Aerothermodynamic Research in the HIFiRE Program

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HIFiRE Program

- Hypersonic International Flight Research and Experimentation
- Air Vehicles Directorate, Australian Defence Science and Technology Organisation
- National, international partners
- Computation and test culminating in flight
- 8 flights emphasize multiple disciplines
  - Propulsion
  - Guidance, navigation, control
  - 2 Aerothermodynamics flights

HIFiRE-1
March 2010

Axisymmetric
BLT, SBLI

HIFiRE-5
April 2012

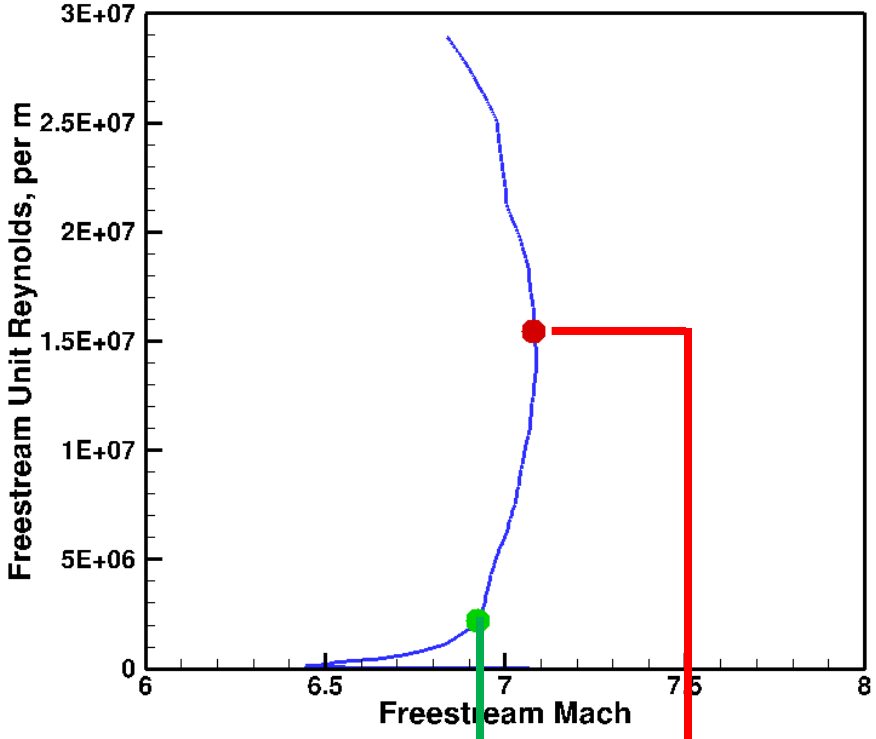
Elliptic
Cone - 3D
Transition

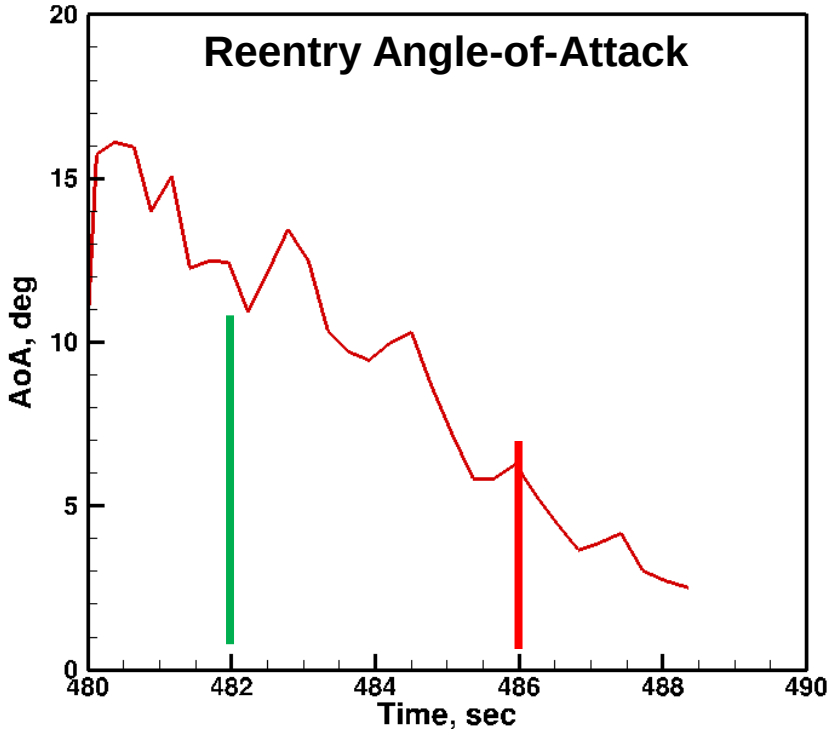
Overview

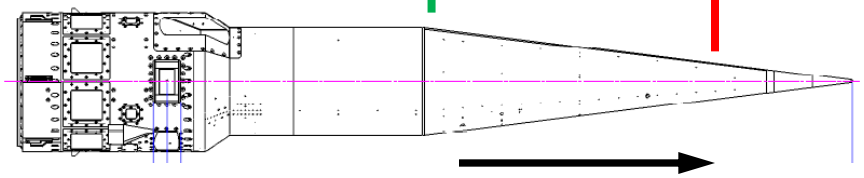
- **HIFiRE-1 flight test analysis**
  - **Descent, high AoA BLT**
  - **Ascent SBLI**
- **HIFiRE-5 wind tunnel tests**
  - **Stationary crossflow and roughness**
  - **Traveling crossflow**

Developing understanding of transition in 3D flows

HIFiRE-1 Descent





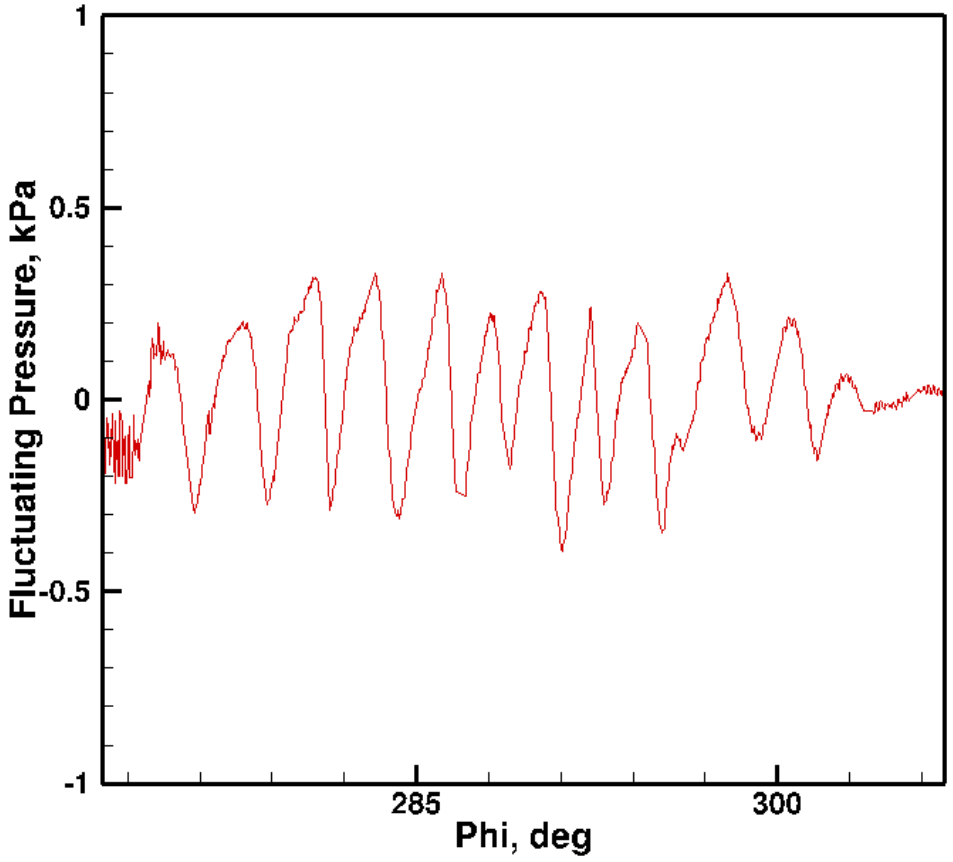


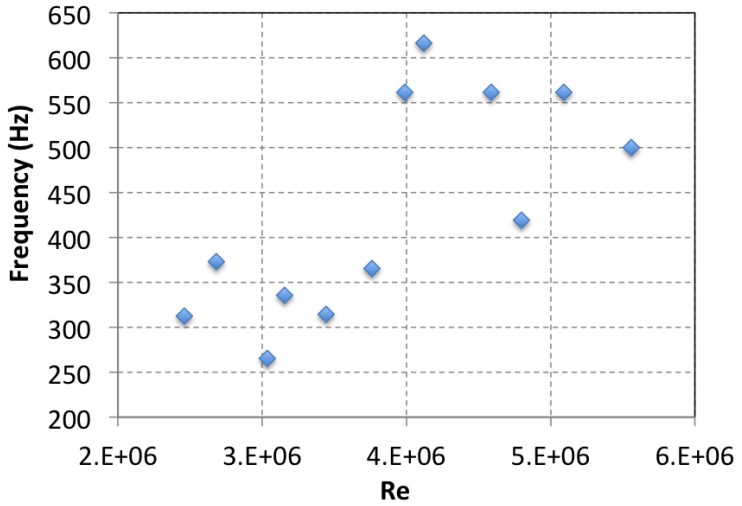
Reentry Transition Front Movement

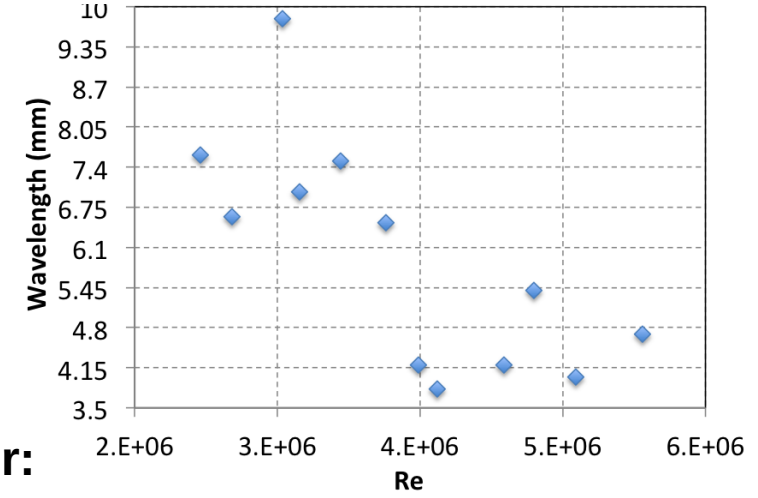
High bandwidth surface sensors resolve 3D transition front

4

Periodic Pressure Fluctuations



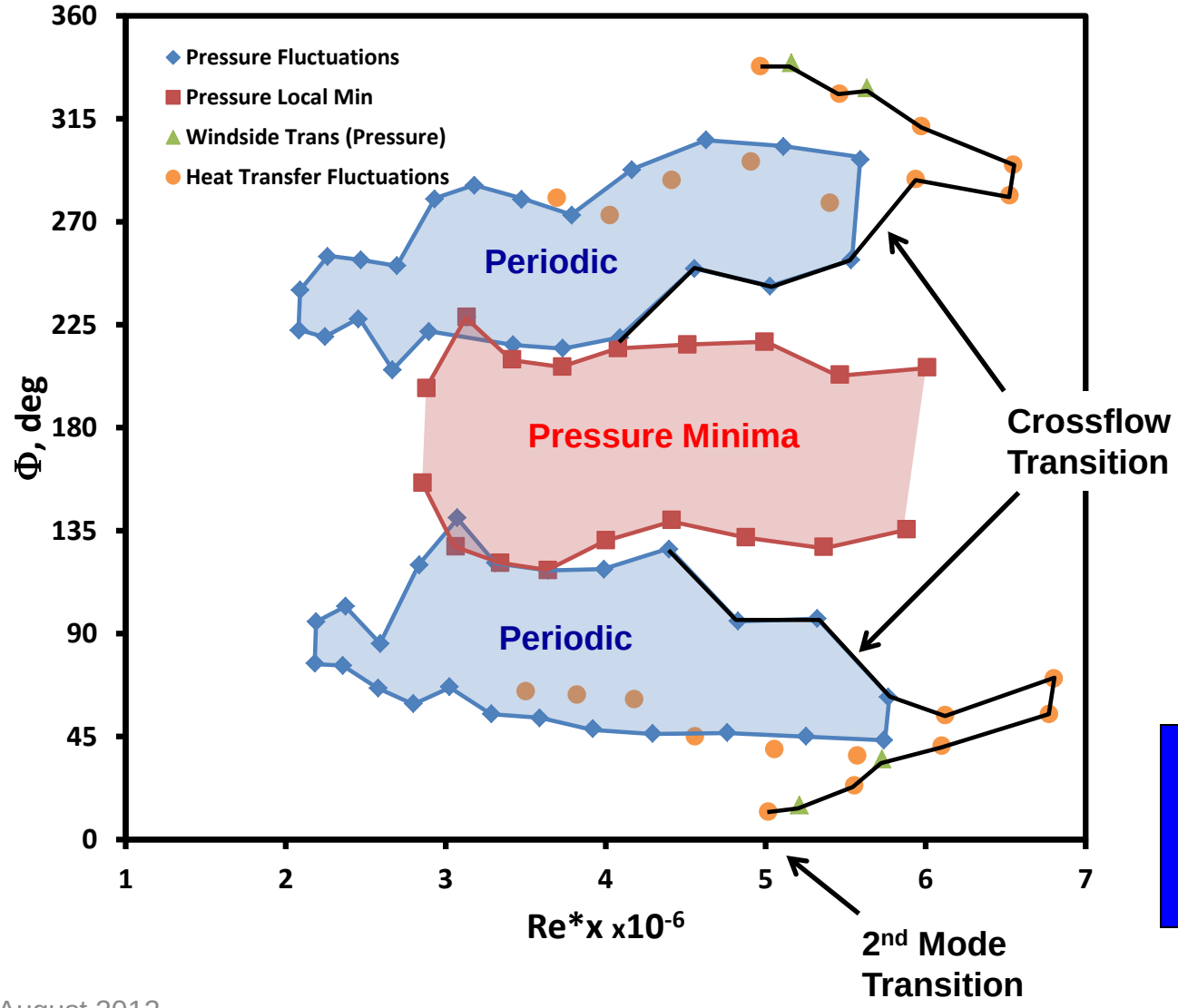




Stationary cross flow azimuthal wavenumber:
60<n<90 Flight
n~90 LASTRAC (Li et al.)

Consistent with stationary crossflow instability

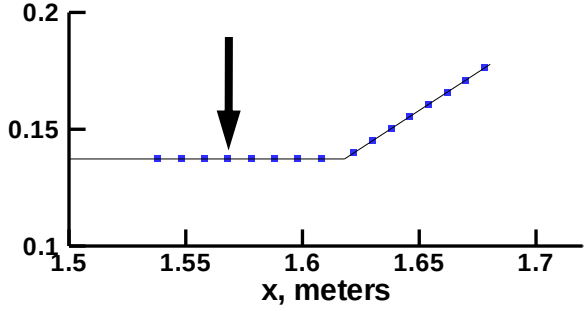
Reentry High AoA Transition Map

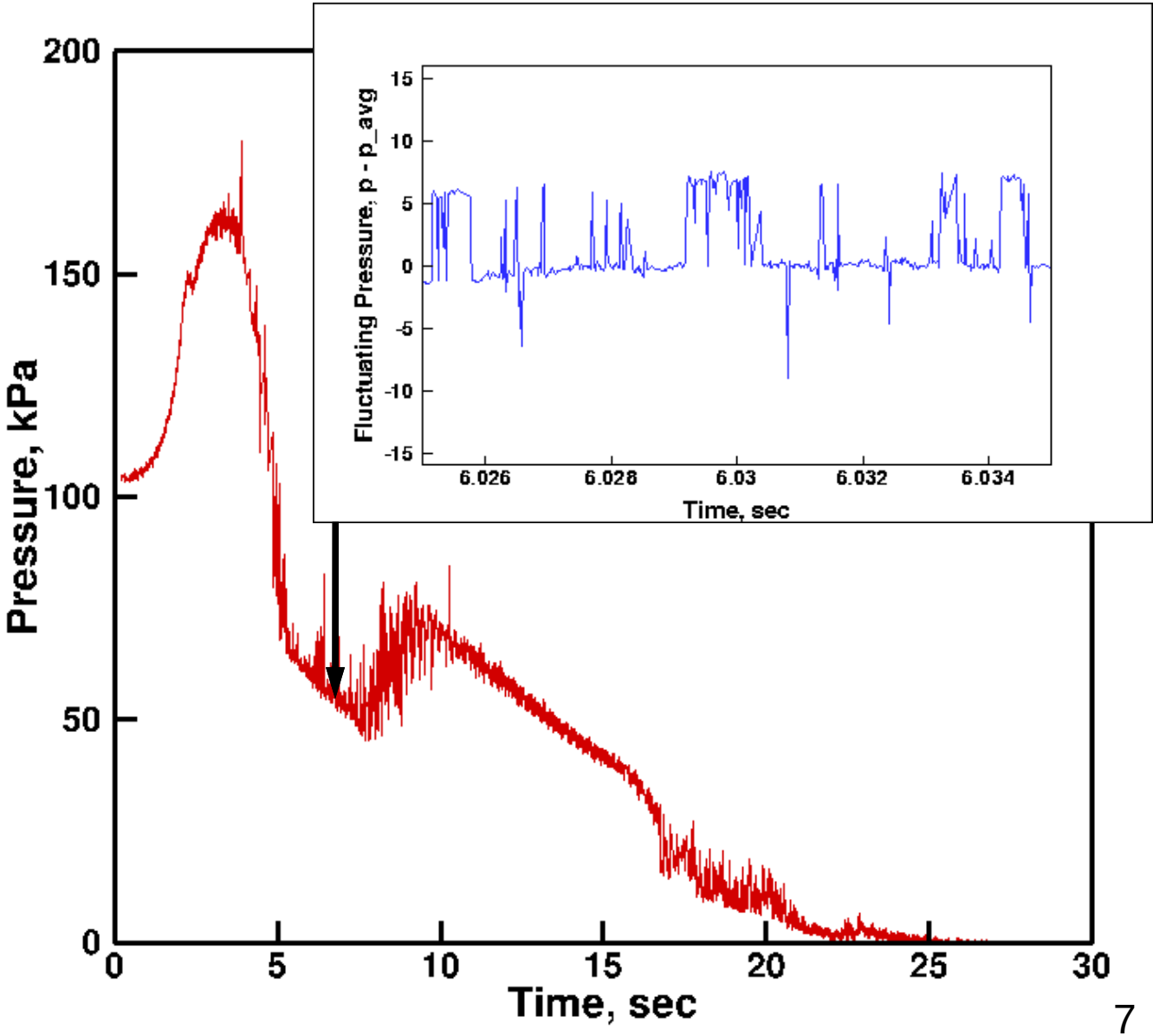


N-factor calibration

Linear mechanisms in flight

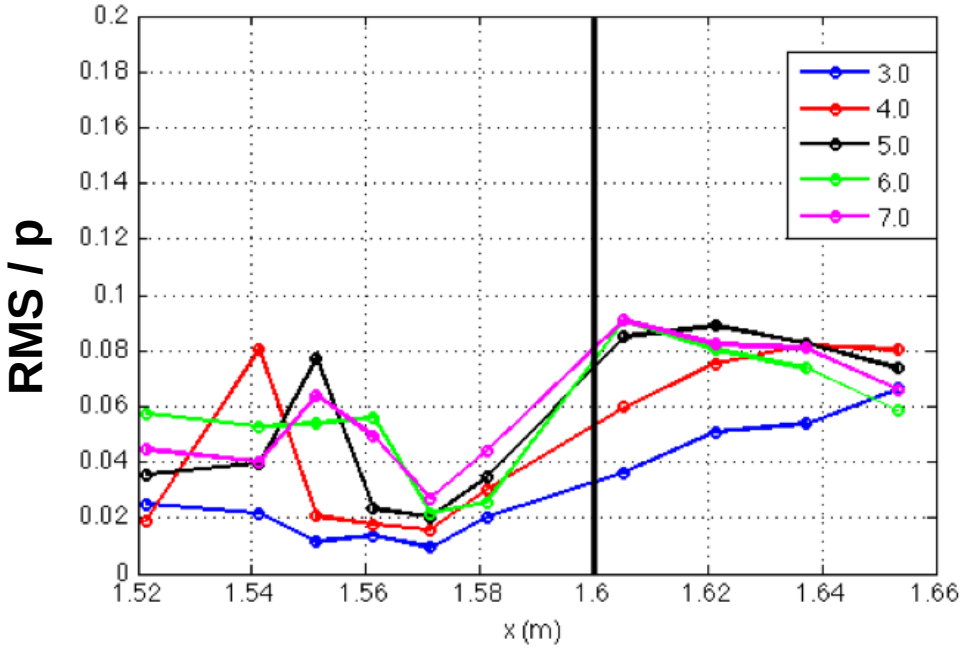
SBLI Shock Dynamics





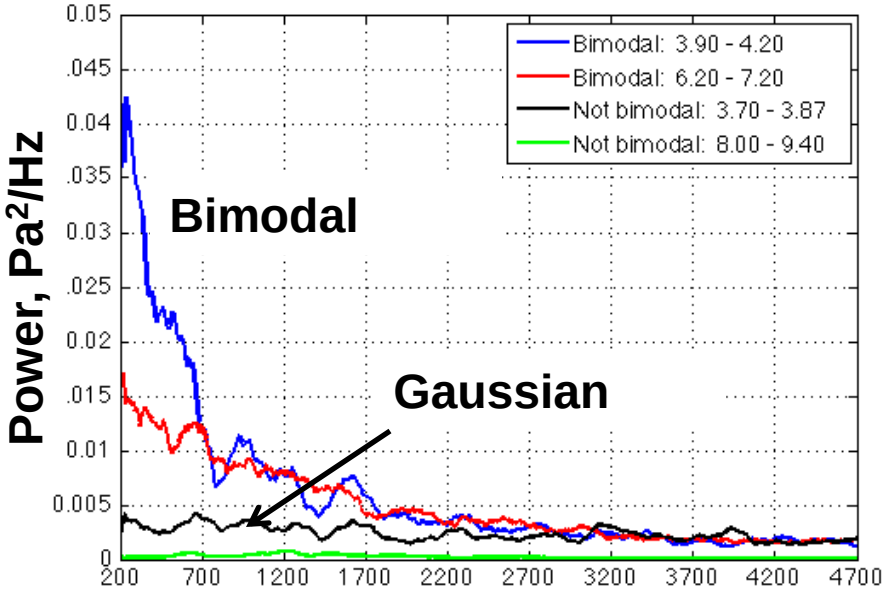
HIFiRE-1 Ascent SBLI

Normalized Pressure Fluctuations



x, mm

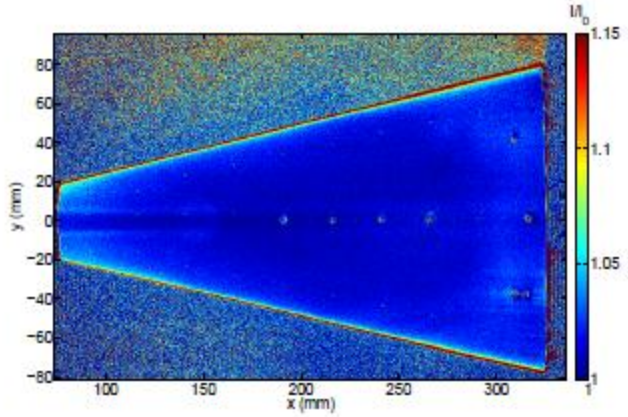
Power Spectral Density



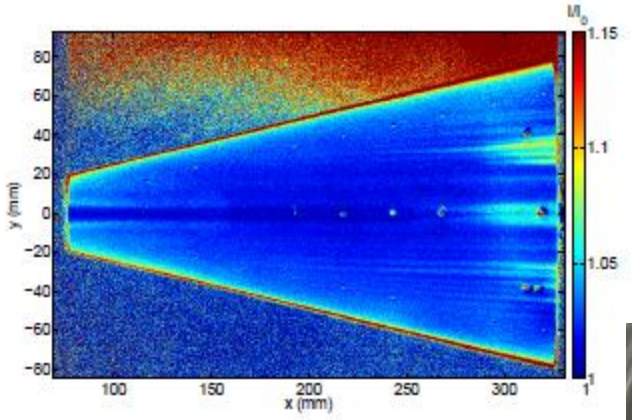
Frequency, Hz

SBLI pressure fluctuations in flight quantified

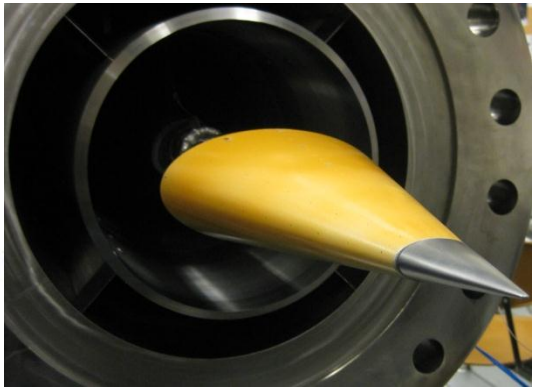
HIFiRE-5 TSP, Purdue M=6 Quiet Tunnel

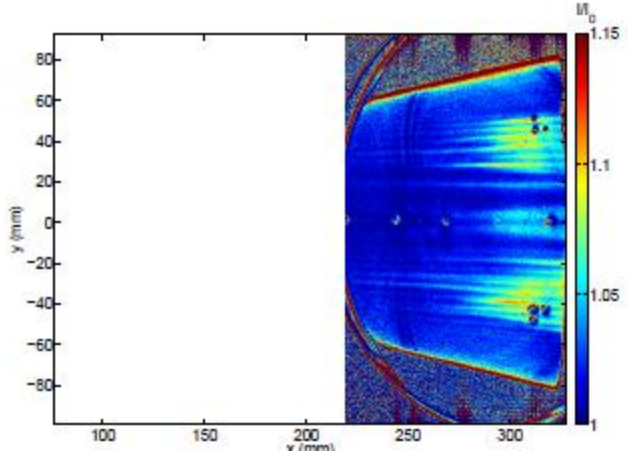


Re = 7.2x10^6 / m

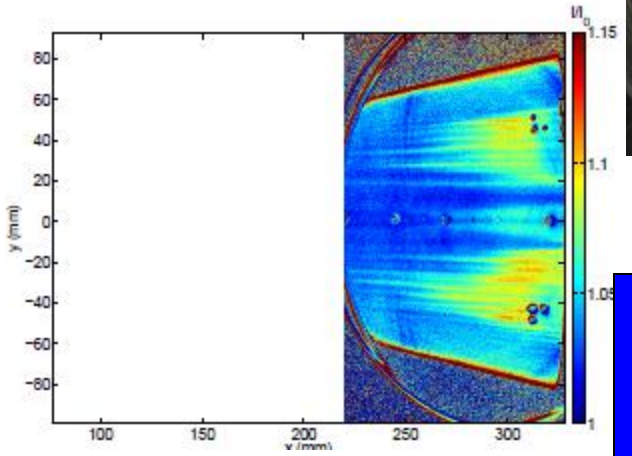


Re = 10.2x10^6 / m





Re = 12.1x10^6 / m

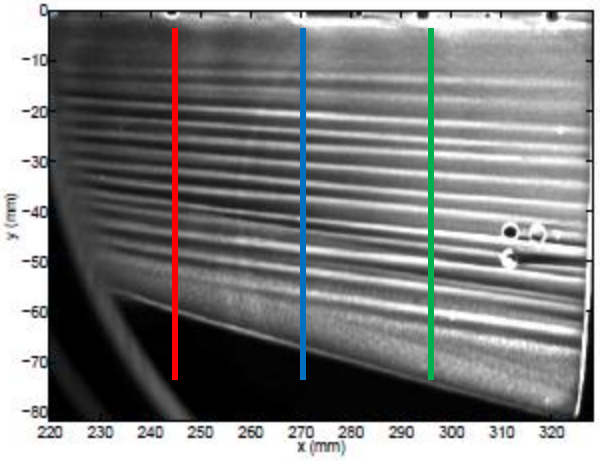


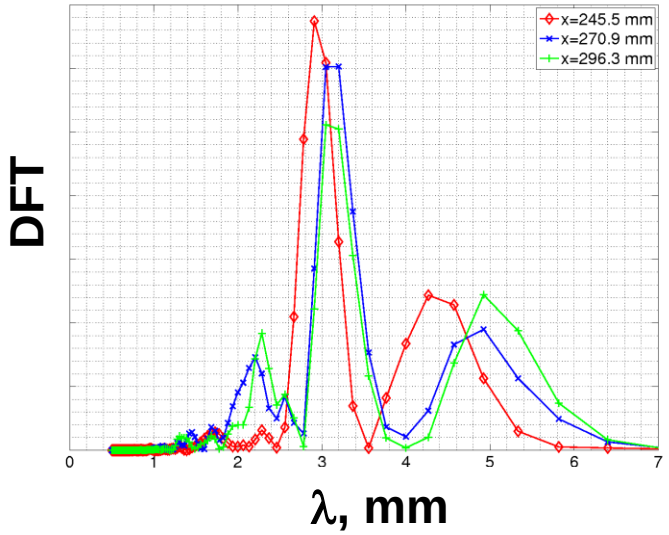
Re = 13.1x10^6 / m

Consistent with stationary cross-flow

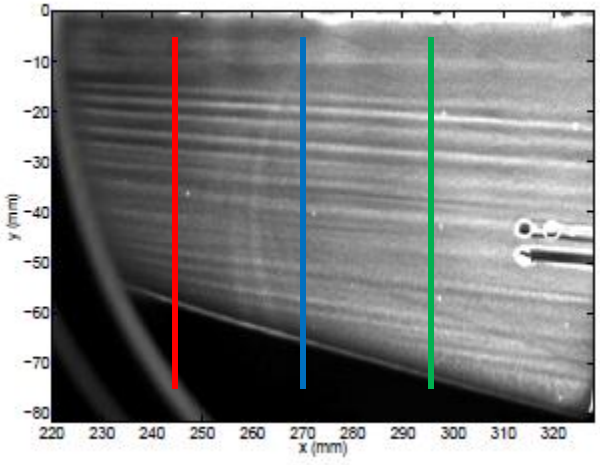
Roughness Effects on Crossflow Vortices

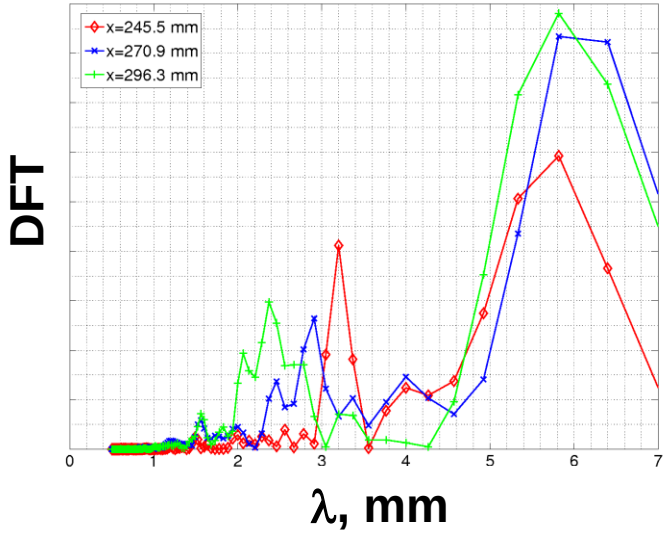
Smooth



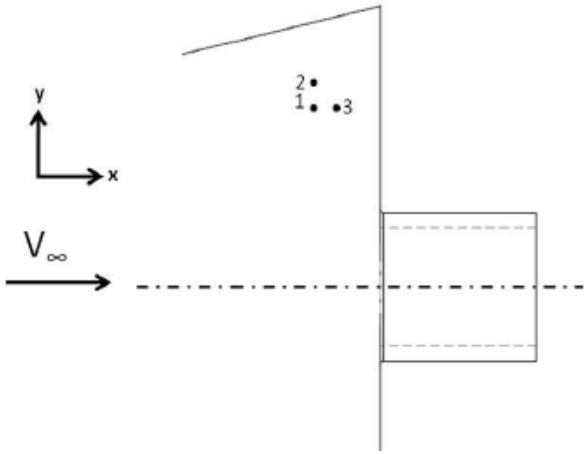


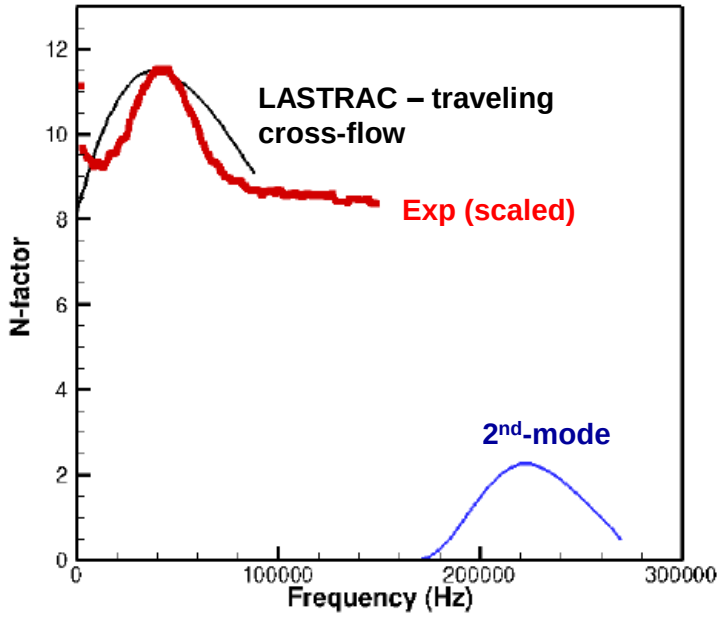
Rough, Δ=0.5 mm



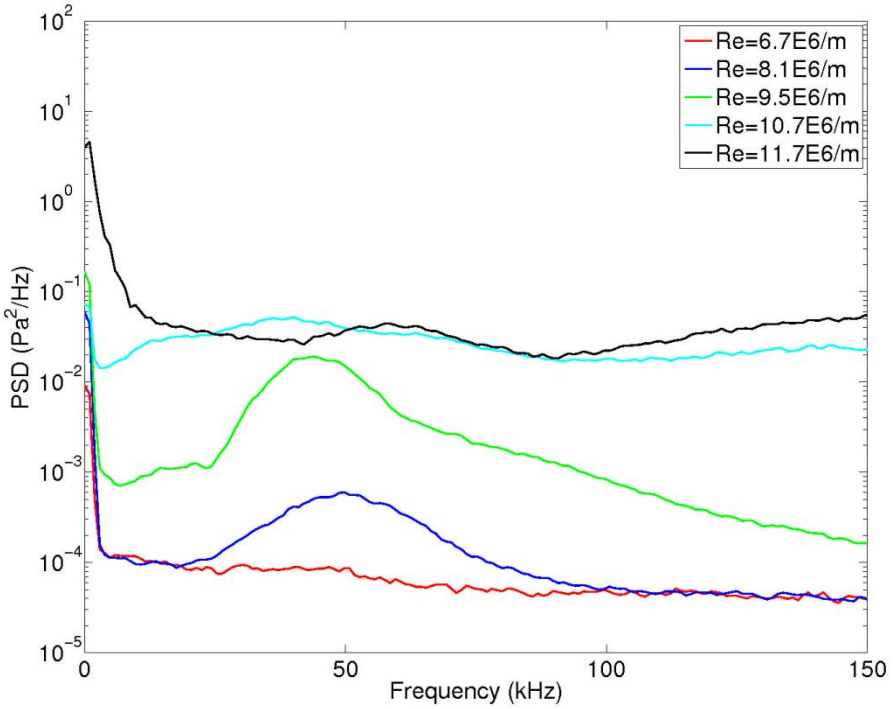


Kulite Surface Pressure Spectra





Li et al, 2012



Co-existing stationary and traveling cross-flow

Summary

- **HIFiRE-1**
  - High AoA and crossflow and 2nd-mode transition observed in flight
  - Crossflow instabilities apparently observed in flight
  - Unsteadiness in SBLI interaction quantified
- **HIFiRE-5**
  - Stationary and traveling crossflow vortices observed in wind tunnel
  - Stationary and traveling crossflow vortices manipulated with roughness
  - Some supersonic flight transition data obtained, evaluation under way

Future Work

- **Wave velocity measurements**
- **Roughness variations**
- **HIFiRE-5 data reduction**

Food for Thought

- How do crossflow instabilities grow?
- What are the eigenfunctions of the disturbances we measure?
- How do traveling and stationary crossflow instabilities interact?
- What is the receptivity to roughness for crossflow?

Acknowledgments

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