NTSB National Transportation Safety Board

NTSB Focus Area – Inflight Icing

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Board Member

International Winter Operations Conference

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NTSB Mission

The NTSB is an independent U.S. Federal agency charged with determining the probable cause(s) of transportation accidents, making recommendations to prevent their recurrence, conducting special studies and investigations, and coordinating resources to assist victims and their families after an accident.

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NTSB view of Airframe Icing

- Majority of icing conditions encountered are not a problem for certificated aircraft - we deal with the uncommon occurrences
- NTSB recommendations on aircraft icing date back to 1970
- Airframe icing has been on the NTSB's Most Wanted List of safety improvements from 1997 to 2011

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Accidents: October 31, 1994 Roselawn, IN, American Eagle ATR-72

- 68 fatalities
- Involved Supercooled Large Droplets
- Created ridge of ice aft of deice boots
- Caused ailerons to deflect, resulting in loss of control

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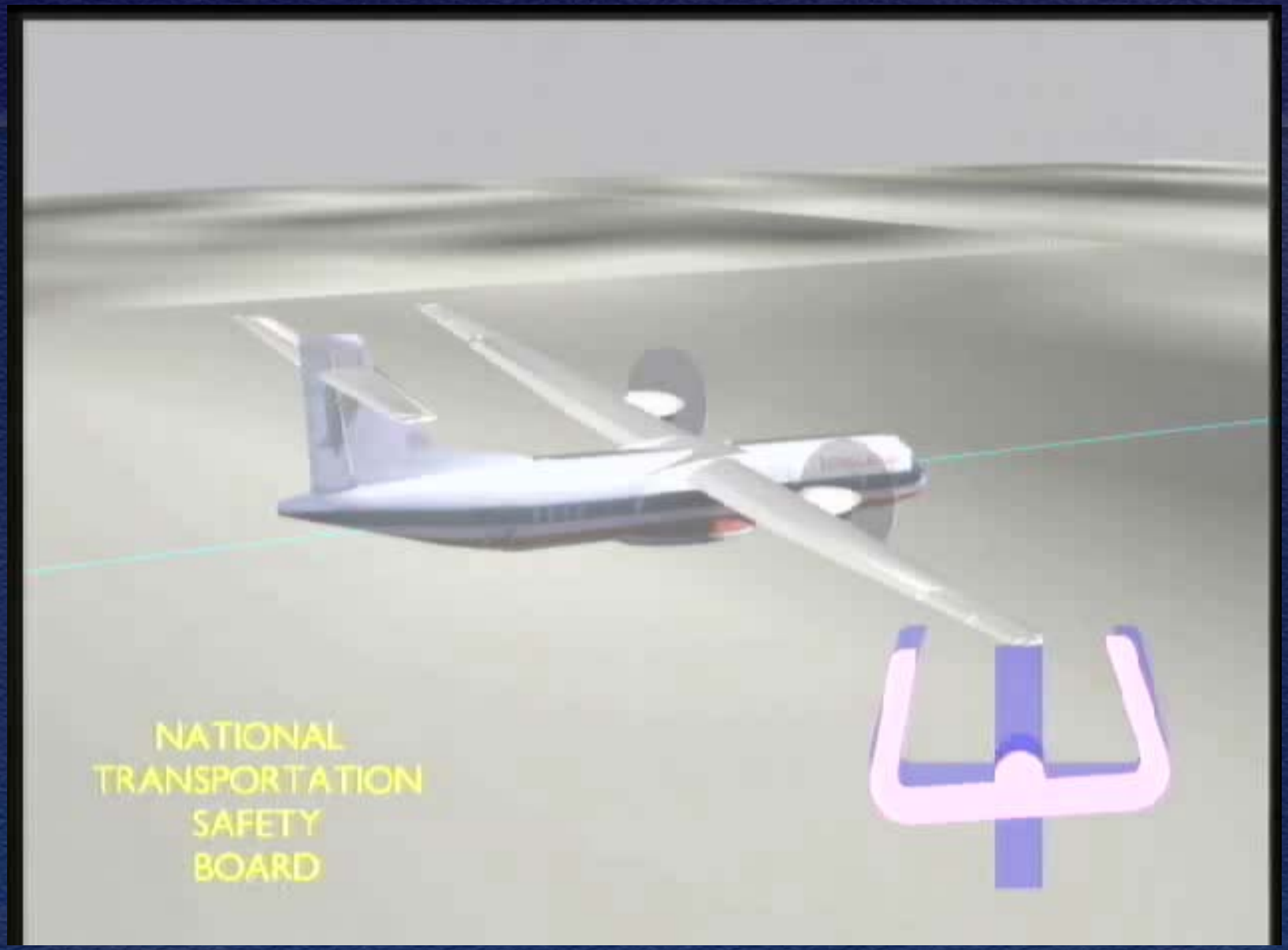

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Why is SLD important to consider?

- Accretions can cause stall or control anomalies at higher airspeed than normally expected
- Ice can accrete aft of ice protection system
- Sometimes difficult to see or detect
- Pilots may not detect an unsafe condition

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Effect of SLD on ice accretion

Wing leading edge cross section

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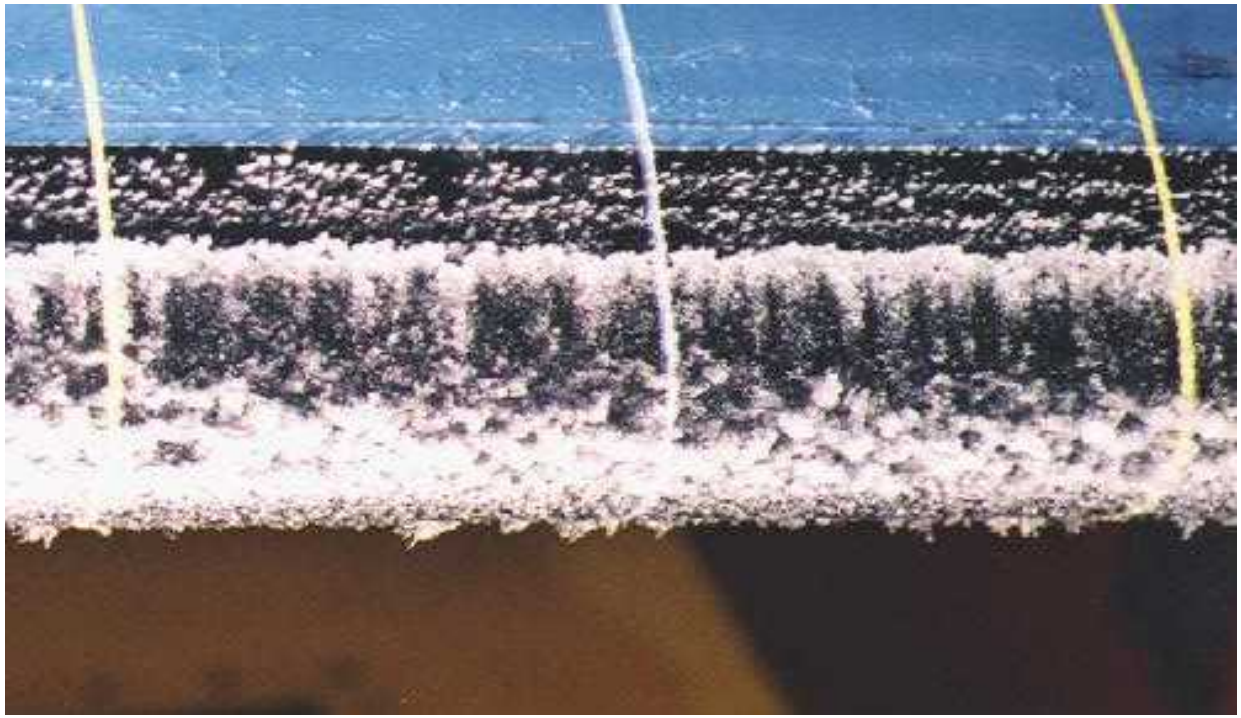
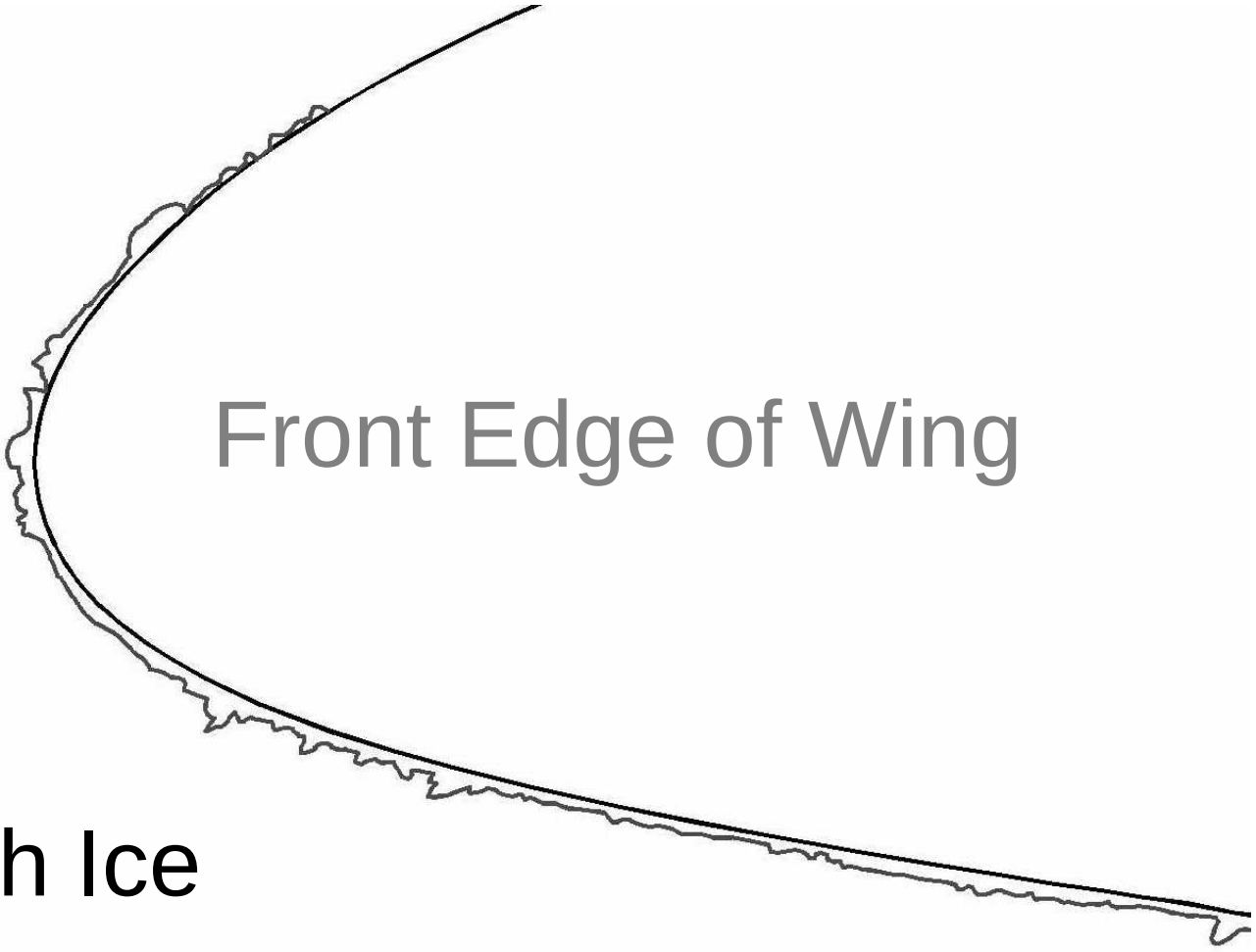
Resultant Ice Shapes



Front Edge of Wing

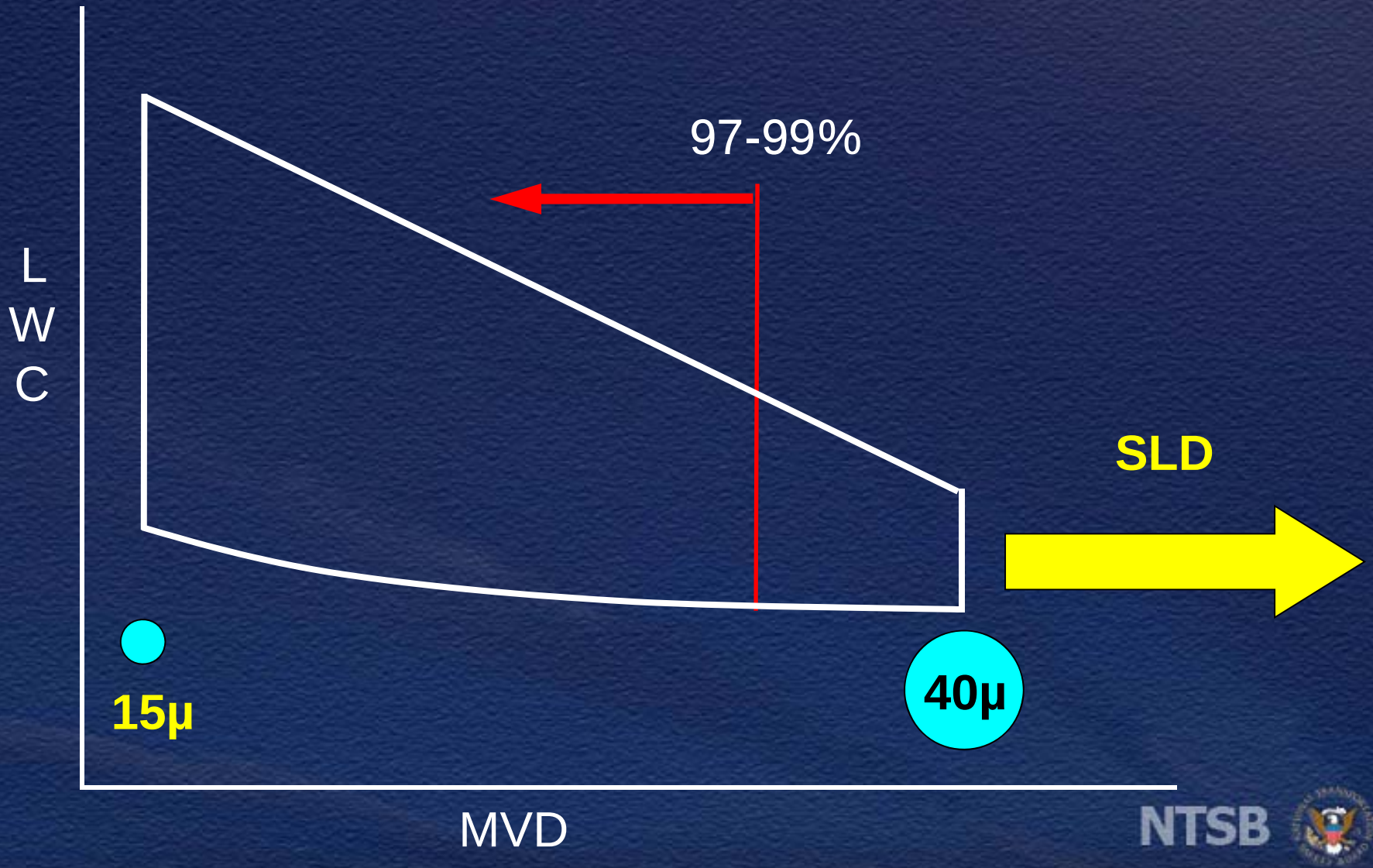
Rough Ice

Resultant Ice Shapes



Rough Ice

Part 25 Appendix C
Continuous Maximum Icing



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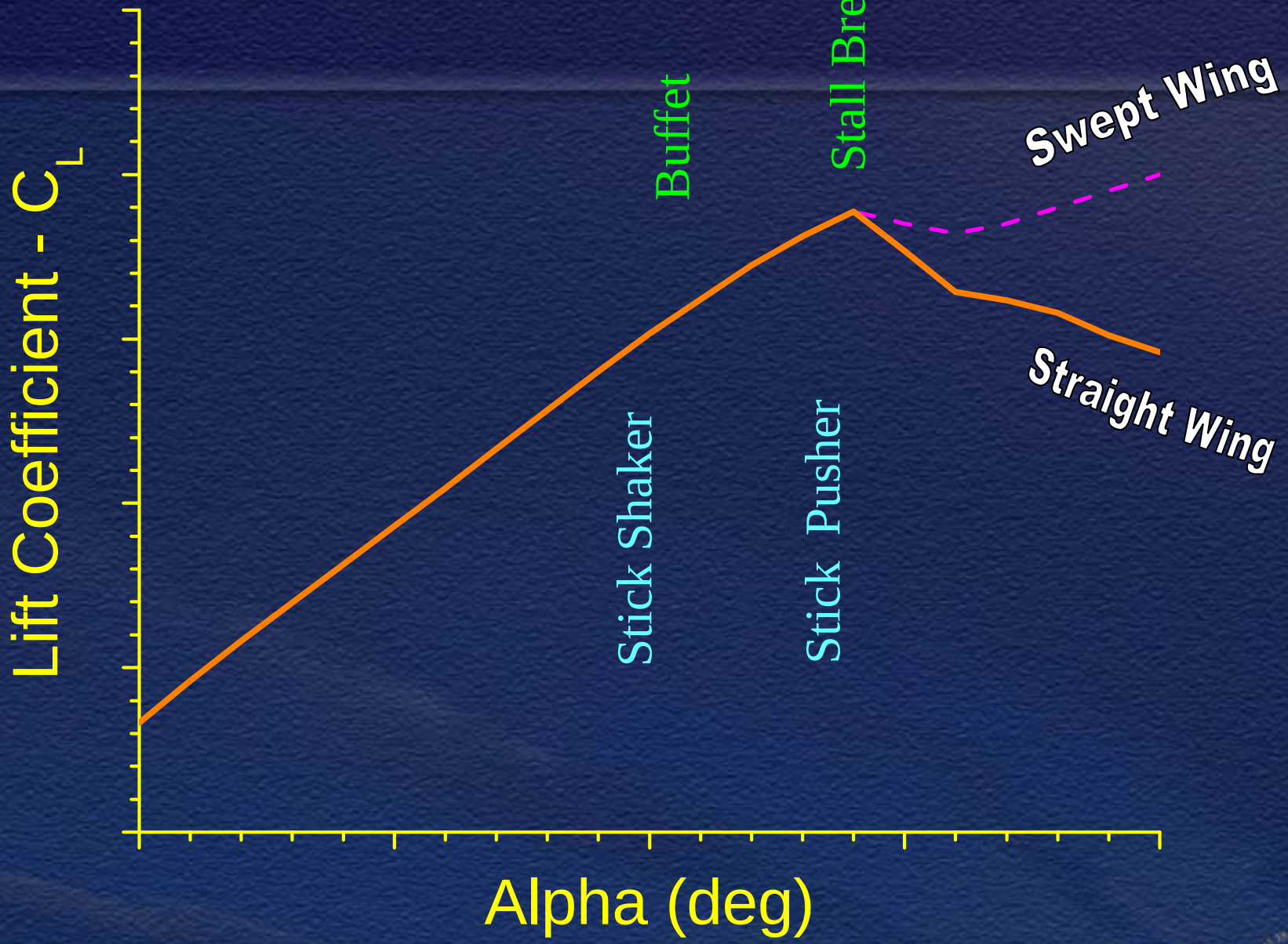
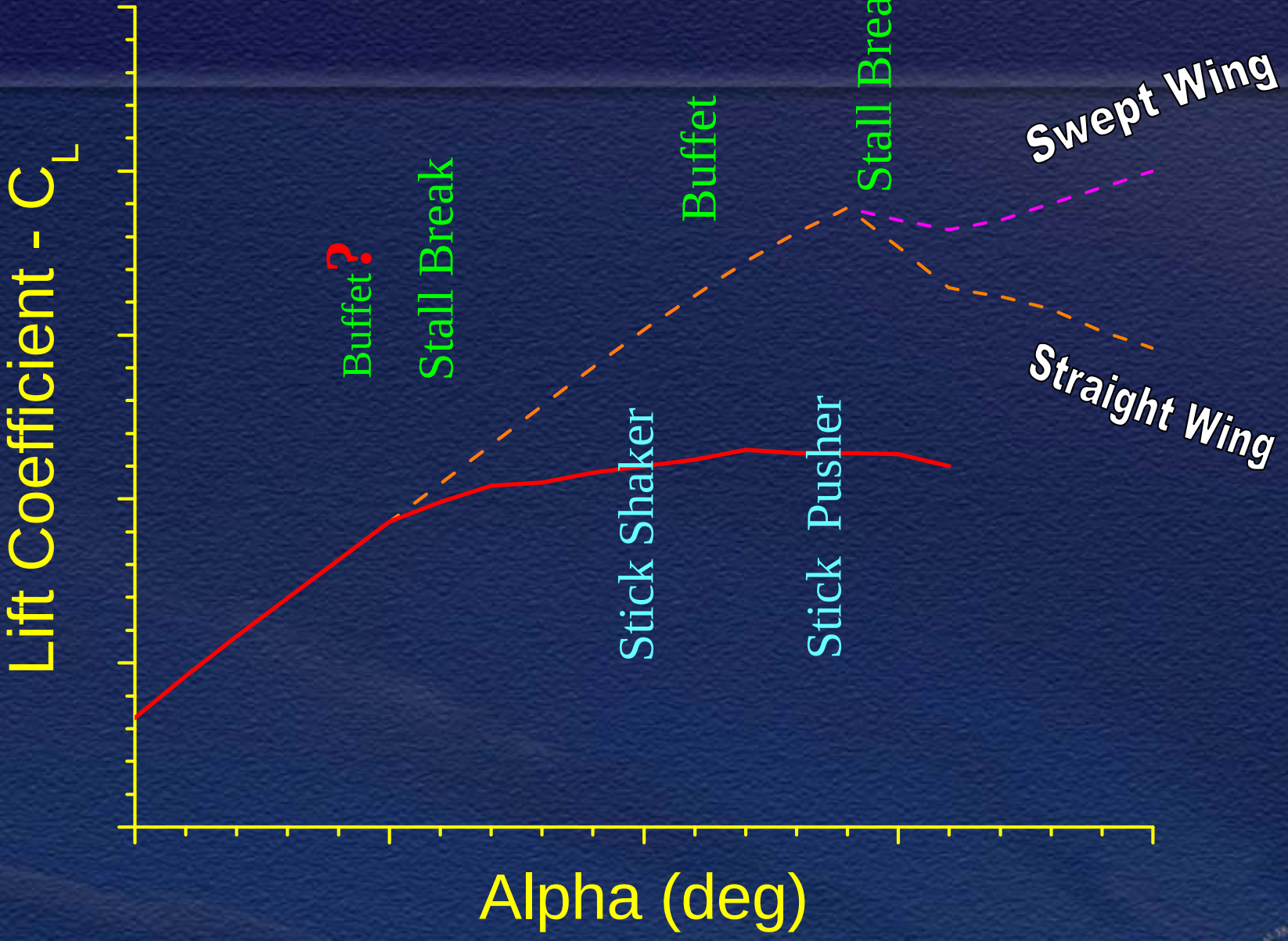

Lift Coefficient - C_L
Alpha (deg)
Buffet
Stall Break
Stick Shaker
Stick Pusher
Swept Wing
Straight Wing


Lift Coefficient - C_L
Alpha (deg)
Buffet?
Stall Break
Stick Shaker
Buffet
Stick Pusher
Stall Break
Swept Wing
Straight Wing

NTSB Recommendations: Roselawn

Summary

- Icing conditions beyond current Part 23 & 25 certification requirements exist
- Continued flight in some icing conditions not possible
- Part 23 & 25 Appendix C certification requirements inadequate for SLD
- Training for Part 121 and 135 needed
- Research into SLD and development of detection and protection needed

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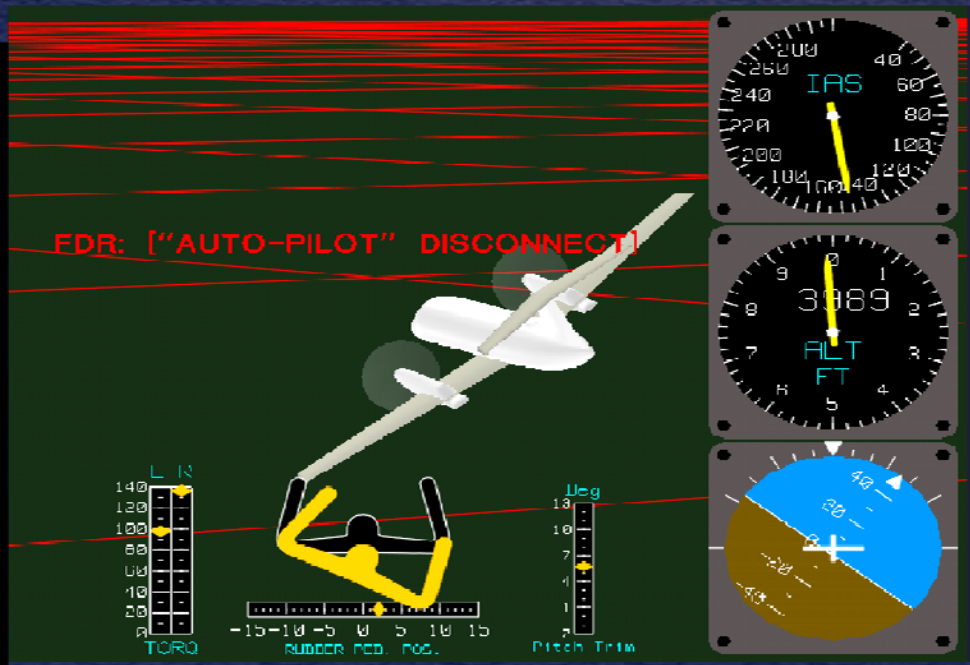
Accidents: January 9, 1997
Monroe, MI – Comair Embraer EMB - 120



- 39 fatalities
- Operated in icing conditions near lower end of operating airspeed envelope (flaps retracted)
- Issues: use of ice protection, airspeed and configuration information, stall warning/protection system capabilities, use of autopilot, aircraft icing certification

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Accident Sequence

- Approach to DTW with autopilot engaged
- Ice accreted for 4 ½ to 5 minutes (some SLD)
- De-ice boots not operated during approach
- Airplane rolled to 45 deg left roll despite autopilot right roll input
- Rapid roll left when autopilot disconnected due to stick shaker
- Presence of an estimated ¼ to 1/2 of an inch of ice created a rolling moment the A/P could not counteract.
- Airplane did not recover in the 3000 feet agl available

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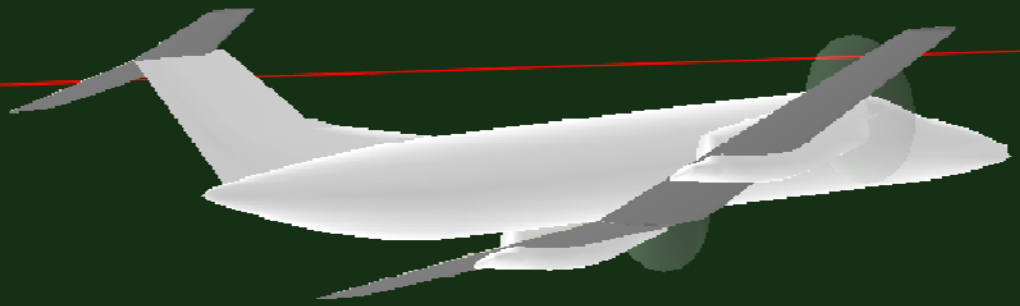
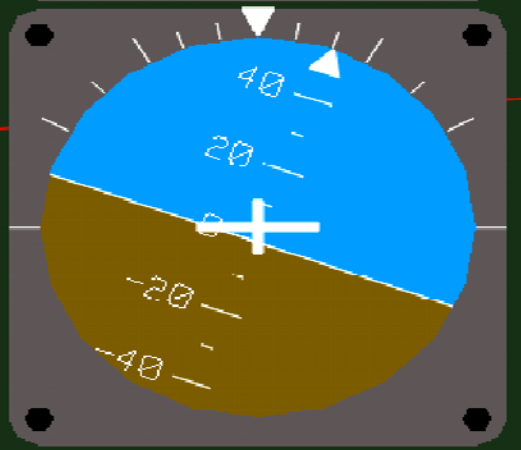
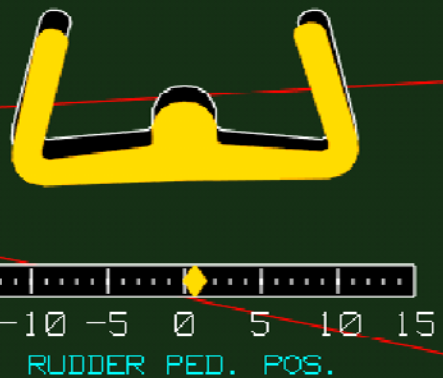
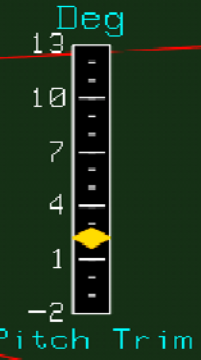
ENTERING THE LEFT TURN

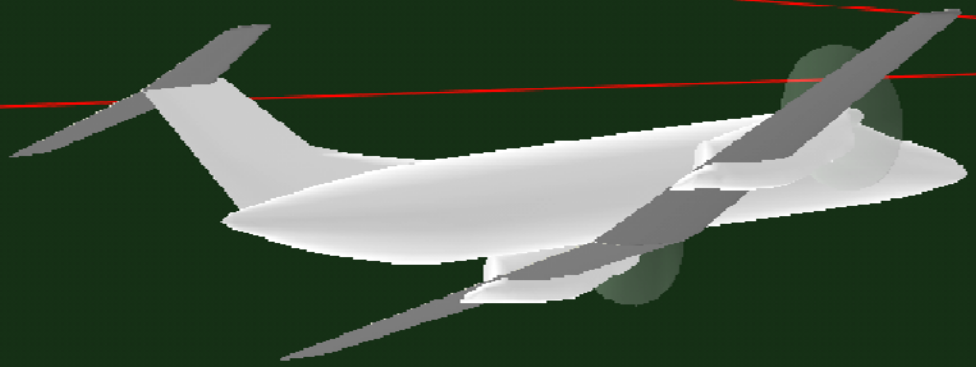


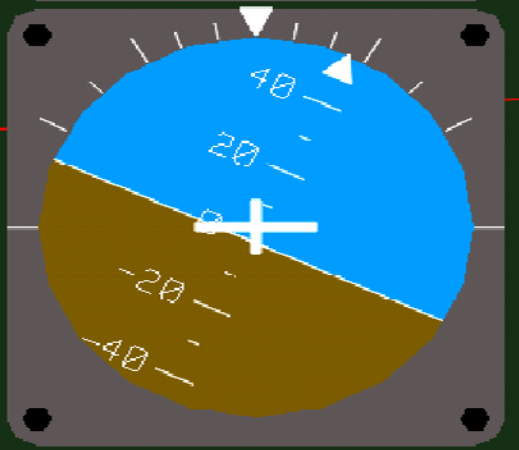


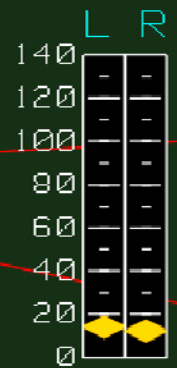


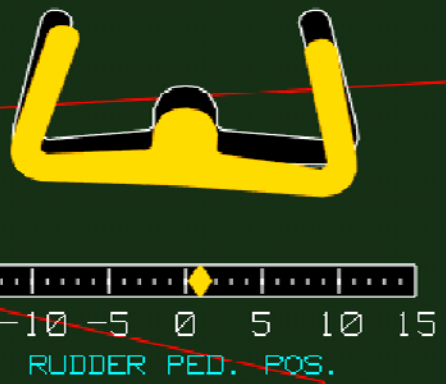


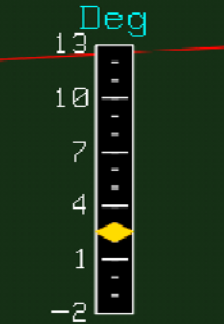
START OF A/P WHEEL TO RIGHT



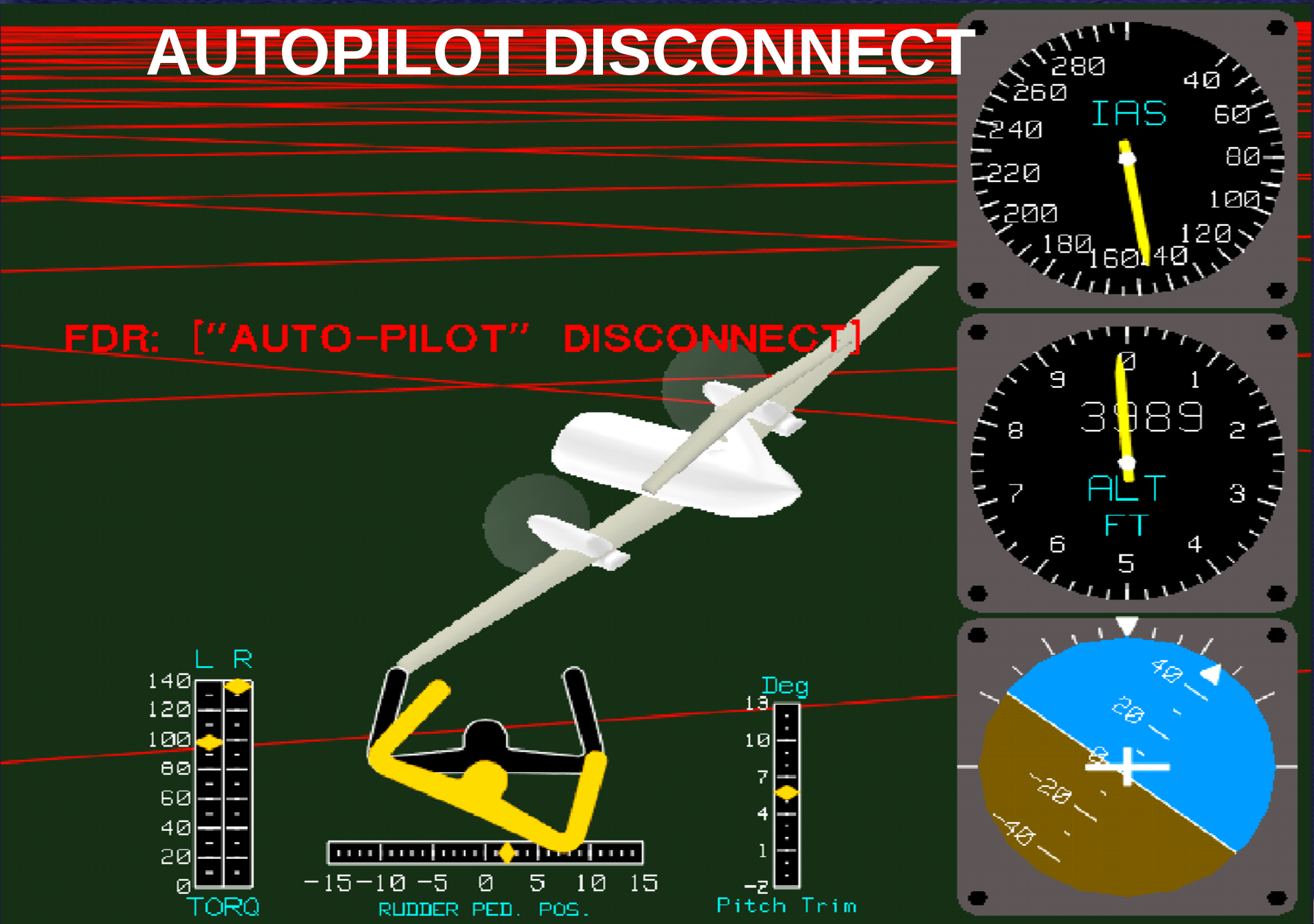






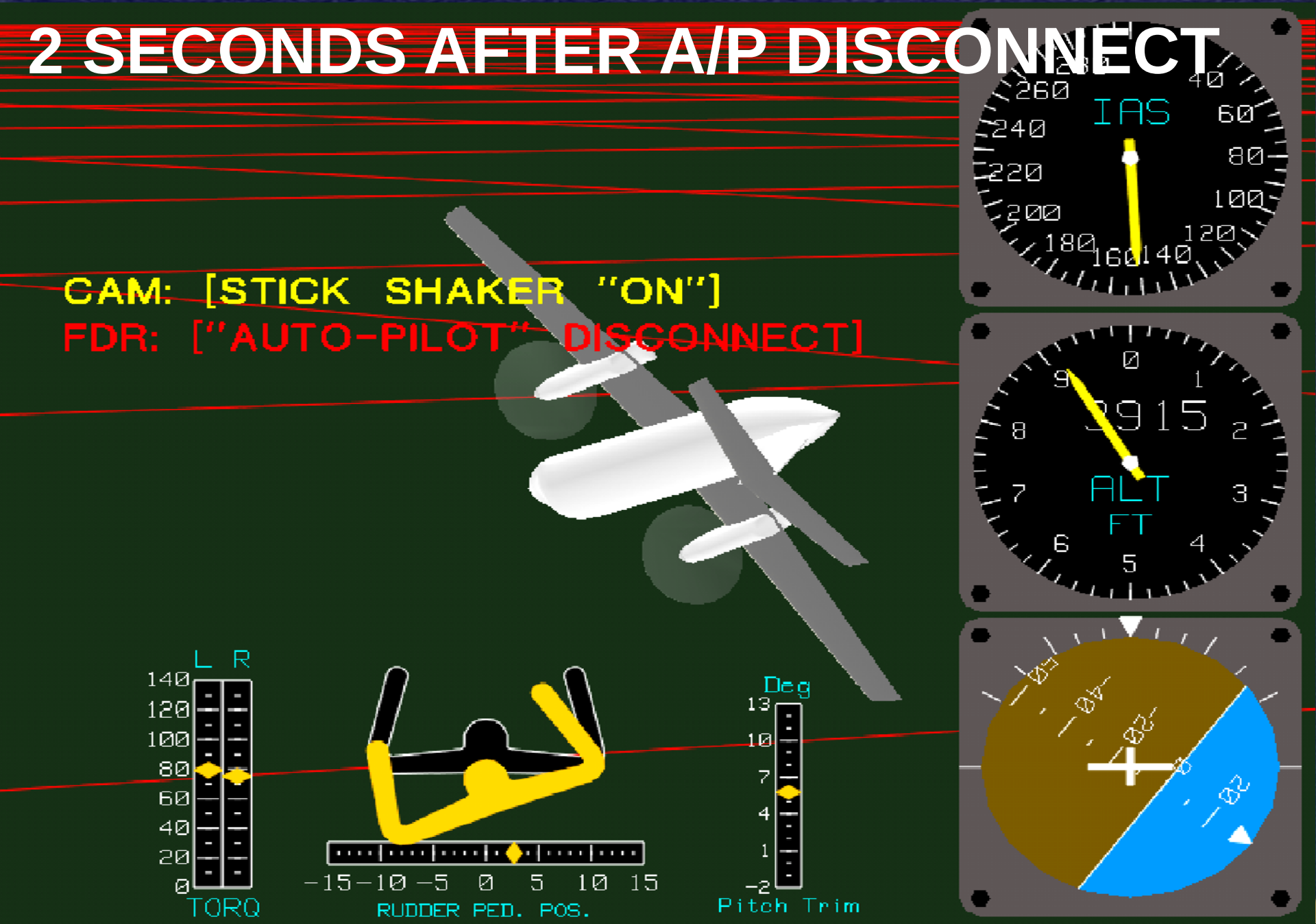


AUTOPILOT DISCONNECT



2 SECONDS AFTER A/P DISCONNECT

CAM: [STICK SHAKER "ON"]
FDR: ["AUTO-PILOT" DISCONNECT]



NTSB Recommendations: Monroe

Summary

- Both thin and imperceptible, as well as rough ice can be hazardous
- Boots need to be activated when entering icing conditions
- Minimum maneuvering speeds for all turbine airplanes, all flight conditions
  - Effects of various types, amounts & locations of ice accumulations
  - Address SLD, rough ice & tailplane icing
- Training for minimum maneuvering operations
- Review/revise AFM & OPS Manuals

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NTSB Recommendations: Monroe (Cont'd)

- Further development of effective detection & protection systems necessary
- Cockpit warning systems for stall in icing conditions
  - Aural warnings
  - Stick shaker/pusher
- Hand fly in icing conditions with icing protection systems operating
- Review/revise certification testing requirements
  - Incorporate realistic certification ice shapes

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Incidents: March 19, 2001
West Palm Beach, FL – Comair Flight 5054
EMB-120

- Pilot reported using de-icing boots (3 minute activation cycle) ; SAT = -4 Deg C
- Autopilot engaged
- Indications from FDR, CVR Ice Detector was active
- Loss of control in icing conditions
- 8000 ft altitude loss, structural damage to horizontal tail and elevator
- Intercycle Ice case

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FDR Data - Comair 5054

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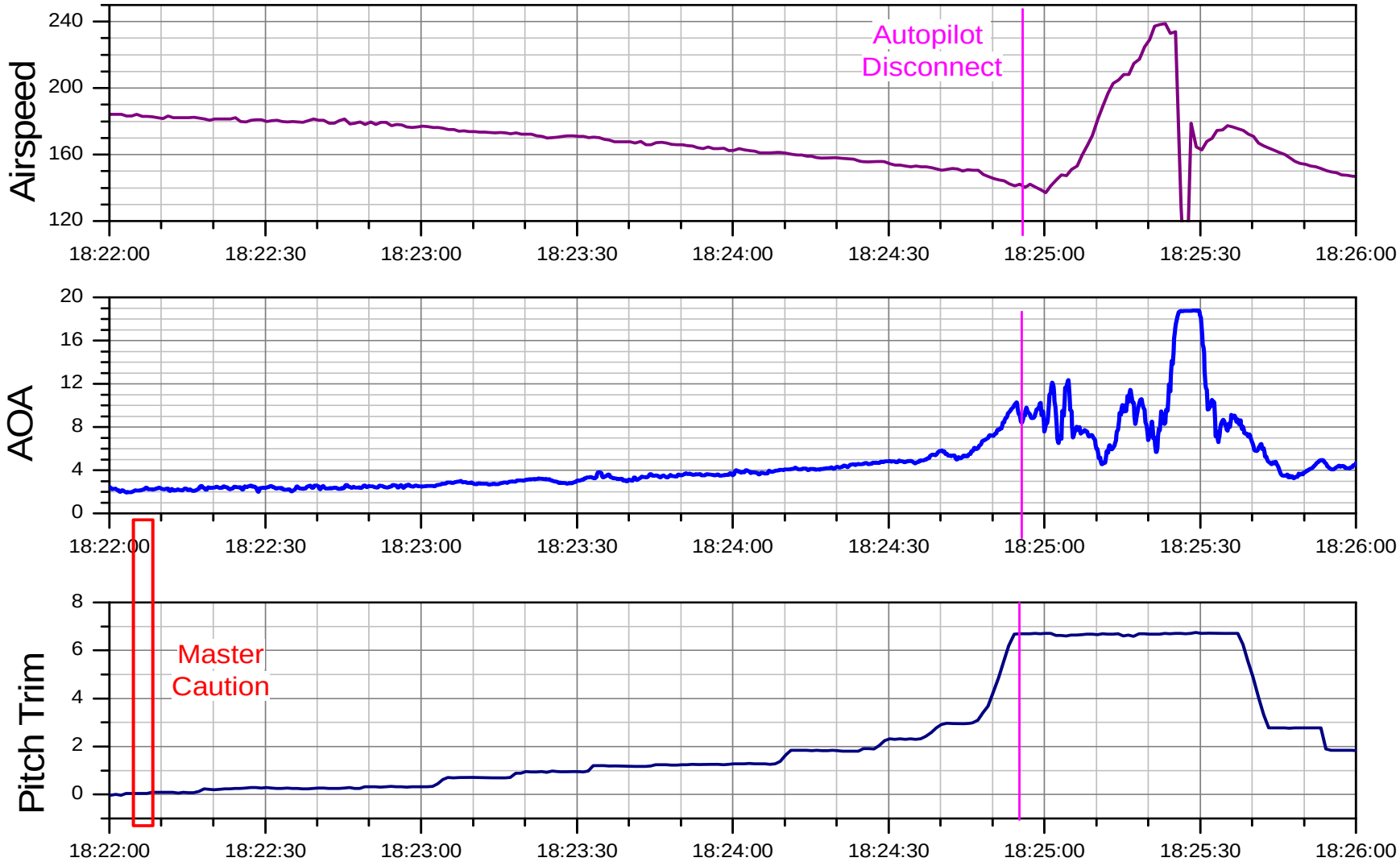
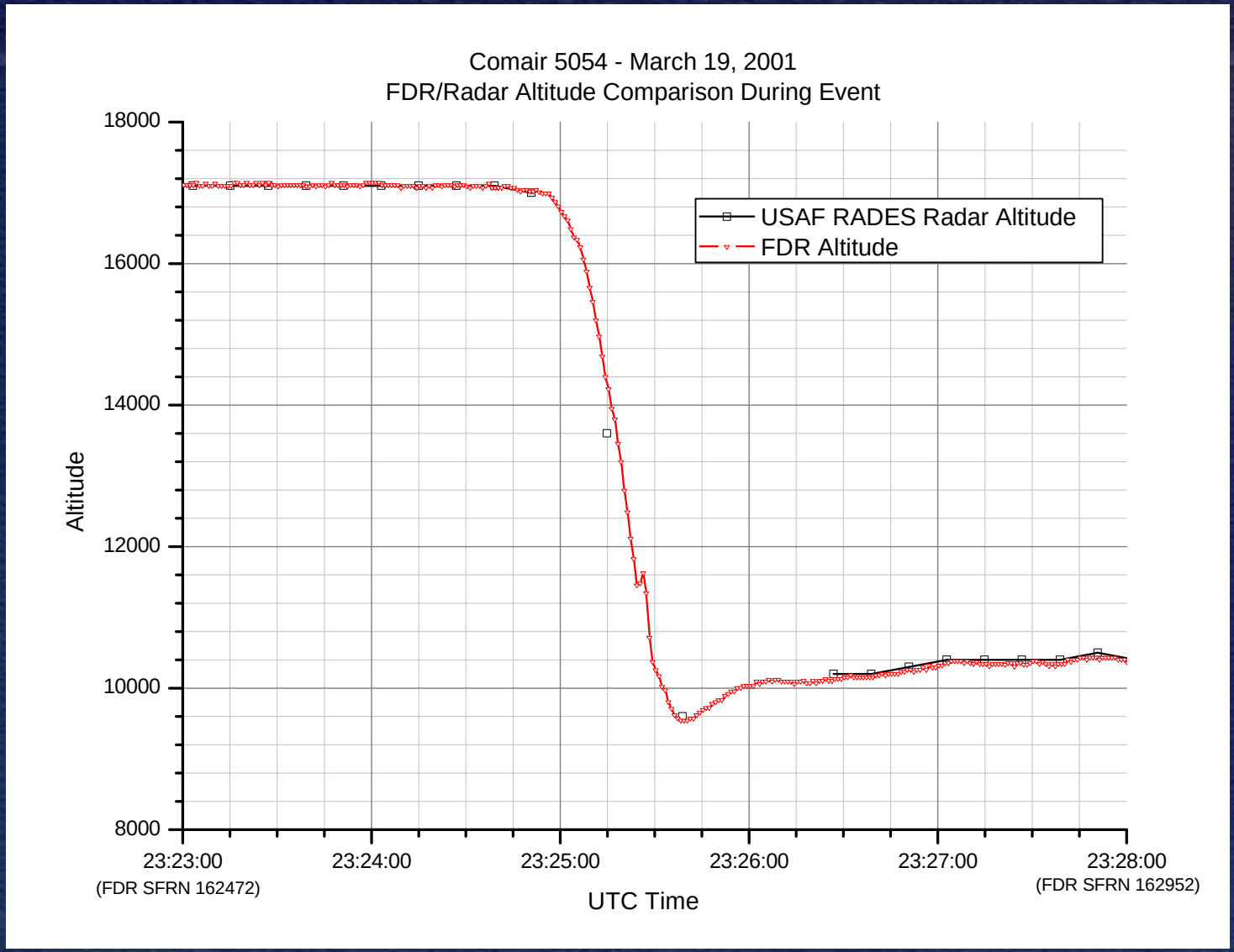
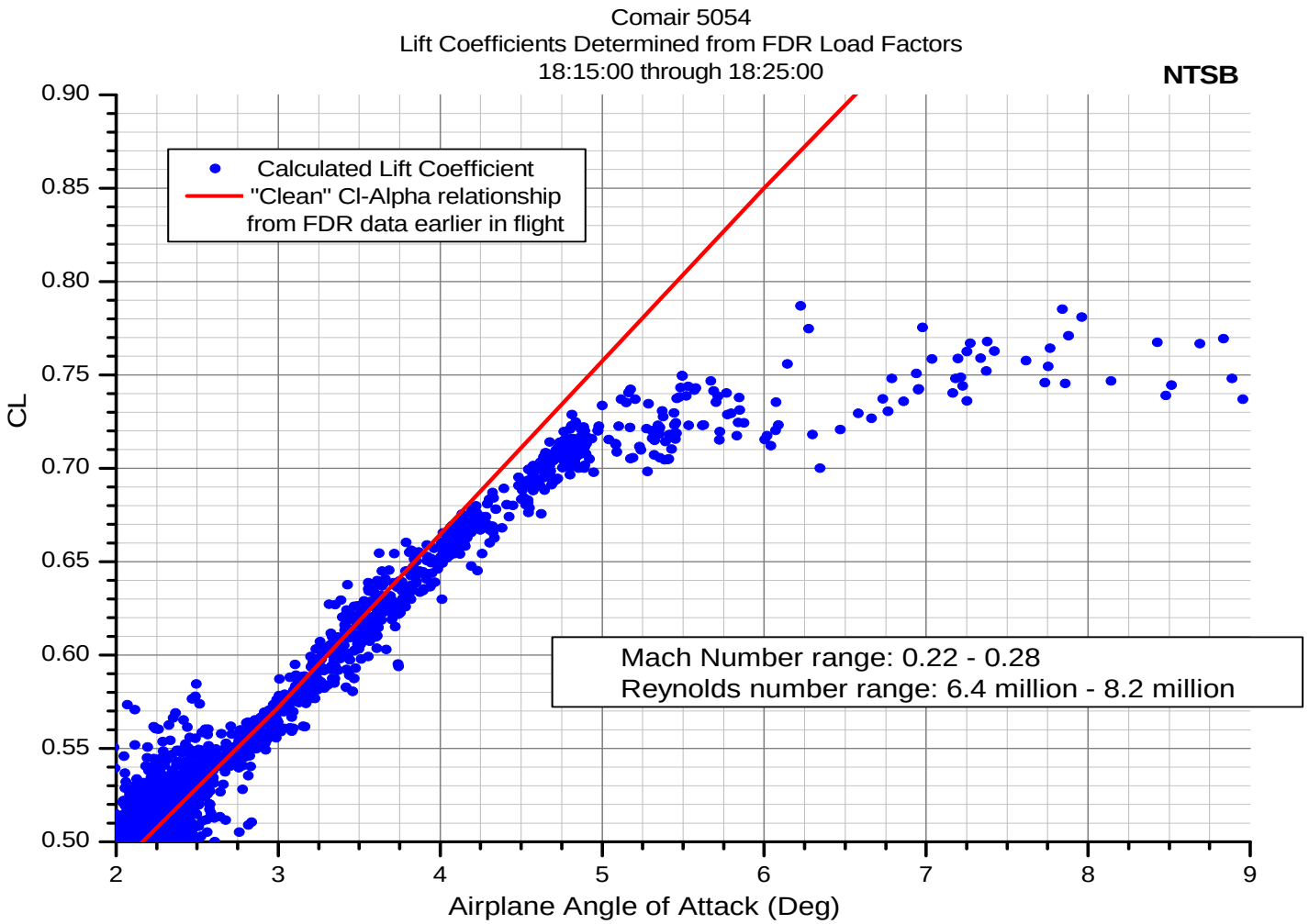



Comair 5054 - March 19, 2001
FDR/Radar Altitude Comparison During Event
USAF RADES Radar Altitude
FDR Altitude
Altitude
18000
16000
14000
12000
10000
8000
23:23:00
(FDR SFRN 162472)
23:24:00
23:25:00
23:26:00
23:27:00
23:28:00
(FDR SFRN 162952)
UTC Time


Comair 5054
Lift Coefficients Determined from FDR Load Factors
18:15:00 through 18:25:00
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Calculated Lift Coefficient
"Clean" Cl-Alpha relationship
from FDR data earlier in flight
Mach Number range: 0.22 - 0.28
Reynolds number range: 6.4 million - 8.2 million
CL
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
2
3
4
5
6
7
8
9
Airplane Angle of Attack (Deg)

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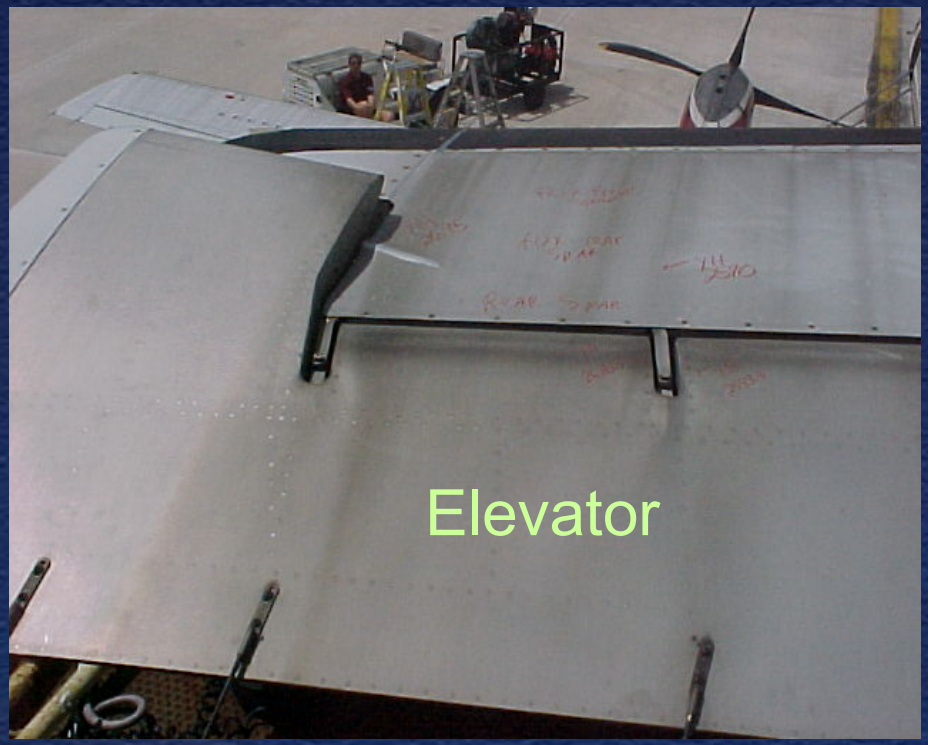
View from above Horizontal Stabilizer



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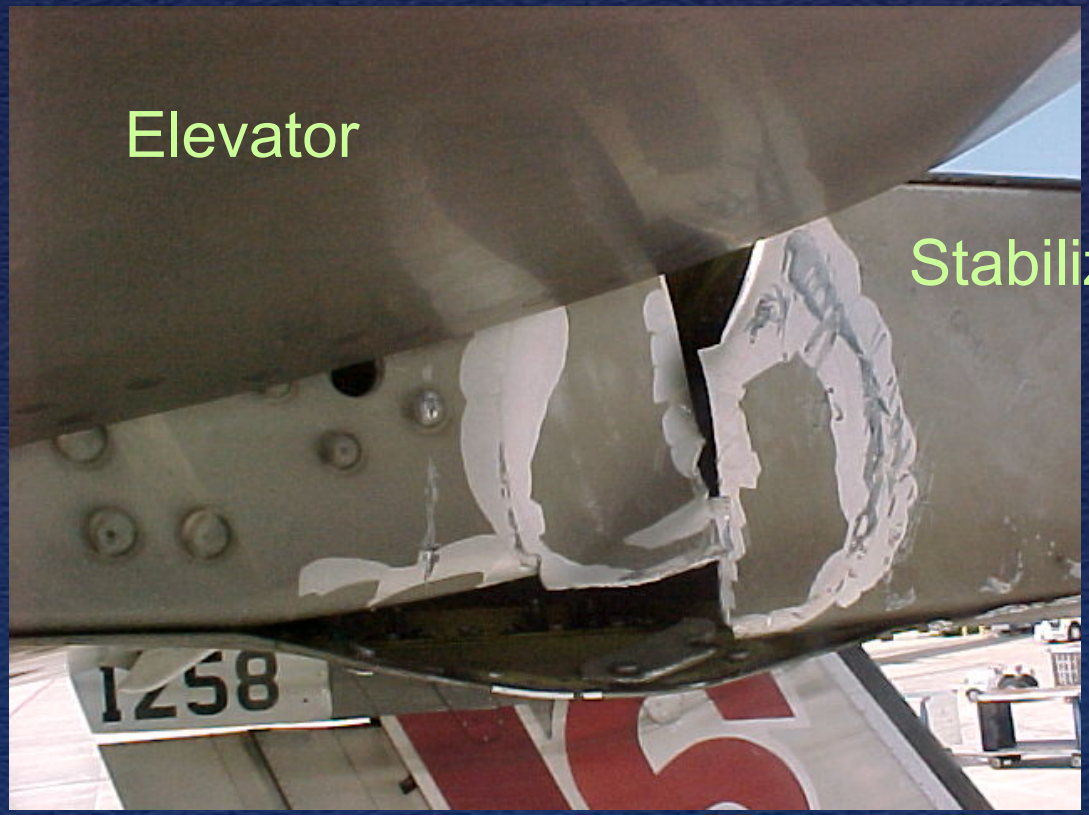
Right Side Stabilizer, Inboard of Elevator



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NTSB Recommendations: West Palm Beach

- No new recommendations on icing issued
  - nothing new to recommend

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Accidents: February 16, 2005 Pueblo, CO – Cessna 560

- 8 fatalities
- Issues: airspeed and deice boot activation

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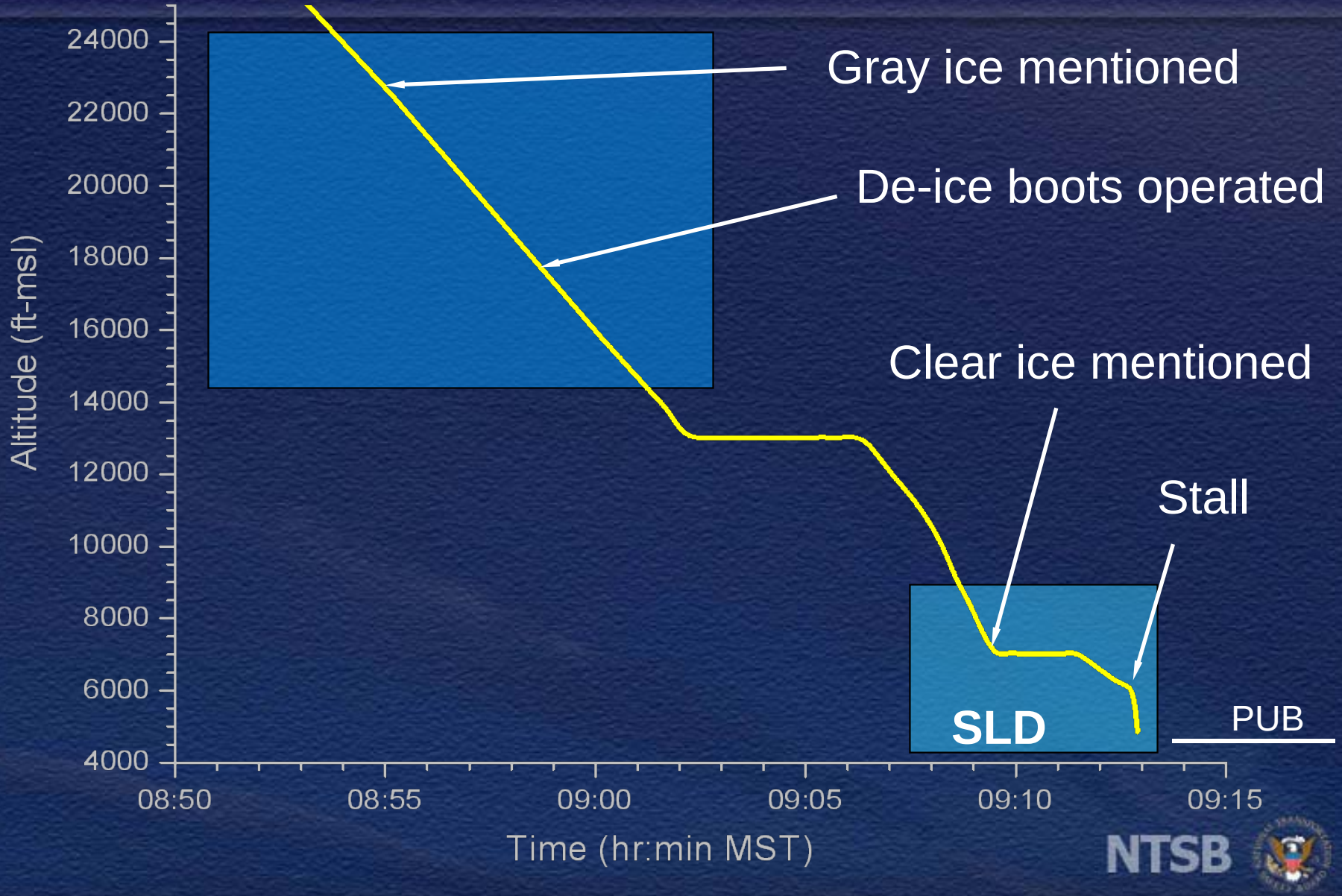
Altitude Time History



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Accident Sequence

- Airplane slowed below $V_{approach}$
- De-ice boots not operated in second icing layer
- Presence of an estimated 1/6 of an inch or less of ice accreted in SLD conditions caused the airplane to stall prior to stick shaker
- Airplane entered a rapid left roll prior to stall warning
- Airplane did not recover in the 1,500 feet agl available

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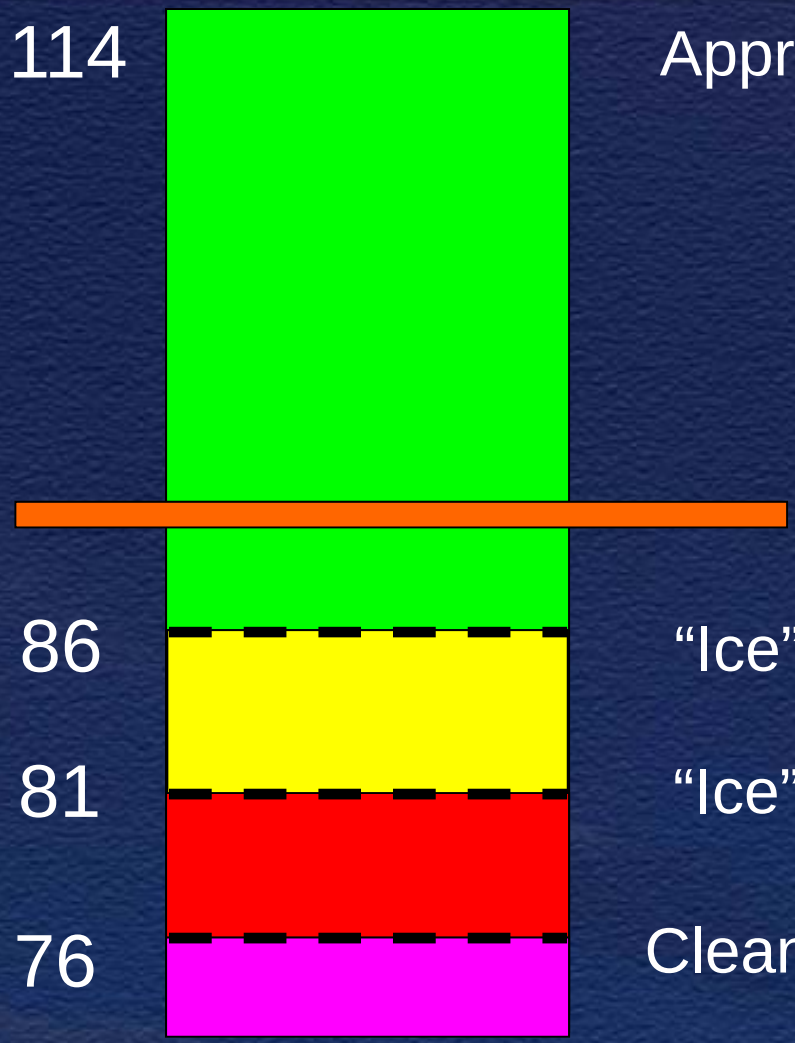
Accident Airplane Relevant Speeds



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NTSB Recommendations: Pueblo

Summary

- In icing conditions – increase speed and operate boots
- Activate boots when entering icing conditions
- Incorporate automatic boot cycling capability
- Review all boot equipped airplanes against revised certification standards when complete
- Specific modifications of Cessna 560 stall warning system regarding both thin & rough ice

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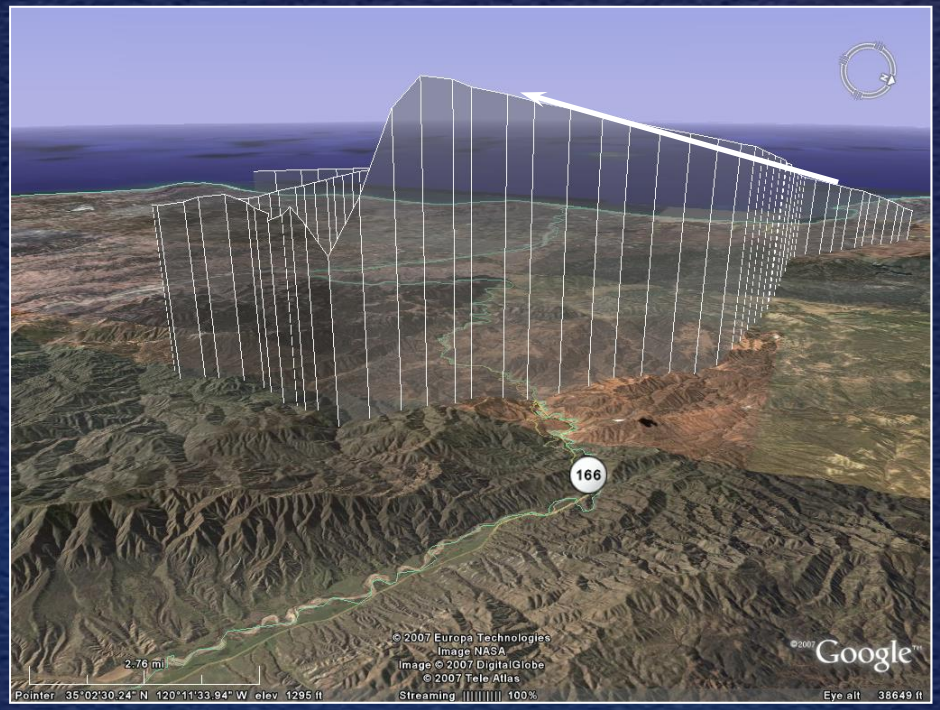
Incidents: January 2, 2006 San Luis Obispo, CA - American Eagle Saab 340B



- Slowed on autopilot
- Lost 5000 feet altitude
- Nearly inverted

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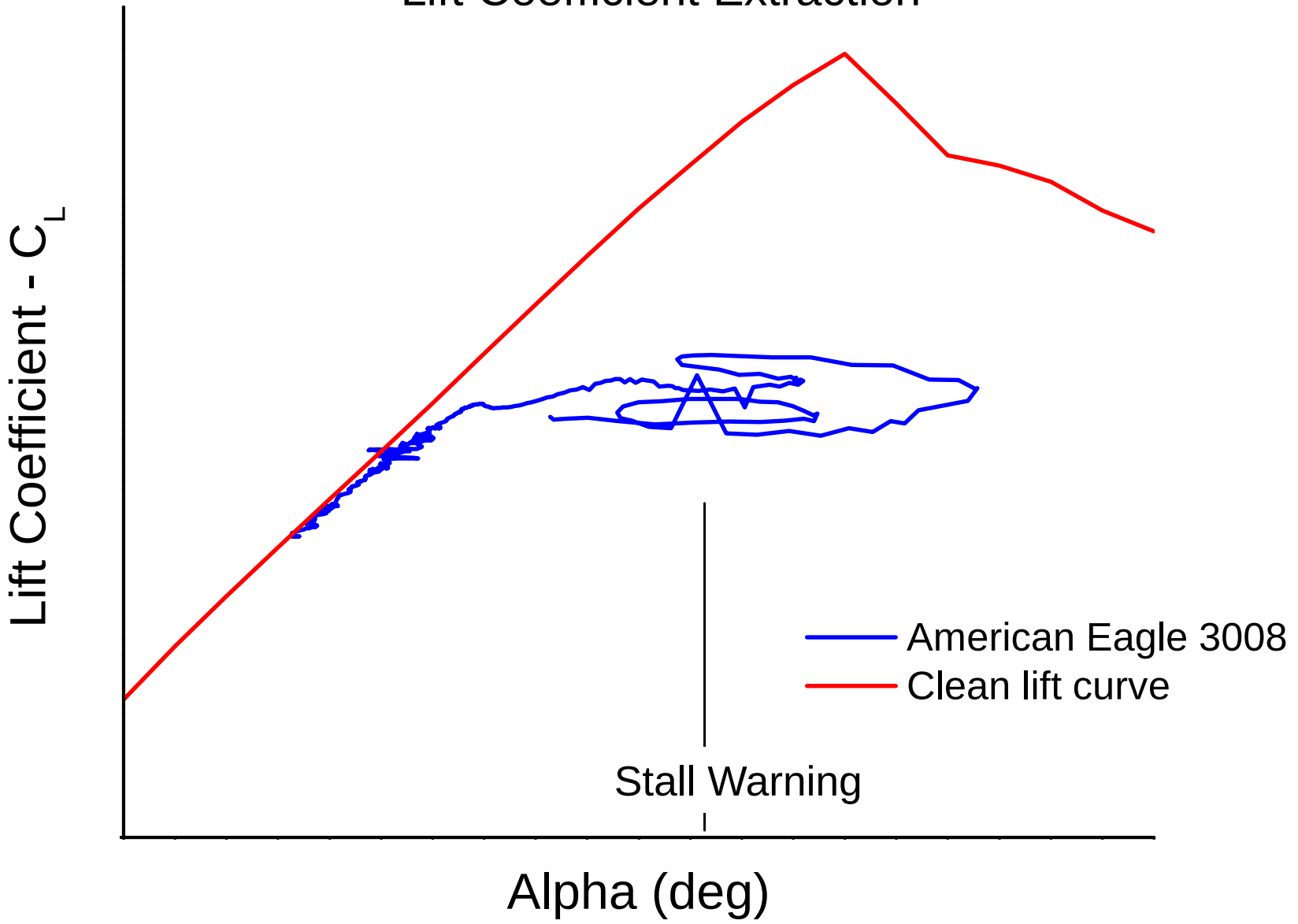
Saab 340

Lift Coefficient Extraction



NTSB Recommendations: San Luis Obispo

- NTSB issued 4 recommendations
  - Minimum airspeed
  - Modify stall protection
  - Ice detection
  - Disengage autopilot in icing conditions, except in periods of high workload

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Accidents: January 27, 2009 Lubbock, TX – ATR42-320

- Unstable approach
- Failure to go round
- Airspeed

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National Transportation Safety Board

Office of Research and Engineering

Flight Path

Crash During Approach to Landing
Empire Airlines doing business as
FedEx ATR-42-320

Lubbock, Texas
January 27, 2009

CEN09MA142

NTSB Recommendations: Lubbock

- Simulator fidelity for ice accretion should be consistent with icing accidents and incidents
- Flight crew simulation training for icing should include
  - Recognizing changes in flight characteristics as icing develops
  - Monitoring and maintaining appropriate icing speeds
  - Stalls and approach to stalls with and without ice protection systems
- Performance monitoring system

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Accidents and Incidents Demonstrate:

- Icing continues to be a threat to aviation safety
- Airplanes are operating in SLD environments for which they are not certified, particularly in lower layers of the atmosphere
- Rough ice shapes and intercycle ice shapes can cause large aerodynamic penalties, larger than some ice shapes currently used in certification
- Updating simulator models and incorporating previous icing incident/accident data to ensure accuracy can help to mitigate the icing threat
- Consideration by airplane manufacturers of an aircraft performance monitoring system for better flight crew awareness of severe icing encounters (like ATR's)

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