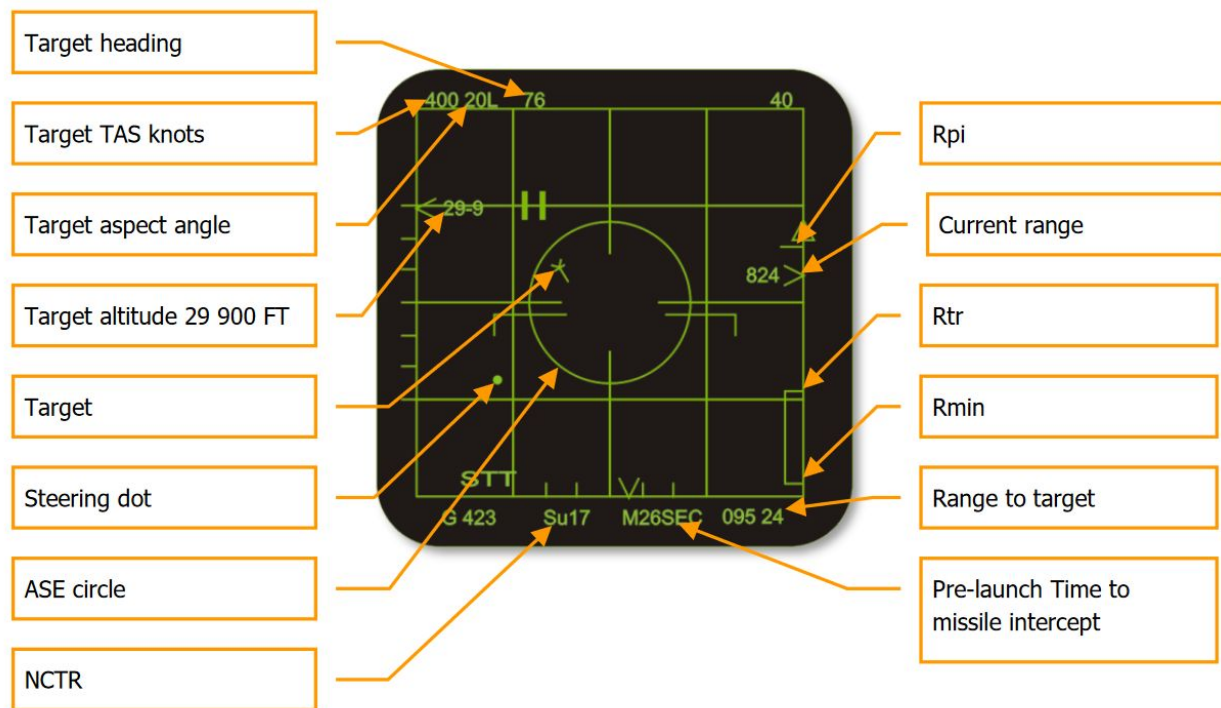
Rmax/Rpi: The maximum range you can expect to hit a relatively non-maneuvering target, such as a transport aircraft/tanker, and still have limited maneuvering capability. Against fighters Rmax launches are not recommended, as almost any evasive maneuvers will prevent successful intercept. Note that some refer to Rpi differently, almost as Rdef.

RTR: The maximum range you can expect to hit a target that runs away at launch. This is the missile's MAR. It is sometimes referred to as Rmax2.

Rmin: The minimum range the missile can be fired at, either due to fuzing, LOS limits, or maneuverability capabilities. Any maneuver should be sufficient to trash a Rmin shot, as the missile will be unable to maneuver to kill you.

Other Important Ranges:

Stern WEZ: The stern WEZ of a missile is the maximum range it can "run you down" in a tail-chase. Unlike RTR, this does not assume a hot target that turns around; this assumes a cold target at launch.

NEZ: The No Escape Zone (NEZ) is the range inside which kinematically defeating the missile is impossible. The NEZ is typically a bit under RTR. NEZ shots will always have the energy to reach you, so the only ways to defeat an NEZ shot involve causing the missile seeker to lose track, or increasing miss distance beyond proxy fuze range.

Rdef: An Rdef shot will be defined as any shot that over 70deg of aspect change (crank) is required to defeat. Not shown on most DLZs, but is about twice the NEZ. Also known as Crank Through Range (CTR).

Ropt: As a result of the drawbacks of a maximum range shot, tactics often associate an optimal range for shooting, called Ropt. Ropt is generally a compromise between having enough shot

range to not be defensive to the bandit, while also shooting close enough to have ample end-game energy for the missile.

Missile Employment Considerations

When employing BVR missiles, there are several factors to consider.

Shot Range: The range a fighter employs weapons can have a significant effect on the success of the missile. At long range, the bandit has the time to recognize he is being shot at and maneuver to defeat the missile. It is for this reason the NEZ is an important range to understand. The closer to the NEZ, the higher the chance of shooting down the bandit.

The shot range is primarily determined by these 3 things: Weapons performance, Shot intent, and launch conditions.

Weapons Performance: The performance of your weapons, will influence how far/close you employ weapons. See the weapons specifications for weapon performance

Shot Intent: The intent for the shot is a big factor in employment. The main property of shot intent is Probability of Kill, or Pk. It is how "lethal" the missile shot is, as the diagram on the below illustrates.

Rmax

Launchers Perspective --Employment

Targets Perspective -- Defending

This is the low Pk shot zone. Do not take shots at this range unless the target has no SA, or no RWR, etc. If the bandit cranks the missile is defeated.

This is the low Pk shot zone. Shots at this range can be defeated by cranking.

Crank-Through Range/Rdef

This is the medium Pk shot zone. This is a good zone to take initial BVR shots at. He will have to turn cold before reaching MAR to defend. If the bandit turns cold assume the missile to be defeated. These are also known as turn signalling shots, as they force him to turn cold, or loose a lot of altitude.

This is the medium Pk shot zone. These shots can be defeated by beaming near the top of the zone, and by running away at the bottom of the zone. The MAR is the closest you can wait to go fully defensive. Notching is a less-preferable option.

MAR

This is the high Pk shot zone. This is the optimal endgame BVR shot. He will have to commit to the notch to defend your MRM. The only way he can reliably trash the missile here is either notching, or LOS jinking. If he notches, condiser the shot defeated.

This is the high Pk shot zone. Against radar missiles notching is the best option here. You cannot outrun his missiles. Depending on the missile engagement geometry LOS jinking may also be an option.

Launch Conditions: One of the most overlooked factors in shot range is launch conditions. The main factors are speed, altitude, and target aspect. As a general, for altitude differences up to 20kft, the launcher's altitude matters much more than the target's altitude. Speed is not quite as important as altitude, but still helpful in giving

missiles a range boost. Aspect is also critical, as it controls the closure of the bandit. The hotter the aspect (closer to 180 AA) the more closure. As a rule, to give your missiles the biggest range boost, get as high as you can while still maintaining at least M 0.9. Once you are 20kft above him, level off and accelerate.

ATA: Another overlooked pre-launch consideration is the ATA at launch. Most jets have a form of indicating the optimal launch steering for the missile.When launched like this, the missile has to make no turns at launch, barring target maneuvers. Always attempt to get as close to this as possible before firing. Rmin is decreased the closer to collision settering. Range is also improved, as the missile doesn't waste energy in the initial turn. Finally it makes the shot less LOS jinkable. The exact reason for this is a bit math-y so I won't go into details but essentially, the closer to optimal speering, the harder it is for the bandit to LOS jink it. This is why ITR is important with HOBS missiles; the guy with the higher ITR can take a shot at the same time as the other guy but with a lower ATA, increasing the relative Pk of his missile.

MRM Employment Considerations: When employing MRMs, such as AIM-120s and AA-10s, there are several specific factors to consider.

Radar Considerations:

Radar Mode: With MRMs you need to ensure you are in the correct radar mode. SARH missiles need an STT lock to guide. With ARH missiles, STT vs TWS depends on the aircrafts capabilities. STT provides the most accurate bandit information and smallest uncertainty volume. If a mode other than STT(e.g, TWS, SAM, or DTT) is used, there is a greater uncertainty to the bandit's actual location. Refer to the aircrafts radar manual for plane specific weapons employment.
Trackfile Stability: Closely associated with the concepts of radar mode effects on employment are those related to the quality of the trackfile just prior to, and after launch. If a trackfile is consistently in and out of a MEM condition (such as in the case of a beaming bandit), or the TD box is drifting significantly from the bandits actual location, then the quality of that trackfile is suspect. Weapons employment should be delayed until the trackfile quality improves, or if not in STT, an STT can be commanded on that track, which often improves trackfile quality.

Post-Launch Considerations:

Maneuvers: The bandit will often maneuver to reduce the Pk of your fighter's missiles. For specifics of how bandit maneuvering will affect Pk see the section on missile defense, and the diagram above.
ECM: The bandit may also use electronic counter measures (ECM) to deny your radar system from attaining a reliable radar track.

UNCLASSIFIED

Radar Support: Depending on the type of MRM differing forms of post-launch radar support may be required. SARH missiles need consistent support throughout the TOF. Although reacquiring from a briefly lost lock is technically possible, the Pk is significantly reduced. ARH missiles Pk is maximized the longer you support it until pitbull. If you snip the lock before pitbull, there is a greater uncertainty area regarding the bandits location. Sometimes, if the bandit maneuvers enough, the he may be outside of the missiles FoV when the missile goes pitbull. Therefore, to maximize Pk, support the missile until pitbull.
Bandit Maneuvers/CMs: If the bandits maneuvers/CMs cause a lost lock, or cause the missile to stop tracking, you need to assess follow-up employment options. Often, such maneuvers that cause a lost lock put the bandit in a defensive position, and allow you to close the range for a follow-up "Pk enhancing" shot when he starts to turn back in:

Second Employment, Enhancing the Probability of Kill (P$_K$)

SRM Employment Considerations: Infrared SRMs also have specific employment considerations.

Seeker Considerations:

Seeker Lock: You need to ensure the seeker is actually tracking the target, and has a stable lock. Use of a radar-slave feature will often increase acquisition range.
Countermeasures: If the bandit is launching flares, depending on the missiles flare resistance, it may be advisable to wait until he stops flaring to launch.

Missile Employment Terminology: The terms below are commonly communicated during an intercept where BVR missiles are launched. You will use these terms employing MRMs and SRMs. There are certainly more terms to know, but these are an excellent starting point and utilized in almost every air-to-air intercept.

Fox-1 is the radio call made to announce that a fighter has employed a semi-active radar air-to-air missile.
Fox-2 is the radio call made to announce that a fighter has employed an infrared air-to-air missile.
Fox-3 is the radio call made to announce that a fighter has launched an active radar air-to-air missile.

If two missiles are employed on two separate contacts in a multi-track mode, the comm will be "**Fox-X, two-ship**"

If two missiles are employed on the same contact, the comm will be "**Second Fox-X**"

Trashed is an informative comm brevity term that the current missile in flight has been defeated by ECM, bandit maneuvers, or radar problems. Comm is "**Shot Trashed**"
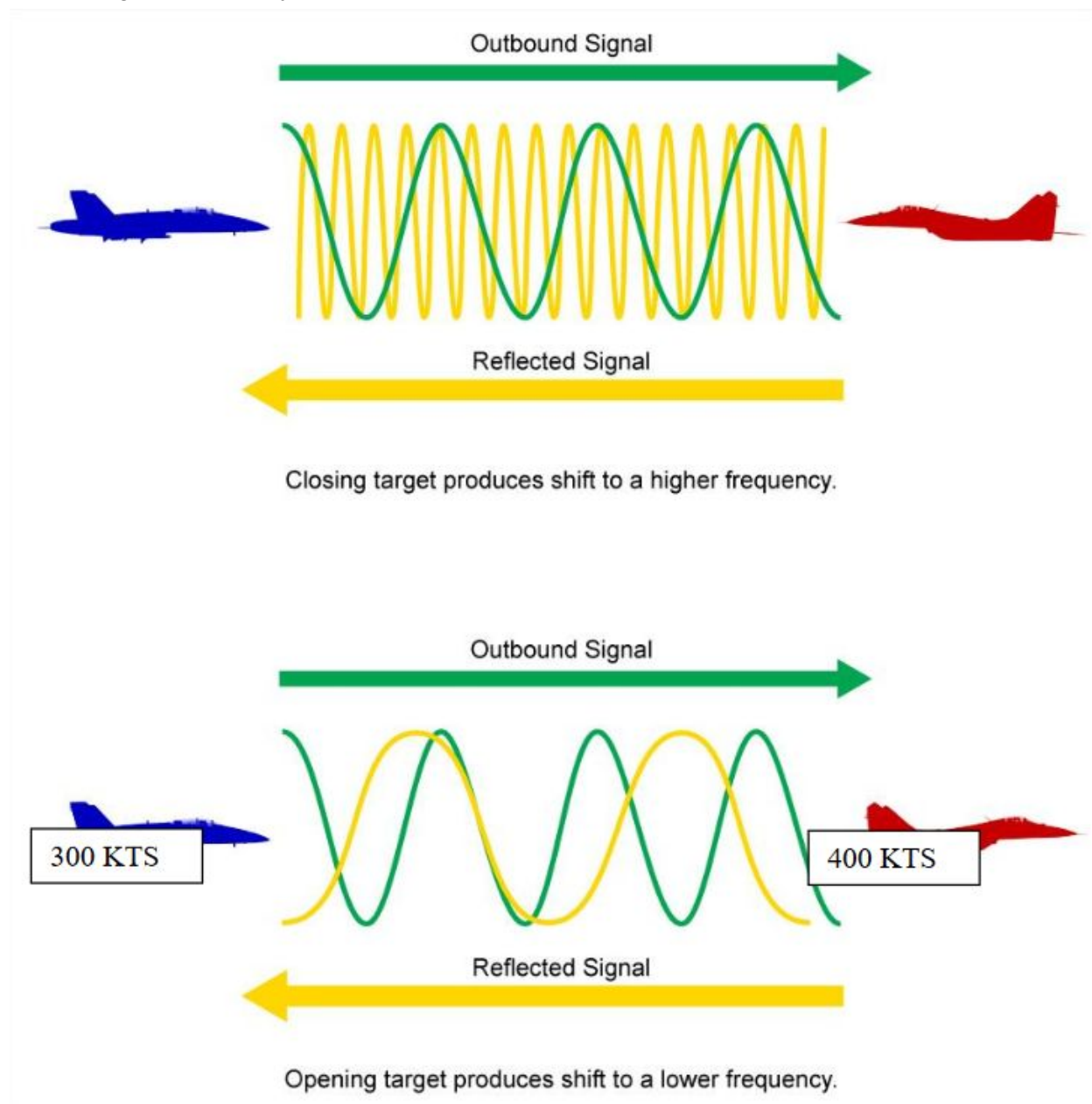
Radar Fundamentals

One essential skill to successful BVR combat is knowing how to operate your radar (refer to the aircraft manuals, or tutorials on the subject for actual operation of specific aircraft radars), and how to effectively use them in combat(which is what is covered here).

Pulse Radars: The first radars were pulse radars. A pulse radar operates by emitting focused radio frequency (RF) energy and then receiving, or "listening," for the reflected return of that signal. Bearing to the target is determined by the direction the antenna is pointing and range by the time it takes for the pulse to travel to the target and be reflected back to the antenna. These returns, called "echoes" were then displayed to the operator on the scope.

Pulse radars have an advantage in that they "see" everything. The problem, however, with seeing everything is that it takes a very well trained operator to discriminate real returns

from clutter and potential decoys, such as chaff. This makes their successful application in the A/A environment dependent on the skill of the user. Early radar equipped fighters used pulse radars and CW illumination for radar guided missiles. Many incorporated a dedicated radar operator due to the nature of early radar systems.

Pulse-Doppler Radars: A Pulse-Doppler, or PD, radar emits pulses of energy, but interprets the returns in a different way. Rather than display only the echo, the PD radar evaluates the change in frequency comparing the relative velocity of the transmitter to the returned signal. This change in frequency is called the "Doppler effect." An illustration is below:

Outbound Signal

Reflected Signal

Closing target produces shift to a higher frequency.

Outbound Signal

300 KTS

400 KTS

Reflected Signal

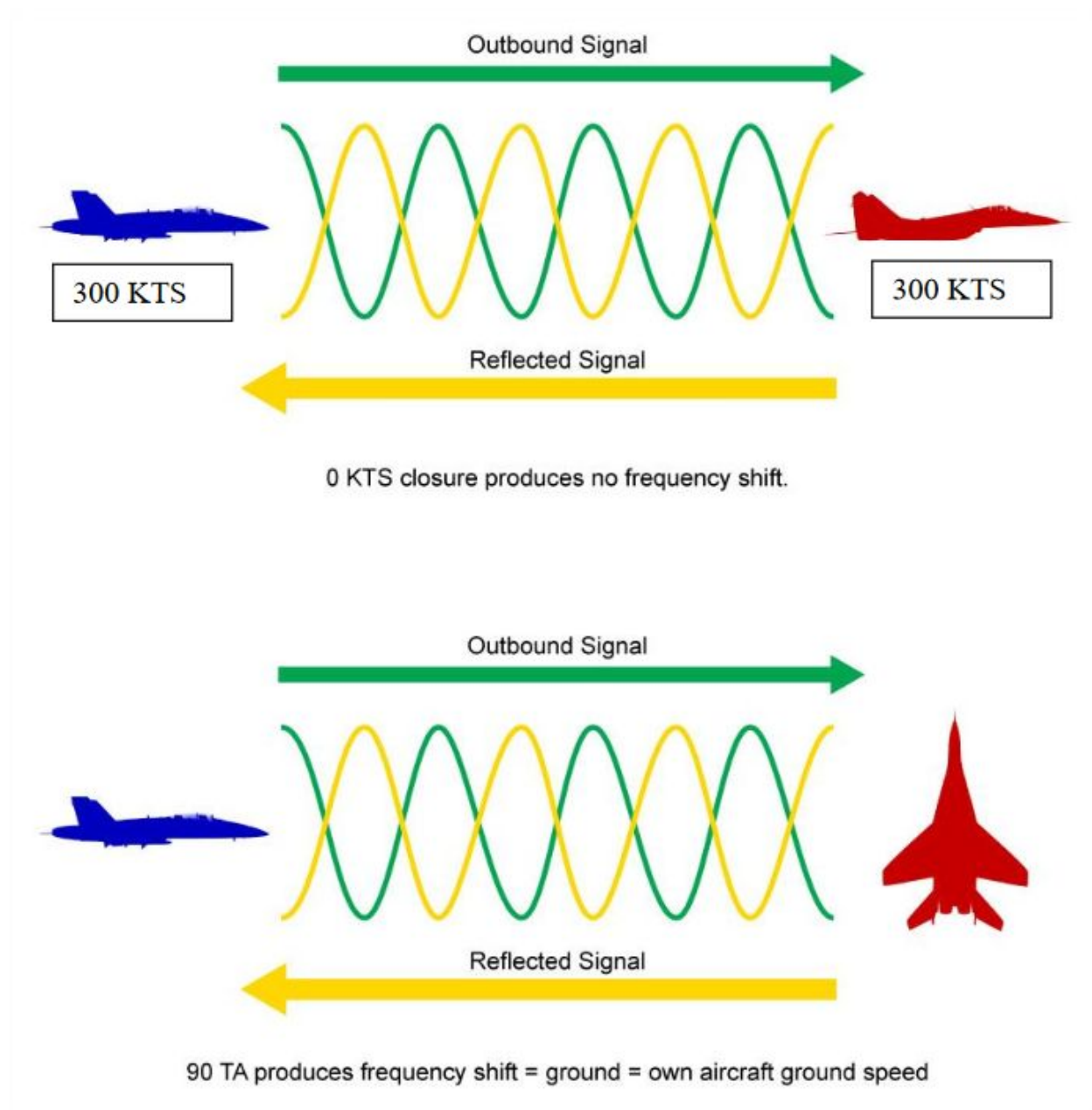Opening target produces shift to a lower frequency.

The Doppler effect is noticeable in sound waves when a vehicle such as a car or train horn passes by. As the vehicle approaches, the sound waves are compressed in frequency,

raising the pitch of the sound. After the vehicle passes, the sound waves frequency is reduced; therefore, lowering the pitch of the sound. If two vehicles are traveling at the same speed, there is no change in pitch as there is no frequency change.

This same principle applies to electromagnetic (EM) waves emitted from a radar. That is, the frequency increases for approaching targets and decreases for receding targets. In a true Doppler radar, the radar only detects and displays contacts with Doppler shift in the returned energy. This limits the applications of radars that are only Doppler radars.

When the PD radar receives returns, it filters out frequencies that are expected from stationary objects like terrain, moisture and dust. If your ownship is traveling at 300 KTS ground speed, the return signals from these stationary objects will have a Doppler shift as there is 300 KTS of closure velocity (Vc) from your aircraft. Therefore, radar returns from objects with Vc about the same as ownship ground speed will be filtered out, in order to provide as clutter free scope as possible.The region of velocities around ownshipgroundspeed that are filtered out is called the "Doppler notch." Filtering the Doppler notch provides for a very clutter free radar display for the operator, since all targets with velocities outside the notch are recognized immediately as targets. However, if a target is at an aspect of 90 degrees TA to the antenna, then its return gets filtered out, even if the return is received.

Outbound Signal

300 KTS   300 KTS

Reflected Signal

0 KTS closure produces no frequency shift.

Outbound Signal

Reflected Signal

90 TA produces frequency shift = ground = own aircraft ground speed

In a PD radar, the Doppler effect is used to determine target parameters or aid in developing an image of ground return. This provides a number of advantages over a pulse only system, including:

(1) Ability to track more than one contact while continuing to search and detect others; also called track while scan capability.

(2) Ability to detect moving targets on the ground.

(3) Ability to generate real-time spot mapping in high detail at long range through the use of Doppler image sharpening.

(4) Inherent resistance to chaff and some types of jamming.

(5) Improved detection of maneuvering targets due to highly accurate measurements of Doppler shifts

Radar Bar Scan Pattern: Fighter radars employ a bar scan movement to alter the elevation angle of the antenna. As the number of bars increases, the elevation of the radar beam increases. One bar is the simplest and most common; the radar searches at a constant elevation unless the antenna angle is manually changed by the aircrew. Multibar scan allows the radar to change elevation with every sweep in a set pattern.

One Bar

Two Bar

Four Bar

Six Bar
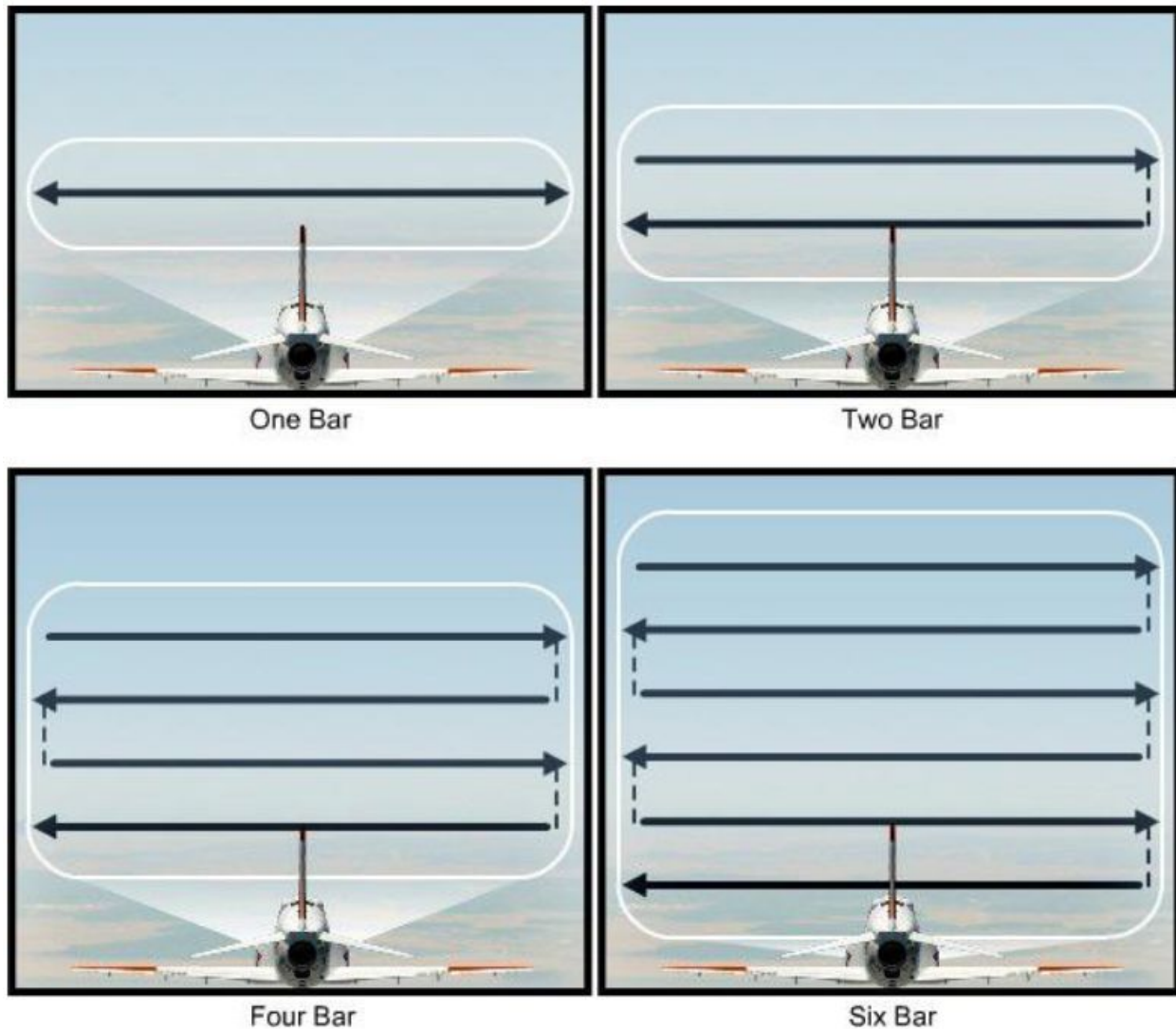
Radar Frame: The radar frame is one full cycle from the first bar, through the remaining bars, and back to the start. The time a frame takes to complete depends on the bar and azimuth setting; a 6 bar 140° azimuth scan on the F/A-18C takes 13 seconds!

Pulse Repetition Frequency (PRF): PRF is a measurement of how many pulses per second the radar transmits. The percentage of time sharing between transmitting and receiving is called the radar's duty cycle. There are three types of duty cycles; low, medium, and high. Each duty cycle has its own important employment considerations.

Low PRF: Low PRF is an all aspect duty cycle and is defined as a 1percent transmit and 99 percent receiving time sharing. It is often used in A/G modes. Low PRF offers all-aspect contact with no filters, good range resolution due to shorter transmission times, and less sidelobe clutter; however, these advantages come with the drawbacks of low power out and therefore short detection ranges.

Medium PRF: Medium PRF duty cycle is a 10 percent transmit and 90 percent receive time sharing scheme. This provides nearly all aspect contact detection, but requires some filtering. It additionally provides for medium power out, and the detection of fighter-sized contacts at medium ranges with moderate relative Doppler velocities. MPRF has the disadvantage of relatively short detection ranges.

High PRF: High PRF duty cycles are represented by a 30-percent transmitting and 70-percent receiving time sharing scheme. HPRF provides for the longest range detection due to higher average power out and is used in situations and modes where long range detection is required. HPRF has distinct disadvantages, however, including the need for high closure rates (and thus poor performance against beaming/cold targets), detection of more clutter due to higher power out and poor range resolution due to increased pulse time.

Interleavened PRF: Most modern fighter PD radars use some kind of an interleaving scheme to counter the negative aspects of medium and HPRF. Interleaving means that the radar ensures that if a bar is scanned in medium PRF in the current frame, it will be scanned in high PRF in the next frame and vice versa. This prevents any displayed frame from being the result of only one type of PRF unless the operator has manually selected the PRF. In the figure below, the first and third bars are HPRF and the second and fourth are Medium PRF in the first frame. This will be reversed in the next frame.
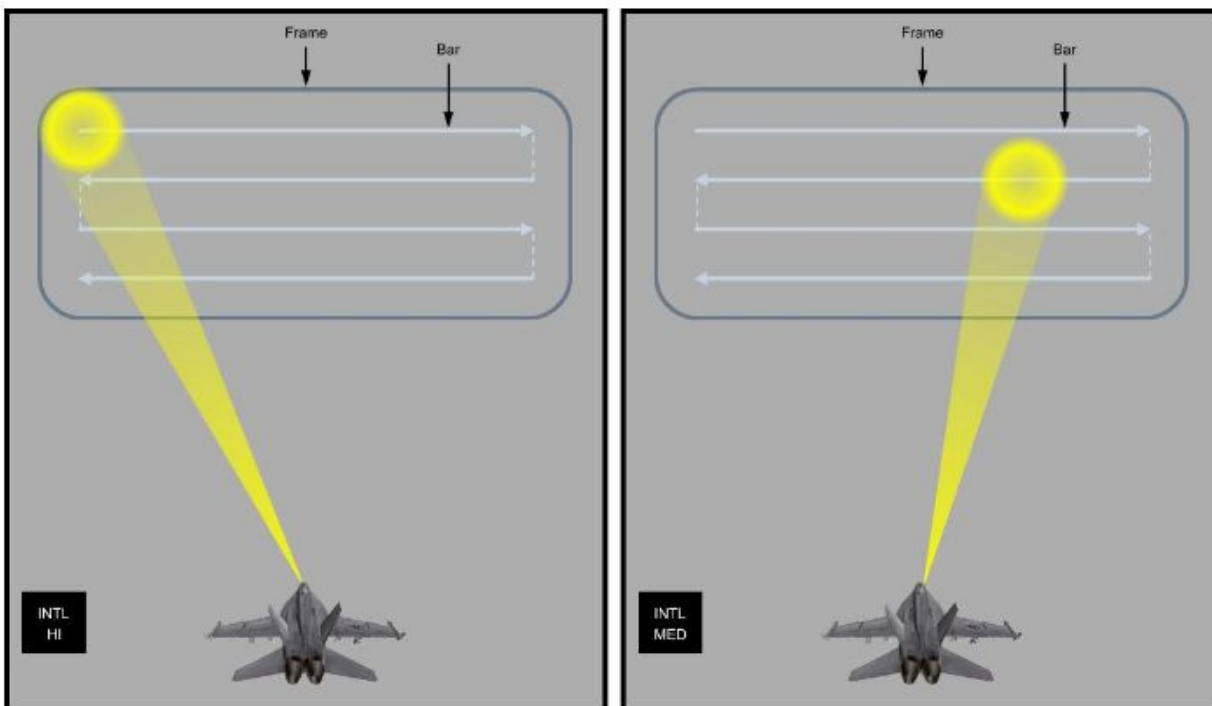
Search Volume: The combination of bar scan, azimuth selection, and range define the radar's search volume. The search volume can be defined as the volume of airspace that the radar may detect contacts and is based on its current operating settings. The aircrew are responsible for adjusting the scan volume's size and elevation to ensure that their area of responsibility (AOR) is sanitized, that is, clear of any unknown or hostile contacts. In the figure below, the radar's search volume is a 3-D volume of space scanned each frame. The parameters that make up the frame determine the volume at any range.
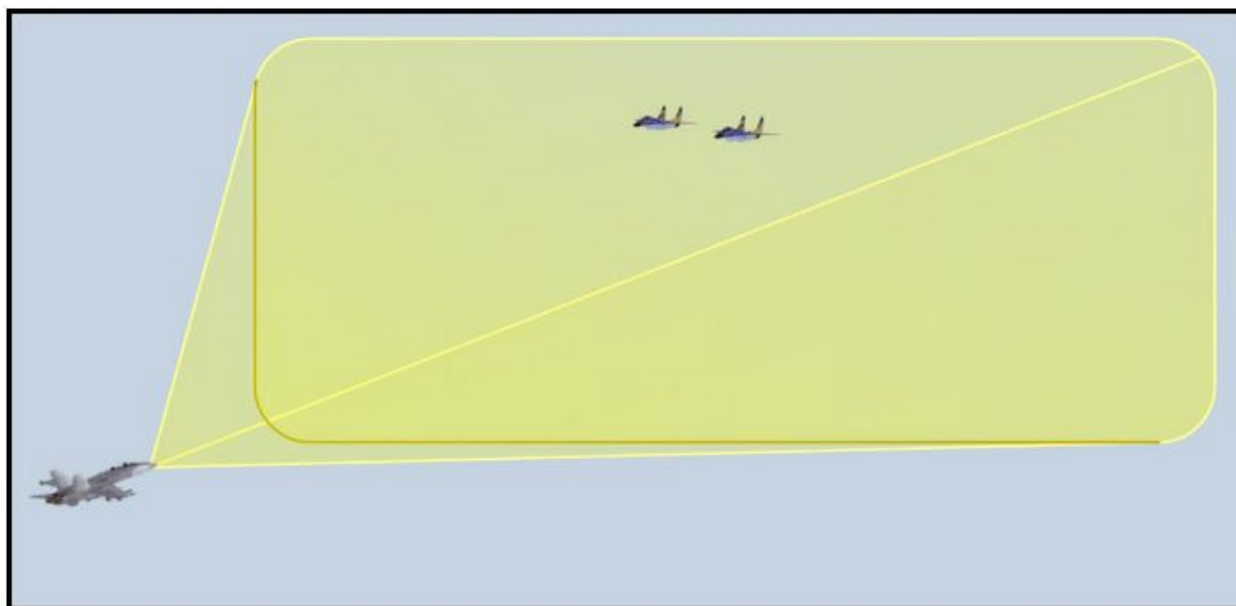
Radar Modes:

Range While Scan: RWS is the basic radar search mode for most fighters. In RWS, the radar typically scans the largest area; however, RWS only reports contact bearing, range, and sometimes altitude/aspect. RWS gives a normal nails on an enemy RWR. Weapons CANNOT be employed from RWS.

Single Target Track: In STT, the radar concentrates its pulses on a single target and gives detailed information for weapons employment. STT is the most accurate radar mode, with the lowest location uncertainty. STT, however, gives a hard lock "spike" on a bandit RWR. Despite this, it is the recommended mode for missile employment BVR, even over the much-hyped TWS.

Track While Scan: TWS attempts to compromise between RWS and STT. TWS scans a narrower area than in RWS. However, by extrapolating target info between scan hits, TWS builds track files of multiple targets. TWS has several advantages. First, you can guide weapons on multiple targets at once. Also, you can track one target and still keep limited SA on other targets. However, TWS has one major disadvantage: inaccuracy. Because it has to extrapolate target information between radar scan hits, sudden bandit high-G maneuvers (which are typical of fighter aircraft) have the potential to move the bandit out of the area where the radar expects it, and the lock will be "dropped". This is amplified the larger area the radar is scanning, and at closer ranges. For this reason, TWS is NOT a recommended mode for weapons employment, or for supporting ARH missiles, unless targeting multiple bandits is needed (note that the FC3 "TWS" modes function like STT, so they do not have these disadvantages).

Many will be quick to point out "but muh lack of launch warning". This really doesn't matter; any pilot with a decent amount of knowledge will know to anticipate your missile launch, and abort/notch before the MAR. And assuming all bandits you encounter are incapable of basic missile defense is a horrible idea, and a great way to die *very* quickly.

Radar Scanning

Minimum Sanitisation Range (MSR): When using the radar, you must know how to effectively sanitise(scan) the airspace. One term that will be used is Minimum Sanitisation Range (MSR). MSR is the closest range that the radar(s) of a member(s) will be able to cover the entire threat elevation sector (TES) (typically from SL to 40kft). Outside of MSR you do not need to change the elevation if it is properly centered at MSR, you are already covering the entire TES. Inside MSR, however, the entire TES will not be covered, so usage of the elevation slew is required to detect all possible threats. For a typical 4-bar 10deg elevation scan, MSR is ~40mi. The more flight members, the shorter the MSR, because the fighters can have high/low search responsibilities. In a 2-ship, MSR is ~20mi, with one scanning from SL to ~20k at 20mi, and the other scanning from 20k to 40k. In a 4-ship you technically can have a MSR as low aS 10nmi; however, 20mi is normally within the garinteed detection range.

Area Of Responsibility (AOR): Your AOR is the airspace you are expected to sanitize. As mentioned above, the MSR represents the closest range where a radar frame can cover the entire TES. Typically, the AOR is the entire TES up to about 40-80 miles depending on radar

capabilities. One useful mnemonic for remembering how to vary the scan is ABC: to scan **A**bove, **B**elow, and then **C**enter the scan. What this means is that when you need to cover as much of the AOR as possible at closer ranges (inside MSR), you start by scanning from your altitude and above for 1-2 radar frame(s). This allows you to detect those flying significantly higher than you, and these bandits can be the most dangerous. Interleaved or HPRF is advised. Next, you scan below, in order to pick up those approaching from beneath you for 1-2 frame(s). These bandits can be dangerous as well, as they are a lot harder to spot visually. Finally, you center the scan to the normal pattern so you are scanning the TES at MSR. This is your default scan pattern (e.g, 0-40k at 40nm) How often you perform this procedure depends on the circumstances and capabilities. Over flat terrain with a powerful radar, you may be able to pick up most bandits before they reach MSR. Thus, you may only need to do this once every 5 or so centered radar frames. On the other hand, over mountainous terrain, you may need to do this every other frame, for example.

Bracketing: Bracketing is the process of centering the scan zone at a particular altitude at a specific range. Bracketing is often referenced when attempting to find targets after a drag/notch. By bracketing the contacts last known altitude, you make reacquisition much easier than if you randomly scanned any altitude. If after 2 frames he does not show up, you need to transition to the ABC scan technique.

Lock Range (LR): Lock range is the closest you can lock someone and still have time to employ weapons with FLO (First Launch Opportunity). It is generally 2-5nm past the expected shot range. LR will be briefed in plane-specific tactics. You need to be aware that if you lock too late, you may end up employing missiles late on the timeline and have to stop supporting them early to defend, so remembering the LR is critical. Also note that before you reach LR, you need to be sure the airspace has been sanitized.

Notching Targets: When a bandit enters a notch, there are a few things you can do to speed up reacquisition. Firstly, if you have visual and he is in-range of your ACM modes, put him in the HUD and aim the ACM modes at him so that when he exits the notch you will instantly reacquire him. If you don't have visual, or he is well outside ACM mode range, you still have a couple of options. First, if the altitude difference is small, consider diving below him to force a look-up situation. Many radars are much harder to notch in a look-up. Also, consider changing heading. By taking an offset, you cause the geometry to change, and he would no longer be at 90° to you. Be sure to do this in the opposite direction of his notch. In the diagram below, the fighter should make a turn to the right:
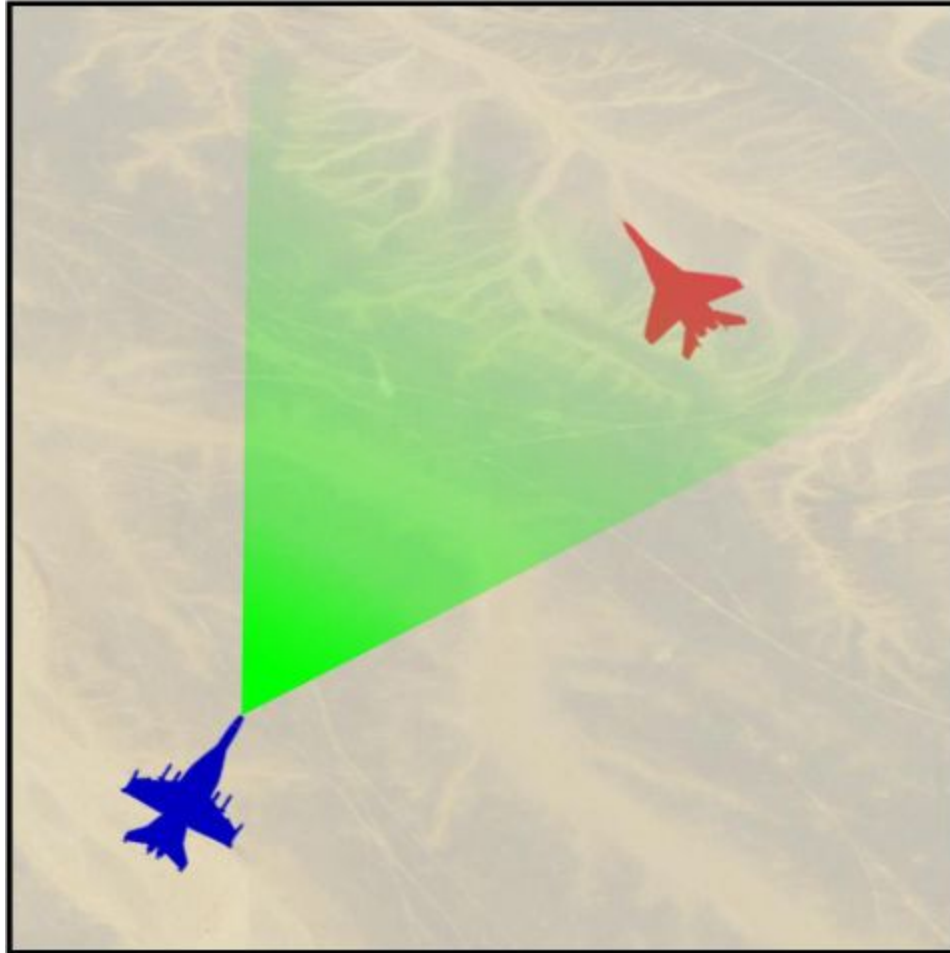
If your plane has an IRST/EOS system, use it to track notching targets as well. Also, if you are employing ARH missiles, you need to remember that you really cannot reliably notch both you and the missile at the same time if you position yourself properly. If he is notching you your missile is likely still guiding.

BVR INTERCEPTS: PRE MAR

An intercept is the series of maneuvers, using a ground controlled intercept (GCI), Airborne Warning and Control System (AWACS), on-board systems, or dead reckoning, which places the aircraft in a position from which a weapon (MRM or SRM) may be employed, visual identification (VID) can be made, or a visual engagement can be initiated. The type of intercept geometry utilized is based on experience, proficiency, avionics, weather/night, ECM, and other tactical considerations.

Basic Concepts and Considerations

Terms: Listed below is a review of a few of the terms essential to intercept geometry.

Aspect Angle (AA): The angle between the longitudinal axis of the target (projected rearward) and the line-of-sight to the fighter, measured from the tail of the target. The fighter's heading is not a consideration.

Antenna Train Angle (ATA): This is the angle between the nose of the fighter and the radar line-of-sight to the target. ATA is referenced in degrees left or right of 0° azimuth on the MFD.

Collision Antenna Train Angle (CATA): CATA is the azimuth of the radar antenna when tracking a target that is on a collision course with the fighter. This is the fighter's quickest route to an intercept/collision/tally with the target. A target on a collision course drifts straight down the MFD. Its azimuth never changes. An easy way to determine CATA for a co-speed target is to subtract aspect angle from 180°. For example, the CATA for a target with a 150° aspect angle is 30° (180 - 150).
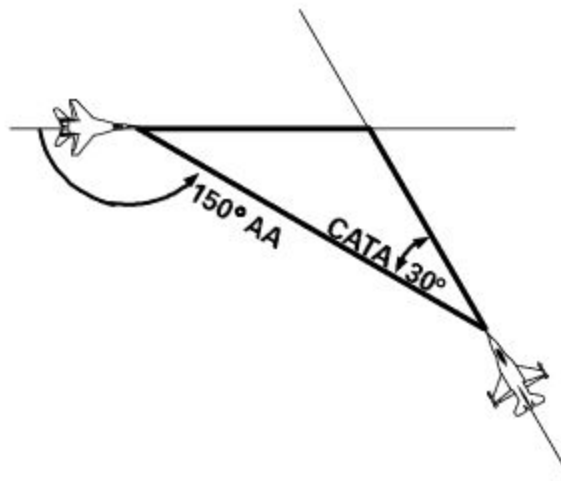
Aspect Control: Being able to control target aspect allows you to manipulate a BVR intercept and allow you to gain an advantage.

In order to **increase** aspect, (bring his nose closer to you), fly a **lead pursuit** trajectory that is also in front of the collision course (e.g, you will end up in front of him when you cross flight paths). The further away from a collision course, the faster you will reduce aspect.

| Type of Cut	LS	TA
1) Cut > Collision	↕	↕
2) Cut = Collision	↕	—
3) Cut < Collision	↕	↑
4) Cut = 0	—	↑
5) Cut Away	↑	↑
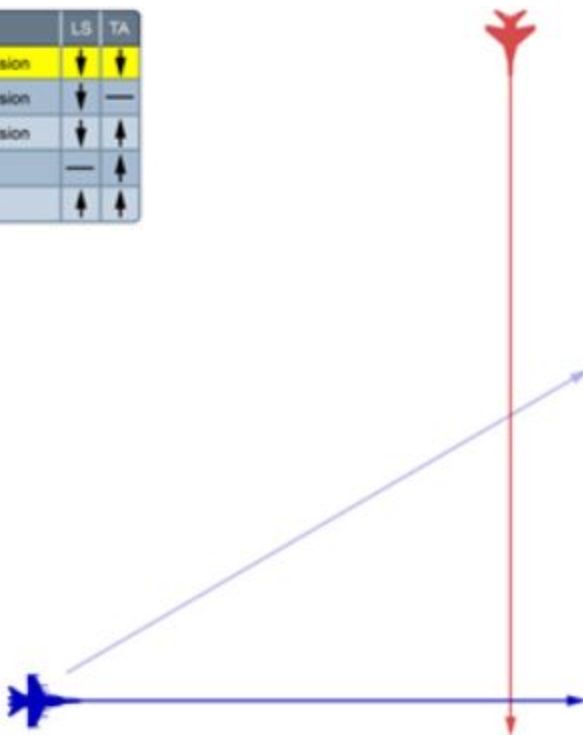
To **maintain** aspect, fly a collision course (CATA). This will result in a collision if held. This also produces the maximum closure rate, and the fastest type of intercept.

Type of Cut	LS	TA
1) Cut > Collision	↓	↓
2) Cut = Collision	↓	—
3) Cut < Collision	↓	↑
4) Cut = 0	—	↑
5) Cut Away	↑	↑
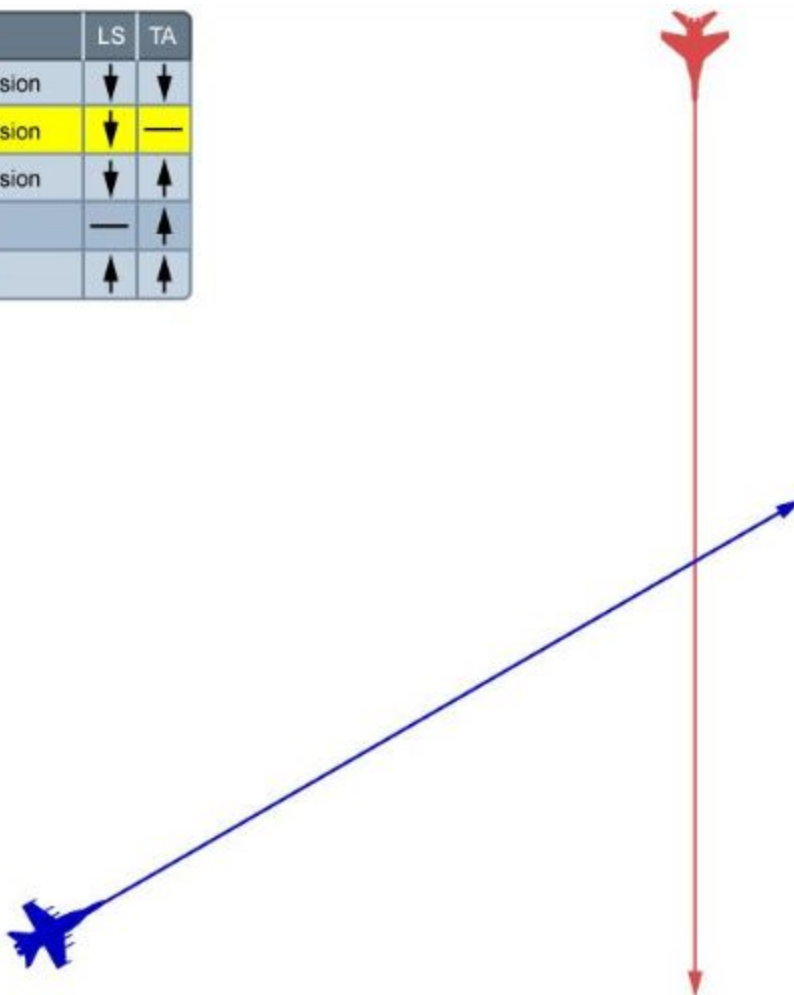
To **decrease** aspect, fly a course behind a collision course. As with increasing aspect, the further away from a CATA course, the faster you will decrease aspect.

Type of Cut	LS	TA
1) Cut > Collision	↓	↓
2) Cut = Collision	↓	—
3) Cut < Collision	↓	↑
4) Cut = 0	—	↑
5) Cut Away	↑	↑

Type of Cut	LS	TA
1) Cut > Collision	↓	↓
2) Cut = Collision	↓	—
3) Cut < Collision	↓	↑
4) Cut = 0	—	↑
5) Cut Away	↑	↑
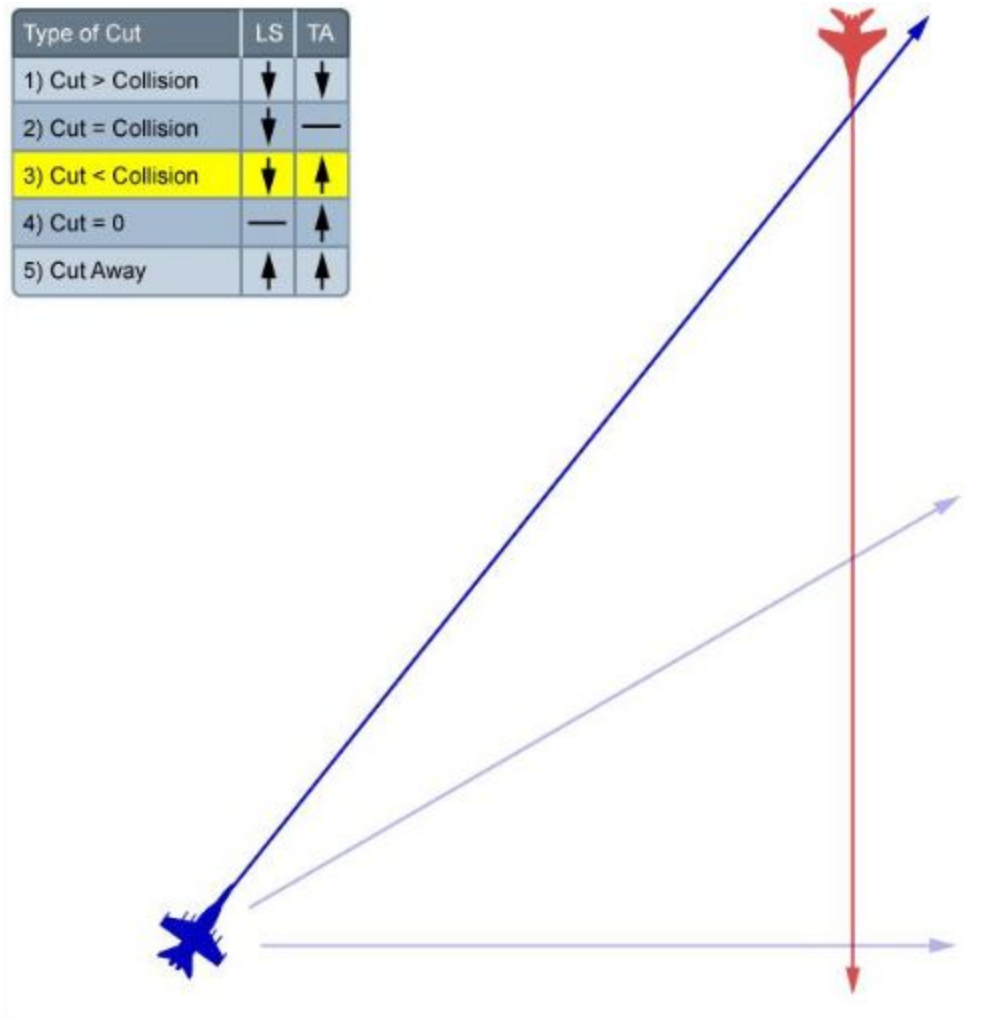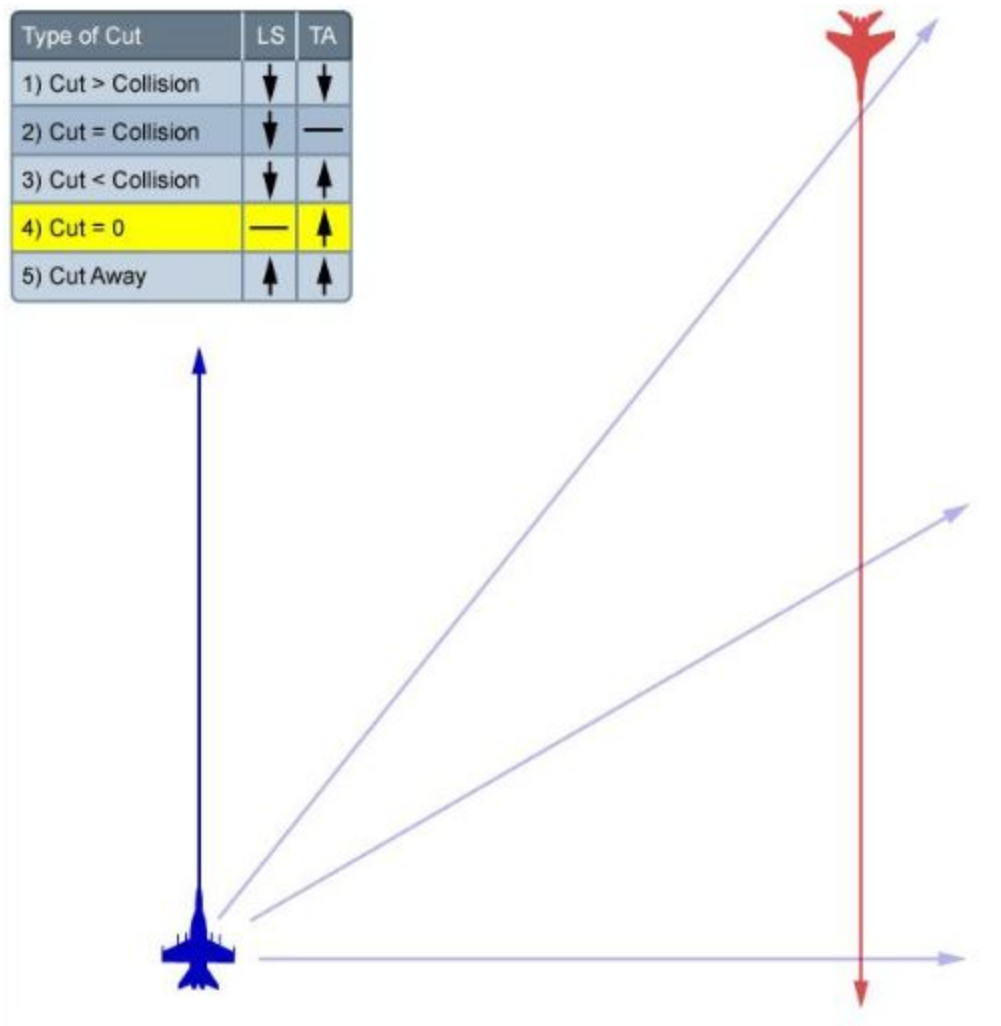
Commit Criteria: The commit criteria is the range you begin maneuvering to engage a specific group. Commit criteria is very flexible, and varies quite a bit between mission types. A sweep mission has much more permissive commit criteria than a escort mission, as in an escort you cannot get dragged too far away from the group you are escorting. As a rule, however, commit criteria will be no closer than missile employment range + 15nm for HOT/FLANK aspect targets. More will be mentioned in aircraft specific manuals.

The Baseline Intercept: The baseline intercept is the basic BVR intercept. Although you will almost never use it in combat, the principles and techniques are used in other useful intercepts. The baseline (as it will be referred to from now on) assumes a lack of IFF, so a VID (Visual IDentification) is required. You might think that simply flying head-to-head with the bandit and VIDing at the merge. However, by the time you get close enough to VID, you may be too close to employ weapons. This means that you will have to merge high-aspect, and turn at least 180° to get in a WEZ. Also, if he spots you in the merge, the fight quickly becomes a neutral

high-aspect merge. By flying an intercept that takes you behind the target at a low aspect you allow yourself time and room to employ without worrying about getting shot. An illustration is below:
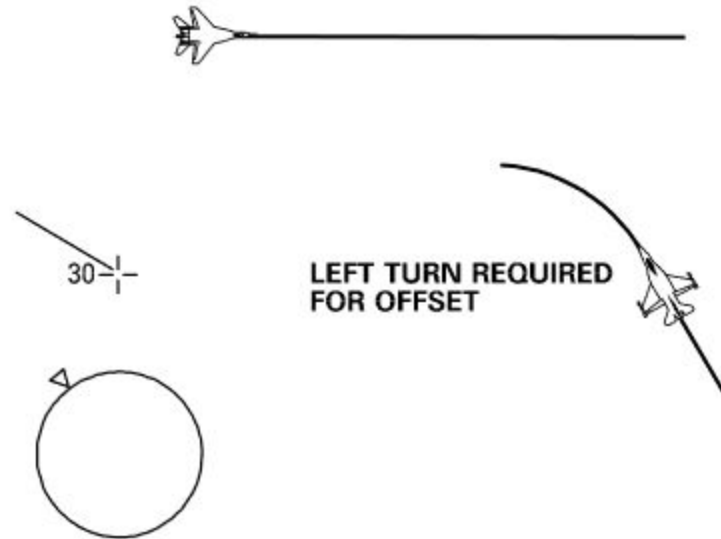

Baseline Intercept
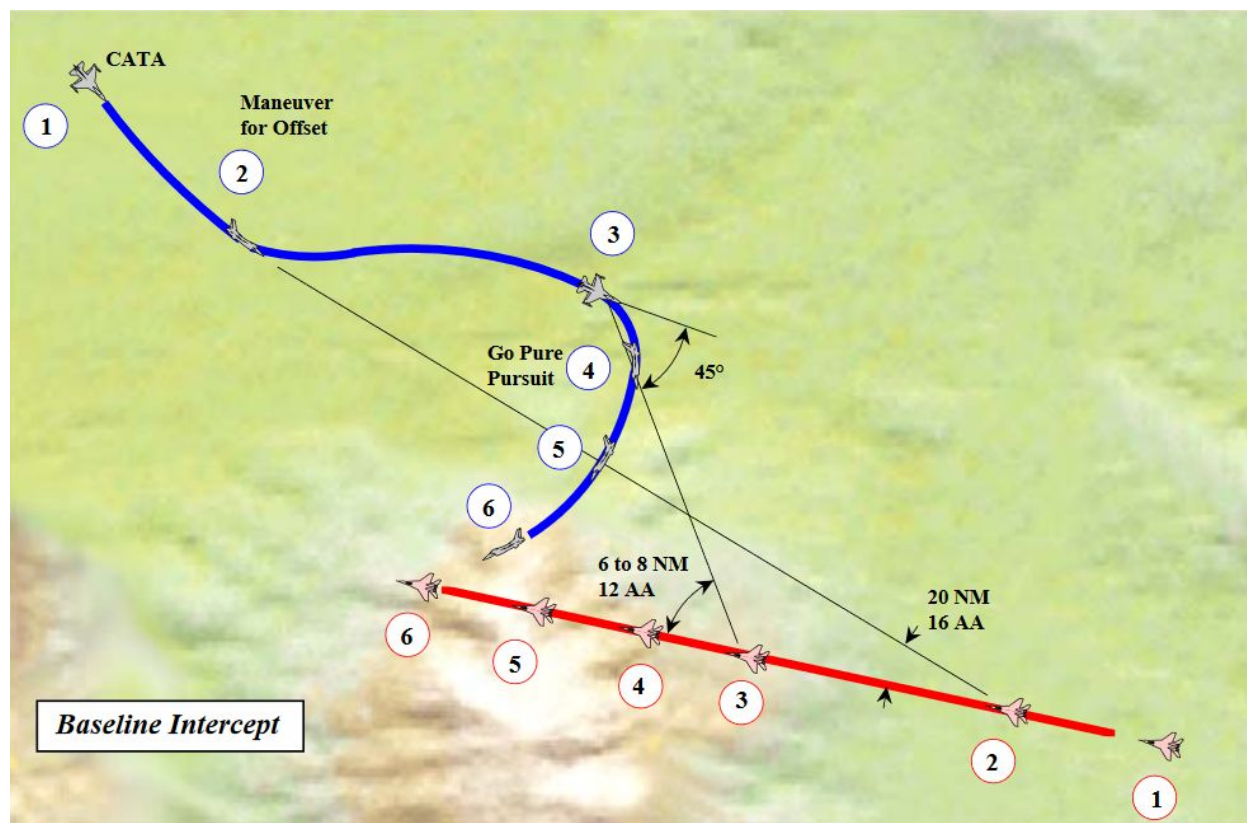
The baseline intercept has five steps:

> **Point and Assess:** Before performing the intercept, you obviously need to have a radar contact on the desired target, and detect him. You need to then assess his aspect. If he is HOT or FLANK, go pure pursuit. If he is BEAM, fly a CATA intercept and skip to the last step. If he is dragging, you need to use a tail-chase gameplan.
>
> **Get an Advantage:** Once you have radar SA on him, you need to get a speed advantage, and an altitude difference to make him detecting you a lot harder.
>
> **Take an Offset:** Once you hit 20nm, take an offset that takes you to about 40-50° ATA. Which direction to go is a common question. You take an offset away from the bandits flight path, as shown below:

LEFT TURN REQUIRED
FOR OFFSET

The reason to take an offset is because in the baseline, you start at high aspect, and are attempting to reduce it to 120° AA (60° TA). This means you need to fly away from a collision course and away from his flight past, as you learned in the intercept section.

Control Aspect: Once you have offset, you need to monitor the target aspect. The goal is to reach 120° AA (60° TA) before reaching 10nm. If you reach 120° aspect, switch to a CATA intercept.

Go Pure Pursuit: Regardless of aspect, at 5nm, transition to pure pursuit. This step is known as a stern conversion. If you executed the above steps correctly, you should arrive in his rear quadrant, with a VID, and ready to employ weapons. A video of the entire process is below:

ARH Intercepts: In head-to-head BVR combat with ARH missiles against hot, aware bandits, there are three basic flows, launch and leave, launch and decide, and launch and notch.

Launch and Leave (L&L) is the defensive flow for BVR. The L&L involves employing weapons, then performing an abort to kinematically defeat any missiles that have or could have been launched. There are two gameplans under the L&L, skate and short skate.

Skate (DOR Abort): In a skate gameplan, the fighters will employ weapons, and go out/abort before the Desired Out Range (DOR). DOR is further away than MAR, and allows you to abort, and recommit on the group with room to execute banzai/short skate tactics (to be covered soon). In other words, you have the option to recommit without having to merge with him. An illustration of a skate flow is below:

Launch Range, anywhere between
Rmax and DOR

MAR
DOR

MAR
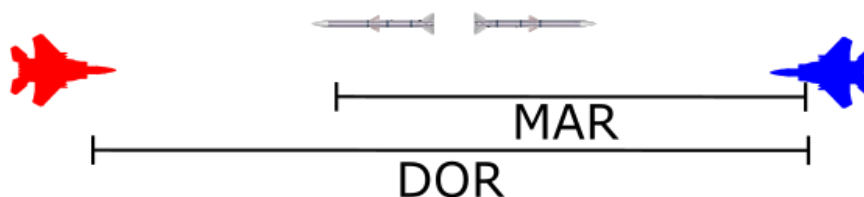
DOR, and oustide of rear aspect WEZ
Plenty of space to recommit.

MAR
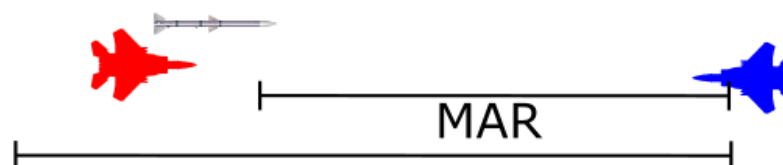
Recomitting for Skort Skate/Banzai/L&N

Skate tactics are used when you either are at a numerical disadvantage, or a significant altitude/speed disadvantage. There are 2 options for the defense/recommit from a Skate.

Short Drag Defense: In a short drag defense, the fighter never stops turning. After reaching the end of the pitchback/split-S/level turn, continue the turn until you have reached the original heading. A short drag is the primary recommit option for the skate option. When trying to re-acquire him from a short drag, bracket the bandits last known altitude at the range you aborted at, and transition to an ABC search gameplan if he does not show up in a few frames.

Medium Drag Defense: In a medium drag defense, the fighter will change heading 180°, and remain on that heading for 15 seconds. If any altitude was lost in the abort, now is the time to regain it. After the 15 seconds, the fighter will again change heading 180°, and reach the original heading. This is used when the bandit has a significant missile performance or potential/kinetic energy advantage. To reacquire, bracket his last known altitude at the abort range + ~5nm, and transition to an ABC search gameplan if he does not show up in a few frames.

Short Skate (MAR Abort): In a short skate gameplan, the fighter will employ weapons, and abort before reaching the MAR. Unlike a with skate, a Launch and Leave recommit option is **not** guaranteed. You may be forced into either a launch and notch gameplan, or a delouse (having a friendly fighter/element shoot the bandit off your 6). An illustration of a skate flow is below.

Launch Range, anywhere between Rmax and MAR

MAR

MAR, and oustide of rear aspect WEZ;
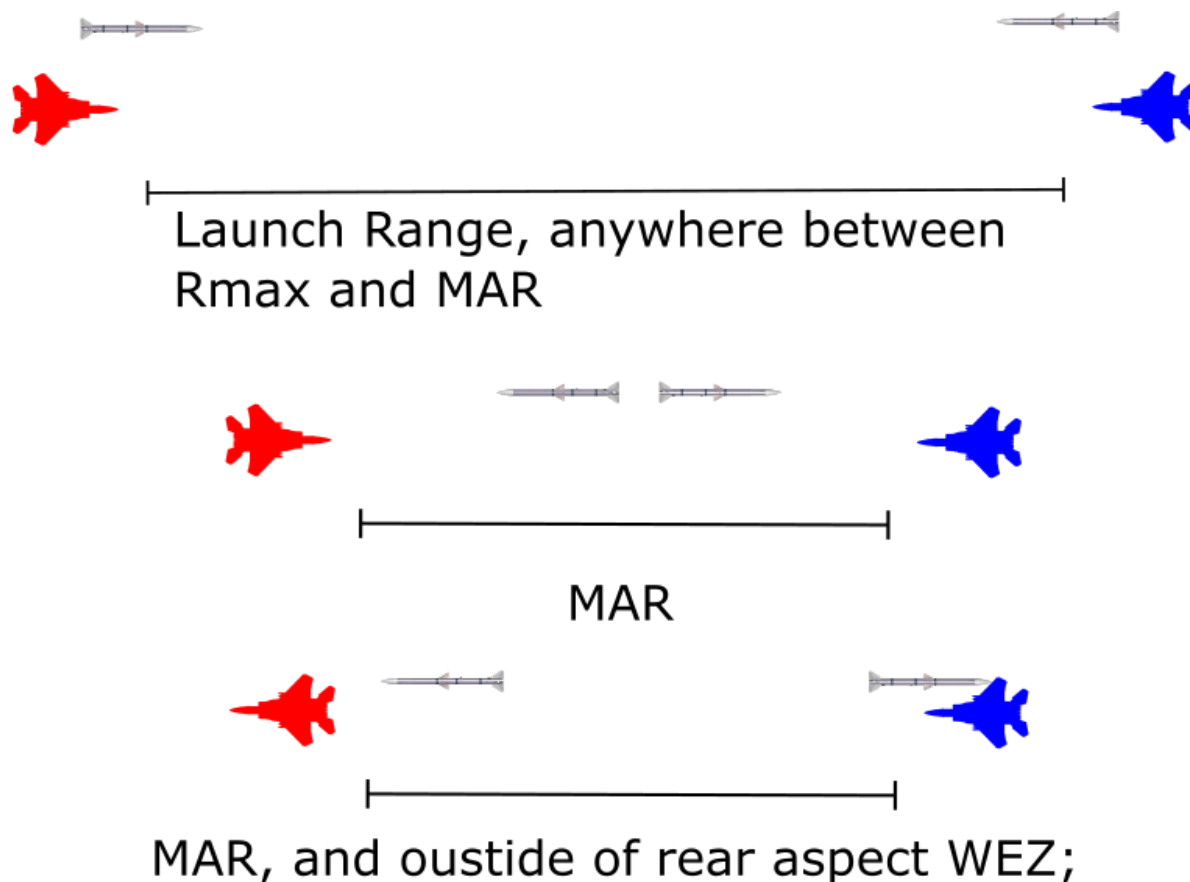
As with a skate there are short and medium drag defense options.

Short Drag Defense: Execution is the same as for the skate. Unlike in a skate, a short drag poses the risk of you turning right back into the missile if he fired it close to MAR (when you began your abort). Therefore, short drag is only used when the bandit launches his missiles between his Rmax and his Rdef, or when

your missiles have a significant performance edge. If unsure when he fired, perform a medium drag defense.

Medium Drag Defense: Execution is the same as for the skate. In a short skate, this allows for time to drag the missile before turning in again, allowing you to defeat the missile.

Launch and Decide (L&D) is an offensive BVR flow. In an L&D, the fighter employs weapons, executes a notch, and decides whether he should pitch in, or go out/abort. There is one primary L&D tactic, the banzai. The L&D is used when you have either a numerical advantage, significant weapons range advantage, weapons type advantage (ARH vs SARH), or a significant potential energy advantage.

Banzai (DR Notch): In a banzai, the fighter will employ weapons, then enter a notch at the Decision Range (DR). DR is the minimum range between a fighter and the threat which will allow the fighter to notch, break the lock, then decide to abort or continue to the merge if naked. Obviously this has to be greater than MAR (typically by 2-3nm) to allow the time to attempt to break the lock of the radar/missile. Two illustrations of the pitch-in and abort options are below. At times 1 and 2 in both diagrams, the fighters are spiked. At time 3 in the left photo, the spike is lost, and the fighters pitch in. In the right photo, they elect to abort. If you pitch in (and the bandit did not skate/short skate), you will transition into launch and notch tactics (covered in the next paragraph). If the bandit did turn cold when you pitch in, refer to the section on Tail Chase Targets in the next section.
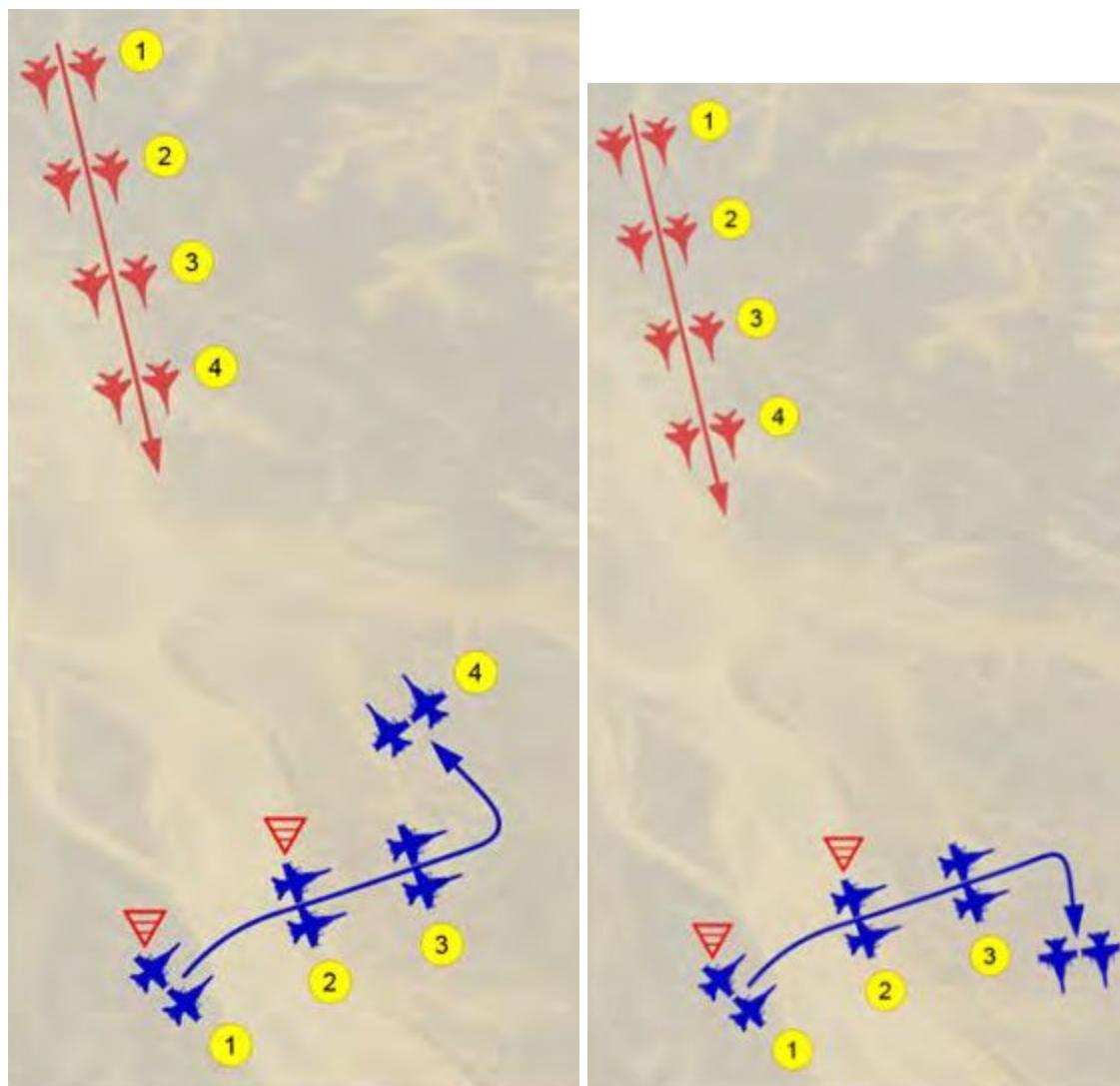
Launch and Notch (L&N) is the offensive post-MAR flow for BVR. The L&N involves employing ARH weapons then immediately notching to defend incoming missiles. Unlike with a L&D, you are inside MAR when you commence evasion, so there is no option to abort; you must proceed to the merge. Rarely are L&N tactics intentionally initiated as a first tactic against an aware bandit; they typically initiate from other tactics, such as a banzai, or a short skate recommit. More on the L&N will be discussed in the section on post-MAR tactics and gameplans.

Recommit Tips: When recommitting from a drag/notch, you need to remember: defend and recommit as fast as possible. If you can get your nose around first, you can target and shoot them before they can, giving you a decisive A/F-Pole advantage even over a superior adversary.

Which Gameplan to choose?: Being able to quickly choose the appropriate BVR gameplan is one of the skills essential to BVR combat, and to some extent, you will need to actually get in the sim and practice. However, here are some general guidelines:

1v1: In a 1v1, it is not recommended you use L&L gameplans. If the bandit chooses to use a L&D/N, you will end up with a bandit on your 6 near MAR, as recomitting from a notch is much faster than from a drag. If you do use a L&L use a Skate, it will allow you to recommit with enough space to target again, and employ for a L&D

1v2: In a 1v2, a L&L is the best option unless the bandits are seriously inferior in capabilities. Specifically, a Skate gameplan is best, as it allows you to engage 2 bandits without TWS; you can skate on the first, then short skate/banzai on the second depending on how aggressively the first bandit defends.

1v1 In Airquake: In an airquake 1v1 scenario, the Short Skate is the recommended gameplan. It maximizes missile Pk, while still avoiding a merge. In an airquake scenario, merges (and as a whole L&D/N gameplans) should be avoided unless you are sure there are no other bandits around. You could easily get in a merge/notch-to-merge against a bandit only to have another bandit jump you unaware. You can't just run away, because you have a bandit in the NEZ. Whether to choose a short or medium drag depends on the circumstances. If you have low SA on the fight, or numerous other bandits are around a medium drag is recommended in order gain separation. If the bandit is (relatively) isolated, a short drag may work.

F-Pole (SARH) Tactics: F-Pole tactics are primarily used with SARH missiles. As you may recall from earlier, F-Pole is the target-shooter range at missile impact. We want this to be as large as possible. This is the goal with F-Pole tactics. As mentioned in the missile defense section, you need to reduce closure to maximize F-Pole. You also need to launch as far as possible, so you maximize F-Pole. At the same time, you cannot launch too far away, else his cranking will defeat it. Remember, we need to maximize our F-Pole because the fighter who's missile impacts first (i.e, further away, longer F-Pole) wins the fight, because if you die you stop giving the missile support. One rule of thumb you need to remember is the missile TOF rule: As a general rule, F-Pole is just over half the launch range for MRMs if you crank, and are inside a medium Pk WEZ.

Another aspect is minimizing the bandits F-Pole. The easiest way to do this is to slow down his missile, typically by dropping altitude and dragging his missile into denser air. You do this after you fire your initial shot, however.

SARH vs ARH Tactics (Pre-MAR): First, remember that if you are facing an ARH carrier in an SARH carrier, you are at a disadvantage. The exceptions are when you have such a missile range advantage (AA-10C vs AA-12) so your SARH missile will F-Pole well before theirs reaches A-Pole, or you have an altitude advantage that does the same. Although there may be plane-specific tactics for taking SARH shots outside MAR and still supporting it, as a rule shots outside of MAR are a waste of missiles against ARH carriers. Shots from inside MAR will be considered in the next section.

Cold Ops: Cold Ops deals with your actions after you abort/turn cold to a threat. To remember the critical steps to perform in cold ops, remember the PAST checklist.

Put the threat on your six o'clock. Although it seems kind of obvious, you need to remember to put the threat as close to your six o'clock as possible, so you can gain as much separation as possible.

Assess Target Status. This involves any form of assessing the status of the target you aborted to. It can be as simple as a six o'clock check to see if your missiles impacted, or it could be an AWACS bogey dope/picture, or a datalink check. Either way, you need to be sure what happened to the bandits, and if they survived, what they are doing. You also need to decide the follow-on flow and tactics, which will be covered soon.

System Setup. After assessing what the targets are doing, and having decided on what to do, set up the radar scan. For a single ship, bracket below the bandits last known altitude, and last known range + 5nm (use datalink/AWACS info to update to the exact location).

Target / Turn in. After setting up your radar, you finally turn in on the target. Turn in on his last known heading (either from when you aborted, or from AWACS/DL). If the preset radar scan does not pick him up in ~2 radar frames go to the ABC scan technique, and consider that he may be hiding in the notch.

Cold Ops Recommit Options: When in the Assess stage of PABST, there are several recommit options to consider based on the range to the target behind you given by AWACS/Datalink, or when you turn around and reacquire them.

>**DOR:** If the range is outside of DOR, you can recommit freely without concern of the enemy's missiles. You have all employment options available.

< DOR, > MAR + 3nm: In this case, you do not quite have all the employment options available; Skate is not an option inside DOR. If you choose to skate, beware that at higher altitudes, you may have to launch a "cheapshot", meaning you drop lock before A-Pole.

< MAR + 3nm: Now not even short skate is an option. You can either fire essentially a maddog shot and immediately abort, or transition into Launch and Notch tactics. As an alternative, you can perform a bugout, which is an extension with no intent of recommitting, and let friendly fighters/SAMs deal with him.

POST-MAR TACTICS

Going For the Merge

When you enter the MAR and press for a merge, the tactics you have to use drastically change. There is no abort option; kinematic defeat of missiles will be nearly impossible especially as you close within the NEZ. Thus, you need to remember: avoid penetrating the MAR without a decisive positional/nose position advantage (which we will define soon); Once both jets are inside its almost certain someone is going to die, so don't make it a 50/50.

Speed Management: When inside MAR, extra speed becomes a major hindrance; it may give a slight range boost to your missiles, but severely limits your ability to quickly enter a notch, as extra speed makes notching a lot harder. In addition, you are making your turn circle bigger, and reducing your turn capabilities. This is detrimental to both maintaining a positional advantage when offensive, and minimizing the bandits positional advantage when you are defensive (more on these in a minute). When inside MAR you ideally want to be in your aircrafts sustained turn rate (STR) band. For most 4th gen aircraft this is around 350-400kts, or 650-750kmh. This allows you to maintain enough energy for missile employment, but not so much that it limits your notching and maneuvering capabilities.

BVR Positioning: Once past MAR, positioning becomes very important. Inside MAR, the main method positional advantages/disadvantages are assessed is nose position, through ATA and AA/TA. ATA is important because it tells you how far you are from a valid WEZ; the AA/TA tells you how far the bandit is from a WEZ. If you can defend and recommit faster than him, you can end up in a position where you are in a WEZ, while he is still defending. An illustration is below:
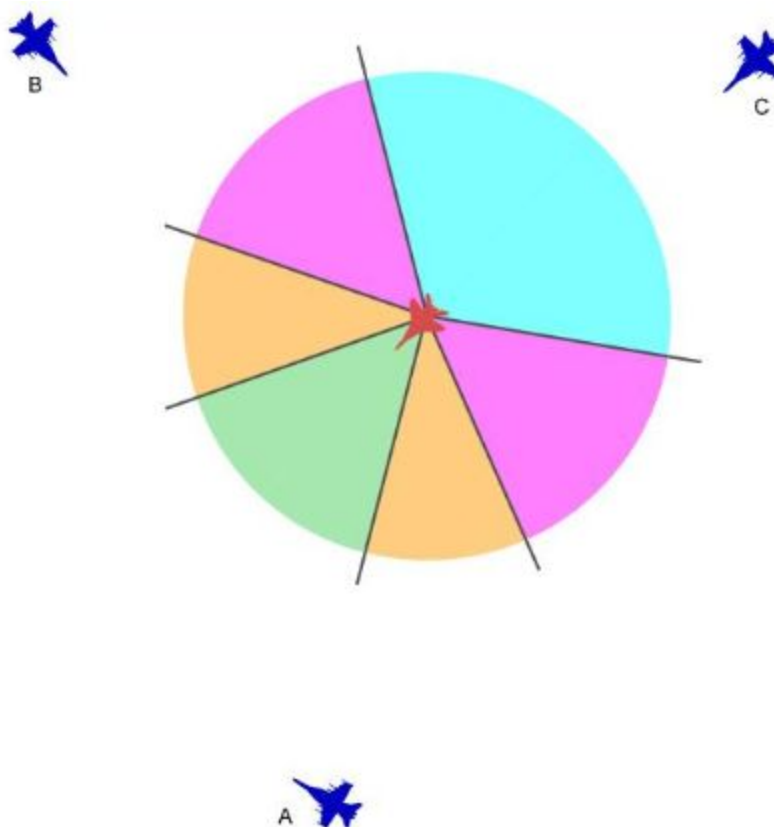
Fighter A is at a positional disadvantage; his nose is further from the target (ATA) than the target's is from him (TA). With a typical MRM, the bandit is in a WEZ and can force him defensive, while the fighter has to make a choice: either turn (which takes time) to get in a WEZ, and potentially get killed by the bandits MRM, or defend, and ultimately allow him to fly around to his 6 o'clock in a stern conversion

Fighter B is in a positional advantage. He is in the bandits beam quadrant, and has his nose on the bandit. This is essentially a complete role-reversal from Fighter A.

Fighter C is in an even better position: the rear quadrant. Provided Fighter C is in his NEZ, the targeted fighter has little chance to evade his MRMs; even if he wanted to snap the nose around for a trade, he would need to turn at least 145°, which may not be possible before the missile impacts. Note one thing: Fighter B has the potential to transition to a fighter C scenario. We will discuss how to do it, and why this means a lot in regards to missile employment in a minute.

Gaining the Advantage: Knowing how to gain the advantage is key to BVR combat especially as you get inside MAR. The main way to gain advantage is to recommit from a defense (drag/notch) faster than the bandit does. This allows you to get in a WEZ first, as you can get your nose on him first. You also need to quickly find, lock, and sort him so you can employ weapons.

Keeping the Advantage: When you get a positional advantage in BVR, you need to know how to keep it. There are two methods of doing this: Missile Employment, or Lag Pursuit. First, however, we need to discuss when you simply will not be able to hold the advantage. Firstly, if you are outside MAR, you cannot hold the advantage. He can simply turn around, put a missile on you, then abort and stay outside MAR. He also needs to be inside the NEZ. If he is outside of the NEZ, he will be able to snap his nose around for a shot, then quickly get into a notch.

> **Missile Employment:** Missiles are surprisingly effective to maintain a positional advantage. Remember, if you can get in a WEZ first, you can put a missile on him. He will have to respect your missile and defend. The key thing is that you need to keep sending him missiles every 5-10 seconds, or if it appears he has defeated it. After firing, switch to lag pursuit until you are firing again. This allows you to change bearing if you use ARH missiles, making it impossible for him to notch both of you. Also, consider using both ARH and SARH missiles; you may make it impossible for him to notch and defend both of them.
> **Lag Pursuit:** By using lag pursuit after firing, you will reduce aspect, and be able fo fly around to his rear quadrant while he is defending your missiles. A diagram is below:
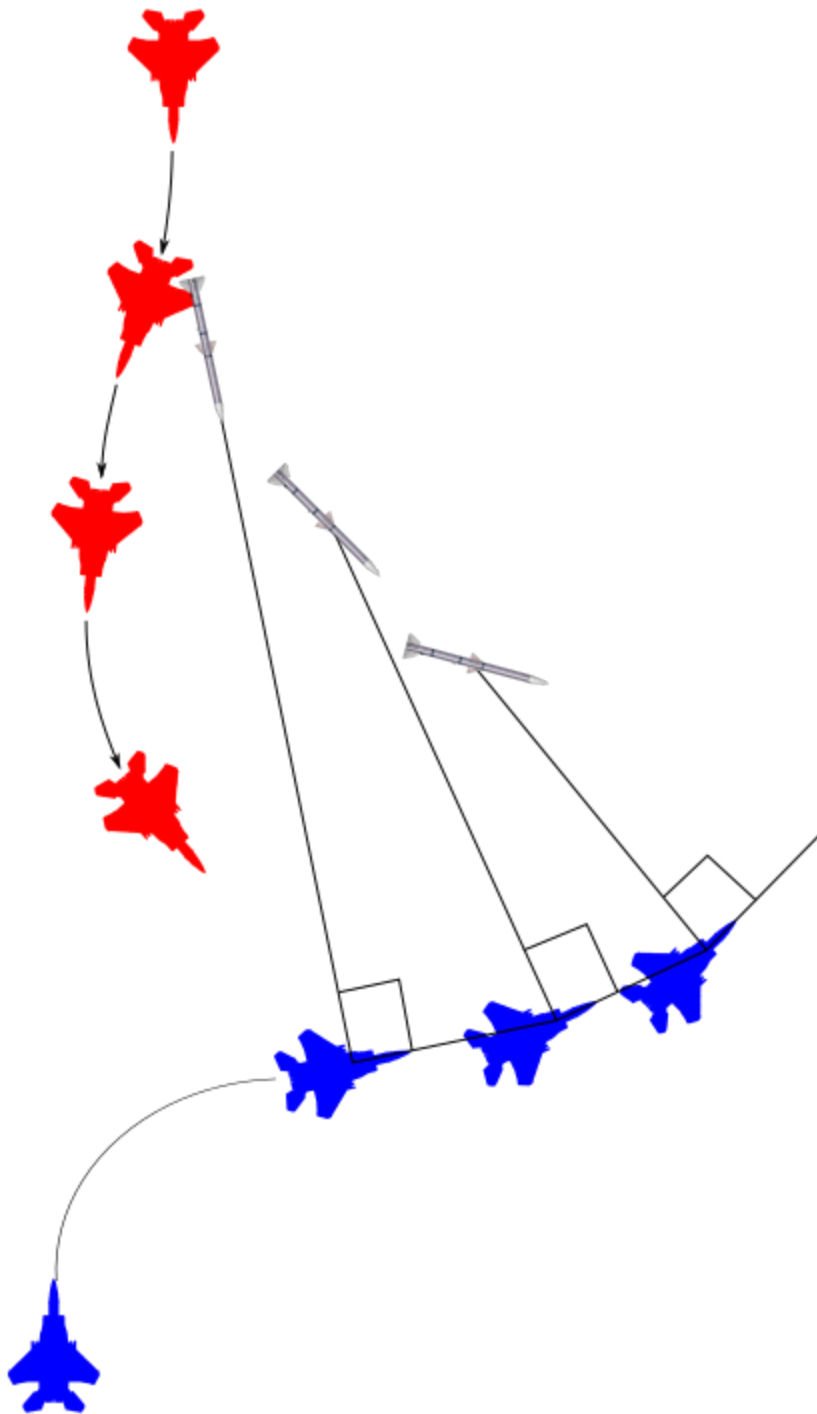
Remember, you need to be using missiles frequently (every 5-10 seconds) to force him to keep notching and defending while you fly to his 6.

Control Zone: The control zone (CZ) is the area directly behind the bandit where you are immune to attack from him if you employ weapons and kill him. A shot from the CZ will hit before he has the chance to snap his nose around for a SRM/MRM shot. The CZ varies based on you and the threats capabilities, but it typically extends to about 3-4nm behind a bandit at low alt, and all the way up to about 7nm at high altitudes. A diagram is below:
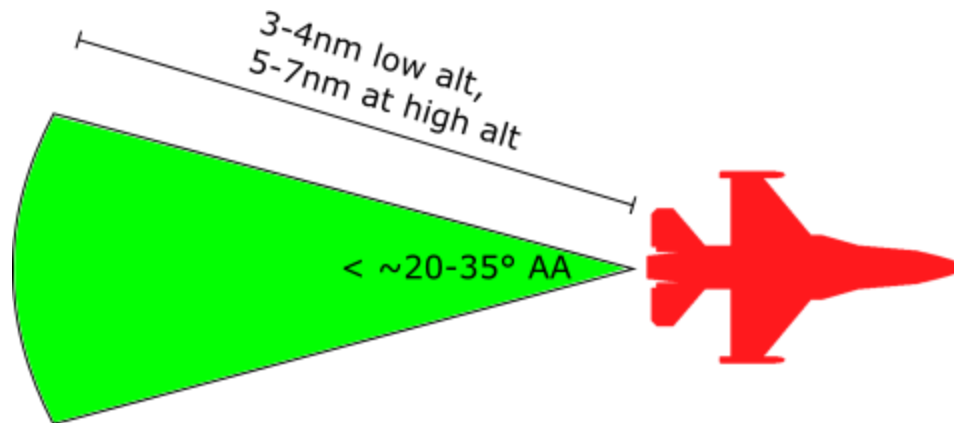
The goal of managing/maintaining your positional advantage is to end up in the bandits CZ. In order to do that you need to understand another concept however, the attack window.

Attack Window: If you maintained the positional advantage correctly, you should end in the "attack window". The attack window is the place in his turn circle you enter to get in his CZ. The attack window entry (AWE) point is where you stop using lag pursuit and you perform a max-performance break turn to enter the CZ. An illustration is below:
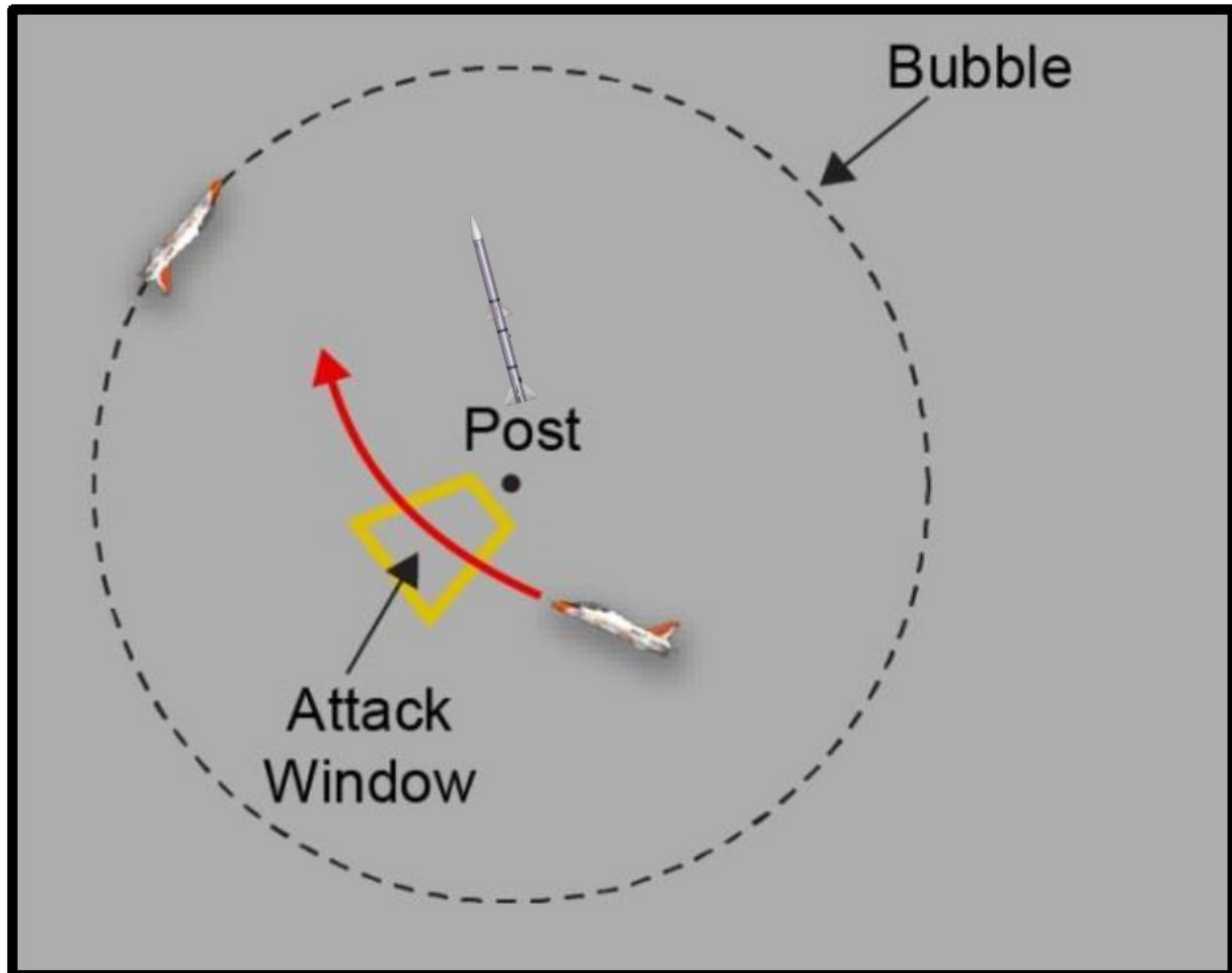
Once you are inside his "bubble" (the smallest possible TC he can generate), he has to rely on off-boresight snapshots to shoot you, as he cannot point his nose at you. And once you get in the CZ, it will be impossible for him to kill you.

> **AWE Cues:** There are several cues that you are about to enter the Attack Window. First, the range will always be under 2nm at low altitudes, and 5nm at high altitudes. Secondly, you will see a rapid LOS rate change, meaning that if you hold the nose steady he will drift quickly away from the boreline. Once you get these cues, perform a maximum-performance break turn into him to enter the CZ.

Notching Targets: If a bandit commits to a notch-to-merge (attempting to sit in the notch until the Rmin of your MRMs), you need to apply the principles from above. Do not go pure/lead pursuit until the AWE; you will overshoot at the merge and he can reverse and capitalize. Be sure also to remember the advice on keeping a SA on notching targets. And always remember: he can notch your MRM, and flare your SRM, but he cannot jam your gun. A skilled opponent will make it difficult for you to obtain a CZ position. If this happens, you may need to close for a gun snapshot on him while he is still in the notch.

Tail-Chase Targets: Sometimes, in BVR you end up chasing the bandit in a tail-chase scenario. There are several gameplans to deal with tail-chase scenarios, depending on how far away the bandit is. One thing must be noted: extended tail chases are NOT recommended in a multi-bandit environment. A lot of the time you are simply being dragged into another friendly. In a tail-chase your SA on your surroundings is reduced as you focus your radar on him.

> **Reset Tactics:** Especially in NvN/airquake environments, it is wise to not participate in an extended tailchase. If you are well outside of his NEZ if he were to turn around suddenly, you will be fine with a simple abort. If you are close to being in his NEZ, you will need to crank to reduce the closure, and wait until you are well outside his NEZ to abort.
> **Pressing:** Sometimes, you need to press and employ weapons on a cold bandit. Remember, ensure there is nobody waiting to sneak up on you. When pressing, you need to climb slowly, this allows you to get faster than he can at a lower altitude. If possible, use some sort of TWS or Situational Awareness mode to allow you to detect any pop-up groups. Once you get just outside the NEZ, fire, and keep firing every 10 seconds at low altitudes, and 15-20 seconds at high altitude until you are well inside the NEZ.

Notch-Recommit: The notch-recommit is one of the most common tactics when inside the MAR and in a 1v1 situation. Note that notch-recommit assumes that you have Fox 3s. The notch-recommit is essentially a lot of L&N intercepts in quick succession. You need to remember, the guy that can turn in, fire, and get back into the notch or press faster will win. The RWR will be one of your main sensors, as it allows you to determine aware/unaware status. The goal of a notch-recommit is to defend and recommit as quickly as possible. If you can do this faster than him, you can force a positional advantage, and can transition to the gameplan for maintaining the positional advantage.

An example of some notch-recommit fights are below:
https://www.youtube.com/watch?v=hFuPh56Sh9k

Notch-To-Merge: In a notch-to-merge (N2M), you are attempting to "sit" in the notch until the merge, executing RMD and IRMD as needed. Once you get inside his MRM Rmin, you can perform a Tighten Down (a hard, brief, instantaneous turn rate pull), and try to take back as many angles as possible. There is one main mistake to exploit: many pilots will fly pure/lag pursuit while closing you down. If they continue doing this, it will end in an in-close/3-9 line overshoot, as illustrated below:
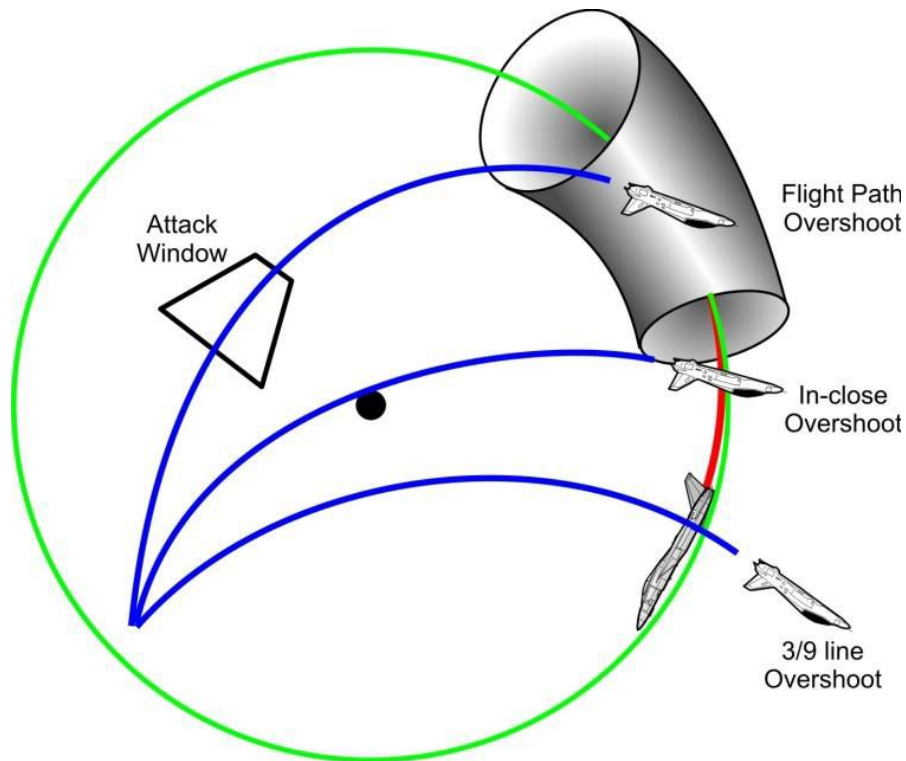
If he does this, you can reverse flight path, and get a gun/SRM/MRM shot depending on how badly he overshot.

SARH Tactics vs ARH Carriers: When inside MAR, you really need to be aware of your SARH employment options. One mistake is to employ from outside the CZ/AWE at all but the closest ranges; your missile launch warning will alert him, and he has the opportunity to snap his nose, shoot an ARH missile, and at the very least trade, if not come out on top. Only take CZ/AWE shots from inside MAR. If you get targeted inside MAR, do not waste a missile on him. Transition into a Notch to Merge gameplan.