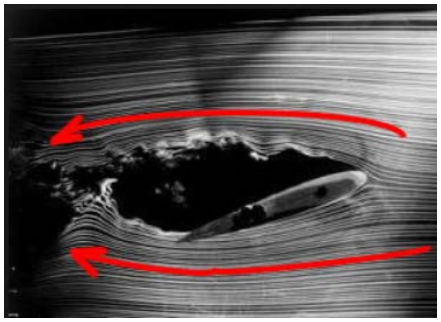
Academic Upset Training

Top Points

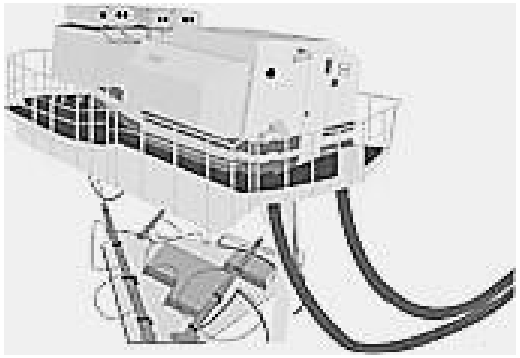
- An ounce of prevention is worth a pound of cure

"I'll have an ounce of prevention"

- 

  Reducing angle-of-attack is THE most important pilot action in an upset event

- Pilot upset training in simulators must account for their limitations



Outline

- Definitions
- Aerodynamics
  - Trim
  - Dihedral effect
  - Speed stability
  - Performance considerations
  - Roll stability

Outline, continued

- Stalls
- Upsets without stall
- Loss of reliable airspeed
- Pilot monitoring
- Instructor operating station

Definitions

- *Upset*:
  - Unintentionally exceeding parameters normally experienced in line operations or training:
    - Pitch > 25 degs nose up or > 10 degs nose down
    - Bank > 45 degs
    - Within above, but at airspeeds inappropriate for the conditions

from Airplane Upset Recovery Training Aid, Ed. 2

Definitions

- Full stall condition – any one, or combination, of the following:
  - A nose-down pitch that cannot be readily arrested, which may be accompanied by an uncommanded rolling motion
  - Buffeting of a magnitude and severity that is a strong and effective deterrent to further increase in angle of attack
  - The pitch control reaches the aft stop for 2 sec and no further increase in pitch attitude occurs when the control is held full aft, which can lead to an excessive descent rate
  - Activation of a stall identification device (e.g., stick pusher)

Adapted from part 25.201

Definitions

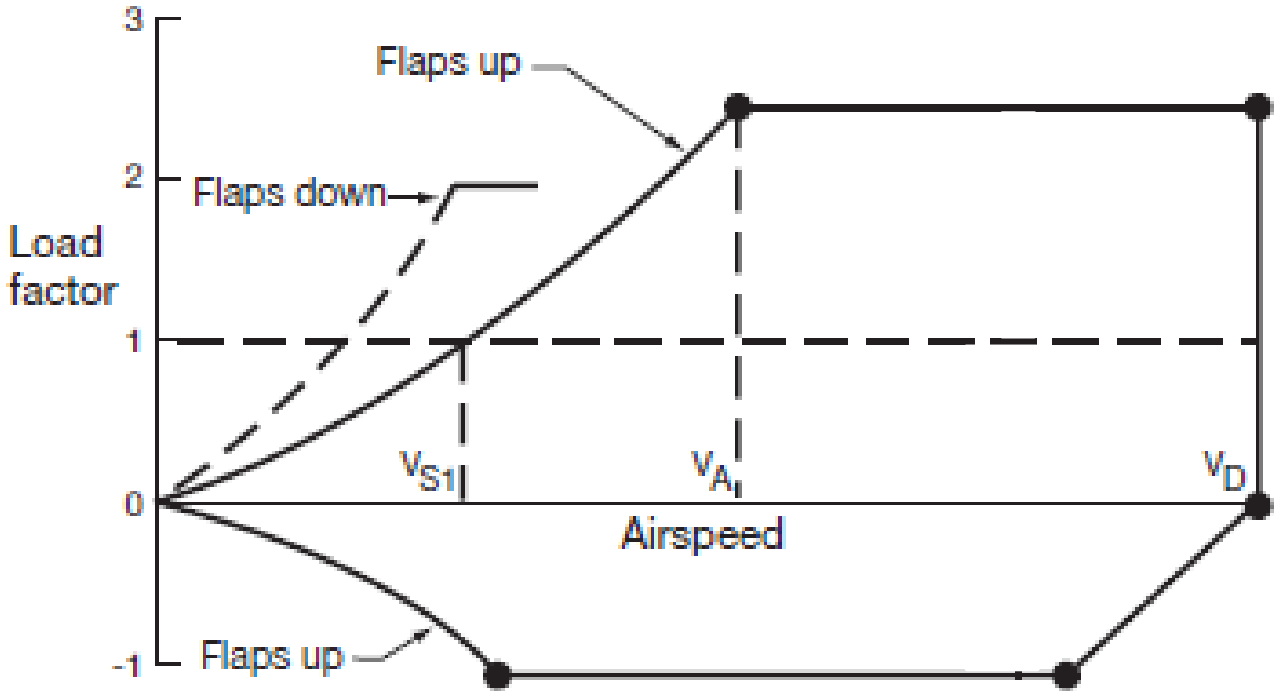
- Stall characteristics
  - must be able to produce, and correct, roll and yaw up to the stall
  - no abnormal pitching
  - for wings level stalls, the amount of roll between stall and completion of recovery < 20 degs
  - for turning stalls, roll during recovery must not be more than
    - 60 degs in direction of turn, or 30 degs in opposite direction, if deceleration is 1 kt/sec or less
    - 90 degs in direction of turn, or 60 degs in opposite direction, if deceleration is more than 1 kt/sec

Adapted from part 25.203

Definitions

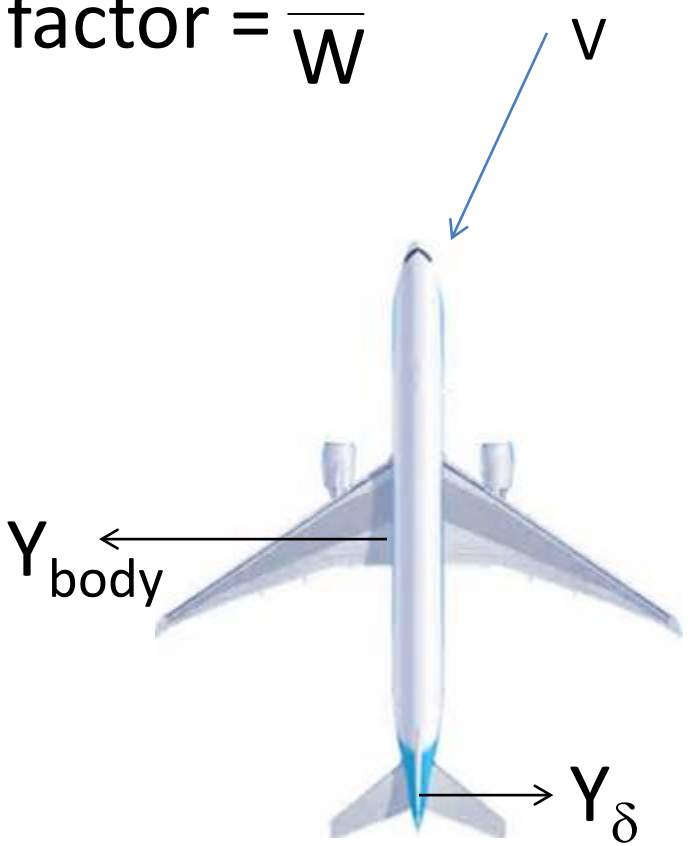
- Extended envelope training
  - Maneuvers and procedures conducted in a simulator that may extend beyond the limits where typical simulator performance and handling qualities have been validated with heavy reliance on flight data to represent the actual aircraft
- Energy State
  - How much kind of energy (kinetic, potential, or chemical) the airplane has at any given time
- Negative transfer of training
  - When knowledge or skills learned in the classroom or in the simulator impede those necessary in the aircraft

Aerodynamics



Aerodynamics

- Lateral load factor = $\frac{Y}{W}$



$$Y = Y_{body} + Y_{\delta}$$

AA587 example

Aerodynamics
Trim

- Nagoya, 1994 – China Airlines #140

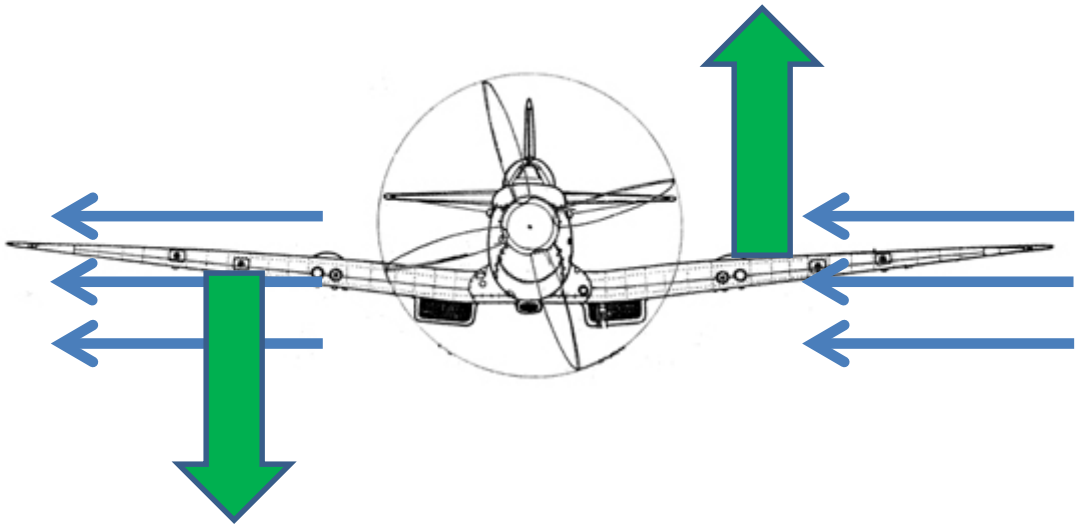
Aerodynamics
Trim

- Nagoya, 1994 – China Airlines #140
- ATR & Saab 340 icing incidents/accidents
- Important to understand potential insidious effects of the trim system in your aircraft
  - will discuss in simulator

Aerodynamics

Dihedral effect

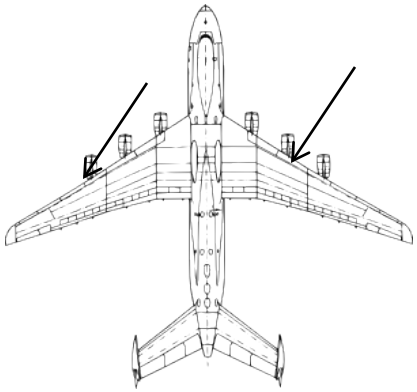
- What is it?



Aerodynamics

Dihedral effect

- Things to know for commercial transports…



Swept wing increases dihedral effect

Aerodynamics

Dihedral effect

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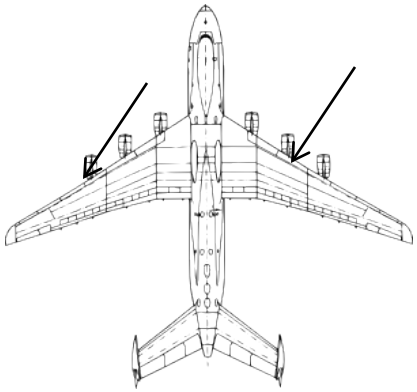
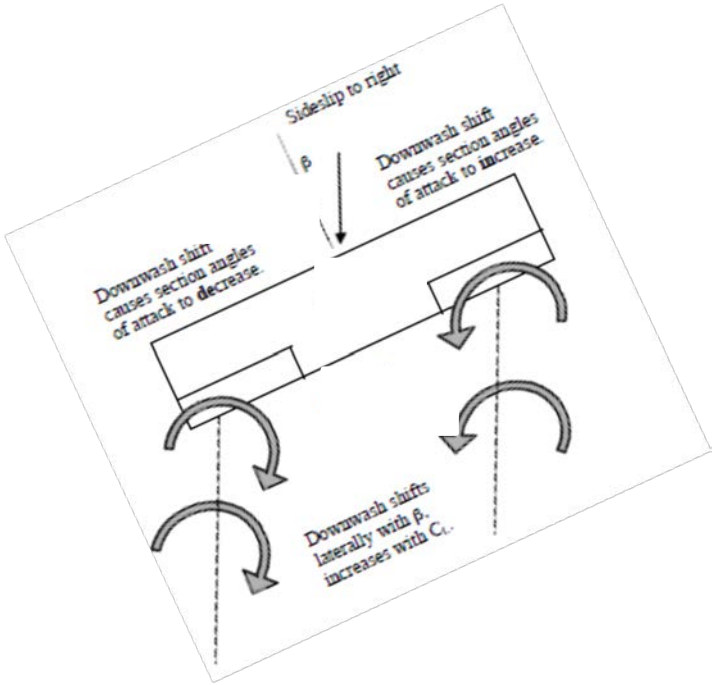


Swept wing increases dihedral effect



Increasing AoA increases dihedral effect

Aerodynamics

Dihedral effect

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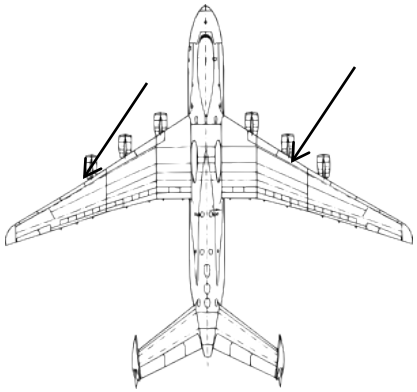

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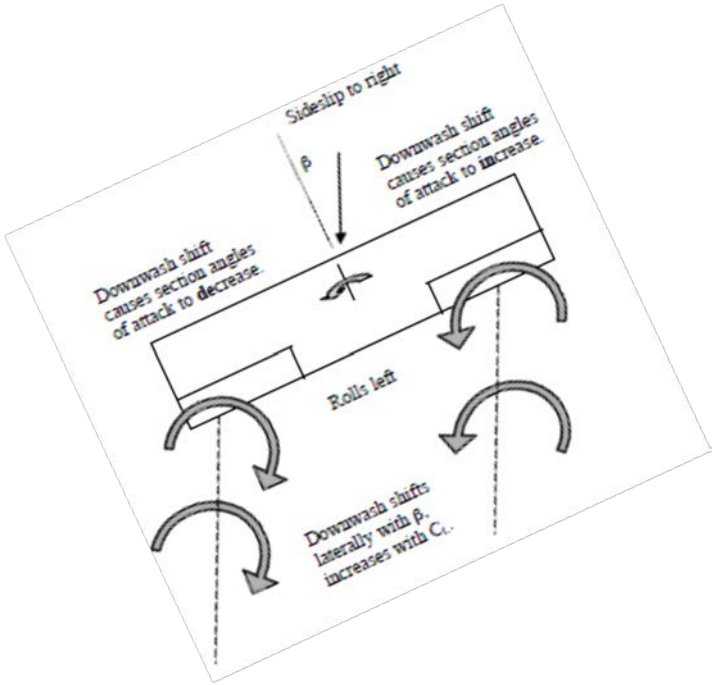


Increasing AoA increases dihedral effect

Once you get it going, it's like a train, it's hard to stop

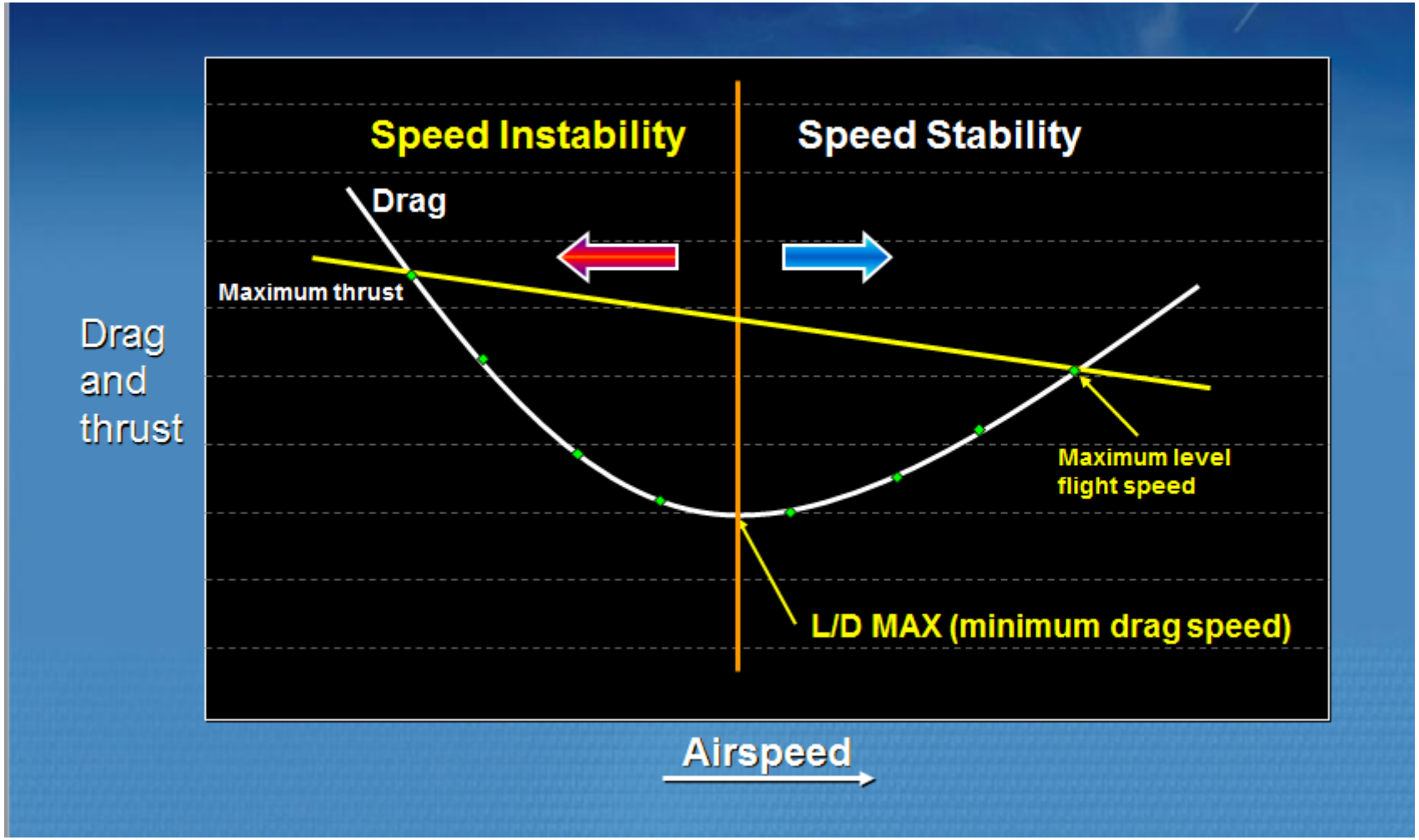
Aerodynamics

Stability

- Tendency to return if moved from trim and released

Aerodynamics

Speed stability



Aerodynamics

Performance considerations

Examples: LNAV **vs.** HDG SEL

15° bank

30° bank

Pilot Tip: When in a turn, the airplane drag may exceed available thrust, and speed decreases.

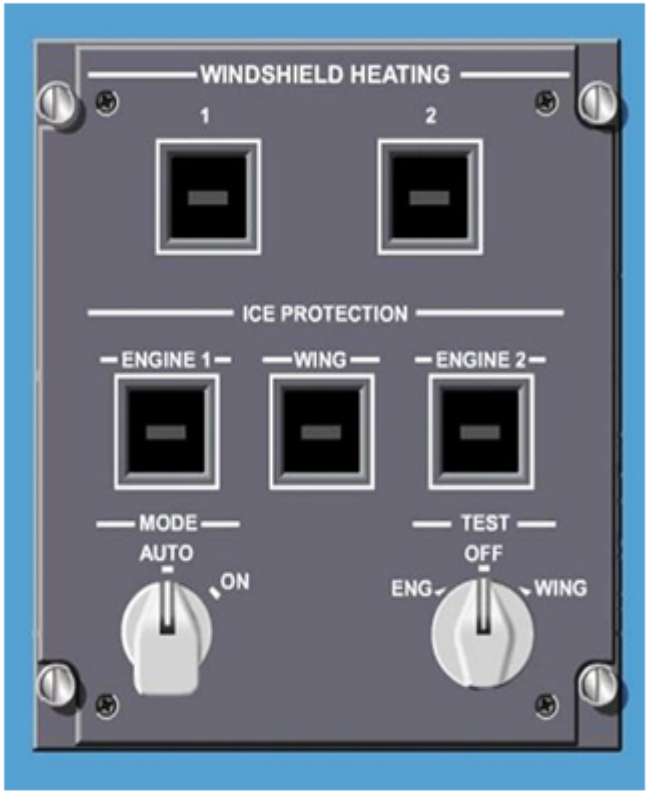
Decelerating the airplane to the minimum normal operating limit may create a situation where it is impossible to maintain altitude.

Aerodynamics

Performance considerations

Pneumatic anti-ice – may result in bleed penalty

- ✈ Negative effect on the ability to recover from decaying airspeed
- ✈ Airplane may not maintain cruise speed or cruise altitude

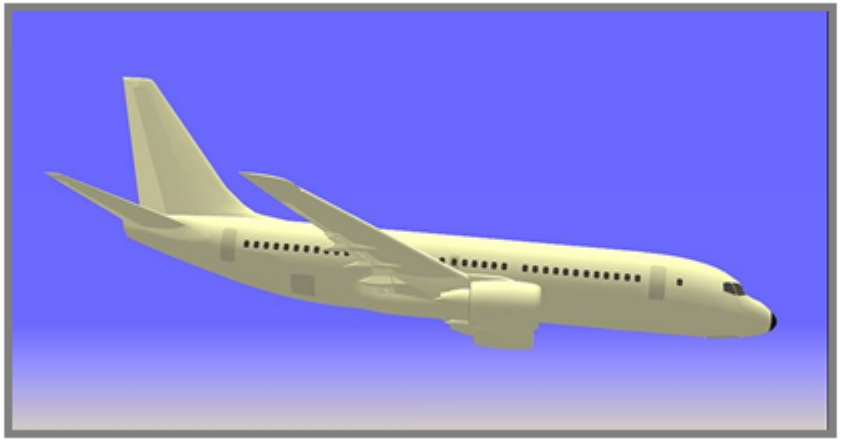


Pilot Tip: **The bleed penalty for anti-ice results in a reduction of available thrust and an increase in specific fuel consumption.**

Aerodynamics
Performance considerations

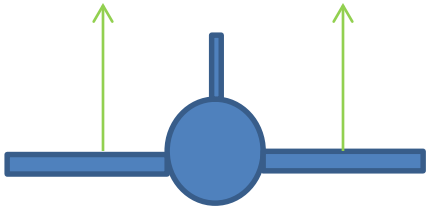
Pilot Tip: If a condition or airspeed decay occurs, take immediate action to recover:

- ✈ Reduce bank angle
- ✈ Increase thrust – select maximum continuous thrust (MCT) if the aircraft is controlling to a lower limit
- ✈ Airspeed continues to deteriorate – Descend

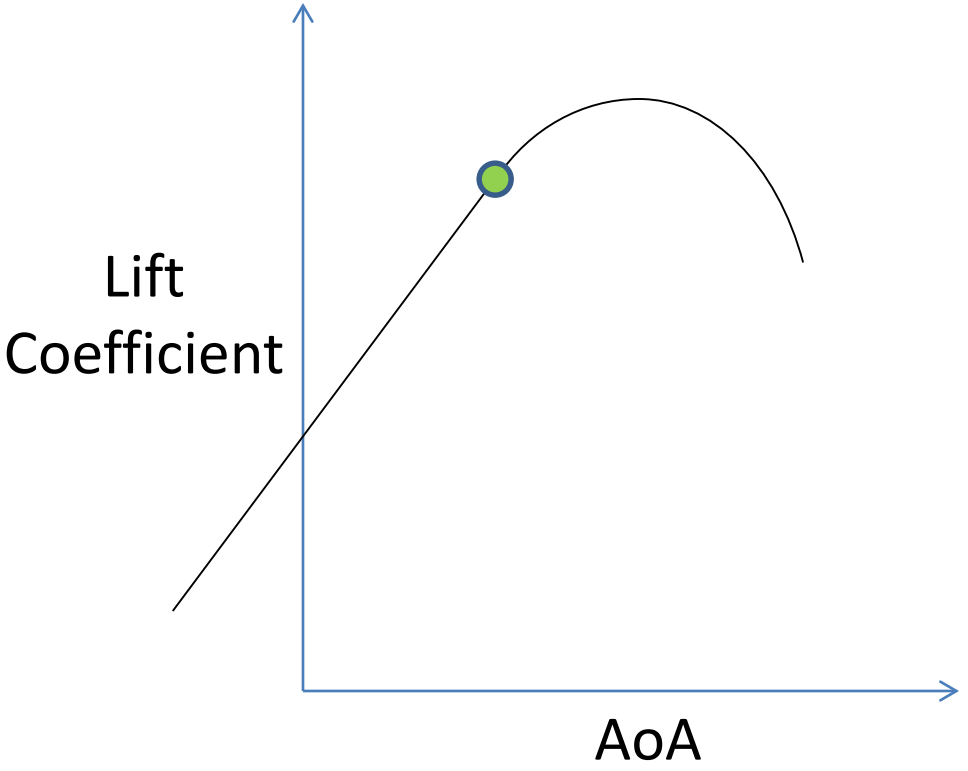


Aerodynamics

Roll stability

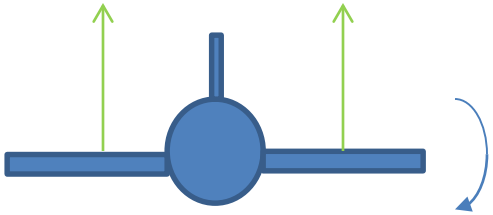


Rear
View



Aerodynamics

Roll stability



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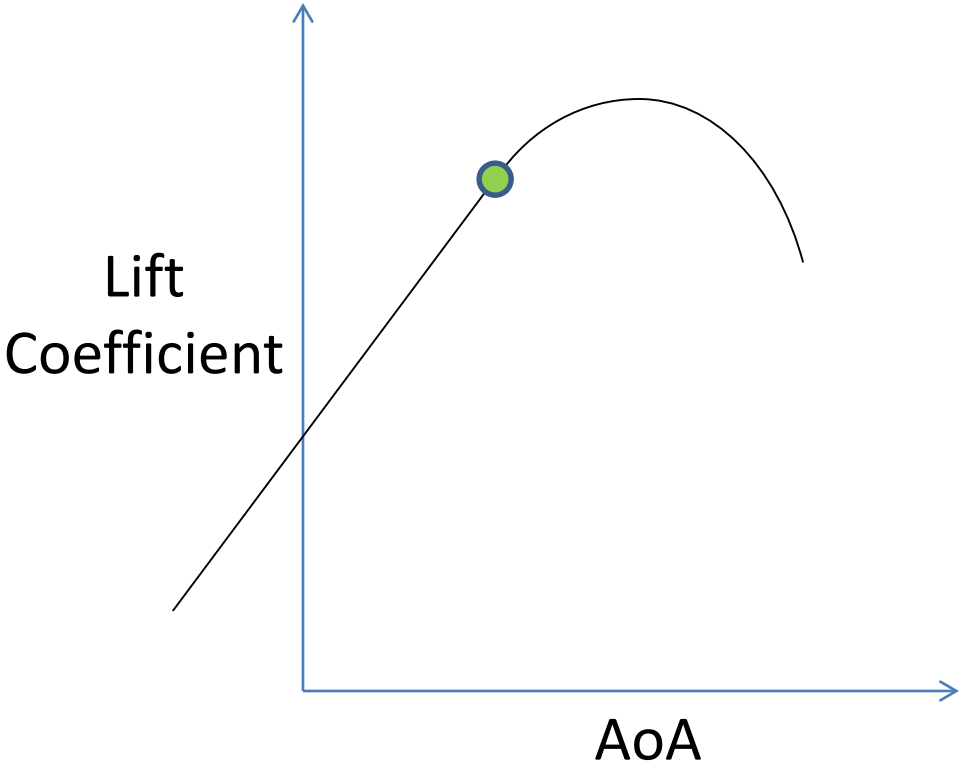

Aerodynamics

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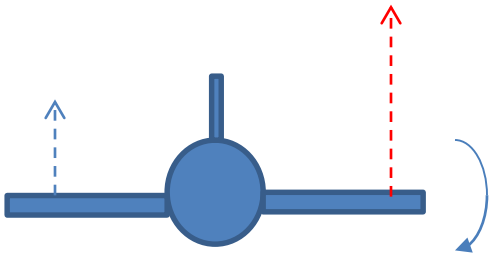

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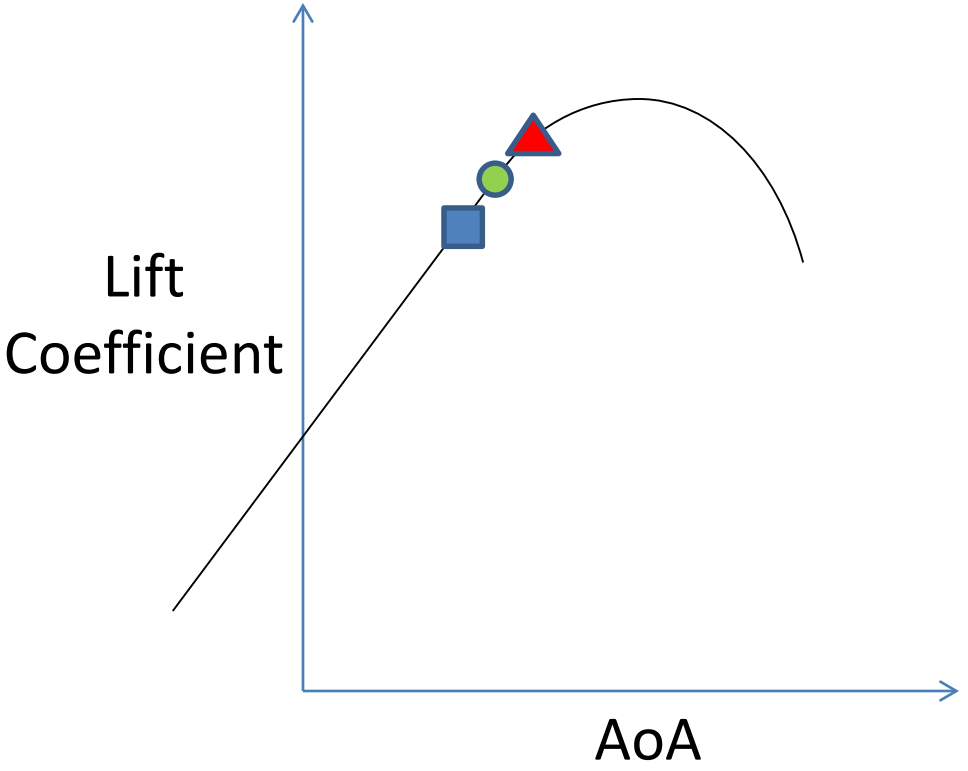

Aerodynamics

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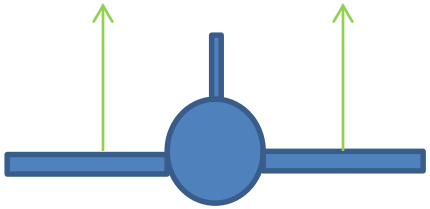

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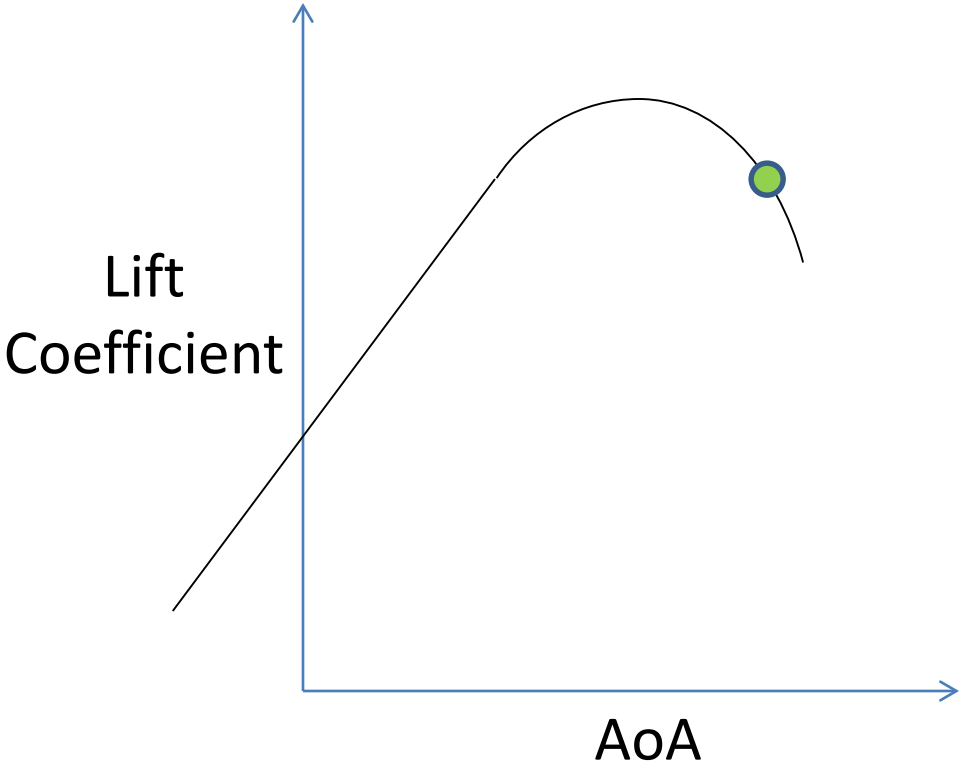

Aerodynamics

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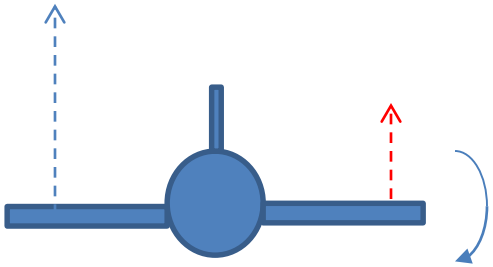

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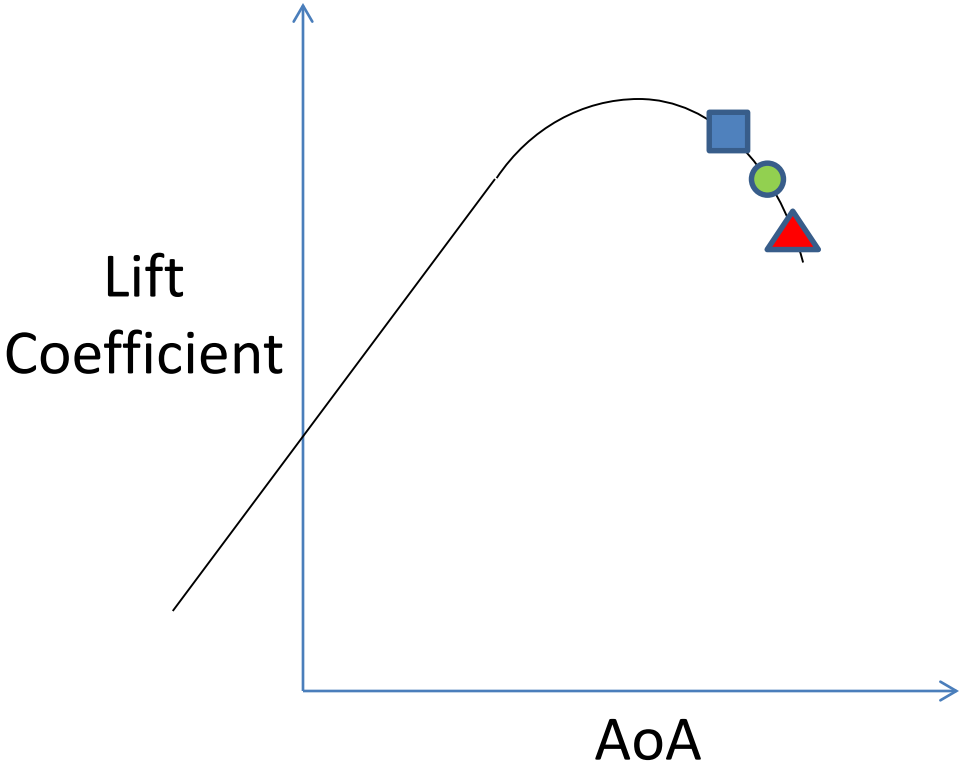

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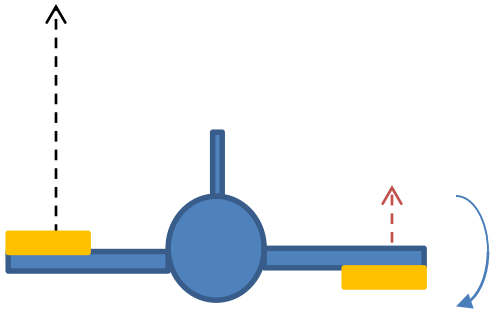

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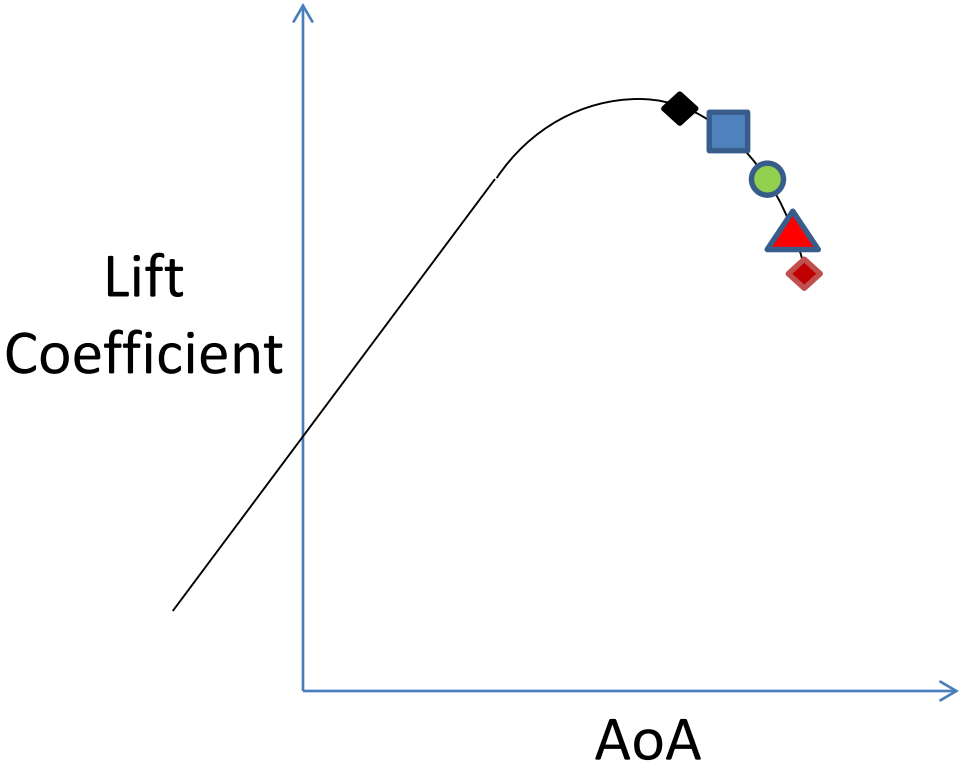
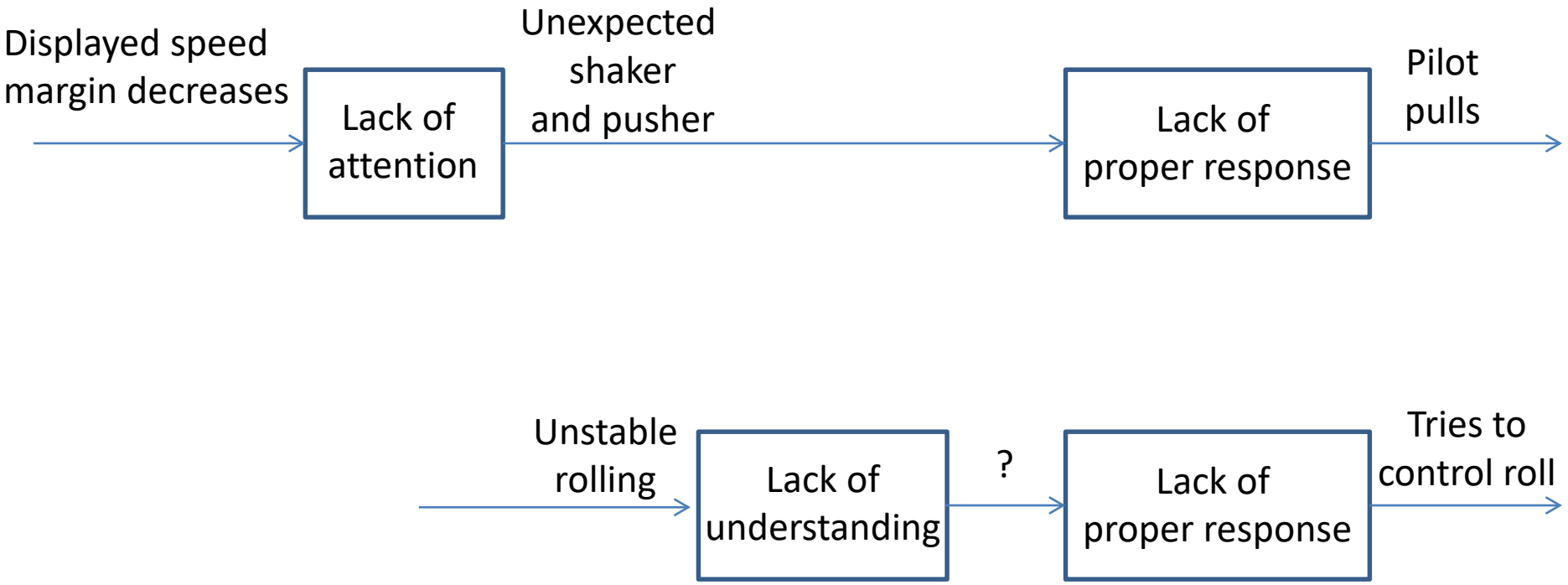


Why?

Colgan 3407



Stalls

- So, are we really stalling airplanes in the U.S.?

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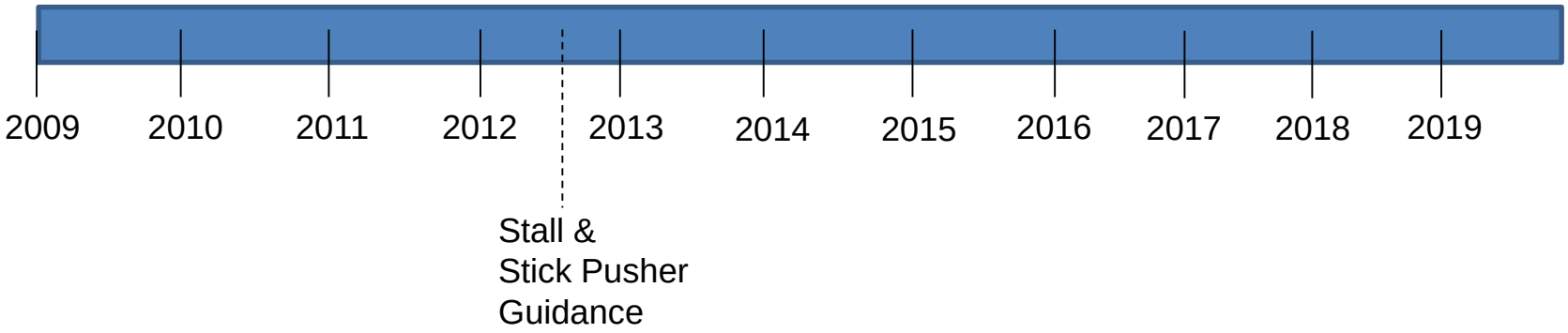
Stalls

So, are U.S. operators stalling airplanes?



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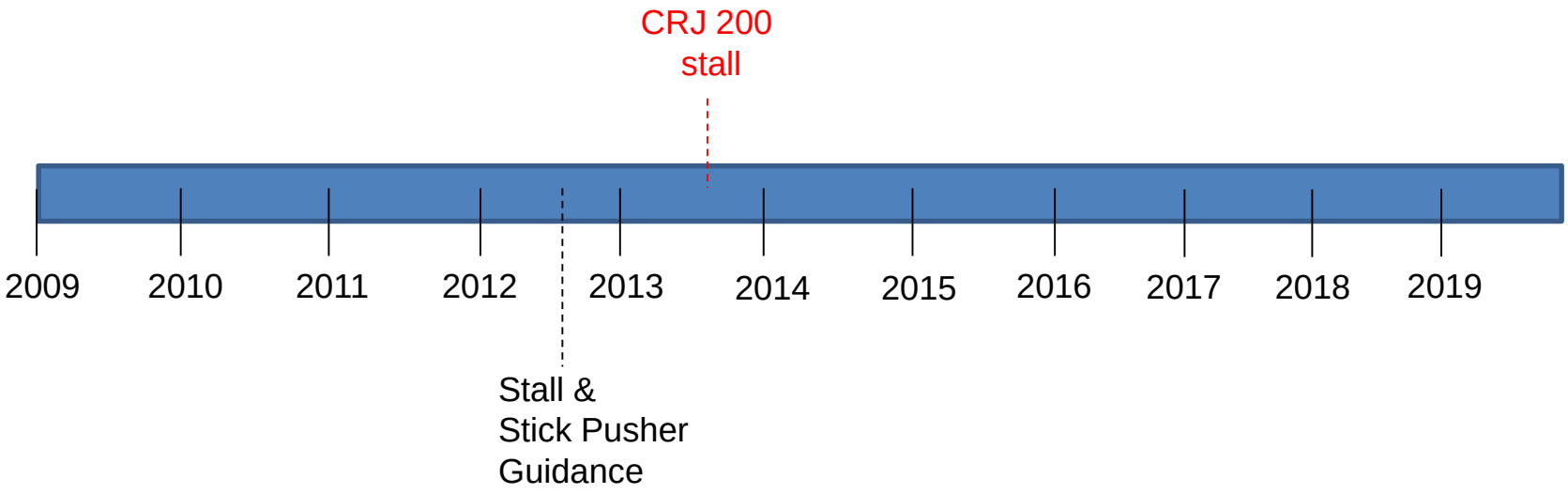

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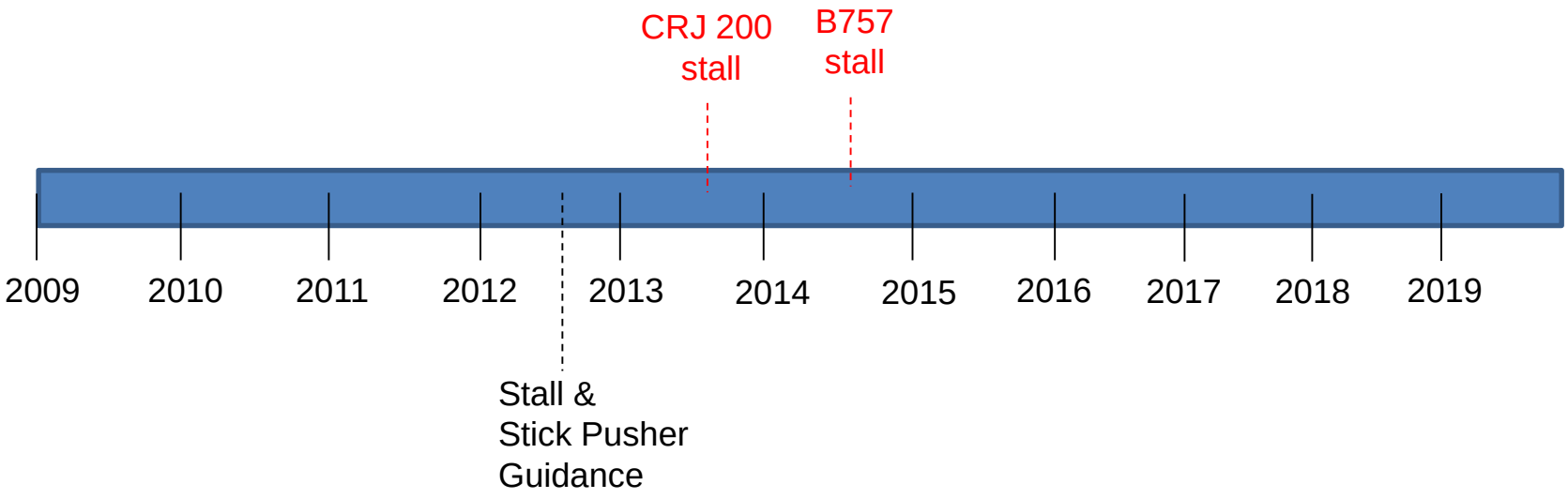

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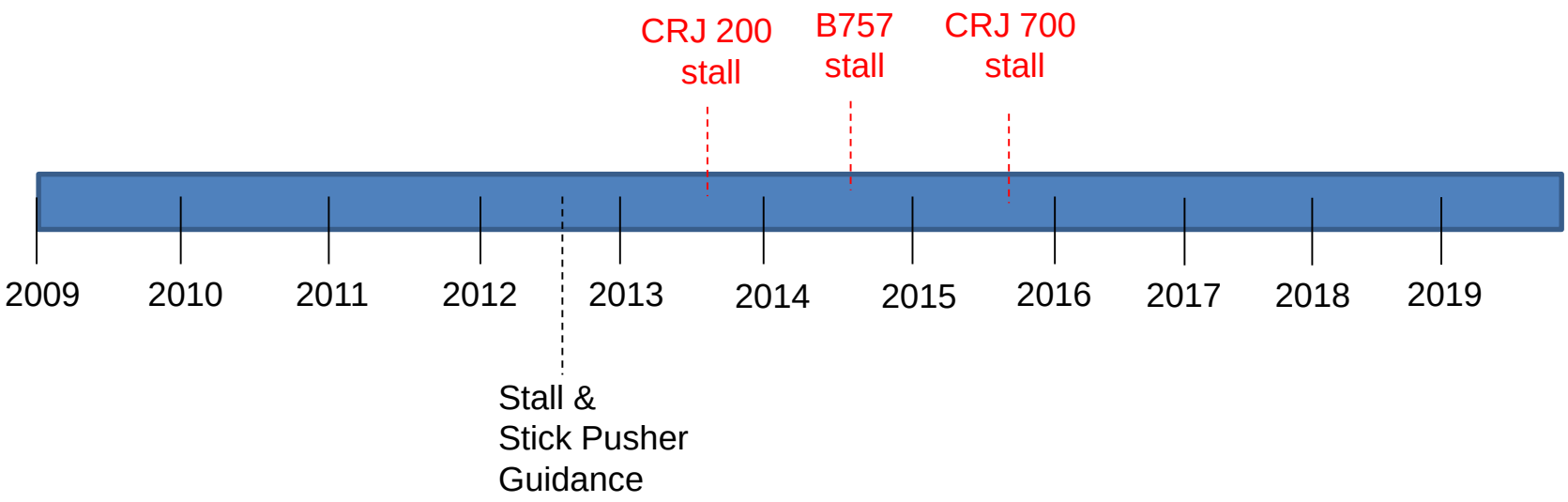
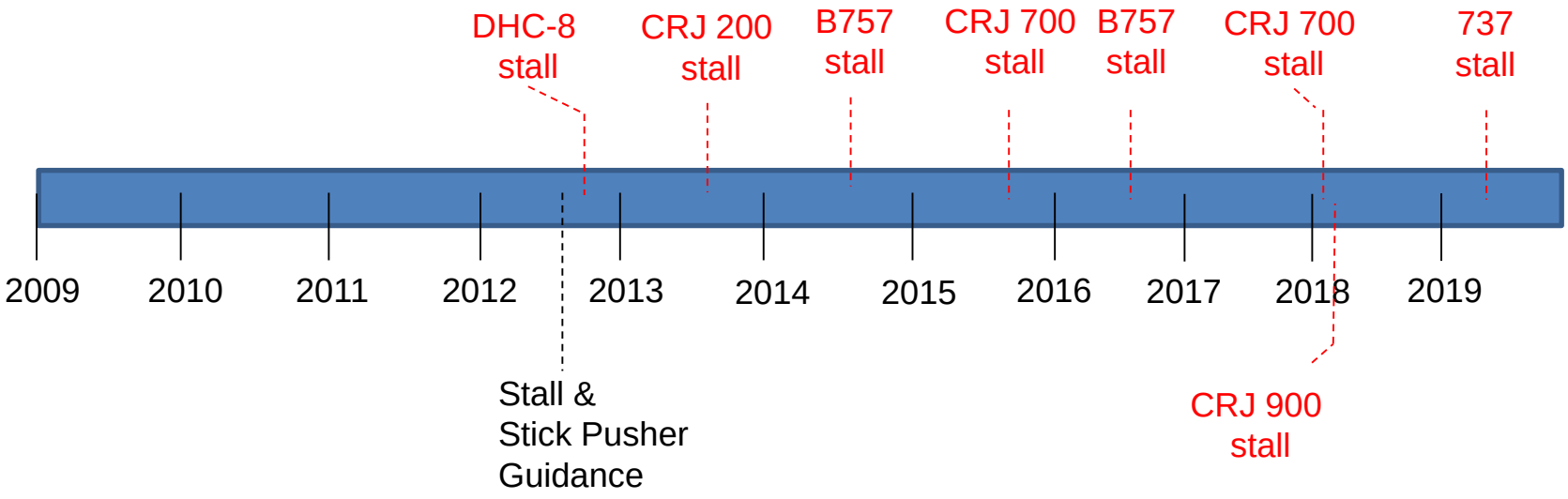
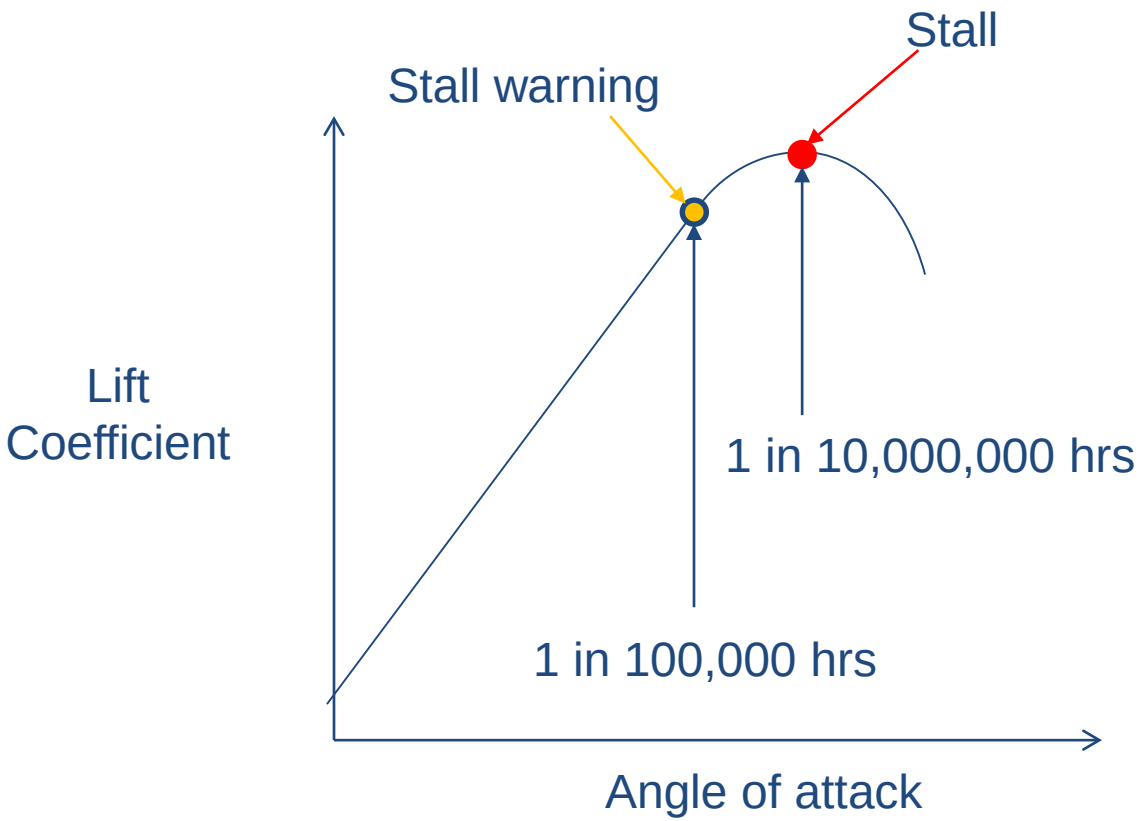


Stalls

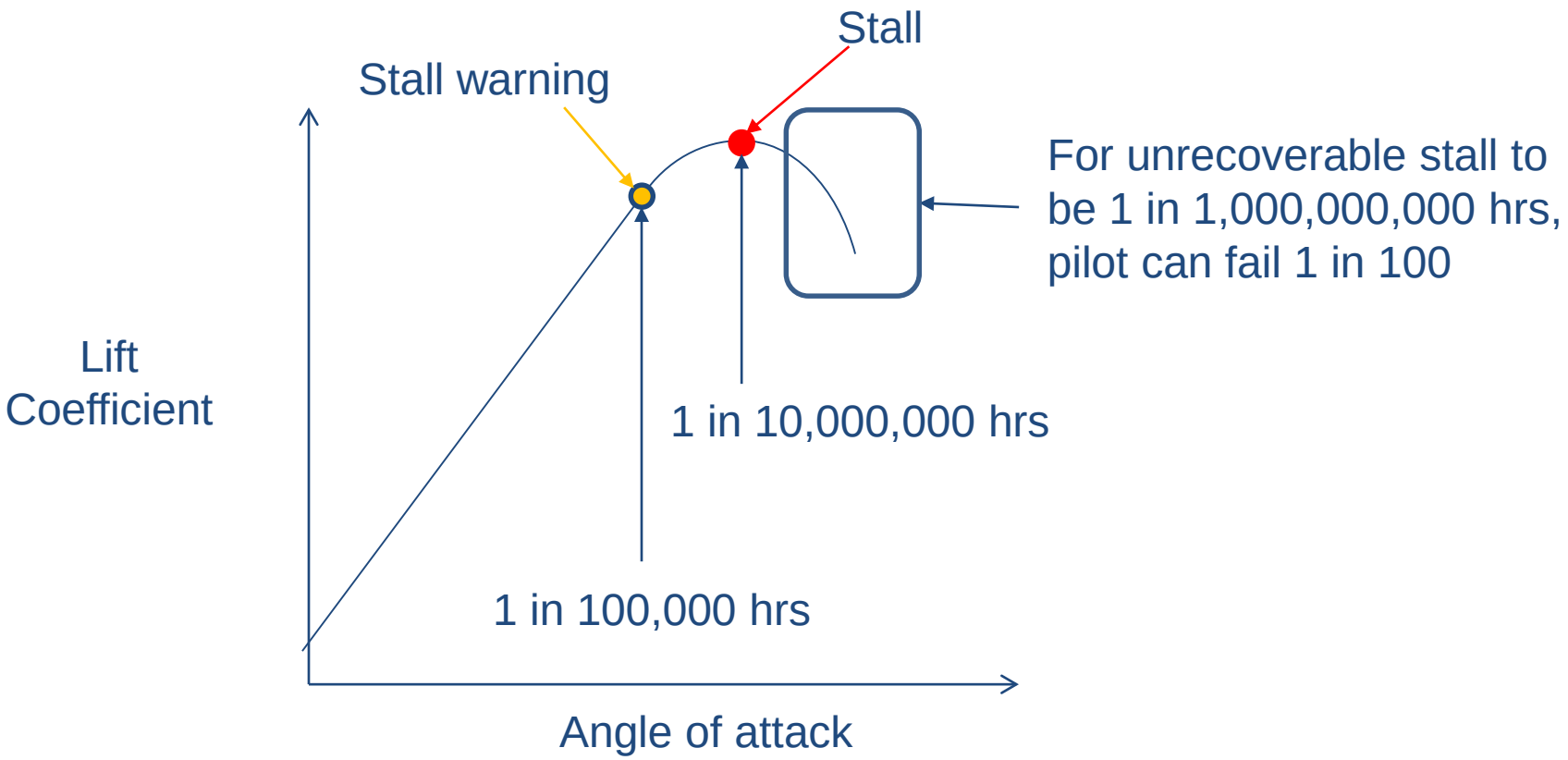
Know of 8 full stalls in part 121 operations
(everyone recovered)
in last 7 years



Frequency of stalls *that I know of* (part 121 operations)



How good does a pilot have to be?



Stalls

- What does a stall fundamentally depend on?
  - Airspeed?
  - Bank angle?
  - Load factor?
  - Altitude?
  - Gross weight?
  - Angle of attack?
  - Mach number?
  - Configuration or contamination (e.g., flap or slat position or ice)?

Stalls

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  - ~~Airspeed~~
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  - ~~Load factor~~
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  - ~~Gross weight~~
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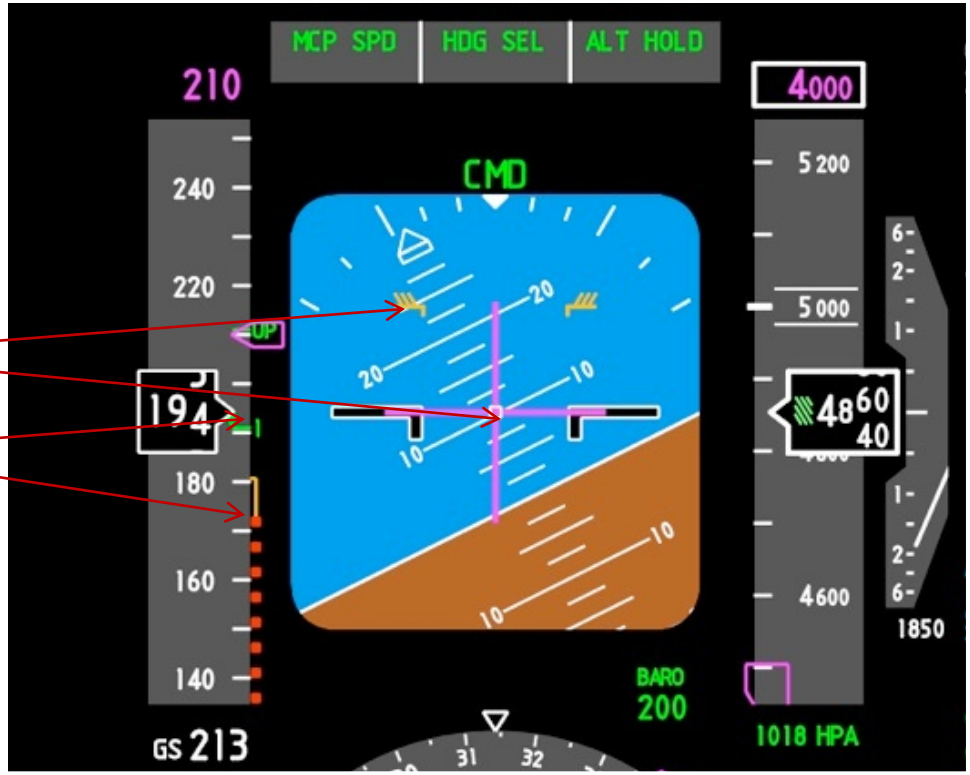
Stalls

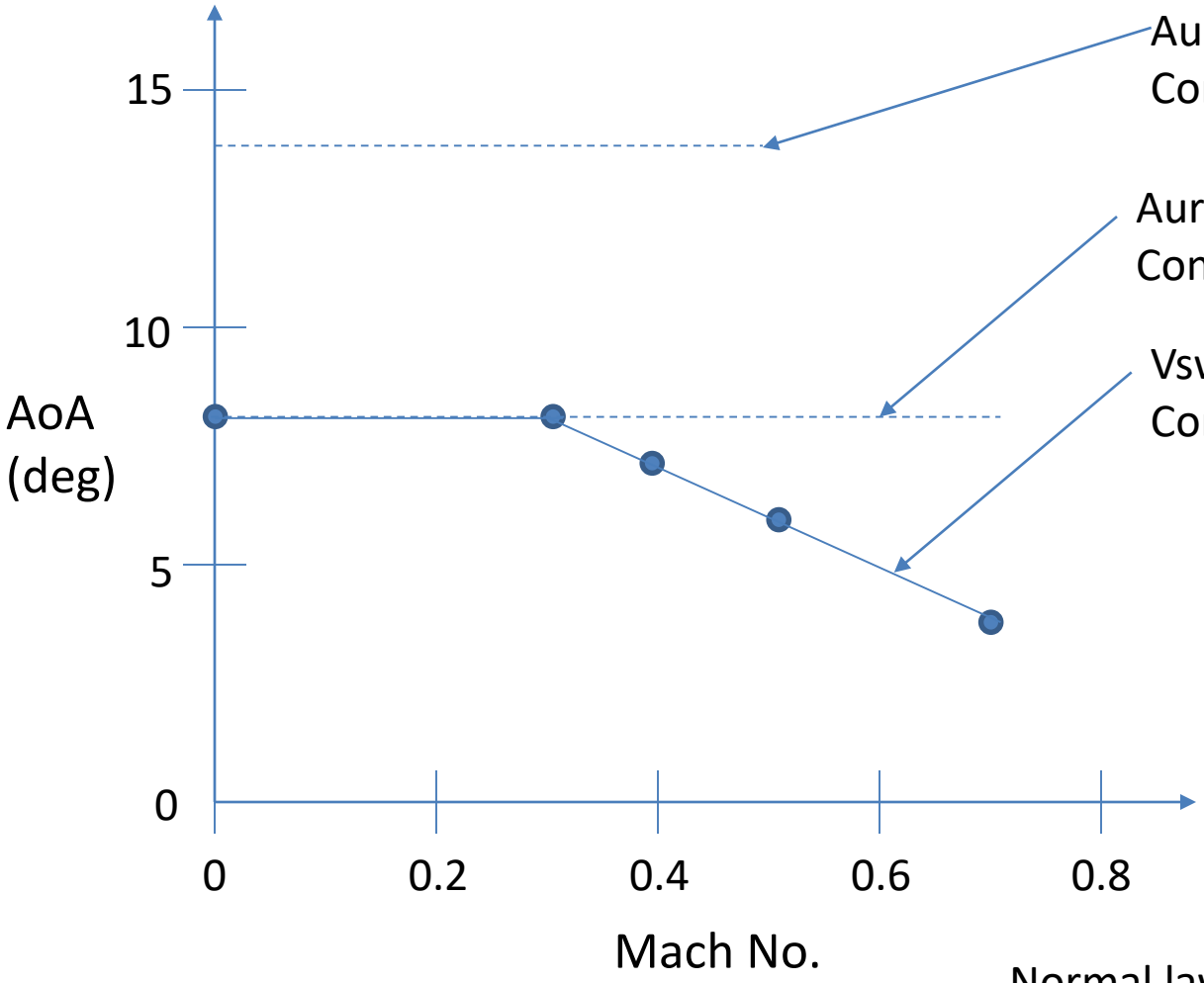
* - can be a little more complicated that this…asymmetric flap and thrust bias (flaps down) and a speedbrake input

Angle of attack margin

AoA margin to stall warning



A320 stall warning



<u>Normal law</u>

Aural stall warning, 23 deg AoA, Conf not 0

Aural stall warning, 15 deg AoA, Conf 0

Stalls

- Physical confusion…
  - Airspeed?
    - Can stall at any speed

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  - Bank angle?
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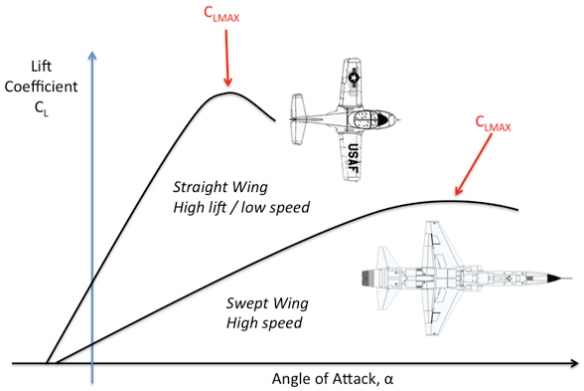
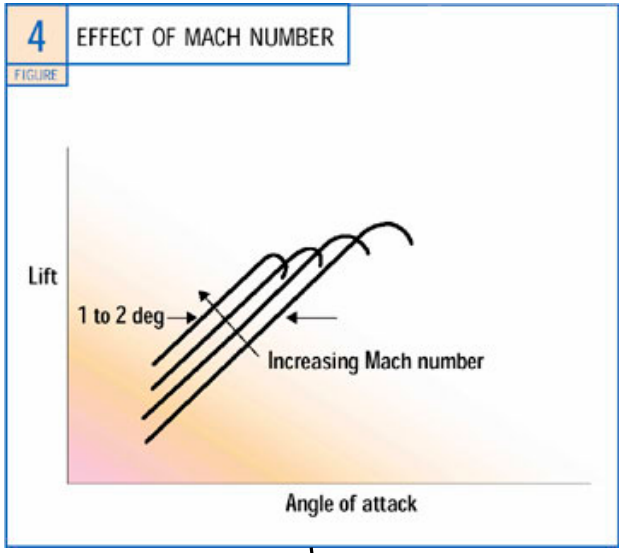
  - Load factor?
    - Can get load factor from both AoA and speed
  - Altitude?
    - Wing does not care what the altitude is
  - Gross weight?
    - Stall speed goes up with weight…but wing stalls at same AoA

Stalls

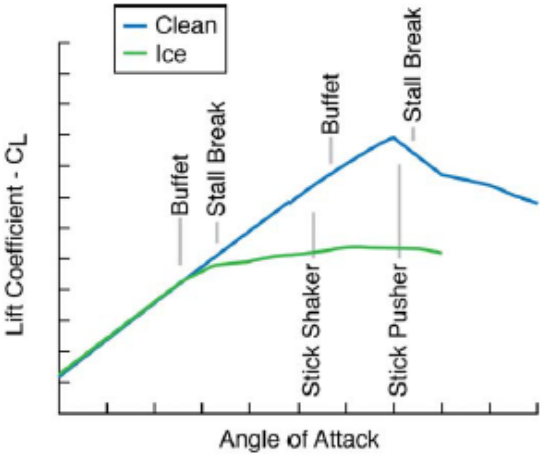
Angle-of-attack

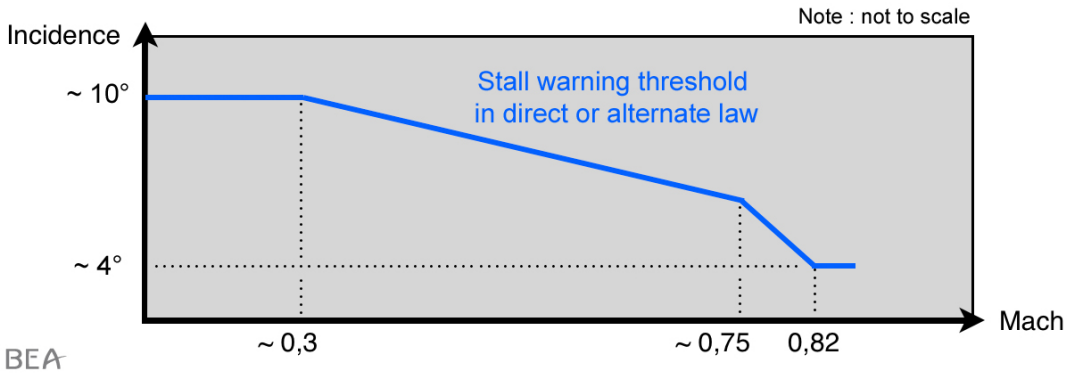


Mach



Configuration or contamination



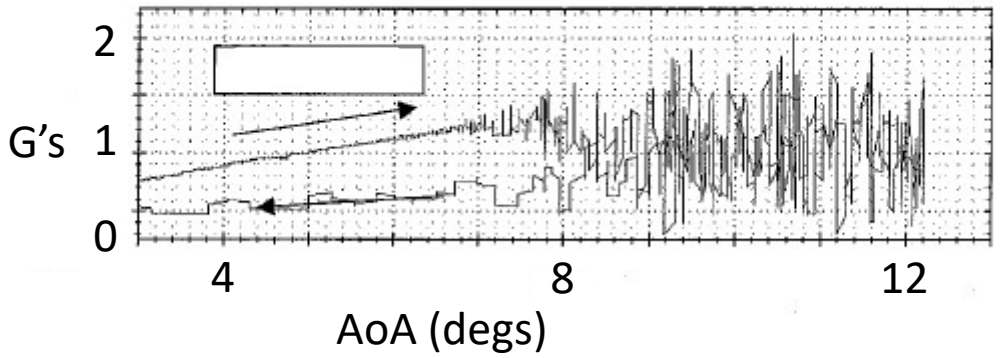


BEA

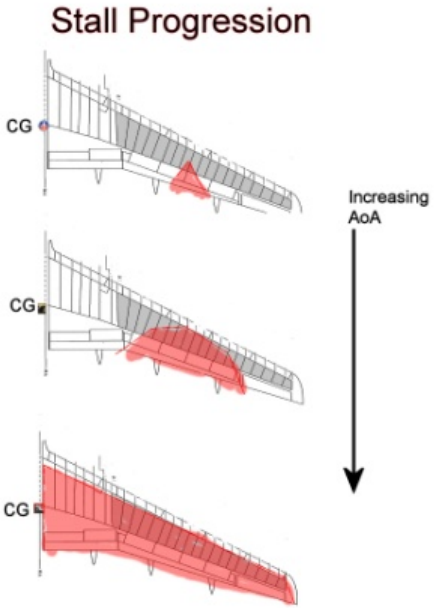
Stalls

Important identification cues…based on earlier stall definition

- Pitch break
- Strong buffet



- Control stop, no more pitch
- Pusher activation



Stalls

Recovery template, abridged

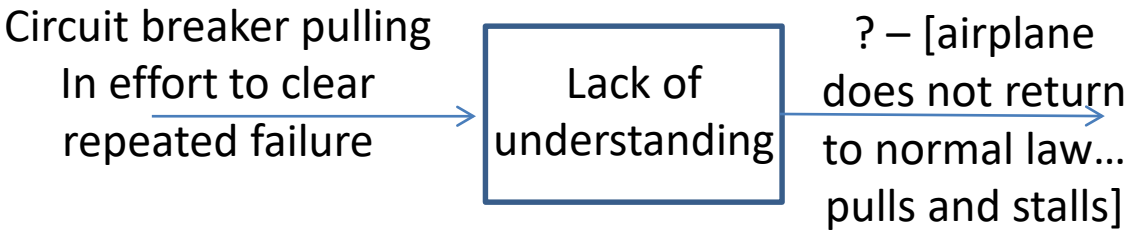
Autopilot and autothrottle	**Disconnect**
Nose down pitch control	**Apply until stall warning eliminated**
Nose-down pitch trim	**As needed**
Bank	**Wings level**
Thrust	**As needed**
Speed brake/spoilers…	**Retract**
Return to desired flightpath	

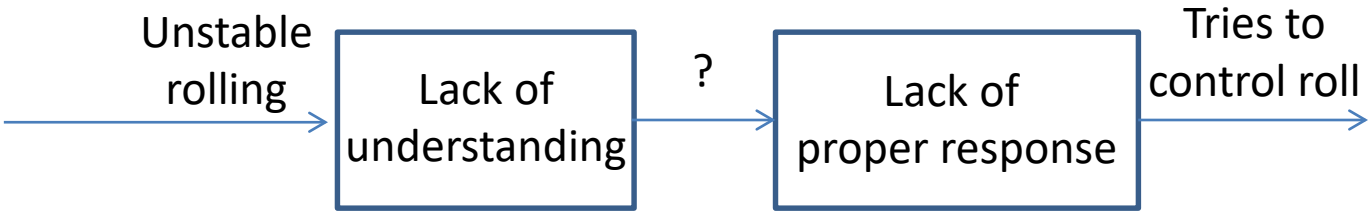
Procedure developed by
Boeing, Airbus, Bombardier, ATR and Embraer

British Airways #38, Jan. 2008

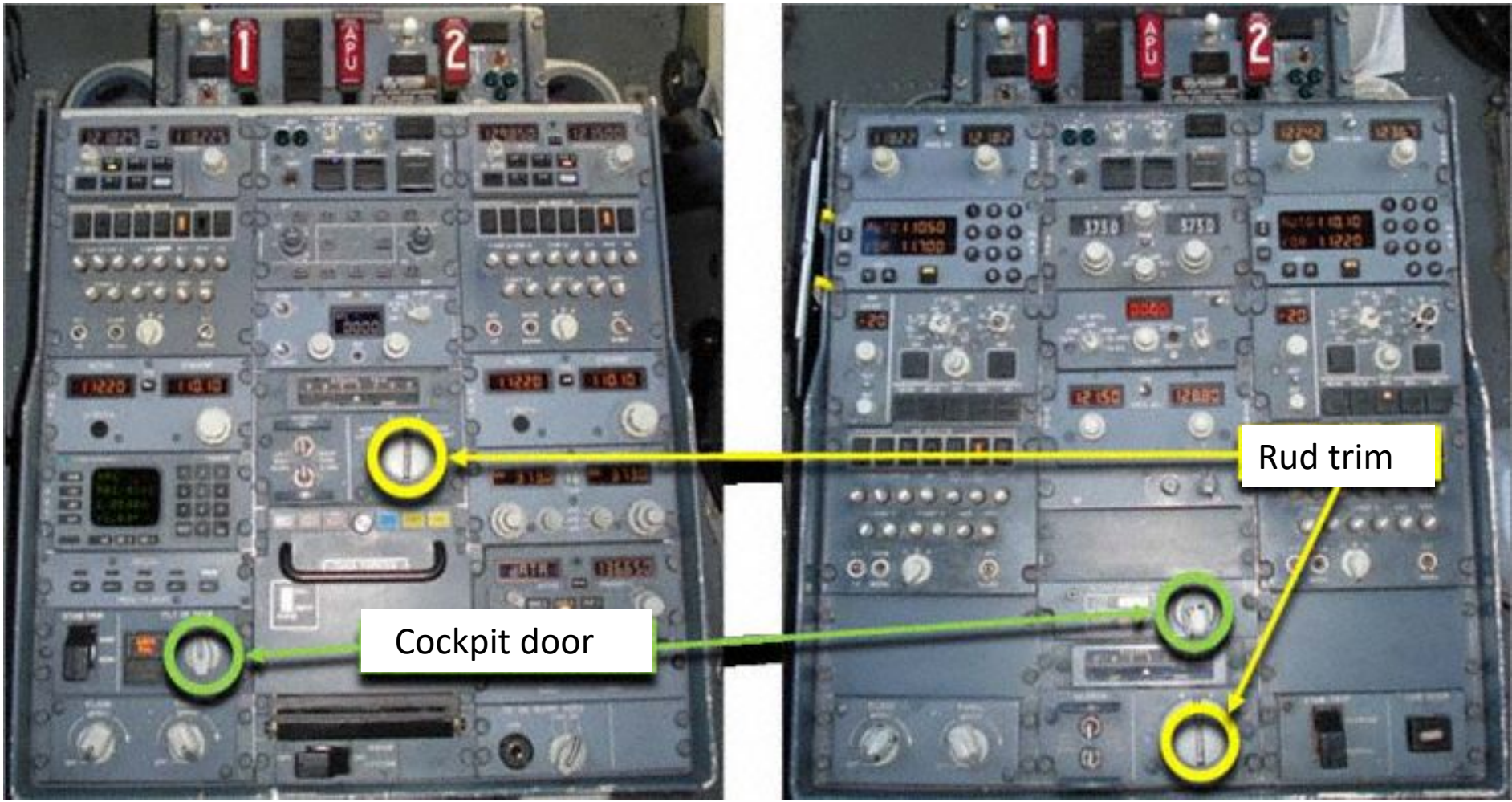
Why?

Air Asia 8501





Upsets without stall



B737-700

B737-500

Upsets without stall

Recovery techniques

- Troubleshooting the cause is secondary to initiating the recovery
- Crew communication between assists in recovery actions
- Use primary and performance instruments when analyzing situation

Upsets without stall

Recovery techniques

- Analysis process is
  - Communicate with crew members
  - Locate the bank indicator
  - Determine pitch attitude
  - Confirm attitude by reference to other indicators
  - Assess the energy

Upsets without stall

Recovery techniques

- Nose-high, wings-level recovery technique #1a
  - A/P and A/T disengage
  - Apply nose-down elevator to achieve nose-down pitch rate…may require full nose-down input (not normally necessary to go below 0g)
- Nose-high, wings-level recovery technique #1b
  - A/P and A/T disengage
  - Apply nose-down elevator AND trim to achieve nose-down pitch rate…may require full nose-down input (not normally necessary to go below 0g)
- Nose-high, wings-level recovery technique #2
  - A/P and A/T disengage
  - For under-wing-mounted engines, reduce thrust until nose-down pitch rate is achieved

Upsets without stall

Recovery techniques

- Nose-high, wings-level recovery technique #3
  - A/P and A/T disengage
  - Bank to establish nose-down pitch rate
    - Between 30 to 60 degs bank should be sufficient
    - Avoid bank angles greater than 60 degs
- Be aware of simulator limitations

Upsets without stall

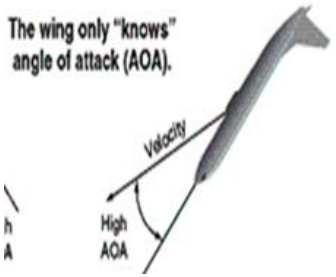
Recovery techniques

- Nose-low, banked recovery technique
  - A/P and A/T disengage
  - **Push**…unload to relieve excessive positive load
  - Roll to approaching wings level
  - Apply nose-up elevator; trim as necessary
  - Adjust thrust and drag as necessary
- Target pitch rate using pitch-limit-indicator (if available), or approximately takeoff rotation rate

Upsets without stall

Recovery techniques

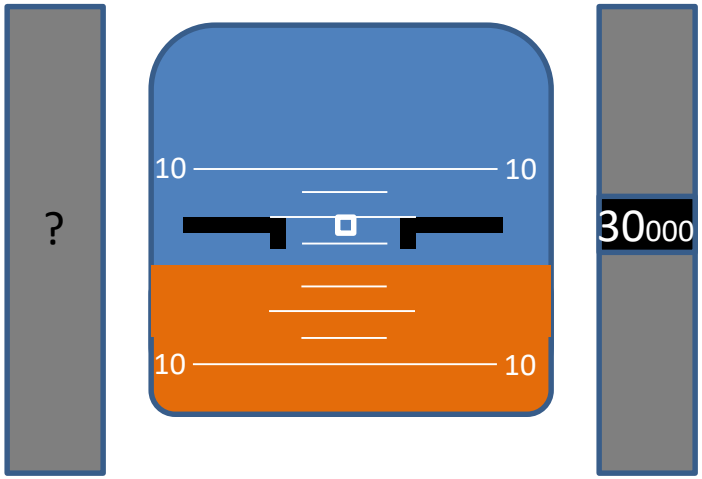
- High bank angle/inverted flight
  - NOTE: The maneuver is controversial due to its unlikelihood. However, it reinforces useful principles of AoA. Key is to unload then roll.
  - A/P and A/T disengage
  - **Push**…unload to relieve excessive positive load
  - **Roll** to nearest horizon
  - When approaching wings level, **pull** by applying nose-up elevator and trim as necessary
  - Adjust **thrust** and drag as necessary
- Again, guide pitch rate with either PLI, if available, or takeoff rotation rate to stay within g-limits (unless ground contact is imminent)



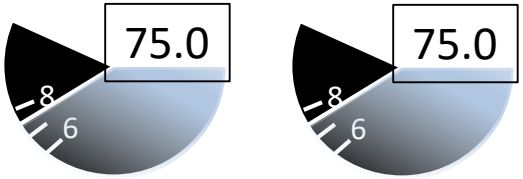
Question

- You are flying a B737. Flaps are up. Airspeed is unreliable.

Pitch attitude = 4 degs



Both engines = 75% N1



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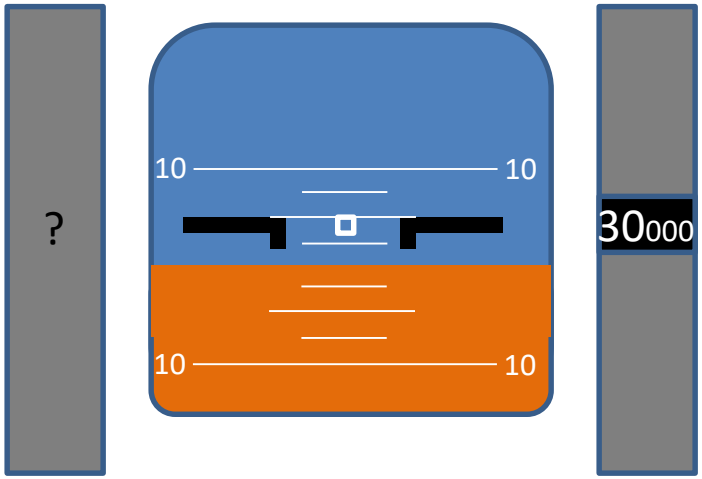

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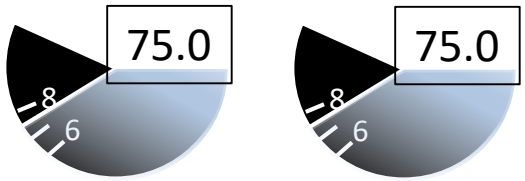


Are you in safe flight?

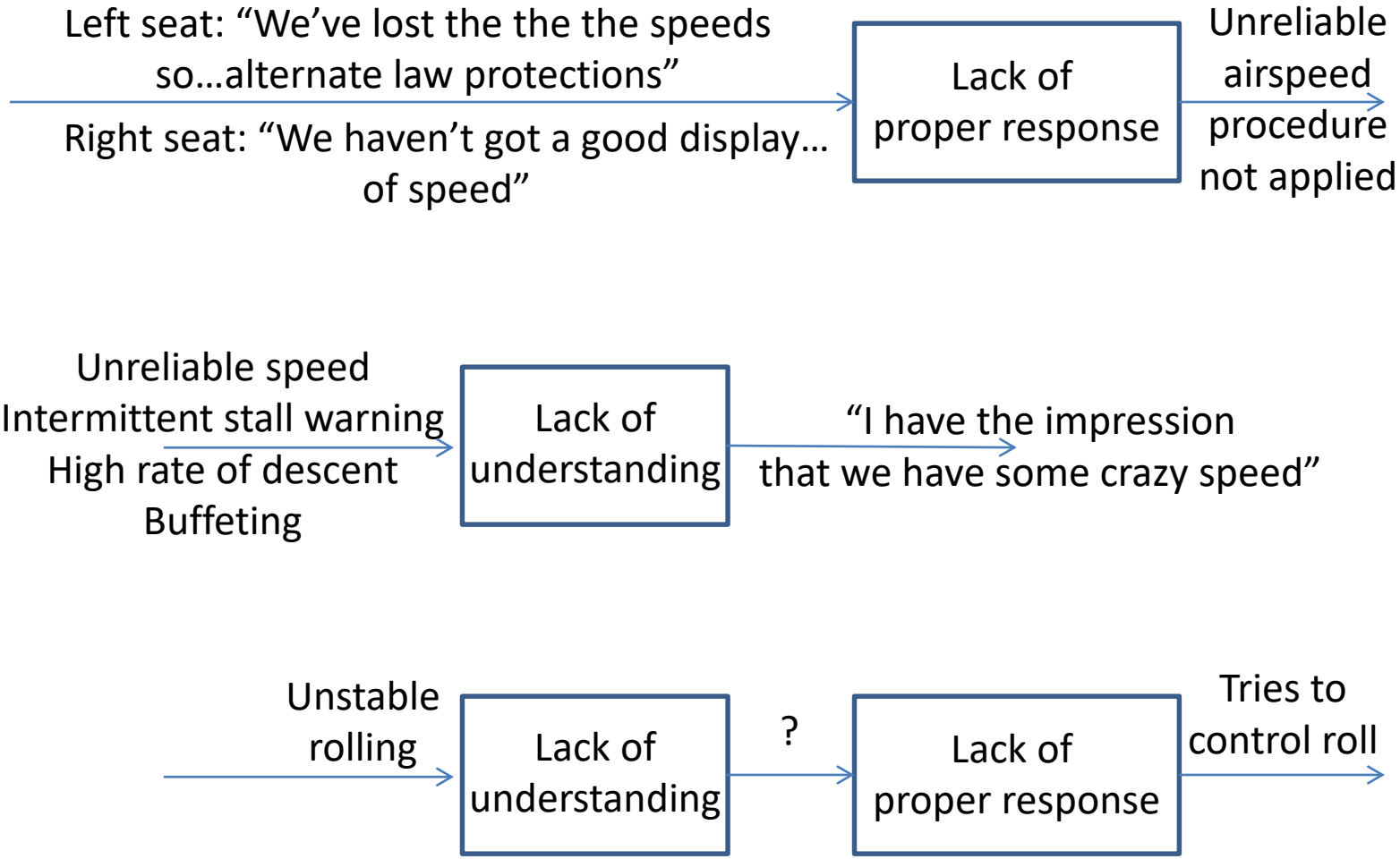
Loss of reliable airspeed—AF447

UTC 2:10:15 – Right seat says "We haven't got a good display of speed"
UTC 2:10:22 – Left seat says "Alternate law protections"
UTC 2:10:27,28 Left seat says "Watch your speed, watch your speed"
UTC 2:10:33 – Left seat says "According to all three you are going up so go back down" Right seat "okay"
UTC 2:10:51 – First stall warning
UTC 2:10:56 – Right seat calls and goes to TOGA [Airplane does not have available thrust to help at this point]
UTC 2:11:21 – Left seat says "But we've got the engines what's happening?"
UTC 2:11:32 – Right seat says "I don't have control of the airplane anymore now"
UTC 2:11:41 – Right seat says "I have the impression we have the speed"
UTC 2:11:42 – Captain enters and says "Er what are you doing?"
UTC 2:11:46 – Left seat says "We lost all control of the aeroplane we don't understand anything we've tried everything"
UTC 2:12:04 – Right seat says "I have the impression that we have some crazy speed no what do you think?"
UTC 2:12:07 – Left seat says "No above all don't extend" Right seat says ok
UTC 2:12:23 – Captain says "The wings to flat horizon the standby horizon"
UTC 2:12:32 – Captain says "No you climb there you are climbing"…perhaps he is referring to pitch attitude
UTC 2:12:43 – Captain says "it's impossible"
UTC 2:12:48 – Right seat says "Yeah yeah yeah I'm going down no?"
UTC 2:12:54, 56: Captain says "Get the wings horizontal" Right seat says "That's what I am trying to do"
UTC 2:12:58: Right seat says "I am at the limit with the roll"…then dual input
UTC 2:13:38: Captain says "careful with the rudder bar there"
UTC 2:13:39: Left seat says "Climb climb climb climb"
UTC 2:13:40-41: Right seat says "But I've been at maxi nose up for awhile"
UTC 2:13:42: Captain says "No no no don't climb"
UTC 2:13:43: Left seat says "so go down"
UTC 2:13:45: Left seat says "so give me the controls the control to me controls to me"
UTC 2:14:05: Captain says "watch out you are pitching up there"
UTC 2:14:06: Captain says "you are pitching up" Left seat says "I'm pitching up" Right seat says "Well we need to we are at four thousand feet:

UTC 2:14:16,17: They get "sink rate and pull up"
UTC 2:14:18: Captain says "Go on pull"
UTC 2:14:23: Right seat says "We're going to crash. This can't be true"
UTC 2:14:26: Captain says "10° pitch attitude"

Why?

Air France 447



Pilot monitoring

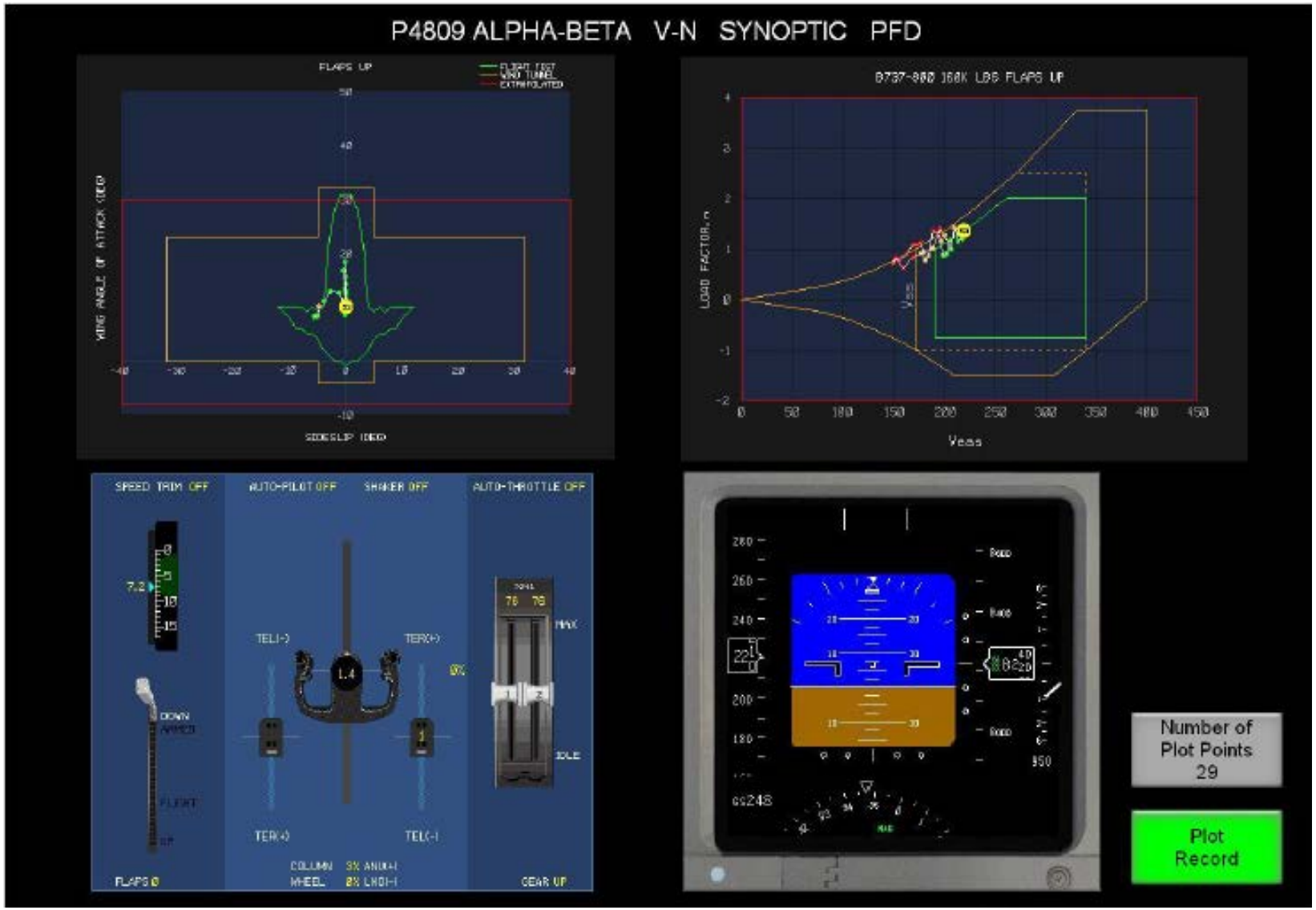
See

1. *"Standard Operating Procedures and Pilot Monitoring Duties for Flight Deck Crewmembers" Advisory Circular 120-71B*
2. *"Monitoring Matters" CAA Paper 2013/02*
3. *"A Practical Guide for Improving Flight Path Monitoring" Flight Safety Foundation*

Instructor training

- By law, instructors need additional training…this is the guidance
- From Upset Prevention and Recovery Advisory Circular
  - Limitations of simulator (part 121.414)
  - Instructor operating station
  - History of events
  - Energy management
  - Spatial disorientation
  - Distraction
  - Recognition and recovery strategies
  - Recognition and correction of pilot errors
  - Type-specific characteristics
  - OEM recommendations
  - Operating environment
  - Startle and surprise
  - Assessing proficiency

Instructor operating station



Simulator limitations

- Need to stay within valid training envelope
- G cues are seriously lacking

Startle/surprise

- What's the difference? Does anyone really care?
- **star•tle:** An uncontrollable, automatic muscle reflex, raised heart rate, blood pressure, etc., elicited by exposure to a sudden, intense event that violates a pilot's expectations
  - Example: BAM! You wince, and maybe cower, after a bird hits your windshield
- **sur•prise:** An unexpected event that violates a pilot's expectations and can affect mental processes used to respond to the event
  - Example: The "what's it doing now" question for your autopilot
- So, startle can lead to surprise, but it does not have to
- You can have surprise without startle

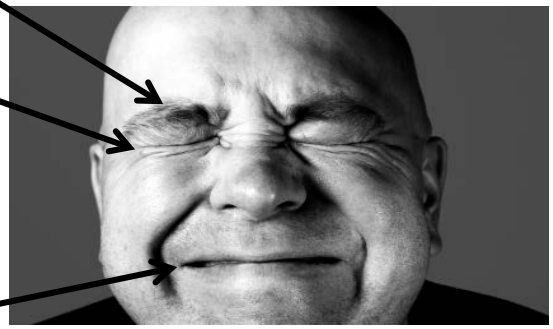
Startle/surprise

Startle

Eyebrows lowered

Eye-lids tightened and closed

Lips stretched horizontally

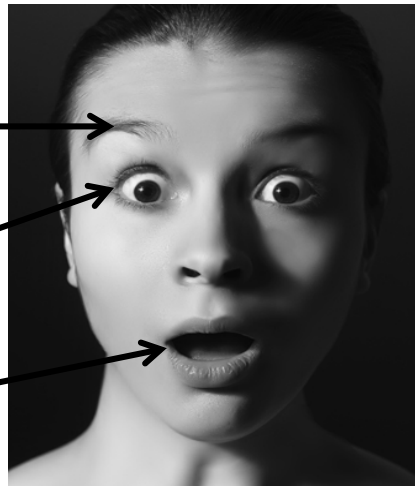


Surprise

Eyebrows raised

Raised upper lids, and widened eyes

Open jaw, lips relaxed



Startle/surprise

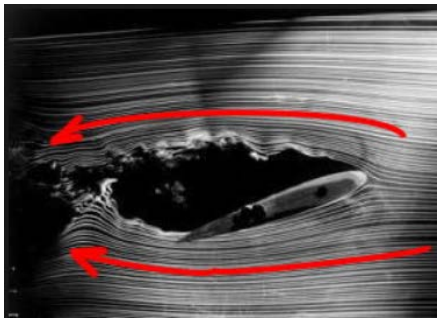
- Fair to say we are interested mostly in surprise
- Hard, but not impossible, to do in simulation
- Key is to create an expectation…and then violate it
- Paper by Casner suggests change it up, train for surprise, turn off automation, and reevaluation testing practices

Casner, S, et. al., "The Effectiveness of Airline Pilot Training for Abnormal Events," *Human Factors*, Vol. 55, No. 3, June 2013, pp. 477-485

Conclusions

- An ounce of prevention is worth a pound of cure

"I'll have an ounce of prevention"

- 

  Reducing angle-of-attack is THE most important pilot action in an upset event

- Pilot upset training in simulators must account for their limitations