GROUND SCHOOL

TOC

Piloting an aircraft requires an understanding of aerodynamics and how they govern the control of an aircraft.

The first half of this chapter explains the theories behind different aspects of flight:

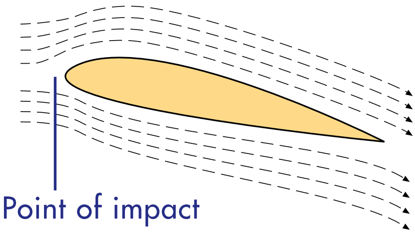
The second consists of practical flight training and instruction:

FLIGHT PHYSICS

Flight is the result of several forces acting on an aircraft. The first is the aircraft's **weight**, or the gravitational force pulling it toward the ground. A second is **thrust**, the force produced by the engines, which propels the plane through the air. This thrust causes air to move over the wings, which in turn creates a **lift** force that counteracts gravity and gets the aircraft off the ground.

Two factors — Bernouilli's Priniciple and angle of attack — explain how air moving over an airplane's wings creates lift.

Bernoulli's Principle



Bernoulli's Principle states that as the speed of a fluid increases, its pressure decreases. Air behaves much like a fluid as it flows around a wing – it separates at the point of impact (the point on the airfoil that first meets the air) and flows both over and under the exterior surfaces.

The top surface of the wing is more curved and thus longer than the bottom surface. However, as the aircraft moves through the air, this air must move both over and under the wing in the same amount of time. The air flowing over the top moves a greater distance and therefore must move faster than the air traveling over the bottom. According to Bernoulli's principle, this difference in speed creates more pressure below the wing and less pressure above it. The high pressure beneath the airplane creates lift.

Consequences of Bernoulli's Principle

Two consequences of Bernoulli's principle directly affect an air-craft's perforance. You can use this to your advantage by bearing in mind the following:

- **Speed is important.**

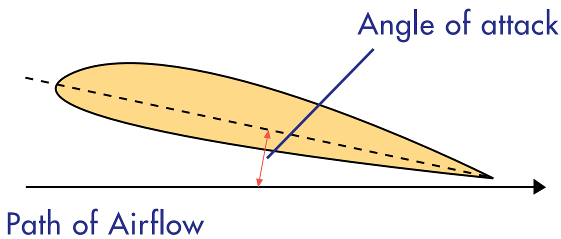
At faster speeds, the pressure differential between the air above and below the wings is greater and more lift is available.

- **Higher altitude means less lift.**

At high altitudes, air is less dense. Thus, the pressure differential between the air above and below the wings is less, making less lift available.

Angle of Attack

The shape of the wing creates lift in other ways. The wings of most airplanes are angled slightly upward, with the leading (front) edge higher than the trailing (back) edge. The angle at which the wing hits the air is called the **angle of attack** (AoA).

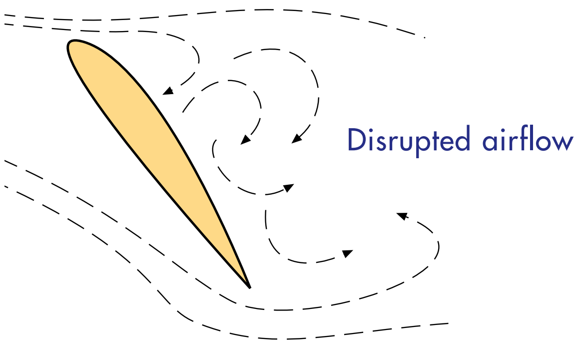


To understand how AoA increases lift, imagine holding your hand outside a car window while the car is moving. If your palm is facing the ground, the edge of your hand cuts through the air with relatively little resistance. If you hold your hand perpendicular to the ground, the force of the air rushing against your palm pushes it back. But if you angle your hand so that the front edge is tilted slightly upward, the force of the air will push your hand slightly up as well as back.

If an aircraft is flying straight and level, its wings meet the airflow at a low AoA. As the airplane pitches up, AoA increases and thus lift increases — up to a point.

Dynamics of a Stall

Lift does not increase indefinitely with AoA. As you saw with your hand, there is a point at which the angle of your hand becomes too steep, and the force of the air pushing backward is greater than the force of the air pushing up. Drag against the aircraft's forward momentum slows it down, decreasing the amount of air flowing over the wings and further decreasing lift. The pilot can increase AoA to the point where the flow of air is disrupted. When this happens, lift ends and gravitational force takes over, and the aircraft can literally fall out of the sky. This is known as a **stall**.



High Angle-of-Attack Maneuvers

Several of the *ATF* aircraft are designed to be maneuverable at high angles of attack:

The **F/A-18D Hornet** is well-known for flying at 30-40° AoA.

The **X-29's** forward-swept wings allow great agility and maneu-verability at 45° and limited control at 60°.

The **X-31 EFM** (Enhanced Fighter Maneuverability) has demon-strated controllable flight at up to 70° AoA and an incredible post-stall, minimum-radius 180° turn known as the Herbst Maneuver.

G-FORCES

Gravity is an acceleration. When we speak of **gravitational force**, we actually mean **weight** — an object's mass times gravity. The weight of an airplane and the weight of its pilot are vastly different because their masses are different, yet their gravitational acceleration toward the earth is the same. G-forces provide a way to discuss relative forces without involving differences in mass.

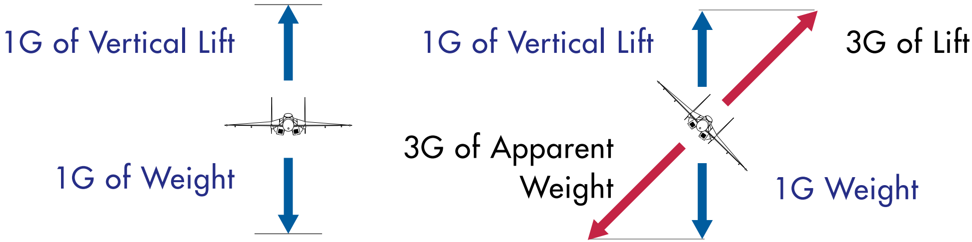
For any given object, 1G is equivalent to the gravitational force on **that** object at sea level.

An airplane in level flight experiences 1G of force (i.e., 1 times its normal weight). The pilot in that aircraft also feels 1G of force (i.e., 1 times **his** normal weight). If the aircraft and pilot were to accelerate at twice the rate of gravity, both would experience 2G's of force — force twice as strong as the normal gravitational force. The pilot would feel twice as heavy as he does normally.

In order for an aircraft to fly, its wings must generate more than 1G of lift to overcome its weight (the 1G of gravitational force exerted on it).

Apparent Weight

In level flight, the lift and weight forces push perpendicularly to the wings — roughly straight up and down. When the aircraft rolls, the lift force continues to push perpendicular to the wings, so the direction of the lift force is no longer vertical. However, gravity is still accelerating the aircraft downward. In order for the aircraft to maintain altitude, the vertical component of the lift force must equal or exceed the weight of the aircraft. As a result, more lift must be generated to maintain sufficient vertical force to offset gravity.



In the diagram, 3G of actual lift must be generated to provide 1G of vertical lift. The pilot achieves this by pulling back on the flight stick, sending the aircraft into a tighter, and thus more accelerated turn. The pilot feels the increased acceleration as apparent weight — in other words, the pilot actually feels 3 times heavier than normal, pushed against the back of his seat. This is called **apparent weight.** The same forces are at work when you're pinned to your seat in the tight turn of a roller-coaster.

As the aircraft banks even further, acceleration and apparent weight increase proportionally. A pilot in a 90° banking turn may experience 8 or 9G of force.

Instantaneous vs. Sustained G-Force

Lift increases or decreases according to airspeed, altitude and the severity of the aircraft's maneuvers. These three factors interact dynamically — that is to say, they influence each other at all times. This is readily evident when considering two kinds of G-forces: **instantaneous** and **sustained**.

When a pilot pulls back on the stick in order to turn, more of the airplane's surface area meets air resistance. Drag increases, which in turn slows the airplane down. The slower airspeed reduces the amount of lift generated. In order to maintain the turn, more thrust is needed to overcome the greater drag.

For example, if an airplane flying 400 knots at 24,000ft banks into a 5G turn, this initial 5G load is called **instantaneous G**.

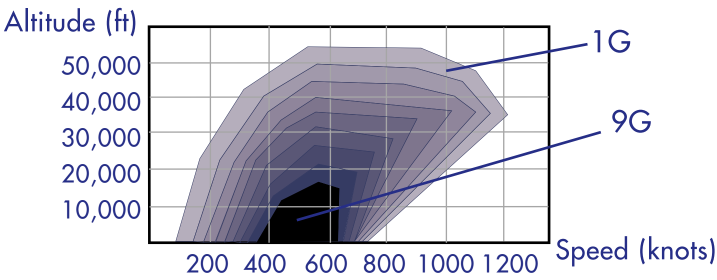
As the aircraft banks, increased drag exceeds available thrust, slowing the aircraft down to 350 knots. With a lower airspeed, the airplane falls into its 4G envelope. This lower G-load in turn decreases drag slightly, but continues to exceed thrust, and the aircraft slows to 325 knots. At 325 knots, the aircraft can only pull 3G.

At 3G, drag no longer exceeds thrust, and the aircraft maintains 325 knots at 3G. At this point, the airplane has reached equilibrium — it can maintain this speed and G-load. This equilibrium point is called **sustained G**.

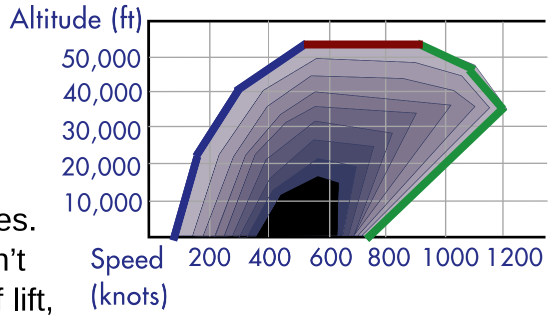
THE FLIGHT ENVELOPE

Lift is a function of airspeed, altitude and the aircraft's flight attitude. All of these factors work together to enable flight, and all three must be considered together to determine how an airplane will maneuver. These factors are graphically described by an aircraft's flight envelope.

Below is the flight envelope for a fictitious fighter. The fighter's altitude is on the vertical axis; its speed is on the horizontal axis. Plotted on the graph are curves representing G-load envelopes.



The **outside curve** of the flight envelope defines the aircraft's absolute flight parameters:



The **left edge** plots the airplane's minimum speed at various altitudes. Beyond this edge, the airplane isn't going fast enough to create 1G of lift, and it will stall.

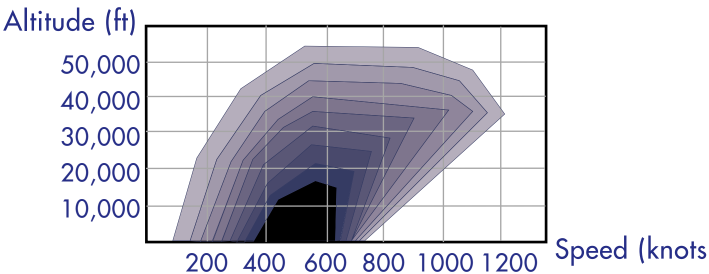
The **top edge** defines the aircraft's maximum altitude. Above this altitude, the air is too thin (and the airplane's wing too small) to create 1G of lift.

The **right edge** defines the airplane's maximum speed at various altitudes. Note that the airplane depicted in the chart can fly fastest at 36,600ft. Above this altitude, the air is too thin for the airplane's engines to create more thrust. Below it, the air is much thicker, and the airplane's structure limits its speed. If the pilot takes the airplane beyond its structural limit, air resistance weakens the air-frame and the wings will eventually tear off.

The **inner curves** plot the maximum G's you can pull at various speeds and altitudes. You can use this information in two ways:

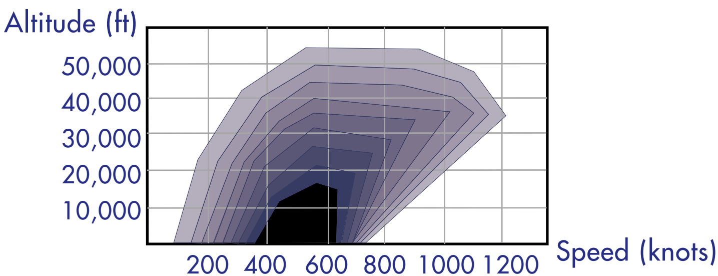
1. **You can find out how many G's you can pull in your current situation.**

Say you are flying the aircraft described in the graph below 700 knots at 40,000ft. The flight envelope tells you that you could potentially pull a maximum of 3G's — a very low banking turn. If the airplane were to climb to 45,000ft, its maximum G-load would decrease to 2G. At 49,000ft, the airplane would scarcely be able to do more than fly level.



2. **You can figure out what altitude and speed changes to make in order to pull more G's.**

For example, if you're near the upper left of your aircraft's envelope (at high altitude but medium speed), losing altitude will put you in a better G-load envelope. If you are over at the far right of the graph, you need to bleed off speed.



During combat, the Flight Envelope Window can give you an idea of the number of G's you can pull.

TURN PERFORMANCE

The number of G's you can pull is only a general indication of how tightly you can turn. G's represent the physics of your overall turn performance; however, your aircraft's **turn rate**, **turn radius**, **corner speed** and **weapons load** are also factors.

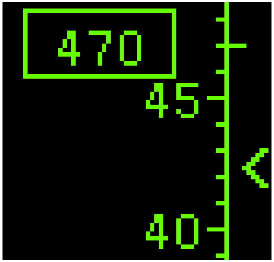
Turn Rate and Turn Radius

Turn performance is measured in terms of turn rate and turn radius. **Turn rate** the is number of degrees per second a particular aircraft can turn. **Turn radius** is the distance required to complete the turn. A high turn rate and a low turn radius yield good turn performance.

Corner Speed

Turn rate and turn radius depend on two variables: airspeed and lift. Both turn rate and radius improve as airspeed increases, but only to the point where maximum lift (the highest amount of lift that can be generated by an aircraft's wings at a given altitude) is achieved. Once an aircraft achieves maximum lift, airspeed has the reverse effect — it reduces turn rate and increases turn radius.

The point where maximum lift occurs with the least amount of air-speed is known as the **corner speed.** Corner speed is the velocity at a given altitude at which the best turn performance is achieved — that is, the highest possible turn rate with the lowest possible turn radius.



Corner speed at the current altitude is always marked on the airspeed ribbon by the corner velocity indicator.

Using Corner Speed To Your Advantage

Flying above or below corner speed reduces your aircraft's turn performance. If you're involved in a turning fight with an enemy fighter, you want to stick to the corner speed. If the corner speed is above your current airspeed, you usually want to increase airspeed by adding power (igniting afterburners) or diving. If the corner speed is below your current airspeed, you want to decrease airspeed by climbing.

Keep in mind that your corner speed varies by altitude. Turning at corner speed only allows you to pull the maximum-Gs for your current altitude. If you are at an altitude outside the 7G envelope on your Flight Envelope Window, then you won't be able to pull 7G's, even at your corner speed. If you want maximum turn performance against an enemy, you need to be at an altitude that gives you your maximum G.

Effects of Weapons Loads

The Flight Envelope Window depicts the performance of your airplane when it's "clean" (not loaded down by ordnance). Since weapons increase weight and drag, airplane performance suffers when carrying weapons. As a general rule of thumb, you can assume that G-loading suffers in proportion to the extra weight carried by your airplane. If 50% of your total weight is ordnance, you can expect a 50% reduction in the number of G's you can pull. In a bad situation you may have to reduce your weapons load to lighten your airplane. You can press Shift K to jettison all air-to-ground ordnance. You may be unable to complete your mission, but at least you'll come home alive.

Fuel weight affects performance in the same manner. As your airplane consumes fuel during the mission, it becomes progressively lighter; however, you may be carrying external fuel tanks to increase your mission range. If you find yourself in a turning fight that isn't going right, you can jettison your excess fuel by pressing Shift J.

MANEUVERING THE AIRCRAFT

Lift is generated perpendicular to the wing. Movable control surfaces — ailerons, rudders and elevators — alter lift to rotate the aircraft around its center of gravity.

Flight controls include:

- Flight Stick
- Rudder Pedals
- Throttle
- Vectored Thrust

Aircraft maneuver in three dimensions:

- Pitch
- Roll
- Yaw

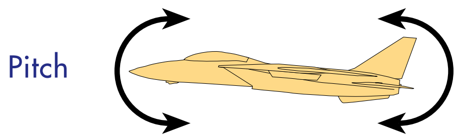
(These dimensions are always referenced from the pilot's point of view, regardless of the aircraft's orientation or flight attitude.)

Ground School

Pitch

Pitch is the movement of an aircraft's nose up and down. A pilot uses the flight stick to control the aircraft's flaps (and in some cases, small variable winglets called canards). The flaps on both wings move up and down in tandem, changing the lift over both wings equally and causing the entire aircraft to pitch up or down.

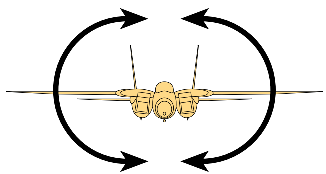
In the F-22, X-32 and X-31, thrust vectoring can also be used to control pitch.



Roll

Roll is the movement of an aircraft's wingtips up and down. A pilot uses his flight stick to control the aircraft's ailerons, which are hinged panels on the wings. Unlike flaps, ailerons move in opposition to each other, increasing lift on one wing to decreasing and lift on the other. The lift differential tilts the wings and rolls the airplane.

Roll

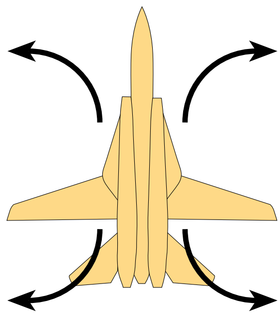


Yaw

Yaw is the sideways movement of an aircraft's nose. A pilot moves an aircraft's tail rudders by pressing the rudder pedals, causing the aircraft to yaw left and right.

In the X-31, yaw can also be controlled by thrust vectoring.

Yaw



Flight Stick

Moving the stick forward and backward moves the aircraft's elevators and flaps and causes a change in pitch. Pulling the stick back, or "applying aft stick," causes the aircraft's nose to rise. Pushing the stick forward — "applying forward stick" — causes the aircraft's nose to drop. (If you are playing *ATF* with the keyboard, you control a airplane's pitch with ↑ and ↓).

Moving the stick right and left, or "applying lateral stick", controls the ailerons and causes the aircraft to roll. For example, moving the stick left causes the left wing to drop and the right wing to rise, rolling the aircraft left. (On the keyboard, use ← and →).

Rudder Pedals

The rudder pedals move the aircraft's rudders, controlling yaw. Applying right rudder yaws the aircraft's nose right. Pushing the left rudder yaws the aircraft's nose left.

Rudder usage also induces roll. When using rudder, most aircraft will in roll the direction that rudder is applied. The amount of roll varies with aircraft type. Some aircraft, like the F-104, roll the opposite direction of rudder inputs.

Rudders are primarily used for lining up shots and spin recovery. You can control the rudder with rudder pedals if you have them, or by number keys on the **numeric** keypad:

1 Apply left rudder

2 Center the rudder

3 Apply right rudder

Throttle

The throttle controls the engine's output. Pulling the throttle back closes it, decreasing engine output. Pushing the throttle forward opens it and increases engine output.

Afterburners increase thrust by dumping fuel into the engine's exhaust and igniting it. The thrust increase is significant but consumes four times as much fuel as full throttle without afterburners. Reserve afterburners for critical situations — to pull out of a stall or to catch up with (or outrun) an enemy.

In *ATF*, throttle is controlled with the keys 1 through 8 or a throttle device on your joystick:

1	**0% throttle**	4	**75%**	7	**Increase 5%**
2	**25%**	5	**100%**	8	**Decrease 5%**
3	**50%**	6	**100%+afterburner**		

Note that not all aircraft have afterburners — the B-2, F-117, AC 130, AV-8B and Sea Harrier, for example, do not.

Maneuvering

Flight Stick | Rudder Pedals | Throttle | Vectored Thrust

Vectored Thrust

X-31, X-32 and F-22

On the X-31, X-32 and F-22, small “strake” flaps (vanes) on the engine outlets are angled to redirect the engine’s thrust. This is called *thrust vectoring*. The pilot in an F-22 and X-32 can use thrust vectoring to change pitch. An XF-31 is capable of thrust vectoring both horizontally and vertically.

Ctrl + ← → ↑ ↓ **Thrust vector** in the F-22, X-32 and X-31.

STOVL Aircraft

Thrust vectoring is also used in STOVL airplanes for short or vertical takeoff and landings. In the AV-8B and Sea Harrier, the engine nozzles are actually rotated downward to thrust the aircraft vertically off the ground. In the X-32, a lift fan on the underside of the aircraft generates a thrust force for vertical takeoff and hovering.

To thrust vector in STOVL airplanes:

X	Vector nozzles **down –10°**.
Shift X	Pressing once vectors the nozzles down to a **completely vertical position (–90°)**. Pressing again moves the nozzles further forward to -100° (120° in an ASTOVL). This can be useful in slowing the craft down for vertical landings.
Z	Vector nozzles **10° back**.
Shift Z	Vector nozzles back to a **completely horizontal position (0°)**. (Press twice in the X-32.)

TAKING OFF AND LANDING

The **Take-Off Tutorial** and **Landing Tutorial** — were designed to accompany the **TRAIN 01** single mission. (One of the options available when you choose PLAY SINGLE MISSION from the *Choose Activity* screen).

If you want to skip to the Landing Tutorial, it begins at waypoint B of this mission.

Take-Off Tutorial

Landing Tutorial

Taking Off/Landing in a STOVL

Take-Off Tutorial

Pre-Flight

To begin the takeoff mission, select PLAY SINGLE MISSION from the *Choose Activity* screen. When the *Mission Selection* screen appears, select TRAIN 01 and click OK.

HUD

Once you click FLY, you'll find yourself seated on a runway in the cockpit of an X-29. If you are unfamiliar with the HUD — the flight information displayed in green in the center of your view — you might want to look over Cockpit Elements.

Useful Keys

Ctrl P	**Pause flight** at any time (press again to resume play).
Esc	Pause flight and **display *In-Flight* menu bar.** (Press again to resume play.)

(**Note:** Ctrl P allows you to pan the camera in external views while paused)

If you have trouble at any point in this first fly-through mission, you can jump into an external view of your aircraft and activate autopilot. This allows you to watch the correct procedure.

F10	**External camera view** (press F1 to return to normal front view).
A	**Activate autopilot** (press again to de-activate).

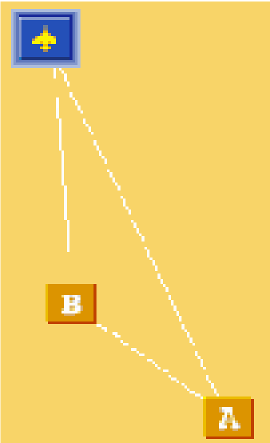
Taking Off

- ♦ Check the upper-right corner of the HUD to verify that flaps are extended. (FLAP appears there.) This happens automatically at takeoff; when you land, you'll have to manually extend them (press F).
- 5 Engage your throttle to 100%. (Some other aircraft allow you to use afterburners by pressing 6.)
- ♦ When you see the nose raise up slightly, pull back on the joystick. (You'll know it's time to pitch up when the horizon line drops below the center of your HUD.)
- G As soon as you're airborne, retract the landing gear.
- ♦ Fly at a slight climb until airspeed reaches 200 knots.
- F Raise your flaps. (Extending flaps provides lift and increases drag; raising them reduces both lift and drag.)
- ♦ When flying airplanes with afterburners, reduce throttle to 5.

Navigating

DETAILS: Navigation Window

Next, you need to travel to your first waypoint (A), a position approximately 14nm southeast of the airport. Then, you'll travel to a second "marshal" waypoint (B), where you'll be able to make an approach for a landing at (C).

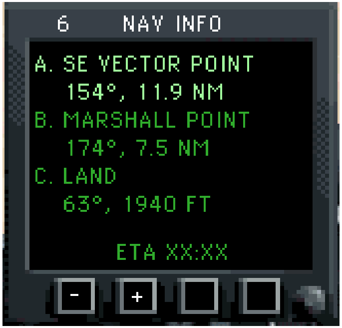


To maneuver to your waypoint:

- Level the nose and fly a forward course until airspeed reaches 250 knots.
- Look at the Navigation Window.

(This window opens by default when this mission begins. Later, you'll need to press Shift 6 to open/close it.)

This window shows your waypoints. The current one is highlighted and labeled SE VECTOR POINT. It lies about 14 nautical miles southeast of the airstrip at a heading of roughly 180°.



The bearing in the Navigation Window shows you how off-course you are — when you're headed directly at the waypoint, it read 0°. If it's positive, the waypoint is to your left. If it's negative, the waypoint is to your right.

Note: Bearing refers to directions relative to your plane, while **heading** refers to compass directions. In the Navigation Window, 90° bearing to a waypoint means that the waypoint is to your right. On the heading tape, 90° means you're flying due east.

- Bank right and pull back on the joystick (or use Z on the keyboard).
- Continue this right-hand turn for 180°. Pull gently back on the stick until the indicator reads 3G, then hold the stick at that position. (Watch the G reading in the HUD's upper left corner — if you exceed 3G's in this turn, you risk stalling.)
- When the waypoint indicator becomes visible under your heading tape, slowly level the wings. Center the waypoint indicator under the tape.
- Keeping the throttle at 100%, pull back on the stick until the nose pitches up 10°, and fly directly at the waypoint. (If you want to get there quickly, press C. This cycles through 1x, 2x, 4x and 8x settings, which increase the rate at which time passes.)
- At 10,000 feet (i.e., "Angels 10"), gently push the stick forward and level the nose.

When you get within a mile of the SE VECTOR POINT waypoint, the range in the Navigation Window switches to feet (ft) instead of nautical miles (nm). (The range is the rightmost number under the waypoint name.)

- ♦ Fly directly toward the waypoint until the heading suddenly changes and the carat under the heading tape disappears. This indicates that you've passed the waypoint.
- ♦ Continue flying for 5nm or so, and gradually bleed off about 5,000 feet of altitude by pitching down slightly.

N Activate the HUD Navigation mode (you'll see NAV or ILS in the left bottom corner of the HUD).

W Switch to the next waypoint in your Navigation Window (this highlights MARSHAL POINT). The marshal point lies approximately 5nm out from the runway and is off to the right, at approximately 4 o'clock (a bearing of approximately 160˚). This lines your aircraft up with the runway before you land.

- ♦ Bank into a gradual 180° turn until you see the waypoint carat in your HUD. Center the carat under your heading tape and approach the waypoint. As you approach it, pitch the nose down 10° until your altitude drops to 5,000 feet. Then, level your nose.

- W When the range begins increasing instead of decreasing, switch to the third and final waypoint, LANDING. You'll be in a perfect position for an approach.

The approach begins at this MARSHAL POINT (a point that aligns returning aircraft with the runway). Your aircraft receives first landing clearance; all other aircraft hold marshal while you land.

Landing Tutorial

Landings require a pilot to perform several tasks within a short span of time:

- Control the Aircraft
- Monitor HUD Information
- Make a Final Approach.
- Avoid Possible Problems

Controlling The Aircraft

A landing is only as good as the approach, and your speed, altitude and execution must be perfect. Making and maintaining a proper approach requires the following criteria:

- Right Altitude/Airspeed
- Good Descent Rate
- Good Angle of Attack
- Controlled Approach

Taking Off/Landing

Right Altitude/Airspeed. Know where your aircraft is supposed to be, and when. Know the altitude and airspeed requirements for all critical points along the approach.

Good Descent Rate. You should maintain a constant descent rate of 500-700 feet per minute. There's no easy way to determine this. Just keep an eye on the Inertial Landing System — it will tell you if you're too high or too low.

Good Angle-of-Attack. To determine your current angle of attack, watch the HUD pitch ladder indicator. Its tick marks occur in 5° increments.

You should keep your nose level (or even pitched slightly down) during the first part of your approach. As you near the runway, pitch the nose up and down to adjust speed. (Don't use the throttle.) The drag created as the nose pitches up helps bleed off velocity. Pitching the nose down slightly will increase velocity. Typically, your AoA just before touchdown should be about 10°-15°.

Controlled Approach. Knowing how to control your aircraft during the approach is mandatory. You need to reduce airspeed and altitude at appropriate rates, and at an appropriate distance from the runway. During landings, you use your throttle to control altitude, and use pitch to control your speed. Although this might seem counter-intuitive, it's correct.

↑ **Pitch**
↓ **Altitude**

If you're coming in too high, pitch the nose up to lose altitude. At high speeds, pitching the nose up causes the aircraft to gain altitude. When you pitch the nose up at low speeds, however, the wings don't create enough lift to climb. Instead, the nose of the aircraft increases drag, and airspeed decays. Lower airspeed, in turn, causes a loss of lift and altitude.

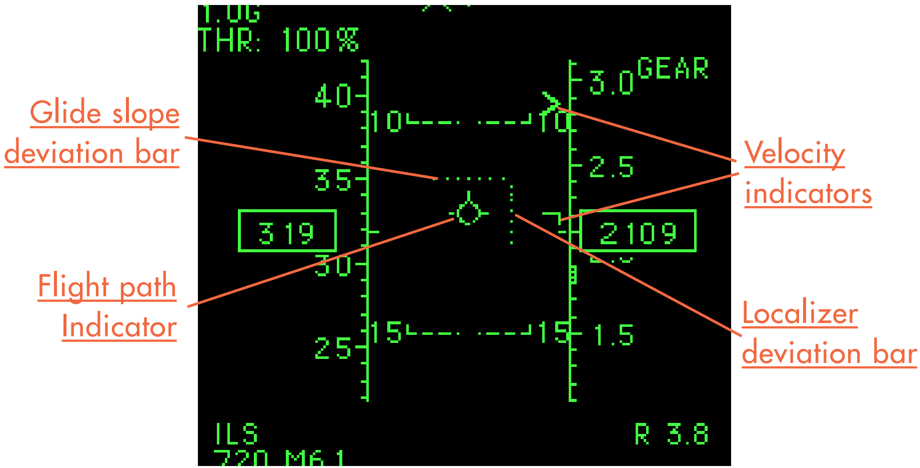
↑ **Throttle**
↑ **Altitude**

If you're losing altitude too quickly, increase the throttle and keep your pitch constant. Throttling increases airspeed, which creates more lift under the wings. You don't want to pitch the nose up at low speeds — this counteracts the throttle by creating drag.

Monitoring HUD Information

To set your aircraft down on the runway, you'll need to understand the indicators marked on the HUD below.

(If you can't see any of these indicators, make sure your HUD is in navigation mode — press N to switch HUD modes; ILS or NAV will appear in the bottom of the screen.



Landing Tutorial

Localizer Deviation Bar

This vertical row of dots indicates your horizontal lineup. If you are too far to the right, the dots drift to the left side of the HUD. Moving too far left shifts the dots to the right side of the HUD.

Glide Slope Deviation Bar

This horizontal row of dots indicates your vertical position. If you have too much altitude, the dots moves to the bottom of the HUD, and vice versa. If you’re too low, they move to the top of the HUD.

Velocity Indicator

The two corner brackets and caret that scroll to the right of the velocity tape indicate your landing speed range. The brackets designate the high and low speed limits. The small tick line extending from the center of the tape marks your current speed — keep the caret as close to this small tick mark as possible when landing.

Flight Path Indicator

The flight path indicator is a dynamic circle on the HUD that shows the direction in which your aircraft is actually moving. Keep an eye on it during landing. It lies beneath the HUD center when you’re descending, and above it when you’re gaining altitude.

If the flight path indicator is short of the runway, you’re descending too fast and will likely crash. If the flight path indicator is positioned beyond the runway, you’re coming in too fast and will have to abort the landing.

Try to keep the flight path indicator on the HUD centerpoint during the approach, then move it 13° to 15° below the HUD centerpoint. This indicates an AoA of about 13 to 15°, considered a good touchdown angle.

Making Your Final Approach

- ♦ You should now be aligned with the LANDING waypoint (C), about 5nm out. If the bearing in the Navigation Window doesn't read 0°, use the rudder pedals — numpad [1] (left), [2] (center) and [3] (right) — to yaw, or change headings without banking the wings.
- [F] Extend your flaps. This creates additional lift when you're flying at low speeds.
- [2] Set your throttle to 25% and pitch the nose down to -5°. This should drop airspeed. Different aircraft have different approach speeds. Look at the landing speed indicator tape on the left side of the HUD — the carat represents your speed. Keep it between the upper and lower brackets (these indicate the upper and lower speed limits for a safe landing).
- [B] If your speed exceeds 200 knots, extend the speed brake. If speed drops to 150 knots, lower the nose slightly.

- When you're about 2nm out from the runway, you should be at about 1,000 feet. Pitch the nose up to 10°.
- Work the nose up and down to maintain a speed between the brackets. Be sure to keep the Localizer deviation bar and the Glide slope deviation bar centered in your HUD.
- Check your Target Window for range, and your Altimeter indicator for altitude. (The tick marks on the altimeter represents feet above ground level, not sea level.) You should be about 2,000 feet up when 10nm out from the runway.
- As you reach the runway, level the wings and keep your heading steady.
- The aircraft should touch down approximately a quarter down the length of the runway.

[1], [B] Reduce throttle to 0% (press [1]), and apply the brakes ([B]).

Congratulations — you've completed your first landing! Choose END MISSION from the **?** menu to exit the mission.

Possible Problems

Before touching down, verify that the landing gear and flaps are extended. You'll see FLAP and GEAR in the upper-right corner of the HUD if they are. If not, press F to extend flaps, and G to lower landing gear.

- Wind and Turbulence
- Misalignment
- Too Much Altitude
- Too Little Altitude

In the end, you may end up needing to abort a bad landing.

Wind and Turbulence

Wind and turbulence can affect your approach somewhat and cause your aircraft to drift. When you go in for a landing, the control tower will tell you the wind conditions. In the event of a crosswind, use your rudder to yaw slightly in the opposite direction of the drift.

In windy landing conditions, don’t bank your wings to correct your flight path. This might blow you off course and make landing very dangerous.

Misalignment

If the localizer deviation bar indicates that you’re drifting left or right, dip one wing slightly to correct your course. Use the rudder to correct this. Do not, in any case, dip your wings— this can cause you to sideslip (continue on an errant course, even though the nose is turned in the correct direction).

Too Much Altitude

If you're coming in high (check the Glide slope deviation bar), cut the throttle immediately. Do not pitch the nose down. It has to have a proper AoA at touchdown so that the main gear absorbs the brunt of the landing shock. If you point the nose down, the nose gear takes the heaviest part of the impact and could collapse.

Too Little Altitude

If you're too low, you need some lift. Your first response might be to raise the nose, but this is potentially disastrous. Raising the nose slows the aircraft more and causes it to drop even faster. If anything, drop the nose *slightly* to recover airspeed and gain lift (but don't ever drop it below the horizon line).

To gain altitude, increase throttle quickly by pressing $\boxed{5}$. Keep a careful eye on your speed; if it drops below 180 knots or so, you may stall and crash. Once you're back up to the correct altitude, reduce the throttle to its original 25% setting.

Aborting a Bad Landing

If you're too low, too high, too fast or too slow, you may not be able to correct your landing in time. If this happens, abort the landing and try again:

5	Punch your throttle to 100%, but don't change course. (In aircraft with afterburners, press 6 instead.)
F,B,G	Retract your flaps, and extend your speed brakes and landing gear.
♦	Climb back to an altitude of 6,000 feet.
♦	Make a sweeping, 180-degree turn to the left, straighten out, and move to your original approach position.
♦	Give the landing another try.

Taking Off/Landing in a STOVL

If you're flying a Short Takeoff and Vertical Landing (STOVL) craft, the steps for takeoff and landing are slightly different. These aircraft can take off vertically or from a short runway. Their engine nozzles can rotate 100° to provide upward or forward thrust. (Vertical thrust is provided by a lift fan on a STOVL. Hovering ability varies with weight — a fully loaded STOVL can't hover.

Short Takeoff

Vertical Takeoff

Landing

Vertical Takeoff

With an unloaded STOVL, you can perform a vertical takeoff:

N	Activate the Navigation Window.
Shift X	Rotate the vector nozzles to -90° (straight down).
5	Increase throttle to 100 percent. Your aircraft will lift off.
♦	Keep the nose of the aircraft level with the horizon, and don't stall. Don't move the stick sideways; this will cause you to crash.
Z (3x)	(three times) After you climb to 500 feet, rotate the vector nozzles to 60°.
Shift Z	As you pass stall speed (80-90 knots), rotate the vector nozzles back to 0°. You'll go into forward flight.

Short Takeoff

If your aircraft is loaded, you can perform a short runway takeoff:

F	Extend your flaps.
5	Increase throttle to 100 percent. Your aircraft will start to move forward.
X (4x)	(four times) As you pass stall speed (80-90 knots), rotate the vector nozzles to -40°.
G	When airborne, retract the landing gear.
Shift Z	Rotate the vector nozzles back to 0.

Landing

Landing a STOVL aircraft can be a challenge, but you'll be able to accomplish it after a few practice rounds:

2	At about 2 miles out from the runway, throttle back to 25%.
F, G	Extend your flaps and landing gear.
Shift X	Rotate the vector nozzles to -90° (straight down).
♦	Keep the nose up just enough to keep the engine from stalling as you drop down onto the runway.

Note: Don't use your rudders when you're near stalling speed.

STALLS

A stall occurs when AoA exceeds maximum allowable levels and a smooth airflow over the wings is disrupted. Lift evaporates and the airplane falls toward the earth.

Avoidance

- Always monitor airspeed, especially if you have to pitch up more than 45°.
- Pay attention to stall tickle. If the aircraft tickles, pitch down or punch out.
- Take particular care to avoid stalls at low altitude. If you can't dive to regain speed, you're going to buy the farm.

First Warning: Buffet and Tickle

As a stall approaches and the airflow over the wings roughens, the aircraft begins to vibrate, with severity increasing as the airflow worsens. The point where the vibrations or buffet first begins is called **tickle**. Pilots with a light touch can feel the tickle and realize they've reached maximum performance without looking at their instruments. In *ATF*, you'll see "Approaching Stall" in the viewscreen when you reach the tickle point.

Second Warning: Stall Horn

If you do not take action to increase airflow (usually by relaxing G-load and pitching your nose down) airflow disruption and buffeting worsen. Fighter aircraft have a stall horn which makes a loud, distinguishable wail that warns of a potential stall. When you hear this, dive or punch your afterburners.

Stall Recovery

- If you've got afterburners, punch them. (Press 6.)
- If you don't have afterburners, or they aren't enough, dive.
- Attempt stall recovery as soon as possible. The longer you wallow uncontrolled around the sky the greater the chance someone will shoot you or you will crash.

Controlled Stall (Post-Stall Maneuvers)

Controlled stall occurs in highly maneuverable aircraft, such as the X-31. This means that technically you are in a stall, but in a perfect situation to execute a post-stall maneuver such as the Herbst or J-turn. You cannot continue flying in a controlled stall forever, however — the maneuvers discussed above will take you out of a stall, or you can attempt a recovery by dropping your nose and punching your afterburner, or by diving to regain speed.

SPINS

Spins occur when one wing loses significantly more lift than the other. The wing drops, pulling the aircraft into a rotating, spiral dive. As long as the rotation continues, most control inputs are useless, and some may even aggravate the spin.

Spins were deadly killers during the early days of aviation, before pioneer pilots discovered spin recovery procedures. Some historians estimate that during World War I, more pilots died from spin-related crashes than from combat with the enemy.

Spin Recovery

Spin recovery is relatively easy, but requires prompt action. A spin may consume several thousand feet of altitude on each revolution, and spin recovery may require several revolutions. Spins at low altitude, therefore, are extremely dangerous.

1. Center your joystick — using the ailerons at this point often aggravates the spin.
2. Apply full opposite rudder. A message on the HUD will indicate which rudder to apply.
3. Push the stick forward slightly to keep the nose down.
4. Maintain these stick and rudder positions until the aircraft stops rotating. You will generally find yourself in a low speed dive — a perfect target for any nearby bandits. Gently pull out of the dive, raise throttle to 100% (5), and return to normal flight.
5. If you've done all of the above cannot recover, go through the procedure again, increasing your throttle somewhat.