Train-the-Trainer Handbook

For L2T Pilot Proficiency Clinics

version 1.0

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Schedule

Learn to Turn Clinic

Antidote for Inflight Loss of Control

Pilot Proficiency Center
EAA Aviation Museum, Oshkosh, WI

Thursday, July 28, 2022

Agenda	Time	Duration
Check-in / Breakfast	0730–0800	30 mins
Keynote	0800–0845	45 mins
Break	0845–0900	15 mins
Breakout Sessions	0900–0945	45 mins
Break	0945–1000	15 mins
Breakout Sessions	1000–1045	45 mins
Break	1045–1100	15 mins
Breakout Sessions	1100–1145	45 mins
Debriefing	1145–1230	up to 45 mins

About the Participants
- Pre-registered
- Hold at least a Sport or Private Pilot Certificate
- Max capacity for the Keynote: 72 participants
- Max capacity per Breakout Session: 24 participants

Keynote
- 45 minutes
- Presenter: Judy Phelps
- Facilitators: Rob Dumovic & Mark King
- Objective: Emphasize that the pilot ultimately determines the fate of each flight. Thus, training solutions aimed at reducing the frequency of LOC-I need to be pilot-centric, as well as knowledge- and skills-based.

Keynote Sub-topic	Speaker	Duration
Welcome Exits, Bathrooms, Breakout Rooms, Sim Area	Phelps	3 mins
Introductions – who are you? What common issues do you see as a CFI / DPE? When did you become fully aware of turn dynamics? Why do you support the L2T program?	Phelps Dumovic King	8 mins
Learn to Turn (L2T) – the why and the philosophy	Phelps	24 mins
Brief descriptions of the breakout sessions	Dumovic King Phelps	5 mins
Logistics – rotating thru the breakout sessions Questions	Phelps	5 mins

Breakout Sessions
- 45 minutes per session, with each breakout activity delivered a total of (3) times
- Mark King – *Training Mindset and Exercises*
- Rob Dumovic – *Traffic Pattern Scenarios*
- Staff Instructors and Redbird Sims – *Warm-up Exercises and a Pressure Scenario*

Special note: Please do not discuss, reference, or allude to specifics about the L2T Sim Scenario, which will replicate the conditions surrounding the October 2006 crash involving Yankees pitcher Cory Lidle and a flight instructor as they flew a Cirrus up the East River Corridor in New York City. The goal is to see if participants can correlate and apply prior knowledge and experience to an unknown/unfamiliar scenario.

Learn to Turn Pilot Proficiency Clinic

A Stick and Rudder Approach to Reducing Loss of Control

Contents

Lesson Plans

Notes for PowerPoint Slides

Curated Content

Lesson Plans

Knowledge Module (Learn)

Lesson – Training Mindset & Exercises

Lesson – Traffic Pattern Operations

Simulator Module (Do)

Lesson – Warm-up Exercises & Pressure Scenario

In-Airplane Module (Fly)

Lesson – L2T Exercises

The L2T Knowledge Module

Lesson Plan

Training Mindset and Exercises

Duration: 45 minutes

Essential Question: How do you structure your training time and effort for maximum effect?

Objectives:

- Reinforce the need for pilots to retain a learner's mindset.
- Expand the understanding of turning flight in three dimensions
- Puzzle out the specific control movements required to perform specific L2T exercises.

Overview: Participants will review what the aircraft controls do, as well as basic turn dynamics. They will apply this knowledge to describe maneuvers in the L2T Flight Simulation Exercises booklet.

Material & Equipment Needs:

- Model airplane
- PowerPoint slides
- Computer, projector, screen
- Optional – white board and markers; note paper and pens

Instructor Mindset:

- Understand and support L2T concepts and training.
- Lay the foundation for the lesson by reviewing key concepts.
- Facilitate deep thinking by posing questions rather than lecturing.
- Bring your unique style, techniques, and experiences to the lesson.

Participant Mindset:

- Be engaged and interactive.
- Visualize and simulate.
- Do the mental and physical work needed to answer the questions posed.

Lesson Content:

- See the L2T Clinic PowerPoint slide deck and supporting notes.
    - The notes are less a script and more a reminder of key points to stress.
- Review all the Learn to Turn Assets at https://www.richstowell.com/learn-to-turn/

The L2T Knowledge Module

Lesson Plan

Traffic Pattern Scenarios

Duration: 45 minutes

Essential Question: How do we maneuver safely and competently around the traffic pattern?

Objectives:

- Reinforce the concept of Aviate, Navigate, and Communicate—with emphasis on "Aviate."
- Increase awareness about the relationship between airspeed, G-load, angle of attack, and stalls during critical operations in the traffic pattern.
- Visualize and properly identify the types of turns routinely performed in the pattern.

Overview: Participants will apply the concepts of turning flight in three dimensions as they identify and puzzle out the details of various turns that are—or might have to be—performed in the traffic pattern.

Material & Equipment Needs:

- Model airplane
- PowerPoint slides
- Computer, projector, screen
- Optional – white board and markers; note paper and pens

Instructor Mindset:

- Understand and support L2T concepts and training.
- Lay the foundation for the lesson by reviewing key concepts.
- Facilitate deep thinking by posing questions rather than lecturing.
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The L2T Simulation Module

Lesson Plan

Warm-up Exercises and a Pressure Scenario

Duration: 45 minutes

Essential Question: What does correlation-level learning mean in actual practice?

Objectives:

- Determine if participants can correlate and apply prior knowledge and experience to an unknown scenario in a simulated flight environment.
- Instill in the trainee that the elevator is the turn control.

Overview: Participants will warm up with some L2T training exercises, then fly a real-world scenario multiple times with increasing situational challenges.

Material & Equipment Needs

- Flight simulation training device with access to this scenario
- Optional – model airplane
- Optional – note paper and pens

Instructor Mindset

- Understand and support L2T concepts and training.
- Be a flight instructor by coaching the trainee through the warm-up exercises
- Be a facilitator during the pressure scenario.
    - Facilitate deep thinking by posing open-ended questions to the trainee after each attempt.
- Lay the foundation for the lesson through the warm-up exercises.
- Bring your unique style, techniques, and experiences to the lesson.

Participant Mindset

- Fly the airplane.
- Remain situationally aware and plan ahead.
- Do the mental and physical work needed to answer the questions posed.

Instructor Notes

- Please be consistent when talking about what the primary controls do, specifically:
    - Ailerons roll or bank the airplane (and that's all the ailerons do).
    - Rudder is used mostly to cancel yaw; otherwise, the consequence is a slip or a skid-spin.
    - Elevator controls the AOA of the wing, which presents as changes in at least a couple of these parameters: airspeed, G-load, pitch attitude, flight path.
- Review the Learn to Turn Program Assets at https://www.richstowell.com/learn-to-turn/, especially the Flight Simulation Exercises document.

Warm-up Exercises

Coach the trainee through these warm-up exercises.

- Power-off Stalls
  - Reinforce the need to push forward on the elevator far enough to recover from the stall.
    - Maintain heading and wings level with rudder until unstalled.
  - Configure for and perform a few stalls.
    - Wings level, flaps up, power off.
    - Pitch to bleed off airspeed while maintaining altitude.
    - Release aft elevator pressure at the stall.
    - Recover in a glide, repeat the stall and recovery.
  - Common errors.
    - Losing altitude prior to the stall.
    - Overcontrolling the elevator during stall recovery vs. relaxing back pressure.
    - Misapplying aileron and rudder during the process.
- Dutch Roll Coordination Exercise
  - Demonstrates banking without turning.
  - Rock the wings smoothly and continuously left and right, remaining on heading.
  - Apply coordinated aileron and rudder inputs.
    - Same time and same side (left aileron and left rudder, right and right).
    - Typically more aileron than rudder.
    - Use outside visual references (ignore the slip/skid indicator).
    - Look for symmetry, e.g., 30 to 45 degrees of bank left and right.
  - Common errors.
    - Too little aileron deflection (more is better during this exercise).
    - Too much rudder applied too late (add just enough rudder simultaneously with the aileron input).
    - Failing to reverse rudder with aileron, i.e., lagging with the rudder.
- S-turns
  - Perform two opposite but equal half-circles on each side of a ground reference.
  - Divide attention between controlling the flightpath, looking for hazards, and checking the instruments.
  - Improve the coordination of inputs
    - Proper coordination of aileron and rudder while banking into and out of the turns.
    - Proper coordination of *bank and yank*, i.e., matching the right amount of G-load (i.e., pull) for the angle of bank to fly level turns, while compensating for the wind.

<u>The Pressure Scenario</u>

DO NOT coach the trainee through the scenario. Facilitate deep thinking by posing open-ended questions after each attempt.

- In between attempts, elicit reflection and self-critique by the trainee by posing questions such as:
  - What worked?
  - What didn't work?
  - What could you do differently next time?
  - What alternative courses of action might be possible?

Facilitator's Script

We are now going to do the pressure scenario part of the lesson.

You will fly the scenario several times, and it will be slightly different each time.

I will not coach you while you are flying the scenario — how you choose to handle the scenario is entirely up to you as the pilot-in-command.

In between the attempts, I will help you reflect on your decisions and actions by asking a few questions.

Here is your briefing for the scenario — *<u>repeat this briefing before each attempt</u>*

- You are on a VFR sightseeing flight in an exclusion corridor surrounded by Class B airspace.

- The corridor is 2,100 feet wide — shoreline to shoreline before Class B airspace.
- Class B airspace starts above at 1,100 feet MSL.
- A wall of Class B airspace starts at the far end of that island in front of you.

- You are *Darkstar 72*.
- You are expected to fly a left-hand pattern in the corridor.
- You are flying at 97 knots.

- ATC has issued the following instruction: *Darkstar 72, remain clear of Class Bravo*.
- Trainee must respond out loud: *Will remain clear of Class Bravo, Darkstar 72*.

The L2T Flying Module

Lesson Plan

In-airplane Training Exercises

Duration: 45 minutes

Essential Question: What is the connection between knowledge, simulation, and real flight maneuvers?

Objectives:

- Reinforce the need for pilots to retain a learner's mindset.
- Expand the understanding of turning flight in three dimensions
- Puzzle out the specific control movements required to perform specific L2T exercises.

Overview: Participants will review what the aircraft controls do, as well as basic turn dynamics. They will apply this knowledge to describe maneuvers in the L2T Flight Simulation Exercises booklet.

Material & Equipment Needs:

- Suitable training airplane and flight gear
- Model airplane
- Optional – white board and markers; note paper and pens

Instructor Mindset:

- Understand and support L2T concepts and training.
- Lay the foundation for the lesson by reviewing concepts and procedures.
- Facilitate deep thinking by posing questions rather than lecturing.
- Reinforce G-cueing and other sight, sound, and feel cues.
- Bring your unique style, techniques, and experiences to the lesson.

Participant Mindset:

- Be engaged and interactive.
- Develop more awareness of your control actions and their performance consequences.
- Acknowledge and correlate changes in G-load with changes in AOA and proximity to stall.

Lesson Content:

- Review all the Learn to Turn Assets—especially the training exercises—at https://www.richstowell.com/learn-to-turn/
- To be developed further.

Notes for PowerPoint Slides

Keynote

See PowerPoint Slide Notes, PPT Slides #1–49

See PowerPoint Slide Deck, Slides #1–49

Knowledge Lesson – Training Mindset & Exercises

See PowerPoint Slide Notes, PPT Slides #51–68

See PowerPoint Slide Deck, Slides #51–68

Knowledge Lesson – Traffic Pattern Operations

See PowerPoint Slide Notes, PPT Slides #70–110

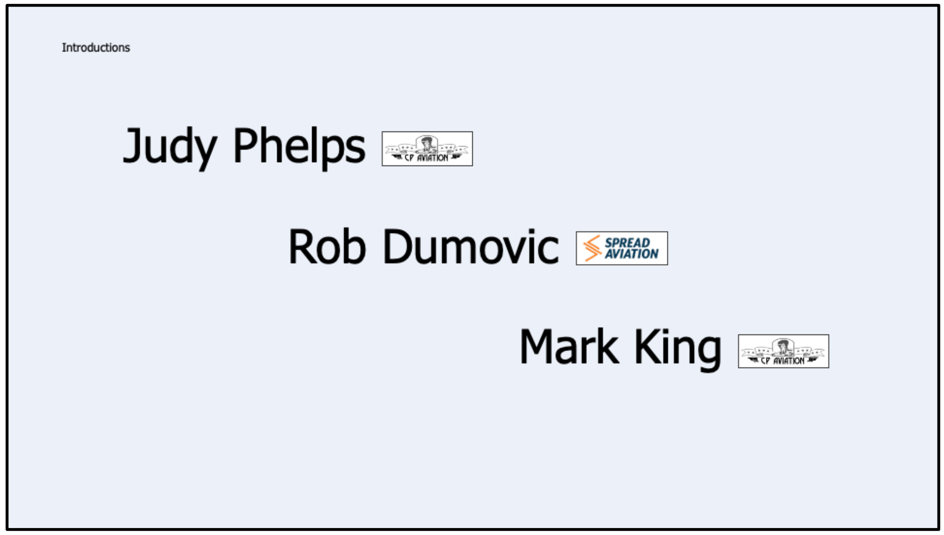
See PowerPoint Slide Deck, Slides #70–110

Debrief

See PowerPoint Slide Notes, PPT Slides #112–116

See PowerPoint Slide Deck, Slides #112–116

WELCOME and thank you for signing up for the Learn to Turn track at the new EAA Pilot Proficiency Center!



Introduce yourself:

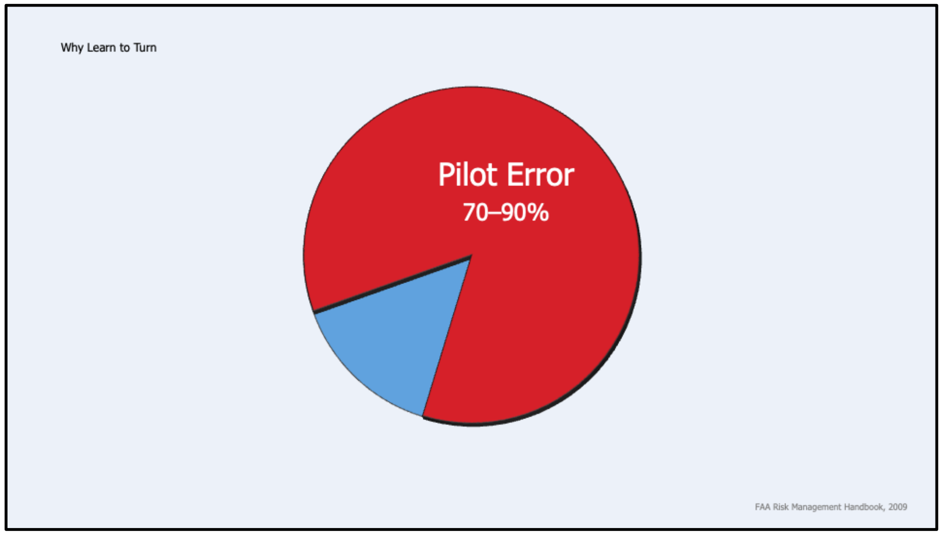
- Provide a little background about yourself.
- Mention any L2T-related issues do you see as a CFI/DPE?
- When did you become fully aware of turn dynamics?
- Why do you support the L2T program?

Introduce the facilitators, each of whom:

- Provides a little background about himself.
- Mentions any L2T-related issues he sees as a CFI?
- When did he become fully aware of turn dynamics?
- Why does he support the L2T program?

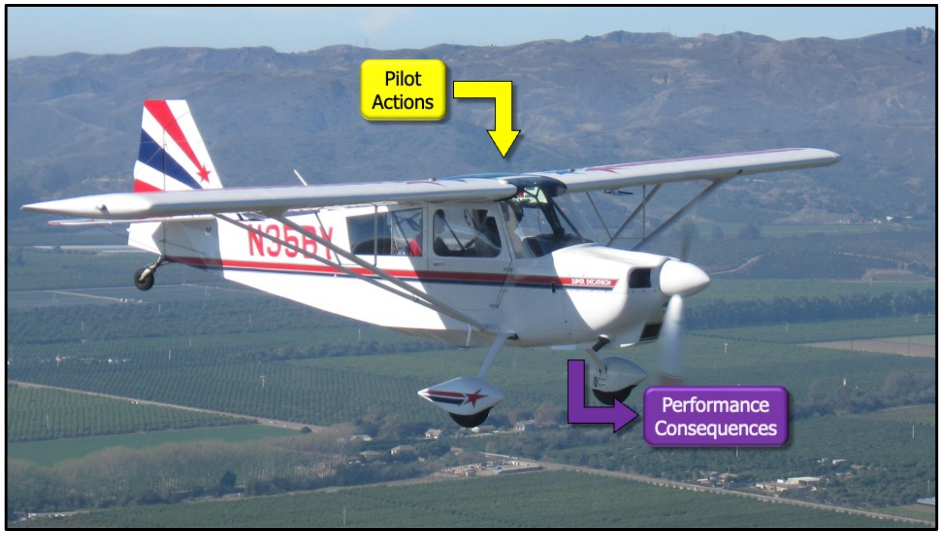
Point out the locations:

Breakout rooms and simulator area.
Restrooms.
Exits.



Risk Management Handbook: Historically "pilot error" has been assigned as a cause or a factor in 70 to 90 percent of GA accidents.

But is it fair to blame so many accidents on pilot error if the pilot never received the appropriate knowledge or skill during training to handle LOC-I scenarios?



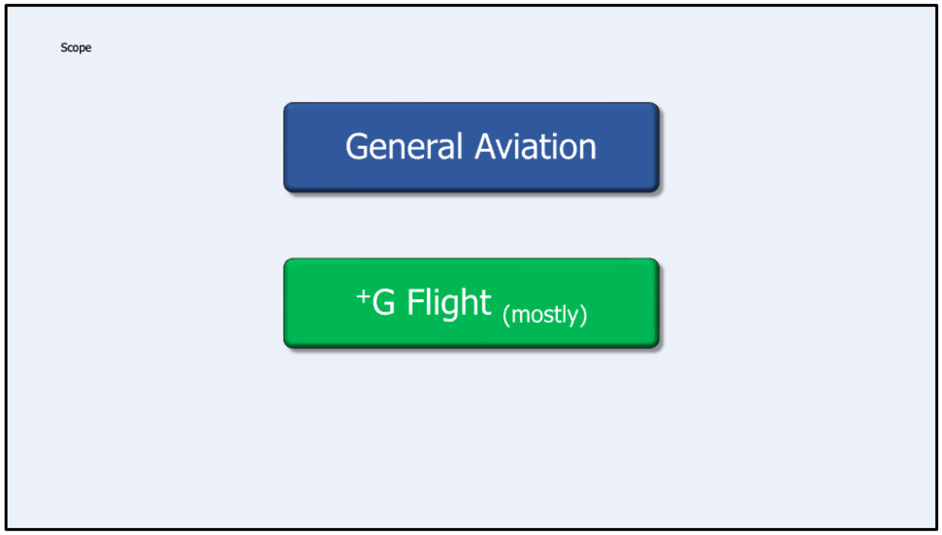
Learn to Turn (L2T) takes a pilot-centric approach to training.

“Pilot-centric” means we recognize that “flying is not done **TO** the pilot; instead, flying is done **BY** the pilot.”

The actions we take (or don’t take) will have performance consequences.

”Actions” can be physical (stick-and-rudder) or mental (decision making).

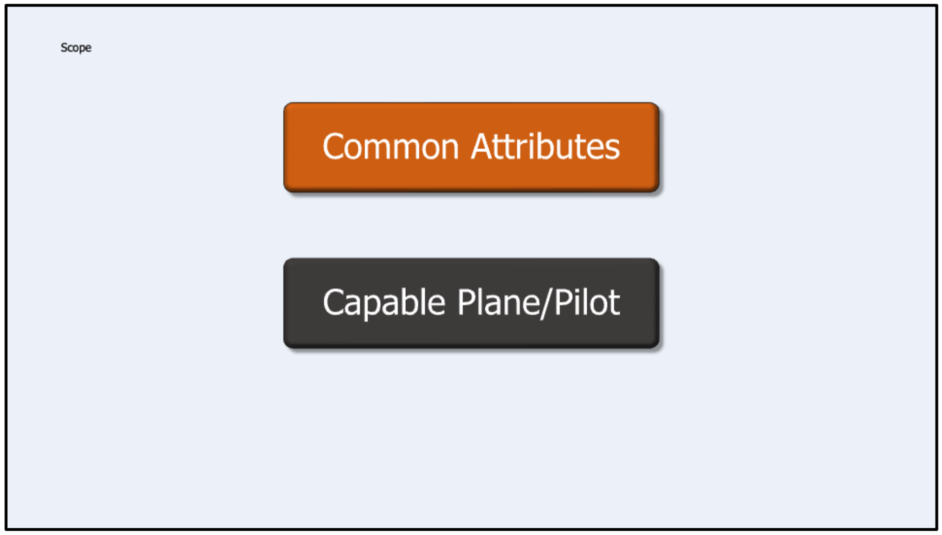
We need to know exactly what the consequences of our actions will be.



For today's activities, let's assume:

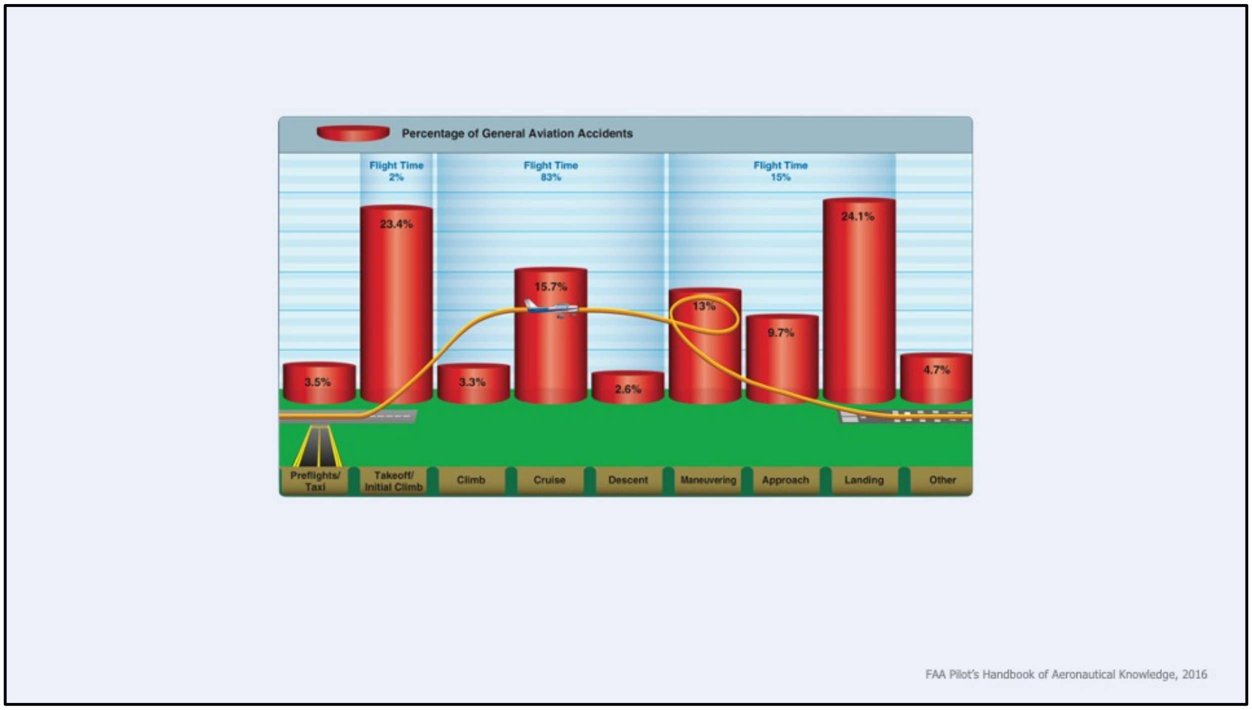
We are light airplane pilots flying typical general aviation airplanes.

Except for a few interesting cases, we are in positive G flight.



We will review the common attributes of turning flight.

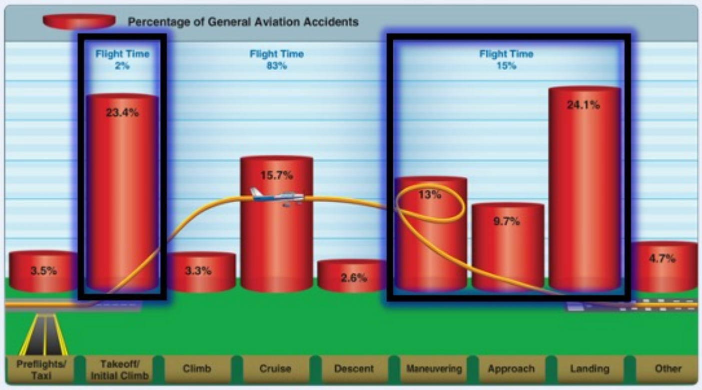
And in our examples, let’s imagine a capable airplane being flown by a competent pilot.



Here is an interesting breakdown of GA accidents taken from the Pilot's Handbook of Aeronautical Knowledge.

The red bars are the percentage of accidents by phase of flight.

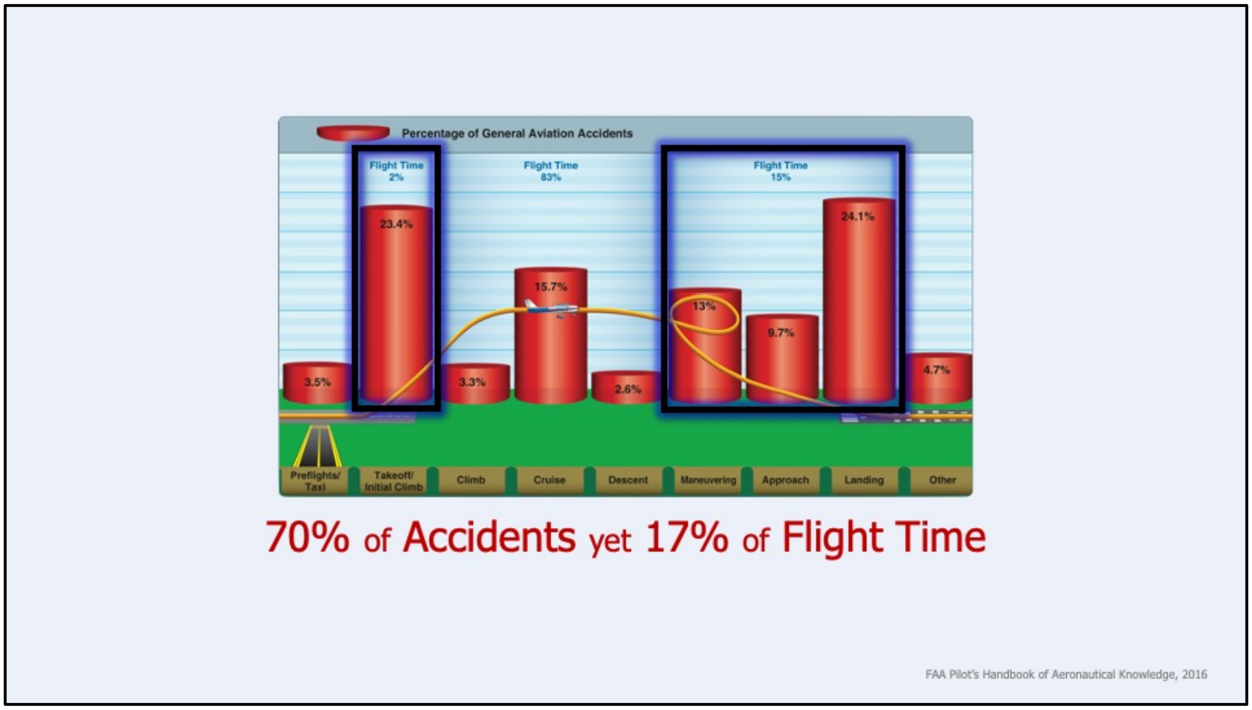
The light blue shading shows the estimated flight time typical GA pilots spend in the various phases over the course of their flying careers.



FAA Pilot's Handbook of Aeronautical Knowledge, 2016

The four busiest phases:

Takeoff / Initial Climb
Maneuvering
Approach
Landing



70% of accidents occur where we spend just 17% of our flight time.

Those numbers are disproportionate.

ASK: What do these phases have in common?

Answers include:

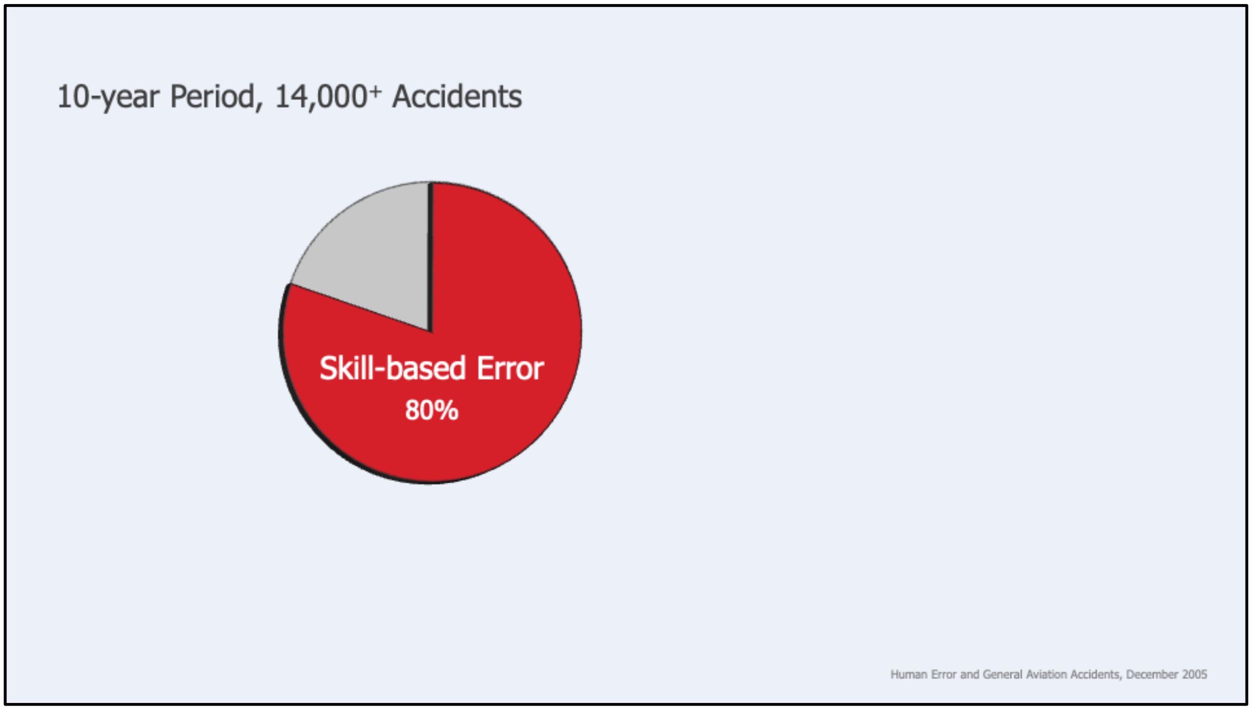
Higher workload.
More interactive with the flight controls.
Generally higher AOAs with less margin to the stall.
Increased potential for distraction.
e.g., Flying in closer proximity to other planes, terrain, obstacles.

10-year Period, 14,000+ Accidents

Human Error and General Aviation Accidents, December 2005

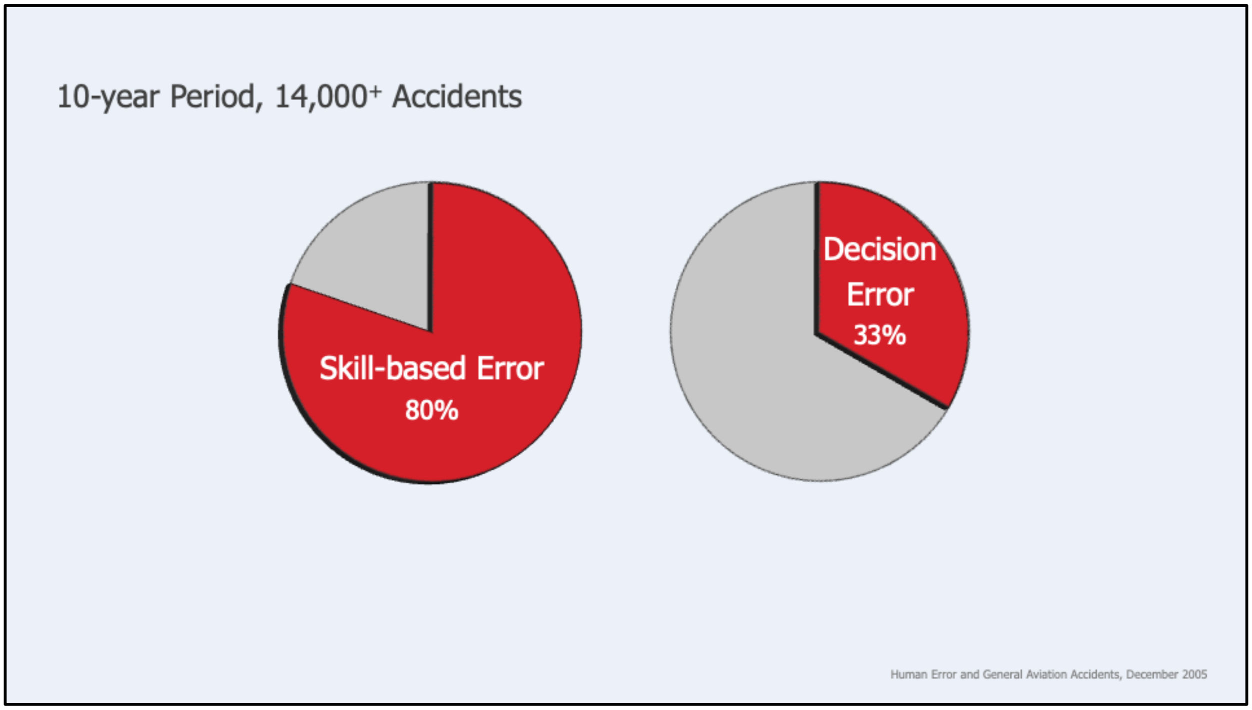
Study on Human Error in GA Accidents.

10-year period included more than 14,000 accidents.

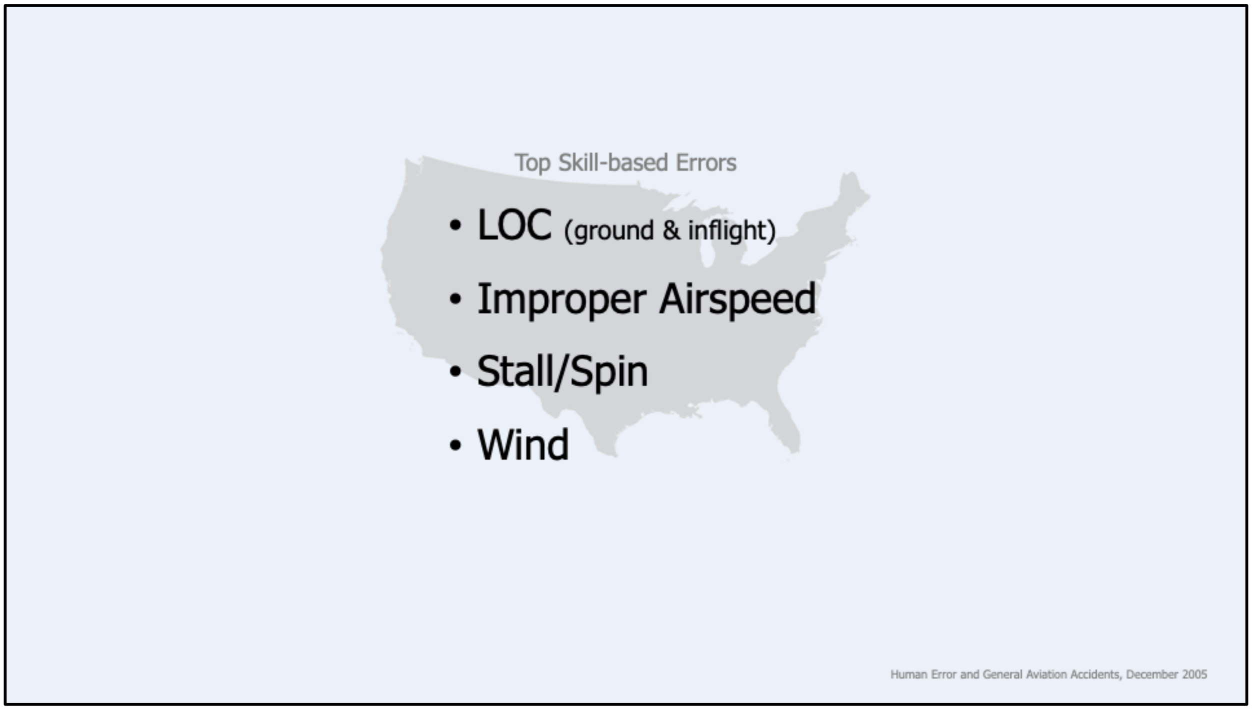


80% of all the GA accidents involved at least one skill-based error.

Nearly half of the skill-based errors were the first human causal factor in the accident chain.



Decision errors were present in about one-third of all the accidents.



The top skill-based errors for fatal and non-fatal accidents:

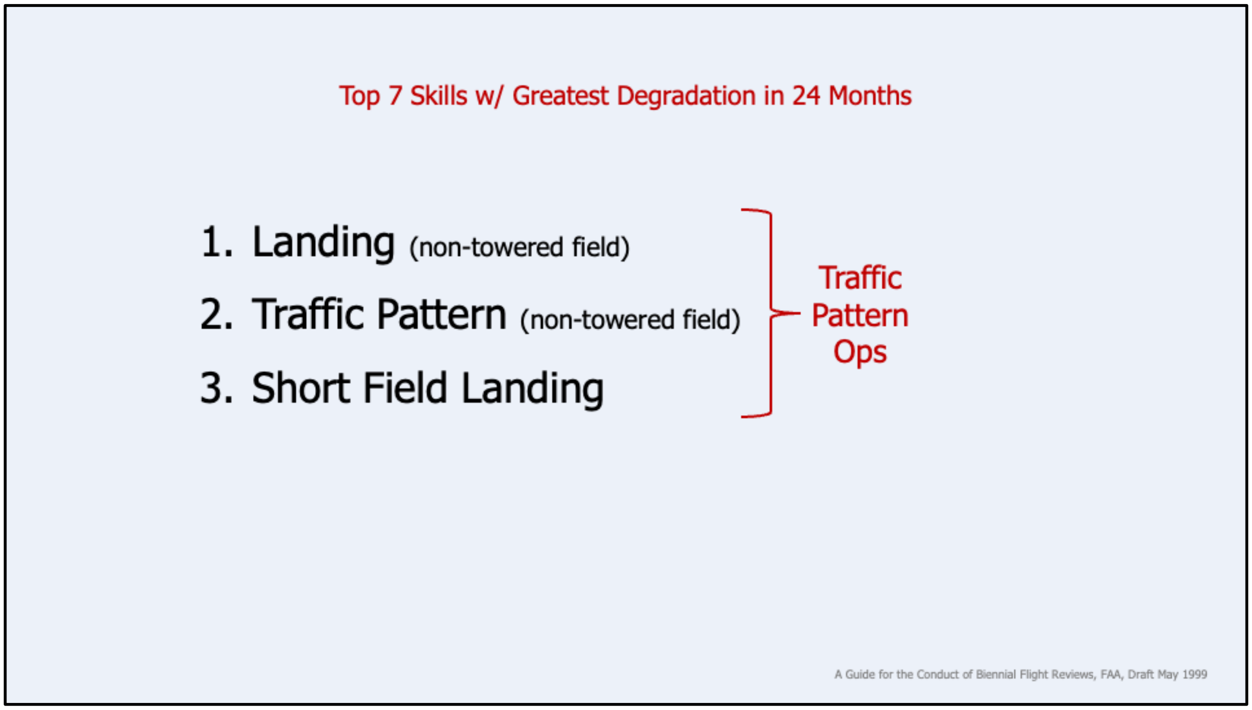
Loss of Control (ground & inflight)
Improper airspeed
Stall/spin
Inadequate compensation for the effects of the wind

A 1999 draft guide for the conduct of the flight review identified the top seven piloting skills that suffered the greatest degradation over a 24-month period.

The piloting skills of a group of Private pilots were compared on the day of their check rides and 24 months after their check rides.

The first three on the list:

Landing at non-towered fields.
Traffic patterns at non-towered fields.
Short field landings.

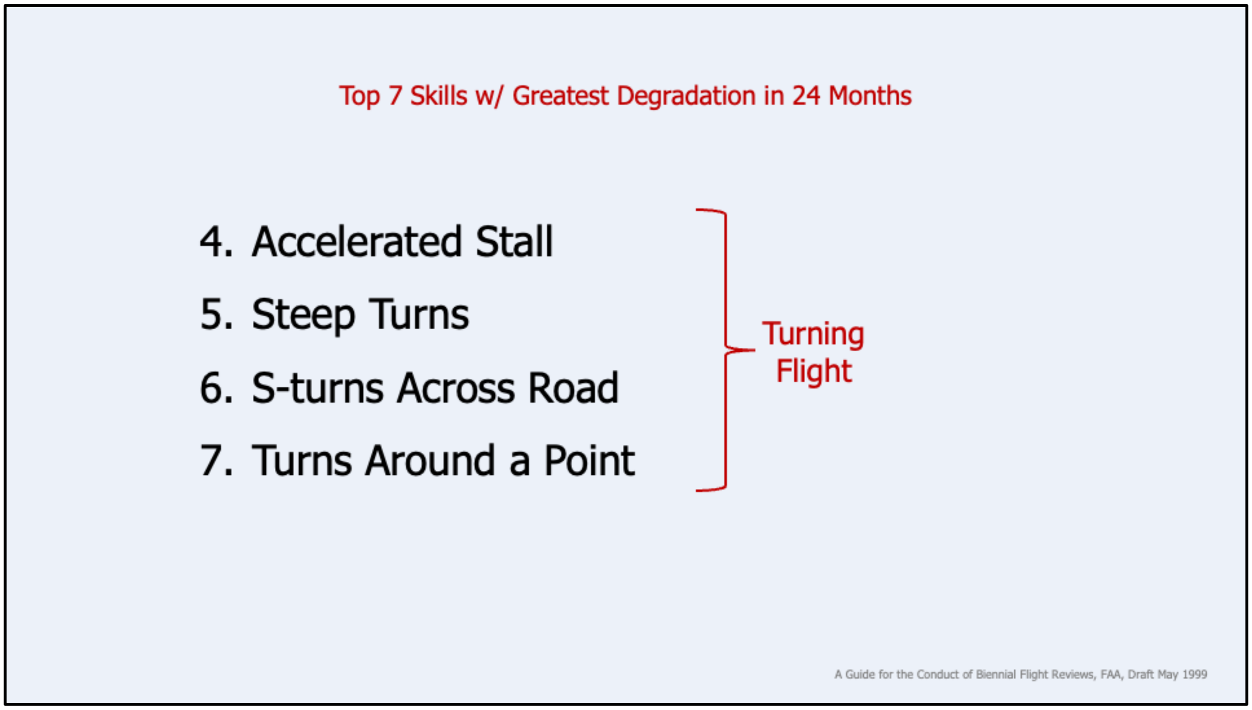


We can lump these three under "Traffic Pattern Operations."

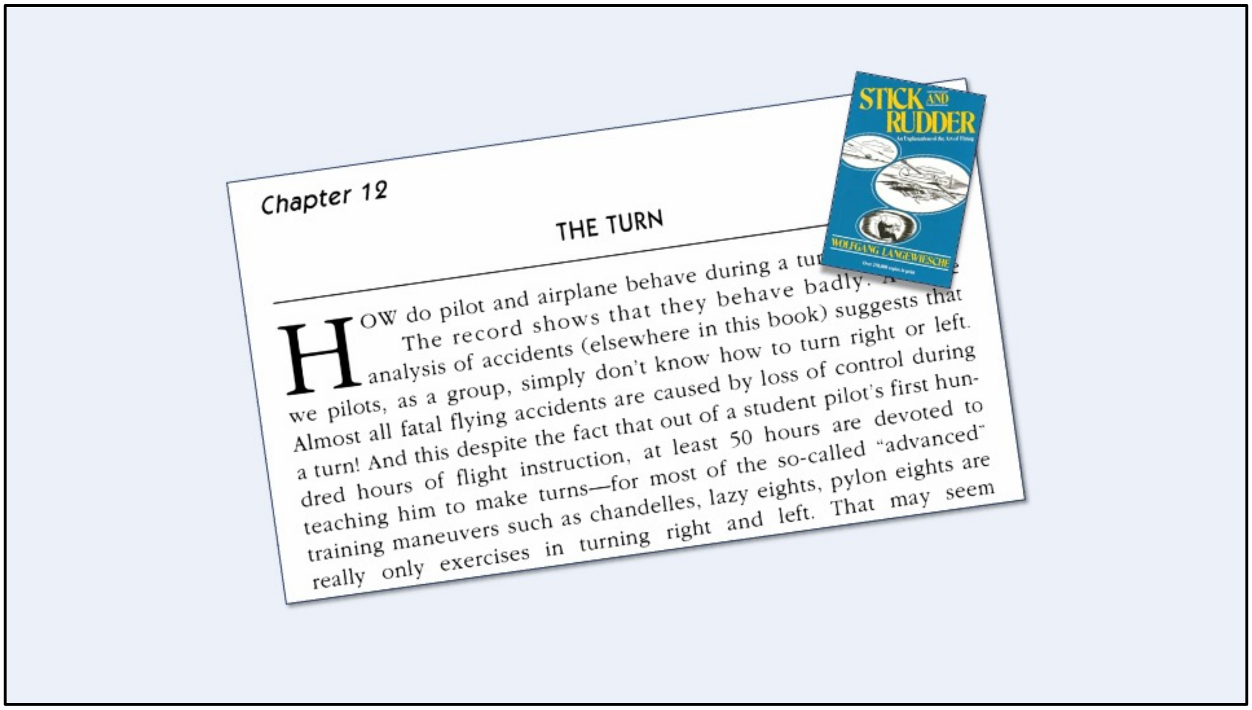
Note: Most GA airports are "Non-towered fields" with runways that might qualify as "short fields."

The next four skills that showed the most degradation over 24 months were:

Accelerated stalls.
Steep turns.
S-turns across a road.
Turns around a point.

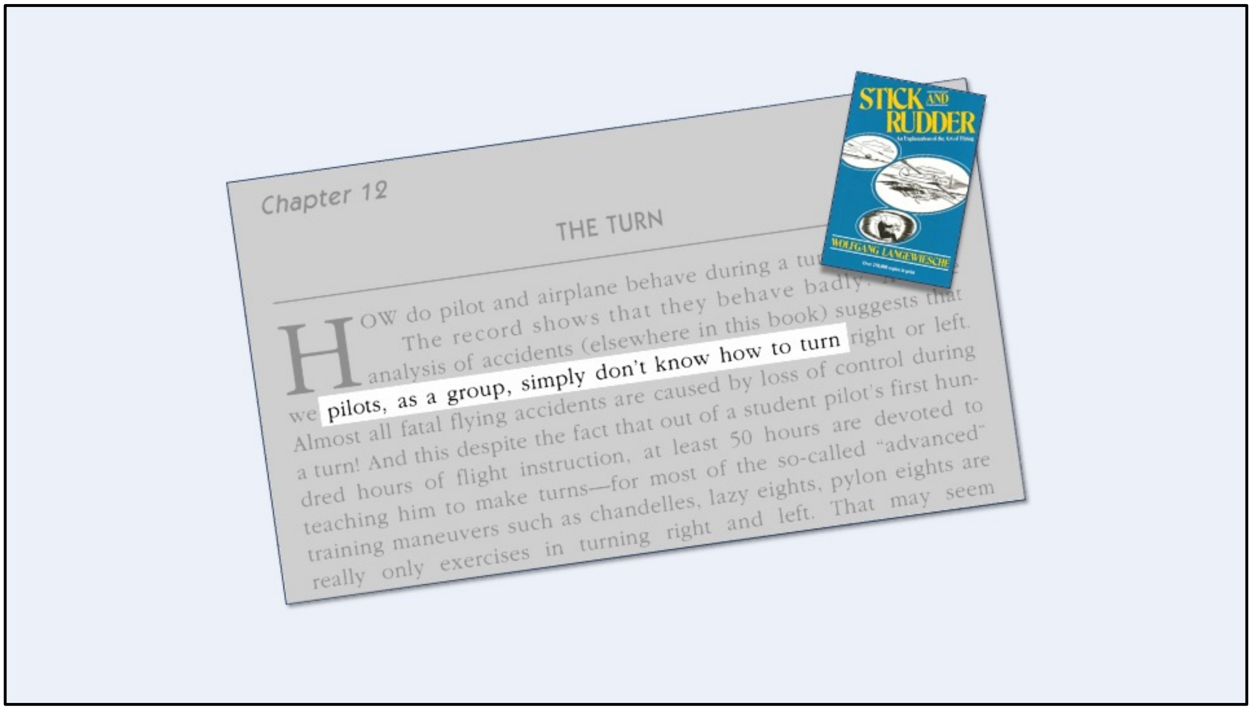


And we can lump these under the heading of “Turning Flight.”



Problems surrounding turning flight are not new.

ASK: How many of you have read the classic book, “Stick and Rudder”?



In 1946, Wolfgang Langewiesche wrote:

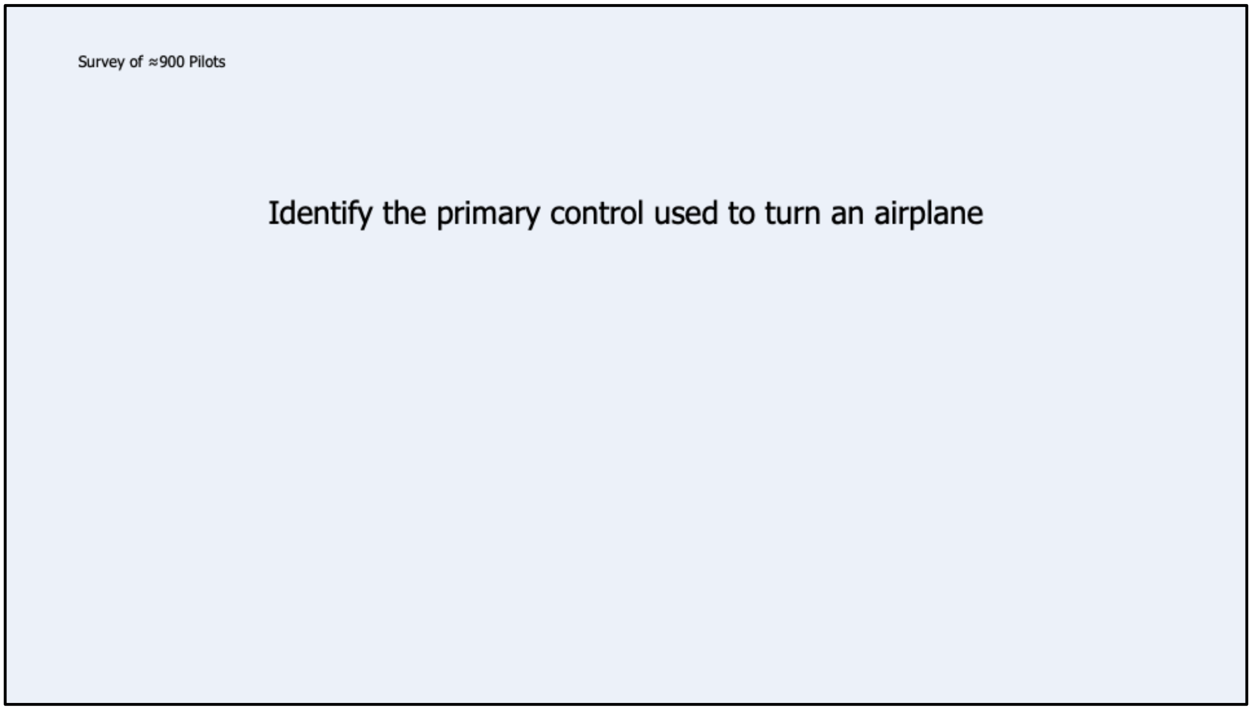
> "Pilots, as a group, simply don't know how to turn."

Unfortunately, loss of control while maneuvering – in other words, while turning – remains a significant cause of fatal accidents.

Of course, we turn airplanes all the time.

But how many pilots are fully aware of what they are doing to make their turns happen?

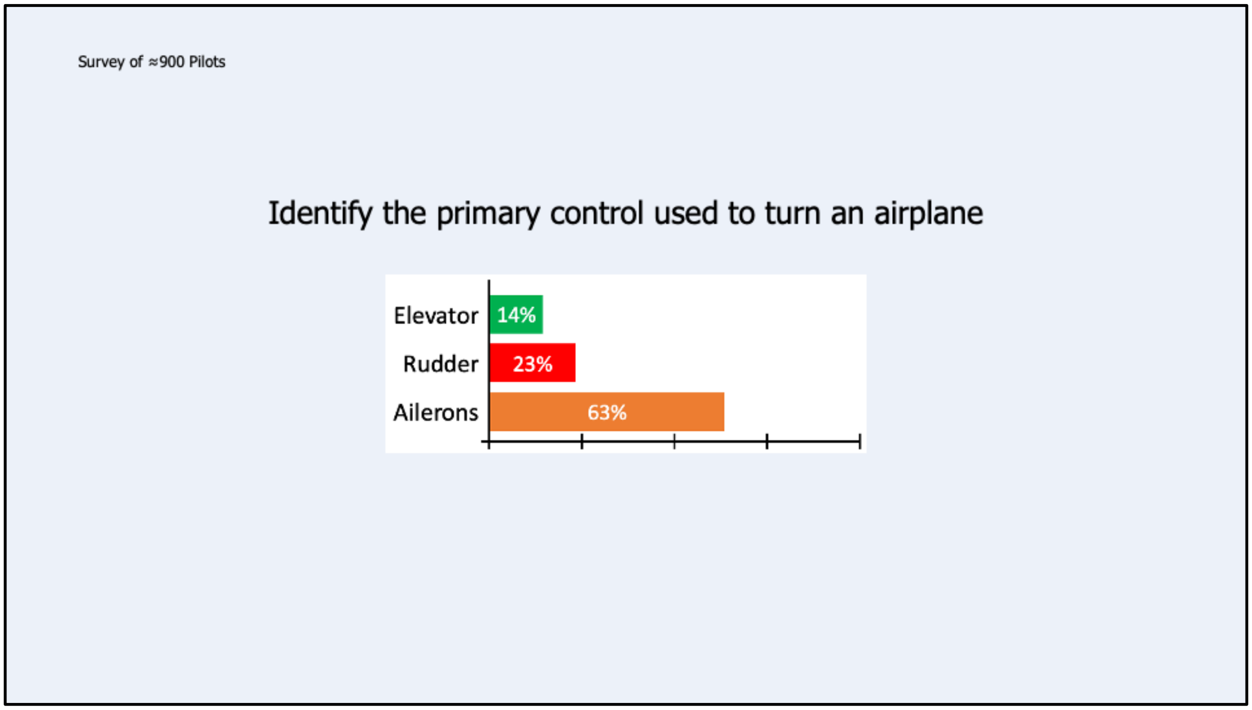
And how many pilots realize that they routinely turn in the horizontal, the oblique, and even the vertical?



A while back, Rich Stowell surveyed nearly 900 pilots.

The pilots were asked to identify the primary control used to turn an airplane.

Notice Rich did not say what kind of "turn" it was, though most pilots probably pictured it as a level turn.



Nearly two-thirds of the pilots said they used “ailerons” to turn the airplane.

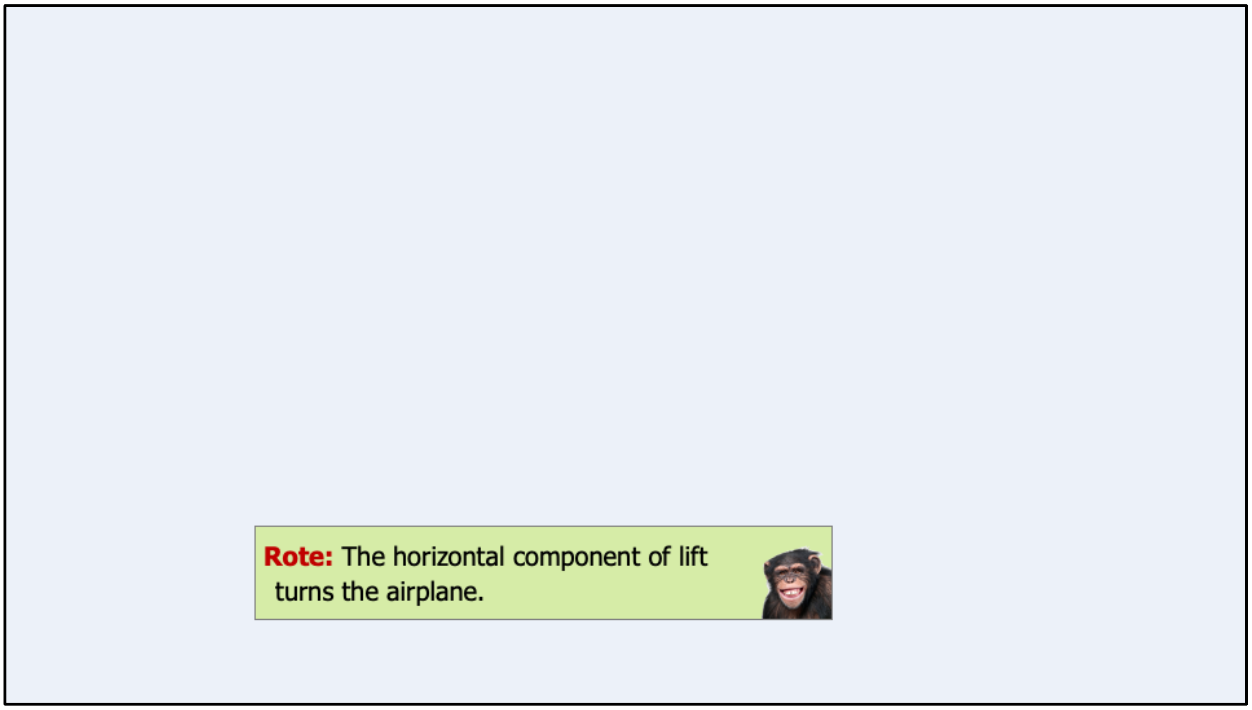
Yet using ailerons doesn’t explain the ability of airshow pilots here at Oshkosh to perform 4-point rolls without turning, or knife-edge passes without turning.

Using ailerons doesn’t explain the vertical turn more commonly called a Loop.

One in four pilots said the rudder turns the airplane. This despite FAA warnings that rudder DOES NOT turn the airplane. The function of the rudder is to cancel yaw. If we use rudder to generate yaw, the results are either a slip, or a skid-spin.

Only 14 percent of the pilots identified the elevator as the turn control. The bottom line is the elevator controls the AOA of the wing.

And in the process of manipulating the AOA, the elevator directly affects not only airspeed and G-load, but it also bends or straightens our flight path.



All of us learned and can recite this mantra.

Repeat along with me: “The horizontal component of lift turns the airplane.”

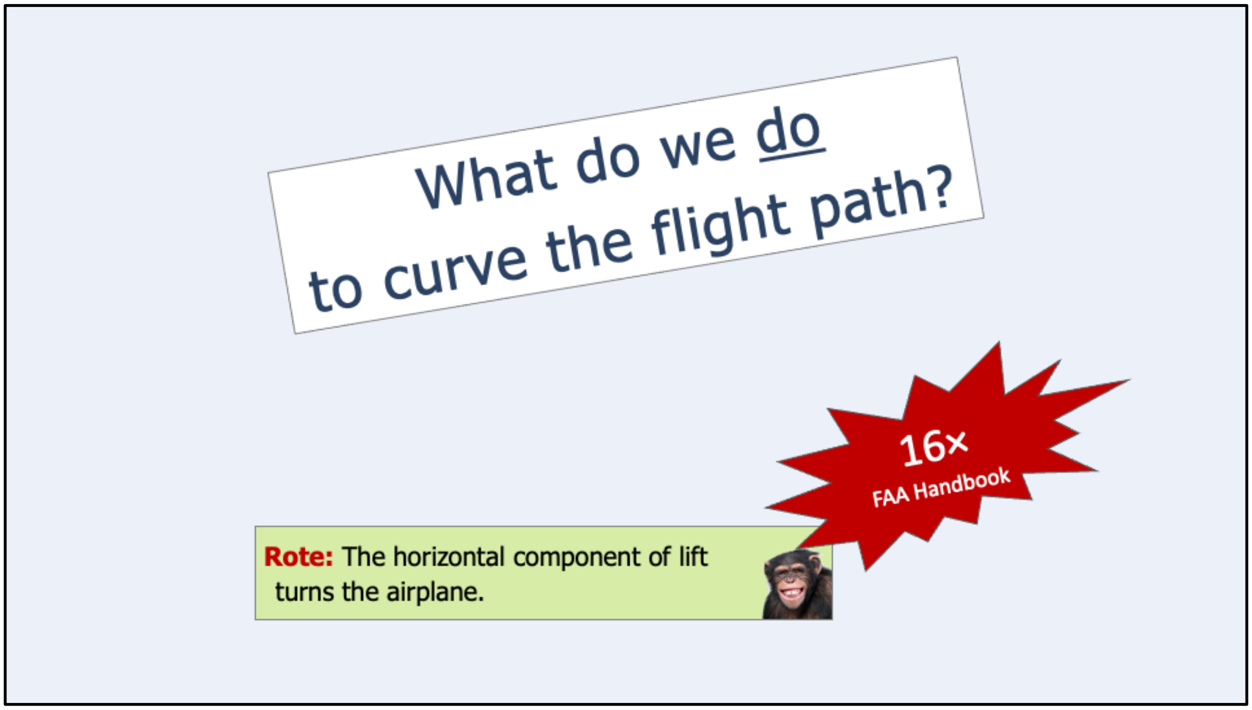
This is rote level learning. Monkey-see, monkey-do.

Apparently, this is such an important concept that the Airplane Flying Handbook references “horizontal com[ponent of lift” at least 16 times.

But what is the operational relevance/usefulness of this to us in the airplane?

Who imagines lift vectors pointing every which way when we’re flying?

And where is the horizontal component of lift during vertical turns like Loops, or pullouts from dives, or the round outs for landing?



While we talk a lot about the horizontal component of lift, we don't do a very good job of clearly identifying what we actually DO to curve the flight path.

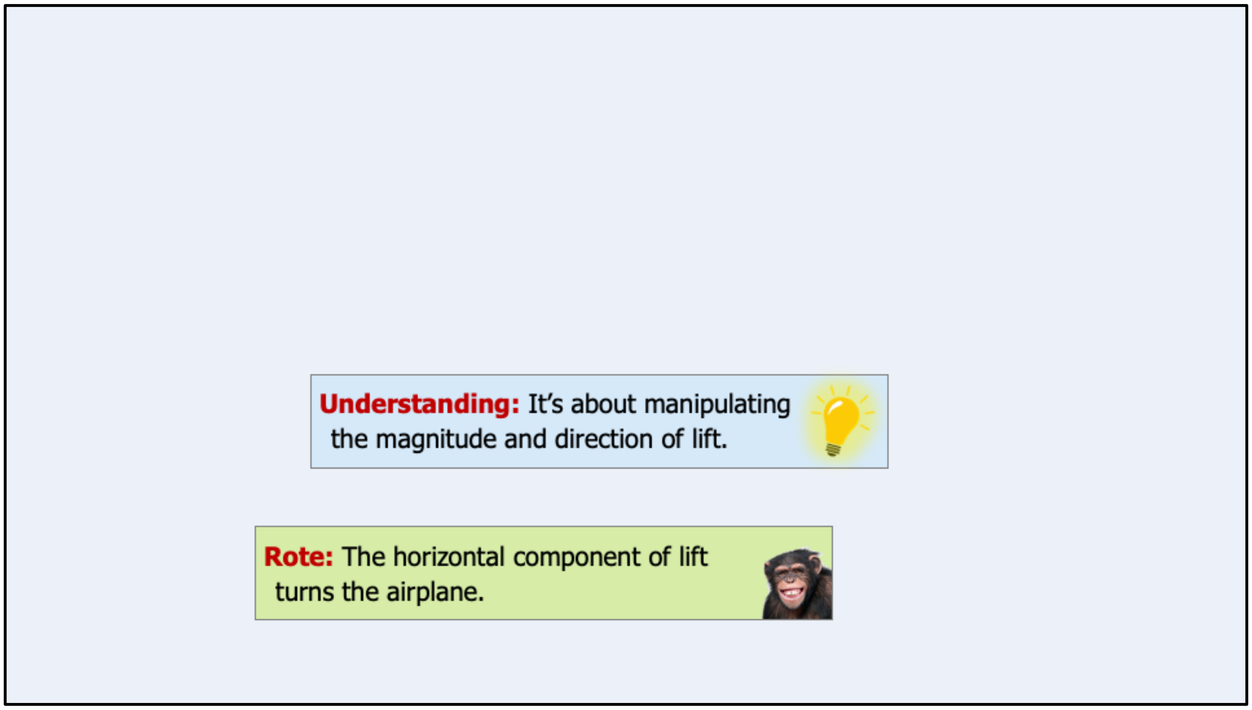
What do the the higher levels of learning look like regarding turning flight?

Let’s watch this short video…

<Click to Start the Video on this Slide>

There certainly was a horizontal component of lift there, right? But probably not the way you normally would have envisioned it.

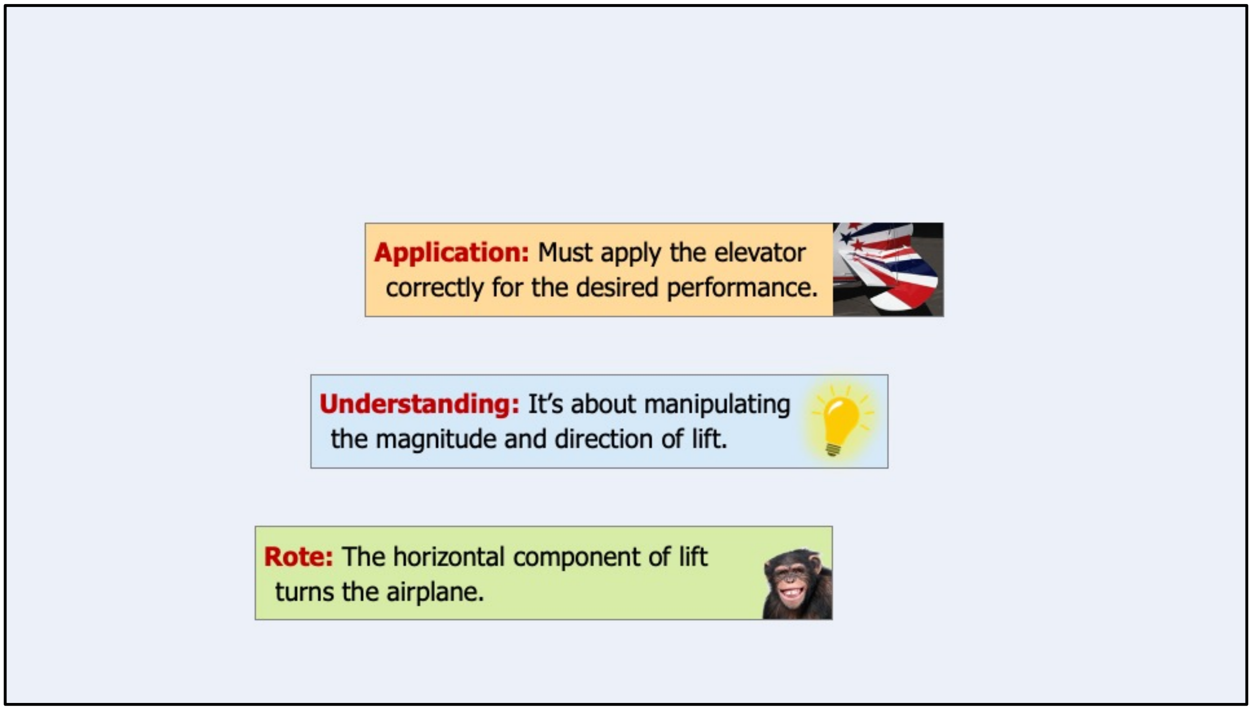
What is the broader concept we should be trying to discover?



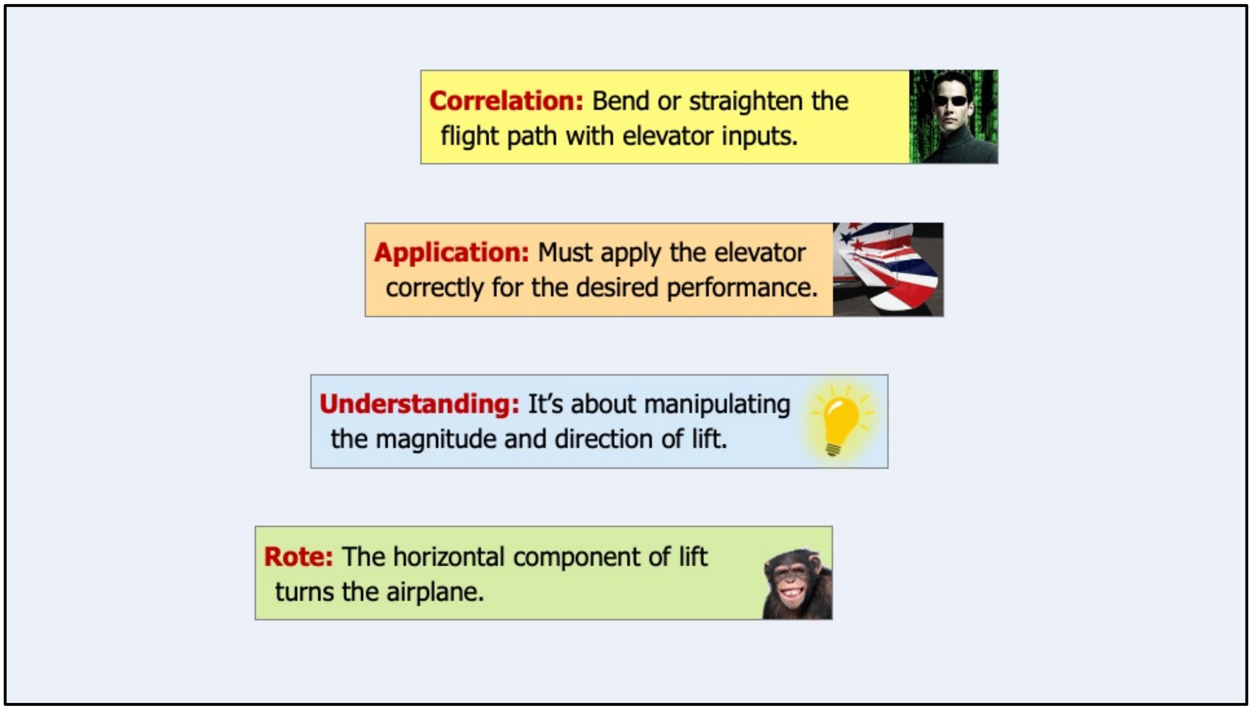
At the understanding level, it dawns on us that turning flight is about manipulating the magnitude and the direction of lift.

In the video we just saw, the pilot changed not only the magnitude of the lift on the wings, but also from which side of the wings the lift vector pointed.

ASK: From a pilot-centric point of view, what control do you think the pilot used to make the airplane turn in that direction?



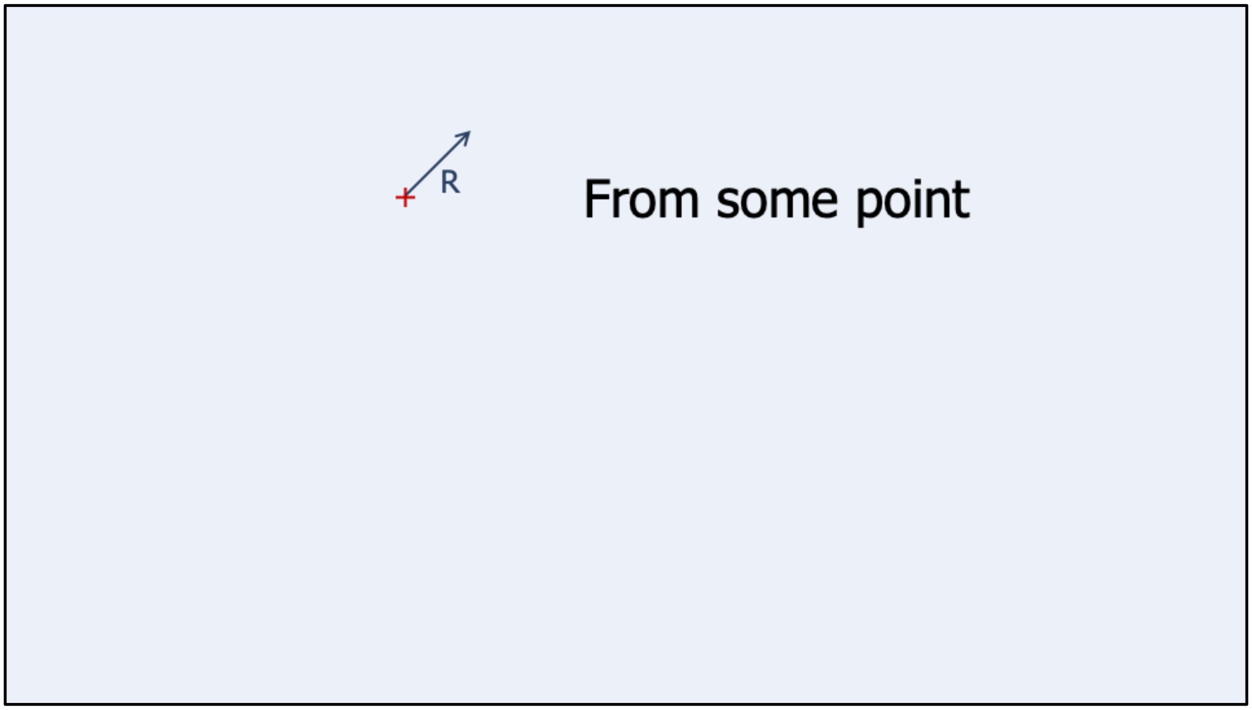
At the application level, we realize that we must apply the elevator correctly for the desired turn performance.



And at the correlation level of learning, we can see the underlying code just like Neo in the matrix movies, namely:

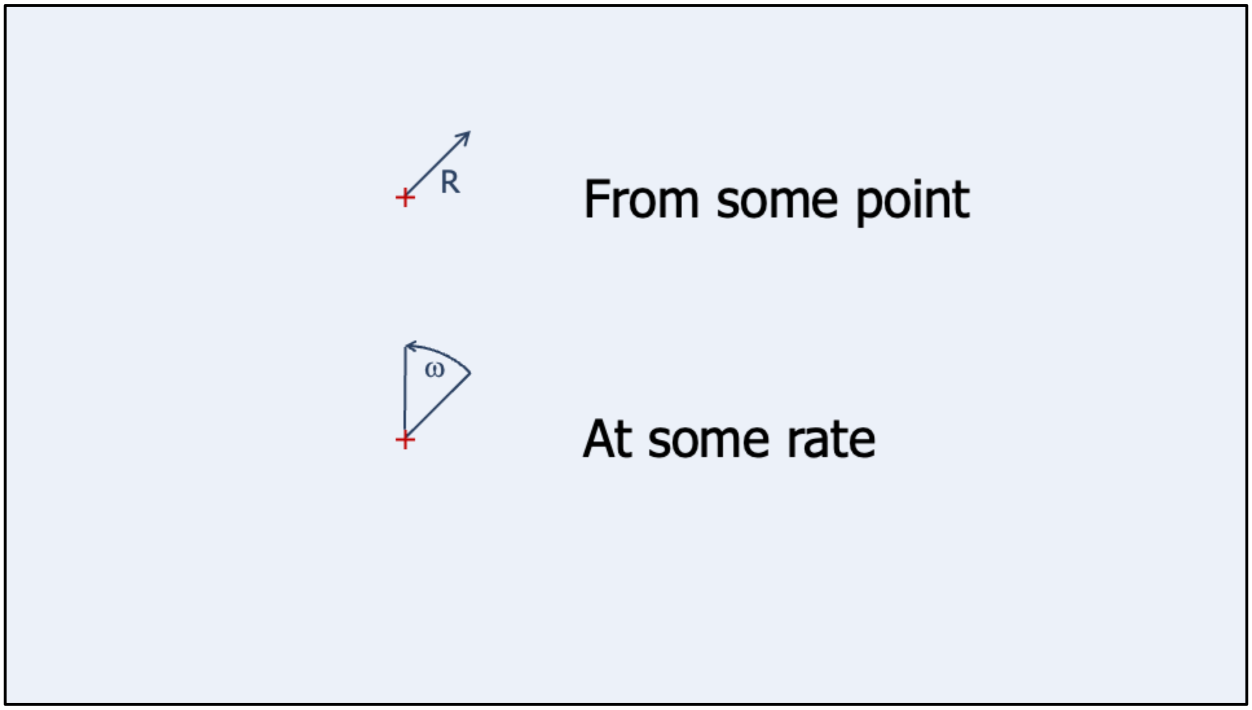
We bend or straighten our flight path with elevator inputs.

Also keep in mind that adjusting the elevator trim is equivalent to making an elevator input.



Ok, let’s review the common attributes shared by turning flight.

First, we turn at some distance from some point. Turning flight has a radius.

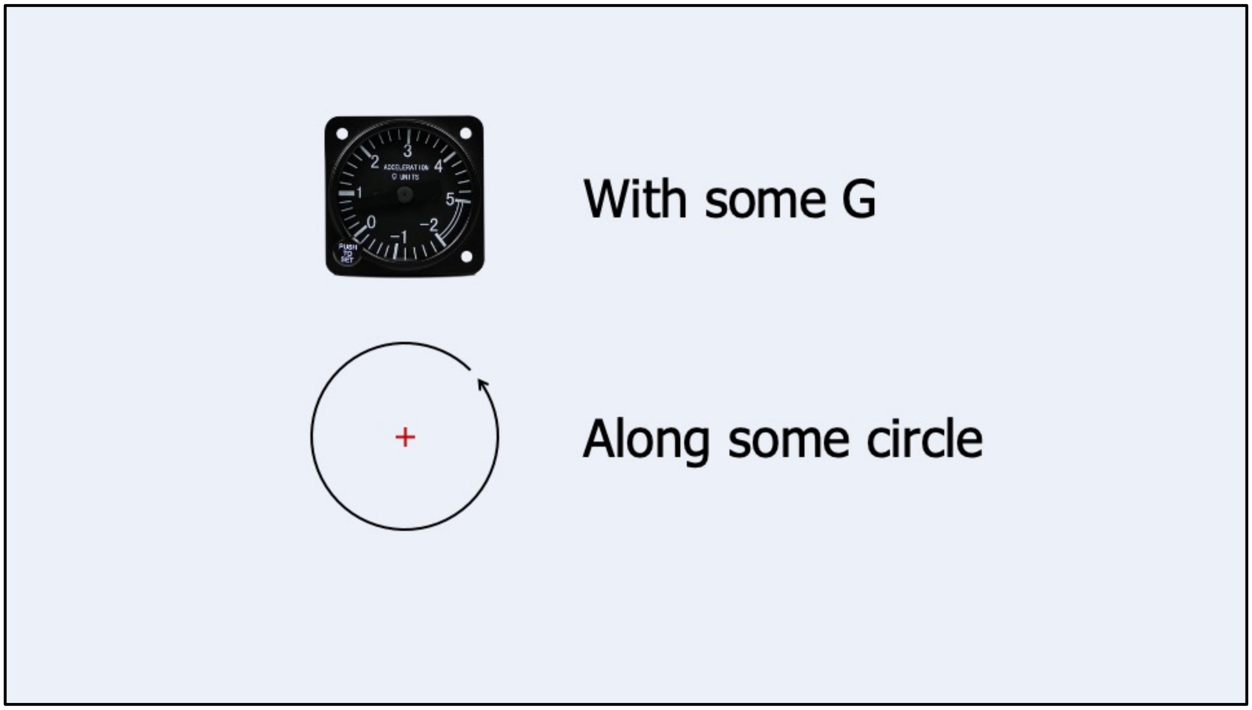


And we move around that point at some rate of turn.

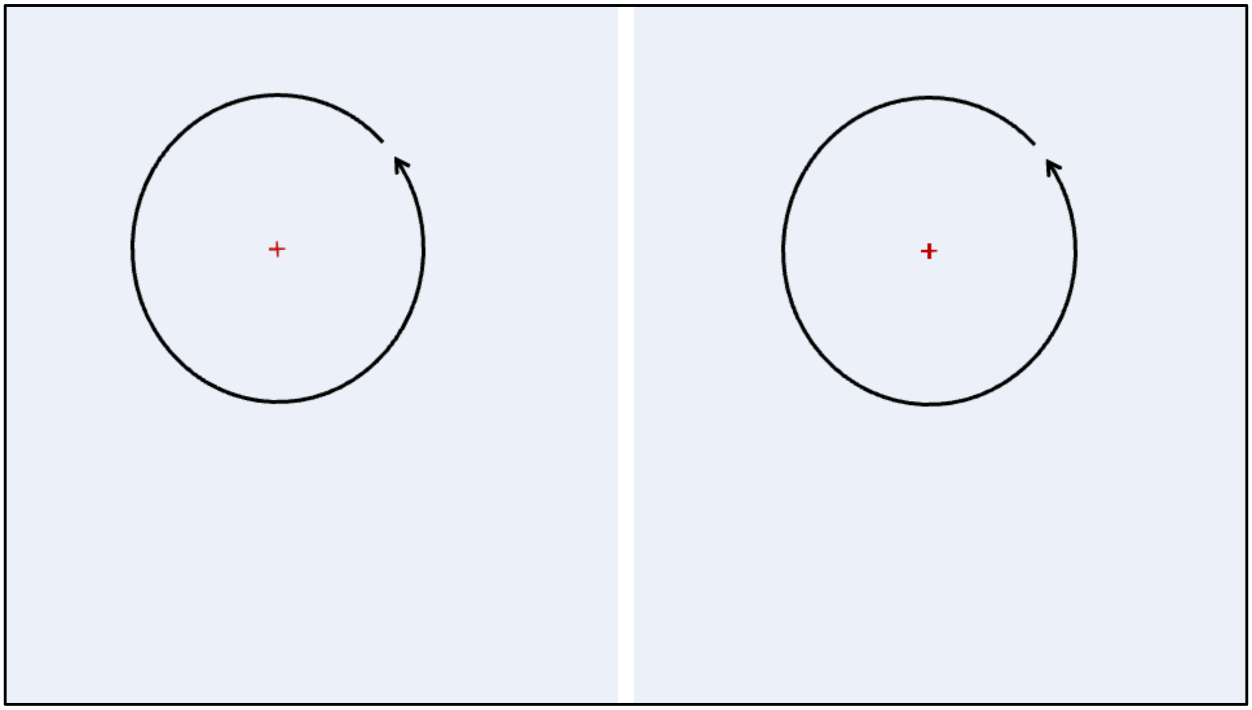
With some G

Turning flight is also accelerated flight.

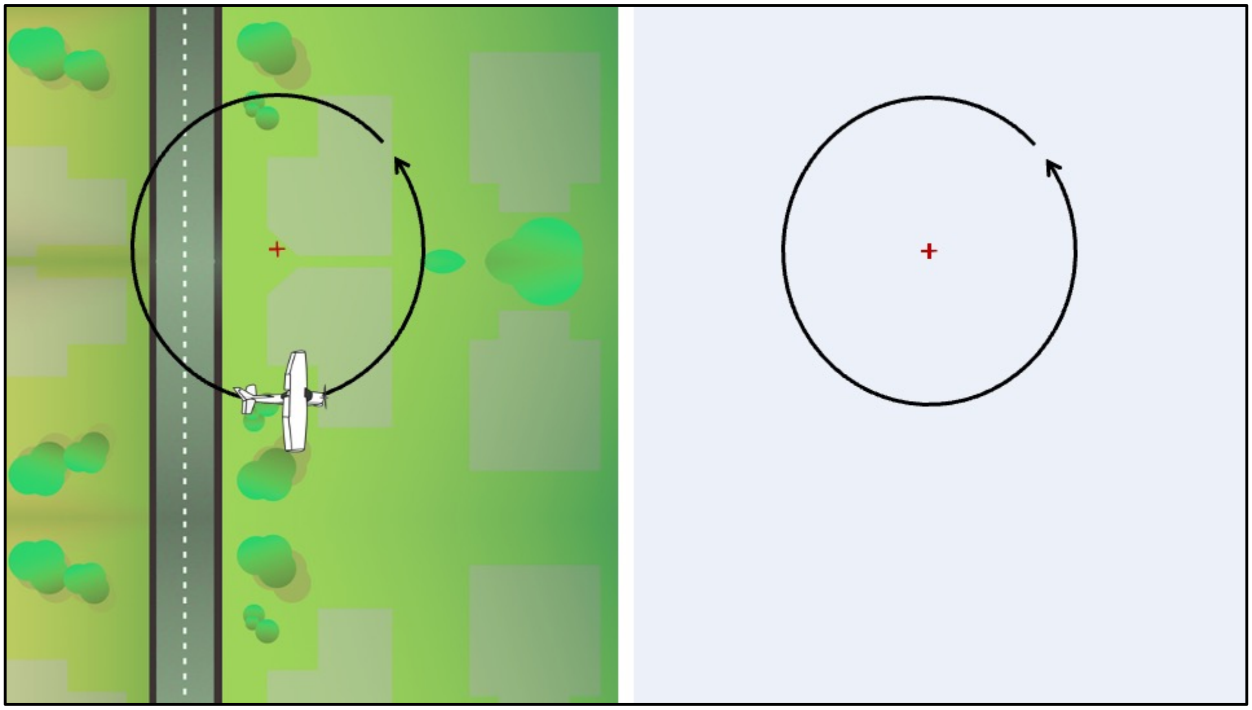
We experience a G-load other than one.



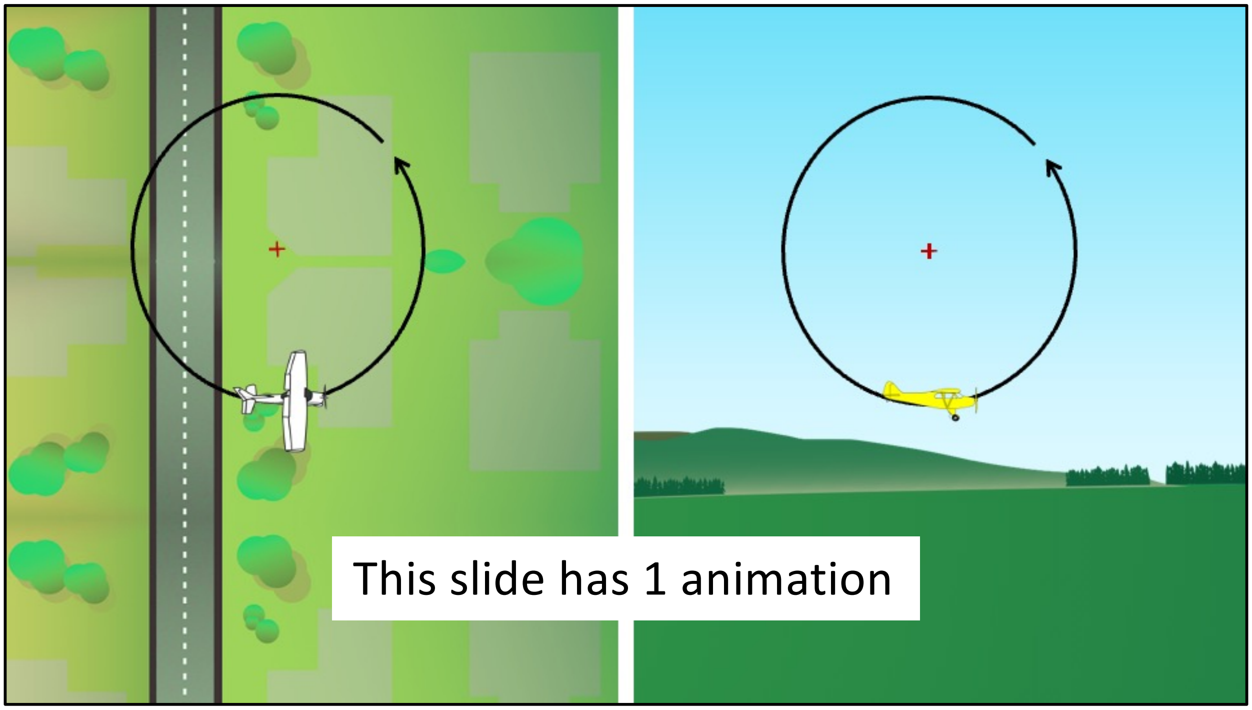
And ultimately, we follow the arc of some circle.



Ok, now imagine you are watching an airplane in turning flight.



Maybe you are flying at a higher altitude looking down on another airplane that is practicing turns around a point.



Or maybe you are on the ground watching an airplane perform a loop during an air show.

<Click to Start the Animation on this Slide – both airplanes fly around their circles>

Regardless, both airplanes are flying circles in the sky.

Maneuver	Geometric Plane	Attributes			
		Radius	Rate	$G \neq 1$	Circle

Let’s now look at perhaps the three most popular maneuvers known to pilots.

I’ll break them down by the geometric plane in which each is flown, and see if they check the boxes of attributes for turning flight.

Maneuver	Geometric Plane	Attributes			
		Radius	Rate	G ≠ 1	Circle
Level Turn	Horizontal	✓	✓	✓	✓
Chandelle	Oblique	✓	✓	✓	✓
Loop	Vertical	✓	✓	✓	✓

The Level Turn occurs in the horizontal.

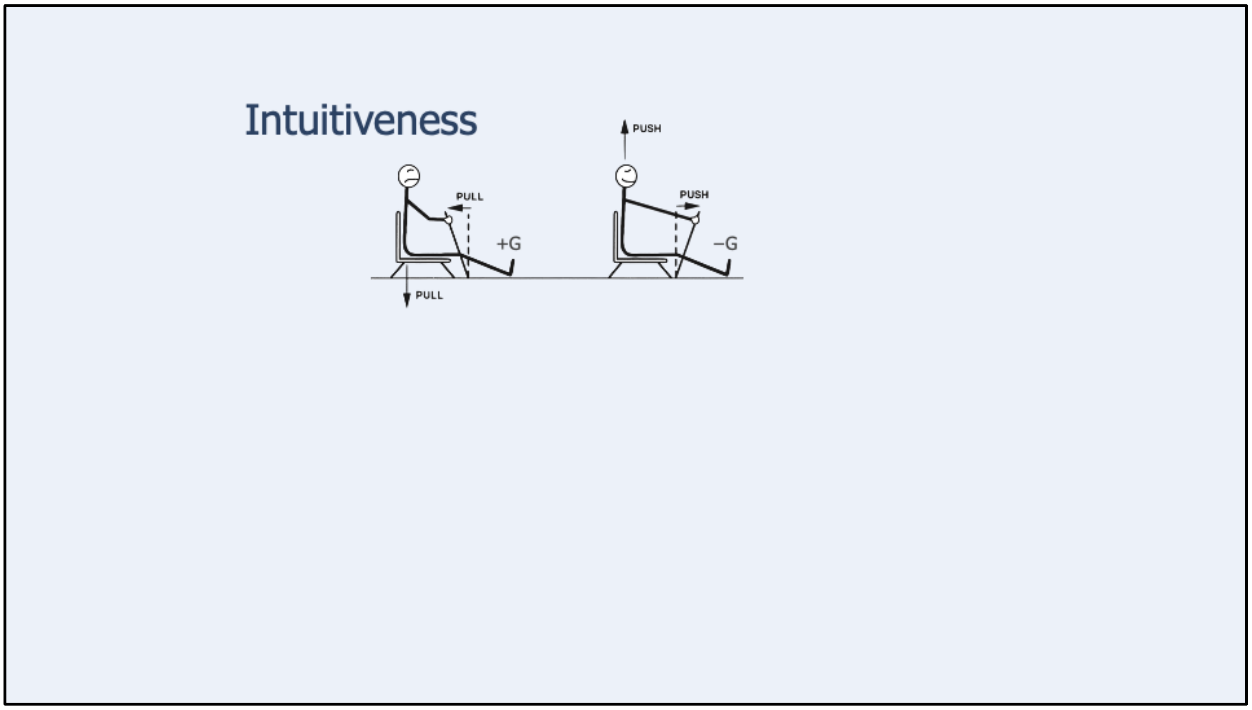
The Chandelle occurs in the oblique plane. The airplane describes a shape similar to the coil of a spring.

And the Loop occurs in the vertical.

These three maneuvers are manifestations of the same thing — turning flight.

Each one has a turn radius and a turn rate.
Each one occurs at some G-load other than one.
And each one is drawing a circle in the sky.

ASK: Which control is making the airplane carve these circular flight paths?



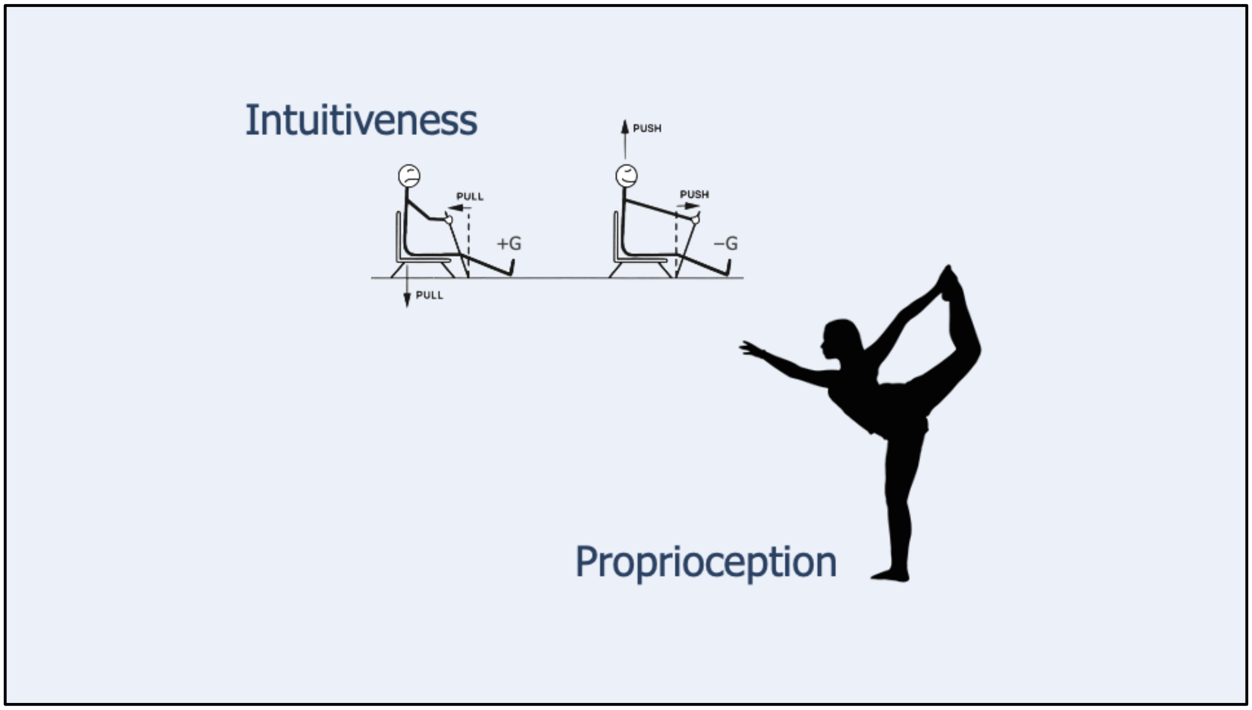
From a pilot-centric point of view, thinking in terms of G-load has far more operational relevance to the pilot than thinking about forces.

First, G-load is intuitive. Elevator inputs and G-load are connected.

For example, pulling the elevator faster and farther aft correlates with an increase in positive G.

Pushing the elevator faster and farther forward correlates with a decrease in positive G. And in some cases, a transition to negative G.

Pulling can make you feel heavier in your seat; pushing can make you feel lighter in your seat.



Proprioception is our sense of our body in space.

ASK: Everyone, close your eyes for a moment. Without looking, touch your index finger to your nose.

That is an example of proprioception. We know where all of our parts are in space even without looking.

This is what we mean when we talk about developing the ability to fly by “the seat of your pants.”

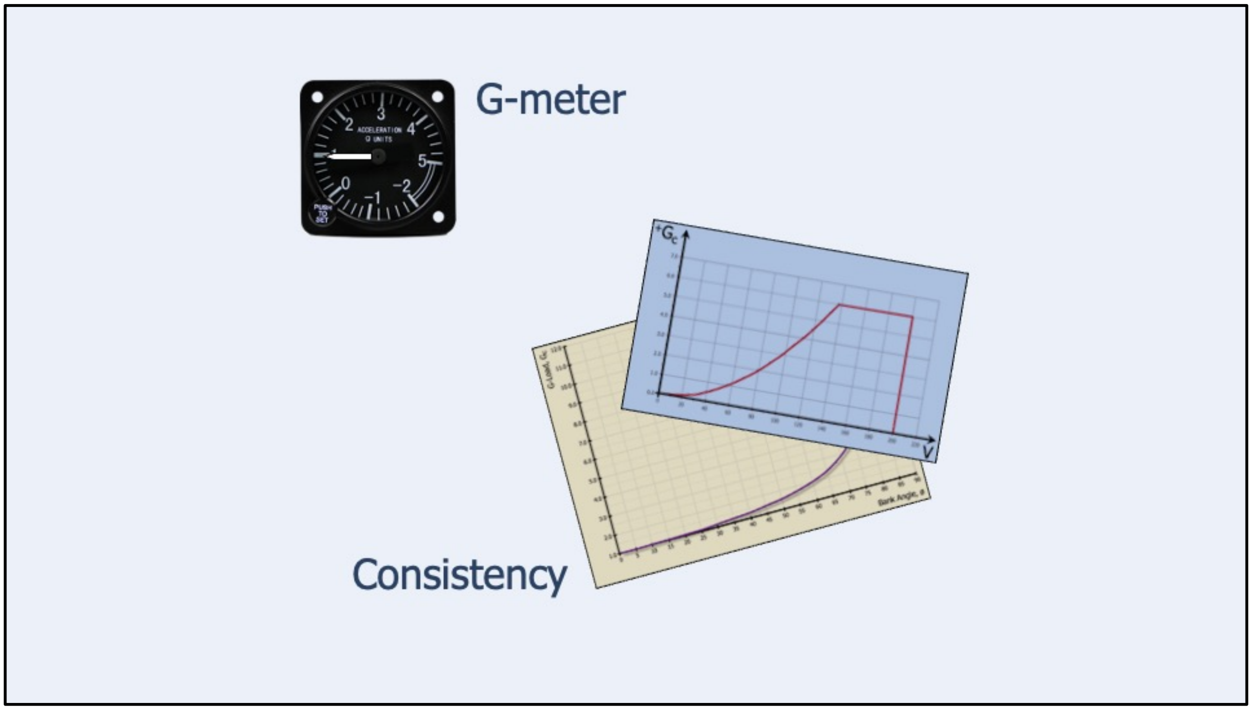
Our bodies are sensitive to changes in G-load. The more relaxed we are, the better our sense of feel in the airplane.

G-meter

When was the last time you heard a pilot say “I’m going to go pull some pounds?”

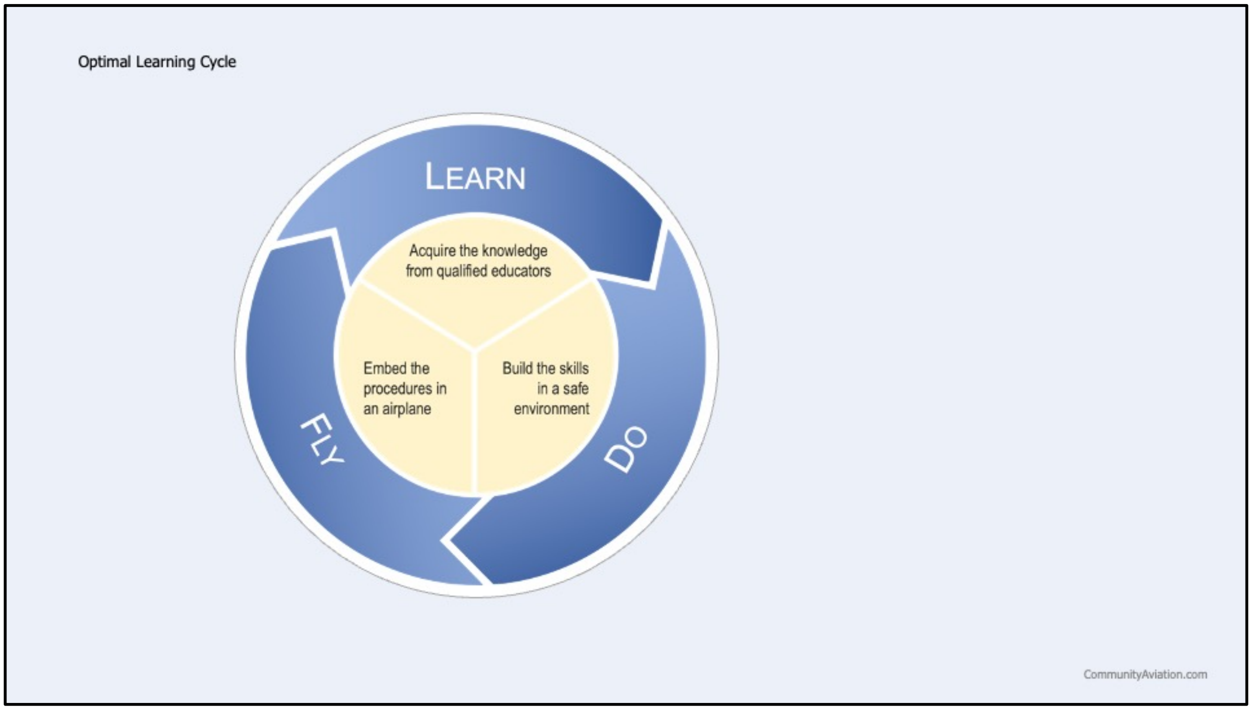
We don’t think like that. And it would be useless to equip the airplane with a scale in the instrument panel.

Instead, we might install a G-meter to give us feedback about how hard we are pulling or pushing on the elevator control relative to one-G.



Airplane design limits are given to us in terms of G-load as well.

And the V-G and Bank-G diagrams use G-load. Both diagrams provide important insights into airplane performance.



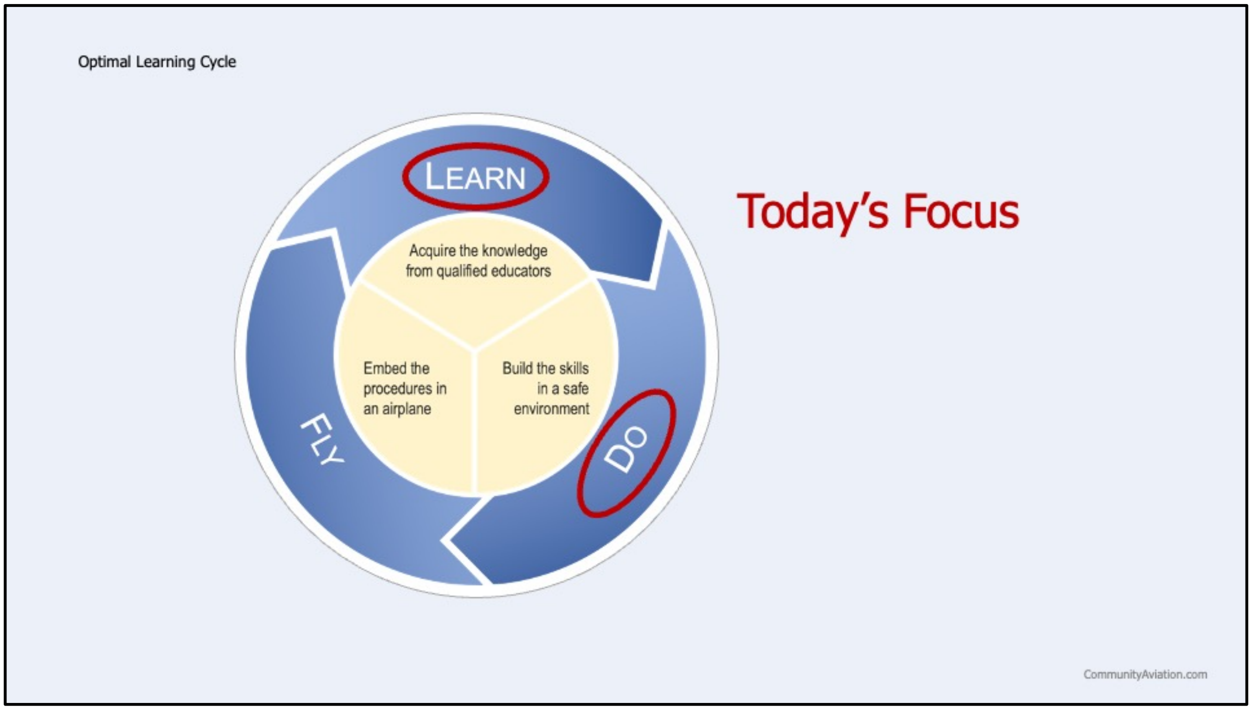
The best way to learn has been known for a long time.

The learning cycle has three parts. Community Aviation's version is "Learn – Do – Fly"

"Learn" is the academic part, where you acquire the knowledge.

"Do" is the simulation part, where you can build the skills in a safe environment.

"Do" can be as simple as visualizing while sitting in a chair, or as complex as flying a full motion flight simulator.



Today you'll be experiencing the Learn and Do parts.

The LEARN part is where we are right now, and what you'll be going through in two of the breakout sessions.

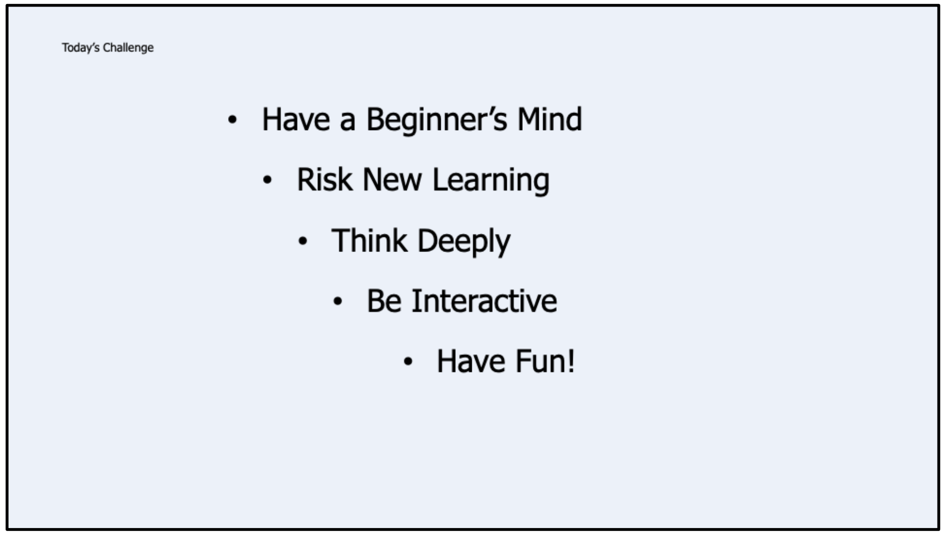
The DO part is what you'll be experiencing ion the Redbird simulators.

Notice that this a continuous process of Learning, Doing, Flying, then repeating.

Over and over again. Always challenging yourself to improve.

The hope after today is that you will complete the cycle by flying Learn to Turn exercises in an airplane with a qualified instructor.

Before we split up, let’s touch on the breakout sessions.



The challenge for each of you is to:

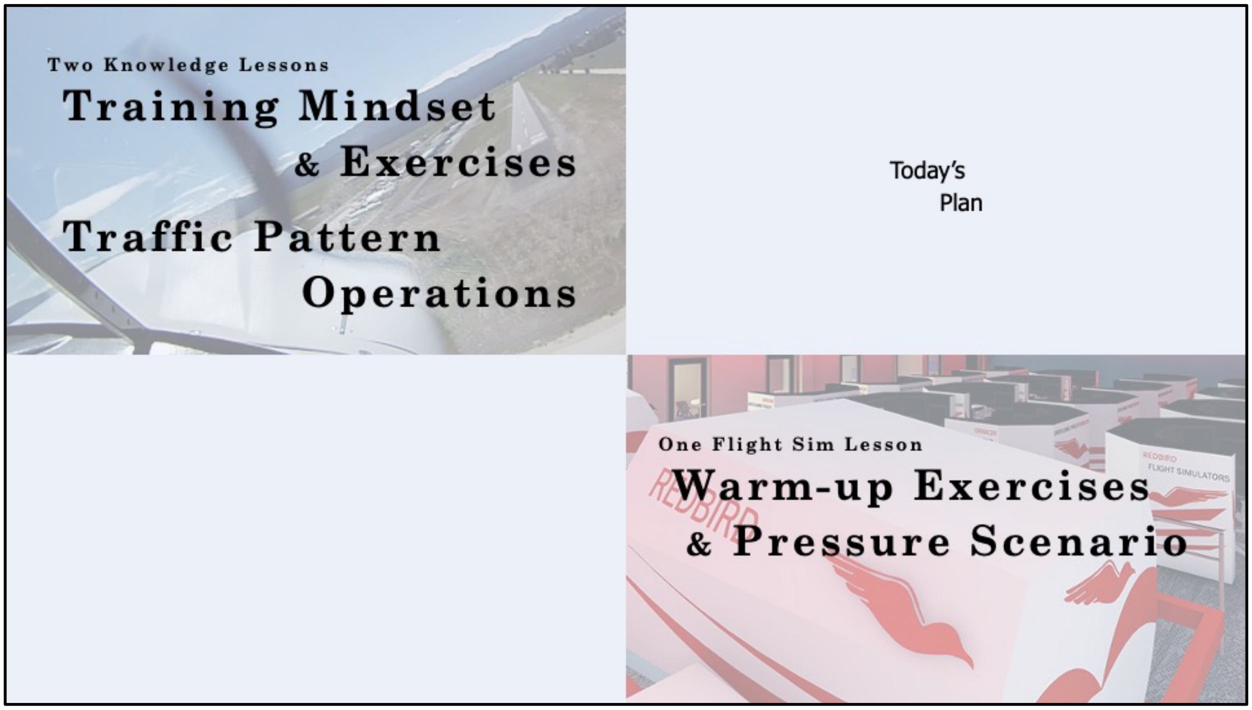
Have a beginner's mind.

Risk new learning. No doubt that's why you are here already.

Think deeply.

Be interactive. You'll certainly need to be hands-on and minds-on during your sim session. But you will also need to actively participate in the other breakouts. They are not lectures, and you will definitely need to be minds-on.

Above all, have a fun learning experience!

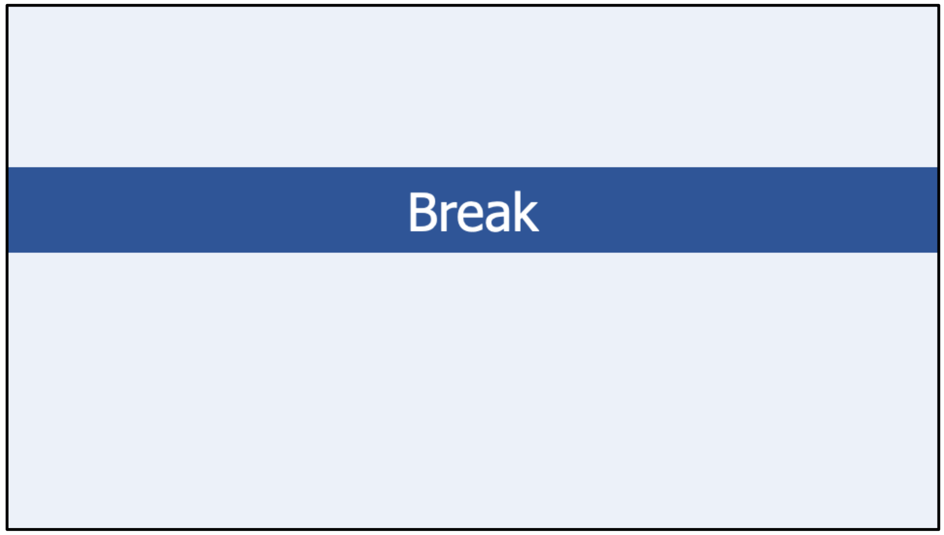


Today's knowledge lessons are:

- Training Mindset & Exercises, and
- Traffic Pattern Operations

Your flight sim lesson includes a couple of Warm-up Exercises, followed by a Pressure Scenario

There's a lot to do today, so PLEASE stay on schedule and be where you are supposed to be at the appointed time.



Again, thank you for signing up for Learn to Turn.

Ok, it’s time for your first scheduled break.

Please be on time for the next session on the schedule.

This is the knowledge lesson **Training Mindset and Exercises**.

I'm here as a facilitator, not as an instructor or lecturer. My job is to help broaden your understanding and guide your thought process.

As mentioned in the keynote, get your minds ready to work.

Let's start by imagining yourself sitting in your airplane.

As you move the primary controls, I want you to visualize how the airplane responds relative to you sitting in the airplane.

For the time being, ignore the secondary effects of your control inputs.

Here we go…

Ailerons of course roll the airplane.

What does pure roll look like to you sitting in the airplane?

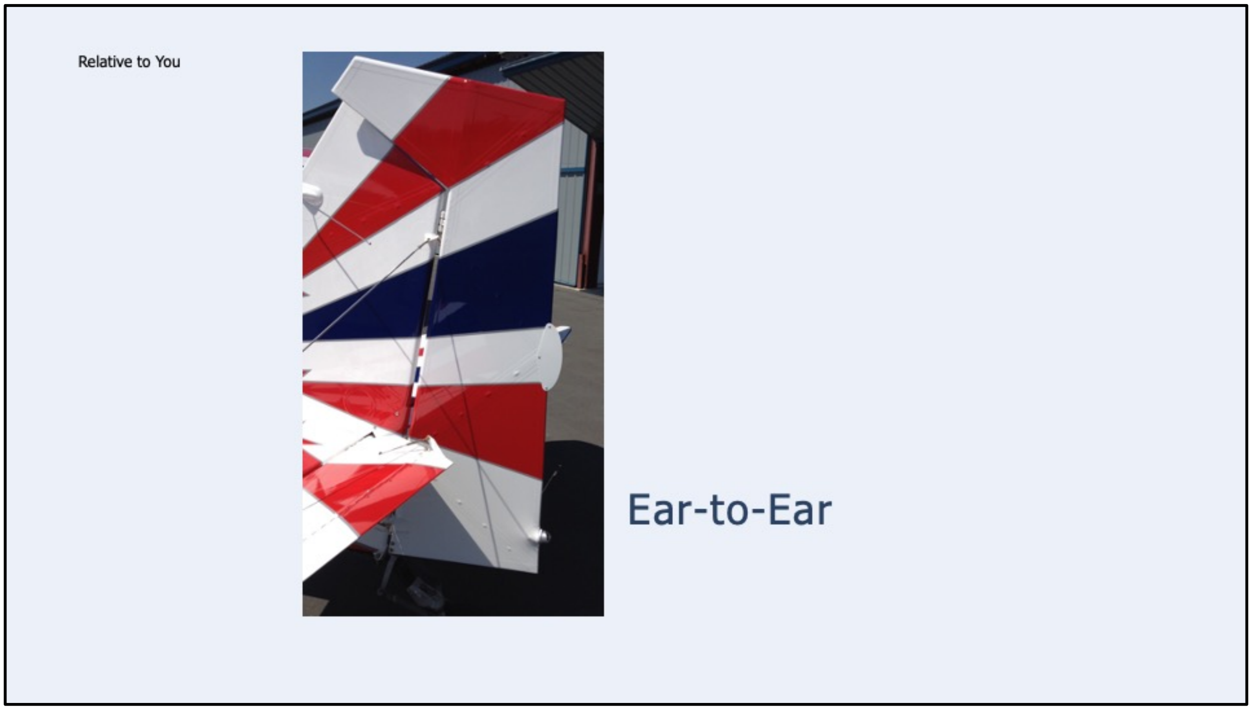
Imagine looking over the nose as you roll the airplane back and forth, left and right.

Relative to you, you see the nose rotating from your head to your hip.

Now imagine looking at the left wingtip as you roll left and right.

The wingtip also rotates in a line from your head to your hip.

The cool thing is this head-to-hip rolling motion will always look the same relative to you regardless of the attitude of the airplane.



Rudder yaws the airplane.

What does pure yaw look like to you sitting in the airplane?

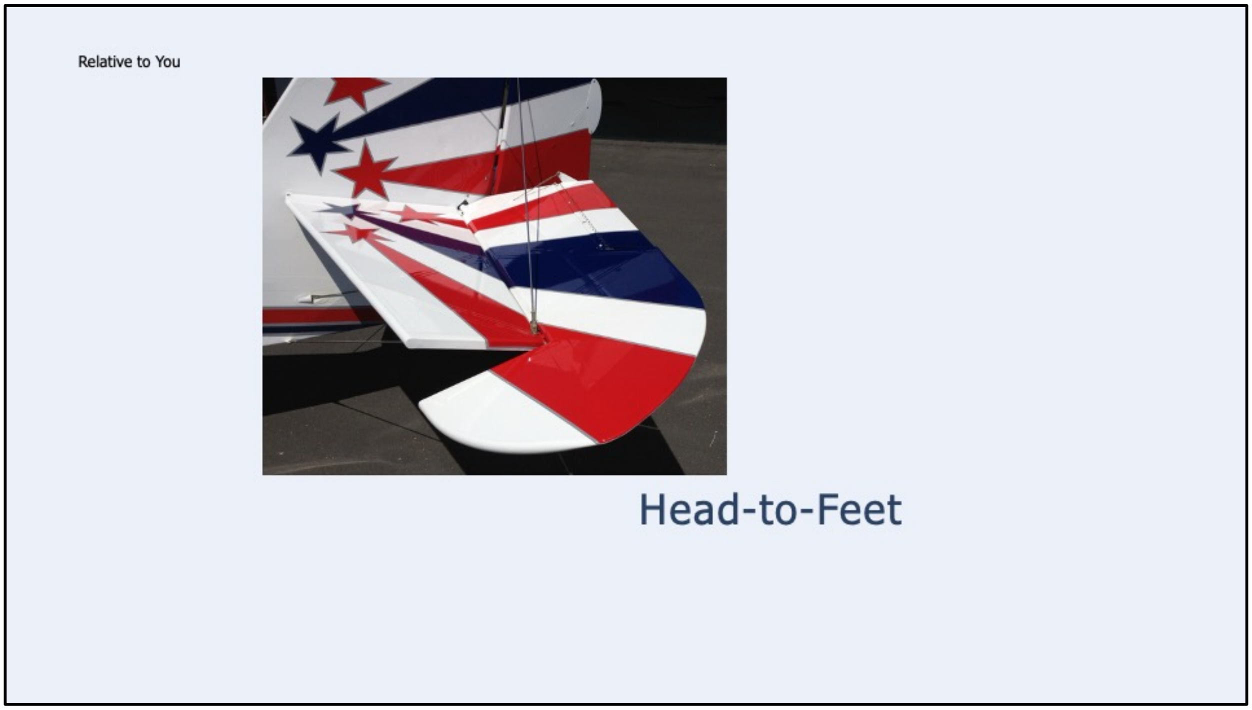
Imagine looking over the nose as you yaw the airplane back and forth, left and right.

Relative to you, you see the nose sliding from ear-to-ear.

Now imagine looking at the left wingtip as you yaw left and right.

The wingtip also slides from ear to ear.

Again, this ear-to-ear yawing motion will always look the same relative to you regardless of the attitude of the airplane.



Elevator pitches the airplane.

What does pure pitch look like to you sitting in the airplane?

Imagine looking over the nose as you pitch the airplane fore and aft.

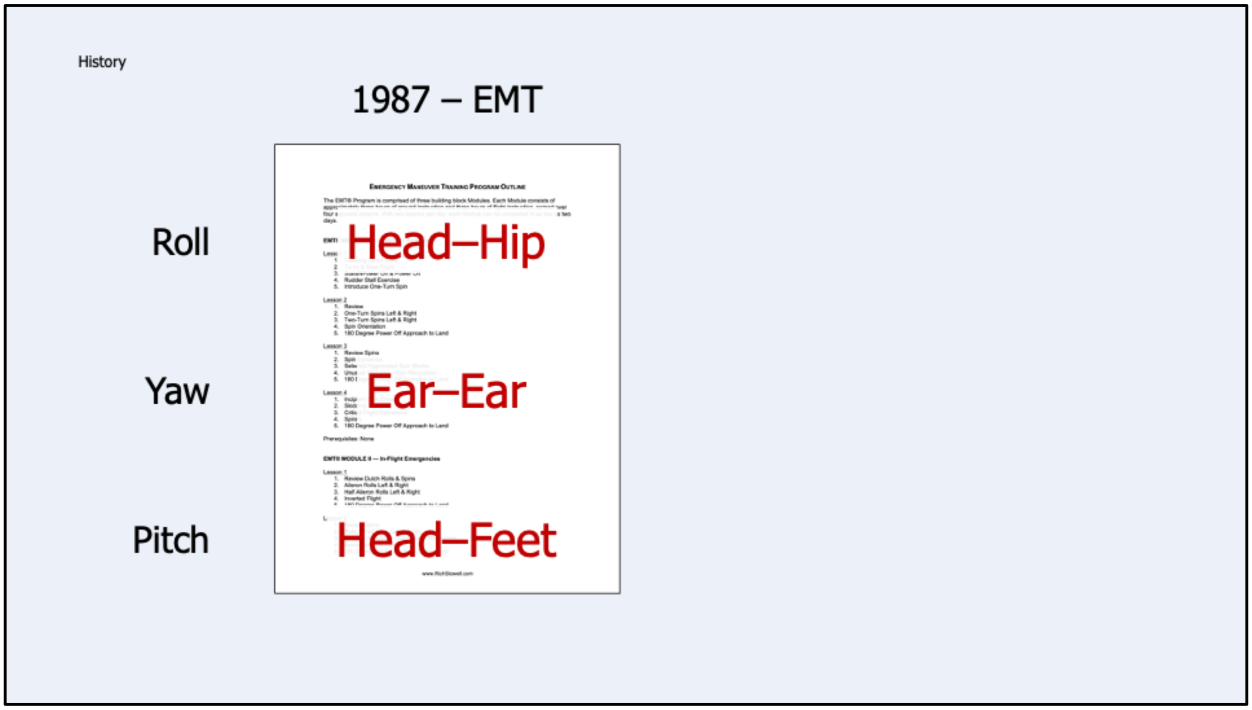
Relative to you, you see the nose rotating from your head to your feet.

Now imagine looking at the left wingtip as you pitch fore and aft.

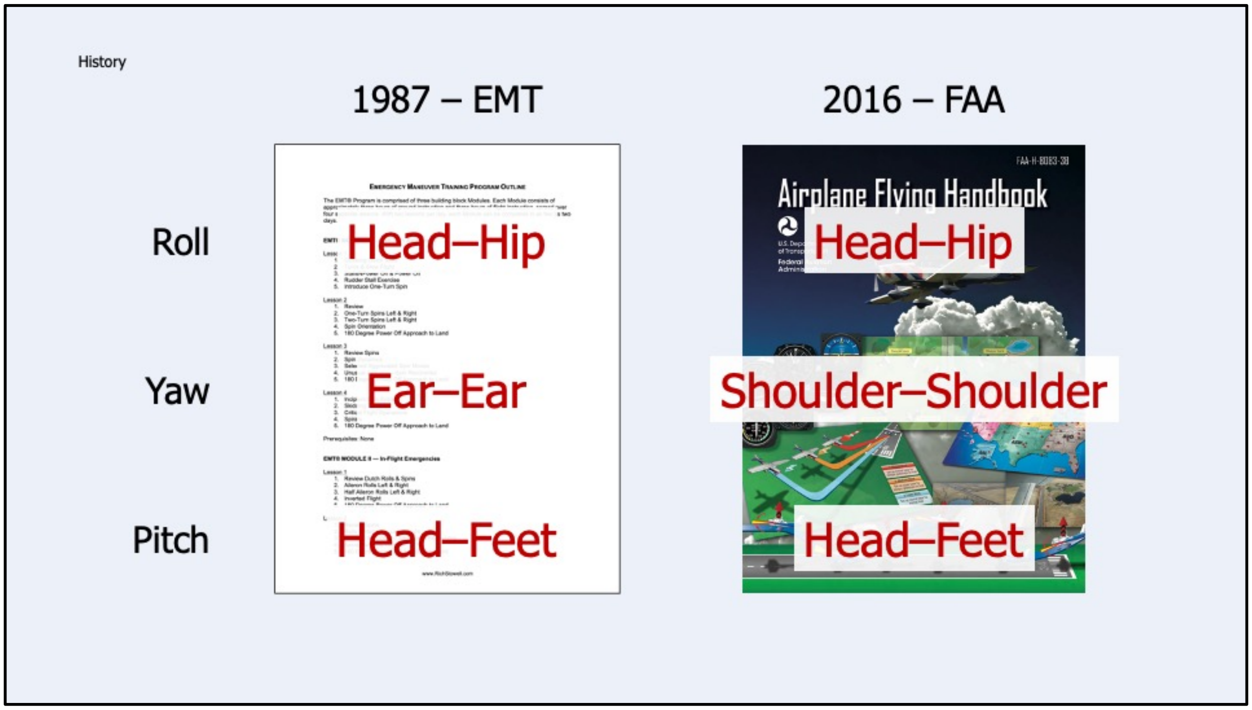
The wingtip also rotates from your head to your feet.

This head-to-feet motion will always look the same relative to you regardless of the attitude of the airplane.

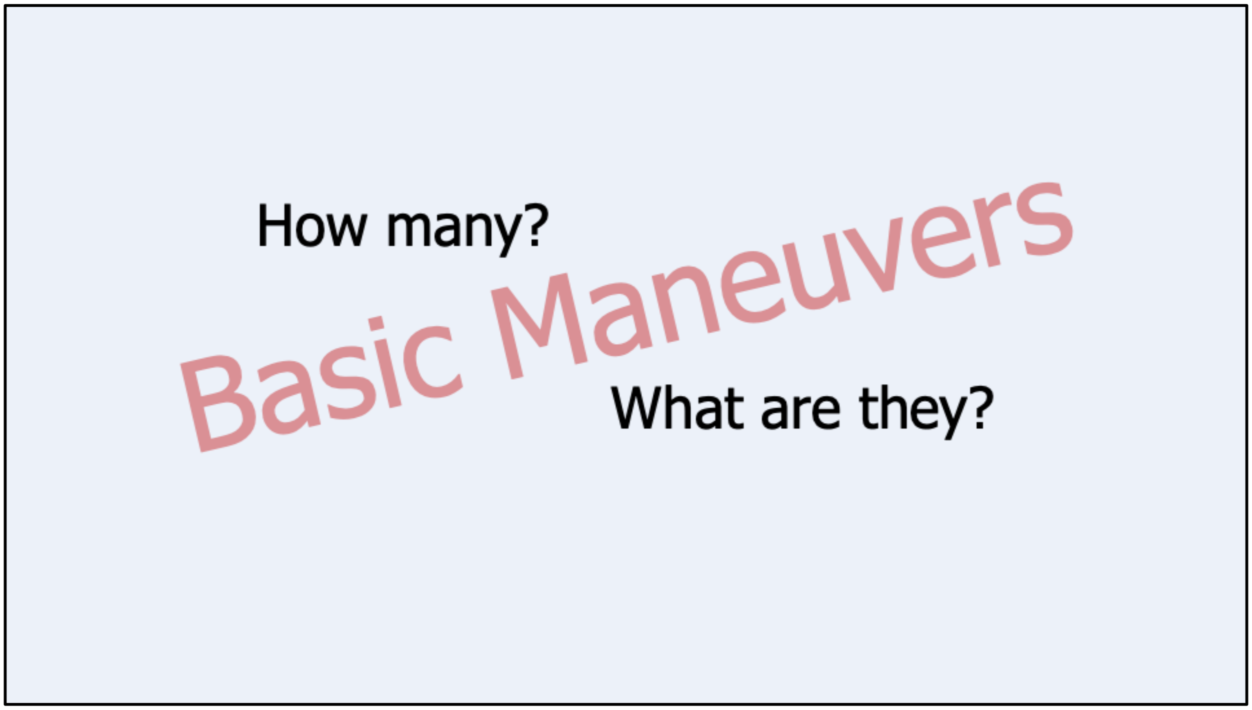
The words “up” and “down” become less meaningful now. Instead, you pitch in the direction you want the nose of the airplane to go: toward your head, or toward your feet.



Teaching pilots how to perceive roll, yaw, and pitch relative to them in the airplane has been part of the Emergency Maneuver Training program since 1987.



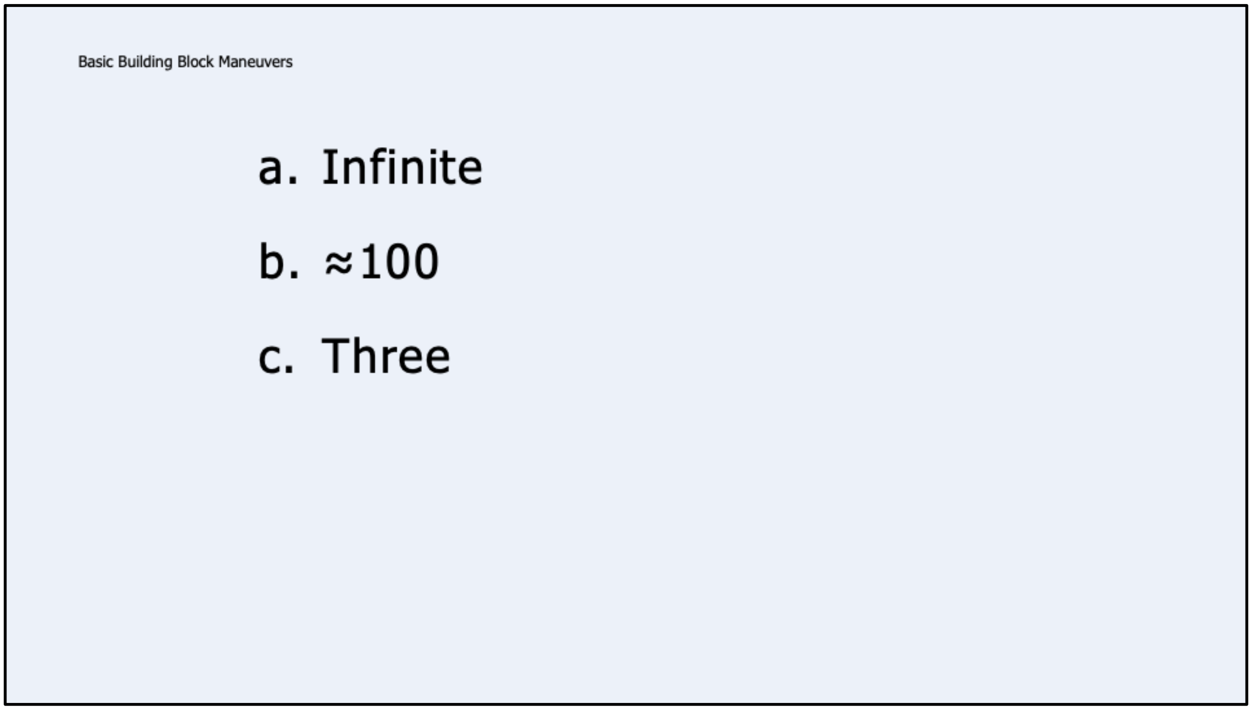
Nearly 30 years later, the same concept with virtually identical language appeared in the FAA Airplane Flying Handbook.



The next question is this:

How many basic building block maneuvers are there, and what are they?

Think deeply and broadly. Even more basic than the FAA’s FAB FOUR of Straight & Level, Climb, Descend, and Turn.



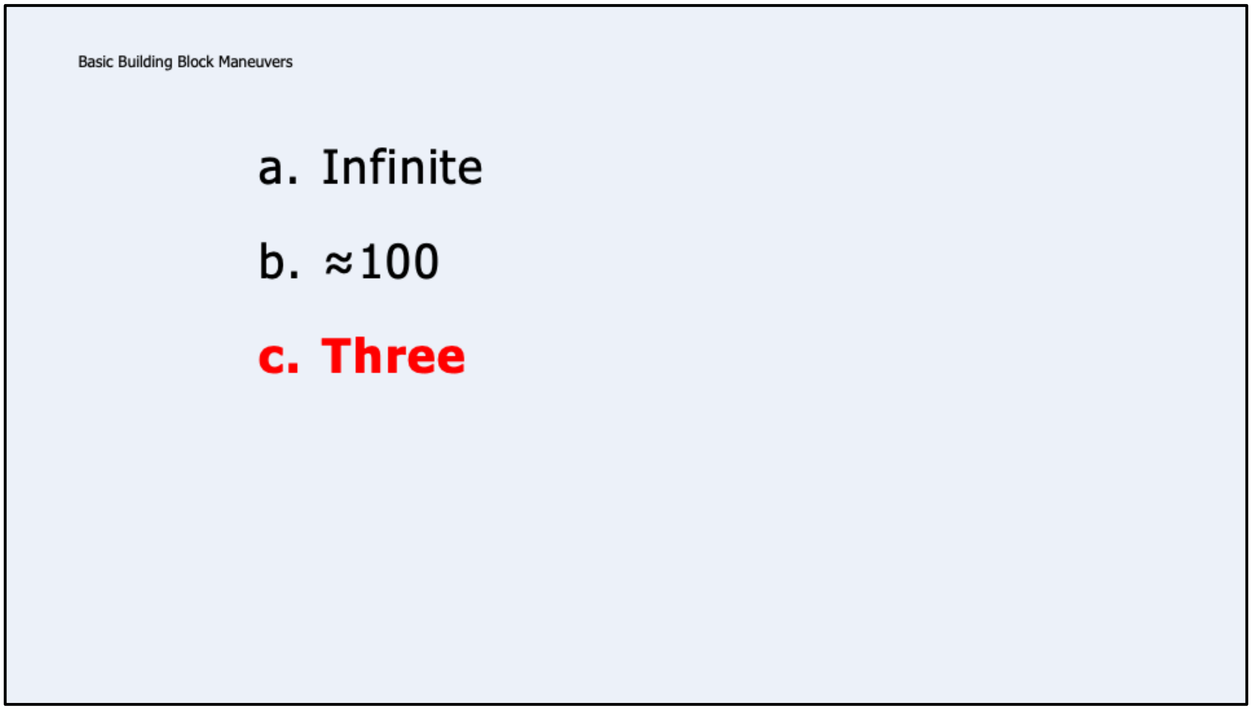
I’ll make things easier with multiple choice.

Remember: it’s up to you to be interactive here.

So, raise your hand if you think the answer is “a.”

Raise your hand if you think it’s “b.”

Hand up for answer “c.”?



Yes, the answer is “c.”

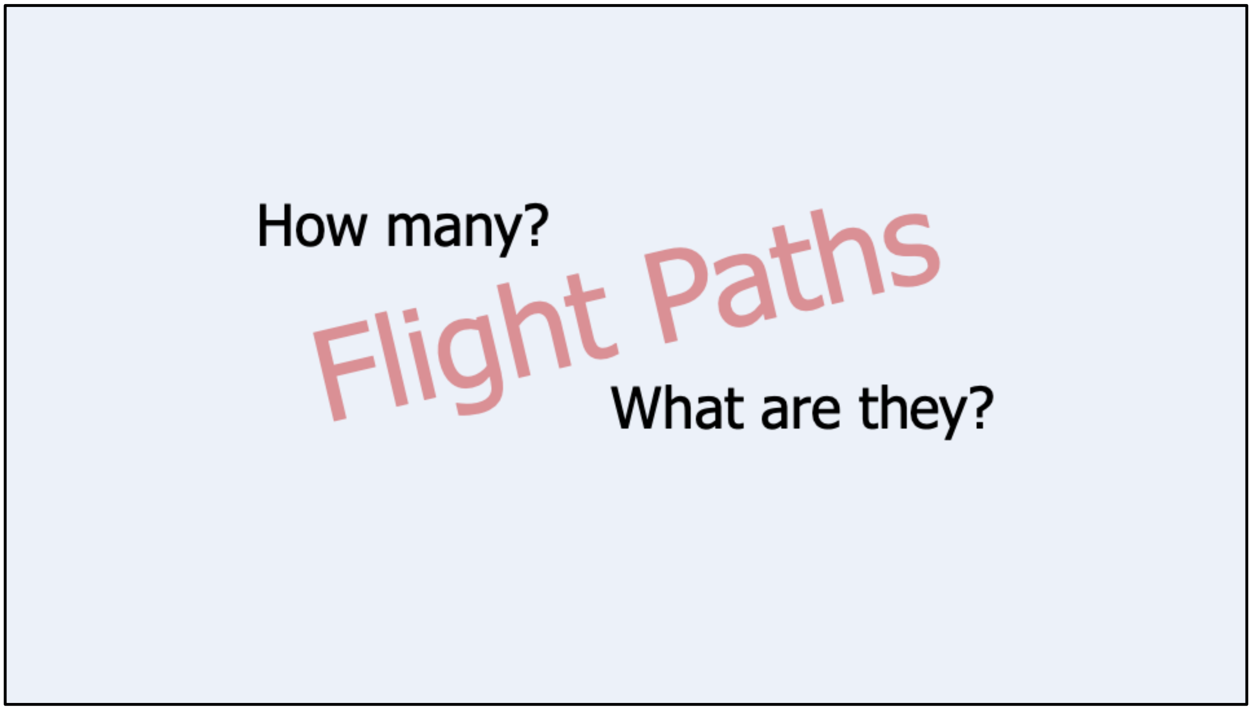
We have three basic building block maneuvers — one for each primary control surface.

We can make the airplane move in roll, yaw, and pitch.

All other maneuvers are made up of different combinations of these three ingredients.

In normal flying, we use the rudder mostly to cancel other yaw effects. Yaw-inspired maneuvering comes in two flavors: the slip, and the skid-spin.

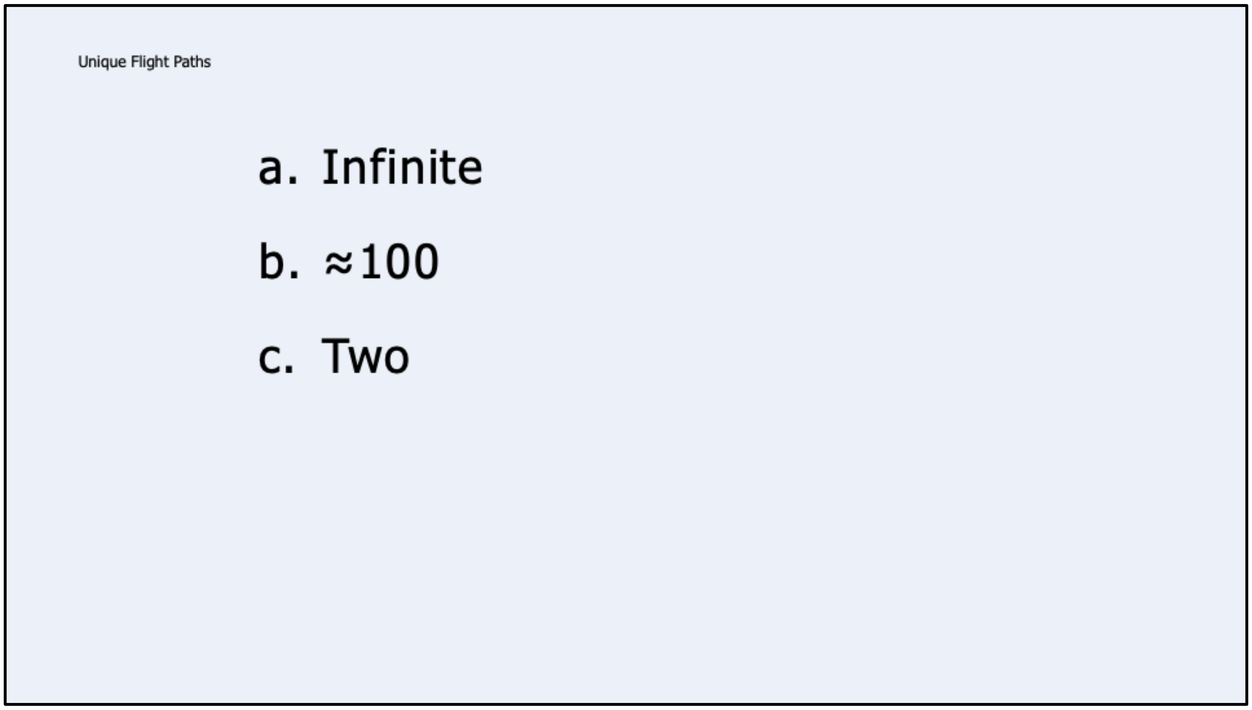
You should get in the habit of linking the words “skid” and “spin” in your mind because those two in particular often go hand-in-hand.



Alright, we have three building block maneuvers.

How many unique flight paths can the airplane follow, and what are they?

Again, think deeply and broadly.

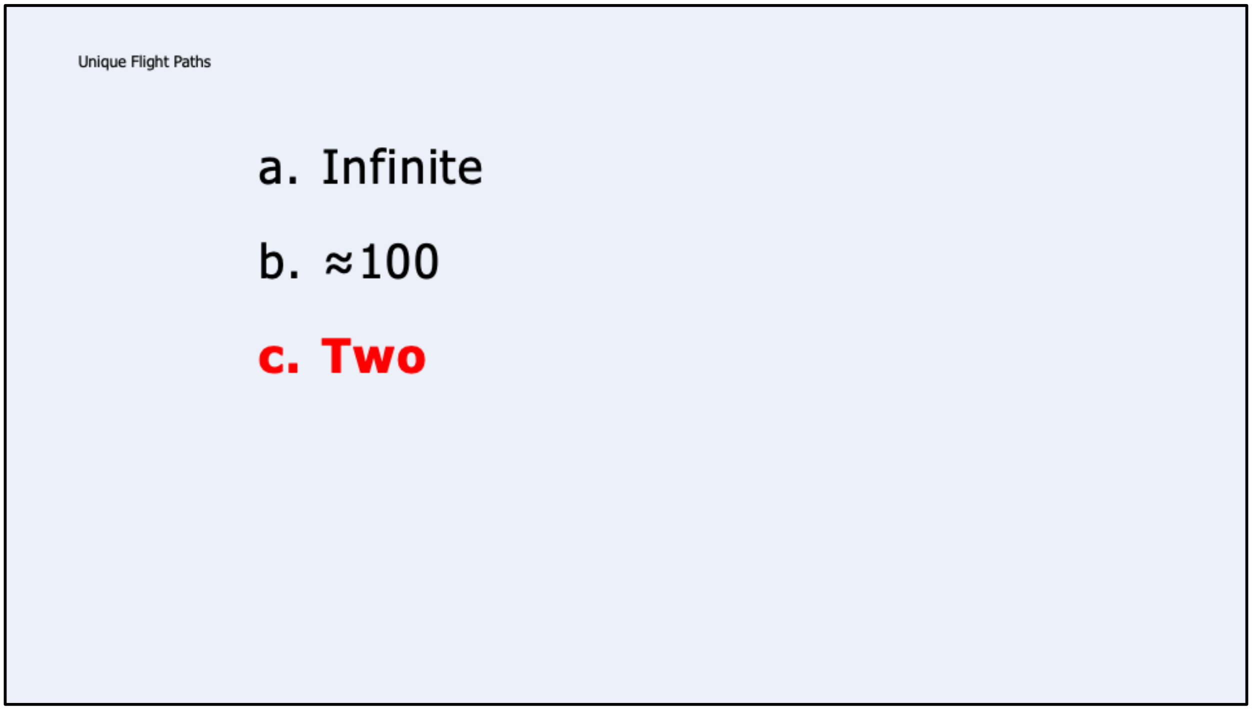


Multiple choice.

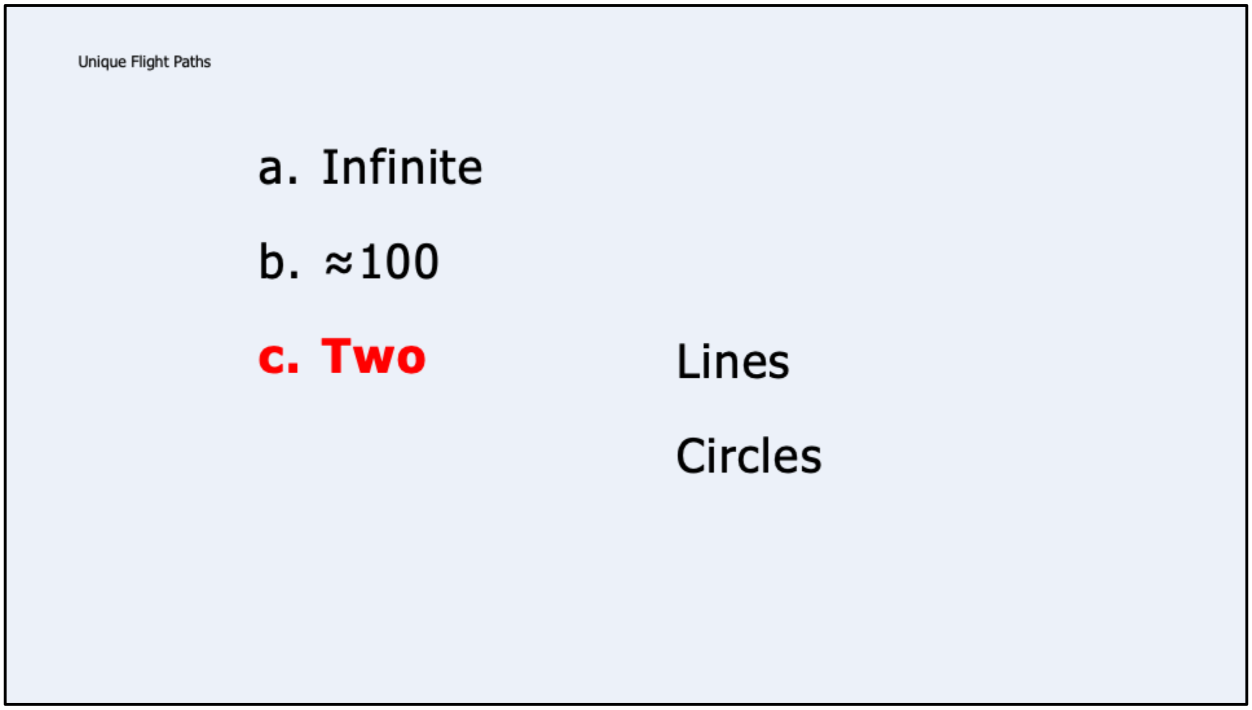
Raise your hand for “a.”

Raise your hand for “b.”

Raise your hand for “c.”

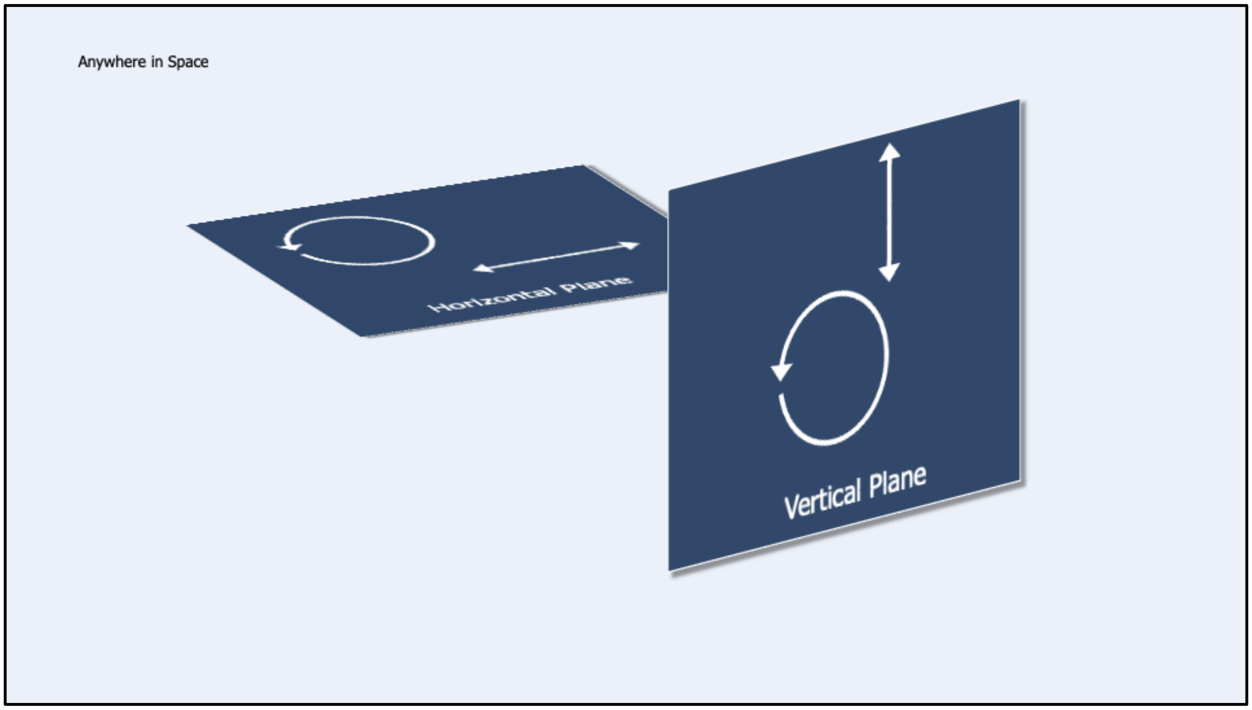


It’s “c” – Only two unique flight paths.



Airplanes move in lines and circles.

Can the airplane do anything else other than move in lines and circles? NO.



And the lines and circles can occur anywhere in space.

Lines and circles in the horizontal, or the vertical, or anywhere in between.

So:

- Roll, yaw, and pitch motions are relative to you sitting in the airplane.
- All maneuvers can be broken down into roll, yaw, and pitch components.
- And we can only fly in straight lines or in circles.

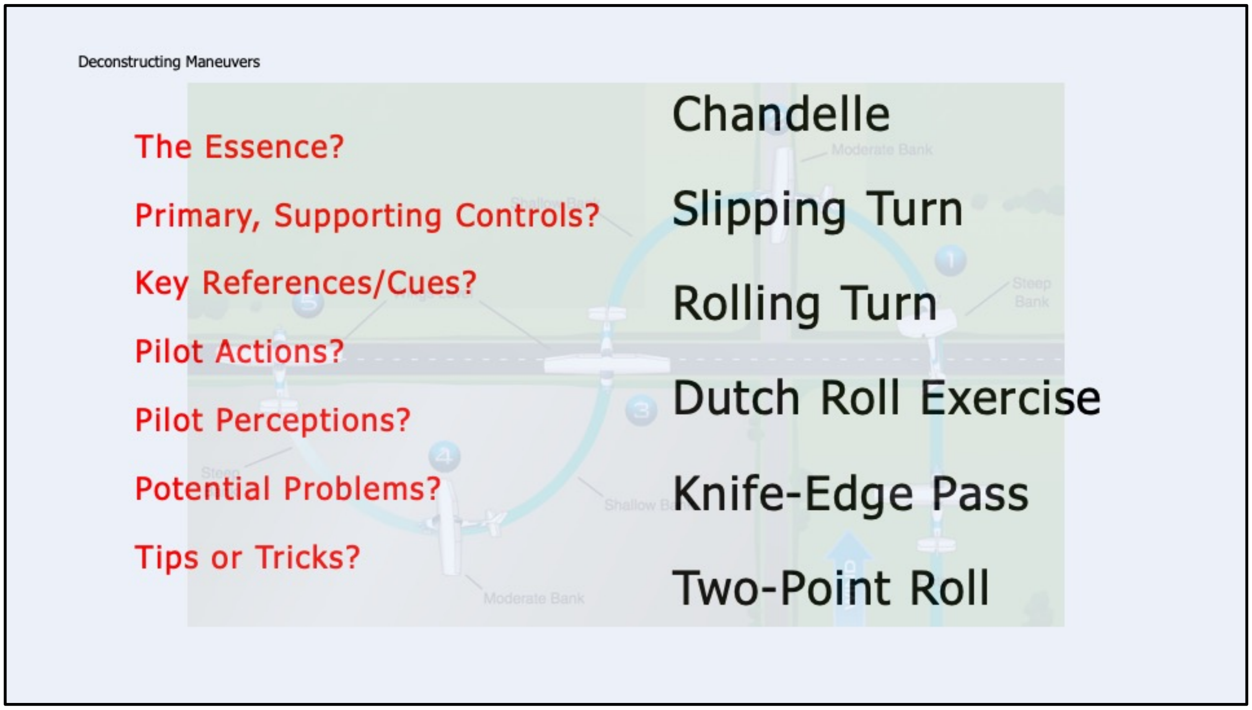
Consider these as FIRST PRINCIPLES.

You'll need them for the next exercise.

You are now going to deconstruct some maneuvers, keeping these questions in mind:

- What is the essence of the maneuver? In other words, and in as few words as possible, what does the airplane do, where does it end up compared to the start, and so on?
- What are the primary and supporting controls during the maneuver?
- What and where are the key ground references and any other cues?
- Step-by-step, what control actions are needed to perform the maneuver?
- What do you perceive during the maneuver – sight, sound, feel?
- Are there potential gotchas or problems you could encounter?
- Do you have any tips or tricks to share?

ASSUME the area has been cleared already, the airplane is properly configured already, and you will not need to adjust the power setting. Your description starts at the moment the maneuver begins, and stops at the moment the maneuver ends.



These are the maneuvers you will deconstruct.

ASK: What do the first three maneuvers have in common, and what do the last three have in common?

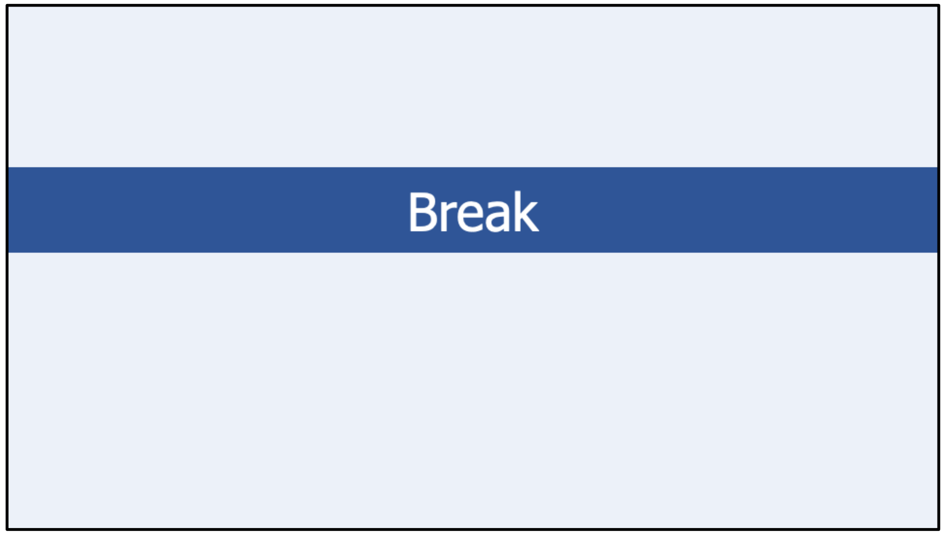
First three: Turning Flight. Last three: Straight-line Flight.

It doesn't matter if you know how to do the assigned maneuver or not. I will come by and demonstrate your assigned maneuver twice.

- Quickly divide into six groups and assign each group a maneuver from the list.
- Go from group to group and demonstrate their assigned maneuver twice (use a model airplane or your hand).
- **Do not verbalize the maneuver at all — SHOW IT ONLY.**

Remember the first principles. Visualize yourself sitting in the airplane. Break the maneuver down into roll, yaw, and pitch, and straight lines and circles.

In a few minutes, each group will report out to everyone else here. GO!



Well done everybody!

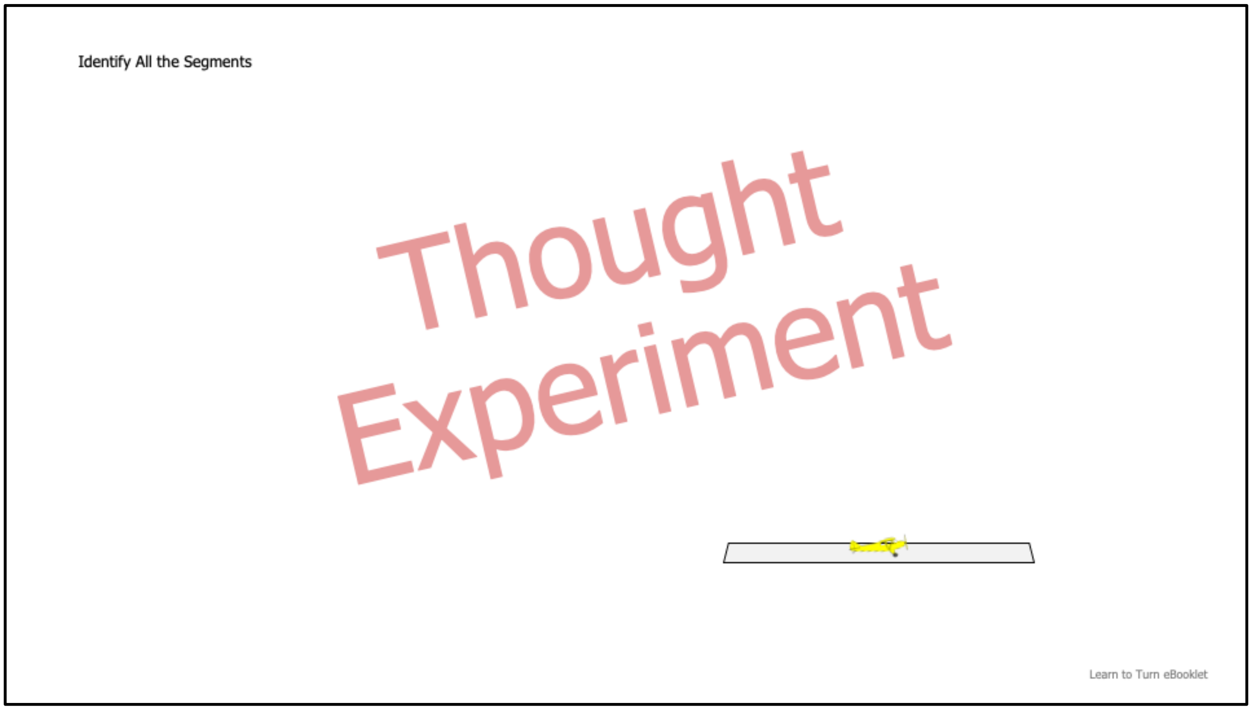
We’ll address any other questions during the debrief session.

Please be on time for your next session.

This is the knowledge lesson **Traffic Pattern Operations**.

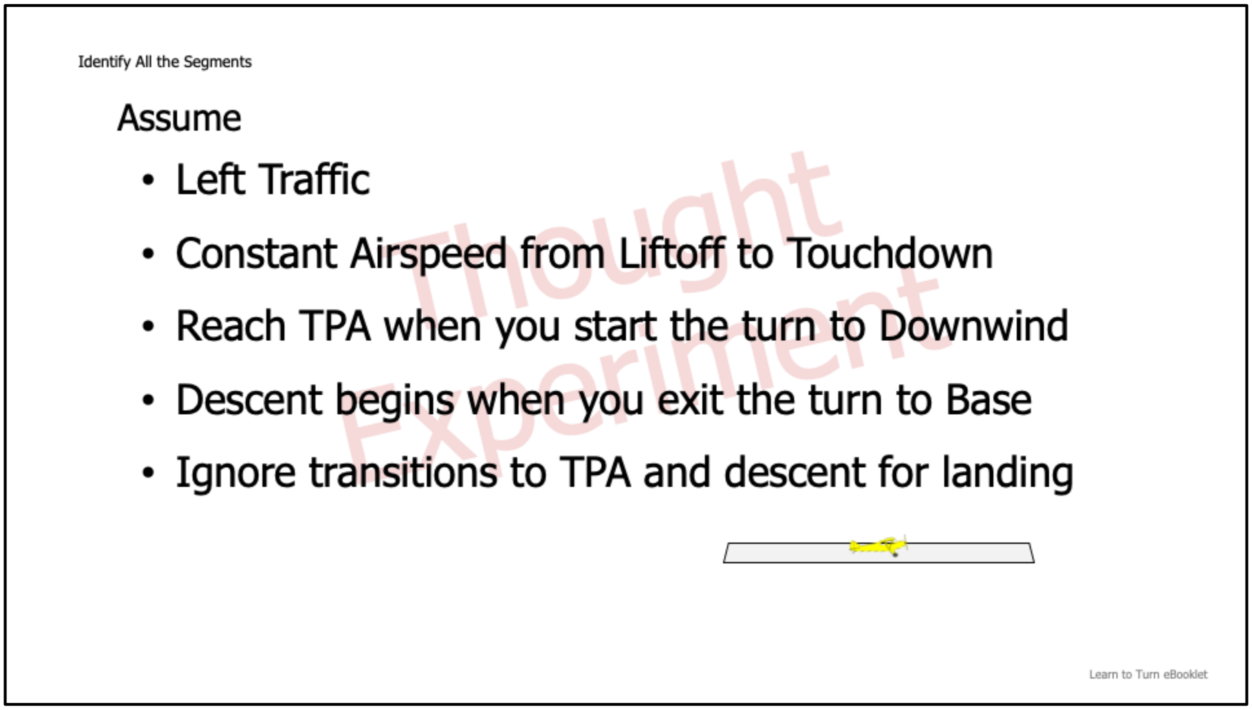
I'm here as a facilitator, not as an instructor or lecturer. My job is to help broaden your understanding and guide your thought process.

As mentioned in the keynote, get your minds ready to work.



We'll start with a thought experiment.

Picture flying around the traffic pattern. I want you to break up the flight path around the pattern into its various segments.

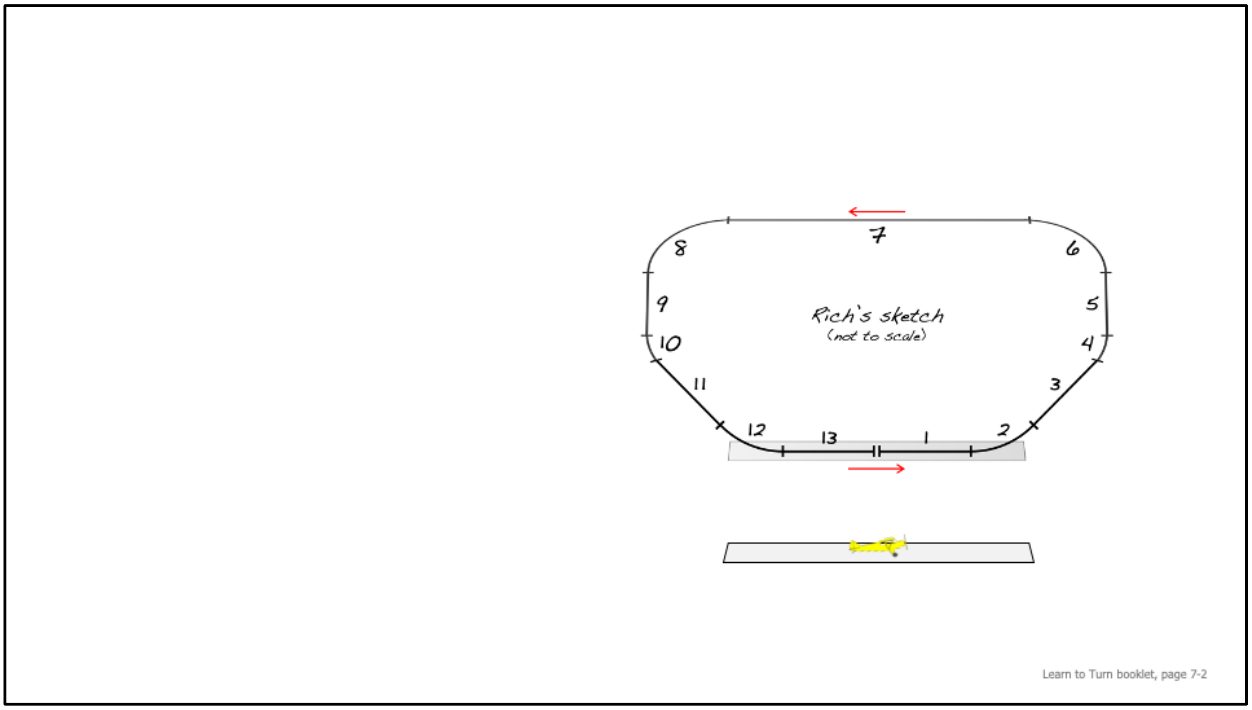


Assume:

- A left hand pattern.
- You fly at constant airspeed from the point of liftoff to the point of touchdown.
- You reach traffic pattern altitude the instant you begin the turn from crosswind to downwind.
- You start your descent for landing the instant you exit the turn from downwind to base.
- Ignore the transitional bits from the climb to the level off at traffic pattern altitude, and from level flight to the descent for landing.

Here is your assignment:

1. Sketch the different segments of the traffic pattern;
2. Label the segments according to the type of flight path; and,
3. Identify whether or not the airplane is experiencing acceleration during each segment.

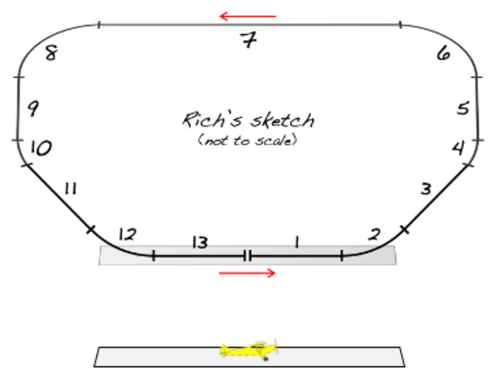


Ok. Here is the sketch from this exercise in the “Learn to Turn” booklet.

Rich has identified 13 segments around the pattern.

Segment		Flight Path[1]	Accelerated[2]
#	Name		
1	Takeoff Roll	SL	Yes
2	Rotation	TV	Yes
3	Departure Leg	SC	No
4	X-wind Turn	TO	Yes
5	X-wind Leg	SC	No
6	Downwind Turn	TH	Yes
7	Downwind Leg	SL	No
8	Base Turn	TH	Yes
9	Base Leg	SD	No
10	Final Turn	TO	Yes
11	Final Leg	SD	No
12	Round Out	TV	Yes
13	Landing Roll	SL	Yes

[1] Flight Path Key: SL = Straight Level; SC = Straight Climb; SD = Straight Descent; TH = Turn Horizontal; TO = Turn Oblique; TV = Turn Vertical.
[2] Accelerated Key: Yes; No



Learn to Turn booklet, page 7-2

And he has made a table listing the flight paths and other information.

Notice the key to symbols used in the table.

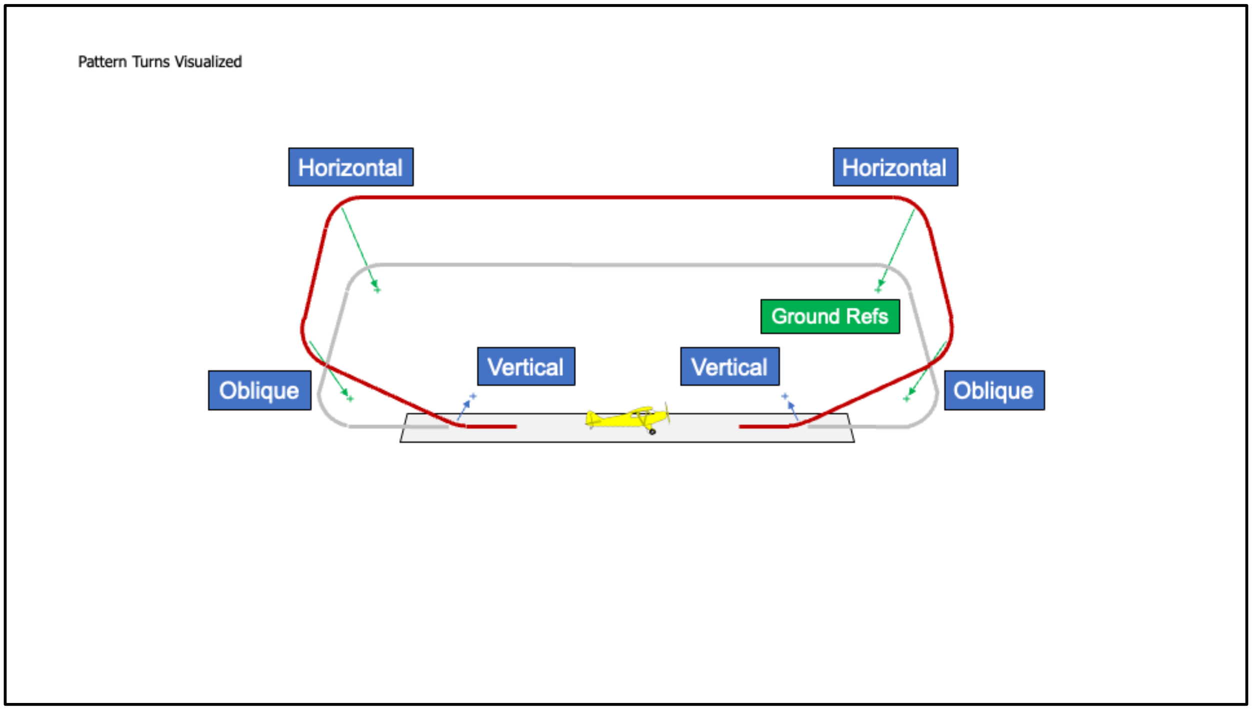
For the flight paths:

- The letter "S" stands for "straight."
  - And the straight paths can occur in a climb, in level flight, or in a descent.
- The letter "T" stands for "turn."
  - And the turns can occur in the horizontal, the oblique, or the vertical.

ASK: What does "accelerated flight" mean?

Answer: A change in either speed, direction, or both. Since speed is constant, acceleration in this case happens whenever the airplane changes direction. That is, whenever the airplane turns in any geometric plane.

DISCUSSION.



Here is the same traffic pattern with the various turns identified.

ASK: What is the point of learning ground reference maneuvers like Turns Around a Point?

Answer: To be able to fly turns with constant radius regardless of the wind.

To fly a truly rectangular traffic pattern — which should be the objective — you must correct for the effects of the wind.

Especially when turning from the departure leg to crosswind, crosswind to downwind, downwind to base, and base to final.

ASK: What are some of the critical flight operations we undertake in the pattern?

Answers include:

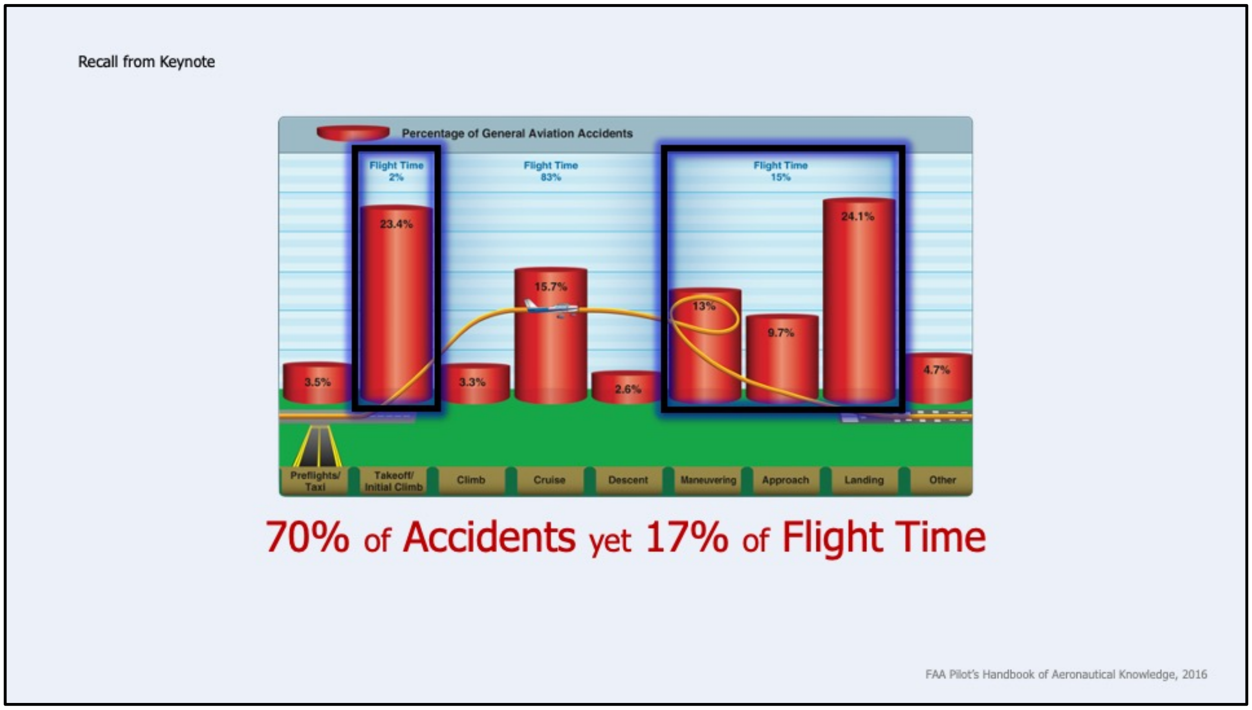
- Managing short field takeoffs and landings.
- Possibly dealing with engine issues, especially during takeoff and on final.
- Maneuvering for spacing with other traffic, especially slower traffic ahead.
- Dealing with wind and the possibility of overshooting the turn to final.
- Having to go around.

Operating in the pattern requires good situational awareness.

ASK: What barriers could negatively impact our situational awareness?

Things that can degrade our awareness include:

- Distraction.
- Stress or Novel Situations. For example, having to follow a much slower airplane, or flying at an unfamiliar airport that has a non-standard pattern.
- Lack of confidence or competence.
- And misunderstanding or misinterpretation. As an example, I'll describe the classic skidded base-to-final turn scenario a little later.



Remember that 70% of accidents occur where we only spend about 17% of our flight time.

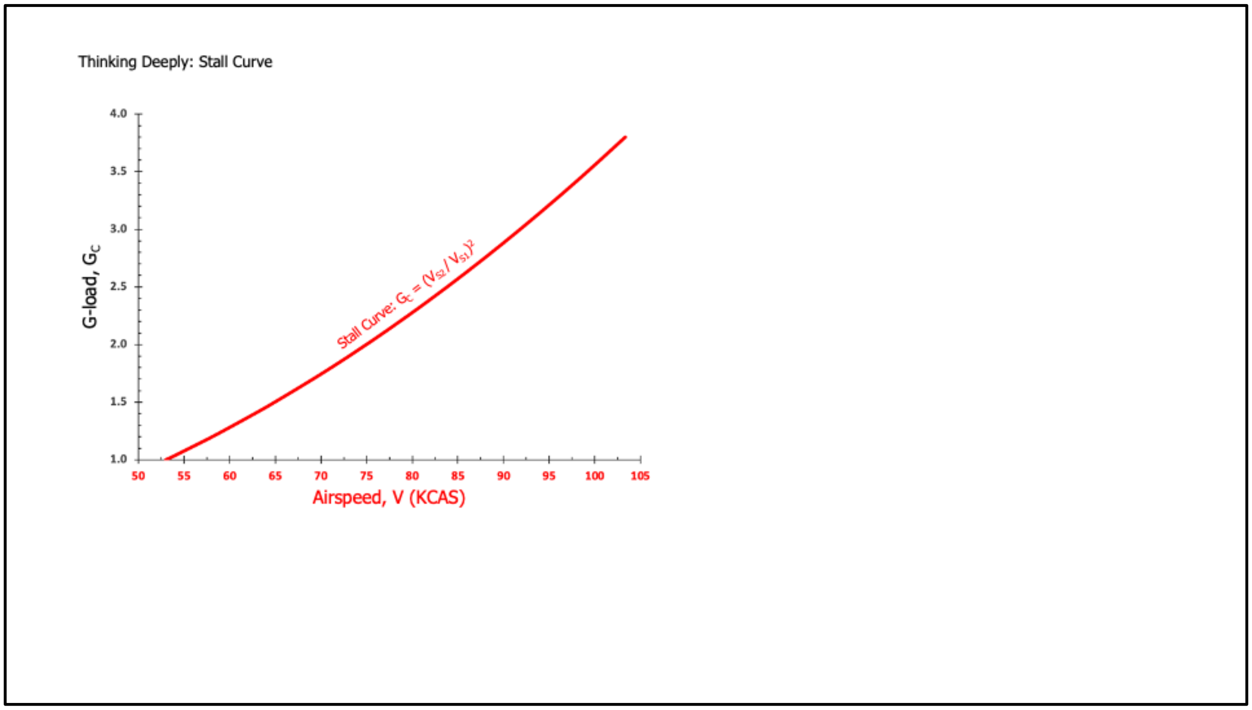
No doubt there is a lot going on during these phases.

Let's dig deeper into the concept of stalling **in any attitude, at any airspeed, and at any power setting.**

We talk a lot about the stall speed of our airplanes.

But thinking more broadly, we realize that airplanes have stall curves.

And stalling isn't about speed alone. It's really about the combinations of speed and G-load that land you on the stall curve.



This is a stall curve for a typical light airplane.

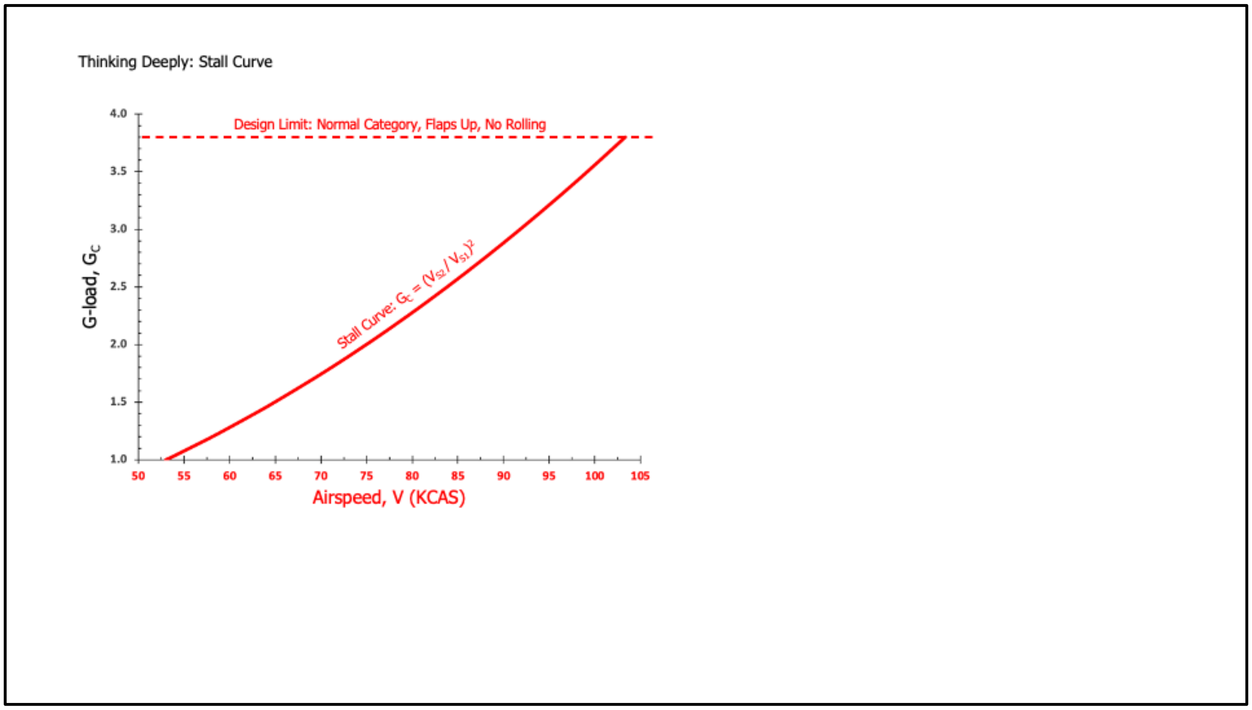
It shows calibrated airspeed along the horizontal.

G-load is shown along the vertical. G-load is the G you feel when moving the elevator control and the G that you would see on a G-meter. We'll refer to this as the cockpit G, or GC.

The combinations of G and speed that result in a stall depend on the ratio of the speeds squared. Typically, VS1 is the one-G stall speed. From that, we can derive the stall curve for other speeds and G-loads.

We can extend this stall curve farther to the left, all the way down to zero G and zero speed.

But for our purposes, we'll cut it off at one-G.

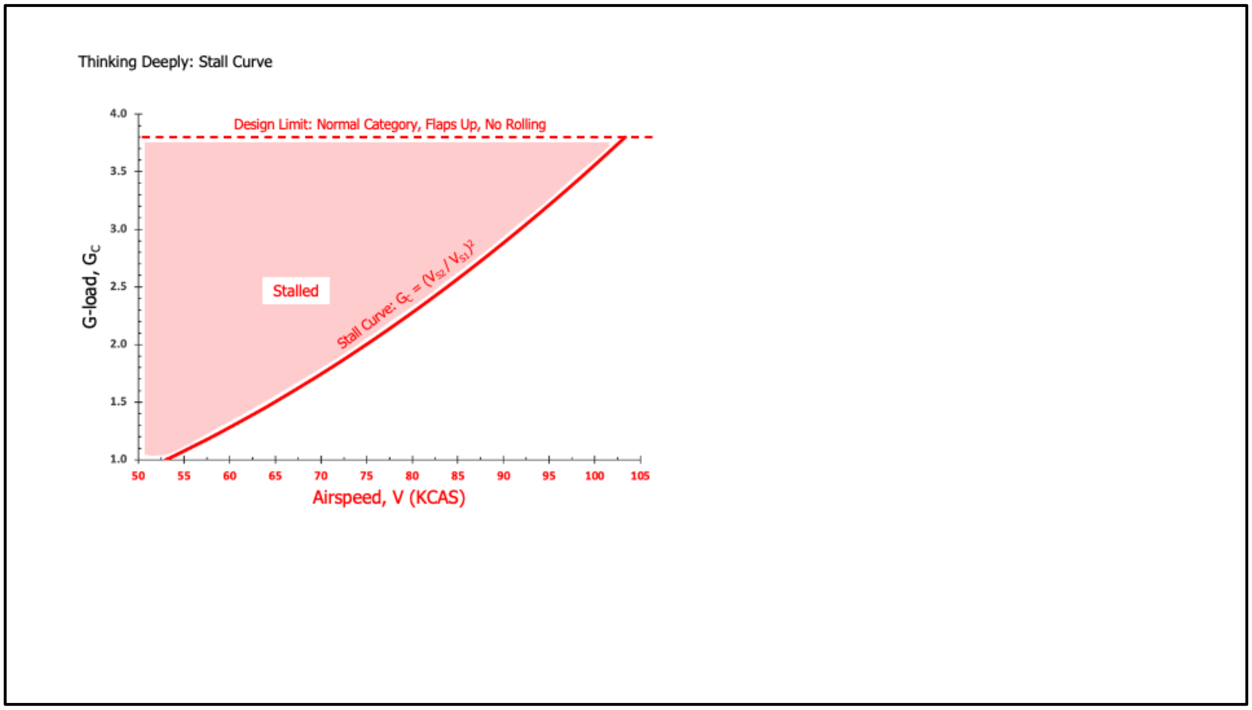


We can also add airplane design limits to the picture.

The dotted horizontal line is the 3.8G design limit.

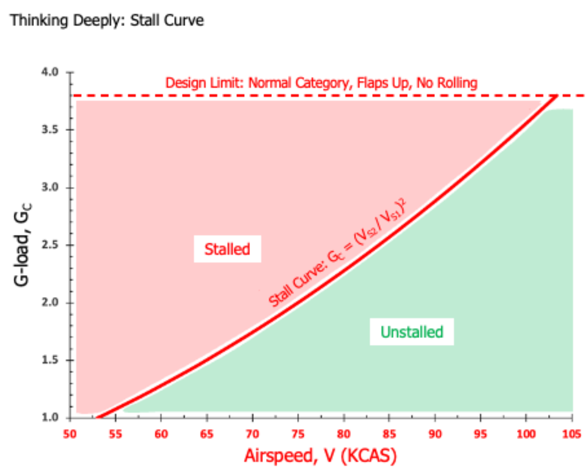
This applies in the Normal category, with the Flaps up and no rolling.

ASK: If the red curve represents stalling the airplane, what can we say about the area to the left of the curve?

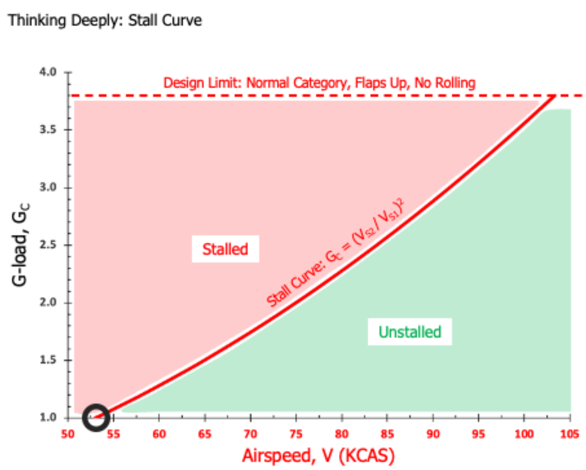


This is stalled flight.

ASK: Ok, so what can we say about the area to the right of the stall curve?

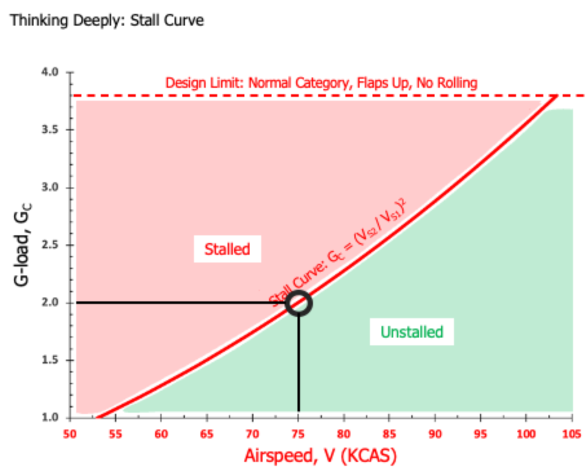


We would be in unstalled flight with these combinations of speed and G.



The donut circles the one-G stall speed.

In this example, that's about 53 knots calibrated.



This donut highlights the 2G stall speed.

In this example, it's about 75 knots calibrated.

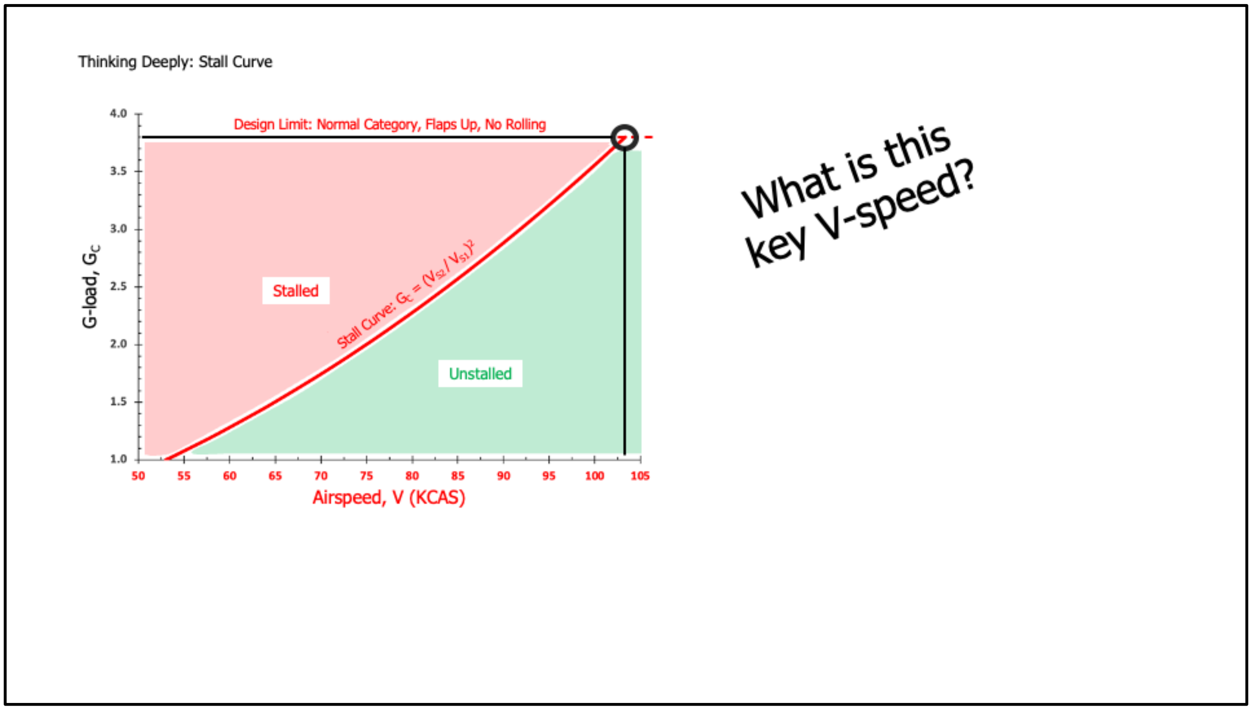
ASK: What do we know about stall speed in general? What trend do you see between stall speed and G?

Answer: Stall speed increases as G increases; conversely, stall speed decreases with decreasing G.

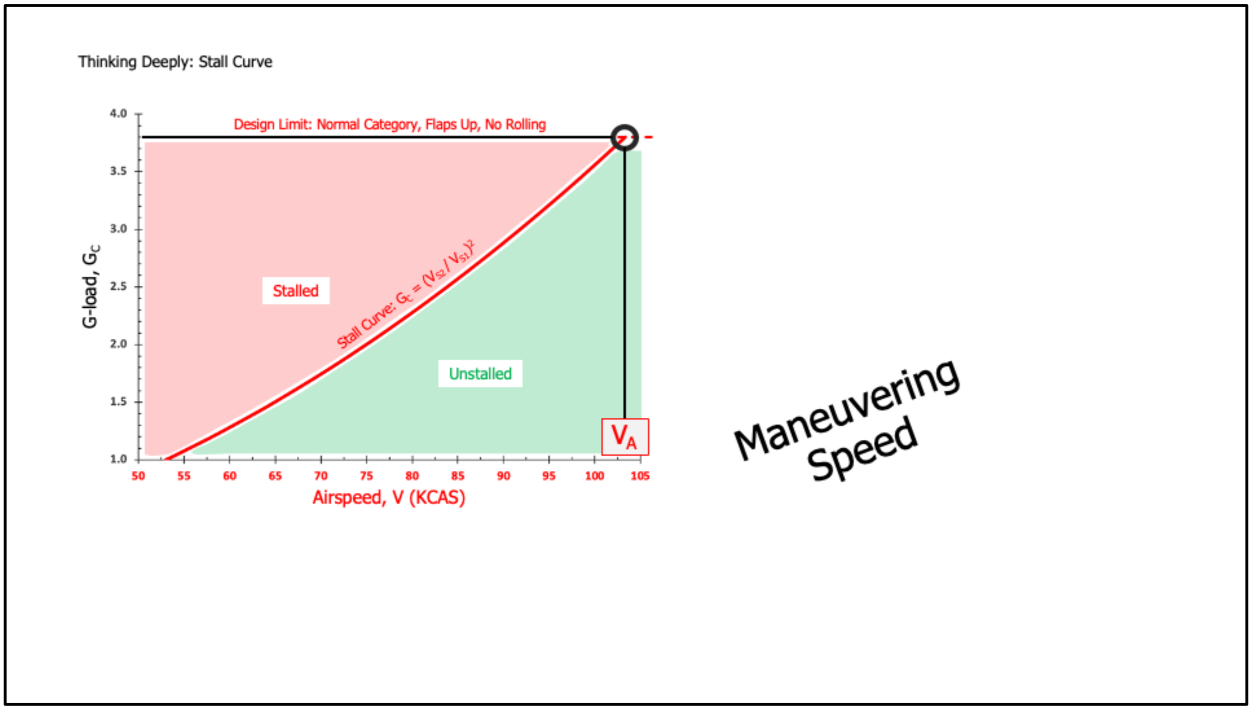
ASK: What could happen during a turn in the pattern if you pull harder on the elevator? In other words, if G increases as speed decreases?

Answer: An accelerated stall. In other words, a stall at a speed greater than the 1G stall speed.

TIP: Be aware of your airspeed and G-load trends.



ASK: Ok, who can tell us what V-speed this donut is highlighting?



Answer: this is maneuvering speed, VA.

ASK: What is the definition of maneuvering speed?

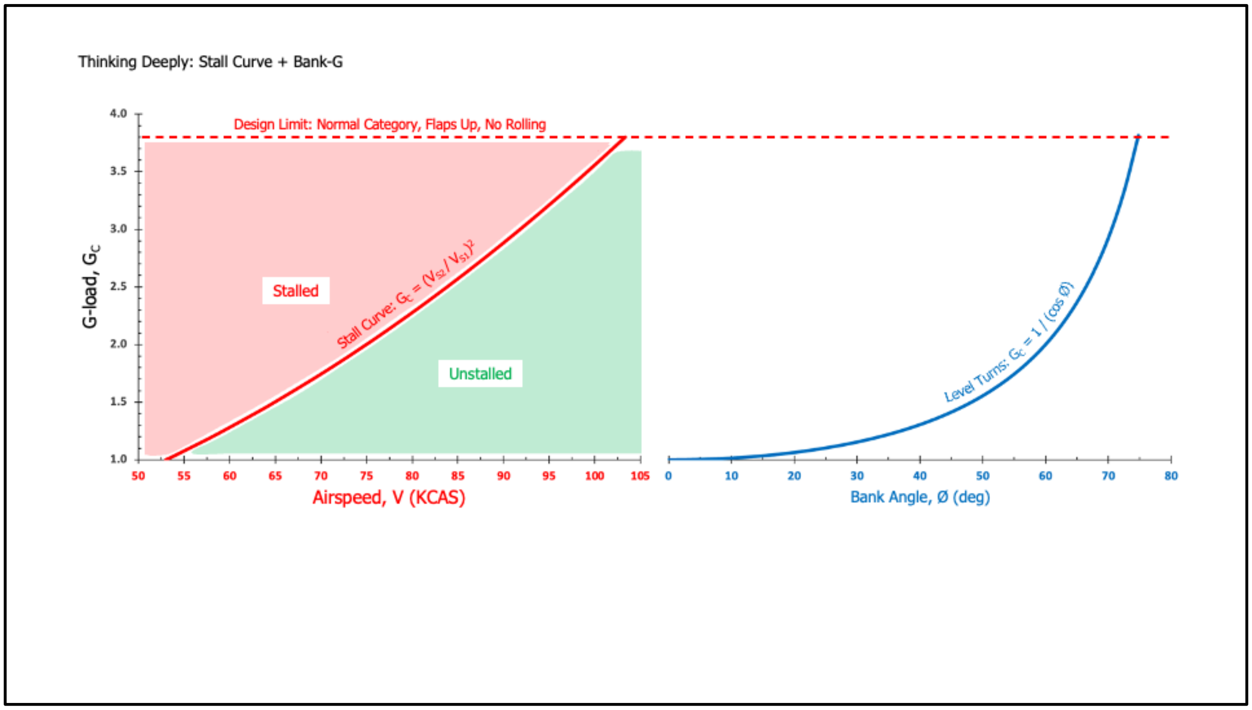
ASK: What is maneuvering speed, really?

Answer: The stall speed at 3.8G.

ASK: Why does maneuvering speed vary with weight?

Answer: Because VA is a stall speed, and all stall speeds vary with weight. G-load is weight induced by elevator inputs.

Let’s add another diagram next to this one.



I've put the classic Bank-G diagram to the right of the stall curve diagram.

Bank angle is along the horizontal here.

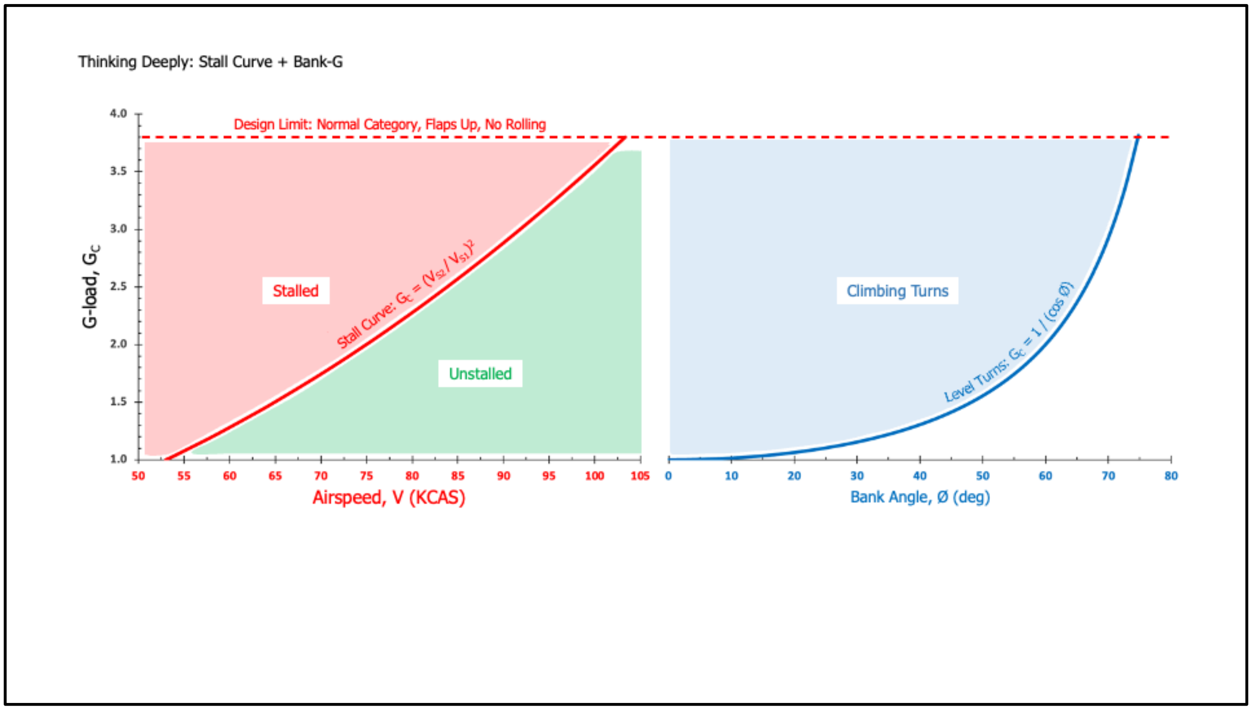
As before, cockpit G is along the vertical, over on the left side.

The blue curve represents **the special case of level turns.**

In other words, and assuming we have the energy, the consequence of G-loads and bank angles that meet on this blue curve will be turns in the horizontal.

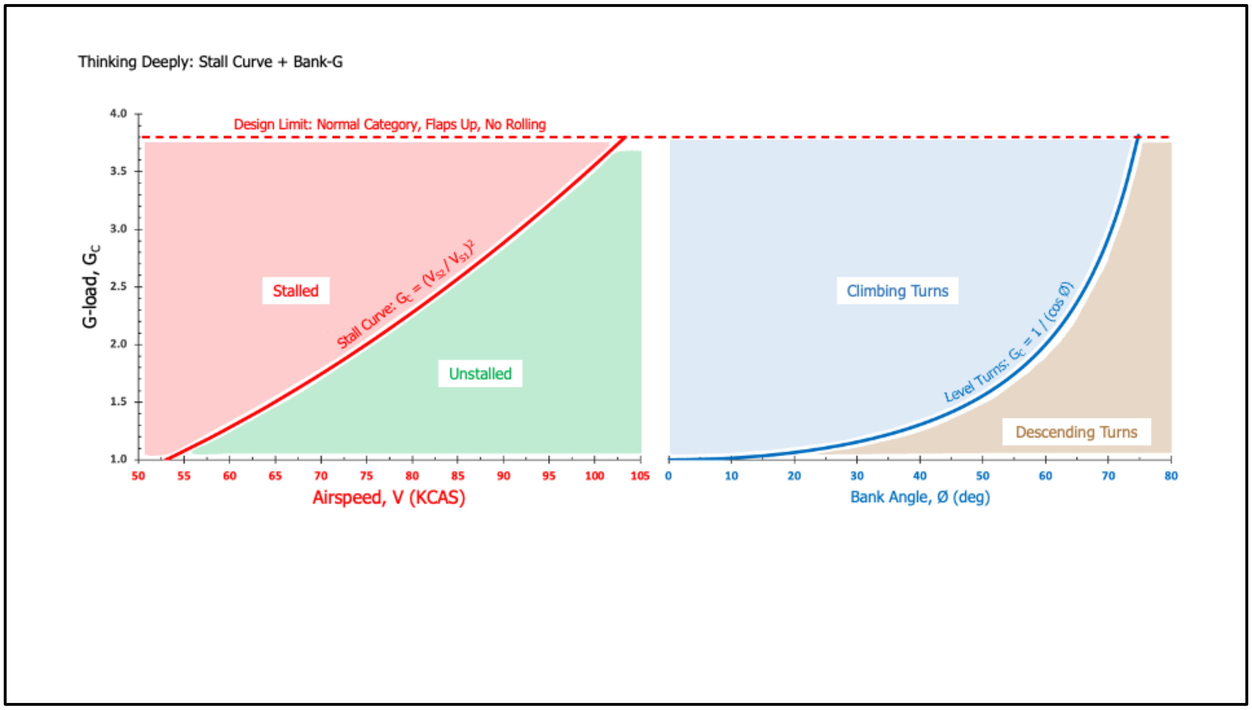
The combinations of G and bank angle that result in level turns are a function of the cosine of the bank angle.

ASK: If the blue curve represents horizontal turns, what is happening if we are in the area to the left of the blue curve?



Answer: These combinations of bank and G result in climbing turns.

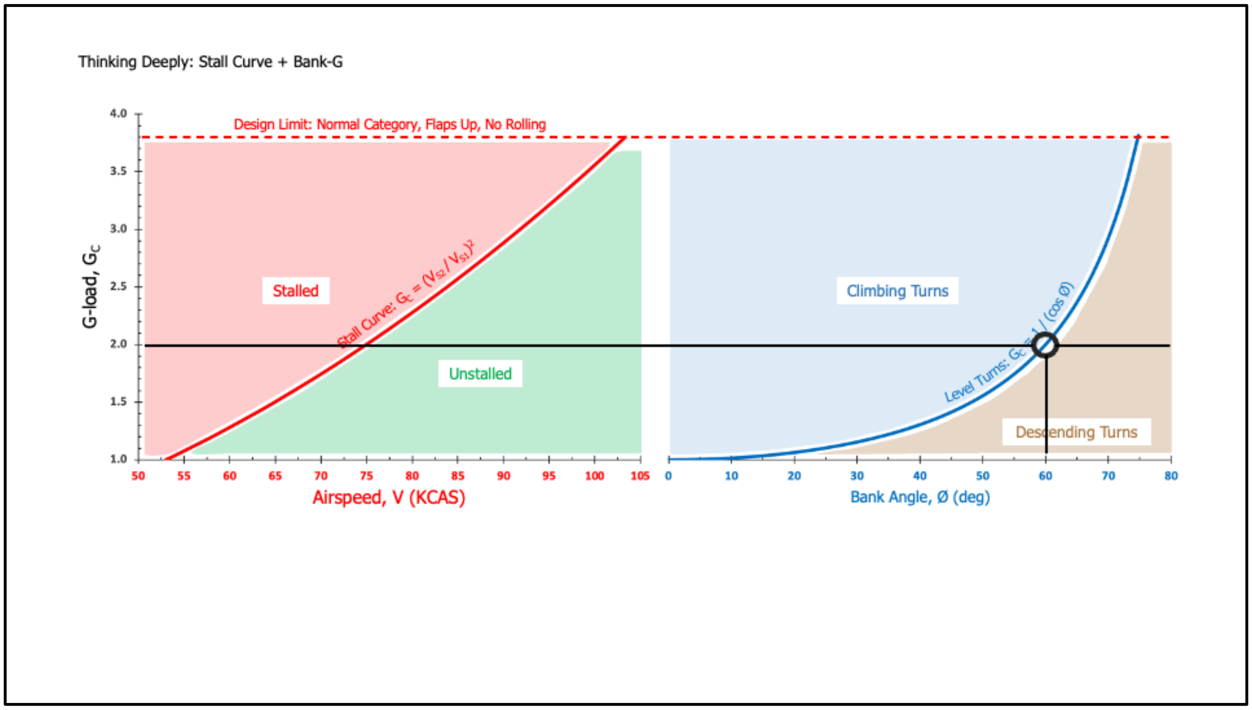
ASK: What is happening if we are in the area to the right of the blue curve?



Answer: These combinations of bank and G result in descending turns.

Notice that the classic bank-G diagram isn't just about level turns.

Thinking a little more deeply about it, we can use this diagram to talk about climbing and descending turns, too.



Assuming we have enough energy to start with, two things are required to perform a coordinated, level turn at 60 degrees of bank.

ASK: Being as specific as possible, what are those two things?

Answer: The PILOT must roll the airplane to 60 degrees of bank with coordinated aileron and rudder inputs, and the PILOT must pitch to 2G by pulling the elevator control aft.

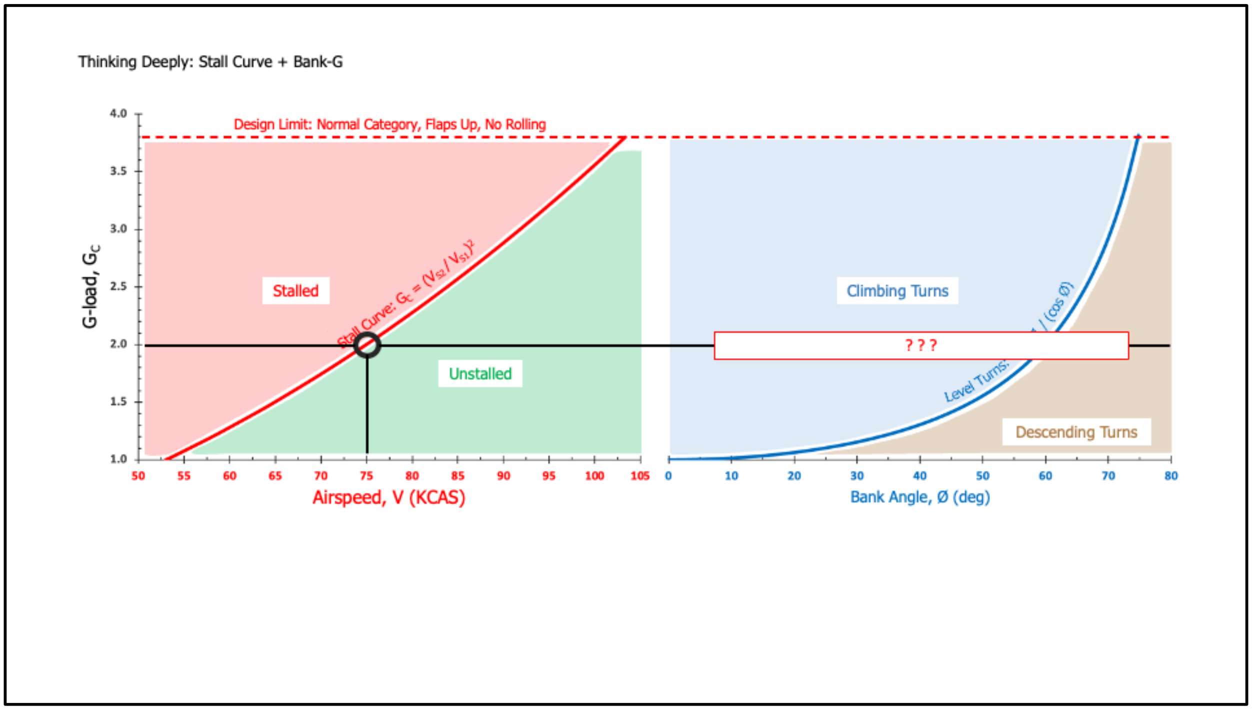
ASK: What if I pull 2.5G at 60 degrees of bank?

Answer: You start a climbing turn.

ASK: What if I pull 1.5G at 60 degrees of bank?

Answer: You start a descending turn.

Remember, flying — and especially turning — doesn't happen TO us; it happens BECAUSE of us.

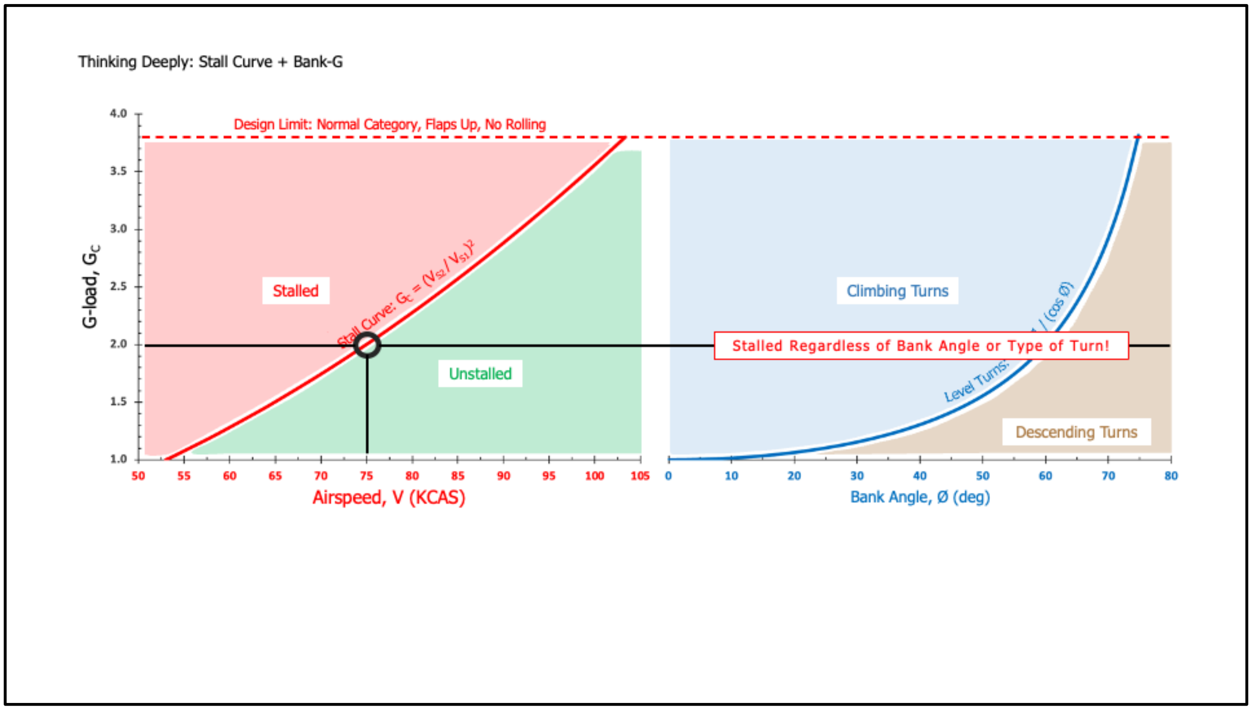


ASK: Ok, so where are we if we pull 2G at a calibrated airspeed of 75 knots?

Answer: We land on the stall curve in an accelerated stall.

ASK: Does it matter what our bank angle is, or what else we might be trying to do at that moment?

In other words, what does this mean regarding the bank-G diagram and our ability to maneuver?



Answer: Regardless of the angle of bank or the type of maneuver we were trying to do, WE have stalled the airplane! **Any attitude, any airspeed.**

ASK: How should we respond to this or any other stall?

Answer: Push to unload the G and reduce the AOA.

ASK: Does it matter how close to the ground we might be at the time?

Answer: No.

ASK: Assume you are 300 feet above the ground. How much altitude can you afford to give away to recover from this or any other stall?

Answer: If necessary, all but the last foot.

ASK: When are pilots more prone to inadvertently stall, spin, or spiral out of a turn in the traffic pattern?

Answers:
- Attempting to turn back to the runway after engine failure on takeoff.
- Overshooting the turn to final.

The Three Ss in the Pattern

Awareness		Prevention	Recovery
Action	**Consequence**	**Reaction**	**Reaction**
	STALL		
	SPIN		
	SPIRAL		

Reducing loss of control hinges on three levels of mitigation and intervention:

Awareness, Prevention, and Recovery.

Let's consider stalls, spins, and spirals in the context of traffic pattern operations.

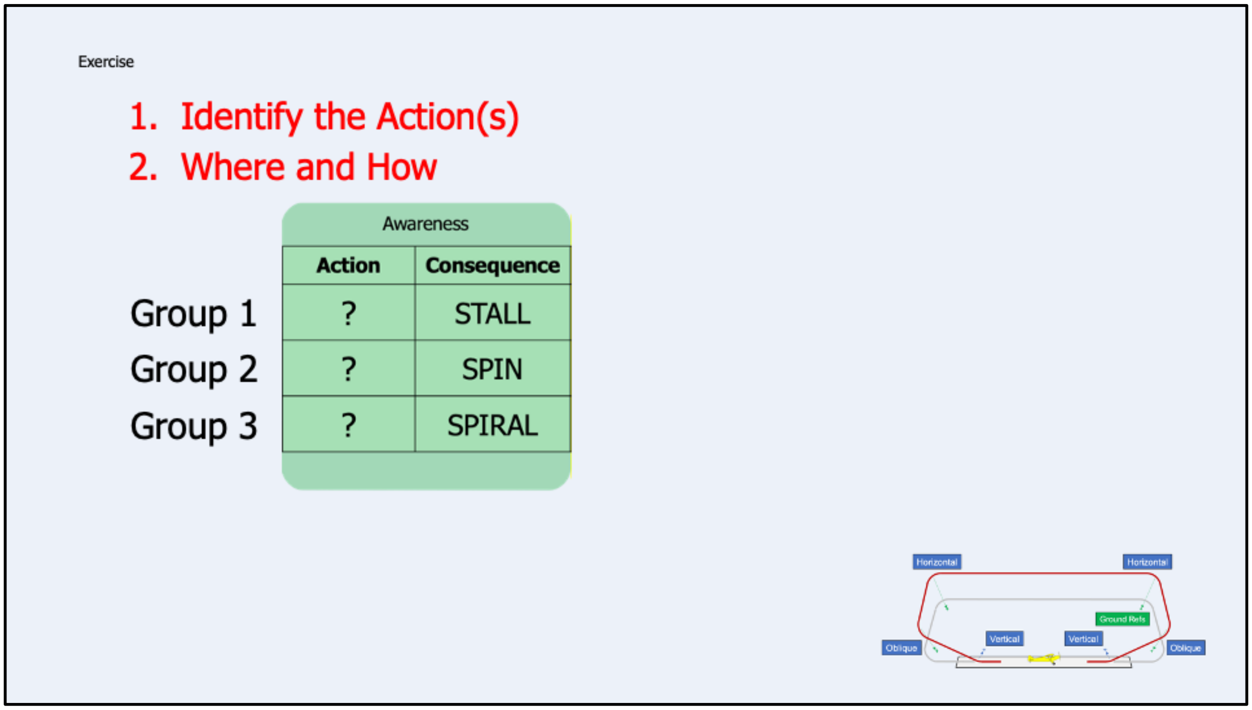
The Three Ss in the Pattern

Awareness		Prevention	Recovery
Action	**Consequence**	**Reaction**	**Reaction**
?	STALL	?	?
?	SPIN	?	?
?	SPIRAL	?	?

You're going to work in groups now.

Each group will be tasked with filling in certain blanks in the table.

Quickly divide into six groups.



<u>Groups 1, 2, and 3</u>

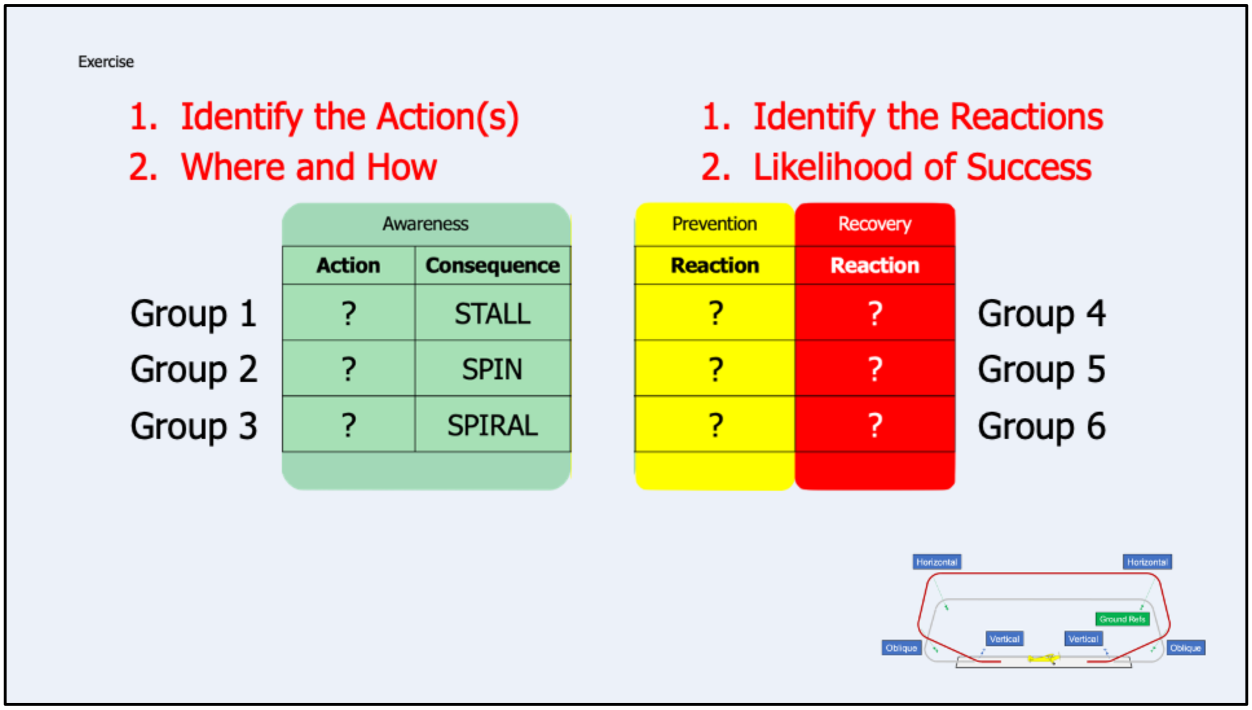
Your task is Awareness. Your groups will address two issues:

1. Identify the pilot actions that could lead to the consequence you've been assigned.
2. Identify where in the pattern the consequence is more likely to occur, as well as how losing situational awareness could lead a pilot to make inputs that trigger the consequence.

Group 1: address the Stall.

Group 2: address the Spin.

Group 3: address the Spiral.



<u>Groups 4, 5, and 6</u>

Your task is Prevention and Recovery. Your groups will address two issues:

1. Identify how the pilot should react to prevent the consequence you have been assigned, as well as how to recover from it.
2. Using a scale of Low, Medium, and High, determine the likelihood of success in avoiding a loss of control accident if the pilot reacts correctly at the Prevention level, as well as if the pilot reacts correctly at the Recovery level.

Group 4: address the Stall.

Group 5: address the Spin.

Group 6: address the Spiral.

In a few minutes, each group will report out to everyone else here. GO!

The Three Ss in the Pattern

Awareness		Prevention	Recovery
Action	**Consequence**	**Reaction**	**Reaction**
	STALL		
	SPIN		
	SPIRAL		

Groups 1 and 4 dealt with the Stall.

Group 1 report.

Group 4 report.

DISCUSSION.

An example: The airplane is low on final approach (the “where”). The pilot instinctively begins pulling back on the elevator control without any increase in power (the “how”). The airplane gets even lower and slower, and possibly stalls.

We can summarize actions and reactions to the Stall as follows:

The Three Ss in the Pattern

Awareness		Prevention	Recovery
Action	**Consequence**	**Reaction**	**Reaction**
Pull	STALL	Relax & Trim	Push
	SPIN		
	SPIRAL		

Awareness: Pulling enough leads to stalling.

Prevention: Relax and make better use of your elevator trim.

Recovery: Push forward to unload the G and reduce the AOA. Do this even if the nose of the airplane is below the horizon, and even if you are close to the ground.

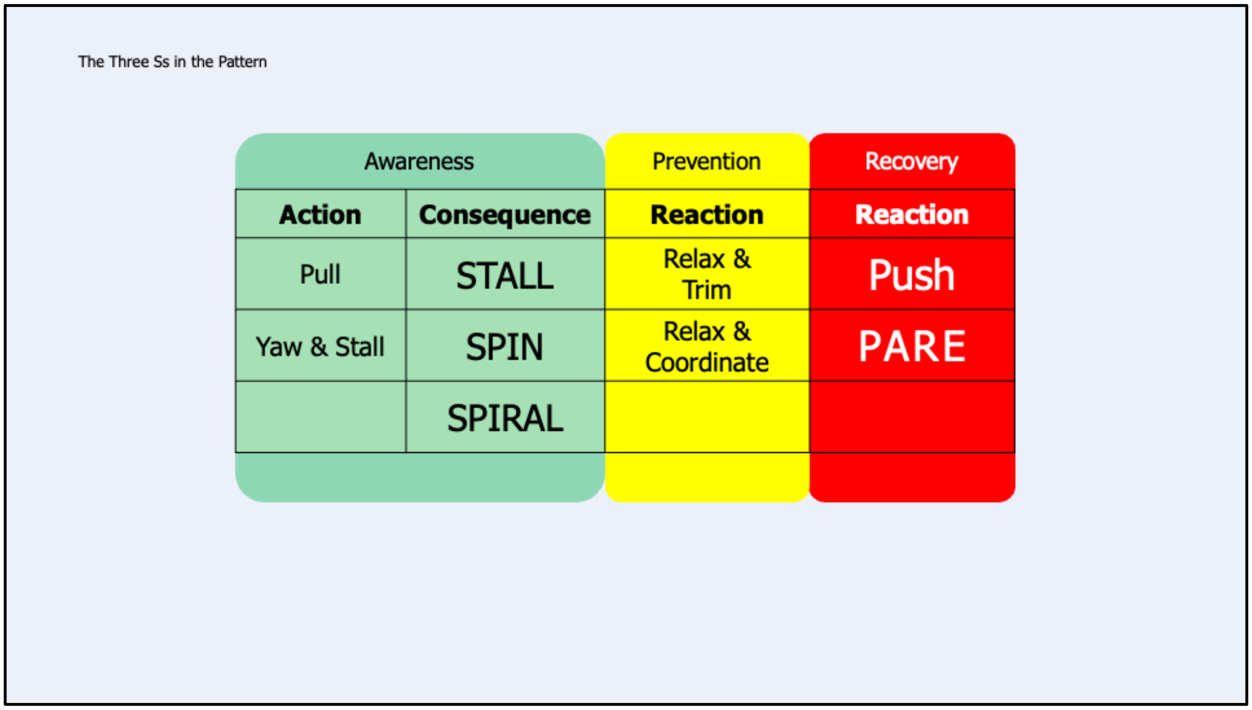
Groups 2 and 5 dealt with the Spin.

Group 2 report.

Group 5 report.

DISCUSSION.

We can summarize actions and reactions to the Spin as follows:



Awareness: Sufficient yawing while stalling triggers a spin.

Prevention: Relax and get coordinated.

Recovery:

Power Off;
Ailerons Neutral;
Rudder Full Opposite; and,
Elevator Forward.

Groups 3 and 6 dealt with the Spiral.

Group 3 report.

Group 6 report.

DISCUSSION.

We can summarize actions and reactions to the Spiral as follows:

The Three Ss in the Pattern

Awareness		Prevention	Recovery
Action	**Consequence**	**Reaction**	**Reaction**
Pull	STALL	Relax & Trim	Push
Yaw & Stall	SPIN	Relax & Coordinate	PARE
Bank & Yank	SPIRAL	Relax & Shallow	Power-Push-Roll

Awareness: Although "yank" is a somewhat strong word, you'll sometimes hear the phrase "bank and yank" for turns.

Mismanaging the amount of pull required for a level turn at a given bank angle, for example, leads to unplanned spirals.

Prevention: Relax and shallow the bank. Basically hit reset and start the turn over again.

Recovery:

Power – off or on, depending on the situation;
Push – reduce the G and the AOA, and provide more margin to design limits;
Roll – shallow the bank using coordinated aileron and rudder inputs.

The Three Ss in the Pattern

Awareness		Prevention	Recovery
Action	**Consequence**	**Reaction**	**Reaction**
Pull	STALL	Relax & Trim	Push
Yaw & Pull	SPIN	Relax & Coordinate	PARE
Bank & Pull	SPIRAL	Relax & Shallow	Power-Push-Roll

Under Awareness, I've replaced the words "stall" and "yank" in the Action column with the word "pull."

I've also highlighted the word "Relax" in the Prevention column.

Notice the common thread.

Accidental stalls, spins, and spirals result from an inappropriate amount of pull on the elevator control.

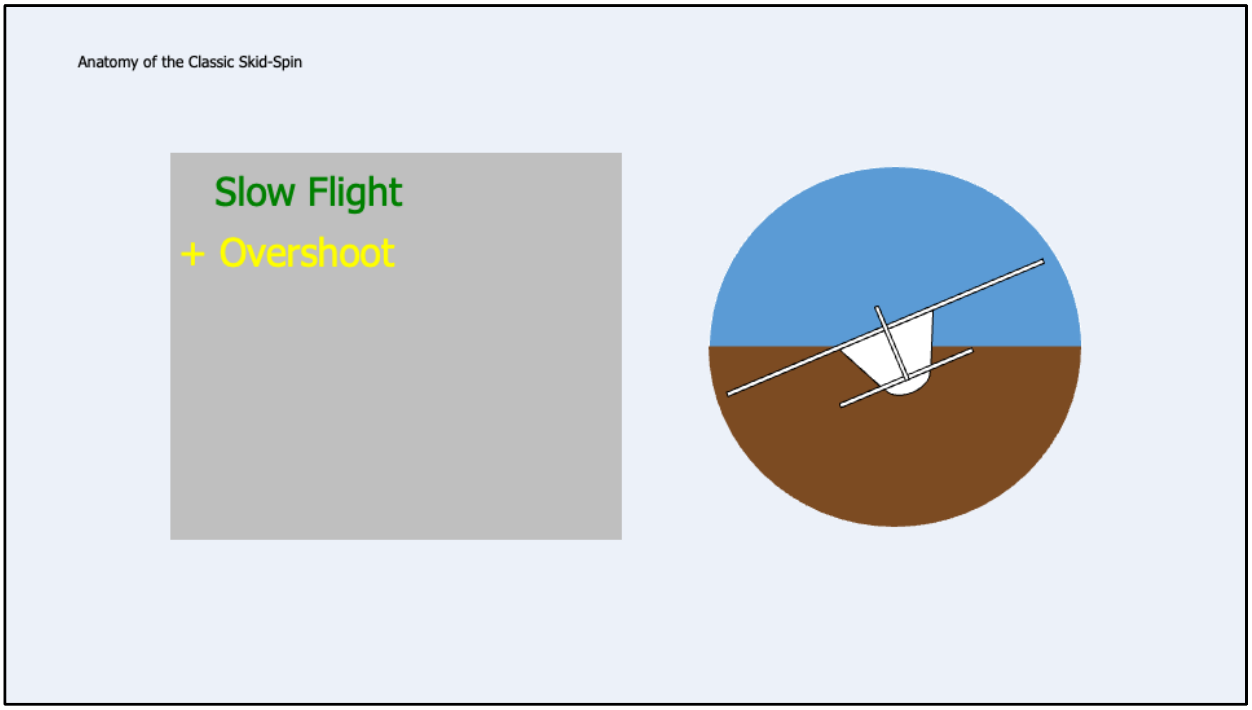
Relaxing more — in other words, making better use of elevator trim to relieve some of the physical workload in the pattern — is a key mitigation strategy against loss of control.

Also, the more stressed we are and the more tense we become on the controls, the less we can feel what the airplane is doing.

Ok, I mentioned earlier that I'd talk about the classic skidded turn to final.

I'll break down the pilot inputs into an exploded view of the sequence leading to a loss of control.

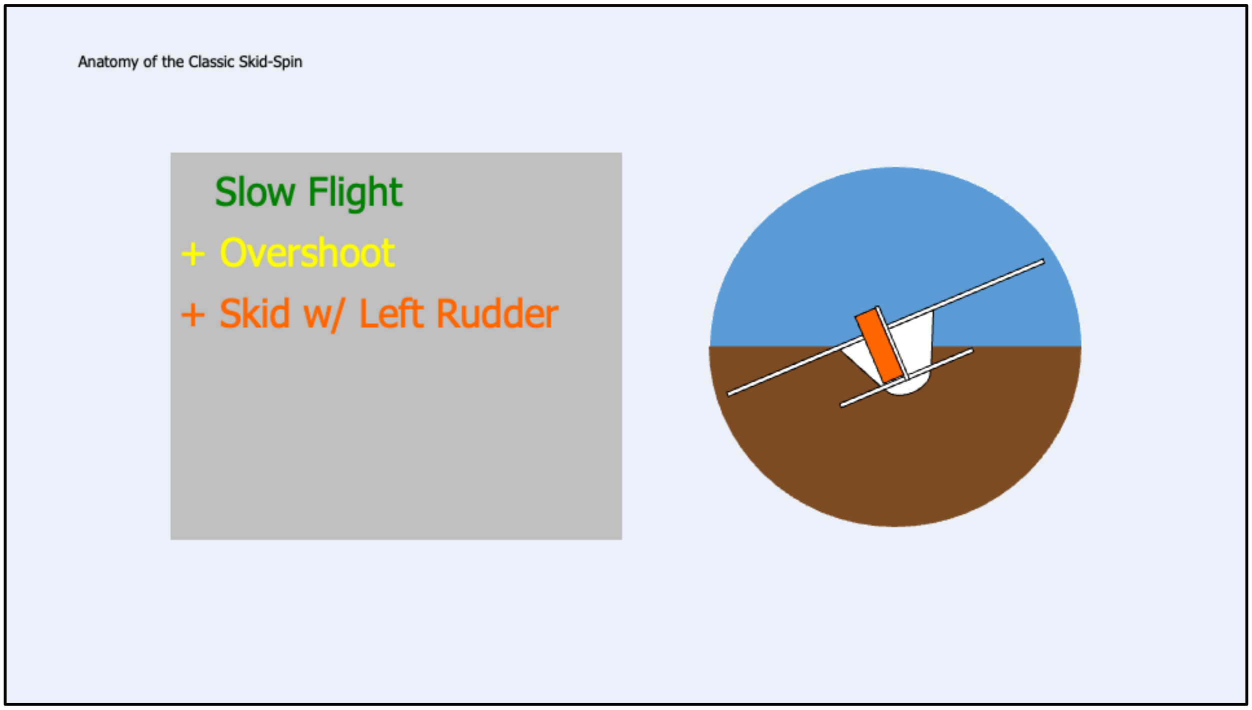
We could do something similar for the botched attempt to turn back to the runway after an engine failure.



Imagine we are in slow flight in a left-hand traffic pattern.

And we have overshot the turn to final.

Maybe we had a tailwind on base leg, or we simply misjudged the turn.



For whatever reason, we don't consider going around and trying again.

Let's say we are also a bit tense because we haven't been flying much lately.

And we don't have a clear understanding of turn dynamics.

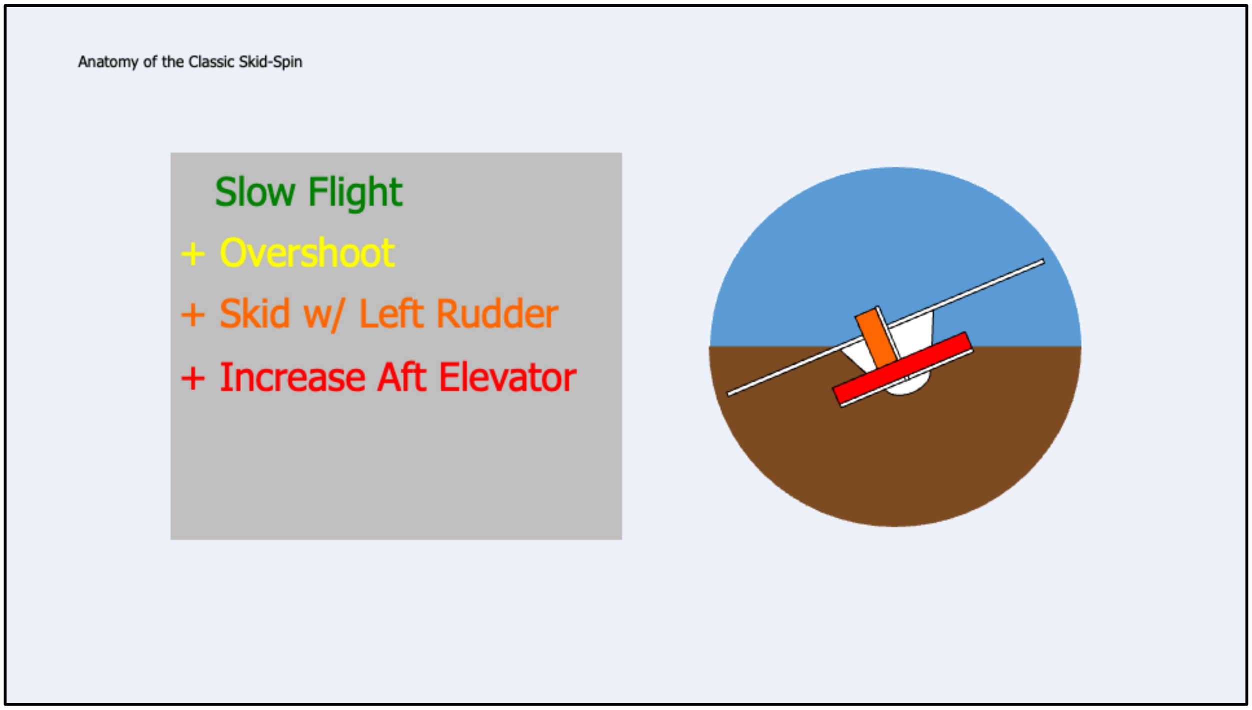
Consequently, we try to correct back to the runway by skidding the turn by adding left rudder.

ASK: What are the consequences of the additional left rudder we are applying?

Possible answers:

> The nose of the airplane slices in yaw toward our left ear. We probably perceive this as the nose dropping.
>
> The bank angle might increase because of something called proverse roll. That is, an increase in bank as a secondary effect of our rudder input.

ASK: What is our natural reaction to the nose dropping when we're close to the ground?



Answer: Our instinct is to try to pull the nose "up."

ASK: What is the consequence of pulling back more on the elevator control?

Possible answers:

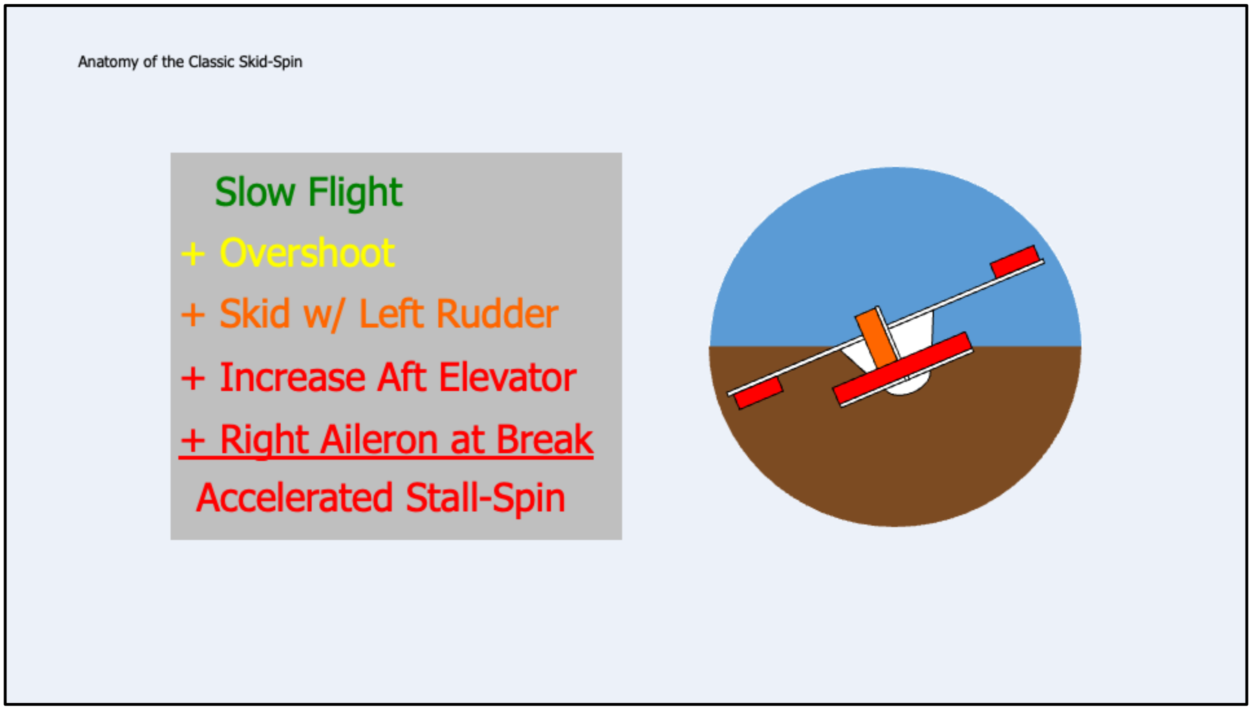
Nose pitching toward your head.
Increasing AOA.
Increasing G.
Maybe decreasing speed.
Tightening of the turn.

ASK: Picture the stall curve we discussed earlier. Where are we headed on that diagram?

Answer: Toward the stall curve. Specifically, toward an accelerated stall.

At the moment of stall departure, we're likely to see a rapid increase in bank angle.

ASK: What's the likely reaction to that?



Answer: To apply opposite aileron. But that tends to further aggravate the situation.

This combination of inputs **by the pilot** can lead to an accelerated stall, maybe even a spin.

If the airplane doesn't stall, it's likely to be an uncommanded spiral prior to ground impact.

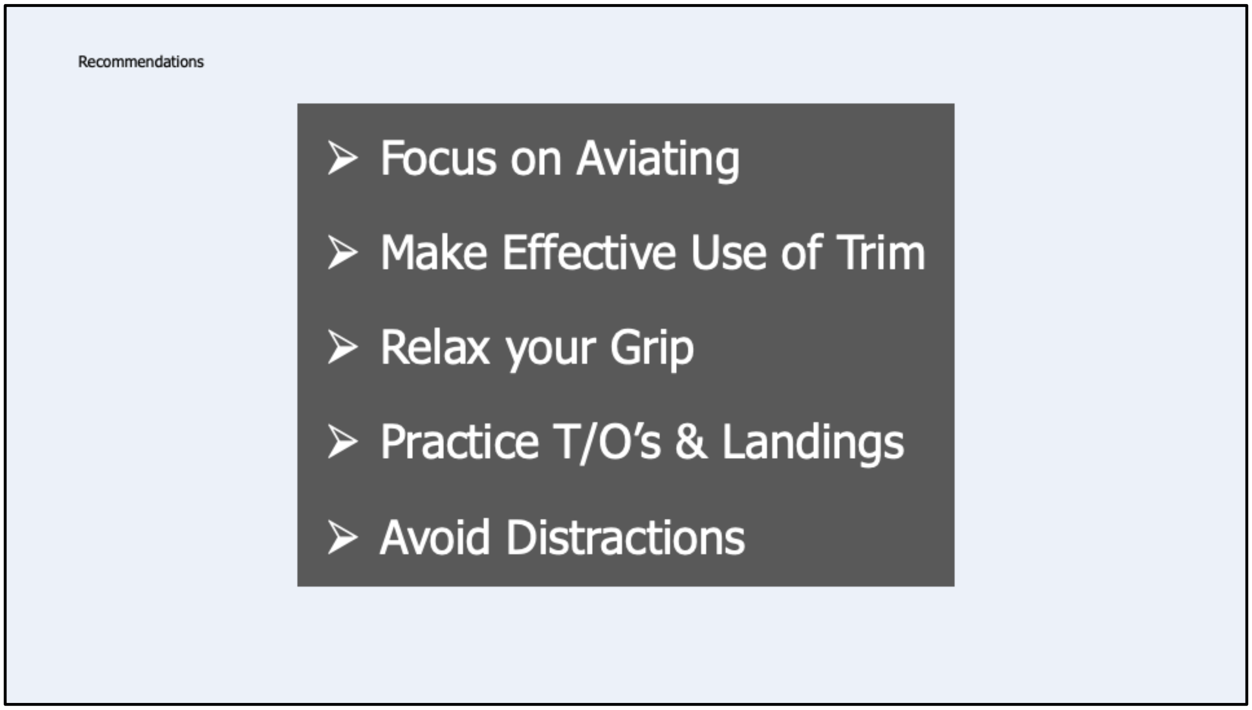
Whether a stall, spin, or spiral, the loss of control occurs from a nose-low attitude.

Any attitude, any airspeed.

And rudder does not turn the airplane.

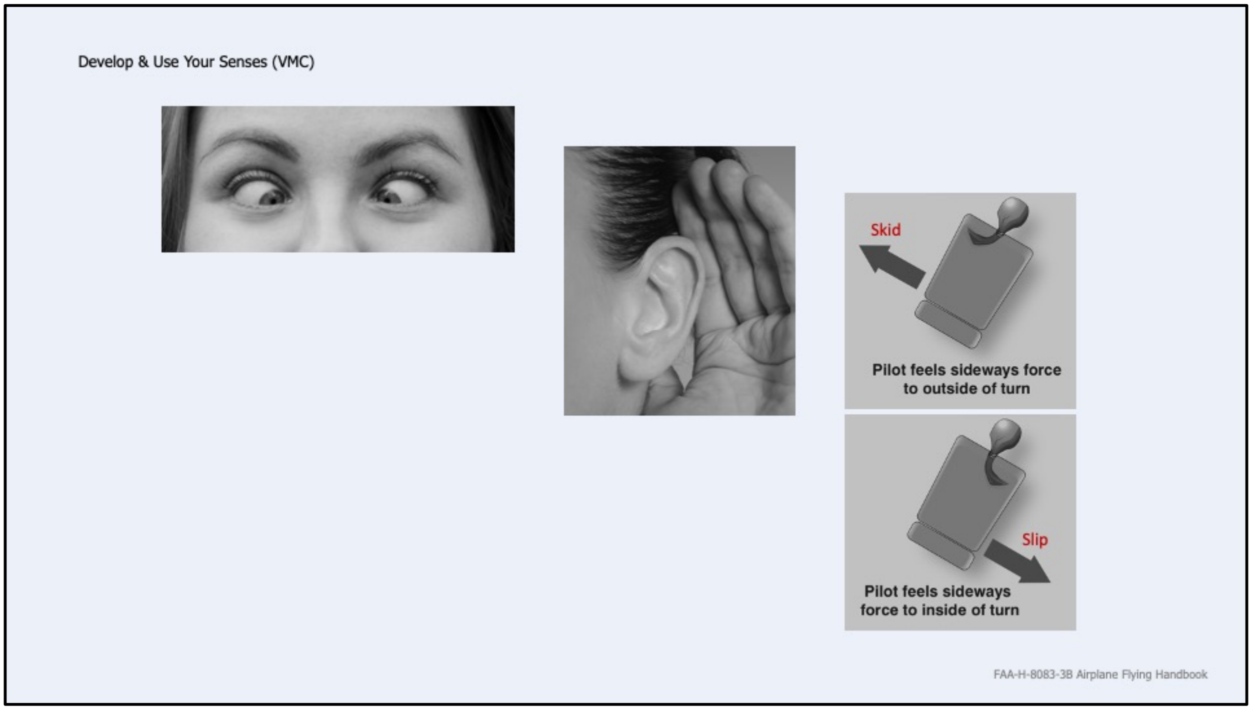
Recall the mitigation strategies Awareness, Prevention, and Recovery. Given where we are in the pattern, it's probably too late for Recovery.

We must prevent loss of control in the first place by remaining aware of what we are asking the airplane to do.

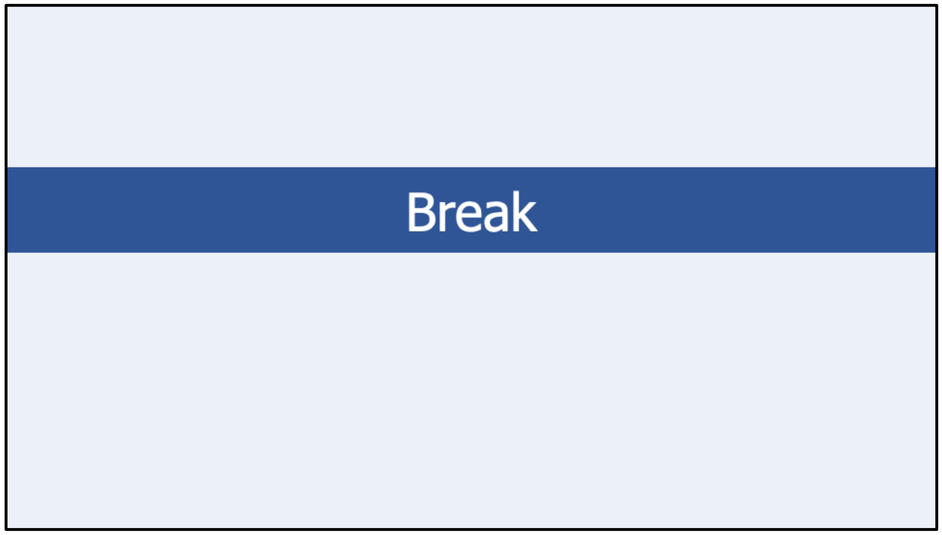


Here some recommendations to keep in mind:

- Focus on flying your airplane in the pattern.
- Make effective use of the elevator trim.
- Relax, especially your grip on the controls.
- Practice takeoffs and landings more often, like you did when you were a student pilot.
- Avoid getting distracted. Three things you can do to deal with distractions:
    1. Defer it until later;
    2. Delegate it to someone else; or,
    3. Deal with it and move on.



And keep refining your senses of sight, sound, and feel, especially when you're flying VFR in VMC.

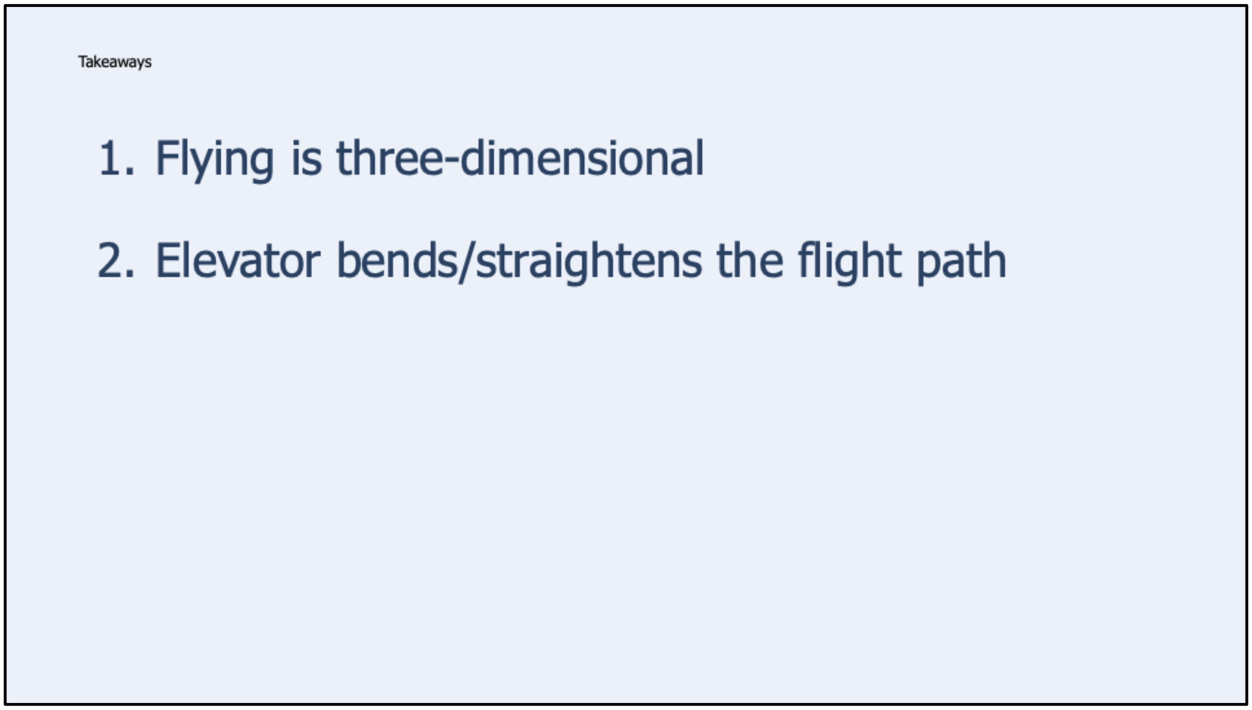


Well done everybody!

We’ll address any other questions during the debrief session.

Please be on time for your next session.

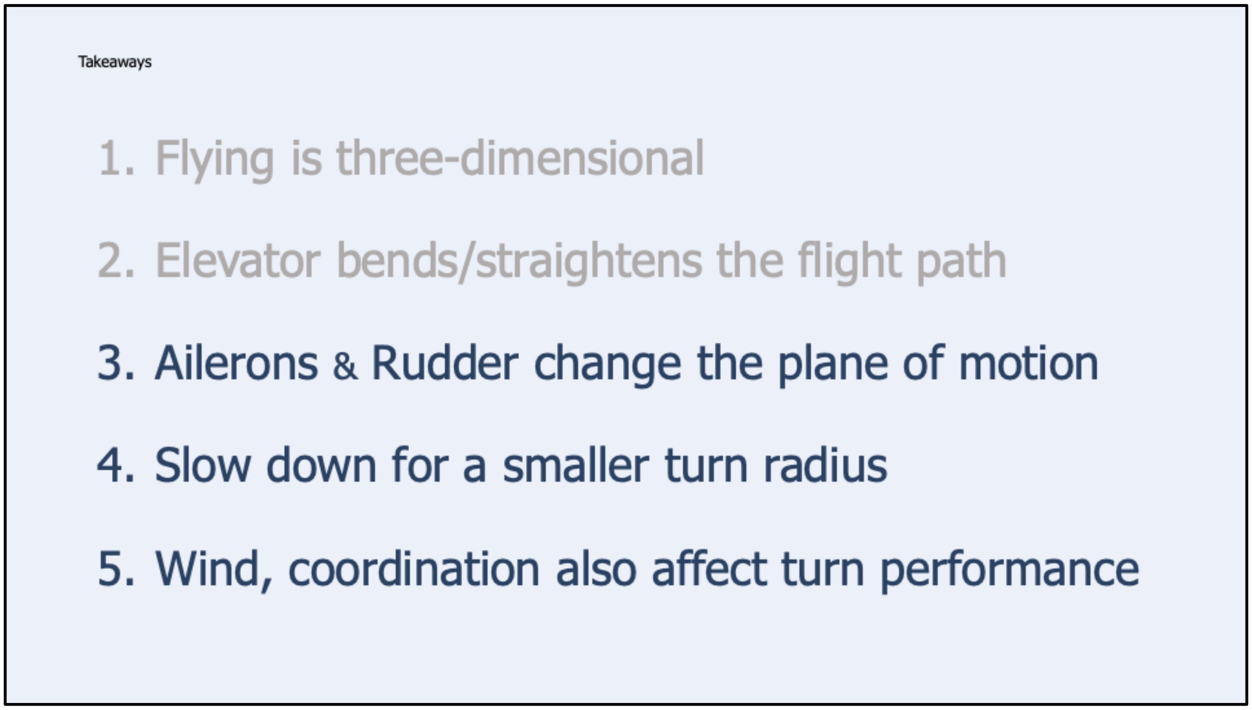

L2T Wrap Up
Debrief
AirVenture 2022
Pilot Proficiency Center



Here are a few takeaways we hope you'll remember:

1. Flying is three dimensional. We routinely operate in the horizontal, oblique, and vertical planes.
2. We use the elevator to bend or straighten our flight path.

Also, elevator inputs manifest as changes in AOA, airspeed, G-load, flight path, attitude, or at least some combination of these.



3. We use ailerons and coordinating rudder to change the plane of motion.
4. At a given angle of bank, slowing down results in a smaller turn radius.
5. And wind and our own coordination can affect our turn performance.

The Learn to Turn program has free online assets that include a booklet, webinar recording, video, graphics supplement, and flight simulation exercises.

For more information, see RichStowell.com/Learn-to-Turn or CommunityAviation.com/Learn-to-Turn

If you are insured by Avemco, you can get 10% off your premiums by going through this program.

QUESTIONS?

Thank you everyone. Enjoy the rest of AirVenture!

Curated Content

Excerpt – Risk Management Handbook, 2009
Reference: PowerPoint Slide Notes, PPT Slide #4

Excerpt – Pilot's Handbook of Aeronautical Knowledge, 2016
Reference: PowerPoint Slide Notes, PPT Slides #8–10

Study – Human Error and General Aviation Accidents, 2005
Reference: PowerPoint Slide Notes, PPT Slides #11–14

Draft – Guide for the Conduct of Biennial Flight Reviews, 1999
Reference: PowerPoint Slide Notes, PPT Slides #15–19

Excerpt – Airplane Flying Handbook, 2016
Reference: PowerPoint Slide Notes, PPT Slide #56

Article – Maneuvering Performance: Stall Curves, 2020
Reference: PowerPoint Slide Notes, PPT Slides #80–87

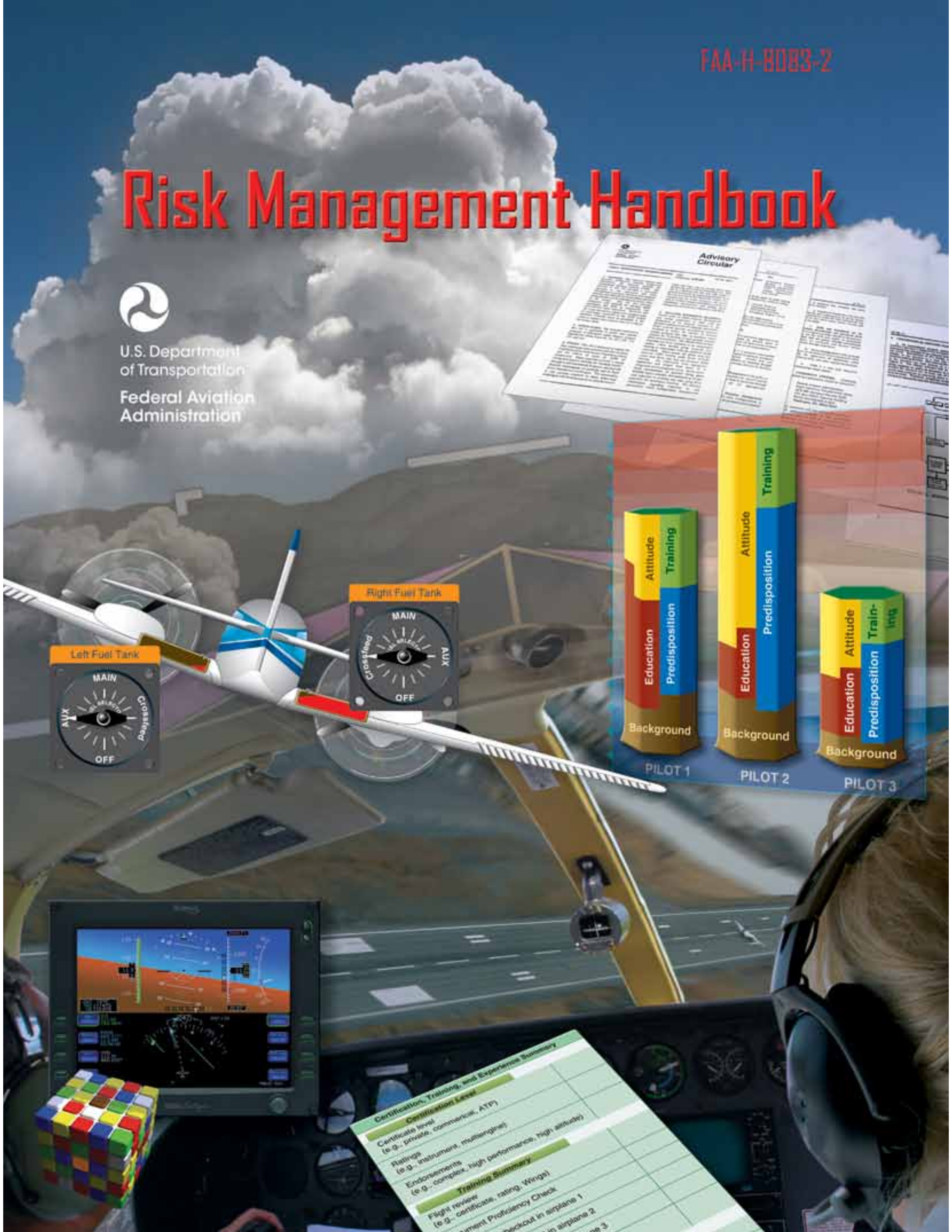
Background Info – Turning Flight Accident, Manhattan, NY, 2006
Reference: Flight Simulation Pressure Scenario
- NTSB Factual Report (narrative only)
- Screenshot – NTSB animation
- Article – Aviation Safety, Dec 2006
- Article – AOPA Pilot, Nov 2007
- Article – Aviation Safety, Apr 2008
- Excerpt – PowerPoint Slides, Human Factors seminar

FAA-H-8083-2

Risk Management Handbook

U.S. Department of Transportation

Federal Aviation Administration



Risk Management Handbook

2009

U.S. Department of Transportation
FEDERAL AVIATION ADMINISTRATION
Flight Standards Service

Preface

This handbook is a tool designed to help recognize and manage risk. It provides a higher level of training to the pilot in command (PIC) who wishes to aspire to a greater understanding of the aviation environment and become a better pilot. This handbook is for pilots of all aircraft from Weight-Shift Control (WSC) to a Piper Cub, a Twin Beechcraft, or a Boeing 747. A pilot's continued interest in building skills is paramount for safe flight and can assist in rising above the challenges which face pilots of all backgrounds.

Some basic tools are provided in this handbook for developing a competent evaluation of one's surroundings that allows for assessing risk and thereby managing it in a positive manner. Risk management is examined by reviewing the components that affect risk thereby allowing the pilot to be better prepared to mitigate risk.

The pilot's work requirements vary depending on the mode of flight. As for a driver transitioning from an interstate onto the city streets of New York, the tasks increase significantly during the landing phase, creating greater risk to the pilot and warranting actions that require greater precision and attention. This handbook attempts to bring forward methods a pilot can use in managing the workloads, making the environment safer for the pilot and the passengers. *[Figure I-1]*

This handbook may be purchased from the Superintendent of Documents, United States Government Printing Office (GPO), Washington, DC 20402-9325, or from the GPO website at http://bookstore.gpo.gov.

This handbook is also available for download, in PDF format, from the Regulatory Support Division (AFS-600) website at http://www.faa.gov.

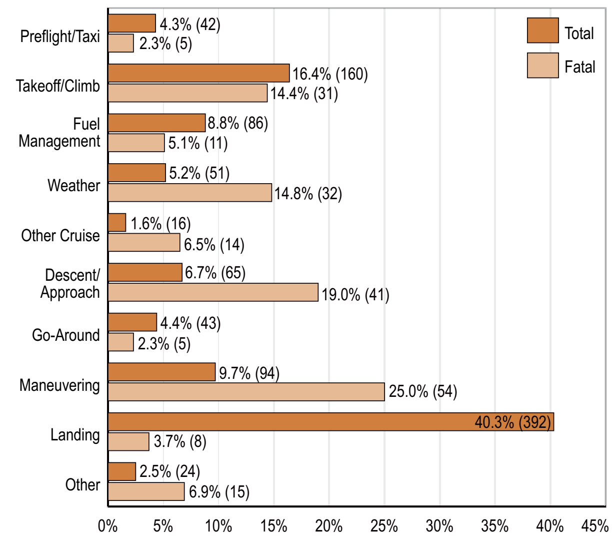


Figure I-1. *The percentage of aviation accidents by phase of flight.*

Occasionally, the word "must" or similar language is used where the desired action is deemed critical. The use of such language is not intended to add to, interpret, or relieve a duty imposed by Title 14 of the Code of Federal Regulations (14 CFR).

Comments regarding this publication should be sent, in email form, to the following address:

AFS630comments@faa.gov

Introduction

According to National Transportation Board (NTSB) statistics, in the last 20 years, approximately 85 percent of aviation accidents have been caused by "pilot error." Many of these accidents are the result of the tendency to focus flight training on the physical aspects of flying the aircraft by teaching the student pilot enough aeronautical knowledge and skill to pass the written and practical tests. Risk management is ignored, with sometimes fatal results. The certificated flight instructor (CFI) who integrates risk management into flight training teaches aspiring pilots how to be more aware of potential risks in flying, how to clearly identify those risks, and how to manage them successfully.

"A key element of risk decision-making is determining if the risk is justified."

The risks involved with flying are quite different from those experienced in daily activities. Managing these risks requires a conscious effort and established standards (or a maximum risk threshold). Pilots who practice effective risk management have predetermined personal standards and have formed habit patterns and checklists to incorporate them.

If the procedures and techniques described in this handbook are taught and employed, pilots will have tools to determine the risks of a flight and manage them successfully. The goal is to reduce the general aviation accident rate involving poor risk management. Pilots who make a habit of using risk management tools will find their flights considerably more enjoyable and less stressful for themselves and their passengers. In addition, some aircraft insurance companies reduce insurance rates after a pilot completes a formal risk management course.

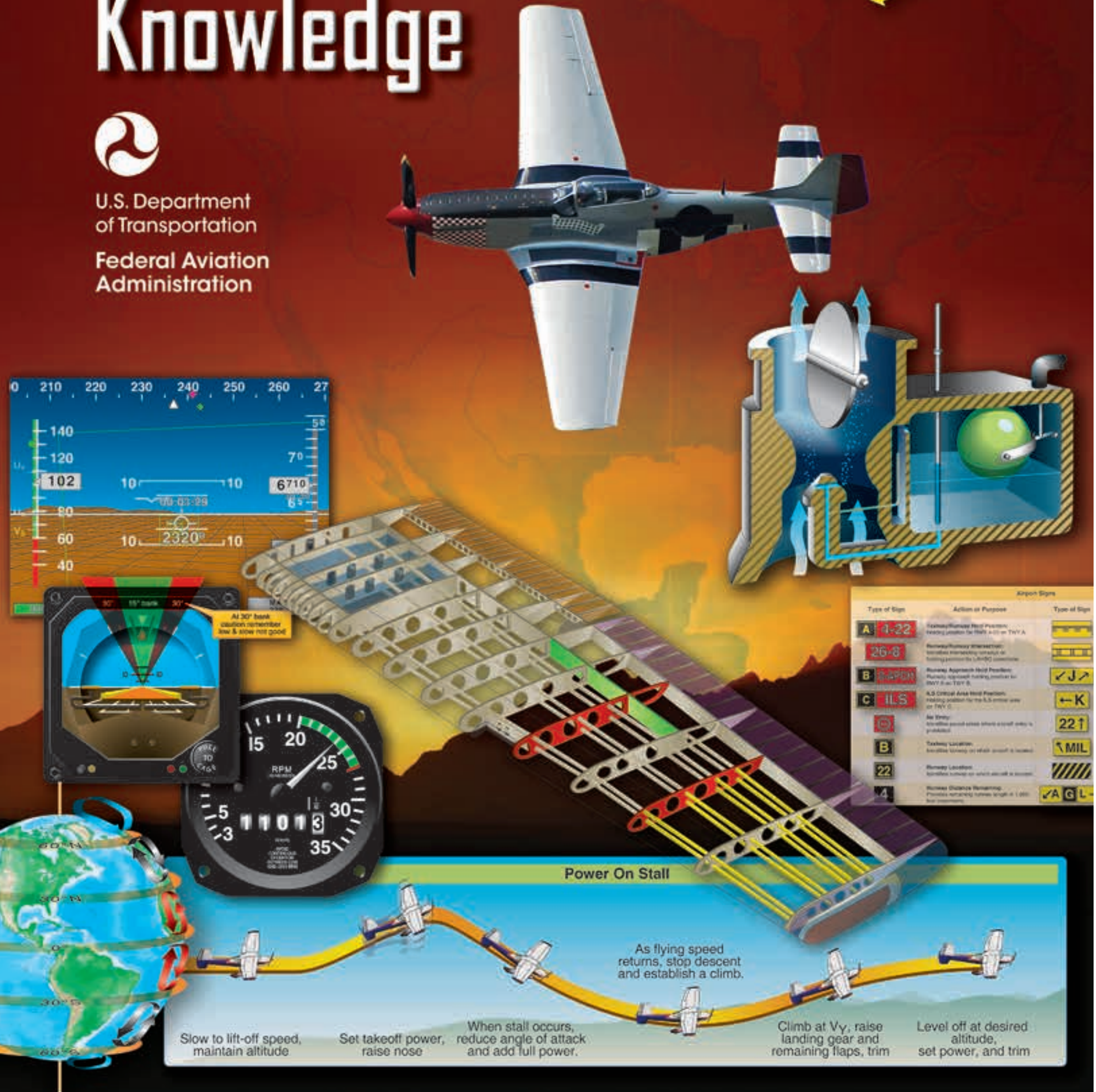
This Risk Management Handbook makes available recommended tools for determining and assessing risk in order to make the safest possible flight with the least amount of risk. The appendices at the end of this handbook contain checklists and scenarios to aid in risk management consideration, flight planning, and training.

FAA-H-8083-25B

Pilot's Handbook of Aeronautical Knowledge

U.S. Department of Transportation

Federal Aviation Administration



Pilot's Handbook of Aeronautical Knowledge

2016

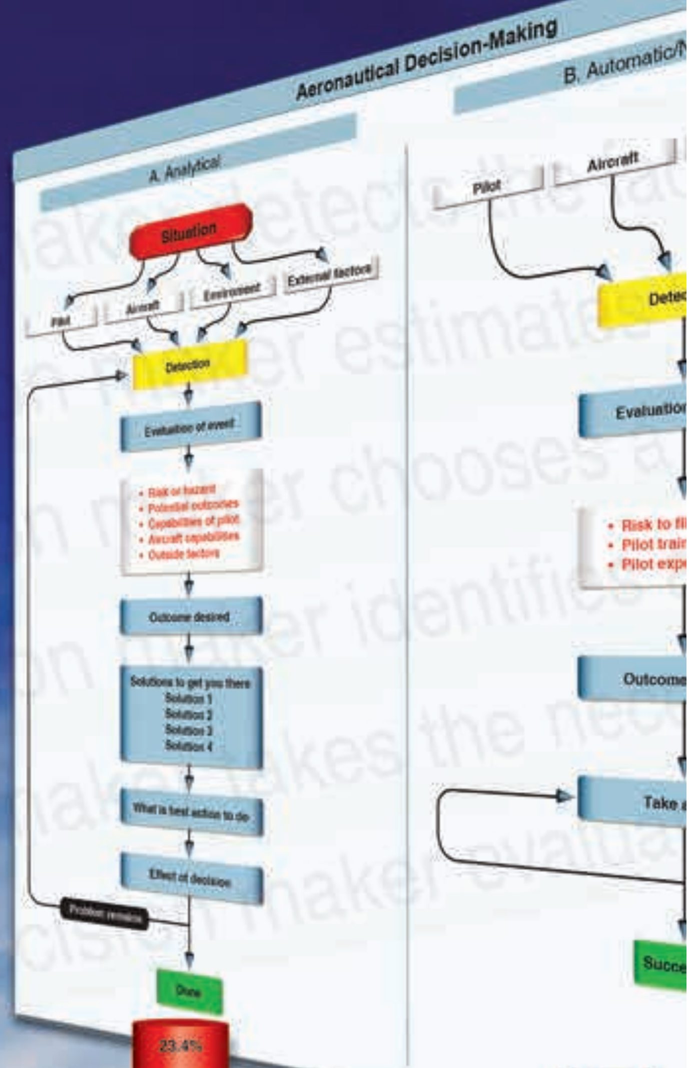
U.S. Department of Transportation
FEDERAL AVIATION ADMINISTRATION
Flight Standards Service

Chapter 2

Aeronautical Decision-Making

Introduction

Aeronautical decision-making (ADM) is decision-making in a unique environment—aviation. It is a systematic approach to the mental process used by pilots to consistently determine the best course of action in response to a given set of circumstances. It is what a pilot intends to do based on the latest information he or she has.



The importance of learning and understanding effective ADM skills cannot be overemphasized. While progress is continually being made in the advancement of pilot training methods, aircraft equipment and systems, and services for pilots, accidents still occur. Despite all the changes in technology to improve flight safety, one factor remains the same: the human factor which leads to errors. It is estimated that approximately 80 percent of all aviation accidents are related to human factors and the vast majority of these accidents occur during landing (24.1 percent) and takeoff (23.4 percent). *[Figure 2-1]*

ADM is a systematic approach to risk assessment and stress management. To understand ADM is to also understand how personal attitudes can influence decision-making and how those attitudes can be modified to enhance safety in the flight deck. It is important to understand the factors that cause humans to make decisions and how the decision-making process not only works, but can be improved.

This chapter focuses on helping the pilot improve his or her ADM skills with the goal of mitigating the risk factors associated with flight. Advisory Circular (AC) 60-22, "Aeronautical Decision-Making," provides background references, definitions, and other pertinent information about ADM training in the general aviation (GA) environment. *[Figure 2-2]*

History of ADM

For over 25 years, the importance of good pilot judgment, or aeronautical decision-making (ADM), has been recognized as critical to the safe operation of aircraft, as well as accident avoidance. The airline industry, motivated by the need to reduce accidents caused by human factors, developed the first training programs based on improving ADM. Crew resource management (CRM) training for flight crews is focused on the effective use of all available resources: human resources, hardware, and information supporting ADM to facilitate crew cooperation and improve decision-making. The goal of all flight crews is good ADM and the use of CRM is one way to make good decisions.

Research in this area prompted the Federal Aviation Administration (FAA) to produce training directed at improving the decision-making of pilots and led to current FAA regulations that require that decision-making be taught as part of the pilot training curriculum. ADM research, development, and testing culminated in 1987 with the publication of six manuals oriented to the decision-making needs of variously rated pilots. These manuals provided multifaceted materials designed to reduce the number of decision-related accidents. The effectiveness of these materials was validated in independent studies where student pilots received such training in conjunction with the standard flying curriculum. When tested, the pilots who had received ADM-training made fewer in-flight errors than those who had

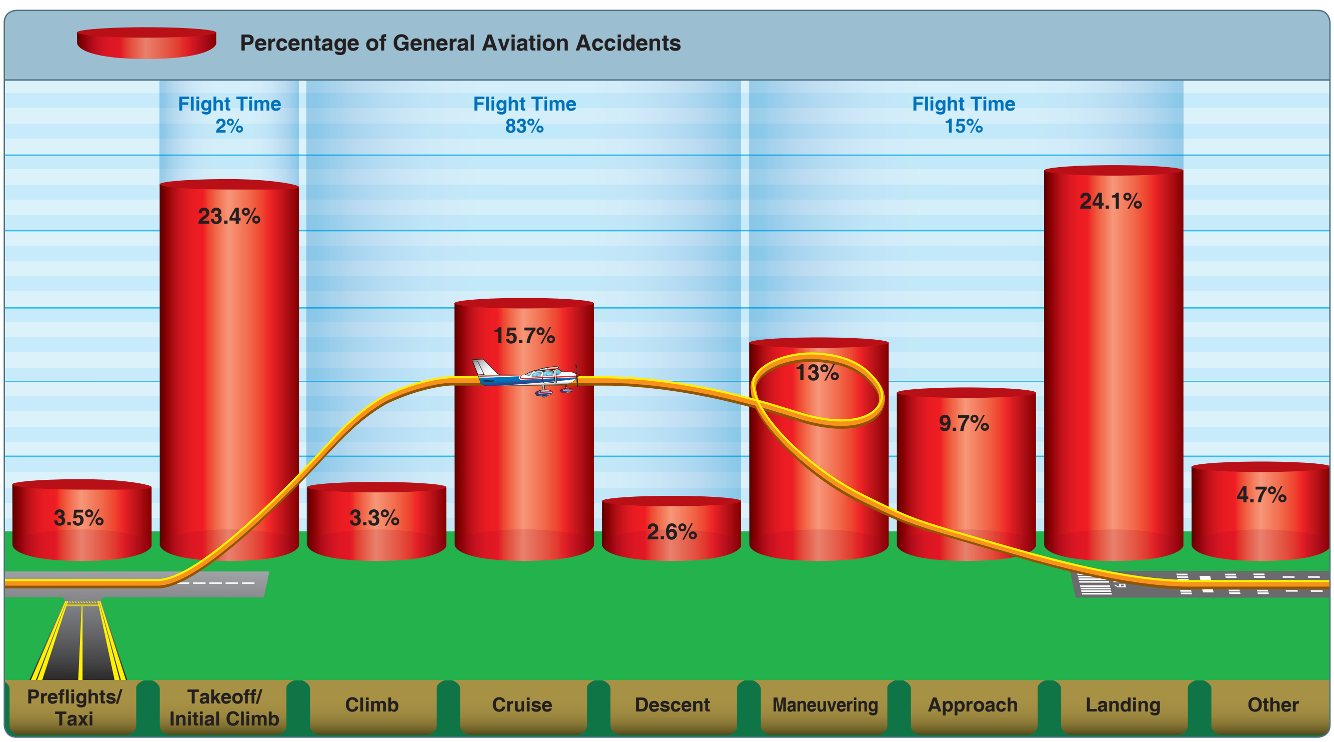


Figure 2-1. *The percentage of aviation accidents as they relate to the different phases of flight. Note that the greatest percentage of accidents take place during a minor percentage of the total flight.*

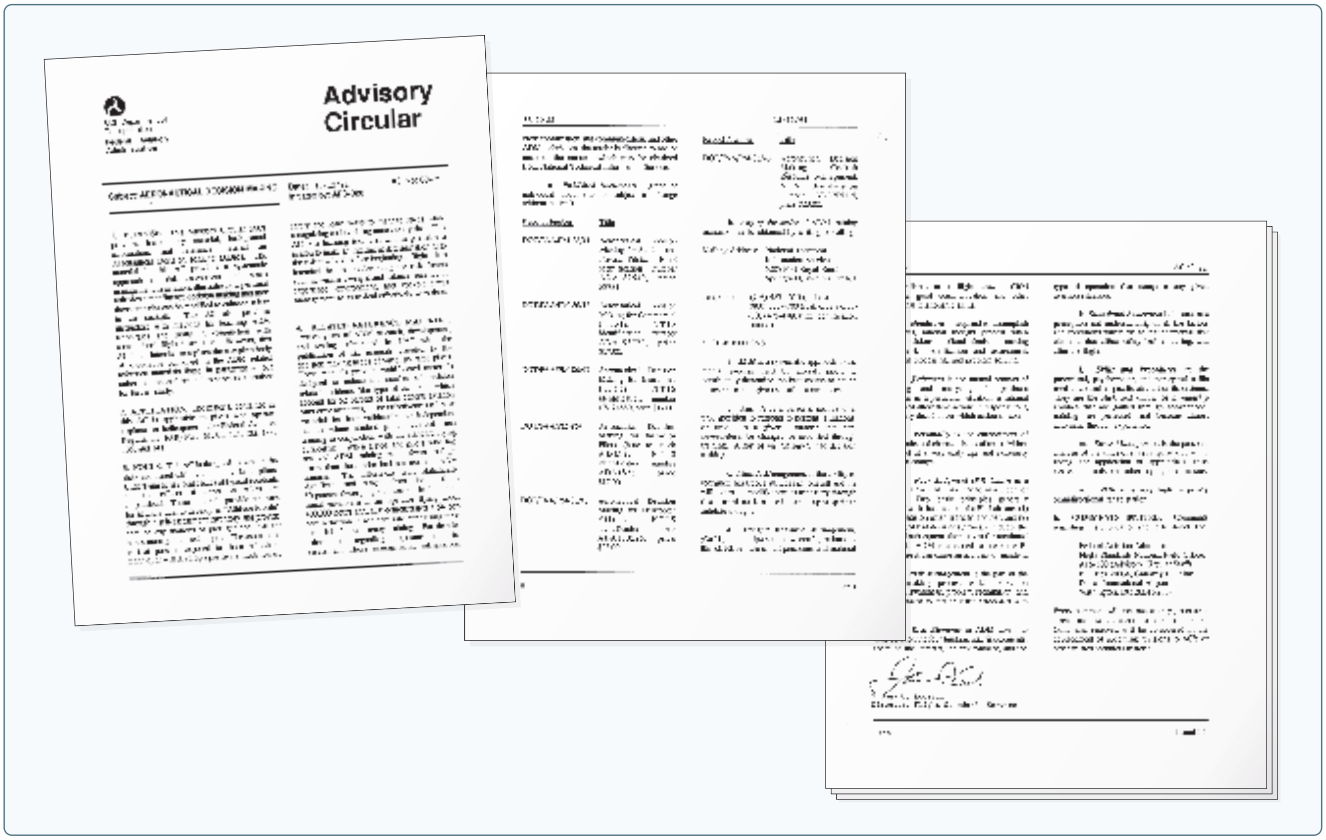

Advisory
Circular

Figure 2-2. *Advisory Circular (AC) 60-22, "Aeronautical Decision Making," carries a wealth of information for the pilot to learn.*

not received ADM training. The differences were statistically significant and ranged from about 10 to 50 percent fewer judgment errors. In the operational environment, an operator flying about 400,000 hours annually demonstrated a 54 percent reduction in accident rate after using these materials for recurrency training.

Contrary to popular opinion, good judgment can be taught. Tradition held that good judgment was a natural by-product of experience, but as pilots continued to log accident-free flight hours, a corresponding increase of good judgment was assumed. Building upon the foundation of conventional decision-making, ADM enhances the process to decrease the probability of human error and increase the probability of a safe flight. ADM provides a structured, systematic approach to analyzing changes that occur during a flight and how these changes might affect the safe outcome of a flight. The ADM process addresses all aspects of decision-making in the flight deck and identifies the steps involved in good decision-making.

Steps for good decision-making are:

1. Identifying personal attitudes hazardous to safe flight
2. Learning behavior modification techniques
3. Learning how to recognize and cope with stress
4. Developing risk assessment skills
5. Using all resources
6. Evaluating the effectiveness of one's ADM skills

Risk Management

The goal of risk management is to proactively identify safety-related hazards and mitigate the associated risks. Risk management is an important component of ADM. When a pilot follows good decision-making practices, the inherent risk in a flight is reduced or even eliminated. The ability to make good decisions is based upon direct or indirect experience and education. The formal risk management decision-making process involves six steps as shown in *Figure 2-3.*

Consider automotive seat belt use. In just two decades, seat belt use has become the norm, placing those who do not wear seat belts outside the norm, but this group may learn to wear a seat belt by either direct or indirect experience. For example, a driver learns through direct experience about the value of wearing a seat belt when he or she is involved in a car accident that leads to a personal injury. An indirect learning experience occurs when a loved one is injured during a car accident because he or she failed to wear a seat belt.

As you work through the ADM cycle, it is important to remember the four fundamental principles of risk management.

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Human Error and General Aviation Accidents: A Comprehensive, Fine-Grained Analysis Using HFACS

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16. Abstract

The Human Factors Analysis and Classification System (HFACS) is a theoretically based tool for investigating and analyzing human error associated with accidents and incidents. Previous research performed at both the University of Illinois and the Civil Aerospace Medical Institute has successfully shown that HFACS can be reliably used to analyze the underlying human causes of both commercial and general aviation (GA) accidents. These analyses have helped identify general trends in the types of human factors issues and aircrew errors that have contributed to civil aviation accidents. The next step was to identify the exact nature of the human errors identified. The purpose of this research effort therefore, was to address these questions by performing a fine-grained HFACS analysis of the individual human causal factors associated with GA accidents and to assist in the generation of intervention programs. This report details those findings and offers an approach for developing interventions to address them.

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Human Error and General Aviation Accidents: A Comprehensive, Fine-Grained Analysis Using HFACS

INTRODUCTION

It is generally accepted that like most accidents, those in aviation do not happen in isolation. Rather, they are the result of a chain of events often culminating with the unsafe acts of aircrew. Indeed, from Heinrich's (Heinrich, Peterson, & Roos, 1931) axioms of industrial safety, to Bird's (1974) "Domino theory" and Reason's (1990) "Swiss cheese" model of human error, a sequential theory of accident causation has been consistently embraced by most in the field of human error (Wiegmann & Shappell, 2001c). Particularly useful in this regard has been Reason's (1990) description of active and latent failures within the context of his "Swiss cheese" model of human error.

In his model, Reason describes four levels of human failure, each one influencing the next. To hear Reason and others describe it, *organizational influences* often lead to instances of *unsafe supervision* which in turn lead to *preconditions for unsafe acts* and ultimately the *unsafe acts of operators*. It is at this latter level, the unsafe acts of operators, that most accident investigations are focused upon.

Unfortunately, while Reason's seminal work forever changed the way aviation and other accident investigators view human error, it was largely theoretical and did not provide the level of detail necessary to apply it in the real world. It wasn't until Shappell and Wiegmann (2000, 2001) developed a comprehensive human error framework — the Human Factors Analysis and Classification System (HFACS) — that Reason's ideas were folded into the applied setting.

HFACS

The entire HFACS framework includes a total of 19 causal categories within Reason's (1990) four levels of human failure (Figure 1). While in many ways, all of the causal categories are equally important; particularly germane to any examination of GA accident data are the unsafe acts of aircrew. For that reason, we have elected to restrict this analysis to only those causal categories associated with the unsafe acts of GA aircrew. A complete description of all 19 HFACS causal categories is available elsewhere (i.e., Wiegmann & Shappell, 2003).

Unsafe Acts of Operators

In general, the unsafe acts of operators (in the case of aviation, the aircrew) can be loosely classified as either errors or violations (Reason, 1990). Errors represent the mental or physical activities of individuals that fail to achieve their intended outcome. Not surprising, given the fact that human beings, by their very nature, make errors, these unsafe acts dominate most accident databases. Violations, on the other hand, are much less common and refer to the willful disregard for the rules and regulations that govern the safety of flight.

Errors

Within HFACS, the category of errors was expanded to include three basic error types (decision, skill-based, and perceptual errors).

Decision Errors. Decision-making and decision errors have been studied, debated, and reported extensively in the literature. In general, however, decision errors can be grouped into one of three categories: procedural errors, poor choices, and problem-solving errors. Procedural decision errors (Orasanu, 1993) or rule-based mistakes, as referred to by Rasmussen (1982), occur during highly structured tasks of the sorts, if X, then do Y. Aviation is highly structured, and consequently, much of pilot decision-making is procedural. That is, there are very explicit procedures to be performed at virtually all phases of flight. Unfortunately, these procedures are occasionally misapplied or inappropriate for the circumstances, often culminating in an accident.

However, even in aviation, not all situations have corresponding procedures to manage them. Therefore, many situations require that a choice be made among multiple response options. This is particularly true when insufficient experience, time, or other outside pressures may preclude a correct decision. Put simply, sometimes we chose well, and sometimes we do not. The resultant choice decision errors (Orasanu, 1993) or knowledge-based mistakes (Rasmussen, 1982) have been of particular interest to aviation psychologists over the last several decades.

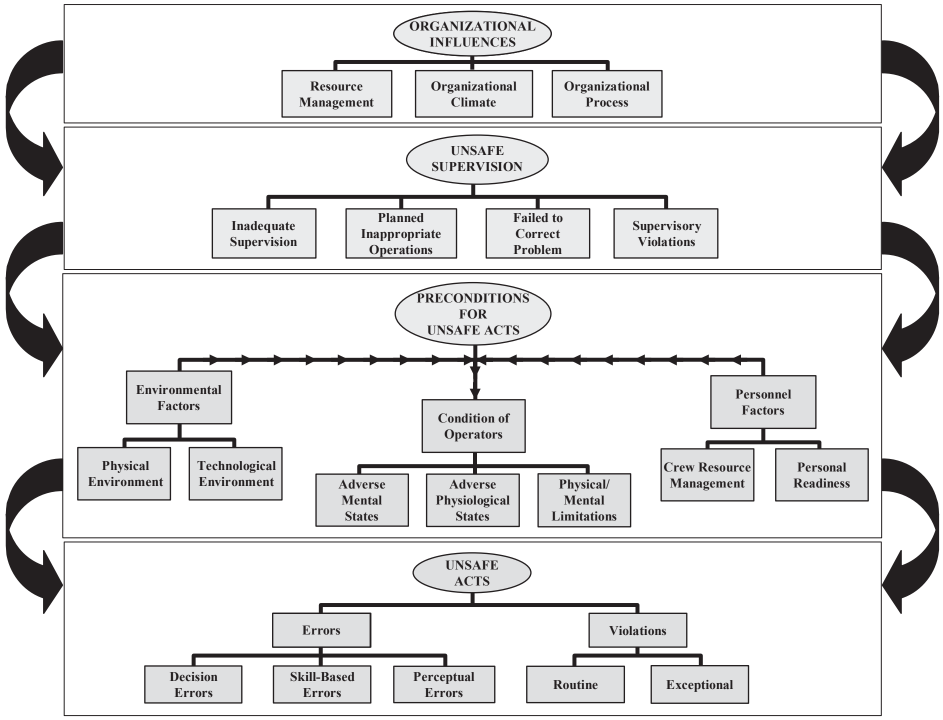

Figure 1. The HFACS framework

Finally, there are instances when a problem is not well understood, and formal procedures and response options are not available. In effect, aircrew find themselves where they have not been before and textbook answers are nowhere to be found. It is during these times that the invention of a novel solution is required. Unfortunately, individuals in these situations must resort to slow and effortful reasoning processes – a luxury rarely afforded in an aviation emergency – particularly in general aviation.

Skill-based Errors. Skill-based behavior within the context of aviation is best described as "stick-and-rudder" and other basic flight skills that occur without significant conscious thought. As a result, these skill-based actions are particularly vulnerable to failures of attention and/or memory. In fact, attention failures have been linked to many skill-based errors such as the breakdown in visual scan patterns, inadvertent activation of controls, and the misordering of steps in procedures. Likewise, memory failures such as omitted items in a checklist, place losing, or forgotten intentions have adversely impacted the unsuspecting aircrew.

Equally compelling, yet not always considered by investigators, is the manner or technique one uses when flying an aircraft. Regardless of one's training, experience, and educational background, pilots vary greatly in the way in which they control their aircraft. Arguably, such techniques are as much an overt expression of one's personality as they are a factor of innate ability and aptitude. More important, however, these techniques can interfere with the safety of flight or may exacerbate seemingly minor flying emergencies.

Perceptual Errors. While decision and skill-based errors have dominated most accident databases and have therefore been included in most error frameworks, perceptual errors have received comparatively less attention. No less important, perceptual errors occur when sensory input is degraded or "unusual," as is often the case when flying at night, in the weather, or in other visually impoverished conditions. Faced with acting on inadequate information, aircrew run the risk of misjudging distances, altitude, and descent rates, as well as responding incorrectly to a variety of visual/vestibular illusions.

It is important to note, however, that it is not the illusion or disorientation that is classified as a perceptual error. Rather, it is the pilot's erroneous response to the illusion or disorientation that is captured here. For example, many pilots have experienced spatial disorientation when flying in instrument meteorological conditions (IMC). In instances such as these, pilots are taught to rely on their primary instruments, rather than their senses when controlling the aircraft. Still, some pilots fail to monitor their instruments when flying in adverse weather or at night, choosing instead to fly using fallible cues from their senses. Tragically, many of these aircrew and others who have been fooled by visual/vestibular illusions have wound up on the wrong end of the accident investigation.

Violations

By definition, errors occur while aircrews are behaving within the rules and regulations implemented by an organization. In contrast, violations represent the willful disregard for the rules and regulations that govern safe flight and, fortunately, occur much less frequently.

Routine Violations. While there are many ways to distinguish between types of violations, two distinct forms have been identified, based on their etiology. The first, routine violations, tend to be habitual by nature and are often tolerated by the governing authority (Reason, 1990). Consider, for example, the individual who drives consistently 5-10 mph faster than allowed by law or someone who routinely flies in marginal weather when authorized for visual meteorological conditions (VMC) only. While both certainly violate governing regulations, many drivers or pilots do the same thing. Furthermore, people who drive 64 mph in a 55-mph zone almost always drive 64 in a 55-mph zone. That is, they *routinely* violate the speed limit.

Often referred to as "bending the rules," these violations are often tolerated and, in effect, sanctioned by authority (i.e., you're not likely to get a traffic citation until you exceed the posted speed limit by more than 10 mph). If, however, local authorities started handing out traffic citations for exceeding the speed limit on the highway by 9 mph or less, then it is less likely that individuals would violate the rules. By definition then, if a routine violation is identified, investigators must look further up the causal chain to identify those individuals in authority who are not enforcing the rules.

Exceptional Violations. In contrast, exceptional violations appear as isolated departures from authority, not necessarily characteristic of an individual's behavior or condoned by management (Reason, 1990). For example, an isolated instance of driving 105 mph in a 55 mph zone is considered an exceptional violation. Likewise, flying under a bridge or engaging in other particularly dangerous and prohibited maneuvers would constitute an exceptional violation. However, it is important to note that, while most exceptional violations are indefensible, they are not considered exceptional because of their extreme nature. Rather, they are considered exceptional because they are neither typical of the individual nor condoned by authority. Unfortunately, the unexpected nature of exceptional violations makes them particularly difficult to predict and problematic for organizations to manage.

PURPOSE

The HFACS framework was originally developed for the U.S. Navy and Marine Corps as an accident investigation and data analysis tool (Shappell & Wiegmann, 2000; 2001; Wiegmann & Shappell, 2003). Since its development, other organizations such as the FAA have explored the use of HFACS as a complement to preexisting systems within civil aviation in an attempt to capitalize on gains realized by the military. These initial attempts, performed at both the University of Illinois and the Civil Aerospace Medical Institute (CAMI) have been highly successful and have shown that HFACS can be reliably and effectively used to analyze the underlying human causes of both commercial and general aviation accidents (Wiegmann & Shappell, 2003). Furthermore, these analyses have helped identify general trends in the types of human factors issues and aircrew errors that have contributed to civil aviation accidents (Shappell & Wiegmann, 2003; Wiegmann & Shappell, 2001a; 2001b).

Indeed, the FAA's General Aviation & Commercial Division (AFS-800) within the Flight Standards Service and the Small Airplane Directorate (ACE-100) have acknowledged the added value and insights gleaned from these HFACS analyses. Likewise, HFACS was cited by the Aeronautical Decision Making (ADM) Joint Safety Analysis Team (JSAT) and the General Aviation Data Improvement Team (GADIT) as being particularly useful in identifying the human error component of aviation accidents.

To date, however, these initial analyses using HFACS have only been performed on a limited set of accident data within the context of civil aviation. Furthermore, these analyses have generally been performed at a global level, leaving several questions unanswered concerning the underlying nature and prevalence of different error types. As a result, AFS-800, ACE-100, the ADM JSAT, and the GADIT committees have directly requested that additional analyses be conducted to answer specific questions about the exact nature of the human errors identified, particularly within the context of GA. Those specific questions include:

Question 1: *Which unsafe acts are associated with the largest percentage of accidents across the entire decade of the 1990s (the 11 years from 1990 through 2000)?* The answer to this question will provide insight into the types of human errors associated with GA accidents from a global perspective.

Question 2: *Has the percentage of accidents associated with each unsafe act changed over the years?* This question addresses whether any interventions implemented over the past 11 years have been successful in reducing accidents caused by specific types of human error. It also provides information as to whether any particular error form has been increasing in occurrence and would therefore pose serious safety concerns in the future, if not addressed today.

Question 3: *Does the pattern of unsafe acts differ across fatal and non-fatal accidents?* Previous research in other aviation venues (e.g., military aviation) has shown that violations of the rules tend to be associated with a larger portion of fatal accidents (Shappell & Wiegmann, 1995, 1997; Wiegmann & Shappell, 1995). Will this same pattern exist in GA accidents, or will other errors more readily distinguish fatal from non-fatal accidents? This question also directly addresses Objective 2 of the FAA Flight Plan that states, "*Reduce the number of fatal accidents in general aviation.*"

Question 4: *Do the patterns of unsafe acts for fatal and non-fatal accidents differ across years?* Similar to question two, this question addresses any increasing or decreasing trends in the specific types of errors across the years, particular as they relate to accident severity.

Question 5: *How often is each error type the "primary" or seminal cause of an accident?* Answers to the previous questions will highlight how often a particular error type is associated with GA accidents. What they do not answer is how often each type of error (e.g., skill-based) is the "initiating" error or simply the "consequence" of another error form (e.g., decision errors). To answer this question, we will examine the seminal unsafe act associated with each accident. Seminal events in this study were defined as the first human error cited within the sequence of events in an accident. Ultimately, information regarding seminal errors will help safety managers within the FAA to refine and/or target intervention strategies so that they can have a greater impact on GA safety.

Question 6: *Do seminal unsafe acts differ across years?* Similar to questions 2 and 4, answers to this question will provide insight into potential trends that will affect efforts aimed at reducing accidents and incidents among GA.

Question 7: *Do seminal unsafe acts differ as a function of accident severity (fatal vs. non-fatal)?* Like question 3, an answer to this question could indicate which seminal errors are most important for preventing fatal aviation accidents.

Question 8: *What are the exact types of errors committed within each error category?* Just knowing that certain types of errors (e.g., skill-based errors) are of major concern typically does not provide enough detail to do anything about it. What we would like to know, for example, is exactly what are the skill-based errors we should focus our safety programs on? A more fine-grained analysis of the specific types of errors within each unsafe act causal category will be conducted to answer this question.

Question 9: *Do the types of errors committed within each error category differ across accident severity?* Like questions 3 and 7, the answer to this question could indicate which specific type of error within each category poses the greatest threat to safety.

Question 10: *Do the types of errors committed within each error category differ between seminal vs. non-seminal unsafe acts?* This question addresses whether there are differences in the specific types of errors within each category that are more likely to initiate the sequence of events. After all, a given causal factor may be the most frequently cited error form but may not be the most frequently cited initiating event. If the goal is to intervene before the accident chain of events is set in motion, this question will determine where to focus safety resources.

Ultimately, answers to these questions will provide us with an unprecedented glimpse into the face of human error within general aviation. The results of these analyses can then be used to map intervention strategies onto different error categories, enabling safety professionals to determine plausible prevention programs for reducing GA accidents. Essentially, this project represents the next step in the development of a larger civil aviation safety program whose ultimate goal is to reduce the aviation accident rate through systematic, data-driven intervention strategies and the objective evaluation of intervention programs.

METHOD

Data

General aviation accident data from calendar years 1990-2000 were obtained from databases maintained by the National Transportation Safety Board (NTSB) and the FAA's National Aviation Safety Data Analysis Center (NASDAC). For analysis purposes, we selected only accident reports that were classified "final" at the time this report was written. The NTSB reports two levels of investigation: factual and final. The factual investigation is a preliminary report that only includes demographic information associated with the accident such as the location of the accident and severity of injuries but no causal factors. Only the final report that contains the causal factors associated with the accident was of interest in this study.

We further eliminated from consideration those accidents that were classified as having "undetermined causes," and those that were attributed to sabotage, suicide, or criminal activity (e.g., stolen aircraft). When the data were parsed in this manner, we were left with only those GA "accidents" for which causal factors had been "determined" and released by the NTSB.

The data were culled further to include only those accidents that involved powered GA aircraft (i.e., airplanes, helicopters, and gyrocopters), thereby excluding blimps, balloons, gliders, and ultra-light aircraft from the analysis. Although the latter is arguably a powered aircraft, ultralights were considered sufficiently different from other powered aircraft to warrant exclusion. Finally, since we were interested in aircrew error, we excluded accidents in which no aircrew-related unsafe act was considered causal or contributory to the accident. In the end, 14,436 accidents involving over 25,000 aircrew causal factors were included and submitted to further analyses using the HFACS framework.

Causal Factor Classification Using HFACS

Seven GA pilots were recruited from the Oklahoma City area as subject matter experts (SMEs). All were certified flight instructors with a minimum of 1,000 flight hours in GA aircraft at the time they were recruited.

Each pilot was provided roughly 16 hours of training on the HFACS framework, which included didactic lecture and practice (with feedback) applying the HFACS framework to accident reports. After training, the seven GA pilot-raters were randomly assigned accidents, so at least two separate pilot-raters analyzed each accident independently.

Using narrative and tabular data obtained from both the NTSB and the FAA NASDAC, the pilot-raters were instructed to classify each human causal factor identified by the NTSB using the HFACS framework. Note, however, that only those causal and contributory factors identified by the NTSB were classified. That is, the pilot-raters were instructed <u>not</u> to introduce additional casual factors that were not identified by the original investigation. To do so would be presumptuous and only infuse additional opinion, conjecture, and guesswork into the analysis.

After our pilot-raters made their initial classifications of the human causal factors (i.e., skill-based error, decision-error, etc.), the two independent ratings were compared. Where disagreements existed, the corresponding pilot-raters were called into the laboratory to reconcile their differences, and the consensus classification was included in the database for further analysis. Overall, pilot-raters agreed on the classification of causal factors within the HFACS framework more than 85% of the time, an excellent level of agreement considering that this was, in effect, a decision-making task.

Human Factors Quality Assurance

The data used in this study were drawn from NTSB investigation reports that are often highly technical in nature, requiring a fundamental understanding of specific terms, flight conditions, and the overall domain of aviation to be effectively classified and coded. As aviation SMEs, the pilot-coders were able to clearly understand each component of the investigation reports studied. What's more, the pilot-coders represent the end users of improved error analysis methods for conducting accident investigations (i.e., aviation experts typically investigate aviation accidents). Therefore, they were considered the appropriate personnel for conducting the overall HFACS analysis of the GA accident reports.

General aviation pilots, however, are not SMEs in the domains of psychology or human factors, and therefore, they may not fully understand the theoretical underpinnings associated with the various error types within the HFACS framework. Hence, pilots might classify human error data somewhat differently than SMEs in human factors. Still, pilots in this study were trained on HFACS, which did give them some level of expertise when assessing human error. In fact, an earlier study addressed this issue by comparing the coded database of a commercial pilot rater to that of a psychologist and found the data to be reliable (Wiegmann & Shappell, 2001a; 2001b).

Nonetheless, to be doubly sure that the pilot coders had grasped the psychological aspects underlying human error and HFACS, three additional SMEs with expertise in human factors/aviation psychology examined each HFACS classification that the pilot SMEs had assigned to a given human cause factor. Essentially, the human factors SMEs were ensuring that the pilots understood the error analysis process and did not code causal factors like spatial disorientation as a decision error, or exhibit any other such blatant misunderstandings of the HFACS model. To aid in the process, descriptive statistics were used to identify outliers in the data, after which the corresponding NTSB report was obtained. The reports were then independently reviewed by a minimum of two human factors SMEs for agreement with the previous codes. After the human factors SMEs came to a consensus, the codes were either changed in the database or left as the pilot SMEs originally coded them. In the end, less than 4% of all causal factors were modified during the human factors quality assurance process.

RESULTS

The results of this research project will be presented in a manner that addresses each of the specific questions raised earlier. Each section will begin by restating the question of interest, followed by a description of the findings pertaining to it.

Question 1: Which unsafe acts are associated with the largest percentage of accidents?

The GA data were initially examined to determine the extent to which each HFACS causal category contributed to GA accidents overall. To accomplish this, the frequency and percentages of GA accidents associated with each HFACS causal category were calculated. However, to avoid over-representation by any single accident, each causal category was counted a maximum of one time per accident. For example, regardless of whether a given accident was associated with one or more skill-based error, the presence of a skill-based error for that accident was only counted once. In this way, the count acted as an indicator of the presence or absence of a particular HFACS causal category for a given accident.

The data were calculated in this manner with the knowledge that most aviation accidents are associated with multiple causal factors, including, on occasion, multiple instances of the same HFACS causal category. However, only by analyzing the data in this way could a true representation of the percentage of accidents associated with each causal category be obtained.

The number and percentage of accidents associated with at least one instance of a particular HFACS causal category can be found in Figure 2, with one notable exception – routine and exceptional violations. As with post-hoc data examined in other venues (e.g., the U.S. Navy/Marine Corps, U.S. Army, U.S. Air Force, etc.) it proved too difficult to differentiate between routine and exceptional violations using narrative data obtained from the NTSB and NASDAC. As a result, the pilot-raters were instructed to use the parent causal category of "violations," rather than distinguish between the two types.

The overall analysis of GA accidents revealed a picture of human error within GA that was not possible before the development of HFACS (Figure 2). Specifically, the data indicate that skill-based errors were associated with the largest portion of GA accidents (79.2% of the 14,436 GA accidents), followed by decision errors (29.7%), violations (13.7%), and perceptual errors (5.7%). Note that many of the accidents were associated with multiple HFACS causal categories. In other words, an accident could have been associated with a skill-based error, decision error, perceptual error, and violation, or any other combination. Therefore, percentages of accidents do not total 100%. Additionally, each accident may be associated with multiple instances of the same type of unsafe act. However, as stated previously, the findings presented here are for those accidents that involve at least one instance of a particular unsafe act category.

Question 2: Has the percentage of accidents associated with each unsafe act changed over the years?

Analysis of the data on a year-by-year basis reveals that the proportion of accidents associated with at least one instance of each unsafe act category remained relatively unchanged over the 11-year period examined in this study (Figure 3). This would seem to suggest that safety efforts directed at GA over the last several years have had little effect on any specific type of human error. If anything, there may have been a general, across-the-board effect, although this seems unlikely, given the safety initiatives employed. The only exceptions seemed to be a small dip in the percentage of accidents associated with decision errors in 1994, a gradual decline in violations observed from 1991 to 1994, and then again from 1995 to 2000. With decision errors, however, the trend quickly re-established itself at levels consistent with the overall average.

Question 3: Does the pattern of unsafe acts differ across fatal and non-fatal accidents?

Figure 4 presents the percentage of fatal (n = 3,256) and non-fatal (n = 11,180) accidents associated with each type of unsafe act. From the graph in Figure 4, some important observations can be made. For instance, it may surprise some that skill-based errors, not decision errors, were the number-one type of human error associated with <u>fatal</u> GA accidents. In fact, fatal accidents associated with skill-based errors (averaging roughly 80.6% across the years of the study) more than doubled the percentage of accidents seen with decision errors (29.5%) and the willful violation of the rules (30.5%). Even perceptual errors, the focus of a great deal of interest over the years, were associated with less than 4% of all fatal accidents. In fact, the proportion of accidents associated with skill-based errors was greater than the three other error types combined.

Upon closer examination, it appears that the percentage of fatal and non-fatal accidents with skill-based, decision, and perceptual errors, was relatively equal (Figure 4). However, as expected, the proportion of accidents associated with violations was considerably higher for fatal than non-fatal accidents. In fact, using a common estimate of risk (known as the odds ratio), fatal accidents were more than four times more likely to be associated with violations than non-fatal accidents (odds ratio = 4.547; 95% confidence interval = 4.11 to 5.021, Mantel-Haenszel

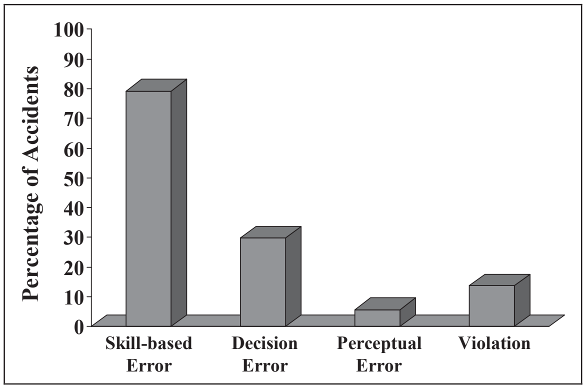

Figure 2. *Percentage of aircrew-related accidents by unsafe act category.*

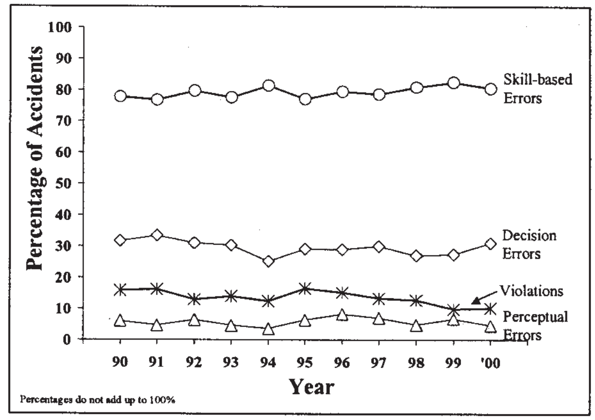

Figure 3. *Percentage of accidents by error category by year.*

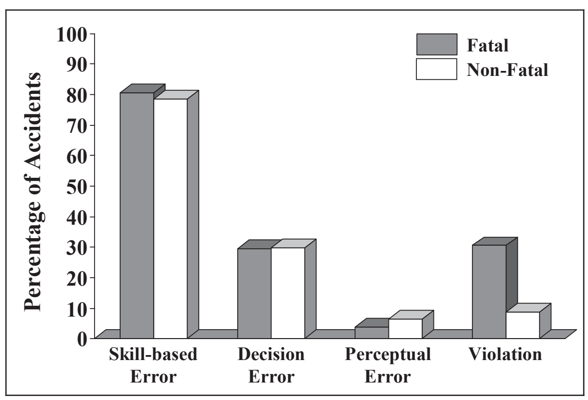

Figure 4. *Percentage of fatal and non-fatal GA accidents associated with each unsafe act.*

test for homogeneity = 1002.358, p<.001). Put simply, if a violation of the rules results in an accident, the pilot is more likely to die or kill someone else than to get up and walk away.

Question 4: Do the patterns of unsafe acts for fatal and non-fatal accidents differ across years?

As with the overall analysis, an examination of the 3,256 fatal accidents on a year-by-year basis revealed that the proportion of accidents associated with at least one instance of each unsafe act category remained relatively stable over the 11-year period examined in the study (Figure 5). As before, there appears to have been a slight downward trend in both decision errors and violations during the early part of the 1990s. However, these trends reversed direction and generally increased during the later half of the decade.

While this is certainly important information, some may wonder how these findings compare with the 11,180 non-fatal accidents. As can be seen in Figure 6, the above results were strikingly similar to those associated with fatalities. Again, the trends across the years were relatively flat, and as with fatal accidents, skill-based errors were associated with more non-fatal accidents than any other error type, followed by decision errors. The percentage of non-fatal accidents associated with violations and perceptual errors were relatively equal across the years. In fact, the only real difference in the pattern of human error seen with fatal and non-fatal GA accidents was with the percentage of accidents attributable, in part, to violations of the rules (Figure 7).

Question 5: How often is each error type the "primary" cause of an accident?

The previous analyses have indicated that, overall, roughly 80% of GA accidents are associated with skill-based errors. More important, however, is how often skill-based errors are the "initiating" error or simply the "consequence" of another type of error, such as decision errors. Consider, for instance, a pilot who knowingly takes off into a forecasted thunderstorm without an instrument rating. Such a choice would be considered a *decision error* within the HFACS framework. Later in the flight, the pilot may be faced with either turning around or flying through the weather (flying in instrument meteorological conditions – IMC) when he/she is authorized for only visual flight rules (VFR) flight. If the pilot willfully penetrates IMC, a *violation* would be committed. This might lead to spatial disorientation (*adverse physiological state*), which, in turn, might lead to a misperception in the aircraft's attitude (*perceptual error*), and ultimately the loss of control of the aircraft (*skill-based error*) resulting in an accident. Given such a scenario, some would argue that the first error in the chain of events is more important than the skill-based error committed well down the error chain.

To resolve this potential issue, we examined the seminal unsafe act associated with each accident, the results of which are presented in Figure 8. As can be seen from the figure, the pattern of unsafe acts was similar to that seen in the overall analysis above (see Figure 2). The only difference is that these percentages will add up to 100%, since there can only be one "seminal" human causal factor. Still, nearly 61% (n = 8,838) of all accidents began with a skill-based error. In contrast, roughly 19% (n = 2,729) began with a decision error, 8% (n = 1,180) began with a violation, and only 4% (n = 564) began with a perceptual error. The remaining 8% (n = 1,125) were associated with a seminal event other than an unsafe act (e.g., a precondition for an unsafe act, such as an adverse physiological state).

Questions 6 and 7: Do seminal unsafe acts differ across years or as a function of accident severity (fatal vs. non-fatal).

Let's begin with accident severity. As depicted in Figure 9, seminal skill-based errors were associated with the largest proportion of both fatal and non-fatal accidents. However, the percentage of non-fatal accidents associated with seminal skill-based errors was somewhat higher than for fatal accidents. In contrast, seminal violations continued to be associated with a much larger percentage of fatal accidents than non-fatal accidents. Percentages of fatal and non-fatal accidents associated with seminal decision errors were equivalent, as they were for perceptual errors. Worth noting, the latter (perceptual errors) were practically non-existent for both fatal and non-fatal accidents. This finding was not surprising given that most perceptual errors occur later in the chain of events; after an individual has committed a violation or following a decision error.

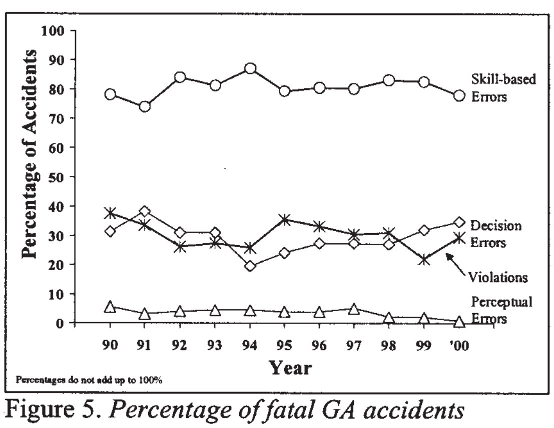

Figure 5. *Percentage of fatal GA accidents associated with each unsafe act across years.*

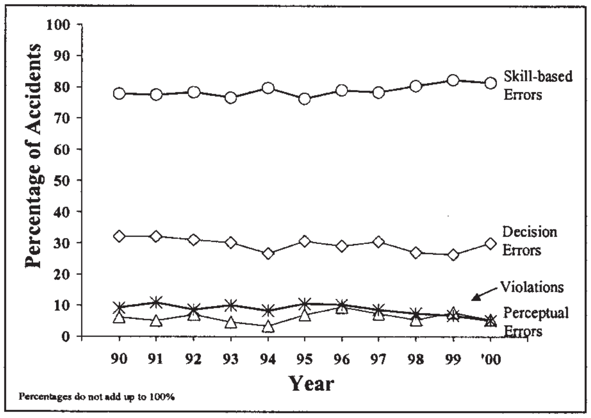

Figure 6. *Percentage of non-fatal GA accidents associated with each unsafe act across years.*

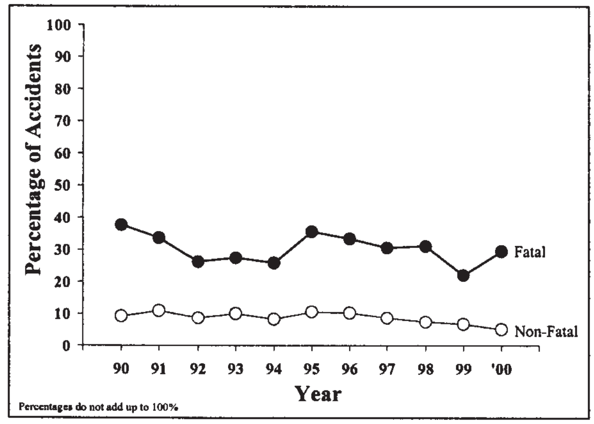

Figure 7. *Percentage of fatal (closed circles) and non-fatal (open circles) GA accidents associated with violations across years.*

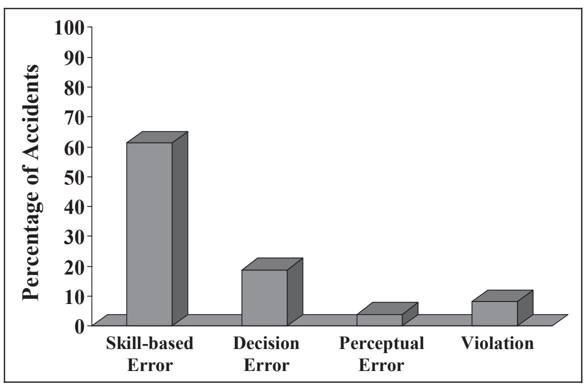

Figure 8. *Percentage of accidents in which each unsafe act was the first (seminal) human error in the accident sequence.*

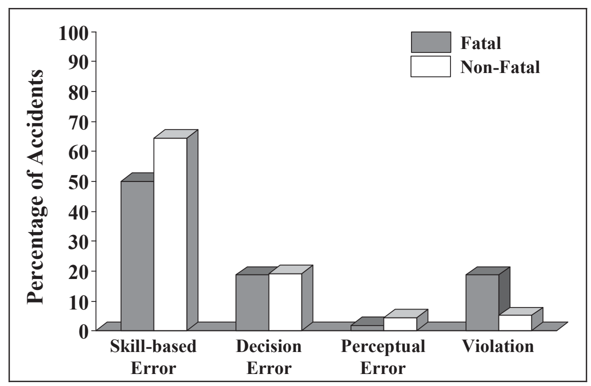

Figure 9. *Percentage of fatal and non-fatal accidents associated with each seminal error category.*

Figures 10 and 11 illustrate the percentage of fatal and non-fatal accidents associated with each seminal error across the 11-year period examined in this study. In general, the patterns of errors across the years were virtually the same as those observed for the overall error trends (see Figures 5 and 6). That is, skill-based errors were consistently the most frequent cause of both fatal and non-fatal accidents, followed by decision errors, violations, and perceptual errors.

What differences did occur between fatal and non-fatal seminal errors (i.e., skill-based and violations) remained relatively constant across the years of this study (Figure 12). Furthermore, the differences were in opposite directions, with a higher percentage of fatal than non-fatal accidents associated with violations and a higher percentage of non-fatal than fatal accidents associated with skill-based errors.

Questions 8, 9, and 10: What are the exact types of errors committed within each error category (question 8) and do these types of errors committed within each error category differ across accident severity (question 9) or seminal events (question 10)?

Just knowing that skill-based errors (or any other type of error) are a major concern does not provide safety professionals sufficient detail to do anything about it. What is needed is a fine-grained analysis of the specific types of errors within each HFACS causal category so that targeted interventions can be developed. With this in mind, we compared each HFACS classification with the NTSB's causal factor designation.

Contained within the NTSB database are three codes (subject, modifier, and person code) associated with each cause/factor for a given accident. For instance, an accident cause may be stated as "VFR flight into IMC" (subject), "continued" (modifier), "pilot in command" (person code). Another might be classified as "directional control" (subject), "not maintained" (modifier), "copilot/second pilot" (person code).

Because all causal factors identified in this analysis involved aircrew, we did not need to differentiate the person code. Of the two remaining codes, the subject code provided the most information. Although the modifier code provided additional clarity, including it at this time would have left us with a list of potential human causal factors well beyond the scope of this study (the list of subject-modifier combinations far exceeds 500). Consequently, we restricted our initial analysis to only the subject codes.

Of note, many of the NTSB subject codes were similar, with only subtle semantic or behavioral differences among them (e.g., stall, stall/mush, stall/spin, and tailplane stall). Where similarities occurred among NTSB causal factors, the descriptions were grouped according to their similar nature. This reduced the number of unsafe act exemplars to a manageable number.

To aid in the presentation of the data, we will examine the fine-grained analysis for each type of unsafe act separately. Included in the results will be the "*top 5*" human causal factors overall, across accident severity and seminal events.

Skill-based errors. The most frequently occurring human error categories within skill-based errors are presented in Table 1. As can be seen, nearly 12% of all skill-based errors involved errors in maintaining direction control, followed by airspeed (10.63%), stall/spin (7.77%), aircraft control (7.62%), and errors associated with compensating for wind conditions (6.18%). Together, these five cause factors accounted for nearly one-half of all the skill-based errors in the database. For clarification, "directional control" typically refers to control of the aircraft on the ground, while "aircraft control" refers to control of the aircraft in-flight.

The types and frequencies of skill-based errors coded as fatal/non fatal and seminal events are also shown in Table 1. As can be seen from this table, the percentage of skill-based errors involving stall/spin, airspeed, and aircraft control was greater for fatal than non-fatal accidents. In fact, causal factors such as directional control and compensation for wind conditions were rarely associated with fatal accidents. This pattern was similar whether one compared fatal and non-fatal accidents, overall, or only within accidents in which a skill-based error was the seminal event.

Such findings make sense when one considers that errors leading to a stall/spin, as well as airspeed and control of the aircraft in the air typically happen at altitude, making survival less likely. In contrast, errors controlling the aircraft on the ground (such as ground loops) and compensation for winds (typically seen during cross-wind landings), while dangerous, do not necessarily result in fatalities.

Decision Errors. Table 2 presents the most frequently occurring decision errors. Improper in-flight planning tops the list, contributing to roughly 18% of all decision errors. Errors categorized as in-flight planning refer to planning or plan revisions performed after the aircraft has taken off and are often studied as plan continuation errors (Orasanu, 1993; Burian, Orasanu, & Hitt, 2000; Wiegmann, Goh, & O'Hare, 2002; Muthard & Wickens, 2003). The remaining decision errors, such as preflight planning/decision errors (8.94%), fuel management (8.73%), poor selection of terrain for takeoff/landing/taxi (7.85%), and go-around decision (6.03) all occurred at

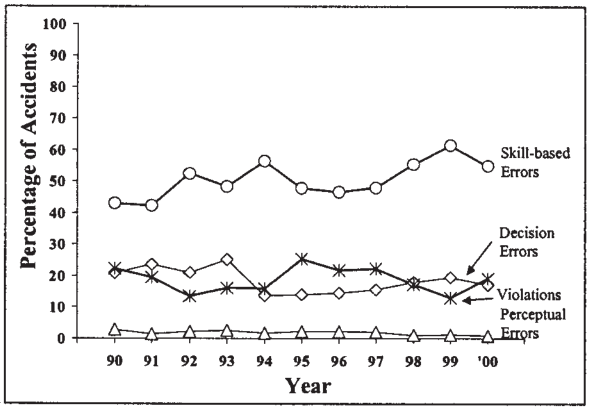

Figure 10. *Percentage of fatal accidents associated with each seminal error category across years.*

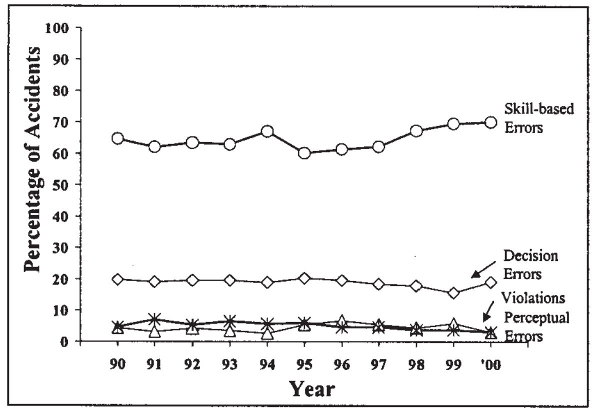

Figure 11. *Percentage of non-fatal accidents associated with each seminal error category across years.*

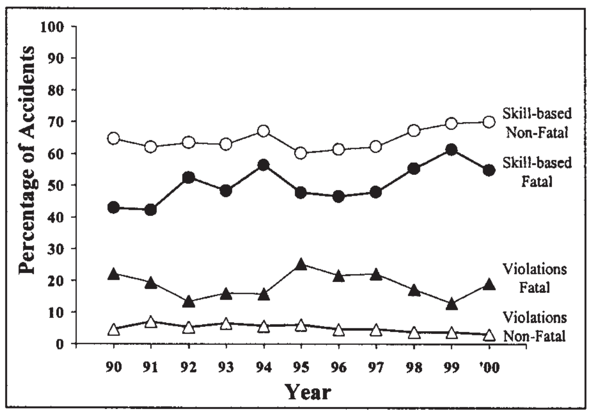

Figure 12. *Percentage of fatal (filled symbols) and non-fatal (open symbols) accidents associated with skill-based errors (circles) and violations (triangles) across years.*

Table 1. *Five Most Frequent Skill-based Error Categories for Fatal and Non-fatal Accidents.*

ERROR CATEGORY	OVERALL Frequency (%)			SEMINAL Frequency (%)		
	Fatal	Non-fatal	Total	Fatal	Non-fatal	Total
Directional Control	20 (0.50)	2018 (15.2)	2038 (11.8)	9 (0.57)	1326 (17.5)	1335 (14.6)
Airspeed	713 (17.9)	1127 (8.5)	1840 (10.6)	302 (19.2)	605 (8.0)	907 (9.9)
Stall/Spin	592 (14.9)	753 (5.7)	1345 (7.8)	84 (5.3)	144 (1.9)	228 (2.5)
Aircraft Control	654 (16.5)	665 (5.0)	1319 (7.6)	311 (19.8)	429 (5.7)	740 (8.1)
Compensation for winds	23 (0.6)	1046 (6.2)	1069 (6.2)	12 (0.8	859 (11.4)	871 (9.5)

Table 2. *Five Most Frequent Decision Error Categories for Fatal and Non-fatal Accidents.*

ERROR CATEGORY	OVERALL Frequency (%)			SEMINAL Frequency (%)		
	Fatal	Non-fatal	Total	Fatal	Non-fatal	Total
In-flight Planning	268 (22.9)	683 (17.0)	951 (18.3)	133 (22.6)	427 (19.8)	560 (20.4)
Planning/Decision-making on the Ground	115 (9.8)	349 (8.7)	464 (8.9)	89 (15.1)	284 (13.1)	373 (13.6)
Fuel Management	40 (3.4)	413 (10.3)	453 (8.7)	20 (3.4)	252 (11.7)	272 (9.9)
Unsuitable Terrain Selection	16 (1.4)	391 (9.8)	407 (7.8)	5 (.85)	284 (13.1)	289 (10.5)
Go Around	22 (1.9)	291 (7.3)	313 (6.0)	5 (.85)	70 (3.2)	75 (2.7)

Table 3. *Five Most Frequent Perceptual Error Categories for Fatal and Non-fatal Accidents.*

ERROR CATEGORY	OVERALL Frequency (%)			SEMINAL Frequency (%)		
	Fatal	Non-fatal	Total	Fatal	Non-fatal	Total
Distance	26 (17.8)	233 (27.7)	259 (26.4)	23 (33.8)	135 (26.5)	158 (27.4)
Flare	5 (3.4)	217 (25.8)	222 (22.5)	4 (5.9)	163 (32.0)	167 (28.9)
Altitude	22 (15.1)	91 (10.8)	113 (11.4)	9 (13.2)	51 (10.0)	60 (10.4)
Clearance	18 (12.3)	51 (6.1)	69 (7.0)	14 (20.6)	41 (8.1)	55 (9.5)
Visual/Aural Perception	15 (9.6)	36 (4.2)	50 (5.1)	3 (4.4)	5 (1.0)	8 (1.4)

Table 4. *Five Most Frequent Violations for Fatal and Non-fatal Accidents.*

ERROR CATEGORY	OVERALL Frequency (%)			SEMINAL Frequency (%)		
	Fatal	Non-fatal	Total	Fatal	Non-fatal	Total
VFR Flight into IMC	305 (25.8)	53 (4.7)	358 (15.5)	182 (30.5)	29 (5.2)	211 (25.8)
Procedures/Directives Not Followed	75 (6.3)	176 (15.6)	251 (10.9)	37 (6.2)	109 (19.6)	146 (12.7)
Operating Aircraft with Known Deficiencies	61 (5.2)	168 (14.9)	229 (9.9)	27 (4.5)	97 (17.4)	124 (10.8)
Hazardous Maneuver	154 (13.0)	47 (4.2)	201 (8.7)	83 (13.9)	24 (13.9)	107 (9.3)
Flight into Known Adverse Weather	135 (11.4)	61 (5.4)	196 (8.5)	85 (14.3)	41 (7.4)	126 (10.9)

approximately the same frequencies. Combined, these five causal categories accounted for roughly half (49.89%) of all decision errors in the database. It should be noted that individual factors related to weather-related decision making did not reach the top of the list (e.g., weather evaluation, flight into adverse weather, and inadvertent VFR flight into IMC). However, when combined, they did constitute a significant portion of the factors related to decision- making (6%).

Table 2 also presents the types and frequencies of decision errors for fatal/non fatal and seminal events. As indicated, the categories *in-flight planning* and *planning/decision making on the ground* tended to be associated more often with fatal than non-fatal accidents. Whereas the categories *unsuitable terrain*, *go around*, and *fuel management* were associated more often with non-fatal accidents. This pattern was generally consistent for the overall data, as well as within seminal events.

Perceptual errors. A review of accident causes and factors coded as perceptual errors revealed that *misjudging distance* was the most common, accounting for over a quarter of all perceptual errors (26.4%; see Table 3). The next highest was flare (22.5%), followed by misperceiving altitude (11.4%), misjudging clearance (7.0%) and visual/aural perception (5.1%). Together, these errors accounted for nearly three-quarters of all perceptual errors in the database.

The types and frequencies of perceptual errors as they occurred within fatal/non-fatal accidents are also shown in Table 3. As can be seen from this table, there is very little difference in the percentage of fatal and non-fatal accidents associated with any particular type of perceptual error. The only exception appears to be perceptual errors related to performing the flare, which, in most cases, was associated more with non-fatal than fatal accidents.

Violations. The *top five* violations are presented in Table 4. Analysis of the fundamental types of unsafe acts that are included within the violations categories reveals that the most common violation involved visual flight rules (VFR) flight into instrument meteorological conditions (IMC) (15.5%) and not following known procedures or directives (10.9%). The remaining top violations included operating aircraft with known deficiencies (9.9%), performing hazardous maneuvers such as low-altitude flight or buzzing (8.7%), and flight into adverse weather (8.5%). Together, these five variables accounted for more than half of all violations in the database.

The types and frequencies of violations for fatal/non-fatal and seminal events are also presented in Table 4. As indicated, the categories VFR flight into IMC, hazardous maneuver, and flight into known adverse weather were much more likely to be fatal than non-fatal, both overall and for seminal events only. This pattern is consistent with the observation that accidents involving violations of the rules are, in general, more likely to be fatal.

DISCUSSION

The present study of GA accidents examined literally thousands of unsafe acts committed by pilots, perhaps suggesting that, correspondingly, there are literally thousands of unique ways to crash an airplane. The results of this study, however, demonstrate that accidents that may appear to be unique can be reliably grouped, based upon underlying cognitive mechanisms of pilot errors. By applying HFACS, a theoretically based model of human error, we were able to highlight several human error trends and identify the categories of unsafe acts that contribute to both fatal and non-fatal GA accidents.

While there are many ways to describe the accident data, perhaps the best way is to discuss the findings in the order of their relative contributions to the accidents examined, beginning with skill-based errors.

Skill-Based Errors

By far, skill-based errors were the most common type of error in the accident database as nearly 80% of all GA accidents were associated with at least one skill-based error. Of these, roughly half were the first human causal factor in the chain of events.

The most common skill-based errors among more than 17,000 identified in this study included: control or handling of the aircraft on the ground and in the air, improperly maintaining airspeed, the occurrence of a stall or spin, and compensating for wind. Notably, these skill-based errors occurred more often than any other error category across all types of unsafe acts – not just the skill-based error category.

These findings are not without precedent in aviation. In fact, our previous work has shown that skill-based errors are the most prevalent form of aircrew error in commercial and military aviation accidents as well (Wiegmann & Shappell, 1997; Wiegmann & Shappell, 1999; Wiegmann & Shappell, 2001a, 2001b). Still, the percentages reported here were generally higher than those found in our other investigations, suggesting that skill-based errors are even more prevalent in GA than in other domains.

So, what caused these skill-based errors in the first place? Historically, these types of errors are often attributed to failures of the pilot to monitor crucial flight parameters, a fundamental aspect of cockpit task management (Funk, 1991). For instance, if interrupted or distracted by a situation or event, a pilot can quickly become sidetracked from the primary task of flying the airplane. Furthermore, individuals are more susceptible to distraction during low processing tasks. Ultimately, these intrusions, uncertainties, and general distractions may keep the pilot from effectively monitoring the aircraft's airspeed and altitude as well as other parameters critical to the flight. As a result, a skill-based error is committed that may lead to an incident/accident.

Another possibility is that the lower levels of experience and training obtained by GA pilots may account for the larger proportion of accidents involving skill-based errors than those observed in military and commercial aviation. Presumably, GA pilots fly less frequently than their military or commercial counterparts do, such that recency of experience is less. Herein lies the rub. According to models by Reason (1990) and Rasmussen (1982), skill-based errors, by definition, occur during the execution of routine events. Furthermore, once a particular skill is developed, it must be maintained through repetition and experience. Given that many GA pilots fly less and typically participate in less recurrent training than commercial and military pilots, it stands to reason that their proficiency would be degraded. In turn, this lack of proficiency may explain the increase in skill-based errors evident in the accident data.

Indeed, one can imagine a situation where increased workload in-flight (e.g., while flying in IMC or adverse weather) quickly overcomes an inexperienced pilot and diminishes the capacity to monitor altitude, fuel state, visual clearances, communication, or directional control. Furthermore, the inattention that results from a high workload situation could manifest as failing to monitor critical flight instruments, the failure to accomplish required in-flight checklist items, or the gradual, inadvertent loss of airspeed, all of which would appear in the present study as skill-based errors.

The real question is, "How do you go about reducing skill-based errors?" Perhaps the obvious answer is through experience and effective training. In that way, pilots are able to increase their familiarity with the rules governing flight and increase their knowledge of all aspects of their domain, improve their overall proficiency, and become less prone to attention slips or memory lapses due to high workload or distractions. However, that may not be the only answer. Other proposed ways to manage pilot workload include detailed checklists (Degani & Wiener, 1993), automation such as auditory reminders of critical tasks (Norman, 1988), and task or workload management training (Wiener, Kanki, & Helmreich, 1993). Whether these or any other interventions can be effectively integrated into the GA environment remains to be determined.

Violations

Violations are the classic glass half-empty, glass half-full conundrum. On the one hand, GA accidents associated with at least one violation were present in "only" 14% of the data (i.e., glass half-full). On the other hand, GA accidents associated with violations were second only to skill-based errors when fatalities were involved (glass half-empty). The latter is of more concern to the FAA.

As stated previously, this finding indicates that if a pilot breaks a rule that results in an accident, he or she is much more likely to perish than if the accident was due to some other (non-rule breaking) action. These results are similar to those observed in the military and commercial aviation domains (Wiegmann & Shappell, 2001a, 2001b).

Many of the violations cited in the database involved weather-related factors, including VFR flight into IMC. The question remains, however, as to why a pilot would willfully fly into such dangerous weather conditions. Goh and Wiegmann (2002), along with O'Hare and Smitheram (1995) found that social pressures often contribute to continued flight into adverse weather. For example, Goh and Wiegmann reported that GA accidents resulting from VFR flight into IMC were more likely to have passengers on board than any other type of accident. Furthermore, in a study of weather-related decision-making, Holbrook, Orasanu, and McCoy (2003) found that "systemic pressures" to fly, such as those from passengers or other pilots, may "contribute to pilots' decisions to continue flight despite cues suggesting they should do otherwise" (p. 581). Further analysis is needed, however, to determine the extent to which these factors contribute to accidents within the present database.

Beyond social pressures previously addressed, O'Hare and his colleagues (O'Hare & Owen, 1999; O'Hare & Smitheram, 1995) have explored this question by investigating how pilots frame the situation of continuing or discontinuing flight into adverse weather. They found that pilots who framed diverting from a flight plan as a loss (e.g., loss of time, economic loss, or expense of effort) tend to continue flight into adverse weather; whereas those who frame a diverting decision as a gain (e.g., in personal safety) tend to divert more.

Some research (i.e., O'Hare, 1990; Goh & Wiegmann, 2002) suggests that pilot overconfidence and a limited appreciation of the risks involved with flight into adverse weather may also contribute to weather-related violations. Others contend that there are GA pilots who "simply do not mind taking risks and yet who also either lack the experience to assess those risks, or perhaps have just enough experience to overestimate their own abilities" (Knecht, Harris, & Shappell, 2003; p.673).

While the percentage of accidents involving violations shows no appreciable decline over the years studied, the simplest way to reduce the occurrence of violations is through continually and consistently enforcing the rules. Unfortunately, simply enforcing rules more effectively is extremely difficult within GA due to its organizational structure. Since it is often not clear exactly whose authority GA pilots fly under (as compared with military and commercial pilots), it becomes very difficult to police the GA system.

As a result, other interventions have been proposed to reduce the occurrence of violations, such as the education of GA pilots on the extent of the real risks of violating established rules and regulations. Another proposal involves simulator training of difficult tasks such as emergencies or risky situations to directly demonstrate the hazards associated with violating rules (Knecht et al., 2003).

While many cases of flight into adverse weather are rightfully coded as violations, there are many that may not represent a willful departure from established procedures and are instead the result of the misdiagnosis of weather conditions, improper planning, or a decision not to use preflight briefing service information. Rather than coding them as willful violations, these errors represent a breakdown in the decision-making process and are thus captured within the next category to be addressed — decision errors.

Decision Errors

Decision errors were present in roughly one-third of all accidents, which is also consistent with proportions observed within other aviation domains (O'Hare, Wiggins, Batt, & Morrison, 1994; Murray, 1997; Shappell & Wiegmann, 2001; Wiegmann & Shappell, 2001a, 2001b). These percentages were roughly equivalent for both fatal and non-fatal accidents, even when only seminal decision errors were examined.

Upon closer examination, it appears that many of the decision errors involved planning, both in-flight and on the ground, as well as issues related to weather evaluation. Recently, Burian, Orasanu, and Hitt (2000) found that 28% of accidents involving weather events involved plan continuation errors, and suggest that pilots with less experience may "not trust what their eyes are telling them and so proceed on blindly" (p. 25). Wiegmann, Goh, and O'Hare (2002) also studied the occurrence of plan continuation errors of VFR flight into IMC and presented findings that suggest that under certain conditions these errors are more often attributable to poor situation assessment (early stages of information processing) than to motivational judgment. In either case, however, proper planning, both in the air and on the ground, is a critical component of flight safety.

Proposals for ways of improving pilots' judgment often involve training in aeronautical decision-making. It is generally believed that novices may lack a full understanding of the significance of some weather-related cues. Therefore, by examining techniques used by expert pilots to assess situations and solve problems, a better training method may be developed. For example, Wiggins and O'Hare (2003) recently developed a program for the FAA that uses static weather images and short video clips to help teach pilots how to more effectively identify critical weather cues. Based on initial evaluations, the computer-based training program shows positive effects on aeronautical decision-making.

Another method of assisting pilot decision-making is the implementation of planning aids. Layton, Smith, and McCoy (1994) evaluated the effectiveness of three different planning aid (cooperative) systems and demonstrated that different system design concepts can strongly influence the cognitive processes and resultant performance. Through their findings, the researchers recommended further research into better information displays, geographical interfaces of alternative route manipulation, access to more complete and accurate weather and traffic information, and optimization technologies to assist users in generating alternative plans. Others have encouraged further study of the improved design of displays that present critical data such as weather, traffic, and other environmental information (Wickens & Hollands, 2000).

Finally, scenario-based training has been shown to be an effective technique for improving decision-making in a variety of domains. The training method involves embedding decision-making tasks within a "real world" context, similar to those in an operational setting. This is in contrast to traditional training methods that compartmentalize or modularize training, teaching decision strategies in isolation or independently from a particular context. Indeed, the FAA's General Aviation & Commercial Division (AFS-800) has recently introduced the FAA/Industry Training Standards (FITS) program aimed at improving GA flight training using scenario-based training and other technologies. While the program is currently focusing on "personal or professionally flown single-pilot aircraft for transportation with new technologies" (Glista, 2003), there is no reason to believe that FITS will not benefit the light-sport and recreational pilots as well.

Perceptual Errors

Not surprisingly, perceptual errors contribute to the smallest percentage of accidents within the present analysis (5.7%), a percentage that is much lower than that found in military research (Wiegmann & Shappell, 2003). Given the non-tactical, non-aerobatic nature of GA flight, spatial disorientation and difficulties in perception are expected to occur at a lower frequency than is found within military aviation, particularly within the dynamic domains of fighter, tactical, aerobatic, or night operating aircraft.

Furthermore, due to the relatively small numbers of perceptual errors coded within the GA accidents studied, it is difficult to draw any conclusions. Nevertheless, it is reasonably clear that errors involving misjudging information comprise the majority of perceptual errors and represent misperception, as opposed to non-detection. Analogous to other errors made in the presence of correct and adequate information, misperception errors are disheartening, as pilots inaccurately code or improperly process accurate cues from the environment. Ultimately, this leads to the misjudging of altitude, distance, or descent, which encompass a large proportion of the perceptual errors cited within the present database.

That being said, one may wonder why spatial disorientation did not make the *top 5* of the perceptual error list. Spatial disorientation, although often leading to perceptual errors (e.g., misjudging altitude/attitude), is not considered an error. Rather, it is considered a physiological state that cannot be controlled by the individual. That is, you are either disoriented or you are not and more important, not every instance of spatial disorientation leads to a perceptual error (e.g., Type 1 – recognized spatial disorientation, otherwise referred to as the "leans").

Consequently, our SMEs classified instances of spatial disorientation within the HFACS category of *adverse physiological states*. Unfortunately, when NTSB investigators did identify spatial disorientation (an *adverse physiological state* using HFACS) they often <u>did not</u> identify the resultant perceptual error when reporting the causes/factors associated with an accident. Hence, perceptual errors were under-reported here. For completeness, there were 279 accidents out of the 14,436 we examined (1.9%) associated with spatial disorientation, of which all but 34 involved fatalities.

Perceptual errors, whether caused by spatial disorientation or other factors, are much like skill-based errors and can degrade due to lack of recency, experience, or training. However, in addition to training and practice, other interventions such as enhanced displays may improve the veridical nature of pilots' perceptions. For example, such technologies as radar altimeters, angle-of-attack indicators, or other such displays may ultimately reduce accidents due to perceptual errors.

Additional Issues

As previously described, the present study examined only those causes or contributing factors that were classified as unsafe acts by the aircrew. There are a number of other accident cause factors that involve humans that are not unsafe acts. For instance, in addition to spatial disorientation, a breakdown in communication is another example of a human error that is not considered an unsafe act within HFACS. Rather, the category of crew resource management (CRM) captures errors of communication between pilots and their crew, other pilots, and air traffic controllers, and is classified under the "preconditions for unsafe acts" within HFACS (Shappell & Wiegmann, 2000, 2001; Wiegmann & Shappell, 2003).

Many other potentially important human factors related accident causes are also captured within other levels of analysis such as fatigue, alcohol use, self medication (use of over-the-counter medications), workload, medical history, and work environment. While important human factors, these are also not considered to be unsafe acts and were not examined within the present study.

Nevertheless, such causal factors were rarely cited in the NTSB database. In fact, analysis of all seminal events indicated that less than 8% of all seminal cause factors were anything other than an unsafe act by the aircrew. So, although we can all agree that such factors as spatial disorientation, self-medication, and poor CRM are important issues (and HFACS does account for these as preconditions), they were virtually non-existent in the general aviation database.

Such limited information concerning pre-conditions for unsafe acts does result in only a partial picture of the entire sequence of events that contributed to the accident. However, the present study represents the most comprehensive human error analysis of GA data ever conducted and provides useful information for understanding the immediate causes of accidents. Furthermore, the absence of critical preconditions in the database clearly indicates a need to improve the accident investigation process so that more in-depth information concerning the causes of aircrew error can be identified. Indeed, HFACS provides an effective tool for improving this process (Shappell & Wiegmann, 2003).

CONCLUSIONS

The high level of safety currently achieved within aviation should not obscure the fact that many aviation accidents are preventable. It is important to realize that safety measures and defenses currently in place in GA may be inadequate, circumvented, or perhaps ignored, and that the intervention strategies aimed at reducing the occurrence or consequences of human error may not be as effective as possible.

Even though the results of the present study point to several ways to reduce the rate of GA fatalities, there may be several more and far better solutions that have yet to be identified.

Historically, accident and incident interventions have been generated by the NTSB in the form of recommendations or have come from experts in the government (FAA, NASA, etc.), military, or other aviation organizations. As a result, they tend to focus on the prevention of specific types of accidents such as those related to loss of control in flight or controlled flight into terrain, rather than specific types of human error per se. What's more, the interventions tend to be rather narrow in scope, often emphasizing only changes to the aircraft in the form of automation and displays or simply recommending changes to existing policies or regulations. Even when attempts are made to address specific types of human error, the emphasis has traditionally been placed on pilot decision-making, which accounts for just over 30% of the GA accidents that occur annually.

What is needed is a systematic approach to generating intervention/prevention strategies that can tie into the HFACS framework that has proven success with civilian aviation accident and incident data. Within epidemiology, one such approach, the Haddon matrix, was developed to address injuries sustained as the result of automobile accidents (Haddon, 1980). Haddon's argument was that we often overlook potentially useful interventions by not considering all aspects of the accident/incident. In fact, when one examines the typical interventions recommended by the NTSB and others following an accident, they typically focus on only a few areas rather than the gamut of intervention possibilities.

Along these lines, Wiegmann and Rantanen (2002) examined over 75 intervention strategies identified by NASA for use within U.S. civilian aviation using a similar matrix. In that study, the vast majority of the interventions were technologically oriented, leaving one to believe that a variety of other potentially useful strategies had been left on the drawing board or not even considered. Ideally, a similar matrix using HFACS causal categories could be developed that would be both manageable and effective at generating putative intervention strategies and assessing their impact prior to deployment.

It is apparent from the current study that human error associated with GA accidents is multi-faceted. Specifically, our analyses have revealed that the largest percentage of accidents is associated with skill-based errors, followed by decision errors, violations of the rules and regulations, and perceptual errors. While individual interventions may address one error form more than another, a true intervention "strategy" will identify a variety of interventions targeted at all four error forms. The next step in this research effort will be the development of the Human Factors Intervention Matrix (HFIX) that pits the unsafe acts of operators (i.e., skill-based errors, decision errors, perceptual errors, and violations) against several putative intervention approaches (e.g., organizational, human-centered, technology, task, and environment; Figure 13). In addition, other features will be integrated into the model/matrix such as feasibility, efficacy, and acceptance.

	Organizational/ Administrative	Human/ Crew	Technology/ Engineering	Task/ Mission	Operational/ Physical Environment
Decision Errors					
Skill-based Errors					
Perceptual Errors					
Violations					

Figure 13. *The Human Factors Intervention Matrix (HFIX).*

Once developed, HFIX will be validated and assessed using intervention programs currently in use and planned within the Small Airplane Directorate (ACE-100), the General Aviation & Commercial Division (AFS-800), Alaska Region (AAL), and other FAA offices.

Ultimately, the systematic application of HFACS, coupled with the methodical utilization of HFIX (once fully developed) to generate intervention solutions, should ensure that the aviation industry's personnel and monetary resources are utilized wisely. This should occur because such efforts will be needs-based and data-driven. Together, these tools will allow the true effectiveness of intervention programs to be objectively and impartially evaluated so that they can be either modified or reinforced to improve system performance. Only then can any great strides in improving the GA accident rate be achieved.

REFERENCES

Bird, F. (1974). Management guide to loss control. Atlanta, GA: Institute Press.

Burian, B., Orasanu, J., & Hitt, J. (2000). Weather-related decision errors: differences across flight types. Proceedings of the XIVth triennial Congress of the International Ergonomics Association/44th annual meeting of the Human Factors and Ergonomics Society. 22-4.

Degani, A. & Wiener, E. (1993). Cockpit checklists: Concepts, design, and use. *Human Factors*, 35(4), 345-60.

Funk, K. (1991). Cockpit task management: Preliminary definitions, normative theory, error taxonomy, and design recommendations. *The International Journal of Aviation Psychology*, 1(4), 271-85.

Glista, T. (2003). FAA/Industry Training Standards (FITS): Times (and training requirements are a changing). *FAA Aviation News*, 42(4), 1-6.

Goh, J. & Wiegmann, D. (2002). Human error analysis of accidents involving visual flight rules flight into adverse weather. *Aviation, Space, and Environmental Medicine*, 78(8), 817-22.

Haddon, W. (1980). Options for the prevention of motor vehicle crash injury. *Israeli Medical Journal*, 16, 45-65.

Heinrich, H., Petersen, D., & Roos, N. (1931). Industrial accident prevention: A safety management approach (1st ed.). New York, NY: McGraw-Hill.

Holbrook, J., Orasanu, J., & McCoy, C., (2003). Weather-related decision making by aviators in Alaska. Proceedings of the 12th International Symposium on Aviation Psychology, 576-81.

Knecht, W., Harris, H., & Shappell, S. (2003). Effects of visibility, cloud ceiling and financial incentive on general aviation voluntary takeoff into adverse weather. Proceedings of the 12th International Symposium on Aviation Psychology, 669-73.

Layton, C., Smith, P., & McCoy, E. (1994). Design of a cooperative problem-solving system for en-route flight planning: An empirical evaluation. *Human Factors*, *36*(1), 94-119.

Murray, S. (1997). Deliberate decision making by aircraft pilots: A simple reminder to avoid decision making under panic. *The International Journal of Aviation Psychology*, *7*(1), 83-100.

Muthard, E., & Wickens, C. (2003). Factors that mediate flight plan monitoring and errors in plan revision: Planning under automated and high workload conditions. Proceedings of the 12th International Symposium on Aviation Psychology, 857-62.

Norman, D. (1988). The Psychology of Everyday Things. New York: Basic Books.

O'Hare, D. (1990). Pilots' perception of risks and hazards in general aviation. *Aviation, Space, and Environmental Medicine*, *61*, 599-603.

O'Hare, D., Wiggins, M., Batt, R., & Morrison, D. (1994). Cognitive failure analysis for aircraft accident investigation. *Ergonomics*, 37(11), 1855-69.

O'Hare, D., & Owen, D. (1999). Continued VFR into IMC: An empirical investigation of the possible causes: Final report on preliminary study. Unpublished manuscript. University of Otago, Dunedin, New Zealand.

O'Hare, D., & Smitheram, T. (1995). "Pressing on" into deteriorating conditions: An application of behavioral decision theory to pilot decision making. *International Journal of Aviation Psychology, 5*, 351-70.

Orasanu, J.M. (1993). Decision-making in the cockpit. In E. L. Wiener, B. G. Kanki, and R. L. Helmreich (Eds.), Cockpit resource management (pp. 137-72). San Diego, CA: Academic Press.

Rasmussen, J. (1982). Human errors: A taxonomy for describing human malfunction in industrial installations. *Journal of Occupational Accidents, 4*, 311-33.

Reason, J. (1990). Human Error. New York: Cambridge University Press.

Shappell, S. & Wiegmann, D. (1995). Controlled flight into terrain: The utility of an information processing approach to mishap causal factors. Proceedings of the Eighth International Symposium on Aviation Psychology, The Ohio State University, 1300-6.

Shappell, S. & Wiegmann, D. (1997). Why would and experienced aviator fly a perfectly good aircraft into the ground? Proceedings of the Ninth International Symposium on Aviation Psychology, The Ohio State University, 26-32.

Shappell, S. & Wiegmann, D. (2000). The Human Factors Analysis and Classification System (HFACS). Federal Aviation Administration, Office of Aviation Medicine Report No. DOT/FAA/AM-00/7. Office of Aviation Medicine: Washington, DC.[1]

Shappell, S. & Wiegmann, D. (2001). Applying Reason: the human factors analysis and classification system (HFACS). *Human Factors and Aerospace Safety, 1*, 59-86.

Shappell, S. & Wiegmann, D. (2003). A human error analysis of general aviation controlled flight into terrain (CFIT) accidents occurring between 1990-1998. Federal Aviation Administration, Office of Aerospace Medicine Technical Report No. DOT/FAA/AM-03/4. Office of Aerospace Medicine: Washington, DC.[1]

Wickens, C., & Hollands, J. (2000). Engineering psychology and human performance. Upper-Saddle River, NJ: Prentice-Hall.

Wiegmann, D., Goh, J., & O'Hare, D. (2002). The role of situation assessment and flight experience in pilots' decisions to continue visual flight rules flight into adverse weather. *Human Factors*, *44*(2), 189-97.

Wiegmann, D. & Rantanen, E. (2002). Defining the Relationship Between Human Error Classes and Technology Intervention Strategies (Technical Report ARL-02-1/NASA-02-1). Savoy, IL: University of Illinois, Aviation Research Lab.

Wiegmann, D & Shappell, S. (1995). Human factors in U.S. naval aviation mishaps: An information processing approach. Proceedings of the Eighth International Symposium on Aviation Psychology, The Ohio State University, 1295-99.

Wiegmann, D., & Shappell, S. (1997). Human factors analysis of post-accident data: Applying theoretical taxonomies of human error. *The International Journal of Aviation Psychology*, *7*(1), 67-81.

[1]This publication and all Office of Aerospace Medicine technical reports are available in full-text from the Civil Aerospace Medical Institute's publications Web site: www.faa.gov/library/reports/medical/oamtechreports/index.cfm

Wiegmann, D., & Shappell, S. (1999). Human error and crew resource management failures in naval aviation mishaps: A review of U.S. Naval Safety Center data, 1990-96. *Aviation, Space, and Environmental Medicine*, *70*(12), 1147-51.

Wiegmann, D. & Shappell, S. (2001a). Human error analysis of commercial aviation accidents: Application of the Human Factors Analysis and Classification System (HFACS). *Proceedings of the Eleventh International Symposium on Aviation Psychology*, The Ohio State University.

Wiegmann, D. & Shappell, S. (2001b). Human error analysis of commercial aviation accidents: Application of the Human Factors Analysis and Classification System (HFACS). *Aviation, Space and Environmental Medicine*, *72*, 1006-16.

Wiegmann, D., & Shappell, S. (2001c). Human error perspectives in aviation. *International Journal of Aviation Psychology, 11*(4), 341-57.

Wiegmann, D. & Shappell, S. (2003). A human error approach to aviation accident analysis: The human factors analysis and classification system. Burlington, VT: Ashgate

Wiener, E., Kanki, B., & Helmreich, R. (Eds.) (1993). Cockpit resource management. San Diego, CA: Academic Press.

Wiggins, M., & O'Hare, D. (2003). Expert and novice pilot perceptions of static in-flight images of weather. *The International Journal of Aviation Psychology*, *13*(2), 173-87.

A Guide for the Conduct of Biennial Flight Reviews

DRAFT

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This guide has not been approved for general public release and is provided solely for the purpose of public comment and feedback. Please do not make copies of this document. Your comments on the content and format of the document are invited. Please send comments to:

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Preface

This report presents a protocol for the conduct of a standardized Biennial Flight Review (BFR) based upon a multi-year research program to assess objectively the skill retention levels of pilots (Jensen, et al, 1998). This protocol includes guidance for Certificated Flight Instructors (CFIs) on the selection of specific maneuvers to be performed based upon pilot characteristics such as total and recent experience, ordering of maneuvers, standardized grading procedures based upon the FAA practical test standards, and procedures for the assessment of pilot judgment. The protocol addresses both ground and in-flight assessment.

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A Guide for the Conduct of Biennial Flight Reviews

The retention of pilot flight skills is a critical factor in the overall safety and efficiency of general aviation operations. Data records of the National Transportation Safety Board indicate that the problem of flight skill retention among pilots of all experience levels is of great concern. This report implements the results of two studies performed to assess objectively the skill retention levels of pilots.

The first study evaluated the performance of relatively inexperienced private pilots 8, 16, and 24 months following their certification (Childs, Spears and Prophet, 1983). This two year longitudinal investigation evaluated pilot skills from the time of their certification as private pilots using four skill checkrides. The objective in-flight data collection instrument used to gather performance data for the retention checks was also used at the point of initial certification insuring meaningful data comparisons. These flight skill retention checks conducted at eight month intervals over a two year period identified the specific nature and degree of the decrement function that occurs for infrequently practiced flight skills. The empirical data provided by these checks should enable Certificated Flight Instructors (CFIs) to make a more valid judgment concerning the contents and performance of a Biennial Flight Review.

I. BACKGROUND

Flight skills, like any complex skills, will degrade over time if not exercised sufficiently for the pilot to be able to retain or improve them. Therefore, when pilots do not fly for extended periods of time, their flying skills degrade and they often will make errors when they resume flying. Even if pilots fly regularly, their skill in executing flight tasks that are not performed frequently, such as running out of fuel or inadvertent IMC, still may degrade significantly. In addition, flight tasks that are routinely performed improperly also deteriorate, and if consistently practiced incorrectly result in undesirable habit patterns which may be unsafe.

Historical Perspectives

The flying skill degradation problem can only be addressed through effective continuation training programs. To be effective, such training and associated pilot proficiency evaluations should focus on critical flight skills that are the most likely to degrade over time. To determine the flight tasks that demonstrated the greatest overall decrement during the two year period studied by Childs (1983), a composite ranking procedure was developed. This was considered necessary since skill decrement on some tasks manifested itself differently over the retention interval than skill decrement on others. For example, certain flight tasks showed a decline in performance after 16 months, but remained relatively stable thereafter, while other tasks continued to decline. Composite skill loss was derived by:

1. Error rate on the 24 month checkride
2. Increment in error rate from the private pilot check to the 24 month check
3. Increment in error rate from the private pilot check to the 16 month check.

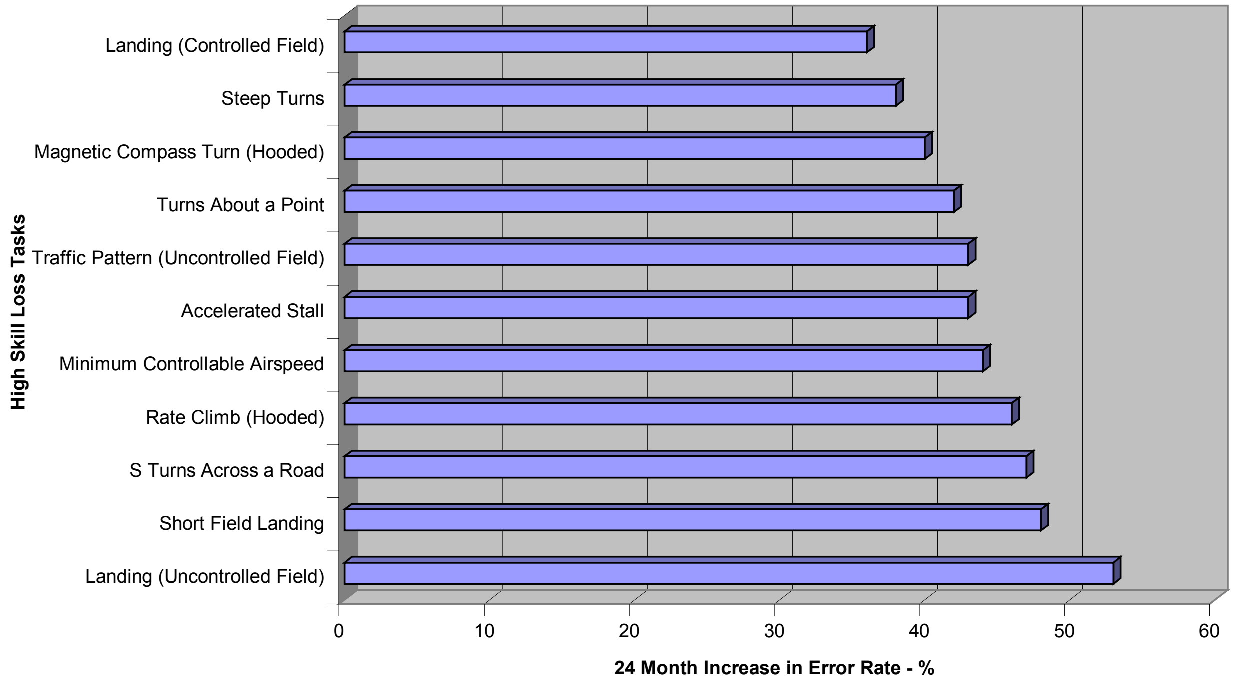
The three ranks generated for each flight task were then averaged to derive a composite rank. Based on this ranking procedure, the flight tasks that exhibited the greatest and least relative amounts of skill loss were determined as shown in Table 1 (Childs, 1983).

Table 1 Composite Skill Loss for Flight Tasks
(Lowest Rank = Greatest Skill Loss)

1. Landing (Uncontrolled Field)
2. Traffic Pattern (Uncontrolled Field)
3. Short Field Landing
4. Accelerated Stall
5. Steep Turns
6. S Turns Across a Road
7. Turns About a Point
8. Rate Climb (Hooded)
9. Magnetic Compass Turn (Hooded)
10. Minimum Controllable Airspeed
11. Short Field Takeoff
12. Crosswind Landing
13. Landing (Controlled Field)
14. VOR Tracking
15. Crosswind Takeoff
16. 180° Turn (Hooded)
17. Normal Takeoff and Departure
18. Soft Field Takeoff
19. Unusual Attitude Recovery (Hooded)
20. Takeoff/Departure Stall
21. Forced Landing
22. Straight and Level
23. Approach Stall
24. Communications
25. Engine Failure
26. Go-Around
27. Engine Runup/Before Takeoff Check

This composite data can be compared with skill loss data at the 24 month checkride. Figure 1 shows the tasks that demonstrated the greatest and least absolute amounts of skill loss over that period. The mean decrement (private pilot check to 24 month check) for the 11 tasks that underwent the greatest absolute amount of skill loss was 44.5%. The eight tasks with the least absolute amount of skill loss had a mean decrement of 19.3%. Comparing this data with Table 1, it can be seen that there is substantial agreement in the tasks included by the two procedures used. However, the rankings of tasks within groupings vary.

Since the composite ranking procedure represents more aspects of performance, it was used in characterizing the high and low skill loss tasks for purposes of preparing the Standardized BFR Guidelines. These guidelines will identify those areas where weakness exist for the BFR candidate and aid the CFI in identifying those flight tasks that may require intermediate flight training to forestall skill decrement.



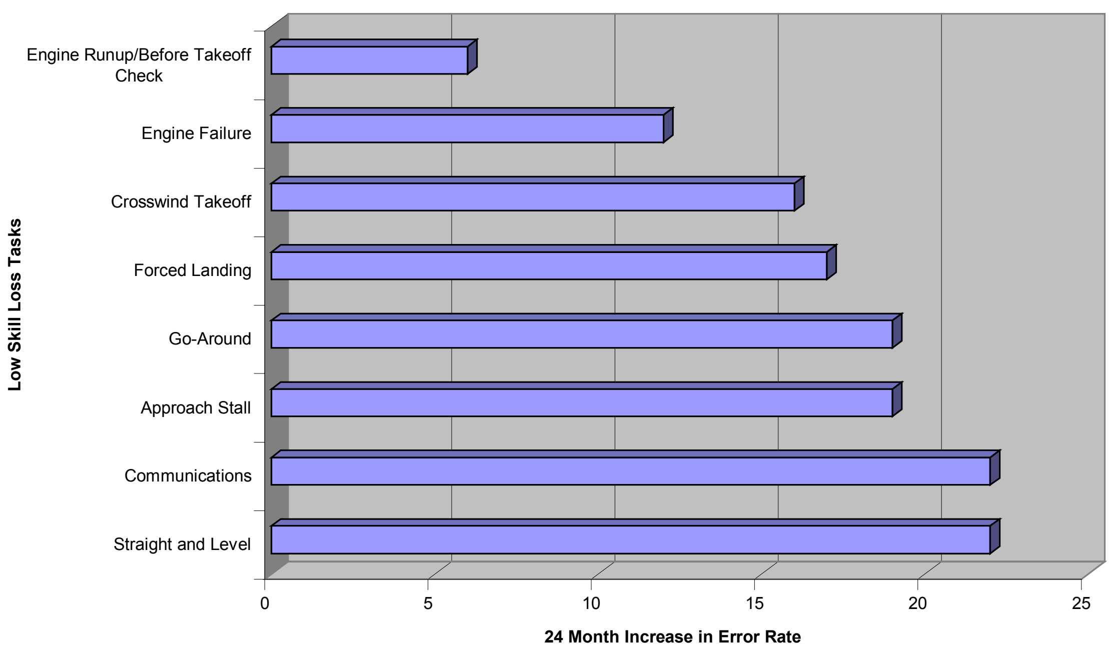


Figure 1 Flight Tasks Exhibiting the Greatest and Least 24 month Skill Loss

Procedures for the Assessment of Pilot Judgment

This material is designed to aid instructors and examiners in assessing Aeronautical Decision Making. Both quantitative and qualitative techniques are provided for use in ground and inflight evaluations as appropriate for each individual and situation.

OBJECTIVES

To determine that the applicant:

1. Is aware of and applies the principles of Aeronautical Decision Making.
2. Demonstrates sound decision making throughout the process of a typical flight.
3. Maintains adequate situation awareness in all Areas of Operation to insure appropriate decisions can be made.
4. Displays motivations, attitudes and decision making habits consistent with safe flight operations.

INFLIGHT DECISION MAKING

The basic measurement of pilot decision making will contain both subjective and objective components. The subjective components will be the examiner's evaluation of the applicant's response to theoretical (on-the-ground) decisions and in-flight decisions which specifically impact safety of flight. The objective components include the examiner's evaluation of the applicant's score on a 10-item checklist of decisional activities performed by the applicant during a test flight. The items to be evaluated are listed in Table 2.

Table 2 Pilot Decision Making Rating Checklist

1. Obtained preflight weather information
2. Activated flight plan
3. Checked fuel
4. Requested radar service
5. Checked weather enroute
6. Accurately calculated ETA (Estimated Time of Arrival) for first intersection
7. Activated flight plan to alternate
8. Initiated DR (Dead Reckoning) navigation procedures following equipment failure
9. Elected cruise altitude above Minimum Enroute Altitude (MEA)
10. Requested assistance and/or confessed problems

By assessing the applicant with this checklist and scoring one point for each correct decision, the examiner will develop a score from 0 to 10 for the applicant. A minimum score of 7 is required to pass this part of the decision making evaluation.

SITUATIONAL AWARENESS EVALUATION

In addition to this quantitative decision making rating, the following pages present a shopping list of 72 decision making test items for use by the examiner. It is suggested that from 10-20 of these test items be used by the examiner in different areas of operation to qualitatively assess the applicant's situational awareness and its impact on decision making performance. Examiner's should make note of the applicant's responses for two reasons. First to supplement their responses to the scored decision making Rating Checklist. Second, to provide topics for discussion and further evaluation if necessary after the checkride. The applicant should be evaluated based upon the number of correct responses and the timeliness of his/her response. Refer to the ADM Examiners Evaluation form on page 12 for suggested scoring categories.

VERY IMPORTANT -- Some of these items describe potentially hazardous situations. The instructor must not allow the applicant to proceed in those situations where the test conditions might present an undue hazard. For example, if the instructor places a piece of tape on the leading edge of the wing to assess what the applicant will do, then the instructor MUST be certain to remove the tape, should the applicant fail to do so. In addition, the instructor must explain to the applicant why the instructor may have suggested that the applicant perform a potentially hazardous action. Do NOT allow the applicant to leave the evaluation unless it is clear to the applicant that the instructor was testing his or her judgment and that the instructor definitely DOES NOT recommend that the applicant perform these actions.

AREAS OF OPERATION

Preflight Preparation

1. Ask applicant how they would know if specific inspection requirements have been accomplished. (transponder, ELT, altimeter, static system inspections and tests).

2. Give applicant "estimated" weights for passengers and baggage. Ask applicant the implications for situations where CG will be close to aft limit or max-gross. (applicant should verify estimated weights).

Preflight Procedures

1. While applicant is using the checklist, attempt to distract them.
2. Observe applicant's reaction if you do not fasten or wear your shoulder harness.
3. Ask applicant if it is always necessary to check the fuel for contamination after refueling.
4. Note if applicant overlooks items when you distract him/her during the preflight inspection.
5. Ask applicant how he/she can tell if the landing gear struts/tires are properly inflated.
6. Ask applicant how to visually determine if there are any hydraulic fluid or oil leaks other than checking the reservoirs (fluid/oil puddles or smears).
7. Ask applicant to plan a cross-country flight below 1,200 feet AGL in uncontrolled airspace and give weather information that is poor (2 ½ miles visibility in fog and

haze), but legal.

8. Ask applicant to plan a cross-country flight that would penetrate a restricted area if flown direct. Note applicant's response.

9. During the preflight, ask applicant what he/she would do if the airplane's checklist was missing.

10. During the preflight, observe the applicant's reaction to a piece of duct tape on the leading edge of the airplane's wing (might cover crack or damage).

11. Ask applicant the wisdom of grossly overestimating the time en route for a proposed cross-country flight plan in order to allow for possible unexpected delays (delay of search and rescue efforts).

12. Give applicant weather information for a proposed cross-country flight which is marginal but legal VFR. Note applicant's reaction.

13. Ask applicant to assume that weather is marginal VFR for a proposed cross-country flight and that the turn coordinator was reported as intermittent or the suction gauge showed bottom of the green arc readings. Ask applicant to make a go/no-go decision.

14. Observe applicant's reaction to a situation where his/her own propwash will blast persons or property behind after starting the engine.

15. Ask applicant to decide on whether a bug-smeared windshield should be cleaned prior to a short local flight. Tell him/her you will help look for other traffic.

16. Ask applicant the implications of flying with minor damage (one stall strip missing, dents, paint chips, etc.) to the leading edge of the wing.

17. During the preflight check of flight controls, block the free movement of the yoke with your arm or leg. Note applicant's reaction.

18. Ask applicant about the advisability of going on a long cross-country flight when fatigued, hungry or ill.

19. Ask applicant if it is always OK to fly when taking medications prescribed by an MD (AME must approve).

20. Ask applicant to comment on the implications of grass or straw in engine compartment or tail cone.

Inflight Procedures

1. Observe applicant's reaction if an unsecured object (flashlight, clipboard, etc.) is placed in a dangerous location (floor of front seat, baggage shelf, etc.).

2. Note if applicant objects to the placement of an object (clipboard, chart, hat, etc.) on the glareshield which might obscure vision.

3. Note applicant's reaction and reasoning after suggesting that he/she use an inappropriate VFR cruising altitude while enroute on a cross-country flight.

4. Ask applicant about the advisability of flying a course at low altitude over rough terrain or a large body of water (climb or circumnavigate).

5. At an appropriate time during the flight test, determine whether applicant has maintained position awareness by asking him/her to locate position.

6. While over a congested area (city, town, etc.) ask applicant about the advisability of conducting a ground reference maneuver slightly above 1,000 feet AGL.

7. During the flight test, unexpectedly ask applicant to estimate the remaining fuel on board in hours and minutes (within 20 minutes accuracy).

8. During the cross-country portion of the flight test, ask applicant to divert to an alternate airport. Note applicant's response.

9. Disconnect the mike plug and note applicant's reaction when no response is made to a call on UNICOM.

10. Ask applicant to decide on a course of action if unsure of position (lost). Note applicant's actions.

11. Cover the airspeed indicator to simulate an instrument failure while flying in the traffic pattern. Observe applicant's actions.

12. Ask applicant to comment on the selection of a safe altitude in order to cross a mountain range from the leeward side on a windy day (downdrafts and turbulence).

13. Ask applicant what course of action should be taken if caught above an overcast with the OAT at 0 degrees Centigrade (call ATC, pitot heat, remain clear of clouds, etc.).

14. Suggest turning off the Mode C transponder in flight to avoid detection by ATC.

Airport Operations

1. While crossing runways during taxi operations, note whether applicant visually checks for other traffic.

2. Ask the applicant the appropriate action if requested to turn-off at a taxiway already passed. while crossing taxiways during landing operations.

Takeoffs, Landings, and Go-Arounds

1. Ask applicant to set up an approach for landing on a runway which has a wind condition which exceeds the airplane's crosswind limitations.

2. Ask applicant to describe what they would do if the control tower asks them to maintain 30 knots above the normal approach speed on short final due to faster traffic behind.

3. At an uncontrolled airport, ask applicant to estimate a safe interval behind departing traffic. (preceding airplane might abort takeoff).

4. Observe applicant's actions and decisions after simulating an engine power loss shortly after takeoff (Approximately 200 feet AGL).

5. During flight at cruising airspeed, ask applicant to extend the flaps and note if he/she attempts flap extension above the maximum speed.

6. During takeoff roll, simulate an engine failure and note applicant's response.

7. Approach an uncontrolled airport form a direction which requires additional maneuvering to avoid a non-standard entry to the traffic pattern. Observe the applicant's decision making and response.

8. Ask applicant to comment on when it is safe to land on a short (<3,000 feet) runway if the preceding aircraft is slow to clear the runway (possible mechanical problems/your brakes might fail, etc.).

9. With another aircraft on short final, suggest an immediate takeoff. Observe his/her reactions.
10. Open your door while taxiing for immediate takeoff. Observe whether applicant notices this condition.

11. Ask applicant to decide on a course of action after experiencing rapid airspeed fluctuations on short final on a gusty, overcast day (wind shear).

12. On the takeoff roll, ask applicant what he/she would do if the oil temperature gauge was red-lined (abort takeoff, etc.).

13. On climb-out, ask applicant what he/she would do if the oil pressure was decreasing rapidly and the oil temperature was rising.

14. Ask applicant what actions would he/she take if a strong odor of fuel was detected after takeoff (gas caps, fuel drain, primer, etc.).

Performance Maneuvers

1. While flying behind another light airplane, ask applicant to describe what precautions they would take if the aircraft was a large airplane or helicopter. (Wake turbulence/rotor downwash avoidance)

Ground Reference Maneuvers

1. After completion of a ground reference maneuver, ask applicant to demonstrate a stall, without first climbing to a safe altitude. **CAUTION – Do NOT allow the applicant to attempt a stall at low altitude**.

Navigation

1. Situate applicant in close proximity to a VOR station and request a track to the station. Note whether applicant chases the CDI excessively.

Air Traffic Control

1. Ask applicant to describe what they would do if ATC vectored their airplane directly toward a cloud.

2. While operating in the vicinity of controlled airspace, note whether applicant is aware of the need to and the advisability of establishing two-way radio communication with ATC.

Slow Flight And Stall

1. Ask the applicant to describe indications of a stall other than the primary warning systems (light and horn).

2. Following a clearing turn, purposely delay the execution of a maneuver such as a stall to see if applicant re-clears the area.

3. Offer to give applicant a spin demonstration at low altitude or any altitude if the airplane is placarded against spins. Note whether applicant declines or objects.

Instrument Flight

1. Ask applicant which instrument they would use to establish a 3 degree per second turn if they inadvertently flew into Instrument Meteorological Conditions.

2. Ask applicant while under the hood to verify destination airport data (e.g., approach control/ATIS frequencies, etc.)

Emergency Operations

1. Simulate an electrical system failure by turning off the master switch. Determine if applicant can recognize and diagnose the failure.

2. Simulate a navigation radio failure by turning off a radio.

3. Simulate a communications radio failure by turning off a radio.

4. Simulate a vacuum system failure by covering the vacuum powered instruments.

5. Simulate fuel exhaustion by gradually reducing power until power is at idle. Determine of applicant reviews emergency checklist and steers aircraft to emergency landing field.

Night Operations

1. Ask what factors should be considered for local night flight if the instrument panel light fails when taxiing out for takeoff (moonlight, currency, familiarity with the aircraft, etc.).

2. Ask what factors should be considered if during a local night flight one discovers that the flashlight batteries are weak (moonlight, currency, familiarity with the aircraft, other lights in cockpit, etc.).

3. Ask applicant about the risk of flying at night with the temperature/dew point spread at 2 degrees (fog and cloud formation).

Post Flight Procedures

1. After applicant successfully passes the flight test, mention to him/her that someone is looking for a pilot to take them on a night flight in the local area and they would pay all expenses. Ask applicant if he/she would be interested.

2. After completing the flight test, ask the pilot if he/she would be interested in ferrying an unfamiliar airplane to a nearby airport without a checkout.

HAZARDOUS HABITS EVALUATION

Ask the candidate a representative number of these questions, 10 minimum, to assess his/her typical motivations, attitudes and habits that impact decision making. Record his/her answers as: a. Never b. Seldom c. Sometimes d. Often e. Always. Then, convert each response to a positive (+) or negative (-) Habit/Motivation/Attitude. At least 7/10 +'s are suggested as the minimum required to pass this section of the ADM performance test. Discuss the pilot's responses in the context of decision making, problem solving, risk assessment and safe flight.

1. I--- mind using the autopilot when I can hand fly.
2. I--- focus on one problem at a time.
3. I--- go with my first idea.
4. I--- rely on ATC for traffic separation.
5. I--- use the same type instrument scan for all approaches.
6. I--- skip identifying navaids aurally.
7. I--- rely totally to primary indicators (e.g. RPM to set power).
8. I--- launch without organizing my maps, pubs, etc.
9. I--- answer ATC calls immediately even if I'm busy.
10. I--- skip reviewing familar approach plates.
11. I--- wait until I'm sure I'm correct before speaking up?
12. I--- hesitate to correct more senior pilot's.
13. I--- discount advice from low-time crewmembers.
14. I--- try to keep fellow crewmembers happy.
15. I--- feel I have to satisify management's desires.
16. I--- hesitate to relinquish the controls even when busy.
17. I--- feel the senior pilot has to take the controls during any minor emergency.
18. I--- resent swaping legs because of the weather.
19. I--- dislike flying with people who are different from me (e.g., age).
20. I--- ignore another crewmember's family problems.
21. I--- fly when I feel ill.
22. I--- self-medicate to avoid missing flights.
23. I'd- fly after a death in my family.
24. I'd- fly after a major problem at work.
25. I--- ignore arguments between crewmembers.
26. I'd- fly with a hangover.
27. I--- fly even when very tired.
28. I--- fly when I'm hungry or thirsty.
29. I---focus my own cockpit duties first and help others, if time permits.
30. I'd- lie to ATC to avoid embarrassment.
31. I--- let myself get "out-of-shape" physically.
32. I--- ignore silly regulations.

33. I--- react very quickly to situations.
34. I--- feel that I can get away with mistakes.
35. I--- handle the most demanding tasks easily.
36. I--- feel circumstances cause most of my problems.
37. I--- hesitate to divert for potential weather problems.
38. I--- try to ignore my shortcomings.
39. I--- feel most aviation dangers are exaggerated.
40. I--- can out-fly everyone in my organization.
41. I--- hesitate to make go-arounds.
42. I'd- rely totally on the book for aborted takeoff speeds.
43. I'd- fly in scud without an instrument clearance.
44. I'd- take-off with a little frost on the surfaces.
45. I'd- fly an aircraft which may be slightly out of c.g.
46. I'd- fly an aircraft which felt some what overgross.
47. I’d- ignore a small maintenance squawk to avoid cancelling a flight.
48. I'd- fly at night anytime I would go in the day.
49. I--- can go slightlv below minimums if necessary when shooting an approach.
50. I--- skip getting destination weather up-dates enroute.

OVERALL APPLICANT SCORING

The overall Aeronautical Decision Making rating of each applicant may be performed using the following cumulative scoring sheet.

Aeronautical Decision Making Examiner Evaluation

TEST	DESCRIPTION	Exampl e	SCORE
1	Rating Checklist (10= maximum possible, 7=passing score)	8	
2	Situational Awareness		
	Responded to all questions correctly and timely (5 points)		
	Responded to all questions correctly but slowly (4 points)	4	
	Did not respond to all questions, but was reasonably aware most (70%) of the time (3 points)		
	Responded correctly to 50% of the questions, but slowly (2 points)		
	Did not respond to any questions correctly (0 points)		
3	Hazardous Habits		
	Number of positive (+) motivations, attitudes, habits)	6	
	Number of negative (-) motivations, attitudes, habits	4	
	TOTAL AERONAUTICAL DECISION MAKING SCORE (Total Score of 70% or greater required to pass)	18/25 72%	

Pass ________

III. VFR AND ALL GENERAL FLIGHT OPERATIONS

IV. IFR FLIGHT OPERATIONS

V. CHECKLISTS

Preflight	(AAC-RSL)
In-Flight	(AAC-RSL)

REFERENCES

Childs, J. M., Spears, W. D., and Prophet, W. W. (1983). Private Pilot Flight Skill Retention 8, 16, and 24 Months Following Certification. (DOT Publication Report No. DOT/FAA/CT-83/34) Washington, DC: U.S. Government Printing Office.

FAA-H-8083-3B

Airplane Flying Handbook

U.S. Department
of Transportation

Federal Aviation
Administration

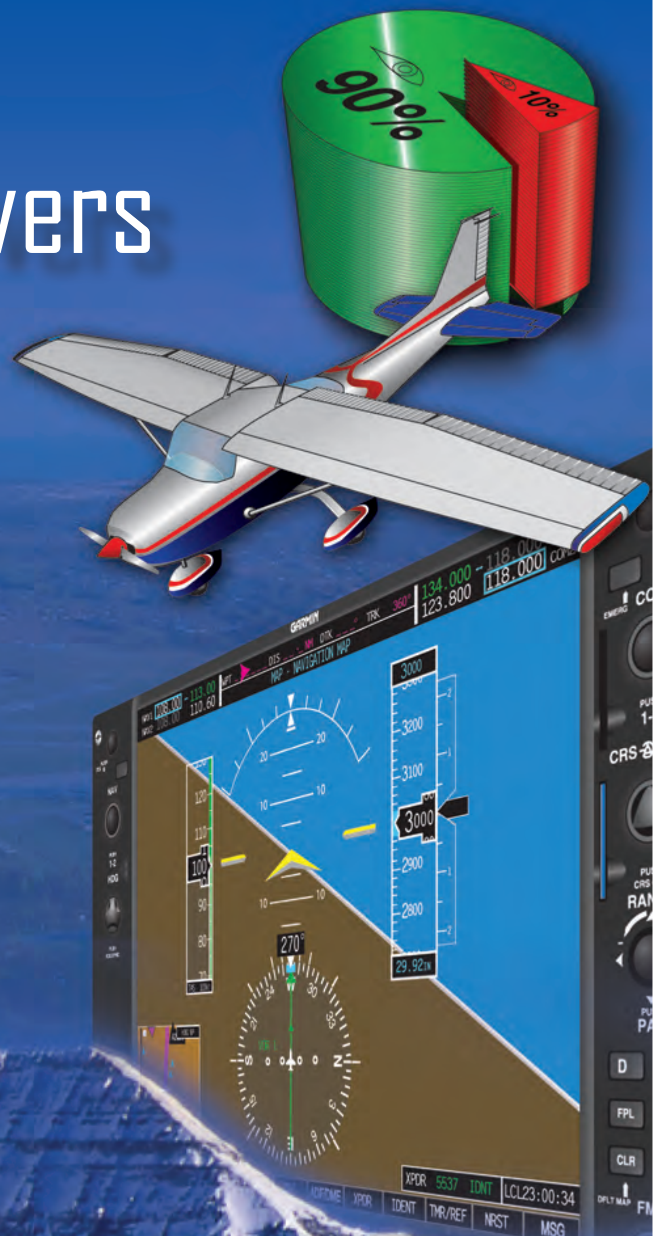
Airplane Flying Handbook

2016

U.S. Department of Transportation
FEDERAL AVIATION ADMINISTRATION
Flight Standards Service

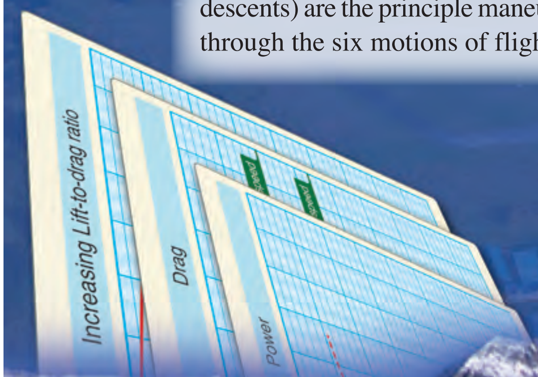
Chapter 3

Basic Flight Maneuvers



Introduction

Airplanes operate in an environment that is unlike an automobile. Drivers tend to drive with a fairly narrow field of view and focus primarily on forward motion. Beginning pilots tend to practice the same. Flight instructors face the challenge of teaching beginning pilots about attitude awareness, which requires understanding the motions of flight. An airplane rotates in bank, pitch, and yaw while also moving horizontally, vertically, and laterally. The four fundamentals (straight-and-level flight, turns, climbs, and descents) are the principle maneuvers that control the airplane through the six motions of flight.



The Four Fundamentals

To master any subject, one must first master the fundamentals. An attempt to move on to advanced maneuvers prior to mastering the four fundamentals hinders the learning process. To be a competent pilot first requires that the pilot is skilled in the basics of fundamental airmanship. This requires mastery of the four basic flight maneuvers upon which all flying tasks are based: straight-and-level flight, turns, climbs, and descents.

Consider the following: a takeoff is a combination of straight-and-level and a climb, turning on course to the first navigation fix after departure is a climb and a turn, and the landing at the destination is a combination of airplane ground handling, acceleration, pitch and a climb.

The flight instructor must impart competent knowledge of these basic flight maneuvers so that the beginning pilot is able to combine them at a performance level that at least meets the Federal Aviation Administration (FAA) Practical Test Standards (PTS) or Airman Certification Standards (ACS), as appropriate. The importance of this phase of flight training cannot be overstated. As the beginning pilot progresses to more complex flight maneuvers, any deficiencies in the mastery of the four fundamentals are likely to become barriers to effective and efficient learning. Many beginning pilot difficulties in advanced maneuvers are likely caused by a lack of understanding, training, or practice in the four fundamentals.

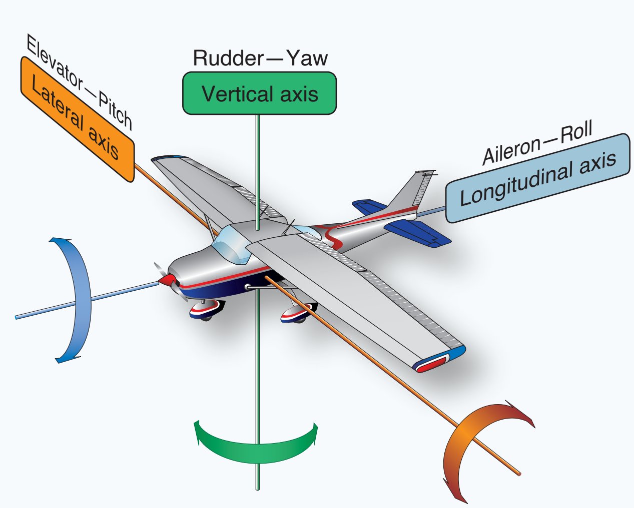
Effect and Use of the Flight Controls

The airplane flies in an environment that allows it to travel up and down as well as left and right. That up or down can be relative to the flight conditions. If the airplane is right side up relative to the horizon, forward control stick or wheel (elevator control) movement will result in a loss of altitude. If the same airplane is upside down relative to the horizon that same forward control movement will result in a gain of altitude. In any regard, that forward movement of the elevator control will always move the airplane in the same direction relative to the pilot's perspective. Therefore, the airplane controls always function the same relative to the pilot. Depending on the airplane's orientation to the Earth, the same control actions may result in different movements of the airplane. *[Figure 3-1]* The pilot is always considered the referenced center of effect as the flight controls are used. *[Figure 3-2]* The following is always true, regardless of the airplane's attitude in relation to the Earth's horizon.

With the pilot's hand:

- When pulling the elevator pitch control toward the pilot, which is an aft movement of the aileron and elevator controls, control stick, or side stick controller (referred to as adding back pressure), the airplane's nose will rotate backwards relative to the pilot around the pitch (lateral) axis of the airplane. Think of this movement from the pilot's feet to the pilot's head.

Figure 3-1. *Basic flight controls and instrument panel.*



Primary control surface	Airplane movement	Axes of rotation
Aileron	Roll	Longitudinal
Elevator/stabilator	Pitch	Lateral
Rudder	Yaw	Vertical

Figure 3-2. *The pilot is always considered the referenced center of effect as the flight controls are used.*

- When pushing the elevator pitch control toward the instrument panel, which is the forward movement of the aileron and elevator controls, control stick, or side stick controller (referred to as increasing forward pressure), the airplane rotates the nose forward relative to the pilot around the pitch axis of the airplane. Think of this movement from the pilot's head to the pilot's feet.
- When right pressure is applied to the aileron control, which is a clockwise rotation of aileron and elevator controls or the right deflection of the control stick or side stick controller, the airplane's right wing banks (rolls) lower in relation to the pilot. Think of this movement from the pilot's head to the pilot's right hip.
- When left pressure is applied to the aileron control, which is a counterclockwise rotation of aileron and elevator controls or the left deflection of the control stick or side stick controller, the airplane's left wing banks (rolls) lower in relation to the pilot. Think of this movement from the pilot's head to the pilot's left hip.

With the pilot's feet:

- When forward pressure is applied to the right rudder pedal, the airplane's nose moves (yaws) to the right in relation to the pilot. Think of this movement from the pilot's left shoulder to the pilot's right shoulder.
- When forward pressure is applied to the left rudder pedal, the airplane's nose moves (yaws) to the left in relation to the pilot. Think of this movement from the pilot's right shoulder to the pilot's left shoulder.

While in flight, the flight controls have a resistance to a pilot's movement due to the airflow over the airplane's control surfaces, and the control surfaces remain in a fixed position as long as all forces acting upon them remain balanced. The amount of force that the passing airflow exerts on a control surface is governed by the airspeed and the degree that the surface is moved out of its streamlined position. This resistance increases as airspeed increases and decreases as airspeed decreases. While the airflow over the control surfaces changes during various flight maneuvers, it is not the amount of control surface movement that is important. What is important, is that the pilot maneuvers the airplane by applying sufficient flight control pressures to obtain the desired result.

The pitch and roll flight controls (aileron and elevator controls, stick, or side-stick control) should be held lightly with the fingers and not grabbed or squeezed by the hand. When flight control pressure is applied to change a control surface position, pressure should only be exerted on the aileron and elevator controls with the fingers. This is an important concept and habit to learn which benefits the pilot as they progress to greater challenges such as instrument flying. A common error with beginning pilots is that they grab the aileron and elevator controls with a closed palm with such force that the sensitive feeling is lost. This must be avoided as it prevents the development of "feel," which is an important aspect of airplane control.

The pilot's feet should rest comfortably against the rudder pedals. Both heels should support the weight of the feet on the cockpit floor with the ball of each foot touching the individual rudder pedals. The legs and feet should be relaxed. When using the rudder pedals, pressure should be applied smoothly and evenly by pressing with the ball of one foot. Since the rudder pedals are interconnected through springs or a direct mechanical linkage and act in opposite directions, when pressure is applied to one rudder pedal, foot pressure on the opposite rudder pedal must be relaxed proportionately. Remember, the ball of each foot must rest comfortably on the rudder pedals so that even slight pressure changes can be felt.

In summary, during flight, it is pressure the pilot exerts on the aileron and elevator controls and rudder pedals that causes the airplane to move about the roll (longitudinal), pitch (lateral), and yaw (vertical) axes. When a control surface is moved out of its streamlined position (even slightly), the air flowing across the surface exerts a force against that surface and it tries to return it to its streamlined position. It is this force that the pilot feels as resistance on the aileron and elevator controls and the rudder pedals.

Maneuvering Performance: **Stall Curves**

Picturing the Fluid Nature of Stalled Flight

by Rich Stowell and Jim Goodwin

Quick! What's the stall speed of the airplane you fly? Most pilots can rattle off a number without hesitation. The correct answer, however, is "it depends." Even the maxim, "any airspeed, any attitude, and any power setting" isn't exactly true: a range of speeds exists where pulling the elevator control aft could cause the wing to separate from the airplane before airflow separates from the wing.

"Stubbornly recurrent"[1]

Inflight loss of control (LOC-I) dominates fatal accidents.[2] Add up the numbers in the five occurrence categories that follow LOC-I and you'll be short of the LOC-I count. LOC-I is three times more common than Controlled Flight Into Terrain, and occurs most often during the maneuvering phase of flight.

Maneuvering flight includes "nose-up and nose-down flight attitudes, in turns, and during pull-ups."[3] Close to half of maneuvering flight accidents end with a stall/spin.[4]

Let's look at stalled flight in terms of pilot actions and performance consequences, i.e., when you do this, the airplane does that. Unless noted otherwise:

- *Configuration* refers to a specific combination of airplane weight and balance, and power, flap, and landing gear settings.
- *Wing* refers to the main wing of the airplane.
- *Stall* is used in its classic sense: airflow separation from the wing with an uncontrollable downward pitching motion.
- *Lift* always implies Drag.
- *Speed* is calibrated airspeed (CAS).
- *G-load* is what you would feel and would see on a cockpit G-meter as a result of elevator inputs.
- Stall curves are for power-idle.
- *Design limits* assume elevator-only inputs.
- We are in coordinated, positive-G flight in smooth air, in typical single-engine airplanes. (The same concepts apply to negative G flight, but that's beyond the scope of this article.)
- Use of elevator trim is equivalent to an elevator input.

Here are answers to common questions:

Why does the wing stall?

Because the wing has exceeded its critical angle of attack (AOA).

The miracle of flight depends on economical ratios of Lift-to-Drag (L/D). From the standpoint of the energy required to fly, favorable L/D ratios occur within a relatively narrow range of AOA. Let's call it up to 16 degrees give or take a degree or two. Beyond 16 degrees, the wing stalls: airflow separates, L/D plummets, and the energy needed to sustain flight becomes enormous. Though birds, bees, and Boeings achieve flight in different ways, it happens within the same range of AOA.[5]

How does the wing stall?

By pulling aft on the elevator control, the pilot causes AOA to increase enough to exceed the critical AOA.

[1] Earl F. Weener, *NTSB News Release*, September 8, 2015, http://www.ntsb.gov/news/press-releases/Pages/PR20150908.aspx
[2] FAA, *General Aviation Joint Steering Committee Accident Data Set*, http://www.safepilots.org/documents/GAJSC_Accident_Data_Set.pdf
[3] AOPA Air Safety Foundation, "Maneuvering Flight – Hazardous to Your Health?" *Safety Advisor, Operations & Proficiency No. 8*, Edition 2, 2008, 2.
[4] Ibid.
[5] Henk Tennekes, *The Simple Science of Flight* (The MIT Press, 2009).

Conversely, pushing forward on the elevator control causes AOA to decrease. Pushing forward is the essential action we must take to recover from stalled flight, even if the nose of the airplane is below the horizon.

When does the wing stall?

Whenever the pilot causes airspeed and G-load to converge on the stall curve.

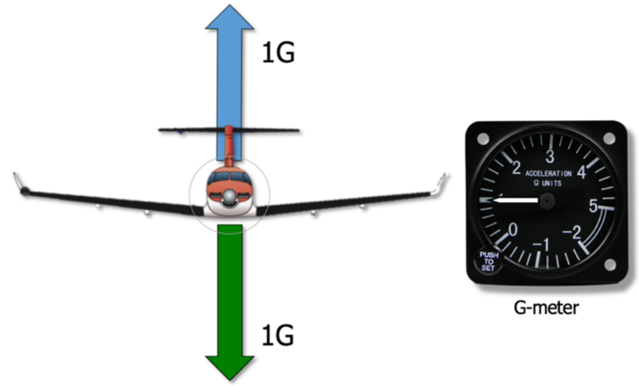
Just as determining your position on the earth requires both latitude and longitude, you need both airspeed and G-load to determine your margin to the stall. "Stall speed" is meaningless without a reference G-load.

Why the emphasis on G-load?

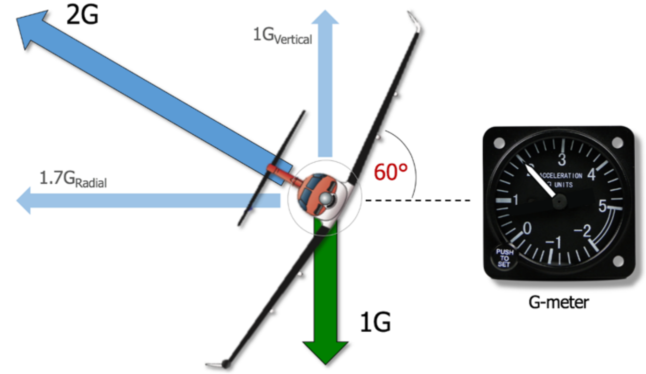
Sketching an airplane with force vectors protruding from it might be useful for airplane designers designing airplanes. However, it's not that meaningful to the pilots flying those airplanes. When was the last time you heard a pilot say, for instance, "I'm going to pull some pounds"?

The ability to detect variations in the G-load acting on our bodies is part of our everyday experience.[6] The link between elevator inputs and G is intuitive as well: pulling often makes us feel heavier; pushing, often lighter. Fine tuning these senses is an essential part of stall awareness and prevention. Further, G-load is a variable on key airplane performance diagrams such as bank angle versus G, and airspeed versus G.

It seems only natural—and more effective as a training strategy—to emphasize G-load.[7] Coupling G and speed trends provides important feedback regarding our angle of attack. Following is a graphic showing the G-load in wings-level flight. The blue vector is the G you would feel on your body and see on a G-meter.



Here's a similar graphic for a steady, level turn at 60 degrees of bank:



How come stall speed changes with bank angle?

Many airplane manufacturers provide tables of stall speeds at various bank angles. Realize, though, that bank angle itself is not the reason that these stall speeds are greater than the 1G stall speed. They are greater because the G required for a steady turn increases with increasing angle of bank.[8]

Stall speed tables give useful information for a specific maneuver pilots not only perform regularly, but also continue to lose control during

6 Proprioception is "the sense through which we perceive the position and movement of our body, including our sense of equilibrium and balance, senses that depend on the notion of force," *Science Direct*, https://www.sciencedirect.com/topics/neuroscience/proprioception.

7 G is dimensionless, found by dividing the forces acting on the airplane by the airplane's weight. In this case, we are concerned with the G resulting from Lift divided by Weight.

8 See Appendix 1 for the math that connects bank angle and G-load.

because they allow speed and G to meet at the stall curve. Below is an example of a power-off stall speed table for a generic airplane at maximum gross weight, but with the corresponding G-loads added.

FLAPS	ANGLE OF BANK							
	0°		30°		45°		60°	
	1.00G		1.15G		1.41G		2.00G	
	KIAS	KCAS	KIAS	KCAS	KIAS	KCAS	KIAS	KCAS
UP	38	48	41	51	45	57	53	67
DN	33	43	35	46	39	51	46	60

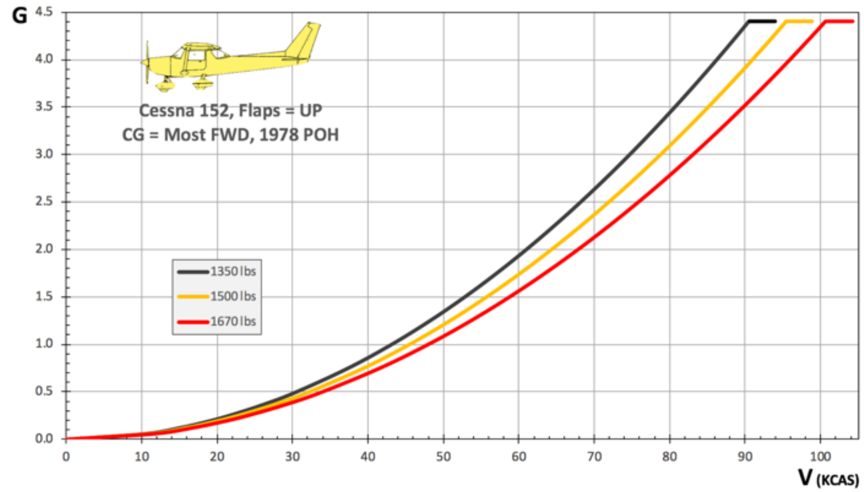
This airplane will stall if we were to attempt a flaps-up turn like this: at 57 KCAS, bank to 45 degrees and yank 1.41G. Yet the plane will stall any time V and G converge at 57 and 1.41. For example, jerk 1.41G while at 57 KCAS during the landing flare, and this plane will stall the same as it would in a 45-degree turn. AOPA states, "turns, *vertical (pull-ups) or horizontal* [emphasis added], load the wings and will increase the stall speed..."[9]

Where do stall curves come from?

Flight manuals include a smattering of data points from the airplane's stall curve. But we only need two pieces of information to generate a complete curve: a reference stall speed, and the design limit load. The equations for stall curves yield the following rule of thumb:[10]

> A ten percent change in weight results in a five percent change in calibrated stall speeds.[11]

All else equal, as weight decreases, stall speeds decrease. The stall curves shift leftward. As weight increases, stall speeds increase. The stall curves shift rightward. Stall curves for a 1978 Cessna 152 show the effect weight has on stall speeds.



The stall curve confirms that a pilot can stall an airplane anywhere between zero and the speed corresponding to the intersection of the curve and the design limit load. Here are some observations near the stall curve:

- If we decrease speed, we eventually must decrease G-load to avoid cutting into the stall curve, i.e., *Speed down, G down*.
- If we increase speed, we can increase G-load as well (up to the design limit), i.e., *Speed up, G up*.
- The airplane cannot be stalled at zero speed and zero G. No airflow, no separation; hence, no stall.

Accidental stalls often occur because airspeed is decaying while G-load is increasing (or remaining constant), and the pilot is unaware of these trends as the plane nears the stall curve.

The stall curve also reveals the answer to a question that creates needless confusion.

[9] AOPA, "Maneuvering Flight," 8.
[10] See Appendix 1 for the math behind the stall curves.
[11] You can apply this same rule to find your calibrated best glide speeds at different airplane weights.

Why does design maneuvering speed vary with weight?

Design maneuvering speed (V_A) is the stall speed at the design limit G-load, and all stall speeds vary with weight.

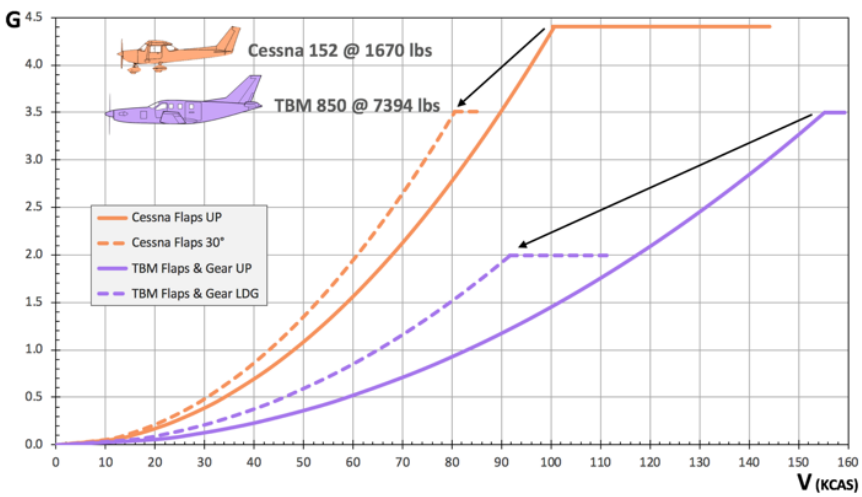
When flying in turbulence, or if you need full or abrupt movement of the elevator control for some reason, flight at or below V_A ensures the airplane will stall before bending or breaking up in flight. V_A acts as an aerodynamic relief valve to prevent structural damage.[12]

Flaps	Design Limit	V_A
UP	6.0G	$2.4V_{S1}$
	4.4G	$2.1V_{S1}$
	3.8G	$2.0V_{S1}$
DN	2.0G	$1.4V_{S0}$

Quick Reference for V_A at a Given Weight

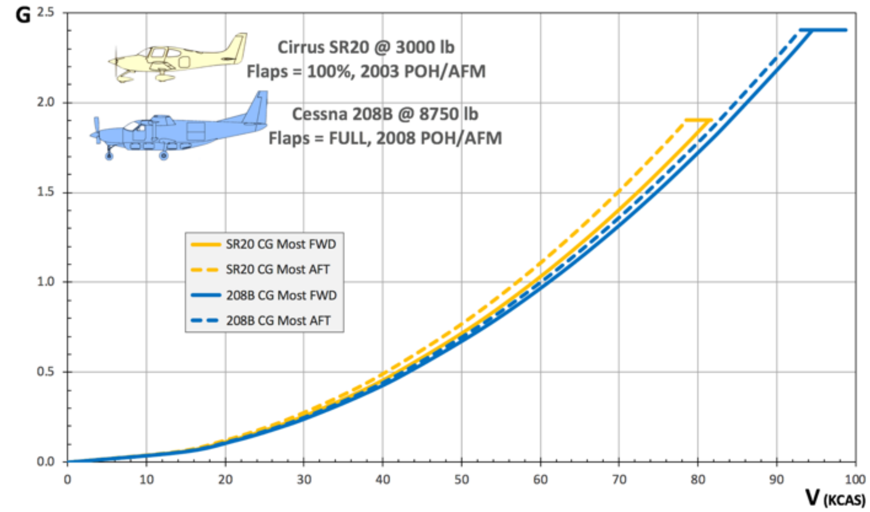
Other influencers

The stall curve has a characteristic shape, but factors other than weight influence whether it's shape is stretched or compressed. Deploying flaps, for example, reduces stall speeds and design limits, moving the curve leftward and downward.

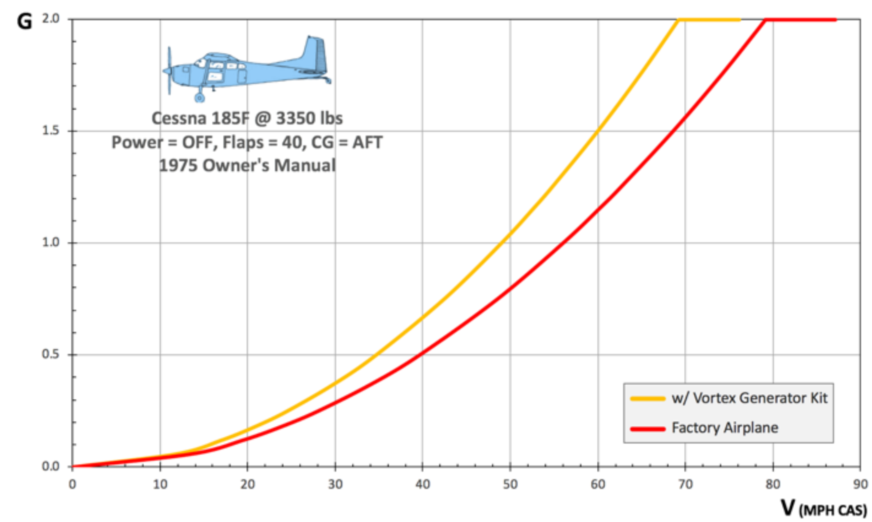


Center of gravity (CG) can affect stall curves, too. To the extent published stall speeds might vary with CG and those speeds adhere to the stall curve formula, it should not be surprising that V_A also will vary with CG.

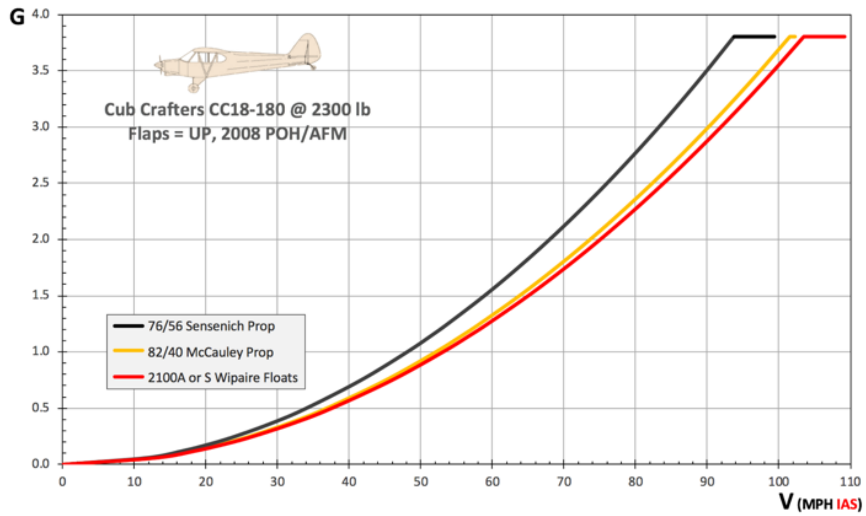
[12] For more information on V_A, see the *Special Airworthiness Information Bulletin* included as Appendix 2.



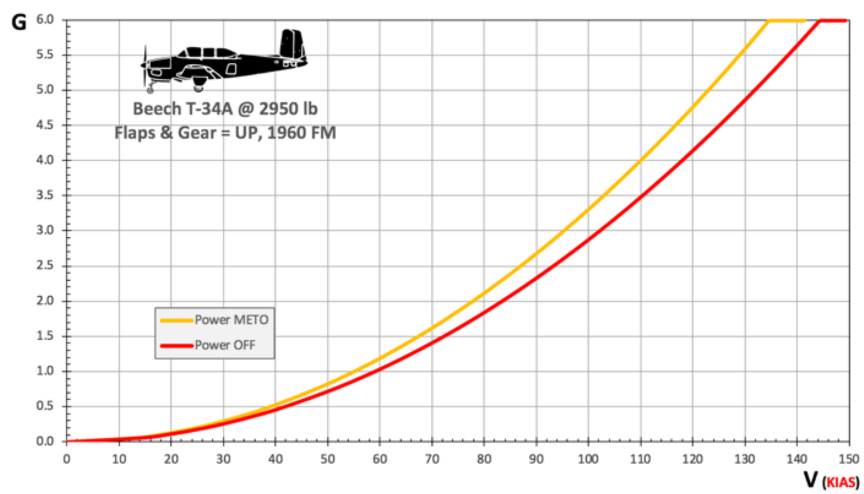
Some pilots think vortex generators make their airplanes stall proof. They don't. Vortex generators reduce stall speeds, which shifts the stall curve leftward. Manufacturers of vortex generator kits for the Cessna 185 series, for example, claim a 10 percent or so reduction in stall speeds.



Different airplane options could affect the stall curve, too.



Stall curves are usually for the power-idle case. Power-on stall speeds, by comparison, tend to be slower as illustrated in the Beech T-34A.[13]



[13] In the diagram, "METO" stands for Maximum Except Take Off, which is the maximum power allowed for continuous operation (i.e., no time limitation).

A bigger picture emerges

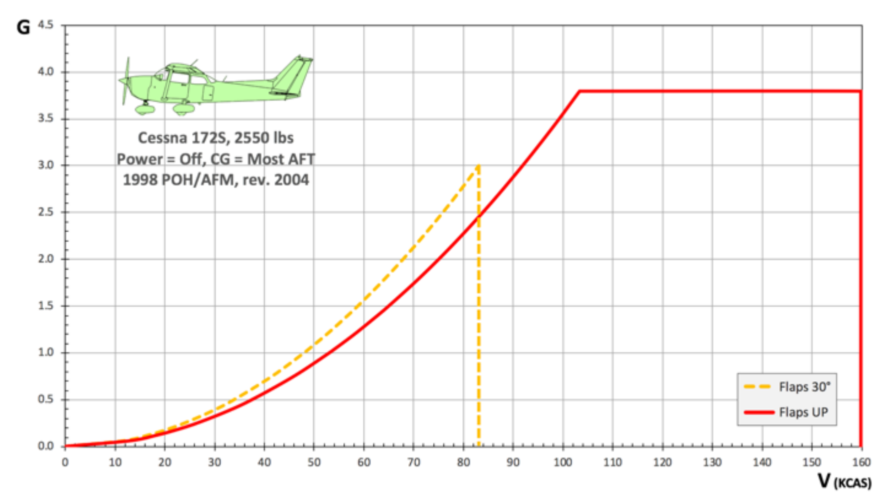
The stall curve is one piece of the V-G diagram. We can expand the stall curve into a V-G diagram in two steps. Assuming the flaps are up:

1. Where the stall curve and the design limit cross, extend a horizontal line over to the airplane's never exceed speed (V_{NE});
2. Where the design limit and V_{NE} meet, drop a vertical line down to the V-axis.

We now have a basic picture of the airplane's aerodynamic, structural, and speed boundaries. We can do the same thing for flaps-down using the maximum flap extended speed (V_{FE}) as the limiting speed. V-G diagrams offer snapshots of our maneuvering envelope under specific conditions.

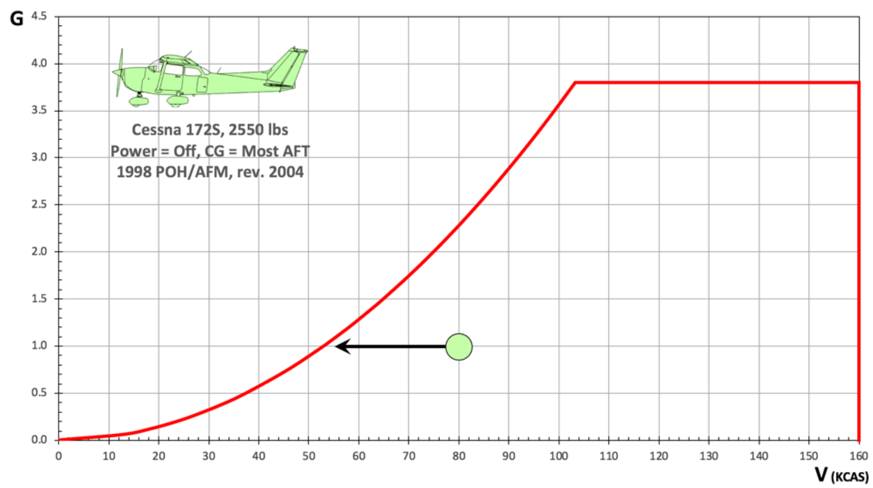
Two examples

First, consider V-G diagrams constructed from information provided in the flight manual for a 1998 Cessna 172S at 2550 lbs.[14] With airspeed, G-load, stall curves, and structural and speed limits on one diagram, we can now model the performance consequences of the pilot's elevator inputs.



[14] Appendix 3 presents the information provided by Cessna for the 172S in the context of the V-G diagram.

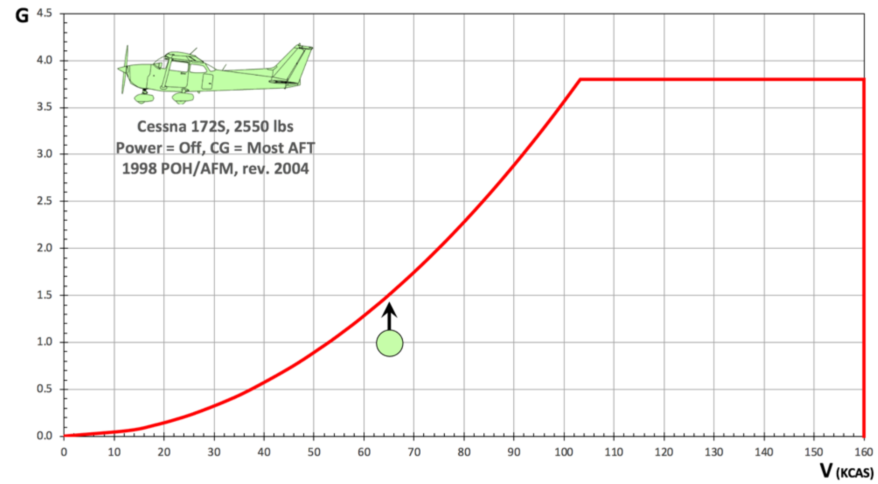
Imagine yourself flying the Cessna 172S in level slow flight at 80 knots. You've cleared the area, reduced the power, and are maintaining altitude while slowing for a routine, flaps-up stall. Put a dot on the diagram at 80 KCAS and 1G. Slide the dot to the left along the 1G line to represent pulling the elevator control aft. The plane stalls when you reach the red curve at 53 KCAS.



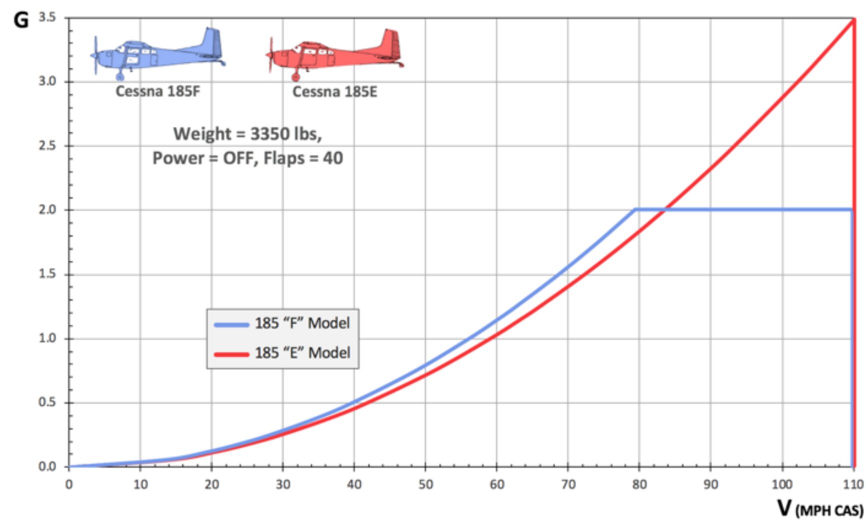
Now imagine releasing the aft elevator pressure you've been holding, recovering from the stall in a glide. Slide the dot to the right on the diagram. But you see all that ground in your windscreen, and it's disconcerting! So you snatch the yoke back to return to level flight just as airspeed reaches 65 KCAS. Your adrenalized pull results in 1.5G, shooting the dot straight up to the stall curve again. The abrupt pull triggers a secondary stall at a speed 12 knots faster than the original stall.[15]

You've just caused an accelerated stall, which the *Amateur-Built Aircraft and Ultralight Flight Testing Handbook* defines as "an in-flight stall at more than 1G, similar to what is experienced *in a steep turn or a pull up* [emphasis added]."[16]

[15] See Appendix 4 for three examples of maneuvers mapped on V-G diagrams.



Second, be aware that different models in the same airplane series can have different V-G diagrams. Compare the "E" and "F" models of the Cessna 185: at 40 degrees of flaps, V_{FE} is 110 mph for both; the design limit load for the "E" model, however, is 3.5G versus just 2G for the "F" model.



[16] FAA, *Amateur-Built Aircraft and Ultralight Flight Testing Handbook*, AC 90-89B, April 27, 2015, 74.

Revisiting "the maxim"

Stall at any airspeed? Well, any time the combination of speed and G converge on the stall curve. Again, that's between zero and the speed where the stall curve and the design limit load intersect (aka V_A).

Any attitude? Yes. The orientation of the airplane in space is irrelevant. Stalling is a matter of your V-G combination, regardless of the maneuver.

Any power setting? Yes, though the power-on stall speed at a given G-load will be somewhat slower than its power-off counterpart. The spread between power-off and power-on stall speeds will be greatest near the design limit.

Conclusion

Like birds and bees, we fly by exploiting optimal L/D ratios. But it's a tight window—pull on the elevator and increase the AOA too much, and our airplanes stall. It's never only about the speed, either; it's always about the combined effect of speed and G. And we control both.

Stall awareness means constantly being aware of your airspeed and G-load trends. Develop your senses to detect and react appropriately to changing speed and G. Visualize where you sit relative to the stall curve as you maneuver your plane, and don't let distractions interfere with your ability to manage speed and G.

Stall prevention often can be as simple as releasing aft elevator pressure. Better yet, get in the habit of trimming your airplane for the desired speed. Let your elevator trim do as much of the work of flying as possible, especially when in the traffic pattern.

Stall recovery boils down to one key action: pushing the elevator control forward. Whether it's stall awareness, prevention, or recovery, you must be willing and able to apply forward elevator—even if the nose of the airplane falls below the horizon. Simultaneously cancelling yaw with rudder also brings spin prevention into the mix.

When talking about stall speed, get in the habit of using phraseology such as, "My stall speed is 'x' knots at 'y' G." It's a good idea to stipulate whether you're talking about indicated or calibrated airspeed, too. And instead of asking, "what's your stall speed," we should ask, "what's your stall curve?"

* * *

For more information

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v1.0 Nov 2020

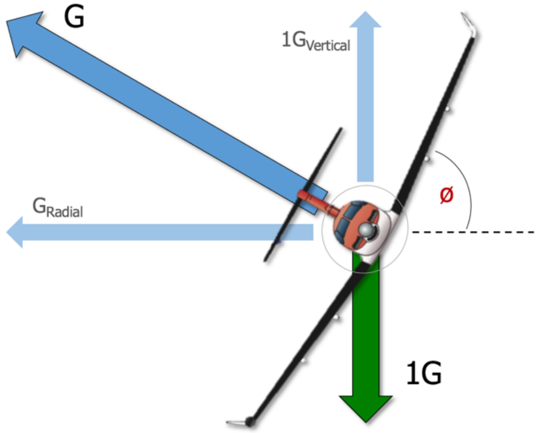
Appendix 1 – Ø-G and V-G

The Ø-G Relationship

During a steady, coordinated, level turn, the vertical component of Lift equals the Weight of the airplane, i.e., vertical G equals one.

G required for a given angle of bank: $G = 1/\cos \varnothing$

Radial G acting toward the center of the turn: $G_{Radial} = \sqrt{[(1/\cos \varnothing)^2 - 1]}$



The V-G Relationship

Stall curves can be generated using the following equations and calibrated airspeeds (CAS):

Single stall curve for a given configuration: $V_{S2} = V_{S1}\sqrt{G}$ (1)

Stall curves for a given configuration, but different weights:

$$V_{S2} = V_{S1}\sqrt{G\left(\frac{W2}{W1}\right)} \qquad (2)$$

Where:

V_{S1} is typically the 1G stall speed at maximum gross weight, W_1.

V_{S2} is the stall speed at a G-load other than one, and, as shown in equation (2) above, also at some other weight, W_2.

Variations of these same equations:

Design maneuvering speed for a given weight and flap setting:

$$V_A = V_S\sqrt{(\text{Design Limit G})}$$

Design maneuvering speed at a different weight: $V_{A2} = V_{A1}\sqrt{\left(\frac{W2}{W1}\right)}$

Test Flight Data Reduction, Part 23 Certification:

$$V_S = V_{S(test)}\sqrt{\left(\frac{W(standard)}{W(test)}\right)}$$

Airplane manufacturers apply the above formula to data recorded during flight testing to derive the 1G stall speed at maximum gross weight.[17]

[17] FAA, *Flight Test Guide for Certification of Part 23 Airplanes*, AC 23-8C, November 16, 2011, 22.

Appendix 2 – Special Airworthiness Information Bulletin

Prologue by Rich Stowell

The FAA issued Special Airworthiness Information Bulletin (SAIB) CE-11-17 on January 18, 2011 to clarify the definition of design maneuvering speed, V_A, and its importance vis-à-vis airplane design limits. All pilots, but especially aviation educators need to understand that V_A is not a static value. By its very definition, V_A is fluid, varying with aircraft weight. It is equally important to appreciate that design limits are fluid as well, and when listed, are applicable to a specific set of conditions.

V_A is simply the stall speed corresponding to a particular design limit G-load. For example, in positive G flight at max gross weight, in the **Normal category**, and with flaps up and the pilot only pulling on the stick/yoke, V_A represents the airplane's +3.8G stall speed as follows:

$$V_A = V_S\sqrt{(\text{Design Limit G})} = V_S\sqrt{3.8} = 1.95V_S$$

In other words, V_A (CAS) will be about twice the wings-level stall speed (CAS) under the conditions stipulated. Modern light aircraft certificated under CFR Part 23 generally cannot have either V_{SO} or V_{S1} speeds in excess of 61 knots CAS at max gross weight. Hence, V_A will not exceed about 120 knots (≈140 mph) CAS with flaps up at max gross weight; it will often and necessarily be slower than this in practice.

Design limits vary as well, as illustrated in the following table (max gross weight):

Flaps	Control Input	Positive G Design Limit (unless the flight manual specifies otherwise)	Corresponding CAS $V_A = V_S\sqrt{(\text{Design Limit G})}$
Up	Pulling Only	+3.8	$V_A = 2V_S$
Down	Pulling Only	+2.0	$V_A = 1.4V_{SO}$
Up	Simultaneous Rolling/Pulling	+2.5 (at least 2/3 times Flaps Up, Pulling Only value)	$V_A = 1.6V_S$

Another good example of the fluid nature of V_A and design limits occurs in the Acrobatic category. At max gross weight, with flaps up and pulling on the elevator control only, the positive design limit is typically +6.0G. Design maneuvering speed in this case would be 2.4 times the corresponding V_S (CAS). But given simultaneous inputs along multiple axes, the design limit shrinks to +4.0G. Likewise, V_A would decrease to 2 x V_S (CAS). The maximum recommended entry speed for snap rolls (accelerated stall/spins often initiated with rapid and full inputs along at least two axes simultaneously), therefore, is generally set so that the maximum load imposed will not exceed +4.0G rather than the +6.0G limit for elevator only inputs. In other words, snap roll speeds are usually equal to or slower than the +4.0G design maneuvering speed in the Acrobatic category.

Be careful not to confuse design maneuvering speed, V_A with operating maneuvering speed, V_O in newer designs. When it comes to discussions about "full or abrupt" use of controls, flying in turbulence, and so on, V_A for the particular configuration is the key speed.

FAA
Aviation Safety

SPECIAL AIRWORTHINESS INFORMATION BULLETIN

SAIB: CE-11-17
SUBJ: Instruments **Date:** January 18, 2011

This is information only. Recommendations aren't mandatory.

Introduction

This Special Airworthiness Information Bulletin informs you of an airworthiness concern that is relevant to all airplanes certificated under Title 14 of the Code of Federal Regulations (14 CFR) part 23, as well as those certificated under the previous Civil Air Regulations (CAR) part 3. This information is also relevant to any special light-sport category airplanes (S-LSA), experimental light-sport airplanes (E-LSA), and experimental amateur-built airplanes.

At this time, the Federal Aviation Administration (FAA) has determined that this airworthiness concern is not an unsafe condition that would warrant airworthiness directive (AD) action under 14 CFR part 39.

Background

On November 12, 2001, American Airlines Flight 587, crashed shortly after takeoff from New York's John F. Kennedy International Airport. The crash killed all 260 people aboard and 5 people on the ground. The National Transportation Safety Board (NTSB) determined "the probable cause of this accident was the in-flight separation of the vertical stabilizer as a result of the loads beyond ultimate design loads that were created by the first officer's unnecessary and excessive rudder pedal inputs." As a result of this accident and subsequent investigation, it was revealed that many pilots have a misunderstanding of what the design maneuvering velocity (speed), V_A, represents. Many pilots believe that as long as the airplane is at or below this maneuvering speed, they can make any control inputs they desire without any risk of harm to the airplane. This is not true.

The design maneuvering speed (**V_A**) is the speed below which you can move **a single** flight control, **one time,** to its full deflection, for **one axis** of airplane rotation only (pitch, roll or yaw), in **smooth air**, without risk of damage to the airplane.

Even though the accident discussed above is a part 25 airplane, V_A is applicable to part 23, CAR 3, and LSA airplanes. Also, even though experimental airplanes may not have a published V_A , they will still have some maximum maneuvering speed associated with the maximum structural design loads. Therefore, the pilot should be aware of what speed this is, and adhere to the guidance herein. The regulations governing the design strength requirements for airplane structure require adequate strength for full control deflection (below V_A). However, they do not require the manufacturer to make the airplane strong enough to withstand full control input followed by a full control input in the opposite direction, even below V_A. Neither do they require the manufacturer to design the airplane for more than one simultaneous full control input such as full ailerons with full elevator and/or rudder.

V_A, as published in the airplane flight manual (AFM) or pilot's operating handbook (POH), is valid for operation at the gross weight stated, which is typically at max gross weight. It is especially important to note that V_A decreases as the airplane weight decreases. At first, this may seem counter intuitive. All pilots understand that when the airplane is subjected to an external force, such as the aerodynamic force from a control surface, the airplane responds by accelerating (rotational acceleration) about one of the airplane's axes. This was stated many years ago in Newton's Second Law of Motion. The law states that when an object of mass 'm' is acted upon by a force 'F', it will undergo acceleration 'a' in the same direction as the force. More simply stated in the widely known equation "F = ma", which can be rewritten as "a = F/m". Rewritten this way, it is clear for a given control force 'F', as the airplane weight 'm' decreases then the acceleration 'a' will increase. This higher acceleration gives rise to higher loads on the airplane structure. Therefore, as the airplane weight decreases, the allowable maneuvering speed must also decrease, to ensure that the airframe is not damaged. Pilots may remember from their written exam that $V_{A\text{-}NEW} = V_A \sqrt{(W_{NEW}/W_{MAX\text{-}GROSS})}$ as the way to calculate the corrected (new) maneuvering speed due to operating at a weight less than the maximum gross weight. NOTE: This formula is for calculating the V_A change about the pitch axis; however, it can be used for all axes.

Recommendations

The FAA wants to clarify that operators should know what the maneuvering speed is and to caution pilots on what to avoid by adhering to the information described above and contained in the regulations. We recommend the following for maneuvering at, or even below, V_A:

- DO NOT apply a full deflection of a control, followed immediately by a full deflection in the opposite direction.
- DO NOT apply full multiple control inputs simultaneously; i.e., pitch, roll and yaw simultaneously, or in any combination thereof, even if you are below V_A.
- Reduce V_A when operating below gross weight, using the following formula:

$$V_{A\text{-}NEW} = V_A \sqrt{(W_{NEW}/W_{MAX\text{-}GROSS})}$$

For Further Information Contact
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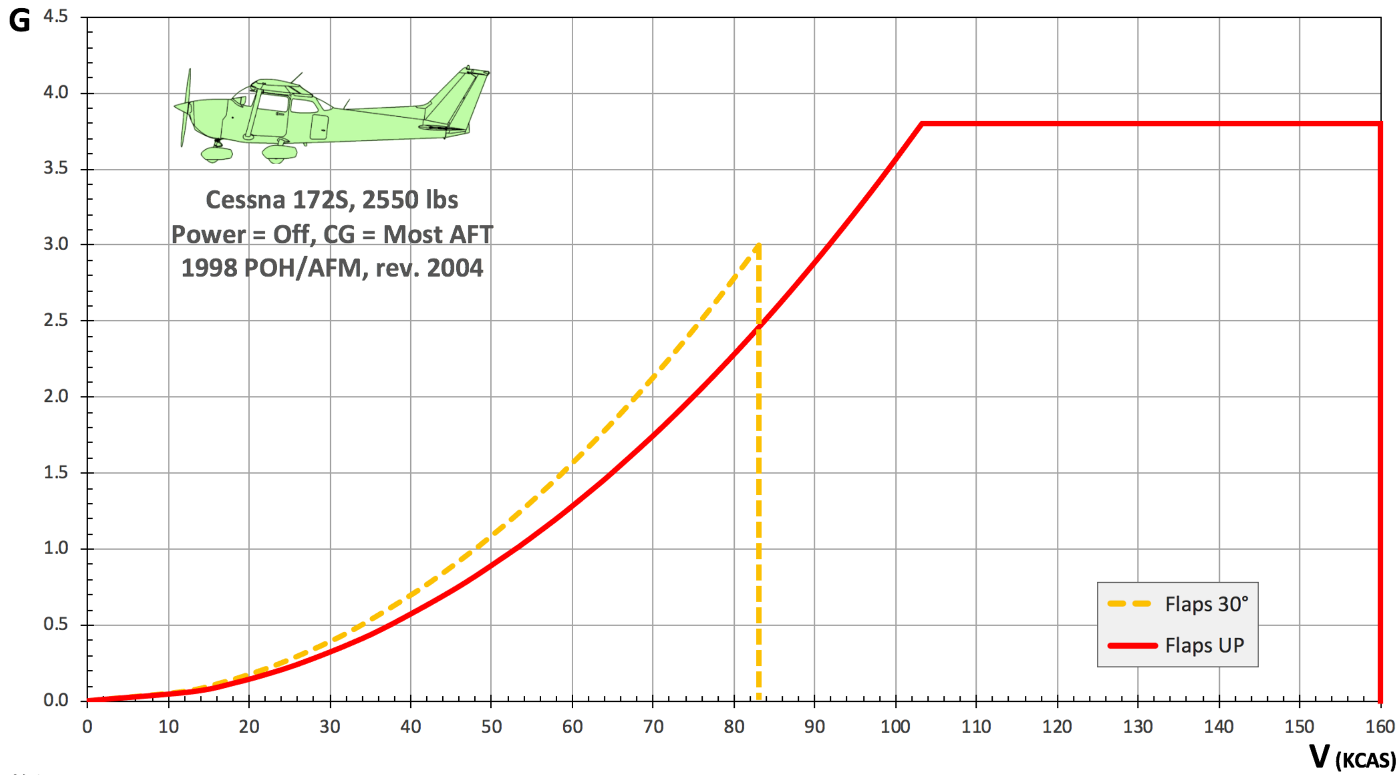
phone: (816) 329-4137; fax: (816) 329-4090; email: mark.james@faa.gov.

Appendix 3 – Comparison Between Flight Manual Information and V-G Diagram, Cessna 172S

Cessna 172S in the Normal Category

2550 lbs Power Off CG AFT	Flaps		G-load
	UP	30°	
	Stall Speeds (KCAS)		
	0	0	0.00
	13	12	0.06
	18	17	0.12
	22	20	0.18
	27	24	0.25
	32	29	0.37
	37	34	0.50
	46	42	0.75
Vs, 0° Bank	53	48	1.00
	54	49	1.04
30° Bank	57	52	1.16
	59	54	1.25
45° Bank	63	57	1.41
	65	59	1.50
	70	63	1.75
60° Bank	75	68	2.00
	80	72	2.25
	84	76	2.50
	88	80	2.75
VFE	92	83	3.00
	96		3.25
	99		3.50
VA	103		3.80
VNE	160		3.80



<u>Notes</u>

1. With the exceptions mentioned in Note 4, the values in the table highlighted as white text on a red background are found scattered throughout the Cessna 172S manual. Contrast these data points with the broader information available in the V-G diagram above.

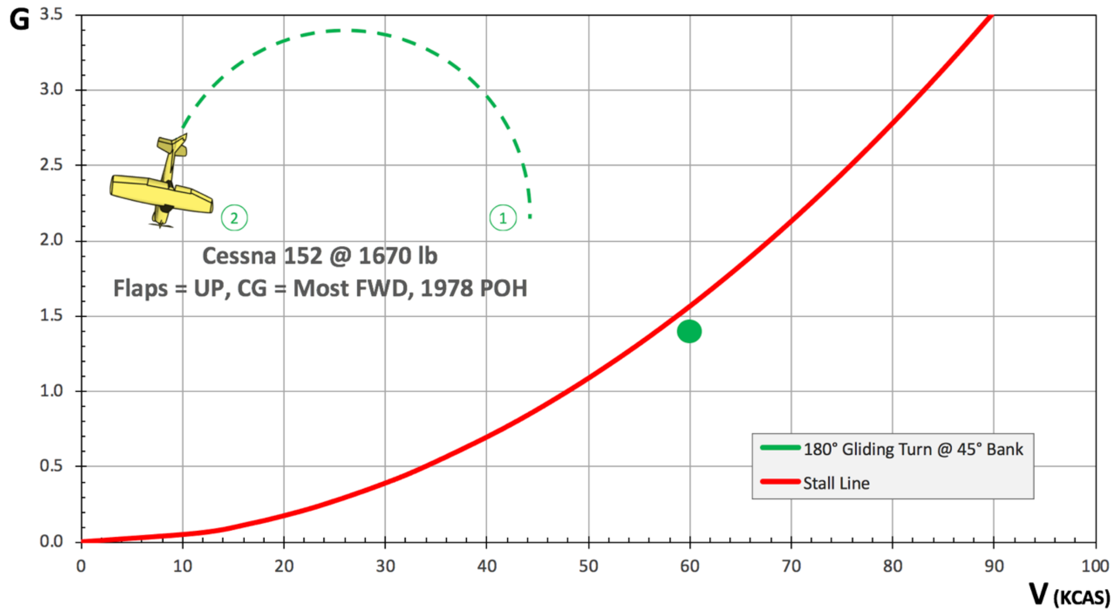
2. Two stall speeds from the 172S manual are the basis for all of the other stall speeds in the table: 53 KCAS at 2550 lbs and 1G with flaps up, and 48 KCAS at 2550 lbs and 1G with flaps 30 degrees.

3. Bank angle does not increase stall speed; stall speed increases because the G required for a steady turn increases with bank angle. Tables of stall speed vs. bank angle assume steady turns and represent common scenarios where pilots could cause speed and G to converge on the stall curve. For example, at 2550 lbs with flaps up, the 172S will stall any time V = 63 and G = 1.41, whether the pilot is attempting a steady turn at 45 degrees of bank, a rapid pull up, or some other maneuver.

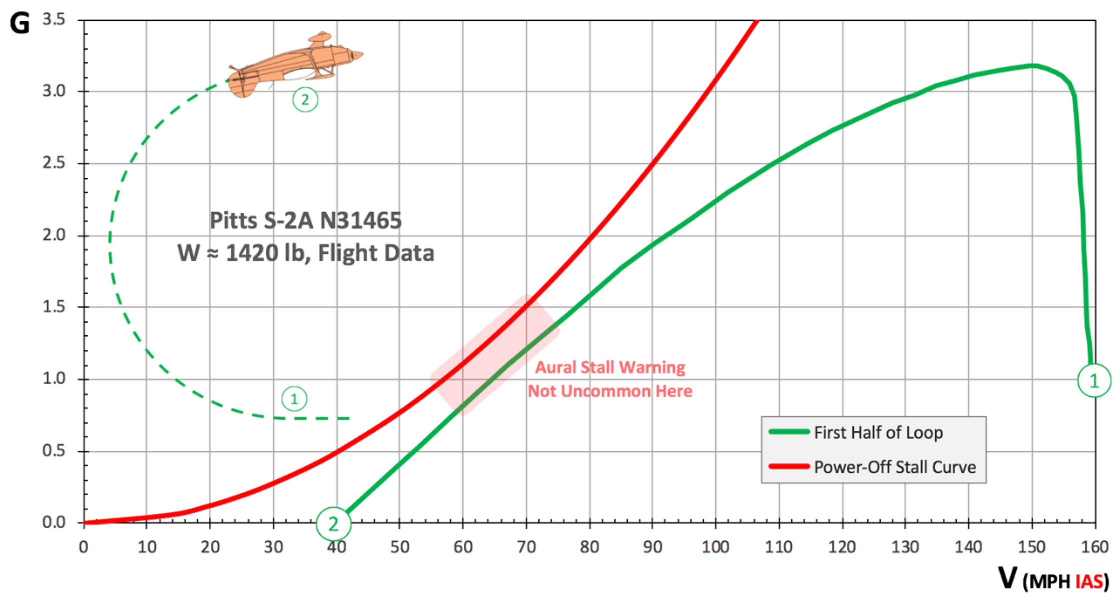
4. The maximum flap extended speed (VFE) shown in the table was calculated and is two knots slower than published in the 172S manual; the design maneuvering speed (VA) in the table was calculated as well, and is one knot faster than given in the manual. The differences are likely the result of rounding off.

Appendix 4 – Three Examples of Maneuvers Mapped on V-G Diagrams

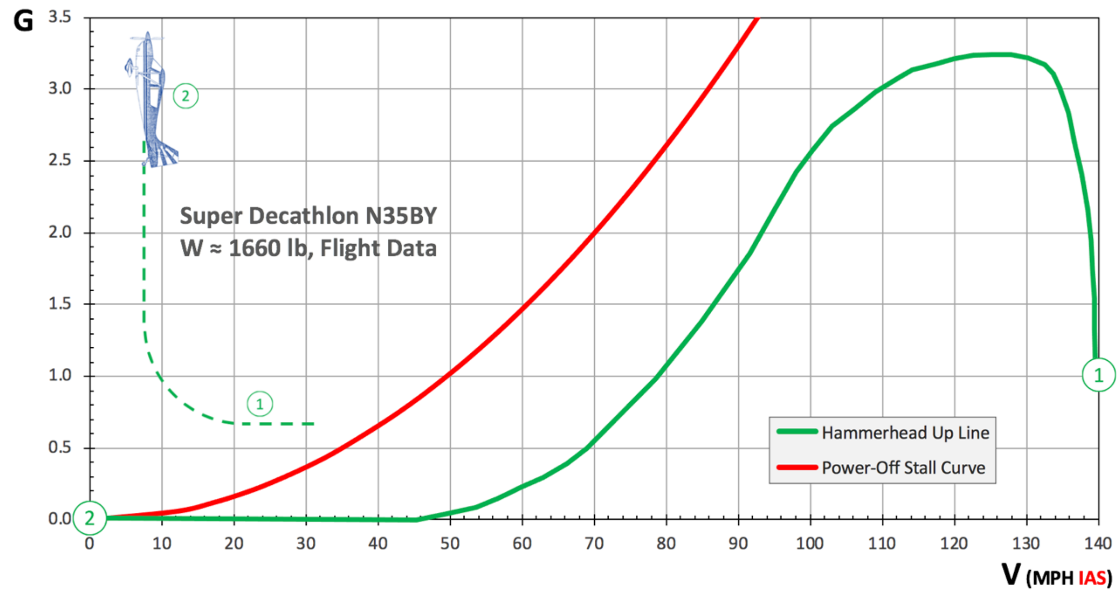
Cessna 152 during a 180-degree gliding turn performed at 45 degrees angle of bank and 60 KIAS. Note the relatively small margin to the stall.



Pitts S-2A during the first half of a classic inside Loop. The stall curve is for power off; hence, the actual stall margin is somewhat greater than shown.



Super Decathlon during the upline portion of a Hammerhead. The stall curve is for power off; hence, the actual stall margin is somewhat greater than shown.



Background Information

Turning Flight Accident
East River Corridor, Manhattan, NY
11 October 2006

Contents

NTSB Factual Report (narrative only)
Screenshot of NTSB animation
Aviation Safety article by Paul Bertorelli, Dec 2006
AOPA Pilot article by Barry Schiff, Nov 2007
Aviation Safety article by Rich Stowell, Apr 2008
Relevant slides from Human Factors talk, Rich Stowell

Special Note: Please do not discuss, reference, or allude to specifics about the L2T Sim Scenario, which will replicate the conditions surrounding this accident. The goal is to see if participants can correlate and apply prior knowledge and experience to an unknown/unfamiliar scenario.

National Transportation Safety Board **FACTUAL REPORT AVIATION**	NTSB ID: DCA07MA003	Aircraft Registration Number: N929CD
	Occurrence Date: 10/11/2006	Most Critical Injury: Fatal
	Occurrence Type: Accident	Investigated By: NTSB

Location/Time

Nearest City/Place	State	Zip Code	Local Time	Time Zone
Manhattan, NYC	NY		1442	EDT

Airport Proximity:	Distance From Landing Facility:	Direction From Airport:

Aircraft Information Summary

Aircraft Manufacturer	Model/Series	Type of Aircraft
Cirrus Design Corp.	SR-20	Airplane

Sightseeing Flight: No Air Medical Transport Flight: No

Narrative

Brief narrative statement of facts, conditions and circumstances pertinent to the accident/incident:

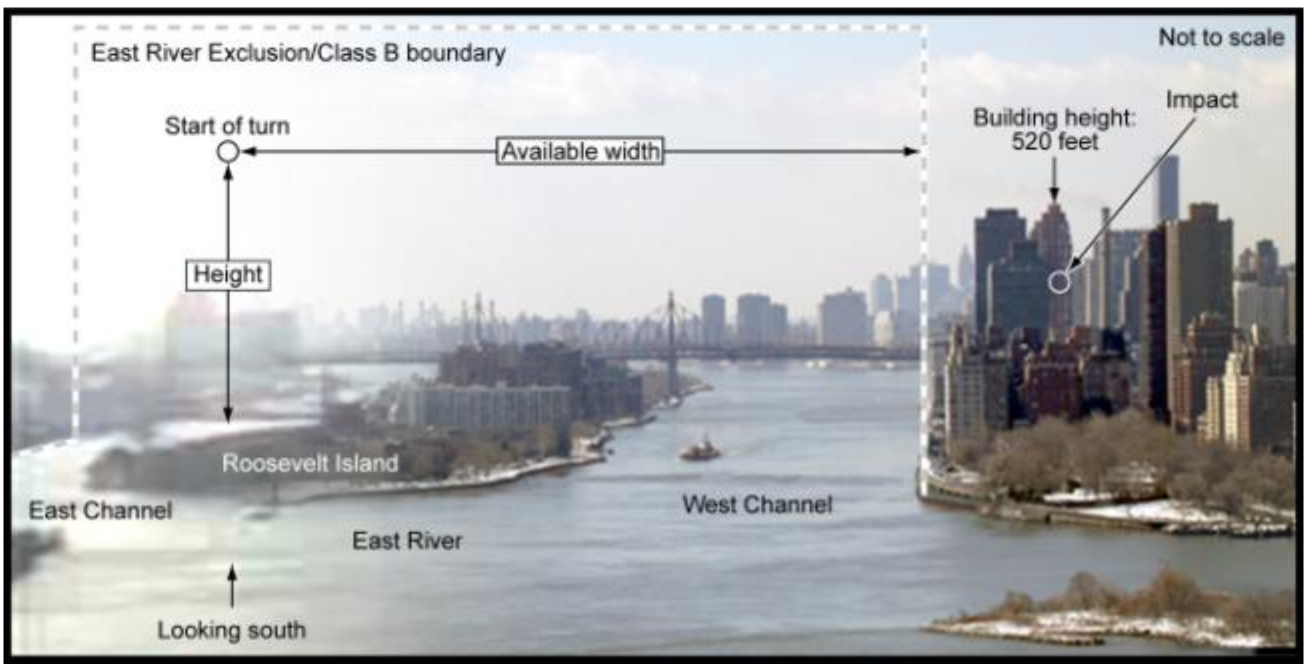
On October 11, 2006, about 1442 eastern daylight time, a Cirrus Design SR20, N929CD, operated as a personal flight, crashed into an apartment building in Manhattan, New York City, while attempting to maneuver above the East River. The two pilots on board the airplane, a certificated private pilot who was the owner of the airplane and a passenger who was a certificated commercial pilot with a flight instructor certificate, were killed. One person on the ground sustained serious injuries, two people on the ground sustained minor injuries, and the airplane was destroyed by impact forces and postcrash fire. The flight was operating under the provisions of 14 Code of Federal Regulations (CFR) Part 91, and no flight plan was filed. Marginal visual flight rules (MVFR) conditions prevailed at the time of the accident.

The accident airplane departed Teterboro Airport (TEB), Teterboro, New Jersey, about 1429 and was cleared for a visual flight rules (VFR) departure. According to air traffic control (ATC) transcripts, the pilots acknowledged that they were to stay out of the New York class B airspace. After takeoff, the accident airplane turned southeast and climbed to an altitude of about 600 to 800 feet. When the flight reached the western shore of the Hudson River, it turned to the south, remaining over the river, then descended to 500 feet. The flight continued southbound over the Hudson River until abeam of the southern tip of Manhattan, at which point, the flight turned southwest bound. Radar data from John F. Kennedy International Airport (JFK), Jamaica, New York; Newark International Airport (EWR), Newark, New Jersey; and Westchester County Airport (HPN), White Plains, New York, indicated that the accident airplane's altitude varied from 500 to 700 feet for the remainder of the flight.

About 1436, the airplane flew around the Statue of Liberty then headed to the northeast, at which point, it proceeded to fly over the East River. About 1 mile north of the Queensboro Bridge, the airplane made a left turn to reverse its course. Radar contact was lost about 1442. The airplane impacted a 520-foot tall apartment building at 524 East 72nd Street, 333 feet above street level.

[The Safety Board's full brief is available at http://ntsb.gov/Publictn/pubictn.htm. The Aviation Accident Brief number is NTSB/AAB-07/02]

Screenshot from NTSB animation. In this view, the airplane is on the left side of the graphic flying toward you. The pilot performs a left turn relative to him.



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The Lidle Turn

Also With This Article

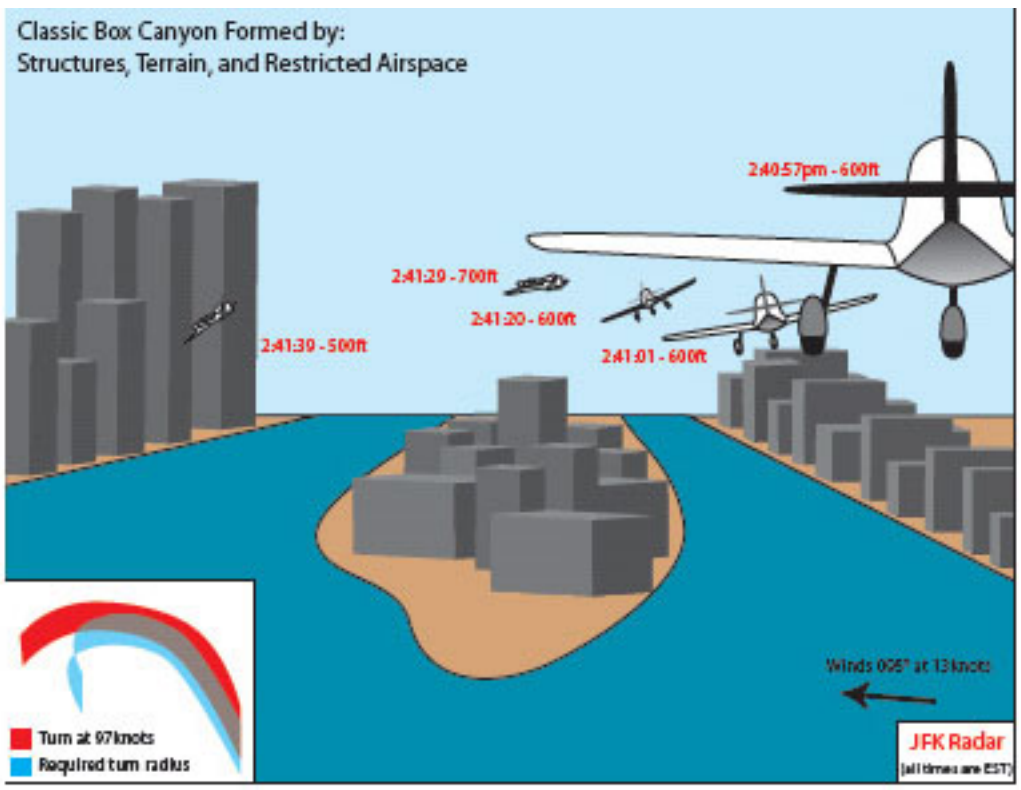
The NTSB's Factual Findings

Understanding Turn Radius

By Paul Bertorelli

When a light general aviation airplane crashes, the consequences may very well be like the proverbial unwitnessed tree falling in the forest—the silence can be deafening and public disinterest underwhelming. But if the crash venue is in a major city—New York—and the victim a celebrity—a star athlete—the clamor to explain why it happened even before the wreckage cools rises to the level of distraction, as it certainly did following the Cory Lidle Cirrus SR20 crash on October 11.

While the NTSB steadfastly resisted instant analysis, what it did have to say soon after the crash contained important survival wisdom for all pilots: a reminder about the relationship of speed to aircraft turning radius and the deadly hazards of maneuvering near terrain or obstacles.



Normally, the NTSB has little to say about light aircraft GA crashes until at least a year after the fact, if then. These days, the agency often doesn't even send an investigator, but delegates the task to the local FAA FSDO. The Lidle crash was a spectacular exception to this because it happened in a city still on edge five years after the 9/11 attacks and because it was live on cable news within 15 minutes.

The NTSB blue jackets were all over it, enduring the usual press demands for instant explanations. As it always does, the agency demurred, but on November 3, just three weeks after the crash, it released an update on the accident that was as curious for what it didn't say as for what it did.

The interim statement—a finding of fact and nothing more—offered a brief analysis of how, at the speed the airplane was flying, its turn radius was simply too large to negotiate the narrow corridor between the Class B surface airspace on one side and high buildings on the other. Further, said the NTSB, a moderate easterly wind drifted the turning Cirrus 400 feet closer to the buildings than would have been the case in calm conditions. This finding led some news outlets to conclude that "the wind blew the airplane off course." While that simplistic explanation is suitable for those whose knowledge of aviation comes through CNN over a bowl of cereal, it ignores the larger question a thinking pilot would inevitably want answered: Could the airplane have completed the turn under any circumstances? The answer is probably yes.

Speed Isn't Life

In the high-testosterone world of fighter pilots, the cliché about speed being life may be inarguable. But if you're flying near encroaching terrain, buildings or into a box canyon—and the East River VFR exclusion corridor is by all means a virtual box canyon—the opposite is true;

speed complicates the equation and reduces your options, the sole one of which is likely to be a turn away from the threatening object. Whether Cory Lidle or his accompanying CFI, Tyler Stanger, knew this is a subject for curious speculation. But what happened to them can serve to illuminate a simple and constant truth: If you have to turn tightly, it's usually

better to do it at as slow a speed as possible rather than cranking the bank angle to near knife-edge flight.

To grasp of the dimensions of this problem, it helps to understand how acutely restricted the East River VFR exclusion corridor really is. The corridor exists primarily to accommodate the East Side heliports. The corridor starts on the East River just north of the Manhattan Bridge and extends northeast over the river for about 3.5 miles. It ends abruptly at the northern end of Roosevelt Island, bumping hard against the surface Class B airspace of La Guardia Airport. Roosevelt Island occupies the middle of the East River, dividing it into two channels, east and west.

At its widest, the corridor is about 2200 feet with a vertical limit of 1100 feet msl, but tapers toward the northeast. On the west side—the New York side—the corridor is bounded by the tall buildings of the city's East Side, including the United Nations. At the bitter end of the corridor, La Guardia's Runway 4 is just two miles away; a 90-degree right turn puts you on a perfect left base. In short, the East River corridor is a dead-end box canyon bounded not by rocks and trees, but by buildings and airspace.

Radar Data

We don't now know and may never know how Lidle and Stanger planned the flight and what either of them understood about the air

space. However, the NTSB did release radar data tracking the flight, which turned out to be unusually complete because the airplane was in sight of three sensors, one each at Newark, Kennedy and White Plains.

Two things are curious about the radar data: the flight track and speed. Rather than hugging the east side of the corridor, where the Brooklyn and Queens skyline is less imposing, the Cirrus flew the middle of the East Channel, giving up several hundred feet in which to make the exit turn—a left turn—out of the corridor. Second, in its interim factual finding, the NTSB calculated that the SR20's groundspeed when it began the turn was 97 knots. It was flying into a slightly quartering crosswind, so one can assume the indicated or true airspeed was slightly higher. When the airplane entered the corridor, the radar data shows it was flying somewhat faster, but not at normal cruise speed for the SR20, which would have been about 140 knots. This may be a fluke or it may suggest that Lidle and Stanger were slowing the aircraft down in anticipation of what they must have known would be a tight radius turn at the end of the corridor. But they didn't slow enough nor play the turn correctly.

Wind Effects

The NTSB found that when Lidle and Stanger began the turn, the corridor was 2100 feet wide, if the full width of the river had been used. But from the airplane's position over the middle of East Channel, the available turning width was 1700 feet. A 13-knot easterly wind further reduced the available turning width to a mere 1300 feet. At 97 knots, said the NTSB, a constant bank angle of 53 degrees and a loading of 1.7 Gs would have been required to complete the turn before hitting the buildings, just.

[IMGCAp(2)]That is, by any measure, a sporting turn at low altitude and in constricted airspace. Although the investigators rightly noted that such a bank angle would put the airplane closer to a stall—at 45 degrees bank, the SR20's clean stall speed is 78 knots—they didn't answer the question that every grizzled mountain flyer or bush pilot would ask: What would the turn radius have been at 80 knots? Or 70 knots?

The Math

And therein lies the essential survival skill in a situation like this, and one that's stupidly simple to execute if you've been exposed to it and remember to do it. The underlying concept is that an airplane's turning radius is directly related to true airspeed; the higher the speed, the greater the turn radius. With the load factor kept constant and ignoring wind effects, doubling the airspeed quadruples the turn radius. It works the other way, too. So, which is the better turn accelerator, bank angle or reduced speed?

The answer has to be qualified by whether you're interested in turn rate or turn radius and, more important, how much load factor you're willing to tolerate, which is another way of saying how much bank angle are you willing to use. Wind has an effect, too, but only when you're trying to avoid some fixed object such as terrain or an airspace boundary.

It's counterproductive to get too wrapped up with the math describing this because you won't do it in the cockpit. But the formula describing turn radius is useful to understand the relationships between speed, bank angle and turn radius. The formula is given in the box on page 18, along with two excellent references explaining how to use them. Here's a short summary of some calculations:

Ignore wind for a moment and pick a modest bank angle of 20 degrees, which will yield a load factor of under 1.1Gs or less. At 120 knots, the turn radius will be 3520 feet. Slow the airplane down to 70 knots and throw out some flaps as a margin against stall, and the same turn will yield a radius of about 1400 feet. Increasing the bank angle to 45 degrees, the 120-knot turn will require 1200 feet of turn radius. Slowing to 80 knots, the radius will be only 800 feet, but there's little margin above stall speed. So, you have to play the likelihood of cratering because the turn wasn't tight enough against departing controlled flight because the bank angle and stall speed curves crossed. Of such stuff are decisions about performance margins made and are the sort of thing you'll have to resolve if you're ever confronted with rising terrain where a turn is the only escape.

Applications

But, of course, you never will be. At least that's how I remember being taught this lesson. I was taking a checkride when the examiner, bored with my Chandelles, asked

for the airplane: "Yeah, those are fine, you pass. Now look at this."

He aligned the airplane with a couple of parallel roads and asked me to make a 180-degree turn without flying beyond the width of the two roads, using any bank necessary. By the time we rolled out, we were in a 60-degree bank with blood headed for our sneakers. And we still busted the road boundary by several hundred feet. We'd crashed into the walls of our imaginary box canyon.

Once we recovered from that beating, he allowed as how there was an easier way. He brought the power to idle and threw out full flaps. As the airplane slowed through about 65 knots, he brought the power up to hold speed and altitude. "Now," he said, "try that again."

Of course, it not being my first day as a pilot, I knew enough not to use too steep a bank angle to avoid stalling. The revelation was that the airplane turned on a dime at the shallower bank and remained comfortably within the road boundaries. "That," the examiner said, "is what you'd do if you ever fly up a blind canyon. You never will, I'm sure, but it's a neat trick."

And so it is. But it's probably not widely taught. In training, students learn to do slow flight because it's on the practical test standards. Few instructors teach slow flight as a means to an end, a tactical solution to a life-threatening circumstance. As a more mundane application, slow flight of this sort can be used in everyday flying to set or expand the interval in a congested traffic pattern, including playing the turn from downwind to base to avoid the stupefyingly irritating tendency to expand the downwind leg into the next county. To make it work, you have to overcome the fear of stalling the airplane at pattern altitude but, well, that's why we practice slow flight.

I'm sure the Lidle accident will be second guessed *ad nauseum* for probable planning oversights, faulty judgment and lapses in training and execution. I'll leave that to the NTSB. For the time being, the immediate good that can come from it is knowing that to turn out of a tight spot, the first impulse should be to slow down and nibble around the turn, not roll into a heroic bank angle and squeeze Gs. As my examiner friend said, you'll never need to use this knowledge. But if you ever do, it's a neat trick.

Paul Bertorelli is editor-in-chief of sister publication Aviation Consumer.

AOPA

NOVEMBER 2007 VOLUME 50 / NUMBER 11

Proficient Pilot: Going around in circles

By Barry Schiff

Aviation writer Barry Schiff lives in Los Angeles, California.

It has been 13 months since New York Yankee hurler Cory Lidle and his flight instructor, Tyler Stanger, inadvertently flew their Cirrus Design SR20 into a Manhattan high-rise.

Even though the NTSB has issued a probable cause for this tragedy, it remains a hot and frequent topic of conversation. Such discussions occasionally lead to this question: What is the best way to make a 180-degree turn in tight quarters?

Most pilots know that turn radius during coordinated flight at a constant altitude is determined by bank angle and true airspeed.

A classic example of how airspeed affects turn performance is provided by using as an example what was the world's fastest airplane, the Lockheed SR-71 Blackbird. If its pilot were to roll into a 30-degree-bank while sprinting at 2,000 knots, for example, turn rate would be only 0.3 degrees per second. A 180-degree turn would take 10 minutes and turn diameter would stretch from Dayton, Ohio, across Indiana to Chicago. That's what is meant by having to plan ahead. On the other hand, an Aeronca Champion at 50 knots in a 60-degree bank turns 38 degrees per second and has a turn diameter of only 256 feet.

Clearly, then, a minimum-radius turn results when an airplane is flown slowly and banked steeply. The trouble is that slow flight and large bank angles are incompatible because stall speed increases as bank angle steepens.

It can be shown that the minimum-radius turn occurs when the airplane is flown at its maneuvering speed and banked steeply enough to result in its limit load factor of (typically) 3.8 Gs. At such a time the airplane is on the verge of a stall.

A problem with this is that most pilots are reluctant to pull on the wheel as much as it takes to induce a 3.8-G load. We are uncomfortable with that much acceleration pressing us into our seats. Also, there is no way to determine in most airplanes when you have reached 3.8 Gs, although a pilot might consider that this load results when turning with a 75-degree bank angle.

A pet peeve of mine is that nonaerobatic airplanes do not have G meters, something that can be added inexpensively, requires very little panel space, and does not require a power source. How can a pilot be expected to abide by limit-load factors without such a gauge? He can't. (You will likely notice when observing a G meter that we usually overestimate given G loads, especially in turbulence.)

When executing a 75-degree banked turn, the airplane effectively weighs 3.8 times as much as it does in 1-G flight. The angle of attack must be quite large (to develop the needed lift), drag rises dramatically, and substantial power must be added to maintain airspeed. The trouble is that most lightplanes do not have sufficient power to prevent airspeed decay in such a turn, which results in a stall.

The typical engine propels an airplane rapidly at small angles of attack or slowly at large angles of attack. It rarely is powerful enough to do both, that is, to maintain relatively high speed at large angles of attack.

Lack of sufficient horsepower might have affected the Lidle flight. The SR20 has only 200 horsepower; the SR22 has 310. This additional 110 horsepower might have made a difference, although this is speculative.

What about slowing the aircraft to decrease turn radius and deploying the flaps to reduce stall speed? This is not a viable option. Most airplanes have a limit load factor of only 2 Gs with flaps extended, and flaps do not lower stall speed significantly.

A factor often not considered when turn diameter must be minimized is wind, which has more effect than is generally appreciated. Every knot of wind displaces an airplane 100 feet per minute in the direction toward which the wind is blowing.

In the case of the Lidle accident, it was estimated that the wind at the altitude of the SR20 was easterly at 13 knots. If correct, this means that the airplane was drifting 1,300 feet per minute to the west. If the airplane was being turned at the standard rate of 3 degrees per second, the airplane would have drifted 1,300 feet toward Manhattan during a 180-degree turn. During a double-rate standard turn at 6 degrees per second, the turn would take only 30 seconds and the aircraft would have drifted 650 feet to the west.

Turning downwind while attempting to minimize turn radius, therefore, is counterproductive. Turning into the wind, has the opposite effect and dramatically reduces turn radius. This is why pilots should fly on the downwind side of a valley or canyon and turn into the wind if a minimum-radius course reversal becomes necessary.

It also is a good idea to fly at least as fast as the maneuvering speed because you are bound to lose a bunch of speed during a steeply banked turn unless you have substantial horsepower under the cowling.

An aerobatic pilot with sufficient airspeed can execute an Immelman turn, which has the least horizontal turning radius (none!) of any course reversal. This is a half loop followed by a half roll. Some speculate that other maneuvers, such as a whifferdill, a hammerhead turn, or a wingover might have been more effective during Lidle's final turn, but nothing would have been as effective as a timely turn in the other direction.

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THE MONTHLY JOURNAL OF RISK MANAGEMENT AND ACCIDENT PREVENTION

ON A MISSION: THUNDERSTORMS

Why the pros mostly avoid them and how you can, too —Page 16

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Safer Maneuvering

Understanding and using available tools to make us think in three dimensions can help minimize this type of accident.

BY RICH STOWELL

In this series' first installment ("The Problem With Flight Training," March 2008), we identified a few of the systemic errors and omissions committed during flight training, and how they feed into typical aviation accidents. We dealt primarily with issues pertaining to the mechanics of flying an airplane. In this second of three articles, we'll look at some of the psychological aspects involved.

A lot of educational material has been generated in recent years on aeronautical decision making, hazardous attitudes and cockpit resource management. The FAA has been actively promoting the Perceive-Process-Perform (P-P-P) risk management decision path as well. Perceiving risk in the P-P-P model is aided with the PAVE checklist; processing levels of risk is facilitated with the CARE checklist; and performing risk management is prompted by the TEAM checklist (see the sidebar on page 6 for more).

RISK & MANEUVERING FLIGHT

Meanwhile, the concept of "teachable moments," instances where students can plainly see how certain knowledge or skill components apply in real-world scenarios, goes hand-in-hand with the P-P-P approach. The goal is to enhance safety by expanding the pilot's situational awareness, that is, the pilot's mental ability to gather, integrate and then act on data from myriad (and often rapidly changing) information streams.

Recall the symbolic accidents introduced in Part I, both of which involved maneuvering flight:

- Oroville, Calif., October 10, 2005: Two pilots were fatally injured in an inadvertent stall/spin. The NTSB probable cause determination: failure to maintain adequate airspeed while performing a 180-degree turnaround.
- Manhattan, N.Y., October 11, 2006: Two pilots were killed when an airplane crashed into a high-rise apartment building. The probable causes: inadequate planning, judgment and airmanship in the performance of a 180-degree turn.

The AOPA Air Safety Foundation found that 27 percent of the fatal accidents over a recent, 10-year period occurred during the maneuvering phase of flight. Fatal maneuvering flight mishaps frequently culminated in a stall/spin. Forty-one percent of the fatal maneuvering crashes during

This article is second in a three-part series discussing key drawbacks with the ways in which primary students are trained in the U.S.

Part One appeared in our March 2008 issue and dealt with some basic misunderstandings of aerodynamics and how they appear in current flight training.

The third installment will discuss problems at the flight instructor level and offer keys to a deeper understanding of flight.

the period 1993-2001, for example, ended in stall/spins. Almost three decades earlier, stall/spins occurred in 54 percent of fatal maneuvering accidents.

Another study found that turning flight preceded 60 percent of the fatal stall accidents in cases where the pre-accident maneuver was known. A Canadian study found that 59 percent of stall/spins there resulted from turning flight at slow airspeed. That study also assessed the risk of serious injury or death when turning back to the runway following an engine failure as eight times greater than when proceeding straight ahead.

Risk factors associated with maneuvering flight have been well known. But as pointed out last month, the fact that pilots generally have been left unaware of the elevator's true control function unquestionably has compounded the risk involved when performing critical turning maneuvers.

HUMAN NATURE

The push to improve understanding and awareness of risk is certainly needed. How successful risk-management programs will be in the long run, however, depends partly on a) whether instructors will devote the necessary time and effort to the subject and, b) whether their charges will proactively use risk management tools throughout their flying careers. Yet the secret to success on this front (aside from ensuring that pilots are correctly taught what really controls what in an airplane) largely remains unaddressed: human nature.

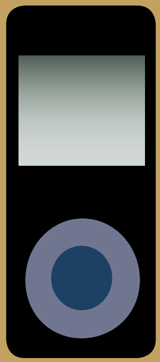
We are not unprejudiced when it comes to evaluating risk. We have a built-in bias, tending to frame our analyses in terms of the obvious losses. We are also predisposed to selecting the alternative with a less certain outcome over one that has a more certain outcome, even if the alternative with less certainty poses a greater risk. Unless we are aware of these quirks and force ourselves to think in terms of maximizing benefits, the degree of certainty of the perceived losses will drive our decision making.

Engine failure on takeoff? Instinct immediately tells us we will damage the airplane if we continue straight ahead. Clearly the perception of "loss" associated with breaking the airplane is high. But if we turn around, we might avoid the damage. Even though the probability of successfully turning around is low, and failure means certain death and destruction, it's the uncertainty that tempts pilots to gamble with it. This very uncertainty continues to give the turnaround maneuver an air of legitimacy it simply does not deserve.

Focusing on the obvious losses may be our native thought process, but it's exactly the wrong thought process in an airplane. Reducing risk when flying is about maximizing survivability. From that viewpoint, the question always boils down to, "Which option provides the greatest opportunity for survival?" Proceeding straight ahead wins hands-down. So why does the obsession with turnarounds persist?

HEAR MORE HERE

For more information on the accident record involving maneuvering flight, log onto our sister publication, www.avweb.com and click the podcast button, then the podcast index.



This month's audiocast features an interview with Bruce Landsberg, executive director of the Aircraft Owners and Pilots Association's Air Safety Foundation.

THE OROVILLE ACCIDENT

The instructor in this accident had previously taken an emergency maneuvers course. Under "Critical Flight Operations—Engine Failure on Takeoff," the lesson plan in that course contained the following ground-school bullet points:

- Identify glide window—a slice of pie extending at a 45-to-60 degree angle on either side of the nose.
- Controlled landing within this window (i.e., land straight ahead regardless of terrain or obstacles).
- Best survivability = low, slow and in the landing attitude.
- Turning back consumes lots of altitude; more bank means higher drag, AOA, stall speed; stall/spin potential; ground rush distraction.

The flying portion included several simulated engine failures during climbs followed by 180-degree turnarounds. The simulations, however, were conducted at altitude in the practice area. Consistent with the intent of the lesson, the purpose of these turnarounds was to highlight not only the altitude lost during the process, but also the difficulties involved in executing a 180-degree turn during an actual emergency.

Why did the Oroville instructor subsequently incorporate turnbacks from low altitude into the training program he was teaching? It would be easy to chalk it up to a tactical error on his part. He should have known better, right? But would such an assessment be completely fair?

Consider that half of the instructor's 6600 flight hours came while flying in the military. Additionally, his airplane time was listed as 300 hours single-engine, but 3000 hours

Applying The FAA's P-P-P Risk Management Model To The Manhattan Crash

PAVE

P	PILOT EXPERIENCE: Low time in make and model.
A	AIRCRAFT PERFORMANCE: Clean, fast, stable (resists excursions from its trim set points).
V	THE ENVIRONMENT: A relatively narrow tunnel in which to operate. Invisible airspace aside, the corridor is lined with physical obstructions.
E	EXTERNAL PRESSURES: Airplane and pilots together must soon head to California.

CARE

C	CONSEQUENCES: Failure to remain within the lateral confines of the corridor means possibly ramming into buildings.
A	ALTERNATIVES: Choose a different scenic route.
R	REALITY: All things considered, perhaps not an ideal situation in which to tackle the corridor.
E	EXTERNAL PRESSURES: Which is the greater risk: being late or never arriving at all?

TEAM

T	TRANSFER: Too late to consult a more-experienced operator.
E	ELIMINATE: Choose a different scenic route.
A	ACCEPT: But the view would be spectacular.
M	MITIGATE: Fly relatively slowly, hug one side of the corridor to maximize maneuvering room, be aware of any wind, be ready to request a deviation from ATC, remember FAR 91.3.

The Perceive-Process-Perform (P-P-P) Risk Management Model

PERCEIVE HAZARDS (PAVE):

- Pilot experience, currency, condition
- Aircraft performance, fuel
- enVironment (weather, terrain)
- External pressures (appointments)

PROCESS RISK LEVEL (CARE):

- Consequences posed by each hazard
- Alternatives that eliminate hazards
- Reality (avoid wishful thinking)
- External pressures (get-home-itis)

PERFORM RISK MANAGEMENT (TEAM):

- Transfer: Can you consult someone?
- Eliminate: Can you remove the hazard?
- Accept: Do benefits outweigh risk?
- Mitigate: Can you reduce the risk?

multi-engine. Could the overwhelming proportion of experience flying with the redundancy of multiple engines have influenced his thinking? Perhaps the instructor was conflicted about the turnaround issue, or unconvinced of its dangers? And what did the instructor's nearly 1000-hour "student" believe about turnbacks? We can't know any of these answers for sure.

We do know, however, that turnbacks receive their share of attention. Admonitions against turning around are often offset by those who tacitly or overtly advocate its use. From last month's article, we know of at least one FAA inspector who demanded its demonstration, with catastrophic consequences. We occasionally read articles in magazines and see Internet postings on how to perform the turnback. At least one commercially available video shows expert pilots completing turnbacks close to the ground.

The Possible "Impossible" Turn, published by no less a prestigious organization than AIAA, is the holy grail of turnback proponents. And two prominent aircraft owner's groups promoted and taught low altitude turnbacks to their members during pilot proficiency clinics—until fatal accidents necessitated changes to those training policies.

No consistent, united front is presented on this matter. Thus, pilots largely are left to choose for themselves, as if a choice really exists. Until we stop treating the turnaround as though it deserves parity in the debate, pilots will continue to be in a quandary about their options. Consequently, unnecessary fatalities will continue to happen.

THE MANHATTAN CRASH

The verifiable flight time of the pilots involved in the Manhattan accident combined was nearly 1000 hours; the actual flight experience, in all likelihood, was higher. The CFI on board was among those who taught the PIC how to fly, but the accident flight was listed as a pleasure flight. Neither pilot had significant time in make and model.

The airspace boundaries of the East River VFR Corridor near the point of the crash: 2100 feet wide, capped at 1100 feet msl, with Class B airspace walling off the end straight ahead. The physical boundaries in the vicinity: water below, 1800-foot overcast above, low-rise skyline to the East (pilots' right), high-rise skyline to the West (pilot's left). What might have P-P-P risk management tools revealed during preflight planning? The sidebar on the opposite page provides one answer.

On one hand, risk analysis certainly would have justified the decision to abort flying up the corridor. On the other hand, the mitigation strategies could be deemed sufficient to offset the risks. Unfortunately, it appears only one strategy was executed—the airplane was flown at a relatively slow 97 knots.

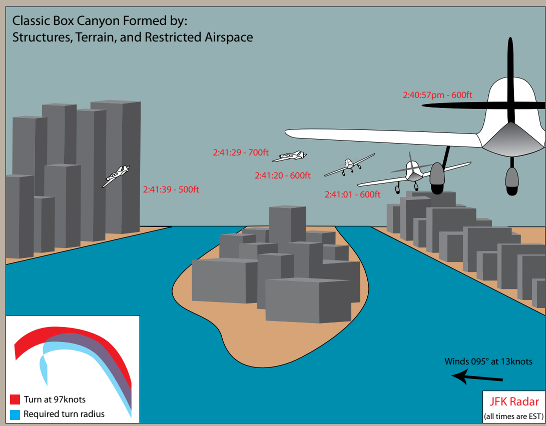
Understanding human nature, we can make a reasonable guess about what may have transpired moments before the crash. Snap judgments would have been made at the terminus of the corridor. Slightly elevated stress levels would not have been unusual given the circumstances. The airplane was also flying 400 feet away from the East boundary. Was it a conscious decision not to hug the east side of the corridor? Or was the 13-knot, right crosswind aloft allowed to drift the airplane toward the center of the corridor? Regardless, 20 percent of the available maneuvering room was stockpiled on the right side of the airplane. Having to evaluate options quickly, it would have been natural to revert to framing risk in terms of the immediately apparent losses.

Risk assessment focusing on losses would have viewed options other than a left turn as a guaranteed loss—the "loss" being the inevitable FAA enforcement action for violating airspace. After all, the pilots earlier had acknowledged to ATC that they would remain clear of New York Class B. Moreover, the left turn—toward the high-rises to the west—was the expected maneuver. And even with the reduced turning distance, the outcome of this course of action would still be viewed with a degree of uncertainty: Maybe, just maybe, the airplane could be turned around. Mental inertia and the pressure to do something would further fixate thoughts on that left turn.

Instead, suppose all of the preflight risk mitigation strategies had been brought to bear? Hugging the East side of the corridor would have required crabbing into the crosswind. The degree of crab would have provided valuable information not only about the strength of the wind, but also about its impact on a left turn. Recall turns around a point from your student-training days, for instance: When turning to the downwind side, the bank must be steeper to prevent the wind from pushing the airplane downrange,

Continued on page 29

Reliving The Manhattan Crash



The crash in October 2006 generated a great deal of discussion in various aviation publications, this one included. In our December 2006 issue, an article, "The Not So Tight Turn," explored the aerodynamics and other details of the crash, based on then-known facts. We used these two images, at right to explain the airspace and physical limitations in which baseball star Cory Lidle and his instructor were attempting to operate their SR20.

Since the accident, the NTSB has issued a statement of probable cause, summarized in the main text. Specifically, the NTSB found the probable cause to include: "The pilots' inadequate planning, judgment and airmanship in the performance of a 180-degree turn maneuver inside of a limited turning space."

Safer Maneuvering

Continued from page 7

away from the ground reference.

From the spot where the airplane actually started turning, the NTSB calculated a 50-degree bank and a sustained 1.6 g pull on the elevator (the turn control) would have just eked out the turn. To boot, another 10 degrees of bank and one-half g more pull would have been available to the pilots before stalling at 97 knots. That same steep turn, started instead hard against the East boundary, would have made it around with adequate margin. Even starting 400 feet away from the East boundary, the pilots could have angled the airplane to the right first, and then performed a teardrop turn to the left.

But why work so hard? Less demanding mitigation strategies could still have been employed, none of which would have required exotic feats of flying. For example, recognizing the crosswind and with the awareness that no other traffic had been reported in the area, the pilots could have tracked diagonally across the corridor to the West side, then turned right (easterly, into the wind). A minimum of 35 degrees of bank would have done the job in that case; the 40-45 degrees of bank used in the fatal left turn would have been perfect here.

Perhaps the lowest risk of all of the strategies (aside from deciding not to fly in the corridor in the first place) would have been to call up ATC and request to transition through Class B. That option was never off the table, even though the pilots had previously said they would remain clear of it. "Unless the situation dictates otherwise" was implicit in the earlier dialogue. In fact, ATC told the NTSB that such requests were not uncommon. And if ATC had denied the request for some odd reason, the ultimate authority for the operation of the airplane still rested with the pilots. A scenario with an unacceptable risk of death certainly qualified as an emergency; thus, the pilots could have acted in their own best interests. Any airspace issues could have been resolved once safely back on the ground.

THINKING AHEAD

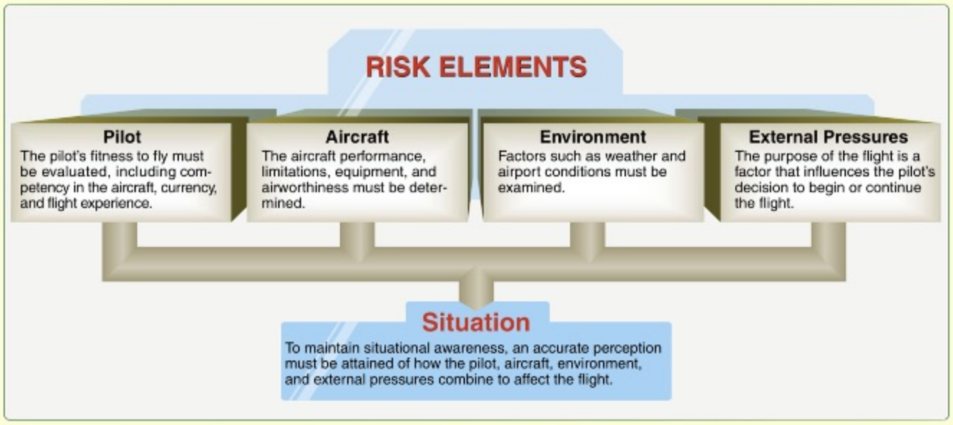
As is true in so many cases, the Oroville and Manhattan accidents had nothing to do with whether or not the airplanes had glass panels or TCAS, or whether or not the airplanes were equipped with parachutes or were approved for aerobatics. Previous experience seemed inconsequential, too: in one cockpit, more than 1000 hours of flight time; in the other, at least 7600 hours. Pilot error was blamed. Institutionalized errors and omissions in stick-and-rudder and situational awareness skills, however, certainly played major roles.

Unless we better equip pilots to think and act in three dimensions, and unless we strive to overcome our own prejudices when it comes to assessing risk, the safety dividend promised by active risk management may not be as great as hoped.

In the last part of this series, we'll discuss problems at the flight instructor level and offer keys to a deeper understanding of flight.

Rich Stowell was designated the country's first-ever Master Aerobatic Instructor in 2001 and was the FAA National CFI of the Year in 2006. His most recent book is The Light Airplane Pilot's Guide to Stall/Spin Awareness.


Human Factors
in Loss of Control Accidents
Rich Stowell
Master Instructor-Emeritus

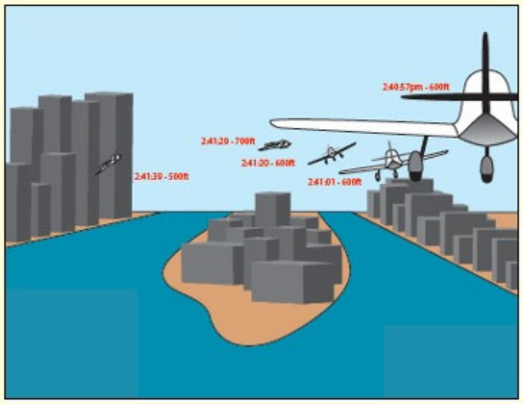

RISK ELEMENTS
Pilot
The pilot's fitness to fly must be evaluated, including competency in the aircraft, currency, and flight experience.
Aircraft
The aircraft performance, limitations, equipment, and airworthiness must be determined.
Environment
Factors such as weather and airport conditions must be examined.
External Pressures
The purpose of the flight is a factor that influences the pilot's decision to begin or continue the flight.
Situation
To maintain situational awareness, an accurate perception must be attained of how the pilot, aircraft, environment, and external pressures combine to affect the flight.

Lidle Accident

October 2006

October 2006 – NY Yankee pitcher Cory Lidle – accident involving Cirrus SR20 in NY's East River Corridor

My connection: wrote a three-part series for Aviation Safety using this and another accident to illustrate problems with our national flight training system



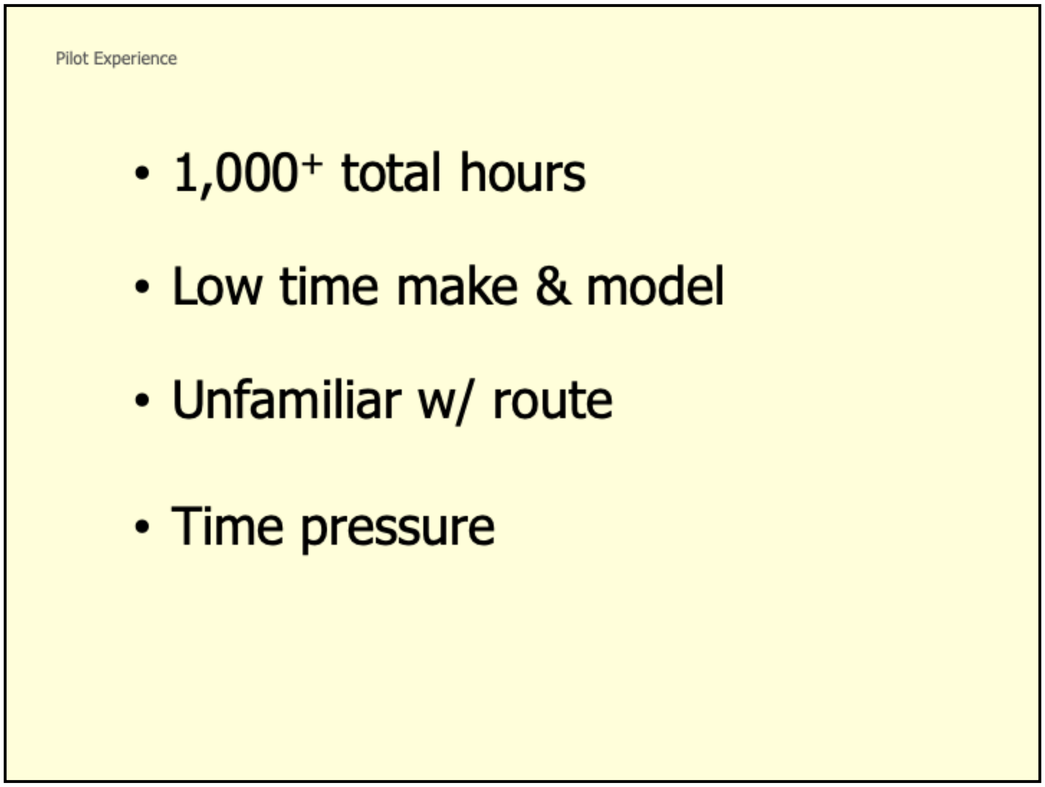
Source: "The Lidle Turn," Paul Bertorelli, Aviation Safety, Dec 2006

Virtual box canyon scenario in MVFR conditions (7 miles visibility)

Operated 500–700' AGL prior to accident

Impacted 520' apartment building at the 333' level while attempting a 180° turn

Pilots fatal; several on the ground injured



Time pressure: last chance, as airplane and pilots heading to CA

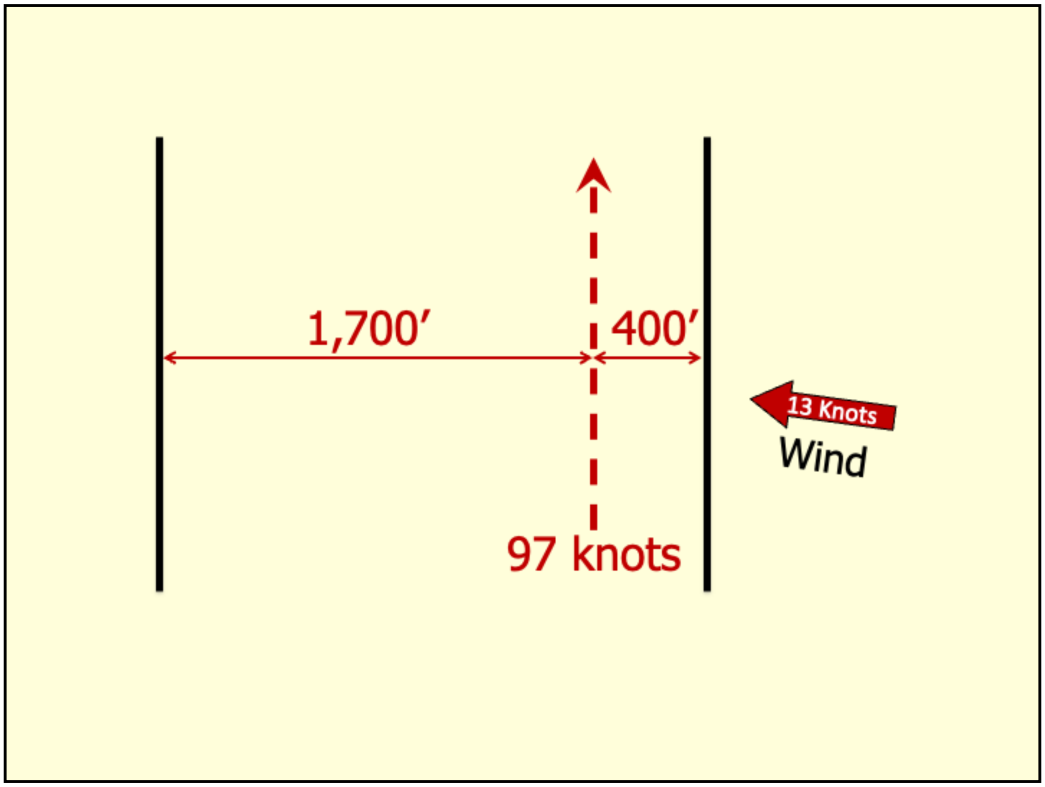
- 2,100’ wide
- 1,100’ MSL cap
- Wall of Class B at terminus

Physical Boundaries

- Water below
- 1,800’ overcast
- High & Low-rise skylines

Other Factors

- Displaced 400’ left
- 13-knot right x-wind
- No other traffic
- “Remain clear of Class B”



400′ ≈ 20% of available width (unknown why the airplane was there)

Left turn was the “expected” maneuver

Inherent bias/native thought process is to frame risk analysis in terms of losses rather than benefits.

We’ll tend to choose an outcome that has less certainty over a more certain outcome, even if the less certain one is higher risk.

Instead, assess options in terms of benefits, not losses.

Also beware of tunnel vision that prevents us from seeing/considering other alternatives.