HeldenMesh Grids

Effect of Slat Bracket Shape on RANS CFD Simulations for Case 1

Andrew Wick Rick Hooker

Slat Bracket Shape Effect

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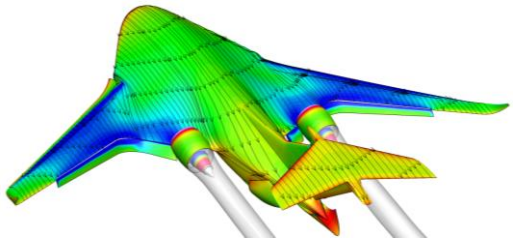
- The current HLPW wind tunnel bracket shapes are difficult for RANS
  - Residual convergence – solution residuals do not converge to machine zero in most flow solvers when brackets are present
  - Pizza slice separation on wing upper surface are caused by brackets

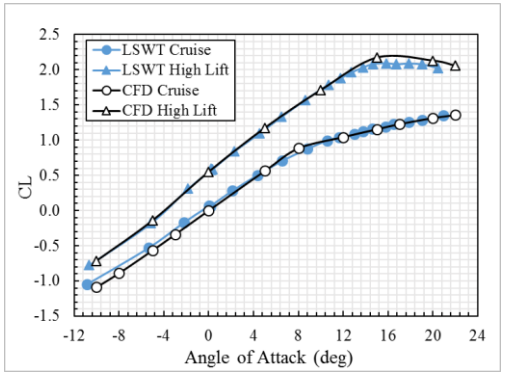


Hybrid Wing Body Conceptual Design
Model w/ Flaps and Slats (no brackets)
*AIAA 2014-1285

- Big Picture: How are aircraft high lift systems designed? (Lockheed)
  - **Conceptual design phase:** slat brackets are usually not defined. Slat and flaps hang out in space. Engineers vary gap, overhang, angle, etc to get best RANS-based performance predictions without brackets
    - The "no bracket" geometry becomes the nominal baseline case
    - These are often the performance estimates that size the airplane
  - **Preliminary design phase:** wind tunnel testing. Model needs WT brackets!
  - **Detailed design phase:** slat tracks and actuation are only considered once the wing and slats designs are finalized and the loads are known. Ideally, CFD analysis is used to verify the actuators do not impact performance (CLmax)

HWB LSWT Powered WT Model
*AIAA 2017-0100

- How should wind tunnel model slat brackets be designed?
  - 1. Replicate typical full scale # brackets, but sized by wind tunnel constraints -> leads to current CRM HL designs
  - 2. Go through bracket design effort and get performance as close to the no bracket case as possible (fewer brackets, stream aligned, aerodynamic cross section) -> naturally leads to more RANS friendly designs.



RANS matches Test Data. No Pizza Sep!

NTF-HL Model Designed for Minimal Impact on Performance

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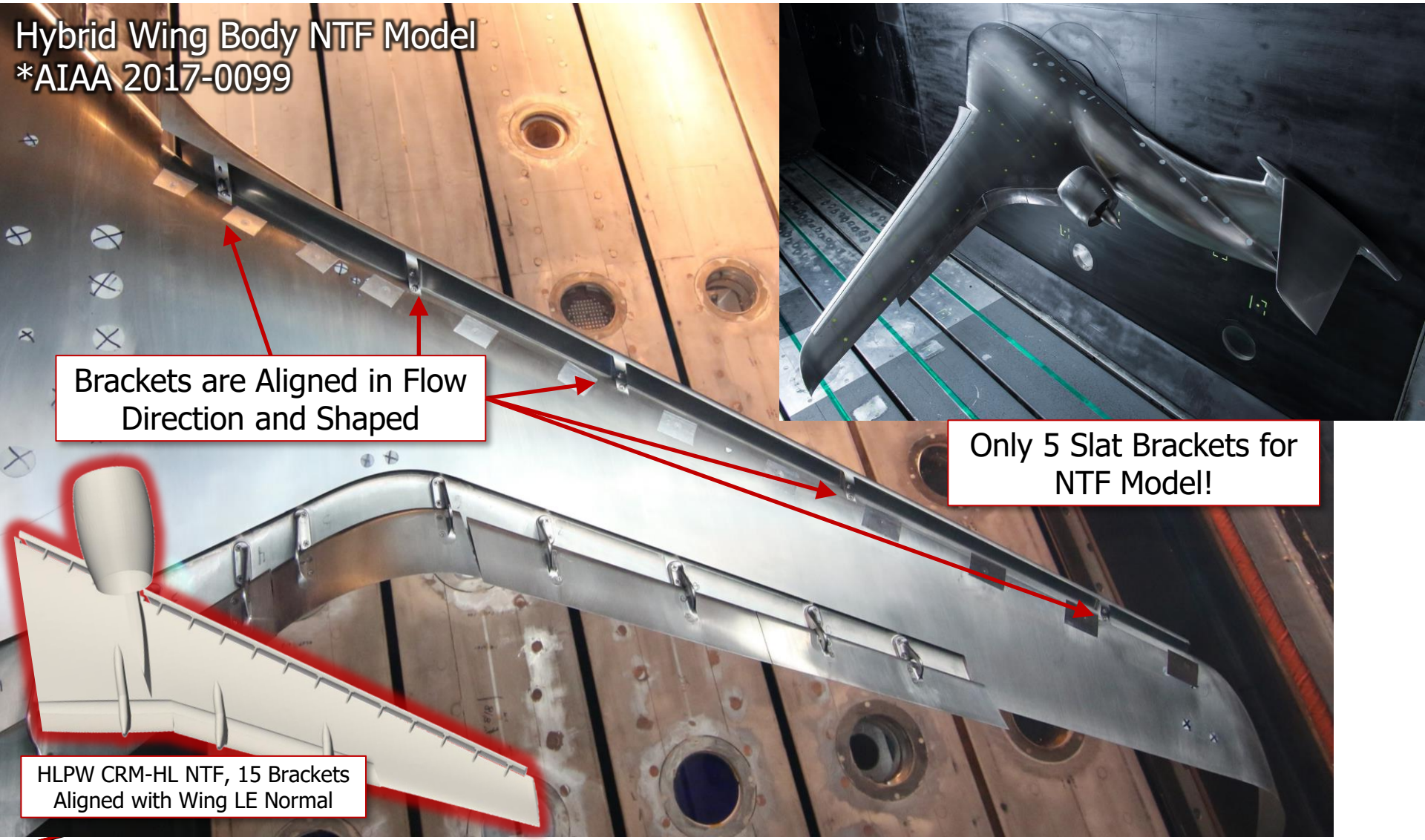

Wind Tunnel Brackets Can be Designed for Minimal Impact

Slat WT Brackets vs. Slat Tracks

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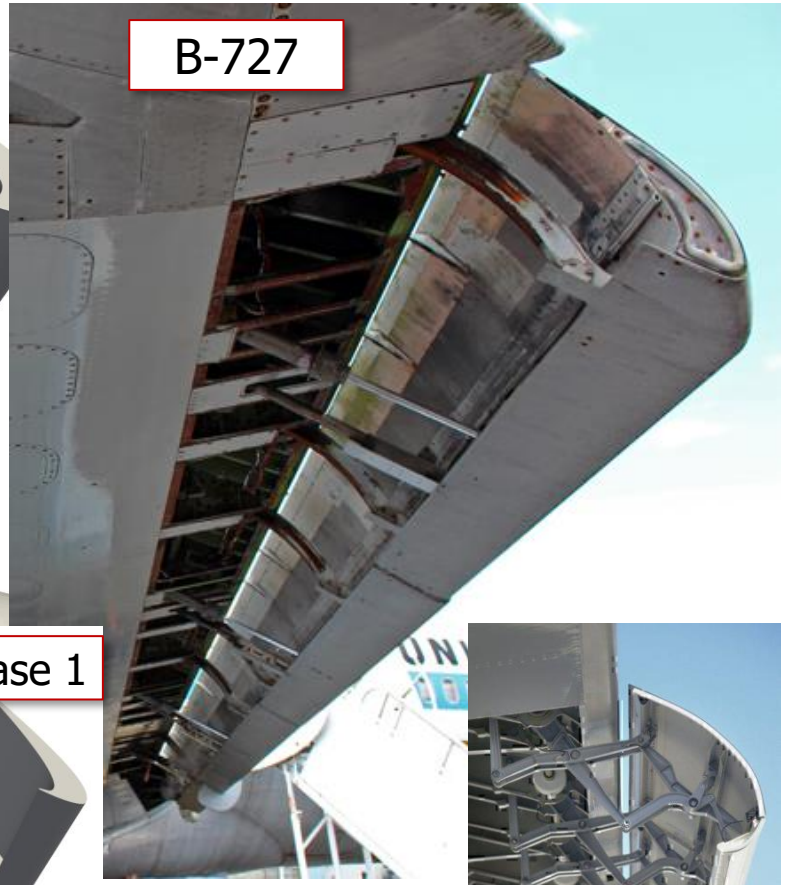
HLPW5 Case 2.4

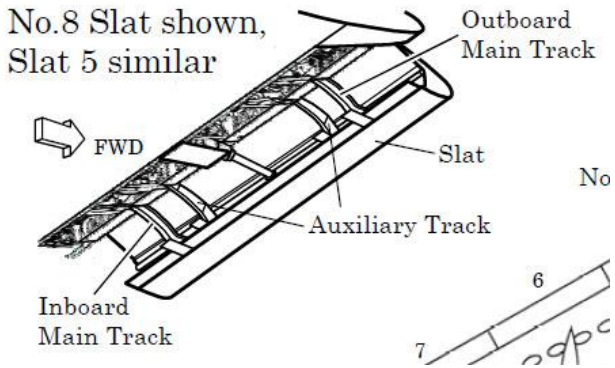
B-727



B-737

HLPW6 Case 1

B-747



http://www.b737.org.uk/slat-track-ad.htm

CRM Brackets are Larger / Chunkier Than Actual Slat Tracks

Case 1: No Brackets

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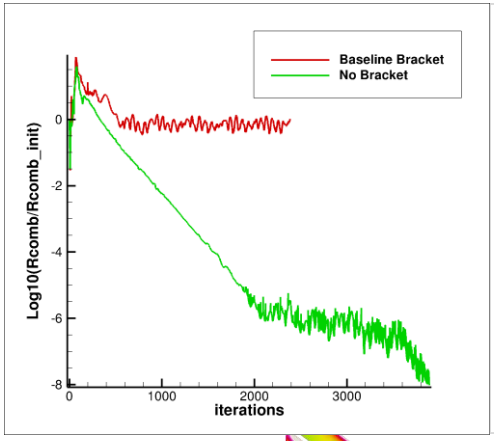
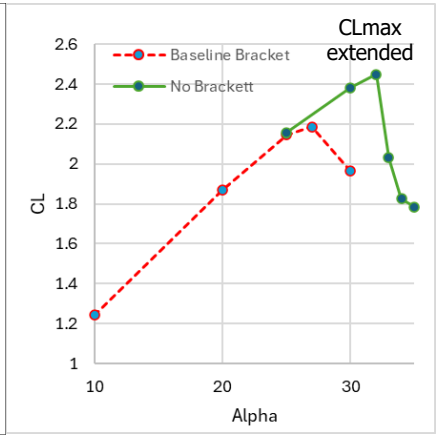
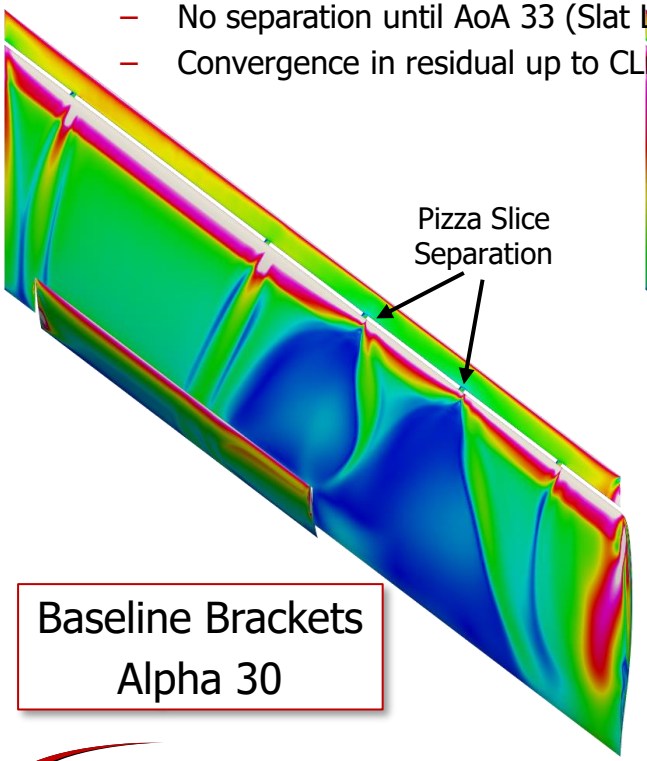
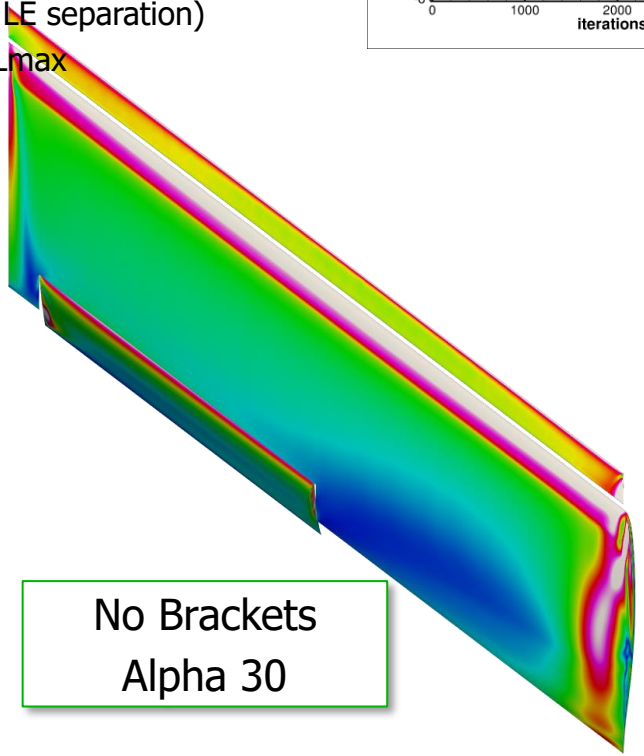
- HeldenMesh, USM3DME used for meshing/CFD
  - Series 3, D level fixed mesh spacing + wake sources
  - ~40M cells for each bracket variation
- Baseline bracket design impact on RANS
  - Residual convergence difficulties with HANIM
  - Pizza Slices on wing upper surface at AoA 30
- No bracket impact on RANS
  - No separation until AoA 33 (Slat LE separation)
  - Convergence in residual up to CLmax



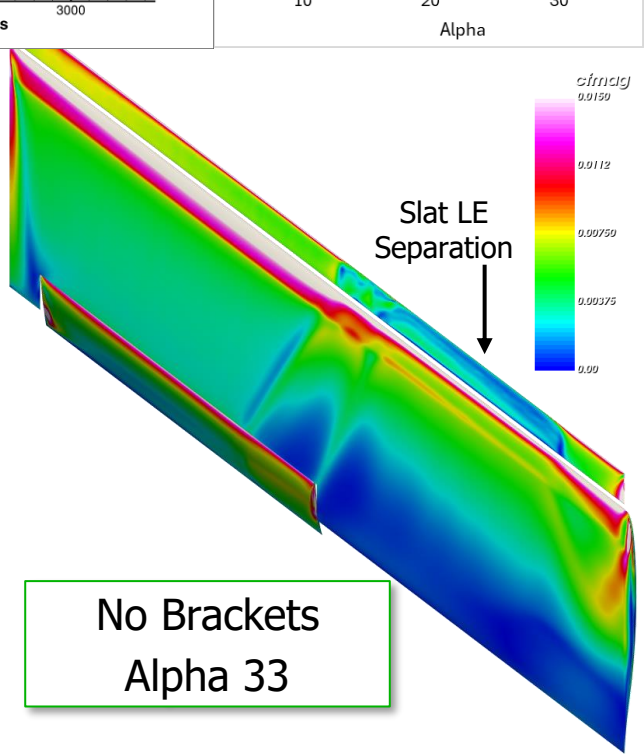




Baseline Brackets
Alpha 30



No Brackets
Alpha 30



No Brackets
Alpha 33

No Bracket = Solution Convergence and no Pizza

Bracket Design Effort (1/2)

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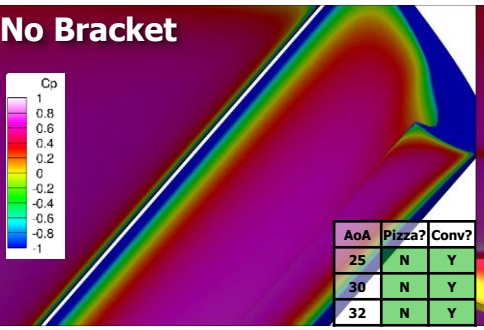

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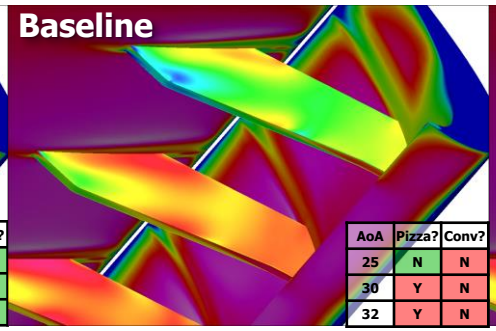
30	N	Y
32	N	Y



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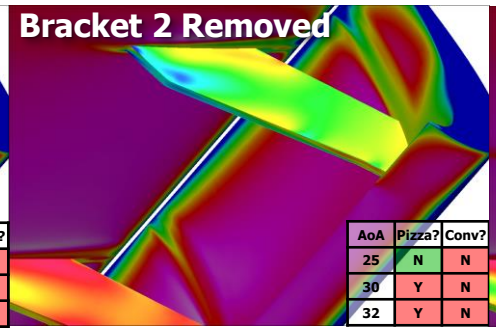
32	Y	N



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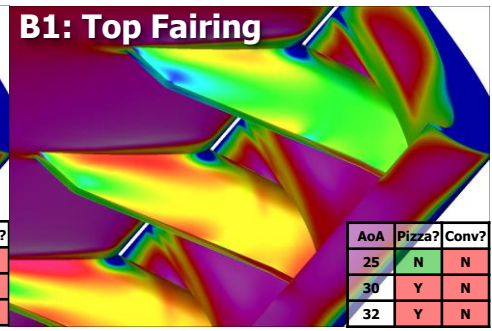
32	Y	N



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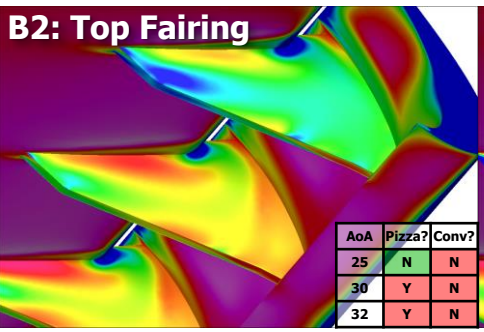
32	Y	N



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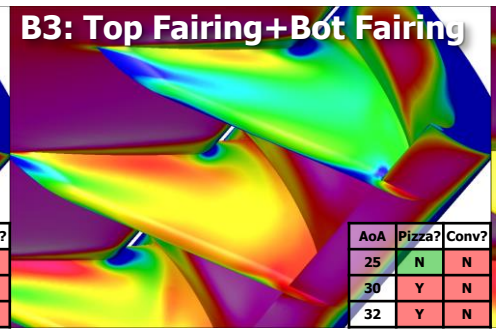
32	Y	N



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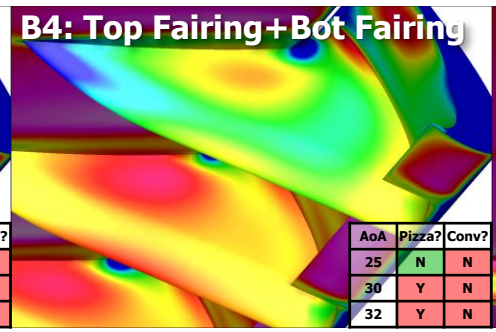

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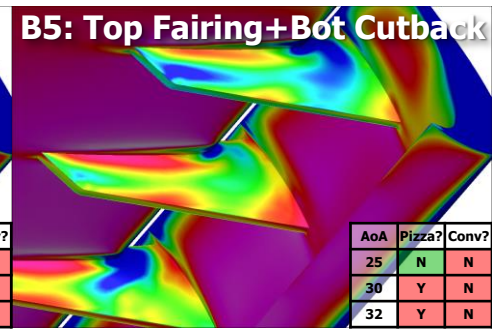

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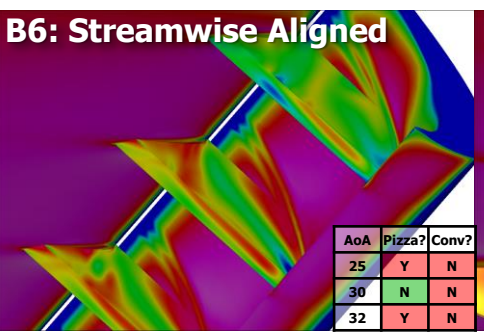

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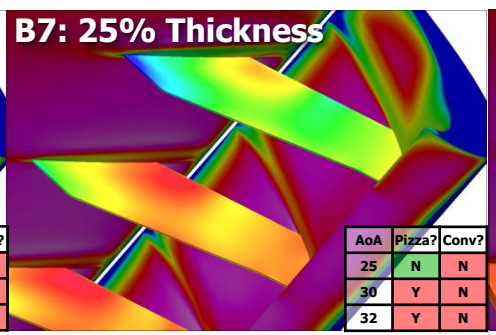

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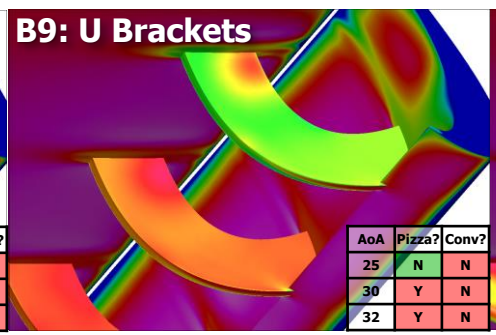

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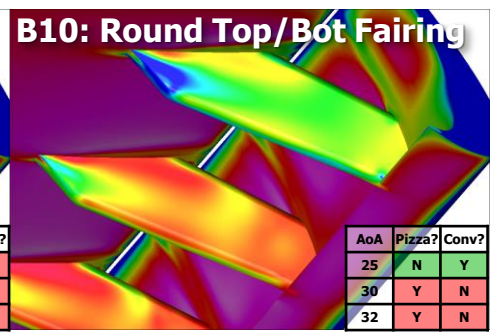

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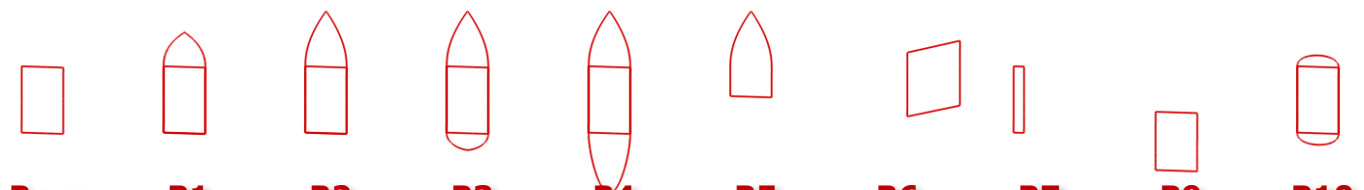
32	Y	N

Cross Sections of Brackets:



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Bracket Design Effort (2/2)

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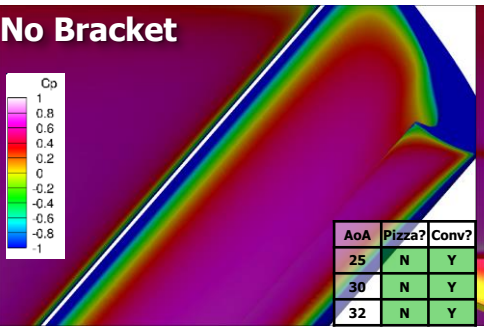

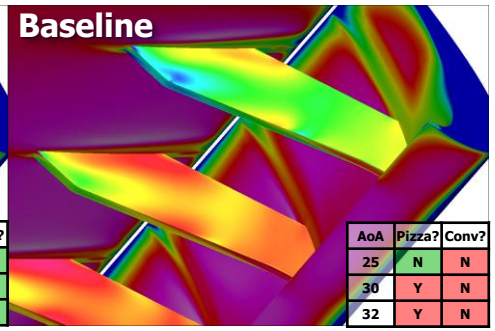

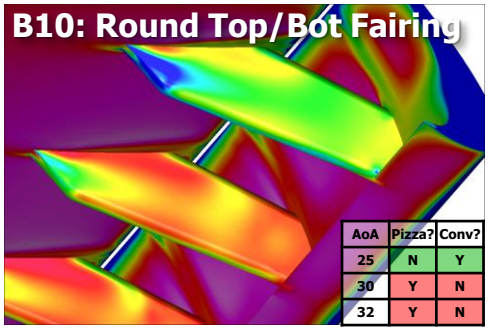

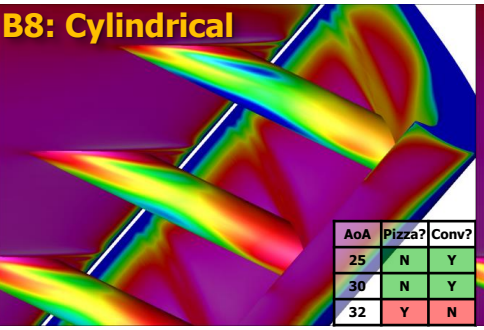

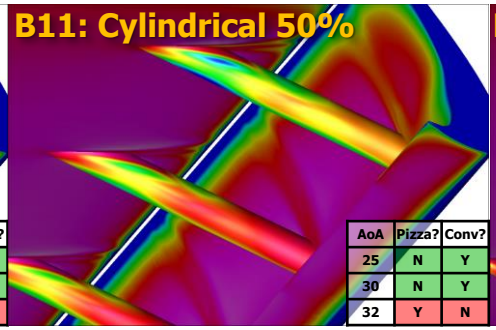

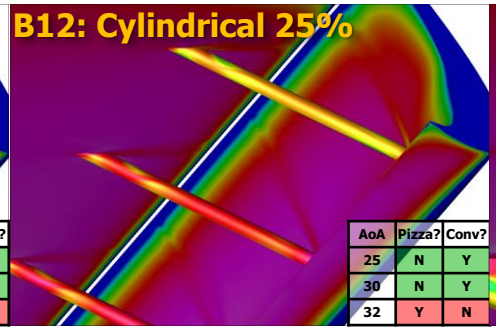

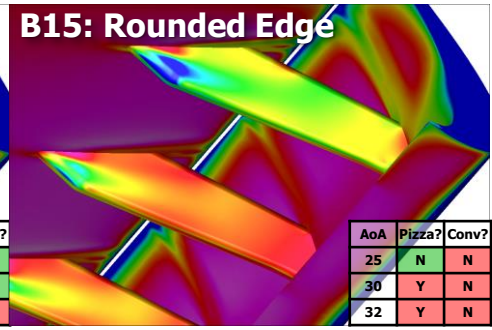

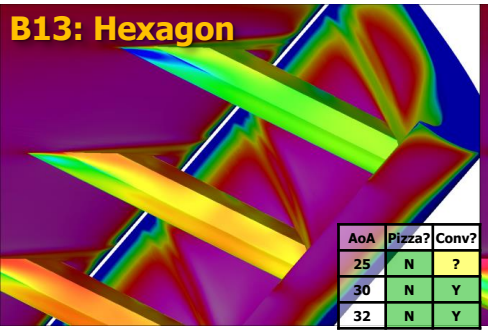

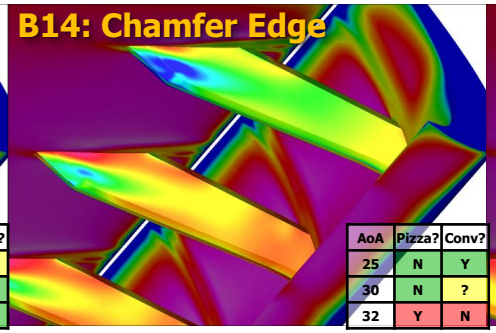

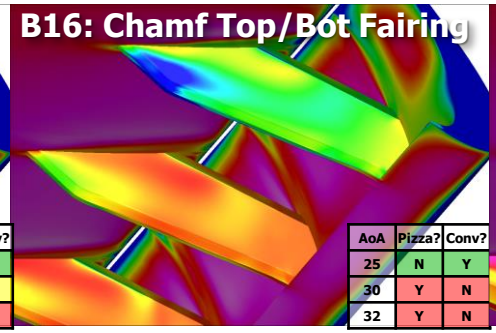

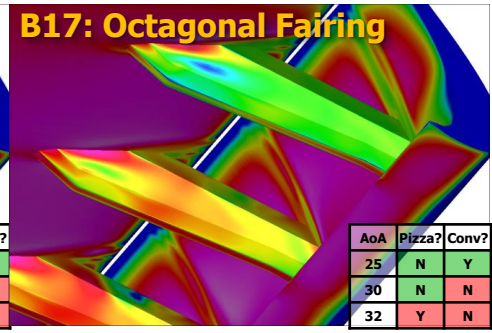

Cross Sections of Brackets:

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Bracket Study Summary

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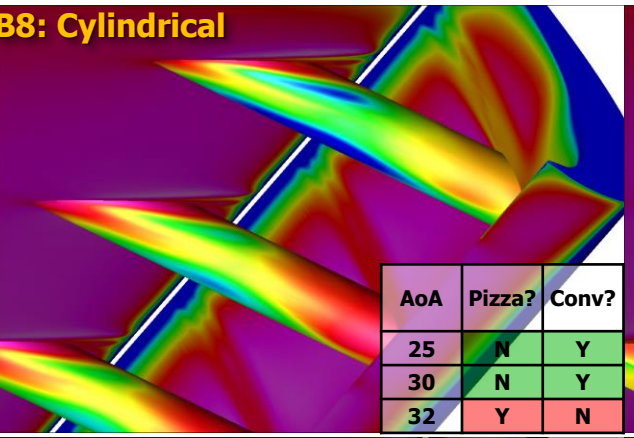

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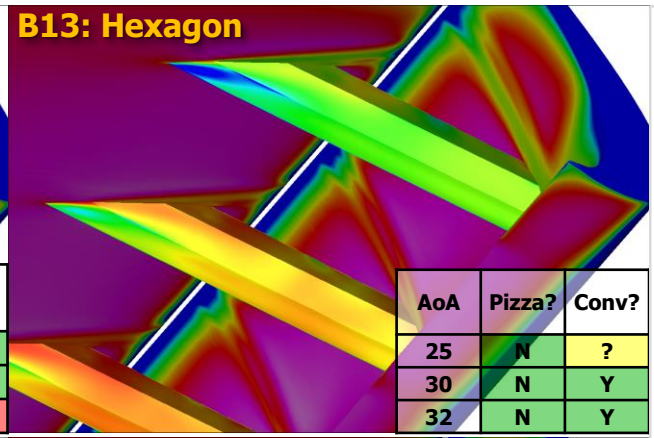
30	N	Y
32	Y	N



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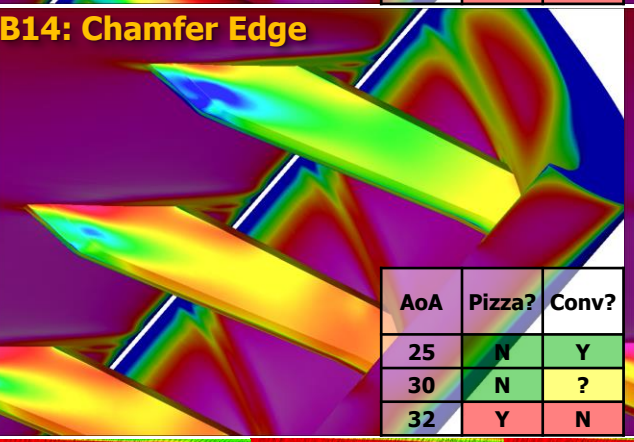

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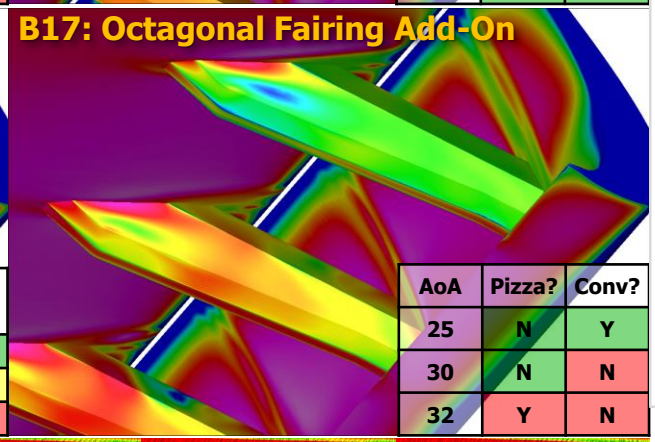

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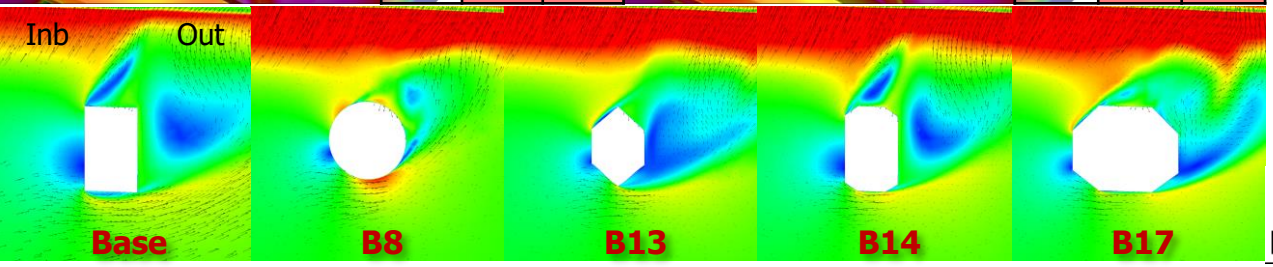

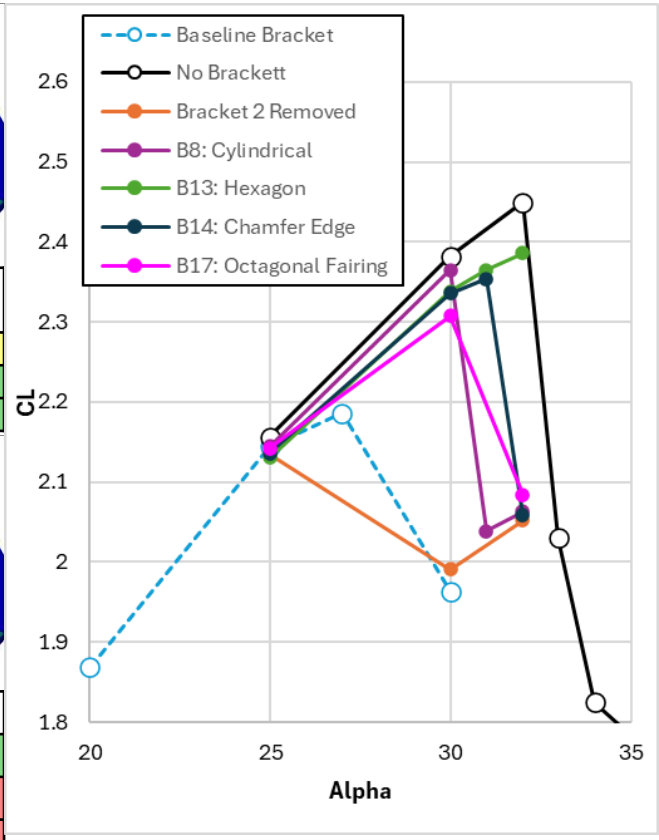

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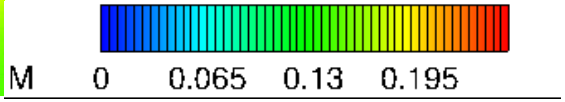

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Bracket Shape Can Improve Convergence and Reduce Pizza Sep

Bracket Study Conclusions

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- 17 Brackets assessed at 3-4 AoA. 60+ USM3DME Solutions
- Some minor adjustments to the bracket geometry can result in improved RANS simulations (no pizza and residual convergence)
  - Cylindrical cross section
  - Hexagon cross section
  - Chamfering on sharp edges of existing brackets.
  - Fairings can be added to the sides of the existing brackets.
- The "No Bracket" Case is still useful, even if it can't be tested
  - Simulates the nominal performance of the high lift system.
  - Easier to simulate with RANS. Free of pizza and convergence issues.
  - For HLPW5 Case 2, RANS simulations without brackets matched the test data
  - Do scale resolving sims show a bracket effect on CLMax?
- Final Thoughts: Are pizza slices a show-stopper for RANS High Lift?
  - Most flight slat tracks are less obstructive than the HLPW wind tunnel brackets. RANS CFD on a flight model might not show pizza anyways
  - In the aircraft design process, most pre-test RANS CFD probably doesn't even model the slat brackets. These are the performance estimates that size the aircraft!
  - The pizza issue can be eliminated from WT model through some basic bracket shaping (whether these changes are warranted or not)
  - How common are pizza slices on geometries other than CRM HL?