Academic Upset Prevention and Recovery Training – The Highlights

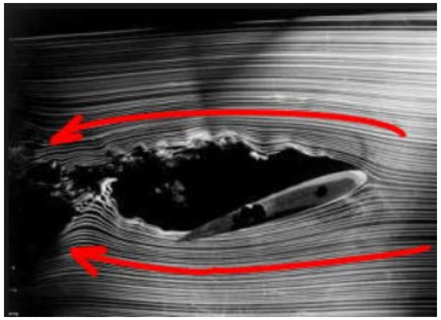
Jeffery A. Schroeder

Federal Aviation Administration

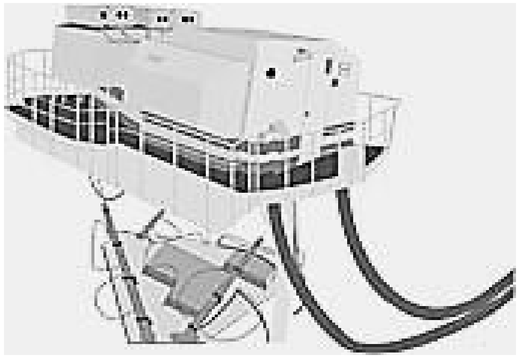
December, 2016

Top Points

- An ounce of prevention is worth a pound of cure

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

- Pilot upset training in simulators must account for their limitations



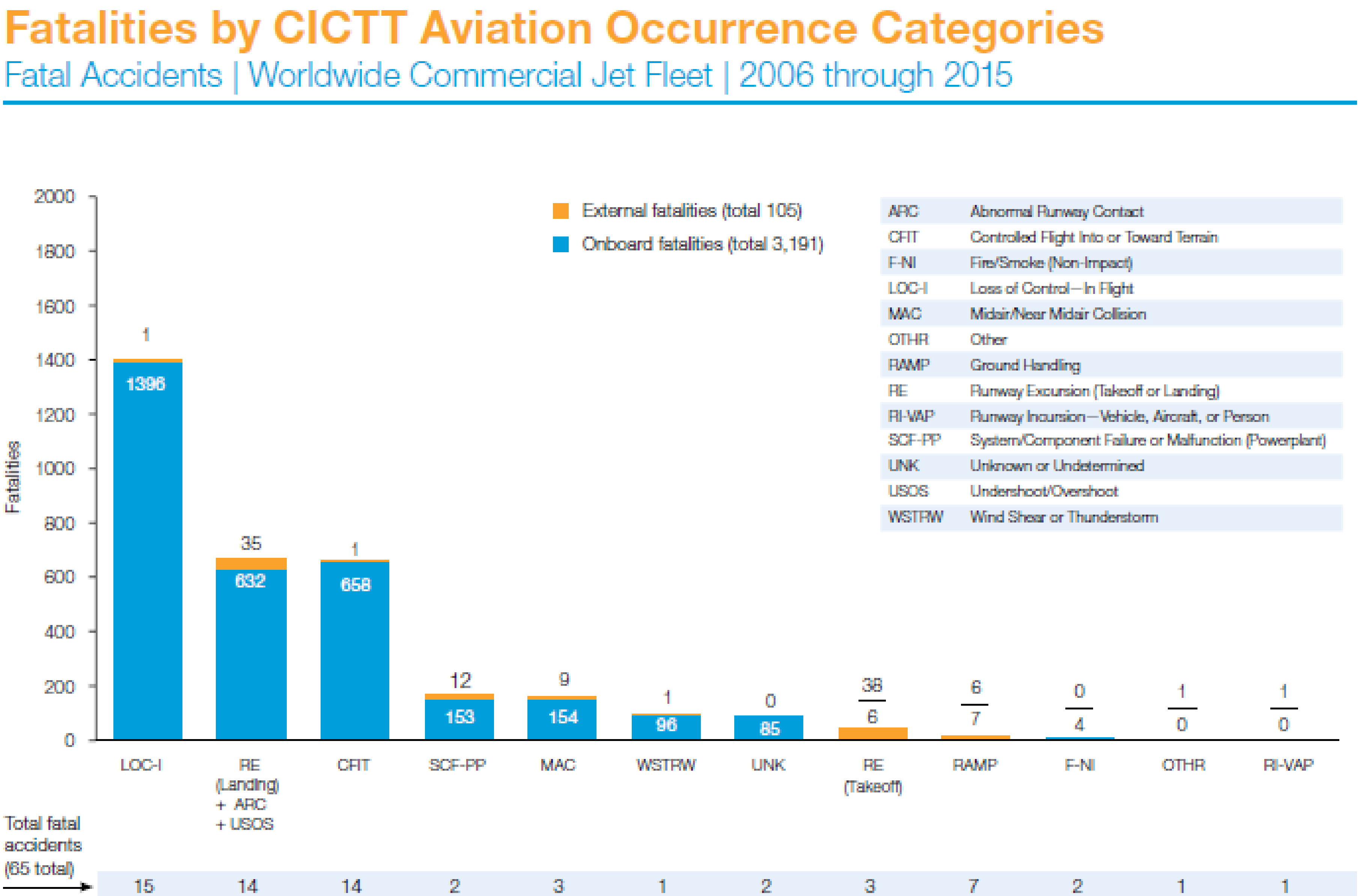
Outline

- Upset accidents and incidents
- New regulations and guidance
- Definitions
- Aerodynamics
  - Trim
  - Dihedral effect
  - Speed stability
  - Performance considerations
  - Roll stability

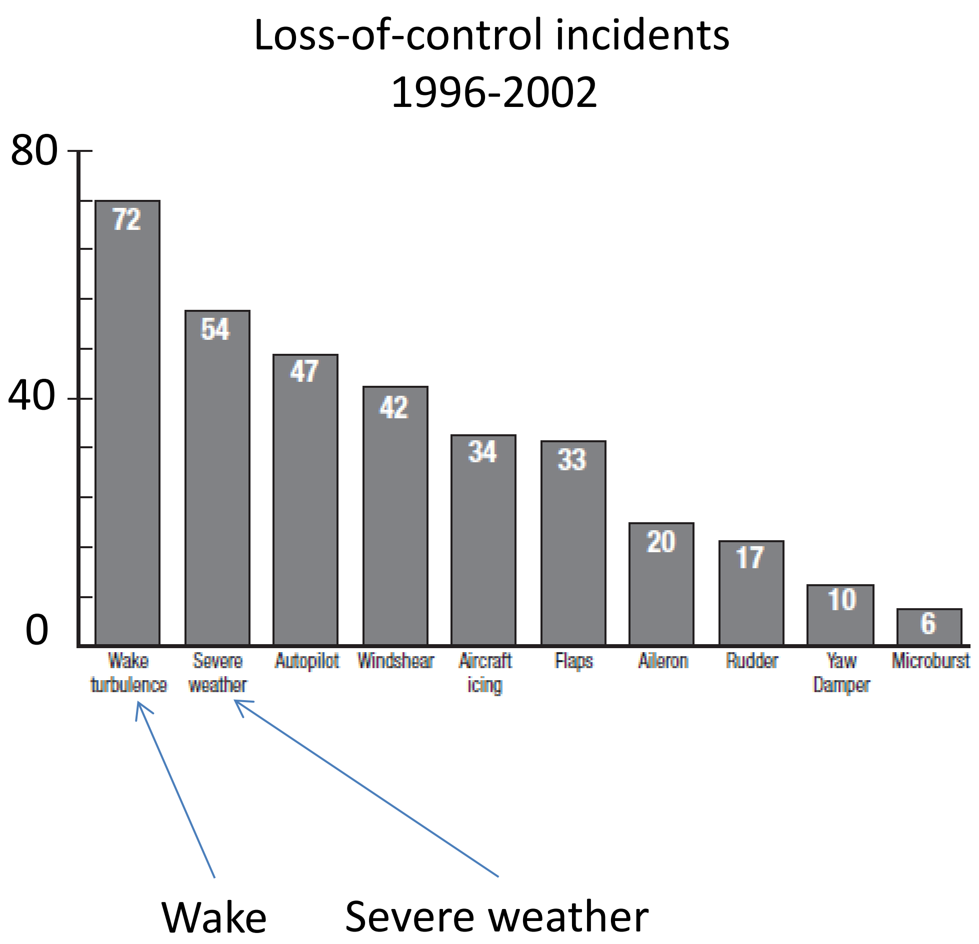
Outline, continued

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

Upset Accidents and Incidents

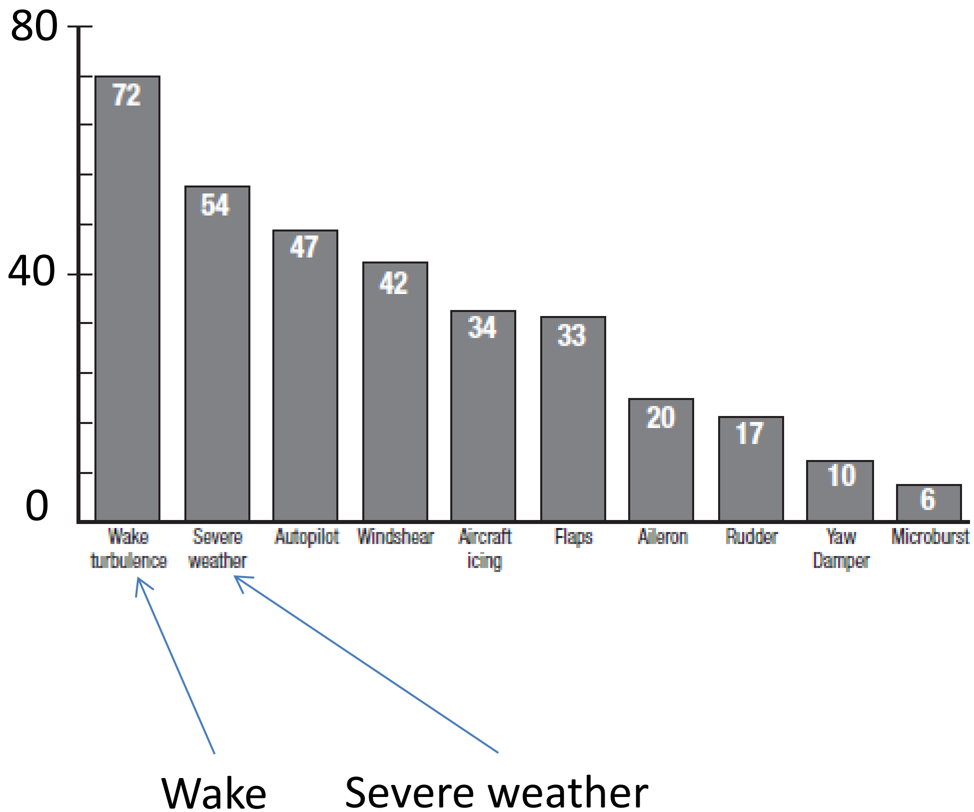


Upset Accidents and Incidents

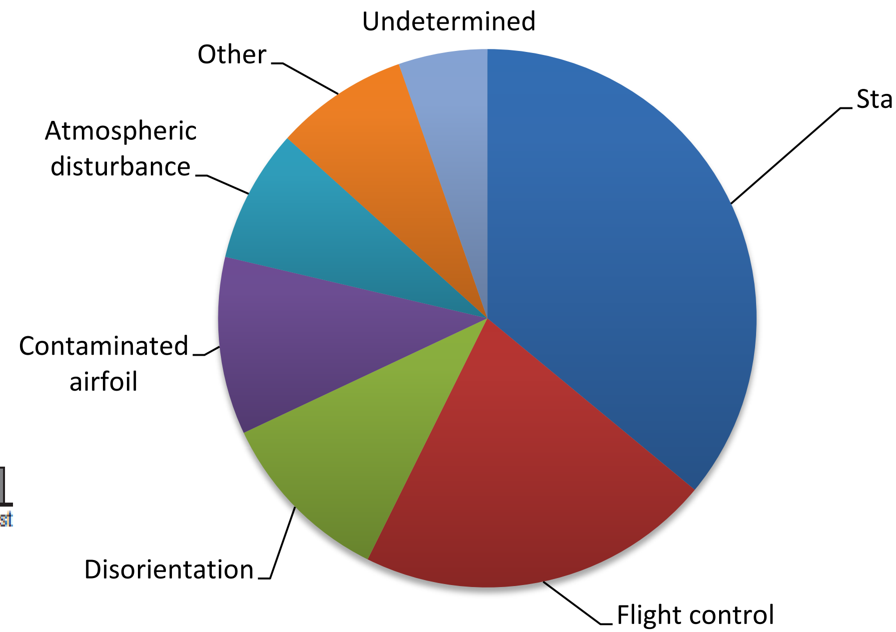


Upset Accidents and Incidents

Loss-of-control incidents
1996-2002



Loss-of-control accidents
1993-2007



Upset Accidents and Incidents

Catastrophic upsets are still rare

49×10^{-9} catastrophic upsets/flight hour

Upset Accidents and Incidents

Upset Accidents and Incidents

Why?

Lack of attention

Lack of understanding

Lack of proper response

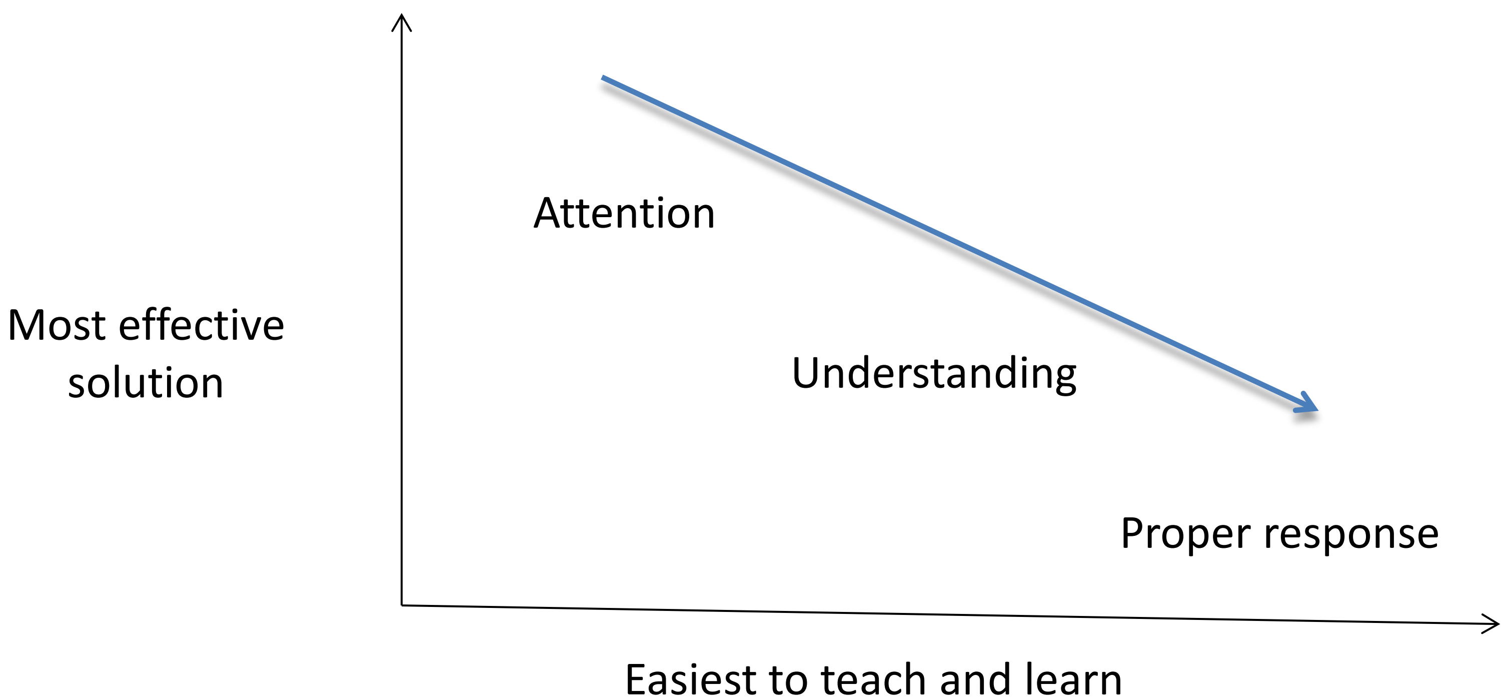
Upset Accidents and Incidents

Why?

Lack of attention

Lack of understanding

Lack of proper response



New regulations

- §121.423 – Pilot Extended Envelope Training
  - Extended envelope training must include
    - Manually controlled slow flight
    - Manually controlled loss of reliable airspeed
    - Manually controlled instrument departure and arrival
    - Upset recovery maneuvers
    - Recovery from bounced landing
  - Instructor-guided hands-on experience from full stall and stick pusher activation, if equipped
  - Have to use a Level C, or higher, simulator
  - All maneuvers every 2 years, except bounced landings (every 3 years)

New regulations

- Part 60…modify simulators to
  - Improve aerodynamics past stall warning through post-stall
  - Add icing physics instead of only end effects like stall speed increase
  - Upgrade instructor operating station to help instructors understand simulator limitations

New regulations

- For ALL pilots (in part 121 operations)
  - Extended envelope training compliance by March 12, 2019 for initial, upgrade, transition, or requalification training
  - Extended envelope training compliance by March 31, 2020 for recurrent training

New guidance

AC 120-109A

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Stall Prevention and Recovery Training | **Date:** 11/24/15 | **AC No:** 120-109A
Initiated by: AFS-200 | **Change:**

This advisory circular (AC) provides guidance for training, testing, and checking pilots to ensure correct responses to impending and full stalls. For air carriers, Title 14 of the Code of Federal Regulations (14 CFR) part 121 contains the applicable regulatory requirements. Although this AC is directed to part 121 air carriers, the Federal Aviation Administration (FAA) encourages all air carriers, airplane operators, pilot schools, and training centers to use this guidance for stall prevention training, testing, and checking. This guidance was created for operators of transport category airplanes; however, many of the principles apply to all airplanes. The content was developed based on a review of recommended practices developed by major airplane manufacturers, labor organizations, air carriers, training organizations, simulator manufacturers, and industry representative organizations.

This AC includes the following core principles:

- Reducing angle of attack (AOA) is the most important pilot action in recovering from an impending or full stall.
- Pilot training should emphasize teaching the same recovery technique for impending stalls and full stalls.
- Evaluation criteria for a recovery from an impending stall should not include a predetermined value for altitude loss. Instead, criteria should consider the multitude of external and internal variables that affect the recovery altitude.
- Once the stall recovery procedure is mastered by maneuver-based training, stall prevention training should include realistic scenarios that could be encountered in operational conditions, including impending stalls with the autopilot engaged at high altitudes.
- Full stall training is an instructor-guided, hands-on experience of applying the stall recovery procedure and will allow the pilot to experience the associated flight dynamics from stall onset through the recovery.

This revision of AC 120-109 reflects new part 121 regulatory terms and incorporates the full stall training requirement of Public Law 111-216. Considerable evaluation of the full flight simulator (FFS) must occur before conducting full stall training in simulation. Reference Appendix 5 for FFS evaluation considerations.

John S. Duncan
Director, Flight Standards Service

AC 120-111

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Upset Prevention and Recovery Training | **Date:** | **AC No:** 120-UPRT
Initiated by: AFS-200 | **Change:**

This advisory circular (AC) describes the philosophy and recommended training for airplane Upset Prevention and Recovery Training (UPRT). The goal of this AC is to provide recommended practices and guidance for academic and flight simulation training device (FSTD) training for pilots to prevent developing upset conditions and ensure correct and consistent recovery responses to upsets. The AC was created from recommended practices developed by major airplane manufacturers, labor organizations, air carriers, training organizations, simulator manufacturers, and industry representative organizations. This AC provides guidance to Title 14 of the Code of Federal Regulations (14 CFR) part 121 air carriers implementing the regulatory requirements of §§ 121.419, 121.423, 121.424, and 121.427. Although this AC is directed to air carriers to implement part 121 regulations, the FAA encourages all airplane operators, pilot schools, and training centers to implement UPRT and to use the guidance contained in this AC, as applicable to the type of airplane in which training is conducted.

Although a stall is categorized as an upset, this AC does not cover stall prevention and recovery training. This training, which includes the requirement for full stall training, is contained in the current edition of AC 120-109, Stall Prevention and Recovery Training.

Core principles of this AC include:

- Enhanced instructor training on the limitations of simulation.
- Comprehensive pilot academic training on aerodynamics.
- Early recognition of divergence from intended flight path.
- Upset prevention through improvements in manual handling skills.
- Progressive intervention strategies for the pilot monitoring.

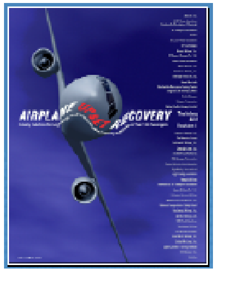
CAUTION: Prior to commencing UPRT, air carriers should review and implement Guidance Bulletin 11-05, *FSTD Evaluation Recommendations for Upset Recovery Training Maneuvers* to ensure FSTDs are specifically evaluated for UPRT maneuvers. Otherwise, negative transfer of training could occur.

John S. Duncan
Director, Flight Standards Service

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

Aerodynamics

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

Aerodynamics

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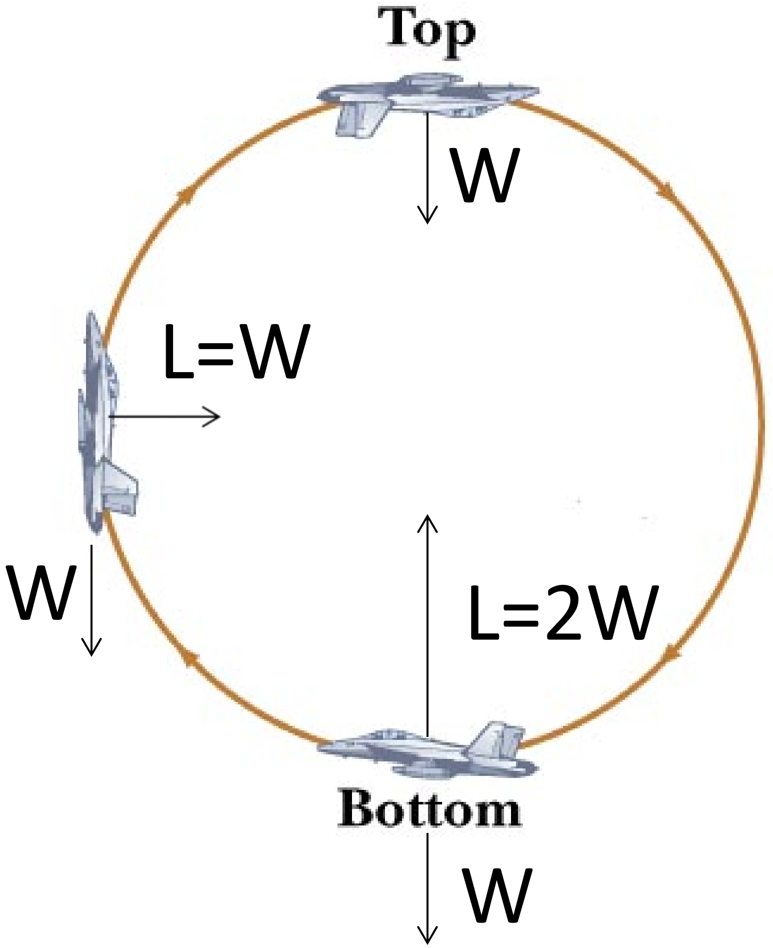

Aerodynamics

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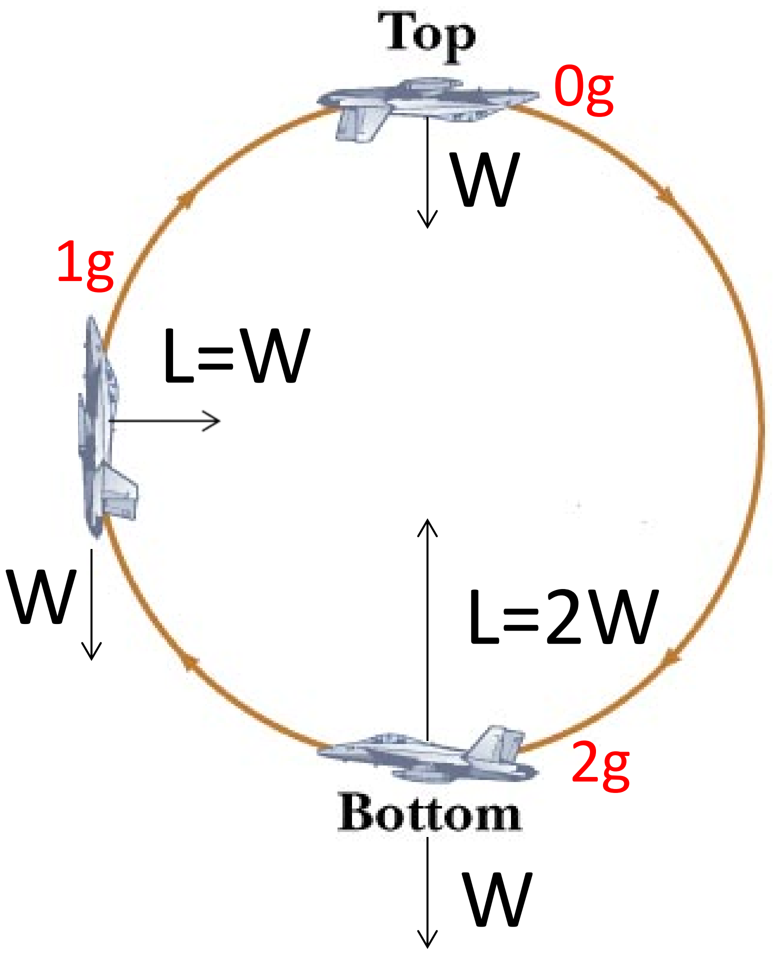
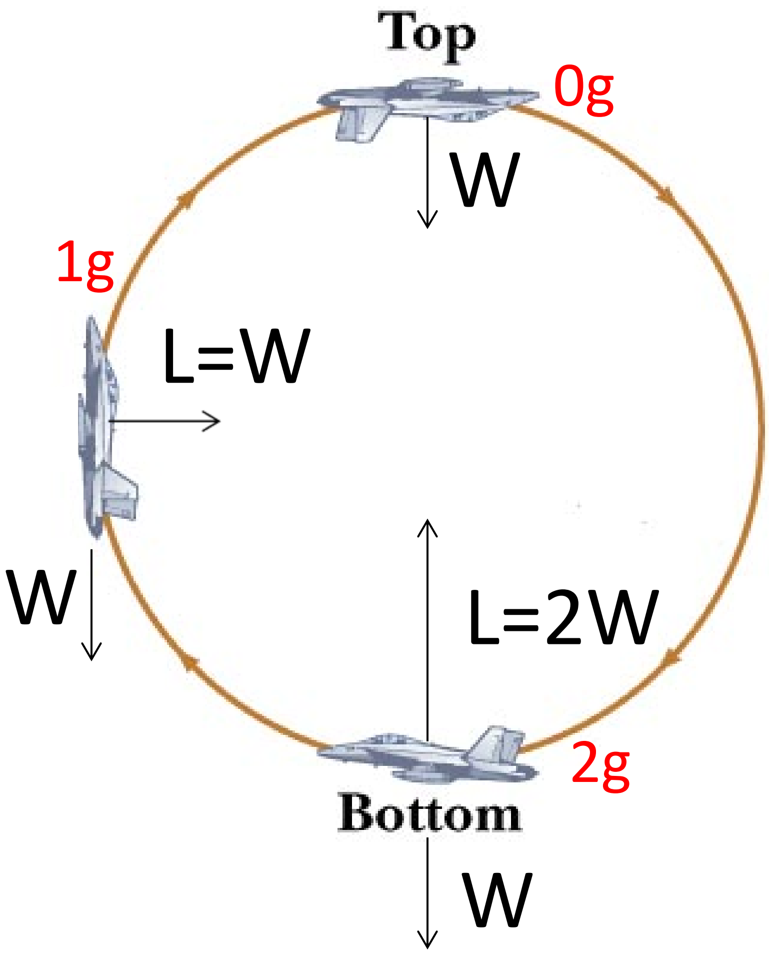


Aerodynamics

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

F=m**a**



Aerodynamics

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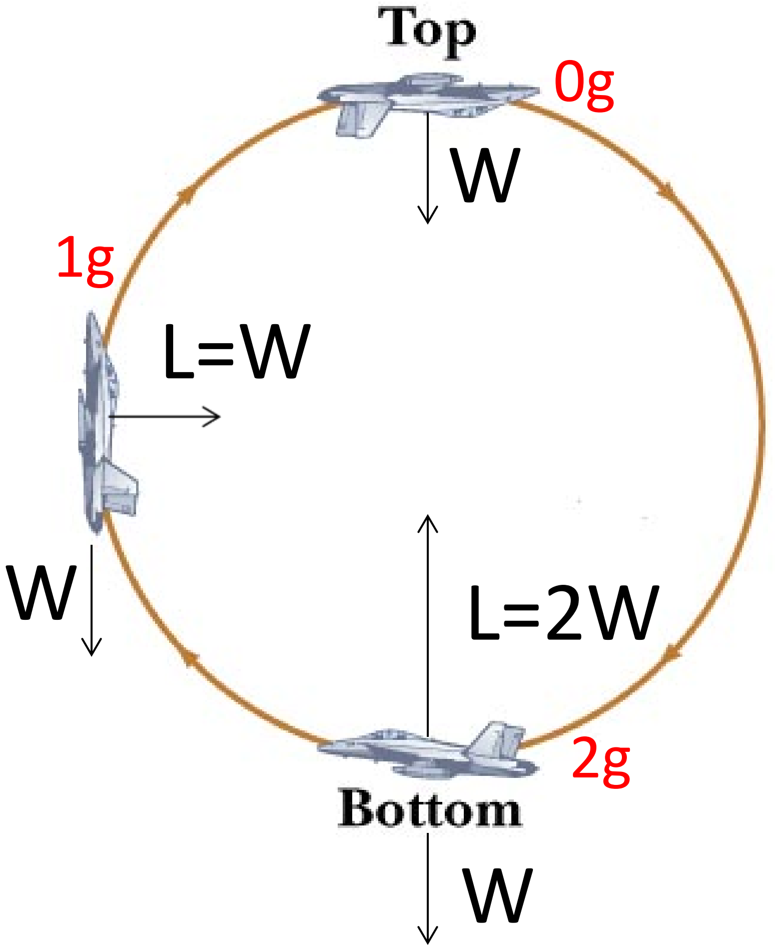
L - W



Aerodynamics

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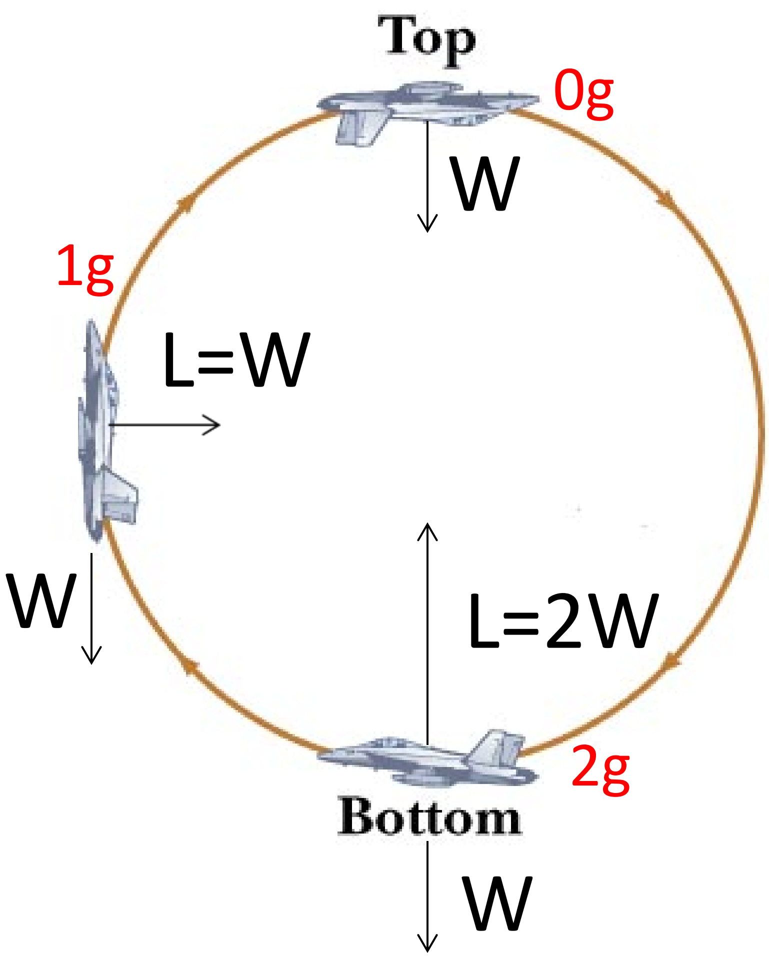

F=m**a**

L - W

Velocity getting bigger or smaller

\+

Velocity changing direction

Aerodynamics

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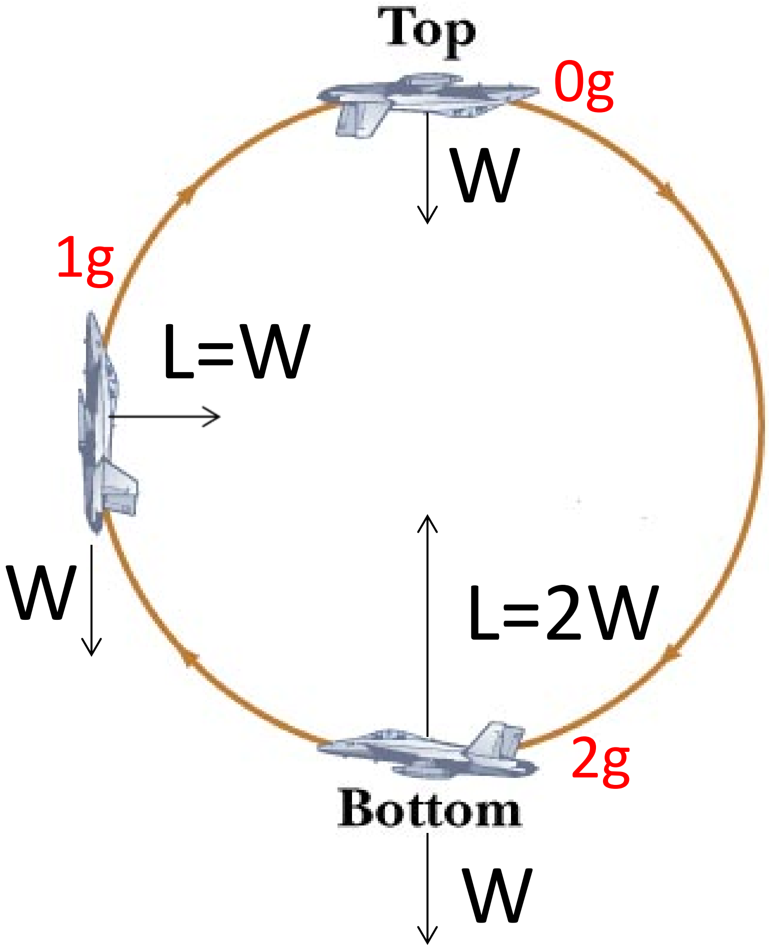

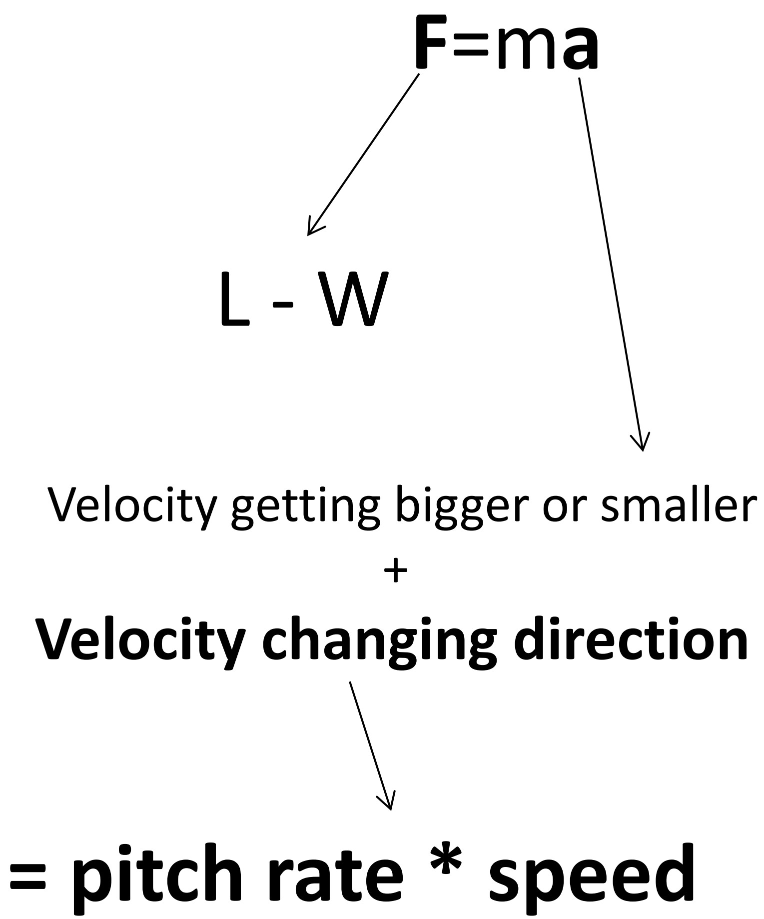

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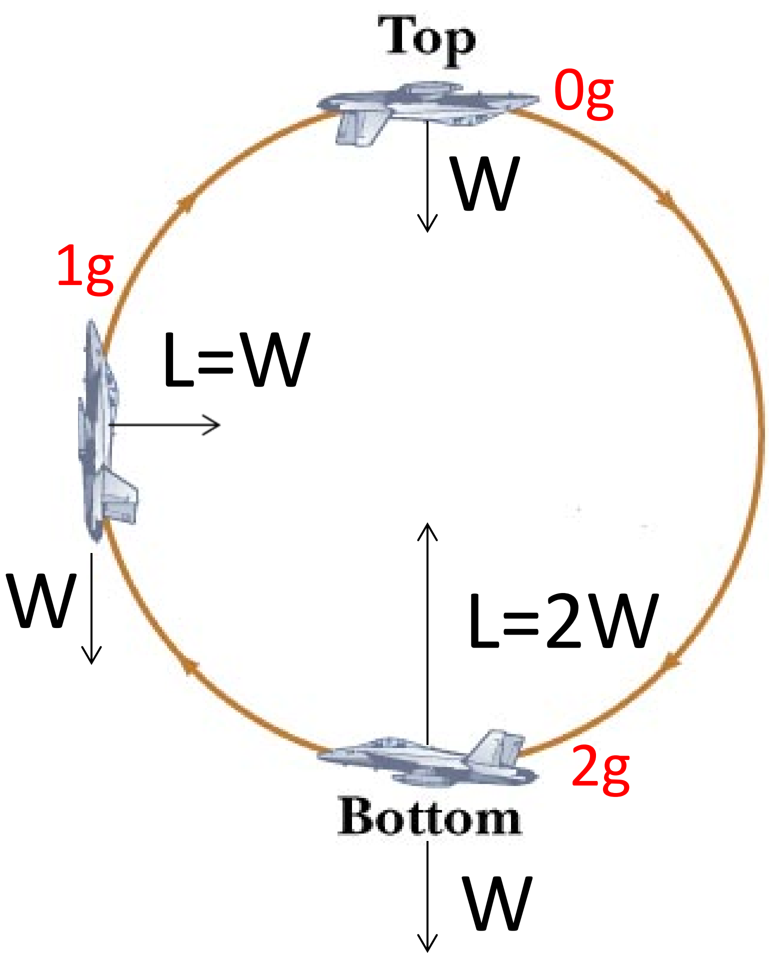


F=ma

L - W

Velocity getting bigger or smaller

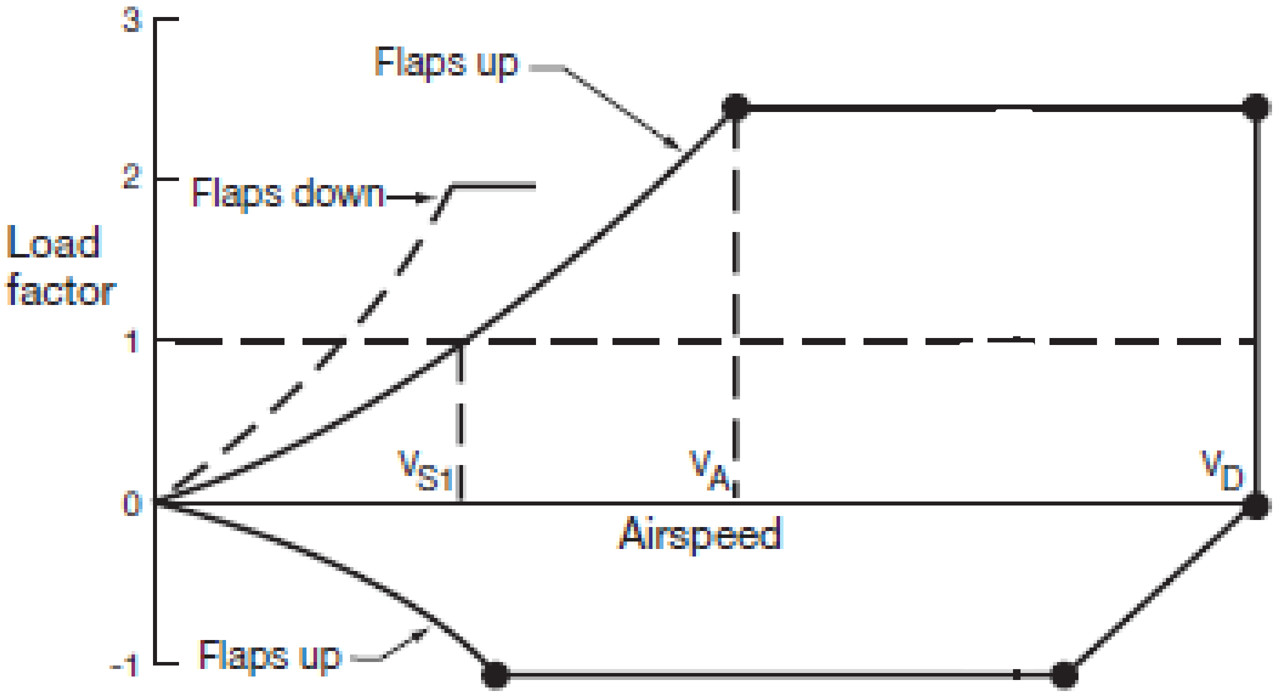
\+

Velocity changing direction

= pitch rate * speed

Both can get big at high altitude

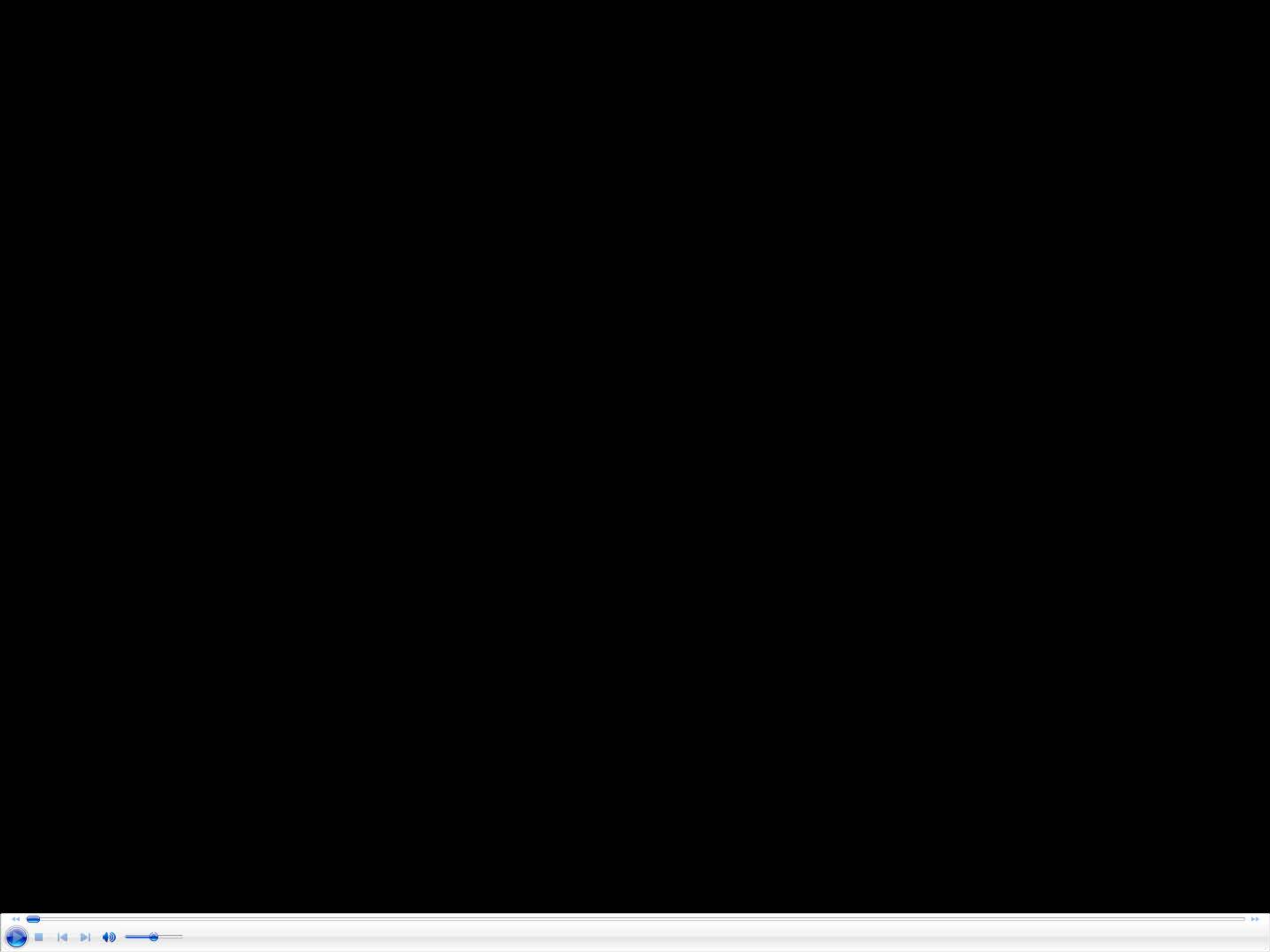
Aerodynamics



Aerodynamics

Trim

- Nagoya, 1994 – China Airlines #140



Aerodynamics

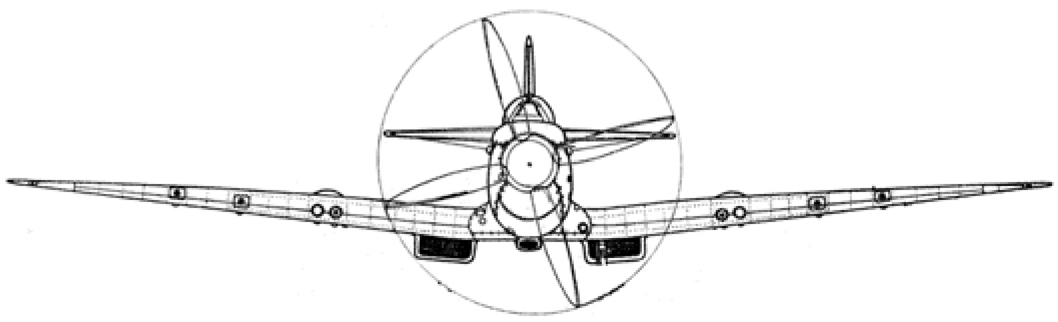
Trim

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

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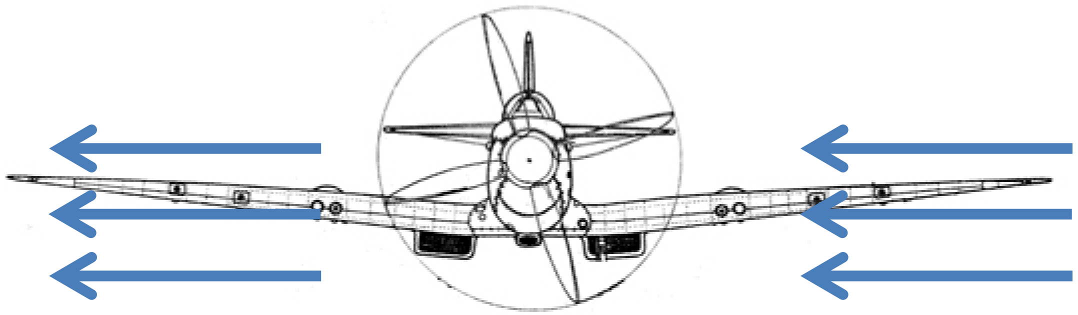
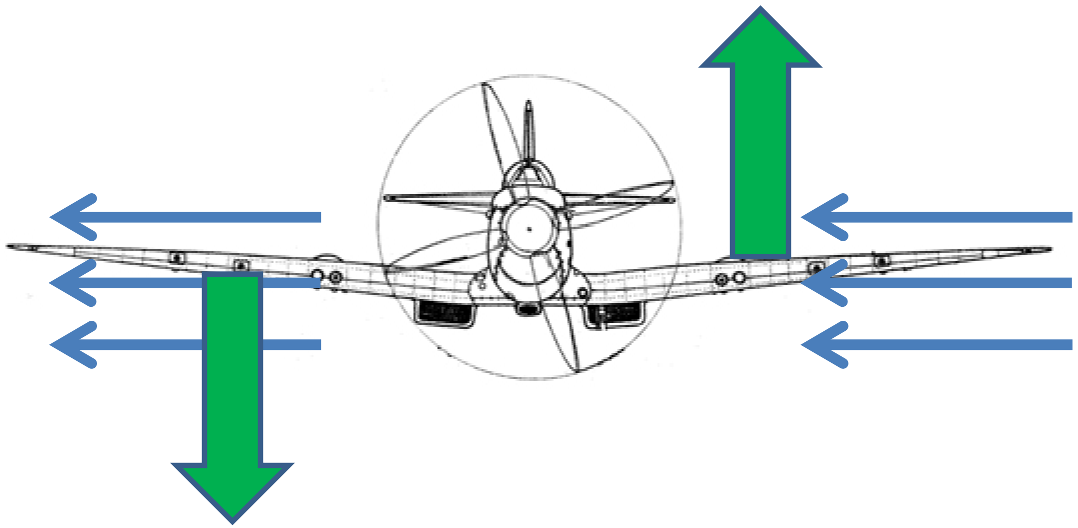


Sideslip causes a side force…might not feel in a simulator

Aerodynamics
Dihedral effect

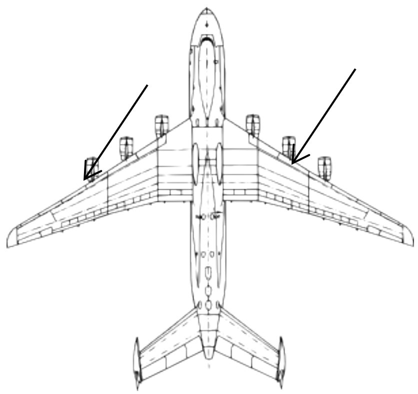
- What is it?



Aerodynamics

Dihedral effect

- Things to know for commercial transports…

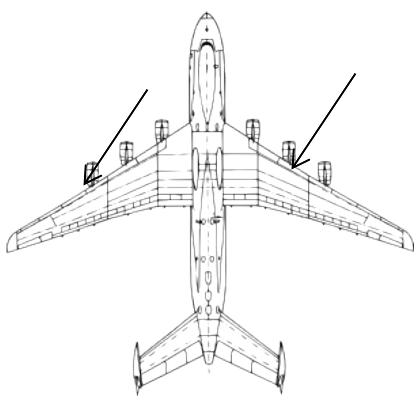


Swept wing increases dihedral effect

Aerodynamics

Dihedral effect

- Things to know for commercial transports…



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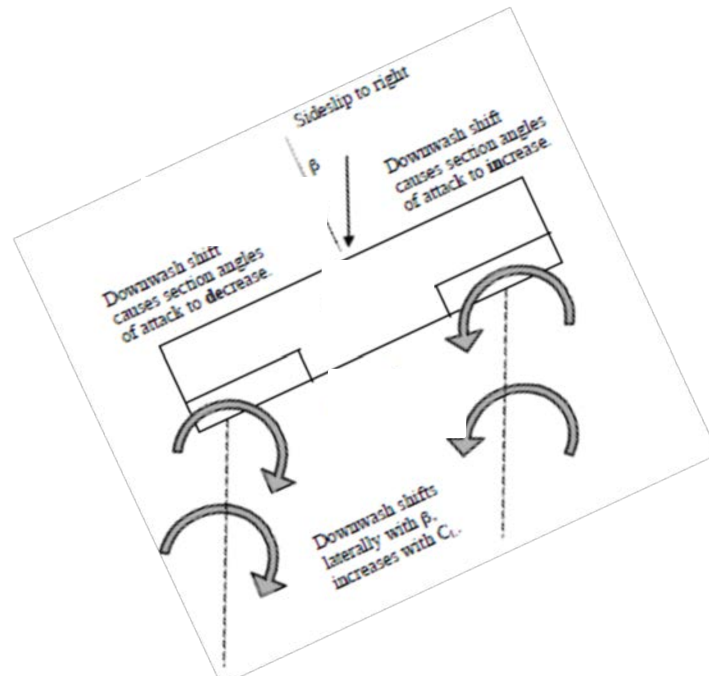
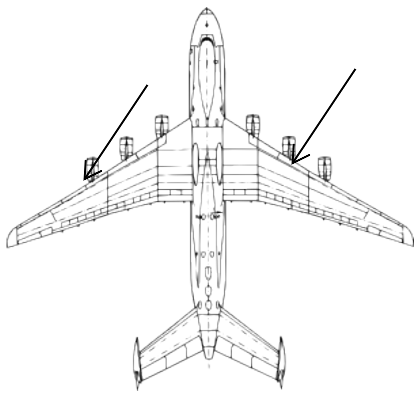


Increasing AoA increases dihedral effect

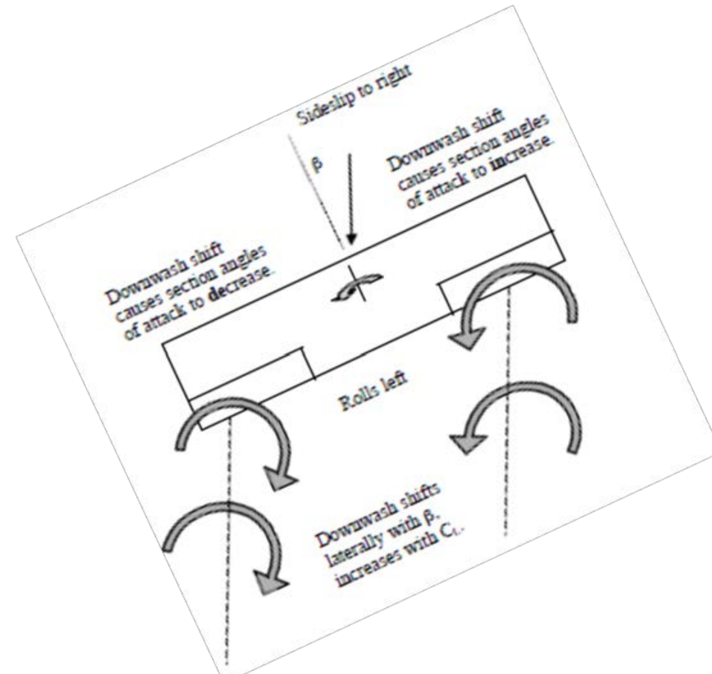
Aerodynamics

Dihedral effect

- Things to know for commercial transports…



Swept wing increases dihedral effect



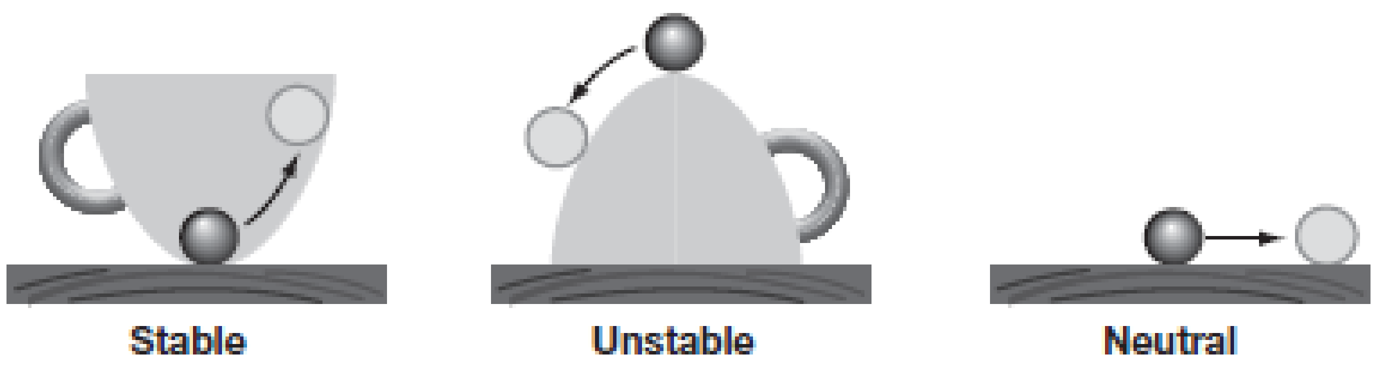
Increasing AoA increases dihedral effect

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

Aerodynamics

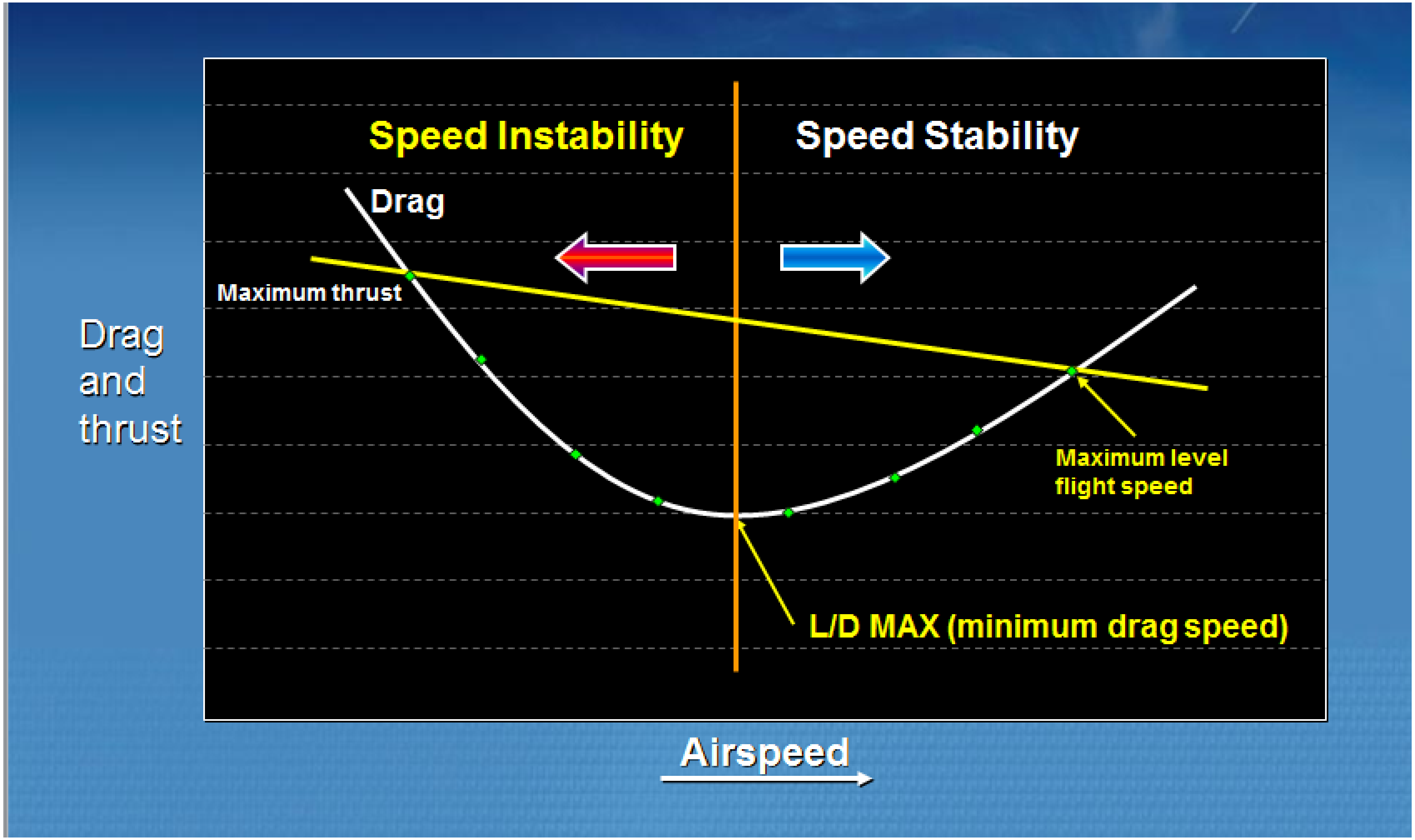
Stability

- Tendency to return if moved from trim and released



Aerodynamics

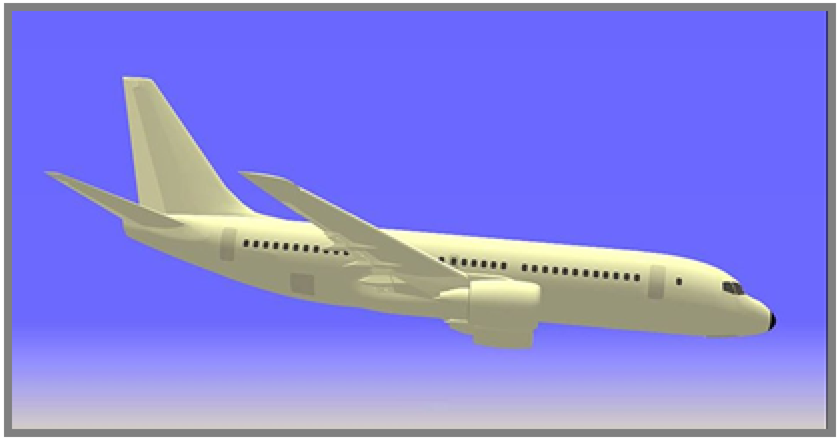
Speed stability



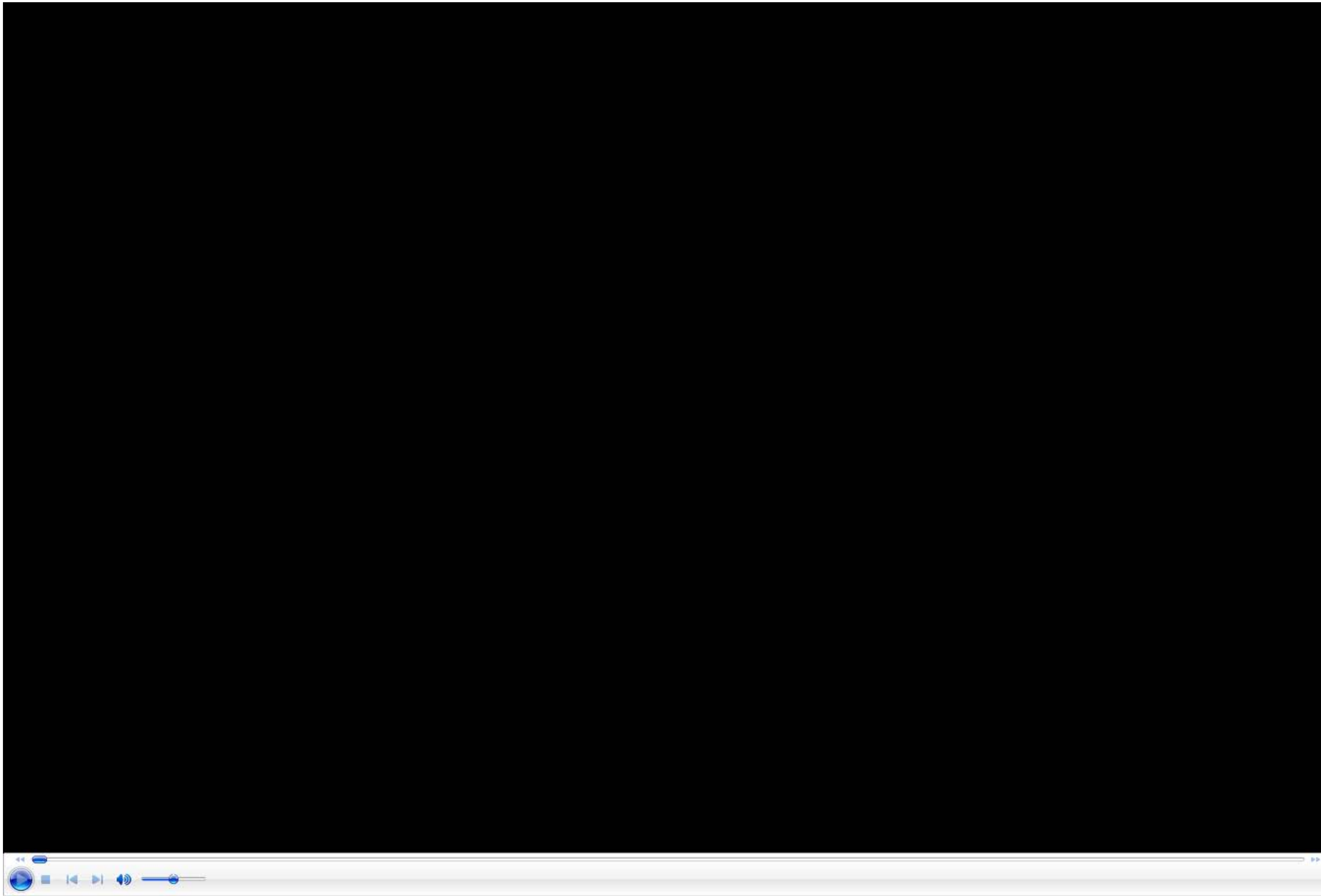
Aerodynamics
Performance considerations

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

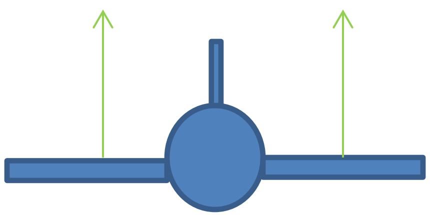


Aerodynamics
Performance considerations

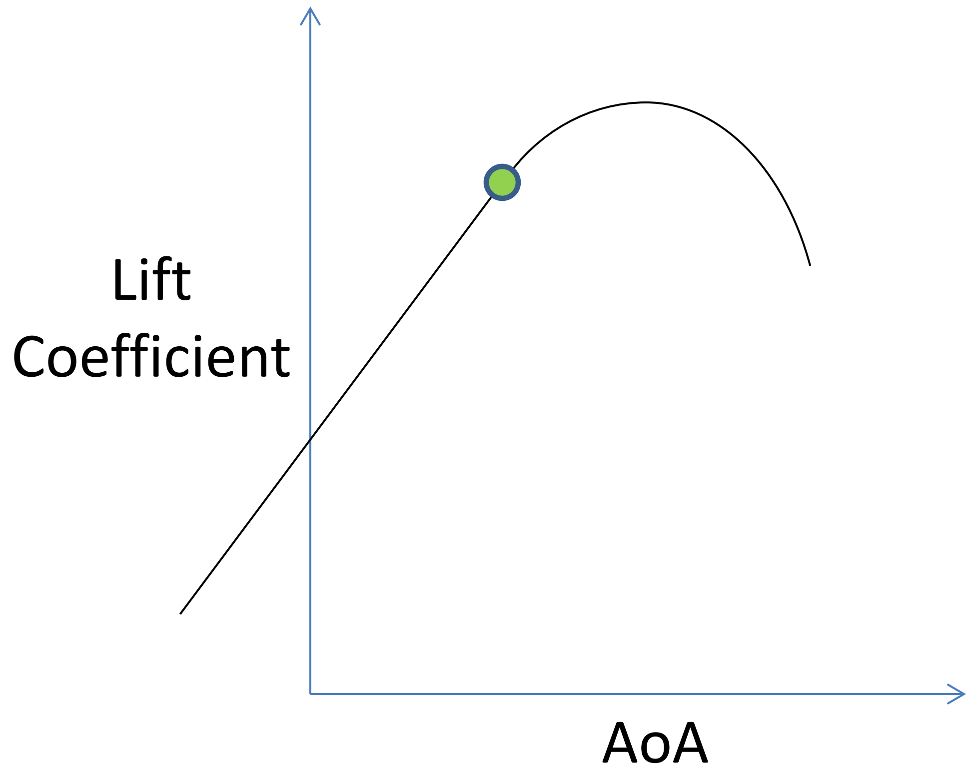


Aerodynamics

Roll stability

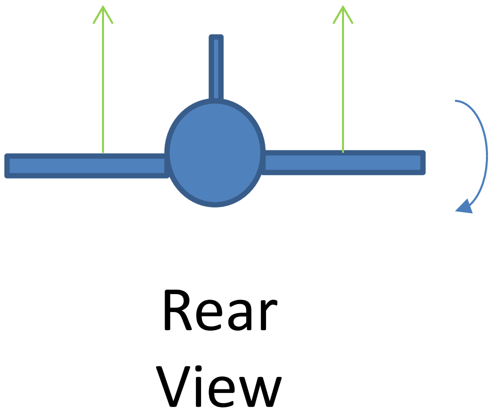


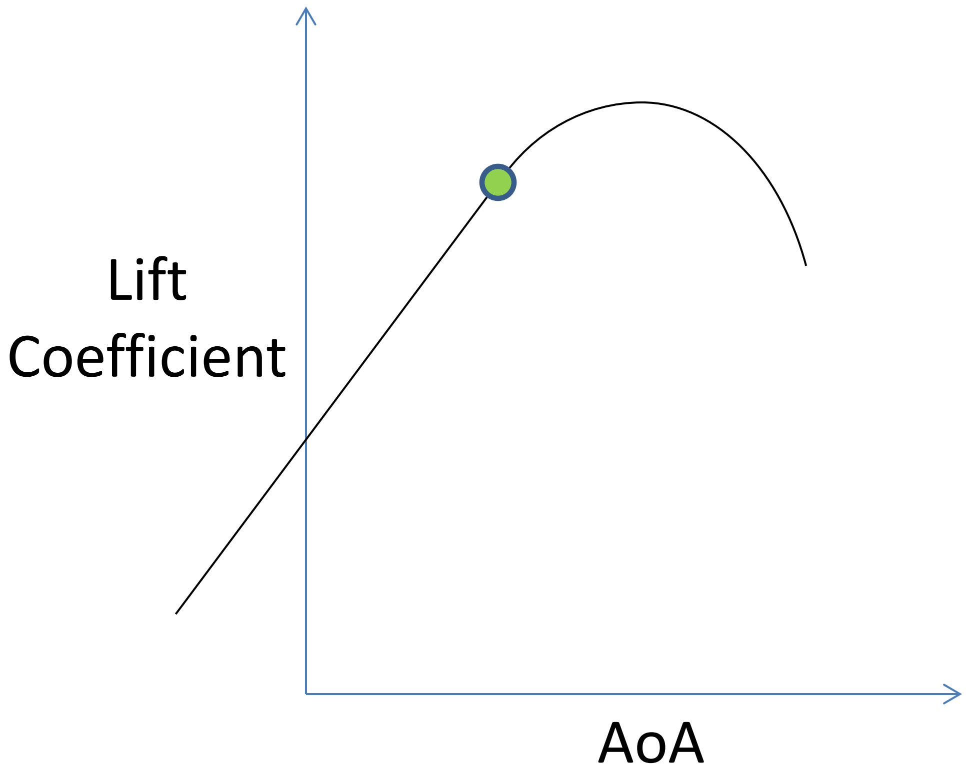
Rear View



Aerodynamics

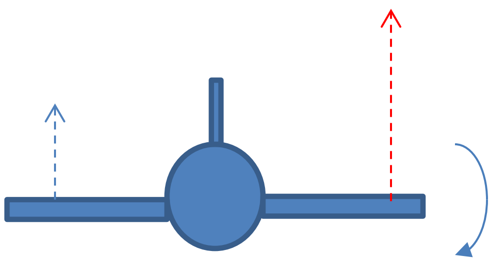
Roll stability





Aerodynamics

Roll stability



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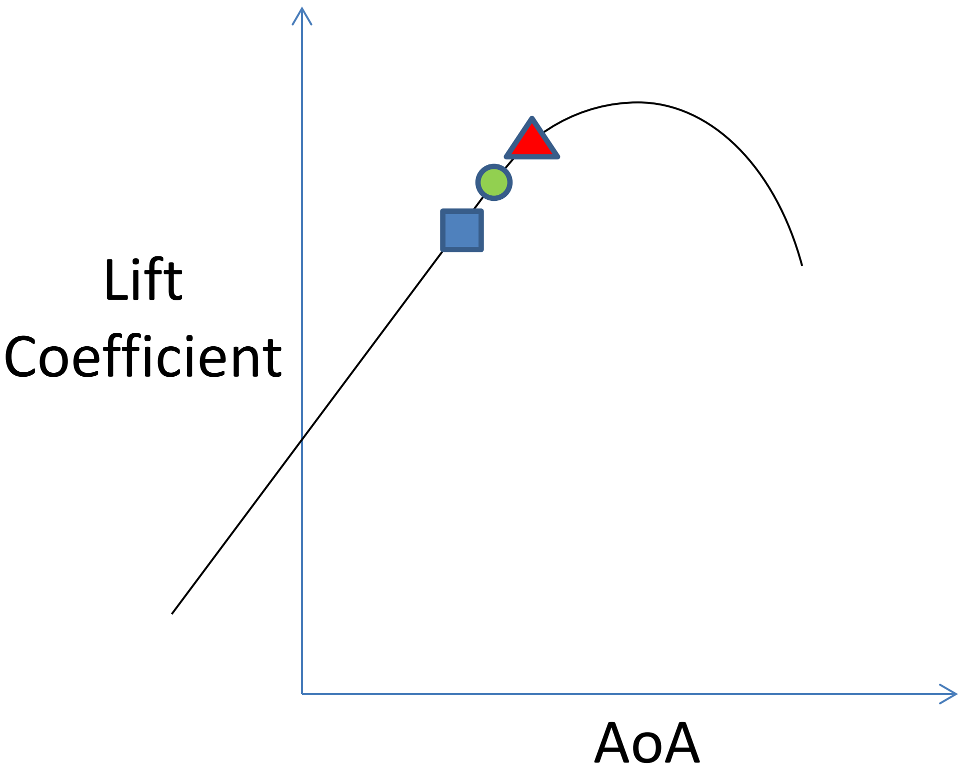
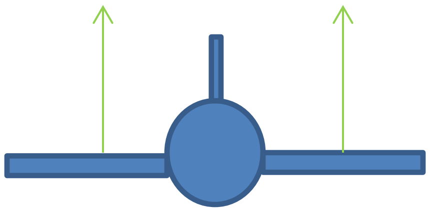


Aerodynamics

Roll stability



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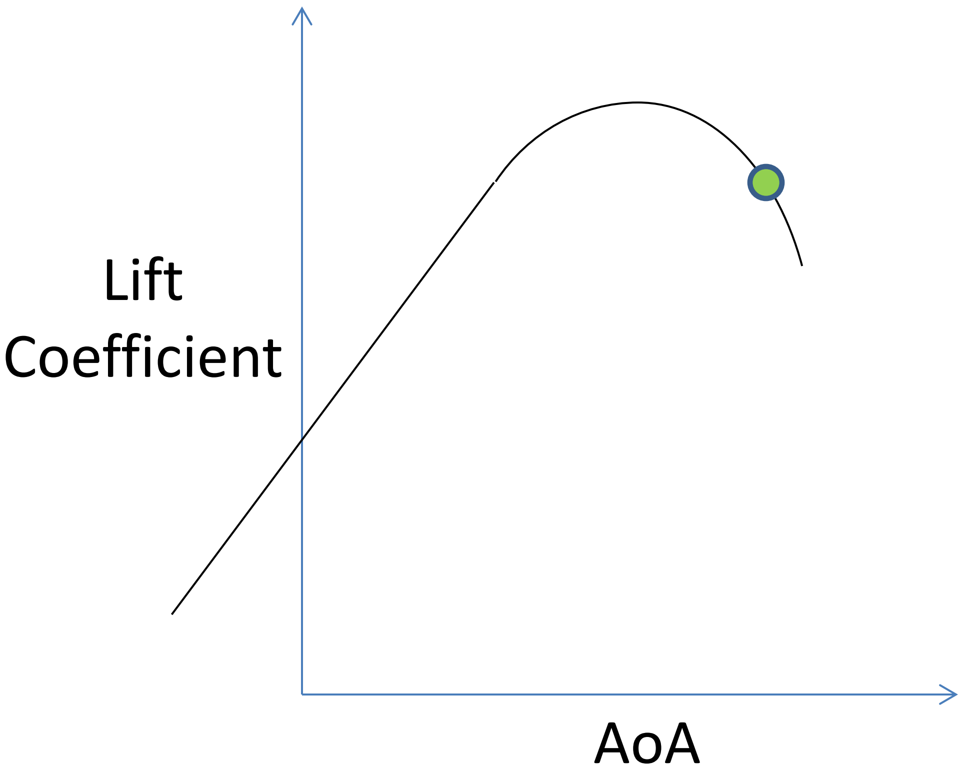
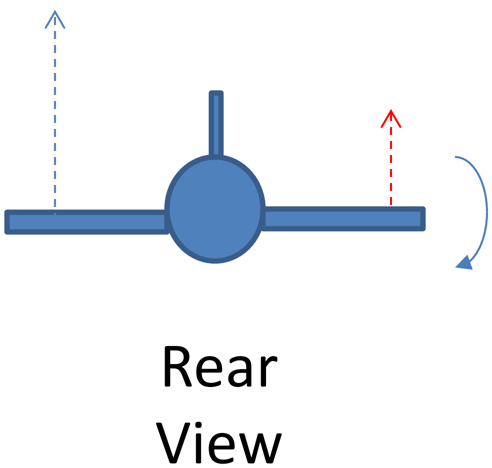
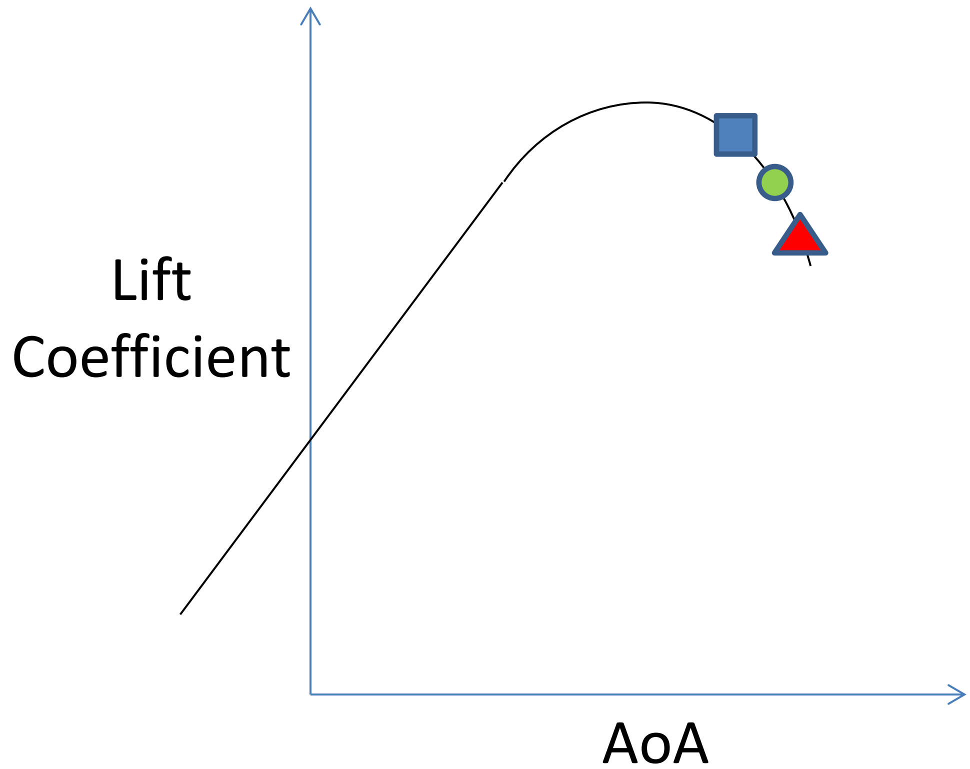


Aerodynamics

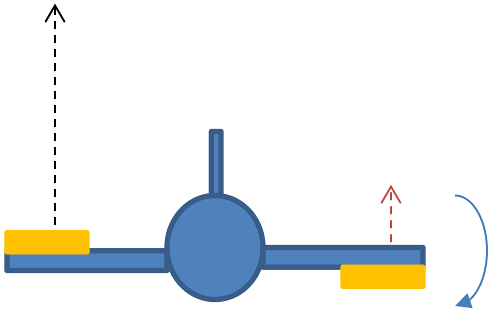
Roll stability

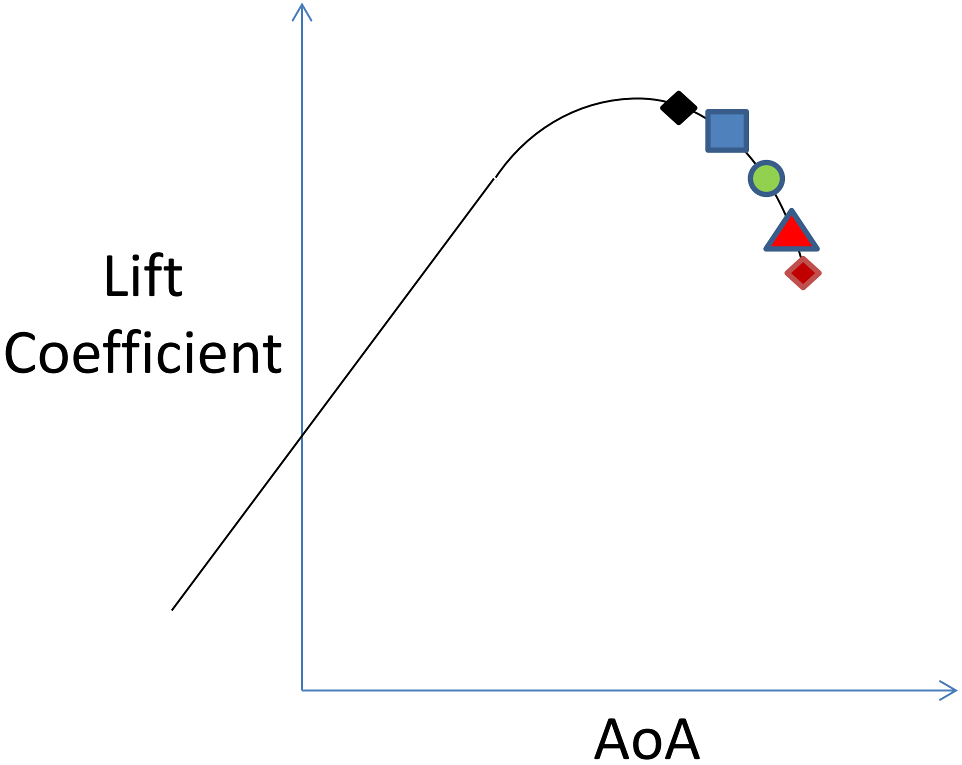




Aerodynamics

Roll stability





NTSB

National Transportation Safety Board

Office of Research and Engineering

Flightpath

Loss of Control on Approach
Colgan Air, Inc., Operating as
Continental Connection Flight 3407
Bombardier DHC-8-400, N200WQ

Clarence Center, New York

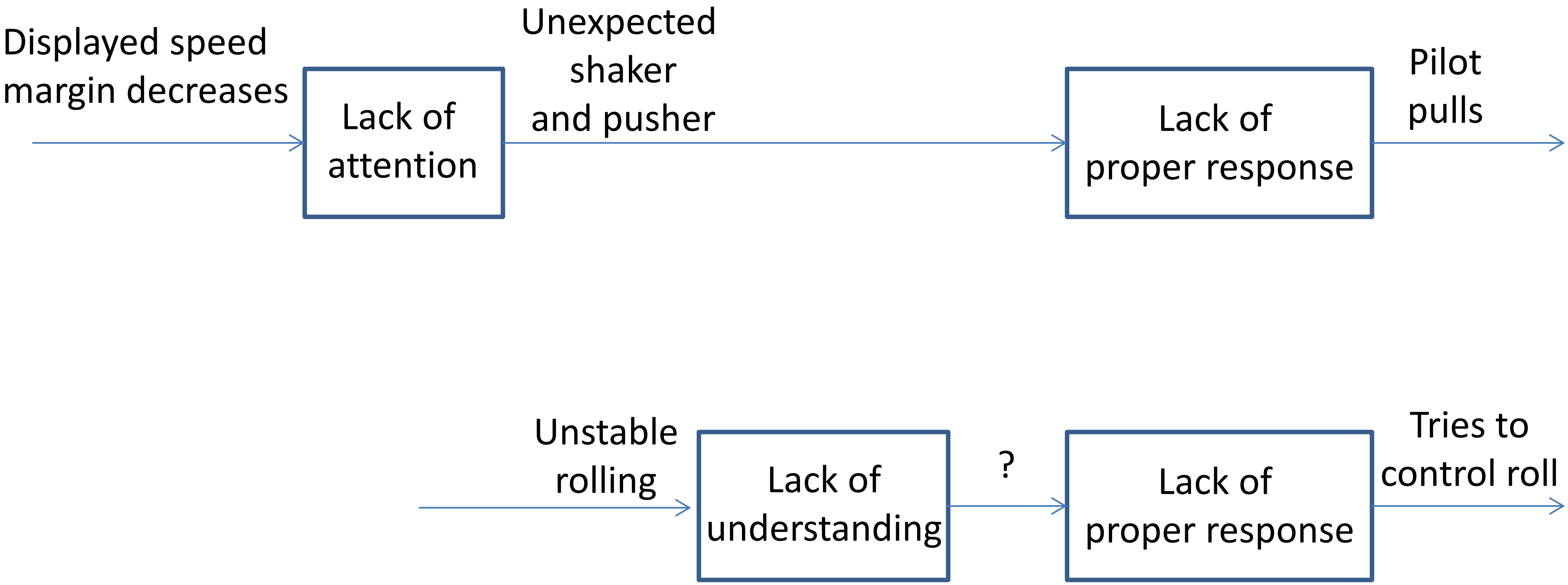
February 12, 2009

DCA09MA027

Board Meeting

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

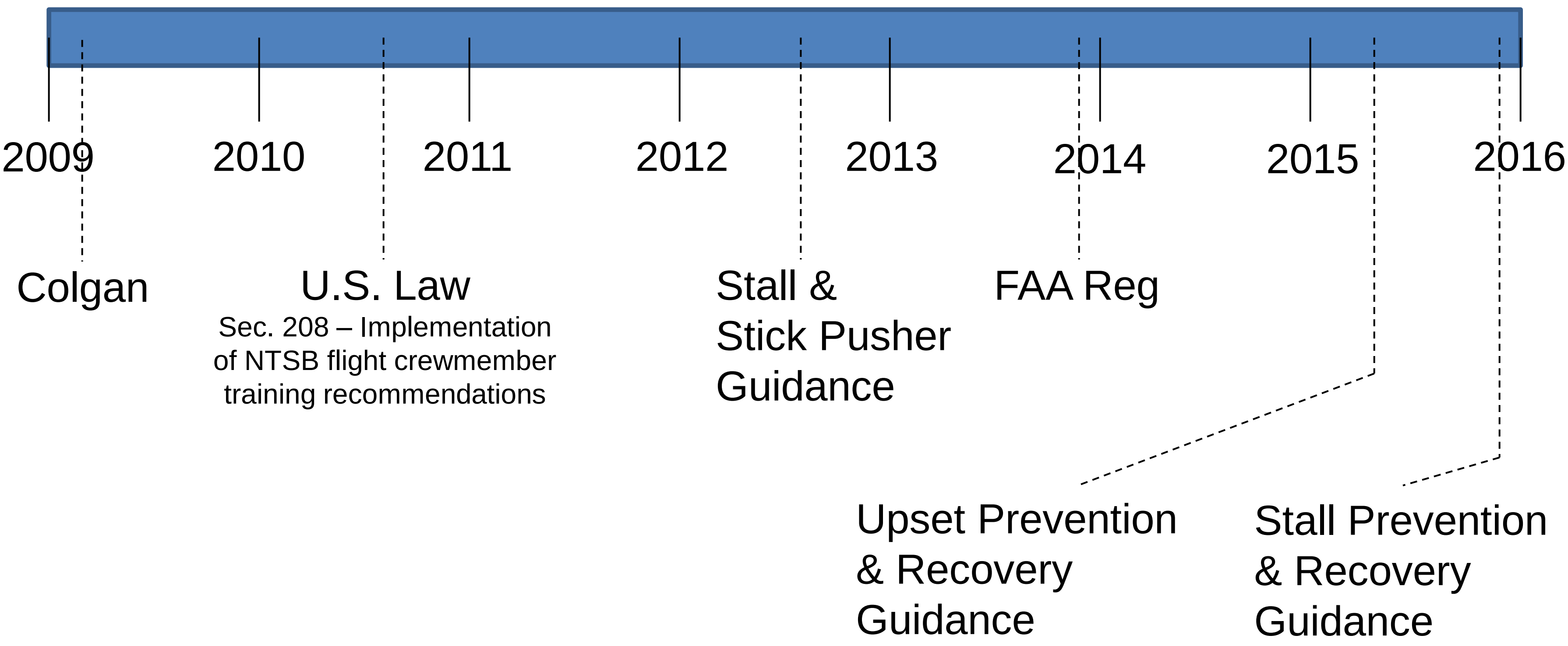
        so, 140 kts --> 700 fpm
  - High altitude stall recovery

Stalls

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

Stalls

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



Stalls

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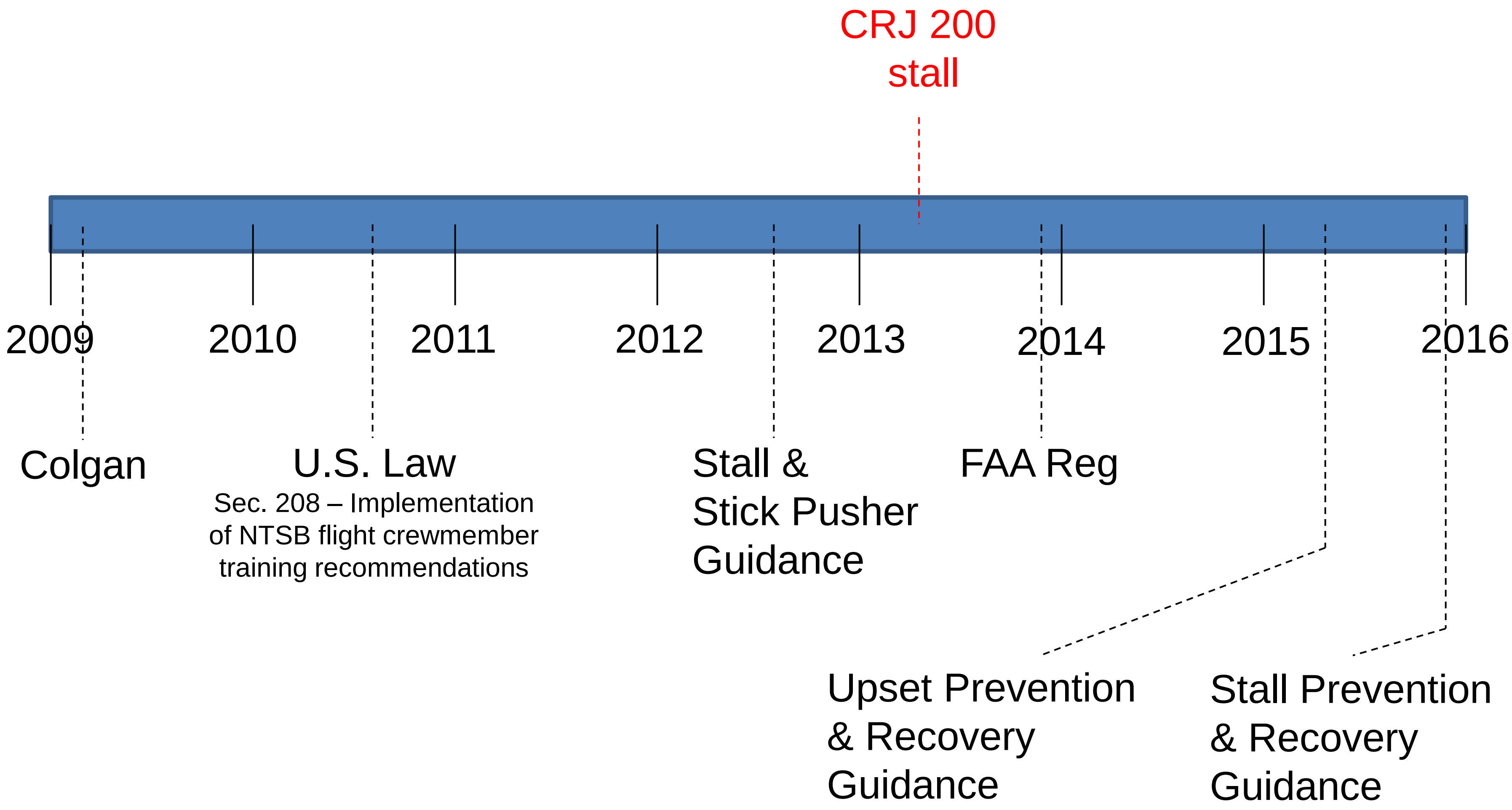


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Accident Investigation Division AVP-100
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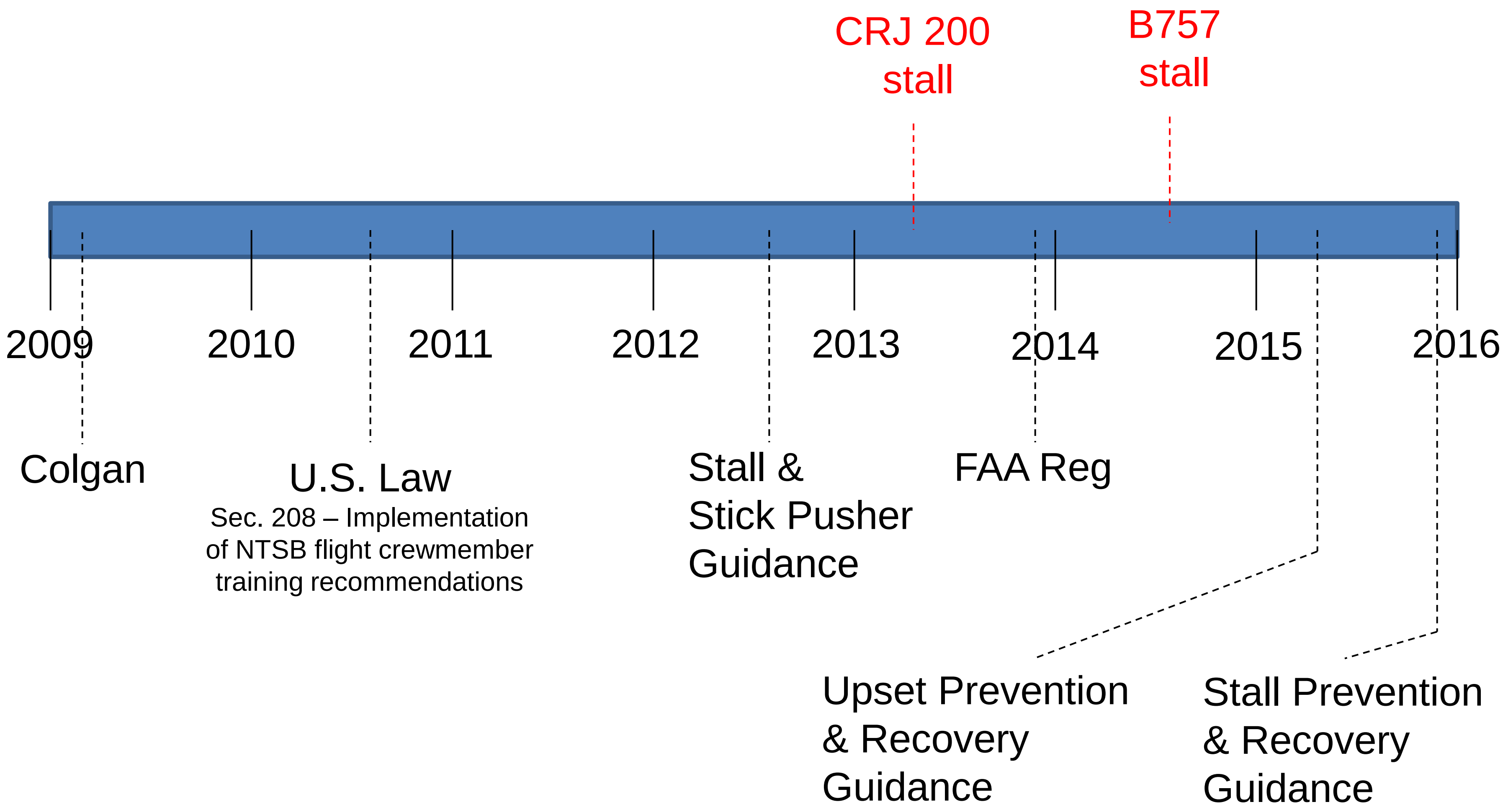
Pitch VS

Stalls

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



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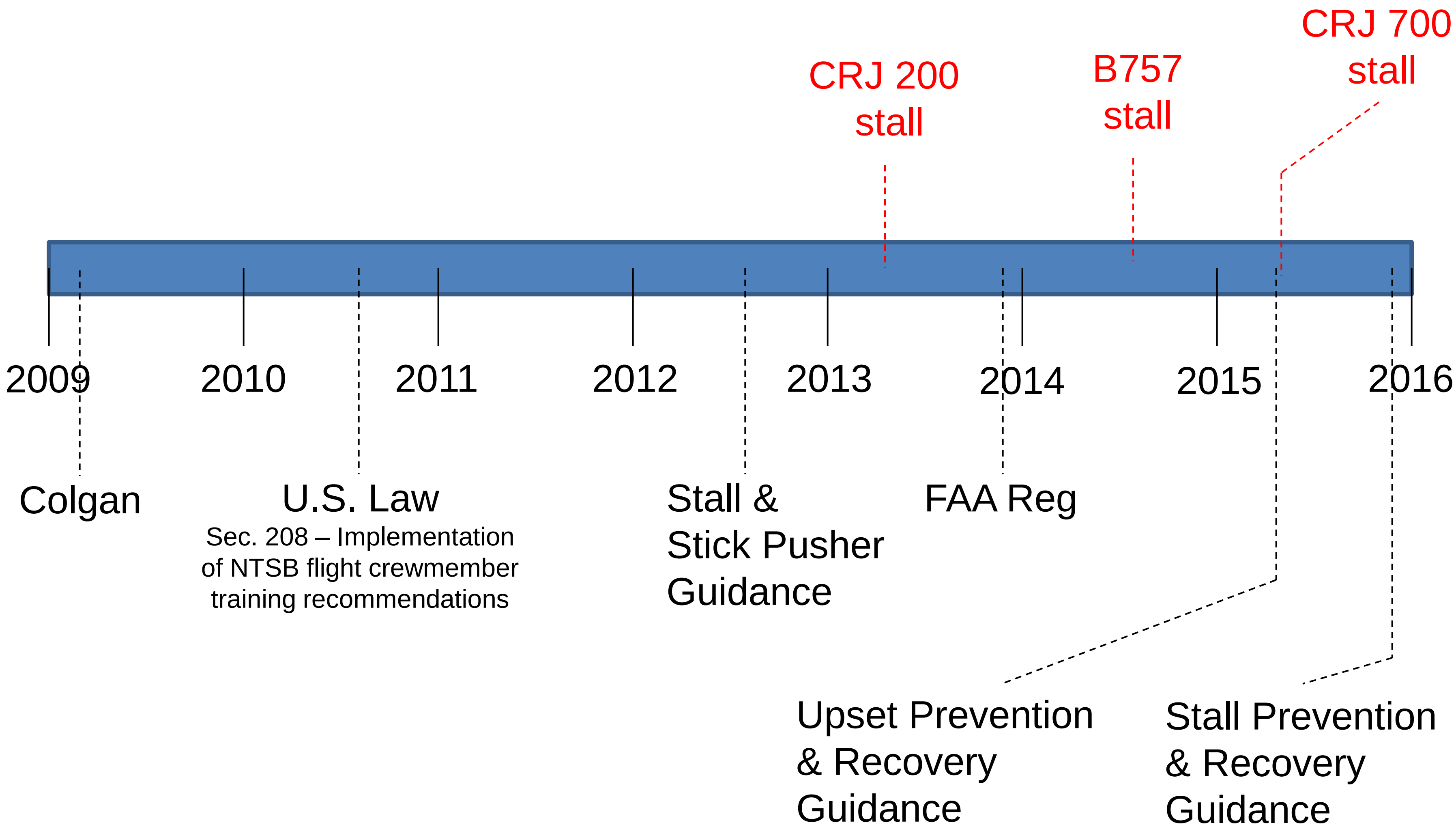


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Office of Accident Investigation AVP-100
AP On
AP Mode
AP Alt Trk

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

Angle of attack

Stall warning system*

Mach

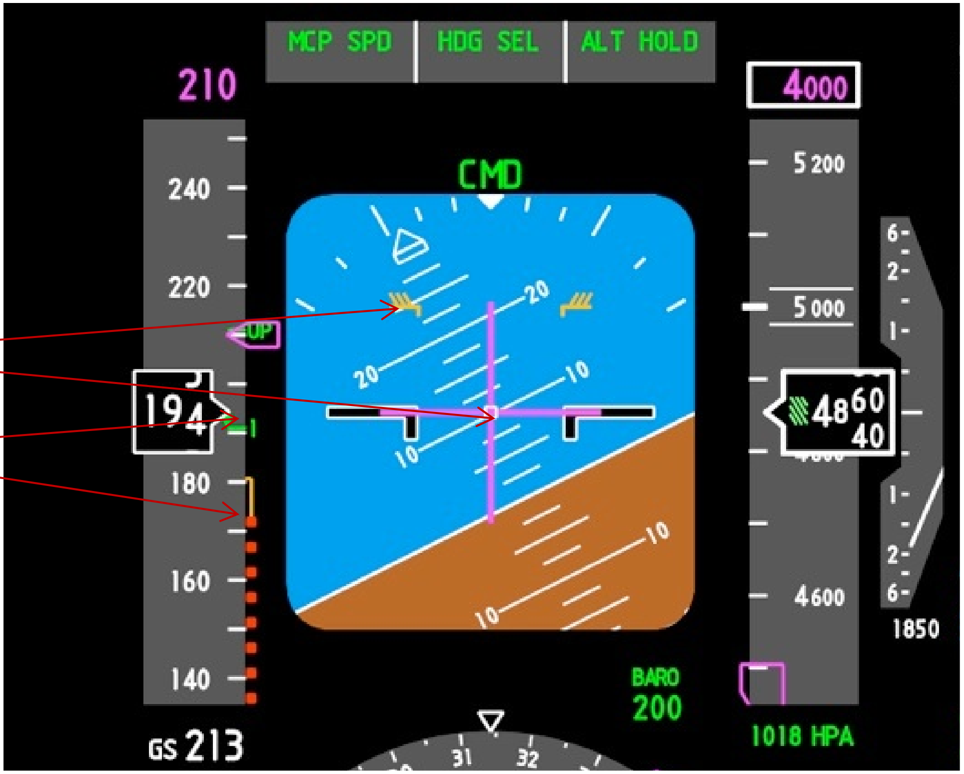
Stick shaker or
Airbus “stall stall <cricket>”

Configuration
or contamination

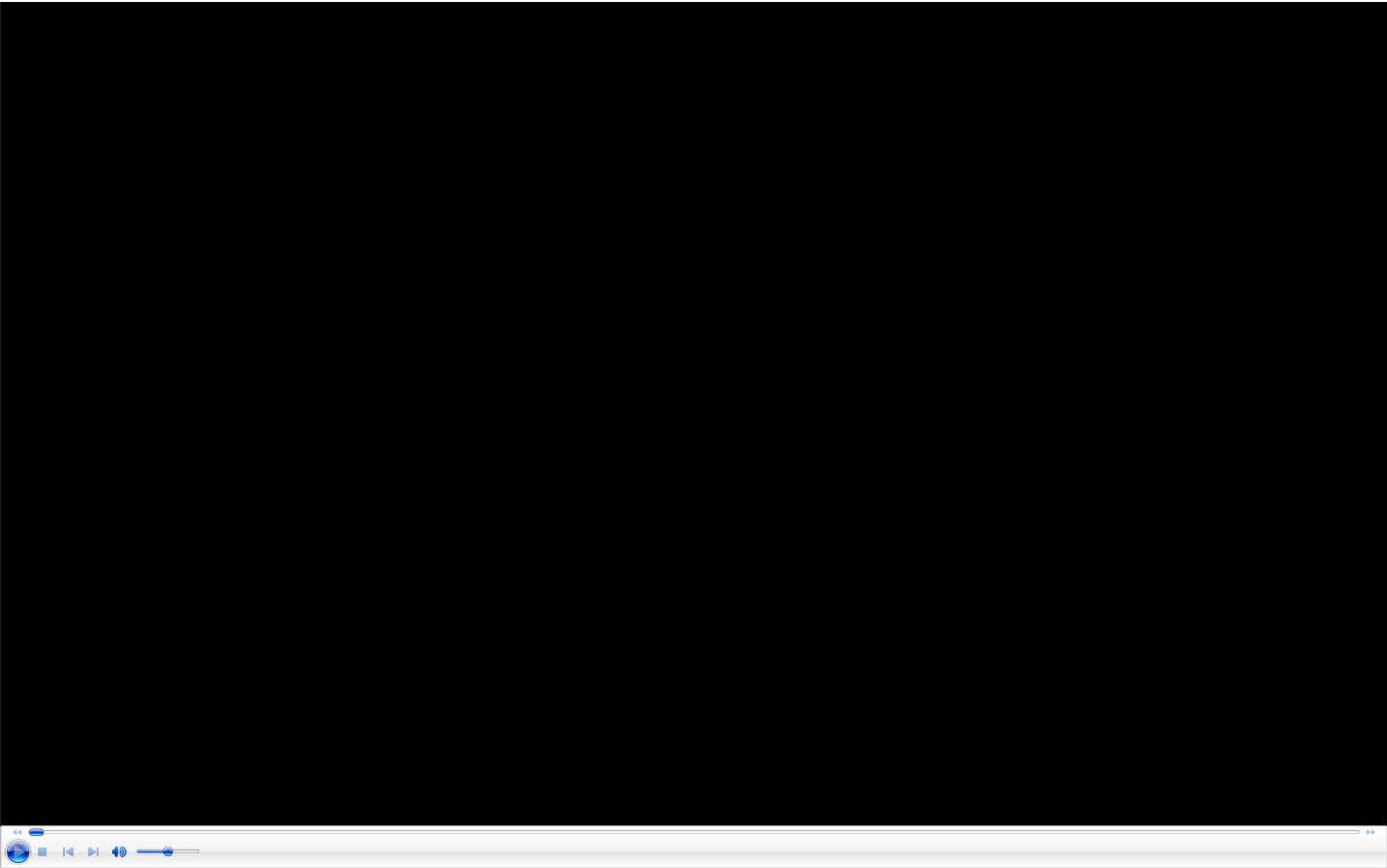
* - can be a little more complicated that this…asymmetric flap and thrust bias (flaps down) and a speedbrake input

Angle of attack margin

AoA
margin
to stall
warning

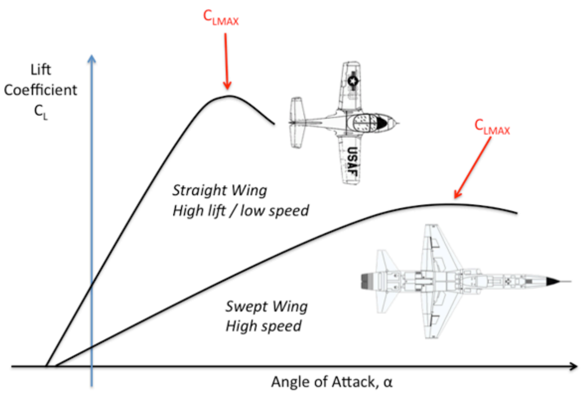


Angle of attack margin

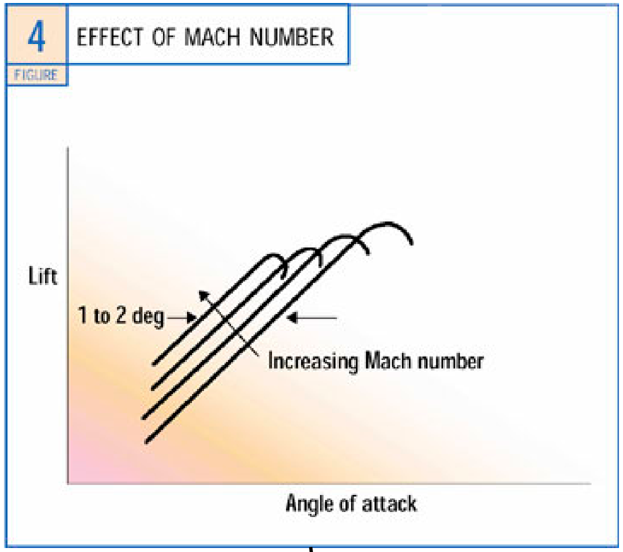


Stalls

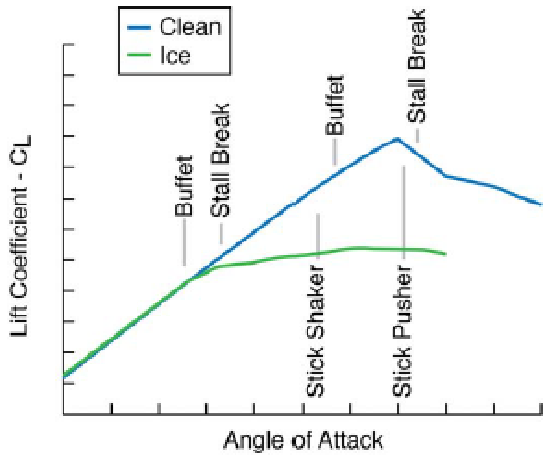
Angle-of-attack

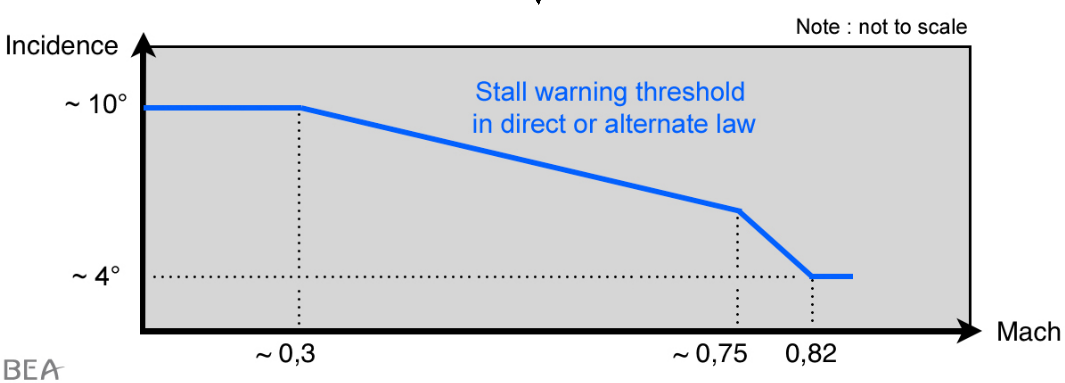


Mach



Configuration or contamination





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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      - 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

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  - Altitude
    - Don’t I stall at a lower AoA at altitude?
      - Not if your Mach number doesn’t change with altitude.

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    - Don’t I stall at a lower AoA if I pull g’s?
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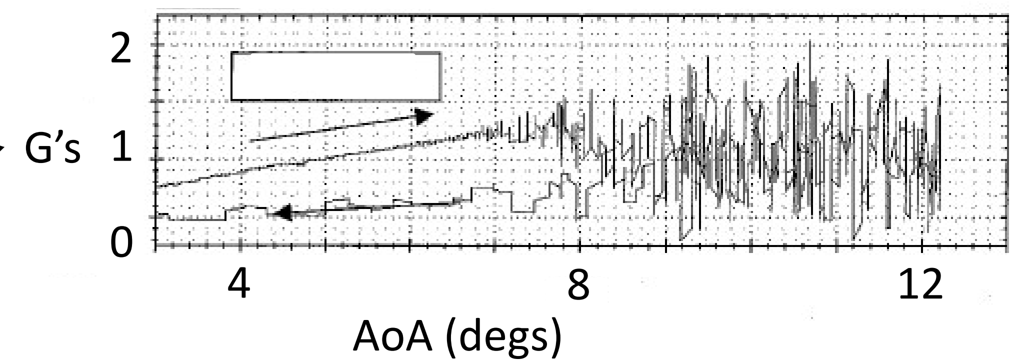
  - Altitude
    - Don’t I stall at a lower AoA at altitude?
      - Not if your Mach number doesn’t change with altitude…but your Mach probably does change, so that is the fundamental parameter
  - Gross weight
    - Don’t I stall at a lower AoA with more weight?
      - No, the wing doesn’t care about how much you weigh

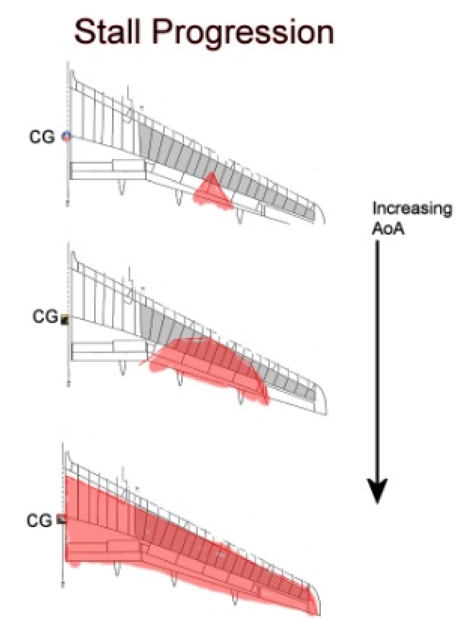
Stalls

Important identification cues…based on earlier stall definition

- Pitch break
- Strong buffet



- Control stop, no more pitch
- Pusher activation



Stalls

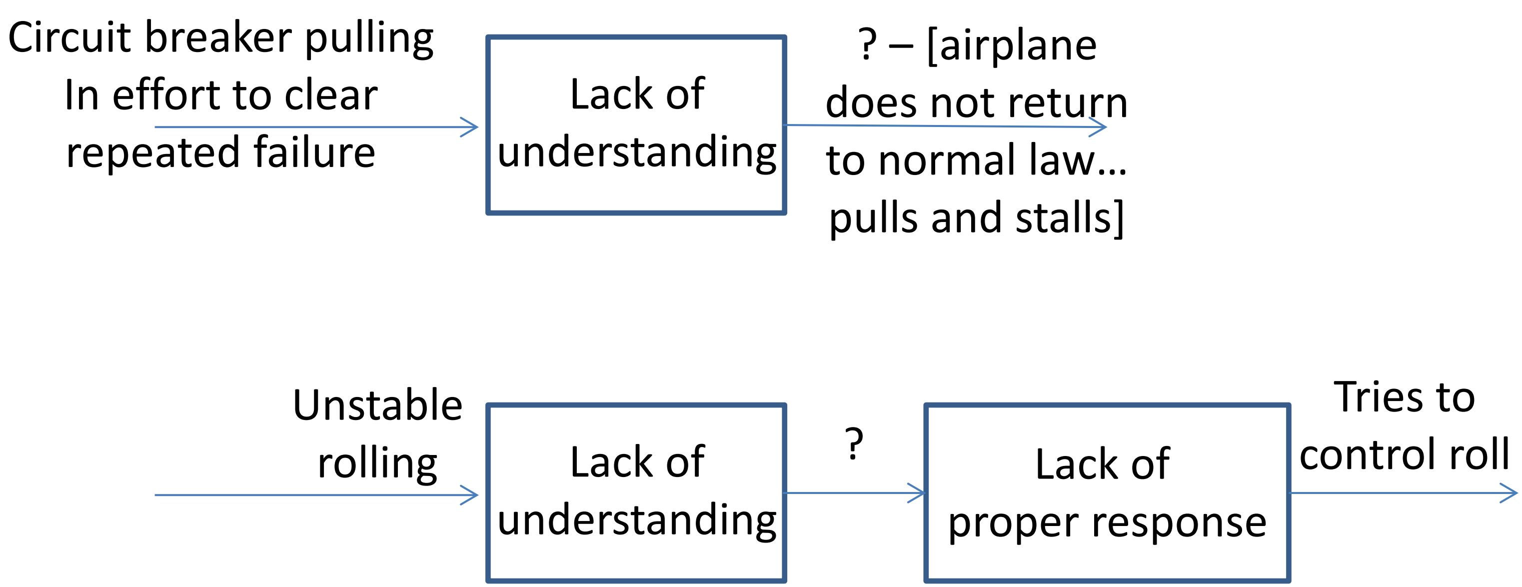
Recovery template, abridged

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

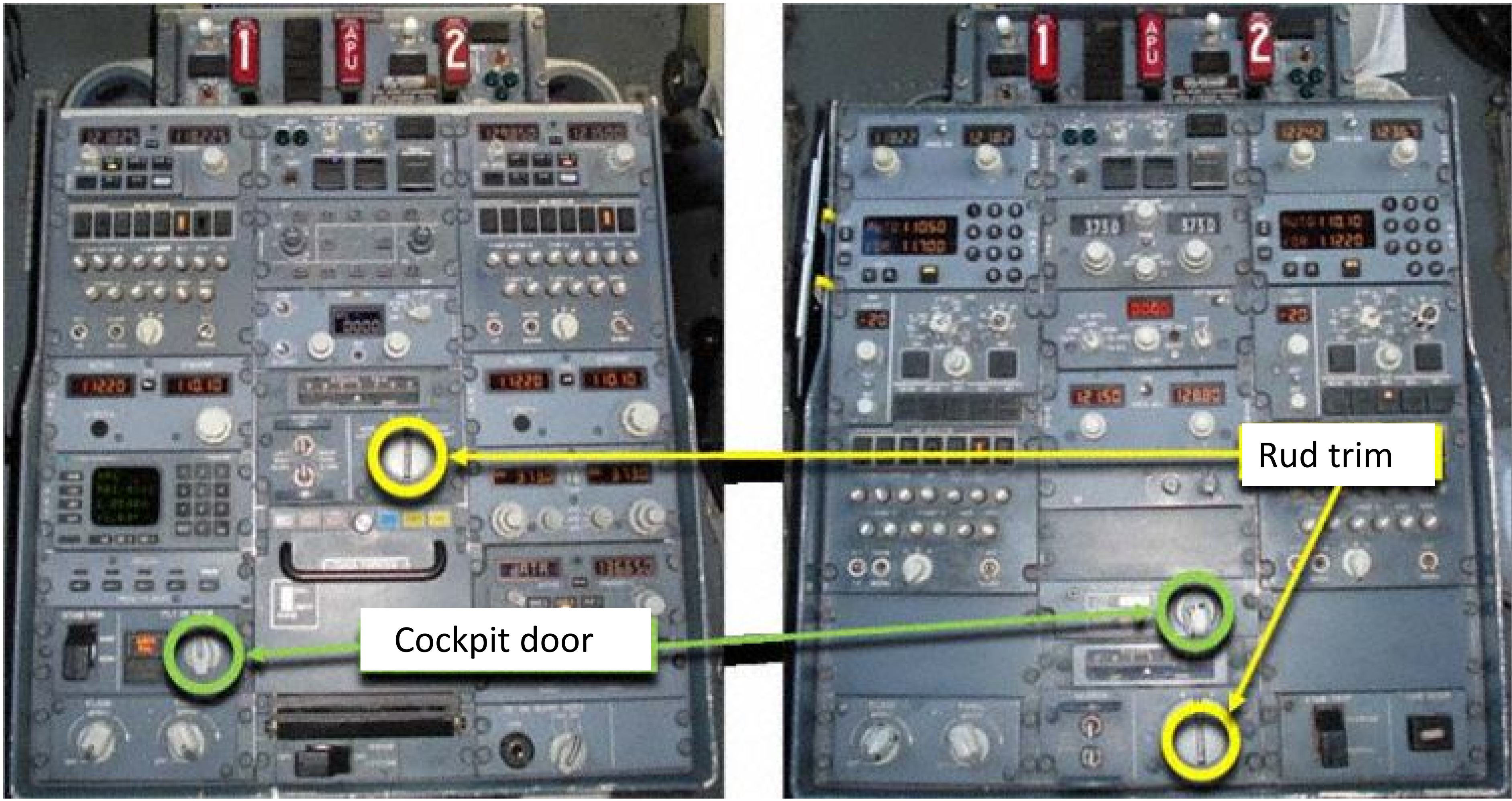
Procedure developed by
Boeing, Airbus, Bombardier, ATR and Embraer

Why?

Air Asia 8501

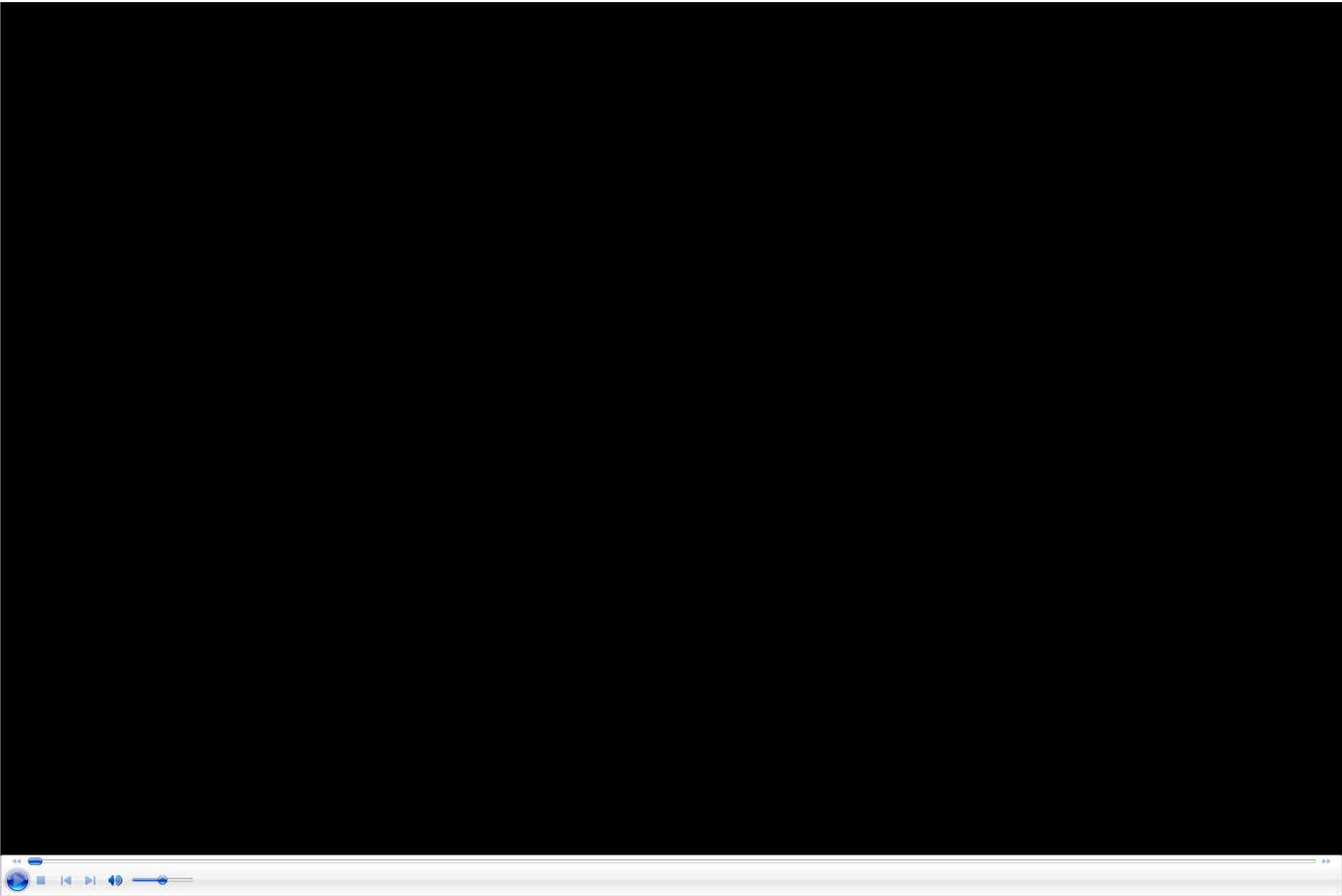


Upsets without stall

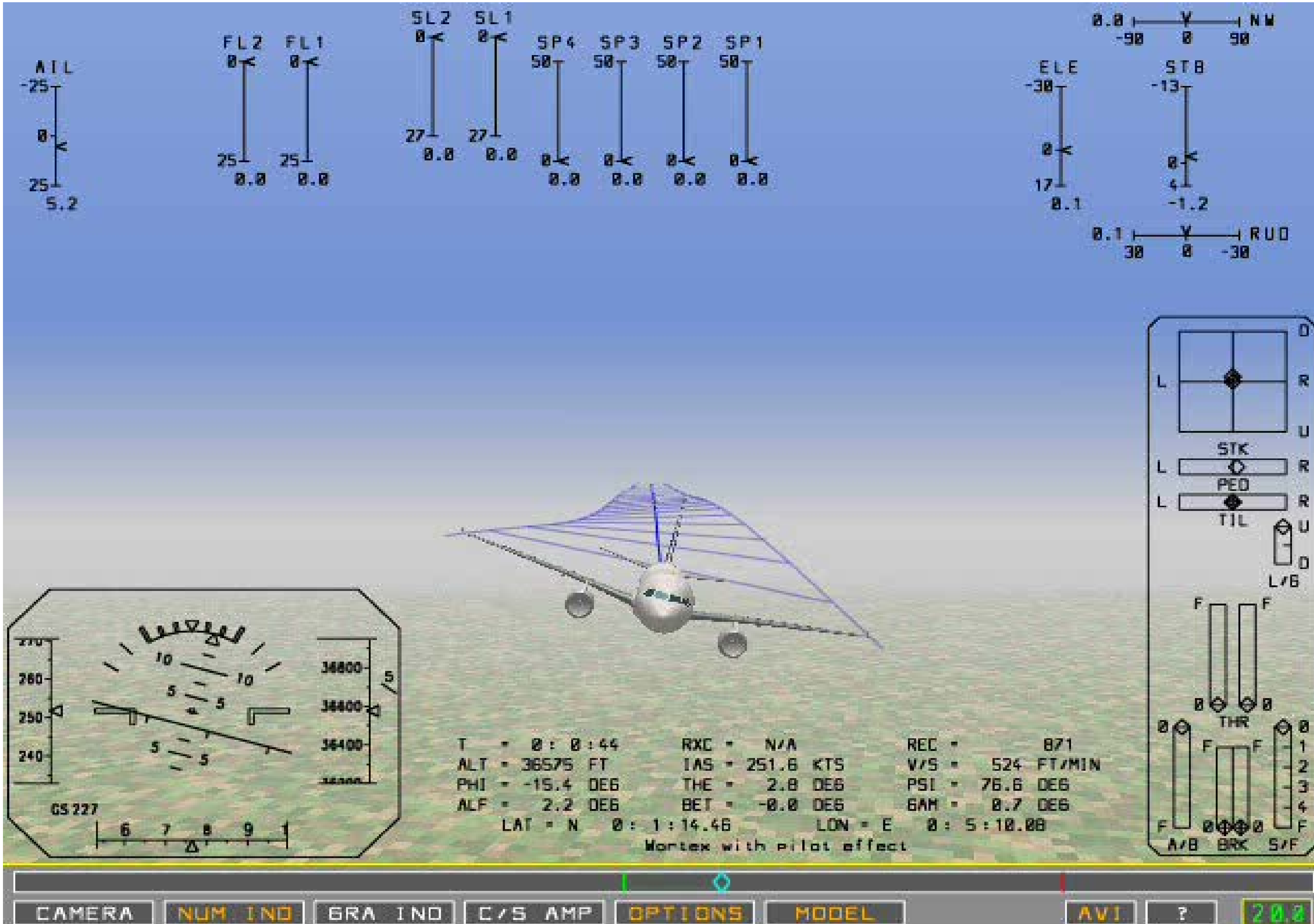


B737-700 B737-500

Upsets without stall



Upsets without stall



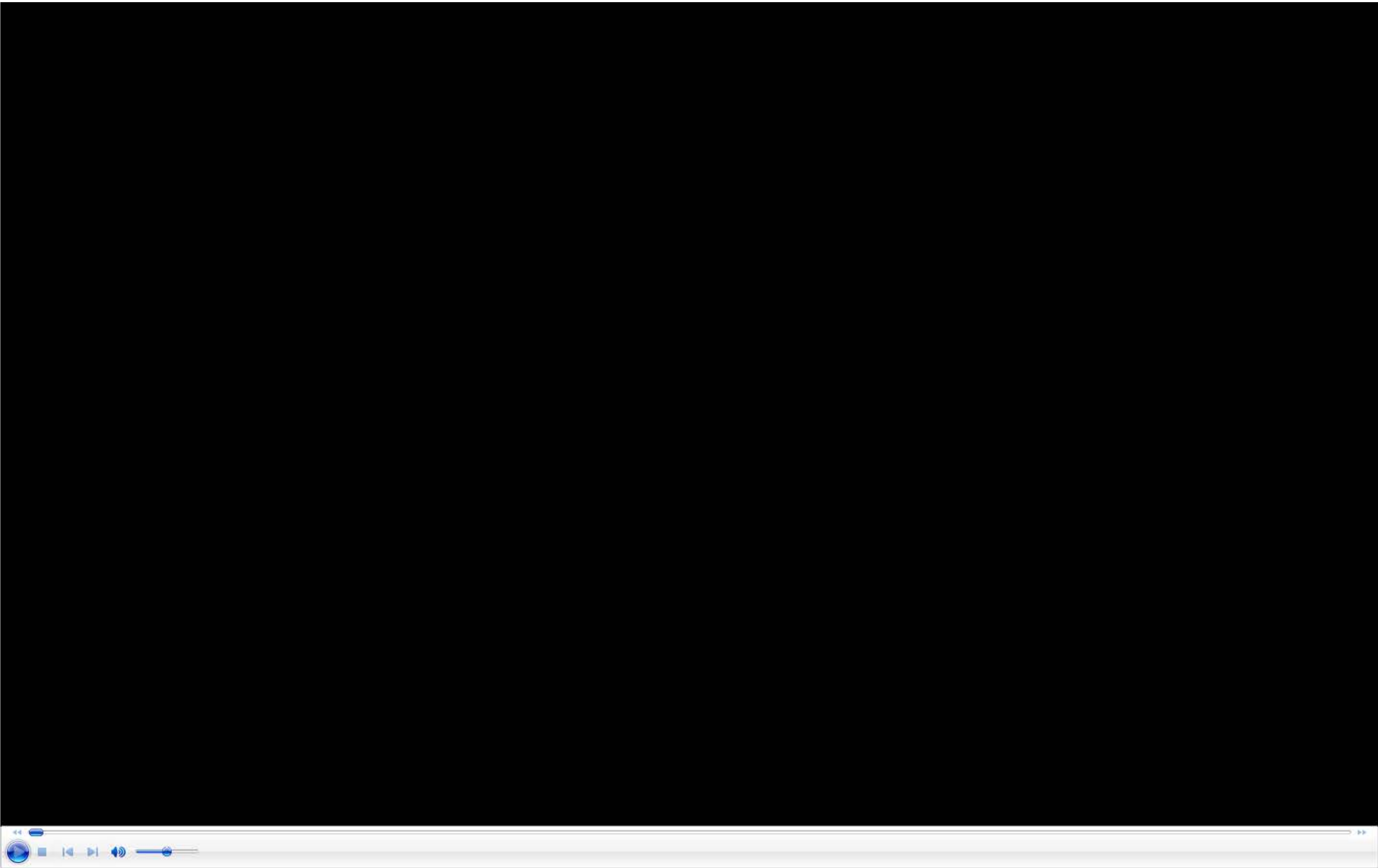
Upsets without stall

Recovery techniques

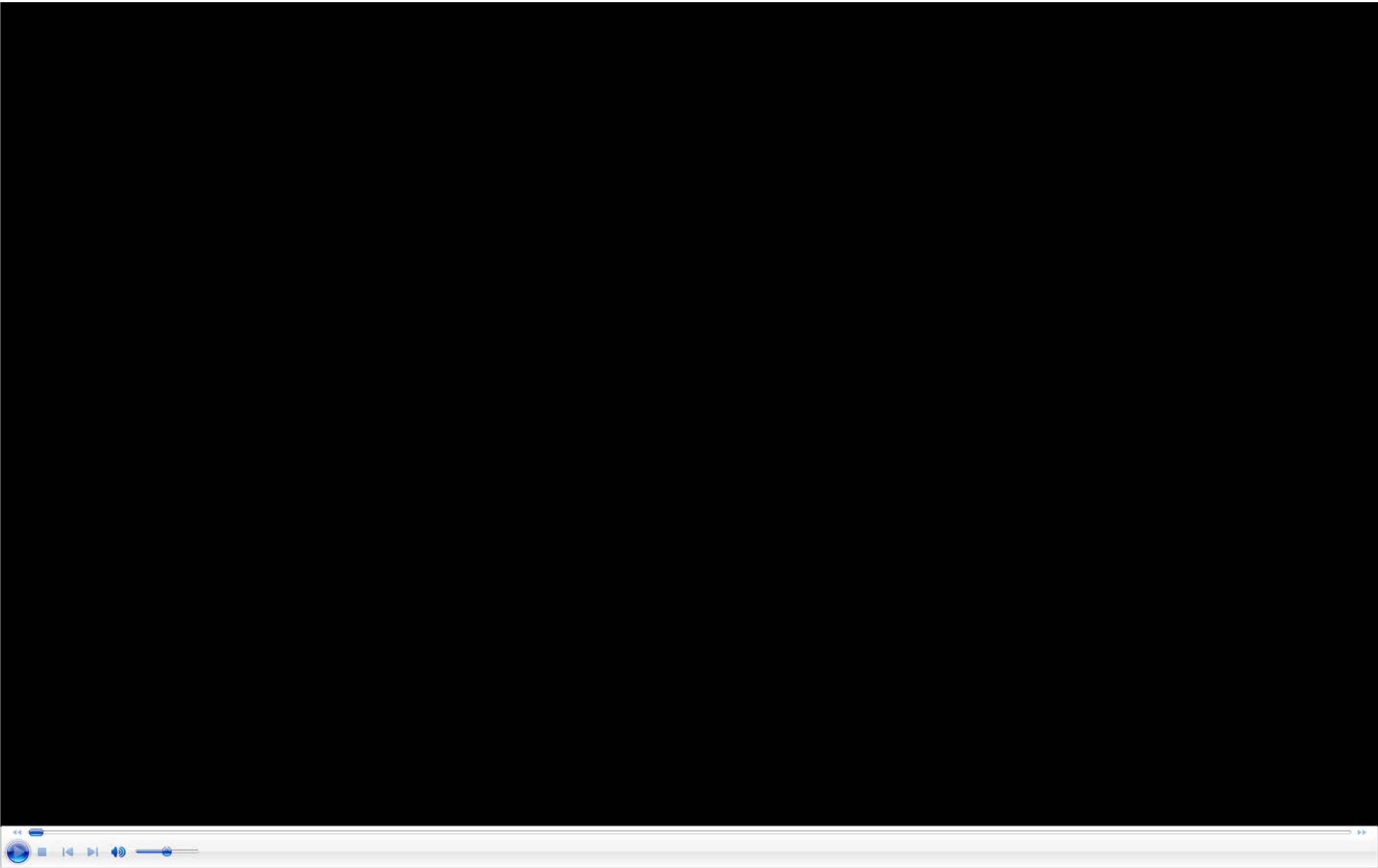
- Recognize and confirm
- A/P & A/T disconnect
- Push
- Roll
- Power
- Climb

We will go over the fine points in the simulator

Loss of reliable airspeed



Loss of reliable airspeed

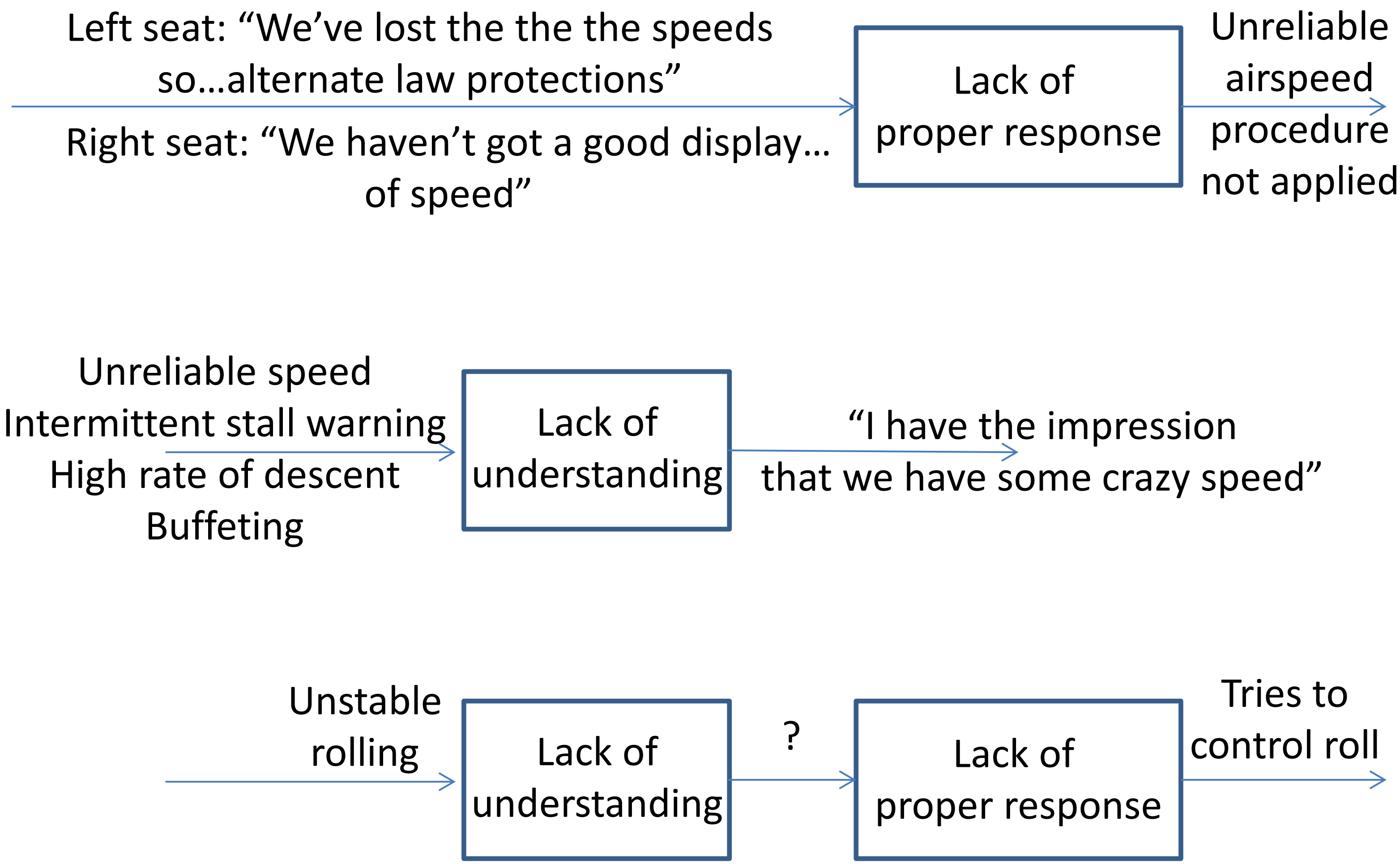


Loss of reliable airspeed—AF447

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

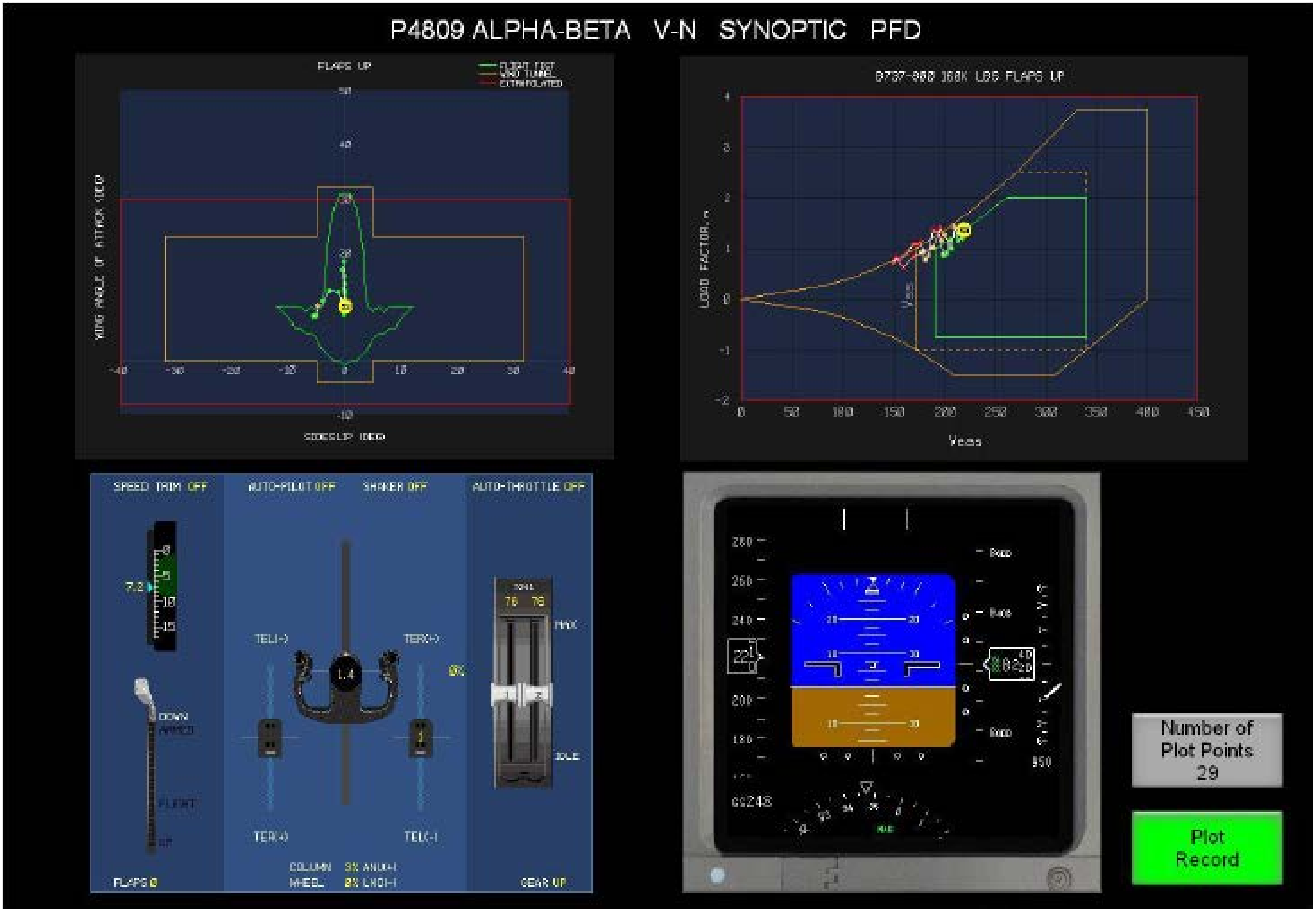
See

- “Monitoring Matters,” CAA Paper 2013/02
- “A Practical Guide for Improving Flight Path Monitoring,” FSF

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

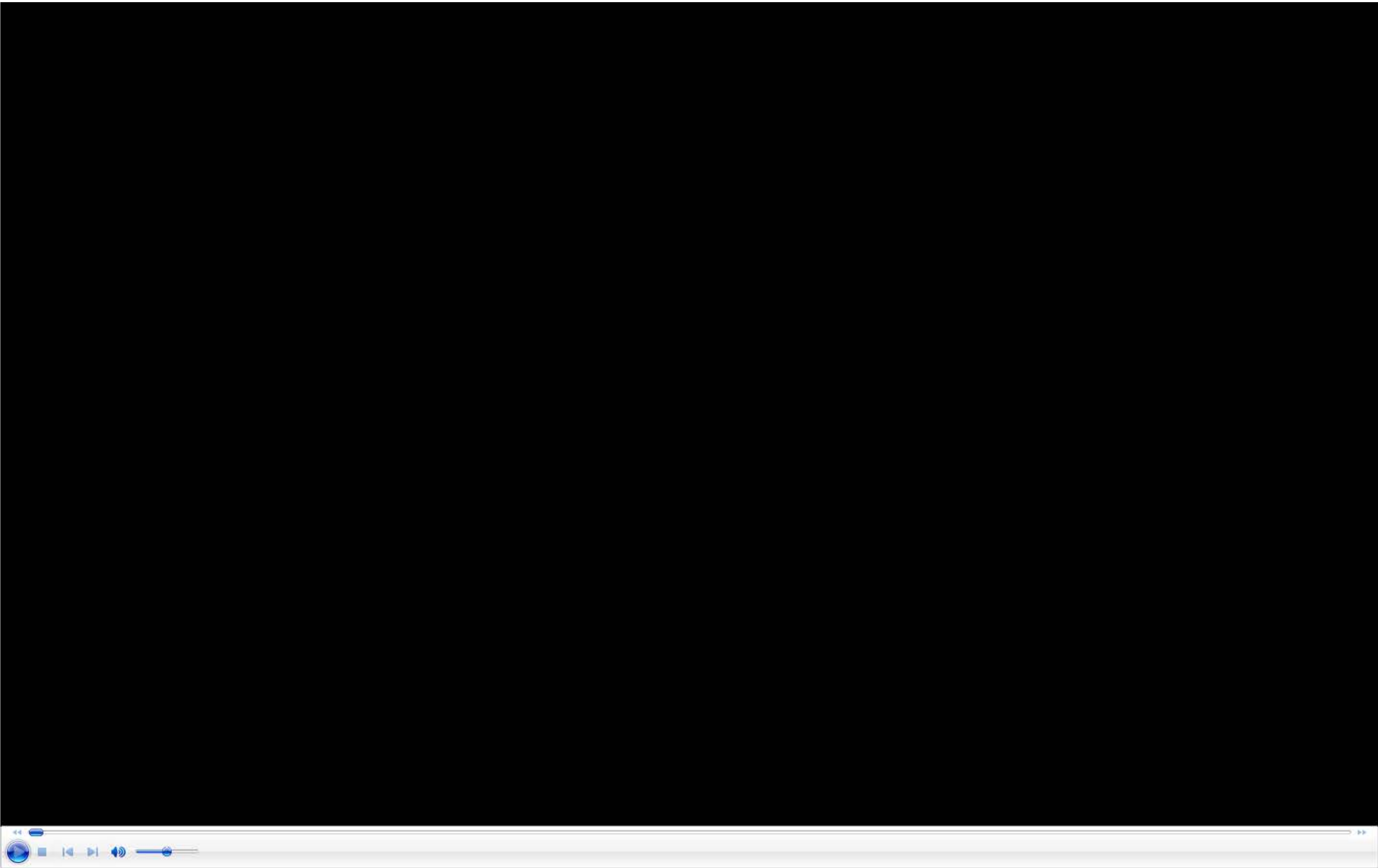
- Need to stay within valid training envelope

Simulator limitations

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

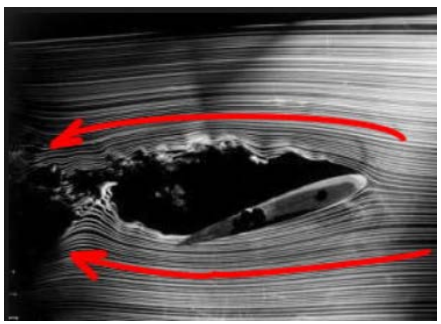
Simulator limitations

- Simulator g-limitations



Conclusions

- An ounce of prevention is worth a pound of cure

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

- Pilot upset training in simulators must account for their limitations