Slow Flight

Objective

To ensure the applicant learns the purpose of and can exhibit a clear understanding of the Slow Flight maneuver and how to perform the maneuver properly.

Purpose

Slow Flight involves maneuvering at low airspeeds, as during takeoff, landing, and go-arounds. It introduces pilots to the strange aircraft behavior 'on the back side of the power curve', and develops skills at maneuvering the airplane safely at the edge of the flight envelope.

Schedule

- **Ground Lesson**: 15 minutes
- Initial
  - **Flight 1**: 40 minutes - *Introduction to Maneuver*
  - **Flight 2**: 50 minutes - *Improve Proficiency (Dual)*
- Solo
  - **Flight 3**: 30 minutes - *Improve Proficiency*
- Pre-Checkride
  - **Flight 4**: 20 minutes - *Demonstrate Proficiency*
- **Debrief**: 10 minutes (*per flight*)

Equipment

- Airplane Checklist
- Whiteboard / Markers (optional)
- Model Airplane (optional)

Student Actions

- Ask any questions, receive study material for the next lesson.
- Watch linked video.
- Review listed references.

Instructor Actions

- Deliver the ground lesson (below).
- Demonstrate the maneuver in flight.
- Debrief after each flight.

Completion Standards

- **Ground**: Student can explain the purpose of the maneuver and how to execute it properly.
  - Can explain the 'region of reverse command', left-turning tendencies, factors that affect stall speed.
- **Flight**: Student can perform the maneuver to the applicable ACS standards.
  - Establishes level, coordinated flight in the specified configuration just above the stall warning.
  - **Private Pilot**: Holds altitude ±100 feet, airspeed +10/-0 knots, bank ±10°, headings ±10°.
  - **Commercial/CFI**: Holds altitude ±50 feet, airspeed +5/-0 knots, bank ±5°, headings ±10°.
  - Recovers to normal cruise flight.
  - See expanded Completion Standards below.

References

- MZeroA Flight Training - “ACS Slow Flight”
    - YouTube - https://www.youtube.com/watch?v=t8wEhhWQISg
- FAA-H-8083-3B (Airplane Flying Handbook) - Chapter 3, Page 10 [Trim Control], Chapter 3, Page 10-12 [Level Turns], Chapter 4, Page 2 [Coordinated Flight/Angle of Attack], Chapter 4, Page 3-5 [Slow Flight], Chapter 4, Page 5-6 [Stalls/Stall Recognition/Stall Recovery]
- FAA-H-8083-25B (Pilot’s Handbook of Aeronautical Knowledge) - Chapter 5, Page 2-4 [Thrust, Lift, and Angle of Attack], Chapter 5, Page 5 [Lift/Drag Ratio], Chapter 5, Page 7 [Induced Drag], Chapter 5, Page 22 [Forces in Turns], Chapter 5, Page 25-26 [Stalls], Chapter 5, Page 30-33 [Left Turning Tendencies], Chapter 5, Page 34 [Load Factors and Stalling Speeds], Chapter 5, Page 37 [Vg Diagram]
- FAA-S-ACS-6B (Private Pilot ACS) - Area VII Task A
- FAA-S-ACS-7A (Commercial Pilot ACS) - Area VII Task A
- FAA-S-8081-6D (CFI PTS) - Area XI Task A

Ground Lesson Outline

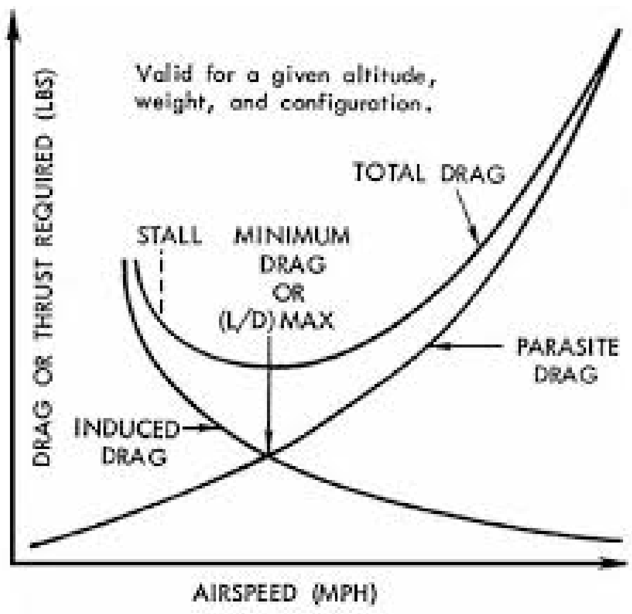
- What is ‘Slow Flight’?
    - Mushy Controls, Reverse Command, High Power Setting, Instability
- Behind the Power Curve
    - Minimum Drag Speed (Best Glide) / Speed Instability
    - Climbs require excess power
- Left Turning Tendencies
    - Torque Reaction
    - Spiraling Slipstream
    - P-Factor
- Bank Angle and Load Factor
- Factors that affect stall speed
    - Load factor, CG, Weight, Coordination
- Airspeed Control, Trim, and Coordination
- Airplane Configurations
    - Clean, Dirty (Landing)
- Safety considerations
    - Use of checklists
    - Visual traffic scanning
- Maneuver Description - step-by-step
    - Entry position, airspeed, etc.
- Expanded Completion Standards

Common Errors

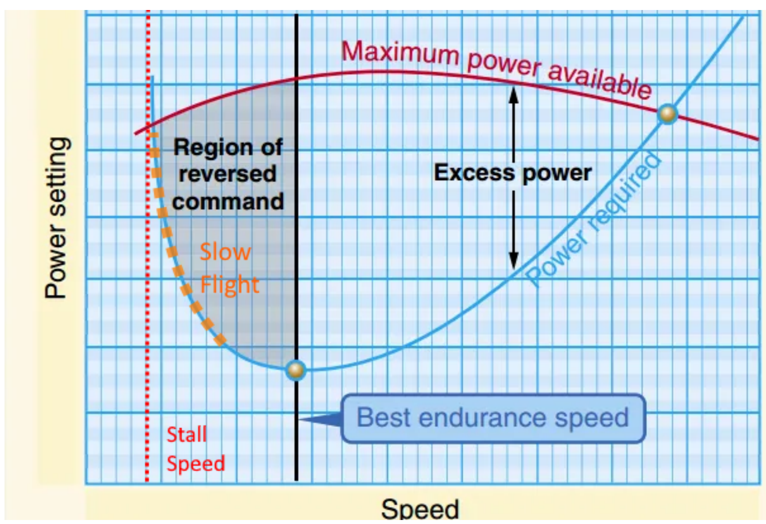
- Failure to establish specified configuration.
- **Improper entry technique.**
- **Failure to establish and maintain the specified airspeed.**
- **Excessive variations of altitude and heading when a constant altitude and heading are specified.**
- Uncoordinated use of flight controls.
- **Improper correction for torque effect.**
- Improper trim technique.
- Unintentional stalls.
- Inappropriate removal of hand from throttles.

Ground Lesson Content

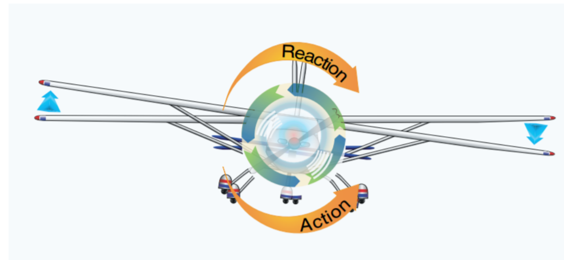
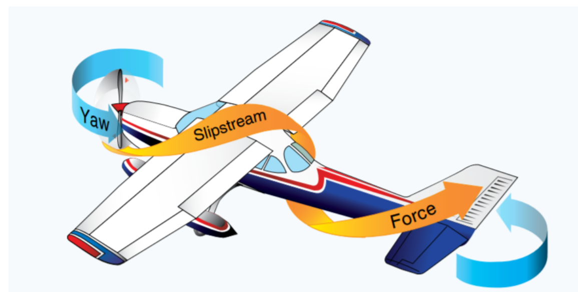
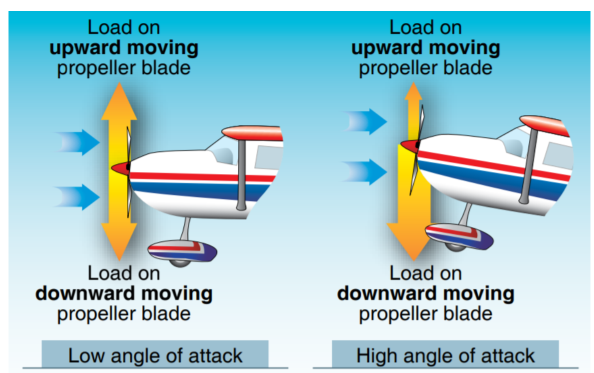
- **What is 'Slow Flight'?** - Aside from the plain meaning, *slow flight* refers specifically to flight which occurs below the 'normal' operating speeds of an airplane. **These speeds are often encountered during takeoff, landing, or a go-around**, for example. Airplanes tend to perform and handle quite differently, and in many cases counter-intuitively during slow flight:
    - **Mushy Controls** - Particularly noticeable is that it requires a lot of aileron input to roll the airplane. Changing pitch also requires large movements of the elevator. There is a considerable 'sloppiness' or 'mushiness' to the controls. The control yoke behaves almost as if there is a large 'dead zone' in the middle where small movements make very little difference.
    - **Reverse Command** - The airplane will behave somewhat paradoxically-- pulling back on the elevator will actually result in the airplane very briefly climbing before descending steadily. Pulling further back will make the airplane descend even more steeply.
    - **High Power Setting** - Compared to slightly higher airspeeds, the airplane requires considerably more engine power to maintain altitude.
    - **Instability** - The airplane will feel less stable. It will require continuous pitch and power correction to maintain altitude and airspeed. It will require continuous management of the bank angle and rudder input to keep the airplane level and the ball centered. When performed very slowly, the airplane may even feel 'bumpy', which is an early warning of an aerodynamic stall..
- **Behind the Power Curve** - When flying at low airspeeds, the airplane is said to be *behind the power curve*. The power curve represents the amount of power required to maintain a given airspeed without accelerating. This is at a minimum when the amount of total drag is at a minimum.
    - **Minimum Drag Speed** - Airspeeds below the minimum drag speed (also known as the *best glide speed*) are sometimes called the *region of reverse command*. This is because any increase in pitch, and therefore angle of attack, will result in more total drag, which will *increase* the rate of descent.
        - *Why?* Refer to the total drag curve. As the speed is reduced below the minimum drag speed, in order to maintain altitude, the airplane must fly at a higher angle of attack, resulting in increased *induced drag*, which is the inherent drag produced by the generation of lift. This means that **for any airspeed below minimum drag speed, flying at slower airspeeds actually requires *more* power to overcome the increased drag.** This creates an unstable situation and is referred to as *speed instability.*



- **Climbs Require Excess Power** - Because of this 'inversion' of speed vs power required, the airplane cannot simply be pitched up to increase altitude. Recall that airplanes climb because of *excess power*. When behind the power curve, in order to control altitude, the first action must be to increase or decrease the throttle! **Add or remove power to maintain altitude, and pitch to maintain airspeed.**

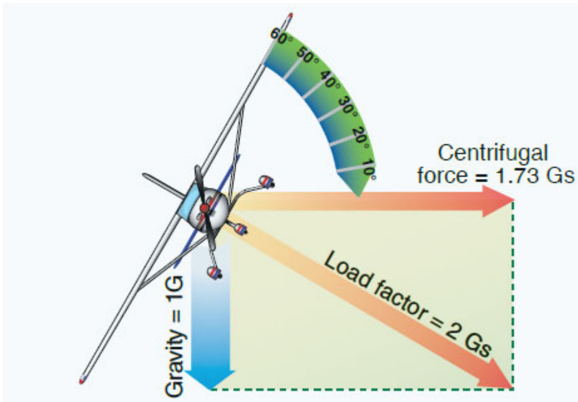


- **Left-Turning Tendencies** - Because slow flight requires a relatively high power setting, and is flown at a high angle of attack, airplanes during slow flight are subject to more pronounced left-turning tendencies.

○ **Torque Reaction -** As the engine turns the propeller to move the air, Newton's laws of motion require an equal and opposite reaction. In particular, as the propeller turns clockwise (from the pilot's point of view), **the airplane wants to rotate (bank) opposite the propeller rotation, to the left**. In order to counteract this, airplanes are generally designed so that the left wing makes slightly more lift than the right wing (which also produces slightly more drag), but these design features are tuned for cruising flight. At higher power settings, this will produce a noticeable left-turning tendency.	
○ **Spiraling Slipstream -** As the airflow moves through the propeller and around the fuselage, wings, and control surfaces, it is spinning. The spinning propeller imparts a considerable spiraling motion to the slipstream, and **because the vertical tail surface extends only above, and not below, the spiraling slipstream pushes the tail slightly right, leading to left yaw.**	
○ **P-Factor** - As the airplane bites into the oncoming air, it is important to realize that it is just a rotating wing, and it has an angle of attack just as any other wing. However, because the engine is mounted in a fixed orientation relative to the airplane, when the airplane itself is flying at a high angle of attack, the angle of attack of the descending blade is considerably different (higher) than the ascending blade. **This produces more thrust on the right side of the propeller disc, and pushes the nose to the left.**	

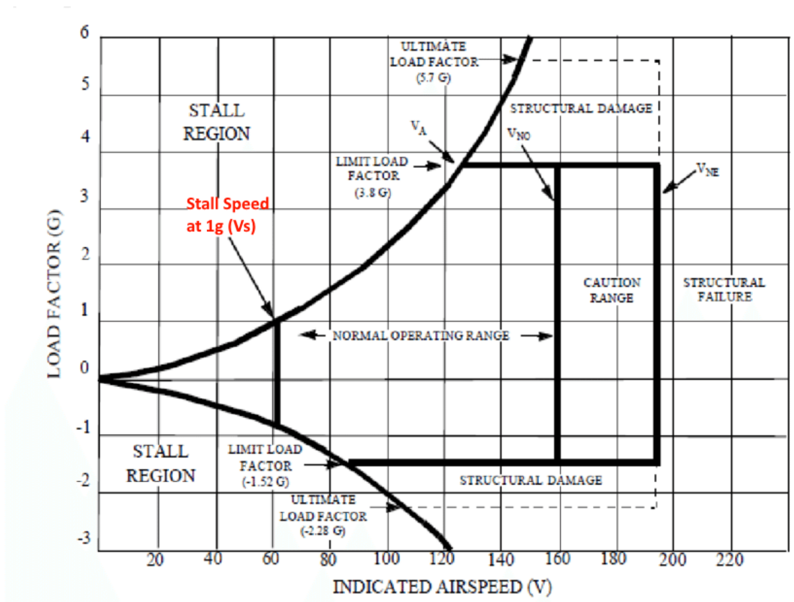
○ Specifically, a high power setting produces a high torque reaction and a larger spiraling slipstream effect, and the high angle of attack makes P-factor very pronounced, **especially in a turn to the right**. Rudder pressure to maintain coordinated flight may be significant.

- **Bank Angle and Load Factor** - As an airplane turns, its weight remains the same, and therefore the upward component of lift must remain equal to its weight. During a turn, some of the lift must be directed towards the center of the turn, reducing the upward component of lift. If no pilot corrections were applied, the airplane would not produce any more than the normal 1g of lift, and the airplane would begin to descend. In order to correct for the loss of vertical lift, and maintain a level altitude, the wing must produce more lift, which requires increased *back elevator pressure*. This increased back elevator pressure will cause the wing to fly at a ***higher angle of attack***, producing the increased lift that is required. This can be felt by the pilot as a higher than normal G-force.
    - In order to maintain 1g of vertical lift, while also turning, the wing must produce more than 1g of total lift. The amount of total lift is called the ***load factor***.

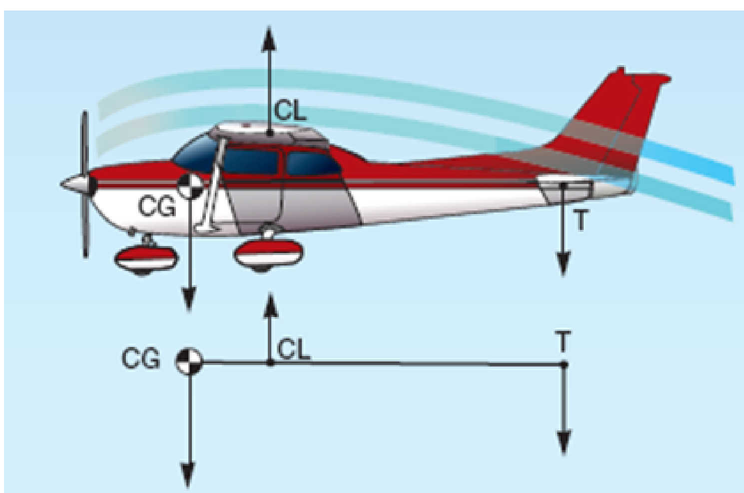


    - As the bank angle increases, the load factor required to maintain level flight increases slowly at first, but increases rapidly, especially at bank angles beyond 45 degrees. The load factor created by a *level, coordinated* turn **depends only on the bank angle**. Note that **airspeed does not affect the load factor of a turn.**
    - While flying at a higher angle of attack necessary to meet the demands of a higher load factor, the wing will produce more *induced drag*. This will result in the airspeed decreasing unless power is added to compensate for the increased drag.

- **Factors that affect Stall Speed**
    - **Load Factor** - As the load factor increases in a turn, it is important to recognize that **the stall speed also increases**. We can see this relationship depicted in a so-called *Vg diagram*, shown below. The Stall Speed we normally see for our aircraft, Vs or Vs_0, applies only to 'unaccelerated' flight--that is, flight at 1g load factor. Observe from the Vg diagram that as the load factor increases, the stall speed also increases.
    - Slow flight, which is usually flown just above 1g stall speed, requires that **bank angles be kept very low** to minimize the increase in load factor.



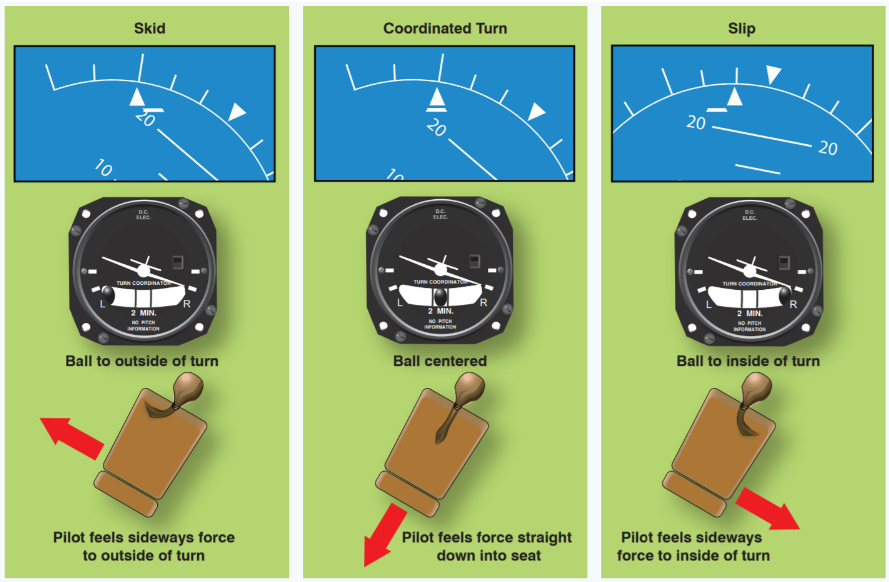
- **Center of Gravity** - When conventionally designed airplanes fly, the center of gravity is always *in front of* the center of lift. You can think of the center of lift as a sort of pivot point in a seesaw. Because the horizontal stabilizer is far behind the center of lift, it produces *downward* force (essentially lift, but downward) to keep the nose of the airplane level. This downward force opposes the upward force of the main wing, requiring it to produce slightly more lift to compensate. Also, because any airfoil that produces lift also produces drag, the amount of drag caused by the horizontal stabilizer depends on the force it must produce.
  - When the center of gravity is further forward, the horizontal stabilizer must produce more downward force, and therefore it creates more drag and causes the main wing to fly at a higher angle of attack for the same airspeed. We know that a wing will always stall at the same angle of attack, so we also know that **as the center of gravity moves further forward, the airplane will stall at a higher airspeed.**



- **Weight** - Likewise, when flying at higher weights, the total load on the wing is higher, again resulting in a higher angle of attack for the same airspeed. **Heavier aircraft stall at a higher airspeed.**
- **Coordination** - Airplanes flying in an uncoordinated fashion generate a considerable amount of increased drag, and the fuselage may blanket one wing or the other, increasing the stall speed.

This can actually cause the left and right wing to stall at a different airspeed! This is a *very* dangerous situation and must be avoided.

- **Airspeed Control, Trim, and Coordination** - When performing slow flight, it is important to maintain a stable airspeed. Generally slow flight is performed just above stall speed, which depends on the configuration of the airplane (clean or landing configuration). **It is important to use the elevator trim to hold approach speed throughout the maneuver!**
  - Because of the proximity to the stall, **it is crucial that slow flight be performed in coordinated flight.** Pay close attention to the ball and the sensations being experienced to ensure that the airplane stays in coordinated flight.



- **Airplane Configuration** - Because conditions similar to Slow Flight are often encountered during takeoffs, landings, and go-arounds, the slow flight maneuver is performed in a variety of configurations:
  - **Clean** - Simulates slow flight after takeoff, typically around Vx.
  - **Dirty (Full Flaps or Landing Flaps)** - Simulates slow flight before landing, or during go-arounds.
    - Flaps add lift as well as drag, and result in lower pitch angles. It is often more comfortable to fly slow flight with landing flaps.
    - **It is important to realize that flaps change the shape of the wing and therefore affect the airspeeds and angle of attack at which the wing stalls!** Airspeeds which work in the Clean configuration will not match.

- **Safety Considerations**
  - As with any maneuver, the **use of checklists is important**. Before beginning the maneuver, perform a pre-maneuver checklist, including performing clearing turns and identifying possible emergency landing sites.
  - It is crucial to not become so focused on performing the maneuver that an unsafe situation is created. Maintain situational awareness, make appropriate practice area radio calls, and **remember to continuously scan for traffic!**

Maneuver Description

- **Entry Altitude** - Slow flight should always be performed at a safe altitude, in case of an inadvertent stall or other problems. The maneuver should be performed **at least 1,500 feet AGL or more**.
- **Entry Airspeed** - The maneuver must be started at less than **Va** (maneuvering speed). Choose a normal level cruise flight airspeed and power setting, at least 5-10 knots below Va.
- **Checklists** - Pilots must perform a pre-maneuver checklist before beginning the maneuver.
- **Entry Power** - Initially, reduce the power to idle.
- **Airspeed and Altitude** - Airspeed should be allowed to slow from entry airspeed down to **an airspeed 5-10 knots above the stall speed** in the current configuration. Maintain altitude by using back elevator pressure and increasing pitch.
- **Maintaining Slow Flight** - Once the appropriate airspeed is reached, add a generous amount of power back to maintain airspeed and altitude. Do not allow the airspeed to decay any further, and do not allow the airspeed to increase.
    - **Airplane is climbing or descending** - Remove or add power, as necessary, to maintain altitude.
    - **Airplane is too slow or too fast** - Pitch down or pitch up, as necessary, to maintain airspeed.
    - *Take care to allow sufficient margin above the stall, and if the stall indication is heard, reduce the pitch and add power!*
- **Bank** - Since this maneuver takes place at very low airspeeds, close to a stall, when making turns, the bank angle should be *less than* **20 degrees** to keep a low load factor. **Very small banks produce very large rates of turn in slow flight!**
- **Coordination** - Due to the strong left-turning tendencies in slow flight, and the risk of a stall, **proper coordination is essential**. Attention should be given to proper rudder input during turns. It may be necessary to apply opposite aileron during turns to prevent overbanking.
- **Recovery** - Recover to normal cruise flight by applying full power and reducing the pitch, allowing the airspeed to increase. If performed in the dirty or landing configuration, progressively retract flaps, landing gear, etc.
- **This is a visual maneuver!** Eyes should remain outside the cockpit as much as possible to scan for traffic and to hold heading.

Expanded Completion Standards

- The pilot can explain the purpose of the slow flight maneuver and how the ‘region of reverse command’, left-turning tendencies, factors that affect stall speed, and other factors that affect the maneuver.
- The pilot can perform the maneuver to the following standards:
    - Pilot clears the area, performs a pre-maneuver checklist, and selects an altitude not less than 1,500ft AGL.
    - Pilot configures the airplane as specified by the evaluator.
    - Pilot establishes properly coordinated, level flight at an airspeed just above stall speed.
    - Pilot performs turns, climbs, and descents as specified by the evaluator.
    - **Private Pilot**: Holds altitude ±100 feet, airspeed +10/-0 knots, bank ±10°, headings ±10°.
    - **Commercial/CFI**: Holds altitude ±50 feet, airspeed +5/-0 knots, bank ±5°, headings ±10°.
    - Recovers to level cruise flight when specified by the evaluator.