Cockpit Basics

Airplanes have evolved from relatively simple to incredibly complex machines. But remember: Whether you're flying a Cessna Skyhawk SP Model 172 or a Boeing 777–300, you're still flying an airplane, and airplanes are more alike than not. In the cockpit, for instance, most modern airplanes share six basic cockpit instruments: airspeed indicator, altimeter, attitude indicator, heading indicator (directional gyro), turn coordinator, and vertical speed indicator. Learning to use these six instruments and a few common controls, such as trim and flaps, will put you far down the runway toward flying any aircraft you wish.

Pilot Static Instruments

Three of the six primary flight instruments measure air pressure. These instruments—the altimeter, airspeed indicator, and vertical speed indicator—are called the pitot static instruments.

All three pitot static instruments are connected to a static port called the pitot tube. This port, or intake, introduces outside air into the case of each instrument. As an airplane climbs or descends, air pressure decreases or increases. The altimeter and vertical speed indicator display these pressure changes as altitude and rate of climb or descent.

The airspeed indicator, which is also connected to the pitot tube, measures the difference between static pressure and ram air pressure. Ram air pressure is the air pressure created when outside air enters the pitot tube. As the airplane flies faster, outside air is forced into the pitot tube more rapidly, increasing the ram air pressure. The airspeed indicator displays the pressure difference between static pressure and ram pressure as airspeed, usually in knots or Mach number.

Gyroscopic Instruments

Three of the six primary flight instruments use gyroscopes to provide pilots with critical flight information about the airplane's attitude, heading, and rate of turn.

Rigidity in Space and Precession

Gyroscopes work like spinning tops. They have two properties—rigidity in space and precession—that make them useful in flight instruments. See sidebar: **Gyroscopic Properties**.

The attitude indicator and heading indicator are based on a gyro's rigidity in space. Because a gyro resists being tipped over, it can provide a stable reference to the real horizon or to a specific direction. The turn coordinator uses precession to display information about the direction and rate of turn. (For more information on precession, see the **Gyroscopic Properties** sidebar.)

Gyro Power

In most light airplanes, an engine-driven vacuum pump spins the gyros in the attitude indicator and the heading indicator. To provide a backup if the vacuum fails, the turn coordinator usually has a gyro spun by an electric motor.

Gyroscopic Properties

- From King Schools' 'Cleared for Takeoff'

What does a child's spinning top have to do with flying an airplane? More than you might imagine.

- Rigidity in Space

Remember how, when you were a kid, you'd spin a top and it would stand upright for almost as long as it had motion. You probably didn't know it then, but it was exhibiting a property common to all spinning discs, a property engineers call rigidity in space. As the name implies, the disc wants to remain as it is.

A gyroscope, or gyro, is a spinning disc whose axis is mounted in a frame that allows it to move freely in several directions. Just like your top, it wants to remain as it is. You'll see that some of the instruments in your Cessna Skyhawk SP Model 172 use gyroscopes that also work on the principle of rigidity in space.

- Precession

Precession is another property of a spinning disc. If you push on the axis of your top, it resists the push and the force actually moves in a direction 90 degrees from where you're pushing. In the same way, when you pitch your Skyhawk SP's nose down, it wants to go left (or 90 degrees from where the force is applied to the disc) because of the propeller's gyroscopic effect. Both are examples of gyroscopic precession.

Precession, by the way, is what lets you turn your bicycle by leaning in the direction you want to go when you're riding with no hands. Precession is predictable and you have a gyroscopic instrument in your Skyhawk SP that uses the principle.

When it's used intentionally, precession can work to your advantage. But it can also work against you. Because of friction in bearings and other reasons, precession sometimes shows up where it's not wanted—for instance, when it causes gyros to drift, instead of remaining rigid in space. In this case, airplane designers offer a couple of choices: they either build in a correction for it over time, or they provide the pilot a means to adjust the gyro.

Airspeed Indicator

The airspeed indicator is a differential pressure gauge. It measures the difference between the air pressure in the pitot tube and the static, relatively undisturbed air surrounding the airplane. A needle displays this difference as airspeed.

Aircraft manufactured in the United States after 1976 have airspeed indicators with markings based on indicated airspeed in knots. Older aircraft typically have markings that reflect indicated airspeed in statute miles per hour.

How the Airspeed Indicator Works

The airspeed indicator is the only instrument connected to both the pitot tube and the static system. Air from the static system fills the case of the airspeed indicator, providing a "base" pressure against an expandable diaphragm. Air forced into the pitot tube as the airplane moves fills the diaphragm, which expands as ram air pressure (and speed) increase. A needle connected to the diaphragm rotates as the diaphragm expands. The needle's position on the instrument face indicates airspeed.

The airspeed indicators for the Bombardier Learjet 45 and Boeing 737–400 include an additional needle with red and white stripes known as the "barber pole." A flight data computer takes information about the current altitude, air temperature, and pressure and continuously computes the maximum allowable airspeed as the aircraft climbs and descends. The barber pole shows this speed.

Note: The speeds used in Flight Simulator checklists, operating procedures, and in the **Aircraft Information** articles are all indicated airspeeds, unless otherwise noted.

Tip: To create a realistic flying experience, Flight Simulator displays indicated airspeed by default. As your aircraft climbs, indicated airspeed decreases while true airspeed increases. The higher you climb, the greater the difference between IAS and TAS. To display true airspeed, choose Preferences from the Options menu and select the Display True Airspeed option on the Instrument tab of the Preferences dialog box.

Altimeter

The altimeter is a sensitive barometer that measures air pressure. It's calibrated to display that air pressure as height, usually in feet above mean sea level (MSL).

How the Altimeter Works

The altimeter is connected to the static ports. The air pressure inside the instrument case decreases as the airplane climbs and increases as it descends. As the pressure in the case drops, sealed wafers in the instrument case expand. Increasing pressure squeezes the wafers. As the wafers expand and contract, needles connected to them rotate around the altimeter dial like hands on a watch.

Reading the Altimeter

Most small aircraft are equipped with two-needle altimeters. The long needle shows hundreds of feet. The short needle points to thousands of feet. A wedge-shaped striped indicator appears whenever the current altitude is less than 10,000 feet (3,048 meters). For example, if the long needle is on 5 and the short needle is between the **2** and **3**, you're at 2,500 feet (762 meters) MSL. If the striped indicator isn't visible, the same needle orientation shows that you're at 12,500 feet (3,810 meters) MSL.

Jets and other high-performance aircraft typically have "needle and drum" altimeters. A long needle shows hundreds of feet and an odometer-like display shows altitude in numerical form.

Setting the Altimeter

To display altitude accurately, the altimeter must be set to the current barometric pressure adjusted to sea-level pressure. This setting appears in the Kohlsman window—the scale between the 2 and 3 on the dial in the Skyhawk SP. Before takeoff, the pilot turns a setting knob to set the correct pressure. When properly set, the altimeter indicates the airport elevation—not zero—before the airplane takes off.

Pilots can get the current altimeter setting from ATIS broadcasts, air traffic controllers, and Flight Service Stations (FSS). If one of these sources isn't available, the pilot should set the altimeter so that it displays the elevation of the departure airport. Pilots should also receive a current altimeter setting en route and for their destination airport.

Types of Altitude

The altimeter in an airplane is designed to show height above sea level (MSL). The instrument is calibrated to show that height under standard atmospheric conditions. The current temperature and pressure rarely match standard conditions, however, so pilots must understand several types of altitude and know how to correct for altimeter errors caused by nonstandard conditions.

- **Indicated** altitude is the altitude shown on the altimeter. If the altimeter is set to the current atmospheric pressure corrected to sea level, indicated altitude is approximately equal to the aircraft's height above sea level (MSL).
- **Pressure** altitude is the altitude shown on the altimeter when the pressure is set to 29.92 inches of mercury (or 1012.2 millibars). Pressure altitude is important in calculating density altitude, a critical factor in determining aircraft performance, true airspeed, and true altitude. In the United States, aircraft fly at pressure altitudes or "flight levels" when operating at or above 18,000 feet MSL (5,486 meters). That's why you must set the altimeter to 29.92 whenever you fly at or above that altitude.
- **Density** altitude is pressure altitude corrected for deviations from standard temperature. You must calculate density altitude to determine how much runway your airplane will need to take off and land, and its rate of climb. Calculating density altitude is especially important on a hot day when you're operating from an airport with an elevation well above sea level.
- **True** altitude is your actual height above sea level. If you set the altimeter to local pressure corrected to sea level, indicated altitude is approximately true altitude.
- **Absolute** altitude is your height at any instant above the terrain. Unless your aircraft is equipped with a radio or radar altimeter, you must estimate absolute altitude by comparing your indicated altitude with the terrain elevations shown on charts.
- **Radio (or radar)** altitude is the absolute altitude displayed by radio or radar altimeters in large aircraft. Pilots use radio or radar altitude during the final phases of approach and landing, particularly when the ceiling and visibility are low, to help them determine decision height.

Altimeter Errors

The altimeter is calibrated to display the correct height above mean sea level when the temperature and pressure of the atmosphere match standard conditions.

Variations in temperature usually don't cause significant errors, but if atmospheric pressure doesn't change at the standard rate, the altimeter won't display the correct altitude unless the pilot periodically adjusts the altimeter setting to the local atmospheric pressure (corrected to sea level). In fact, FAA regulations require you to use the proper altimeter setting as you fly (see FAR 91.121).

For example, suppose the altimeter is set to 30.10 inches before takeoff. If the airplane travels to an airport surrounded by a low-pressure system and the pilot does not change the altimeter setting, the altimeter senses the lower pressure as higher altitude. In other words, the altimeter shows an altitude higher than the airplane's actual height above sea level.

Although the pilot thinks the airplane is at the correct altitude, it may be in conflict with other aircraft in the area whose pilots are using the correct local altimeter setting.

Tip: To set the altimeter to the current atmospheric pressure, press **B**.

Attitude Indicator

Sometimes called the "artificial horizon," the attitude indicator is the only instrument that simultaneously displays both pitch and bank information.

How the Attitude Indicator Works

The gyro mounted in the attitude indicator rotates in the horizontal plane and maintains its orientation relative to the real horizon as the airplane banks, climbs, and descends.

Note, however, that the attitude indicator alone can't tell you whether the airplane is maintaining level flight, climbing, or descending. It simply shows the aircraft's attitude relative to the horizon. To determine your flight path, you must crosscheck the airspeed indicator, altimeter, heading indicator, and other instruments.

The pointer at the top of the attitude indicator moves along a scale with marks at 10, 20, 30, 60, and 90 degrees of bank. The horizontal lines show the aircraft's pitch attitude in degrees above or below the horizon. The converging white lines in the bottom section of the indicator can also help you establish specific bank angles.

Limitations
The gyros in the attitude indicators used in most small aircraft tumble if the pitch attitude exceeds +/-70 degrees or if the angle of bank exceeds 100 degrees. When the gyro tumbles, it gives unreliable indications until it realigns itself, a process that usually requires several minutes of straight and level flight. Aerobatic planes and large aircraft are often equipped with gyros that are reliable through 360 degrees of pitch and bank.

Many modern attitude indicators have a blue "sky" and brown "earth," which is the origin of the phrase "keep the blue side up."

Heading Indicator

The heading indicator, sometimes called the "directional gyro" or "DG," is one of the three gyroscopic instruments. When aligned with the compass, it provides an accurate, stable indication of the aircraft's magnetic heading. It should be emphasized that without a compass, the heading indicator is useless because it "knows" nothing about the magnetic heading. Only a magnetic compass can read earth's magnetic field. For more information on reading a magnetic compass, see **Old-Fashioned Navigation**.
The heading indicator is an important aid because the compass is subject to errors caused by acceleration, deceleration, and the curvature of the earth's magnetic field, especially at high latitudes.

The compass often oscillates or leads or lags a turn and it is especially hard to read in turbulence or during maneuvers. (To see how difficult it is to fly with only a compass, you can display a compass in a separate window.) To display or hide the magnetic compass, press **SHIFT+5**.

How the Heading Indicator Works
The gyro in the heading indicator rotates in the vertical plane. A card marked with headings maintains its orientation as the airplane turns. The apparent movement of the card gives the pilot an immediate, precise indication of the airplane's heading and the direction in which the airplane is turning.

The card is marked off in five-degree increments, with numbers every 30 degrees and the cardinal directions indicated by **N**, **S**, **E**, and **W**.

Aligning the Heading Indicator
On small aircraft like the Skyhawk SP, the pilot sets the heading indicator to coincide with the compass before takeoff and resets it periodically during flight to make sure that it remains in sync with the compass. The heading indicator drifts because it's based on a gyro, which precesses with time. As a rule, the heading should drift no more than three degrees every 15 minutes.

Tip: To reset or adjust the heading indicator manually, press **D**.

Larger aircraft usually have "slaved" heading indicators that automatically keep the instrument properly aligned with the compass.

Note: You can make the heading indicator drift by selecting the **Gyro Drift** option on the Instrument tab of the **Preferences** dialog box.

Turn Coordinator

The turn coordinator is really two instruments. The gyro portion shows the aircraft's rate of turn—how fast it's changing direction. A ball in a tube called the "inclinometer" or "slip/skid indicator" shows the quality of the turn—whether the turn is "coordinated."

How the Turn Coordinator Works
When the airplane turns, forces cause the gyro to precess. The rate of precession makes a miniature airplane on the face of the instrument bank left or right. The faster the turn, the greater the precession, and the steeper the bank of the miniature airplane.

Standard Rate Turn
When the wings of the miniature airplane align with the small lines next to the **L** and **R**, the aircraft is making a standard rate turn. For example, an aircraft with a standard rate of turn of three degrees per second will complete a 360-degree turn in two minutes.

Balancing Act
The black ball in the slip/skid indicator stays between the two vertical reference lines when the forces in a turn are balanced and the airplane is in coordinated flight. If the ball drops toward the inside of the turn, the airplane is slipping. If the ball moves toward the outside of the turn, the airplane is skidding.

To correct a skid, reduce rudder pressure being held in the direction of the turn and/or increase the bank angle.

To correct a slip, add rudder pressure in the direction of the turn and/or decrease the bank angle.

The autocoordination feature automatically moves the rudder to maintain coordinated flight.

Useful Backup
The turn coordinator is usually electrically powered so that it's available if the vacuum pump fails and disables the attitude indicator and heading indicator.

Needle and Ball
The turn coordinator is common in modern light aircraft. Older airplanes often have a similar instrument called the "turn and slip indicator" or the "needle and ball," which uses a different presentation to display the same information.

Vertical Speed Indicator (VSI)

The vertical speed indicator (sometimes called the VSI or rate-of-climb indicator) shows how fast an aircraft is climbing or descending. The VSI is usually calibrated in feet per minute.

Pilots use the VSI primarily during instrument flight to help them establish the correct rate of descent during approaches and to maintain steady rates of climb or descent.

How the VSI Works
The VSI is connected to the static system. Air pressure inside the instrument case decreases as the airplane climbs and increases as the airplane descends. Inside the case, a sealed wafer—much like the one used in the altimeter—expands and contracts as the pressure changes. A needle connected to the wafer rotates as the wafer expands and contracts, indicating a rate of climb or descent. The wafer also has a small, calibrated leak to allow the pressure in the wafer to equalize with the pressure in the case. When the pressure inside the wafer equals the pressure in the case, the needle returns to zero, indicating level flight.

Reading the VSI
You shouldn't use the VSI as the primary indicator of whether you're maintaining level flight. If the airplane begins to climb or descend, the VSI initially indicates the change in the proper direction. But the indicator lags the aircraft's movement and takes several seconds to catch up to the aircraft's actual rate of climb or descent. "Chasing" the needle on the VSI can make you feel like you're riding a roller coaster. Rely instead on the airspeed indicator and altimeter; they give quick, accurate indications of deviations from level flight. Then cross-check the VSI to verify that the airplane is climbing or descending at the rate you want.

Trim Control

The trim control is like the cruise control on a car. It helps you maintain a specific control position so that the airplane stays at a particular speed or attitude without making you hold constant pressure on the controls.

Most small aircraft have only one trim tab, located on the elevator. Larger aircraft usually have trim tabs on all the primary control surfaces: ailerons, rudder, and elevator.

How Trim Control Works

On small aircraft, the pilot moves the trim tab by rotating a wheel. The trim wheel is usually located below the engine controls or between the front seats. To apply nose-down trim, you rotate the wheel forward or up. To apply nose-up trim, you rotate the wheel backward or down.

Moving the trim wheel deflects the trim tab, which in turn moves the control surface in the opposite direction. To hold the elevator up, move the trim tab down.

What Trim Control Does

The elevator trim compensates for the changing force created by the flow of air over the elevator. When the airplane is properly trimmed for level-cruising flight, you can fly "hands off," applying only occasional, small control pressures to compensate for the occasional bump or minor change in heading. If you add power, however, the airplane speeds up, and the nose tends to rise because more air is flowing over the tail. To maintain altitude, you must apply forward pressure on the control yoke.

Holding that forward pressure for more than a few minutes is fatiguing and difficult. To compensate, apply down elevator trim until the pressure disappears.

If you reduce power, the airplane slows down, and the nose tends to fall because less air is flowing over the tail. To maintain altitude, you must apply back pressure on the yoke. To compensate, apply up elevator trim until the pressure disappears.

Trim for Speed

You can also think of the trim control as the airplane speed control. For example, suppose you set the engine controls for cruise power and trim the airplane so that it flies straight and level "hands off." The airspeed will soon stabilize at a particular speed. If you reduce power, the airplane slows down and the nose drops. If you leave the trim setting alone, the airplane will gradually stabilize in a descent at the cruise speed you established earlier. Likewise, if you add power, the nose will rise and the airplane will stabilize in a climb at about cruise speed.

Trim to Relieve Pressure, Not Steer

Remember to use the trim control only to relieve control pressure. Don't try to fly the airplane with the trim control. If you want to change the airplane's pitch attitude, apply the appropriate control pressure on the yoke, change the power setting if necessary, and then adjust the trim after the airplane stabilizes.

Flaps

Flaps change the shape of the wing, creating more lift and adding drag. These two effects allow you to fly at low airspeed and descend at a steep angle without building up speed. Flaps are not primary control surfaces—you don't use them to steer the airplane.

How Flaps Work

Flaps extend from the trailing edge of the wing. They increase the curvature—or camber—of the wing, which increases lift. They also hang down, increasing drag. Pilots extend flaps in increments, typically measured in degrees. On most airplanes, flaps move in five- or ten-degree increments through a range of 0 (fully retracted) to about 40 degrees (fully extended). The first few increments add more lift than drag. On many aircraft, extending 5 to 15 degrees of flaps helps the airplane take off more quickly.

As the flaps extend beyond about 20 degrees, they add more drag than lift. Flap settings of 20 degrees or higher are used for approach and landing.

Pitch Changes

As you extend or retract flaps, be prepared for changes in pitch. For example, as you extend flaps the nose tends to rise. You need to add forward pressure on the yoke to hold the nose on the horizon, and then use the trim control to relieve the forward pressure. Likewise, as you retract flaps, the nose tends to drop, so be ready to add back pressure on the yoke and then use trim to relieve the back pressure as the airplane stabilizes.

Types of Flaps

Flaps come in several varieties:

- **Plain flaps** are mounted on simple hinges. The trailing edge of the wing simply pivots downward. Plain flaps are common on small aircraft because they're simple and inexpensive.
- **Split flaps** hang down from the trailing edge of the wing, but the top surface of the wing doesn't move.

- **Slotted flaps** work much like plain flaps, but they leave a gap between the flap and the wing, allowing air to flow from the bottom of the wing over the top surface of the flap. This airflow dramatically increases lift at low airspeed.
- **Fowler flaps** are the most complicated and efficient arrangement. They move backward and downward as they're deployed, increasing both the wing's area and its curvature. Large jet aircraft usually have Fowler flaps.

Operating the Flaps

Flaps increase drag, but they aren't speed brakes. You can extend the flaps only when the airplane is flying at or below the maximum flap operating speed (indicated by the top of the white arc on the airspeed indicator). Deploying the flaps at higher speeds may cause structural damage.

In general, extend 5 to 10 degrees of flaps before takeoff to help the airplane lift off the runway quickly.
Remember, however, to follow the recommendations in each airplane flight manual. Retract the flaps after reaching a safe altitude and climb speed.

When preparing to land, extend the flaps in increments. A good rule of thumb is to extend about 10 degrees of flaps as you enter the traffic pattern or begin an approach. As you continue around the traffic pattern, add flaps in small increments. For example, in the Skyhawk SP, set 10 degrees of flaps on the downwind leg, set 20 degrees of flaps as you turn from downwind to base, and add flaps as necessary as you turn to final and approach the runway.

On light aircraft, flaps are operated with levers located between the seats. More complex aircraft may have flaps located as buttons on the control panel. Using key commands to extend flaps in increments, press **F5**. To extend flaps fully, press **F6**. To retract flaps in increments, press **F7**. To retract flaps fully, press **F8**.

Landing Gear

Landing gear are the wheels, struts, and other equipment that an aircraft uses to land or maneuver on the ground, and are also known as the "undercarriage." The two most common types of landing gear are "taildragger" and "tricycle" arrangements. On a taildragger, the front of the aircraft is supported on two wheels, while the tail rests on the ground on a skid of a tailwheel. With tricycle landing gear, the aircraft sits level on the ground with one nosewheel and two wheels farther back on the aircraft. In both taildragger and tricycle gear, the main landing gear are located nearest the airplane's center of gravity.

Main landing gear almost always come in pairs and are designed to withstand a greater landing shock than the more-fragile nosewheel or tailwheel.

Fixed landing gear cannot be retracted and lowered; controlling the landing gear position is not an option. But on retractable-gear aircraft, the gear can (and often must) be raised and, of course, lowered. Landing gear controls vary from aircraft to aircraft. To raise/lower the landing gear, press **G**.

Aircraft Information

Flight notes in the **Aircraft Information** articles explain everything you need to know about flying any airplane in the Flight Simulator fleet. You'll learn about each aircraft's handling characteristics, its unique display of gauges, and its signature arrangement of levers and switches.

Joe Scanlon