Enhancing Pressure Recovery in a Serpentine Duct using Active Flow Control

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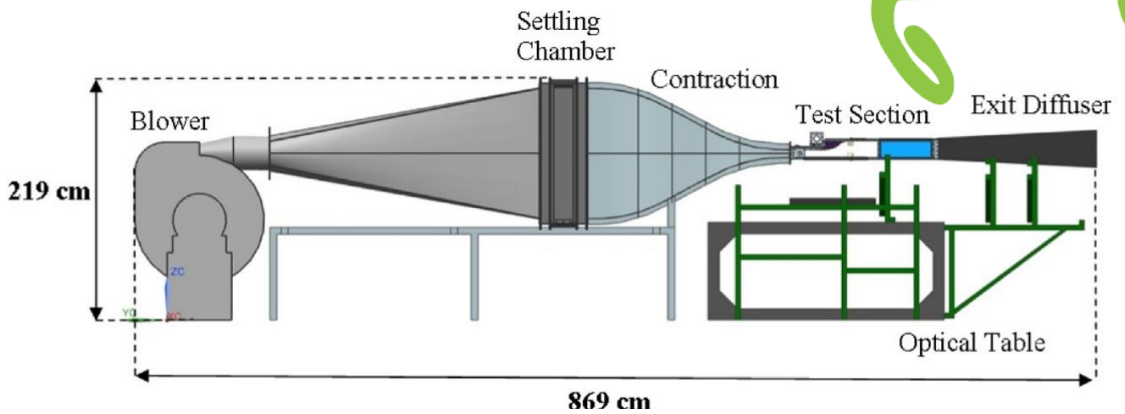
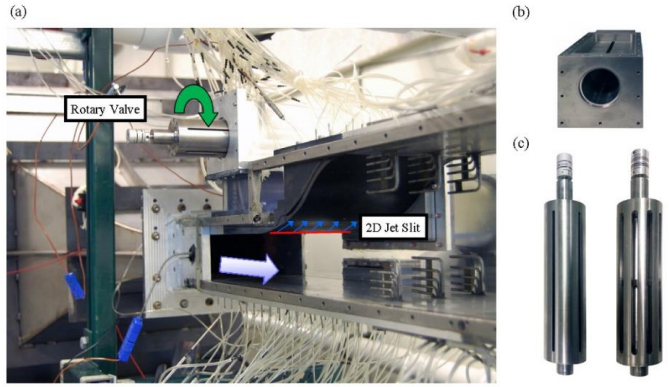
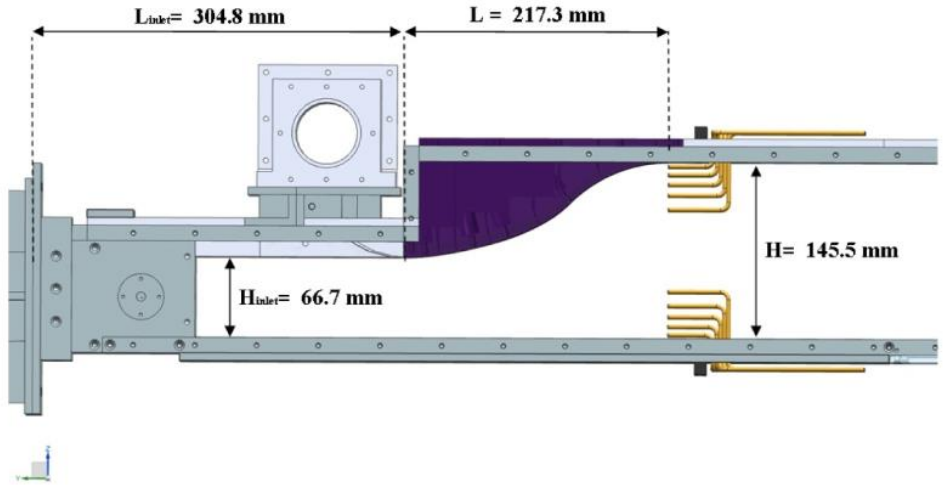
Background and Experimental Facility*

S-Duct Intake**





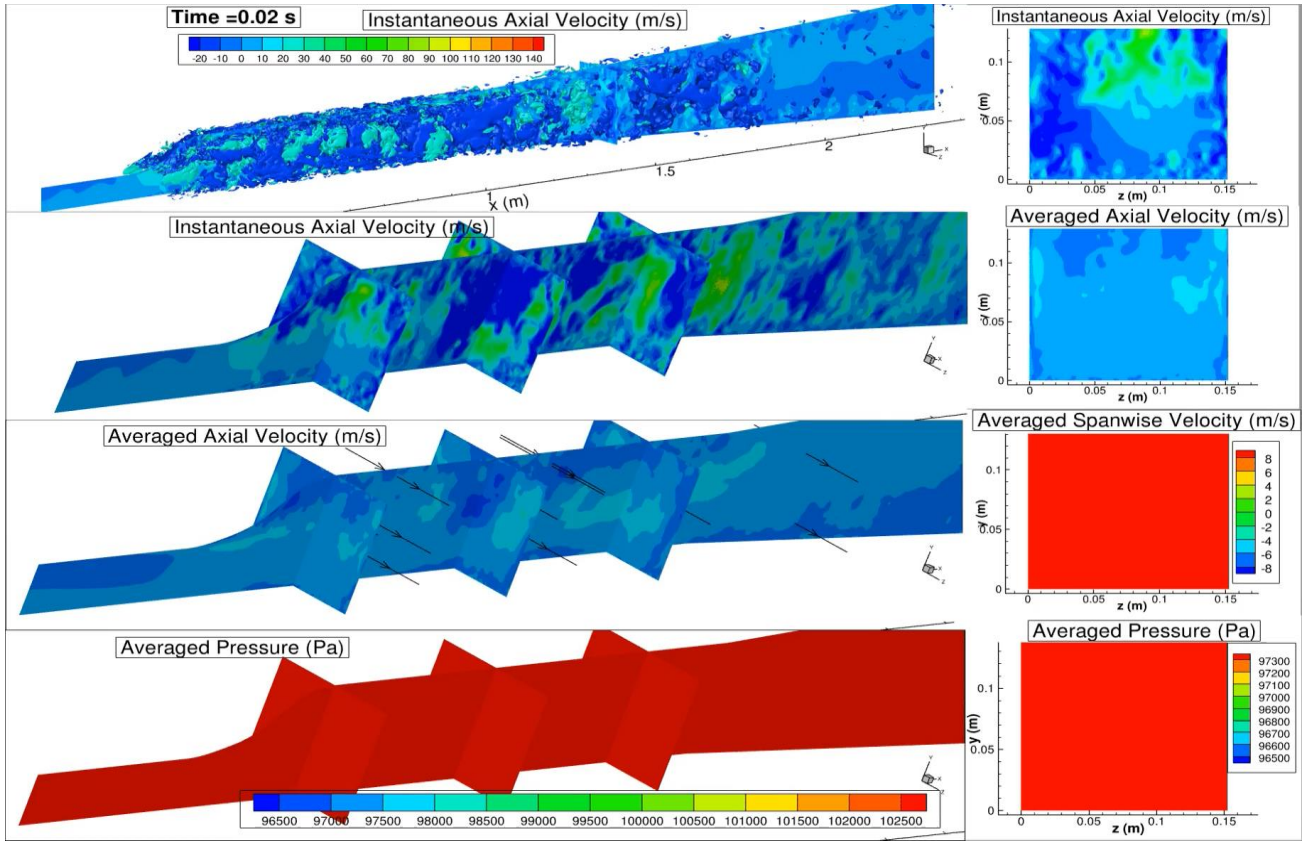


- Active and passive flow control methods were employed by CeFPaC to minimize total pressure losses.
- **Mach 0.4, Re ~ 1.6M.** This case was selected as the baseline, but measurements were conducted across a range of Reynolds and Mach numbers
- In this work, experimental measurements were compared with high-fidelity numerical simulations.

*Gartner, J., Rice, T. T., & Amitay, M. (2019). Mitigation of massively separated flow in a three-dimensional diffuser. *International Journal of Heat and Fluid Flow*, *76*, 242-258.

**Northrop McDonnell Douglas YF-23A PAV-1 87-0800 Black Widow II LEngineIntake R&D NMUSAF 25Sep09 (14414042127) - S-duct - Wikipedia

3D LES Calculations with No Control

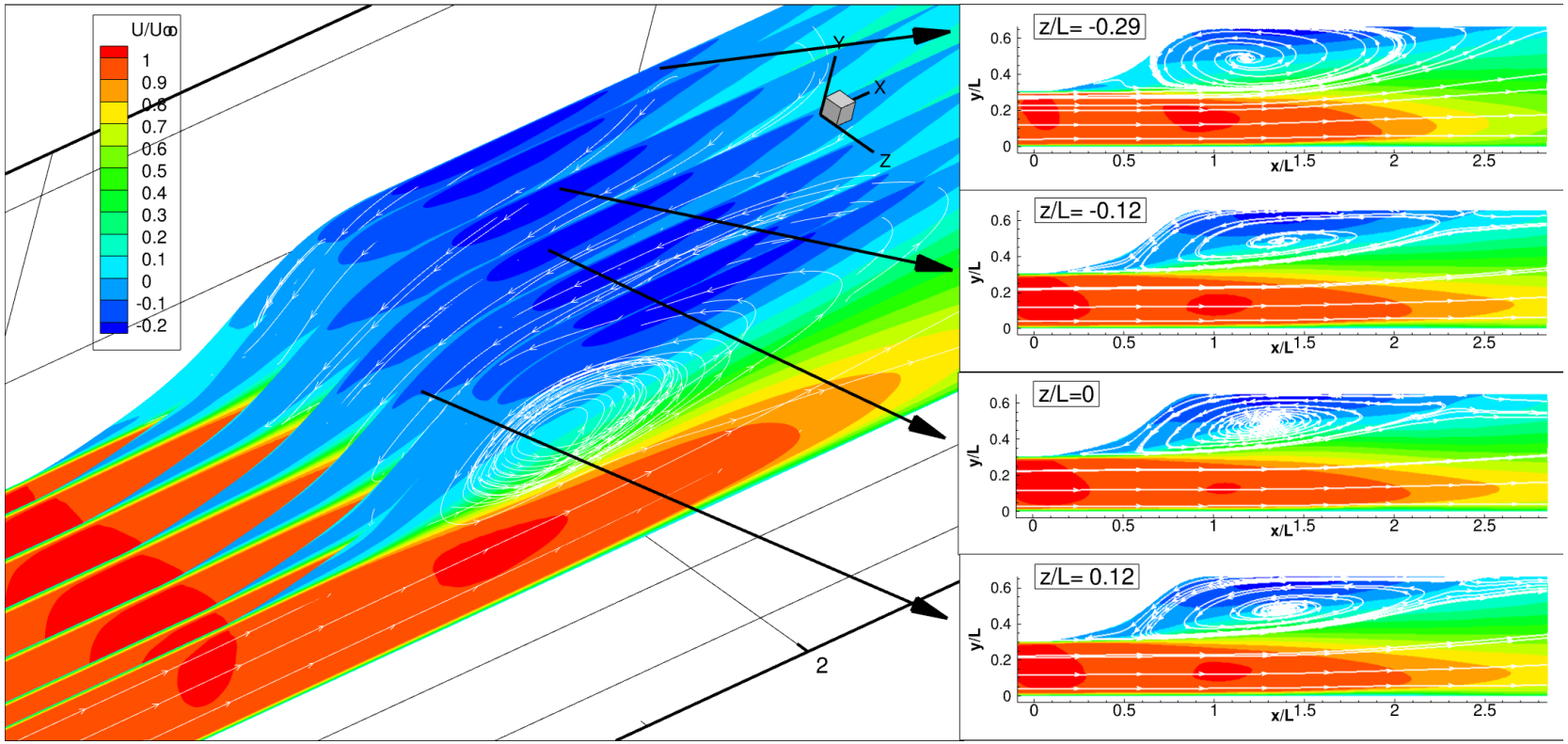


- **Secondary flow structure**, consistent with the experiment*, are captured in full 3D LES simulations.
- The flow establishes after 1 second.

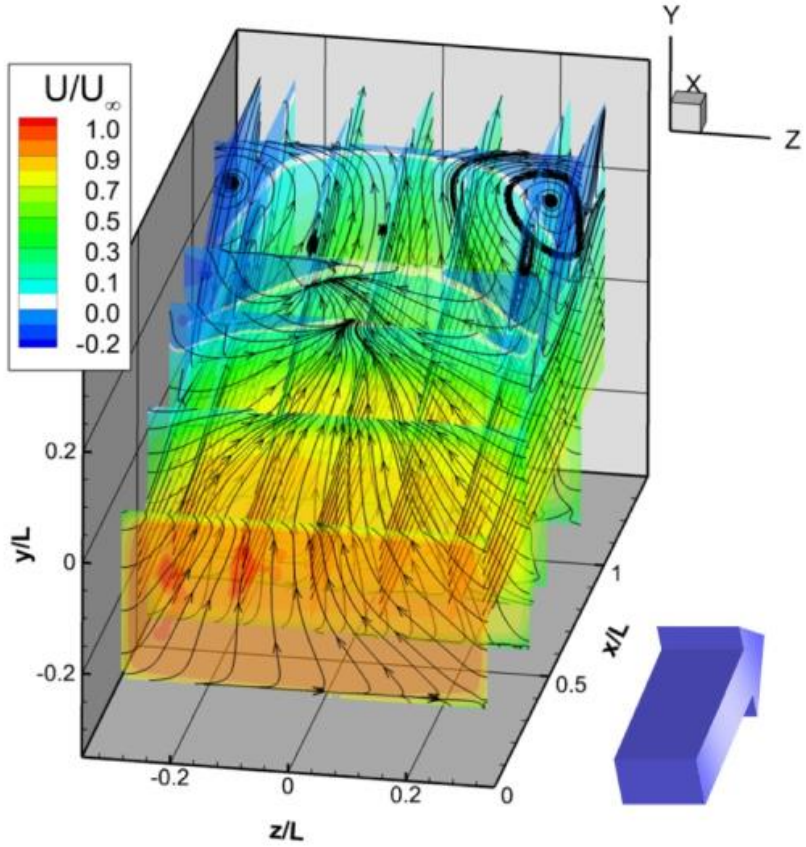
*Gartner, J., Rice, T. T., & Amitay, M. (2019). Mitigation of massively separated flow in a three-dimensional diffuser. *International Journal of Heat and Fluid Flow*, *76*, 242-258.

Comparisons with the Experiments*

3D LES Calculations



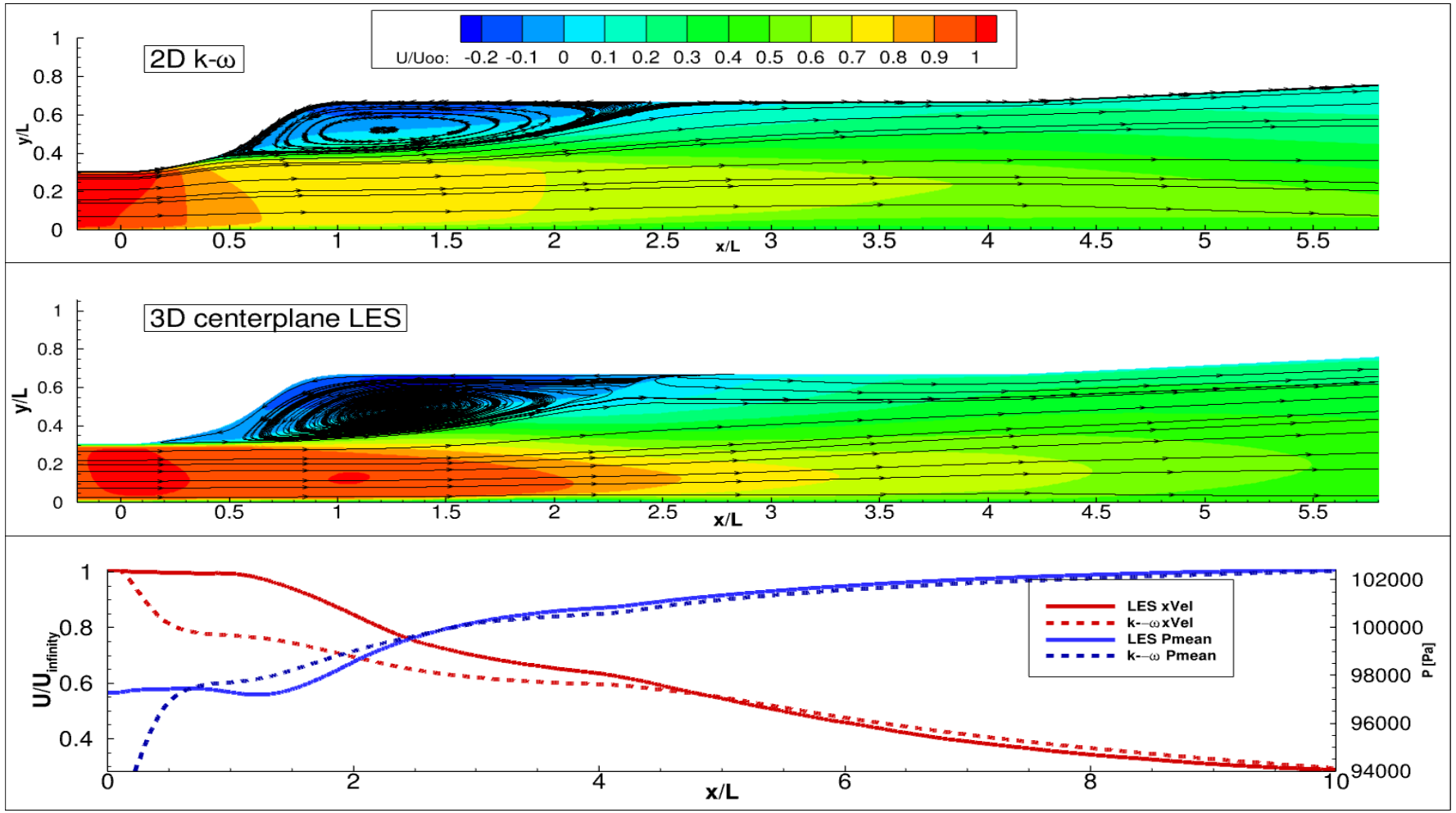
Measurement



- The spatial distribution of velocity magnitude shows good agreement with the measurements.
- The size of the separation region does not vary significantly across different spanwise planes.

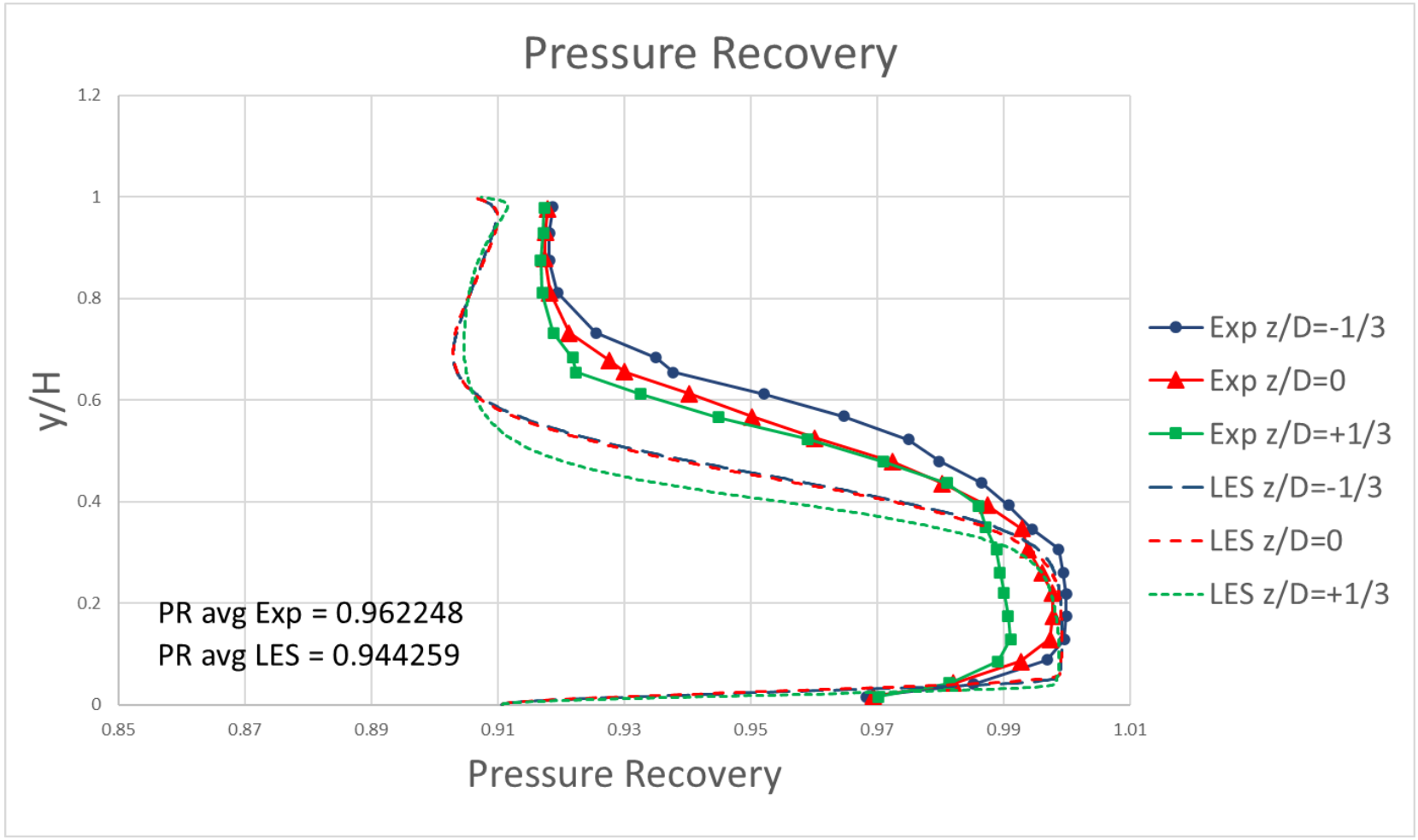
*Gartner, J., Rice, T. T., & Amitay, M. (2019). Mitigation of massively separated flow in a three-dimensional diffuser. *International Journal of Heat and Fluid Flow*, *76*, 242-258.

Comparison of 2D k-ω SST and 3D LES (No Control)



- The size and structure of the separation region are found to be similar.
- Relatively larger gradients are observed in the k-ω SST solution.

Comparison of the Pressure Recovery 3D LES (No Control)

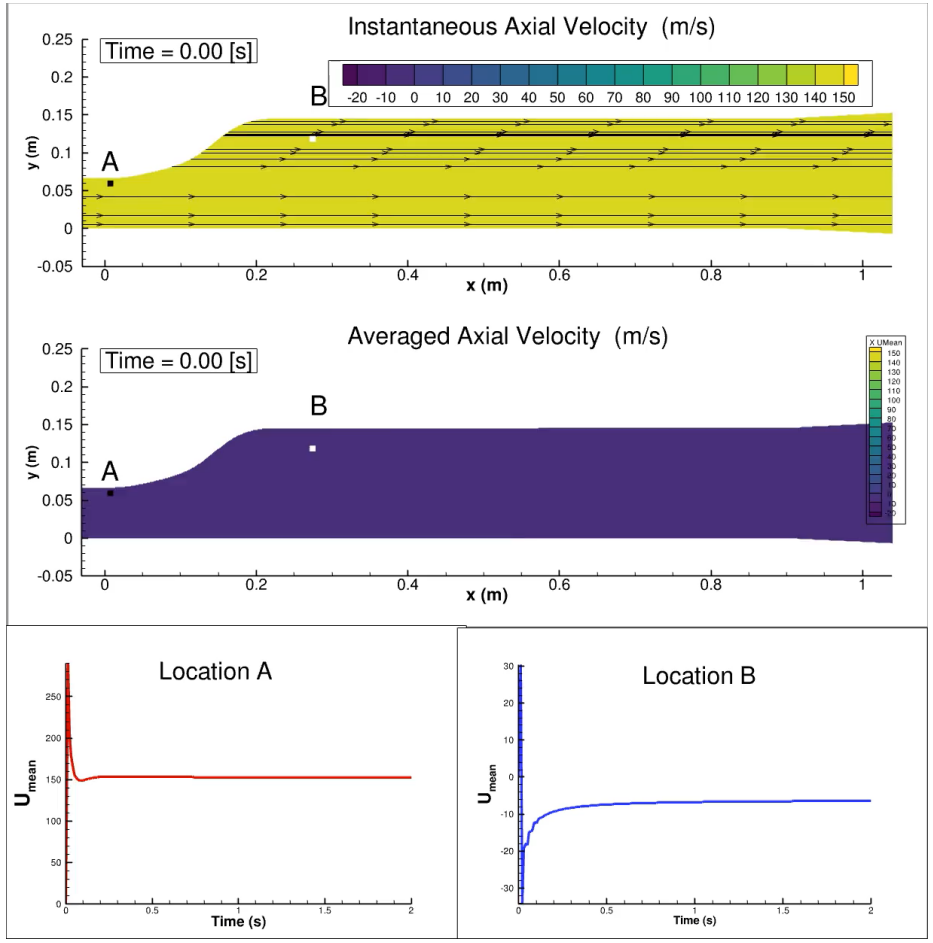


- Similar to the experiments, the pressure recovery at the location, defined as the ratio between the total pressure at the aerodynamic interface plane **(AIP)** and the total pressure at the inlet, does not vary significantly in the spanwise direction.

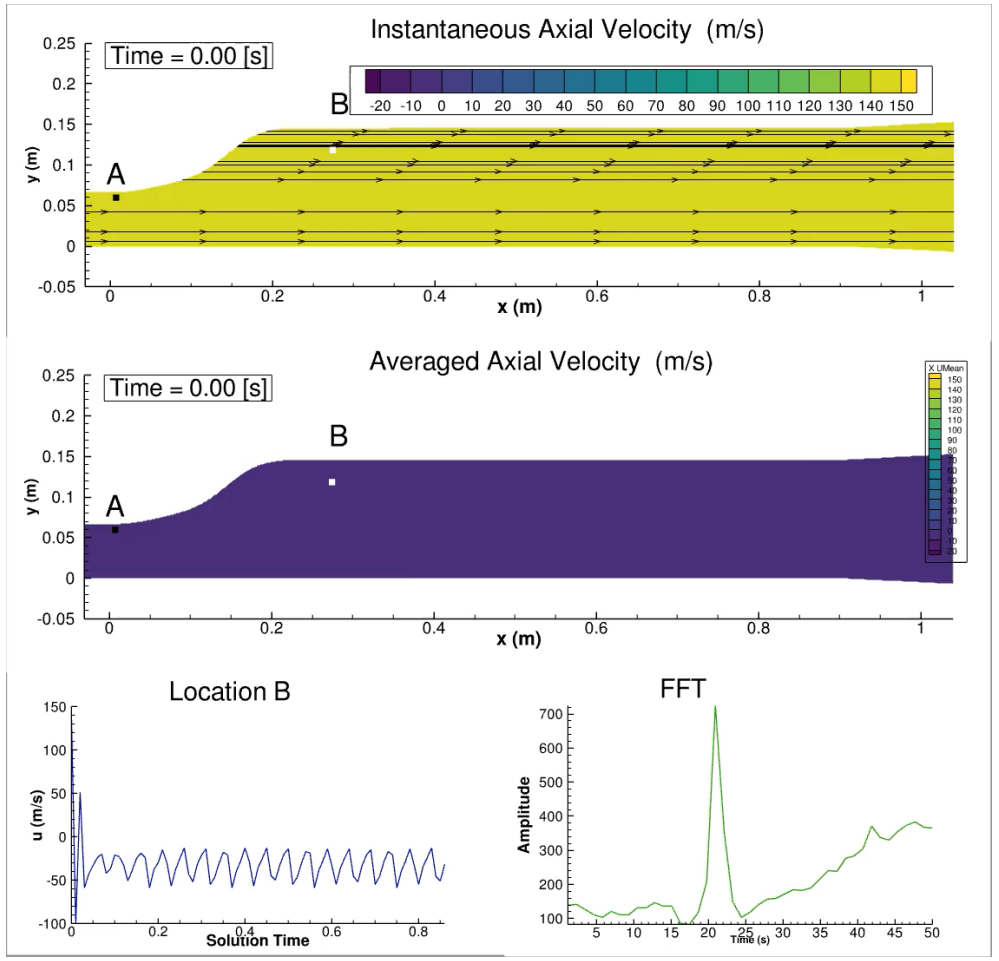
- The LES pressure recovery shows some discrepancies, which require further investigation.

Flow Control with 2D k-ω SST

No Control



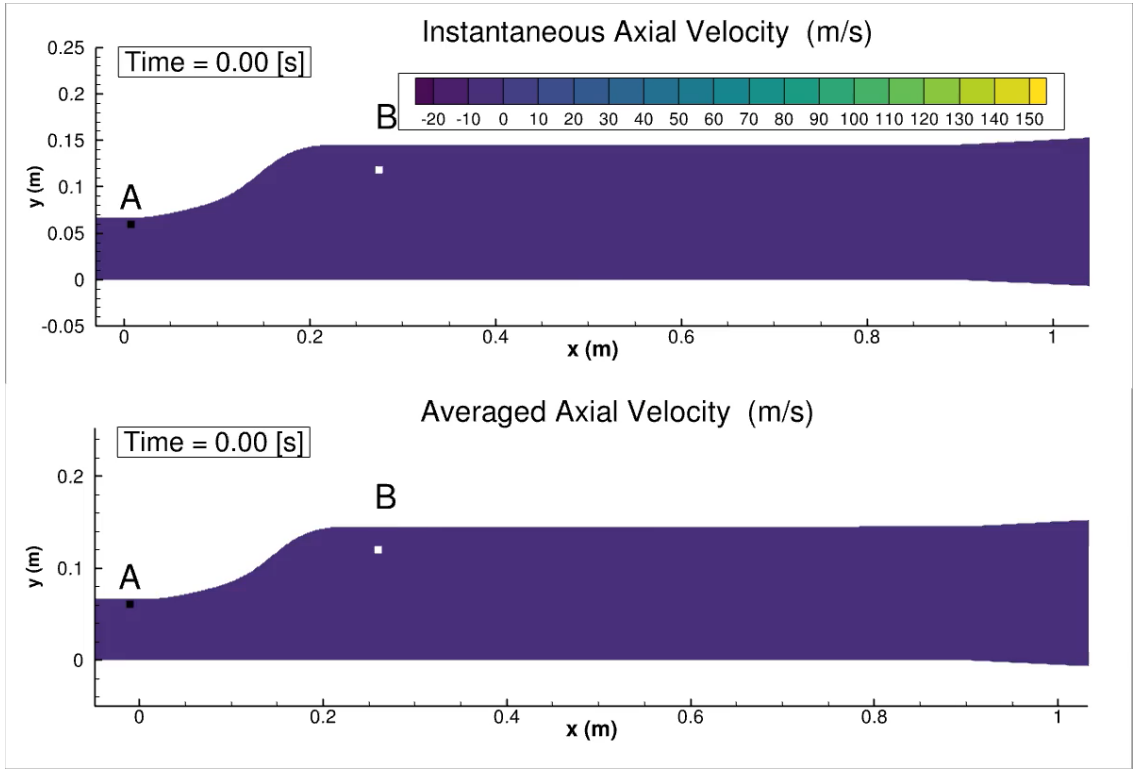
Steady Jet



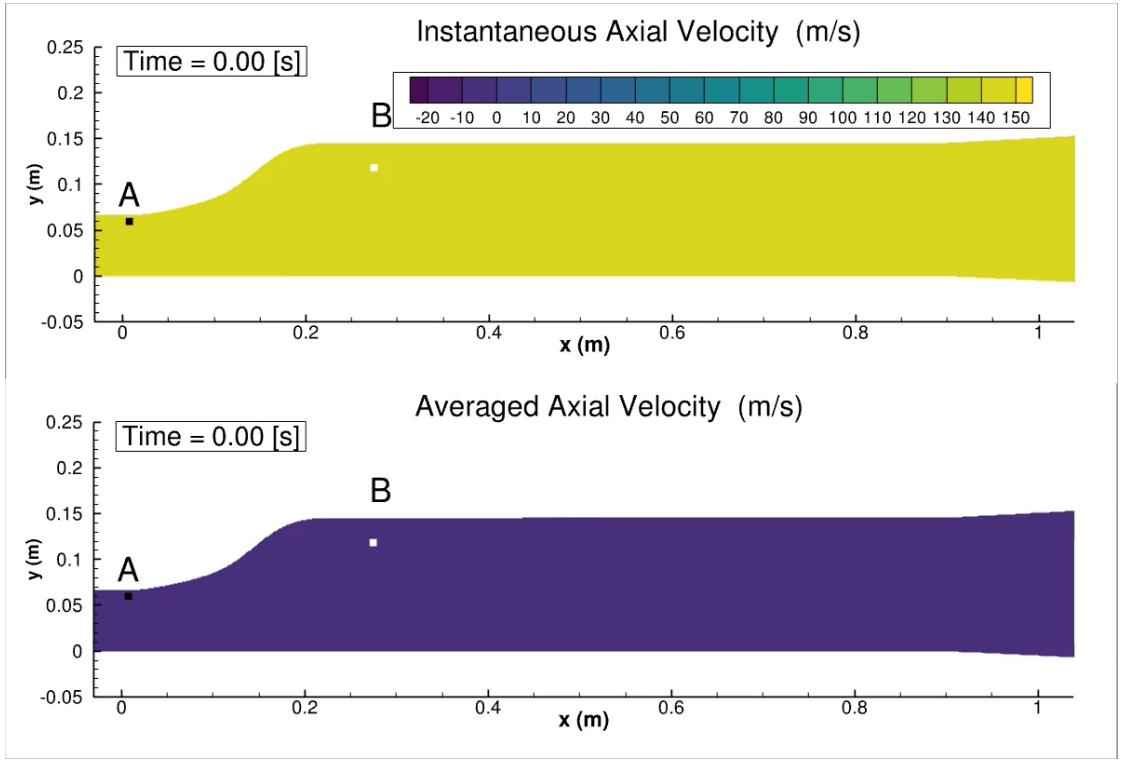
- 2D flow reaches a quasi-steady state earlier than the time predicted by 3D LES, likely due to the lack of secondary flow structures.
- A steady jet at location A, with velocities of 90 and 135 kPa, induces oscillations at a frequency of 22 Hz.

Flow Control with 2D k-ω SST

Low RMS

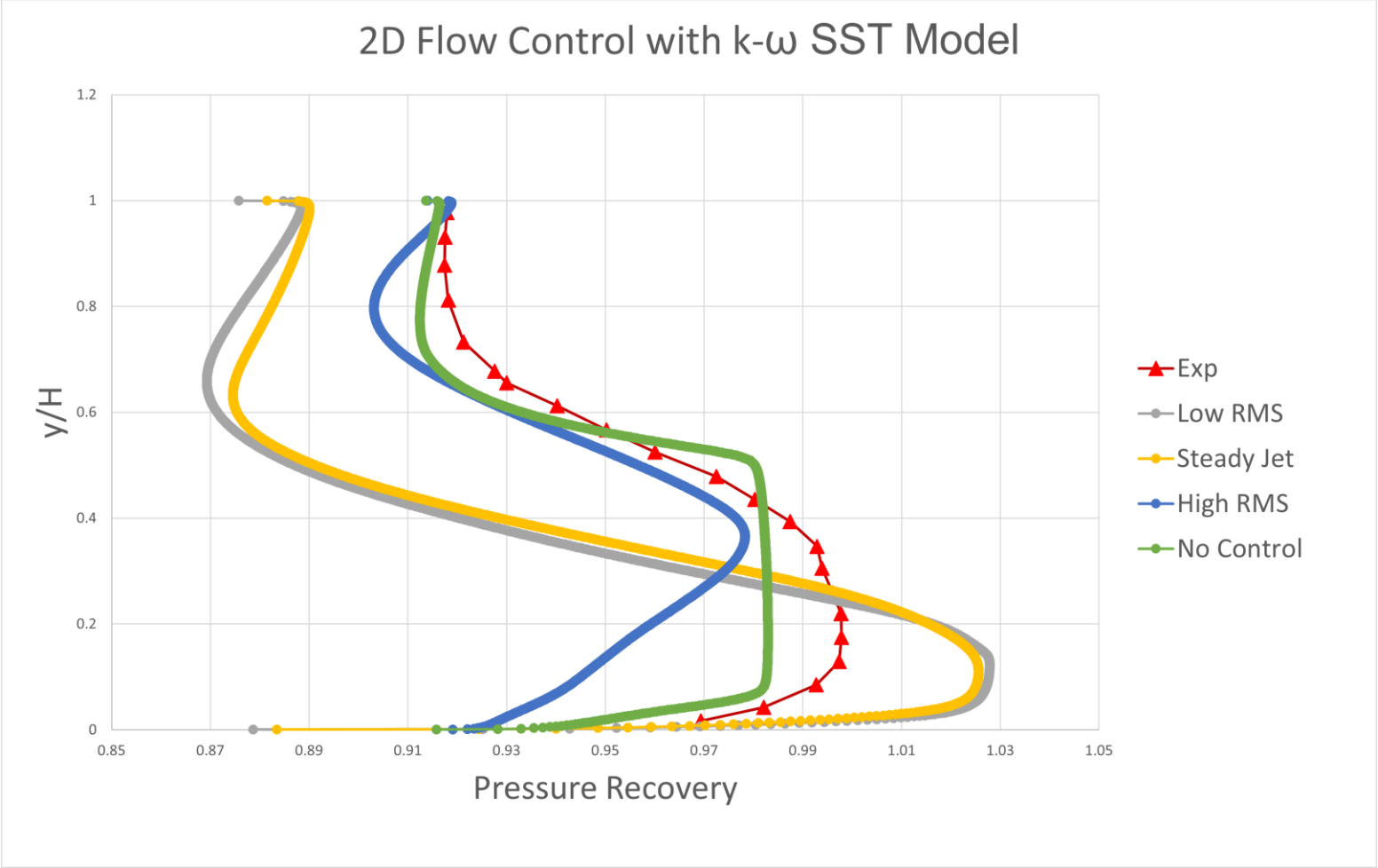


High RMS



- Low RMS jet injection induces flow oscillations with an approximate frequency of 40 Hz.
- High RMS flow injection significantly reduces the size of the separation region.

Comparison of the Pressure Recovery of 2D k-ω SST With Control



- The flow injection direction significantly affects the pressure recovery at the AIP.
- Oscillations induced by synthetic jets notably alter the pressure recovery.

Acknowledgement

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