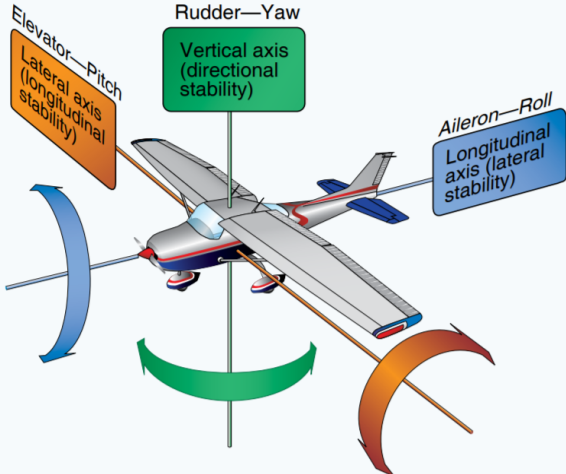


Airplane Flight Controls

Objective	
<p>To ensure the applicant learns the purpose and use of the primary and secondary flight controls.</p>	
Purpose	
<p>The flight controls are what makes pilots. They are the mechanism by which airplanes move in controlled flight. This lesson will introduce new pilots to the various types of flight controls, and their purpose.</p>	Schedule
<ul style="list-style-type: none"> ● Ground Lesson: 15 minutes ● Student Q&A: 10 minutes 	Equipment <ul style="list-style-type: none"> ● Whiteboard / Markers (optional) ● Model Airplane (optional)
Student Actions	Instructor Actions
<ul style="list-style-type: none"> ● Ask any questions, receive study material for the next lesson. ● Watch linked video. ● Review listed references. 	<ul style="list-style-type: none"> ● Deliver the ground lesson (below). ● Answer student questions.
Completion Standards	
<ul style="list-style-type: none"> ● Student can explain the purpose and use of the primary and secondary flight controls, as well as the role of the ailerons and rudder in turns. 	

References

- ERAUSpecialVFR - “Aircraft Systems - 02 - Flight Controls”
 - YouTube - https://www.youtube.com/watch?v=WhQ8Ai4fa_Q
- FAA-H-8083-25B (Pilot's Handbook of Aeronautical Knowledge) - Chapter 6, Page 2-3 [Primary Flight Controls/Axes of Rotation], Chapter 6, Page 3-5 [Ailerons], Chapter 6, Page 5-7 [Elevator], Chapter 6, Page 8 [Rudder], Chapter 6, Page 8-10 [Secondary Flight Controls], Chapter 6, Page 10-12 [Trim Systems]
- FAA-S-8081-6D (CFI PTS) - Area II Task E

Ground Lesson Outline

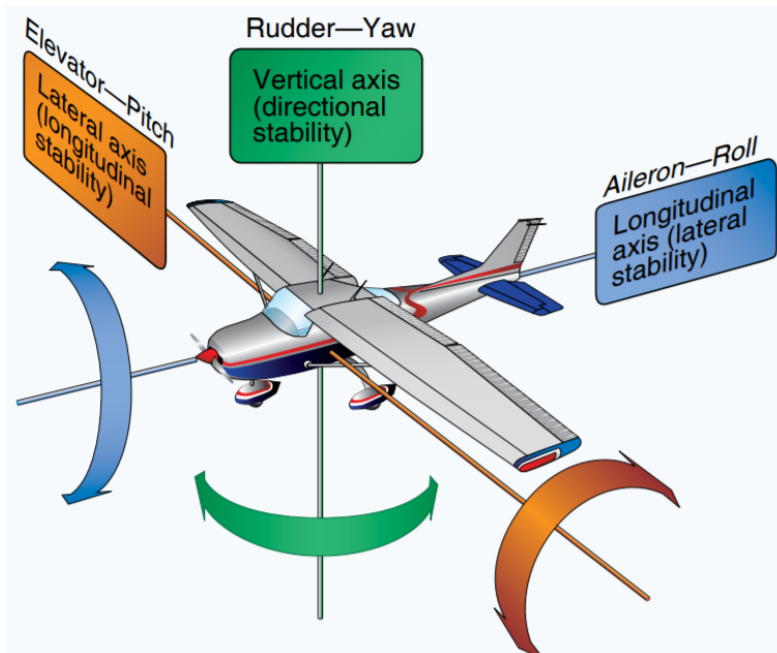
- Flying in Three Dimensions
 - Yaw, Pitch, Roll
 - Airplanes turn with roll (bank)
- The Primary Flight Controls
 - Yoke/Stick, Control Cables
 - Ailerons, Elevator, Rudder
- The Secondary Flight Controls
 - Flaps, Spoilers, Leading Edge Devices
- Elevator Trim
 - Trim Wheel
- Rudder Trim Devices
 - Rudder Trim, Ground Adjustable Tabs
- Proper Yoke Grip and Overcontrolling
- Role of the Rudder in Turning Flight
 - Weathervaning
 - Two Phases of Turning Flight
 - Banking - Adverse Yaw
 - Turning - Tail Position Rear of CG
 - Coordinated Flight

Common Errors

- **Lack of understanding of the purpose and usage of the rudder.**
- Lack of understanding of the purpose and usage of trim devices.

Ground Lesson Content

- **Flying in Three Dimensions** - Unlike cars, which turn only left or right in two dimensions, airplanes can move in three dimensions, and rotate around 3 separate axes. The orientation of the airplane is called the *attitude*. The 3 axes of flight are:
 - **Yaw** - Yaw is the familiar 'turning' left and right. Rotating around the *vertical axis*.
 - **Pitch** - *Pitch* is the up and down axis. The airplane is rotating around the *lateral axis*, and the nose will be pointing 'uphill' or 'downhill'.
 - **Roll** - *Roll* is somewhat unique to airplanes. **Roll is also often called *bank***. The airplane is rotating around the *longitudinal axis*. There is no real similarity to cars in this dimension, but it can be thought of as the airplane *leaning* left or right.



- Airplanes climb and descend in part by increasing or decreasing pitch, however, somewhat unexpectedly, **airplanes do not turn by simply changing yaw. Airplanes turn by banking towards the direction of the turn**, which directs the wings lift force to the side. The vertical tail surface keeps the airplane aligned with the direction of travel, causing the airplane to yaw. This is similar to how the fins or feathers on a dart or arrow keep it flying in the direction it is thrown.



- **The Primary Flight Controls**

- Airplanes are commonly designed with 3 *primary* flight controls, which are connected to a *control yoke*, or *stick* by a series of *control cables* or mechanical linkages like *pushrods*:
 - **Ailerons** - Ailerons move the airplane around its *Roll* axis. **The angle of roll is called the *bank angle* and pilots use the airplane to *bank* in the direction they wish to**

turn. Most airplanes control the ailerons with a yoke, which is similar to a steering wheel. Turning the wheel left or right causes the airplane to bank left or right.

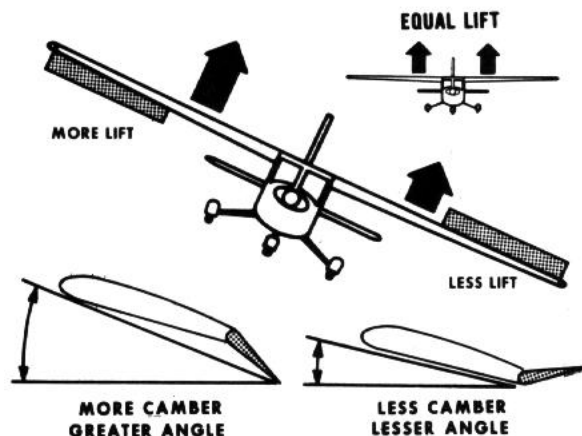
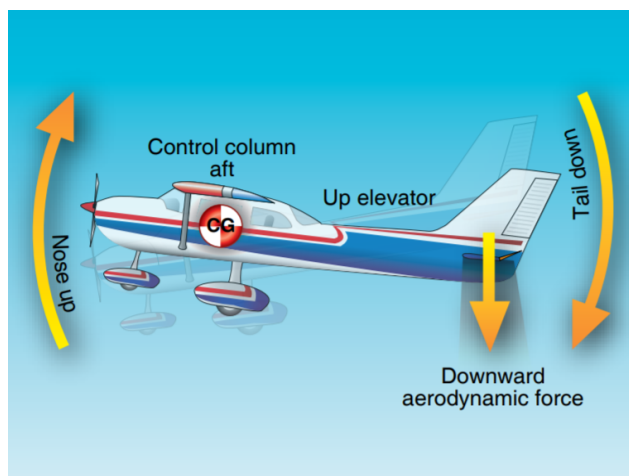
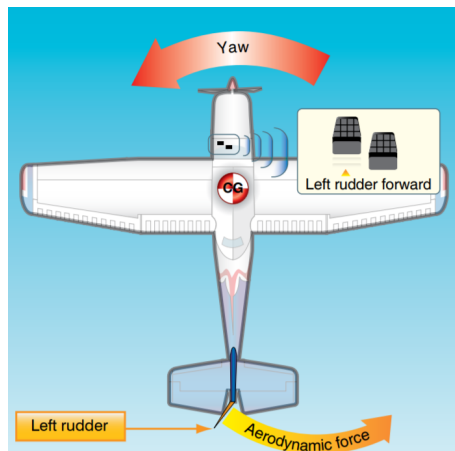


Figure 4-3 Forces Exerted by Ailerons

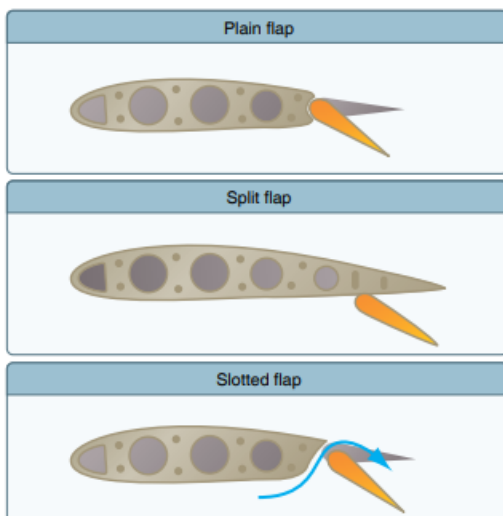
- Elevator** - The Elevator moves the airplane around its *Pitch* axis. Pilots can initiate a climb or descent by pulling back or pushing forward on the yoke, respectively. Most new pilots are already familiar with this concept from TV and movies, e.g. “pull up” to pitch up.



- Rudder** - The Rudder moves the airplane around its *Yaw* axis. The rudder is a very mysterious control for most new pilots, because **it is not used to turn the airplane**, as one might expect. The sole purpose of the rudder is to aid the airplane in maintaining a proper (called *coordinated*) flight path during turns made with the ailerons (bank).



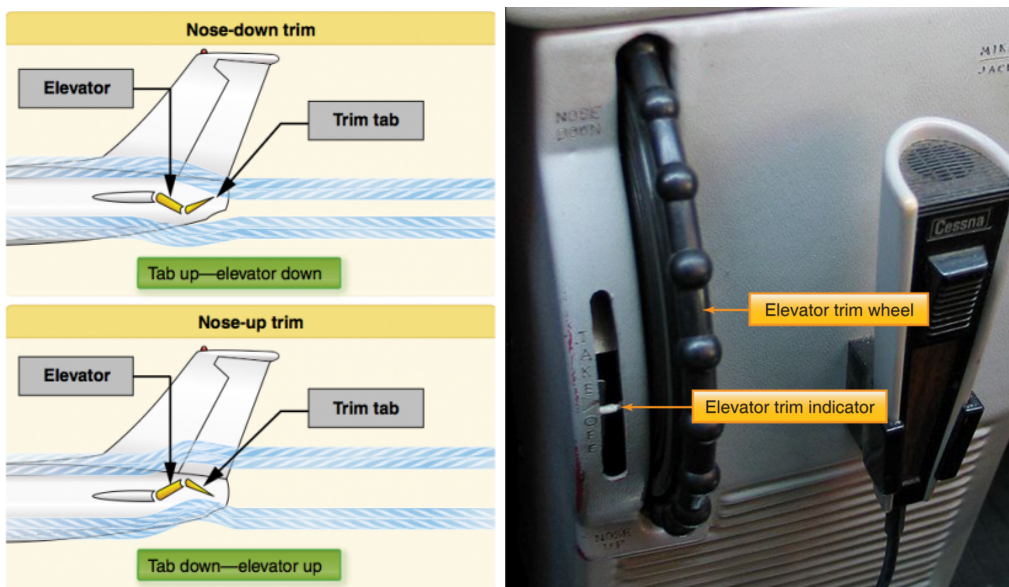
- **Secondary Flight Controls** - Airplanes are also equipped with a variety of *secondary flight controls*, which to some degree affect the aerodynamics of the airplane, but some are typically used only in certain situations.
 - **Trim** - Trim devices are a form of secondary flight controls which will be discussed separately, but their primary function is to alleviate control pressures felt in flight.
 - **Flaps** - The most common secondary flight control is the *flaps*, which simply increase the *camber* of the wing, and sometimes lengthen the *chord line* (See the lesson on *Basic Aerodynamics*), in order to provide more lift and lower the stall speed, while creating more drag to enable a steeper descent for landing. Flaps are usually controlled with a lever or switch in the cockpit, and usually have multiple positions, corresponding to varying degrees of deflection.



- **Spoilers** - Large, fast, and efficient airplanes often include *spoilers* which are devices used to deliberately create drag and 'spoil' lift. These are not normally found on small airplanes.
 - **Leading Edge Devices** - Large airplanes also often include leading edge devices, often *slots*, *leading edge flaps* or *slats*, which also increase lift and lower stall speed by delaying airflow detachment and stall at low airspeeds. Some small airplanes, typically used for very short takeoff and landing roles, are equipped with slots or slats, but these are not common on training airplanes.
- **The Elevator Trim** - In order to hold the nose the proper distance from the horizon and maintain altitude, **new pilots often discover that it may require continuous forwards or backwards elevator**

pressure on the control yoke. This is not only uncomfortable, it also requires pilots to devote more attention to maintaining straight and level flight and prevents them from multitasking effectively. There is another, *secondary* flight control, called *pitch trim* or *elevator trim*. These terms are interchangeable, and refer to a control wheel (**the *trim wheel***) which can be used to relieve these control pressures.

- The trim mechanism is different on different airplanes, but it usually consists of a small tab, called the *trim tab* on the elevator control surface itself. The trim tab services to 'rebalance' the neutral position of the elevator control and help maintain low control pressures.
- The trim tab is moved with the *trim wheel*, which when rolled forward moves the trim *nose down*, and when rolled rearwards, moves the trim *nose up*.



- **Rudder Trim Devices** - Even during cruise flight, airplanes are subject to left-turning tendencies because the airplane is almost never flying at 0 angle of attack, and the spiraling slipstream is continuously pushing the nose slightly to the left. This results in **the airplane naturally flying somewhat uncoordinated, and would necessitate the pilot flying with slight right rudder pressure at all times**, a very uncomfortable situation. To alleviate this, there are a couple types of rudder trim that some airplanes provide:

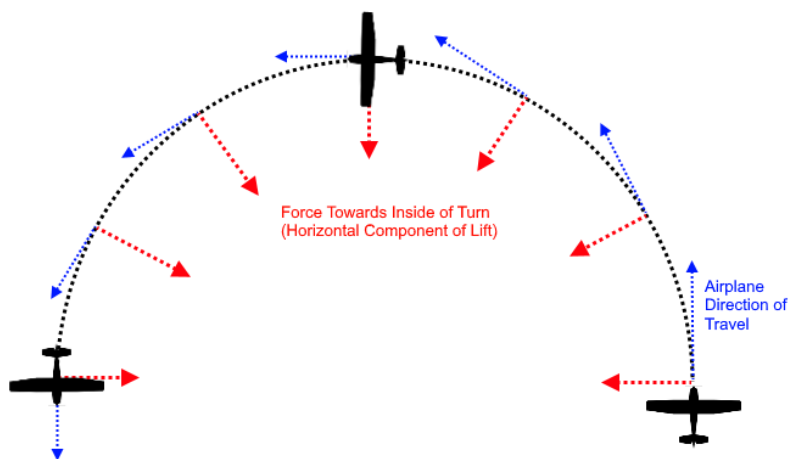
- **Rudder Trim** - Rudder trim is just like elevator trim, in that there is usually a wheel which is turned to alleviate the rudder control forces. Some airplanes have a rudder trim tab on the rudder, but it is also commonly just an adjustment on a spring or cable which applies some force to the rudder pedals directly.
- **Ground Adjustable Rudder Tabs** - Most small airplanes are also equipped with a *ground adjustable tab* on the rudder, which can be literally bent to provide a slight amount of rudder deflection. **This is a trial and error process and should not be done except by the airplane owner or maintenance personnel!**

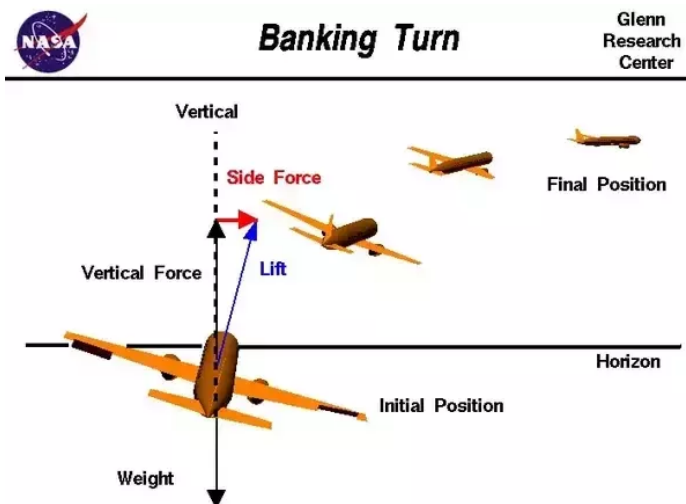


- **Proper Yoke Grip and Overcontrolling** - Proper control of the airplane requires that pilots avoid *overcontrolling*. Unlike driving a car, which requires large movements of the wheel, flying an airplane rarely requires large movements, or a lot of force on the controls.
 - Pilots who grip the yoke tightly with both hands often struggle with maintaining straight and level flight or making smooth turns or other maneuvers. Pilots coping with turbulent or bumpy conditions often make the bumpiness *worse* by holding the yoke too firmly.
 - In most situations, pilots should attempt to relax, as **the airplane can be flown mostly with control pressures, rather than control movements**. A one-handed, light grip on the yoke also frees the pilots other hand for manipulating the throttle, or adjusting the radios, etc.

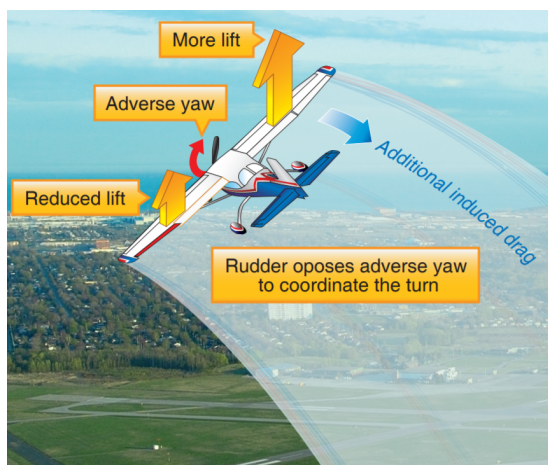


- **Role of the Rudder in Turning Flight** - New pilots discover quickly and intuitively that turning an airplane requires banking, however the rudder also plays a very important role. In order to understand why, it is necessary to briefly describe the aerodynamics involved.
 - **Weathervaning** - As the airplane flies around the turn, there is a horizontal component of lift, which is a force directed towards the center of the turn, and a vertical component of lift, which acts upward and opposes gravity. **As the airplane begins to move sideways, the relative wind strikes the vertical tail surfaces, and causes it to rotate towards the wind, just as in a weather vane.** This keeps the nose of the airplane pointed towards the relative wind, producing a yaw in the direction of the bank.





- **Two 'Phases' of Turning Flight** - The above explanation, however, is oversimplified. There are two distinct phases that an airplane goes through in turning flight:
 - **Banking** - Although banks *cause* airplanes to turn, banking by itself is not a turn. When banking, the airplane uses its ailerons to roll the airplane around the longitudinal axis. The *outside* (away from the turn) wing aileron lowers, producing a higher angle of attack and more lift, and the *inside* wing aileron raises, producing a lower angle of attack and less lift. **This increase in lift on the outside wing causes that wing to produce more drag on that side, which actually initially causes the airplane to turn away from the intended direction of turn!** This tendency is called *adverse yaw*. **Pilots should correct for adverse yaw by using the rudder pedals to counteract it whenever they use the ailerons.**



- **Turning** - Once the airplane is established in a bank, the effects of adverse yaw are mostly no longer present since the ailerons are neutral or nearly neutral. **However, an airplane banked towards a turn will still not by itself fly perfectly in line with the relative wind!** This is because, due to the curve flight path, the relative wind is angled slightly differently at the front and rear of the airplane. The larger, vertical tail surface will tend to assume an orientation that is aligned with the wind, but this causes the nose of the airplane to actually point slightly outside of the turn! This is called a *slipping turn*. A turn where the nose points to the inside of the turn is called a *skidding turn*, and is fairly

similar to a car skidding during a turn. (The turn is 'too flat', with not enough bank angle for the rate of turn) **Both slipping and skidding turns are undesirable!**

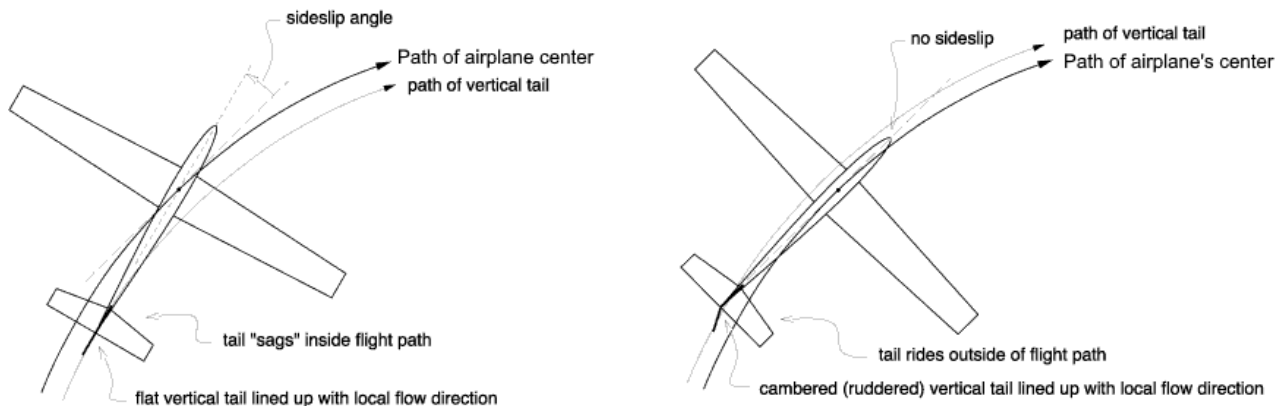
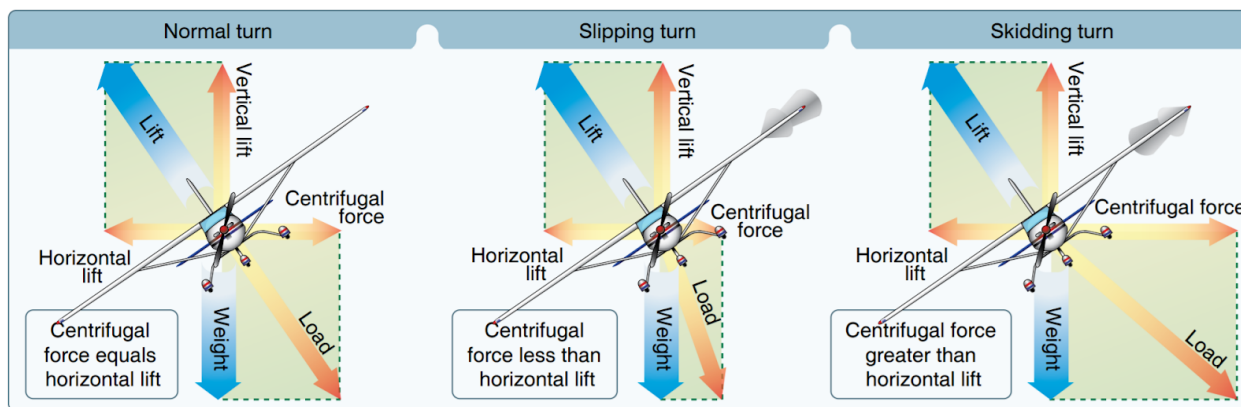


Figure 1a. Zero rudder deflection in sustained tight turn produces sideslip. Figure 1b. Rudder deflection for zero sideslip.



- **Coordinated Flight** - In order to correct for these tendencies, pilots must use the rudder pedals to manage the amount of sideslip or skidding as the pilot rolls the airplane or maintains a turn. Flying with no skid or sideslip is called *coordinated flight*. The instrument which gives the pilot direct information about this is called the *turn coordinator*, however **pilots can also learn to sense when they are being pushed away from the turn or towards the turn.**

