



## **Lesson Title**

R-77 Air-to-Air Missile Evasion Training – Part 1

## **Aim**

To teach pilots about the active Air-to-Air missile threats in Allied Force and how to evade them from outside the 'no-escape zone'.

## **Time Required**

2hr (30 min ground school, 15 min setup, 1 hr flying, 15 minute de-brief)

## **Topics to be Covered**

1. Brevity associated with the lesson.
2. Understanding how an active radar homing missile works.
3. The basic terminology of BVR engagements.
4. Weapon Engagement Zone.
5. Active air-to-air missile threats.
6. Typical R-77 missile ranges.
7. Rules of thumb to keep you alive in the BVR arena.
8. Training for R-77 missile evasion at beyond E-Pole ranges.

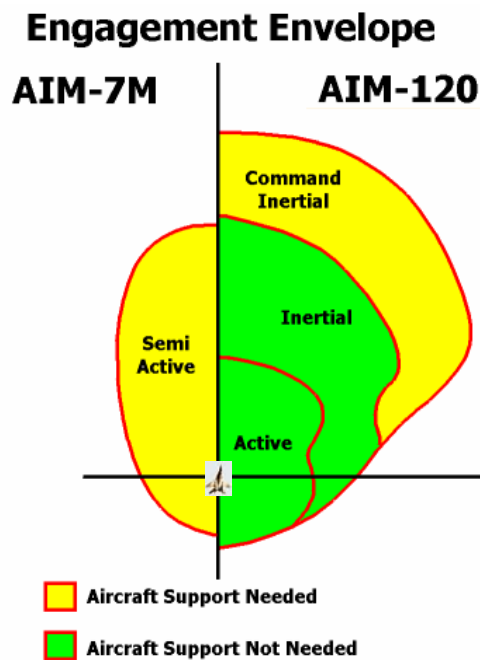
## **Brevity**

All students should understand the following brevity terms which will be used during the training:

- a. ABORT/OUT/RUN/RUNNING (Direction) - Directive/Informative - Perform a defensive maneuver to place the threat radar/missile on the tail.
- b. FOX 3 - Simulated/actual launch of active missile.
- c. PITBULL – ARH missile has gone active.
- d. CRANK (Direction) - F-Pole maneuver; implies illuminating target at radar gimbal limits.
- e. DEFENSIVE (Spike/Missile/SAM/Mud/AAA) - Aircraft is in a defensive position and maneuvering with reference to the stated condition. If no condition stated maneuvering is with respect to A/A threat.
- f. MAD DOG - Visual AIM-120/AIM-54 launch ie with no radar lock on the bandit.

## **Understanding how an Active Radar Homing Missile Works**

All students need to have a basic understanding of how Active Radar Homing (ARH) missile works and how they differ from a Semi-Active Radar Homing (SARH) missile. The diagram below illustrates this principal with a comparison of the Aim-7M Sparrow (SARH) and the AIM-120 AMRAAM (ARH).



#### Comparison of the AIM-7M Sparrow (SARH) and AIM-120 AMRAAM (ARH)

By way of an explanation, where the two axis cross is the position of the bandit. The left side shows the AIM-7M engagement envelope (head-on at the top) and clearly shows the missile is semi-active throughout the entire engagement envelope. This means the firing aircraft needs to keep the target locked up on it's radar for the entire duration of flight in order to guide the Sparrow as it has no internal guidance of it's own. If the lock is broken then the shot is trashed. Keeping the lock also requires the launching aircraft to get much closer to the bandit, putting it in additional danger.

The AIM-120 engagement envelope is shown on the right hand side. Here the aircraft only needs to support the missile during the first part of the engagement for long range shots. During the Command Inertial phase, the missile is too far away from the bandit for it's own small internal radar to be effective so the launch aircraft provides updates on the bandits position by keeping it locked up with the radar (just as with a SARH missile).

Once the missile gets within range of its own seeker head it goes active and guides itself to the target. At this point the launch aircraft can break lock and focus on another threat or keep away from the threat.

The Inertial portion of the envelope is where the missile has not yet gone active but dependant on the velocity and manoeuvrability of the bandit, it is unlikely to get out of the range of the missile seeker before it goes active. During this portion of the flight the launch aircraft can break lock if necessary for its own safety but there is an increased risk that the missile will not hit the target. In the F-16 this inertial region starts at about A-15 (on the active countdown) for low manoeuvring threats, down to approximately A-8 for high manoeuvring threats.

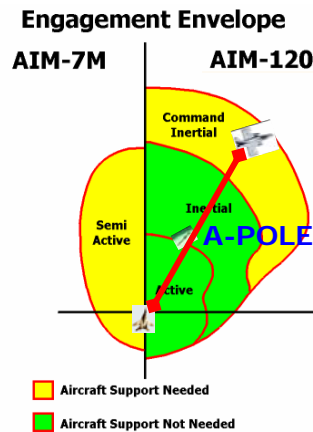
Most active missiles also have a Home on Jam (HOJ) capability that allows them to home in on the energy sent out by a jamming source. This allows the launch aircraft to break lock immediately as it doesn't need to support the missile during the inertial phase.

Clearly then, in the F-16 armed with AIM-120 we have an advantage against an aircraft that can only carry SARH missiles but life is much more difficult against an active threat. He has the same 'fire-and-forget' system as us and breaking the bandit's lock is insufficient to evade the missile once it gets closer, we also need to defeat its active seeker as well.

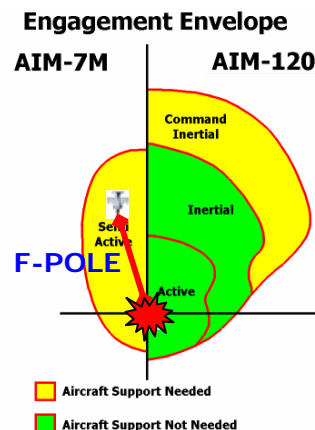
## The Basics Terminology of BVR Engagements

The world of BVR engagement tactics is extremely complex and this lesson is not designed to make the student a master of BVR (we'll save that for our BVR tactics course!). To understand why we do certain things when you are in danger however we do need to understand certain basic concepts:

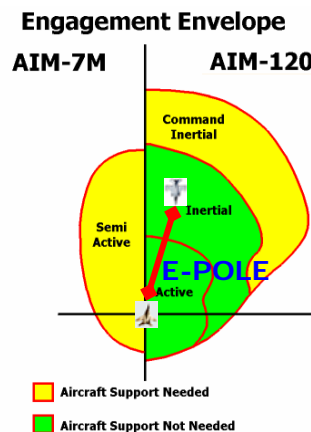
**A-Pole:** Distance from launching aircraft to target when a missile begins active guidance (Clearly this only applies to active missiles). In Allied Force this is the 'pitbull' moment.



**F-Pole:** Distance from launching aircraft to target when a missile endgames/impacts. Most important for aircraft carrying SARH missiles.



**E-Pole:** Distance from a threat aircraft that evasive manoeuvres can be expected to kinematically defeat any missile the bandit is launching or could have launched.

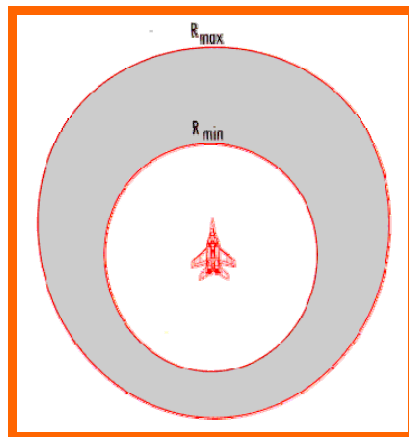


BVR engagements are all about who has the bigger pole! We design our tactics to increase our poles while trying to minimise the bandit's. We achieve this in different ways such as having a missile with a faster speed or longer range, gaining an altitude and airspeed advantage over the bandit and cranking to gimbal to minimise our closer rate.

Ultimately in a one-on-one situation (especially against the Allied Force AI) if we can get to A-Pole (or very close to it) with a Slammer before we place ourselves within the bandit's E-Pole range then we have a very good chance of winning the engagement. Simply put, we are trying to fire and support our missile until it is active while still being able to defeat any shot the enemy launches by turning around to prevent the missile from ever reaching us ie we are trying to stay outside of a missile's 'no-escape zone'.

### **Weapon Engagement Zone**

The no-escape zone is a function of a Weapon Engagement Zone (WEZ). The WEZ is the area in which your missiles (or the enemies) can be effective. It is extremely variable and 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.



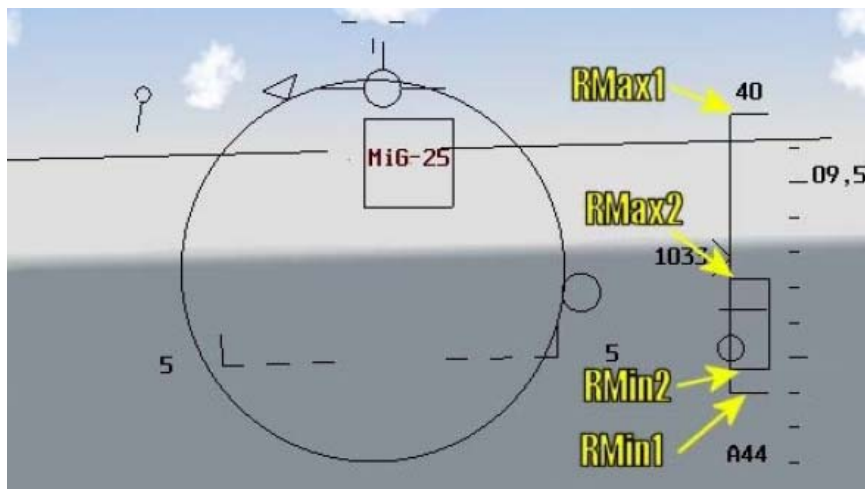
**All Aspect Missile Weapons Envelope**

RMAX is the maximum effective range and RMIN is the minimum effective range of a particular weapon. 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 due to the combined closer speed of the missile and the bandit. Of course this is a predictive system and the WEZ will change constantly unless both the firer and bandit continue to fly at the same speed, altitude and heading. If the bandit reverses direction once a missile is in the air, the missile may not have enough energy to reach the target. It is this fact we are trying to take advantage of with the defensive described later in this lesson.

Of course there is a range at which the bandit can no longer escape just by reversing his direction due to the missile's much greater speed. The bandit has now entered the 'no-escape' zone and the range from the firer to the bandit at which entry to this zone occurs is known as the E-Pole.

In the F-16 the calculation of the WEZ is done automatically by taking into account all of the variables but it is still a predictive system. It is known as the Dynamic Launch Zone (DLZ) bracket as is shown on the right hand side of your HUD:



**The Dynamic Launch Zone Bracket**

**Rmax1** is the maximum range that you can shoot the missile at the target. Even a small change by the bandit such as a climbing, reducing airspeed or changing direction may mean a missile fired at Rmax1 doesn't have enough energy to reach the target. Shots at this range against manoeuvring targets are extremely unlikely to be successful.

**Rmin1** is the minimum range you can shoot a missile. There is a minimum distance because the whole process of the missile being fired off the rails, going active and tracking the target takes time. If a target is too close when you fire, it may already be past you by the time the missile is off the rails.

**Rmax2** represent the top of the manoeuvring zone of the DLZ. Rmax2 is a more realistic maximum range for a target that is manoeuvring. While the bandit is now moving into the no-escape zone, RMax2 only represent represents a 3-4g manoeuvring target. About three quarters of the way between Rmin2 and Rmax2 is a realistic estimate of the E-pole range against a modern 9g fighter and it is here that a bandit truly enters the heart of the 'no-escape zone'.

**Rmin2** represents the bottom of the manoeuvring zone of the DLZ. Rmin2 is a better cue for minimum range as a hard manoeuvring target may get outside the missile seeker gimbal limits before it has had a chance to get off the rails, causing it to go 'maddog'.

While many variables come into play in calculating these ranges, against a 9g target such as the MiG-29 at a similar speed and altitude, the 'no-escape zone' is from around 5nm (RMin2) out to 18nm (RMax2), against a head-on target.

The tactic we are teaching in this lesson will only work if started beyond the E-Pole range and it is therefore vital that you have a good idea of where that range is in different situations. As a guide if you are within RMax2 for the AIM-120 then assume you are also inside E-Pole for any head-on enemy at a similar speed and altitude carrying an active threat.

### **Active Air-to-Air Missile Threats**

Never was the old adage of know your enemy so true as in aerial combat. You need a very good understanding of the different active air-to-air missiles within Allied Force and which aircraft can carry them.

Active threats to review are the R-77, AIM-120, AIM-54 and MICA RF. Further information can be found in the 185<sup>th</sup> Threat Guide, which you can download here:

<http://www.185th.co.uk/forum/docs.asp?action=showsubcat&id=15>

## R-77M Ranges

Based on actual testing, an enemy equipped with the R-77M in a head-on engagement with both aircraft at approximately Angles 25 and 450 knots (a typical flight night setup) the following figures have been determined:

**Rmax1** – 30nm                      **Rmin1** – 3nm

**Rmax2** – 20nm                      **Rmin2** – 5nm

Based on testing in this configuration, it has been determined that the **E-Pole range of the R-77M** against a manoeuvrable target such as the F-16 **is around 18nm** in a CAT III config. If someone fires an R-77 at us from outside this range we have a good chance of reversing course and defeating the missile kinematically, as long as we act immediately.

If fired inside of this range, we will be unlikely to outrun the missile and will have to try and defeat it with a 9g break-turn from a Cat I configuration, which will require us to jettison any A2G stores and possibly forfeit the mission. This is why staying outside of the E-Pole range is so important and requires great discipline and good multi-ship tactics.

## Rules of Thumb to Keep You Alive in the BVR Arena

Remember you don't get an immediate launch warning from an active missile so whenever you are head on to an R-77 equipped threat and inside 30nm then assume you may well have been fired at. If you keep flying blindly towards the enemy and a missile is in the air then you're going to be destroyed so you need to DO something. Get used to recognising launch cues such as RWR spikes, a bandit turning to gimbals and visual indications.

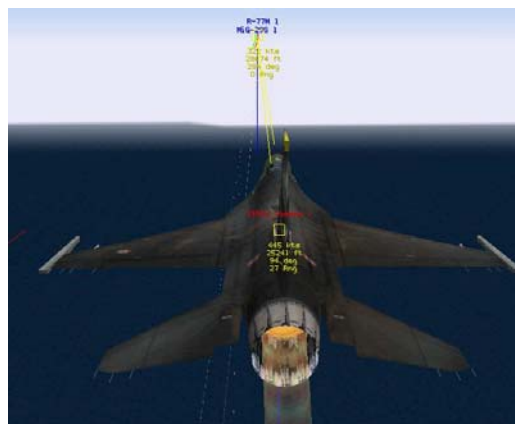
In a typical flight night Cat III setup with both yourselves and the bandit at around Angles 25 and 450 knots aim to 'run/out/abort' by 20nm or you risk entering the 'no-escape zone'. Even if the bandit hasn't fired yet or is cold, if you get close and he turns hot and fires you are right in the heart of his missile kill zone.

If the setup varies significantly from these parameters you need to think about extending the 'run/out/abort' range. As a general guide the higher and faster you are the greater the E-Pole range so you will need to adjust the range upwards especially at Angles 40 and higher where the E-Pole could easily be 25nm or more.

## Training For R-77M Missile Evasion at Beyond E-Pole Ranges

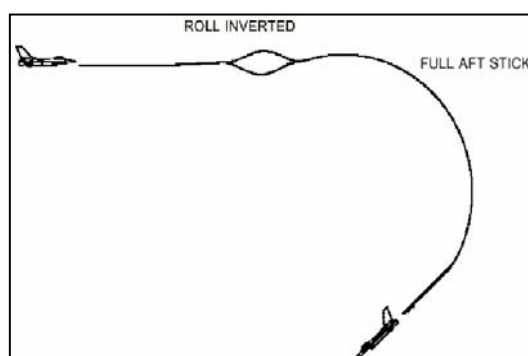
Falcon Version		Patch Status	Theatre of Operations (Check one)					
Allied Force		V1.12	Balkans		Balkans 2005		Balkans 2010	
			Korea		Korea 2005		Korea 2010	X
Package Information								
Takeoff time	Callsign	Task	Target	Time on Target	Package #	AC # & Type		
Dogfight setup – Load the file R-77 Evasion Part 1. The lesson is designed for a maximum of 4 students and 1 instructor.								
Air to Air Weapon Loadout (Free or Fixed)			Fixed					
Air to Ground Weapon Loadout (Free or Fixed)			N/A					
Mission Flight plan (Free or Fixed)			As instructed					

1. This practical lesson covers an R-77M evasion technique designed for use only when you are outside of the E-Pole range. Part 2 of the R-77 Evasion will cover what to do when you find yourself in the 'No-Escape Zone'.
2. Make sure everyone enables invulnerability, unlimited fuel, external views and labels as they join the dogfight.
3. Once everyone is in dogfight module, the instructor should switch teams and get into a MiG-29S. The 4 students should be in the same team and flying the F-16C-52. Move the practice area out over the sea.
4. Commit. Once in the cockpit the students should switch to Cat III mode and turn labels and the ACMI on. They should also split into elements with the second element heading away from the engagement while the first element proceeds in 10 mile trail toward the MiG-29. ECM should not be used during these engagements.
5. The instructor will lock up the element lead F-16 and let him know when he enters Rmax1. He will fire at 25nm and crank to gimbal limits. He will inform the student when the missile goes pitbull and what the A-Pole range is. It may also be useful for those watching if the student evading a missile switches smoke on. Those watching from an external view may also want to use the action view to watch the missile and check its energy state.
6. After launch, the student should take a few seconds to see what the indicators are that a launch has occurred. Things to check include external cues, the RWR and the FCR. The instructor can talk through these points as required.

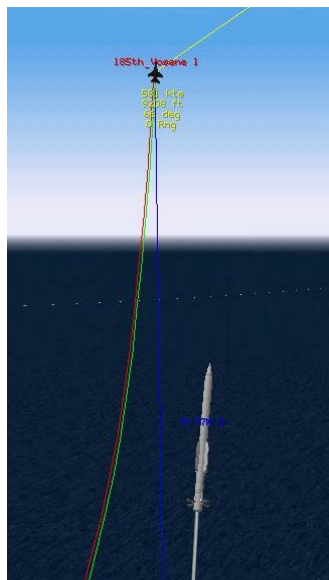


**Missile Launch**

7. After pitbull, the instructor should lock up the 2<sup>nd</sup> student in the element and repeat the process.
8. A maximum of 10 seconds after their launch is called; each student should begin the defensive manoeuvre as follows:
  - a. Perform the first two-thirds of Split-S while accelerating. Be careful to stick within the Cat III limits of 5.5g and 550 knots:



- b. After you have reversed direction, continue your pull back but stop when you reach about 60 degrees nose down. Allow the aircraft to continue accelerating (watch the Cat III limits).
- c. Try to get visual on the missile. It is likely to be at you deep six by now so you may need to adjust your heading slightly to put it at your 5 or 7 o'clock. Don't worry if you can't see it. It will almost certainly be active and showing on your RWR by now.
- d. As you reach low-level pull up to zero pitch and locate the missile, which will be roughly at your 6 o'clock. The reason for going down to low-level is that the air is denser and while you have an engine to power you back towards the heavens, the missile only has its existing speed to turn into height as the motor is not longer burning. You need to do everything you can to make the missile lose its energy before it gets close enough to destroy your aircraft.
- e. During the low-level end-game if the missile is not yet defeated and is still catching you then pull-up into a 30-60 degree climb. As the missile tries to fly lead pursuit it will pull-up even more quickly and go 75+ degrees nose up. It will quickly run out of energy to convert to airspeed and explode harmlessly behind you.



**The End-Game and the Missile is Defeated**

9. Once the first element has completed the defensive manoeuvre, repeat it again with the 2<sup>nd</sup> element.
10. Exit the dogfight and play back the ACMI. The instructor should comment on each student's technique and note any areas for improvement. You should also focus on the missile's energy state at various points in the engagement.
11. Get back into the dogfight module (same settings as before) and repeat the process but as you get more proficient you can wait longer after launch to carry out the defensive manoeuvre (simulating supporting a missile you have fired).
12. You should find that as long as the missile was fired from a minimum of 20nm range (so it has already lost some of its energy) then if you begin the defensive manoeuvre exactly when you hear the missile going active (at the very first RWR chirp before it has even appeared on the RWR) then you will be able to defeat the missile using this manoeuvre.
13. If the bandit fires at E-Pole (approximately 18nm) you need to react immediately or you will be shot down. Any closer than this and the technique is ineffective.

14. As you progress with the training you should become more experienced about how low you need to get to defeat the missile. The closer the missile is to you when you begin the defence, the lower you need to go for it to work. Of course the opposite also applies. As a general rule, you don't want to go any lower than you have to as it puts you at a disadvantage for the next part of the BVR engagement and puts you in range of ground based air defences such as MANPADS. It therefore makes good tactical sense to stay as high as you can while still ensuring the defensive tactic is effective.

15. Ensure you review the ACMI for key learning points.

16. You can view a short video and ACMI of this technique, created by Seeker, here:

[http://185th.co.uk/files/Training/Operational/A2A/R-77\\_Evasion/Part\\_1/R77\\_Evasion\\_Split\\_S.zip](http://185th.co.uk/files/Training/Operational/A2A/R-77_Evasion/Part_1/R77_Evasion_Split_S.zip)