Airspeed Control

Lesson:

Airspeed Control

Objectives:

- Knowledge
  - An understanding of the aerodynamics related to airspeed control
- Skill
  - The ability to establish and maintain a specified airspeed
  - The ability to transition between airspeeds, slowly and quickly
  - The ability to control airspeed primarily by visual reference to the horizon

Materials / Equipment

Publications

- Glider Handbook of Aeronautical Knowledge (Holtz)
  - Lesson 1.1 – The Glider
- Flight Training Manual for Gliders (Holtz)
  - Lesson 1.1 – Primary Flight Controls
  - Lesson 1.2 – Secondary Flight Controls
  - Lesson 1.3 – Using the Flight Instruments
  - Lesson 4.3 – Pitch / Speed Control
  - Lesson 4.24 – Rapid Speed Changes

Documents

Simulation Files

Flight Plan

- Airspeed_Control.fpl

Replay

- AoA_vs_Airspeed.rpy
- Changing_Airspeed_Slowly.rpy
- Changing_Airspeed_Quickly.rpy

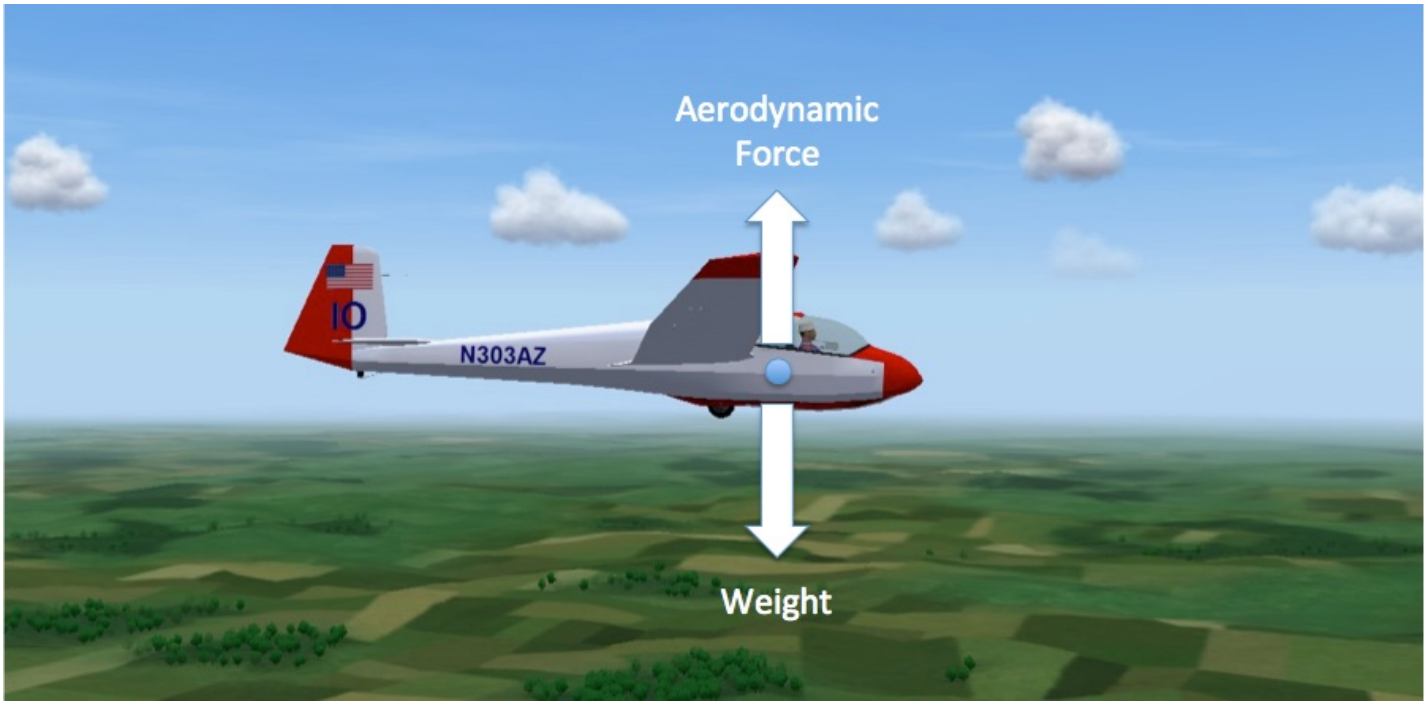
Presentation

Aerodynamics - General

Dynamics is the study of motion. Aerodynamics is the study of the motion of objects through air; for example, a glider in flight.

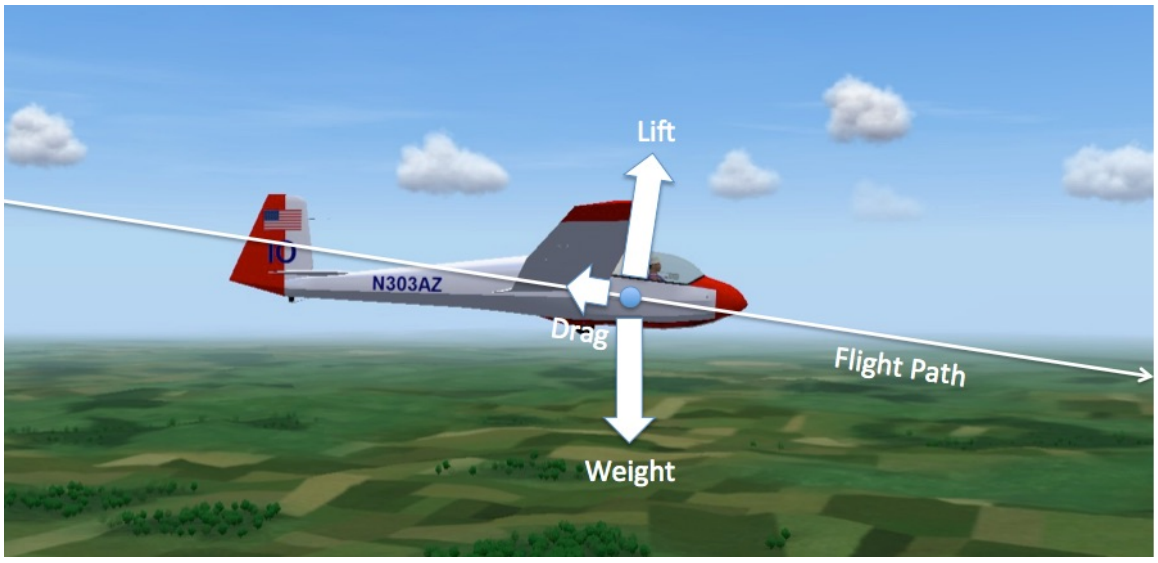
As gravity pulls a glider toward the earth, countless individual reactive forces are generated as the glider's surfaces, especially its wings, interact with billions of surrounding air molecules.

For simplicity's sake, all these reactive forces, when added together and represented as a single conceptual vector, are called the "aerodynamic force"; equal in magnitude and acting directly opposite the acceleration of gravity on the mass of the glider (weight).

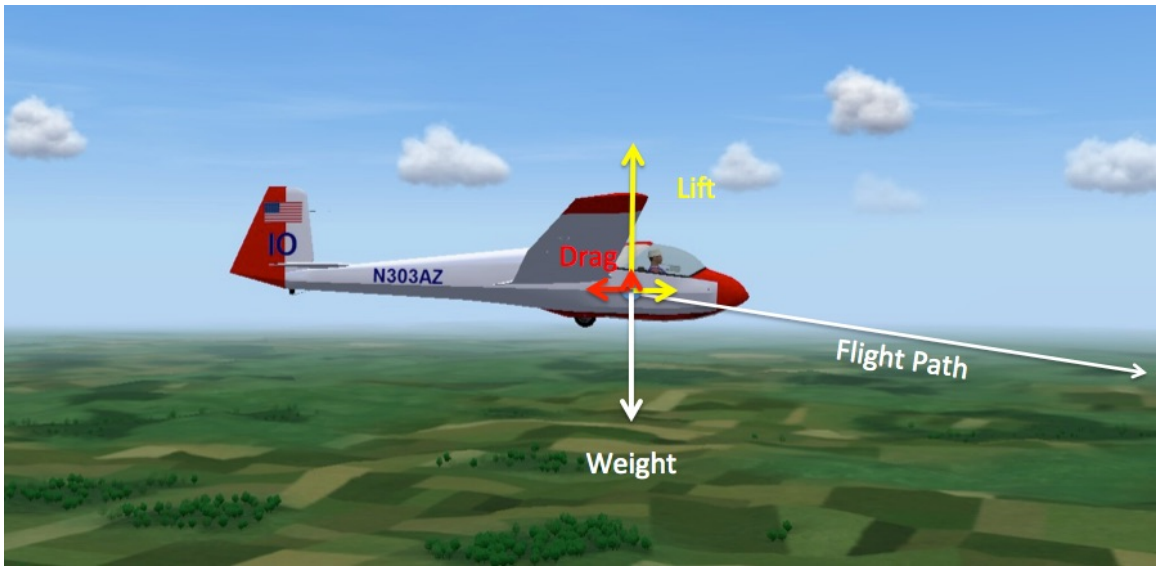


To better understand its effect on glider performance, the aerodynamic force is usually represented as two other conceptual forces using the glider's flight path as the frame of reference. Those conceptual forces are:

- **Lift**: the component of the aerodynamic force acting perpendicular to the flight path
- **Drag**: the component of the aerodynamic force acting parallel and opposite to the flight path



If we then represent the Lift and Drag components back within the gravitational (vertical) frame of reference, we can see that Lift not only resists the pull of gravity but also acts to move the glider forward (horizontally). Drag primarily resists the horizontal component of lift, but also counteracts weight to a small degree.



With these horizontal and vertical force components in equilibrium, the glider moves along its flight path at a constant rate of descent and a constant airspeed.

As a glider is maneuvered, the resulting aerodynamic forces change; affecting the glider's performance, including its rate of descent, direction of flight, and speed through the air.

Aerodynamics of Airspeed Control

In normal gliding flight, lift acts perpendicular to the glide path, giving it a "forward" tilt, which both resists the vertical pull of gravity and causes the glider to move forward along its flight path.

In very simple terms, you can control the speed of the glider by tilting of the Lift vector; tilt the lift vector forward to go faster; tilt the lift vector back to slow down.

In general, the magnitude and direction of aerodynamic forces are determined by:

- The density of the air
- The shape of the object (wing = long airfoil)
- The relative speed of the wing and the air (airspeed)
- The angle of the object's surface (chord line) relative to its direction of motion (flight path)
  This angle is called the "angle of attack", and is often abbreviated "AoA"

Of these factors, the only one, over which the glider pilot has any meaningful control, is the "angle of attack".

The glider's airspeed is the direct result of changes in the wing's angle of attack.

Note: Throughout this document, the concept of "angle of attack" is referred to so often you might begin to wonder why the lesson is not called "Angle of Attack Control". Perhaps, it should be.

For many of the performance issues we care about in glider flying, angle of attack is really the important concept. For example:

- *Stall speed in not a speed; it is an angle of attack*
- *Best glide (L/D) speed is not a speed; it is an angle of attack*
- *Minimum sink speed is not a speed; it is an angle of attack*
- *Maneuvering speed (V_A) is a not a speed; it is an angle of attack*

On the other hand, some important performance concepts are actually a function of speed.

- *Never exceed speed (V_{NE}) is a speed*

The Wright Brothers understood the importance of AoA. The Wright Flyer had an AoA indicator, not an airspeed indicator. Military aircraft are flown primarily by reference to AoA. Commercial airlines all have AoA sensors that feed this important metric to the flight control system.

So, if AoA is so important, why don't all our aircraft have AoA sensing and display systems? The answer is most likely economics. Airspeed indicators are less expensive and less complicated, but they are a poor substitute for AoA.

Fortunately that situation may be changing. With better and more affordable sensing technology, and the FAA's recent advocacy, AoA systems are making a comeback.

In the mean time, however, airspeed indications are what most of us have to work with. We need to make the best of it. We need to understand the relationships between airspeed and angle of attack.

Demonstration – Angle of Attack

Introduction

The purpose of this demonstration is to help you visualize the concept of "angle of attack" (AoA) and the process by which the glider pilot controls the wing's angle of attack, and in so doing, controls the glider's airspeed.

Set-up

- Load Replay == AoA_vs_Airspeed.rpy
- Reset to the Beginning (<<)
- Turn the Replay camera OFF (F9)
- Select External-Glider view (F2)
- Position the Replay camera on the right side of the glider as shown below

Play-by-Play
As the demonstration begins, notice the wing tip smoke. The smoke trail helps you visualize the flight path of the glider, one component of the angle of attack.

As the flight progresses, pay attention to the relationship between the glider's pitch attitude relative to its flight path, and the airspeed value displayed in the parameter panel at the bottom of the screen.

- Press the PAUSE (P) key to start the demonstration.

Explanation
In the Replay, you should have seen the glider's airspeed change as the fuselage pitch attitude changed. Here is what is actually happening:

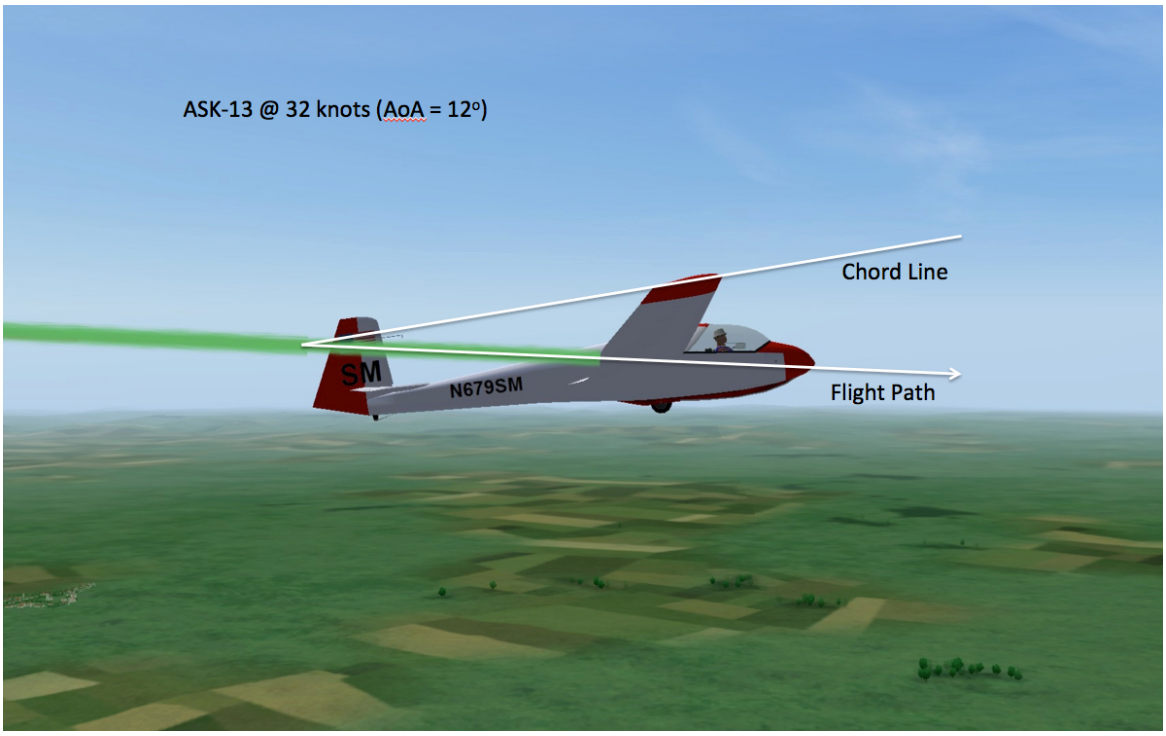
- Angle of Attack is defined as the angle between the wing's chord line and the relative wind (flight path).

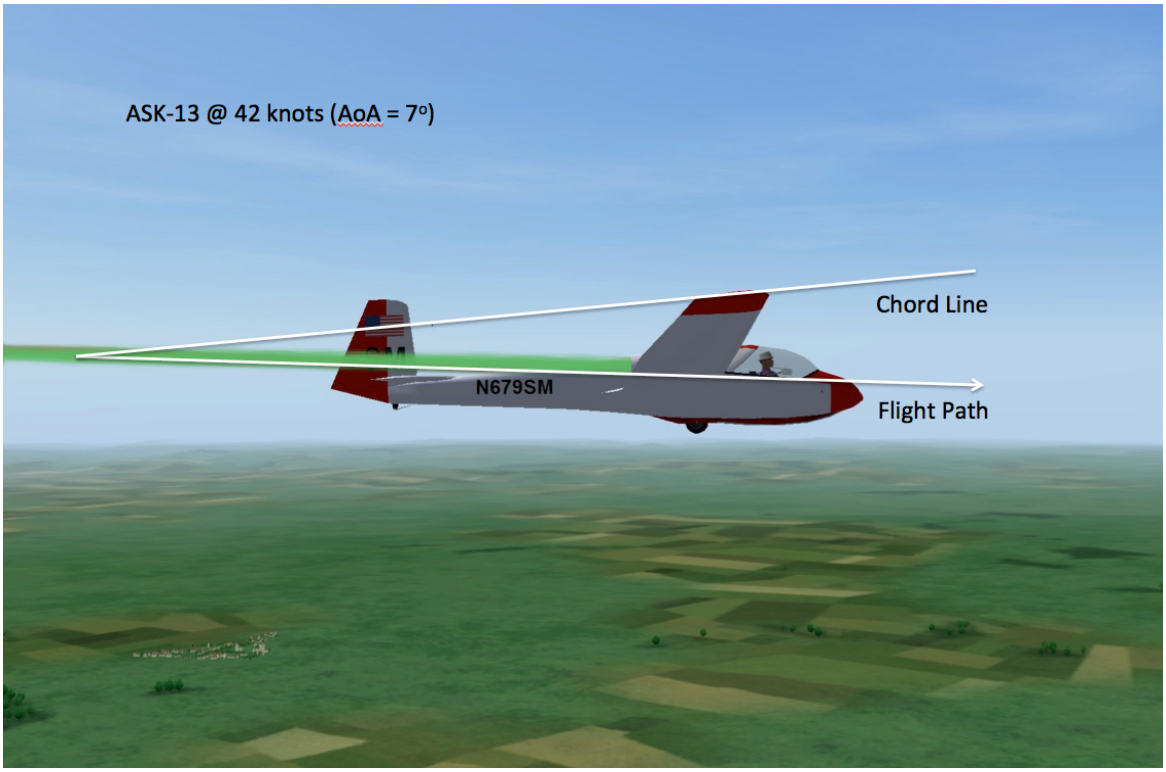
  Another simple definition: "The difference between where the wing is pointed and where it is going."

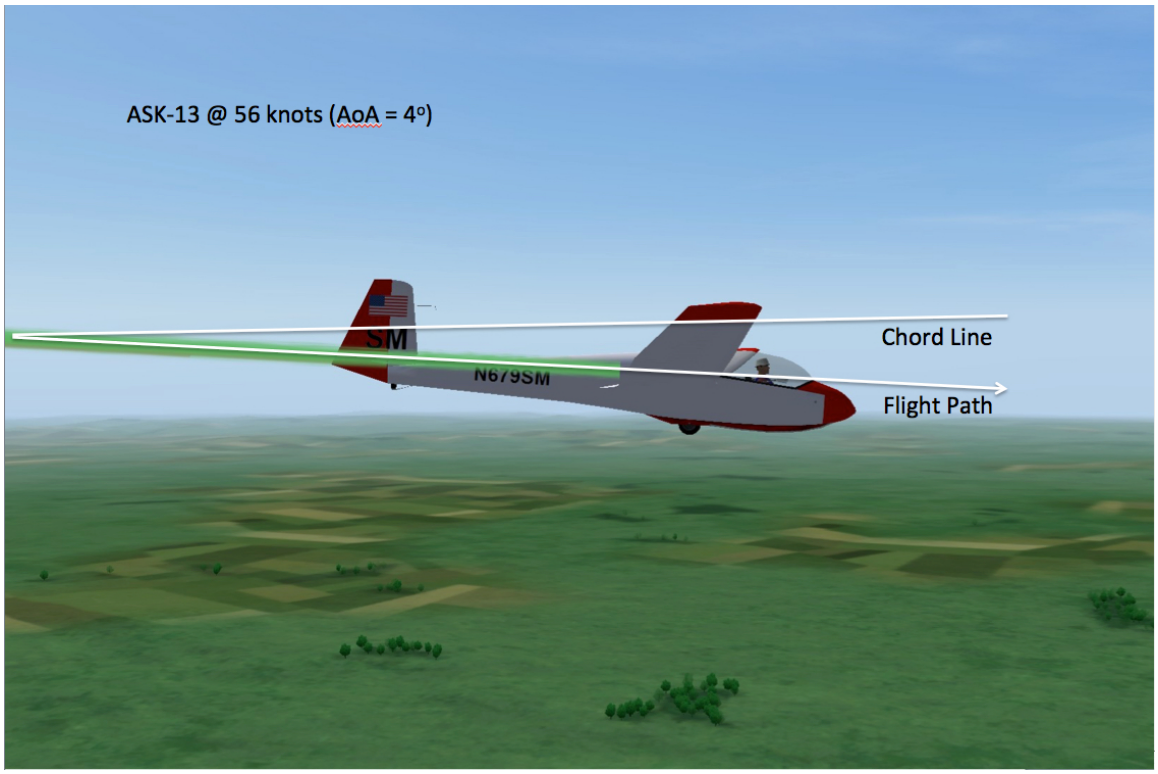
- Because the glider's wing is attached to the fuselage, as the pitch attitude of the fuselage changes, the wing's relationship to the flight path (the angle of attack) changes.

- As the wing's angle of attack changes, the glider's airspeed changes.

The images below were taken from the Replay you just watched. They show the airspeed associated with selected angles of attack, with the wing's angle of attack being established by the glider's pitch attitude relative to the flight path.







Notice large angles of attack result in slower airspeeds; small angles of attack correspond to higher airspeeds.

Demonstration – Pitch Attitude => Angle of Attack => Airspeed

Introduction

The purpose of this demonstration is to help you visualize the pitch attitudes associated with various angles of attack, each angle of attack having an associated airspeed.

Pitch attitude determines angle of attack; angle of attack determines airspeed.

To establish a pitch attitude, you use three points of reference:

1. Your eyes
2. The horizon
3. Some physical part of the glider between your eyes and the horizon

You control the pitch attitude of the glider using the control stick. Pushing the control stick away from you pitches the nose of the glider toward your feet. Pulling the stick toward you pitches the nose of the glider toward your head.

Notice I did not use the terms "up" or "down" when referencing pitch. The glider knows nothing of up and down. In fact, if you were up side down, pushing the stick "away" from you would pitch the glider up, not down. If the glider were in a 90-degree bank relative to the horizon, pushing the stick away from you wouldn't pitch the glider up or down.

Pushing the stick to pitch toward your feet and pulling the stick to pitch toward your head always works.

For the purposes of this lesson and for simplicity's sake, I will use the terms "up" and "down" to describe pitch changes. Keep in mind these two terms are really only valid with the wings level and the sky above you.

In a normal wings-level flight attitude, pushing the stick forward pitches the nose of the glider down, reduces the angle of attack on the wing, and results in an increase in airspeed; pulling the stick back pitches the nose of the glider up, increases the wing's angle of attack, and slows you down.

Set-up

- Load Replay == Changing_Airspeed_Slowly.rpy
- Reset to the Beginning (<<)
- Press PAUSE (P) to start/stop each Replay time segment

Play-by-Play

09:00:21 - 09:00:30
As the demonstration begins, the glider's pitch attitude is established using small fore and aft movements of the stick. Once stabilized, this pitch attitude results in a specific angle of attack, which in turn results in an airspeed of 42 knots.

Notice how the airspeed stabilizes at 42 knots as the following three points of visual reference are held in alignment:

1. the pilot's eyes
2. the top edge of the yaw string tape
3. the horizon

Pitch Attitude – 42 knots

09:00:30 - 09:01:15
The pilot reduces the angle of attack by moving the stick forward, pitching the glider toward the flight path, to find a pitch attitude that will produce an airspeed of 56 knots.

The pitch attitude (angle of attack) site picture associated with 56 knots has the top of the yaw string near the horizon.

Pitch Attitude – 56 knots

09:01:15 - 09:01:40
The pilot moves the stick back, pitching the glider away from the flight path, increasing the wing's angle of attack, and returning the glider to the pitch attitude (angle of attack) known to produce an airspeed of 42 knots.

While the pitch change occurs relatively quickly, notice it takes some time for the airspeed to respond, and for the glider to slow down from 56 to 42 knots.

09:01:40 - 09:02:20
The pilot, once again, increases the angle of attack by pitching the glider away from the flight path, this time looking for a pitch attitude (angle of attack) that will produce an airspeed of 32 knots. This pitch attitude appears to place the bottom of the yaw string tape above the horizon by approximately the length of the yaw string.

Pitch Attitude – 32 knots

09:02:20 – End of Replay
The demonstration concludes with the pilot again reducing the angle of attack to reestablish and hold the 42-knot pitch attitude, causing the glider to accelerate from 32 knots to 42 knots.

Exercise: Changing Airspeed Slowly

Introduction
Now that you understand how to control the glider's airspeed, it is time to apply what you know.

In this exercise, you will make airspeed changes by establishing and holding various pitch attitudes (angles of attack) each of which results in a corresponding airspeed.

As you work on your airspeed control skills, the glider will gradually be losing altitude. As you get close to the ground, use the Altitude Recovery feature ("Q") to buy yourself extra altitude (i.e. more time) to practice. Don't be surprised if the pitch attitude sight picture, required for a specific speed, varies slightly when viewed from different altitudes.

Note: As you practice establishing and holding various speeds, you will notice that holding speeds other than 42 knots requires pressure on the stick; forward pressure for speeds above 42 knots; back pressure for speeds below 42 knots.

We will study what causes this phenomenon, and what you can do about it, in the next lesson. For now, do the best you can to physically hold the aircraft at the appropriate pitch attitude (angle of attack) for each target airspeed.

Gradual speed changes are made by establishing and holding a pitch attitude known to produce the target speed. Use a trial and error method to discover the appropriate pitch attitude for a desired airspeed. Because of the glider's inertia, it will take some time for the airspeed to change to, and stabilize on, the target value, after you initiate the pitch change.

Set-up
- Select Free Flight
- Load Flight Plan / User == Airspeed_Control.fpl
- Select Start Flight
- Press Keyboard "J" to display turn-points
- Press "ESC"
- Select "Ready for Flight"

Exercise: Changing Airspeed Slowly (cont.)

Play-by-Play
As the Free Flight session begins, fly straight ahead by keeping the horizon generally level and using the turn-point pole in the distance as a directional reference.

1. Using very small forward and aft movements of the stick, establish a pitch attitude that holds the top edge of the yaw string tape near the horizon. The glider's airspeed should gradually settle in on 42 knots.

   Note: This "tape on the horizon" visual reference is an example of using parallax to establish a pitch attitude. By using three points of reference (in this case, your eyes, the horizon, and the top of the tape) you can establish and hold a pitch attitude that will result in an airspeed of 42 knots.

   What you use for your intermediate point of reference will change with each speed you fly, each glider you fly, and how you are seated in that glider on any given day.

   Once you understand the concept, however, you can use this one technique to easily adapt to making speed changes in any glider.

2. Move the stick forward to establish and hold the pitch attitude corresponding an airspeed of 56 knots.

3. Move the stick aft to reestablish and hold the pitch attitude for 42 knots.

4. Establish and hold the pitch attitude corresponding to an airspeed of 32 knots.

5. Reestablish 42 knots.

6. Establish and hold pitch attitudes for airspeeds of your choice (e.g. 40 knots, 50 knots, 60 knots).

Demonstration – Rapid Speed Changes

Introduction
In the previous demonstration and exercise, airspeed changes were made slowly by changing the pitch attitude (angle of attack) and holding that pitch attitude as the aircraft gradually transitioned to the corresponding airspeed.

In this demonstration, you will see how to change airspeed more quickly.

Set-up
- Load Replay == Changing_Airspeed_Quickly.rpy
- Reset to the Beginning (<<)
- Press PAUSE (P) to start/stop each Replay time segment

Play-by-Play

09:00:18 - 09:00:30
As the demonstration begins, the glider's pitch attitude (angle of attack) is established to produce an airspeed of 42 knots.

Initial Pitch Attitude – 42 knots

09:00:30 - 09:00:36
To initiate a rapid speed change to 32 knots, the glider is initially pitched beyond the 32-knot attitude.

Notice how much more quickly the airspeed trends toward the target speed of 32 knots.

Initial pitch above the attitude required for 32 knots

09:00:36 - 09:00:57
As the airspeed approaches the 32-knot target, a secondary pitch change is made to capture and hold the attitude (angle of attack) known to produce 32 knots.

Secondary pitch to capture/hold the attitude for 32 knots

09:00:57 – End of Replay
A speed change from 32 knots to 42 knots is initiated by first pitching below the required attitude for 42 knots, then making a secondary pitch change to capture the 42-knot pitch attitude.

Initial pitch below the attitude required for 42 knots

Secondary pitch to capture/hold the 42-knot attitude

The remainder of the demonstration is a series of quick speed changes. Start / Stop the Replay at the end of each speed change segment. Stopping at each secondary pitch is optional.

Do notice that each rapid speed change involves a pair of pitch changes; the first to initiate a quick change of airspeed by dramatically changing the pitch attitude (angle of attack); the second to set and stabilize the pitch attitude corresponding to the target airspeed.

09:01:12 - 09:01:32

42 knots to 56 knots

- 09:01:12 Initial pitch below 56 knot attitude
- 09:01:21 Secondary pitch to capture 56 knots attitude

09:01:33 - 09:01:51

56 knots to 42 knots

- 09:01:33 Initial pitch above 42 knot attitude
- 09:01:38 Secondary pitch to capture 42 knots attitude

09:01:52 - 09:02:10

42 knots to 32 knots

- 09:01:52 Initial pitch above 32 knot attitude
- 09:01:58 Secondary pitch to capture 32 knots attitude

09:02:11 - 09:02:30

32 knots to 56 knots

- 09:02:11 Initial pitch below 56 knot attitude
- 09:02:22 Secondary pitch to capture 56 knots attitude

09:02:30 - 09:02:34

Slight pitch forward for no apparent reason. ‘Most likely a muscle spasm from having to hold all these pitch positions. Test pilot will be really happy when this issue is resolved in the next lesson.

09:02:35 - 09:02:56

56 knots to 32 knots

- 09:02:35 Initial pitch above 32 knot attitude
- 09:02:45 Secondary pitch to capture 32 knots attitude

09:02:57 – End of Replay

32 knots to 42 knots

- 09:02:57 Initial pitch below 42 knot attitude
- 09:03:05 Secondary pitch to capture 42 knots attitude

Exercise: Changing Airspeed Quickly

Introduction
More rapid changes in airspeed are made by pitching beyond the attitude known to produce the target speed. As the airspeed approaches the target, a second pitch change is made to establish and hold the pitch attitude known to produce the target speed.

Set-up
- Select Free Flight
- Load Flight Plan / User == Airspeed_Control.fpl
- Select Start Flight
- Press "ESC"
- Select "Ready for Flight"

Play-by-Play
1. Establish and hold 42 knots.

2. Move the stick forward to establish and hold a pitch attitude greater than that required for an airspeed of 56 knots.

   The more you exceed the required pitch attitude, the more quickly the airspeed will approach the target speed.

3. As the airspeed approaches 56 knots, bring the stick back to establish the pitch attitude known to produce 56 knots.

   If you time the second pitch change properly, you will capture the target 56-knot speed. If you miss by a little, just hold the appropriate pitch attitude and the glider will slowly make up the difference.

4. Practice making rapid speed changes between various pairs of speeds, for example from 42 to 35, 35 to 56, and 56 to 42.

Exercise: Controlling Airspeed by Reference to the Horizon

Introduction
Airspeed indicators can fail or produce erroneous indications. Controlling airspeed by reference to the airspeed indicator also requires you focus your attention inside the cockpit; distracting you from the important task of seeing and avoiding other aircraft.

This exercise will help develop your ability to control the glider's airspeed primarily by reference to the horizon.

Visual reference to the horizon should be your primary method of controlling the airspeed of a glider with occasional glances at the airspeed indicator as a cross-reference. If the two indications disagree, believe your visual reference.

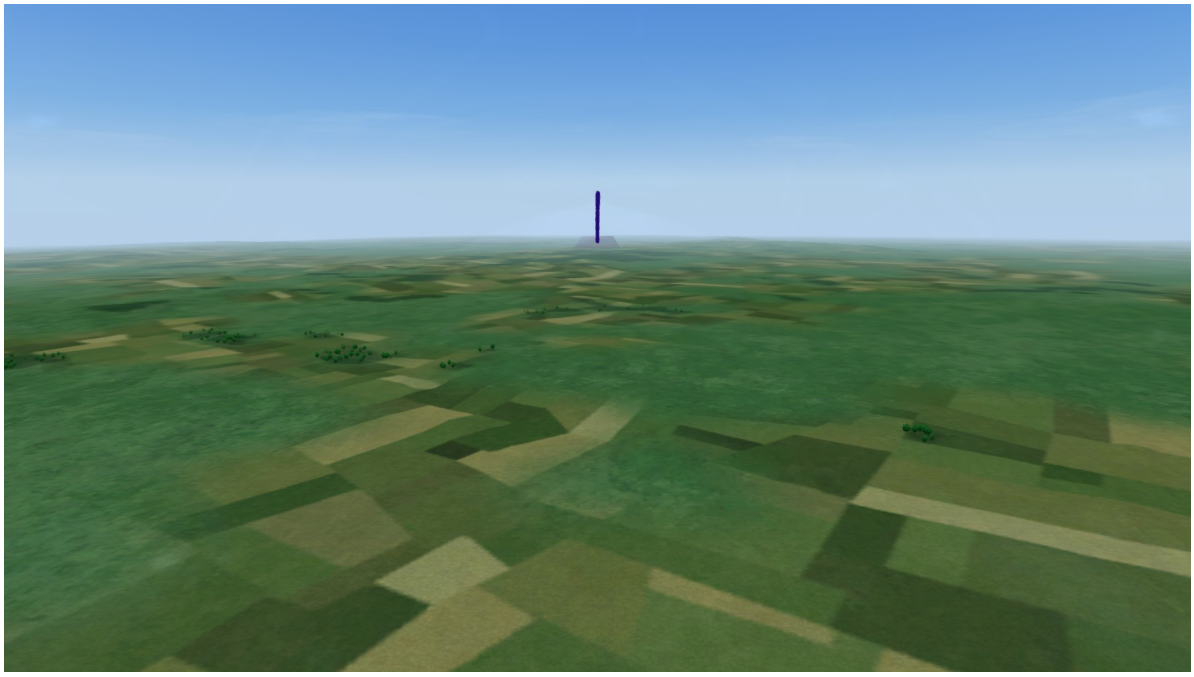
Set-up
- Select Free Flight
- Load Flight Plan / User == Airspeed_Control.fpl
- Select Start Flight

Play-by-Play
1. Before beginning the flight,
   - Press CNTL + F1 in combination.

     You are now in "No Cockpit View", leaving only your visual reference system with which to control your airspeed.

2. Begin the flight
   - Press "ESC"
   - Select "Ready for Flight"

3. While keeping the horizon level, establish the pitch attitude corresponding to an airspeed of 42 knots. Once stabilized, PAUSE. The sight picture should look like this.



To see how accurately your visual pitch reference can control the glider's airspeed

- Press CNTL + F1 to return to Cockpit View.

The sight picture should now look like this, and the airspeed indication should be close to 42 knots.

- Press CNTL + F1 to return to No Cockpit View.

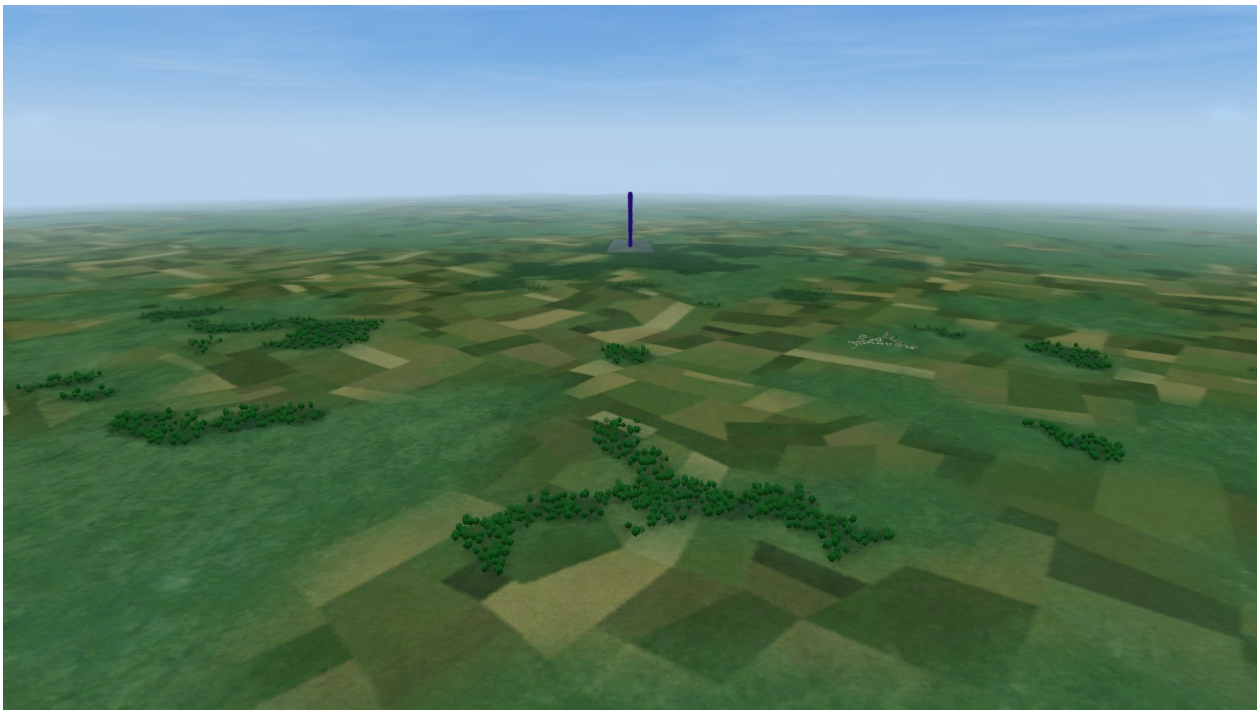
4. Using only your visual pitch reference, establish the pitch attitude known to produce an airspeed of 32 knots. Once stabilized, PAUSE. The sight picture should look like this.

- Press CNTL + F1 to return to Cockpit View.

The sight picture should now look like this, and the airspeed indication should be close to 32 knots.

- Press CNTL + F1 to return to No Cockpit View.

5. Using only your visual pitch reference, establish the pitch attitude known to produce an airspeed of 56 knots. Once stabilized, PAUSE. The sight picture should look like this.



- Press CNTL + F1 to return to Cockpit View.

The sight picture should now look like this, and the airspeed indication should be close to 56 knots.