Academic upset training

Definitions

- *Upset,* [*v., adj.* uhp-**set**; *n.* **uhp**-set] :
  - 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

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 stall, or 30 degs in opposite direction, if deceleration is 1 kt/sec or less
    - 90 degs in direction of stall, or 60 degs in opposite direction, if deceleration is more than 1 kt/sec

Adapted from part 25.203

Definitions

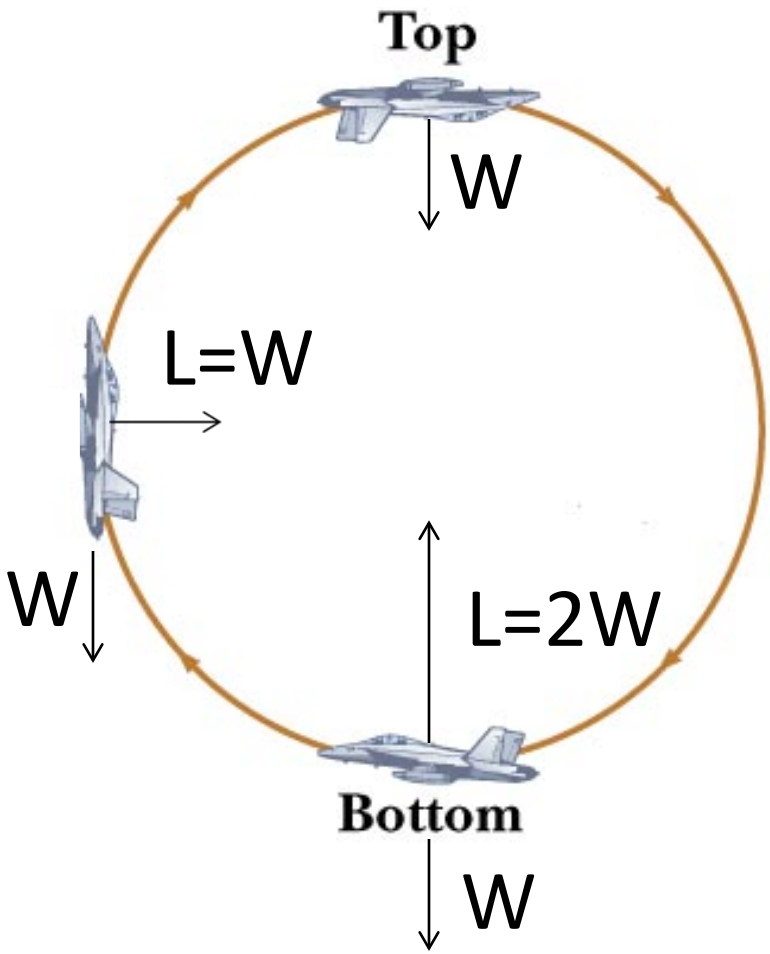
- Extended envelope training
  - Maneuvers and procedures conducted in a simulator that may extend beyond the limits where typical simulator performance and handling qualities have been validated with heavy reliance on flight data to represent the actual aircraft
- Energy State
  - How much kind of energy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

Aerodynamics

- Load factor = $\frac{L}{W}$

Aerodynamics

- Load factor = $\frac{L}{W}$



Aerodynamics

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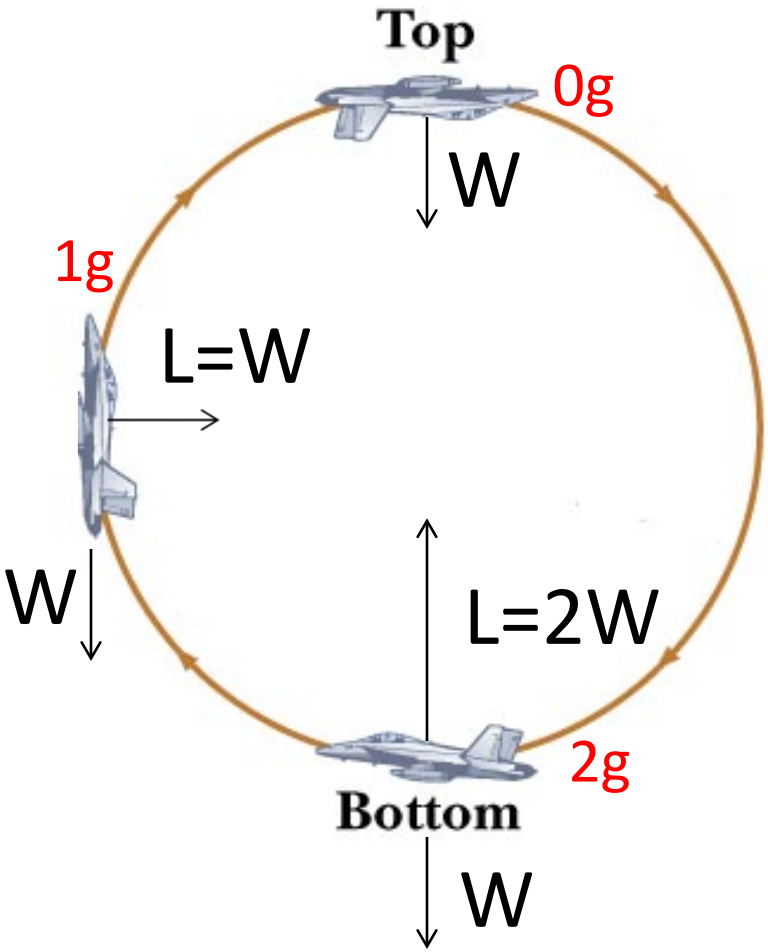

Aerodynamics

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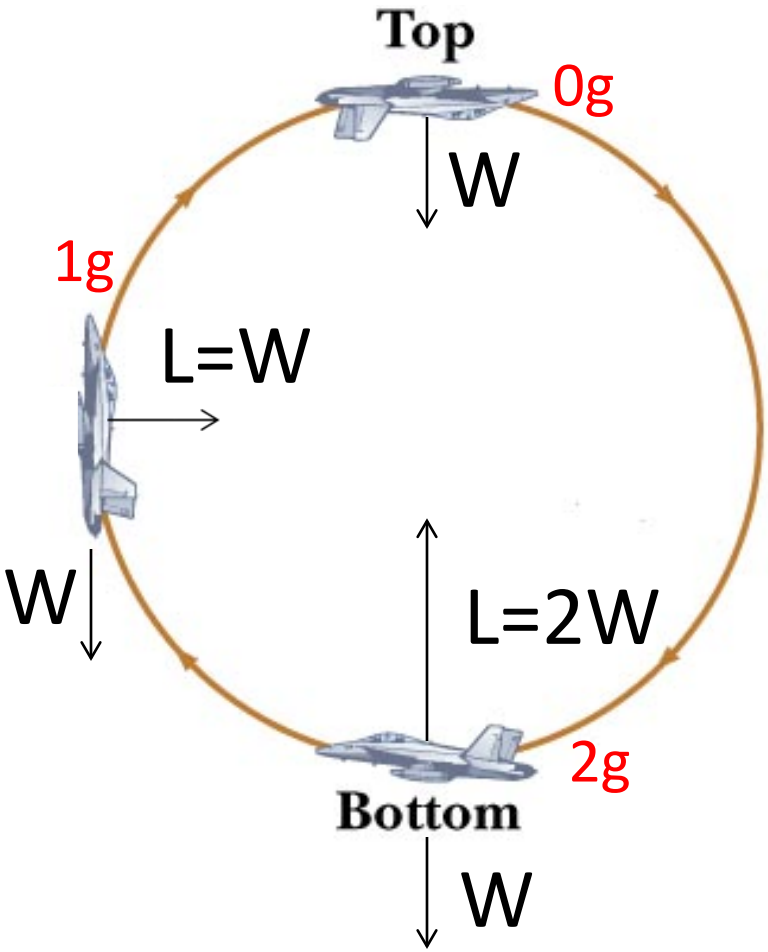
F=m**a**



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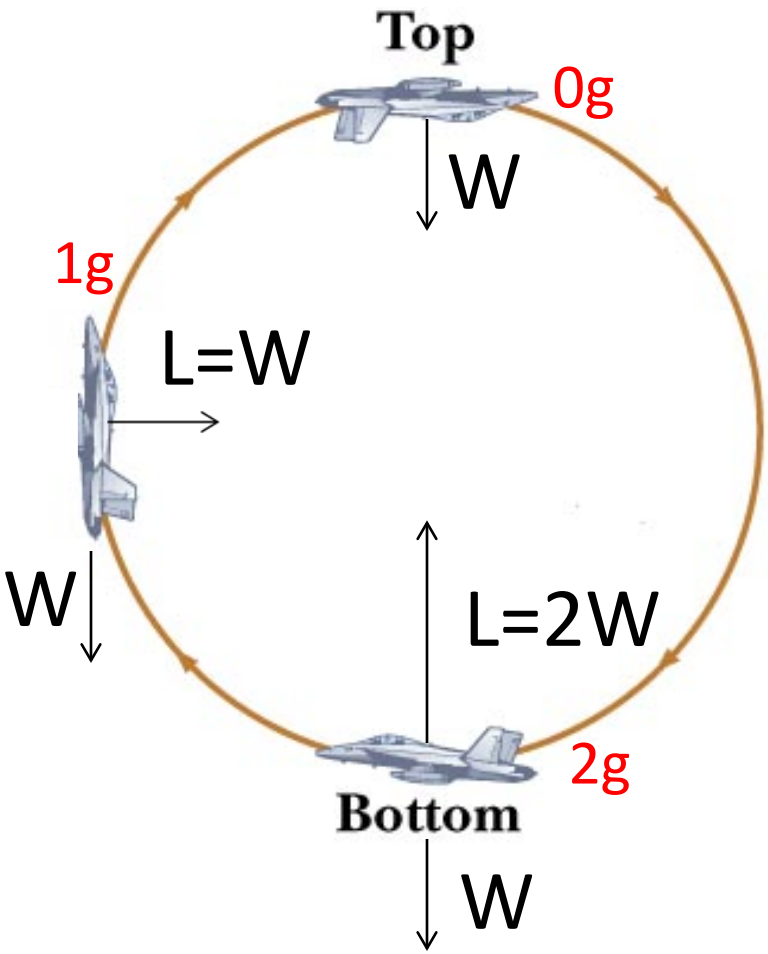
L - W



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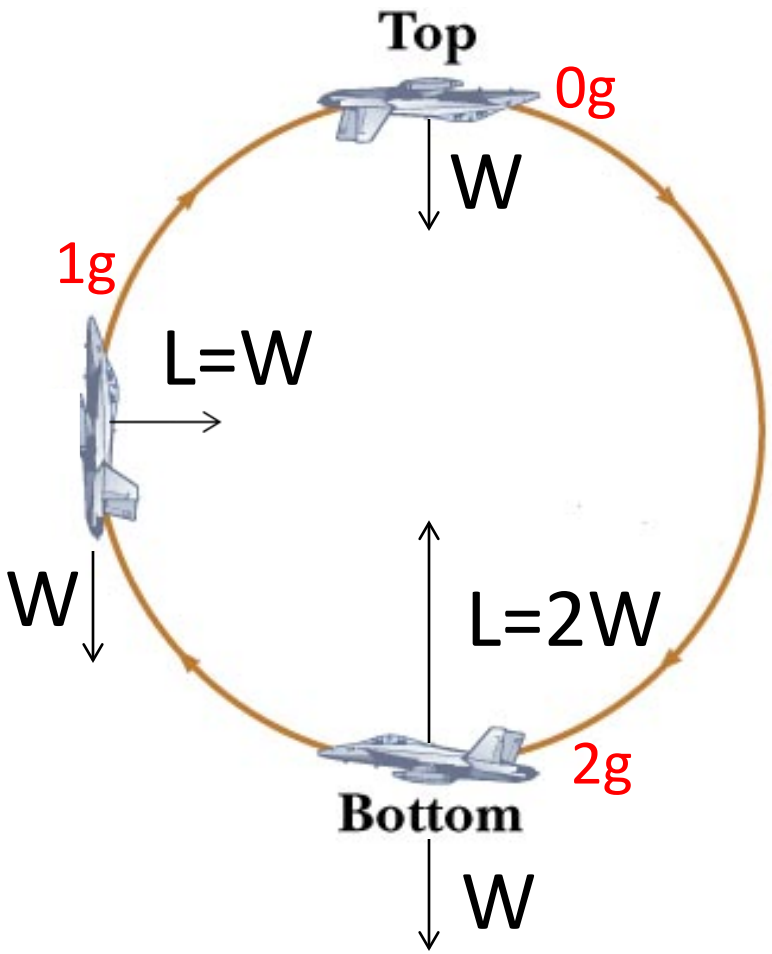


F=ma

L - W

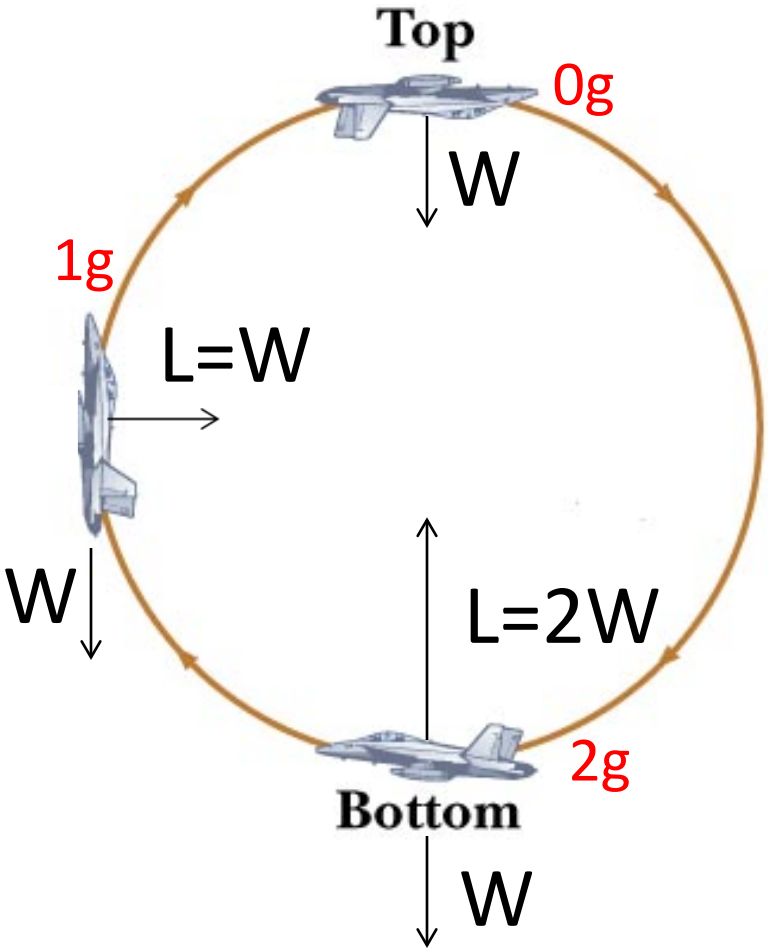
Velocity getting bigger or smaller

+

Velocity changing direction

Aerodynamics

- Load factor = $\frac{L}{W}$



F=ma

L - W

Velocity getting bigger or smaller

+

Velocity changing direction

= pitch rate * speed

Aerodynamics

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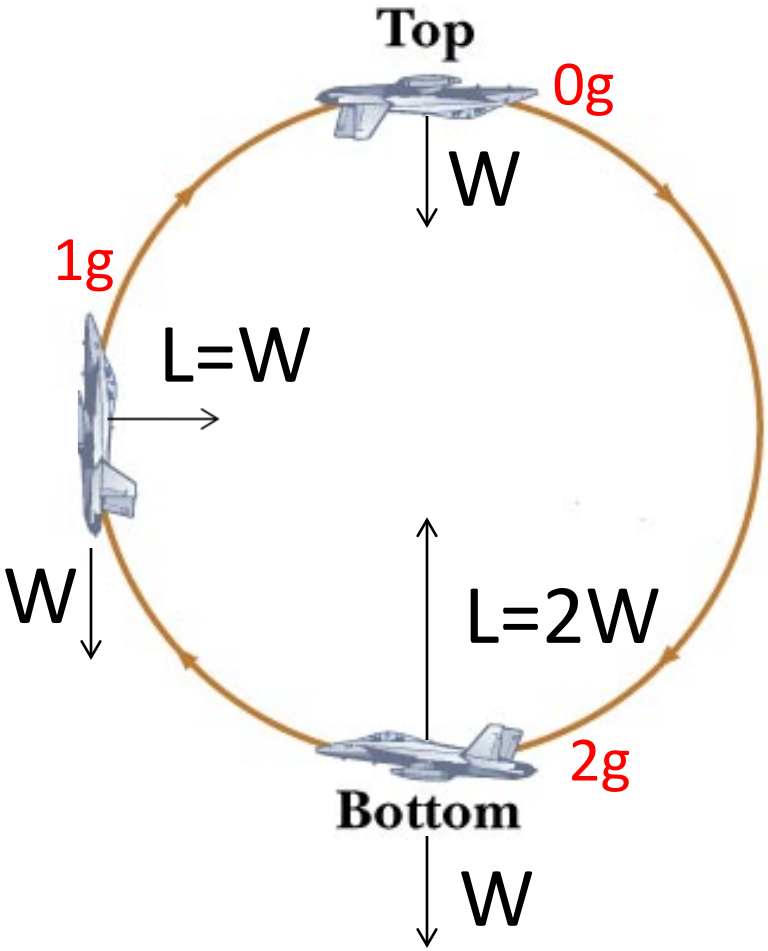


F=ma

L - W

Velocity getting bigger or smaller

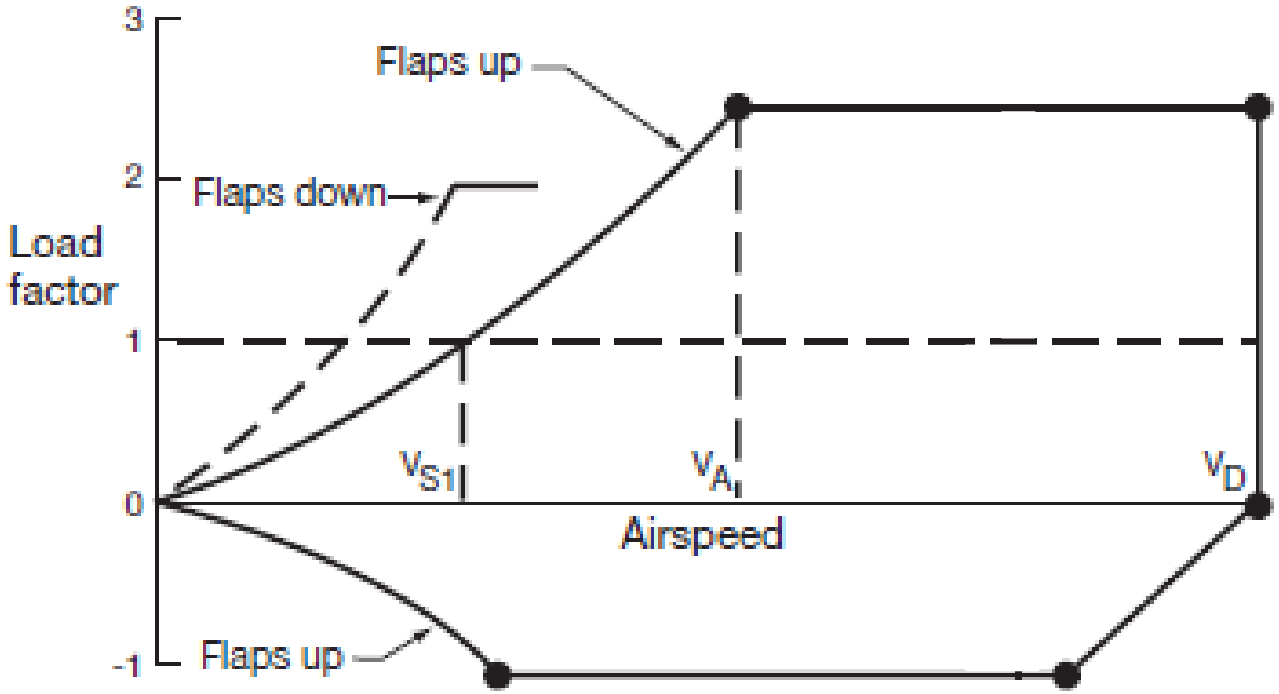
+

Velocity changing direction

= pitch rate * speed

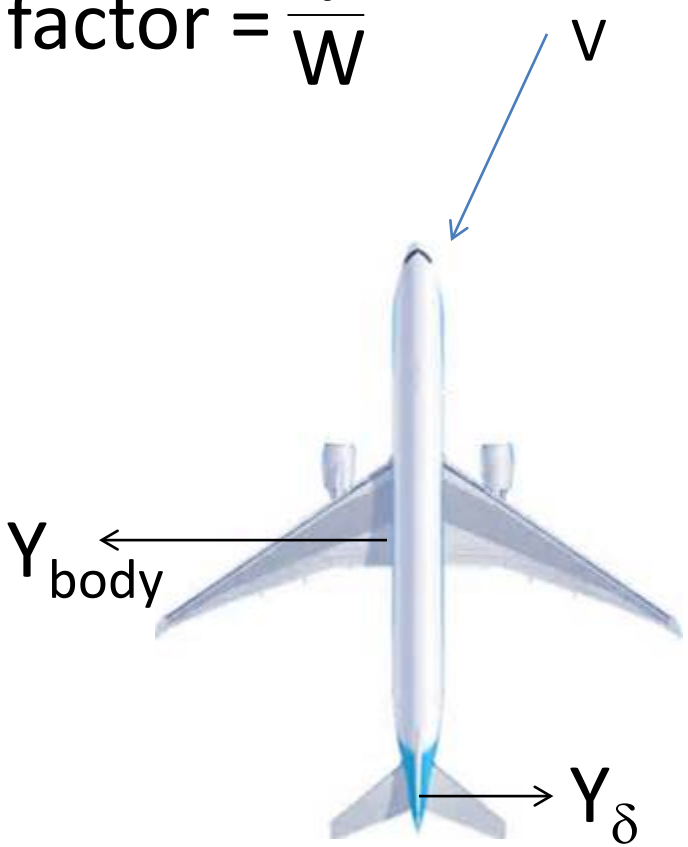
Both can get big at high altitude

Aerodynamics



Aerodynamics

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

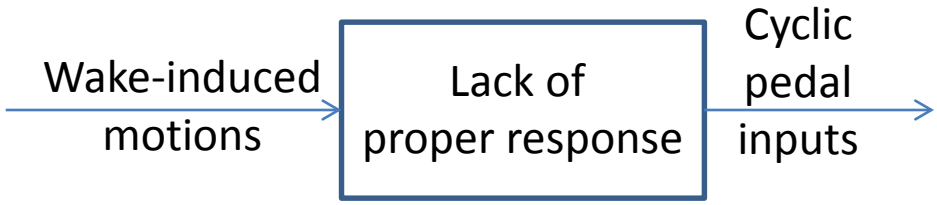


$$Y = Y_{body} + Y_{\delta}$$

AA587 example

Why?

American 587



Aerodynamics

Trim

- Nagoya, 1994 – China Airlines #140
- Roselawn, 1994 – American Eagle #4184

Aerodynamics
Trim

- Trim awareness and use
  - Example, in 737NG, blipping trim switch effectively disables speed trim temporarily
  - Example, in 737NG, elevator feel shift
  - Example, in A330, different alternate laws will trim differently

Aerodynamics

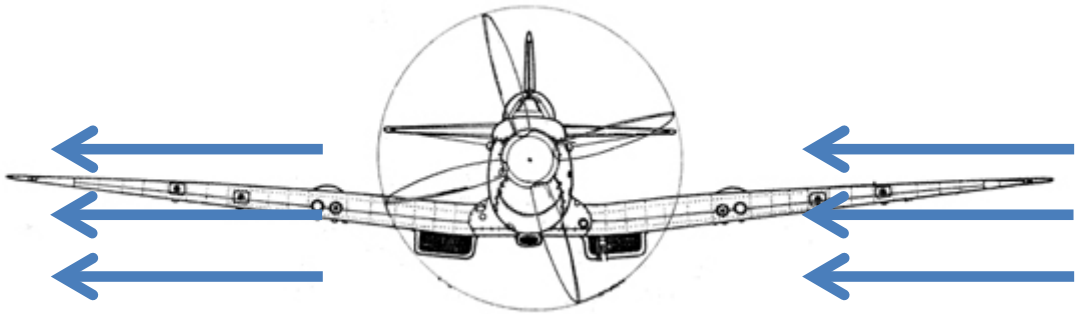
Dihedral effect

- What is it?

Aerodynamics

Dihedral effect

- What is it?

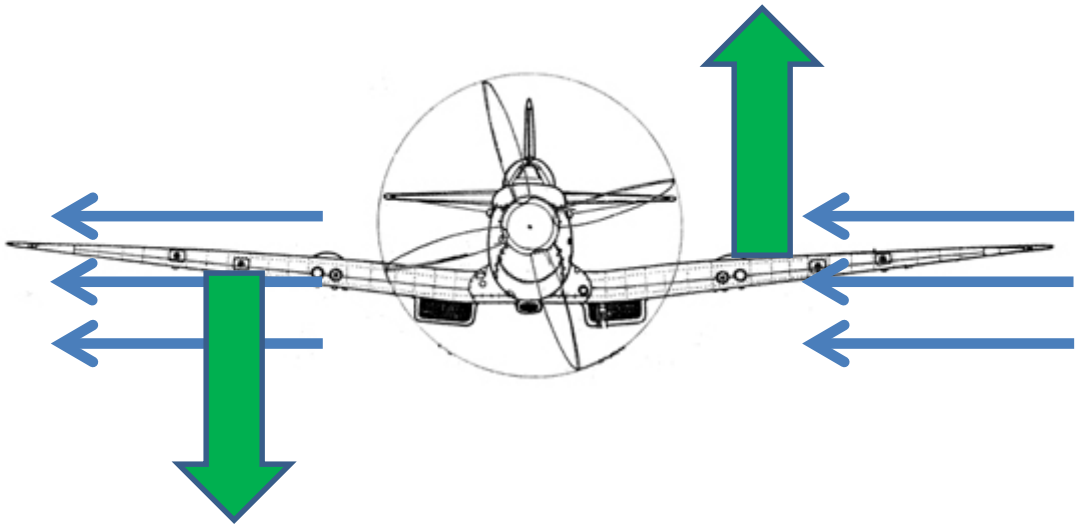


Sideslip causes a side force…might not feel in a simulator

Aerodynamics

Dihedral effect

- What is it?



Aerodynamics

Dihedral effect

- How do you get more of it?

Cant wings up

Aerodynamics

Dihedral effect

- How do you get more of it?

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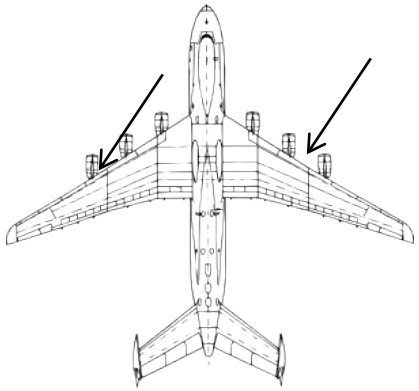


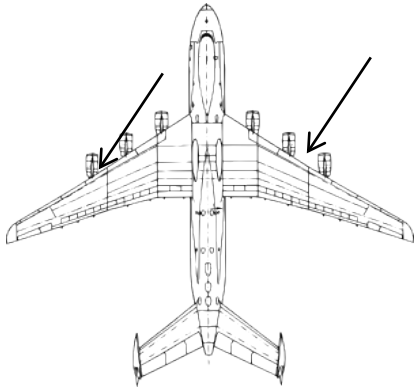
Sweep wings back

Aerodynamics

Dihedral effect

- How do you get more of it?

Cant wings up



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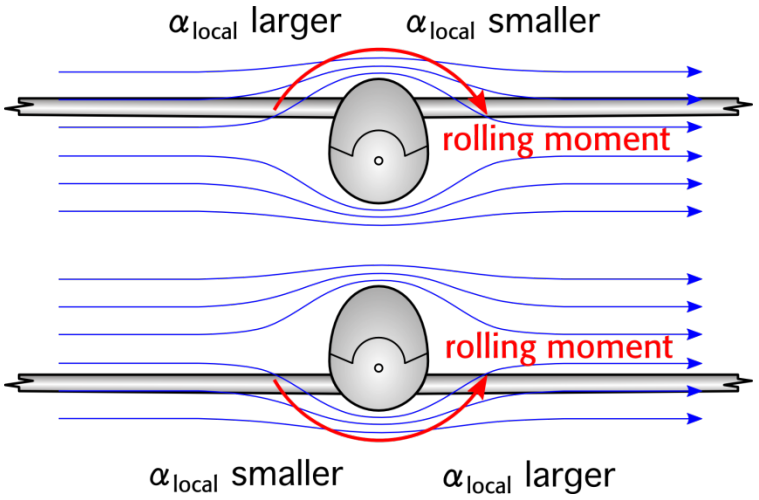


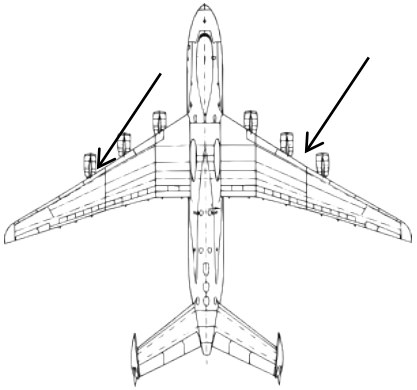
Go to a high wing

Aerodynamics

Dihedral effect

- How do you get more of it?

Cant wings up



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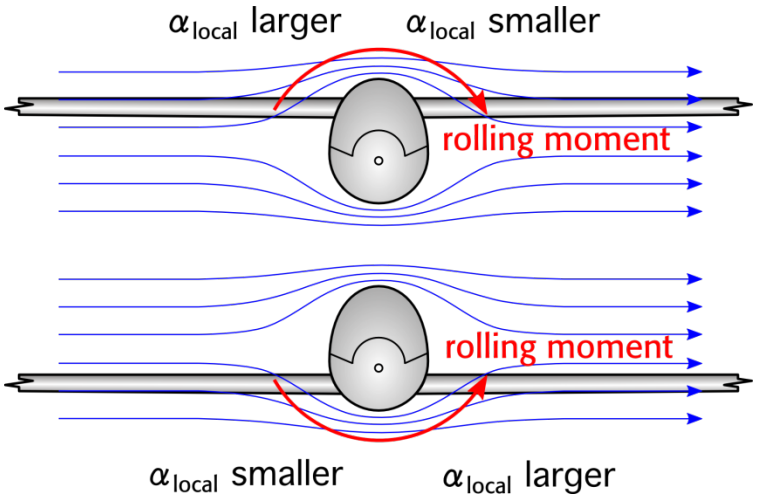

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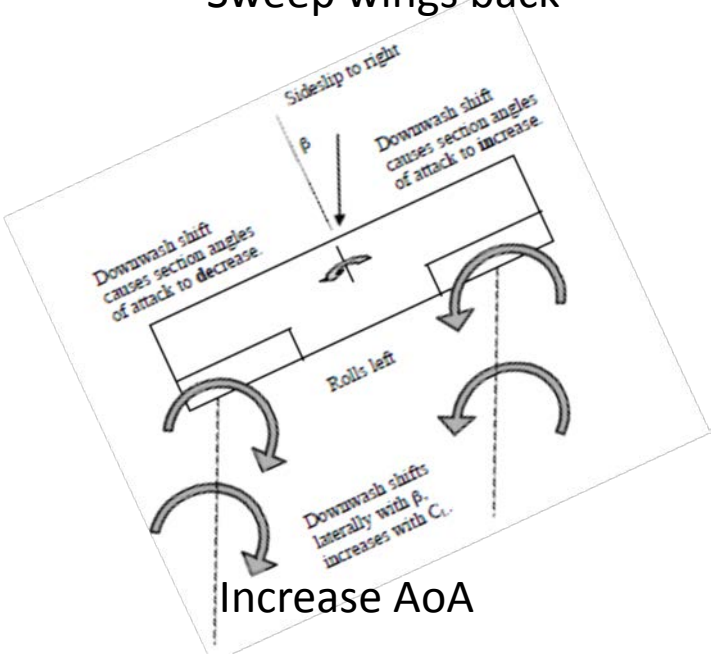
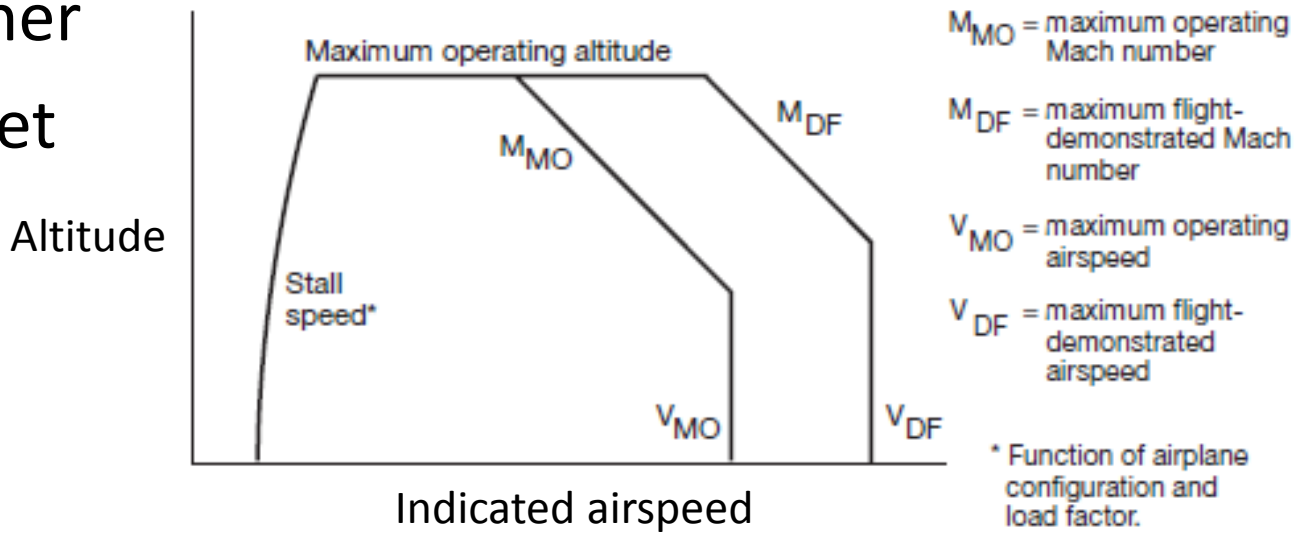


Increase AoA

Anhedral

Aerodynamics

- Mach
  - Stall AoA
  - Coffin corner
  - Mach buffet



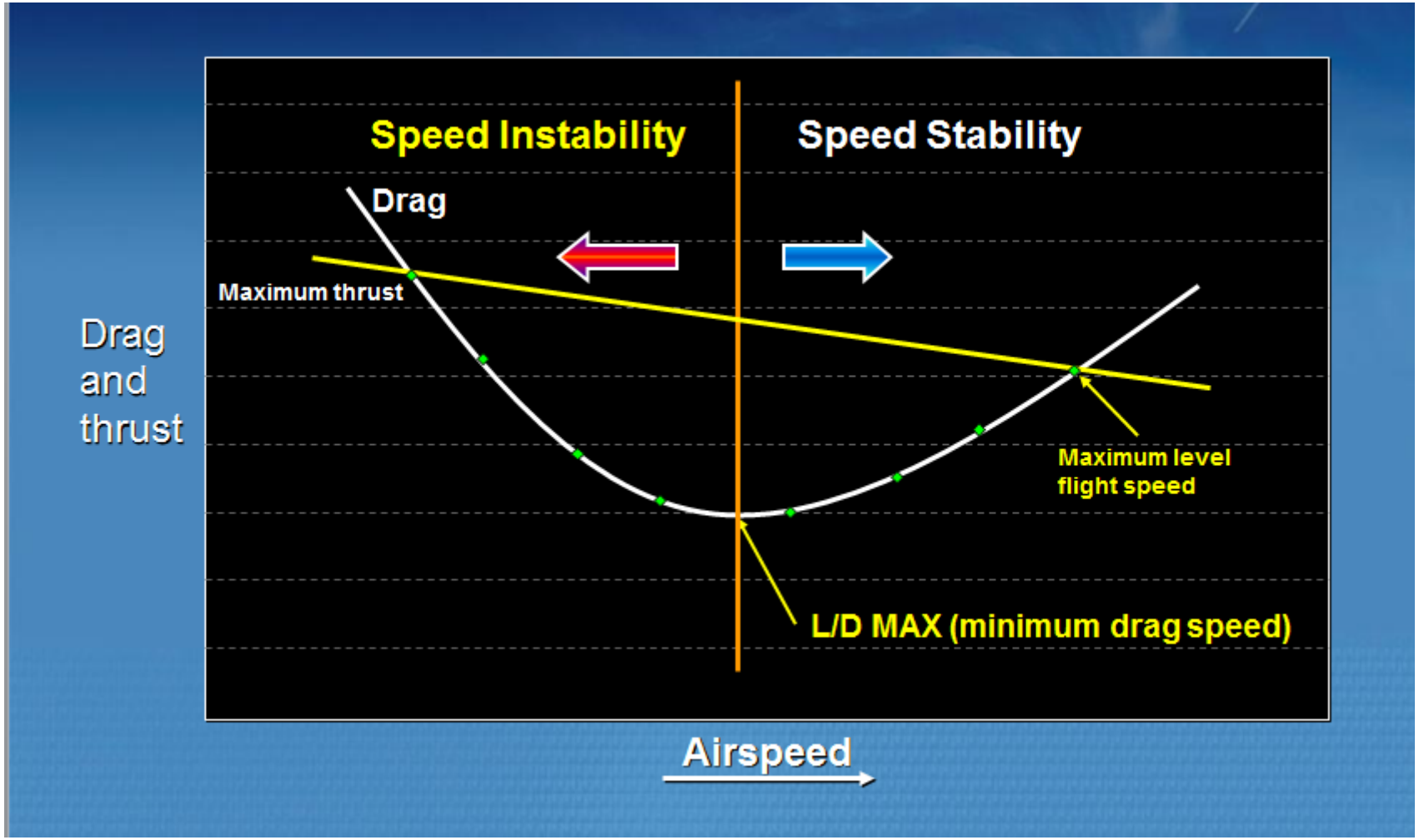
Aerodynamics

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.

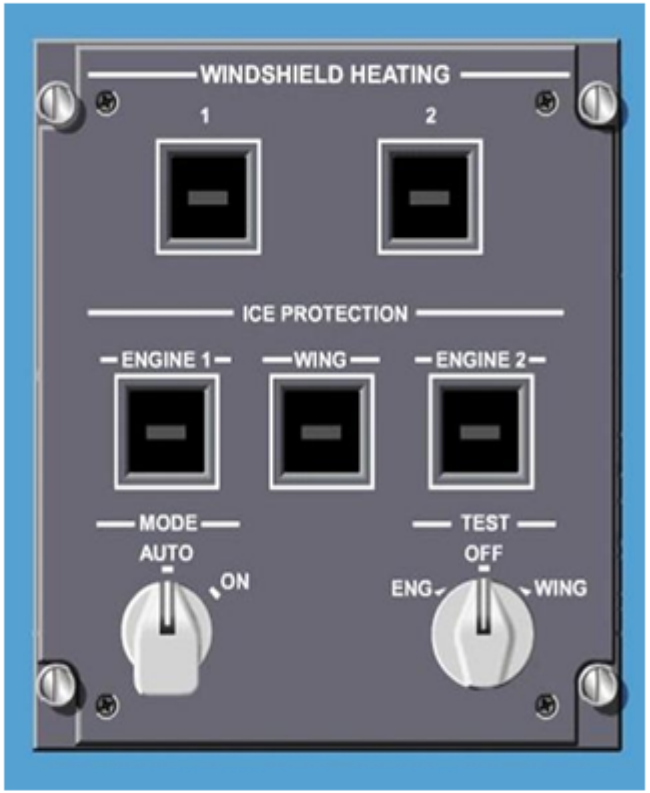
Decelerating the airplane to the minimum normal operating limit may create a situation where it is impossible to maintain altitude.

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

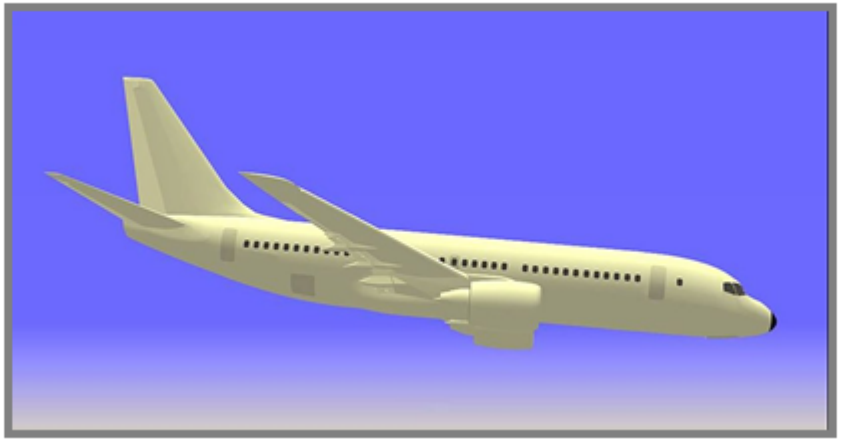


Pilot Tip: **The bleed penalty for anti-ice results in a reduction of available thrust and an increase in specific fuel consumption.**

Aerodynamics
Performance considerations

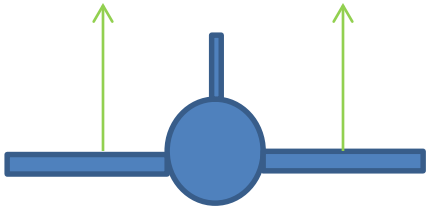
Pilot Tip: If a condition or airspeed decay occurs, take immediate action to recover:

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

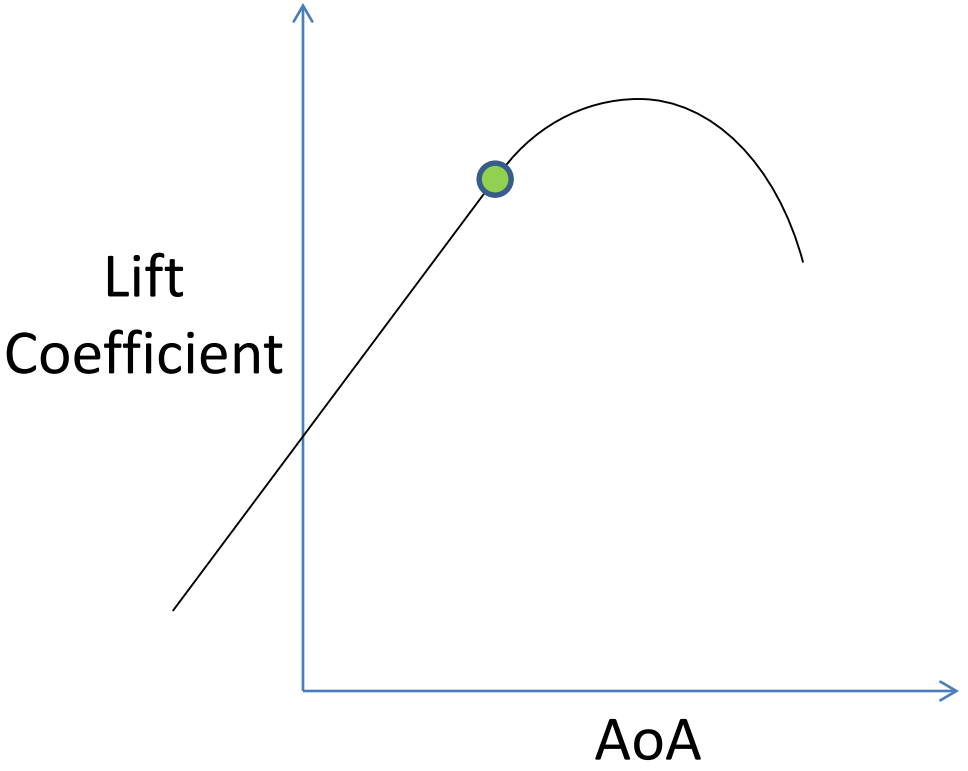


Aerodynamics

Roll stability



Rear
View



Aerodynamics

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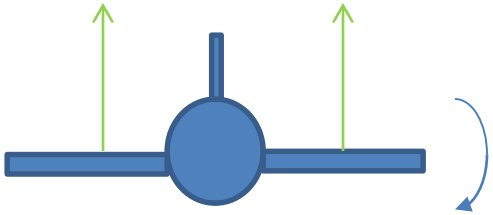

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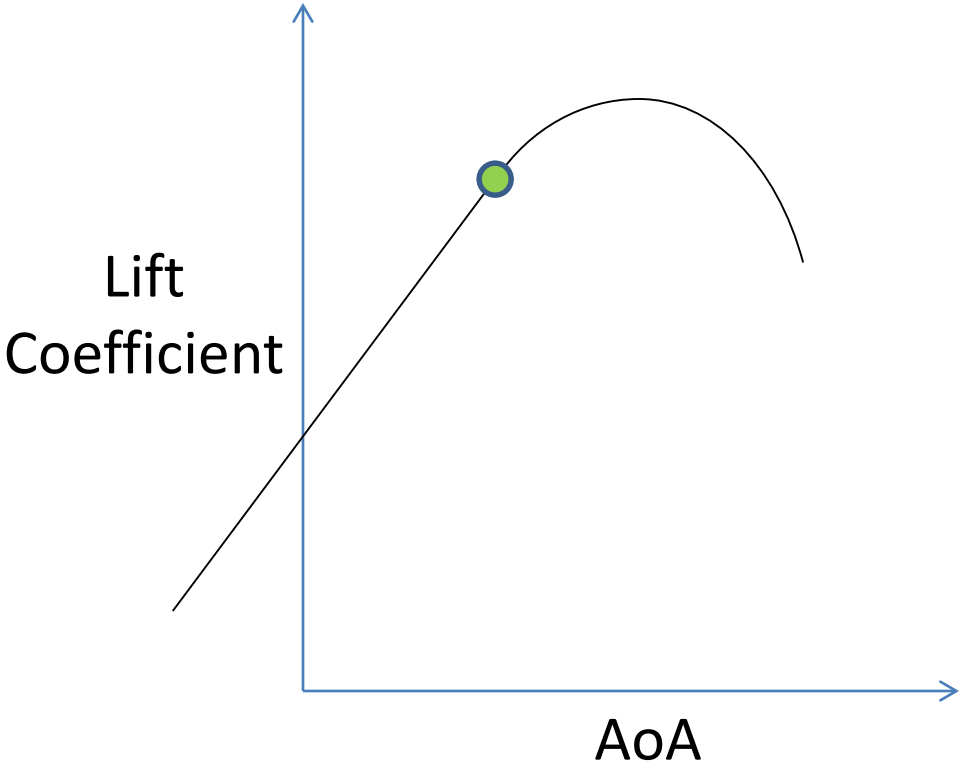

Aerodynamics

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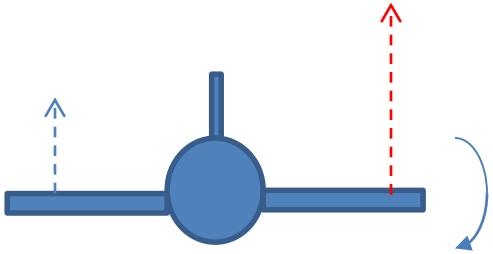

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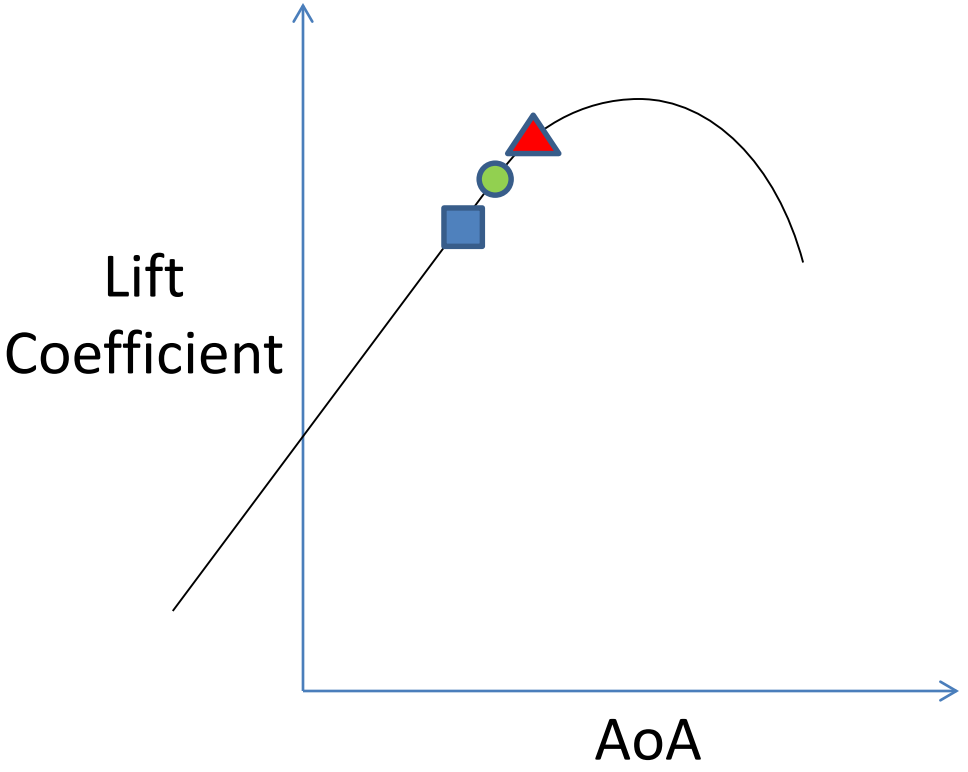

Aerodynamics

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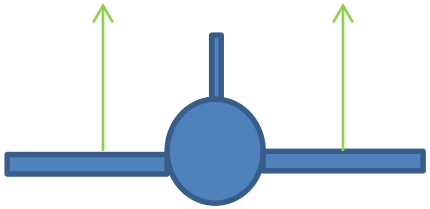

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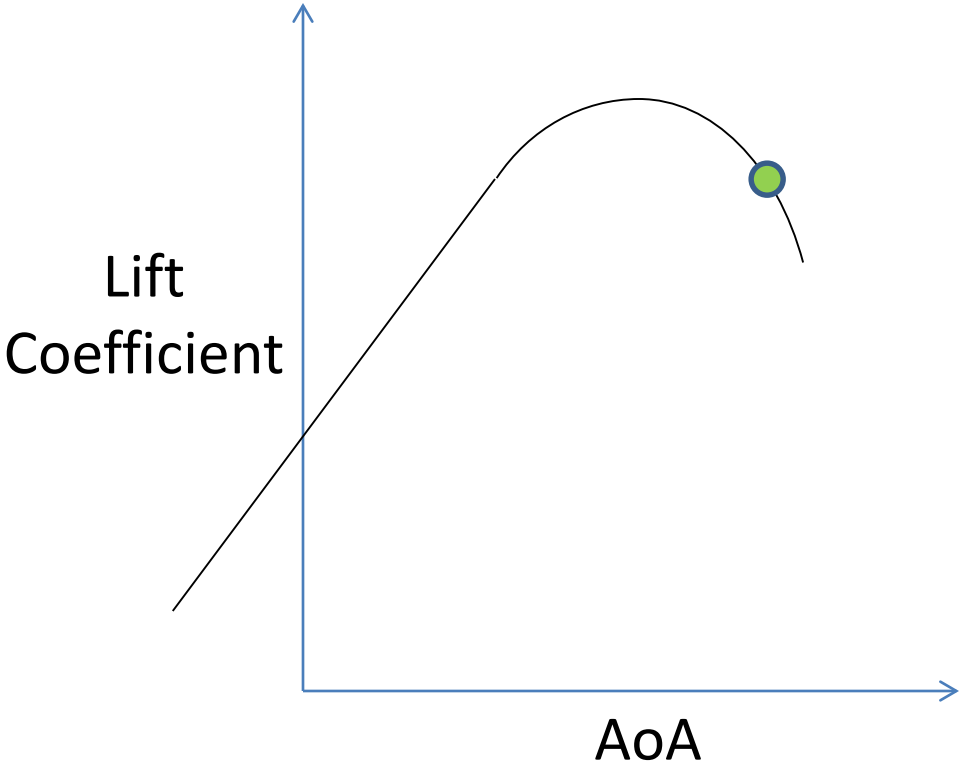

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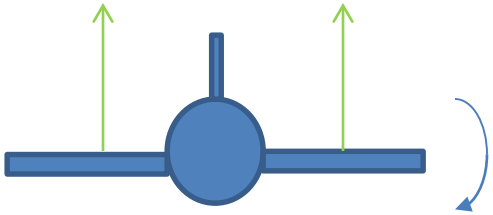

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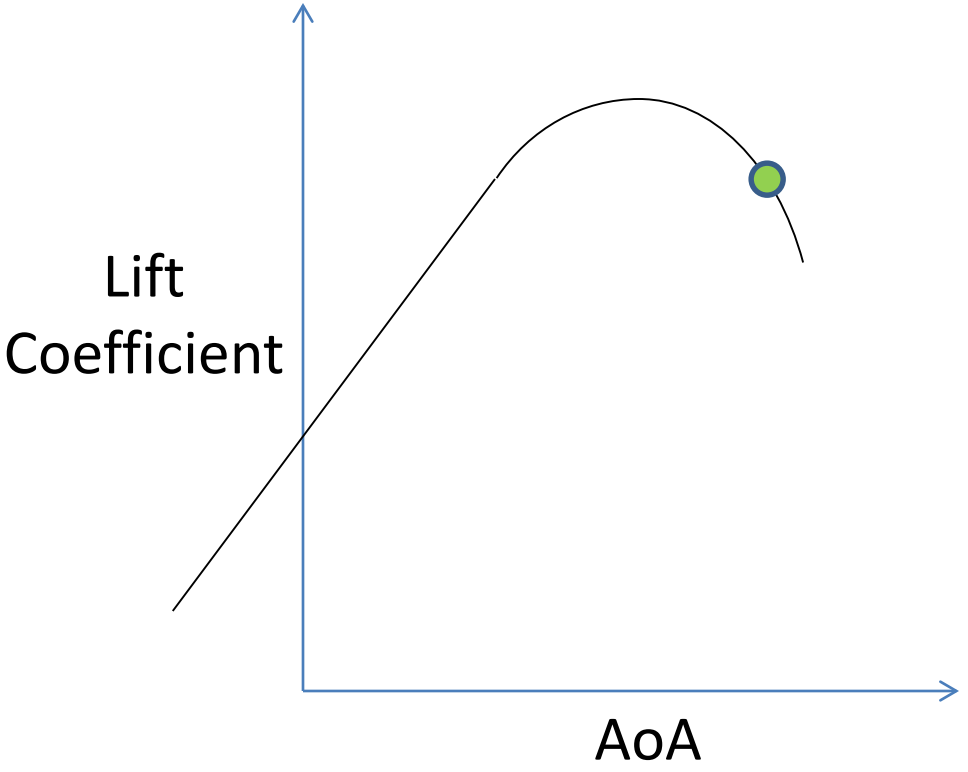
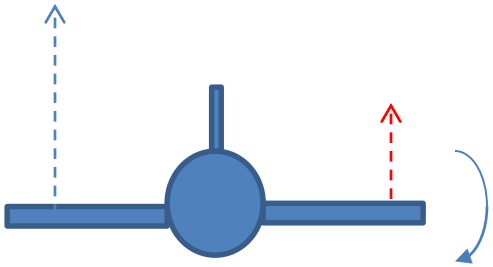


Aerodynamics

Roll stability



Rear
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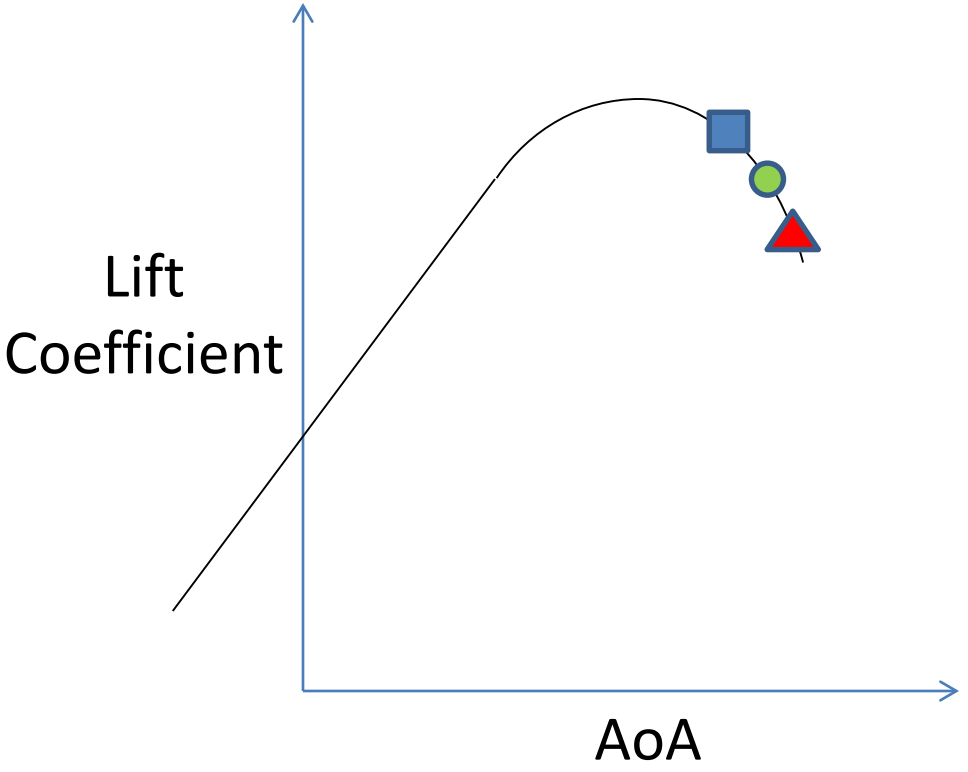
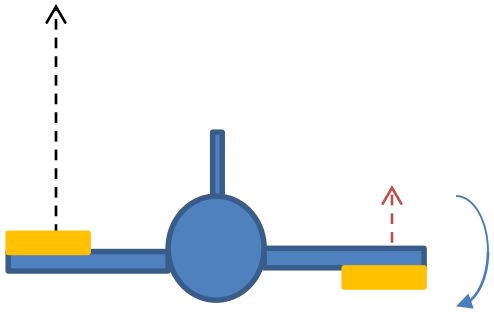


Aerodynamics

Roll stability



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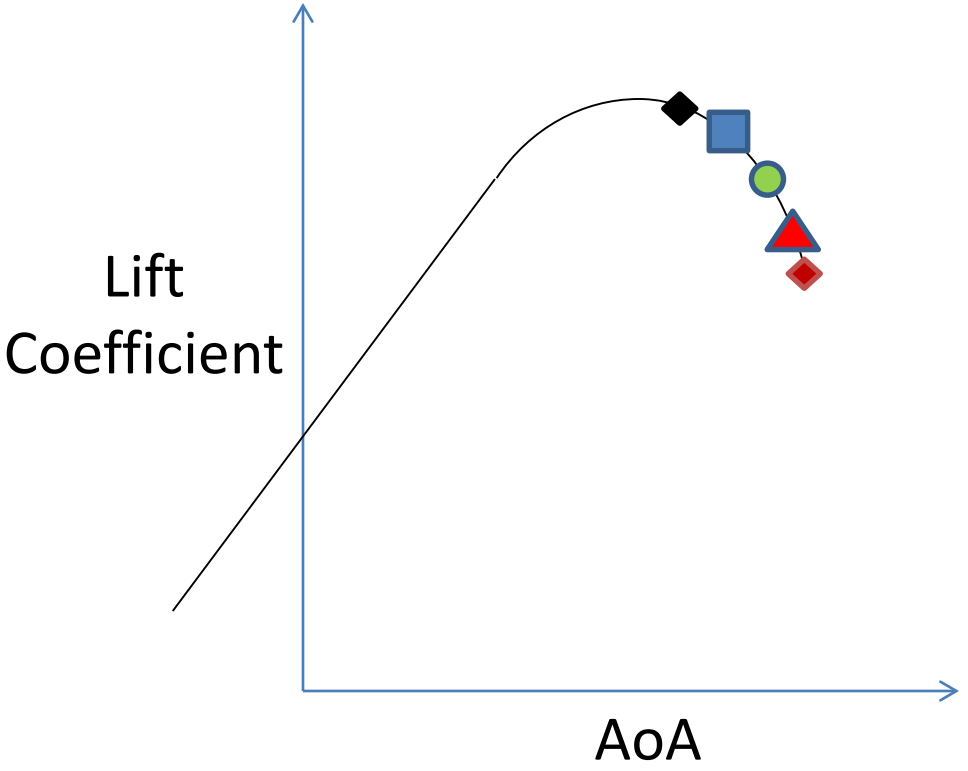
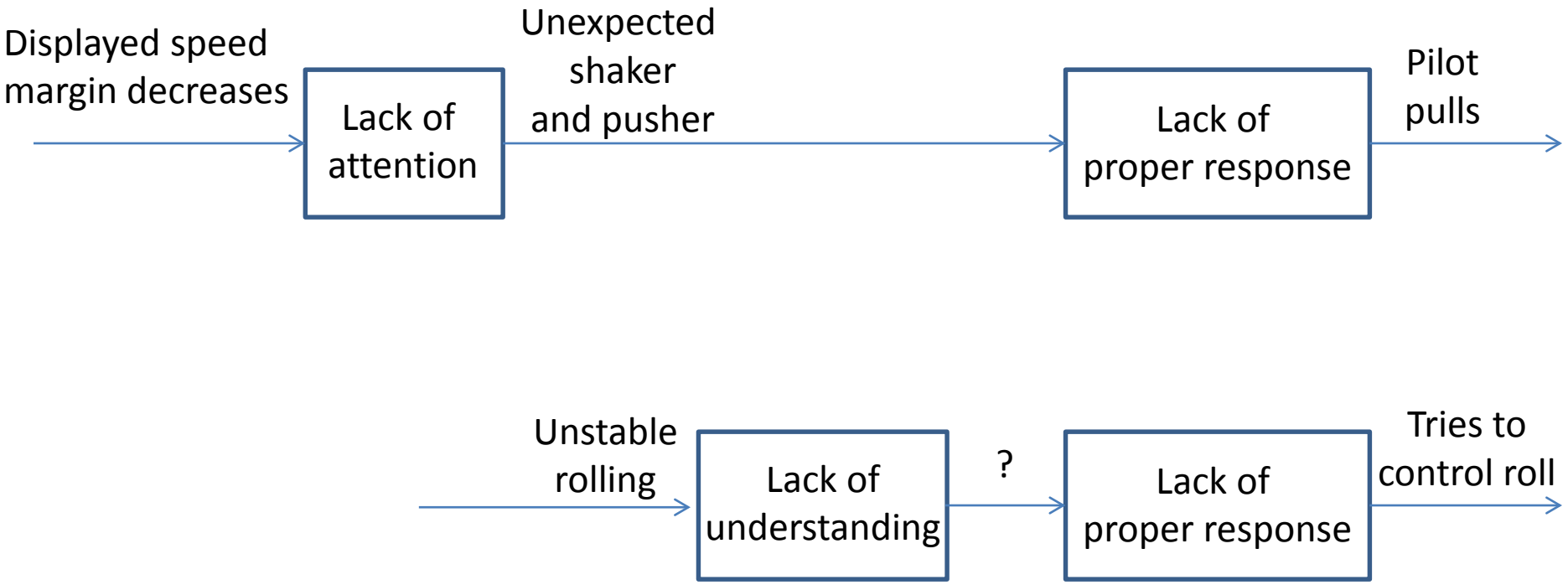


Why?

Colgan 3407



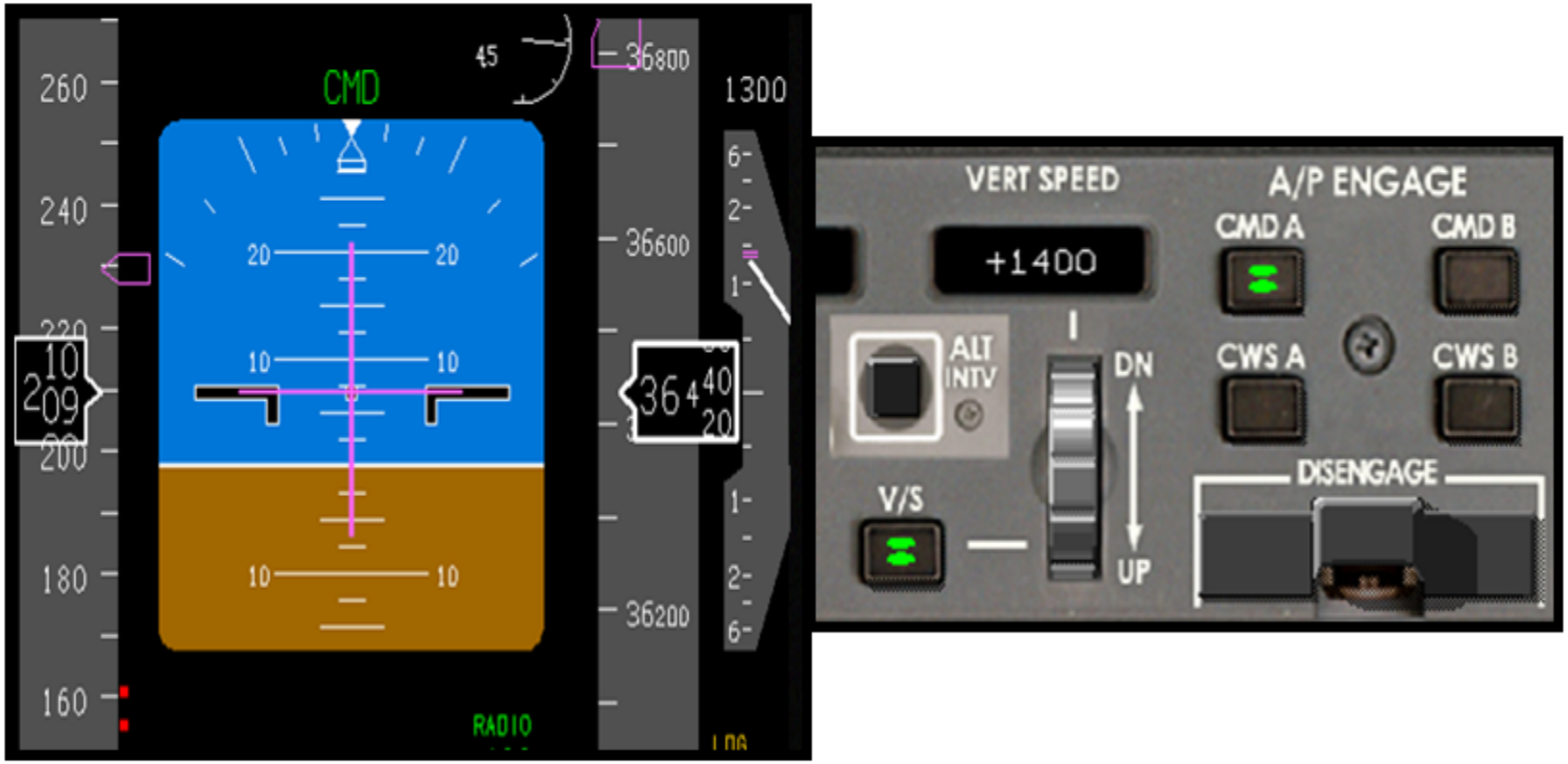
Aerodynamics

- Energy
  - What it is
  - Trades and judgment…keeping final state in mind
    - Mental sanity checks useful
      - Knowing roughly how much speed you can bleed configured versus not in straight-and-level and on glidepath
      - Descent rate on path is about groundspeed/2 x 10

        so, 140 kts --> 700 fpm
  - High altitude stall recovery

Energy

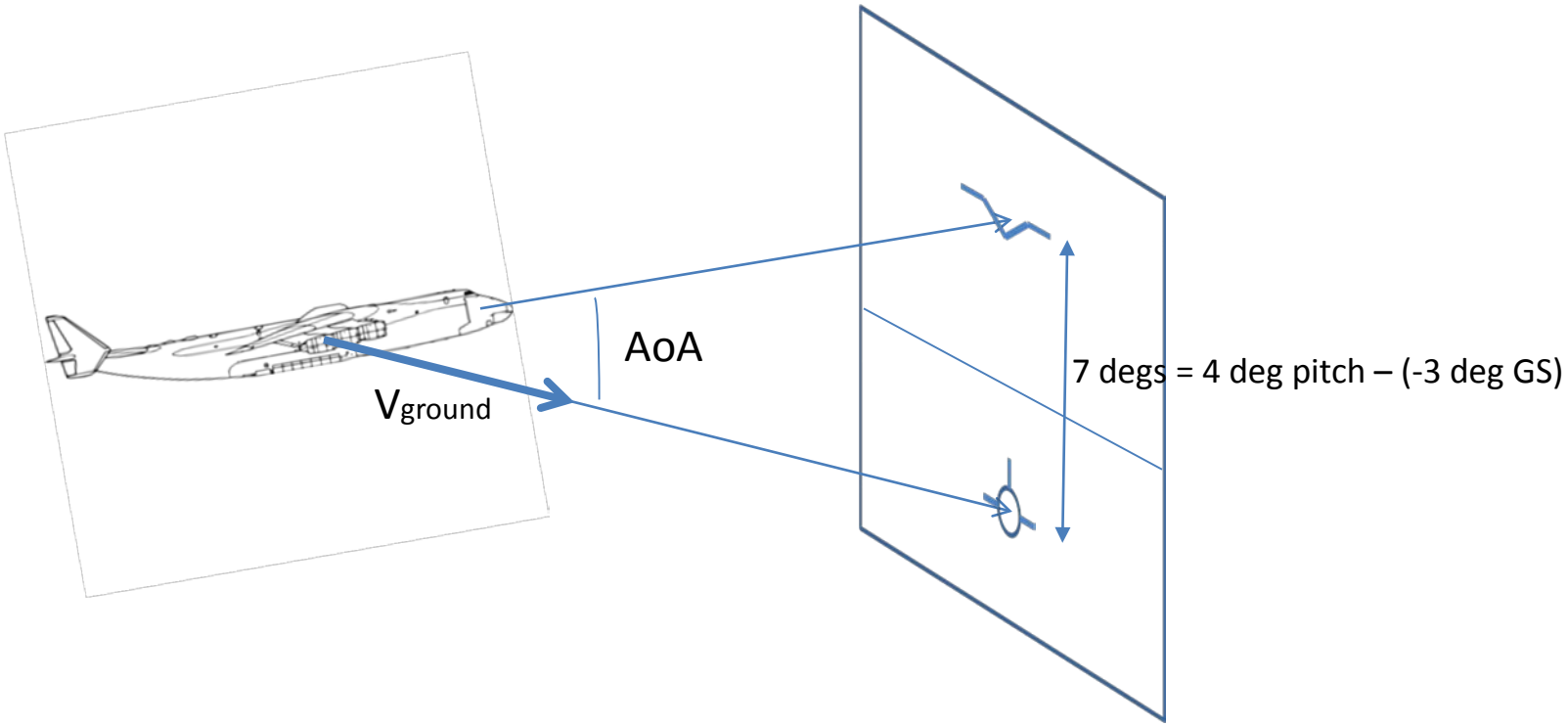
Available thrust limits energy conversion at altitude



Pilot Tip: General guideline – Vertical Speed mode should NOT be used for climbing at high altitudes.

Aircraft displays for energy

- HUD



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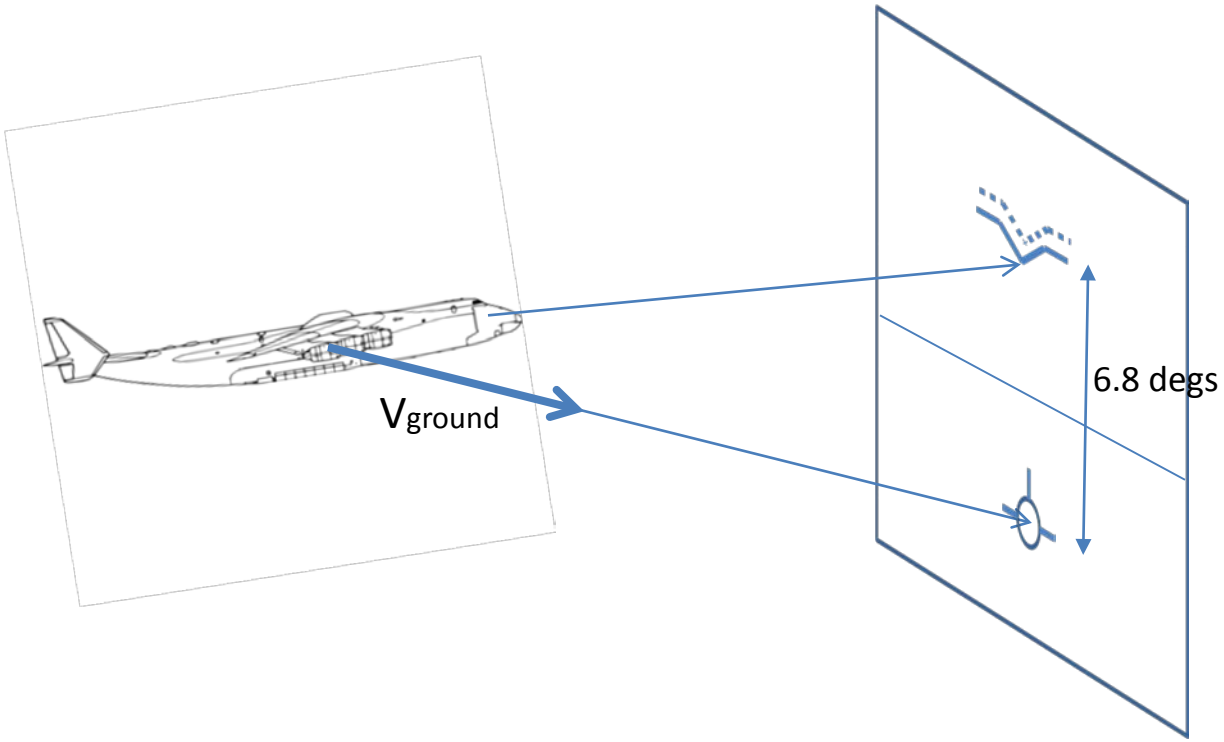

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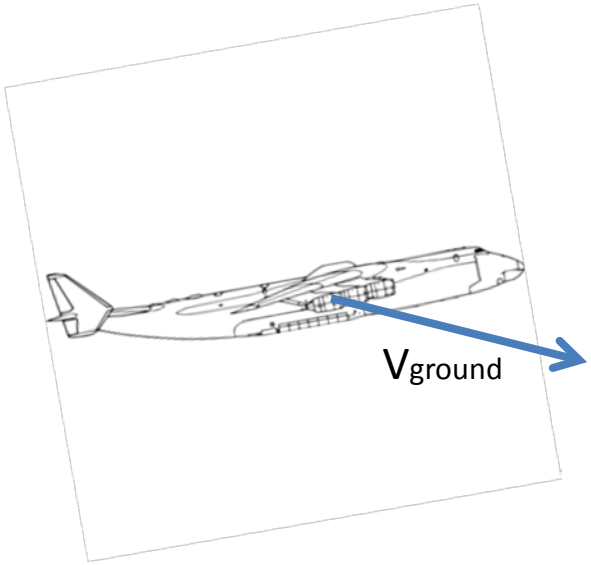

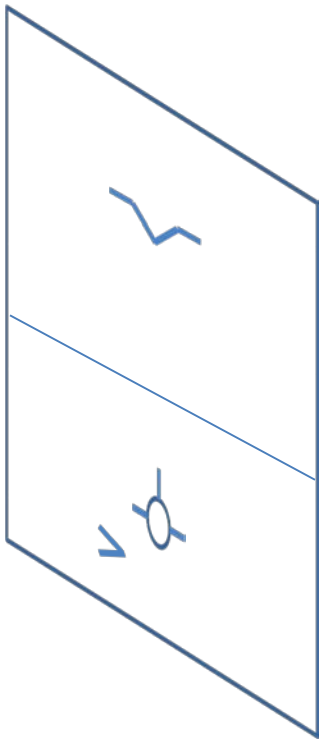

Stalls

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

Stalls

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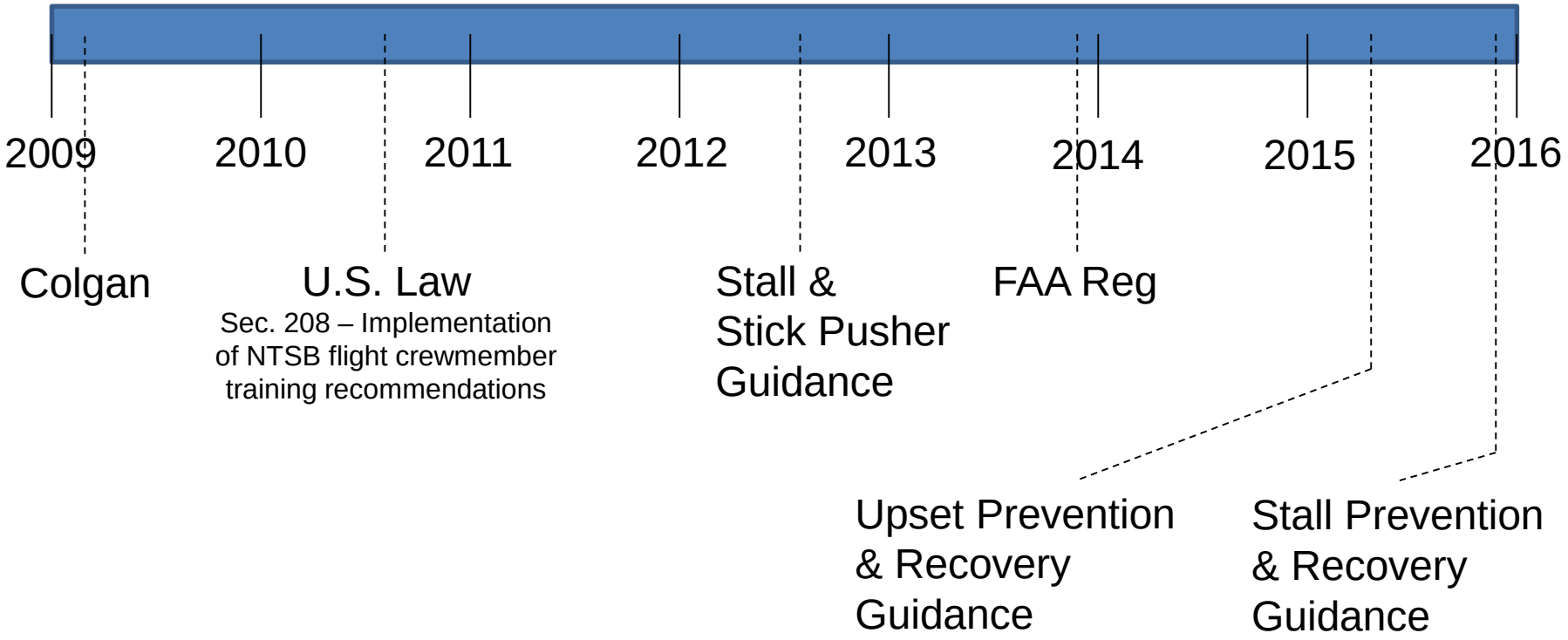

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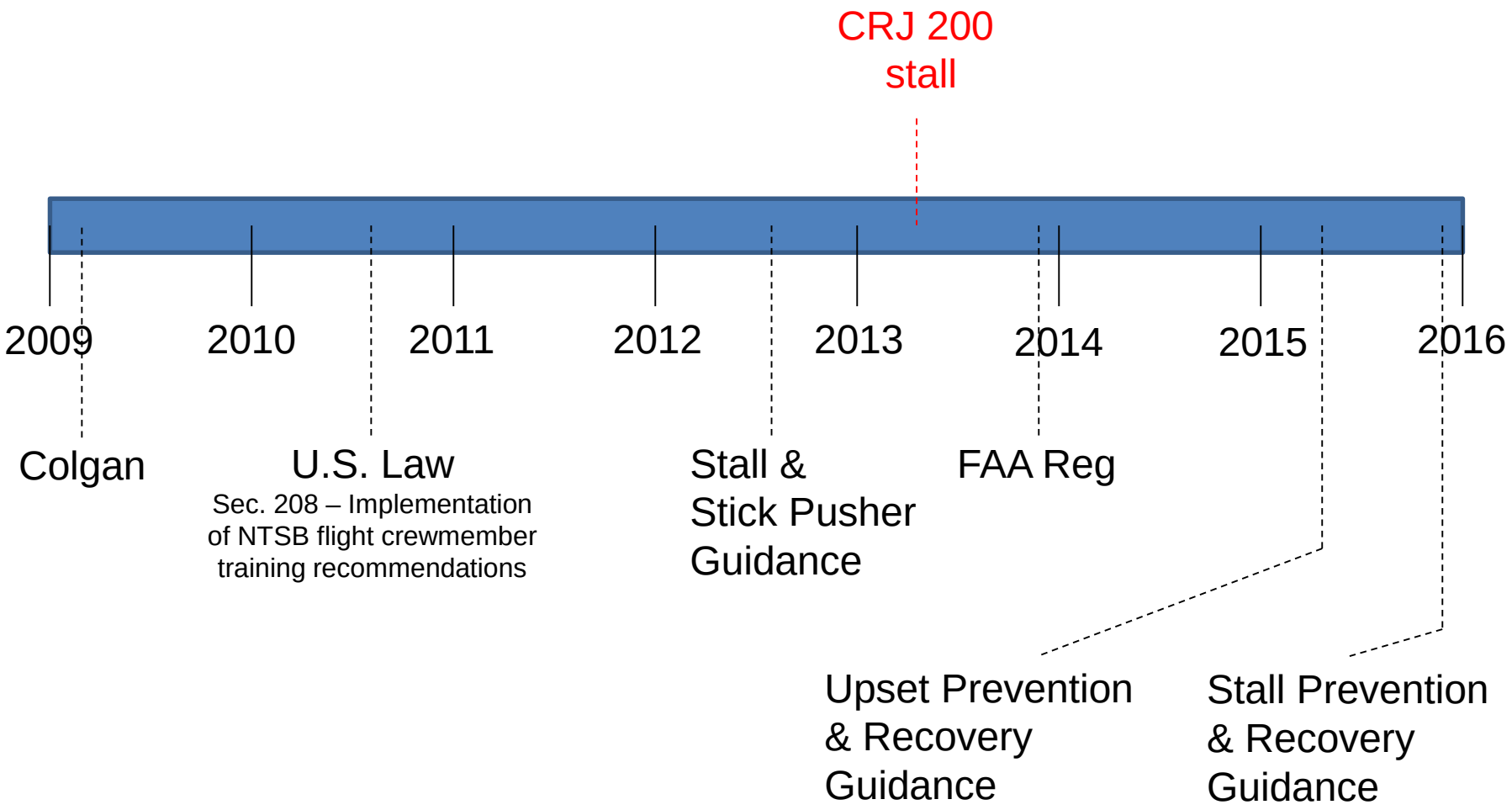

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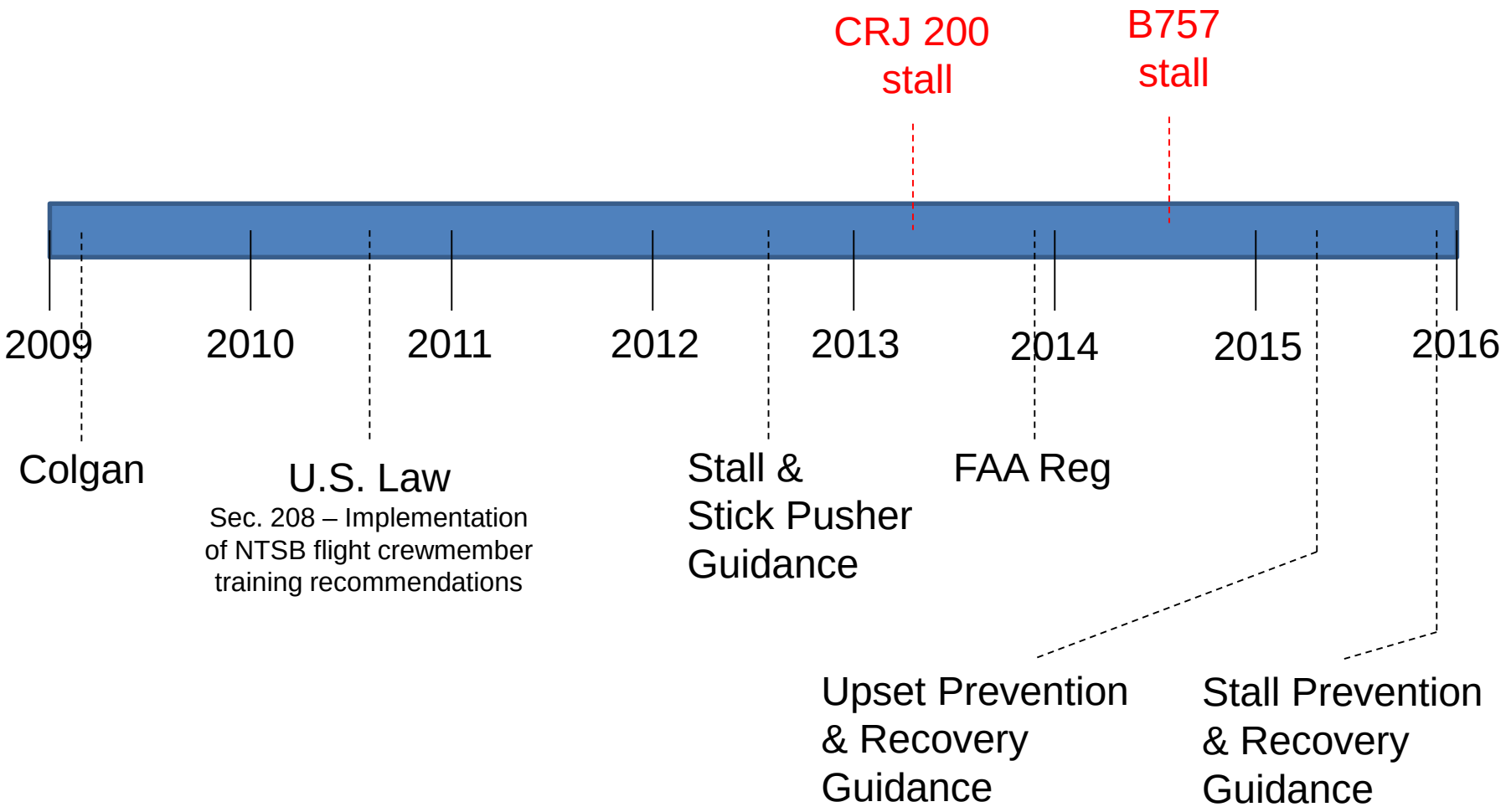

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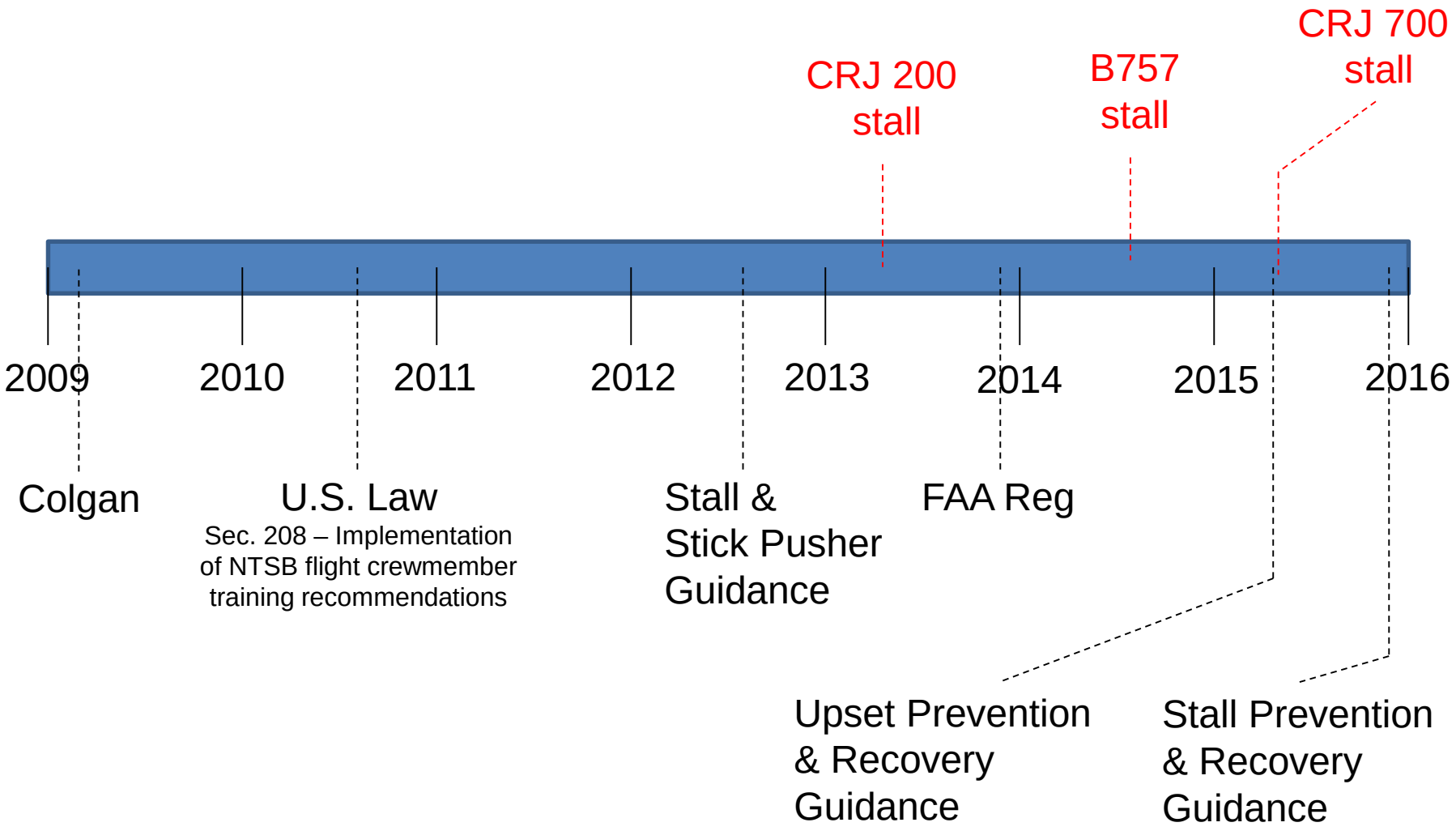


Stalls

- 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

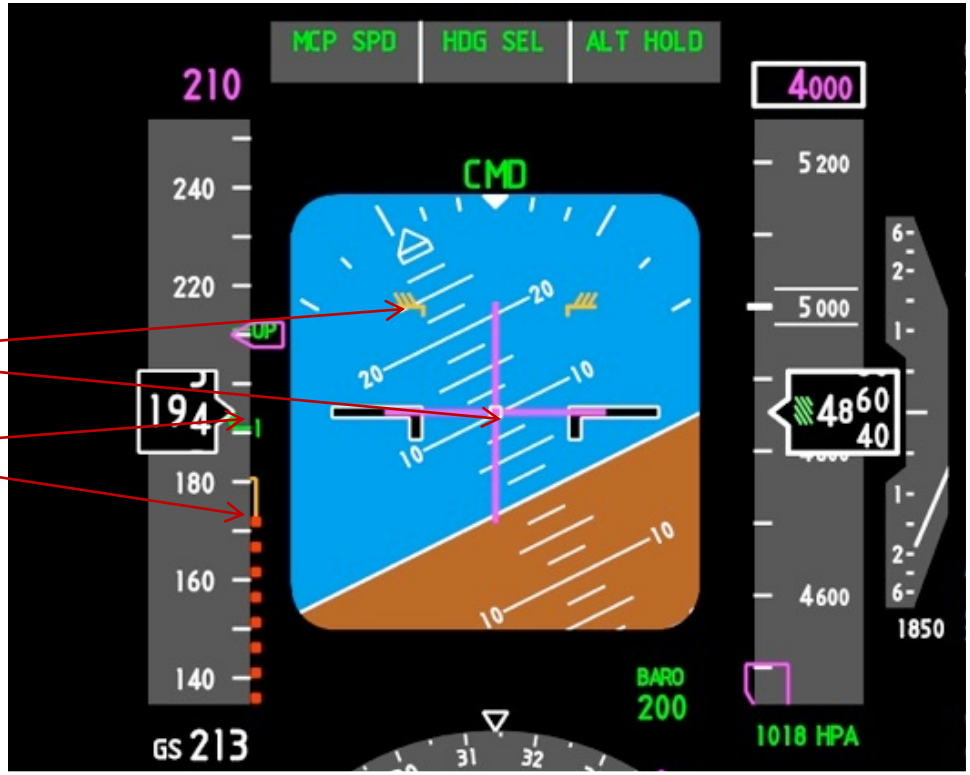
- What does a stall fundamentally depend on?
  - ~~Airspeed~~
  - ~~Bank angle~~
  - ~~Load factor~~
  - ~~Altitude~~
  - ~~Gross weight~~
  - Angle of attack
  - Mach number
  - Configuration or contamination (e.g., flap or slat position or ice)

Stalls

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

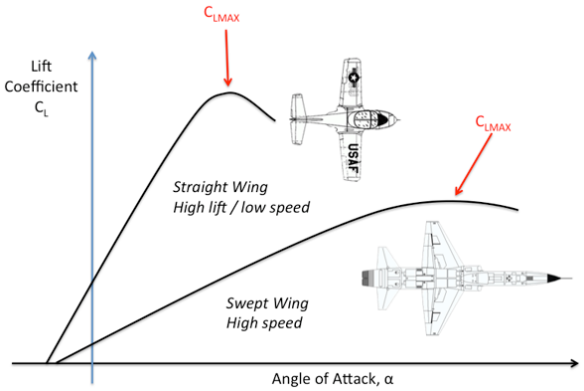
Angle of attack margin

AoA margin to stall warning

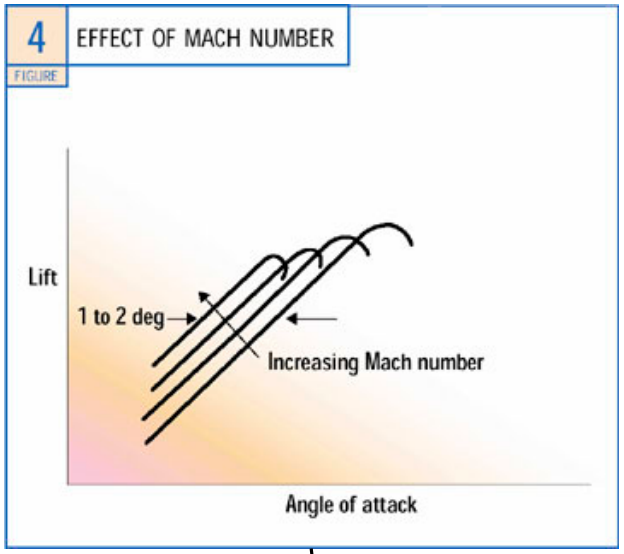


Stalls

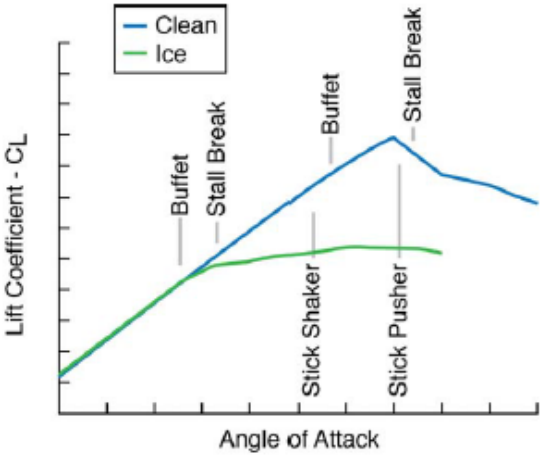
Angle-of-attack

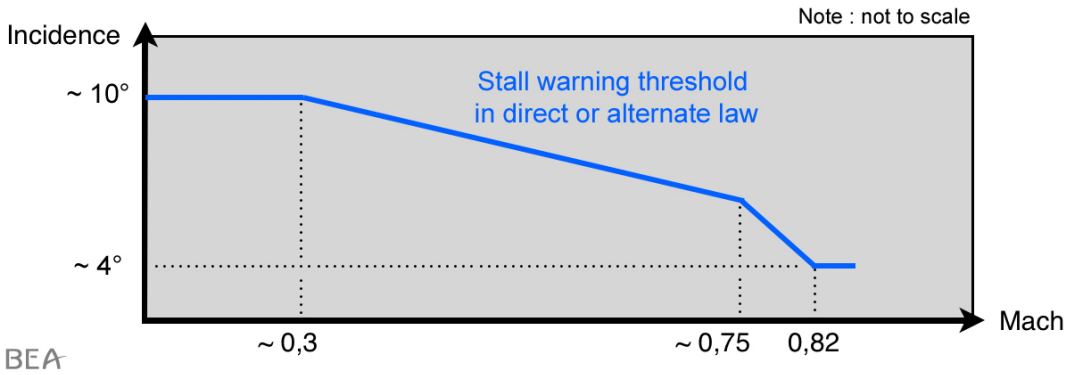


Mach



Configuration or contamination





BEA

Stalls

- Physical confusion…
  - Airspeed
    - I have stall speed in my flight manual for different weights. Won't I be ok if I make sure I fly faster than those?
      - No, those are 1g stall speeds

Stalls

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    - I have stall speed in my flight manual for different weights. Won't I be ok if I make sure I fly faster than those?
      - No, those are 1g stall speeds
  - Bank angle
    - Don't I stall at a lower AoA when banked in a level turn?
      - No, it may seem lower, but that is because you are already at a higher AoA in the turn to get more lift to stay in level flight.
      - Your stall speed goes up because you are already at a higher AoA in the turn, so if you trade speed with AoA to maintain the same lift…you'll run out of AoA sooner
      - Seems like you can bank less at altitude, because you do not have the excess thrust to balance the additional drag that accompanies the additional lift in the turn

Stalls

- Physical confusion…
  - Load factor
    - Don’t I stall at a lower AoA if I pull g’s?
      - No, it may seem like it, but you’ve increased your AoA to pull the g’s, so you have less margin until you reach the AoA for maximum lift

Stalls

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  - Load factor
    - Don’t I stall at a lower AoA if I pull g’s?
      - No, it may seem like it, but you’ve increased your AoA to pull the g’s, so you have less margin until you reach the AoA for maximum lift
  - Altitude
    - Don’t I stall at a lower AoA at altitude?
      - Not if your Mach number doesn’t change with altitude.

Stalls

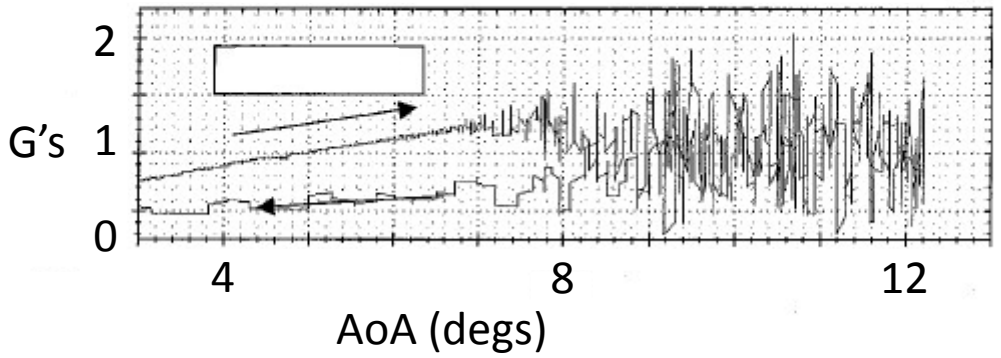
- Physical confusion…
  - Load factor
    - Don’t I stall at a lower AoA if I pull g’s?
      - No, it may seem like it, but you’ve increased your AoA to pull the g’s, so you have less margin until you reach the AoA for maximum lift
  - Altitude
    - Don’t I stall at a lower AoA at altitude?
      - Not if your Mach number doesn’t change with altitude…but your Mach probably does change, so that is the fundamental parameter
  - Gross weight
    - Don’t I stall at a lower AoA with more weight?
      - No, the wing doesn’t care about how much you weigh

Airbus stall video

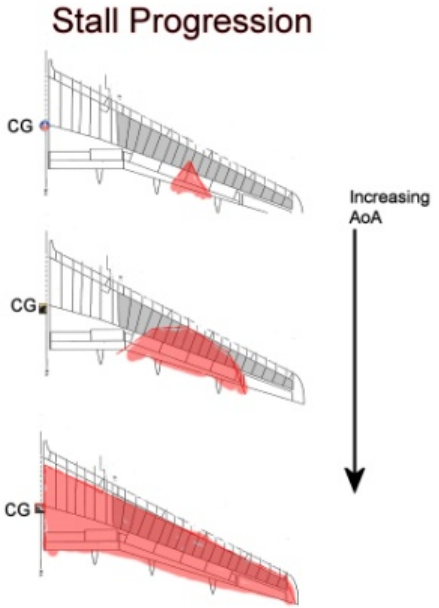
Stalls

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

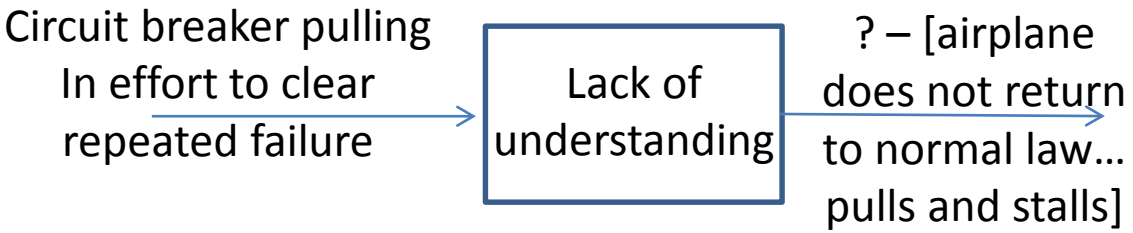
British Airways #38, Jan. 2008

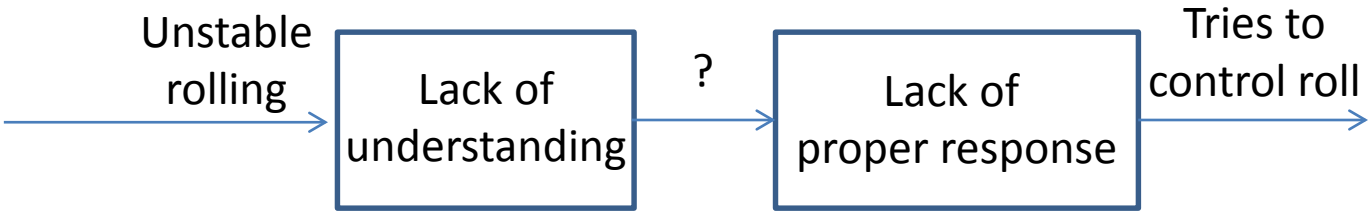
Exercise

- Question: Does the stall recovery template only apply to high altitudes?
- True or False (and why?): The key to properly recovering from a stall is to minimize loss of altitude.
- Question: What is the most important pilot action to recover from a stall and why?
- True or False: If you at a very low altitude, you should still push during an approach-to-stall or stall recovery?

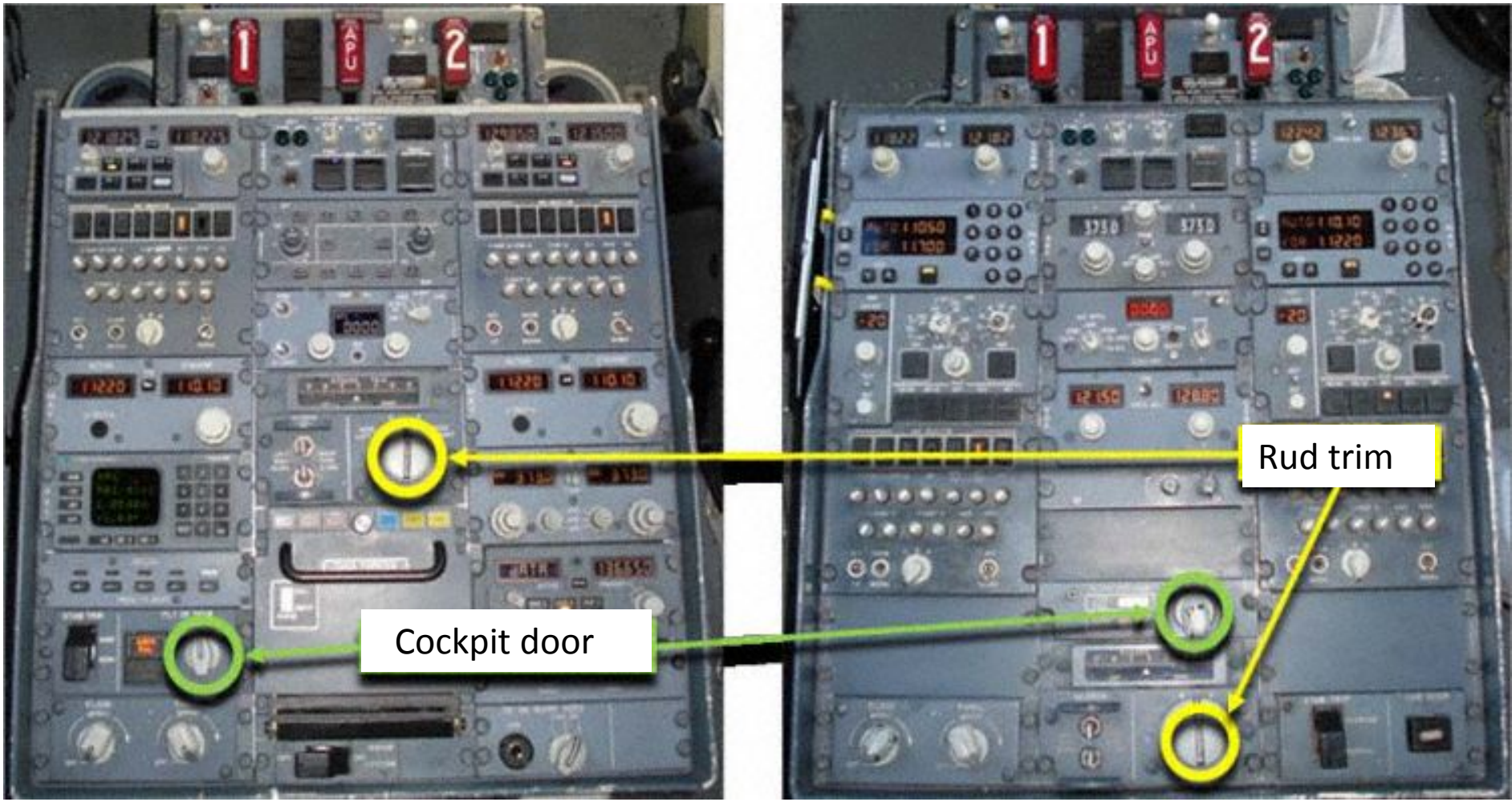
Why?

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
  - Roll to approaching wings level
  - Apply nose-up elevator; trim as necessary
  - Adjust thrust and drag as necessary
- Target pitch rate, use:
  - pitch-limit-indicator (if available), or
  - approximately the 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)

Loss of reliable airspeed

- Not only for “loss of reliable airspeed” but for all possible upsets: **recognition and confirmation is a critical step**
  - **Otherwise you can make a situation worse!**

Loss of reliable airspeed

- Example
  - U.S. operator
  - On descent into Dublin, pitot tubes blocked when passing through FL250
    - Airspeed indicator acting like an altimeter…it decreased as the altitude decreased
  - First Officer's (pilot flying) airspeed indicator read 90 knots…thought aircraft was stalling
  - Without disconnecting A/P or A/T, first officer applied full thrust and pitched down abruptly
  - Aircraft went between -0.4 and 2.0 g's.
  - Airspeed increased to 380 kts and VSI exceeded 12000 ft/min
  - Structural damage; hydraulic servicing door departed the aircraft

Loss of reliable airspeed

- Lessons learned
  - First officer did not confirm the failure
  - Led to unnecessary inputs that damaged the aircraft
  - Pilot monitoring did not announce the condition or aircraft state resulting in the pilot flying executing an unnecessary recovery procedure

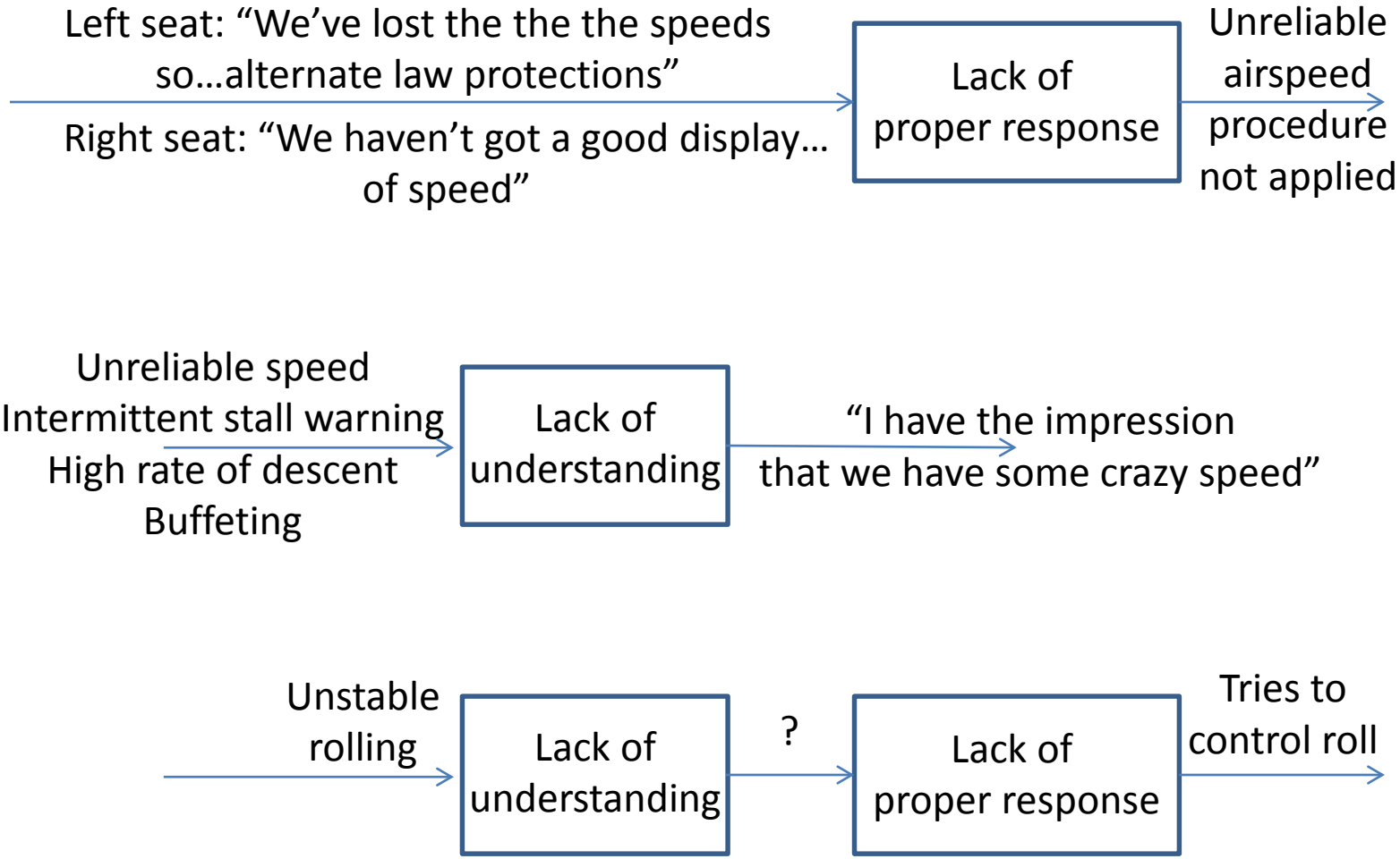
Loss of reliable airspeed—AF447

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?

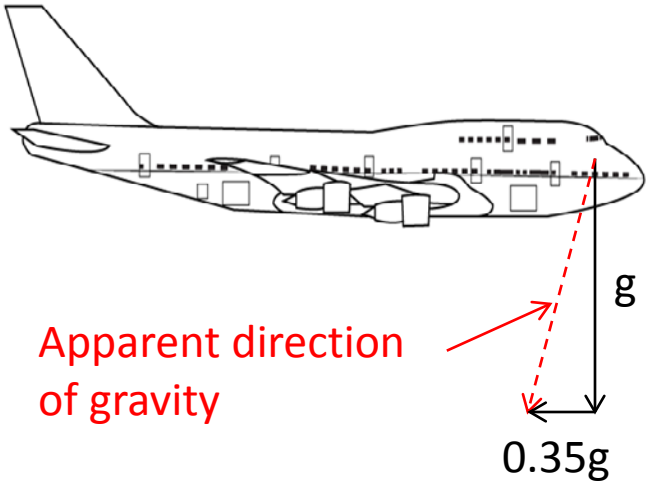
Air France 447



Pitching illusion

- Forward accelerations create illusion of pitching

Reality

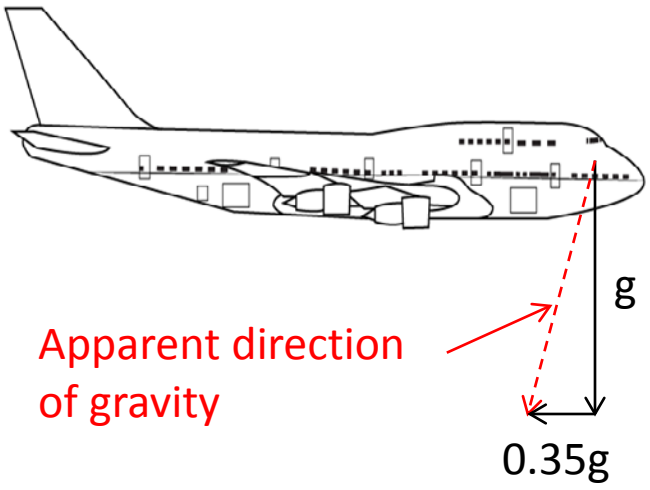


Go around with T/W=0.35

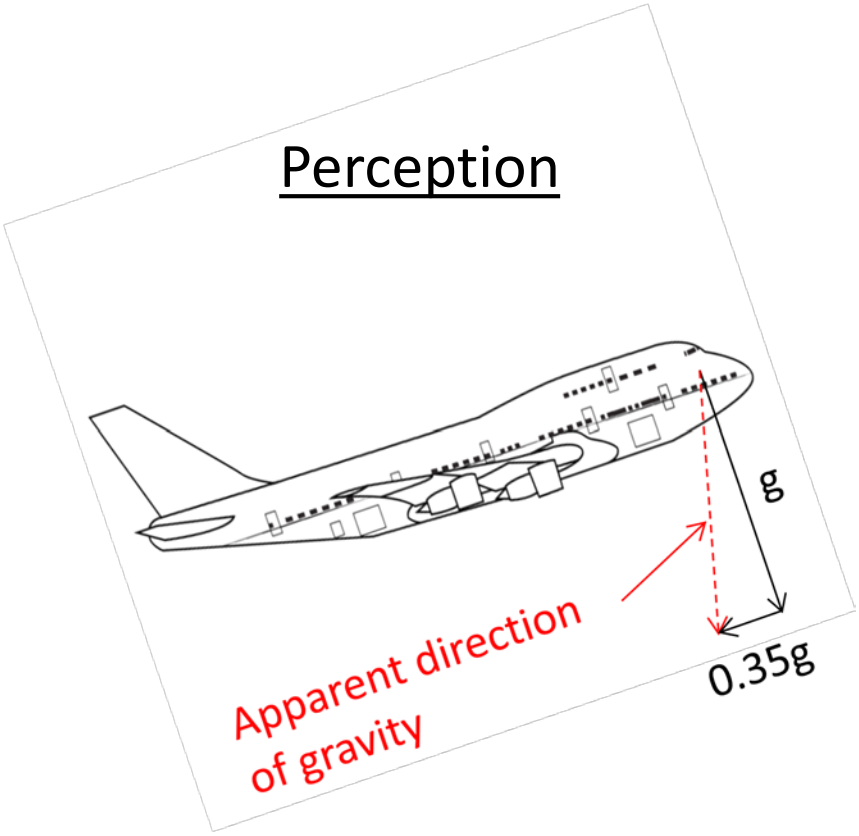
Pitching illusion

- Forward accelerations create illusion of pitching

Reality



Perception

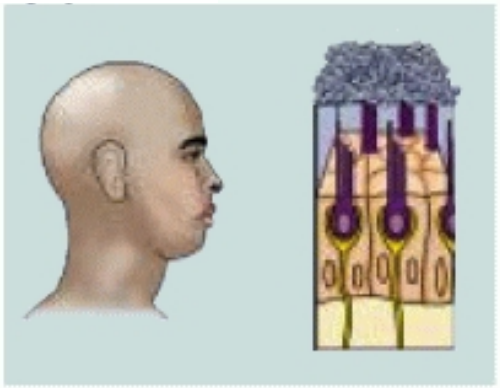


Go around with T/W=0.35

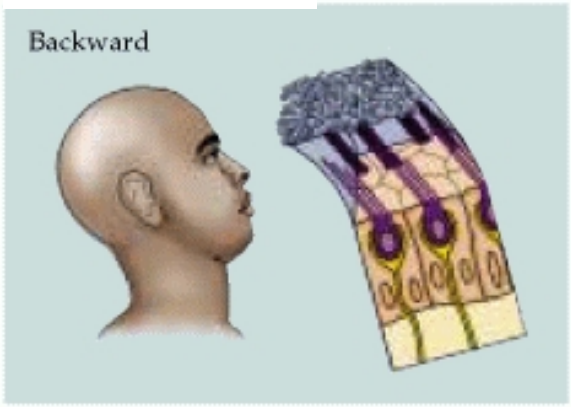
19 deg pitch up

Pitching illusion

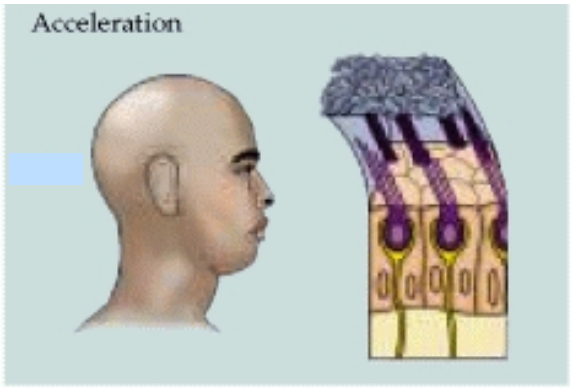
Upright



Pitched up



Accelerating forward



So what?

So what?

- Illusion believed to be a factor in following:
  - Skylink Airlines #70 accident, SA 227, Sept. 1989
    - Go around, day IMC
  - Air Transport Intl #805 accident, DC-8, Feb. 1992
    - 2nd go around, night IMC
  - USAir #1016 accident, DC-9, July 1994
    - Go around, day IMC
  - Gulf Air #72 accident, A320, Aug. 2000
    - 2nd go around, dark night VMC
  - Armavia #967 accident, A320, May 2006
    - Go around, night IMC
  - Afriqiyah Airways #771 accident, A330, May 2010
    - Go around, night IMC

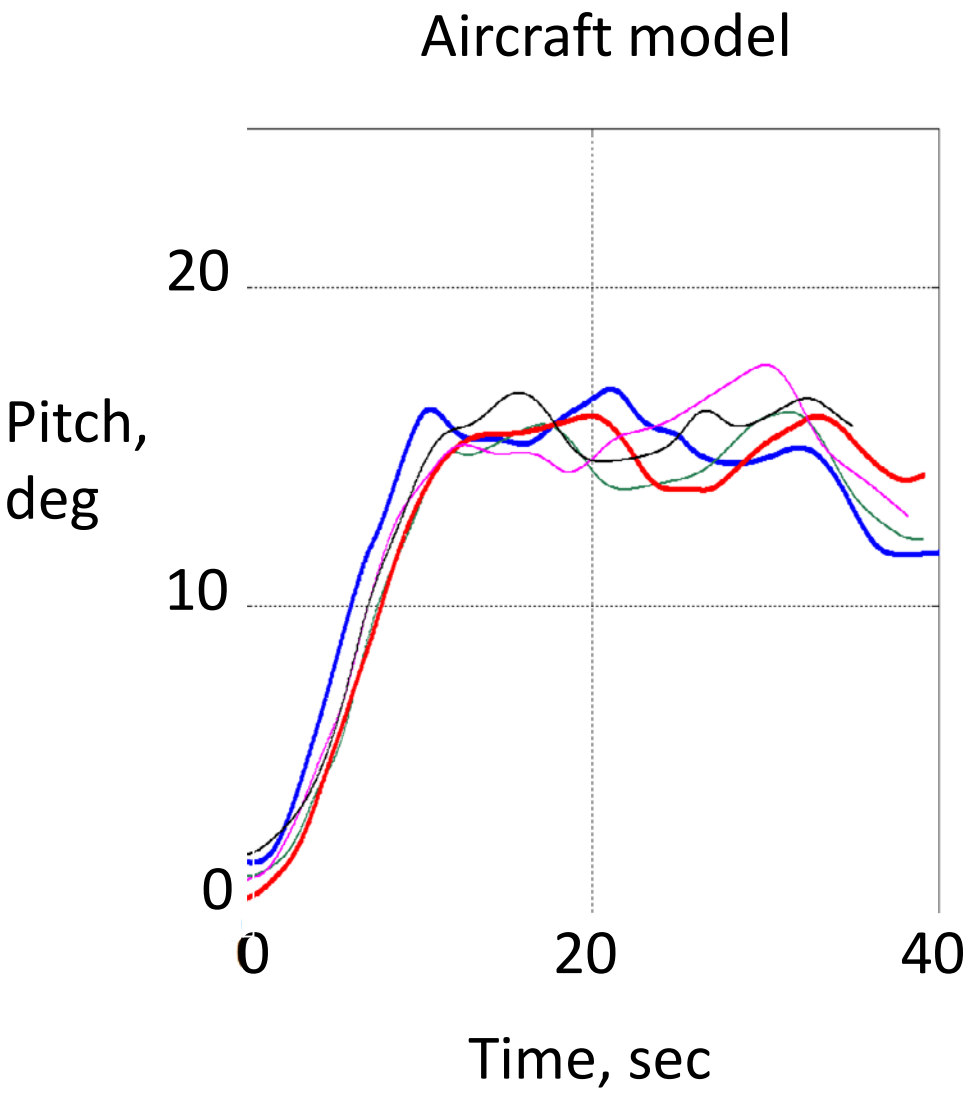
Pitching illusion

- Illusion training recommendations now in:
  - "Aeroplane State Awareness during Go Around"
    - BEA Study, Aug 2013
  - "Manual on Aeroplane Upset Prevention and Recovery Training"
    - ICAO Doc 10011, 2014
  - "Scenario-Based Go-Around Training"
    - FAA Safety Alert for Operators #15004, March 2015
  - "Upset Prevention and Recovery Training"
    - FAA Advisory Circular 120-111, April 2015

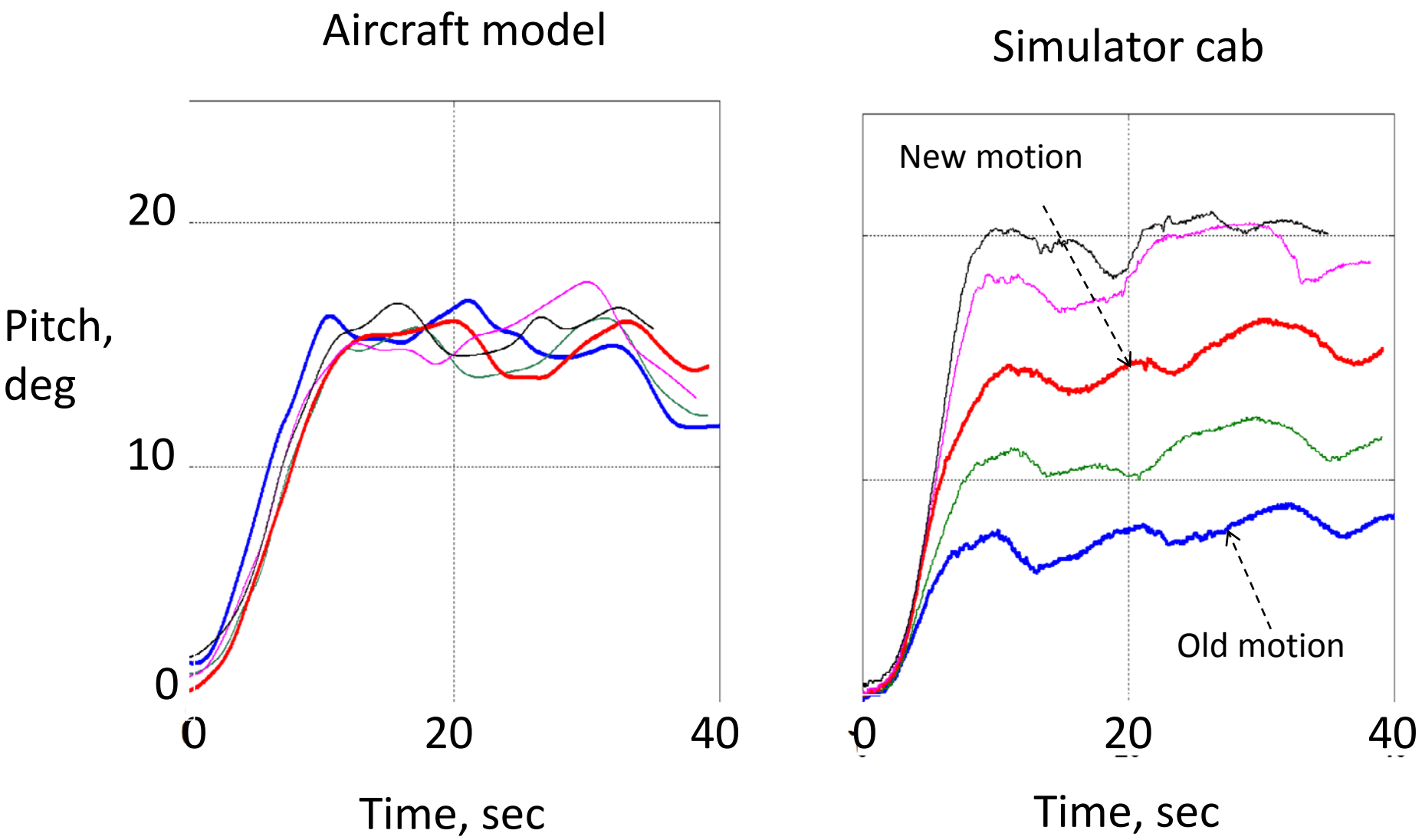
Pitching illusion

- What to do?
  - Pure illusion takes too much fore/aft travel
  - Takes 5.7 secs to create 0.2g with cab tilt below sensory threshold
- Maybe we can temporarily “fake it” and still provide training value

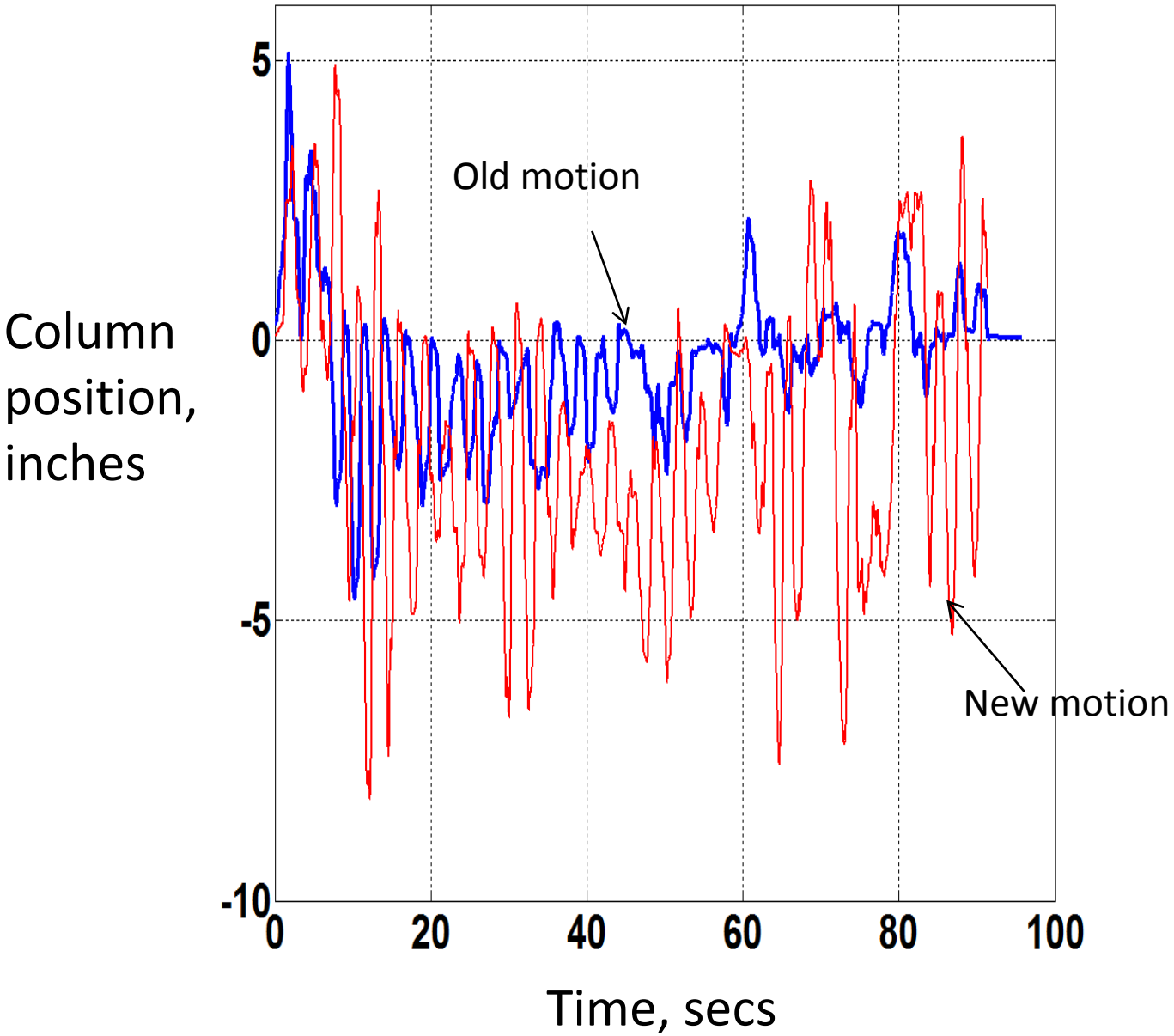
Pitching illusion



Pitching illusion

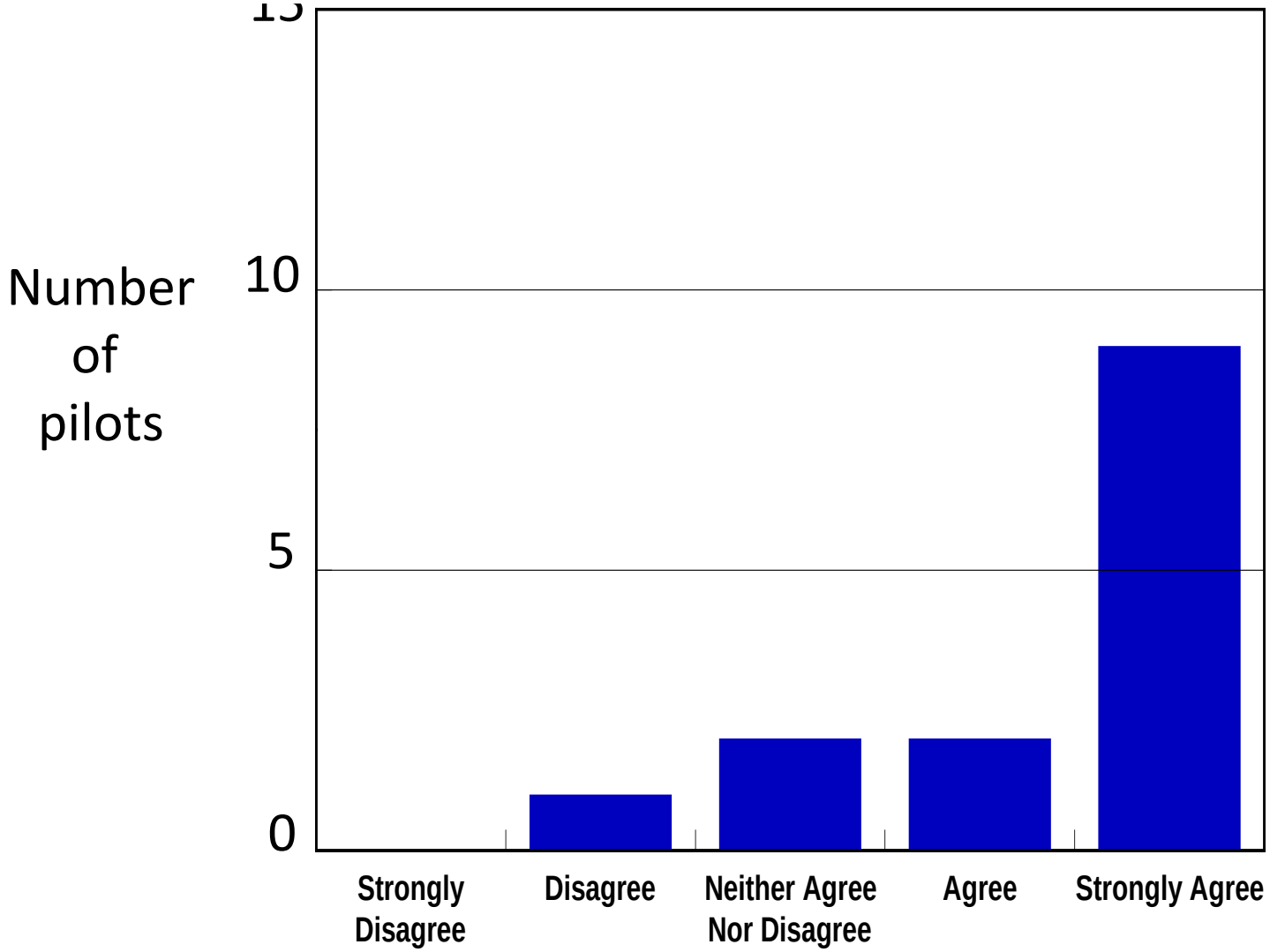


Pitching illusion



Pitching illusion

"The scenario was an effective demonstration of the pitch up illusion"



Negative transfer of training

- Be wary of system design changes (e.g., control locations, menus)
  - Can cause you develop a degree of automaticity
- Obvious mismatches between sim and flight
  - Example: Say, simulator never rolls in a stall, but airplane does, tempting you to control roll before breaking stall
  - Example: Say, simulator does not provide g to a full input, potentially leading to moving controls with abandon
- Some of these can be addressed, hopefully, with knowledge and appreciation of the differences

Pilot monitoring

- The pilot monitoring is a key safety net for preventing loss-of-control
- Types:
  - Passive: keep and eye on, listen to
  - Active: requiring call out
  - Periodic: checks at pre-defined time intervals
  - Mutual: action by one pilot and crosschecked by other
  - Predictive: compare situation against tolerances and advise

Pilot monitoring

- PM provides effective crosscheck and backup (i.e., standard calls and excess deviation callouts, e.g., SPEED MINUS 15)
- PM inquires about all actions not understood or considered inappropriate
- PM monitors AP/FD/ATHR modes
- PM monitors any target selection performed on mode control panel using scales on PFD
- PM monitors minimum safe altitude or minimum vectoring altitude
- Data entry and flight profile adjustments or route changes should be cross monitored

Pilot monitoring

For more, 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 Foundations*