



NTSB National Transportation Safety Board

Lessons from Icing Accidents and Incidents

Presentation of NTSB Board Member

Dr. Earl Weener

to the

Experimental Aircraft Association

February 1, 2011

NTSB Mission

The NTSB is an independent US 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.

NTSB view of Airframe Icing

- Majority of icing conditions encountered will not be a problem for certificated aircraft - we deal with the uncommon occurrences
- NTSB has had recommendations on aircraft icing dating back to 1981
- Airframe Icing has been on the NTSB's Most Wanted List of safety improvements since 1997

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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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

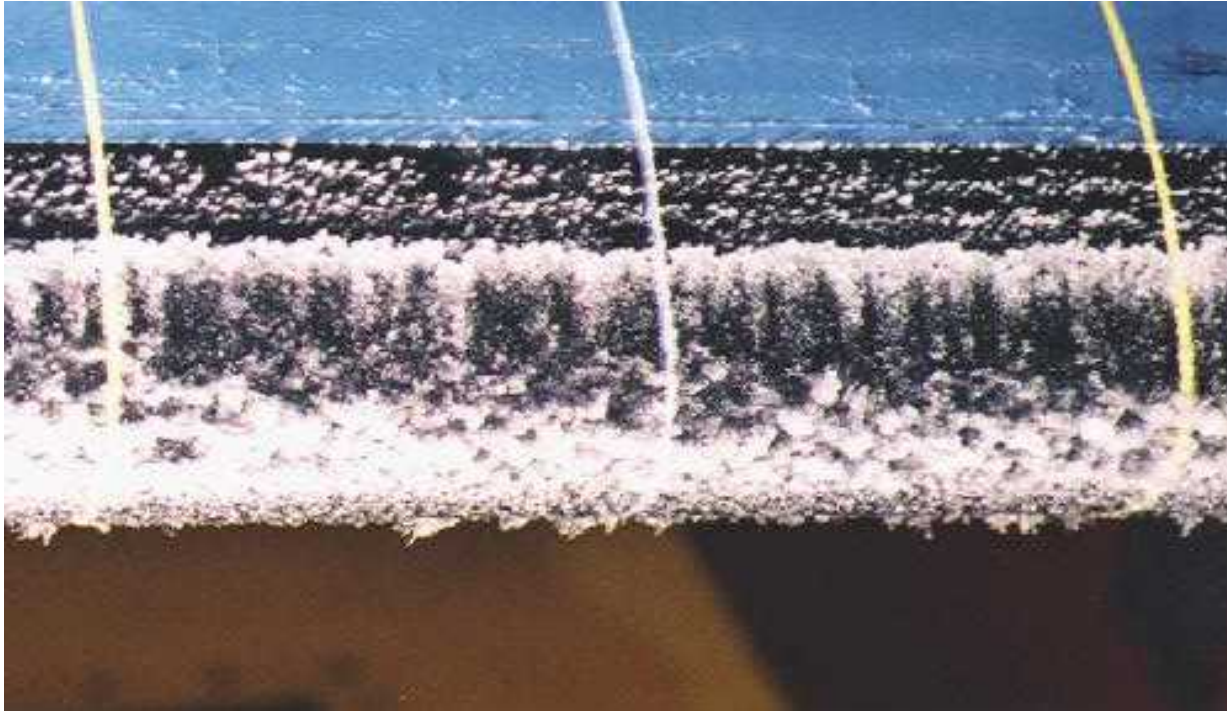


Effect of SLD on ice accretion

Wing leading edge cross section



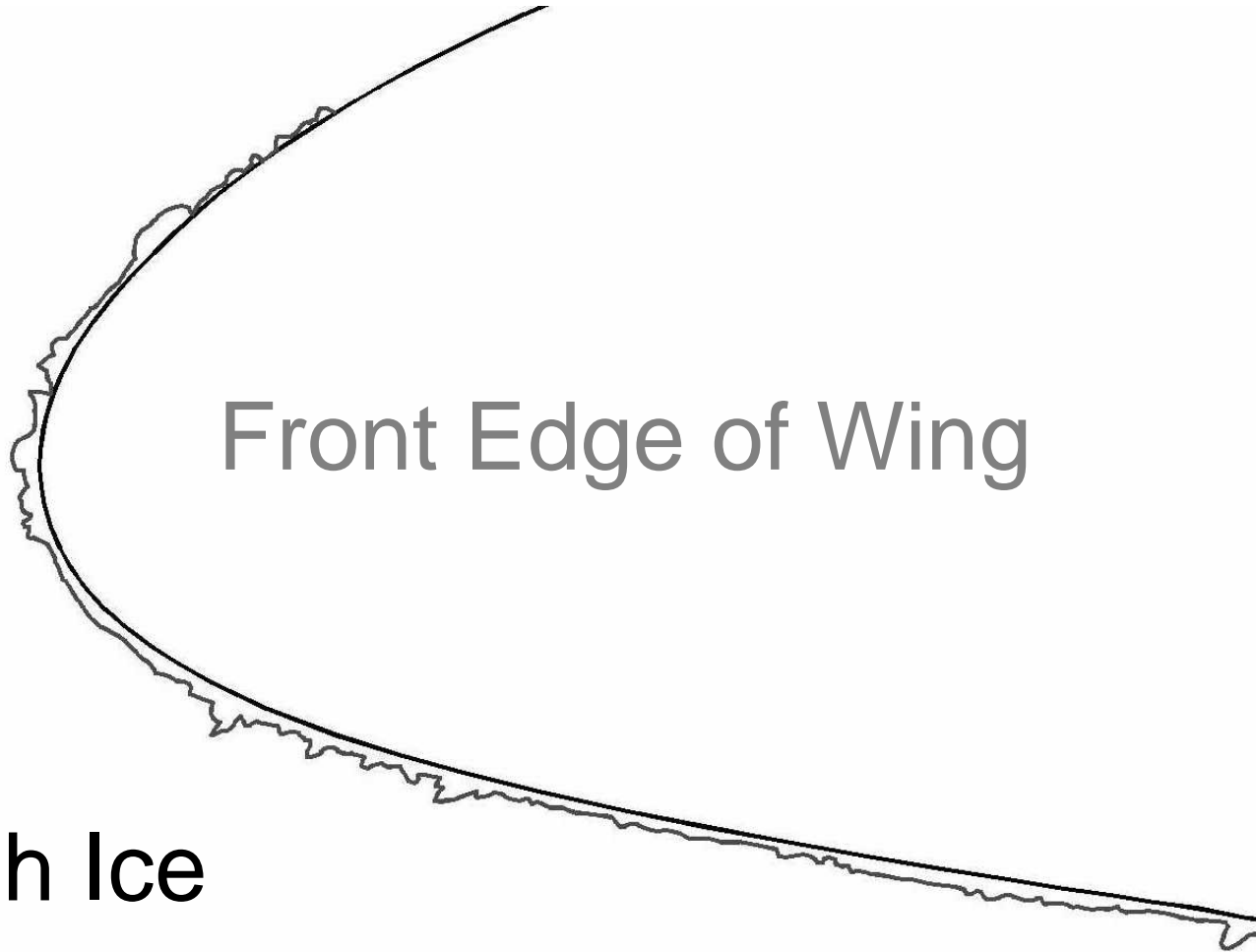
Resultant Ice Shapes



Front Edge of Wing

Rough Ice

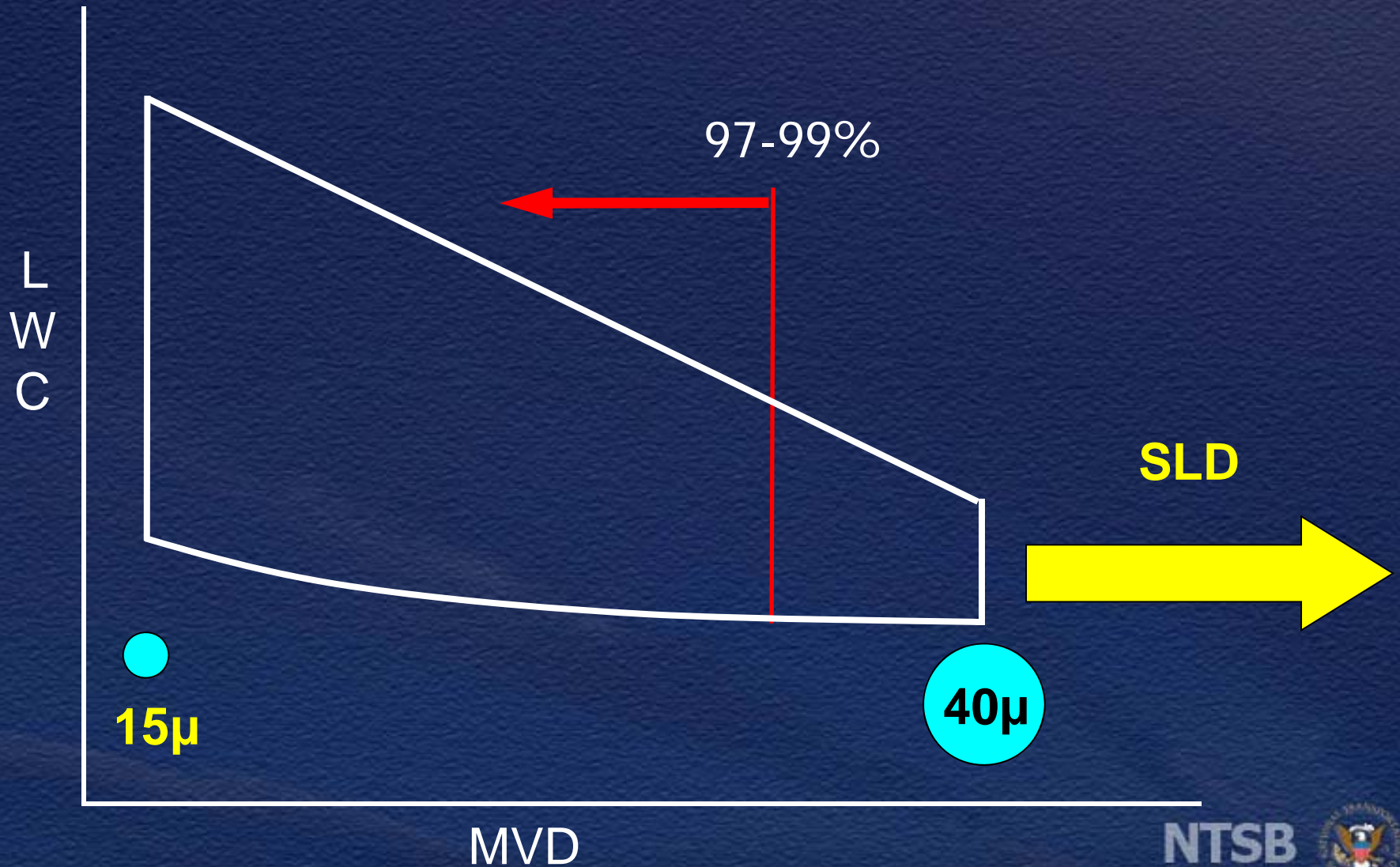
Resultant Ice Shapes



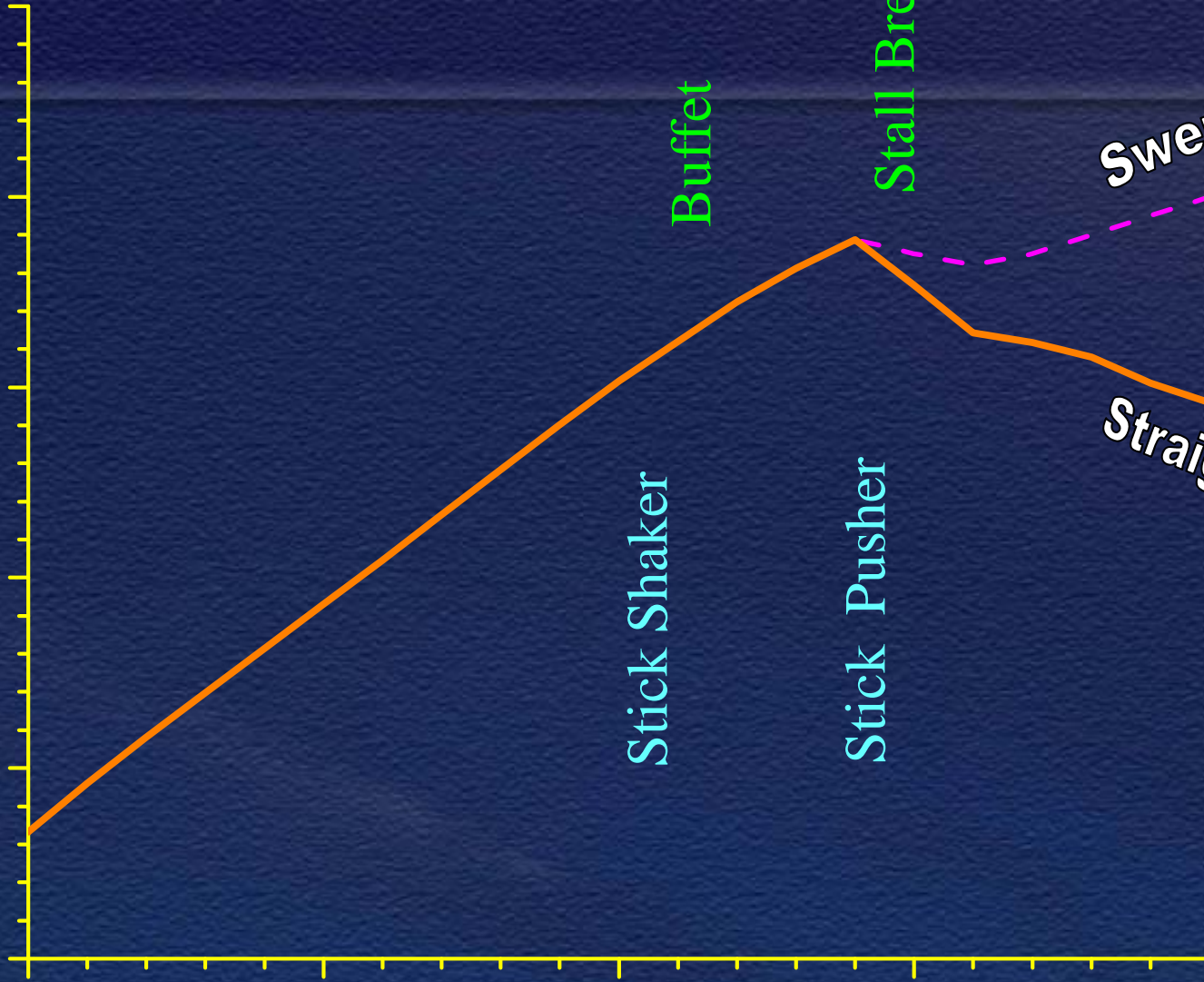
Rough Ice

Part 25 Appendix C

Continuous Maximum Icing



Lift Coefficient - C_L



Alpha (deg)

Stick Shaker

Stick Pusher

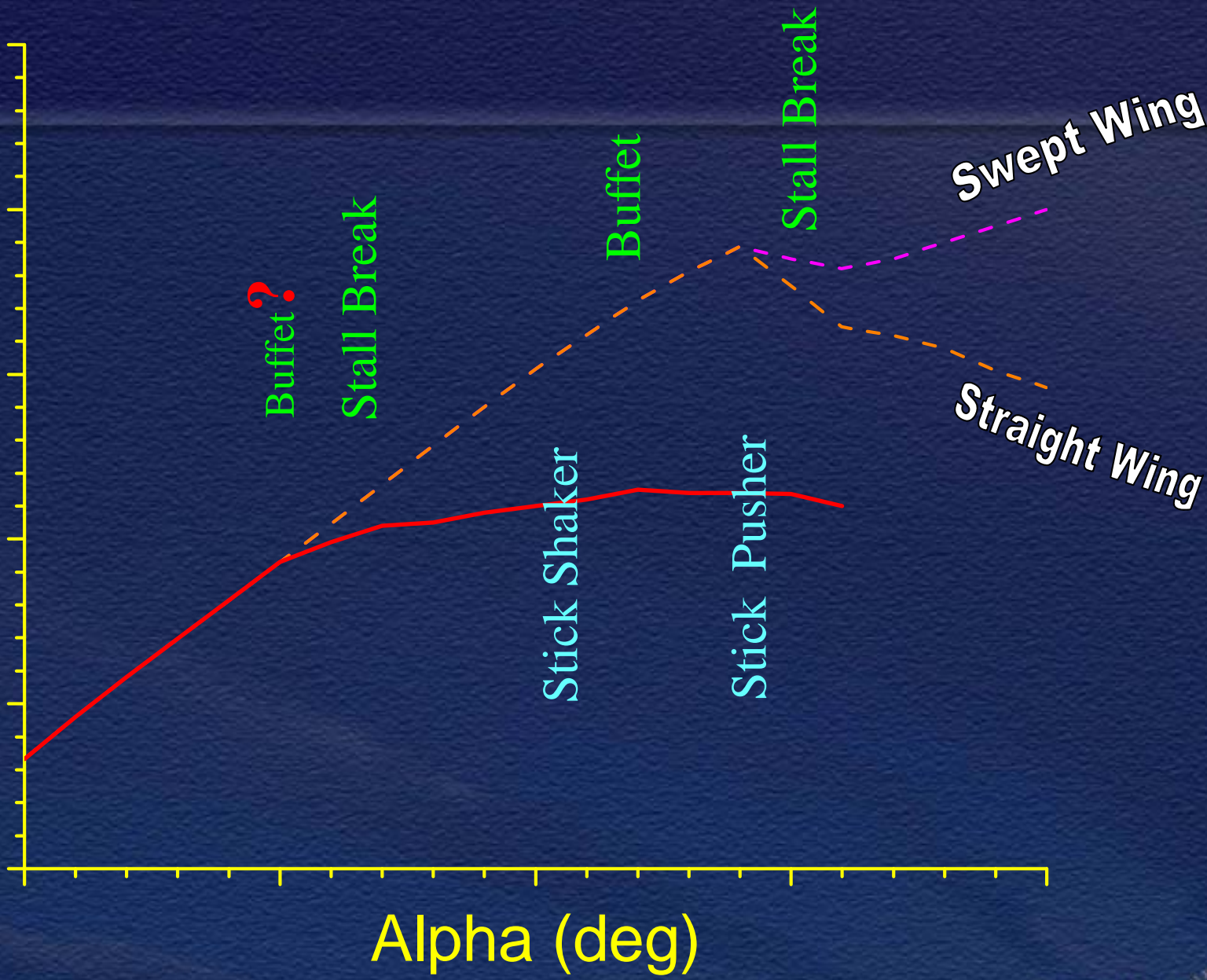
Buffet

Stall Break

Swept Wing

Straight Wing

Lift Coefficient - C_L



Buffet?

Stall Break

Buffet

Stall Break

Swept Wing

Straight Wing

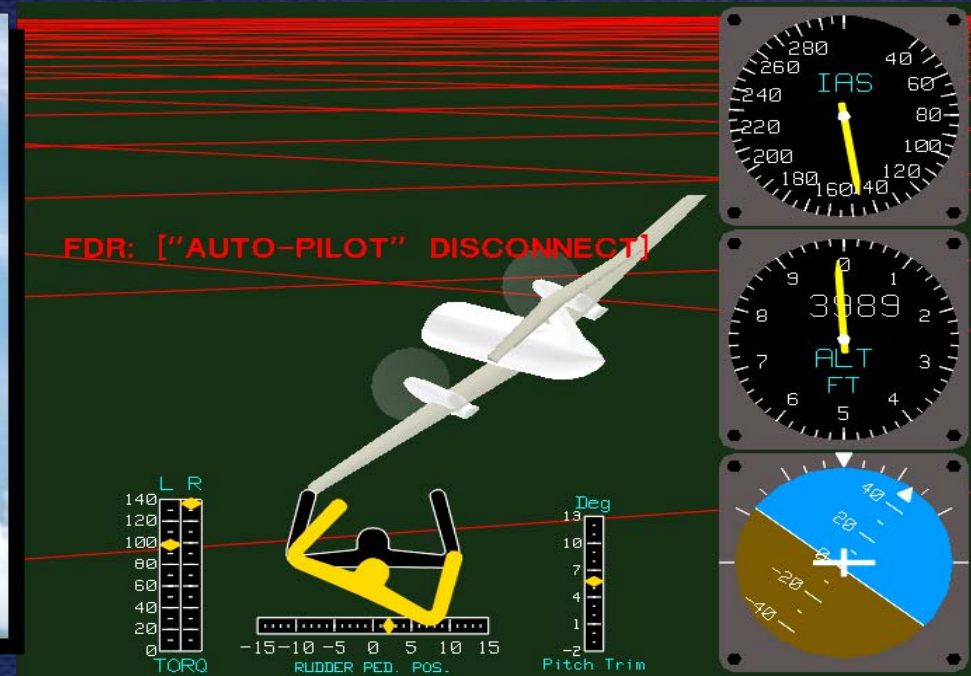
Stick Shaker

Stick Pusher

Alpha (deg)



Fatal Accidents

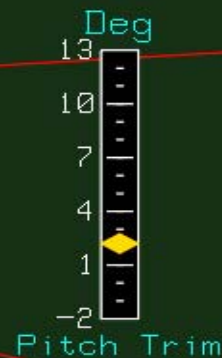
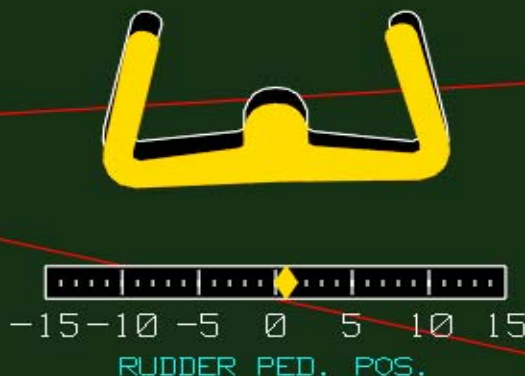
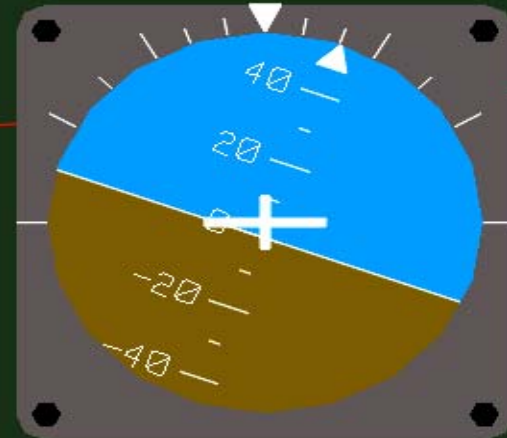
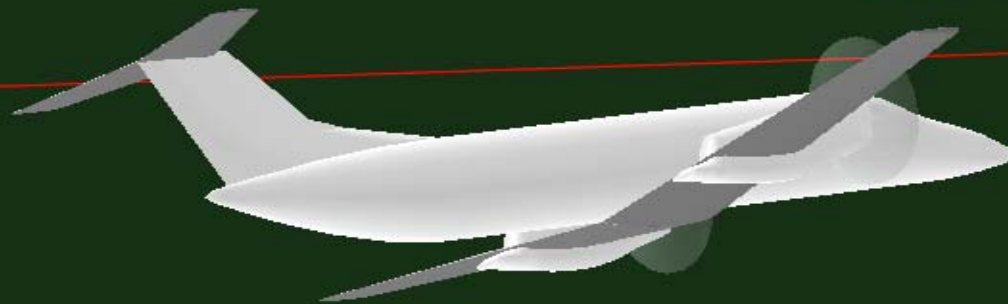


- Comair Embraer EMB-120
Monroe, MI – January, 1997
– 39 fatalities

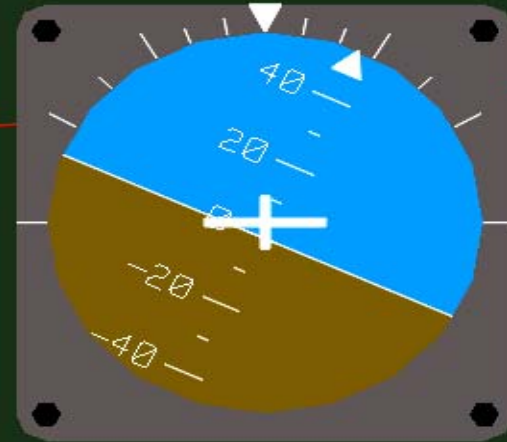
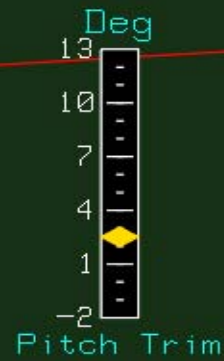
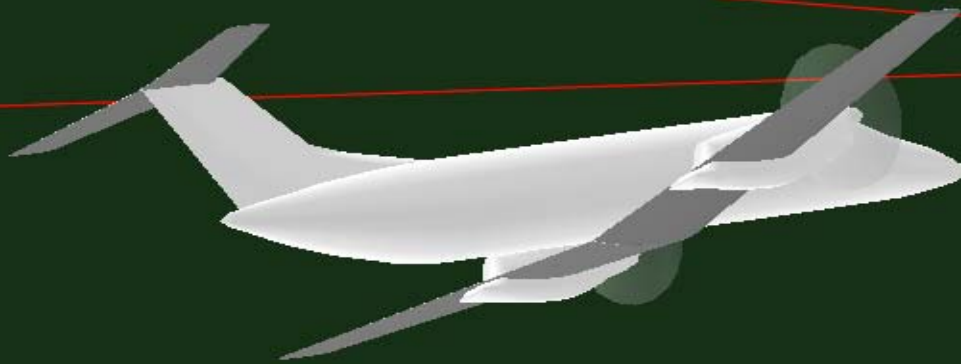
Accident Sequence – COM 3272

- 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

ENTERING THE LEFT TURN

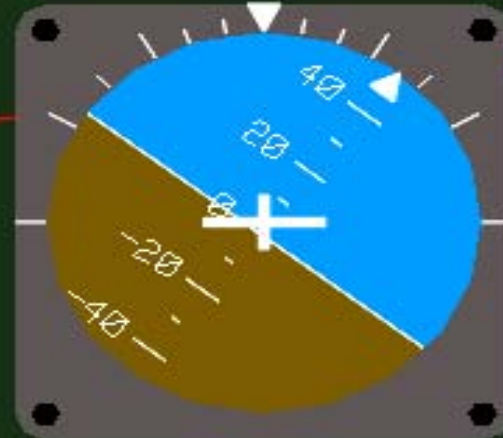
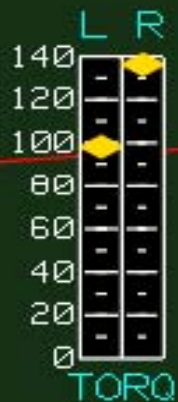


START OF A/P WHEEL TO RIGHT



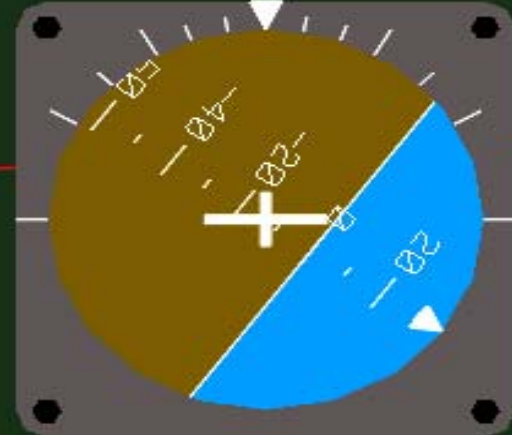
AUTOPILOT DISCONNECT

FDR: ["AUTO-PILOT" DISCONNECT]

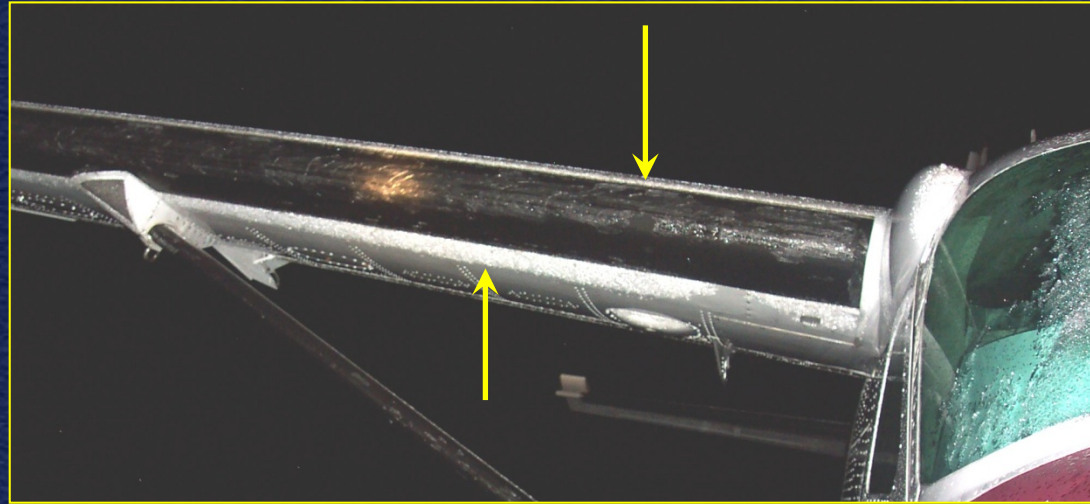


2 SECONDS AFTER A/P DISCONNECT

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



Fatal Accidents



- Numerous Cessna 208B Caravans
 - Totaling 47 fatalities

Cessna 208 Caravan Accident/Incident Assessment:

- Between 1987 and 2003, 26 icing related accidents and incidents
- 15 of 26 ice accumulated in-flight
 - 10 of 15 In-flight were during approach and landing phases
- 10 of 26 involved ice not removed before takeoff

Cessna 208 Icing

- As a result of the NTSB assessment of the Cessna 208 accident and incident history, NTSB issued 4 recommendations to FAA on December 15, 2004

Cessna 208 – Moscow

November, 2005

- 8 fatal
- Accident occurred while on approach
- FDR and CVR equipped
- Leveled off at 4900 ft, and reduced airspeed with autopilot engaged
- Experienced roll excursions after autopilot disconnect
- No stall warning until after onset of roll

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Cessna 208 – Moscow

November, 2005

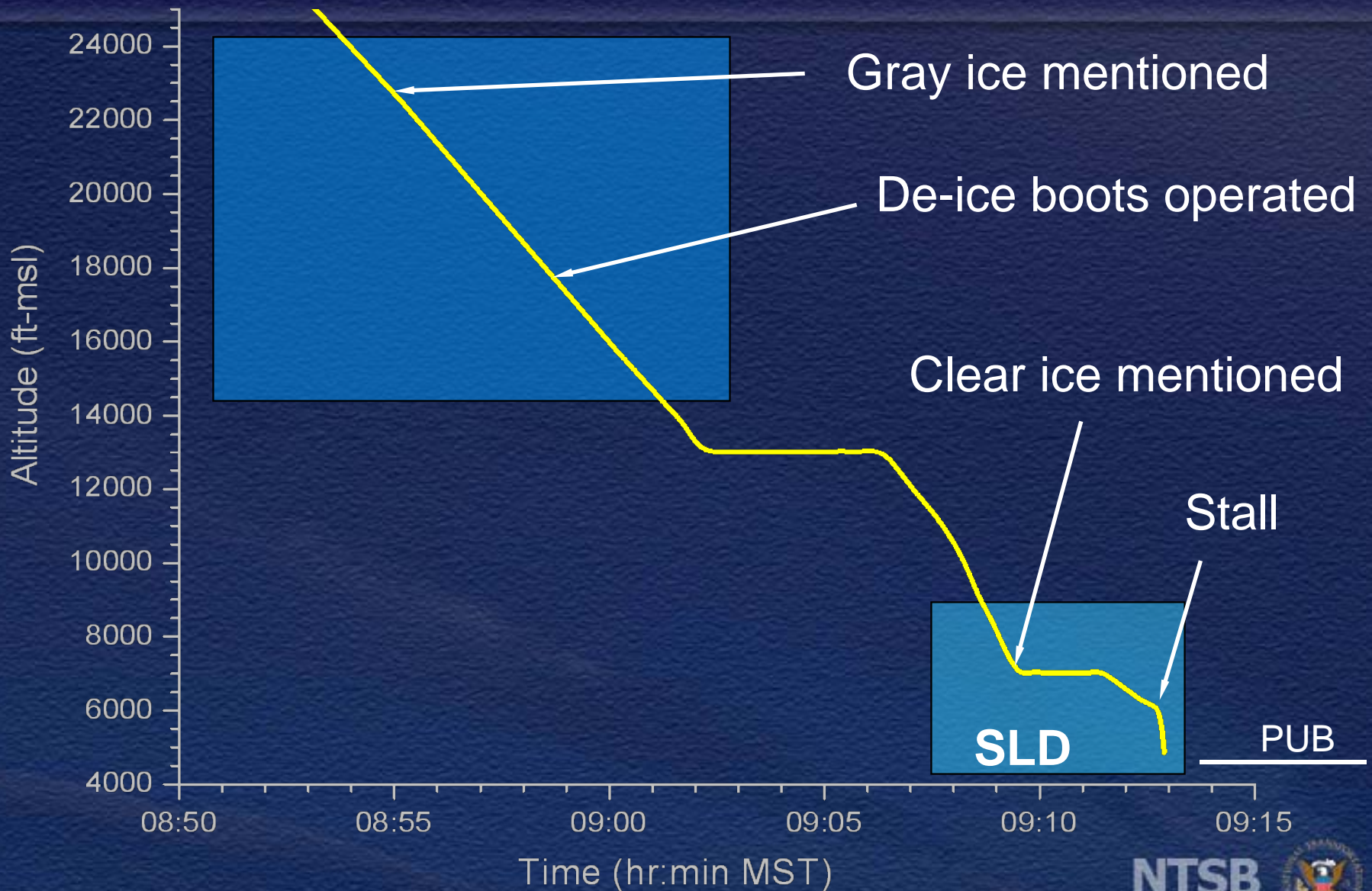
- Resulted in three urgent recommendations
 - 120 knots minimum airspeed
 - Prohibit flight in icing conditions worse than light
 - Disengage autopilot in icing conditions
- All adopted by FAA

Fatal Accidents



- **Circuit City Cessna 560**
Pueblo, CO – February, 2005
– 8 fatalities

Altitude Time History – C560



C560 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

C560 Accident Airplane Relevant Speeds



Safety Board Probable Cause

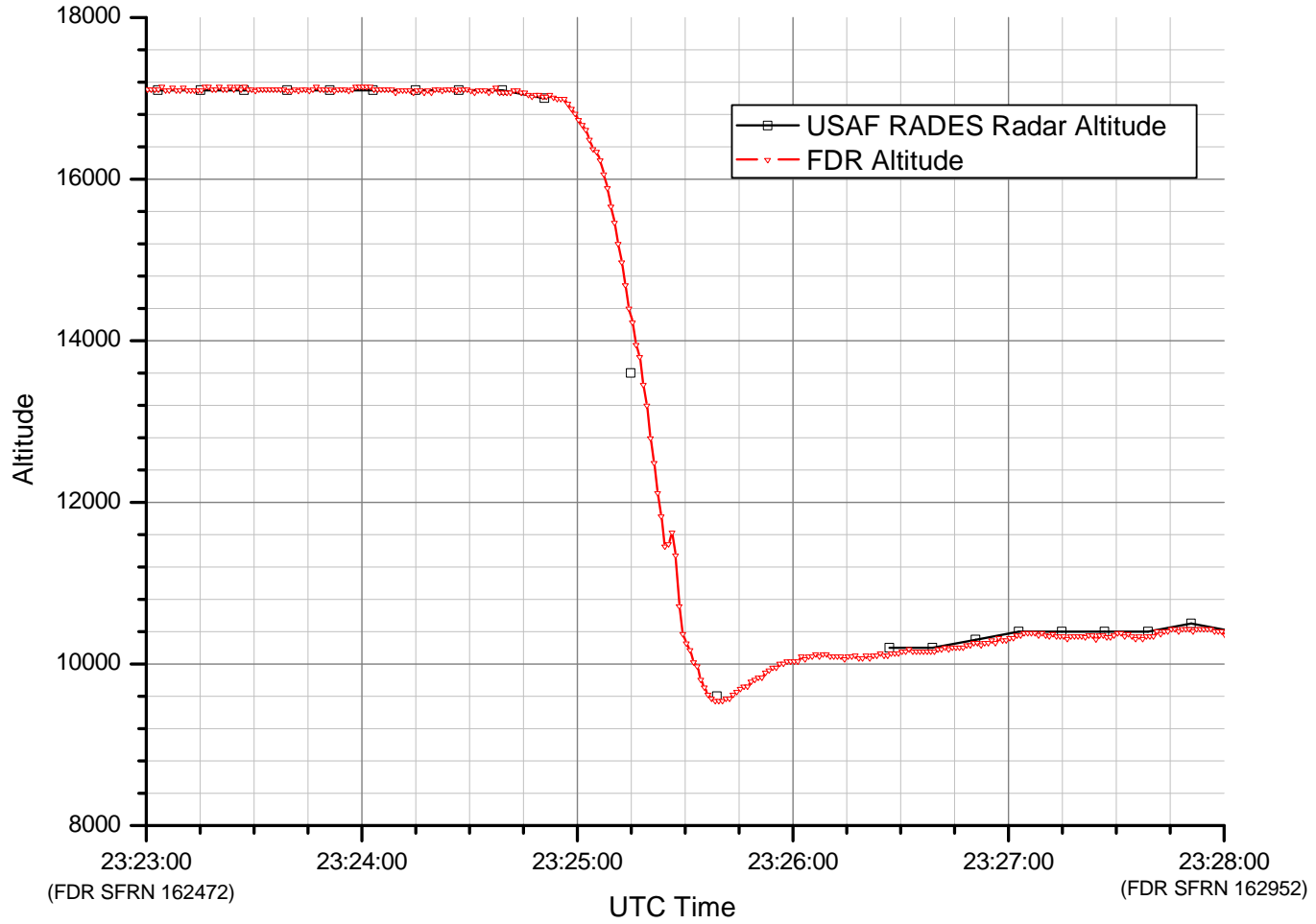
“The flight crew’s failure to effectively monitor and maintain airspeed and comply with procedures for deice boot activation on the approach, which caused an aerodynamic stall from which they did not recover...”

Incidents

Comair Flight 5054 EMB-120 Incident West Palm Beach, FL - March 19 2001

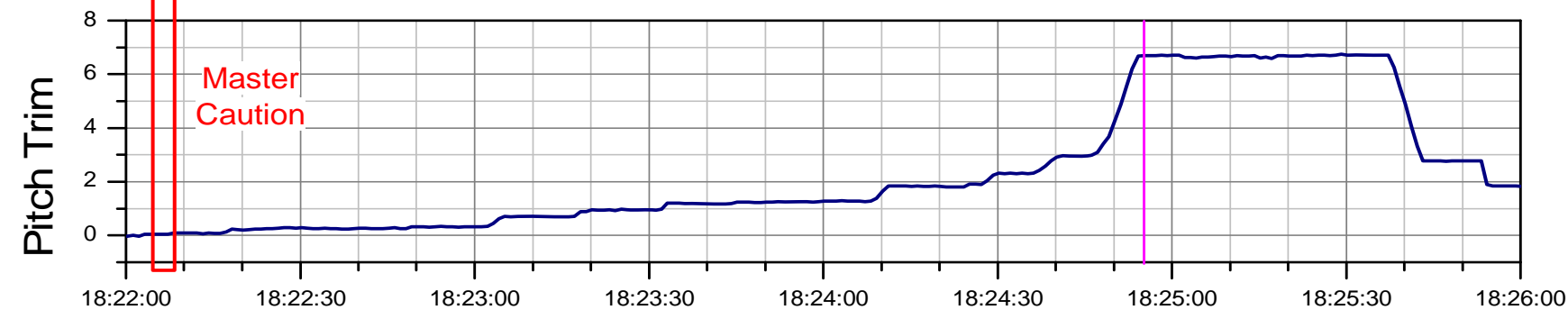
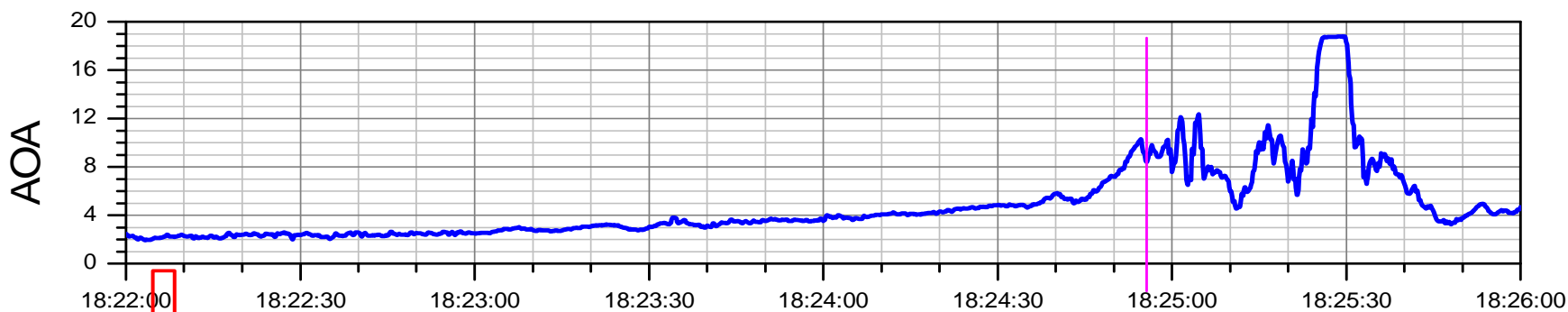
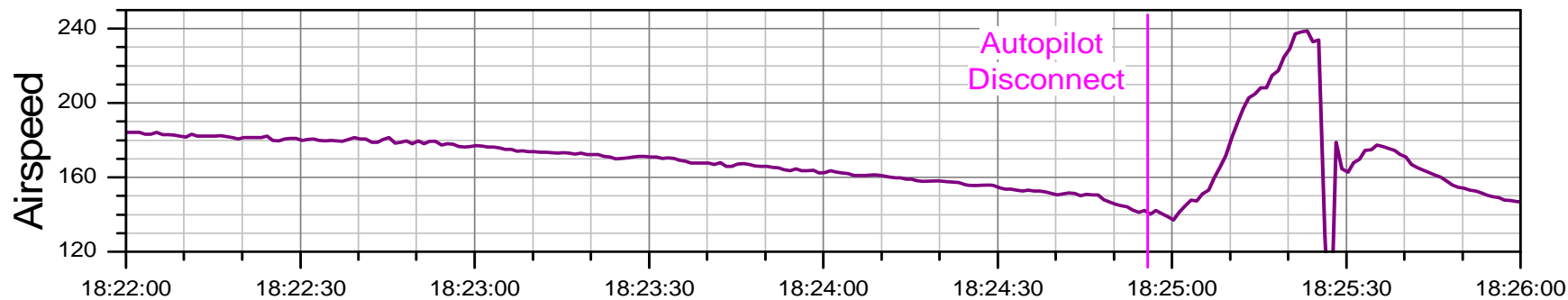
- Pilot reported using de-icing boots (3 minute activation cycle) ; SAT = -4 Deg C
- Autopilot engaged
- Indications from FDR, CVR Ice Detector was active
- Loss of control in icing conditions
- 8000 ft altitude loss, structural damage to horizontal tail and elevator
- Intercycle Ice case

Comair 5054 - March 19, 2001
FDR/Radar Altitude Comparison During Event

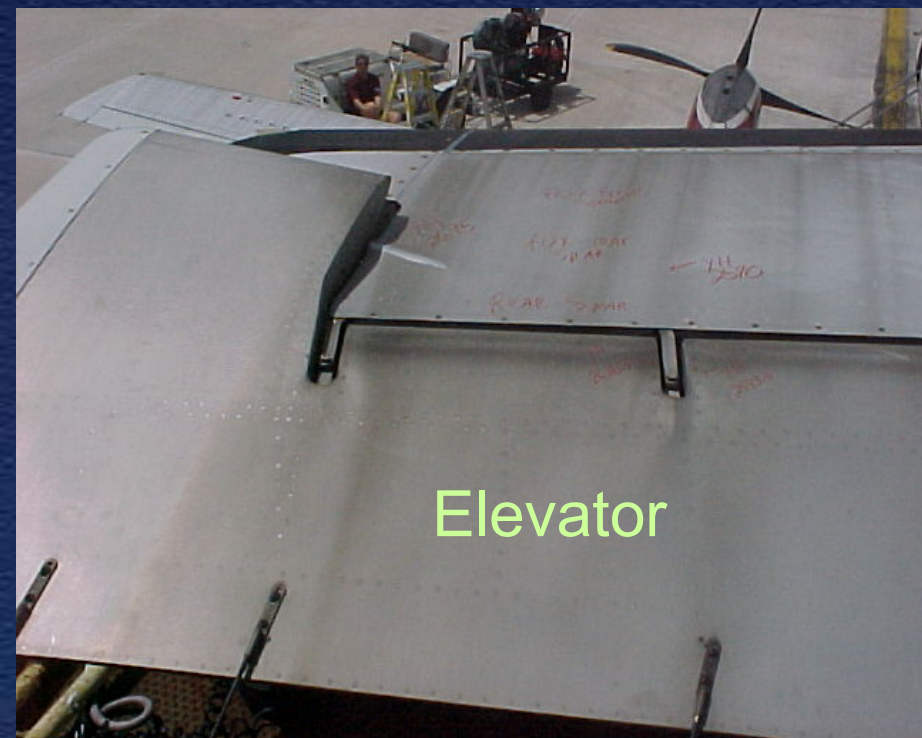


FDR Data - Comair 5054

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View from above Horizontal Stabilizer

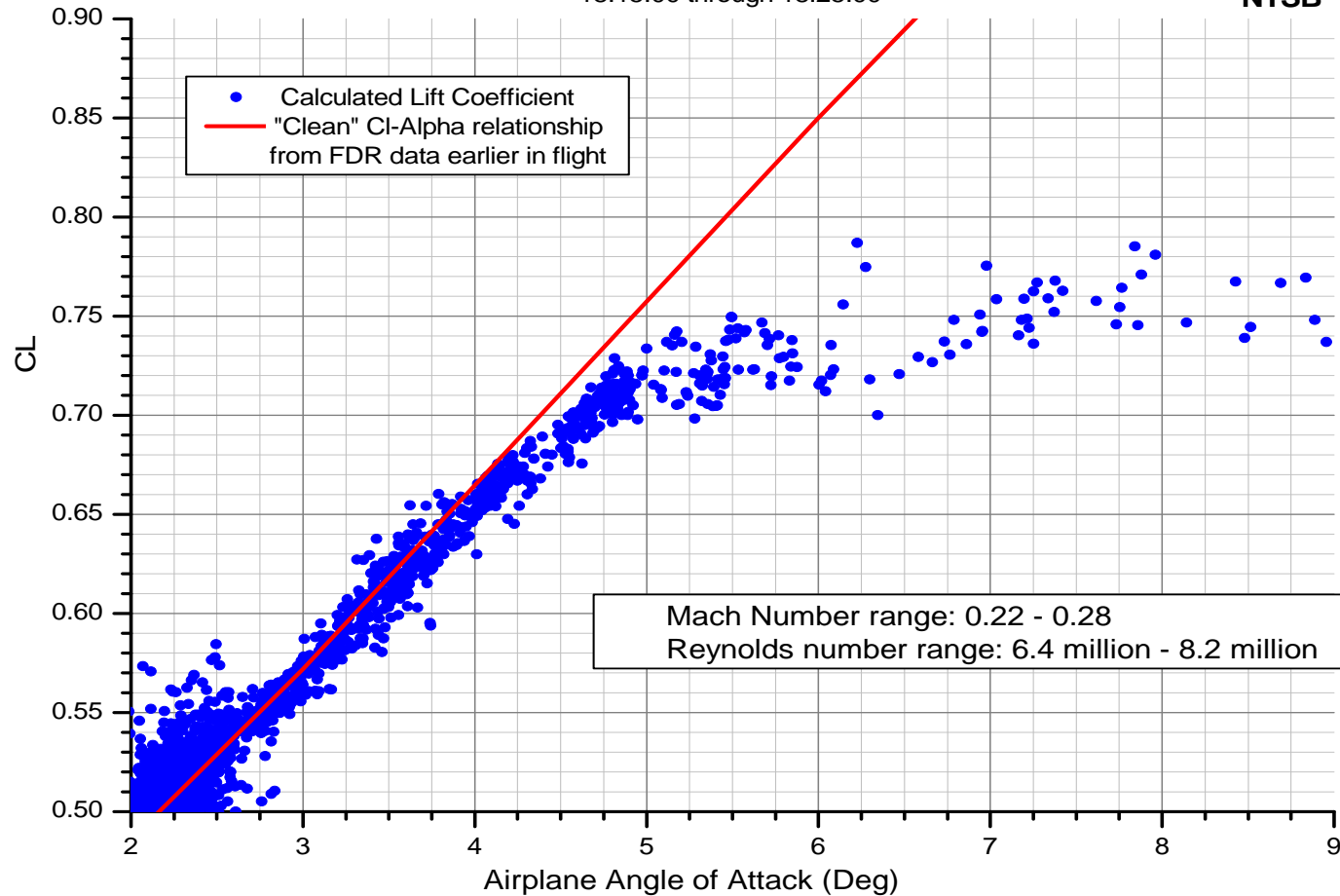


Right Side Stabilizer, Inboard of Elevator

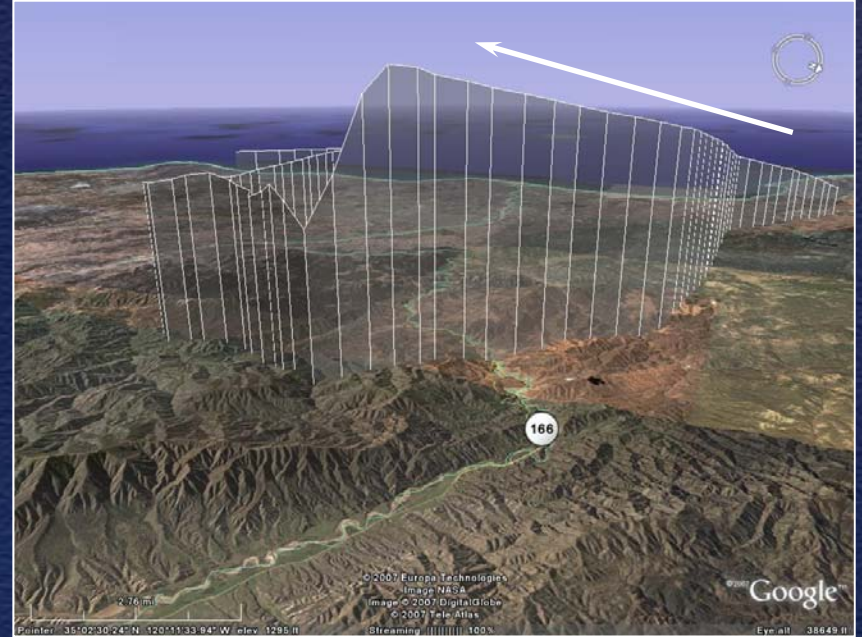


Comair 5054
Lift Coefficients Determined from FDR Load Factors
18:15:00 through 18:25:00

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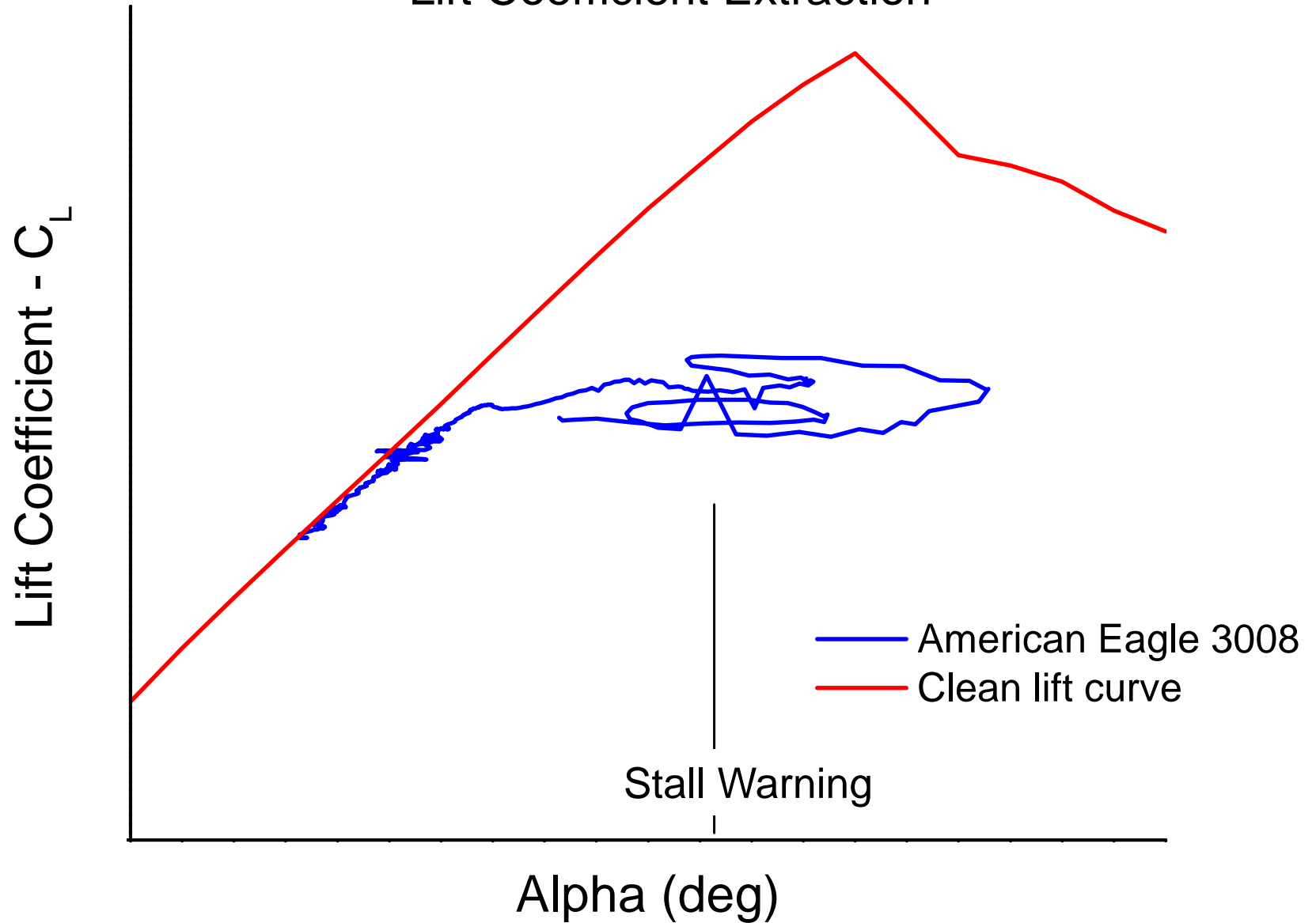
Incidents



- American Eagle Saab 340B
San Louis Obispo, CA - January, 2006
 - Slowed on autopilot
 - Lost 5000 feet altitude
 - Nearly inverted

Saab 340

Lift Coefficient Extraction



Incident - Saab 340B

- Resulted in 4 recommendations
 - Minimum airspeed
 - Modify stall protection
 - Ice detection
 - Disengage autopilot in icing conditions, except in periods of high workload
- FAA working with Saab and EASA to determine response.
- FAA issued Safety Alert for Operators

Incidents



- Cessna 500 – Air Ambulance
Beverly, MA – March, 2007
 - Uncommanded roll during landing
 - Struck wing on runway

Safety Board Recommendations

- Currently 12 open in-flight icing safety recommendations to FAA
 - 7 Open - Acceptable
 - 4 Open - Unacceptable
 - 1 Open – Await response
- NTSB Federal Most Wanted
“Reduce Dangers to Aircraft Flying in Icing Conditions”
 - Condition **RED** (Unacceptable response)

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MOST WANTED LIST

[Transportation Safety Improvements 2009-2010](#)

Actions Needed by Federal Agencies



Rail

The Federal Transit Administration should:

- Improve Transit Railcar Design
 - Provide adequate means for safe and rapid emergency responder entry and passenger evacuation.
 - Prevent the telescoping of transit railcars in collisions.
 - Remove equipment that cannot be modified to meet the new standards.

Marine

The U. S. Coast Guard should:

- Require Safety Management Systems (SMS) for Domestic Vessels
 - Require domestic vessel operators to develop, implement, and maintain a systematic and documented SMS to improve their safety practices and minimize risk.
- Reduce Accidents and Incidents Caused by Human Fatigue in the Marine Industry
 - Set working hour limits for mariners based on fatigue research, circadian rhythms, and sleep and rest requirements.

Aviation

The Federal Aviation Administration should:

- Improve Oversight of Pilot Proficiency
 - Evaluate prior flight check failures for pilot applicants before hiring.
 - Provide training and additional oversight that considers full performance histories for flight crewmembers demonstrating performance deficiencies.
- Require Image Recorders
 - Install crash-protected image recorders in cockpits to give investigators more information to solve complex accidents.
- Improve the Safety of Emergency Medical Services (EMS) Flights
 - Conduct all flights with medical personnel on board in accordance with stricter commuter aircraft regulations.
 - Develop and implement flight risk evaluation programs for EMS operators.

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Recent 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

What can pilots remember?

- AIRSPEED, AIRSPEED, AIRSPEED
- Deice boots for all equipped airplanes need to be operated as soon as airplane enters icing conditions
- Autopilot can mask changes to handling qualities and trim changes due to ice. When possible, disconnect autopilot in icing conditions.



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Positive FAA Actions

- AD's regarding operation in severe icing and identifying SLD
- AD's regarding deice boot operation
- Part 25 performance and handling in icing conditions
- Part 25 ice protection system operation
- NPRM Part 121 ice protection system operation
- NPRM Part 25 to include SLD conditions
- Advisory material has been upgraded

What still needs to be done by FAA?

- Final rule for SLD icing conditions to be used in certification, including Part 23
- Ensure all airplanes certified for flight in icing conditions can either safely operate in SLD, or can detect it and exit safely
- Deice boots for all equipped airplanes need to be operated as soon as airplane enters icing conditions

Bombardier Challenger CL-600

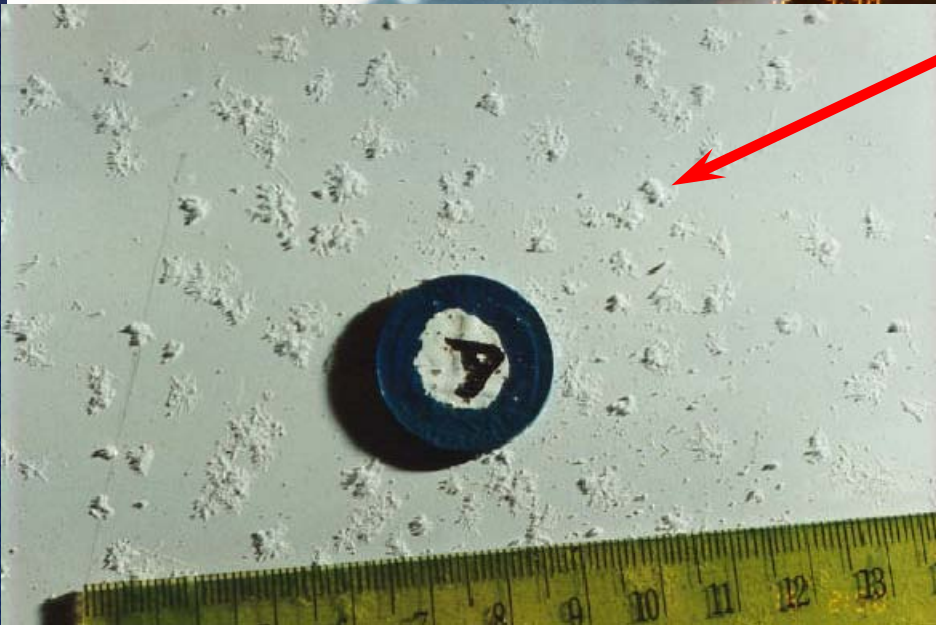
Montrose, CO – November 29, 2004



- 3 fatalities, 3 seriously injured
- Crashed during takeoff in snow

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Small, almost imperceptible accumulations

Photos from Chaput, M., Hanna M., Ruggi E. and Mayhew, J.
Aircraft Full-Scale Test Program for the 1998/99 Winter,
APS Aviation Inc. Montreal, October 1999,
Transportation Development Centre TP 13485E

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