



Transition Analysis for Isolated Trips on BOLT-II Wind-Tunnel and Flight Configurations

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Introduction

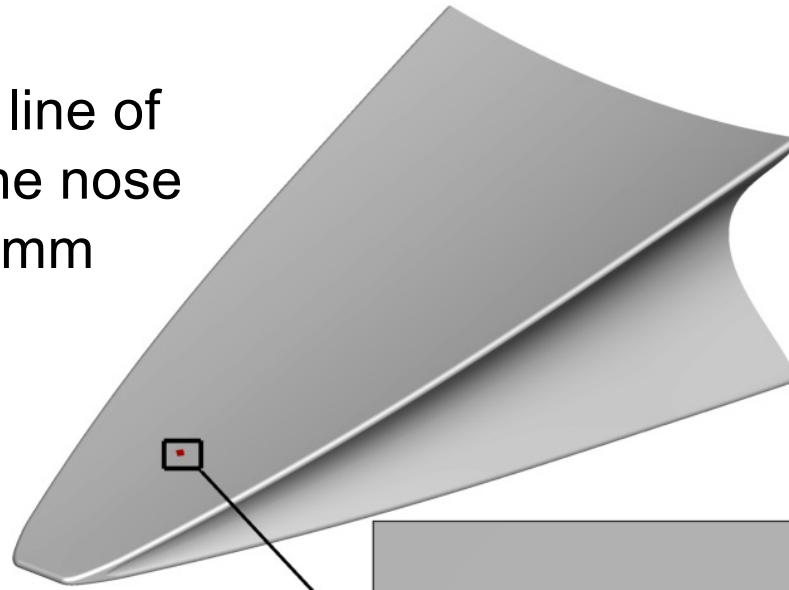
- Roughness in a boundary layer has a substantial impact on transition and, hence, on aerothermodynamic loading of hypersonic vehicles
- The current computational study is part of our effort in support of a NASA-led roughness experiment on the BOLT-II configuration
- Computations are performed for both the flight conditions and for a 1/3-scale wind tunnel model with a diamond-shaped roughness element placed on the symmetry line of the BOLT configuration
- Stability analyses are carried out for the wake region trailing the roughness



Introduction (continued)

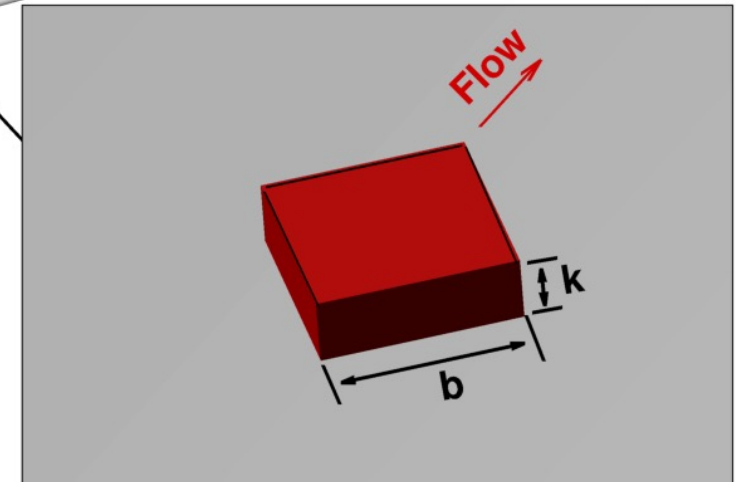
Flight condition:

- Roughness is placed on the line of symmetry at 254 mm from the nose
- Roughness height: $k=2.625$ mm
- Width to height ratio: $b/k = 3$
- $k/\delta \approx 0.7$



Tunnel condition (USAFA):

- Roughness is placed on the line of symmetry at 84.7 mm from the nose
- Roughness height: $k=0.875$ mm
- Width to height ratio: $b/k = 3$
- $k/\delta \approx 0.75$





Introduction (continued)

Freestream conditions

- **Flight:**
 - Mach: 5.44
 - Re: 2.49 M/m
 - Re_L : 2.49 M
 - U: 1637.6 m/s
 - P: 1637.7 Pa
 - T: 225 K
- **Tunnel (USAFA):**
 - Mach: 5.9
 - Re: 20.25 M/m
 - Re_L : 6.75 M
 - U: 918.4 m/s
 - P: 1648.9 Pa
 - T: 60.28 K



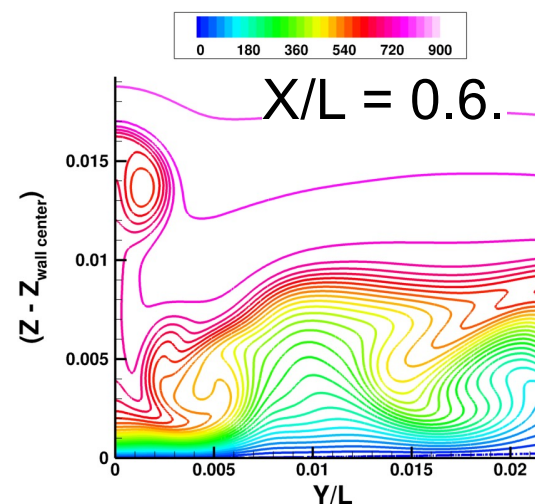
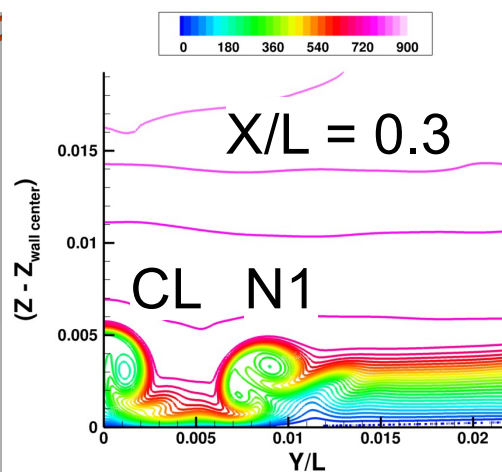
Introduction (continued)

- VULCAN-CFD (2nd order) for base flow computations
- DNS for (7th order) for base flow computations
- Partially nonparallel (PNP) eigenvalue analysis and plane marching parabolized stability equations (PSE) for stability computations
- In the paper, we carried out stability analysis of the wake trailing the roughness as well as an examination of some of the well-known transition correction parameters due to isolated roughness elements. In this ten-minute talk, we will mainly present the stability analysis results

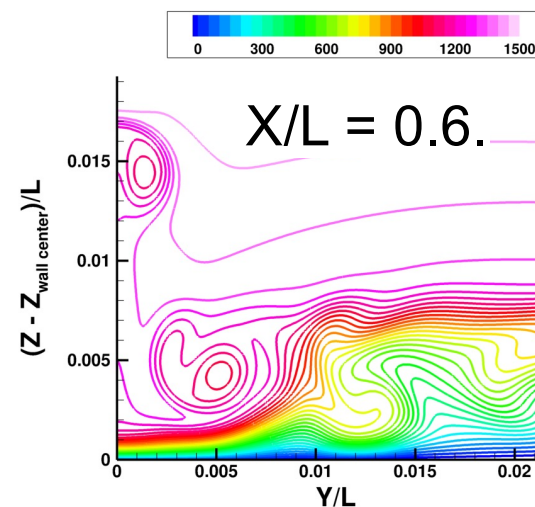
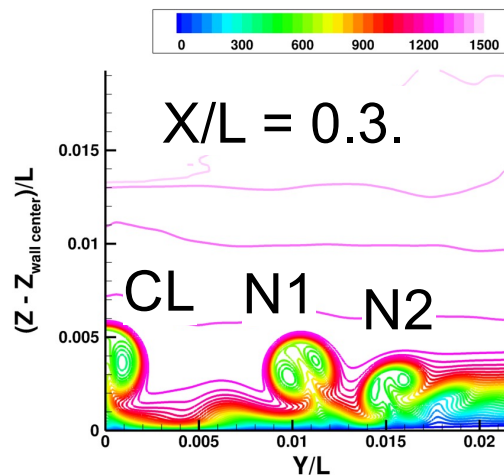
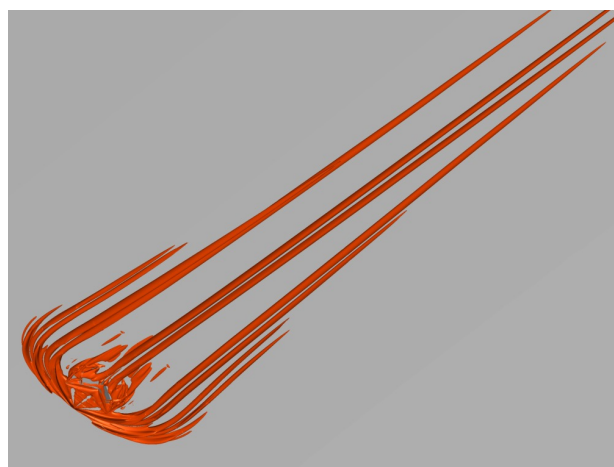


Base Flow

Tunnel, Mach = 5.9, Re = 20.25M/m



Flight, Mach = 5.44, Re = 2.49M/m

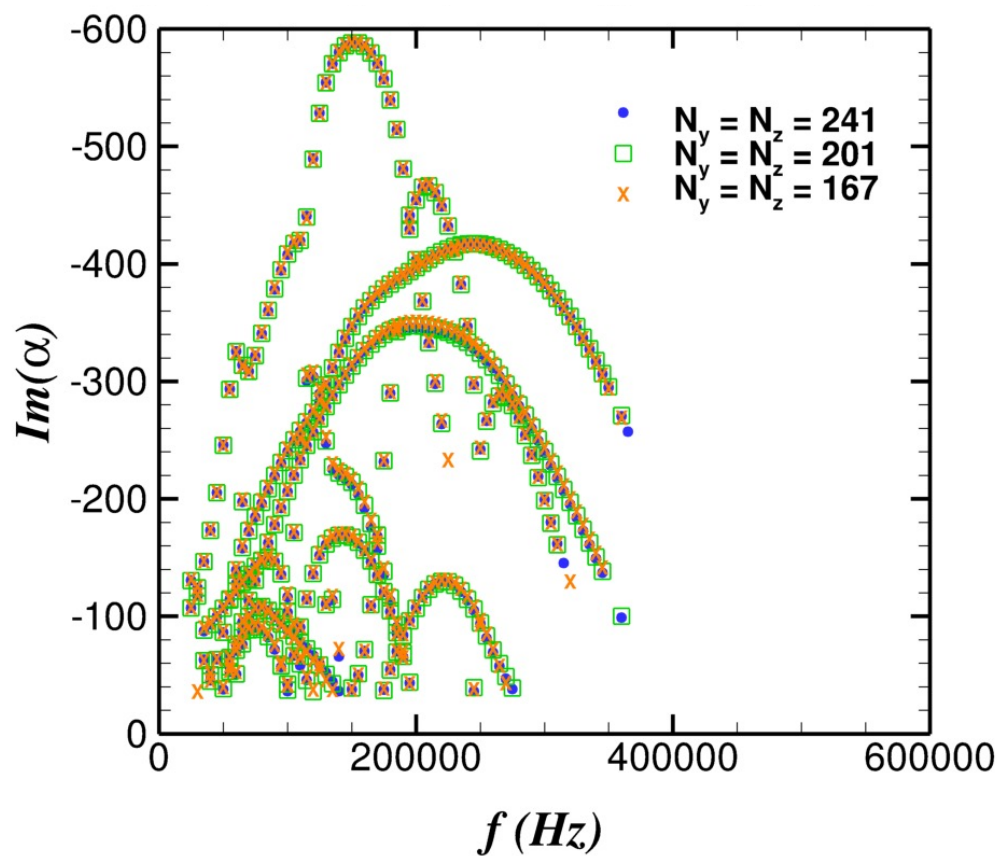




Growth Rate Spectra

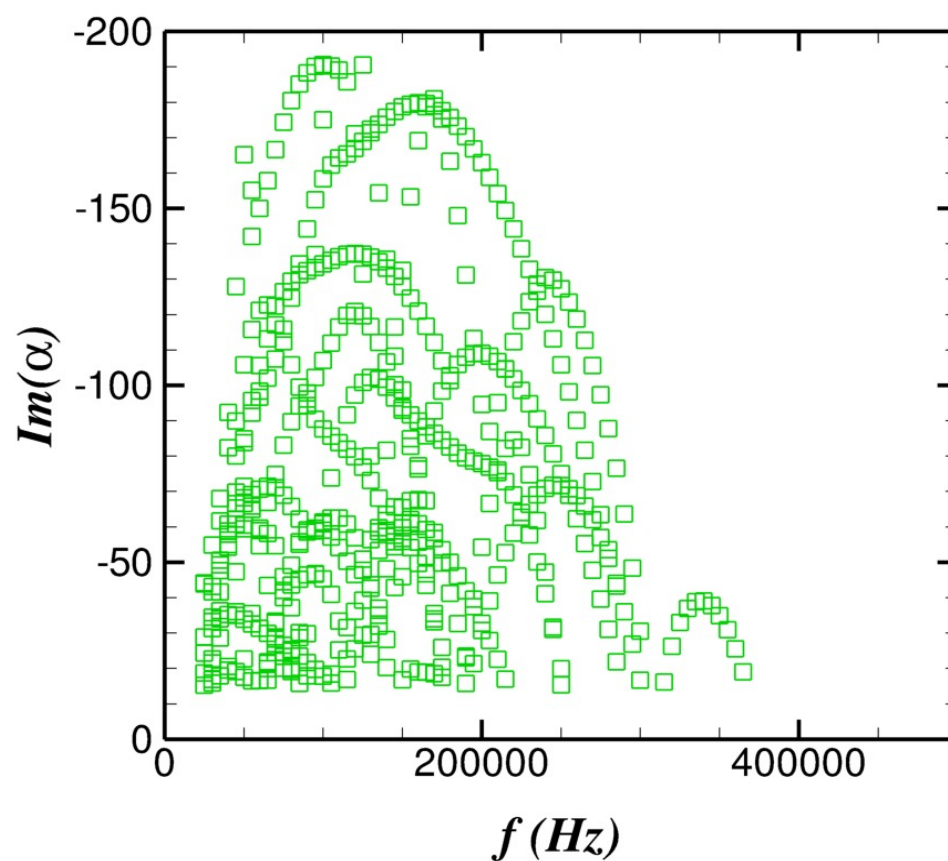
Tunnel

Mach = 5.9, Re = 20.25M/m



Flight

Mach = 5.44, Re = 2.49M/m



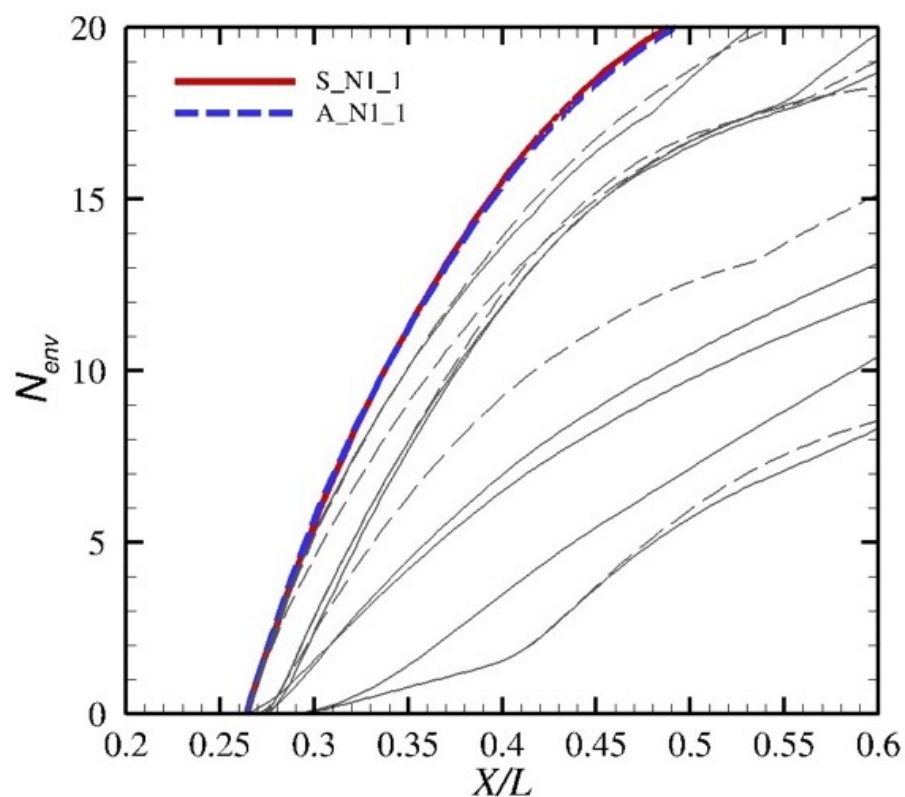
$X/L = 0.275$



N-Factors

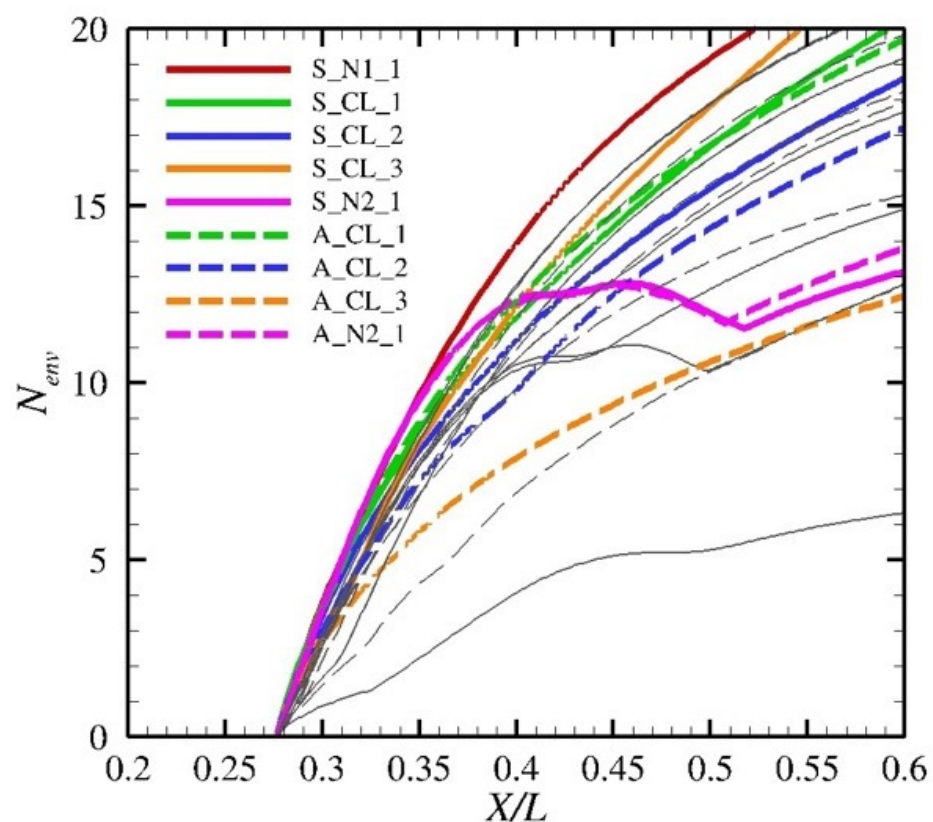
Tunnel

Mach = 5.9, Re = 20.25M/m



Flight

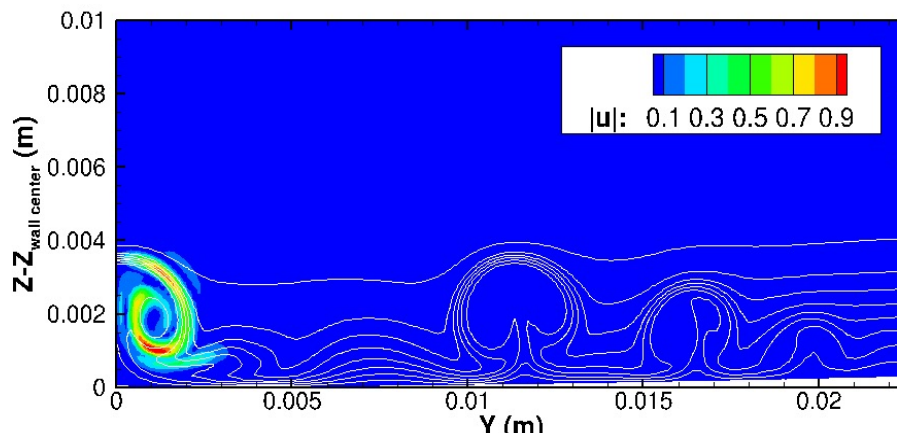
Mach = 5.44, Re = 2.49 M/m



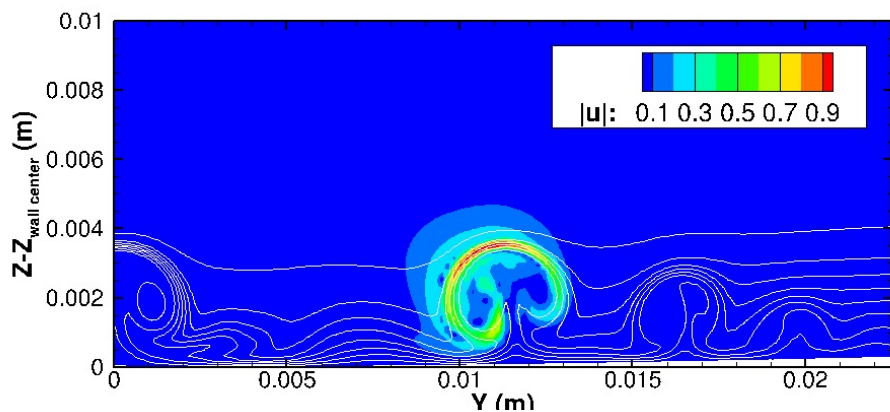


Representative Eigenfunctions

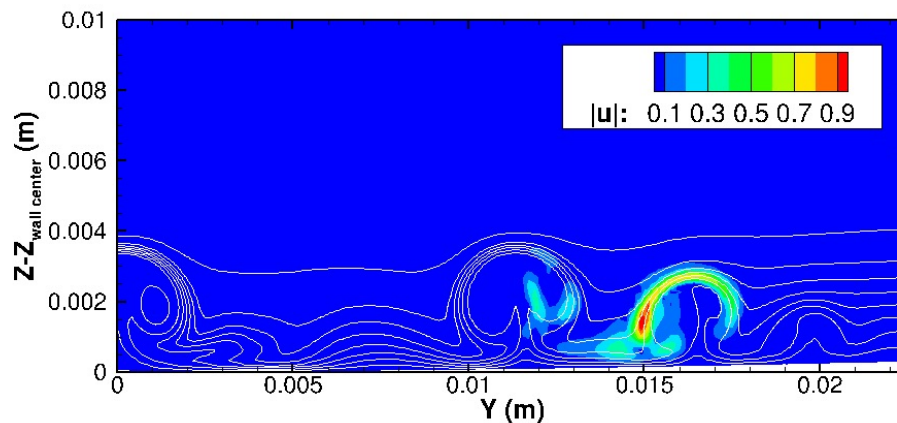
CL mode



N1 mode



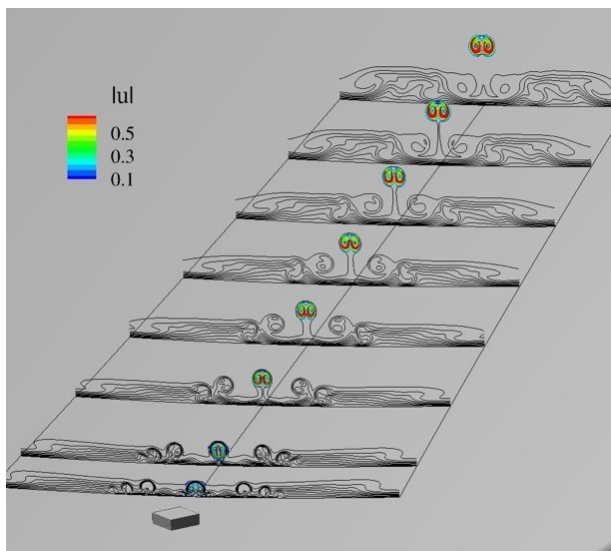
N2 mode



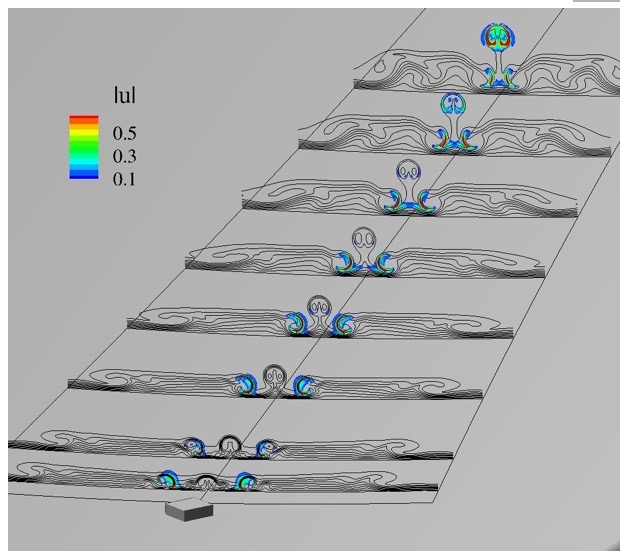


Evolution of Representative Eigenmodes

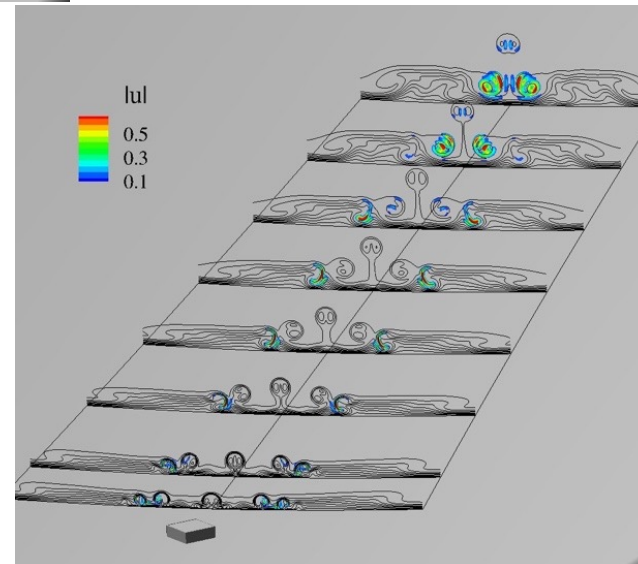
CL mode



N1 mode



N2 mode





Summary

- Multiple types of instability modes were predicted to undergo strong amplification within the wake of the trip
- Several different families of instability modes within the frequency range of 95 kHz – 255 kHz estimated to achieve logarithmic amplification factors of $N = 15$ or greater
- The fastest amplifying mode is concentrated within the necklace vortex N1, has a frequency of approximately 225 kHz and is predicted reach $N = 15$ as early as $X/L = 0.42$ for flight case



Acknowledgements

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- Technical discussions with other team members from the Texas A & M University and the University of Arizona are acknowledged