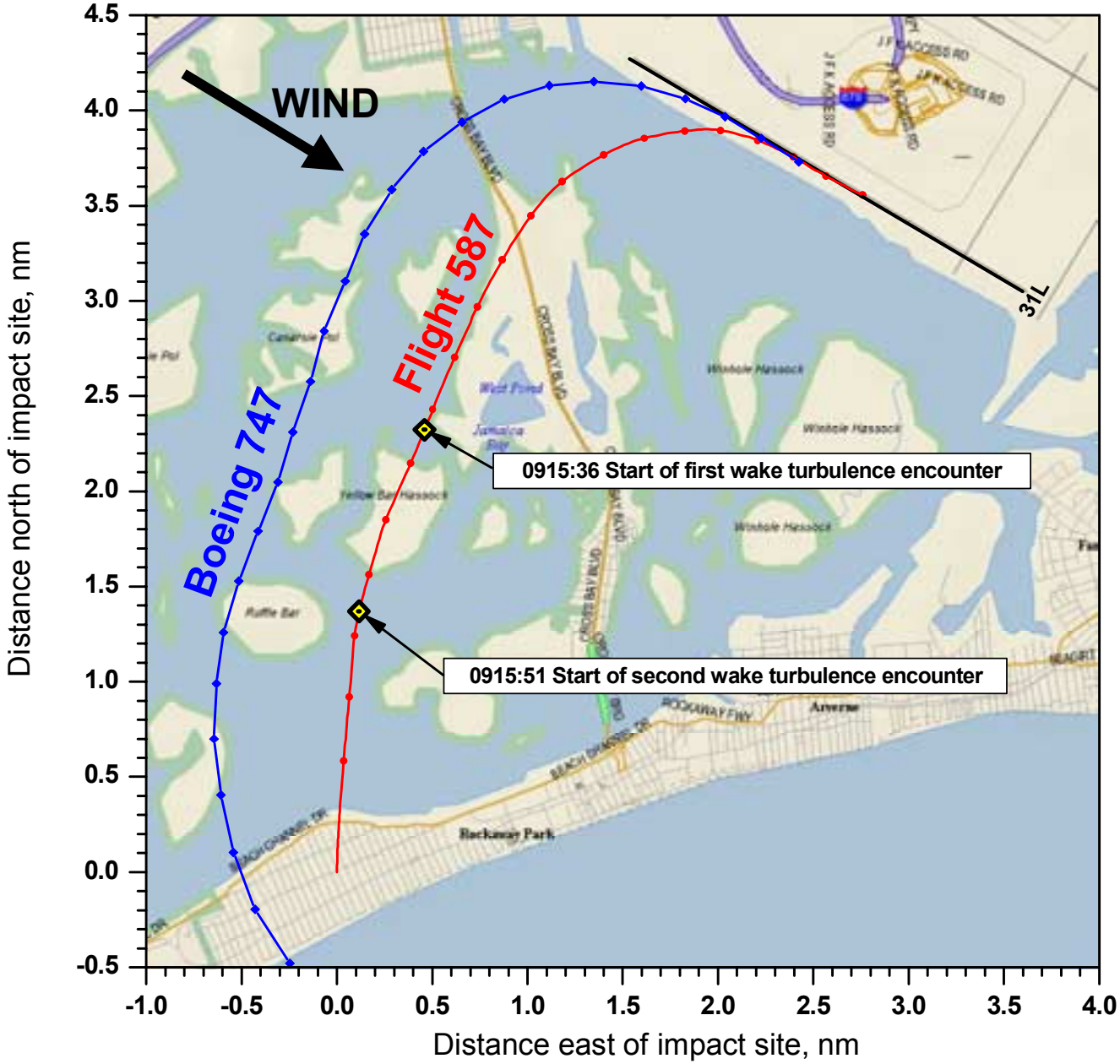
NTSB Board Meeting
AA Flight 587

Airplane Motion and Vertical Stabilizer Loads

John O'Callaghan

Location of Wake Turbulence Encounters

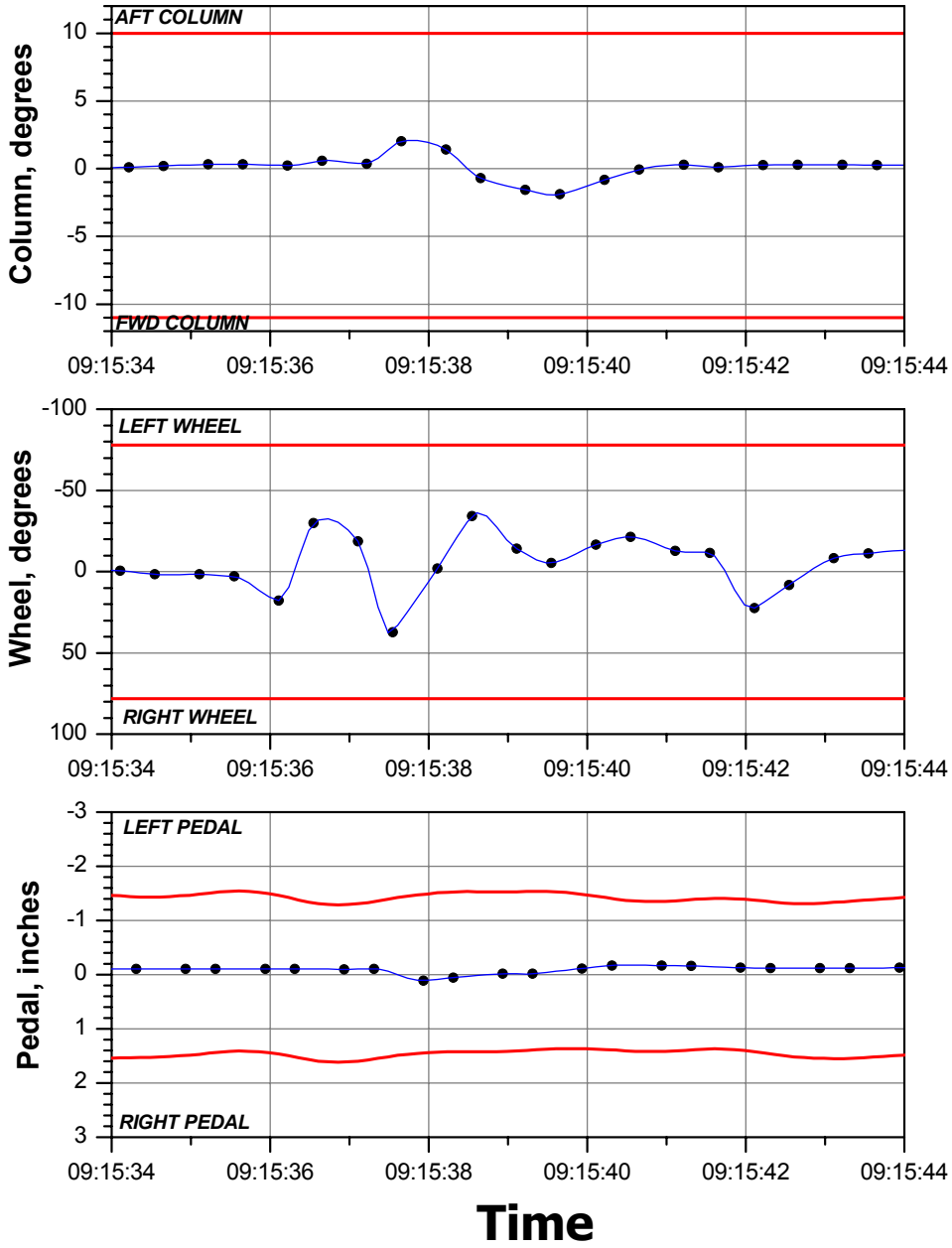


- FDR accelerations were typical of wake encounters
- Crew commented on wake turbulence
- Simulation indicates wake encounter
- NASA wake study supports encounter
- Wake was similar in each encounter

Effect of the Wake Encounters on the Airplane Motion

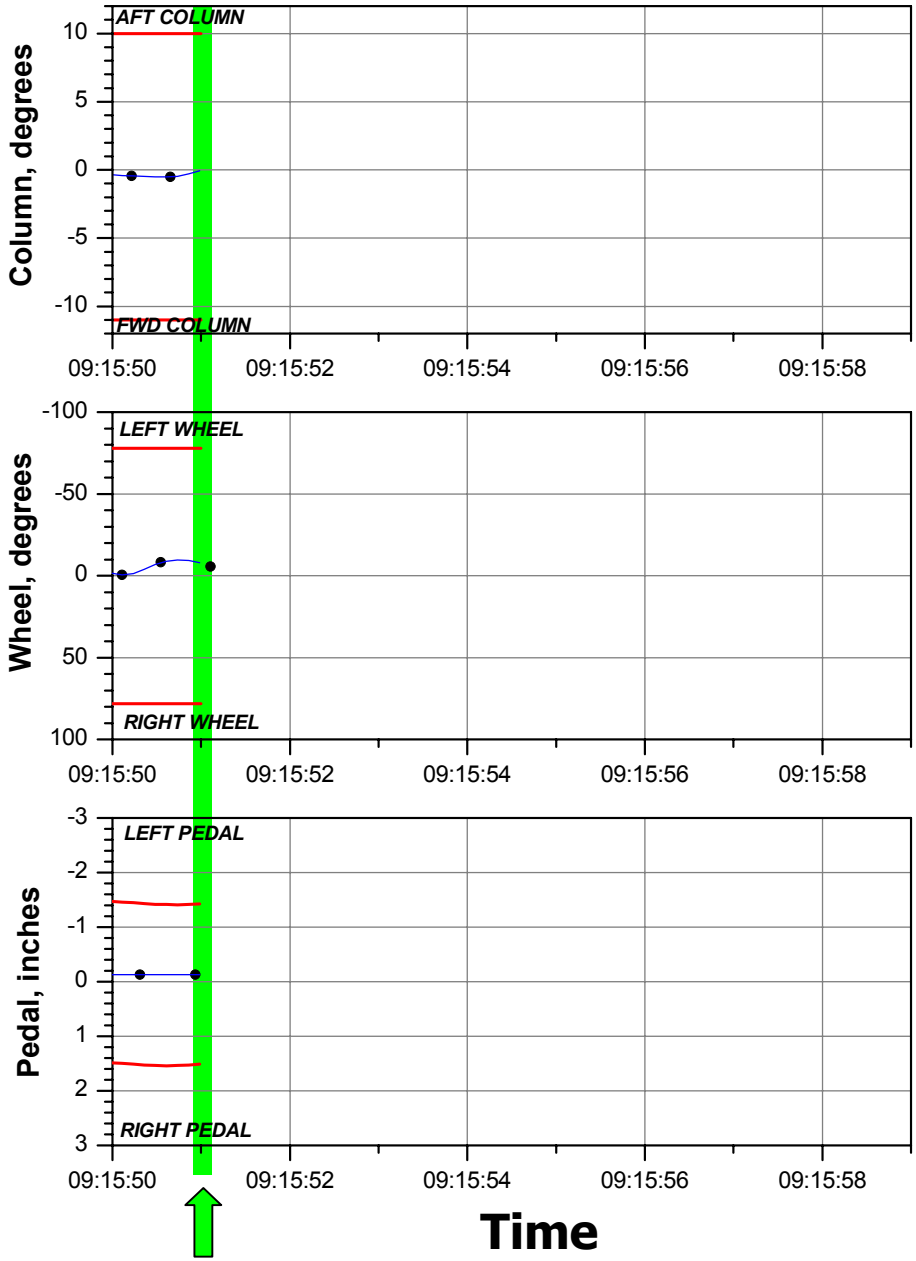
- NASA study indicates nothing unusual about wake.
- NTSB simulations determined that the effect of wake on airplane motion was minor.
- The airplane was not in or at risk of an upset.

Control Inputs Following Start of First Wake Encounter



- First officer responded with column & large wheel inputs
- First officer did not use the rudder pedals
- Small changes in pitch and roll angles
- Airplane motion was unremarkable

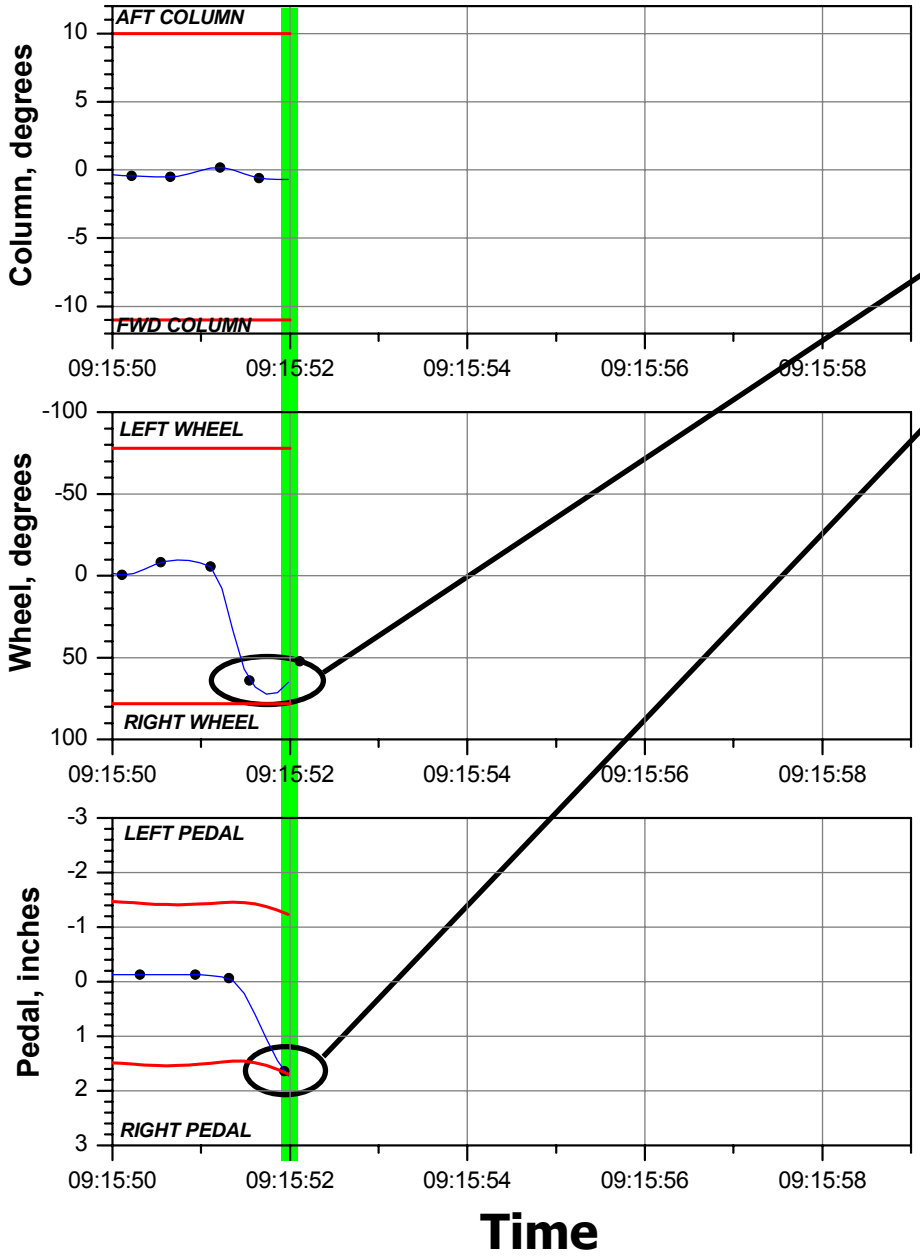
Control Inputs Following Start of Second Wake Encounter



Time = 09:15:51

- Start of second wake encounter
- Airplane in climbing left turn
- Controls approximately neutral

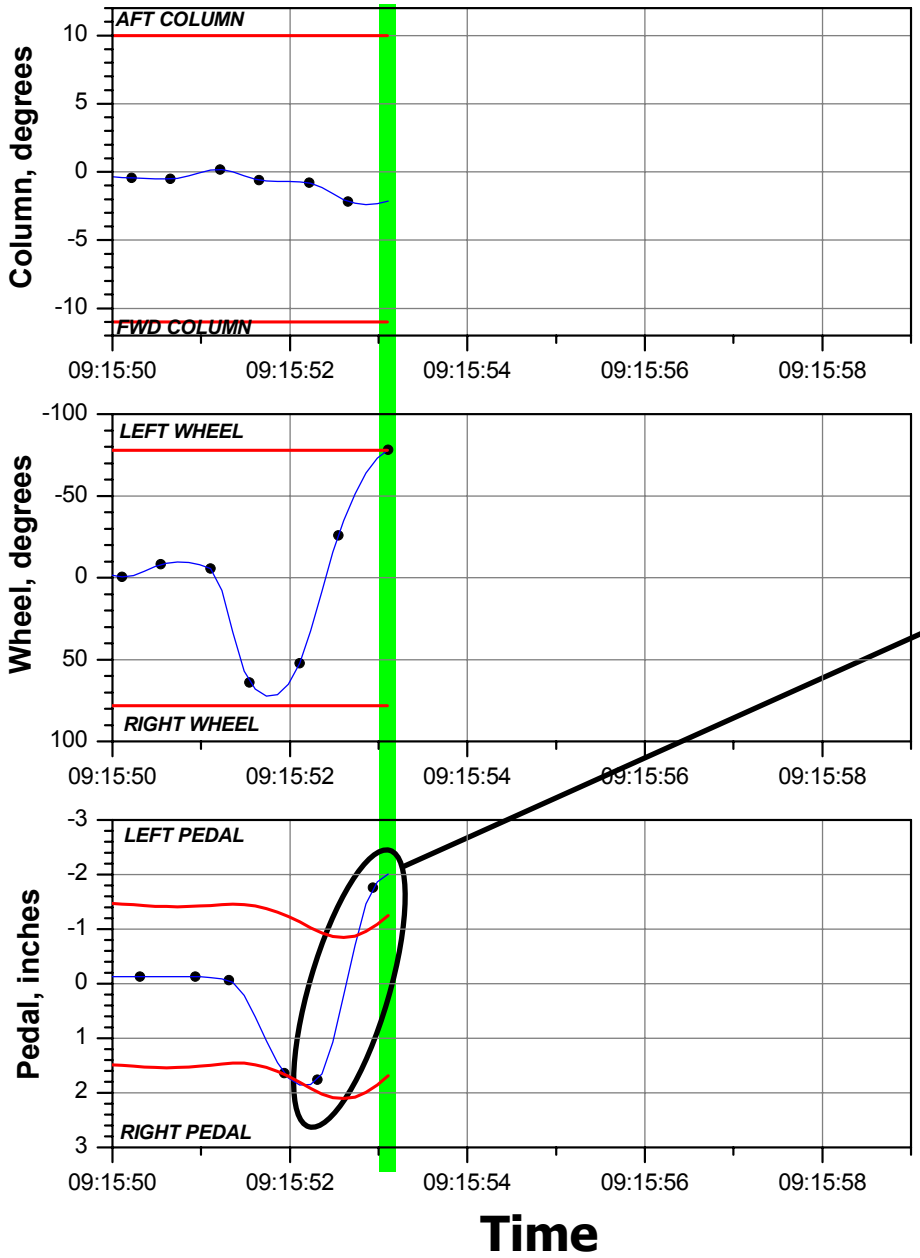
Control Inputs Following Start of Second Wake Encounter



Time = 09:15:52

- Large right wheel input
- Full right pedal input
- Pedal used to help control roll
- Pedal not necessary
- Wheel alone sufficient to control roll
- Full wheel and pedal inputs unnecessary and excessive

Control Inputs Following Start of Second Wake Encounter

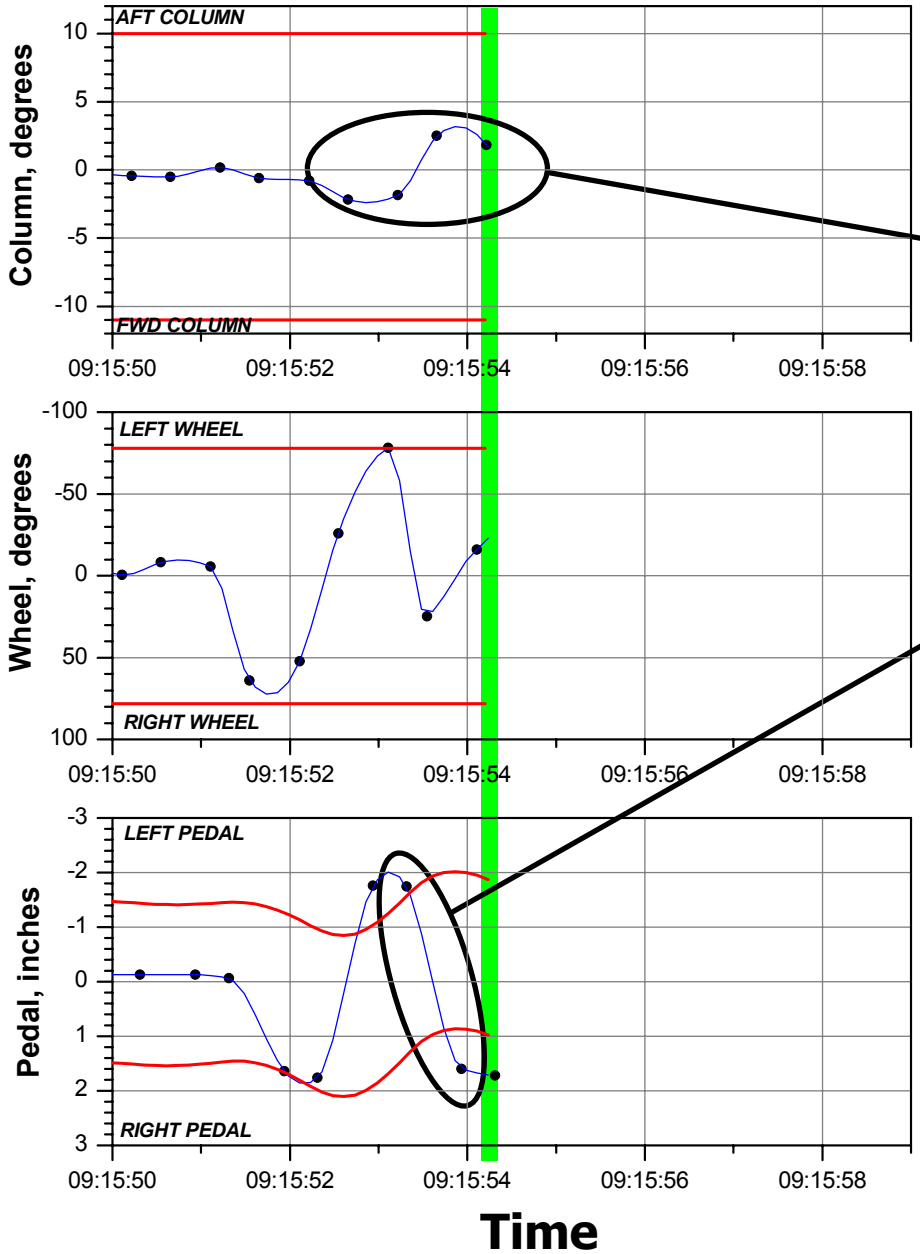


Time = 09:15:53.1

- Full left wheel input (78°)
- Full left pedal input

First full alternating rudder pedal input

Control Inputs Following Start of Second Wake Encounter

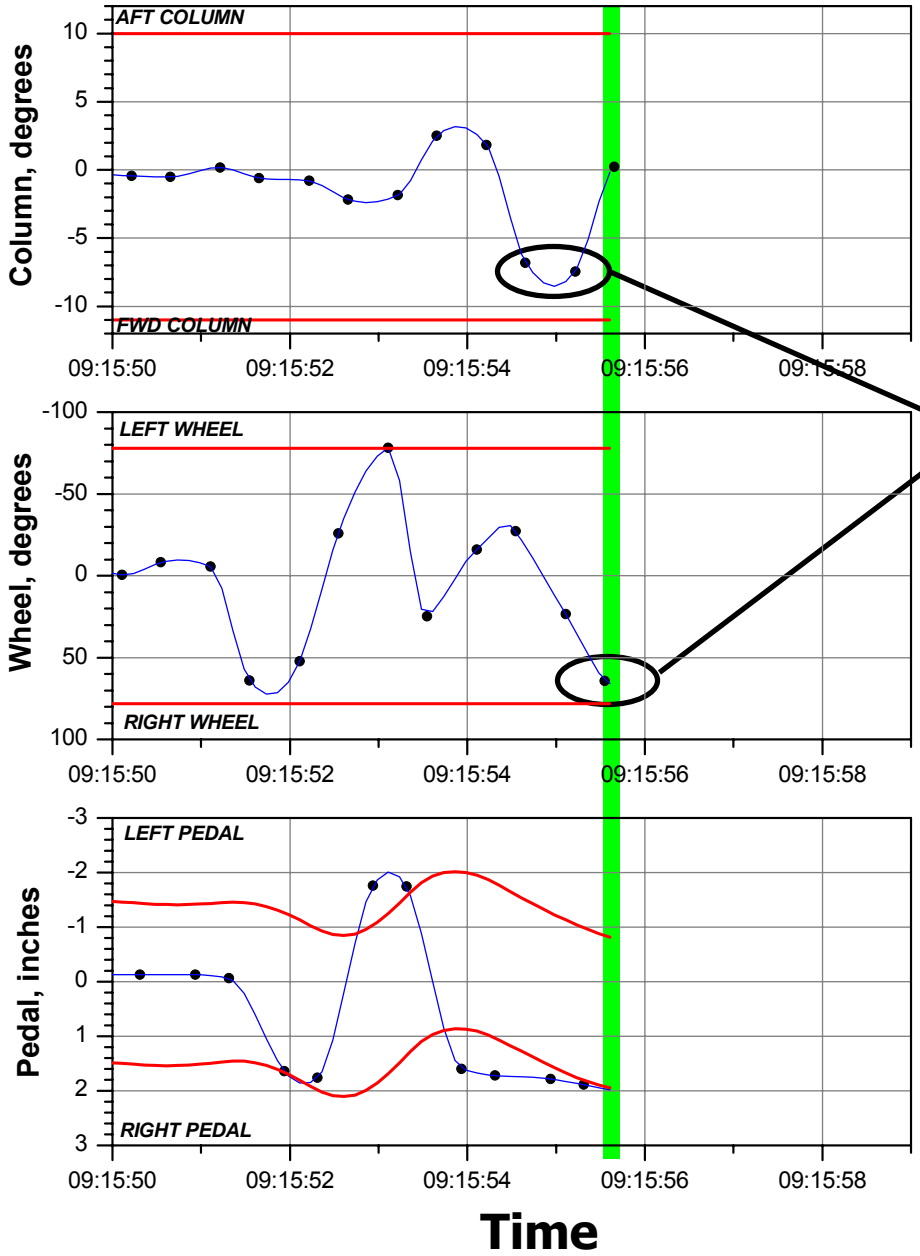


Time = 09:15:54.2

- Full right pedal input
- Growing oscillation in column inputs

Second full alternating rudder pedal input

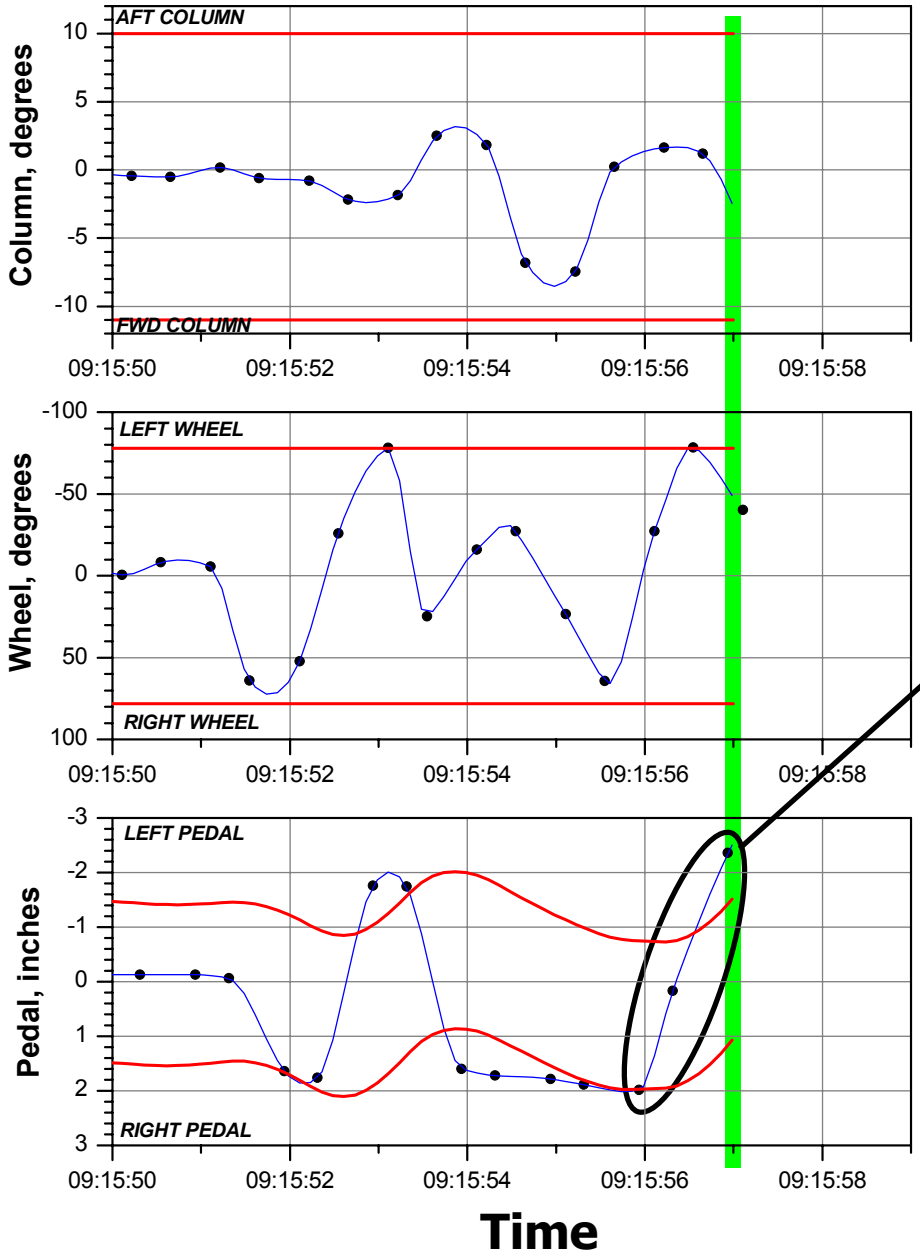
Control Inputs Following Start of Second Wake Encounter



Time = 09:15:55.6

- Full right pedal input maintained
- Wheel moves to large right deflection
- Large nose-down column input

Control Inputs Following Start of Second Wake Encounter

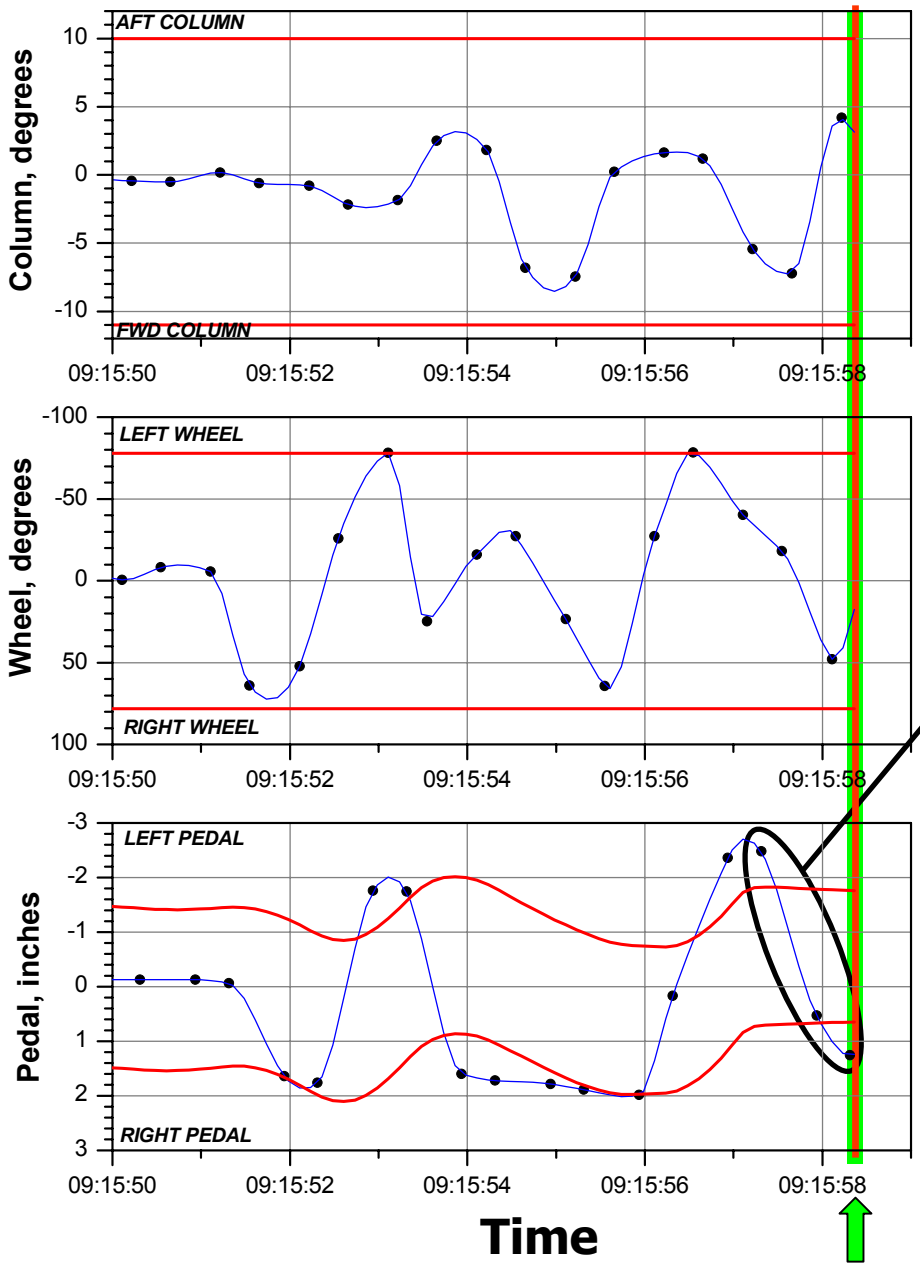


Time = 09:15:57

- Full left wheel input
- Full left pedal input

Third full alternating rudder pedal input

Control Inputs Following Start of Second Wake Encounter



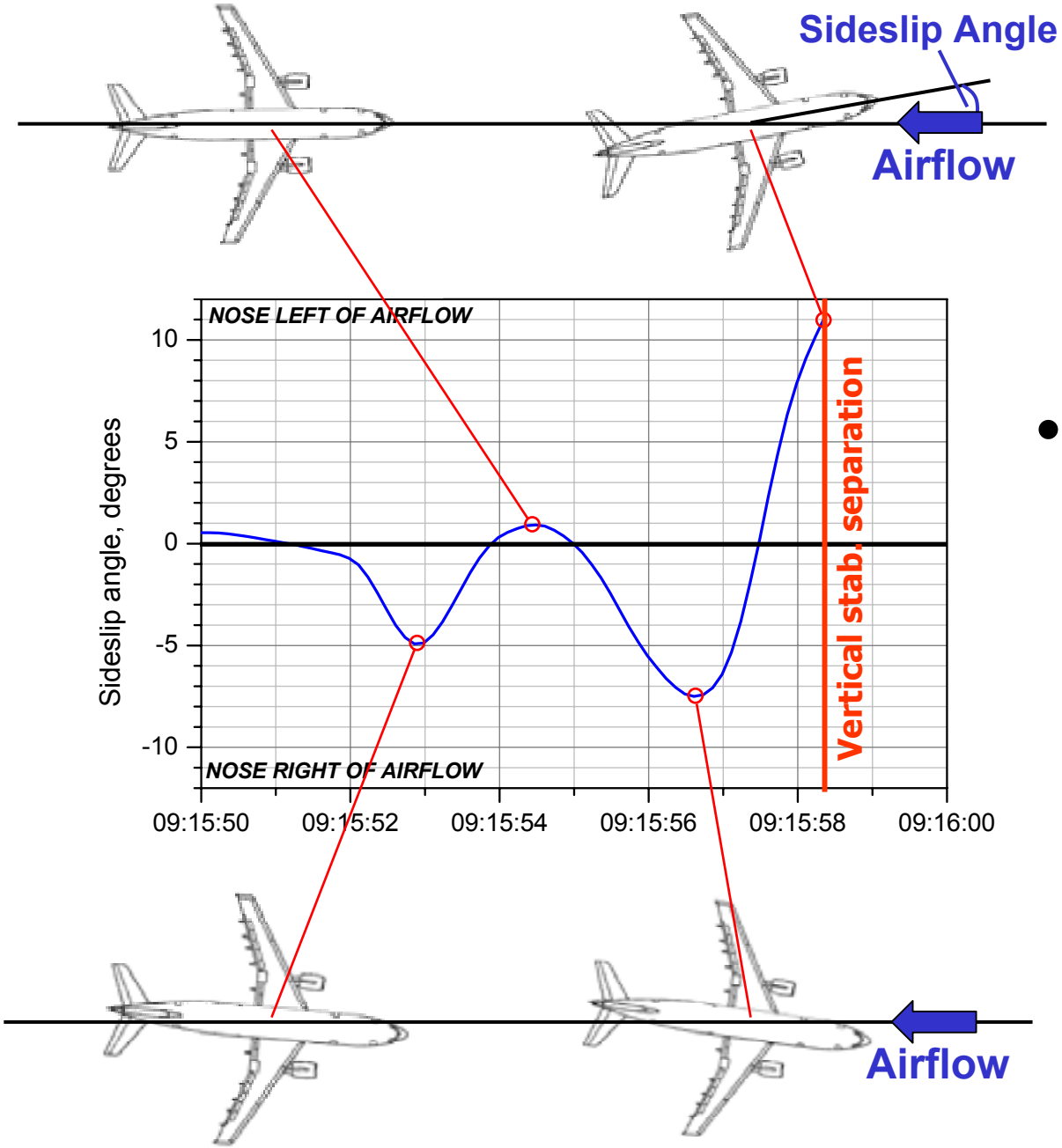
Time = 09:15:58.4

- Wheel moves right
- Full right pedal input

Fourth full alternating rudder pedal input

- **Vertical stabilizer separates from airplane**

Sideslip Angle Buildup Resulting From First Officer's Control Inputs



- Airplane flew as commanded until vertical stabilizer separation

Calculation of Vertical Stabilizer Loads

- Loads dependent on airspeed, sideslip angle, and rudder deflection
- Aerodynamic loads determined by wind tunnel testing during airplane development
- No wind tunnel data available at the extreme sideslip angle corresponding to vertical stabilizer separation
- Other methods required to compute loads at time of separation

Computational Fluid Dynamics (CFD)

- CFD is the use of computers to mathematically determine the aerodynamic characteristics of airplanes.
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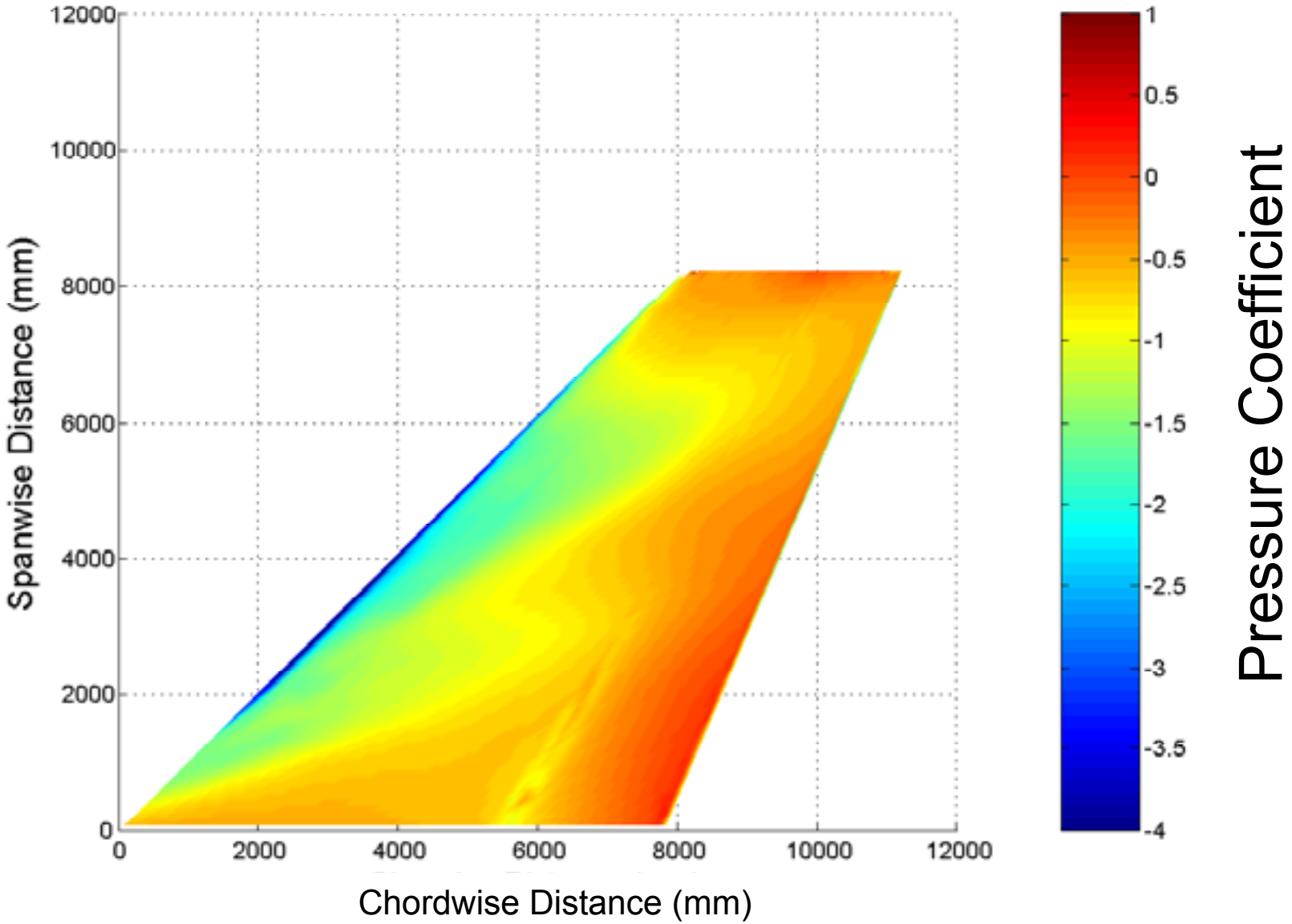
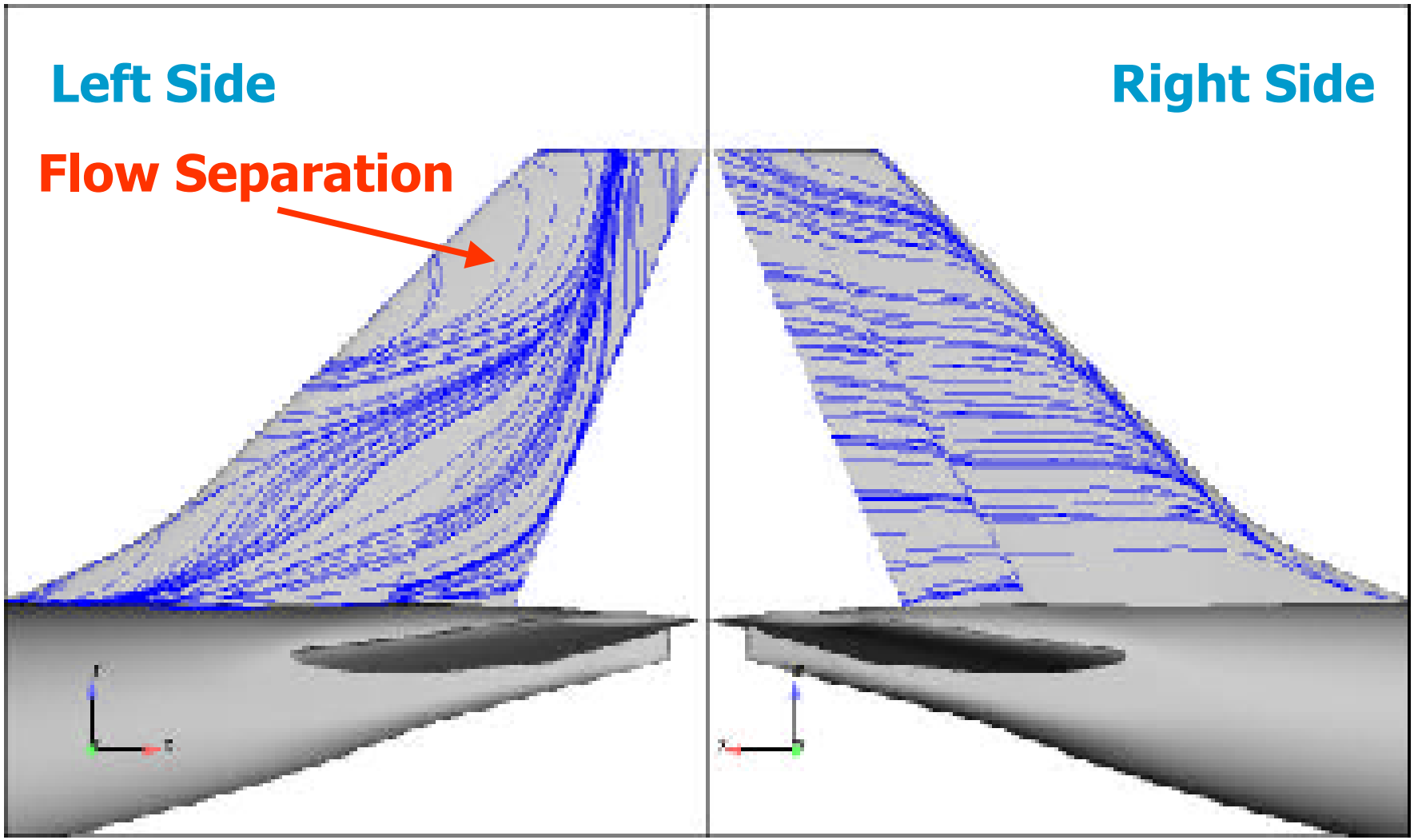
- CFD is used increasingly in the industry to supplement wind tunnel data and optimize airplane designs.
- Airbus CFD code has demonstrated capability for solving flow problems such as flight 587 vertical stabilizer loads.
- CFD studies directed by NTSB and reviewed by NASA Langley Research Center.

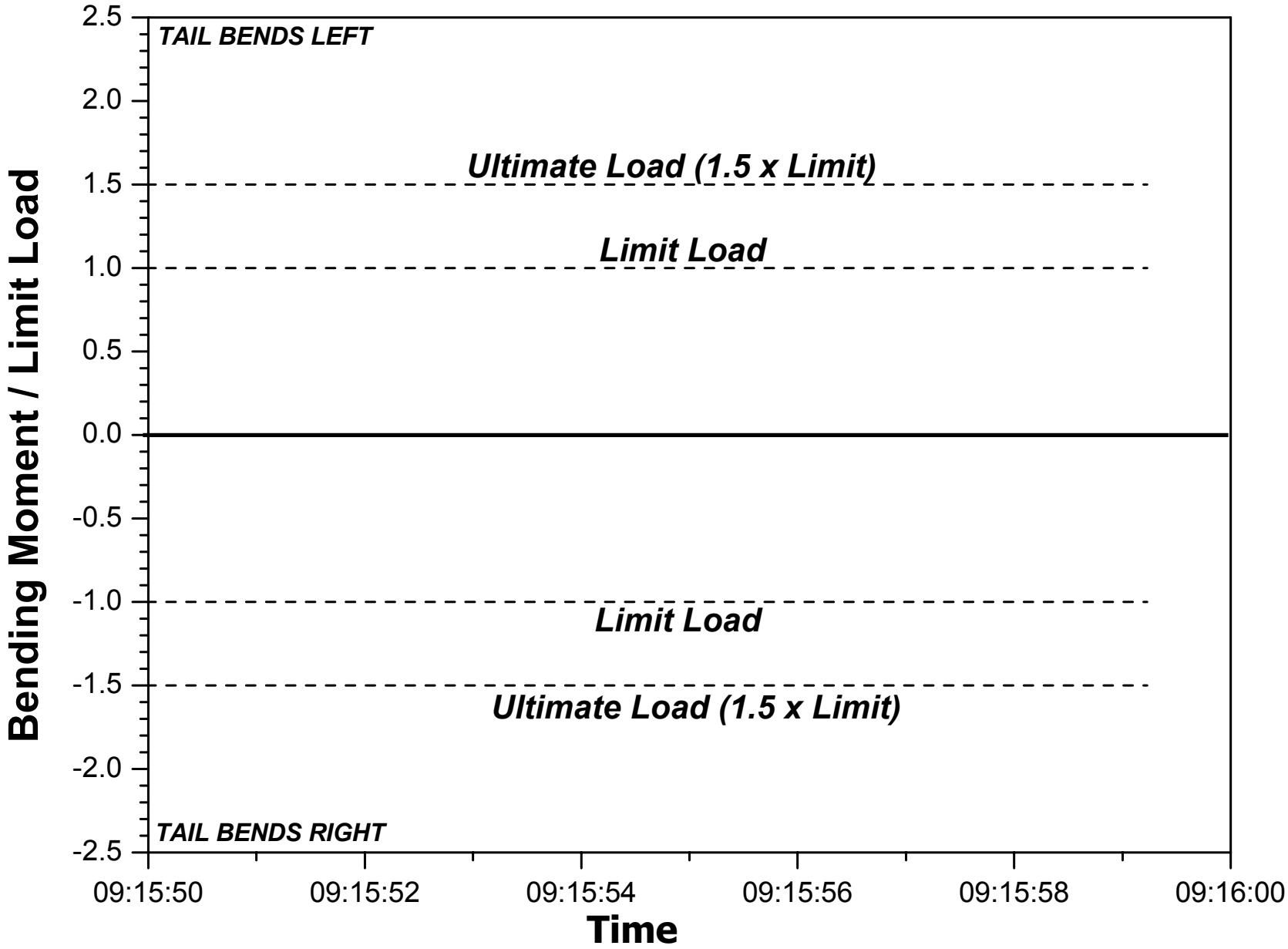
CFD Results: Pressure Distribution Over Vertical Stabilizer



CFD Results: Streamlines of Flow at High Sideslip Angle



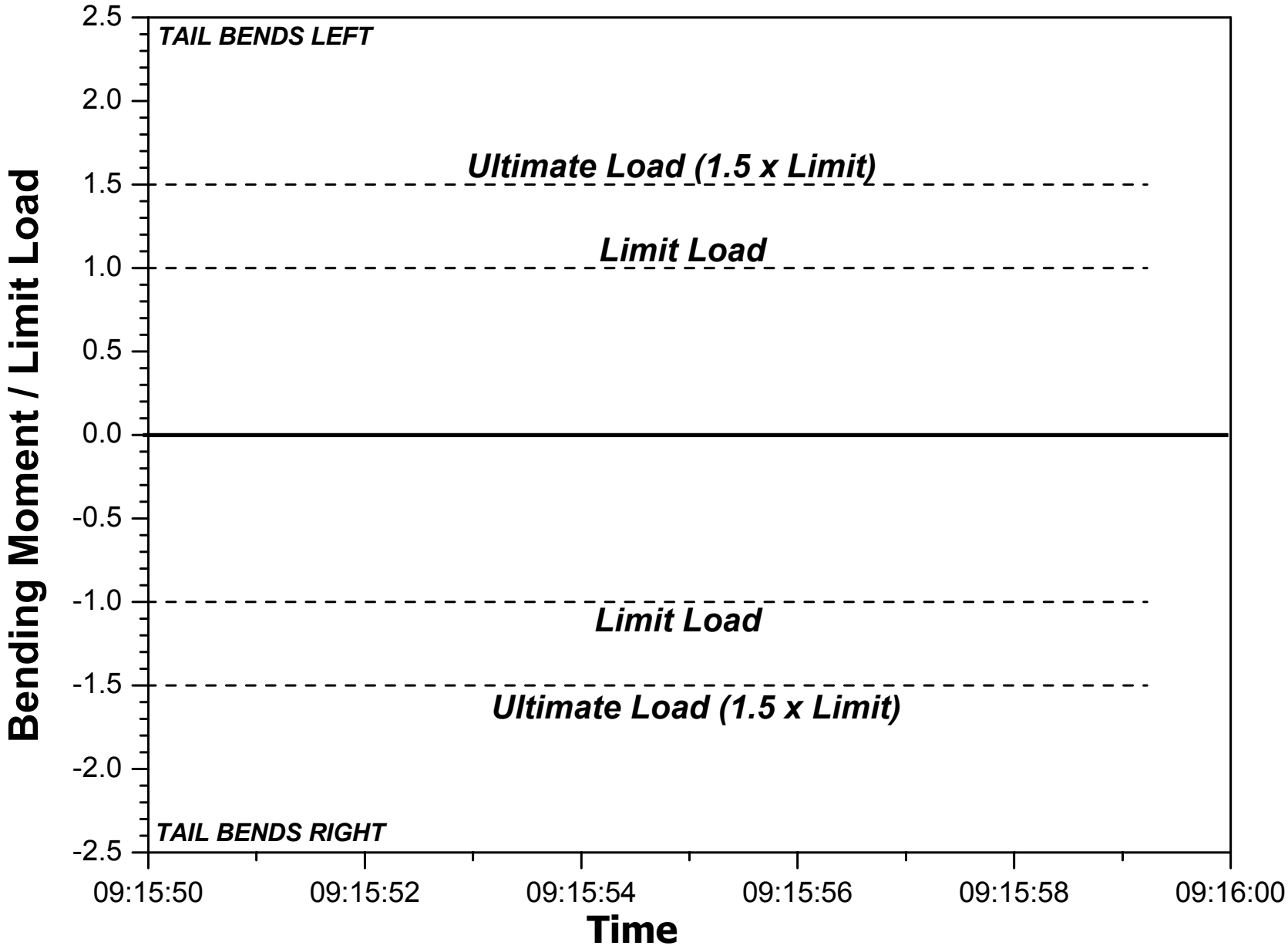
Bending Moment History During Second Wake Encounter



Bending Moment

Base of
Vertical Stabilizer

Bending Moment History During Second Wake Encounter



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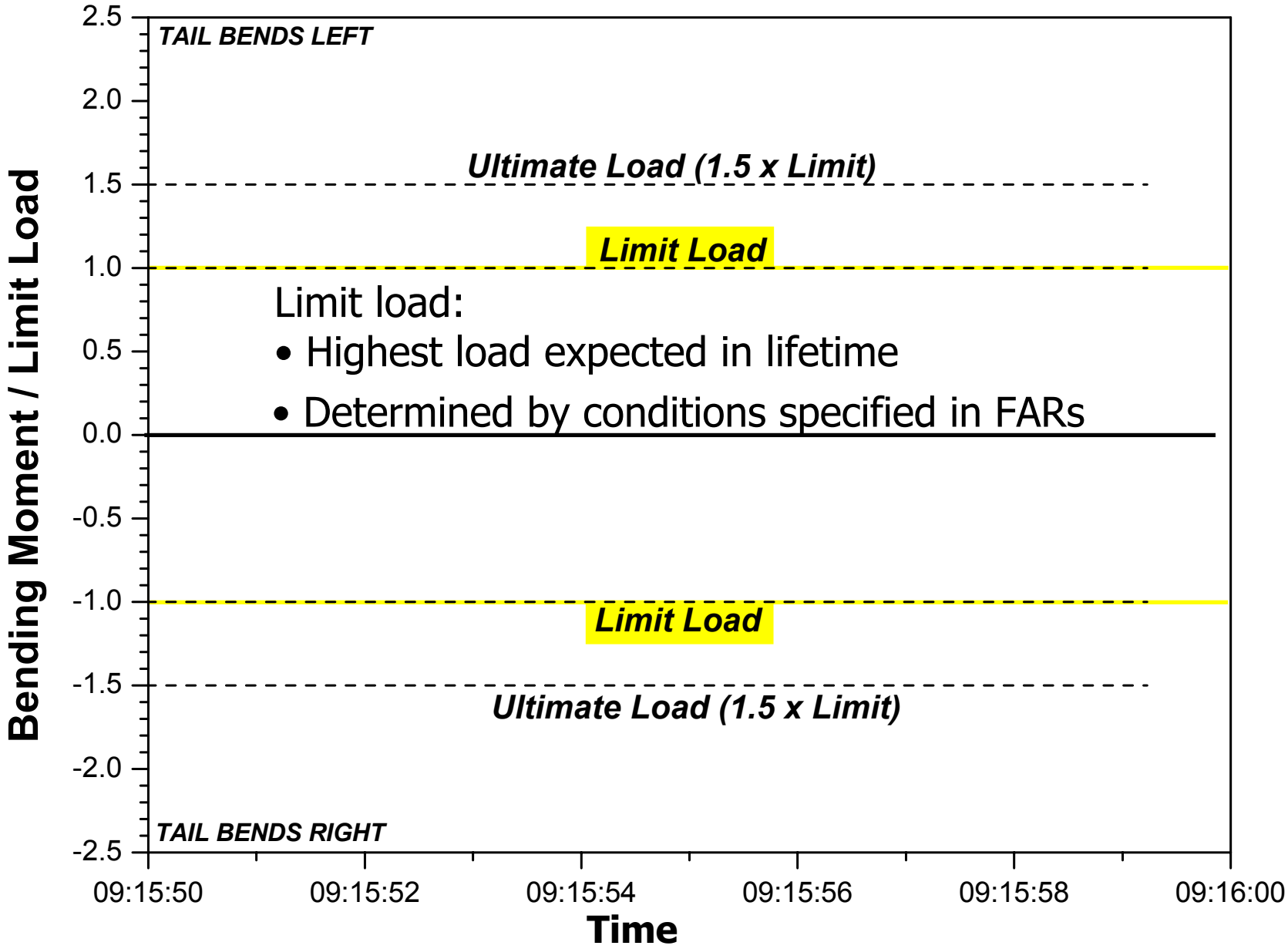

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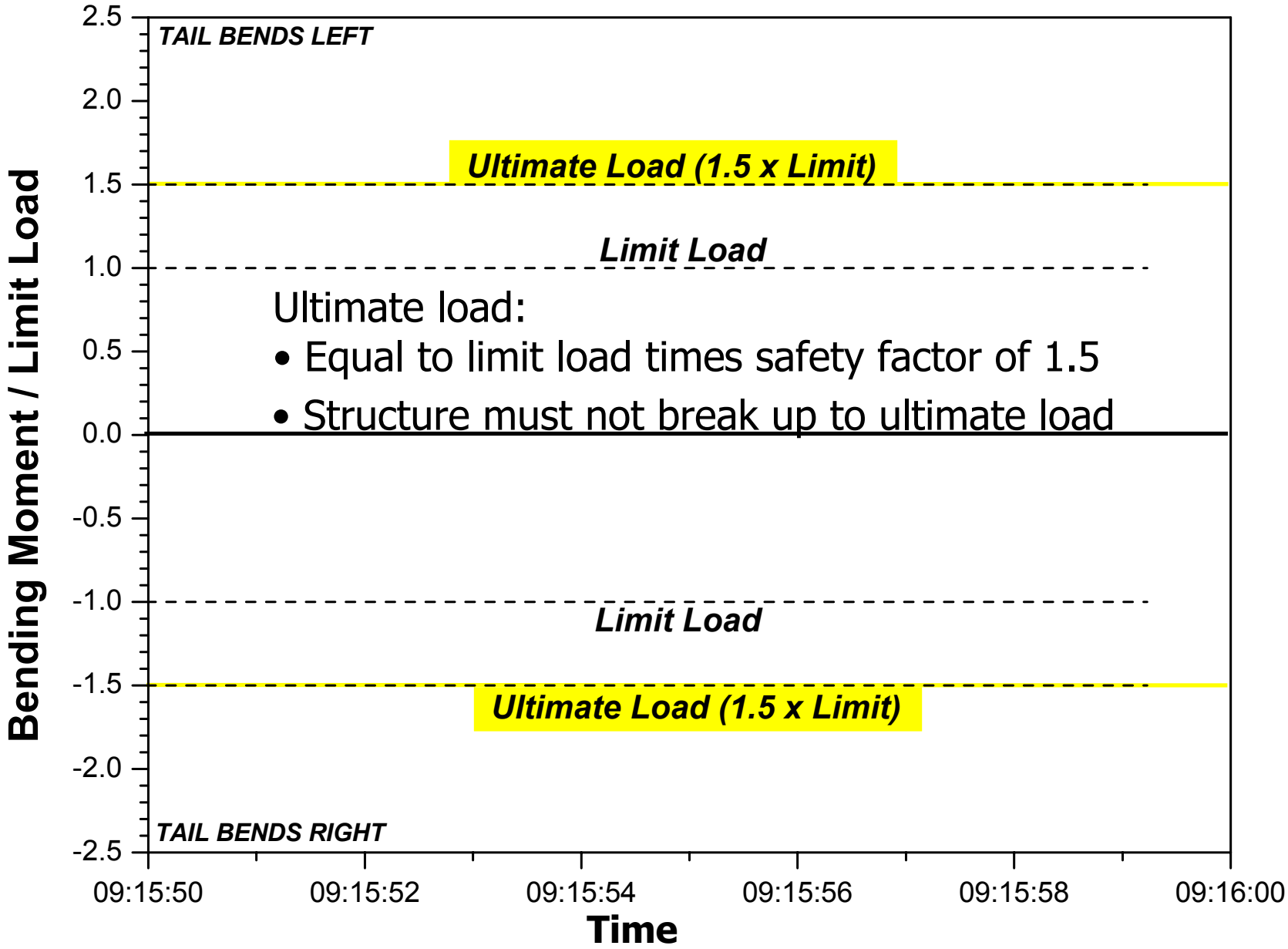

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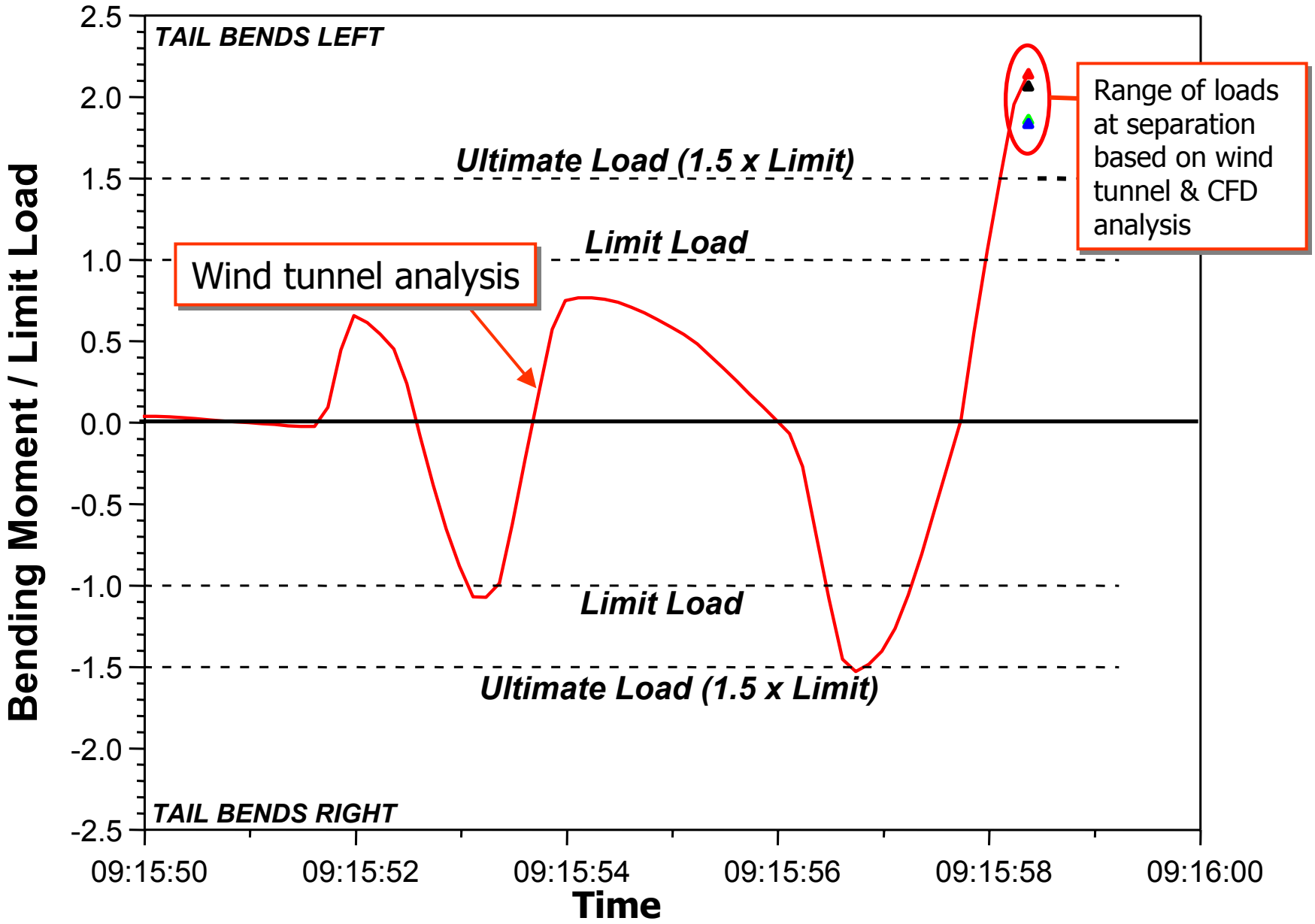

Conclusions

Airplane encountered wake turbulence twice

- Indicated by FDR, CVR, simulation, and wake analysis

First officer's control inputs following second encounter were unnecessary and excessive

- Simulation indicates wake had minor effect on motion
- Airplane was never in an upset condition

Airplane responded to control inputs as expected until vertical stabilizer separation

- Simulation indicates large sideslip angles were the result of control inputs

Vertical stabilizer separated at a bending moment load well above ultimate load

- Determined by wind tunnel and CFD analysis

National Transportation Safety Board

American Airlines Flight 587
Belle Harbor, New York
November 12, 2001

NTSB Board Meeting
October 26, 2004