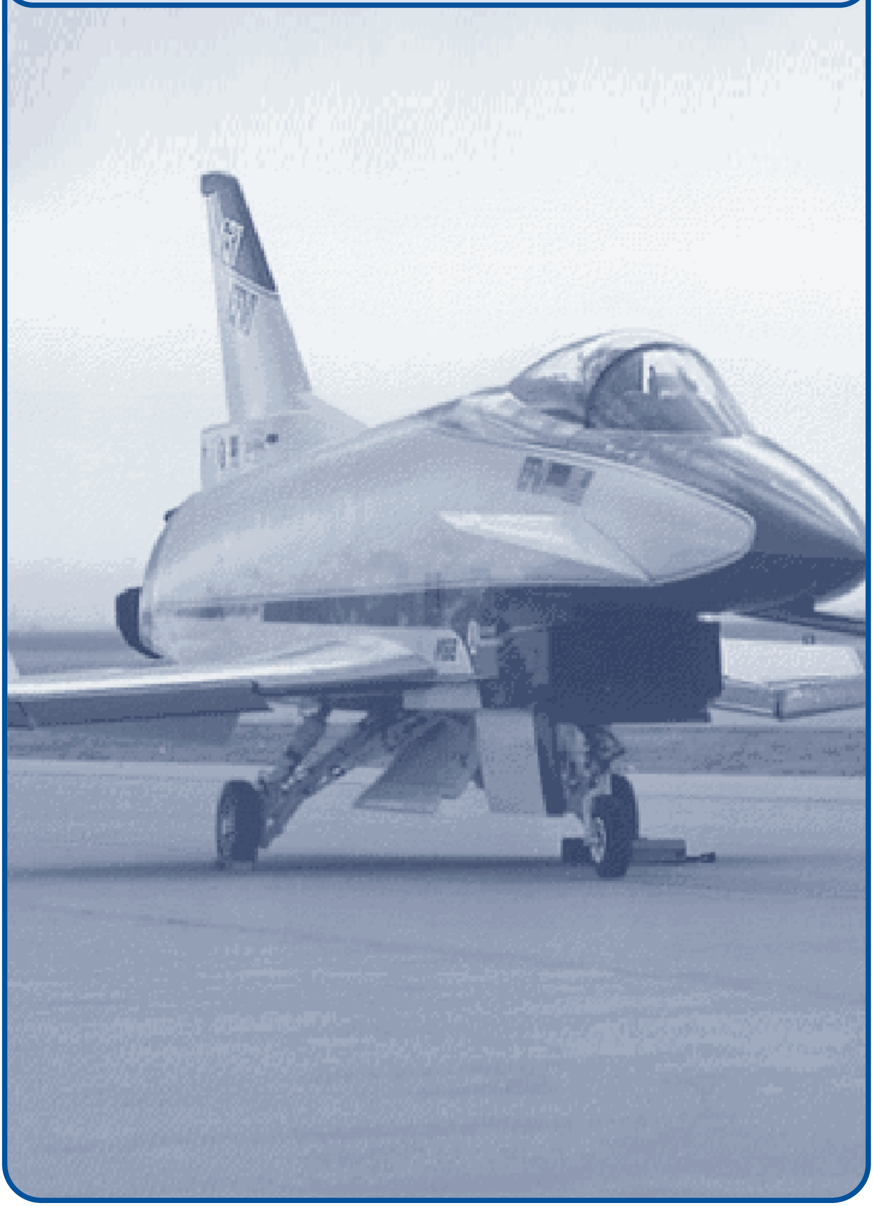
3 — GROUND SCHOOL



3. GROUND SCHOOL

GROUND SCHOOL

Air combat usually boils down to a fight to out-maneuver your opponent, point your nose at him and fire off your weapons before he can fire off his. Understanding how and why your aircraft maneuvers is essential for combat success.

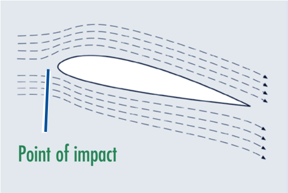
The first part of this chapter explains the basic physics principles of flight, or why the aircraft stays in the air. The second part discusses the physics of turning, G-forces, the flight envelope and how to maximize turn performance. The third section describes some of the control surfaces of the aircraft and explains how a pilot uses them to maneuver the aircraft. The final sections cover takeoffs, landings, stalls and spins.

FLIGHT PHYSICS

Flight is the result of several forces acting upon 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 that propels the plane through the air. This thrust causes air to move over the wings, which in turn creates a *lift* force that counteracts the gravitational force and gets the aircraft off the ground.

Bernoulli's Principle

Bernoulli's Principle explains one way in which air moving over the wings creates lift. The principle states that as the 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* (see diagram) and flows both over and under the exterior surfaces.

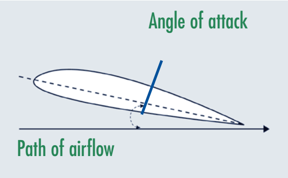


The top surface of the wing is more curved and thus longer than the bottom surface (see diagram). Air flowing around the wing moves both over and under it in the same amount of time. Since air flowing over the top moves a greater distance, it must move faster than the air traveling over the bottom. According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

Two consequences of Bernoulli's principle effect flight performance:

- *Speed is important*. At faster speeds, the pressure differential is greater and more lift is available.
- *Higher altitude means lower lift*. At high altitudes, air is thinner (less dense) and thus creates less pressure and less lift.

Angle of Attack

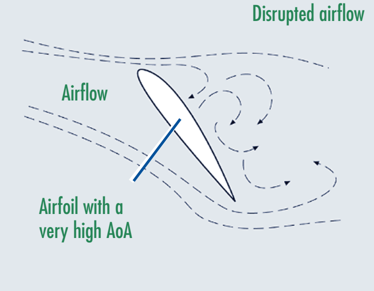


The shape of the wing creates lift in other ways. The wings of most airplanes are angled slightly upward, with the leading (front) edge higher than the trailing (back) edge. The angle at which the wing hits the air is called the *angle of attack* (AoA).

To understand how this design increases the lift of the aircraft, imagine holding your hand outside a car window while the car is moving. If you hold your hand so that your palm faces 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.

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

DYNAMICS OF A STALL



There is a point at which the angle becomes too steep, and the force of the air pushing backward is greater than the force of the air pushing up. This backward force slows the the aircraft down, decreasing the amount of air flowing over the wings and further decreasing lift. If AoA increases, airflow over the wings is disrupted — lift vanishes, and the aircraft can literally fall out of the sky. This is known as a *stall*.

Several of the *Fighters Anthology* 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, and the X-29's forward-swept wings allow great agility and maneuverability at 45° and limited control at 60°. The X-31 EFM (Enhanced Fighter Maneuverability) has demonstrated 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 the object's weight, for force is the product of a mass times its acceleration (F=ma). The weight of an airplane and the weight of its pilot are vastly different because their masses are different, but their acceleration toward the earth due to gravity is the same. G-forces are a way of talking about relative gravitational force without involving differences in mass.

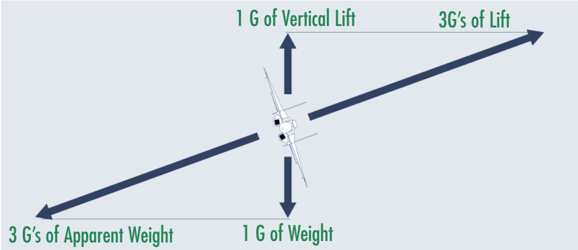
The forces of lift and weight discussed earlier can be described in terms of "G," where for any given object, 1G is equivalent to the gravitational force on *that* object at sea level. An airplane in level flight experiences 1G of force (which is the same as 1 times its normal weight). The pilot in that aircraft also feels 1G of force (which is 1 times *his* normal weight). If the rate of gravity were to suddenly double, or if the aircraft and the 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.

Apparent Weight

In level flight, the lift and weight forces push perpendicularly to the wing, — roughly straight up and down. When the aircraft rolls, the lift force continues to push perpendicularly to the wing, so the direction of lift is no longer completely 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 total lift must be generated to maintain enough vertical force to offset gravity.

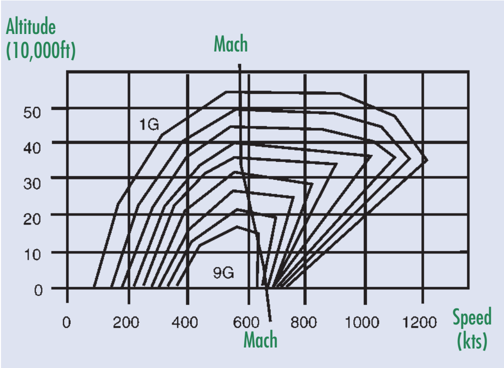
In the figure below, 3G's of actual lift must be generated to provide 1G of vertical lift. The pilot achieves this by pulling back on the flight stick, sending the aircraft into a tighter, more accelerated turn. The pilot feels the increased acceleration as *apparent weight* — in other words, the pilot actually feels 3 times heavier than normal and is pushed 3 times harder against the back of his seat. (This is similar to the force you feel in the tight turn of a rollercoaster.)

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



The Flight Envelope

Lift is a function of airspeed, altitude and the aircraft's flight attitude. All of these factors work together to produce flight, and all three must be considered together when talking about how airplanes maneuver. They are graphically described by the aircraft's flight envelope.



To the left 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.

Absolute Limits

The outside curve shows the aircraft's speed and altitude limits at 1G. This curve 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 of the curve defines the aircraft's maximum altitude. Above this altitude, the air is too thin (and the airplane's wing is 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 36,000ft, the air is thicker, and the airplane's structure limits its speed. If the pilot takes the airplane beyond its structural limit, air resistance begins to weaken the airframe and the wings will eventually tear off.

G-Loading Envelopes

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 see how many G's you can currently pull by finding your current altitude and speed on the graph. Say you are flying the aircraft in the graph on p. 3.4 700 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 you climbed to 45,000ft, your maximum G-load would decrease to 2G. At 49,000ft, the airplane would scarcely be able to do more than fly level.
2. Conversely, if you're in a turning fight and need to pull more G's, you can use the graph to figure out how to get them. 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. In the window, G-envelope curves are delineated by shading. The darker the shade, the fewer G's you can pull at your current speed and altitude. Your aircraft's position on the chart is marked by a white dot.

See **Flight Envelope Window**, p. 90.

Instantaneous vs. Sustained G-Force

So far, you've seen that 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 as a result, which in turn slows the airplane down. The slower airspeed reduces the amount of lift generated. In order to maintain the turn, more thrust from the airplane's engines must overcome the greater drag.

For example, say an airplane flying at a speed of 400 knots and an altitude of 24,000ft is capable of pulling a 5G turn. The airplane banks. The increased drag exceeds available thrust, and the aircraft slows to 350 knots . The initial 5G load is called *instantaneous* G, and is the amount of lift the airplane can initially produce at that speed. As drag slows the airplane, it falls into its 4G envelope. With a lower G-load, drag decreases slightly. The airplane slows to 325 knots, where it can only pull 3G. The drop in G again reduces drag. Now, drag no longer exceeds thrust, and the aircraft maintains 325 knots at 3G. This is called *sustained* G. At this point, the airplane has reached equilibrium — it can maintain this speed and G-load.

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, geometry is also a factor.

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.

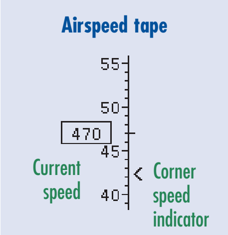
For any given altitude, the speed at which maximum lift occurs is known as the *corner speed*. Corner speed is the velocity at a given altitude at which the best turn performance is achieved — that is, the highest possible turn rate with the lowest possible turn radius.

Using Corner Speed To Your Advantage

Flying above or below corner speed reduces your aircraft's turning 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, braking or reducing throttle.

Corner speed for your current altitude is marked on the airspeed tape by the *corner velocity indicator*.

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



Effects of Weapons Loads

The Flight Envelope Window shows an aircraft's performance potential when "clean" (i.e., not loaded down by ordnance). Weapons increase weight and drag, so performance suffers when are carrying them. Generally speaking, performance 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. The weight of external fuel tanks similarly affect performance.

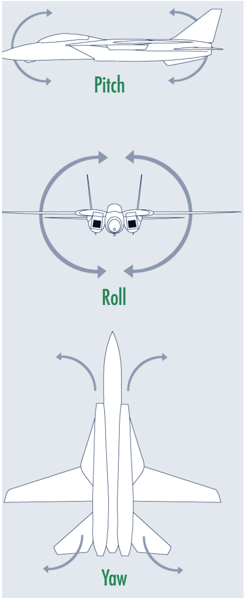
In a desperate situation, you can jettison all air-to-ground ordnance (Shift K) or external fuel tanks (Shift J) to lighten your load.

FLIGHT CONTROLS

Lift is normally generated perpendicular to the wing. Movable control surfaces — ailerons, rudders and elevators — alter this lift to rotate the aircraft around its center of gravity. The pilot uses these controls to maneuver the airplane.

Pitch, Roll and Yaw

Aircraft maneuver in three dimensions: *pitch*, *roll* and *yaw*. These dimensions are always referenced from the pilot's point of view, regardless of the aircraft's orientation or flight attitude.



Pitch is the movement of an aircraft's nose up and down. Pitch is controlled by 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 is the movement of an aircraft's wingtips up and down. Roll is controlled by the aircraft's ailerons. Ailerons, like flaps, are hinged panels on an aircraft's 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.

Yaw is the sideways movement of an aircraft's nose. Yaw is controlled by the aircraft's tail rudders. In the X-31, yaw can also be controlled by thrust vectoring.

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 *Fighters Anthology* with the keyboard, you control a airplane's pitch with ↑ and ↓).

Moving the stick right and left, or *applying lateral stick*, controls the ailerons. 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. Control them with rudder pedals if you have them, or with these keys on the *numeric* keypad:

1	Apply left rudder.	3	Apply right rudder.

Throttle

The throttle controls the engine's output. Pulling the throttle back closes the throttle, decreasing engine output. Rapidly closing the throttle is called *cutting* or *chopping* the throttle. Pushing the throttle forward opens the throttle and increases engine output. The engine's maximum output without using afterburner is called *full military power*.

Afterburners increase engine thrust by dumping fuel into the engine's exhaust and igniting it. The increase in thrust is significant, but fuel is consumed three times faster.

Control throttle with the following keys or a throttle device on your joystick:

1	0% thrust	4	75%	7	Decrease thrust 5%
2	25%	5	100%	8	Increase thrust 5%
3	50%	6	100% plus afterburner		

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

Vectored Thrust

X-31, X-32, Su-35 and F-22

On the X-31, X-32, Su-35 and F-22, small "strake" flaps (vanes) on the engine outlets can be angled to redirect the engine's thrust. This is called *thrust vectoring*. A pilot in an F-22, Su-35 or X-32 can use thrust vectoring to change pitch. An X-31 vectors thrust both horizontally and vertically.

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

X-32, Yak-141, AV-8B and Sea Harrier

Thrust vectoring is also used in STOVL airplanes for short or vertical takeoff and landings. In the AV-8B Harrier and FRS.2 Sea Harrier, the engine nozzles are actually rotated downward to thrust the aircraft vertically off the ground. In the X-32 ASTOVL, a lift fan located on the underside of the aircraft generates an upward thrust force for vertical takeoff and hovering.

To vector thrust in STOVL airplanes:

X	Rotate vector nozzles (or lift fan) down –10°
Shift X	Rotate vector nozzles (or lift fan) to a completely vertical (–90°) position Pressing Shift X again rotates the nozzles forward to –110° (–120° is the ASTOVL). This can be useful in slowing the craft down for vertical landings.
z	Rotate vector nozzles (or lift fan) upward and backward +10°
Shift Z	Rotate vector nozzles to a completely horizontal (0°) position (or to –90° if previously at –110°/–120°)

See **Constant HUD Features — Thrust Vectoring Aircraft**, p. 81, and **Vectored Thrust**, p. 62, for additional information.

IN A HURRY
MULTIPLAYER
GROUND
COCKPIT
COMBAT
CAMPAIGNS
PRO MISSIONS
TECHNOLOGY
SPECS

TAKING OFF AND LANDING

This section teaches you how to take off and land step-by-step using *Fighters Anthology*'s training mission. A **DETAILS** listing under a heading shows where to look for more information on the flight instruments used in this tutorial.

Note**: For instructions that refer to STOVL aircraft, see* **Taking Off and Landing in a STOVL, p. 70. For instructions on carrier takeoffs and landings, see* ***Taking Off and Landing on a Carrier****, p. 71.*

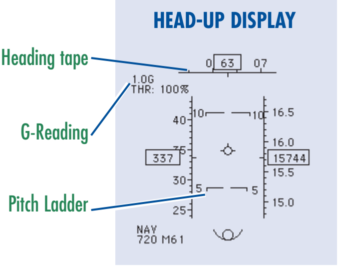
Pre-Flight

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

The HUD

DETAILS: Cockpit Elements (Chapter 4)

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 pause the game and take a second to get acquainted.



Useful Keys

You may want to pause the game at some point in this tutorial and read further:

Ctrl P — Pause flight (press again to resume play)

Esc — Pause flight and bring up the In-Flight menu bar (press again to resume play)

Note:** If you use* Ctrl P *to pause, you will be able to pan the camera in external views while paused. See* ***View Controls*, p. 103. For information on the* In-Flight *menu bar, see* ***Appendix D: In-Flight Menu Bar****.*

If you have trouble after you get up in the air, jump into an external view of your aircraft, activate autopilot and watch the autopilot perform the correct procedure:

F10 — External view (press F1 to return front view)

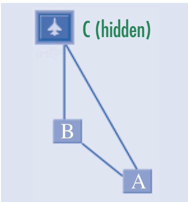
A — Activate autopilot (press again to de-activate)

Taking Off

- ♦ Check the upper-right corner of the HUD to verify that flaps are extended. (FLAP appears if they are.) They are automatically extended at takeoff; when you land, you'll have to manually extend them (press [F]).
- [5] Open your throttle to 100% thrust. (If you have afterburners, press [6] instead to engage them.)
- ♦ When you see the nose rise slightly (i.e, the horizon line drops below the center of the HUD), pull back on the joystick.
- [G] As soon as you're airborne, retract the landing gear.
- ♦ Climb slightly until your airspeed reaches 200 knots.
- [F] Raise your flaps. (Extending flaps provides lift and increases drag; raising them reduces both lift and drag.)
- ♦ If you are flying an aircraft with afterburners, reduce throttle to [5].

Navigating

DETAILS: Navigation Window (p. 93)



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

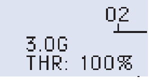
This window shows your waypoints. The current one is highlighted and labeled SE VECTOR POINT. It lies about 14 nautical miles southeast of the airstrip at a heading of roughly 180°.

The bearing beneath a waypoint 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.

Heading tape

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

- Bank right and pull back on the joystick (or use [↓] on the keyboard).
- Continue this right-hand turn for 180°. Pull gently back on the stick until the G-reading in the upper left corner of your HUD is 3G, then hold the stick at that position. (If you exceed 3G's in this turn, you risk stalling.)



- When the waypoint caret 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, cycle through time compression settings — 1X, 2X, 4X and 8X — by pressing [C]. These increase the rate at which time passes.)
- At 6,000 feet, gently push the stick forward and level the nose.

When you get within a mile of the SE VECTOR POINT waypoint, the range beneath it in the Navigation Window switches from nautical miles (NM) to feet (FT).

- Fly directly toward the waypoint until the caret under the heading tape disappears. When this happens, you've flown through the waypoint. Continue flying for 5nm or so, and gradually bleed off about 3,000 feet of altitude by pitching down slightly.
- When you get in range of your waypoint, the next waypoint, MARSHALL POINT, is highlighted your Navigation Window. (You can highlight waypoints manually using [W].)

The marshal point lies approximately 5nm out from the runway and is off to the right, at a bearing of about 160° or so. It is the point at which you begin your landing approach, and in most missions it will be your second-to-last waypoint. In this game, your aircraft always receives first landing clearance; all other aircraft will hold marshal while you land.

- Bank into a gradual 180° turn until you see the waypoint caret beneath your heading tape. Center the caret under the tape and approach the waypoint. As approach, pitch the nose down 10° until your altitude drops to 5,000 feet, then level your nose.
- When the caret disappears from beneath the heading tape, you're in position for landing.

[N] Switch your HUD to navigation mode. (NAV appears in the bottom left.)

Landing

Controlling the Aircraft (below) describes the basic principles behind maneuvering an aircraft at low speeds (these are a bit different than normal flight procedures, so you may want to glance at this section). **Landing Guidance** (facing page) explains how to use the ILS system and features that appear on your HUD during landing. To rejoin to the step-by-step takeoff and landing tutorial, turn to **Making Your Final Approach**, p. 68.

Criteria for a Good Approach

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:

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* indicators (described later in this section) — they will tell you if you're too high or too low.

Good Angle-of-Attack. *Angle of attack (AoA)* is the angle at which your wings meet the air (see p. 54). To keep a good angle of attack, watch the pitch ladder on your HUD (see **Pitch Ladder,** p. 80.). 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 — typically, your AoA just before touchdown should be about 10°-15°.

Controlled Approach. At low speeds, 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 increased angle of attack creates drag, which slows the aircraft down. As airspeed decreases, so does lift, therefore the aircraft also loses altitude.

↑ Throttle ↑ Altitude If you're losing altitude too quickly, increase throttle but keep your pitch constant. Increased thrust speeds the aircraft up and creates more lift under the wings. Don't pitch the nose up to increase altitude at low speeds — this actually counteracts thrust by creating drag.

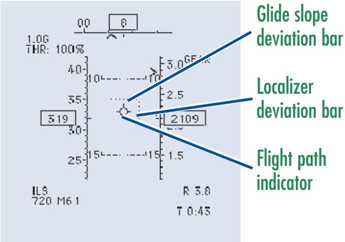
Landing Guidance

To correctly align your aircraft with the runway — especially in at night or reduced-visibility conditions — you'll rely on the Instrument Landing System and indicators on your HUD.

Instrument Landing System

See also: ILS System (p. 87)

The Instrument Landing System projects indicators that help you line up with the runway onto your HUD. It activates automatically 5nm from an airport if you are below 2000ft. You will only see these indicators if your HUD is in navigation mode. (The HUD is in navigation mode if NAV or ILS appears in the bottom left corner. Press [N] to switch modes.)



Glide Slope Deviation Bar. This *horizontal* row of dots indicates your vertical position. If you have too much altitude, the dots move to the bottom of the HUD. If you're too low, they move toward the top of the HUD.

Localizer Deviation Bar. This *vertical* row of dots indicates your horizontal line-up. 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.

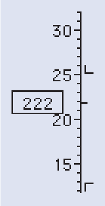
Flight Path Indicator

The flight path indicator is a dynamic circle on the HUD that shows the direction in which your aircraft is actually moving (as opposed to where your nose is pointing). Keep an eye on it while you land — if it falls short of the runway, you're descending too fast and will likely crash. If it is 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.

Velocity Indicator

When ILS is activated, brackets appear on the right side of the airspeed tape. These brackets indicate the high and low speed limits for a good landing. Keep your speed within these brackets.



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) 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 caret 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] Reduce throttle to 0%.
- [B] Apply the brakes.

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.

Misalignment. If the localizer deviation bar indicates that you're drifting left or right, dip one wing slightly to correct your course. Don't yaw — this can cause you to *sideslip* (i.e., continue on an errant course, even though your nose is pointed in the correct direction).

Too Much Altitude. If you're coming in high (check the glide slope deviation bar), cut your throttle immediately. ***Do not pitch the nose down.*** You need a proper AoA at touchdown so that the main (back) gear absorbs the brunt of the landing shock. If you pitch down, you force the nose gear to take heavier impact, and it could collapse.

Too Little Altitude. If you're too low, you need more lift. ***Do not raise the nose.*** Raising the nose at low airspeeds slows the aircraft down and causes it to drop even faster. To gain altitude, increase throttle quickly by pressing 5. Once you've reached a better altitude, reduce the throttle back to 25%.

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 Retract your flaps.
- B Retract your speed brakes.
- G Raise your 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 AND 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.

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%. Your aircraft will lift off.
♦	Keep the nose of the aircraft level and stay above stall speed. Don't move the stick sideways; this will cause you to crash.
G	Retract your gear.
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

2	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 stall speed.*

TAKING OFF AND LANDING ON A CARRIER

The procedure for taking off is exactly the same as on a runway, although you are assisted by a catapult off of the runway. When a carrier mission starts, you begin on the catapult, ready to launch. The Cat officer, visible on your right, is signaling you to take off.

Landing is a bit trickier. Carrier pilots must land their aircraft in a box roughly 40x60ft and hook an arrestor cable in the process. All of the information under **Criteria for a Good Approach** (p. 66) applies, and you will want to understand the **Instrument Landing System** (p. 87). You will also be assisted by a Landing Signal Officer (LSO).

Landing Signal Officer's Commands

The LSO guides every aircraft during the final stages of a carrier landing. He can see your aircraft better than you can see the ship, and he gives you verbal cues to help you perfect your lineup. *Always obey the LSO.*

GO RIGHT	You are too far left. Roll and head *slightly* more to the right.
GO LEFT	You are too far right. Roll and head *slightly* more to the left.
HIGHER	Increase your thrust enough to climb a little.
LOWER	Lower your thrust and let the aircraft sink a bit.
CALL THE BALL	The LSO wants you to verify that you can see the "meat-ball," or lineup guidance lights on the carrier. Normally, at this point you would radio in your ID, aircraft type, fuel remaining, and the word "ball." In this game, this is the signal that you've got a good lineup.
GO AROUND / WAVE OFF	The LSO is ordering you not to land. Apply full power, climb slightly and maintain your current heading until you pass the carrier. Fly back to your approach waypoint and try again.

Touching Down

Make your approach as you would normally, using both the ILS and LSO commands to perfect your line-up. *When you lower your gear, you should also lower your arrestor hook* (H). If you don't lower your hook, you can't snag the arrestor cable that brings you to a halt and you will fly right back off of the carrier.

SPINS AND STALLS

While modern aircraft have overcome many aerodynamic limitations, they are still not completely immune to problems such as spins and stalls. This section discusses the conditions under which stalls and spins occur and how to recover from them.

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 pioneering pilots discovered spin recovery procedures. Some historians estimate that, during World War I, more pilots died from spin-induced crashes than from combat with the enemy

In *Fighters Anthology*, spins only occur if you apply the rudder in the direction of the wing that's dropping. Since rudder control can be automatically coordinated in the game, you will only encounter spins while manually controlling rudders.

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 are extremely dangerous.

Use the following steps if you find yourself in a spin:

1. Center your joystick. Using the ailerons to bank often aggravates the spin.
2. Apply full opposite rudder. (A message on the HUD indicates which rudder to apply.)
3. Now push your joystick 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 enemy aircraft. Gently pull out of the dive, increase throttle to 100% (5) and return to normal flight.
5. If the aircraft is still unwilling to recover after the steps above, go through the procedure again. Try increasing your throttle as you do.

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. Knowing how to recover a stall can be critical.

Avoidance

- Always monitor airspeed, especially if you're pitching above 45°.
- Pay attention to stall tickle (see below). If "*Approaching stall*" appears on your viewscreen, nose down and/or punch out.
- Take particular care to avoid stalls at low speed. 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 airflow over the wings roughens, the aircraft begins to vibrate. The point at which 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 the instrumentation or actually entering a stall. When you've reached the tickle point in *Fighters Anthology*, you'll see "*Approaching Stall*" at the bottom of the viewscreen.

Second Warning: Stall Horn

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

Stall Recovery

- If you've got afterburners, punch them (press 6).
- If you don't have afterburners, or if they aren't enough, dive.
- Attempt stall recovery as soon as possible. As you approach a stall, the air flowing over the aircraft's control surfaces decreases, making the aircraft harder to control. The longer you wait to recover, the greater your chances of totally losing control of the aircraft or getting shot down.

Controlled Stall (Post-Stall Maneuvers)

Controlled stalls can occur in highly maneuverable aircraft, such as the X-31. in a controlled stall, you are technically in a stall, but you still have enough control of the aircraft (either through vectored thrust or advanced control surface design) to maneuver it. When you enter a controlled stall "*Controlled stall*" appears at the bottom of your HUD.

Controlled stalls present the opportunity to execute post-stall maneuvers such as the Herbst or J-turn. If your aircraft is capable of these maneuvers, they can be initiated with vectored thrusting. They are discussed in detail under **Air Combat Maneuvers**, p. 145.

You cannot maintain a controlled stall forever, however — eventually you will begin to rapidly lose lift. Use the maneuvers discussed above to get out of the stall, or you can recover by normal means — dropping your nose and punching your afterburner or diving to regain speed.