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Noise Control of Supersonic Impinging Jets

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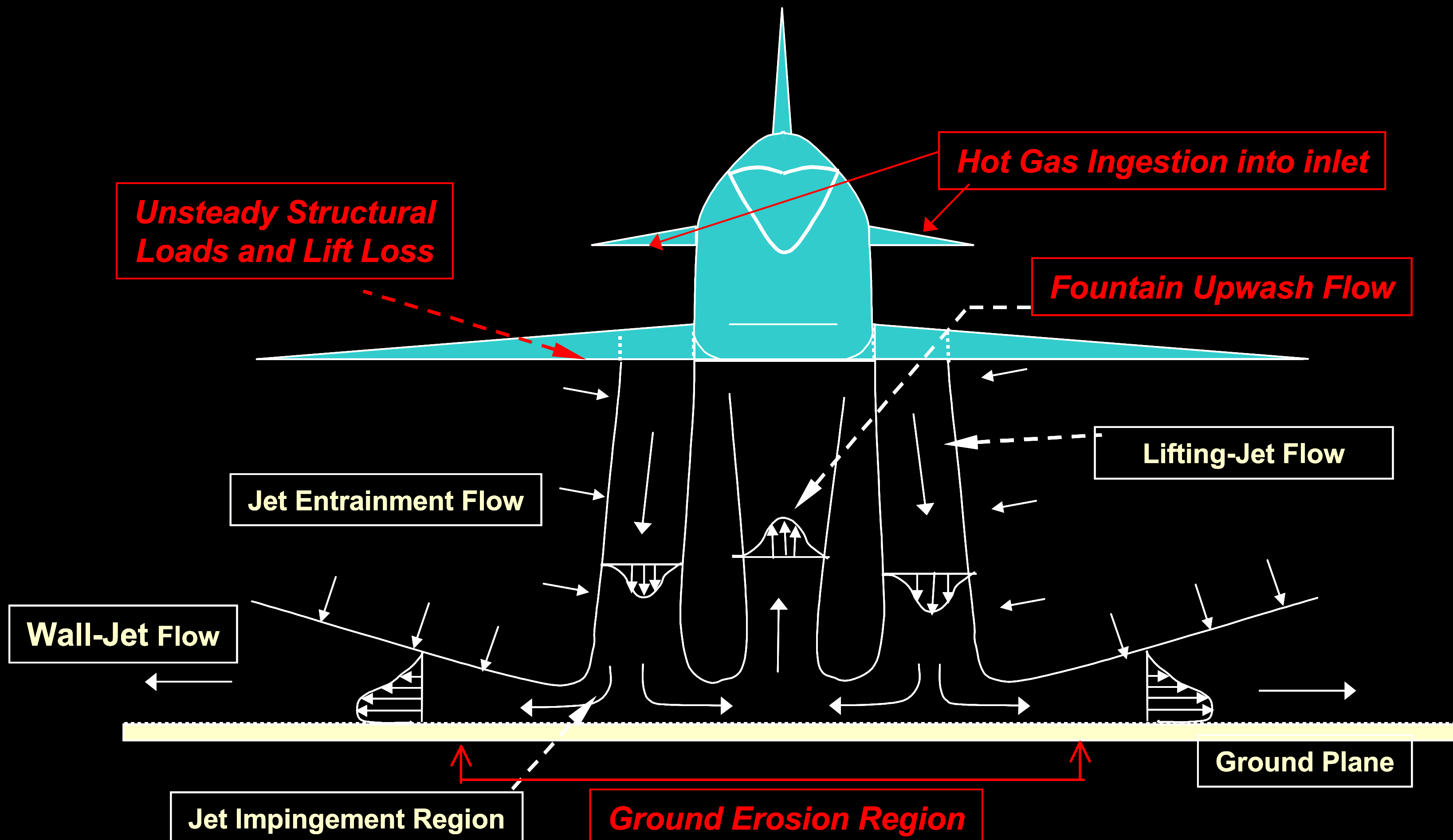
Contents

- Motivation
- Mechanism
- The progress in the past half century.
- What we done
- Future work

Motivation

Flow schematic for a twin jet STOVL aircraft in hover



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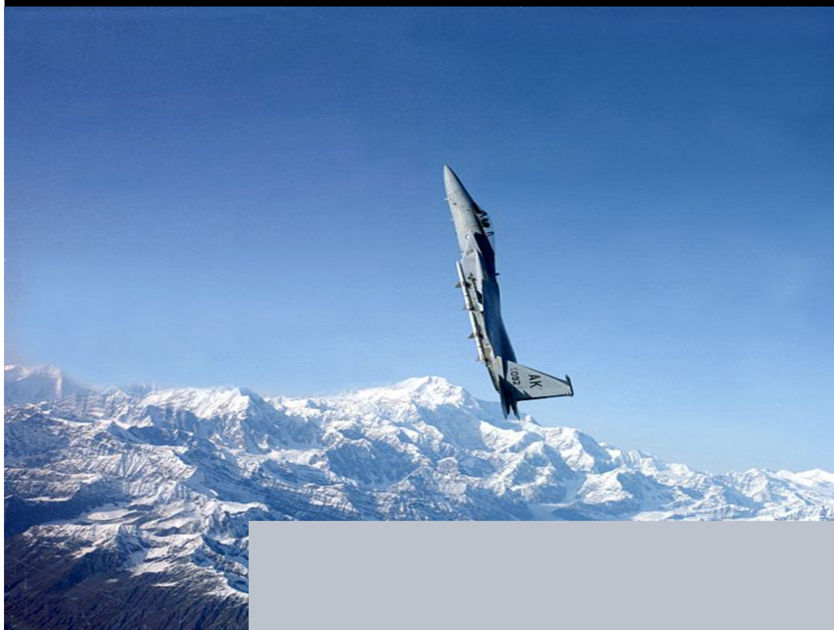
Motivation



F-15

B1-B

Sonic fatigue failure

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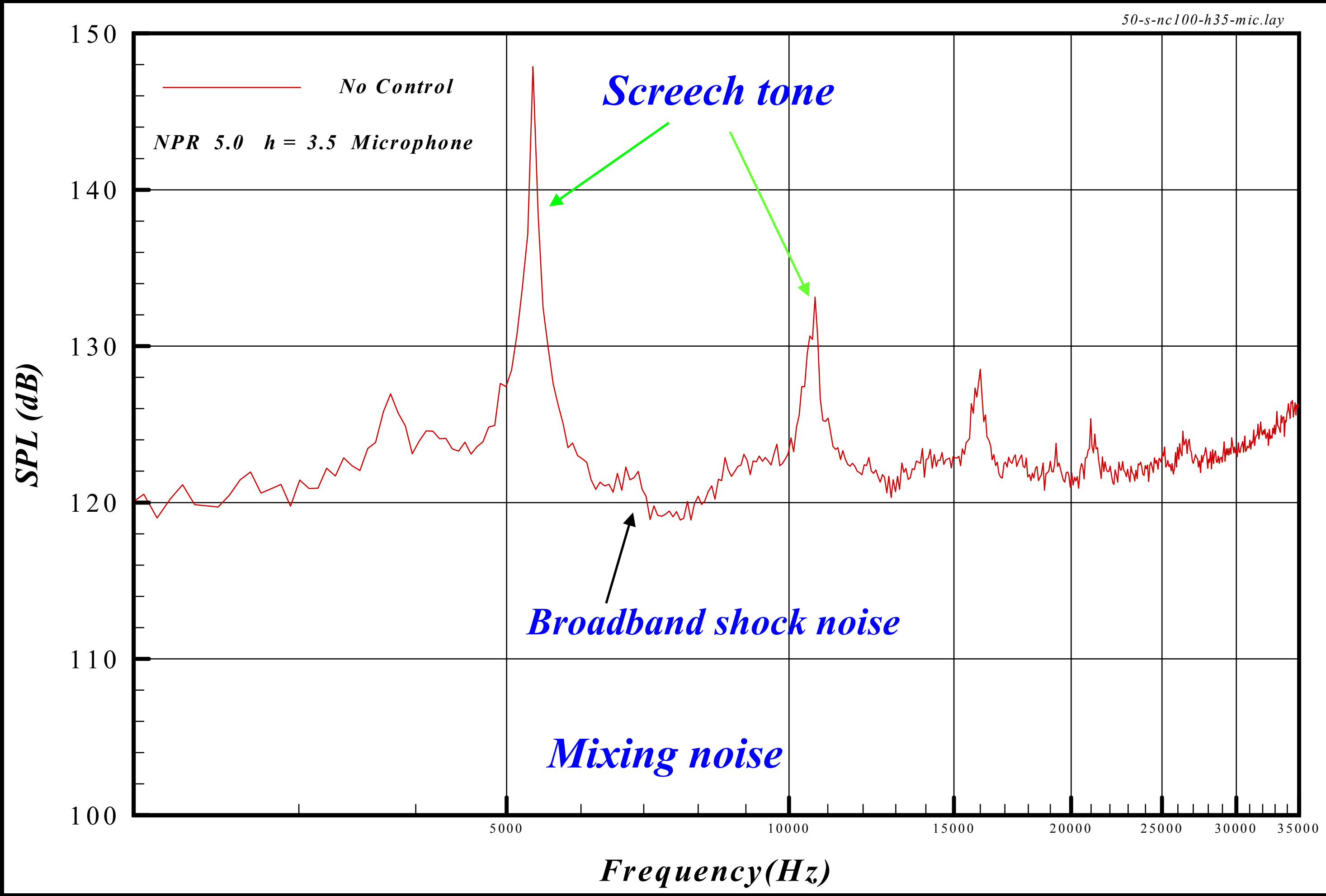
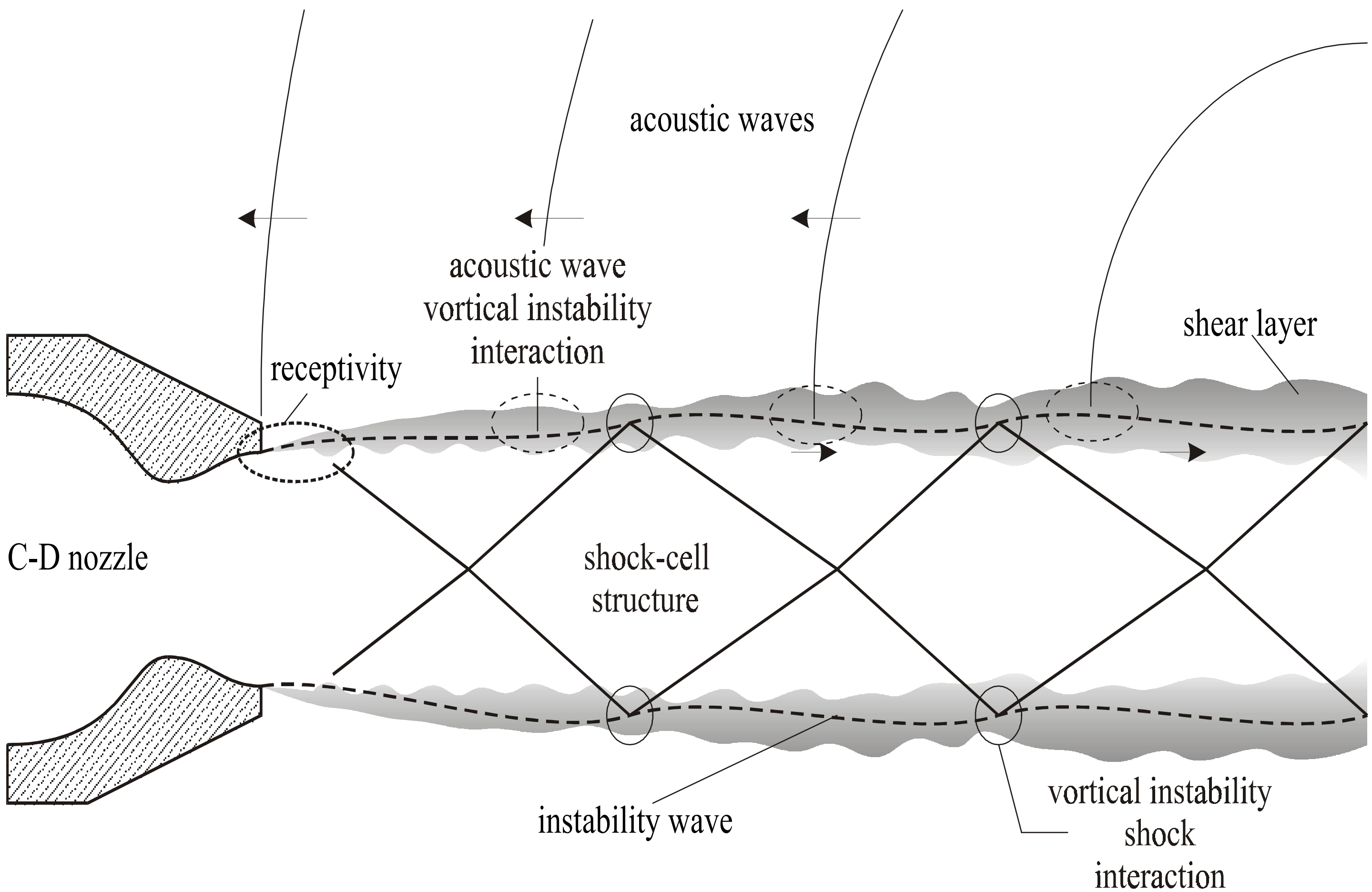
Motivation



Mechanism


acoustic waves
acoustic wave
vortical instability
interaction
receptivity
shear layer
C-D nozzle
shock-cell
structure
instability wave
vortical instability
shock
interaction

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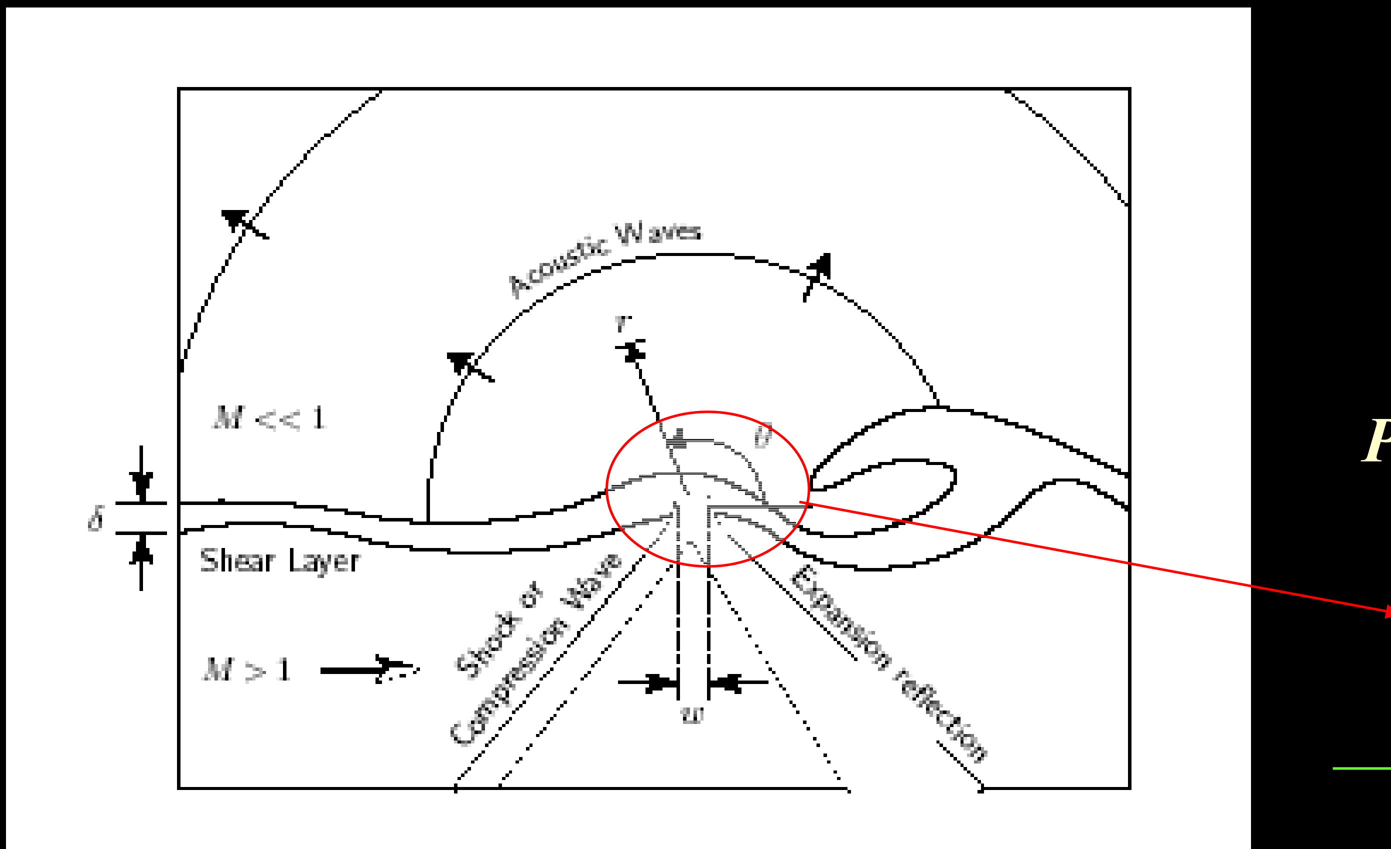
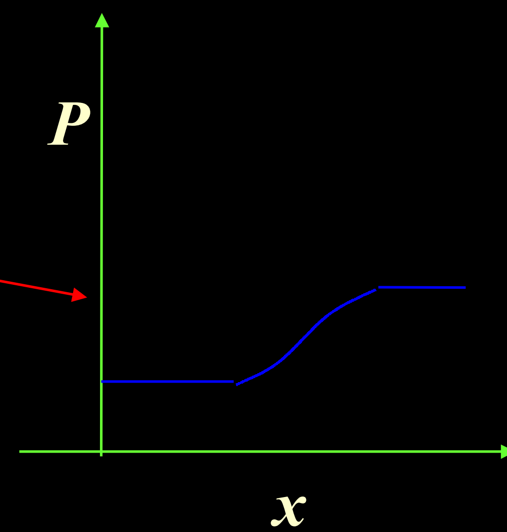
Mechanism

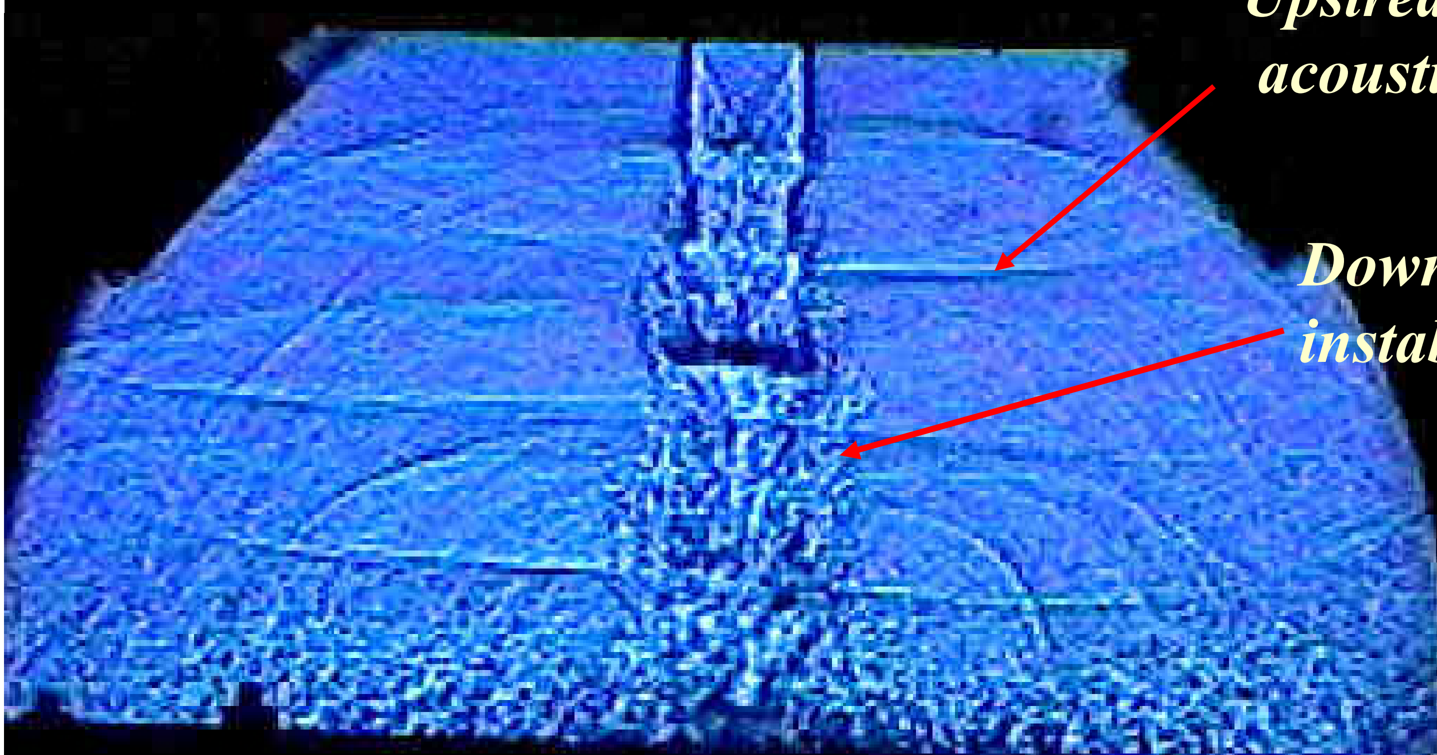




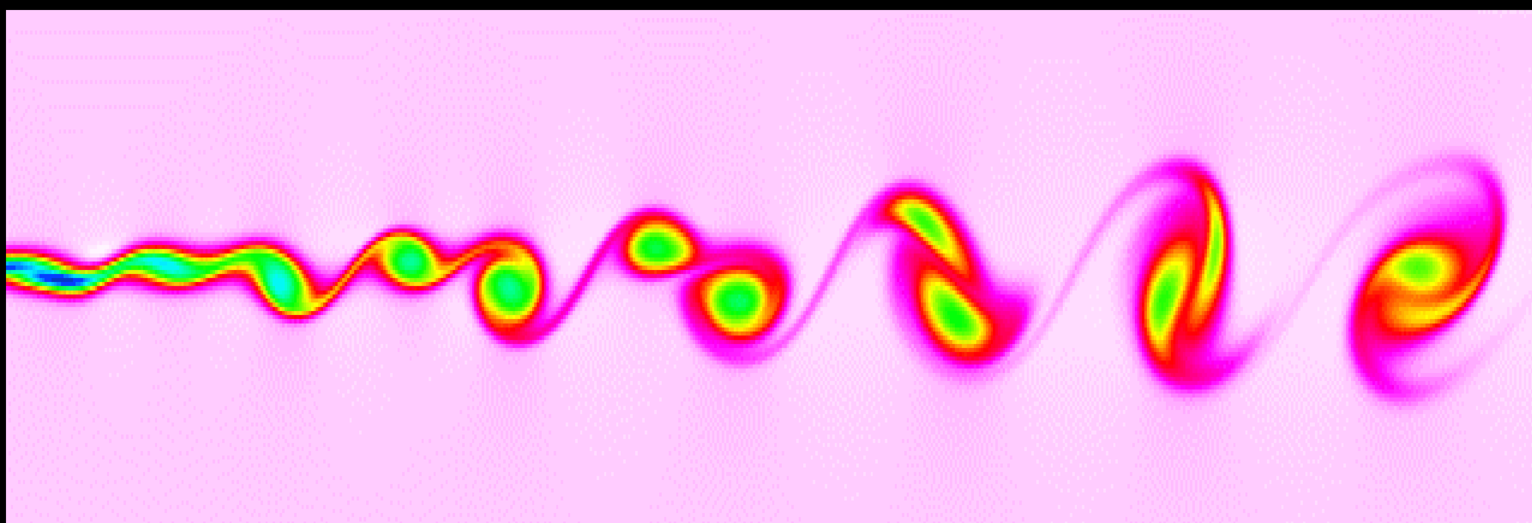
Schematic of the shock-vortex interaction

Mechanism

Feedback loop



Mechanism



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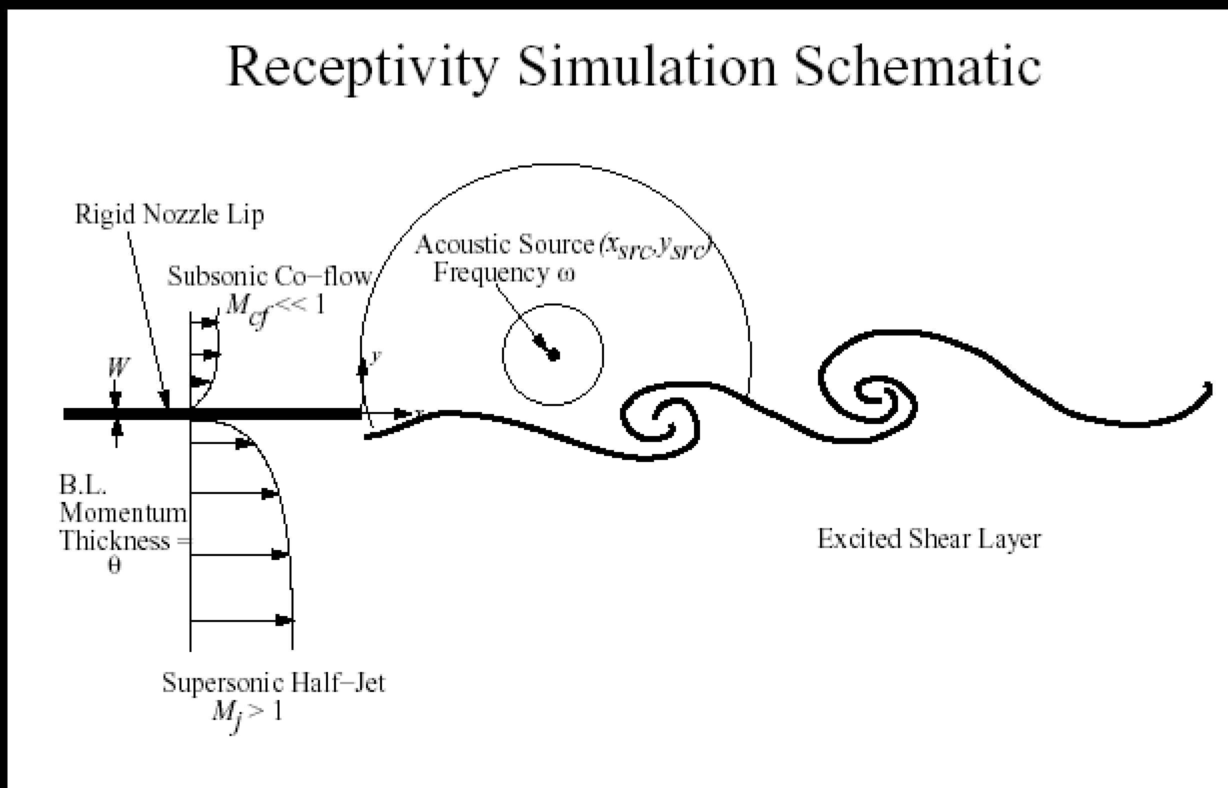
Mechanism



Mechanism

Feedback loop

- Downstream propagating instability wave
- The interaction of vortical disturbance with shock-cell structure in the jet
- The back propagation of the acoustic disturbance to the nozzle lip
- The conversion of acoustic disturbance into instability wave at the nozzle lip

Goal

- **To actively and efficiently control the jet behavior by disrupting the feedback loop.**
  - **Reduce: Tones, OASPL and other related adverse effects**

Prior Attempts at Feedback Control

Suppression the Screech tone

- Hammit : Using reflect plate, stabilize the screech tones
- Tanna: Using the tab combination of the sound absorbing materials.
- Norum: Proved the effectiveness of the plates
- Kozlowski, Nagel et al. Non-intrusive tabs simulating full-scale lip irregularities
- Ahuja et al. Using tabs directly intruding into jet flow

Prior Attempts at Feedback Control

- **Karamcheti et al. (1969) : Edge tone suppression using baffles/plates**
- **Sheplak & Spina (1994): Impinging tone suppression via coflow**
- **Shih et al. (1999): Screech tone suppression using counterflow**
- **Elavarasan et al. (1999): Impinging tone suppression via baffles**

Present Approach

- Use supersonic microjets to disrupt the coherent flow-acoustic coupling.
  - High momentum, small, low mass flow, relatively simple, can be actively manipulated to provide on-demand control.

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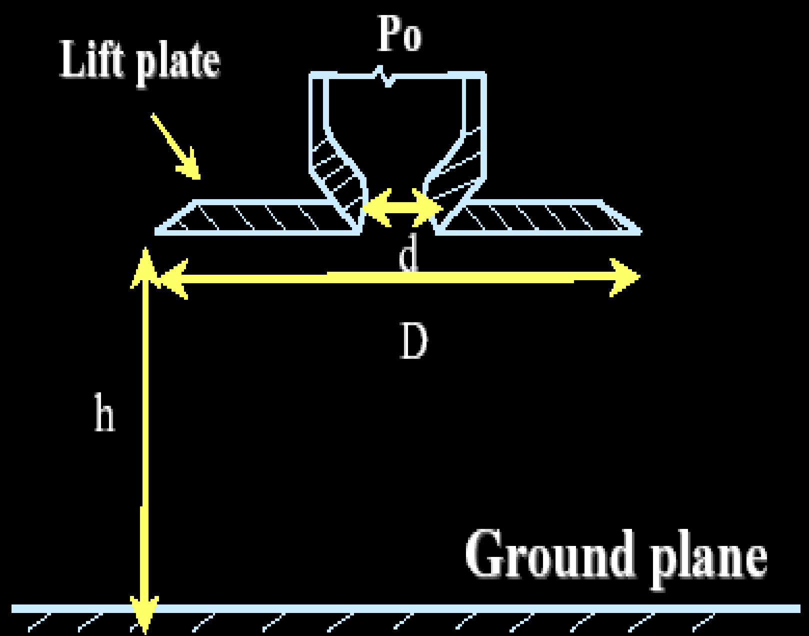


Parametric Space

NPR (Po/Pa) = 3.7 & 5.0

h/d = 2.0 - free

Nozzle = Mach 1 & 1.5

Microjet Press. = 80 - 120 psi

Experimental Details

DIAGNOSTICS

- **Unsteady Pressures Ground & Lift Planes**
- **Acoustic**
- **Flow visualization**

Shadowgraph

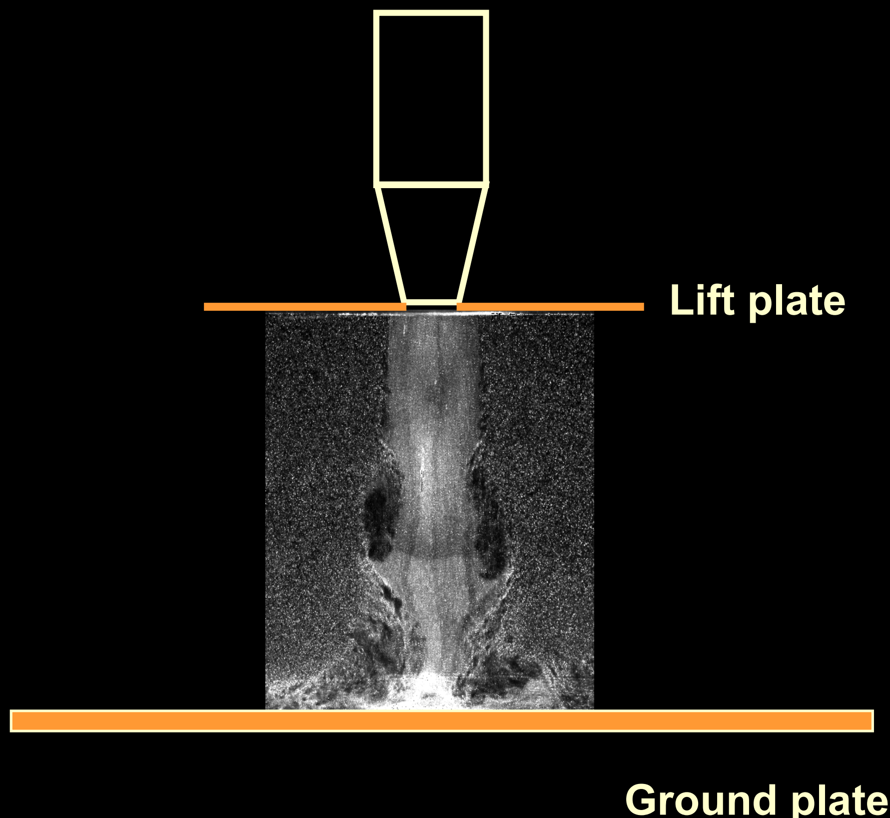
Planar Laser Scattering (PLS)

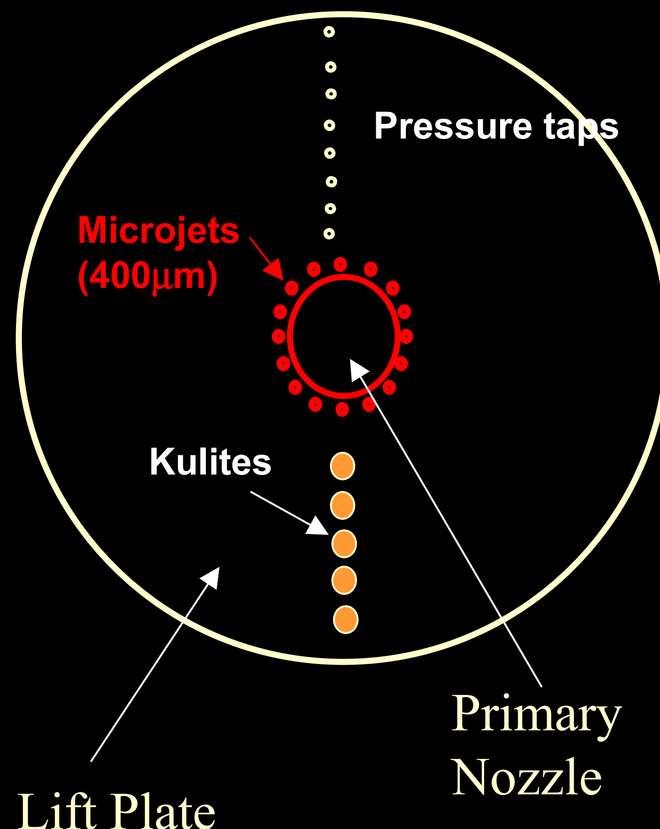
- **Mean Pressures**

Ground & Lift Planes

- **PIV**

Test Geometry & Hardware





Test Conditions: NPR = 2.5, 3.7 & 5

h/d = 2 - 10

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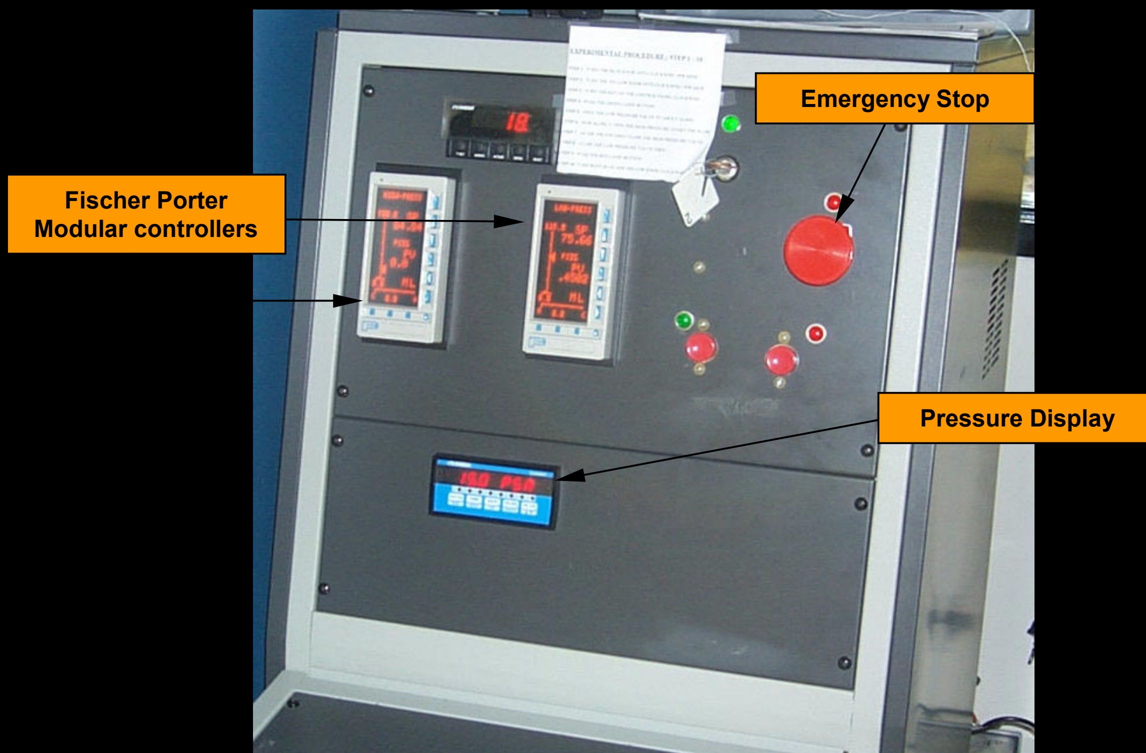
Test Model and Facility

Lift plate

Ground plate

Test Model and Facility



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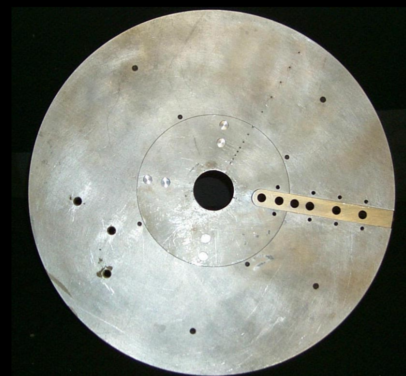
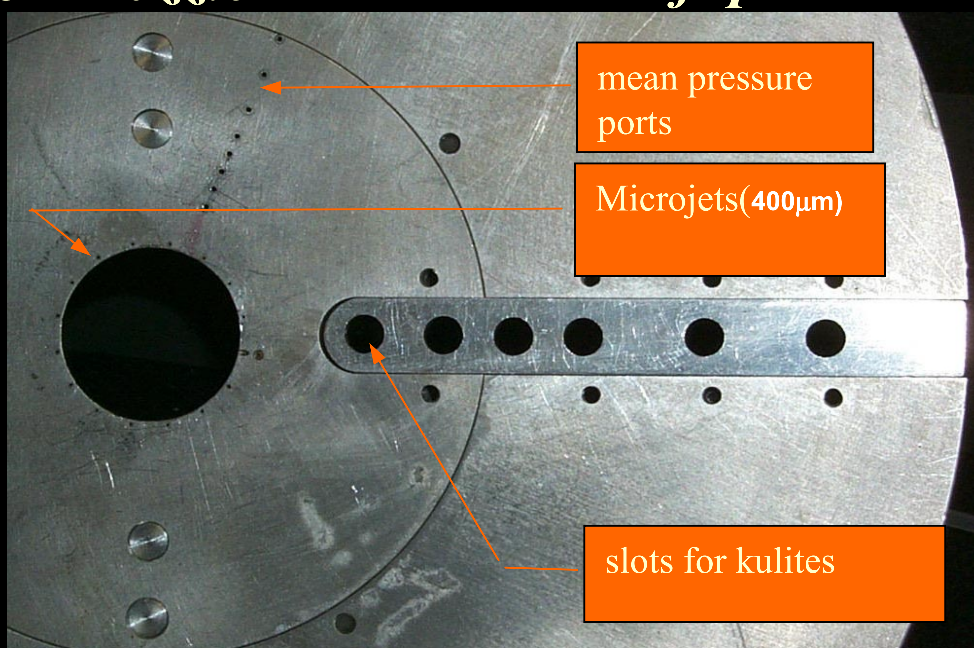
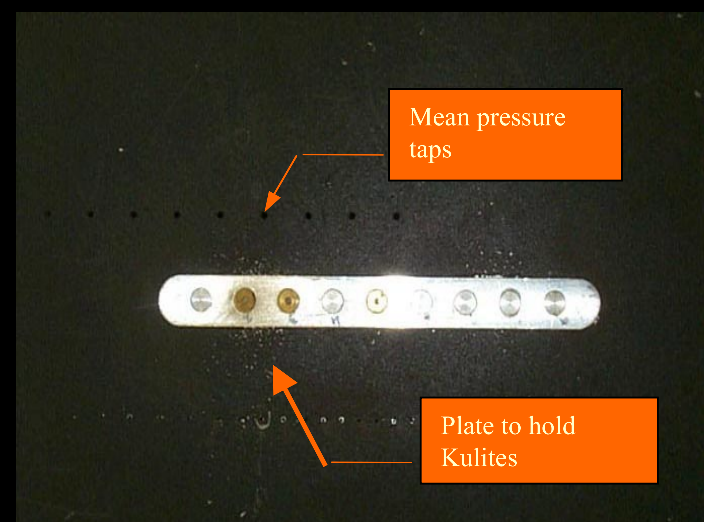
CD nozzle



Lift plate

Ground plane





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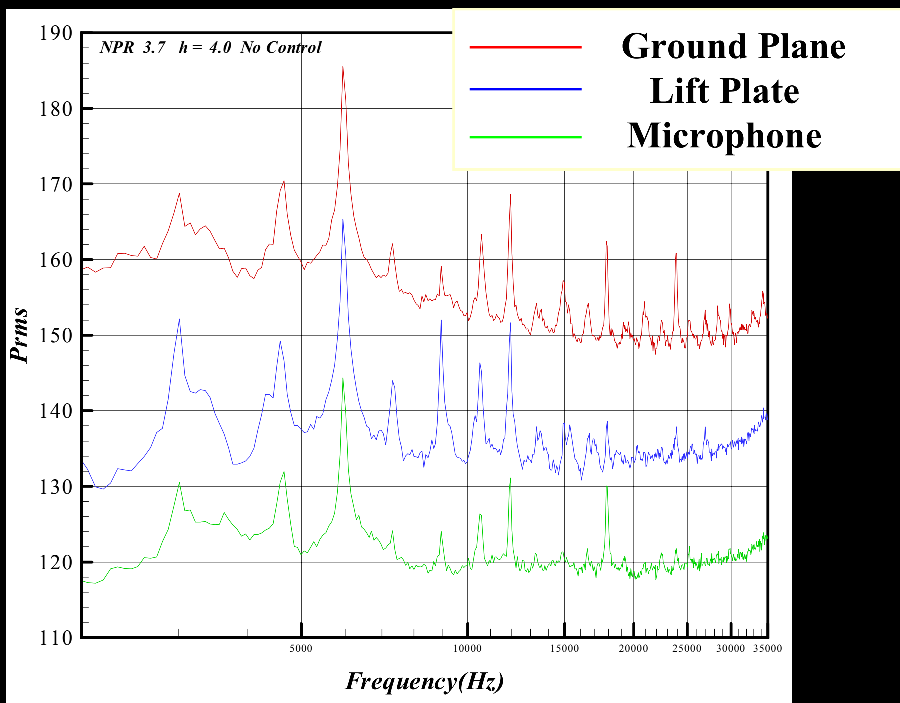
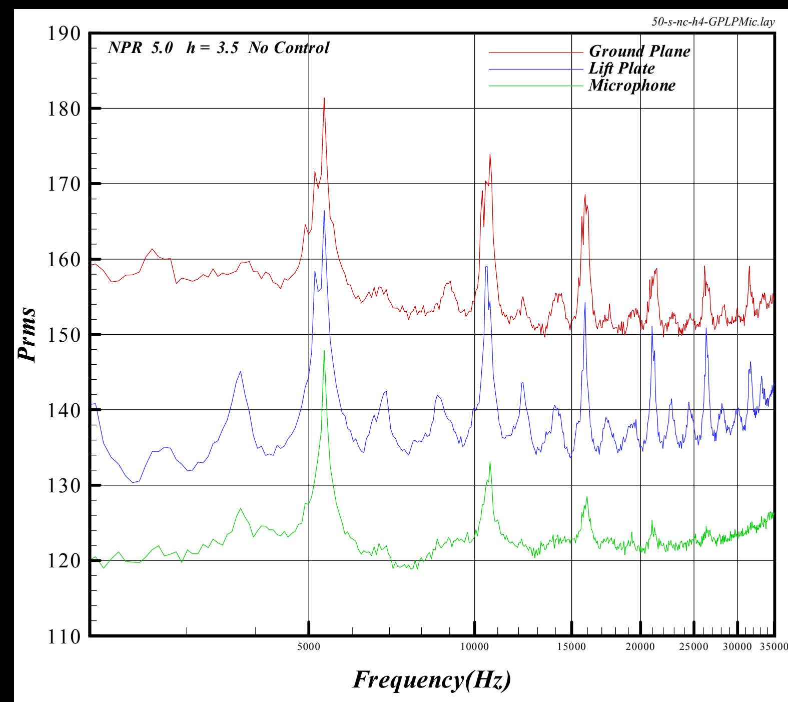
Unsteady Pressure Spectra





NPR = 3.7 h/d=4.0 No Control

NPR = 5.0 h/d=3.5 No Control

Unsteady Pressure Loads:

Ground Plane ~ 185-195 dB

Lift Plate ~ 165-175 dB

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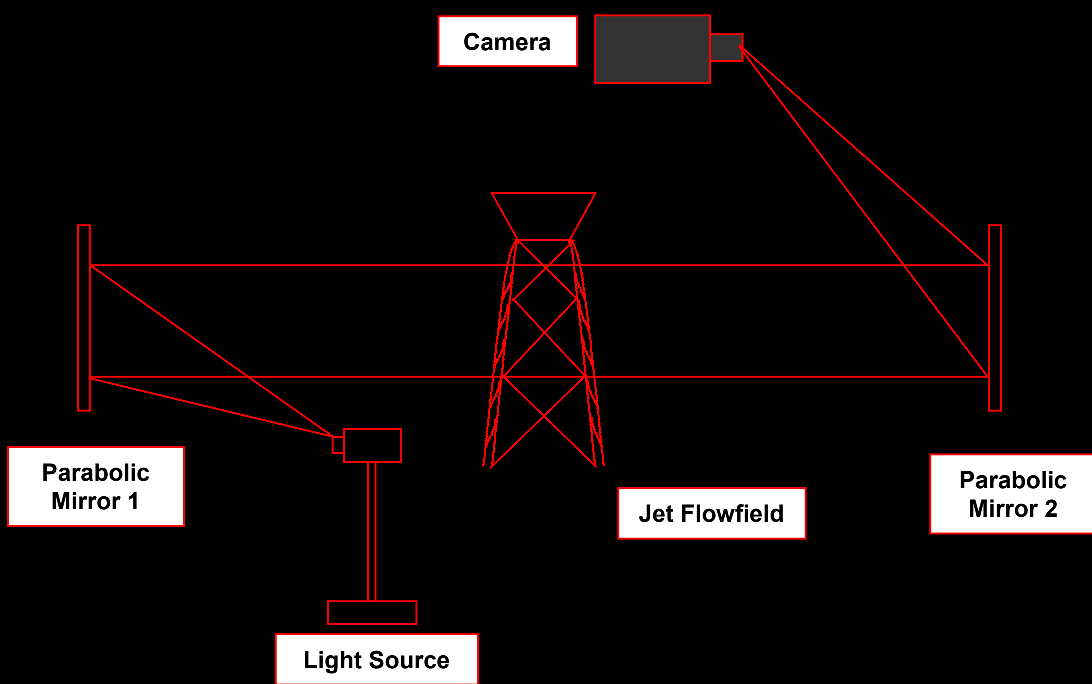
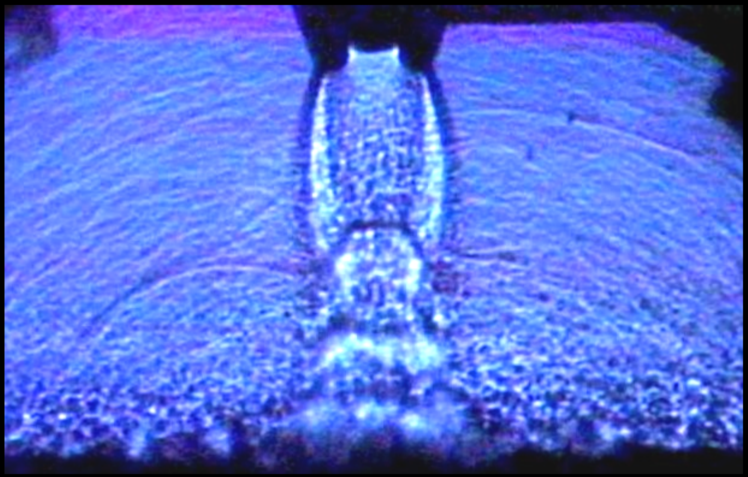
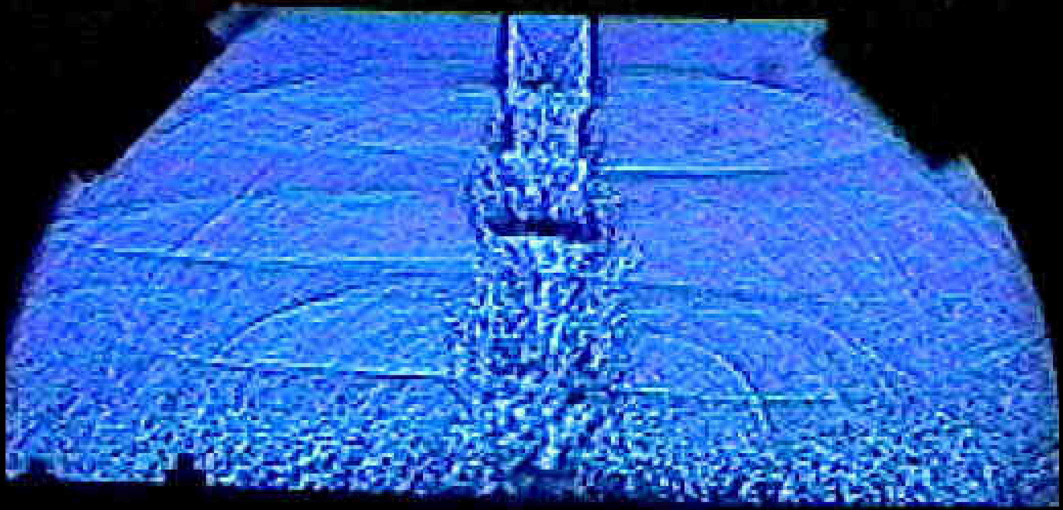
Schematic shadowgraph arrangement



Uncontrolled Impinging Jet Flow Instantaneous Shadowgraphs



Sonic Nozzle, No Lift Plate
NPR = 5, h/d =3



Mach 1.5 C-D Nozzle, Lift Plate
NPR = 3.7, h/d =4

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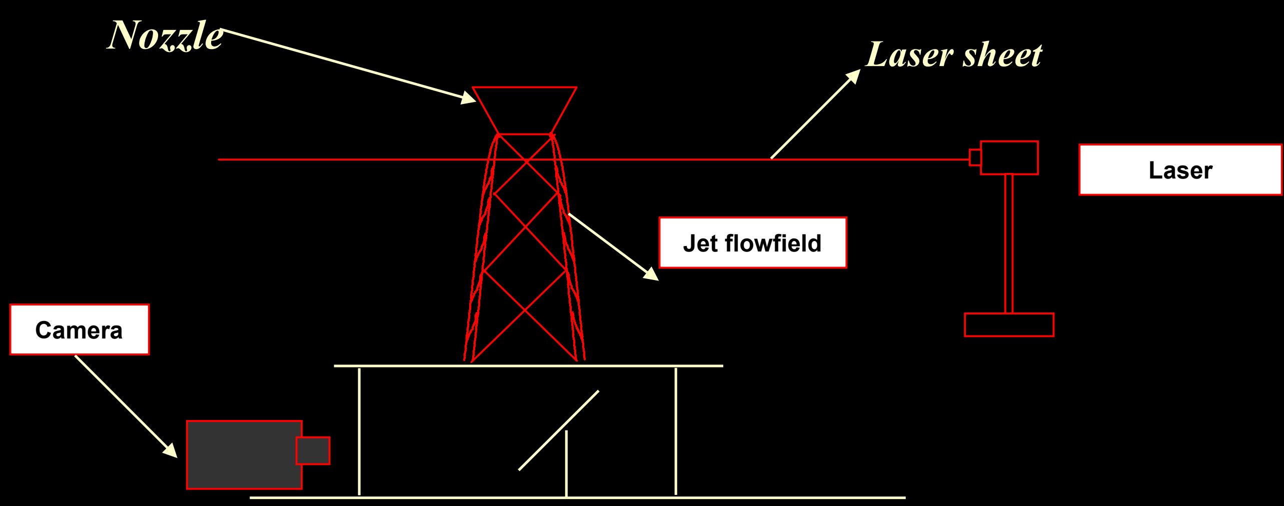
Planar Laser Scattering (PLS)



PLS Images, Averaged

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NPR=5 h/D=4

No Control

With Control

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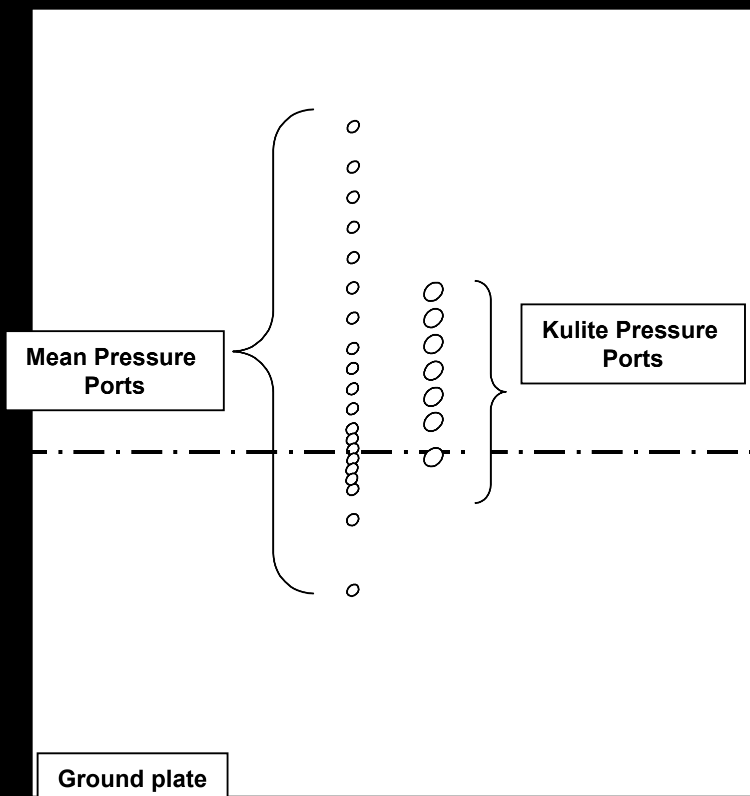
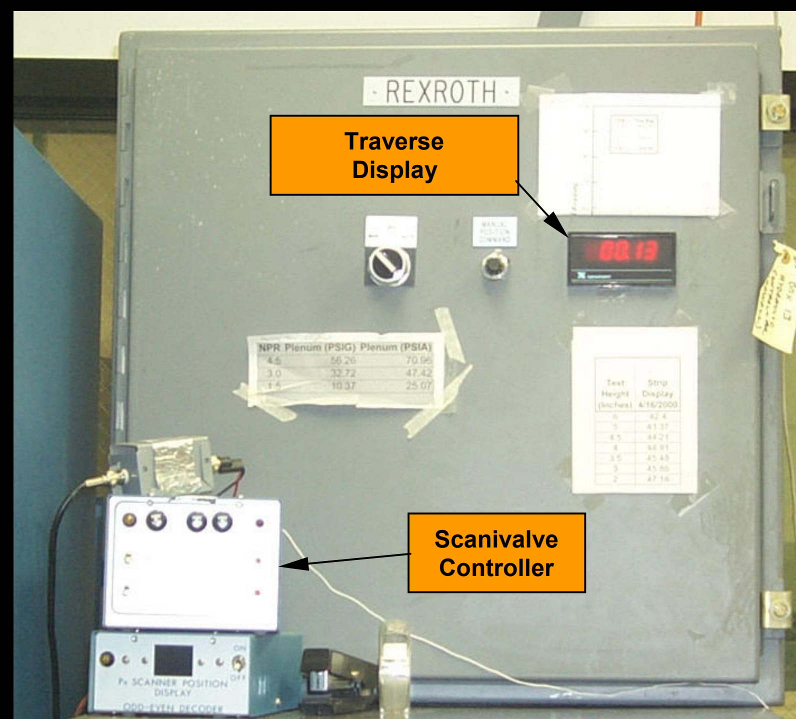
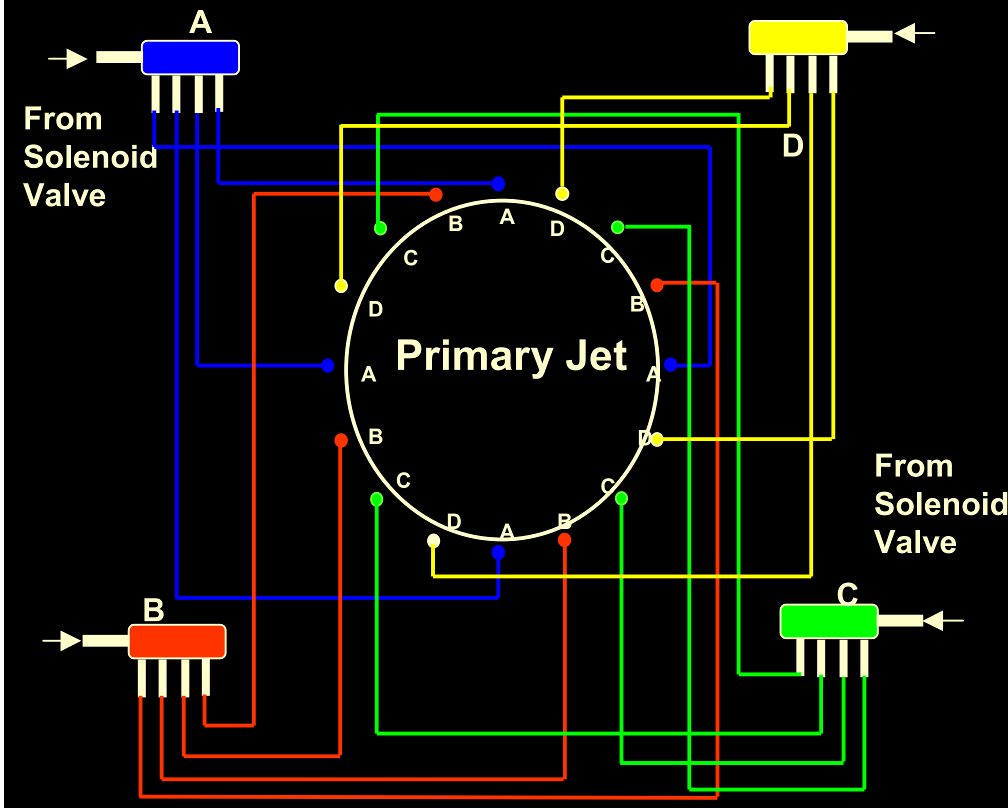
Surface Mean Pressure measurements

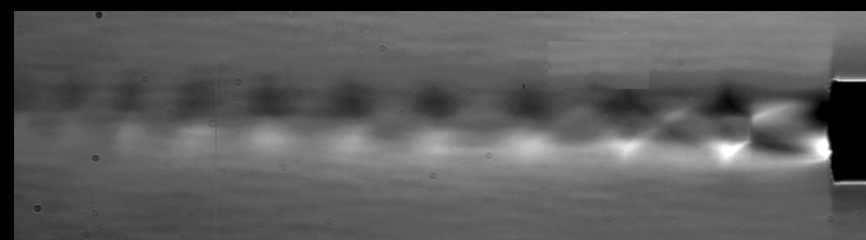




Microjet Details



400 µm Jet



- Microjet diameter – 400 µm
- Operating pressure – 80- 120 psi
- Mass flow (total) ~ 0.4% – 0.7 % of main jet
- Operating gas – Nitrogen/Air
- Microjet inclination angle ~20^0

Effect of Microjet Control

NPR 5, h/d=3.5

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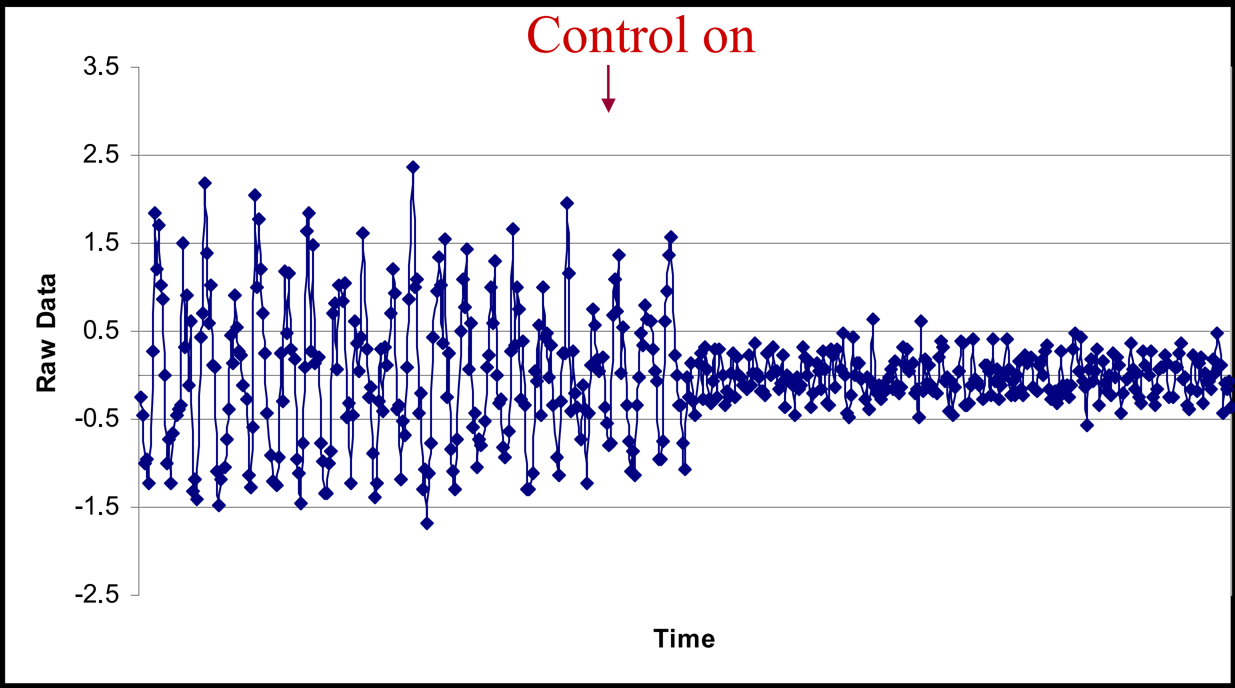
Effect of Microjet Control

NPR 3.7, h/d=3.5



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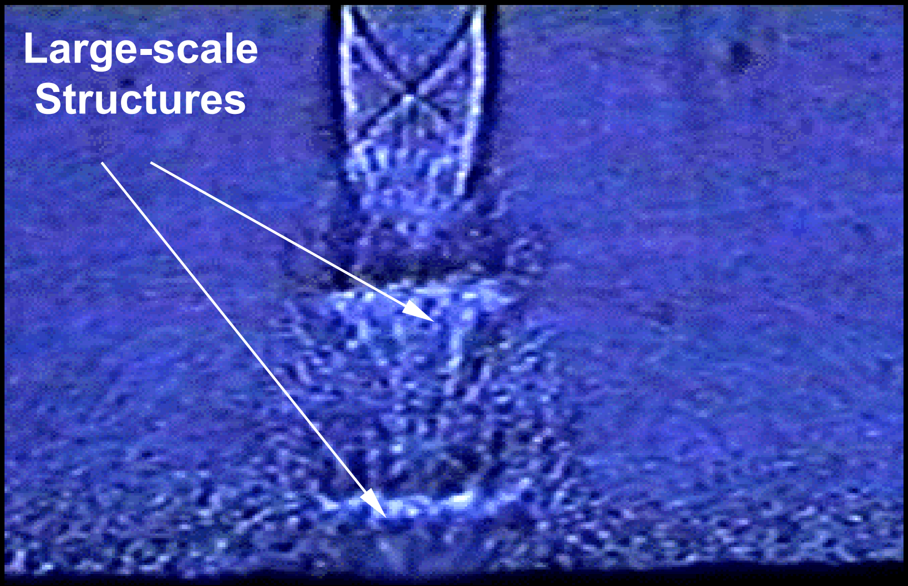
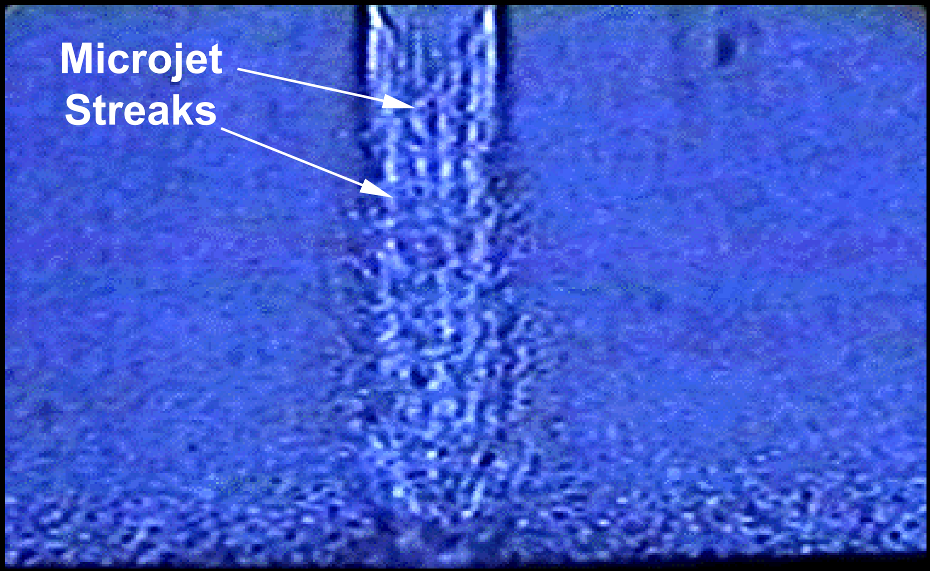
Effect of Microjet Control

Shadowgraphs NPR = 3.7, h/d = 4.5



Without Control

With Control



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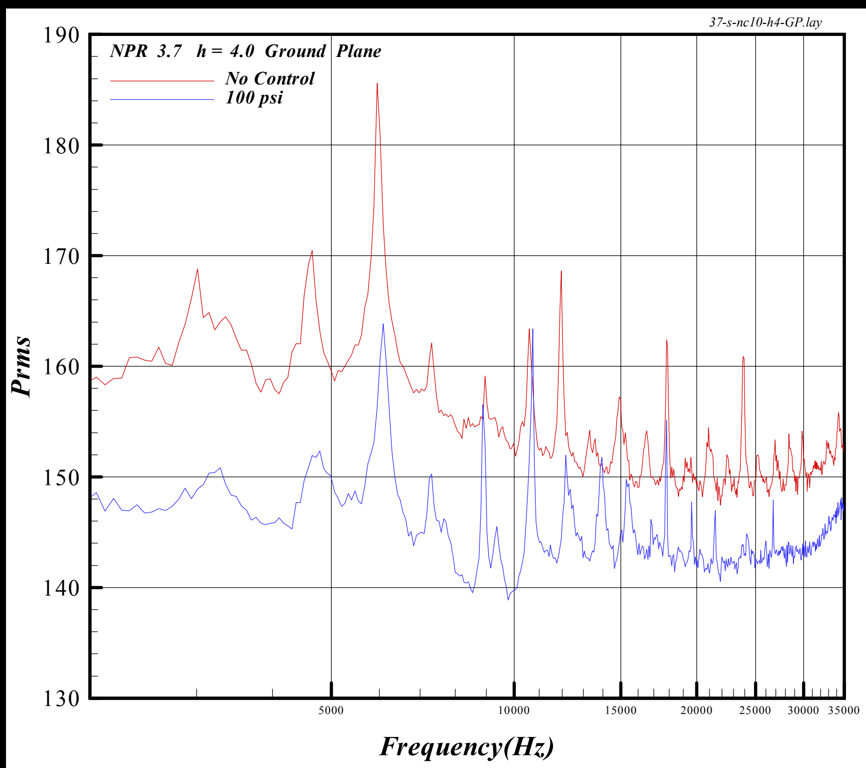
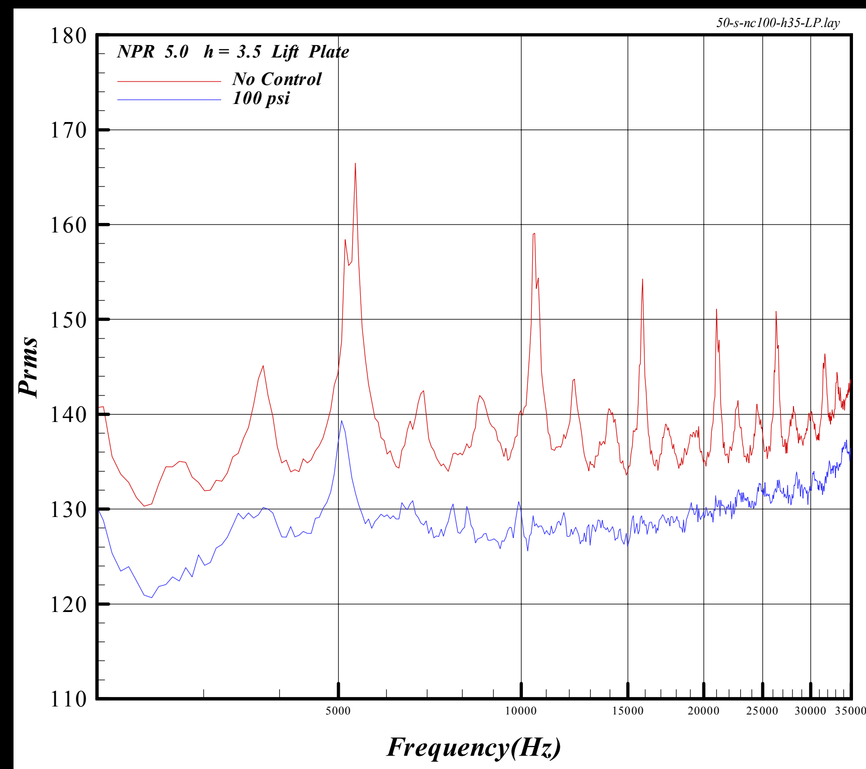
Effect of Microjet Control

20°, 100 psi, 16 microjets



NPR 3.7, h/d = 4
Ground Plane



NPR 5.0, h/d=3.5
Lift Plate

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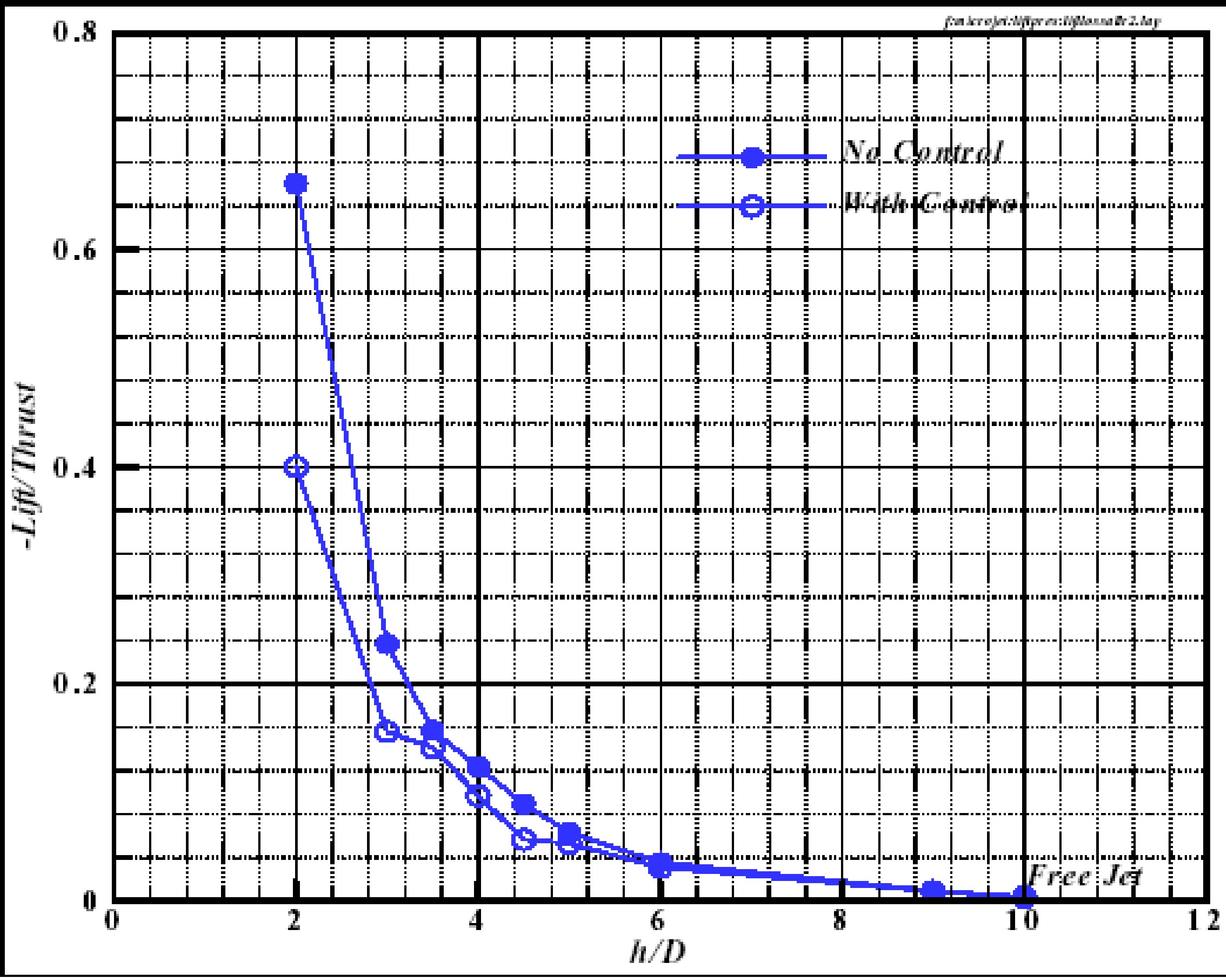
NPR=3.7

Lift Loss



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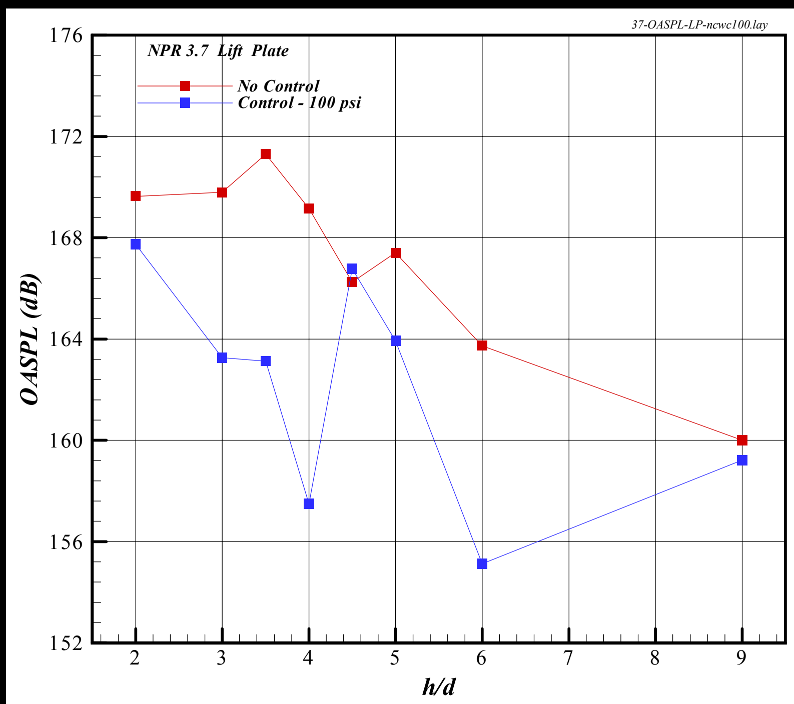
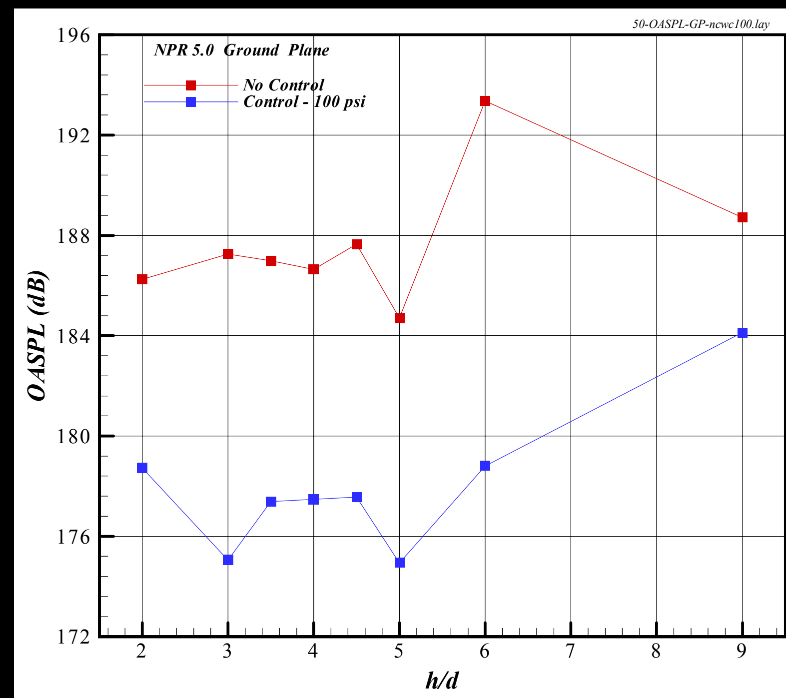
Effect of Microjet Control

20°, 100 psi, 16 microjets



NPR 3.7- Lift Plate



NPR 5 - Ground Plane

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Future Work

- **Characterize the velocity and vorticity field with and without microjets using PIV**

- **Identify relevant control parameters/knobs for effective control**
  - **E.g. mass and momentum flux ratio, number & separation of microjets, scaling.**

- **Explore 'on-line' monitoring and adaptive manipulation of microjets for optimal control.**
  - **Pressure, pulsing, location, number and orientation ….**