AIR COMBAT

TOC

FINDING THE ENEMY

Finding the enemy before he finds you gives you the iniative during a fight, allowing you to gain advantages in altitude, speed and relative position. Once you have him in you sights, you need to verify that he's an enemy, and target him while manuevering into firing position.

Detection Systems

Eyesight

Active Radar

Infrared (IR) Systems

Radar Warning Receiver

Eyesight

- Use eyesight to detect air or ground targets within visual range. This works with both unguided weapons and radar- or IR-guided weapons.

Regardless of how much gadgetry is in the cockpit, your eyes are among your most valuable assets. You must keep a constant watch both in front of you and around your aircraft. If nothing else, use your “check six” key (F2) during combat — this rear camera helps you notice threats on your tail.

Here are some keys to help keep visual contact:

Bksp	Remove cockpit (except for Head-Up Display).
F1	Return to "straight ahead" cockpit view.
F2	Look behind your aircraft.
F3	Look above your aircraft.
F4	Tracking (must have target selected).
F5	Line-of-sight view from your aircraft to an incoming missile.
F6	Line-of-sight view from your aircraft to your wingman.
F7	Line-of-sight view from your aircraft to your current target.
F8	Line-of-sight view from your current target to your aircraft.
Right Shift + ←, →, ↑, ↓	Pan the camera in any direction.

Active Radar

- Use radar to detect air targets outside of visual range.

Radars emit waves of electromagnetic energy into the air. When these waves strike an object, some are reflected back to the transmitter. An onboard computer analyzes the strength of the returning waves, how long they took to return, and their frequency shift to determine an object's range, altitude, bearing and speed.

Radar isn't very adept at finding ground targets — the terrain itself shows up as "snowy" noise on the radarscope. In the air, however, active radar allows you to detect and target aircraft beyond visual range. Radar is also used to guide some missile types (identified by "Active Radar" in the *Load Ordnance* screen).

The major drawback to using your active radar is that enemies — airborne or on the ground — can detect your radar emissions.

Shift 9, then R — Turn on radar, then display Radar Window. For radar symbology, see Radar Window.

NOTE: The F-117 has no active radar, only internal FLIR.

Infrared (IR) Systems

- Use an IR sensor to detect air or ground targets beyond visual range. IR is especially useful against ground targets.

Active radar is only one kind of detection sensor. Some aircraft also carry infrared (IR) sensor systems, housed internally or in a pod mounted on a hardpoint. An infrared detection device searches for anything emitting heat at a particular frequency. By translating heat emissions into visual pictures, IR devices allow you to identify targets at night or in adverse conditions.

Like the radar warning receiver, the IR system is passive — it doesn't emit energy, it just looks for objects that are "hotter" than their environment. It can be used freely in combat because computer enemies never know when they're being tracked by IR-sensors. (In your aircraft, however, the IR detection system can warn you of incoming IR missiles.)

The infrared device used in *ATF* is a called FLIR. Some aircraft, such as the F-22 and X-32, have built-in FLIR sensors; others can be fitted with a FLIR pod that attaches to an available hardpoint. (All seven campaign aircraft have internal FLIR sensors.)

IR sensors are limited in that they have a significantly shorter search range than active radar. In addition, cloudy and foggy weather can reduce IR-sensing effectiveness. However, FLIR can detect ground targets, while active radar cannot. Like radar, FLIR allows you to target contacts that are beyond visual range.

I	Display IR sensor information in the Radar Window. For symbology, see Radar Window.
Shift 4	Display IR target in the Target Window. (If IR/LASER ADVANCED TARGETING is **not** active.)
Shift 2	Display IR target in IR/Laser Target Window. (If IR/LASER ADVANCED TARGETING **is** active.)

When IR/LASER ADVANCED TARGETING is active, brackets appear on your HUD around all detectable IR targets.

Radar Warning Receiver

The Radar Warning Receiver detects targets up to 50nm away that are currently emitting radar signals. It is a passive device, meaning that it doesn't emit energy — it just detects radar emissions from aircraft, ground units, radar vehicles and ships. All sources of radar emissions — friendly or enemy, in the air or on the ground — appear on your RWR.

Anytime you have your radar active, your transmissions can be picked up by an enemy RWR. When you're trying to preserve the element of surprise during an attack, don't activate your radar. Instead, use the RWR.

Shift 5 Display RWR Window. For symbology, see RWR Window.

Weather and Sensors

Adverse atmospheric effects can radically increase or reduce sensor and weapon guidance system performance.

The table shows how the range for each sensor type is modified for each weather type. The numbers are percentages of the sensor's maximum effective range in clear daylight. For example, night reduces visual sensors to 25% of their normal range while extending IR performance to 125% of normal.

	Visual	Laser	Infrared	Active Radar
Day	100%	100%	100%	100%
Twilight	75%	100%	100%	100%
Night	25%	100%	125%	100%
Haze	75%	100%	100%	100%
Clouds	10%	50%	10%	75%
Fog	25%	50%	10%	100%

Which sensor type you choose also depends on what you're attacking. Radar or FLIR, for example, can detect air targets, but radar is useless when you're trying to find ground targets.

Distinguishing Between Friends and Foes

Missiles extend combat to *beyond visual range* (BVR). In a BVR environment, identifying targets as friendly or enemy is understandably difficult, especially if allied countries fly the same aircraft as your enemies. To overcome this problem, air forces typically outfit their aircraft with IFF (Identification Friend or Foe) transmitters. These devices allow the pilot to transmit an electronic code to a targeted aircraft. If the targeted aircraft's IFF box "answers" the code, then the pilot knows that he's targeted a friendly aircraft.

U	Send an IFF signal to the targeted craft.
"Friendly" reply	The recipient is a friendly aircraft.
"Unknown" reply	The recipient may be a damaged friendly, a non-military or an enemy aircraft.

NOTE: The transmitter has a range of 100nm — if the target is beyond that range, you'll receive an "Unknown" message whether it is friendly or not.

Finding the Enemy

Targeting

You can use several methods to target an object in the game. Personal preference and the task at hand should be your guide as to which method to use. Note that all targeting commands assume some kind of detection device — either the object is in visual range directly ahead, or you've turned on your active radar, IR-sensor, or HARM warhead seeker.

Note: The IR/LASER ADVANCED TARGETING option in the **PREF** menu affects how you can designate targets.

Targeting Aircraft

Targeting Ground Objects

IR/Laser Advanced Targeting

Targeting Aircraft

You can target aircraft with **radar** or **IR** sensors, or **visually**, as soon as they are in range.

When looking for targets at long range, use [<,] and [>.] to adjust your radar/IR range.

Use the following keys to target objects in range:

[Enter]	Target something within **visual range**. (This cycles through visible objects, from left to right.)
Left-click on contact (🖱)	Target an air **contact on the Radar Window** viewscreen.
[']	Target **visible object nearest center** of the screen (in [F1] view).
[Shift][T], [T]	Cycle through targets in **radar/IR range** (in radar, HARM or IR mode) IR/LASER ADVANCED TARGETING affects IR targeting.

Note: If you are using radar, you can only target a contact when you're in TWS mode.

Targeting Ground Objects

You can target ground objects **visually**, or with **IR** and **HARM** sensors.

Some aircraft have a built-in IR system; if not you will need to load a FLIR pod from the Load Ordance screen. (IR sensors extend targeting beyond visual range and can detect land targets up to 10nm away, ships up to 20nm away.)

HARM seekers home in on radar emissions, and are especially effective against SAM sites and other radar emitters. If you're carrying HARM missiles, cycle through your weapons until they are selected (press [and]).

I	Display IR information in the Radar Window.
M	Display HARM information in the Radar Window.
Enter	Cycle through target in visual range.
Left-click on contact	Target an air contact on the Radar Window viewscreen.
'	Target visible object nearest to the center of the screen (in 1 view).
Shift T, T	Cycle through targets in Radar Window (in radar, HARM or IR mode).

IR/Laser Advanced Targeting

Activating IR/LASER ADVANCED TARGETING on the **PREF** menu of the *In-Flight* menu bar, changes the way targeting works:

- When you press I or activate a laser weapon, all contacts detectable by IR or laser appear with brackets around them.
- There are two target designation boxes — a square for radar/visual targets and a rectangle for IR/laser targets.
- You can have two targets selected at once — one IR/laser, the other radar/visual. Left-click on a target to select it as your radar target, right-click on it to select it as an IR/laser target.
- Info for IR/laser targets appear in the IR/Laser Target Window. Shift 2 toggles this window on/off. Radar/visual targets appear in the Radar/Visual Target Window. (Shift 4 toggles it.)
- / cycles through bracketed IR or laser targets. T and Shift T cycle through radar or HARM targets.
- You lose your missile lock if the target moves out of view.

Tracking Your Target

ATF has several options that affect target identification and acquisition:

IR/LASER ADVANCED TARGETING. This option from the **PREF** menu of the In-Flight menu bar changes the way targeting works.

SHOW TARGET INFO. This option on the **CHEATS** menu of the In-Flight menu bar displays the identity (and callsign, in multi-player games) of air and ground targets.

Offscreen target marker. This double “XX” appears around the perimeter of your viewscreen when your current target moves off-screen, indicating the direction you need to fly to bring the target back into view.

Target Window (Shift 4**)**.The Target Window displays a picture of your target, and gives its range and current action. You must have a target to open this window.

AIRCRAFT WEAPONS

Fighters carry several weapon types — unguided guns and “iron” bombs, guided air-to-air missiles, guided and unguided air-to-ground missiles and rockets. The weapon guidance systems for various munitions use infrared emissions, laser beams, active radar and passive radar to identify and lock onto enemy threats.

Air-to-Air Weapons Overview

Air-to-Ground Weapons Overview

Weapon Guidance Systems

Weapon Information Chart

Air-to-Air Weapons

Gun Designations: GAU-, GsH
Missile Designations: AA-, AIM-, PL-, MICA, R-
Sensor Systems: IR, FLIR, SARH, Active Radar

Guns used to be the only weapon available during an air battle, and dogfighting used to be a test of a pilot's visual acuity. In modern air combat, however, the majority of battles are fought without opponents ever coming within visual range of one another.

While guns are useful at close range, air-to-air missiles extend air combat by miles. Long-range, air-intercept missiles can effectively target threats as far as 80 miles; short-range air-to-air missiles can be fired from near point-blank range up to 25 nautical miles away.

With the exception of mounted guns, air-to-air weapons are guided by either the aircraft's sensors or an independent "seeker" head. But although these advancements make them effective weapons, striking targets with air-to-air missiles still demands good piloting skills and selective firing.

Air-to-Ground Weapons

Missile Designations: AGM-, HARM, AS- (Anti-Ship), AT- (Anti-Tank)
Bomb Designations: GBU-, MK-
Rocket Designations: LAU-
Sensor Systems: IR, FLIR, HARM, Laser, Active Radar

Air-to-ground weapons include missiles, rockets and bomb.Some air-to-ground missiles, such as the IR-homing AGM-65 Maverick or the active radar-guided AGM-84E SLAM, are long-range, “standoff” weapons. Once fired, these weapons do not require guidance from the launching aircraft. As such, they are “fire-and-forget” weapons — you can launch them and immediately turn toward a new target. During flight, they have the ability to modify their flight path.

Air-to-ground weapons employ the same guidance systems as air-to-air weapons, although some have other sensor types built into the seeker head. The sensor on a HARM weapon homes in on targets that are emitting radar, while the sensor on a laser weapon homes in on targets pinpointed by a laser beam.

Weapon Guidance Systems

Each guidance system has its own method of acquiring and locking a target. Some weapons are “fire-and-forget” and have guidance systems built into their seeker head. Others require that you keep the target in view until weapon impact.

Although effective, guided weapons are not the “one-shot, one-kill” devices they are often perceived to be. Used improperly, they can perform dismally.

SUMMARY

Semi-Active Radar-Homing (SARH)

Active Radar

Infrared-Homing

Laser-Guided

HARM (Radar-Homing)

Aircraft Weapons

Summary

Press the key listed to activate the appropriate guidance system for each weapon type.

Semi-Active Radar Homing weapons (SARHs)

[R] Use aircraft radar to acquire and track a target until impact.

Active Radar weapons

[R] Use aircraft radar to acquire a target, and an internal guidance system for post-launch guidance.

IR weapons

[I] Bring target (air or ground) in view or FLIR (ground targets) to acquire a target, and an internal IR seeker to track targets after launch. If using FLIR, load an internal IR seeker (FLIR pod) or fly B-2, F-117, F-22, X-31 or X-32.

Laser-guided weapons (automatic)

Uses PAVE Spike Laser Designator Pod (internal on F-117, must load as pod on all other aircraft) to acquire and track a target with a reflected radar beam until impact.

HARM weapons

M Uses an internal missile sensor to track targets that are emitting radar.

Semi-Active Radar Homing Weapons (SARHs)

Semi-Active Radar Homing weapons (SARHs) use the aircraft's onboard radar system both to acquire and track a target. No special sensor is required, but this air-to-air missile doesn't have a built-in radar. You must keep the target in view (thus "painting" it with radar) so that the missile can maneuver toward it. If the targeting aircraft breaks its lock — even momentarily — the missile may miss.

SARH missiles can be launched at medium range (usually 15 - 20nm) but perform poorly at short range. They also don't work well when fired from above the target, as radar reflected from the ground confuses the missile.

Important Note

- Use SARHs only against lesser threats — save your "fire-and-forget" missiles for tough combat.

Active Radar Weapons

Active radar weapons use the aircraft's normal radar system to acquire a target. Upon launch, the missile's guidance system receives coordinates from the aircraft's weapon system. The weapon flies to the designated point and activates its own seeker head, which it then uses to home in on the target. Since the weapon guides itself, the launching aircraft can break away from battle anytime after firing. For this reason, active radar arms are known as "fire-and-forget" weapons.

Important Notes

- Radar-guided weapons only work against air targets.
- Radar can penetrate all weather conditions (clouds, however, reduce effectiveness to 75%).

Infrared-Homing Weapons

Infrared ("heat-seeking") missiles use internal sensors to detect and track heat-emitting objects, such as an airplane's engine exhaust or a ground vehicle sitting in the sun. Compared to radar-guided weapons, infrared-homing missiles have short range — point-blank to 8nm for air-to-air and 3nm to 10nm for air-to-ground IR weapons. However, IR-homing weapons have one clear advantage; once launched, they guide themselves to the target, leaving the pilot free to maneuver after launch.

To launch an IR-homing missile, you must first designate a target (see **Targeting**). Once a target has been chosen, you must make certain that the missile has a good lock on the target. The "lock status" of an IR-guided air-to-air missile is apparent on the HUD — as with radar-guided weapons, a floating diamond cursor on the HUD represents the missile seeker. Once the seeker moves on top of the target box, the missile has achieved target lock.

Target lock is also communicated through sound. For air-to-air

missiles, lock is indicated by a growling sound — the louder the growl, the better the lock. For air-to-air weapons, lock is similarly indicated with a ringing tone.

Important Notes

- Clouds and fog reduce effective range of IR weapons to 10% of normal.
- Older IR-homing air-to-air missiles (such as the AIM-9B and AIM-9M) are *rear-aspect*, meaning that they must be fired from *behind* the target, where the hot engine exhaust makes homing easier for the missile. Modern IR missiles are *all-aspect*, meaning they can track a target from any direction (though they are still more accurate from behind).
- All IR-homing air-to-air missiles have a tendency to be confused by the sun and may stray off toward it. This is especially true of the AIM-9B, but less true of the AIM-9M and AIM-9X.
- Loading a FLIR pod in the *Load Ordnance* screen or flying an aircraft with internal FLIR allows you to target contacts beyond visual range.

Laser-Guided Weapons

Laser-guided weapons follow a laser beam that is aimed at the target. They are limited to use against ground targets.

A laser-guided bomb is fitted with a seeker and movable canards, small wing mechanisms that help guide the weapon to the target. The bombing sequence works like this: the aircraft designates a point on the target with a PAVE laser-designator (carried on one of the hardpoints). Once the bomb is dropped, its seeker homes in on the laser reflection and provides directional cues to the movable canards. The canards modify the bomb's glide path to some extent, resulting in more accurate hits than conventional bombs.

Important Notes

- Unless you fly the F-117 or B-2 (which have internal laser designators), you must load the PAVE laser designator in the *Load Ordnance* screen.
- Maintain a lock on the target until the bomb has hit — if you suddenly target another object, the bomb will fall blindly to the ground.

HARM (Radar-Homing) Missile

The AGM-88 HARM missile is a High-Speed, Anti-Radiation Missile that locks onto targets that are emitting radar transmissions. The HARM seeker is built into the missile's nose and requires no onboard guidance. Information from the seeker appears in the Radar Window. HARMs are highly effective against radar vehicles, radar-equipped SAMs and ground-based radar installations. A threat's only defense against such a missile is to turn off the radar altogether.

The HARM is a "fire-and-forget" missile. However, if a HARM is launched and the target turns off its radar, the missile will continue to the target's last known location and detonate.

Weapon Information Chart

ATF gives you a wide choice of guns, air-to-air missiles, air-to-ground missiles and bombs. Some are guided, some are not; some are American, while others are foreign. The charts below list information for each weapon in the game.

Guns, Missiles, Bombs. Weapon type.

Seeker Type. Sensor system used by the weapon.

Effective Range (Eff. Range). Range (in nautical miles) at which the weapon has a chance of striking the target. One nautical mile equals 1.852 kilometers.

Preferred Targets. Targets most vulnerable to that weapon type.

Guns

Air-Intercept Missiles (Long-Range)

Air-to Air Missile (Short-Range)

Anti-Tank Missiles

Air-to-Ground Missiles

Air-to-Ground Bombs

Air-to-Ground Rockets

GUNS

	Seeker Type	Eff. Range (nm)	Preferred Targets
GAU-8, GAU-12, GAU-13	Radar-calculated lead	0-2	Soft targets, Aircraft
GsH 30	Radar-calculated lead	0-2	Soft targets, Aircraft
Aden	Radar-calculated lead	0-2	Soft targets, Aircraft
M-61 Vulcan cannon	Radar-calculated lead	0-2	Soft targets, Aircraft

AIR-INTERCEPT MISSILES (LONG-RANGE)

	Seeker Type	Eff. Range (nm)	Preferred Targets
AIM-7 Sparrow	SARH	Short (0.5-19.7)	Aircraft
AIM-9MB, 9MM, 9MX Sidewinder	IR	Short (0-3.9)	Aircraft
AIM-54C Phoenix	Active Radar	Long (.1-148)	Aircraft
AIM-120 AMRAAM	Active Radar	Medium (0-24.6)	Aircraft
PL-10	SARH	Long (.1-75)	Aircraft
PL-7	IR	Short (0-5.5)	Aircraft
AEMP-1EM Pulse*	Active Radar	Long (0-50.7)	Aircraft

*(fictional weapon that knocks out HUD, radar, etc.)

Weapons Chart

AIR-TO AIR MISSILE (SHORT-RANGE)

	Seeker Type	Eff. Range (nm)	Preferred Targets
AA-2 Atoll	IR	Short (0-1.4)	Aircraft
AA-6 Acrid	SARH	Medium (0-14.8)	Aircraft
AA-8 Aphid	IR	Short (0-1.4)	Aircraft
AA-9 Amos	SARH	Medium (0-41)	Aircraft
AA-10 Alamo	SARH	Medium (0-19.7)	Aircraft
AA-11 Archer	IR	Medium (0-9.8)	Aircraft
AA-12 AMRAAMSKI	Active Radar	Medium (0-24.6)	Aircraft
MICA	Active Radar	Long (0-50)	Aircraft
R-440	IR	Medium (0-18.5)	Aircraft
R-530	SARH	Short (0-3)	Aircraft
R-550	IR	Short (0-3)	Aircraft

ANTI-TANK MISSILES	Seeker Type	Range (nm)	Preferred Targets
AT-2 Swatter	Radio command	Short (0-2.9)	Tanks
AT-12 Swinger	Laser	Short (0-4.2)	Tanks

Weapons Chart

AIR-TO-GROUND MISSILES

	Seeker Type	Range (nm)	Preferred Targets
AGM-65G Maverick	IR	Short (0-9.8)	Tanks
AGM-88 HARM	HARM	Medium (0-12.3)	Radar stations, SAMs
AGM-84A Harpoon	Active Radar	Long (0-59)	Ships
AGM-84E SLAM	Active Radar	Long (0-49)	Hangers, Silos
AM-39 Exocet	Active Radar	Long (0-92.6)	Ships
AS-7 Kerry	SARH	Short (0-4.9)	SAMs, Parked aicraft Light structures
AS-14 Kedge	Laser	Medium (0-6.5)	Ships, Bridges, Runways, Heavy/ hardened structures
AS-15 Kent	Laser	Medium (0-6.5)	As AS-14
AS-16 Kickback	Active Radar	Medium (0-6.5)	Ships
AS-30	Active Radar, Laser	Medium (0-6.5)	Structures, Ships

AIR-TO-GROUND BOMBS

	Seeker Type	Range (nm)	Preferred Targets
GBU-10	Laser	1nm/1000ft of altitude	Large or vital targets
GBU-27	Laser	1nm/1000ft of altitude	Large or vital targets
MK-82	None	1nm (line-of-sight)	Large targets
MK-84	None	1nm (line-of-sight)	Large targets

AIR-TO-GROUND ROCKETS

	Seeker Type	Range (nm)	Preferred Targets
LAU-10	None	1nm (line-of-sight)	Armor, Structures, Personnel
LAU-61	None	1nm (line-of-sight)	Armor, Structures, Personnel

USING WEAPONS

Once you've acquired a target, to fire on it you will need to select a weapon, activate a guidance system for it (if necessary), get into firing position and fire.

Selecting a Weapon

Arming a Guided Weapon

Gaining Firing Position

Firing

Selecting a Weapon

Your currently selected weapon appears in at the bottom left corner of the HUD. You can also open the Weapon Status window to see the number remaining of all weapons.

[or] Cycle through weapons.

Shift 8 Toggle Weapon Status Window.

Arming a Guided Weapon

The steps for arming a guided weapon vary according to the type of weapon:

SARH

Active Radar

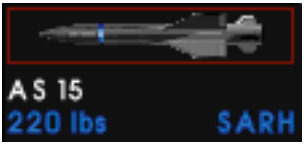
Infrared (AIr-to-Air)

Infrared (AIr-to-Ground)

Laser

HARM

SARH



Target Designation: Radar

Weapon Guidance: After launch, weapon is guided by aircraft's radar

How to Activate:

1. Designate a target.

   Press [R] to activate radar, then [Shift][9] to display Radar Window. Press [,] or [.] to increase or decrease radar range. Fly until target is within TWS range. Cycle through targets by pressing [T] or [Shift][T].
2. Choose radar-guided weapon ([[] or []]).
3. Open Target Window ([Shift][4]).
4. If necessary (F-22, F-117, B-2, X-32), open weapons bay door (letter [O]).

Active Radar

Target Designation: Radar

Weapon Guidance: After launch, weapon navigates to waypoint, switches on internal radar

How to Activate:

1. Designate a target.

   Press R to activate radar, then Shift 9 to display Radar Window. Press , or . to increase or decrease radar range. Fly until target is within TWS range. Cycle through targets by pressing T or Shift T.
2. Choose radar-guided weapon ([or]).
3. Open Target Window (Shift 4).
4. If necessary (F-22, F-117, B-2, X-32), open weapons bay door (letter O).

Infrared (Air-to-Air)

Target Designation: FLIR, radar, visual

Weapon Guidance: After launch, weapon is self-guided by internal IR-seeker

How to Activate:

1. Designate a target by one of the following means:

   (FLIR) Press [I] to activate IR, then [Shift][9] to display Radar Window. Press [T] or [Shift][T] to cycle through targets. (B-2, F-117, F-22, X-31 or X-32 have internal IR seeker. For other aircraft, load a FLIR pod in the *Load Ordnance* screen.)

   (Visual) Turn until the target is in your forward view and press [Enter]. Press [Enter] to cycle through targets.

   (IR/LASER ADVANCED TARGETING active in PREF menu) Press [I] to activate IR sensor. Brackets appear around all IR targets on viewscreen. Press [/] to cycle through IR/laser targets.
2. Open Target Window ([Shift][4]).
3. If necessary (F-22, F-117, B-2, X-32), open weapons bay door (letter [O]).

Infrared (Air-to-Ground)

Target Designation: FLIR, visual

Weapon Guidance: After launch, weapon is self-guided by internal IR-seeker

How to Activate:

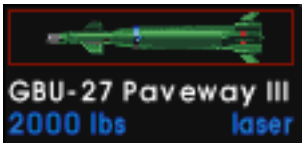
1. Designate a target by one of the following means:

   (FLIR) Press [I] to activate IR, then [Shift][9] to display IR info in Radar Window. Press [T] or [Shift][T] to cycle through targets. (B-2, F-117, F-22, X-31 or X-32 have internal IR seeker. For other aircraft, load a FLIR pod in the *Load Ordnance* screen.)

   (Visual) Turn until the target is in your forward view and press [Enter]. Press [Enter] to cycle through targets.

   (IR/LASER ADVANCED TARGETING actice in PREF menu) Press [I] to activate IR sensor. Brackets appear around all IR targets on viewscreen. Press [/] to cycle through IR/laser targets.
2. Open Target Window ([Shift][4]).
3. If necessary (F-22, F-117, B-2, X-32), open weapons bay door (letter [O]).

Laser



Target Designation: FLIR, visual

Weapon Guidance: After launch, weapon guided by PAVE laser (B-2 and F-117 have internal laser designator. For other aircraft, load a PAVE laser designator pod in the *Load Ordnance* screen.)

How to Activate:

1. Designate a target by one of the following means:

   (FLIR) Press [I] to activate IR, then [Shift][9] to display IR info in Radar Window. Press [T] or [Shift][T] to cycle through targets. (B-2, F-117, F-22, X-31 or X-32 have internal IR seeker. For other aircraft, load a FLIR pod in the *Load Ordnance* screen.)

   (IR/LASER ADVANCED TARGETING active)

   (Visual) Turn until the target is in your forward view and press [Enter].
   Press [Enter] to cycle through targets.
2. Choose laser-guided weapon ([[] or []]). Laser is automatically activated. (You must maintain target lock until weapon impact).
3. Open Target Window ([Shift][4]).
4. If necessary (F-22, F-117, B-2, X-32), open weapons bay door (letter [O]).

HARM

Target Designation: HARM mode

Weapon Guidance: After launch, weapon self-guided by radar-homing warhead

How to Activate:

1. Designate a target.

   Press M to activate HARM mode, then Shift 9 to display Radar Window. Press , or . to increase or decrease radar range. Fly until target is within HARM missile range. Cycle through targets by pressing T or Shift T.
2. Choose HARM missile ([or]).
3. Open Target Window (Shift 4).
4. If necessary (F-22, F-117, B-2, X-32), open weapons bay door (letter O).

Gaining Firing Position

Before using guns (unguided) or missiles (guided), you need to position your aircraft so that you can take the best shot possible. You want to keep the aspect angle between you and your target small. In other words, you want to have a good, straight shot at a threat. In an ideal situation, you should be right behind your target — he can't fire on you when you're tailing him.

Guns

Missiles

Bombs

Guns

Although missiles are the weapon of choice during most fights, guns remain an essential element of air combat. You don't have to have radar, IR or HARM sensors active to use them.

Guns have large ammo stores, and are generally most effective only at short range (0-2nm). A single burst of gunfire generally won't kill an aircraft ... but it may eliminate a ground target.

Guns are easy to use against a stationary ground target. Firing at moving air targets, however, is considerably more difficult. An important aspect of using guns in air combat is calculating how far you need to "lead" the target. The enemy is constantly moving, so you must predict where he's going to be when the bullets reach their mark.

Leading a Target

You must take into account your enemy's speed and current position and guess how much "lead" is needed to hit him. When your

radar is off, you must lead your shots in front of the target to hit it.

If your radar is on, center the pipper on your HUD over the target (see Gun Elements). The pipper circle illustrates the target's current heading and speed and shows where you should aim to make the target fly into your bullets.

With radar active, the pipper automatically calculates lead requirements. A thick line around the perimeter of the pipper measures range from your current position to the target. A longer arc indicates a better chance of hitting the target, and the absence of a thick arc means you have zero chance of hitting the target.

Missiles

Missiles are a fighter's best offense — they're maneuverable, deadly and possess "smart" guidance systems. Guided missiles use a seeker to track targets after launch. The radar, IR or laser seeker identifies the target position and feeds course corrections to the canards (small "wings" on the aft end of the missile). This in-flight maneuverability has given missiles a reputation of being able to take out targets over 100 miles away.

Before firing a missile, make sure you consider range requirements, missile maneuverability, launch parameters, G-loads and aspect angle. These parameters are discussed on the next few pages. To see how they are represented on the HUD, see Weapons Mode Features: Missiles.

Range

Long-range missiles can be fired from as far as 150nm away, while medium- or short-range ones have a maximum launch distance around 25nm. As a general rule, however, hit probability increases as the distance to the target decreases.

Most missiles also have minimum launch ranges (usually about 1.5nm) to ensure that the launcher doesn't inadvertently harm himself. The missile requires room to get up to speed, and the seeker needs a good lock on the target before it starts maneuvering. Since the probability of a direct hit on a maneuvering target is unlikely, missiles are designed to cause damage over a large radius. Some missiles release a giant, expanding ring of iron bars, while others release hundreds of small metal fragments. The idea behind this is that the larger the area covered by the warhead, the greater the probability of a kill.

Launch Parameters

In general, you want to launch within the missile's optimal launch parameters. This can be gauged by watching the Hit Probability indicator on your HUD. The higher the probability, the greater chance you have of striking the target. Many parameters affect the hit percentage — weather, distance, the size of radar or infrared signatures, and more.

Missile Maneuverability

Although canards and guidance systems make the missile a fairly maneuverable, long-range weapon, their maximum effect only occurs during the first 10 seconds of flight. This happens because missile engines do not burn for the entire missile flight. The motor engages after launch, rapidly accelerating the missile to top speed using thrust. During this stage, the missile is highly maneuverable. However, once the engine runs out of fuel (5 - 10 seconds after launch), the missile glides the rest of the way to the target, losing speed as it glides. As speed decays, so does maneuverability.

G-Load Limit

The rail or hardpoint on which the missile is mounted has a maximum G-load limit. When the aircraft turns, climbs or dives suddenly, the rail and missile are stressed because of the incurred G-force. If the G-force is too strong, the missile can't launch properly.

Most missiles can be fired from rails during turns, as long as you have a good target aspect angle (see below). If the force is above the launch maximum (different for all missiles), you'll lose all lock indicators in your HUD. In general, the missile must pull at least 7 times the G-load as the target in order to follow it. If the target is pulling 8G, the missile will need to pull as much as 56G.

Keep this is mind when firing a missile after you enter a turn. A hard maneuver that brings you right onto a bandit's six does little good if you can't fire the missile because you're pulling too many G's.

Aspect Angle

Target aspect angle plays a large role in missile effectiveness. This refers to the angle between your nose and the targeted aircraft. The aspect angle is measured in degrees as follows:

Low-aspect shots (fired from directly behind or in front of the target) have a greater chance of success than those from high-aspect (fired at the target's side). A good aspect is integral to a missile's success.

Target aspect also affects missile range. If the target is moving toward the launching aircraft, the missile has less distance to travel. The missile can therefore be fired sooner because the target will "fly into" it. This effectively extends the missile's maximum range. Conversely, if the target is moving away from the missile, the missile's effective range is reduced. It must be fired at close range to ensure that it has enough energy to travel the additional distance covered by the target after the missile launches.

Bombs

Bombs are short-range weapons that rely on gravity for “propulsion.” Most are fitted with short fins or canards that help keep the bomb aligned nose-first during flight.

Conventional bombs have a range of only 1 to 2 nautical miles, have no supportive guidance systems, and have non-adjustable tail fins. More modern versions have seekers and aircraft guidance systems that make small canard adjustments during glide flight — still, their range is no greater than that of iron bombs.

Dropping bombs is not an easy task — you must figure the correct drop point based on a combination of altitude, airspeed and pitch of the aircraft. The higher you are when you drop the bomb, the further the bomb can travel (in ground miles). This is true because the bomb travels both down and forward when dropped — the longer it’s in the air, the longer range it has.

Accurately dropping a bomb takes a lot of guesswork and can often be dangerous because of the close range required. One guideline to follow is that a bomb has a range of about 1 nm per every 1000 feet of aircraft altitude. (But, if dropped from too far away, the bomb may miss altogether.)

Firing

Once you've locked onto a target, activated a weapon and its sensor system, and moved your aircraft into the correct position, you're ready to fire.

Guns can be fired at any time simply by pulling the trigger button on your joystick, or by pressing Tab. (You don't have to select your gun as your current weapon, it is always active and can be fired at any time.)

Firing other weapons involves a few steps:

Guided Missiles

Guided Bombs

Unguided Bombs

Firing a Guided Missile

1. Bring the targeted object into view in front of you.
2. Make sure you have a guided weapon selected ([or]). If the missile is radar-guided, have your radar on (R).
2. (F-22, F-117A, B-2 only) Open the weapons bay (press O).
3. Watch the range, hit probability and aspect angle indicators on your HUD.

   (Weapons Mode Features: Missiles and Guided Bombs)
4. Fire when you have a good profile by pressing Spacebar or the missile-fire button on your joystick.
4. If using SARHs or laser-guided missiles, keep the target in view until impact.

Dropping a Guided Bomb

1. Attain an appropriate altitude (varies for levels of ground defense: 3000ft for lightly guarded areas, 5000ft or higher for defended areas).
2. Fly within several miles of the intended target (approximately 1nm for each 1000ft of altitude).
3. Make sure you have a guided weapon selected ([or]) and the appropriate sensor (M, R or I, laser activates automatically).
3. Watch the range and hit probability indicators on your HUD.

   (Weapons Mode Features: Missiles and Guided Bombs)
4. (F-22, X-32, F-117A, B-2 only) Open the weapons bay (press O).
5. Drop the bomb when you have a good profile by pressing Spacebar or the missile-fire button on your joystick.
6. If using laser-guided bombs, keep the target in view until impact.

Dropping an Unguided Bomb

1. Attain an appropriate altitude (varies for levels of ground defense: 3000ft for lightly guarded areas, 5000ft or higher for defended areas).
2. Fly within several miles of the intended target (approximately 1nm for each 1000ft of altitude).
3. Make sure an unguided bomb is your current weapon ([or])..
4. Bring the target into your front viewscreen.
5. (F-22, X-32, F-117A, B-2 only) open the weapons bay (press O).

6a. (All aircraft but B-2) Maneuver so that the CCIP pipper overlays the box around the current target in your HUD.

6b. (B-2) A bomb camera window auto-activates when you select an unguided bomb (if not Shift 4 toggles it). Yaw left/right as to center the target inside the window.

7. Drop the bomb by pressing Spacebar or the missile-fire button.

DEFENSES AND COUNTERMEASURES

Attacking the enemy is only half the job — surviving the mission is the other half. Your aircraft carries various defensive systems called *countermeasures* that are designed to protect you and your aircraft. They may be electronic (jamming) or physical (chaff and flares).

Signatures

Before you can effectively evade missiles, you need to understand how they track your aircraft. Every aircraft has a set of “signatures” that give away your presence to radar and infrared sensors. This radar or infrared signature indicates how easily your aircraft can be detected.

Your aircraft’s configuration can modify signature values. For example, using afterburners creates hot exhaust ports and increases your *IR signature* to 200%, making you twice as detectable as normal. Carrying external stores increases your *radar signature* by 33%, making you one-third more detectable than a “clean” aircraft. Likewise, lowering your landing gear increases radar signature by 25%.

Radar jamming with electronic countermeasures (ECM) reduces the chances of being tracked by radar sources, but drastically increases your chances of being detected by an enemy RWR because of the added emissions. This should be your first defense against enemy radar systems.

Defenses and CMs

Pointing your aircraft toward a sensor also greatly reduces the signature. This is because the radar cross-section of your aircraft (amount of surface area visible to radar) appears smaller when it's viewed from the front. Conversely, a full side or top-down view gives a large cross-section.

Shift 0 Open the Radar Cross-Section Window, which graphically displays your aircraft's signature.

For more information on radar signatures and "stealth" technology, see Advances in Fighter Technology: Stealth.

Jamming

To activate ECM (jamming), press J. JAM appears in your RWR Window (Shift 5) when jamming is active.

Since RWRs also detect jamming signals, never use jamming when you still have the element of surprise. Once you're spotted, use it freely.

How Jamming Works

Electronic Countermeasures, or ECMs, attempt to deceive enemy radar by emitting large amounts of electromagnetic energy in the form of microwaves. Jammers have several different operating modes, including noise, pulse, continuous-wave, transponder and repeater. Part of the radar warning receiver's job is to direct the intensity, frequency and direction of the jamming transmission.

These jamming signals reflect false radar returns to the radar source. The radarscope at the point of origination sees both the real radar return, and also the "fake" ones generated by the jam-

mer. The idea is to either make large targets look small, or make small targets look large. Even though the radar can determine the presence of an aircraft and its direction, the false reflections distort the aircraft's true location. Jamming announces your presence to the enemy, but it hides your exact position from them.

For more information on electronic countermeasures, see Advances in Fighter Technology: Electronic Countermeasures.

Warning Tones

The radar warning receiver detects incoming radar emissions and warns you when you're being tracked by a guided missile. Two audible tones support the RWR: one for radar-guided missiles, and another for IR-guided missiles. A slow, pulsing tone indicates an enemy seeker is tracking your aircraft. A fast, pulsing tone indicates an inbound missile is tracking your aircraft. (Both of these tones are lower pitched than the lock tone indicating that one of your missiles is locked on to a target and ready to be fired.)

Chaff

If used carefully, chaff attracts inbound, radar-guided missiles away from your aircraft. A flashing “R” inside the RWR Window (Shift 5) indicates a radar-guided missile is locked on you and you need to drop chaff (press Ins).

How Chaff Works

The chaff dispenser releases a cloud of small, metallic strips called chaff. This chaff distorts incoming radar beams and often attracts missiles that are seeking out the targeted craft. It is compacted in small cartridges called *pods*, which are released at the command of a button. The filaments or strips inside each pod are made of Mylar film or fine glass fibers covered with metallic particles of aluminum or zinc. Cut to match the wavelength of the expected radar emitter (or a multiple of it) they act as two-ended rods (dipoles) that efficiently deflect radiation.

Radar beams operate on different frequencies, a characteristic that has resulted in the development of a “smart” chaff system that can interface with a fighter’s sensors. The onboard computer relays wavelength information to the dispenser. The dispenser then cuts the chaff filaments to an appropriate length (usually from 1/4-inch to 1-inch long) to best reflect the frequency of the currently tracking radar beam. Hopefully, the material will reflect more radar energy than your aircraft, thus providing a “brighter” target for the missile’s seeker.

Flares

Flares decoy IR-guided missles. A flashing “I” inside the RWR Window (Shift 5) indicates that an IR missile has locked onto you and you need to fire a flare (press Del).

How Flares Work

While chaff cartridges are released to attract radar-seeking missiles, flares are fired to decoy infrared homing missiles. Heat-sensitive missiles head for the hottest spot in the vicinity, namely an aircraft’s exhaust pipes and engines. Flares take advantage of this trait by exploding into hot, bright fireballs designed to create an intense burst of heat between the missile and the plane. This sometimes diverts infrared missiles away from the airplane. If the burst is correctly positioned and timed, the missile will turn toward the flare and miss its target.

Defending Yourself

Missiles may be highly maneuverable but they have their limits. Your best defense is to remain outside the enemy missile's range. Failing that, using ECM at moderate to long ranges may confuse enemy radarscopes and prevent enemies from firing at you. ECM measures have no effect against heat-seeking missiles and have unpredictable results against radar-homing missiles fired at close range. Under these conditions, you must rely on maneuvering and chaff or flares to defeat the missile.

Beating Radar-Guided Missiles

Beating IR-Guided Missiles

Jinking

Beating Radar-Guided Missiles

An “R” in your RWR Window and a pulsing tone indicate that a radar-homing missile is tracking you. Its position appears as a bright dot in the display. With a combination of chaff and quick maneuvering, you can shake the missile:

1. If the missile is still far away, turn so that the missile is approaching your aircraft from the side. This forces the missile to continually turn to track you and burns up its fuel supply. (At close-range, you probably can’t avoid being hit.)
2. Keep the missile off your wing using low-G turns (turns under 2-3G).
3. When the missile closes within 2,000 feet (your warning indicator horn will sound), execute a maximum-G break turn *toward* the missile. At the same time, rapidly release 3 or 4 chaff pods (press Insert three or four times). Ideally, the missile will momentarily target the chaff cloud as your turn moves you outside the missile’s field of view.

4. Use alternate views (such as the F5 window) to watch the missile's smoke trail. When the missile loses its lock, it stops pointing at you. If it doesn't seem to be following you, you've fooled it. If you can't tell, listen for your warning horn. It sounds at a fast pace as long as the missile is tracking you

The RWR also shows if you're being tracked by a missile. A flashing "R" indicates a radar-guided missile, and a flashing "I" indicates an IR-homing missile.

Beating IR-Guided Missiles

The same procedure for radar-guided missiles holds true for heat-seeking missiles, except that you fire off flares (press Del three or four times) instead of chaff cartridges.

Heat-seeking missiles work best if they have an unobstructed view of your aircraft's exhaust port.When you execute the break turn, you move out of view and hide your exhaust pipe from the missile's seeker. Turning toward the sun and shutting off your afterburners may also help. With any luck, the flares or the sun will lead the IR missile away from your aircraft.

Jinking

When you've got a bandit on your tail or at very close range, he'll likely use both missiles and guns. Use the previous tactics to distract the missiles, and jinking to evade guns.

"Jinking" refers to making numerous, erratic flight movements. The key to evading enemy gunfire is being quick and unpredictable. Since bullets are unguided, your enemy has to guess where your aircraft will be at any given time after he fires. For this reason, unpredictably changing course is your best defense.

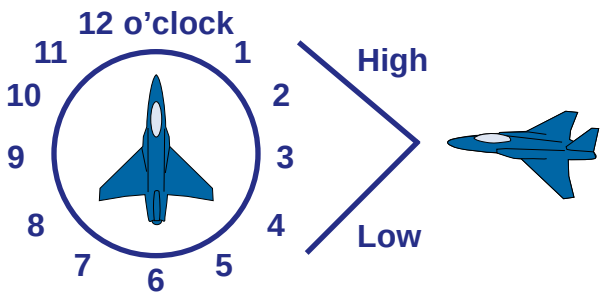
COMBAT TACTICS

Even with all the technological advances of the last few decades, dogfighting still requires the same basic skill set — find the enemy before he finds you and use every tactic you've got to get into an advantageous firing position.

Situational Awareness

Even during the thick of battle, you must constantly remain aware of what's going on in your environment. Not only must you know where your aircraft is, how high it is, and how fast it's going; you also have to know where your targets and wingmen are, and how to respond to attacks. In the meantime, you have to assist your wingmen by alerting them to potential threats.

Headings and "clock-face" communications are common between pilots. Headings on the leading type are measured in degrees (from 0° to 360°), and target positions are given as positions on an analog clock. The clock positions are often accompanied by "high" or "low" to denote altitude advantages.



Combat Tactics

Several cockpit elements and keys in *ATF* keep you apprised of the battle situation:

F10	The **chase view** gives you a view from behind your aircraft.
F2	This **"checks six"** and shows bandits behind your aircraft.
Altimeter	Keep an eye on your **altitude** so you don't attempt a vertically draining maneuver too close to the ground.
Shift 5	The **Radar Warning Receiver Window** identifies threats painting you with radar, and alerts you to incoming guided missiles.
"XX"	This **offscreen target marker** appears on the perimeter of your viewscreen when you've acquired a target and it moves out of view. Maneuvering toward it brings the target back into view**.**
Ctrl Z	"Cheat" that displays the **position of the nearest air threat.**
Ctrl X	"Cheat" that displays the **position of the nearest ground target.**

Combat Geometry

Geometry plays a large role in air combat. To develop a complete understanding of air combat, you need to know a few geometrical concepts: **angle-off-tail**, **aspect angle**, **closure rate, turn rate/radius** and **corner speed**. All pertain to differences in the position, speed and flight path between your aircraft and your air target.

Angle-Off-Tail (AoT)

Cone of Vulnerability

Aspect Angle

Closure Rate

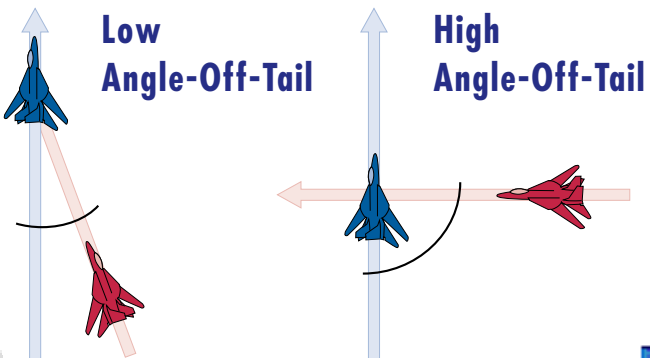
Turn Rate/Radius

Corner Speed

Angle-Off-Tail

Angle-off-tail (AoT) measures the angle between your flight path and that of the target, as shown below. It may be either low (your flight path is nearly parallel to the target's), or high (your flight path is nearly perpendicular to the target's).

At low AoT, you are either headed directly at a target's 6 o'clock as it flies away from you, or at its 12 o'clock as it moves toward you. In either case, your weapons have a direct line of fire to the target. Almost all weapons perform better when fired at low AoT.

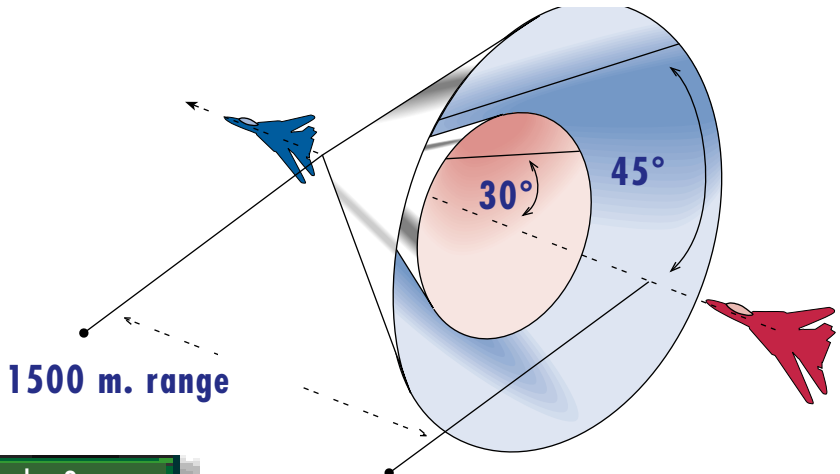


As AoT increases, the target moves away from your flight path (flies more perpendicular to your flight path than parallel). This means that missiles have to turn more to track the target, and bullets must “lead” the target.

During a sustained engagement, your goal is to reduce AoT as much as possible before firing. This usually involves turning so that you align your flight path with that of the target.

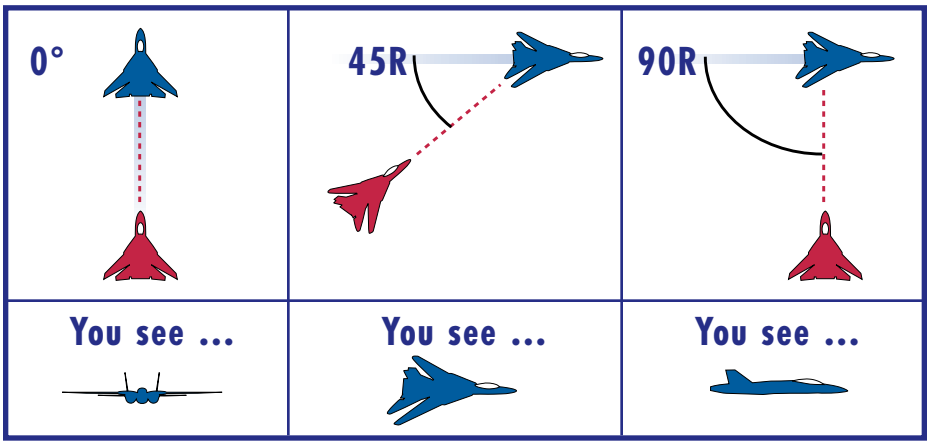
Cone of Vulnerability

When you're within range of an enemy's weapons, you're in the cone of vulnerability. What this means is that if your attacker has closed to 1500 meters (about 4000ft), you're vulnerable to his gun-fire at any AoT less than 45°. As he moves closer in range, you fall within his lethal cone of fire (any AoT less than 30°). You can use break turns to keep an offensive threat out of your lethal cone of fire.



Combat Geometry

Aspect Angle



Aspect angle indicates which aspect of the target is facing you, and is measured in degrees. Think of it as a numerical way of expressing what part of the target you're looking at. In the diagram, you can see that a "90R" aspect angle means you see the target's right wing, which is at a right angle to you. At "45R", you

see the target’s right wing as it crosses your flight path at a 45° angle. The “0” aspect angle means you see the aircraft’s tail (oppositely, at 180°, you see the nose).

Your HUD diplays the aspect angle to the current target next to the "A" in the lower right corner.

Awareness of a target’s aspect angle is vital when you’re using missiles, which must travel at an angle to hit the target. Try to fire from angles that approach 0° or 180° — this gives you a straight shot at either the target’s nose or tail. Aspect angles near 90° are undesirable because the missile must turn to track the target.

Closure Rate

Closure rates describe your aircraft's speed relative to the speed of a moving target. The closure reading appears next to the "C" in the lower right corner of your HUD.

A positive closure means the target is approaching you; a negative closure means it is moving away. The larger the number, the faster the range is changing. A closure of -700 knots means the target is moving away from you very fast while a closure of +70 knots means the target is moving toward you slowly.

Closure rates impact weapon performance. At a high positive closure rate, the range to the target is rapidly decreasing. A missile doesn't have as far to fly, since the target reduces range by flying into the missile. Conversely, if the closure rate is high and negative, the target is moving away and the missile must fly farther to overtake it.

Turn Rate/Radius

An aircraft's ability to turn quickly is called its **turn rate**, and is measured in degrees per second. A related statistic is an aircraft's **turn radius**, or how tightly it can turn. Note that an aircraft can have a fast turn rate, but require a large turn radius. The opposite is also true — these two characteristics are not dependent on one another.

Both turn rate and turn radius play a vital role in pursuing an enemy aircraft. The addition of thrust-vectoring capabilities to modern aircraft has both decreased the turn radii and increased the turn rate. For example, the X-32 EFM fighter can make a tight, low-G turn and alter its AoA independently of its flight path. In this manner, the pilot can control the aspect angle without banking or sacrificing too much forward speed (drag causes some loss of speed).

(See Thrust-Vectoring Turns for more information on using thrust vectoring in combat.)

Corner Speed

Corner speed (also known as calibrated speed) is similar to turn rate, but it is a value that describes the best combination of speed and turn radius for a particular aircraft. In other words, an aircraft's corner speed is a measure of how fast it can take a turn while still maintaining optimal lift and maneuverability.

(See Turn Performance for more information on corner speed.)

Maintaining corner speed is important in a turning fight with an opponent. Keep in mind, however, that every aircraft has different turning capabilities. If your opponent's aircraft has a better turn performance than yours, you may want to avoid a turning fight altogether. In some instances, climbing may prove better than turning.

Your HUD has a corner velocity indicator that shows whether you're above, at or below the aircraft's optimal corner speed. The Other View Window has a similar indicator.

Pursuit Curves

Today's air combat begins before two aircraft ever come within visual range of one another. Long-range air-intercept missiles, electronic countermeasures and radar compose the usual suite of weaponry and defense. But even the best technology in the world can't detect and destroy all threats — some still slip within visual range. When this happens, pilots must use a repertoire of basic combat tactics and skillful maneuvers.

In close-range fighting, your primary aim is to gain a better aspect angle (firing position) than your opponent. Once you have this advantage, you can tail the enemy using three types of pursuit:

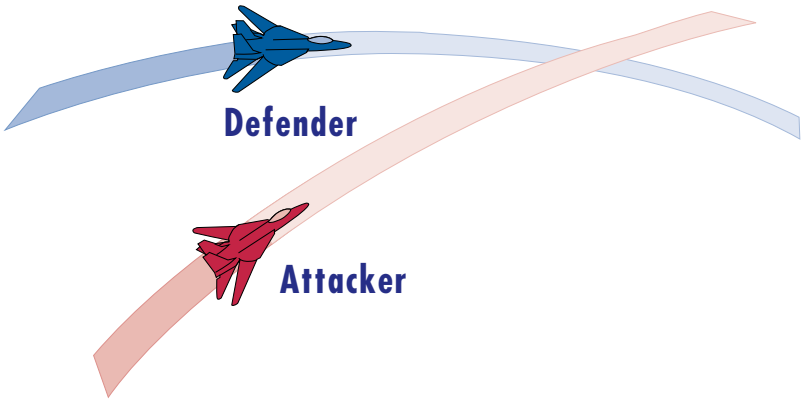
Lead Pursuit

Lag Pursuit

Pure Pursuit

Depending on the situation, you may find all three necessary.

Lead Pursuit



As its name implies, **lead pursuit** refers to predicting the flight path of a target. You guess where the threat will be in the immediate future, and then point your nose at that predicted position. By redirecting your flight path so that it crosses the target's flight path, you stand a better chance of striking the enemy with your weapons. Successful lead pursuit depends upon accurately predicting where the bandit will fly next.

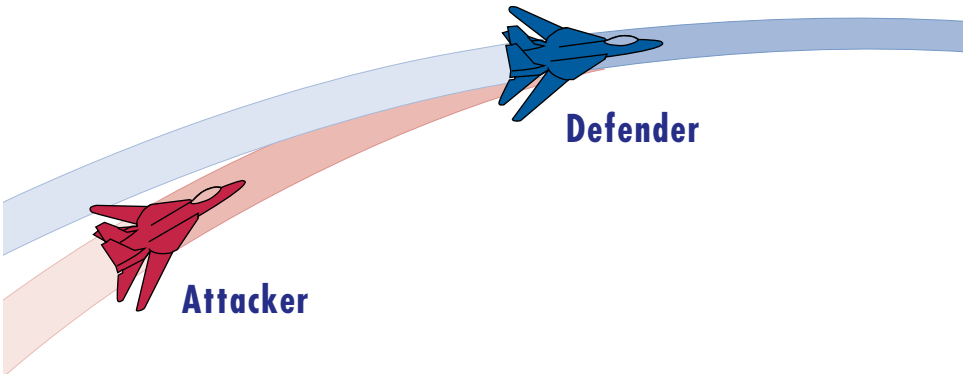
Pursuit Curves

If you fly an aircraft with a smaller turn radius than that of your enemy's aircraft, you can take advantage of lead pursuit. By making sharper turns, you cut across the enemy's flight path. This, in turn, reduces the aspect angle, brings you closer to your opponent, and increases the closure rate.

One disadvantage of lead pursuit is that it can cause the target to momentarily disappear beneath your aircraft's nose. If the target makes an erratic maneuver, you may not see it. Therefore, you should make small, persistent lead-pursuit turns that keep the target in sight.

To initiate lead pursuit, bank your aircraft so that you aim the nose at a point just ahead of the enemy's nose. Keep in mind that tighter turns bleed off kinetic energy.

Lag Pursuit



Lag pursuit is the exact opposite of lead pursuit. Instead of making a tight turn in the direction your opponent is headed, you use a "softer"turn with a larger radius to follow a point just behind the tail of the defender. The potential advantages of lag pursuit are illustrated in the example on the following pages.

Pursuit Curves

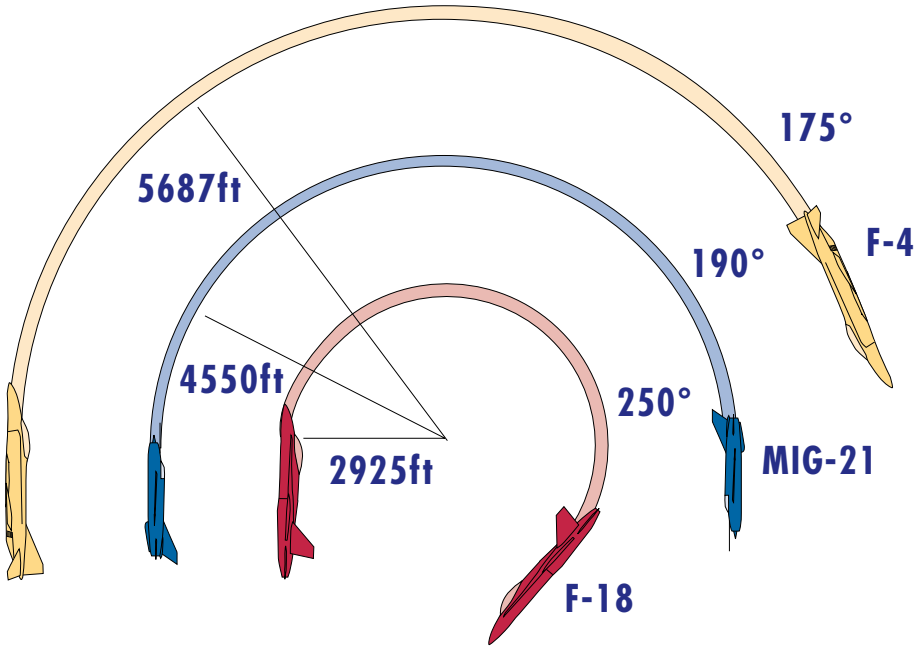
The Turn Radius/Rate diagram compares the different turn rates (measured in degrees per time alotted) and turn radii (measured in feet) of an F-18, F-4 and MiG-21 for a 4G turn at 36,000 feet.

In a low-speed, 4G the F-18 obviously has a significant turn rate and turn radius advantage over both aircraft.

However, imagine that the F-18 Hornet comes screaming in at Mach 1.4 toward the MiG, which is traveling a mere Mach 0.5. At this speed, the F-18 still has a superior turn rate, but its speed has increased its turn radius, and it cannot possibly cut off the MiG's turn (the slower MiG's turn radius is now smaller than the F-18's).

Why shouldn't the F-18 pilot try to match the MiG-21's turn with lead pursuit? If he did, he'd have to pull 5.25G, and he would overshoot the MiG by 3000ft. Additionally, his aircraft will rapidly bleed off speed as drag increases, wasting his initial velocity advantage. However, using lag pursuit would keep him from overshooting and conserve his energy (in the form of speed). Given his turn rate advantage, the F-18 can relax the turn to approximately 4G, while continuing to match the MiG-21’s turn rate. The end result is that the F-18 flies a concentric circle outside the MiG-21.

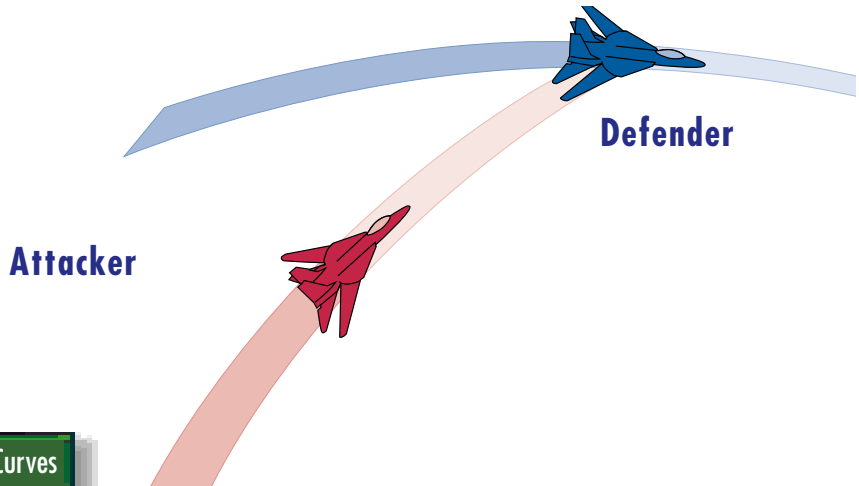
Turn Radius/Rate Diagram



Pure Pursuit

Unlike the two previous examples, pure pursuit is a direct chase. Using pure pursuit is easy — simply point your aircraft directly at the target and follow its maneuvers as closely as possible.

Pure pursuit is most useful when firing weapons at close range. At long ranges, both missiles and guns require some leading, but at close range, you can place your sight directly over the target and fire.



Pursuit Curves

Speed vs. Altitude

The energy elements of speed and altitude are two core elements of aerial combat. Altitude is a measurement of an aircraft's potential energy, which can be converted to speed by diving. Speed is a measure of an aircraft's kinetic energy, which can be converted to altitude by climbing. Kinetic energy is energy in motion, and potential energy is energy in reserve.

At any given instant, an aircraft possesses a certain amount of kinetic energy (speed) and potential energy (altitude). This energy translates directly into maneuverability. Air Combat Maneuvering, or ACM, is a game of managing energy to maximize maneuverability and defeat the enemy. Finding the balance between speed and altitude requires skill and timing.

You have several in-flight controls that help you adjust speed and altitude:

2, 7	**Reducing your throttle** to a low setting will reduce speed, and eventually altitude as lift drops off. Do this if you're overtaking an enemy too quickly. (2 reduces throttle to 25%; 7 reduces current speed by 5%.)
G	**Lowering landing gear** creates extra drag, which reduces speed.
B	**Activating brakes** can slow you down if you're approaching a target too quickly. This helps prevent overshooting, and can often shave off enough speed to keep you behind the craft you're pursuing.
6	**Afterburners** inject extra fuel into your aircraft's exhaust for extra thrust. This can be a lifesaver during escape maneuvers, or moves that require an increase in airspeed or altitude (such as tight turns or vertical climbs and loops). Disadvantages to afterburning are increased fuel consumption for the duration of the burn, and a doubling of your aircraft's heat signature, which makes you a prime target for IR missiles.
F	**Lowering your flaps** provides extra lift and altitude during low-speed turns (under 300 knots or so), by creating a "larger" wing.

Exchanging Energy

Energy types are exchangeable. An aircraft at high altitude and low speed has lots of potential energy, but little kinetic energy. By diving, the aircraft can convert its altitude into speed and increase its kinetic energy. Similarly, the aircraft can convert some kinetic energy back to potential energy by climbing. The aircraft slows down, but its altitude increases.

A cardinal rule of air combat is that an aircraft with energy has maneuvering options; an aircraft without energy becomes a target. Maneuvering uses energy, and every unnecessary maneuver you make “burns” kinetic energy. When it’s gone, you can’t easily get it back.

Because you want maximum maneuverability from your aircraft at all times, you must ration your energy use, always maintaining a sufficient supply for whatever maneuver you might execute. For example, don’t go into a high-G turn if you can accomplish the same task with a lower-G turn. Before expending energy, determine whether what you get in return (such as a shot opportunity) is worth the loss of energy.

Choosing Your Attack

Unarguably, the first few seconds of a fight are the most important and can often determine the outcome. Most dogfights last less than one minute, meaning that whoever gains the initial advantage usually wins. Every fight is different, and an aircraft designed for turn fighting may find itself better suited for an energy fight. How do you decide which to use?

First, estimate your turn performance versus your opponent's.
Maintaining your corner speed (the optimal balance between turn rate and airspeed) means nothing if the bandit can out-maneuver your best turn.

Second, estimate your energy status.
If you enter a fight 200 or 300 knots above your corner speed, don't waste all of that energy and decelerate to achieve your aircraft's corner speed. Instead, initiate an energy fight and make use of your power. A well-flown energy fight is difficult to beat, as proven in Vietnam by F-4 pilots flying against MiG-17 and MiG-21 opponents.

The Energy Fight

In an energy fight, you take advantage of your aircraft's superior speed and avoid unnecessary turning. Ideally, you want to start the fight in an advantageous position, such as directly behind the bandit in his 6 o'clock low blind spot. Most of the time, however, that's not an option. You must rely on your energy advantage and skills to overcome your adversary.

Initiating

When you choose the energy fight, you basically concede turn performance to the enemy and rely instead on speed. You must keep your airspeed extremely high, minimizing the distance between you and your enemy's aircraft as you make a series of head-on attacks. The idea is to strike, then outrun your opponent's weapon range (not too difficult if the bandit has only guns or heat-seeking missiles).

While the bandit busily executes a high-G turn to enter the fight, you (as the energy fighter) zoom away in a spiraling dive or climb. Eventually, you can execute a wide turn (to conserve airspeed) and make another offensive pass.

If you execute the initial turn correctly, you'll remain outside your enemy's weapon envelope (range at which his weapons are effective) for nearly the entire fight. You choose when and where to engage, always bringing the fight on your terms. Thanks to your speed surplus, you can enter and exit the fight almost at will.

The energy fight requires discipline, though. One speed-bleeding turn, and you immediately lose your energy advantage.

The Turning Fight

Your second choice in combat is to enter a maneuvering fight and rely on your turn performance to win the day. The idea behind a turning fight is to reduce the amount of room in which the enemy can make a turn. You accomplish this during the merge (head-on pass) by minimizing lateral separation, or the horizontal distance that separates your aircraft from your enemy's.

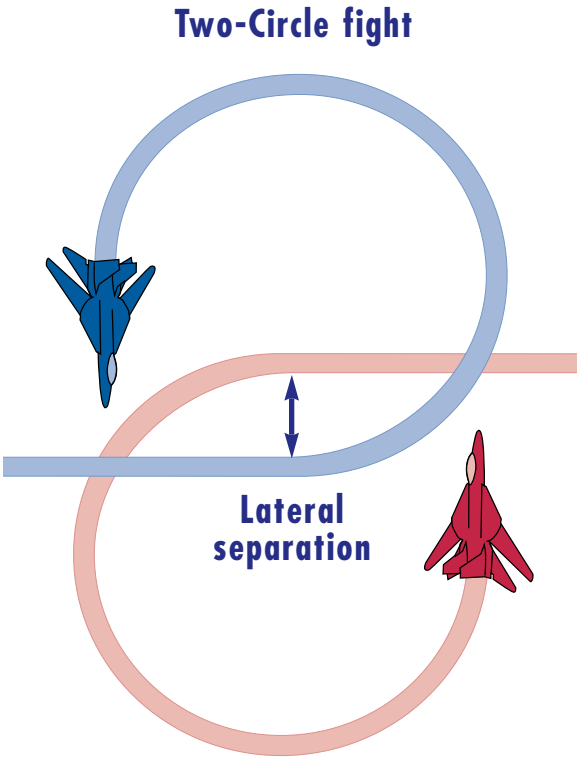
The merge generally leads to one of two types of turning fights:

- Choose a two-circle fight when you're flying a more maneuverable aircraft than your enemy.
- Choose a one-circle fight if you have all-aspect missiles (or if you believe the enemy doesn't have them).

Whichever you follow, you want to time the **initial turn** so as to deny the bandit any advantage and maximize your performance. Turning too soon pulls you across his nose; turning too late puts you out of postion. Optimally, you want to end the fight with the initial turn.

Two-Circle Fights

Two-circle fights, also called nose-to-tail fights, commence when you and your enemy meet head-on. After you pass each other (known as the **merge**), you both loop around in opposite directions, trying to get on each others' tail. The distance between your flight paths is turning room that both of you use. In other words, the turn radii of your aircraft overlap.



Turning Fight

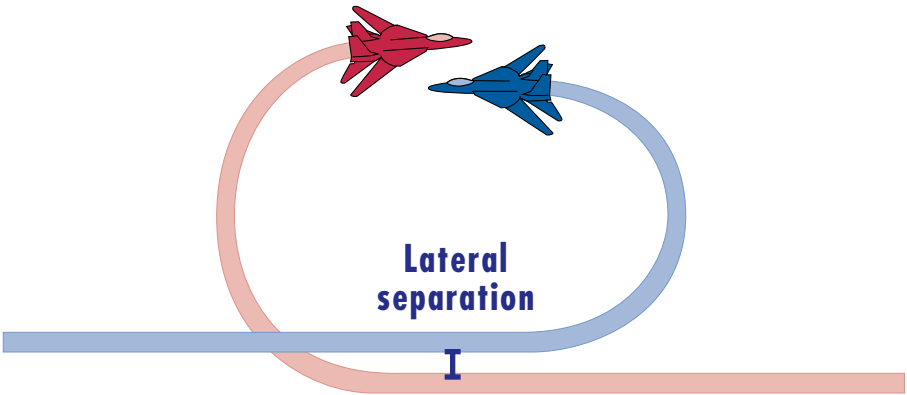
Two-circle fights rely more on turn rate than turn radius. You create only enough lateral separation at the merge point to allow for your full turn radius, and then rely on a superior turn rate to bring your nose back to bear on the threat. Two-circle fights keep your target in view at all times and tend to increase the lateral separation between the two aircraft.

In two-circle fights, always attempt to minimize lateral separation. If the enemy aircraft has substantially worse turn performance than you, don't give him any extra room to work with — keep lateral separation to the bare minimum you require for your turn.

Conversely, if the bandit has significantly better turn performance than your aircraft, deny him the chance to use it by closing in at maximum speed with as little lateral separation as possible.

One-Circle Fights

One-circle fights commence when both you and your opponent happen to loop in the same direction (instead of the opposite direction, as in two-circle fights). One of you sacrifices lateral separation, relying instead on turn radius to out-maneuver the enemy. In general, only use the one-circle fight when you have a significant turn radius advantage over the bandit.



Turning Fight

The one-circle fight tends to keep you and your target closer together than the two-circle fight. If you choose to turn away from your opponent, you'll momentarily lose sight of him as he crosses your tail. In fighters with poor rearward visibility, this loss of visual contact can be devastating. Since taking the one-circle approach surrenders the lateral separation to the bandit, you should minimize lateral separation during your next head-on approach.

AIR COMBAT MANEUVERS

In the world of combat, getting into position for a good shot is often called “achieving a firing solution.” It can happen in half a second, or it may take several minutes. The manner in which you attain this position differs from conflict to conflict, so it’s imperative that you develop a good reserve of combat maneuvers.

This section examines several:

Break Turn
Barrel Roll
Scissors
Spiral Dive
High Speed Yo-Yo
Rollaway
Low Speed Yo-Yo
Immelman
Split-S
Thrust Vectoring Turns
Herbst (Post Stall)
J-Turn
Hover
Engaging Ground Targets

Break Turn

- Use the break turn to evade enemy fire. Follow with a turn in the opposite direction.
- Initiate a break turn by banking (pull the joystick toward you and to one side).

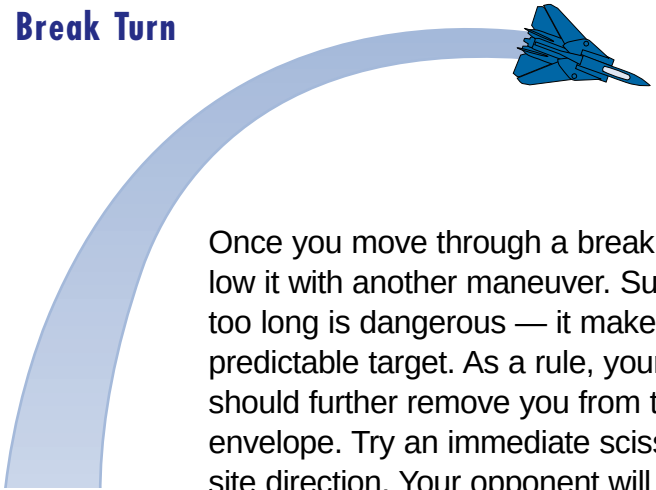
The break turn is the most basic combat maneuver, for it rapidly increases the angle-off-tail (angle between you and your enemy's flight path) when a bandit is preparing to shoot you.

It is a high-G maneuver that takes advantage of a maximum instantaneous turn rate and forces your attacker to take a high-aspect angle shot.

You can make a tight, instantaneous break turn (in which you lose speed, but gain a maximum AoT), or you can make a sustained break turn (in which you conserve speed, but forfeit several degrees of AoT). Making a hard break turn bleeds airspeed, which in turn, can cause your enemy to overshoot. Generally, the closer you think the enemy is to firing, the harder you should turn.

Combat Manuevers

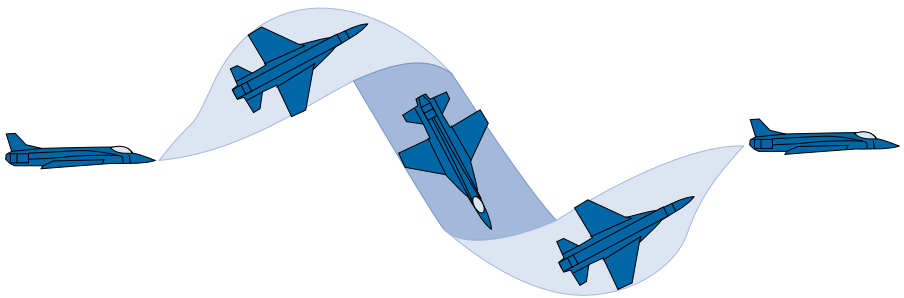
Break Turn



Once you move through a break turn, immediately follow it with another maneuver. Sustaining a break turn too long is dangerous — it makes you a wide-open, predictable target. As a rule, your next maneuver should further remove you from the bandit's weapon envelope. Try an immediate scissors turn in the opposite direction. Your opponent will be going too fast to lead your turn, and you may be able to maneuver into a more advantageous position.

Barrel Roll

- Offensively, use the barrel roll if you're overtaking an enemy too quickly.
- Defensively, use the barrel roll to force your attacker to overshoot and pass you.
- Initiate a barrel roll by rolling slightly and applying pitch. Keep the nose pitched to spiral around the axis of your flight path.



The barrel derives its name from the flight path the aircraft performs, circumscribing the shape of a barrel as the aircraft rolls around a central axis. It is an energy management maneuver possessing both offensive and defensive potential.

Offensive Barrel Rolls

If you find yourself traveling too fast, you may both overshoot your foe and fly directly into his gun envelope. This happens because your closure rate is too high, and you overtake your target. The barrel roll provides an effective solution by wasting speed.

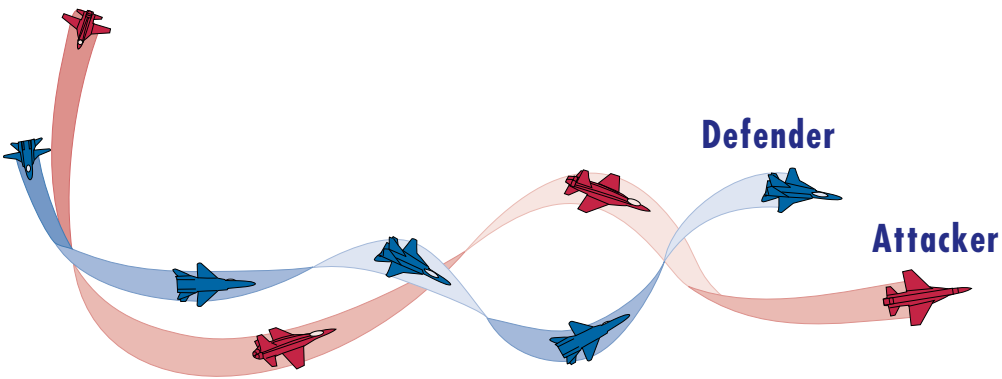
If you can't bleed enough speed with a barrel roll, pull back harder on the stick and execute a roll opposite the direction of your current turn. The increase in pitch reduces airspeed, and the rollout turns you away from the target and keeps you from overshooting. As you complete the roll, you'll be back on your original course, but at a slower airspeed.

Defensive Barrel Rolls

Defensively, the barrel roll can be used to force a quickly approaching attacker to overshoot. It can also maintain enough angle-off-tail to put you out of his lethal cone of fire. Defensive barrel rolls must be carefully timed, however. Initiate the roll too soon, and the bandit will follow you through it. Start too late, and the bandit will have several shot opportunities before you begin the turn. Perfect timing requires that you both surprise the enemy and deny him sufficient reaction time.

Scissors

- Scissoring occurs when an attacker overshoots, and the target reacts by making a reverse turn too early (before the attacker crosses his weapon envelope).
- Never purposefully enter a scissors fight — it bleeds off speed and altitude.
- To break a stalemate, roll 180° during one of the passes.



Scissoring refers to a series of reversing break turns in which two aircraft turn back and forth toward each other, each trying to force the other out in front. This usually begins when the attacker starts a late high yo-yo or barrel-roll and realizes he's going to overshoot his target. The defender, predicting the overshoot, reverses his turn. Although this is the right solution, he turns toward the attacker too soon, resulting in a fairly neutral pass and initiating scissors.

Scissor moves reduce the **forward velocity vector**, or the fighter's speed along the axis of its flight path. The aircraft turns across the flight path at varying speeds, reducing its average forward speed with every turn.

If you're an attacker, the only way you can get into a scissors duel is by starting a maneuver too late and overshooting. If you're on the defensive, you correctly predicted his overshoot, but reacted too quickly and compounded the attacker's error.

Once in a scissors, there's nothing to do but keep turning into the bandit. This bleeds off both speed and kinetic energy. The "winner" of a scissors match is usually whoever can conserve enough energy to force his opponent out front and bring the aircraft's nose around for a shot. More often than not, scissoring ends when one aircraft loses so much speed that it stalls out and plummets. If the other aircraft has any energy left, it can roll, dive and take a shot before the falling aircraft can recover.

Vertical Rolling Scissors

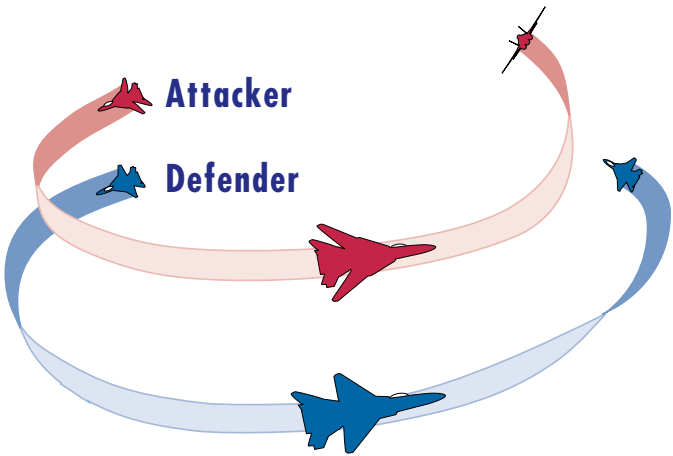
Alternatively, two pilots about to engage may begin a series of barrel rolls instead of break turns. The resulting vertical rolling scissors is a speed-reducing maneuver as well, draining kinetic energy during the series of climbs, reverse turns and overshoots. Each time the aircraft cross paths, they risk both collision and gunfire. Allowing too much lateral separation (passing too far apart) affords your opponent a shot opportunity, while passing too close may result in a crash.

In a guns-only environment, you may be able to escape scissors by executing a split-S immediately after crossing your opponent's tail. Then, by rapidly increasing your speed, you can outrun his guns.

Don't try this if your enemy has IR missiles — the split-S invites a heat seeker up your exhaust pipe. If you can't get outside the bandit's weapon range, then you have to win the scissors fight. If you can't win the fight by out-turning the bandit, you're as good as dead.

Spiral Dive

- Use spiral dives as a last resort, and only if your aircraft has the superior turn radius.
- Fall into a steep dive, then make a hard-G turn. Throttle back midway through the turn and invert. Pull the nose up hard to maneuver onto the enemy's tail.



If you use every maneuver imaginable and still can't shake an opponent despite a better turn radius, try a spiral dive. You carry out this maneuver by leading your opponent into a steep dive as soon as he moves to one side of your tail and falls into an overshoot position. He won't have a direct line of fire at you at that instant, but you can't dive for long without him re-achieving a firing solution.

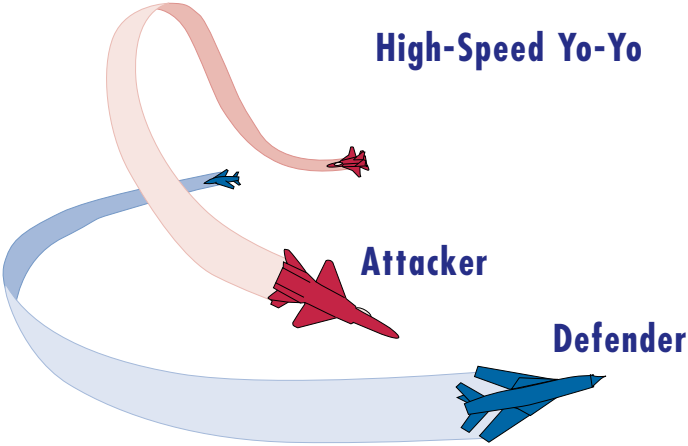
End the dive quickly by taking advantage of your aircraft's superior turn radius and pulling hard pitch (but not so hard that you sacrifice maneuverability). As you come out of the turn, reduce throttle, invert with a 180° roll, and pull up sharply again. Your attacker probably won't notice that you've slowed down and will be forced out in front of you.

High-Speed Yo-Yo

- Use the high-speed yo-yo to reduce AoT and bring a target into your firing cone.
- This maneuver increases the distance between you and the target.
- Perform by relaxing a turn, then pulling up into a sharp climb. Invert, then apply pitch to slide back down onto the threat's tail at a smaller AoT.
- Cycle between the F1 and F7 camera views to keep track of your enemy during a yo-yo.

The high-speed yo-yo is a basic component of offensive air combat and reduces AoT at the cost of increasing the distance between you and your target. The yo-yo begins during a turning fight when you have assumed an aggressive position behind the bandit, but are stuck in lag pursuit and unable to bring your nose to bear. In this case, you can use gravity to your advantage.

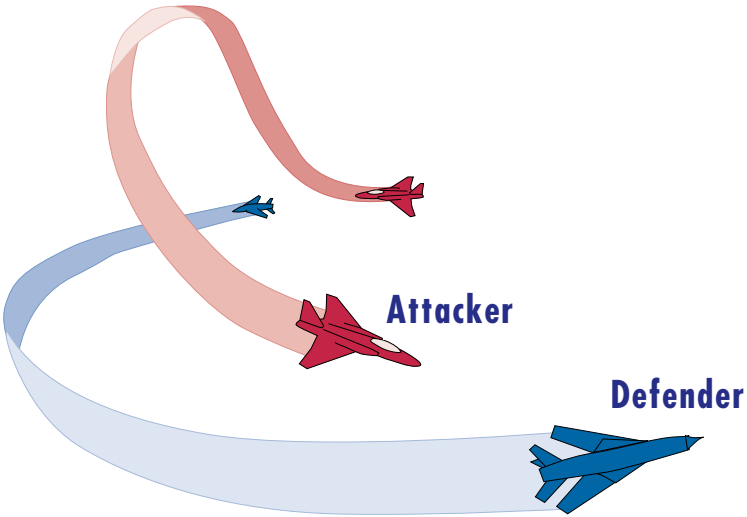
Roll out slightly when your enemy initiates a break turn (maintaining lag pursuit), then pull the nose up. At the apex of the climb, invert and roll back down onto your target's six o'clock position. You'll be further away from him, but in a better firing position.



Don't make the yo-yo too extreme. Once you commit to a large one, you'll be unable to respond to any sudden changes the bandit may make. Patiently work small yo-yos by bringing the nose just above the horizon and chipping away at your AoT problem. This will move you into the target's cone of vulnerability without pulling high-G loads.

Rollaway

A variation of the high-speed yo-yo, the rollaway involves rolling **away** from the defender's turn as you invert. By diving and reversing direction with a 180° turn, you can drop in behind the defender's tail as he ends his break turn.



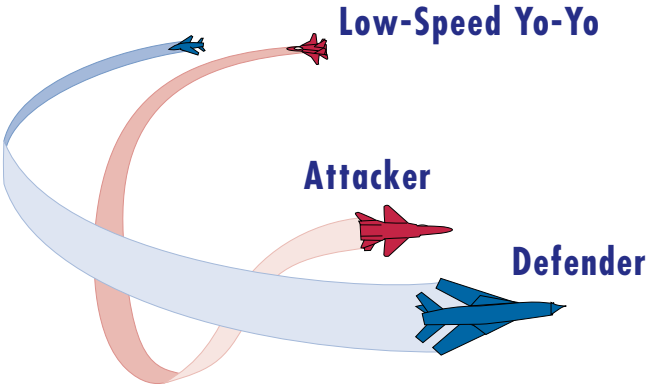
Low-Speed Yo-Yo

- Use the low-speed yo-yo when you have a good firing angle but need to bring the target in range.
- This maneuver decreases range at the cost of increasing AoT.
- Execute by diving inside of a target's turn and gaining airspeed. Then, pitch up and slide onto his tail once more.
- Cycle between the F7 and F8 camera views to keep track of your position as compared to your enemy.

The low yo-yo is the logical opposite of the high yo-yo, and achieves the exact opposite effect. While the purpose of the high yo-yo is to decrease AoT (at the cost of increasing range), the low yo-yo is intended to decrease range (at the cost of increasing AoT).

Use the low-speed yo-yo when you have a good shot opportunity, but you're still outside your weapon's maximum range. This often occurs in chases where the bandit has superior speed and is trying

to run home in level flight. You're chasing him, but he remains just outside your weapon's effective envelope.



To get closer to your target, lower your nose below the horizon and dive. This increases speed, but almost always forces you into lag pursuit and increases AoT. A low yo-yo, therefore, almost always requires an immediate high yo-yo to correct the angle problem generated by the increase in speed.

Be careful not to dive too steeply during this maneuver. If you do, you may be unable to bring your nose to bear on the target — it will be too far above you.

Countering a Low-Speed Yo-Yo

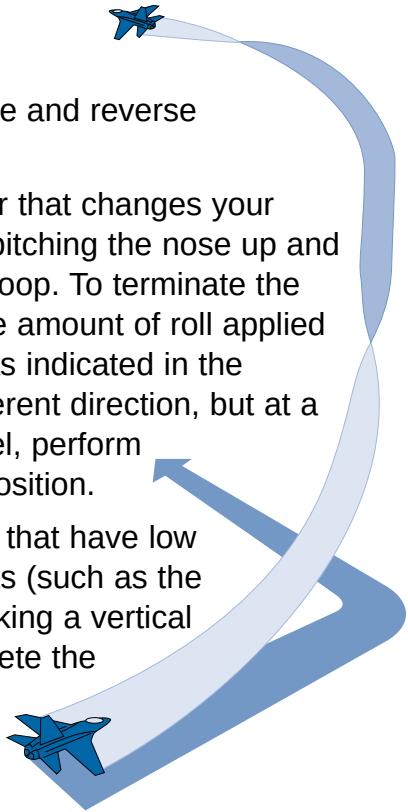
If you anticipate your attacker's low-speed yo-yo, try making a half-roll toward the end of your break turn, then roll out of the turn instead of carrying through with the original break turn. By rolling in the opposite direction, you face your attacker's nose as he emerges from his dive. This brings the fight back to a merge pass.

Immelman

- Use this maneuver to increase altitude and reverse direction.

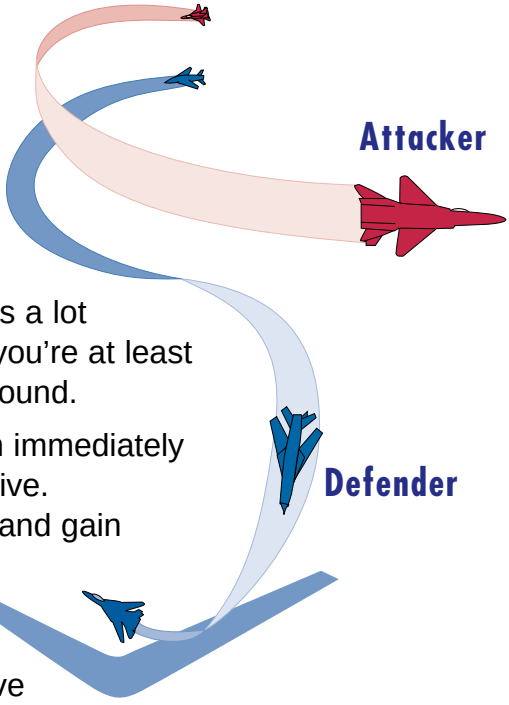
The Immelman is a high-thrust maneuver that changes your bearing and increases your altitude. By pitching the nose up and climbing, you can execute one-half of a loop. To terminate the maneuver, invert and execute a roll. (The amount of roll applied determines your new direction of flight, as indicated in the diagram.) This leaves you flying in a different direction, but at a higher altitude. Once your wings are level, perform a half-roll again to reassume a vertical position.

The Immelman is most useful for aircraft that have low thrust capabilities. Modern high-thrust jets (such as the F-22) can broaden this maneuver by making a vertical climb, then using an aileron roll to complete the half loop.



Split-S

- Use the Split-S to increase airspeed or bleed off altitude.



A Split-S maneuver is a diving half loop that is useful for disengaging a threat. It is a high-altitude maneuver that requires a lot of vertical airspace, so make sure you're at least several thousand feet above the ground.

During a turn, invert by rolling, then immediately pull back on the stick to go into a dive. Your aircraft will rapidly accelerate and gain airspeed. Pull back on the stick until the aircraft levels out, then ease into level flight. You'll be un-inverted, and you'll have a higher airspeed and lower altitude.

The split-S has the advantage of providing a quick burst of speed. Additionally, rolling while inverted adds the aircraft's lift vector to gravity, thus increasing the force of acceleration and adding speed. On the down side, however, this increased speed increases the vertical turning radius, making it hard to pull the nose up into level flight. Starting a split-S from low altitude, or maintaining too much speed during the dive, can prevent the aircraft from pulling out of the dive.

The split-S makes a great escape maneuver in a guns-only environment because the rapid speed gain moves you out of gun range. It's usually ineffective against missiles, though, since they have significantly longer ranges.

Thrust-Vectoring Turns

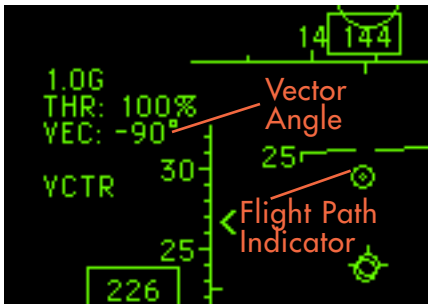
- (F-22, X-31, X-32 only) Use up-down thrust-vectoring to make quick, small-radius turns, climbs and dives.
- Use left-right thrust-vectoring (X-31 only) to make a sharp yaw without banking. This is useful in lining up shots.
- The F7 camera view is useful during a thrust-vectoring maneuver. It helps you compare your position to your enemy's.

Thrust-vectoring engines allow you to decrease your turn radius and make sharper turns than your opponent. Vanes in the exhaust port can be angled, redirecting thrust and decreasing the turn radius by as much as 50%.

To make this type of turn, go into it just above your aircraft's corner speed. Then, apply vectoring in the direction of the turn. The extra drag created when you start to vector will slow your aircraft down to below its corner speed and decrease the amount of G-load.

For example, if you're making a break turn to the left in the X-31, press Ctrl ← to vector the thrust nozzles left. (In an F-22 or X-32, you can also press Ctrl ↑ or ↓ to vector the nozzles up or down.)

In the X-32, watch the VEC: reading in the upper left-hand corner of the HUD — this indicates the current angle of the nozzles. Keep Ctrl ← pressed until the reading falls between 40° and 60°. To re-center the vanes, press 0 (zero).



In other aircraft, the degree of vectoring doesn't display, but small circle flight path indicator moves away from the center reticle indicating your current flight path, relative to the position of your nose.

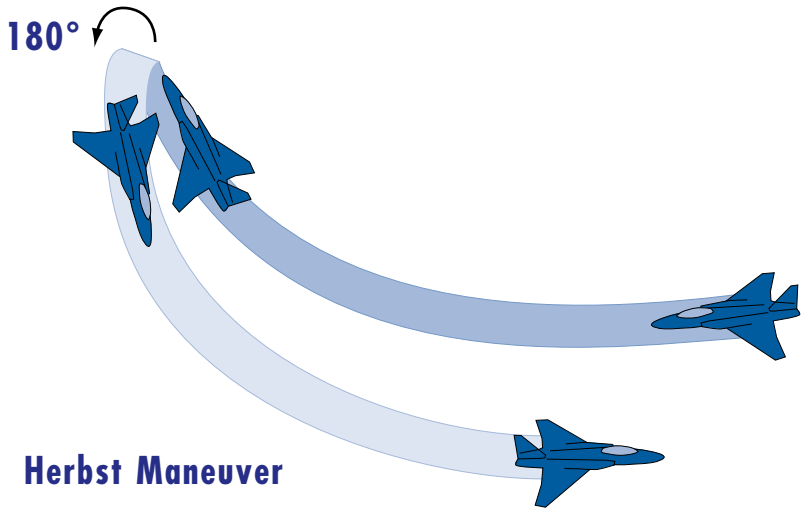
You can apply vectoring during a head-on pass. As the merge begins, reduce throttle and pitch up the nose 5° or 10°. Make a break turn toward the enemy once he has committed to one direction. As your aircraft's nose slides around, you can squeeze off a few rounds.

Herbst (Post-Stall)

- Use this maneuver to reverse heading if a bandit is on your tail.
- Use this maneuver to fire on enemies above you.
- Execute by going into a vertical climb and applying upward thrust vectoring. As the aircraft reaches its stall speed, vector the nose down and bank.

The Herbst Angle-of-Attack (AoA) maneuver was perfected in the X-31, one of the first advanced tactical fighters to incorporate thrust-vectoring. The idea is to maintain control during a tight-radius, post-stall turn by applying vectoring at the apex of the stall. The tactic itself is named after Wolfgang Herbst, a German pilot who first used a variation of this move to attack enemies during vertical stalls. Today, the most common application of the Herbst AoA maneuver is to reverse heading. If an enemy is on your tail, you can vector into a 180° turn and transform the pursuit into a head-to-head fight.

To perform a Herbst in the X-31, increase airspeed and go into a pure vertical climb with an enemy above and slightly behind you. As your aircraft rapidly decelerates, apply upward vectoring (press Ctrl ↓). You can attain as high as a 70° angle of attack, greatly increasing your aspect angle and allowing you to fire on targets above you.



Use thrust-vectoring to maintain control of the aircraft's attitude at this point. As you begin to enter a vertical stall, bank, pitch the nose down and apply vectoring in the opposite direction (press Ctrl ↑) to whip the nose of the aircraft down. Your aircraft will immediately reverse direction by 180° and undergo a tight turn (80% tighter than normal maximum-rate turns). At the end of this maneuver, you've lost some altitude, but you've also made a quick 180° reversal.

This maneuver has been tested (and has been quite successful) against the F-16 and F/A-18. The X-31 is the only aircraft to date able to perform the Herbst Maneuver.

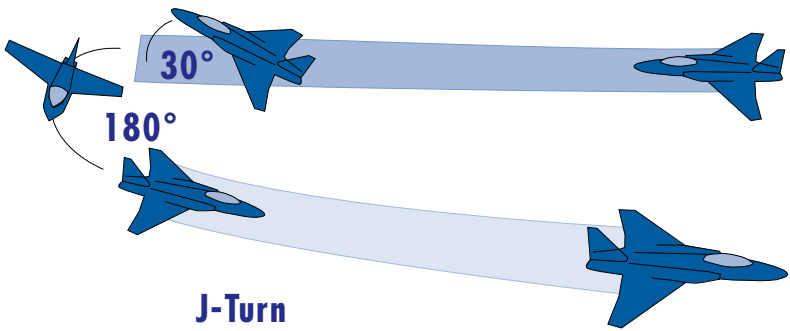
J-Turn

- Use this maneuver to quickly change headings when a bandit's on your six.
- This is similar to the Herbst maneuver, only you don't climb vertically.
- Perform by pitching the nose 30° upward and applying speed brakes. Next, pull the stick back (70° AoA) and vector sideways (Ctrl ←, →). Once you turn 180°, apply throttle and level the wings.

The J-turn is another post-stall maneuver that calls on the X-31's thrust vectoring capabilities. It is similar to the Herbst maneuver. First, the stall occurs because air flow over the wings is reduced, not because you're climbing. Second, horizontal thrust vectoring is used instead of vertical thrust vectoring (pitch). Since the X-31 is the only production aircraft that vectors in the pitch **and** yaw axes (in other words, all four directions), it has the advantage of being the only fighter that can perform the J-turn.

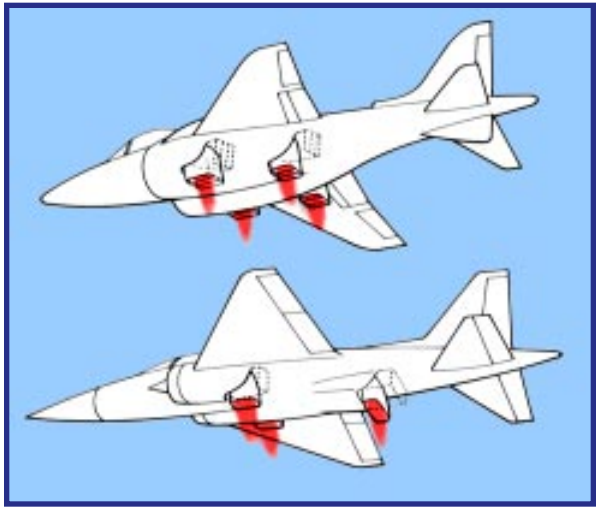
For this move, fly level at around 300 knots. Pitch the nose up 30° and apply speed brakes (B). As you lose airspeed and the wings begin to stall, perform three tasks: pull back on the stick all the way, bank either left or right, and vector in the same direction as the bank to apply yaw (press Ctrl ← or Ctrl →). The yaw thrust effectively “snaps” your aircraft’s nose in the direction of the roll. Finally, apply full thrust and level the wings.

The result of the J-turn is that you “slide” through a quick turn and change your heading by 180° without gaining much altitude.



Hover

- You can only hover in a lightly loaded X-32, or a Yak-141
- To perform, slow down and vector the nozzles -90° (press Shift X).
- To resume forward flight, press 0 and apply 100% throttle (5).



Hovering is not a term generally associated with aircraft. With the advent of the STOVL fighter, however, hovering is making its debut in air combat. The STOVL features variable-thrust engines that use extreme applications of thrust-vectoring to maintain a semi-hover position. This is primarily useful during takeoffs and vertical landings.

As long as you haven't burdened an X-32 or a Yak-141 with a heavy weapons load, you can use their hovering capabilities to attack either air or ground targets. This is especially effective if you're using rockets against air threats, or if you're strafing ground targets with gunfire or rockets.

Engaging Ground Targets

Since ground targets aren't very maneuverable, few actual "combat tactics" exist. The key to surviving ground-attack missions boils down to surprising and striking the enemy while avoiding AA and SAM fire.

Surprise

Enemy Defenses

AAA Weaknesses

To learn how to use air-to-ground weapons, see Using Weapons.

Surprise

Surprising the enemy gives you an advantage on missions that involve ground targets. For starters, take a stealthy aircraft (such as the F-117 or B-2). They're equipped with RAM (radar-absorbent material) that reduces the radar signature. This allows you to move in range undetected.

In an attack fighter, try flying in low (500ft above the ground or less), under the enemy's radar. Ground-based radar systems can detect your aircraft at high altitudes, but not close to the ground. If you approach undetected from an unexpected direction, the air-defenses may be unprepared. It takes time for them to turn and engage, giving you an opportunity to deliver ordnance and escape.

Radar waves are like light; they cannot penetrate solid objects like hills and buildings. Try flying at low altitudes between hills or behind clusters of buildings to hide from enemy radar. As an added measure, leave your radar off as you approach an enemy position. Use it only in short bursts to identify target coordinates — this reduces your chances of being detected by their RWR.

Enemy Defenses

Try to stay outside of enemy defense envelopes. If the target is heavily defended with radar-guided SAMs, approach at low altitude; such SAMs often have trouble engaging low-altitude targets. If the primary defense is automatic anti-aircraft artillery (AAA), stay above 5,000 feet; AAA cannot reach that high.

Similarly, try using long-range weapons. If the enemy defenses have a maximum range of 20nm, attack with a 30nm-ranged weapon. This keeps you safely outside of the enemy's defenses. Obviously, standoff weapons won't always be available or suitable for a given mission, but always consider using them.

AAA Weaknesses

AAA is deadly against low-altitude targets but does have limitations. While modern AAA uses radar to calculate lead requirements, older AAA systems must eyeball you in their sights and therefore, must lead you. If you approach them from any direction other than head on, you're almost guaranteed that they'll miss. Furthermore, the faster you fly and the more you jink, the harder it is for AAA to calculate lead.

WINGMAN COMMUNICATION

Aircraft work in groups called **wings** for mutual support and protection. Your wingman is there to protect you, and you're there to protect him. Although you don't have total control over him, you can direct him to certain targets or ask him for help.

Wingman execute commands based on formation control. During flight, you can toggle through controls using Alt C.

Loose control. Wingman will break out of formation when he detects an enemy or an incoming missile. Once he drops out of formation and finishes his first attack, he'll continue to search out and engage enemies until he gets new orders.

Medium control. Wingman remains in formation unless you specifically direct him to attack a target. (He will, however, break in order to avoid an incoming missile and then return.)

Tight control. Wingman remains in formation, no matter what.

Nineteen wingman commands are available during flight:

Keystroke	Command	Wingman Action
Alt 1	Fly straight and level	Rolls out and flies straight and level
Alt 2	Break left	Breaks left
Alt 3	Break right	Breaks right
Alt 4	Break low	Breaks low
Alt 5	Break high	Breaks high
Alt 6	Approach left	Approaches air target from the left
Alt 7	Approach right	Approaches air target from the right
Alt 8	Approach low	Approaches air target from below
Alt 9	Approach high	Approaches air target from above
Alt B	Bug out	Returns to base (wingman will no longer respond to commands)
Alt C	Cycle formation control	Assumes LOOSE, MEDIUM or TIGHT control
Alt T	Set formation type	Moves into selected formation type

Wingman commands (cont.):

Keystroke	Command	Wingman Action
Alt H	Set formation horizontal spacing	Assumes whatever horizontal separation you specify (toggles between far and near separation)
Alt V	Set formation vertical stacking	Assumes whatever vertical stacking you specify (toggles between HIGH, LOW and LEVEL stacking)
Alt E	Engage my target	Breaks out of formation and engages your current target
Alt W	Engage target class	Engages all targets of the same type as your current target
Alt R	Engage from formation	Engages your target, but remains in formation
Alt P	Protect me	Attacks bandits threatening you
Alt D	Disengage	Breaks off his attack and reforms on your wing

EFFECTS OF DAMAGE

With luck your aircraft will never see damage. In the event that you take some hits, though, it's good to know what's critical and what's not.

Each aircraft has multiple subsystems, such as propulsion and control surfaces, and each subsystem has multiple items, such as fuel flow, elevators, etc.

D Display component damage as a percentage.

Damaged control surfaces make the aircraft difficult to fly or possibly even uncontrollable. The autopilot cannot be used with damaged control surfaces. Damaged elevators reduce pitch control, damaged ailerons reduce roll control, and a damaged rudder usually causes the aircraft to persistently yaw one way or the other. Some types of damage cause the aircraft to porpoise or jolt in random directions. If the hit damages the airframe, pulling high G loads will likely destroy the aircraft.

Several types of propulsion damage ultimately lead to a catastrophic failure. Damage to the oil systems causes engine overheating unless the throttle is kept low. Even then, the aircraft may eventually overheat. Compressor damage risks catastrophic engine failure when the engine is above 25% throttle. Damaged tail cones limit afterburner use.

Generally, when the engine takes damage, reduce power. Engine explosion may be inevitable based on the extent of damage, but reducing power will always delay it. If intuition tells you the aircraft is about to explode, bail out.

You, the pilot, may also take damage from explosions, shrapnel or fire. Each wound requires medical attention or you will die. You have up to 15 minutes or so to return to base after the first wound, but subsequent wounds greatly reduce that time.