



**NTSB** National Transportation Safety Board

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# **The Continuing Threat to Aviation Safety from Aircraft Icing**

**A Review of Recent NTSB Accident and Incident Investigations**

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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

# NTSB View of Airframe Icing

- NTSB recommendations on aircraft icing date back to 1981
- Airframe icing on NTSB Most Wanted List of safety improvements since 1997
- Most icing conditions encountered not a problem for certificated aircraft; we deal with the uncommon occurrences

# Icing Accidents and Incidents Since 2004

**Cessna 208 - Moscow**

**Challenger 601 - Montrose, CO**

**CRJ200 - Baotou, China**

**Cessna 560 - Pueblo, CO**

**Saab 340 - San Luis Obispo, CA**

Includes severe icing, ground icing, intercycle icing, undetected icing

# Cessna 208B Caravan



- Single-engine turboprop airplane
- Several icing-related fatal accidents in recent years

# Cessna 208 Caravan Accident/Incident Assessment

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

# Cessna 208 – Moscow

November 2005

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

# Cessna 208 – Moscow

November 2005

- Resulted in 3 urgent recommendations
  - 120 knots minimum airspeed
  - Prohibit flight in icing conditions worse than light
  - Disengage autopilot in icing conditions
- All adopted by FAA

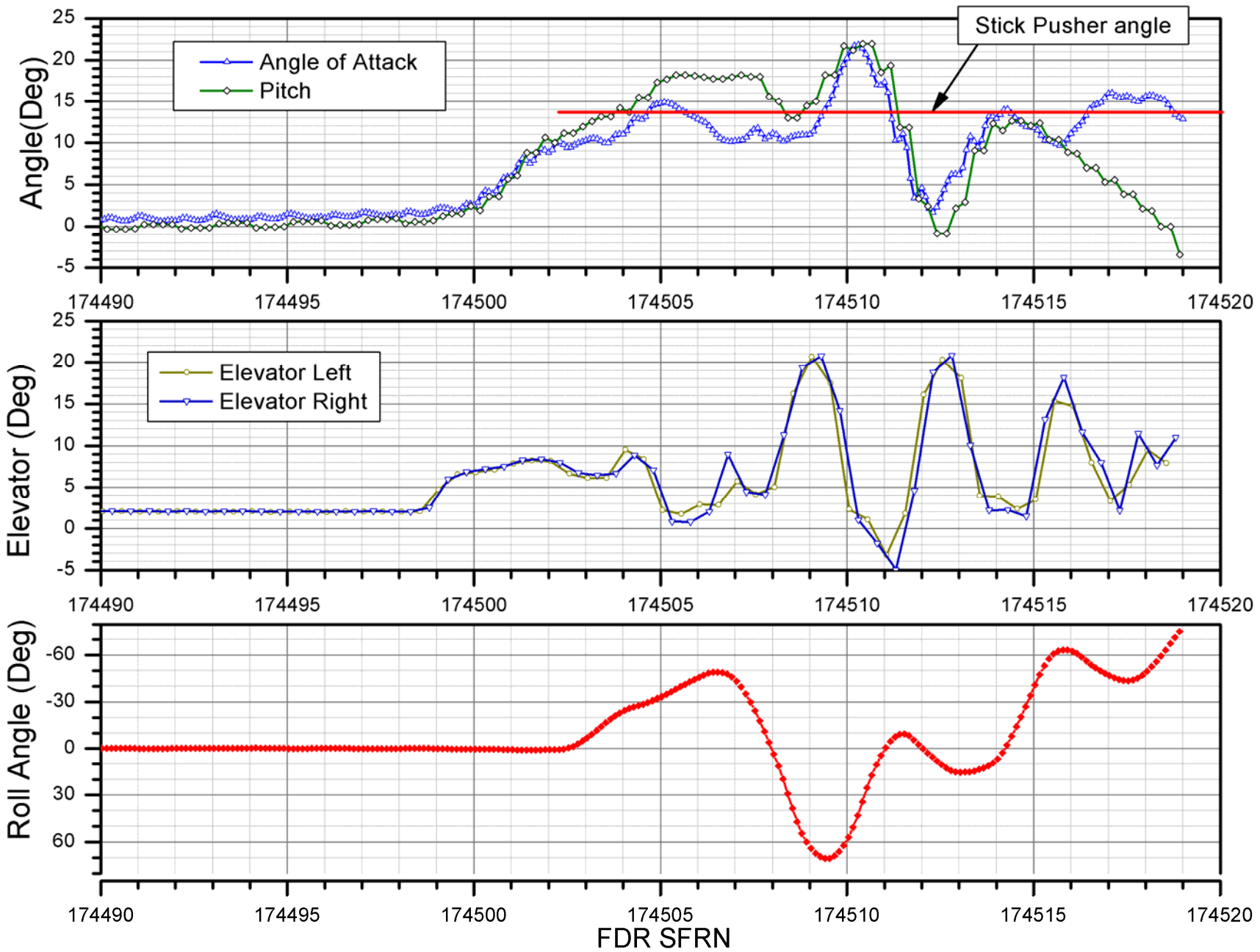
# Baotou, China - China Eastern Airlines November 21, 2004

- CRJ 200 impacted lake shortly after takeoff
- 53 fatalities on aircraft
- Two fatalities on ground



# Accident Flight

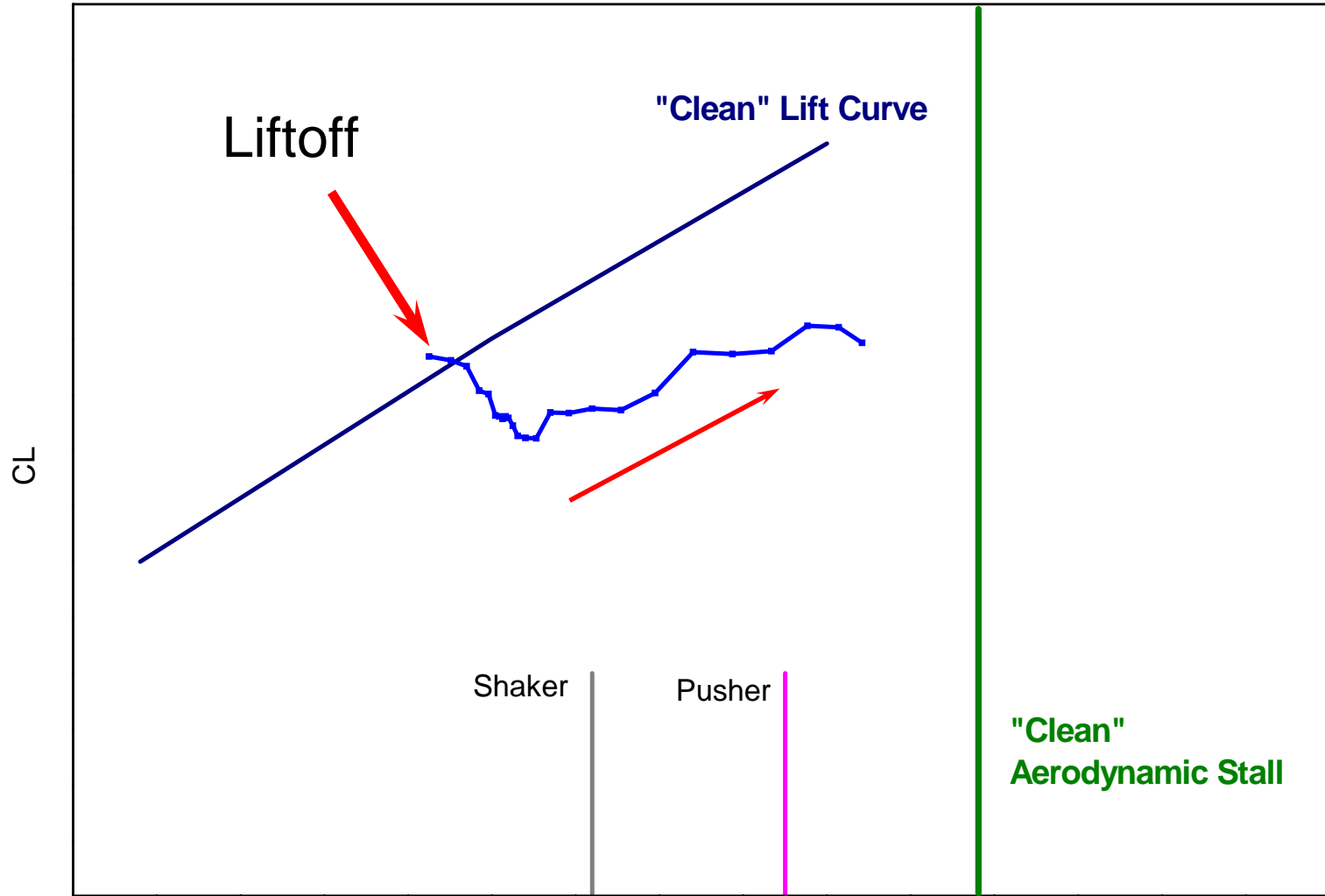
- Rolled past 50 deg left shortly after TO
- Followed by a 70-deg roll to the right
- Bank angles less than 20 deg for about 4 sec
- Final roll to the left
- Never exceeded 180 ft agl
- Wheel opposed roll maneuvers



# Coefficient Extraction

- Kinematics extraction simulation tool
  - Compares aerodynamics required for motion with aerodynamics from simulation model using recorded control input and state

China East Airlines  
0-5 seconds after liftoff

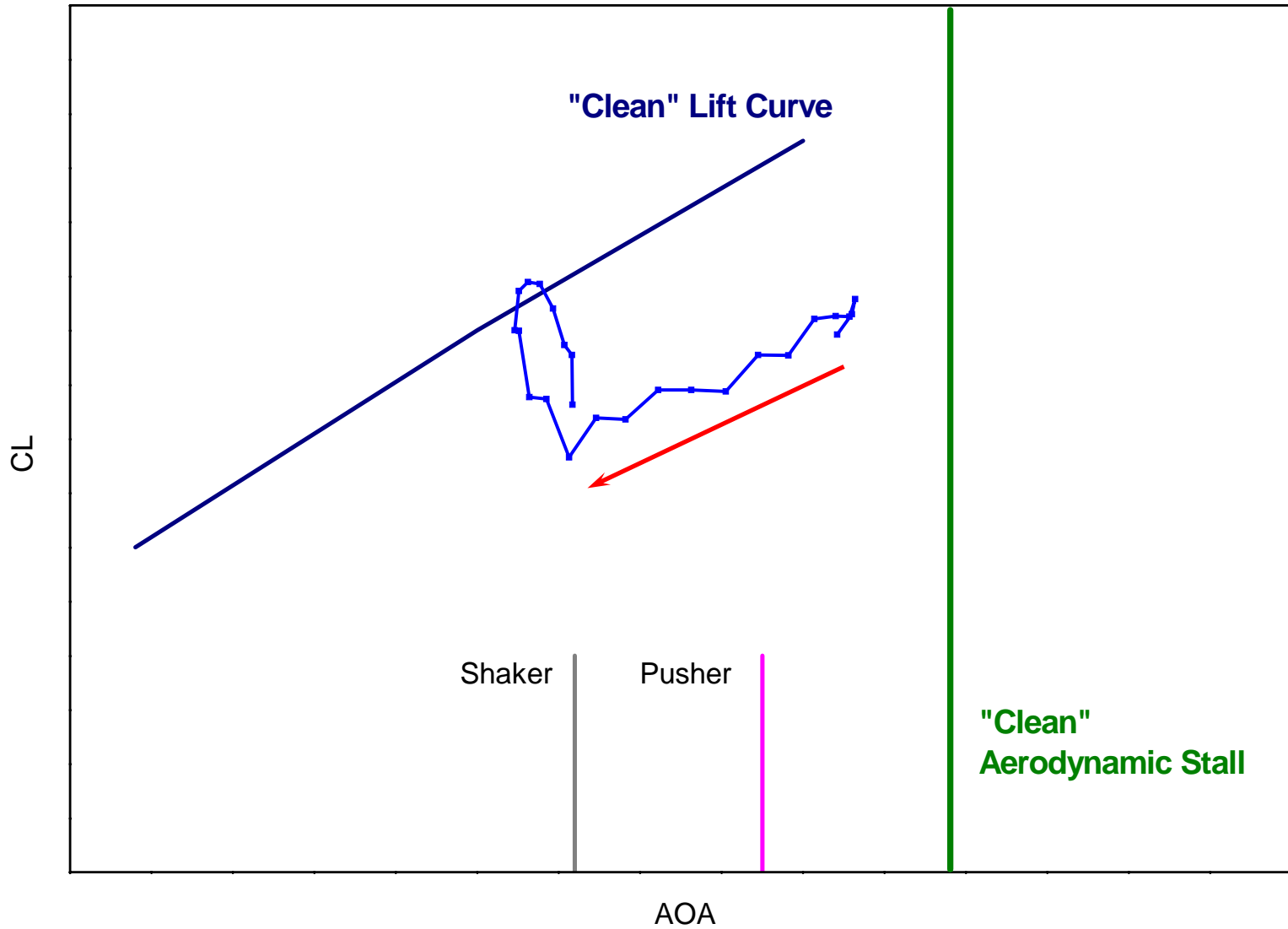


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AOA



China East Airlines  
5-8 seconds after liftoff



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# Bombardier Challenger CL-600

Montrose, CO – November 29, 2004



- 3 fatalities, 3 seriously injured
- Crashed during takeoff



Left wing  
ground scar

# Passenger Observations

- Slushy clumps of snow sliding across window
- Airplane lifted off and climbed about 20 to 50 feet
- Left wing dropped abruptly, then right wing dropped, followed again by left wing
- Passenger heard loud thump and airplane fell straight onto its nose

# NTSB Probable Cause

“The flight crew's failure to ensure that the airplane's wings were free of ice or snow contamination that accumulated while the airplane was on the ground, which resulted in an attempted takeoff with upper wing contamination that induced the subsequent stall and collision with the ground...”

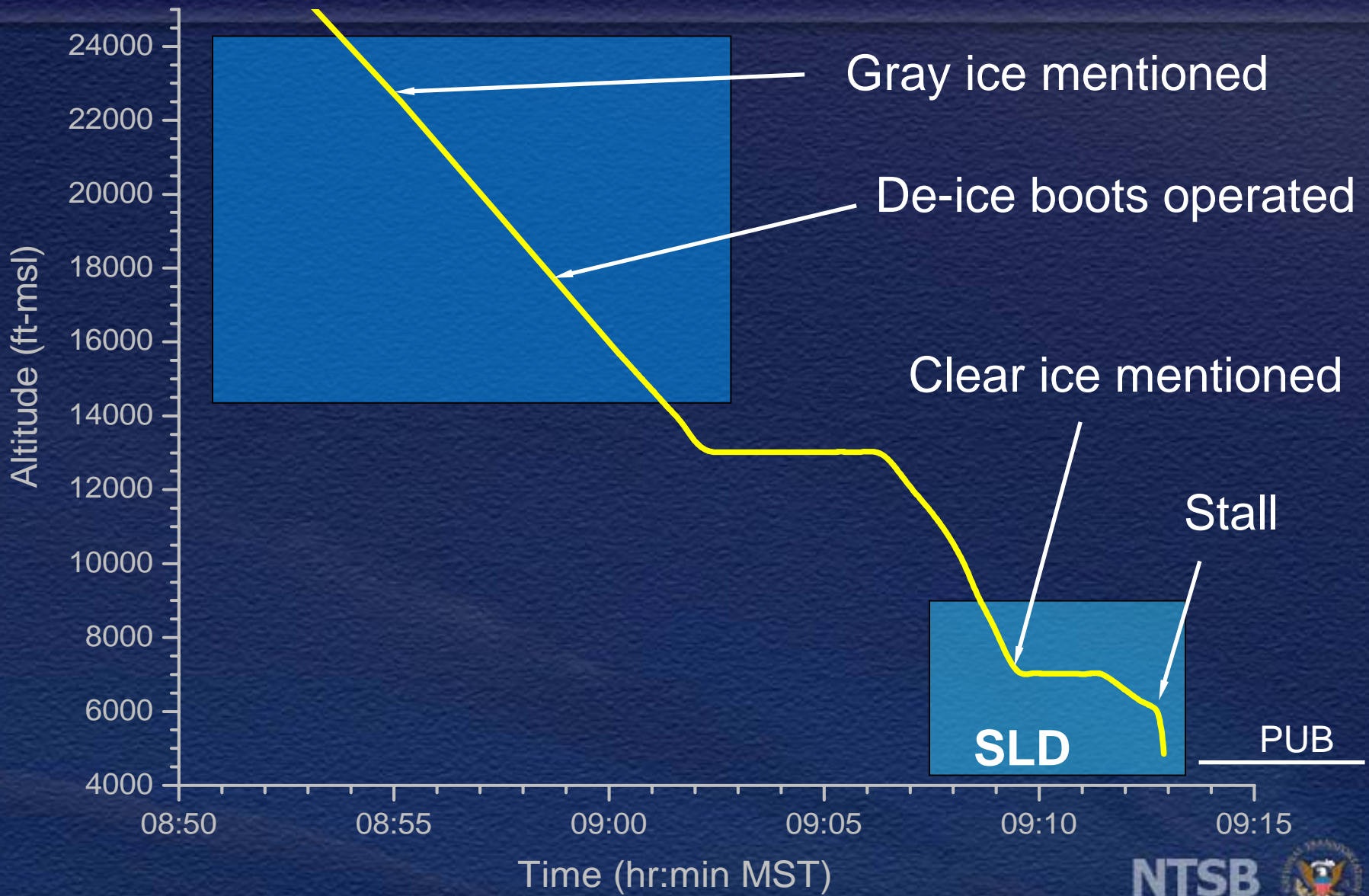
# Cessna 560

Pueblo, CO – February 16, 2005



- 8 fatalities
- Crashed on approach
- Atmospheric conditions conducive to icing

# Altitude Time History



# Accident Sequence

- Airplane slowed below  $V_{approach}$
- De-ice boots not operated in second icing layer
- Presence of estimated 1/6 inch or less of ice accreted in SLD conditions caused 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

# NTSB 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...”

# NTSB Probable Cause

“...Contributing to the accident was the Federal Aviation Administration’s failure to establish adequate certification requirements for flight into icing conditions, which led to the inadequate stall warning margin provided by the airplane’s stall warning system.”

# Saab 340B

American Eagle flight 3008 – January 2, 2006



- Loss of Control Incident
  - Departed controlled flight in icing conditions
  - Lost 5000 feet altitude
  - Nearly inverted

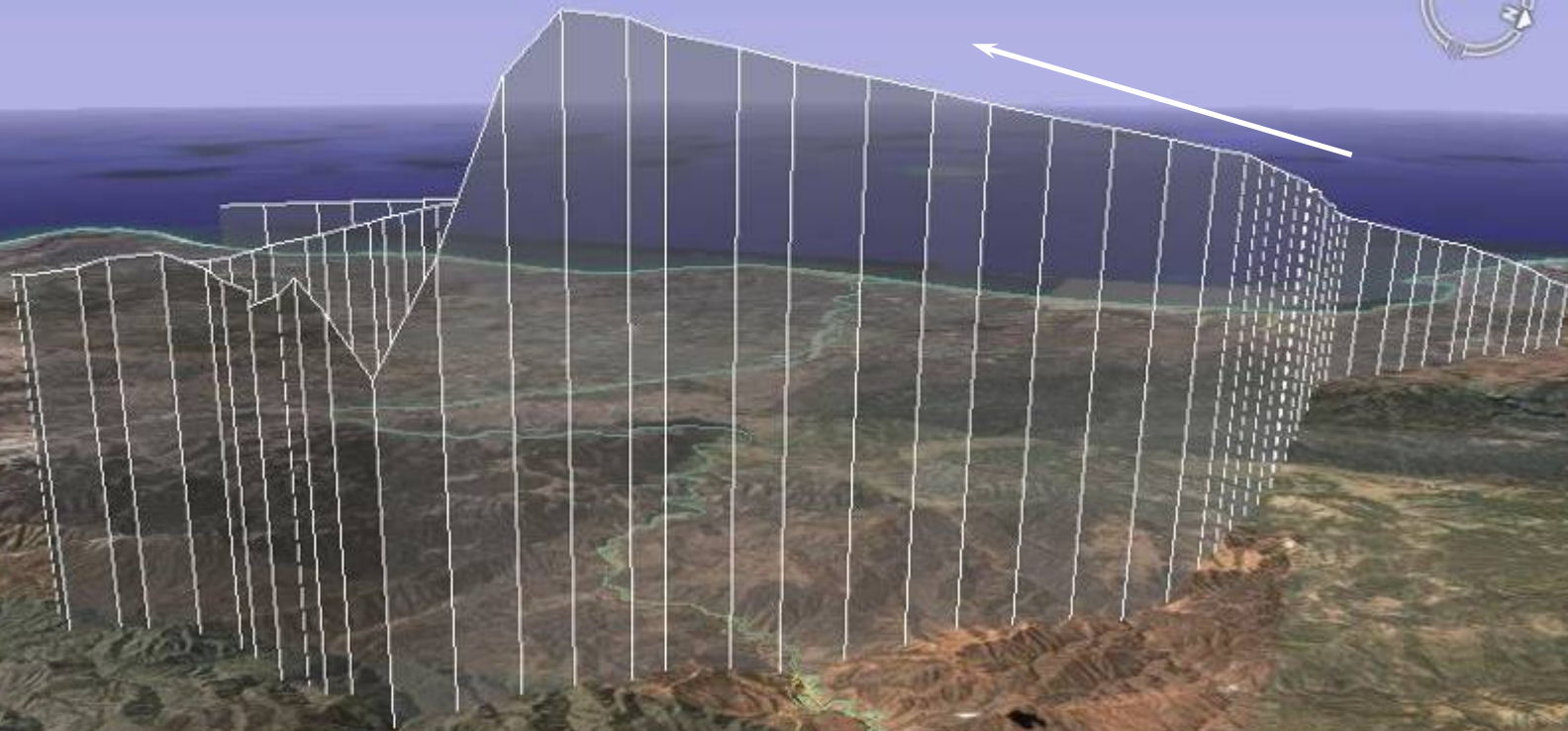
# Other Saab 340 Icing Events

- 1998 - Eildon Weir, Australia
- 2002 - Bathurst, Australia
- 2004 - Albury, Australia
- 2006 - San Luis Obispo, CA



# AE3008 Overview

- Autopilot engaged during climb
- Aircraft continuously lost speed during last 2.5 minutes before entering stall (>55 kts in 2.5 minutes)
- Aircraft departed controlled flight at an indicated air speed of approximately 126 kts, concurrent with stick shaker
- Aircraft dropped from 11,700 ft-msl to 6500 ft-msl



166

2.76 mi

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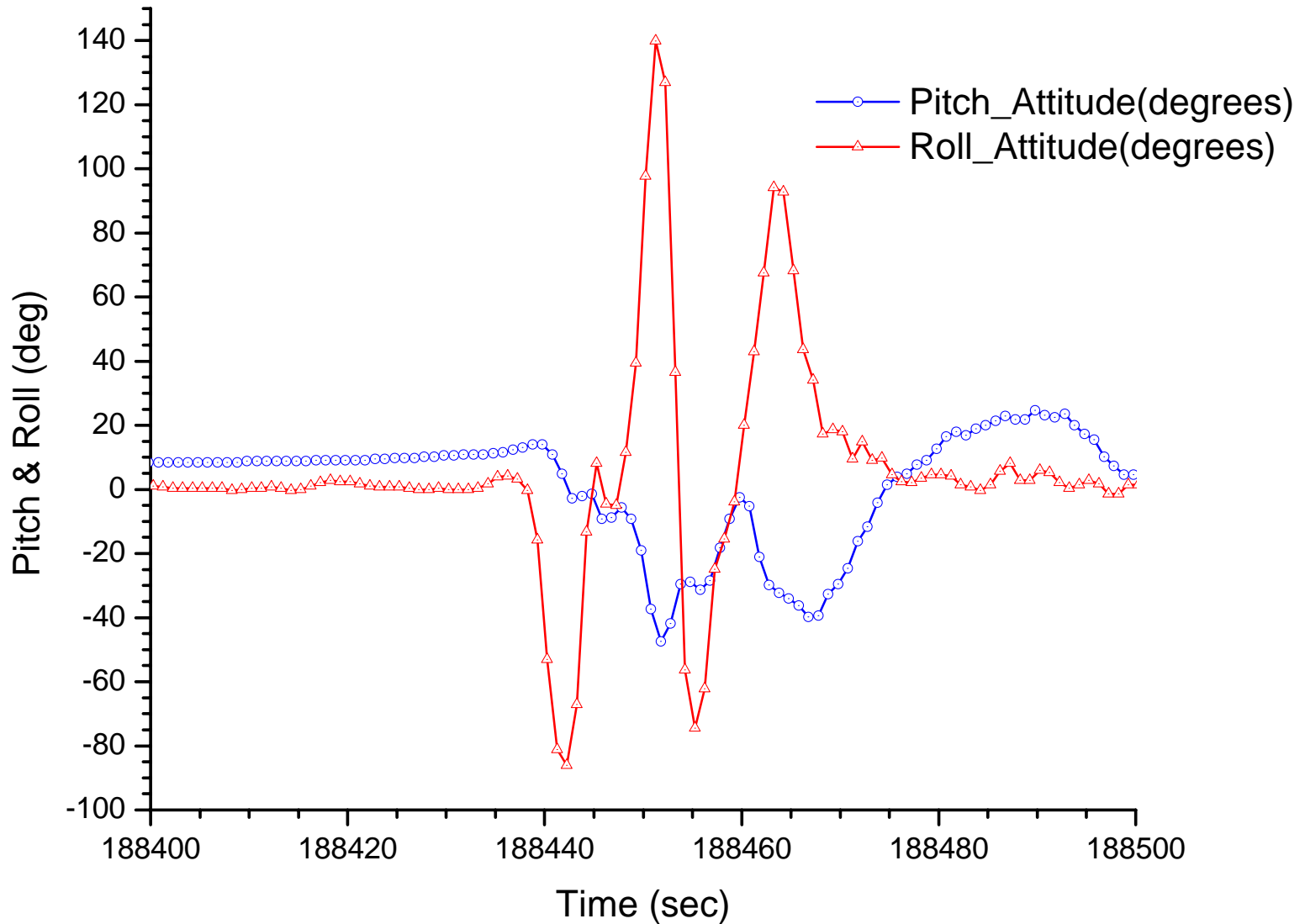
Pointer 35°02'30.24" N 120°11'33.94" W elev 1295 ft

Streaming ██████████ 100%

Eye alt 38649 ft

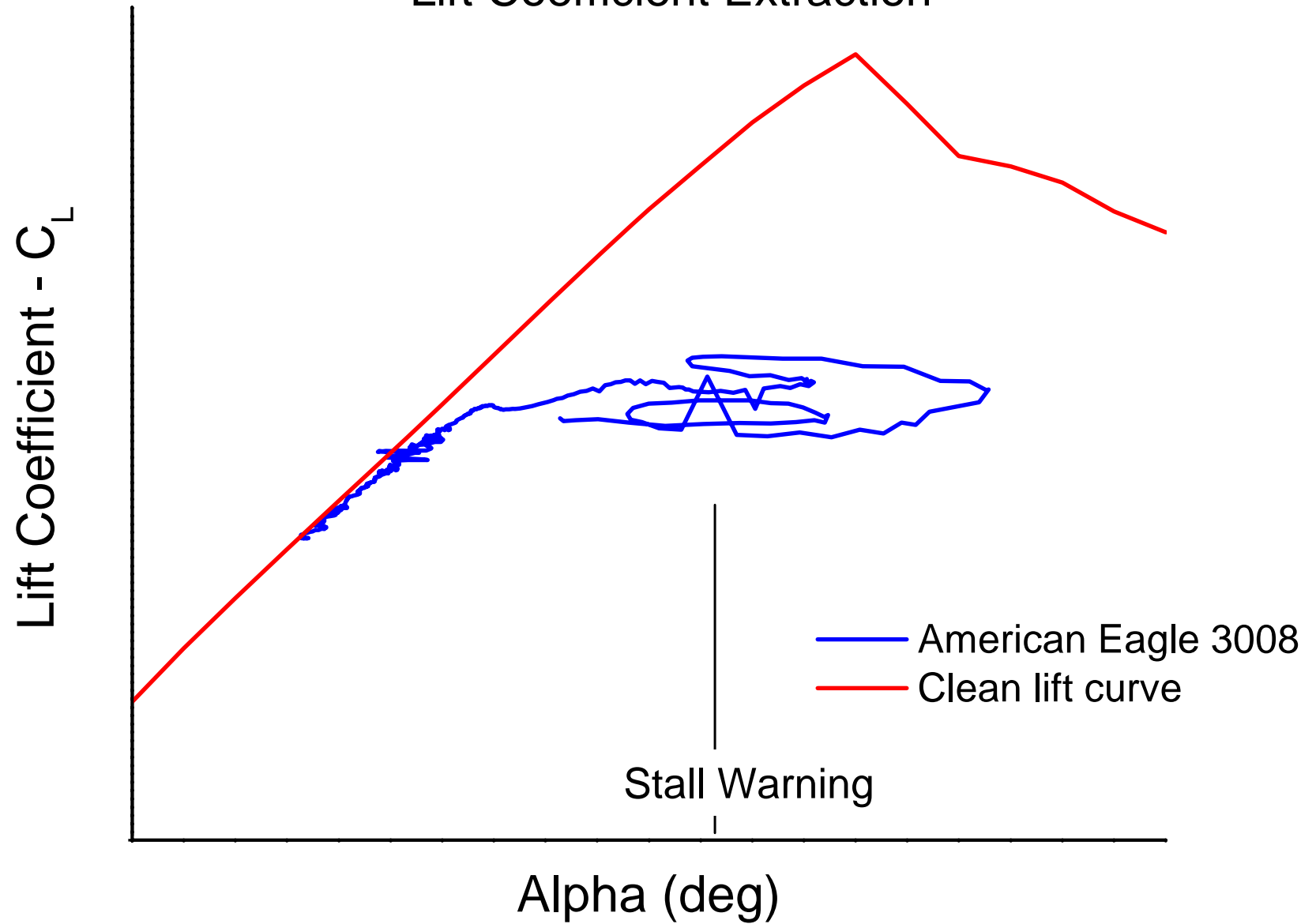
# Pitch and Roll During Upset

American Eagle SAAB SF-340



# Saab 340

## Lift Coefficient Extraction



# AE3008 - Saab 340B

- Resulted in 4 urgent recommendations
  - Minimum airspeed
  - Modify stall protection
  - Ice detection
  - Disengage autopilot in icing conditions
- FAA working with Saab and EASA to determine response
- FAA issued Safety Alert for Operators

# Recent Recommendations

- In the past 4 years:
  - 18 recommendations
  - 1 alert related to icing
- Problem: recent recommendations address aircraft on case-by-case basis
- Most Wanted recommendations address all airplanes

# Safety Improvements Wanted

- Research effects of in-flight icing, including freezing rain and critical ice shapes **A-98-92**
- Upgrade aircraft certification standards and operational procedures **A-96-54, A-96-56, A-98-100**

# FAA - Recent Actions

- FAA issued final rule

*Airplane Performance and Handling Characteristics in Icing Conditions*

- FAA issued NPRM

*Activation of Ice Protection*

# FAA - Recent Actions and Limitations

- Actions satisfy the intent of several recommendations
- Need to ensure full range of Appendix C, including large droplets, are included in determining shapes to be used in testing
- Will only apply to newly certificated airplanes

# 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

# These recent accidents demonstrate:

**Additional research is needed!!**

- Flight crew awareness and training
- Icing conditions near freezing
- Edge of the icing envelope and SLD



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# Cessna 208 Icing

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