Airplane Controls

[Up] [Introduction] [Airplane Controls] [Airplane Aerodynamics] [Flight Instruments]
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Operating Airplane Control Surfaces

Pilots use control surfaces, also called flight controls, to move the airplane about its axes of motion. Control surfaces are actually airfoils that deflect air in one direction and cause the airplane to move in the opposite direction.

Primary and Secondary Controls

Control surfaces fall into two basic categories:

- Primary control surfaces include the ailerons, rudder, and elevator. Primary control surfaces are manipulated by the control yoke or stick and the rudder pedals. In small, general aviation airplanes, the control yoke and pedals are linked directly to the control surfaces by a system of cables and pulleys. In larger aircraft, hydraulic systems boost the pilot's control inputs.
- Secondary control surfaces include trim devices and flaps. Secondary surfaces are controlled either mechanically or electrically.The Axes of FlightEach of the three primary control surfaces moves an airplane about one of the three axes of flight. The ailerons bank or roll the airplane about its longitudinal axis. The rudder yaws the airplane about its vertical axis. The elevator moves the airplane about its lateral axis, changing the aircraft's pitch attitude.


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Elevators

[Up] [Ailerons] [Elevators] [Rudders] [Trim] [Flaps] [Controls Assignment]

Using the Elevator

The elevator is located on the trailing edge of the horizontal stabilizer. It controls pitch—movement about the airplane's lateral axis. Some airplanes have a control surface called a stabilator or "flying tail" instead of an elevator. A stabilator combines the horizontal stabilizer and the elevator into one unit.The elevator moves up and down when you apply back or forward pressure on the control yoke or stick.

Going Up?

The name "elevator" is a bit misleading. The elevator controls the aircraft's pitch attitude, but it doesn't really make the airplane climb or descend. An airplane needs **power** to climb. If you pull back on the yoke without adding power, the airplane will start to climb, but soon the speed begins decreasing and the airplane eventually stops climbing and stabilizes at a lower airspeed. If you raise the nose significantly without adding power, the airplane might even stall. **So in the end, the only thing that the elevator elevates is the aircraft's pitch attitude.** Watch the video again and pay particular attention to the operation of the elevators.

Rudders

[Up] [Ailerons] [Elevators] [Rudders] [Trim] [Flaps] [Controls Assignment]

Using the Rudder

The rudder controls yaw movement about an airplane's vertical axis. The rudder does not turn the airplane. Its primary functions are to maintain coordinated flight during turns and to counteract an airplane's left-turning tendency.

How It Works

The rudder is a hinged control surface attached to the trailing edge of the vertical stabilizer. You control the rudder by pressing pedals in the cockpit.

The Rudder in Action

When you bank the wings with the ailerons, drag from the aileron on the raised wing makes the airplane yaw in the direction opposite to the direction of turn. So when you turn the control yoke to the left, you should simultaneously apply pressure to the left rudder pedal to counteract this "adverse yaw."

Step on the Ball

During takeoff and flight at low airspeeds, such as during a climb, you must apply right rudder to counteract the left-turning tendency—the cumulative effect of several forces that tend to swing the airplane's nose to the left.The ball portion of the turn coordinator shows whether you've applied enough left or right rudder to compensate for yaw and the left-turning tendency. If the ball in the inclinometer moves to the left, add left rudder. If it moves to the right, add right rudder. Watch the video to see how rudders keep turns coordinated, learn the terms slip and skip, and, see how the turn coordinator works.

Move your mouse over this image to play the video

Trim

Using the 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. When using Flight Simulator, with Num Lock OFF, the 7 key trims the airplane nose down while the 1 key trims the airplane nose up. There is no rudder trim on Flight Simulator.

How It 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, the trim tab moves down.

What It 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 changes 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

[Up] [Ailerons] [Elevators] [Rudders] [Trim] [Flaps] [Controls Assignment]

Using the 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 They 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 5–15 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 more are used for approach and landing.

On Flight Simulator, either click the flap lever with the mouse, or key F5 to completely raise the flaps, F6 to raise flaps one notch, F7 to lower flaps one notch, and F8 to lower flaps all the way.

Pitch Changes

As you extend or retract flaps, be prepared for changes in pitch. For example, as you extend flaps in the Cessna Skylane RG, 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 in the Cessna, 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:

1. 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.

2. Split flaps hang down from the trailing edge of the wing, but the top surface of the wing doesn't move.
3. 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.
4. 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 5–10 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 Cessna Skylane RG, set 10 degrees of flaps on the downwind leg. Set 20 degrees of flaps as you turn from downwind to base. Add flaps as necessary as you turn to final and approach the runway.

Controls Assignment

[Up] [Ailerons] [Elevators] [Rudders] [Trim] [Flaps] [Controls Assignment]

Print this this sheet out for each student and answer the following questions:

NAME: ___________________________________

1. ________________________ are located at the ends of the wings. They control ________________, or roll, about an airplane's ________________________ axis.You control the ailerons by moving the control _________________ or ________________ left and right. The ailerons move in _____________________ directions.
2. Remember to ________________________ the yoke or stick when the airplane reaches the angle of ________________ you want.
3. The___________________ is located on the trailing edge of the __________________ stabilizer. It controls ___________________—movement about the airplane's____________________ axis. Some airplanes have a control surface called a ________________________ or "flying tail" instead of an elevator. A stabilator combines the ___________________ stabilizer and the __________________ into one unit.
4. The rudder controls _____________________ movement about an airplane's _______________ axis. The rudder does not __________________ the airplane. Its primary functions are to maintain _________________ flight during turns and to counteract an airplane's ______________-turning tendency.
5. The trim control is like the __________________ control on a car. It helps you maintain a specific control position so that the airplane stays at a particular ________________ or attitude without making you hold constant _____________________ on the controls.
6. Most small aircraft have only _______________ trim tab, located on the ____________________. Larger aircraft usually have trim tabs on all the primary control surfaces—________________, ________________, and elevator.
7. Flaps change the _____________________ of the wing, creating more __________________ and adding ____________________. These two effects allow you to fly at ______________ airspeed and descend at a ___________________ angle without building up __________________. Flaps are not _________________ control surfaces—you don't use them to __________________ the airplane.
8. Flaps extend from the ____________________ edge of the wing. They increase the __________________, or _________________________, of the wing, which increases lift. They also hang down, ______________________ drag. Pilots extend flaps in _________________, typically measured in _________________________. On most airplanes, flaps move in _______________- or ____________-degree increments through a range of 0 (fully ________________) to about 40 degrees (fully ________________).
9. The first few increments add more _____________ than drag. On many aircraft, extending 5–15 degrees of flaps helps the airplane ____________ ___________ more quickly.
10. As the flaps extend beyond about ____________ degrees, they add more _________________

than lift. Flap settings of ___________________ degrees or more are used for ___________________ and __________________

Flight Simulation Exercise:

Instructions: Start Flight Simulator and choose Fly Now after startup. You are at Chicago Meigs Field. Cycle the view (S) key and view your airplane from the town and outside. Cycle the view back to the cockpit. Make sure the NUM LOCK is off, release brakes, and add full throttle. Let the airplane take off by itself. Practice turns left and right. Remember to center the control surfaces after you have set the desired bank angle. Turn the airplane so it is straight. Using your pitch control move the aircraft's nose up and down. See how the speed will increase and decrease. Next move the trim control to see how that effects the pitch of the aircraft. Finally, set the flaps to different positions and see how the aircraft reacts. If you crash, take off again. After you have fly around, switch pilots, then typeX and watch the aircraft land itself at the nearest airport.

After you have completed this exercise, answer the following questions:

1. At what speed does the airplane become airborne when you let it take off by itself?
2. If you do not center your yoke or stick, what happens to the aircraft in a roll?
3. What happens to the aircraft if you use the elevator to pitch nose up too steeply?
4. With the plane level, how fast will it fly with flaps up? With flaps down?
5. Watch the auto land sequence, at what speed does the plan touch down? What is the flap setting?

Center of Gravity

[Up] [Four Forces of Flight] [How Wings Work] [Stalls] [Center of Gravity] [Climbs]
[Descents] [Instrument Intro.] [Straight and Level] [Turns] [Assignments]

Center of Gravity

Helicopters have a longitudinal and lateral center of gravity.

The center of gravity (CG) is the point from which an airplane would hang if it were suspended by a cable. It's also the point at which the longitudinal, vertical, and lateral axes intersect. To ensure that an airplane is stable in flight and responds properly to control inputs, you must load your airplane carefully to keep the CG within its design range.

The CG Seesaw

An empty airplane is like a seesaw. It balances on its center of gravity. Each item added to the airplane shifts the CG slightly. Objects placed forward of the original CG tend to tip the airplane forward. Objects placed behind the CG tend to tip it backward. The amount of tipping force or "moment" depends on the weight of the object and its "arm"—the distance between the object and an arbitrary reference line called the datum. In many airplanes the datum is the firewall that separates the engine compartment from the cockpit.

Managing the CG

Pilots manage the CG by controlling how weight is distributed in the aircraft cabin. In most small airplanes, the fuel tanks and seats are located close to the optimum CG, so the CG doesn't move much as fuel, people, and luggage are added. Nevertheless, before every flight a pilot must ensure that the CG of the loaded airplane falls between the forward and aft limits specified by the manufacturer.

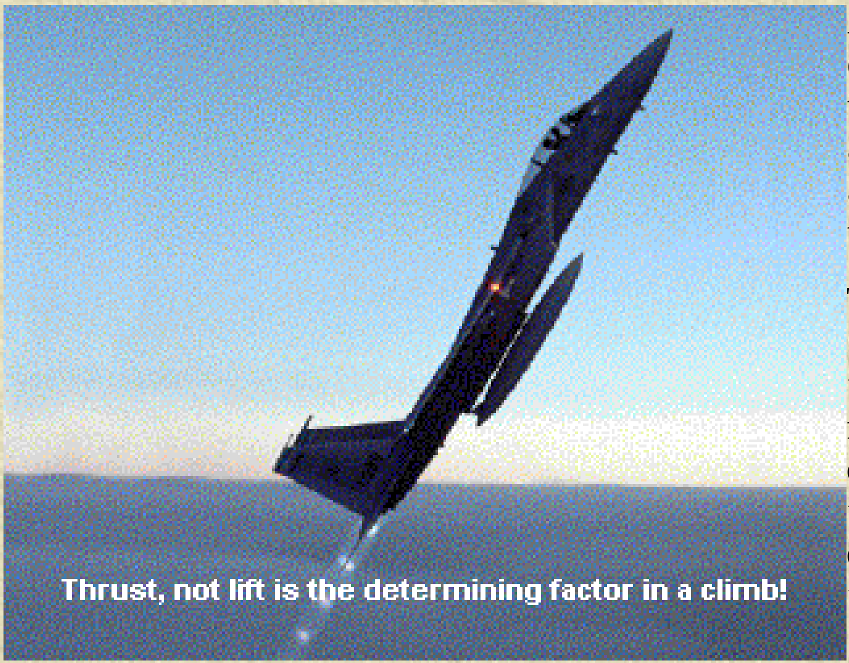
The CG and Stability

Keeping the CG within its design limits is critical because the position of the CG affects an airplane's stability, just as the position of a child on a seesaw changes the board's balance point.As the CG moves aft, an airplane becomes less stable in pitch. If the CG is too far aft, it may be impossible to lower the nose to recover from a stall.If the CG is too far forward, the airplane is "nose heavy," making it difficult or impossible to flare during the final phase of landing.

Climbs

[Up] [Four Forces of Flight] [How Wings Work] [Stalls] [Center of Gravity] [Climbs]
[Descents] [Instrument Intro.] [Straight and Level] [Turns] [Assignments]

Climbs



An airplane climbs when its engine or engines produce more power (thrust) than is required to maintain level flight at a particular weight and angle of attack. Airplanes do not climb because the wings generate more lift.

This point may seem confusing, but it makes sense if you remember that whenever an airplane is in steady-state flight—for example, a climb at a constant airspeed and rate—lift equals weight. If lift exceeded weight during a climb, an airplane would accelerate upward.

A Steady Pull

During a steady-state climb, the component of lift acting vertically toward the ground is actually slightly less than weight, because when the airplane is in a climb attitude, some of the lift vector is directed rearward, not upward. So a climb is caused by the thrust vector pulling the airplane up at an angle. Imagine someone tugging a sled up a hill, and you'll get the general idea.

More Power

If power determines rate of climb, then it's apparent that the throttle, not the control yoke, is the primary "up-down" control in an airplane. Pulling back on the yoke to increase an airplane's pitch attitude usually does start a climb. But an increase in induced drag quickly counteracts the boost in lift, and the airplane, having gained a little altitude, settles into level flight at a lower airspeed or into a slow, constant-rate climb.

To establish and maintain a steady rate of climb, excess thrust must be available, and you must add power.

Try It

If discussions of lift vectors and power seem a little confusing, you can see the principles at work in Flight Simulator. Try the lesson "Climbs, Turns, and Descents."

Descents

Many people assume that to descend you simply push forward on the control yoke or stick to point the airplane's nose down. In fact, the pilot must adjust both pitch and power to establish a stable descent at a constant airspeed.

You can descend with the airplane in a level or even nose-up attitude. Remember that if you hold an airplane's pitch attitude constant, thrust—power—determines whether the airplane maintains altitude, climbs, or descends. If the engine produces more thrust than is required to maintain level flight, the airplane climbs. It descends if you reduce power.

As a rule of thumb, limit descents in unpressurized airplanes to about 500 ft / min (152 m / min). This rate allows passenger's ears to adjust to pressure changes during the descent.

Spend some time with the airplanes in Flight Simulator to familiarize yourself with the performance that you can expect at different power settings and airspeeds. Remember, the lower the power, the greater the rate of descent. Also practice stopping a descent by smoothly adding power.

Aerodynamics 2

[Up] [Aerodynamics 1] [Aerodynamics 2] [Aerodynamics 3] [Quiz] [Video Questions]

Name: ____

Review the pages on Center of Gravity, Climbs, and Descents, then try to answer these questions, then check your work.

CENTER OF GRAVITY

1. The ____________________ of gravity (CG) is the ________________________ from which an airplane would hang if it were suspended by a cable. It's also the point at which the ______________________, vertical, and _______________________ axes _______________________________.
2. To ensure that an airplane is ___________________________ in flight and responds properly to control inputs, you must load your airplane carefully to keep the CG within its design range.
3. Objects placed _____________________________ of the original CG tend to tip the airplane forward. Objects placed behind the CG tend to tip it ___________________________. The amount of ________________ ______________________ or "moment" depends on the weight of the object and its "_______________"—the distance between the object and an arbitrary reference line called the _____________________. In many airplanes the datum is the _____________________ that separates the engine compartment from the cockpit.
4. Before every flight a pilot must ensure that the CG of the loaded airplane falls between the ______________________ and ________________ limits specified by the ____________________.
5. As the CG moves aft, an airplane becomes less _____________________ in ________________________. If the CG is too far aft, it may be impossible to _________________________ the nose to recover from a stall.If the CG is too far ____, the airplane is "nose heavy," making it difficult or impossible to flare during the final phase of _____________________

CLIMBS

1. An airplane climbs when its engine or engines produce more _______________________ (thrust) than is required to maintain level flight at a particular weight and angle of attack. Airplanes do not _____________________ because the _______________________ generate more lift.
2. If power determines rate of climb, then it's apparent that the ____________________, not the control yoke, is the primary "up-down" control in an airplane. Pulling back on the _______________________ to increase an airplane's pitch attitude usually does ________________________ a climb. But an increase in ______________________ drag quickly counteracts the boost in lift.
3. **Try It** -- If discussions of lift vectors and power seem a little confusing, you can see the principles at work in Flight Simulator. Try the lesson "Climbs, Turns, and Descents." You will redo this lesson later during your formal simulator exercises but it is a good iontroduction now. You will need headsets to accomplish this exercise.

DESCENTS

1. Many people assume that to descend you simply push ______________________ on the control yoke or stick to point the airplane's nose down. In fact, the pilot must adjust both _____________________ and __________________ to establish a stable descent at a constant ______________________.
2. You can descend with the airplane in a ________________________ or even nose-up _______________________. Remember that if you hold an airplane's pitch attitude constant, __________________—___________________—determines whether the airplane maintains altitude, climbs, or descends. If the engine produces more __________________________ than is required to maintain level flight, the airplane _______________________. It __________________________ if you reduce power.
3. As a rule of thumb, limit descents in unpressurized airplanes to about _______________________ ft/min (152 m/min). This rate allows passenger's __________________________ to adjust to pressure changes during the descent.
4. Spend some time with the airplanes in Flight Simulator to familiarize yourself with the performance that you can expect at different power settings and airspeeds. Remember, the lower the power, the greater the rate of descent. Also practice stopping a descent by smoothly adding power.

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Instrument Intro.

[Up] [Four Forces of Flight] [How Wings Work] [Stalls] [Center of Gravity] [Climbs]
[Descents] [Instrument Intro.] [Straight and Level] [Turns] [Assignments]

Instrument Overview

You should be familiar with the basic instruments before completing your flight exercises. Review the diagram below and click on the labeled instruments to findout more about how each one works.

airspeed indicator

The instrument that displays an aircraft's speed relative to the air in which it is moving. Most modern aircraft have airspeed indicators calibrated in knots or in Mach number.

attitude indicator (artificial horizon)

The instrument that shows the aircraft's pitch and bank attitudes with respect to the ground. Pilots use the attitude indicator, sometimes called the "artificial horizon," when the true horizon isn't visible.

altimeter

The instrument that shows the aircraft's altitude above sea-level adjusted for atmospheric pressure.

turn coordinator

One of the six primary flight instruments, the turn coordinator shows the rate of turn and the quality of a turn—whether the aircraft is slipping, skidding, or in a balanced turn. In most modern light aircraft the turn coordinator has replaced the "needle and ball," which served the same function.

heading indicator

A gyro instrument that accurately and quickly shows changes in aircraft heading. Sometimes called the "directional gyro" or "DG." Because the heading indicator is driven by a gyro, it provides smooth, precise indication of heading or turns. The compass, which is subject to acceleration, deceleration, dip, and other errors, often oscillates, leads, or lags a turn. However, because gyros are affected by precession, the pilot must periodically set the heading indicator to correspond to the compass (unless the heading indicator is "slaved" electronically to the compass).

vertical speed indicator (VSI)

One of the six basic flight instruments, the vertical speed indicator shows an aircraft's rate of climb or descent, usually in feet per minute. Also known as the rate of climb indicator (RCI) or vertical velocity indicator (VVI). Large aircraft are typically equipped with a sophisticated version of this instrument, called an "instantaneous vertical speed indicator" (IVSI) that reacts immediately to changes in altitude.

tachometer

The instrument that shows the speed of rotation of the engine. It is marked in revolutions per minute (rpm). Engines that produce more than about 180 hp usually have constant speed propellers that can change the blade angle to make more efficient use of engine power throughout a wide range of airspeeds.

Straight and Level

[Up] [Four Forces of Flight] [How Wings Work] [Stalls] [Center of Gravity] [Climbs]
[Descents] [Instrument Intro.] [Straight and Level] [Turns] [Assignments]

Straight-and-Level Flight

Flying straight and level may look simple, but it's actually one of the more difficult flight maneuvers to master. Because pilots want to control airplanes, they overdo it most of the time and interfere with the airplane's basic stability. Like a balancing act, straight-and-level flight requires that you make smooth, small corrections to keep the airplane from wobbling all over the sky.

Divide and Conquer

It's best to break down the task of establishing and maintaining straight-and-level flight into two parts:

1. Holding a constant altitude and airspeed. This part requires that the pairs of opposing forces—lift and weight, thrust and drag—remain balanced.
2. Holding a constant heading. This part requires you to monitor the heading indicator and turn coordinator to hold the wings level, maintain coordinated flight, and correct minor deviations in heading.

Pitch + Power = Performance

Fortunately, there's a simple rule that can help you handle the first task.The basic equation Pitch + Power = Performance is a pilot's golden rule. It means simply that if you establish a specific pitch attitude and set power at a constant level, the airplane will fly at a particular airspeed and either maintain level flight or climb or descend at a constant rate.

For example, to set up a typical cruise configuration at 3,000 ft (915 m) in the Cessna, set the throttle to deliver about 2,300 RPM. To maintain level flight, adjust the pitch attitude so that the miniature airplane on the attitude indicator is level with the horizon. The top of the instrument panel is below the real horizon when you look out the front window.

If you keep the nose from rising or falling and leave the power set at 2,300 RPM, the Cessna will maintain altitude and cruise at about 120 knots indicated airspeed.

If the airplane starts to gain or lose altitude, make small, smooth corrections to the pitch attitude and adjust the elevator trim so eventually the airplane flies "hands off."

Keeping It Straight

Maintaining a constant heading is a little easier than holding altitude, but you still need to keep a close eye on the flight instruments. Check the heading indicator frequently to make sure the nose stays pointed in the right direction. Cross-check the turn coordinator. If the wings on the miniature airplane are level, the airplane isn't turning. If the wings aren't level, you need to apply smooth, slight pressure on the ailerons and rudder to level the wings and maintain coordinated flight.

Turns

Turns

An airplane turns because some of the lift that the wings produce push it "around the corner," not because the rudder swings the nose left or right. In theory, you could skid an airplane through a turn with the rudder, but that's an inefficient (and uncomfortable) way to change direction. That's why airplanes bank to turn.

The Horizontal Component of Lift

Banking the wings with the ailerons deflects some of the lift that the wings produce sideways. This part of the airplane's total lift is called the horizontal component of lift. It's this force that pushes an airplane around in a turn.

Adverse Yaw

Banking the wings changes the angle of attack of each wing. And the deflection of ailerons changes the drag of each wing. These two factors create a tendency for the airplane to yaw opposite the turn. That is, if you bank to the left, the airplane's nose tends to swing toward the right.

To compensate for this effect, called "adverse yaw," you must apply rudder pressure in the same direction as the turn. As you bank left, you should add a little left rudder, and vice-versa.

Loss of Lift

Because some of the lift is deflected sideways in a turn, to maintain altitude you must increase the total lift that the wings produce. To increase lift, you must increase the angle of attack, so add a little up elevator pressure as you roll into a turn. The steeper the turn, the more up elevator pressure you must add. In steeply banked turns of 45 degrees or more, you must add considerable up elevator pressure (and probably add power, as well) to maintain altitude. Just remember to relax that back pressure on the joystick or control yoke as you roll out of the turn.