EXA'S CONTRIBUTION TO THE APC-III

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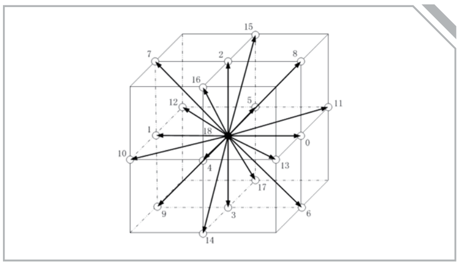
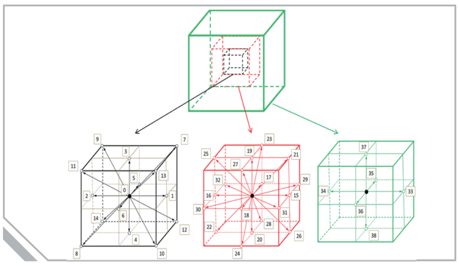
Exa's participation on the APC

- Exa took part of the APC-II
  - Case 1: one angle of attack (more angles available on DPW publications)
  - Case 2: one angle of attack (more angles available on DPW publications)
  - Case 3: both angles of attack
- For the APC-III, the focus will be on the new experimental data for Case 3
- Publications on the CRM/APC:
  - Buffet Simulations with a Lattice-Boltzmann based Transonic Solver. Ribeiro et al., AIAA Paper 2017-1438
  - Exa PowerFLOW Simulations for the Sixth AIAA Drag Prediction Workshop. Koenig and Fares, AIAA Paper 2017-0963.
  - Extended Validation of a Transonic Lattice-Boltzmann Method on the Example of the NASA Common Research Model. Koenig et al., ICAS 2016.
  - Validation of a Transonic Lattice-Boltzmann Method on the NASA Common Research Model. Koenig and Fares, AIAA Paper 2016-2023.

Lattice-Boltzmann based PowerFLOW

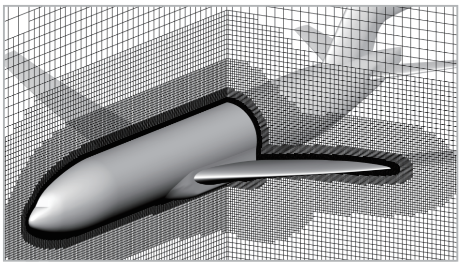
- Extended to transonic flow
- Easily handles complex geometry
  - Cartesian mesh automatically generated based on user-defined regions
- Fully transient
  - Typically orders of magnitude faster than DES/LES with Navier-Stokes solver
- Turbulence approach: LBM-VLES
  - RNG k-ε subgrid model
  - Swirl model to reduce eddy viscosity
  - Extended wall model
- Previously used for airfoils and wings
  - See paper references





Aircraft Description

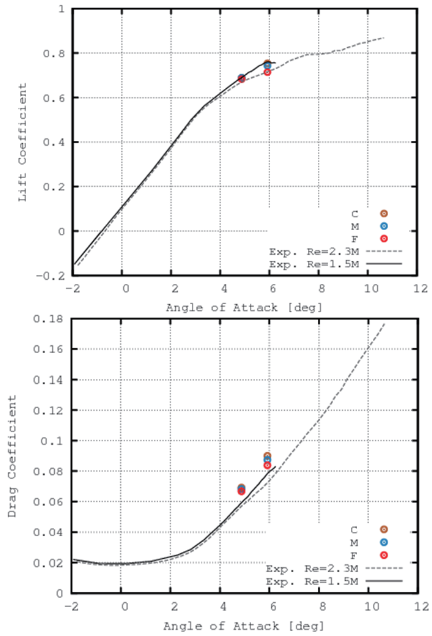
- Common Research Model (CRM) used for the Drag Prediction Workshop (DPW) and Aerodynamic Prediction Challenge (APC)
- 3 grids simulated: Coarse (C), Medium (M), and Fine (F)
  - Factor of $1.15^2 = 1.32$ between grids
- M=0.84, Re= 1.5 million
- Angles of attack = 4.87°, 5.92°, 6.58°
- Forces, Cp, Cp RMS, PSP comparisons to experiments



Resolution Study: Lift and Drag

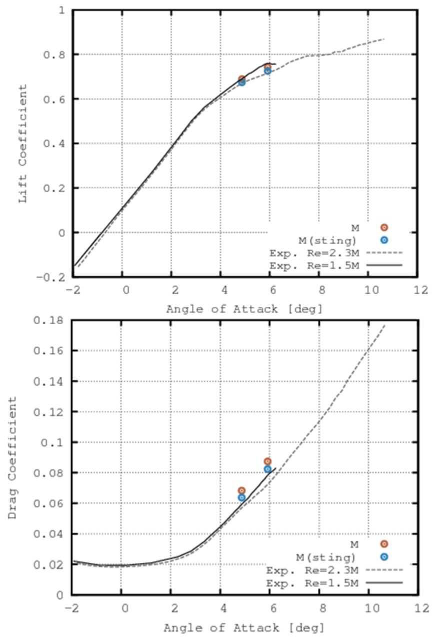
- Grid convergent behavior at 4.87°
- Results at 5.92° tend towards higher Reynolds number experiments
- A deeper analysis of the resolution study was presented in:
  - "Exa PowerFLOW Simulations for the Sixth AIAA Drag Prediction Workshop", AIAA-2017-0963, 11/01/2017.
- Run time (CPUh) for 0.084 seconds physical time

C	M	F
2600	5600	12700



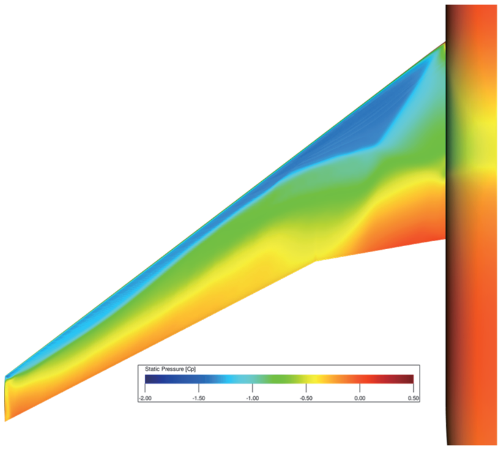
Wind Tunnel Effects: Sting

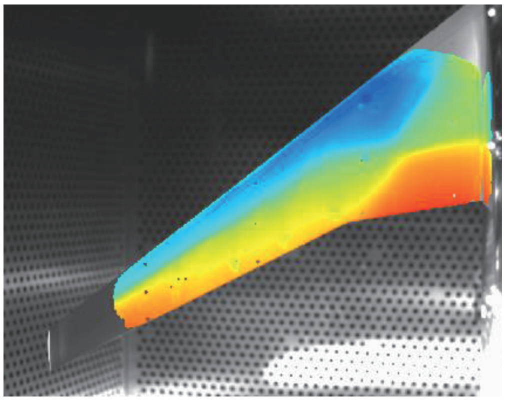
- Significant improvement of drag with sting
- Lift comes even closer to experiments at higher Reynolds number
- Sting plays a big role, but will not be included in the following results, for CPUh saving



Buffet Phenomenon: Cp (6.58°)

- Good comparisons to PSP
  - Shocks are generally more upwind than experiments



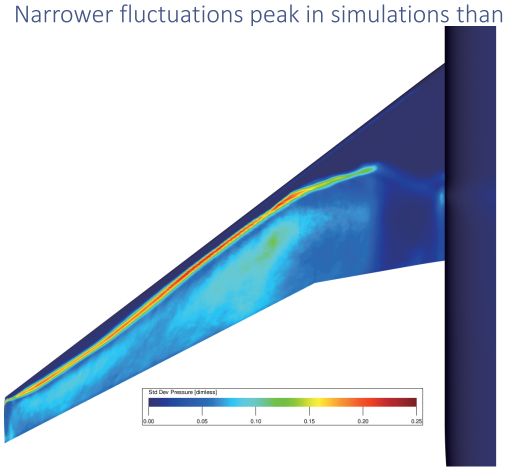


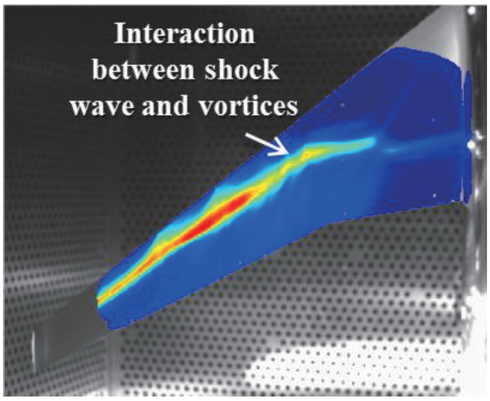
Exa

PSP data from Sugioka et al., “Non-Intrusive Unsteady PSP Technique For Investigation of Transonic Buffeting”, ICAS 2016

Buffet Phenomenon: Cp (6.58°)

- Good comparisons to PSP
  - Higher fluctuations after shock (consistent with Cp cuts in the next slides)
  - Narrower fluctuations peak in simulations than experiments (inconsistent with Cp cuts)





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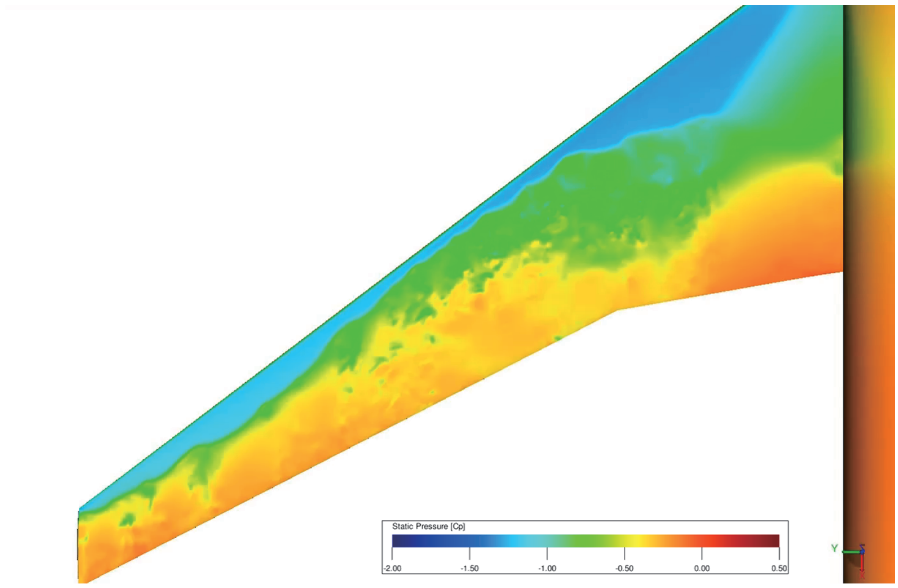
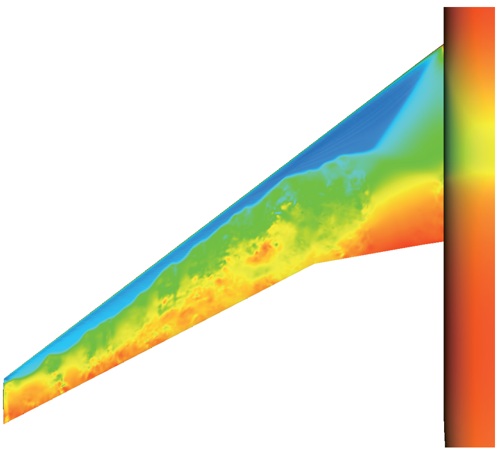
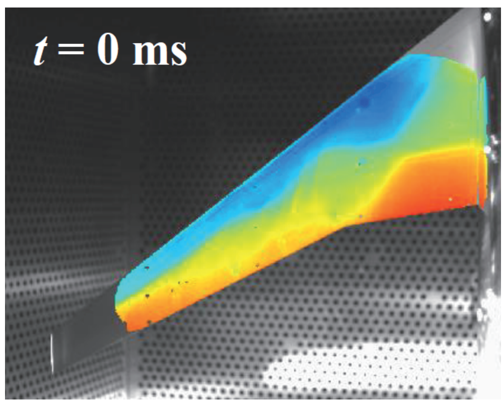


Buffet Phenomenon: Instantaneous Cp (6.58°)

- Good comparisons to PSP
  - Similar spanwise flow structures present in both results





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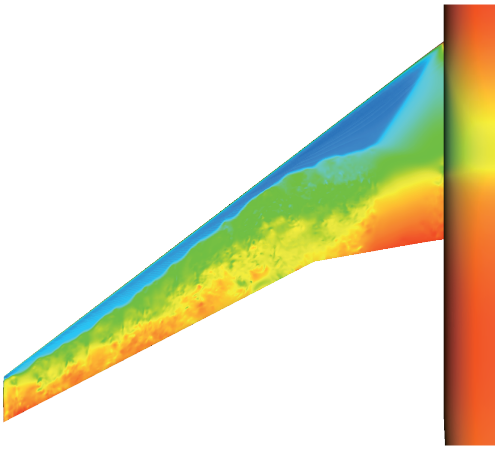

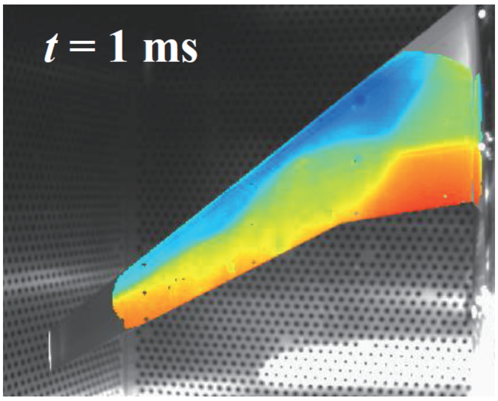

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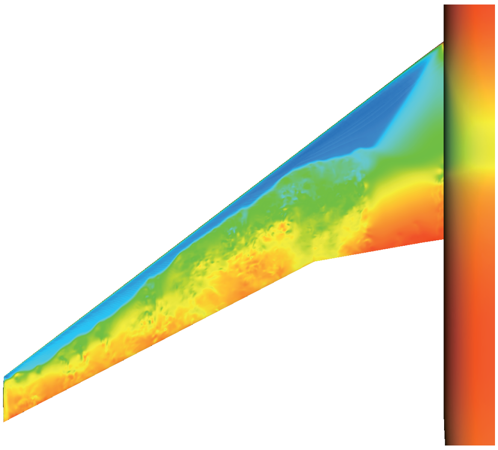

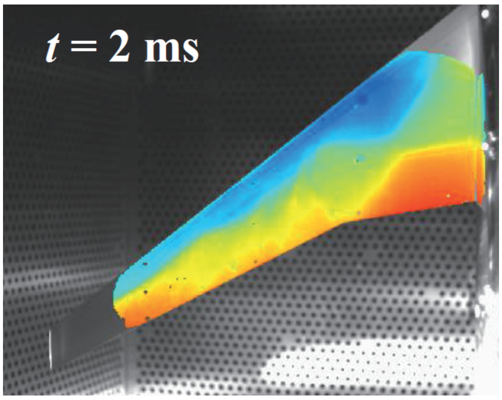

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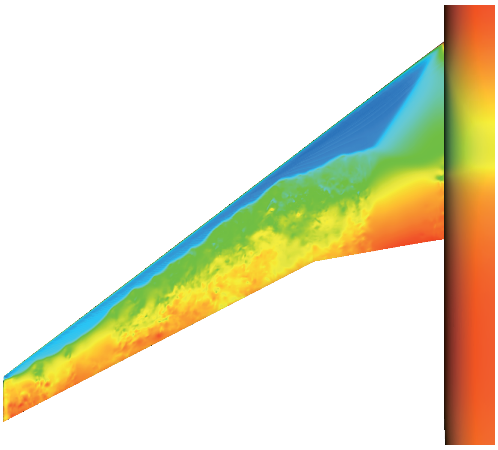
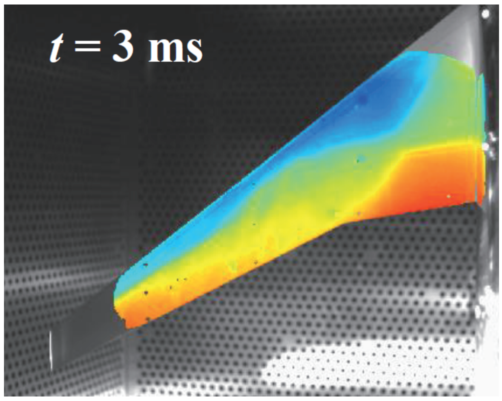
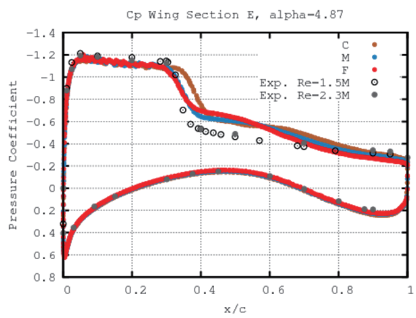


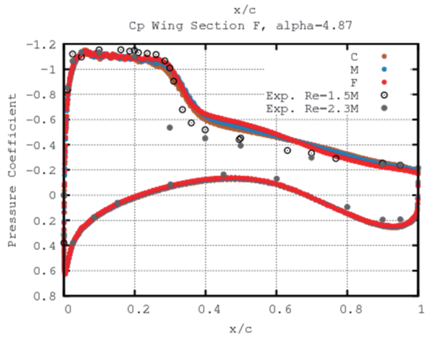


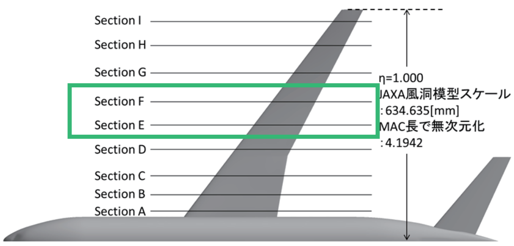
PSP data from Sugioka et al., “Non-Intrusive Unsteady PSP Technique For Investigation of Transonic Buffeting”, ICAS 2016

Resolution Study: Cp (4.87°)

- Good agreement with experiments
  - Small Reynolds effects for this AoA
- Medium and Fine resolutions yield very similar results

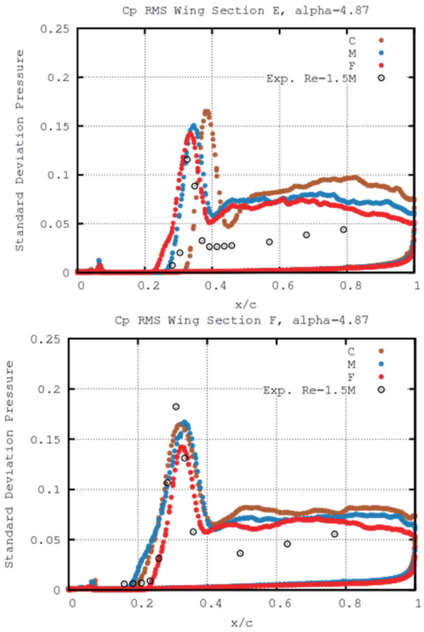


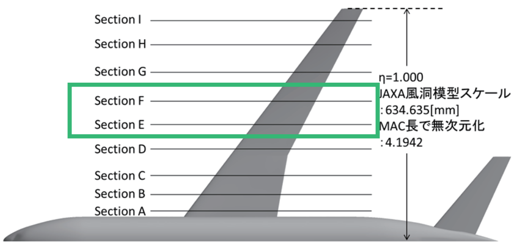




Resolution Study: Cp RMS (4.87°)

- Good agreement with experiments
  - Larger fluctuations in the flow separated region, which reduce with resolution
  - Likely due to flow structures having higher coherence due to coarse mesh
- Medium and Fine resolutions yield very similar results

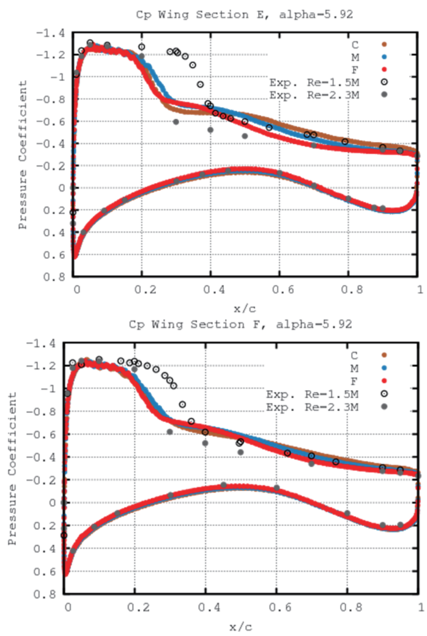


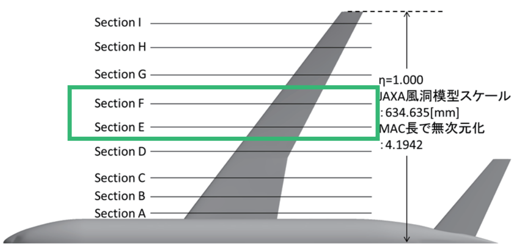


Exa

Resolution Study: Cp (5.92°)

- Good agreement with higher Reynolds number experiments
  - Strong Reynolds effect on shock position
- All resolutions yield very similar results

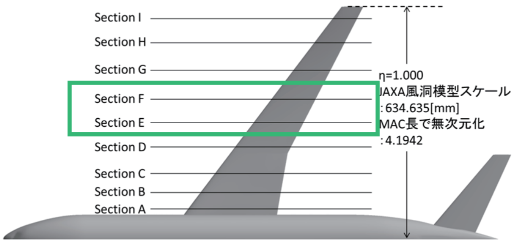


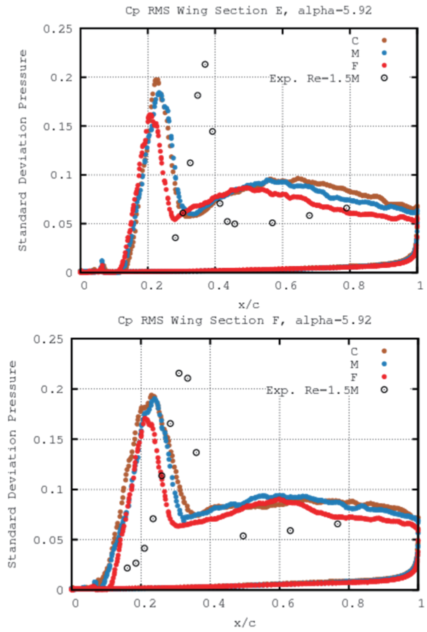


Exa

Resolution Study: Cp RMS (5.92 °)

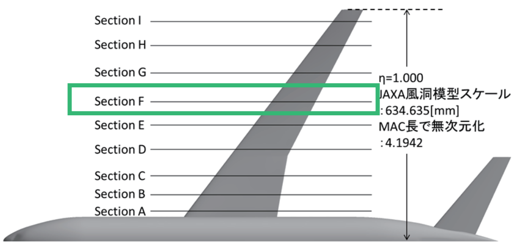
- Shock is too far upstream
  - Consistent with mean results
- All resolutions yield similar results
  - Fluctuations in the separated region are reducing with increased resolution

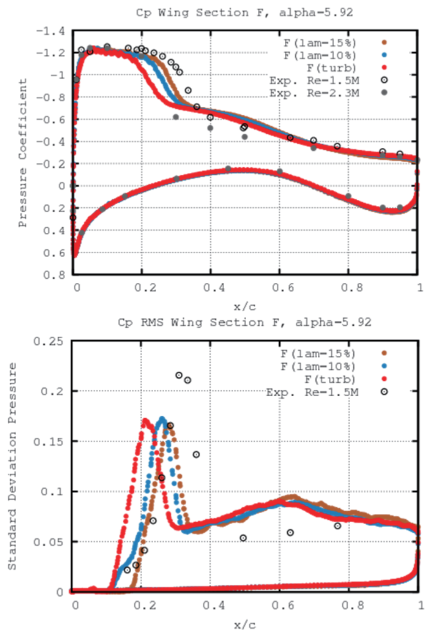




Transition Study: Cp and Cp RMS (5.92°)

- Laminar patches on the leading edge bring results closer to low Reynolds experiments
  - Shock moves downwind with laminar patches
- Experiments were tripped at 10% chord
  - Test with tripping at 15% represent a delayed transition





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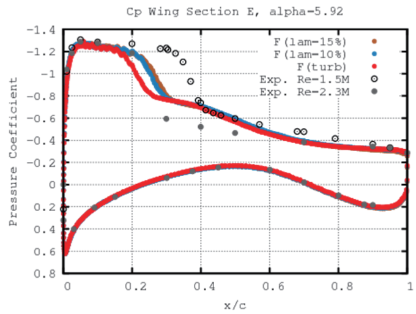

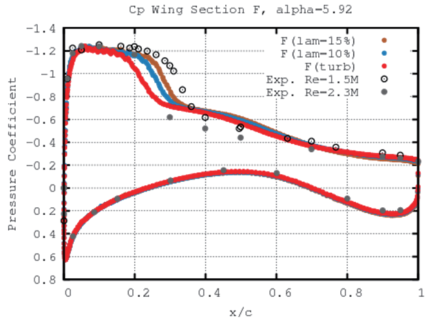

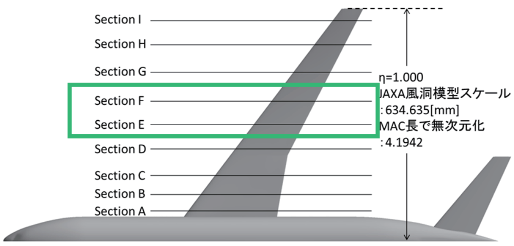

Exa

Transition Study: Cp RMS (5.92 °)

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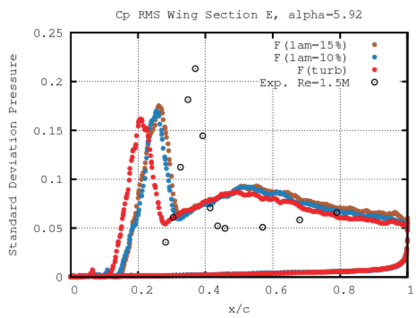
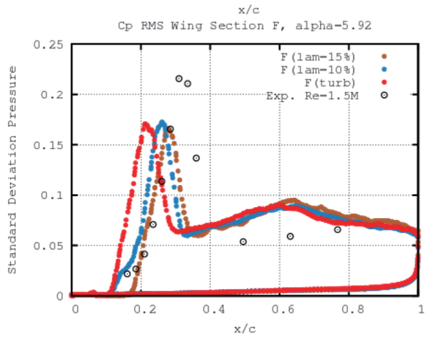
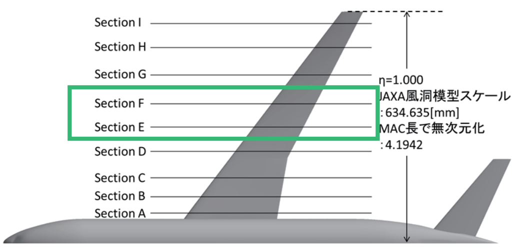


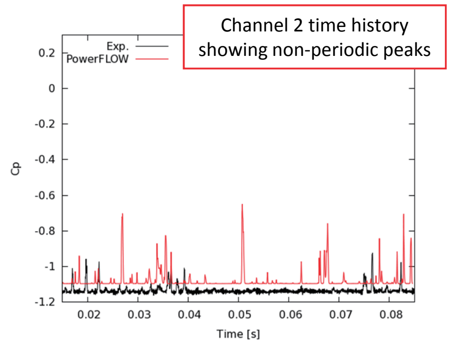


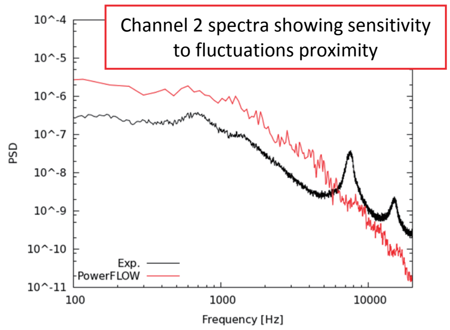


Exa

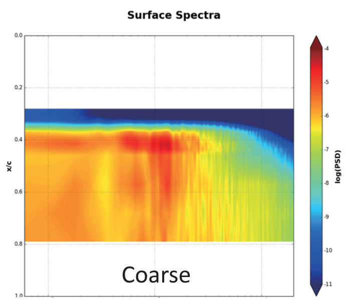
Notes on PSDs

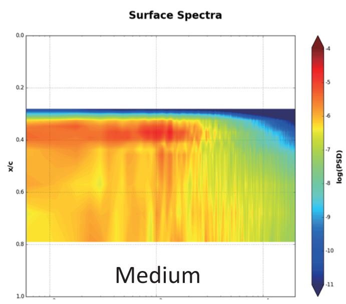
- Upwind of the shock the flow is not periodic, hence Fourier Transforms do not apply
- If the shock location is slightly different, the PSDs will look very different
- Hence, PSD contours are more adequate to check the results
  - Upwind spectra are generally low, so they do not pollute the contours

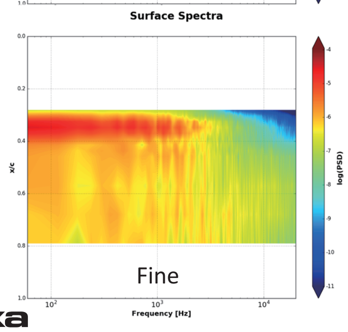


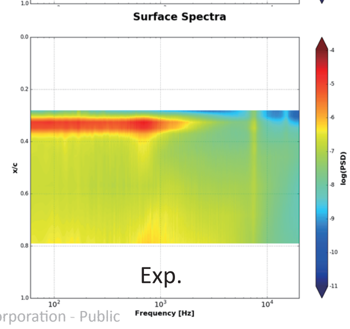


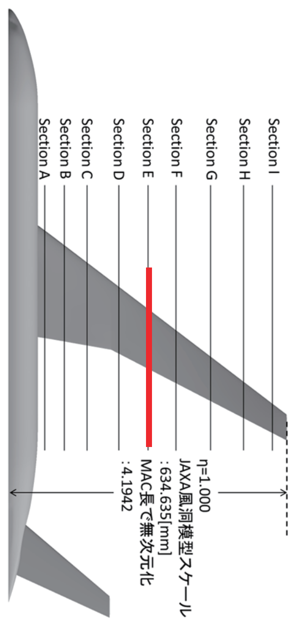
PSD (4.84°) – 50% span



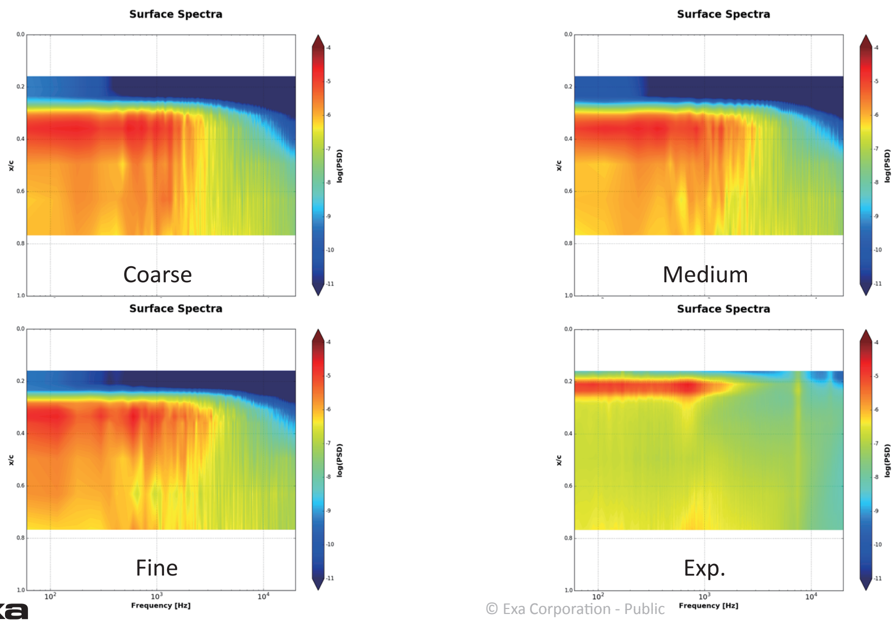


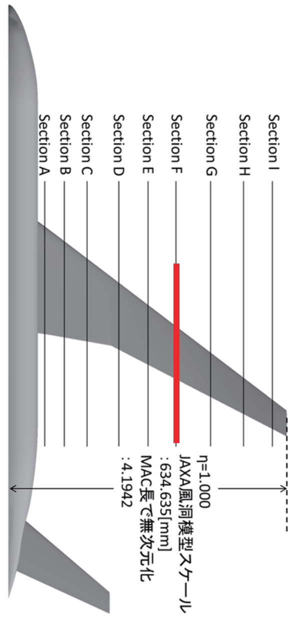






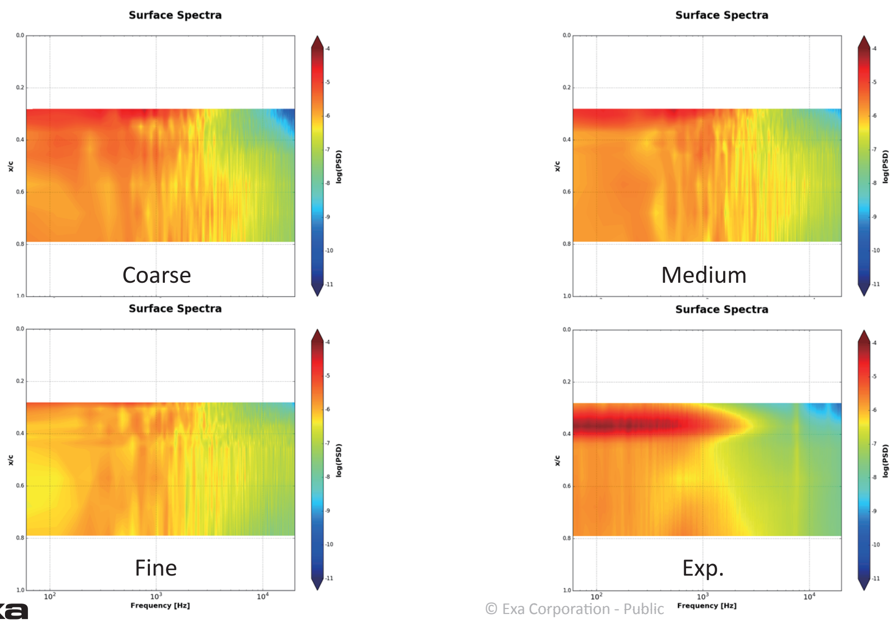
PSD (4.84°) – 60% span

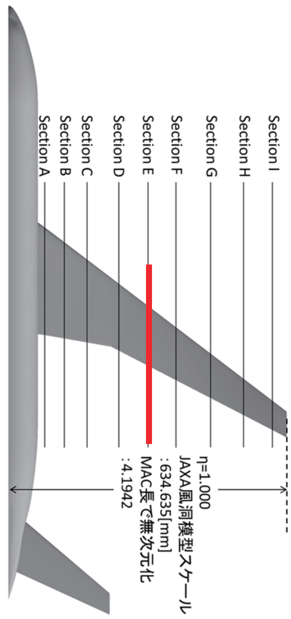




Exa

PSD (5.89°) – 50% span





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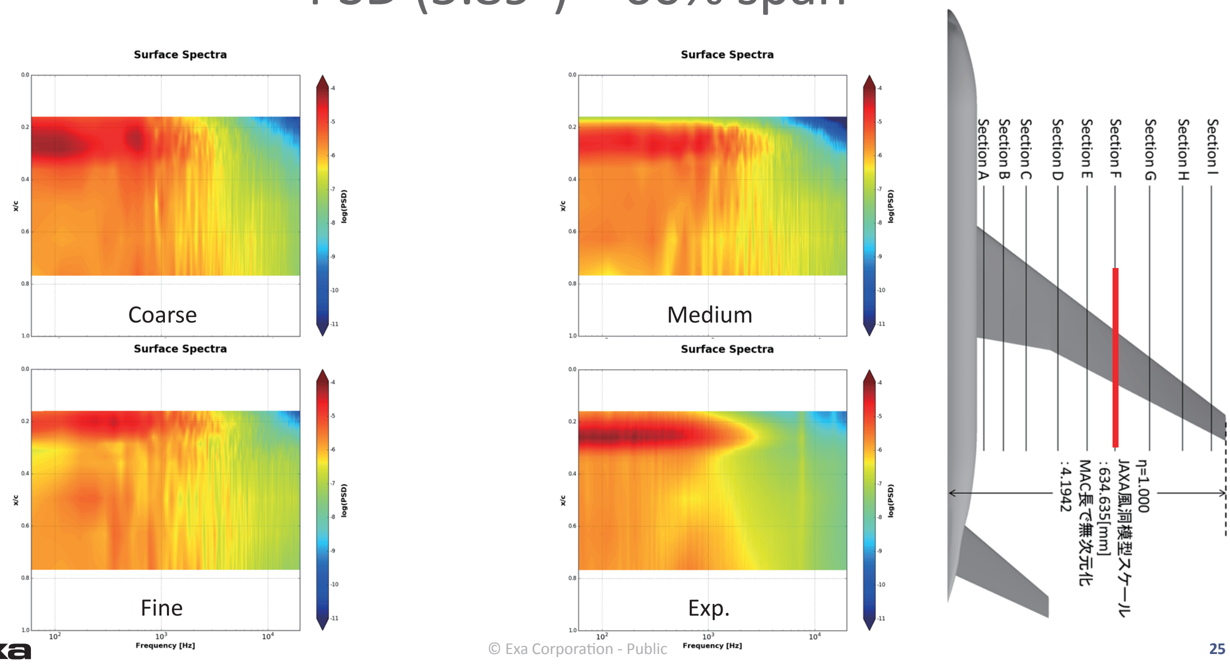

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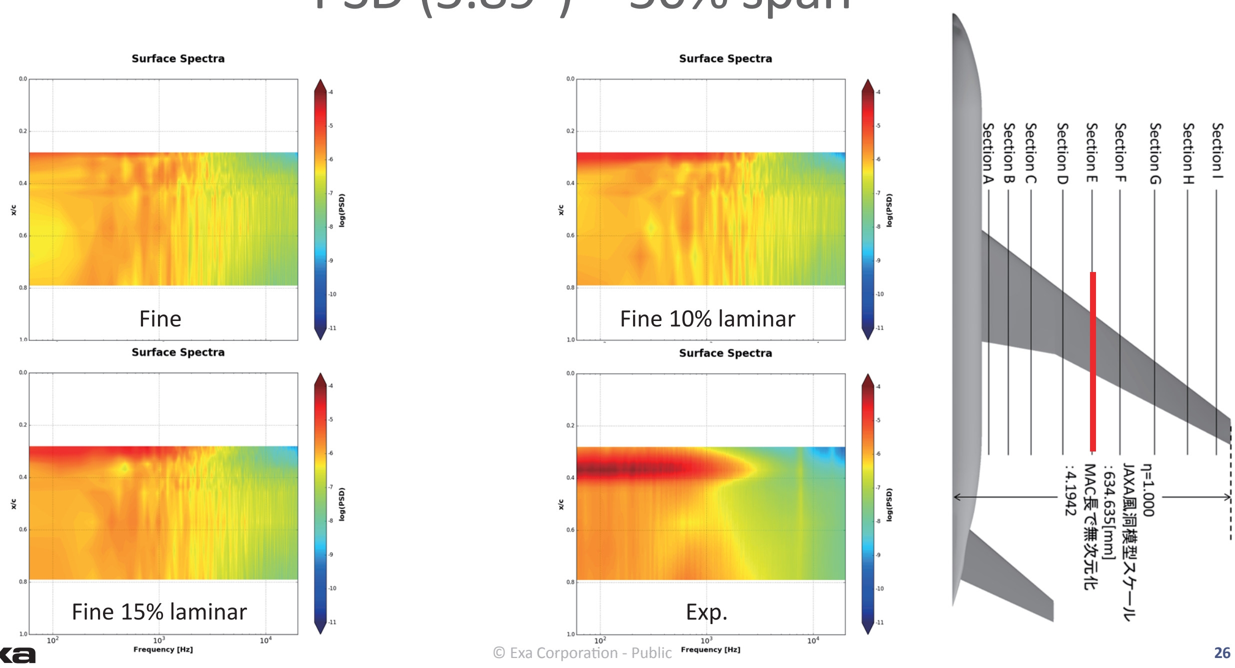
PSD (5.89°) – 50% span



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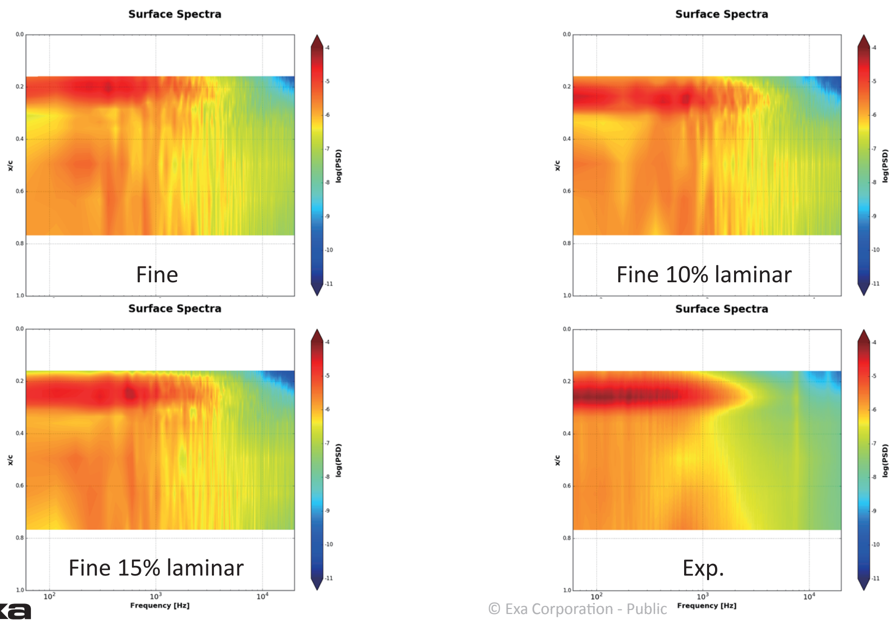
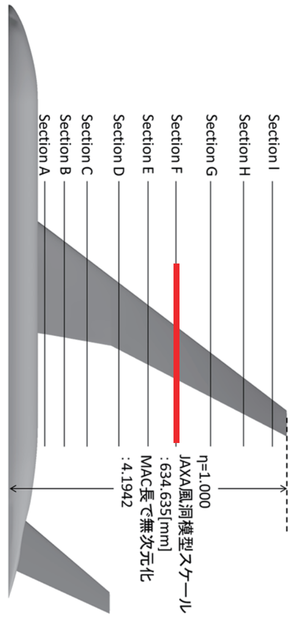
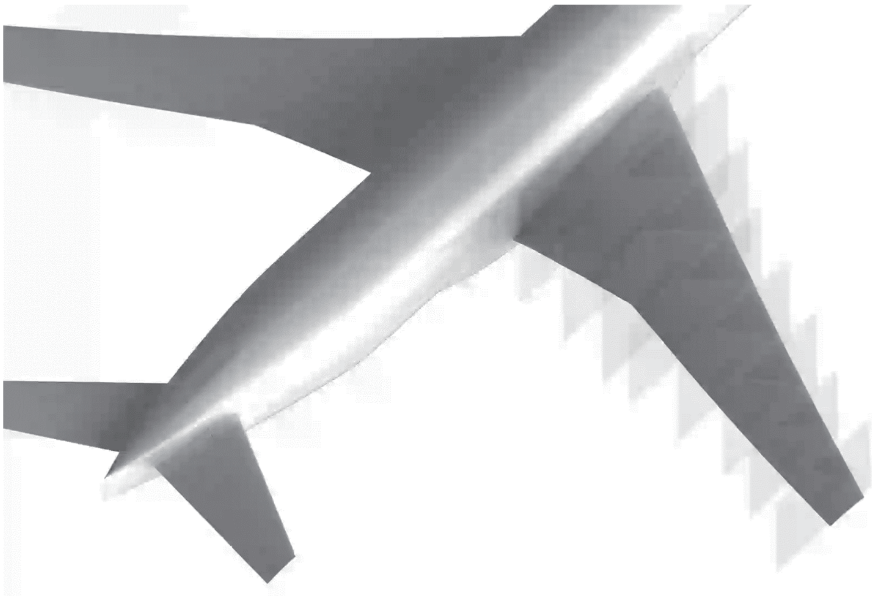




Summary

- CRM
  - Good comparison of mean flow and fluctuations
  - Laminar to turbulent transition was shown to play a key role
  - 3D buffet effect was shown and good agreement with PSP was seen
  - Comparison to PSD data shows good agreement in frequencies and levels

ありがとう



Exa

29