Experiences of FSTD Envelope Expansion Using Non-OEM Models

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“Exemplar” Models

For the purposes of stall maneuver evaluation, the term “exemplar” is defined as a level of fidelity that is type specific of the simulated airplane to the extent that the training objectives can be satisfactorily accomplished.

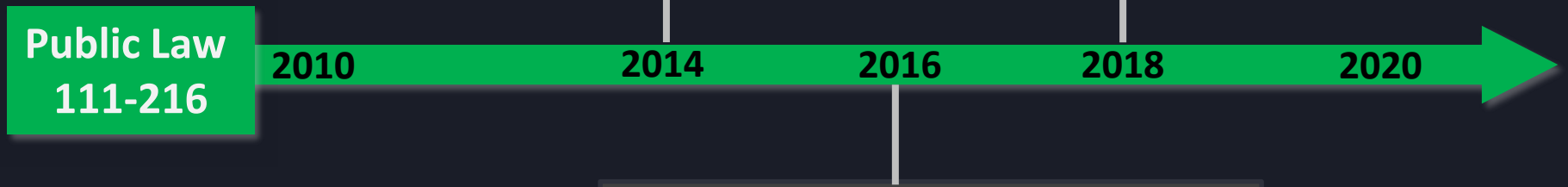
-14 CFR Part 60

Background

Extended envelope training must include instructor-guided hands on experience of recovery from full stall and stick pusher activation, if equipped

- 14 CFR 121.423 5c

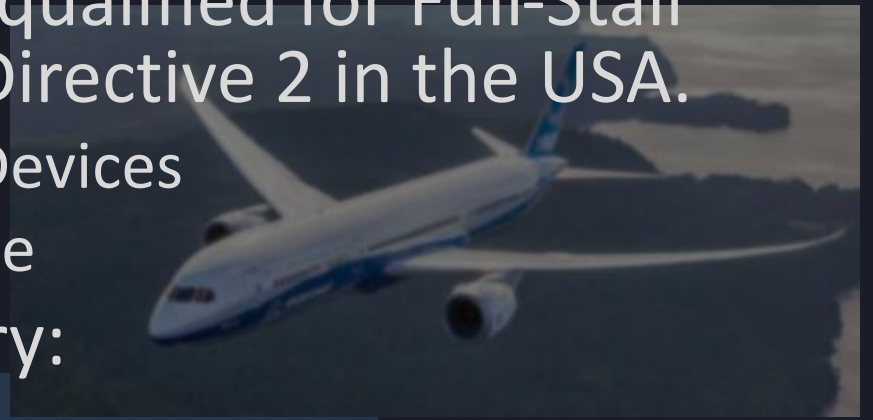
EASA CS-FSTD Issue 2 Released
And includes and full-stall modeling option for Level C and D



14 CFR Part 60 Change 2/Directive 2 released in with new qualification requirements that include full-stall modeling for Level C and D

Task at Hand …

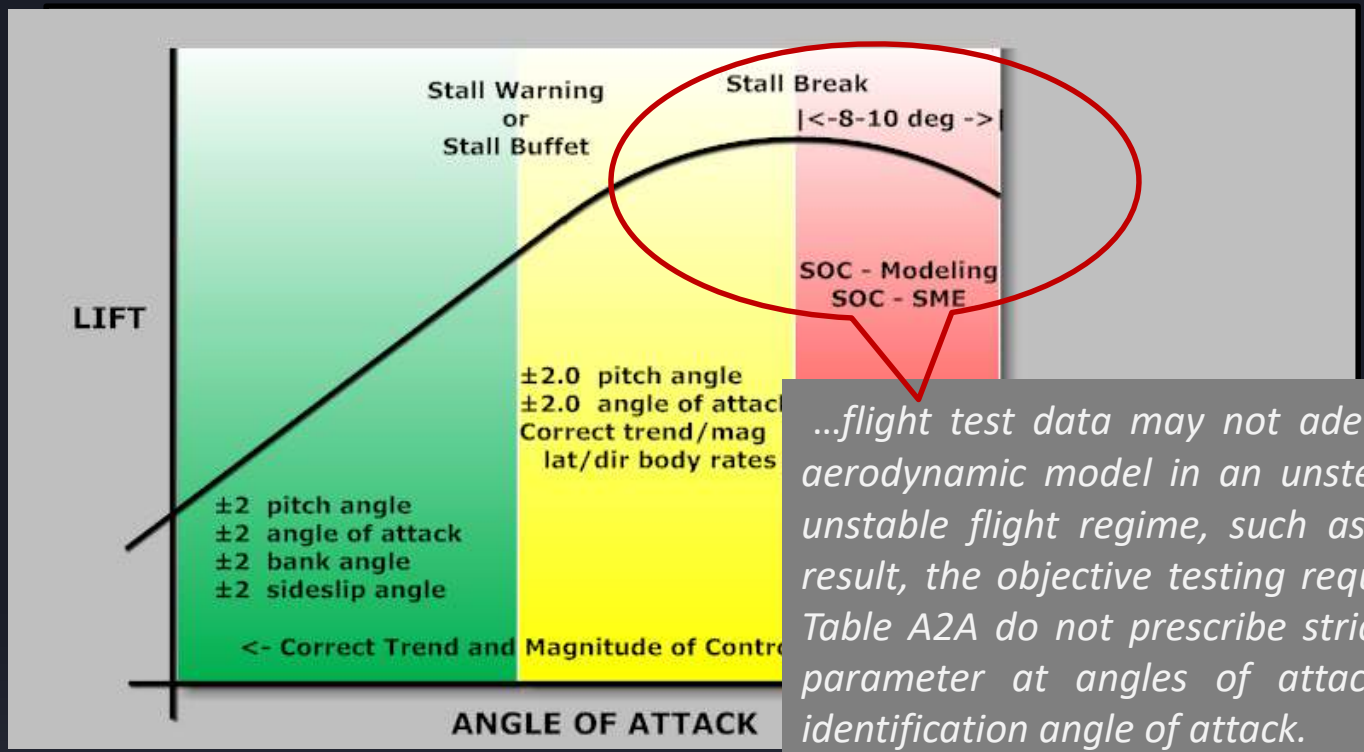
- In the USA approximately 400 training devices have been updated to be qualified for Full-Stall Recovery Training under Directive 2 in the USA.
  - Approximately 400 EASA Devices
  - Hundreds more world-wide
- Devices to be updated vary:
  - Airplane Type
    - Over 30 Types
  - Simulator Vintage
    - 1980's to Present



Requirements

- Full-Stall Modeling…as appropriate to the aircraft type
  - Degradation in static/dynamic stability
  - Degradation in control response
  - Stall Hysteresis
  - Uncommanded roll response
  - Apparent randomness or non-repeatability
  - Mach effects
  - Stall buffet
- Modeling must extend 10 degrees past critical angle of attack
- Statement of Compliance Required

Requirements



...flight test data may not adequately validate the aerodynamic model in an unsteady and potentially unstable flight regime, such as stalled flight. As a result, the objective testing requirements defined in Table A2A do not prescribe strict tolerances on any parameter at angles of attack beyond the stall identification angle of attack.

-14 CFR Part 60 Attachment 7

Data Sources

In cases where it is impractical to develop and validate a stall model with flight-test data (e.g., due to safety concerns involving the collection of flight test data past a certain angle of attack), the data provider is expected to make a reasonable attempt to develop a stall model through the required angle of attack range using analytical methods and empirical data (e.g., wind-tunnel data)

-14 CFR Part 60 Attachment 7

Evaluation

- Subject Matter Expert (SME) Evaluation
  - Type Rating/Qualification in Aircraft being Simulated
  - Direct experience in conducting stall maneuvers in the same type rating
  - Must be familiar with intended stall training maneuvers
- Statement of Compliance Required

In Practice

- Instances where analytical/empirical type-exemplar models become needed
  - Out of production airplanes
    - Little or no OEM available data
  - In productions airplanes
    - No OEM data/models are available
    - OEM data/model are cost prohibitive
      - Can be true for older/version limited simulators

Exemplar Stall Model Development

- Techniques for high-angle-of-attack models for simulation and training have been in development for over 30 years
  - Primarily for high-maneuverable military aircraft

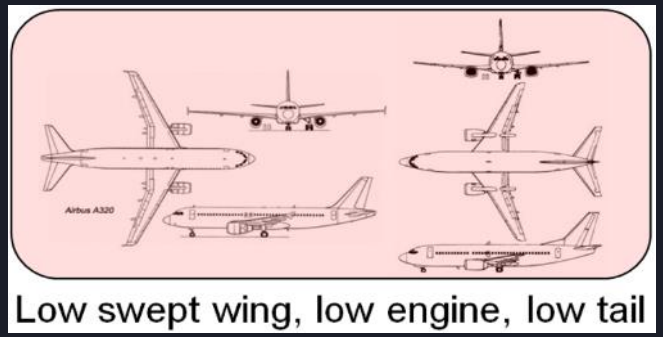
Exemplar Stall Model Development

- Recent US Navy and FAA sponsored research
  - Analytical/empirical techniques developed for highly maneuverable aircraft are suitable for development of transport category stall/post-stall models
  - Geometrically similar aircraft generally have similar stall and post-stall stability and control trends

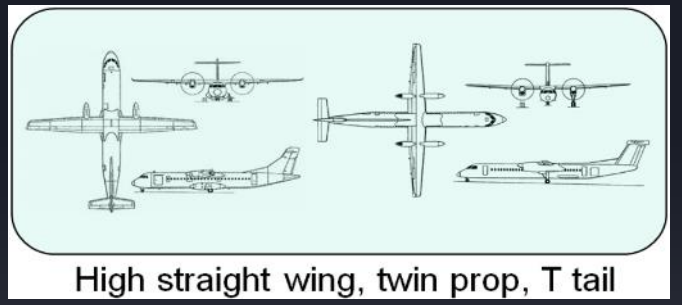
Wind Tunnel Testing Approach

- Representative geometry types identified
  - Low swept wing, low engine, low tail
    - Most Boeing and Airbus,737, A320, 767, A330, etc.
  - Low swept wing, aft engine T-tail
    - CRJ 900, ERJ145, DC-9, F-28, etc.
  - High straight wing, T-Tail
    - Q-400, ATR-42, ATR-72, etc.
  - Low straight wing, T-Tail
    - Beech 1900, PC-21, etc.
  - Low straight wing, low tail
    - Saab 340, etc.

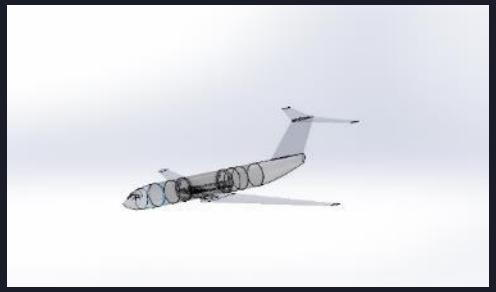
10 discrete configurations were examined, with static and dynamic data collected α to 60º, β± 30º

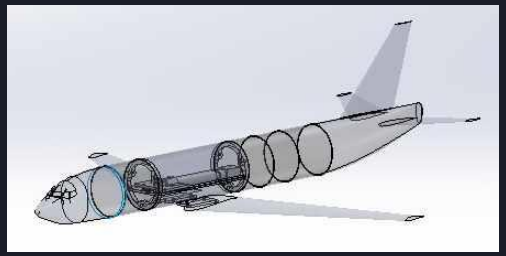


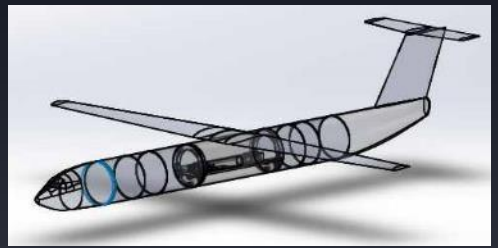
Low swept wing, low engine, low tail


High straight wing, twin prop, T tail

Wind Tunnel Model Adaptation







Representative Model General Approach

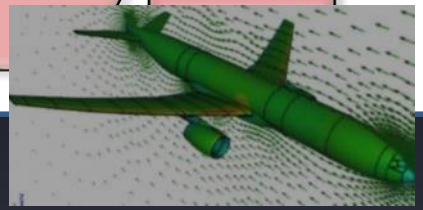
Comparable configuration static & dynamic test data

Stall Model architecture, baseline data

Final Representative Stall Model

Geometric Data

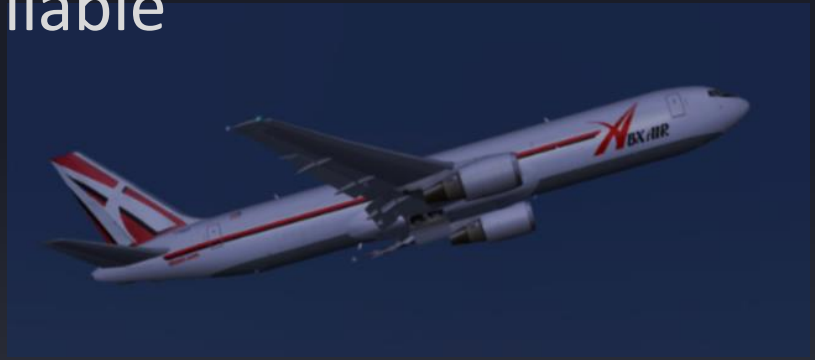
Analytic tools



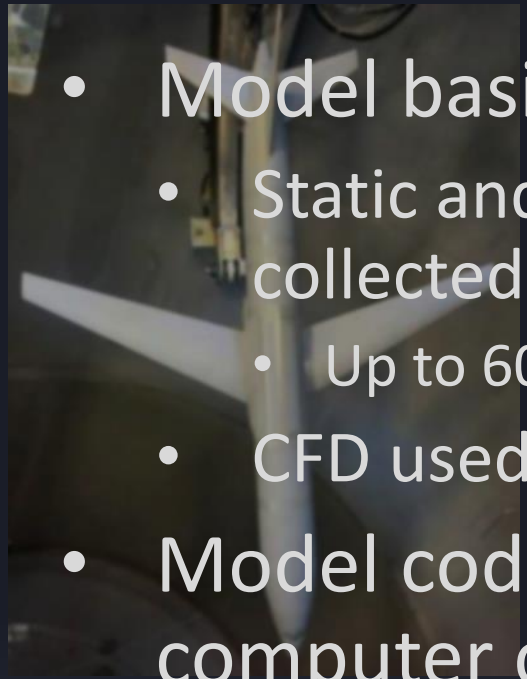
SME Input

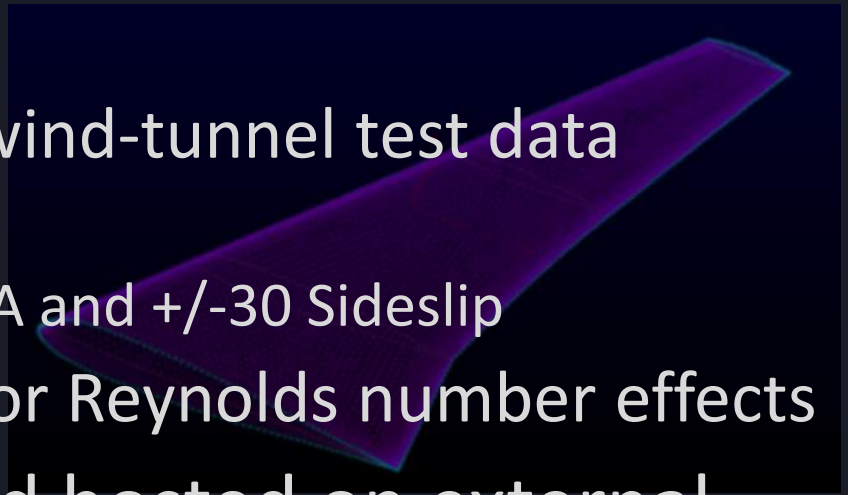
Example – ABX Air 767-200

- ABX-Air 767-200
  - Level C FFS – circa 1997 with 2005 rehost
    - Qualified to AC120-40B
  - Sought Full Part 60 Directive 2 Compliance
  - OEM Model/Data not available



Example- ABX 767-200





- Model basis
  - Static and dynamic wind-tunnel test data collected by Bihrle
    - Up to 60 degrees AOA and +/-30 Sideslip
  - CFD used to adjust for Reynolds number effects
- Model coded in C and hosted on external computer communicating with device via Ethernet

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Example-ABX Air 767-200

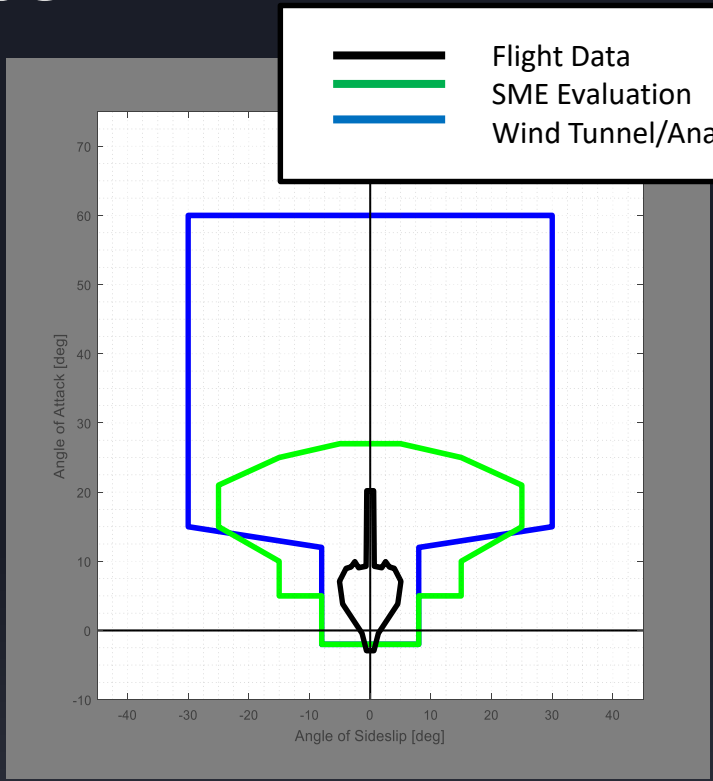
- SME Evaluation
  - Former Boeing test-pilot with stall experience in 767
  - Maneuvers
    - Required -
      - Wings-Level and Turning Stalls
        - 2nd Segment Climb, Landing, Cruise
        - Cruise configuration at low and high altitude
    - Extra –
      - Accelerated Stalls, Power On Stalls, Aggravated Inputs, Poor Recoveries

Example – ABX Air 767-200

- SME Feedback
  - Adjustments to incipient stall pitch stability
  - Adjustments to uncommanded roll magnitudes
  - Adjustments to buffet onset and trends
- Feedback and Evaluation Description was Included in SOC

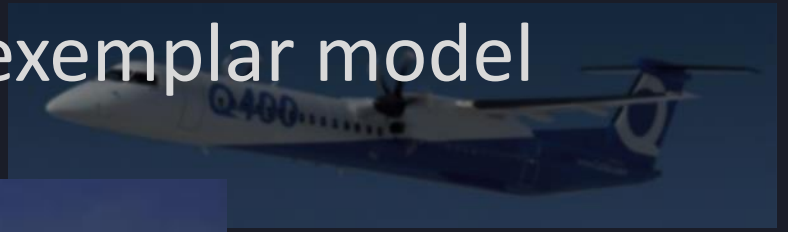
Example – ABX Air 767-200

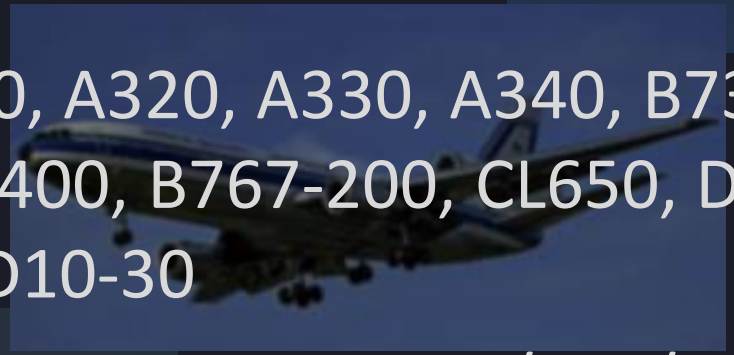
- Updated Simulator Envelope
  - Required
    - Flight Test
    - Analytical/Wind-Tunnel
  - Extra
    - SME Evaluated



Success

- Analytical/empirical type-exemplar model applications
  - A300, A310, A320, A330, A340, B737-700/800, B737-300/400, B767-200, CL650, DC-9, G450, G6000, MD10-30
  - ATR-42, ATR-72, DHC-8-100/200/300, Q400, SAAB 340, SAAB 2000,





Success

- To date 40+ FFS qualified (FAA, GACA) for full-stall recovery training using non-OEM analytical/empirical type exemplar stall models
  - Represents approximately 10% of all updated devices qualified for full stall training per Directive 2
- 18 October 2019 – 1st Issue 2 Qualification
  - Quadrant Systems A320 Qualified by the UK CAA Under CS-FSTD (A) Issue 2, Including Full-Stall Training
    - Solution Included In-flight Icing Aerodynamics Model

Take Away

- Sound Approach …. Proven
  - Non-OEM Analytical/empirical exemplar stall models have been successfully integrated and qualified for full-stall training