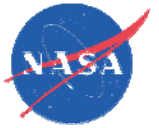

Application of Microramp Flow Control Devices to an Oblique Shock Interaction

Stefanie Hirt

Bernhard Anderson

ABSTRACT

Tests are planned in the 15cm x 15cm supersonic wind tunnel at NASA Glenn to demonstrate the applicability of micro-ramp flow control to the management of shock wave boundary layer interactions. These tests will be used as a database for computational fluid dynamics (CFD) validation and Design of Experiments (DoE) design information. Micro-ramps show potential for mechanically simple and fail-safe boundary layer control.

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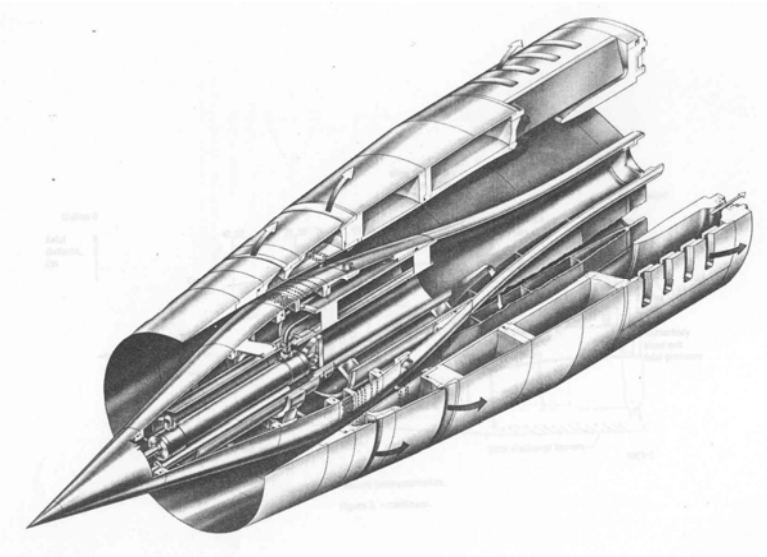
Boundary Layer Management

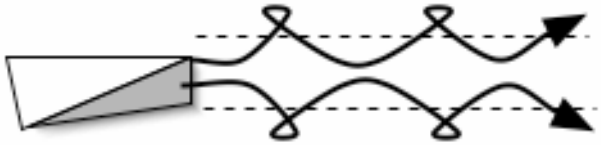
Bleed

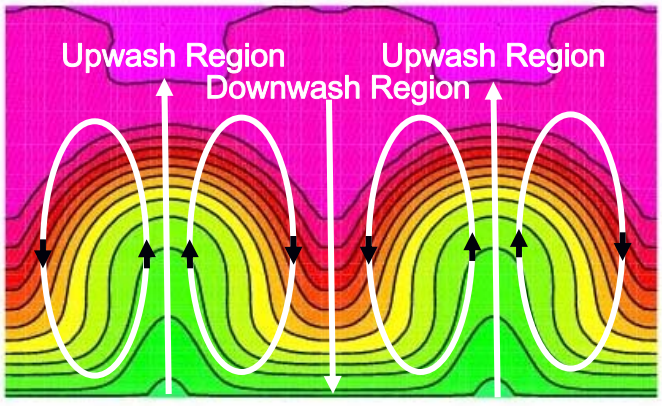
- Removes low energy fluid
- Complex System
- Drag penalties



Microramps

- Boundary layer mixing
- Mechanically simple
- Fail-safe





Test Goals and Objectives

Research Goal:

To demonstrate the applicability of micro-ramp flow control for management of shock wave boundary layer (SWBL) interactions.

Research Objectives:

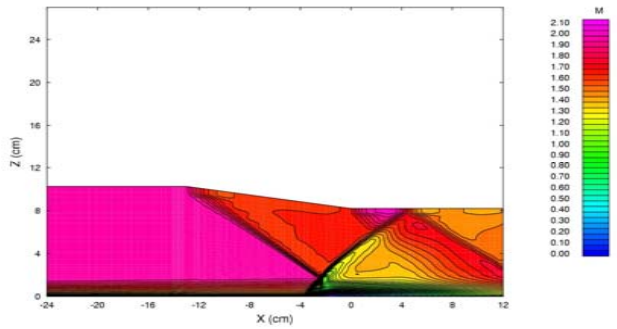
(1) To develop an experimental data base of CFD validation and Design of Experiments (DOE) design information.
(2) To evaluate DOE designs for accuracy and cost effectiveness based on experimental data base.
(3) To validate CFD analysis of micro-ramp actuators based on experimental data base.

Types of Experiments:

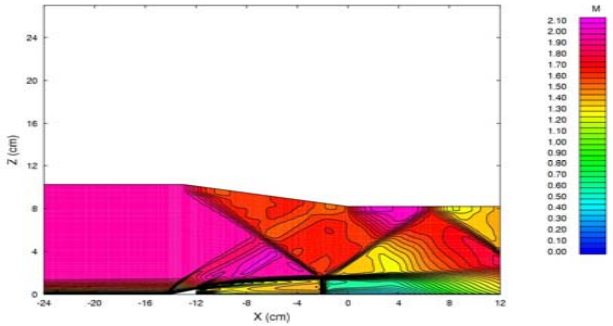
(1) Oblique shock wave boundary layer interactions.
(2) Normal shock wave boundary layer interactions.

15x15cm Microramp Flow Control Tests

Oblique SWBL Experiments

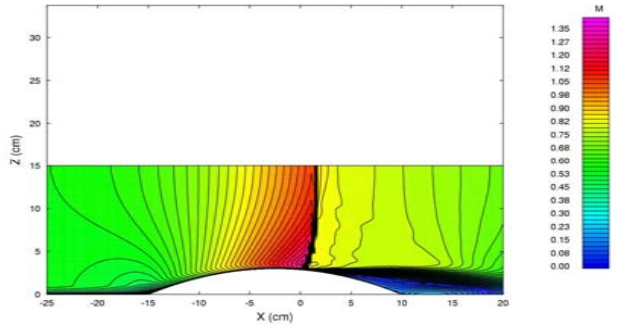


No Flow Control

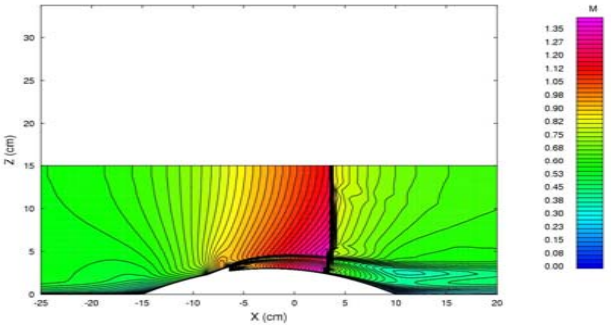


Micro- Ramp Flow Control

Normal SWBL Experiments



No Flow Control

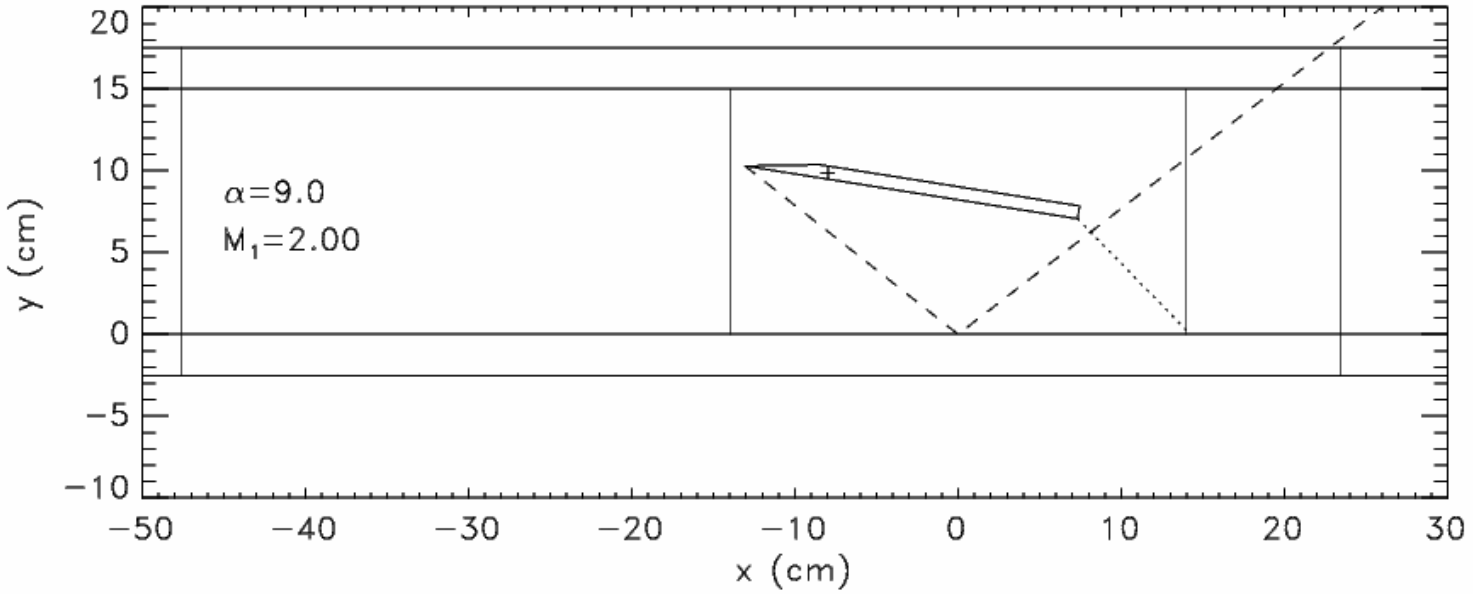


Micro- Ramp Flow Control

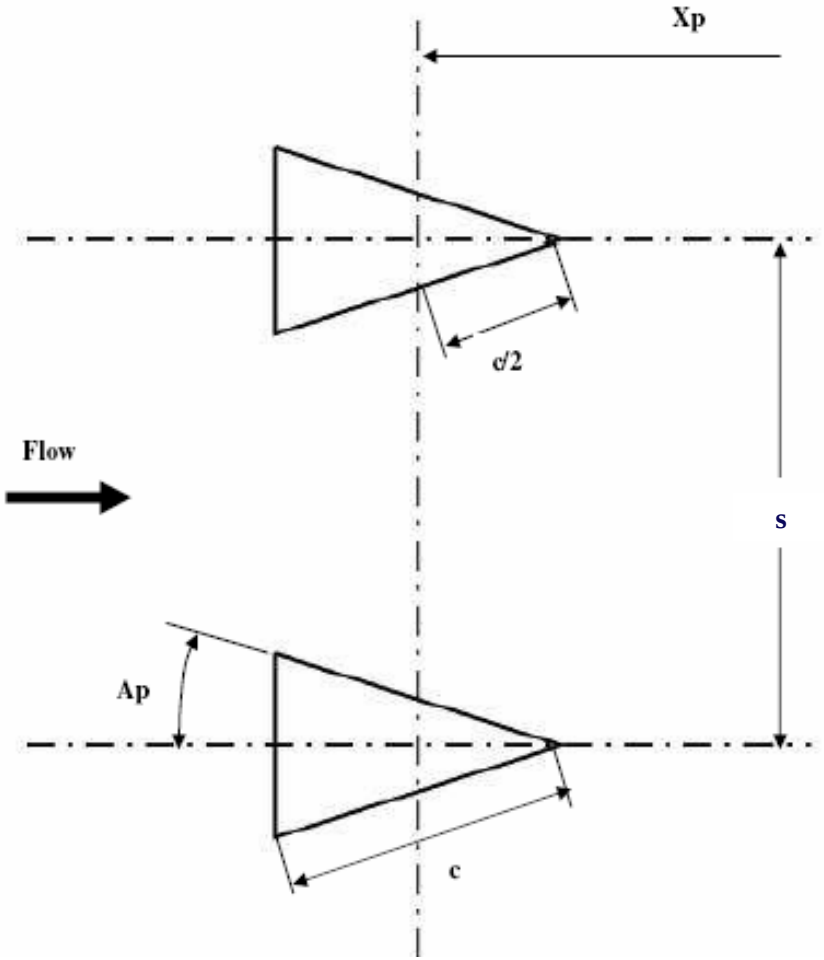
Facility Information

15x15 cm Supersonic Wind Tunnel

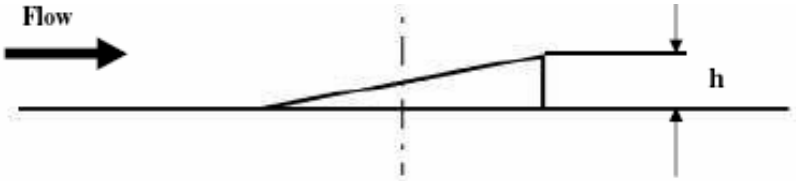
- Mach Number: 2.0
- Reynolds Number: 1.5 x 10^6 – 5 x 10^6 /ft
- Inflow: 40 psig pressure at ambient temperature
- Exhaust: ~ 2.0 psia
- Boundary Layer Thickness: ~ 0.5 in (1.3 cm)
- Microramp x-location: -5.12 in (-13.0 cm)



Microramp Parameters



Top View



Side View

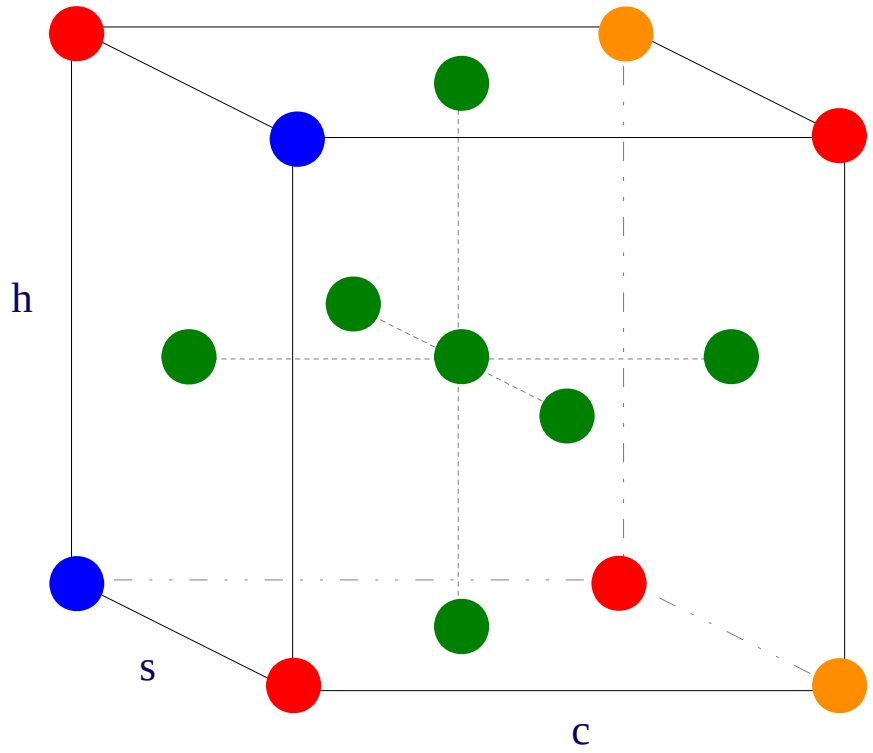
Parameter Values

Spacing, s (mm):	25	30	35
Height, h (mm):	3.0	4.0	5.0
Chord, c (mm):	12	18	24

Central Composite DOE: 15 Cases

Every Combination: 27 Cases

DOE Designs



Main Effects Design - 4 cases

D-Optimal Design - 6 cases

Full Factorial Design - 8 cases

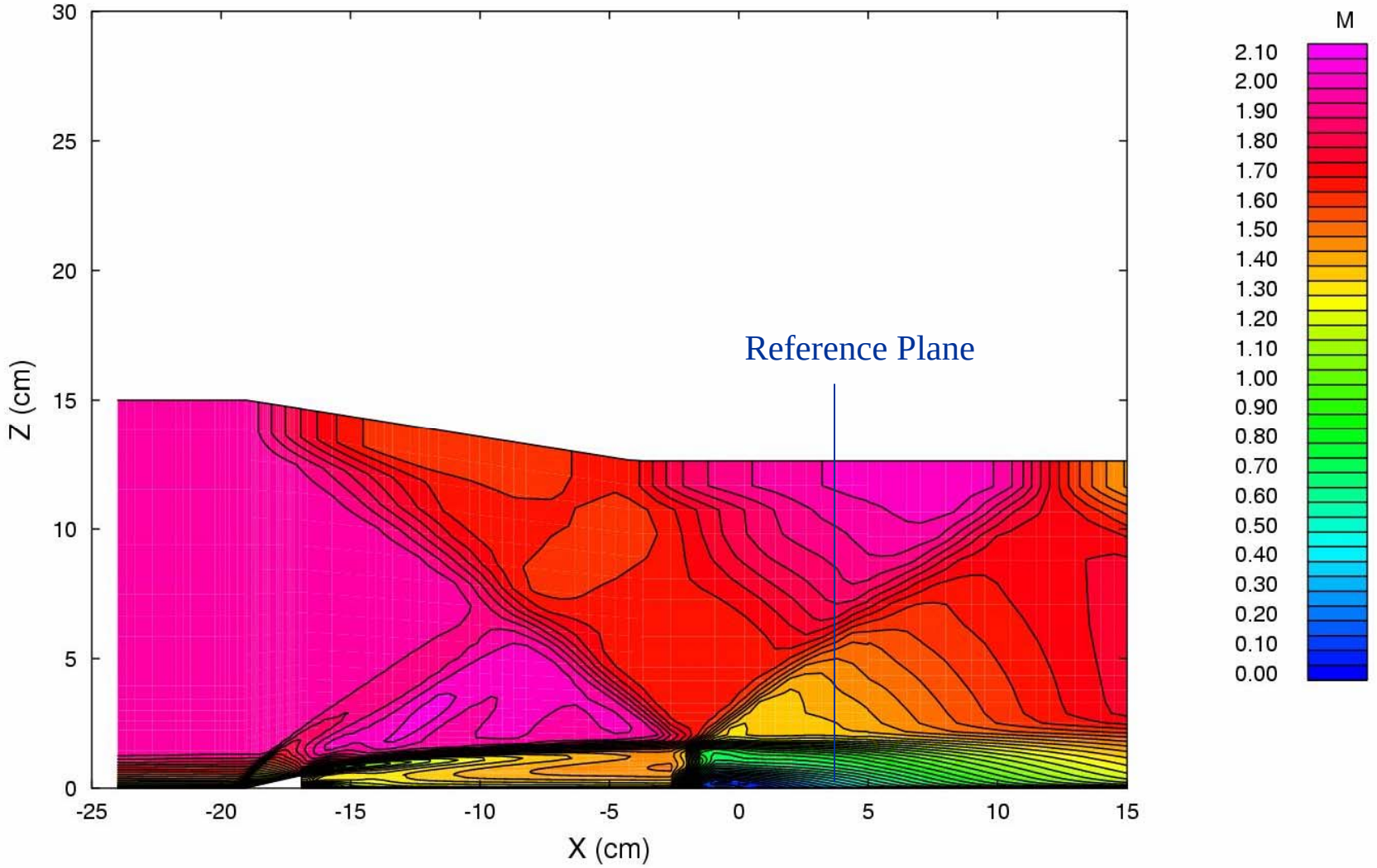
Central Composite Design - 15 cases

Response Variables

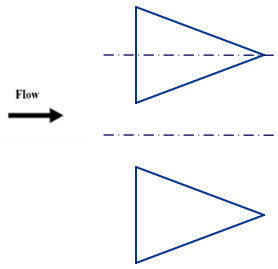
Boundary Layer Pitot Pressure Recovery	PTAVE
Boundary Layer Total Pressure Recovery	PFAVE
Compressible Displacement Thickness	δ^*
Compressible Momentum Thickness	θ
Incompressible Shape Factor	H_i

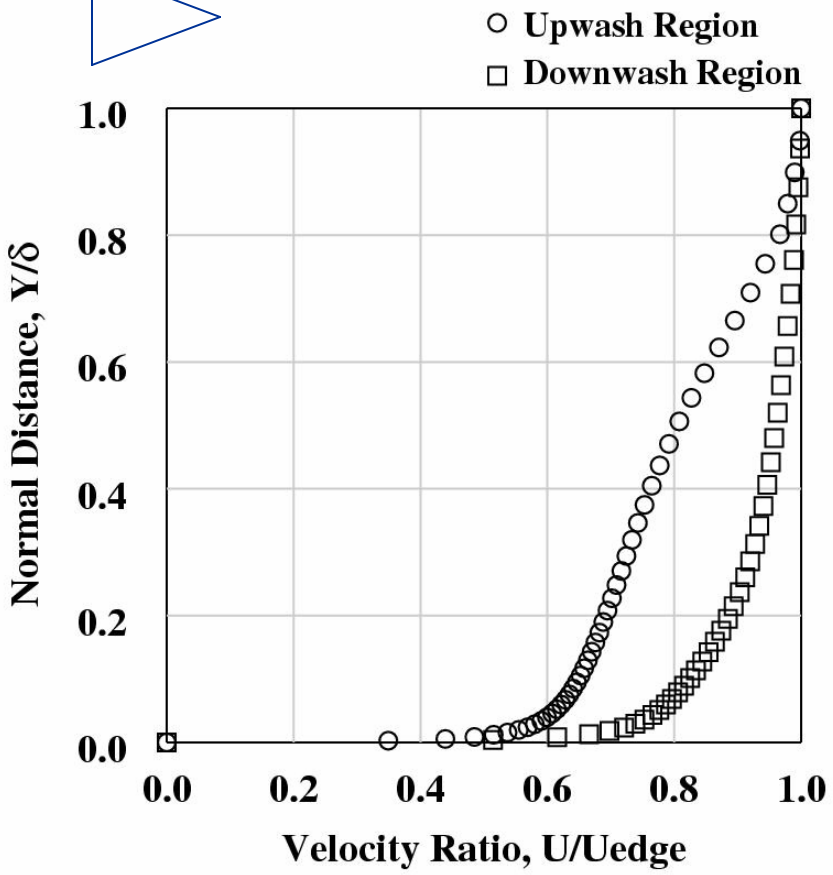
Oblique Shock / Microramp Interaction

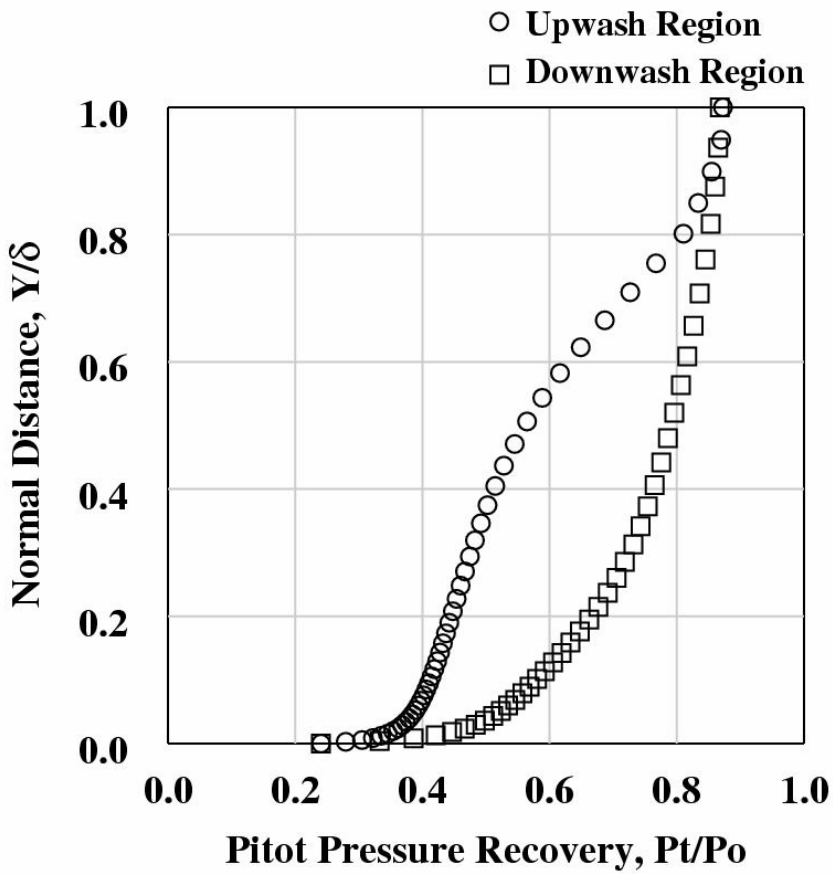
CFD Calculation



Reference Plane Profiles







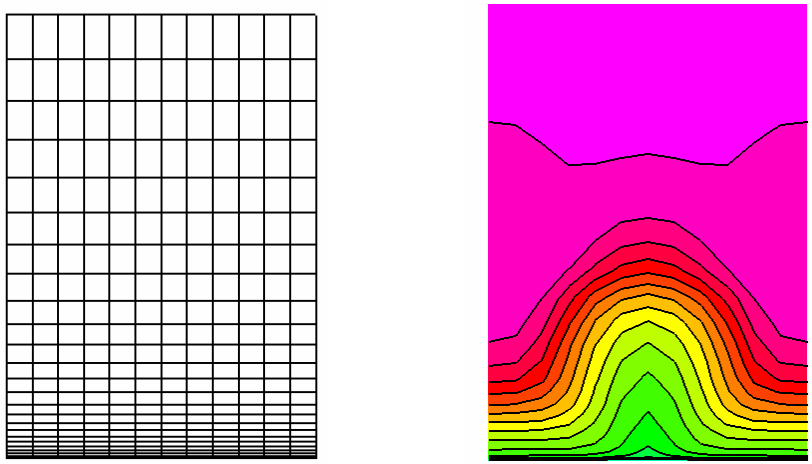
Microramp Optimization

DOE Design	s (mm)	h (mm)	c (mm)	PREF	δ* (cm)	θ (cm)	Htr
Main Effects (4 points)	25.0	5.0	24.0	0.829	0.427	0.247	1.237
D-Optimal (6 points)	25.0	5.0	24.0	0.801	0.433	0.242	1.237
Full Factorial (8 points)	25.0	5.0	24.0	0.793	0.428	0.239	1.254
Central Composite (15 points)	25.0	5.0	24.0	0.813	0.440	0.239	1.239

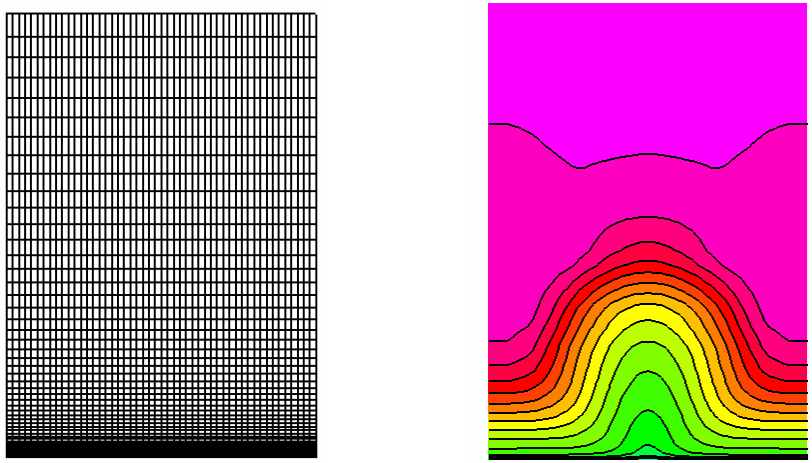
- **Optimal design obtained by minimizing Htr**
- **Based on CFD results**

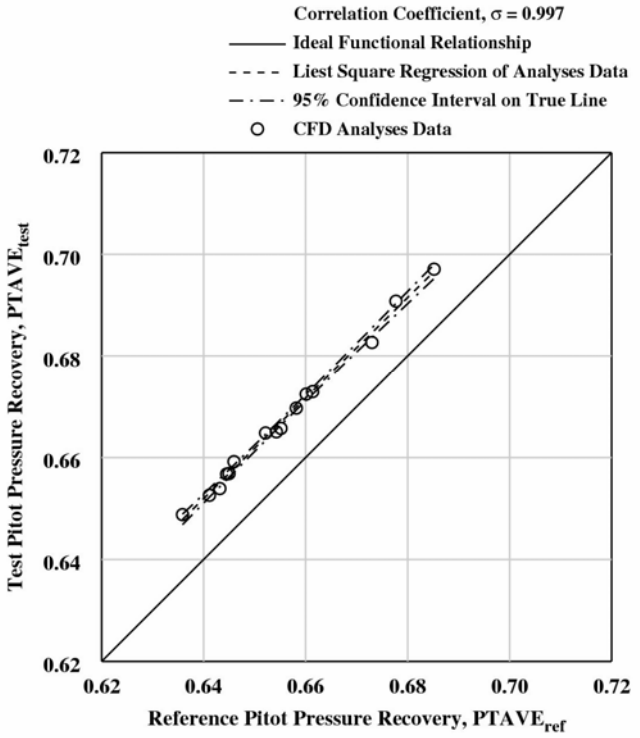
Experimental Grid Resolution Study

13 x 25 (Test)



51 x 50 (Reference)





Test Schedule

	FY07				FY08				FY09				FY10			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
15x15 cm Wind Tunnel																
Test Cell Prep																
Microramps - Oblique																
Isolator Test																
Microramps - Normal																
Buildup Shutdown																
Inlet Wind Tunnel Test																
Microramp Inlet Test																
-Aero Design																
-Design and Fab																
-Testing																

Final Remarks

- CFD for the Oblique Shock Interaction is complete. Experimental testing will begin soon.

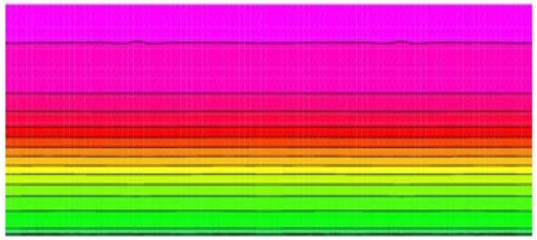
- Issues affecting the experimental data were resolved.
  - Data resolution
  - Static pressure gradient
  - Boundary layer edge selection

- Normal Shock Interaction test conditions are being finalized.

- Future Plans:
  - Fail-Safe Hybrid Flow Control
  - Multiple Shock Interaction with Microramps
  - Large Scale Inlet Test with Microramp Flow Control

Backup

Advanced Inlet Flow Control
Central Composite Face Centered Design
Total Pressure Contours



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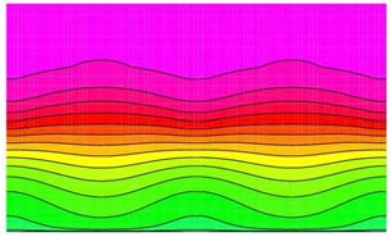

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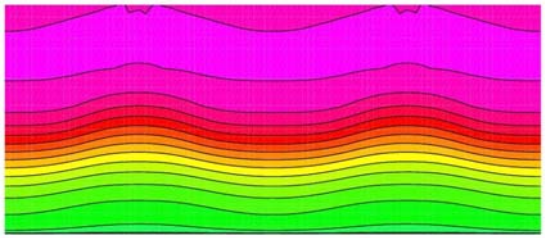

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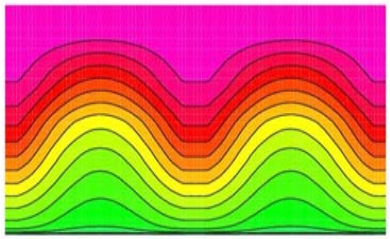

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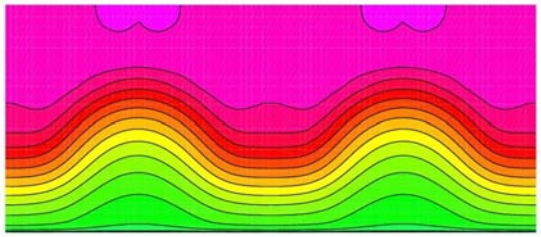

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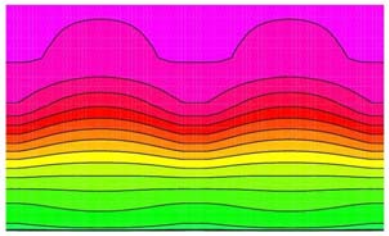

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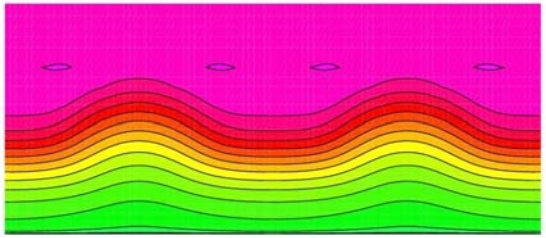

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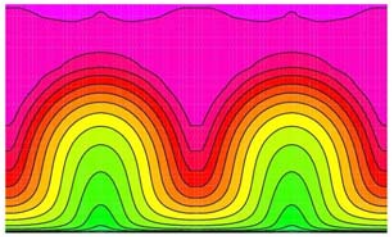

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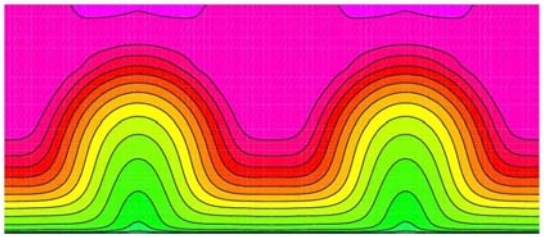

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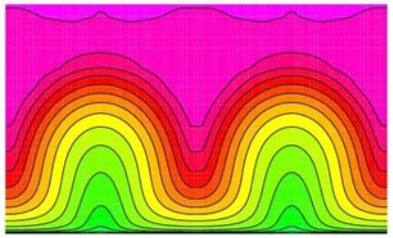
Advanced Inlet Flow Control
Central Composite Face Centered Design
Total Pressure Contours



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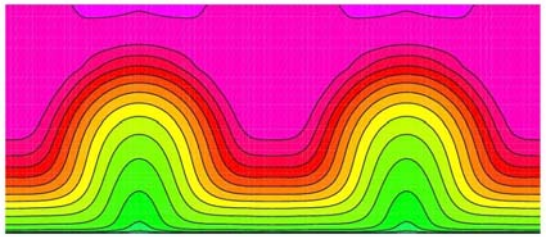

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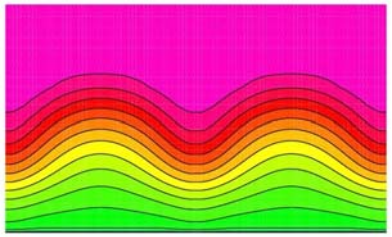

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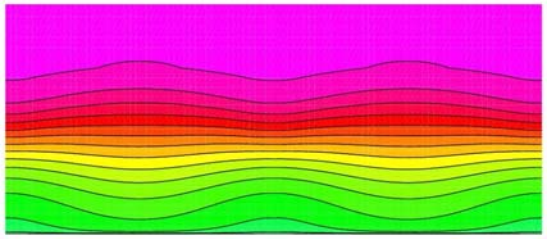

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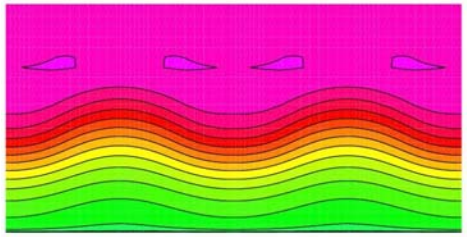

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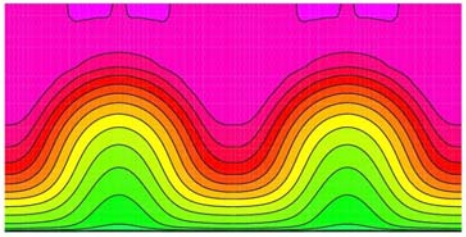

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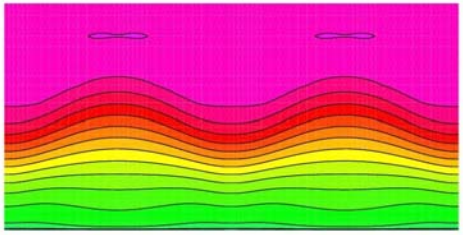

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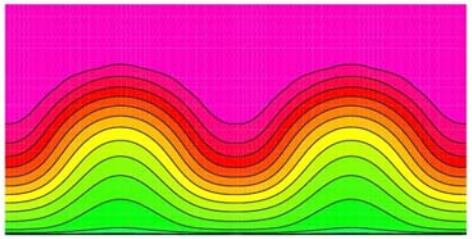

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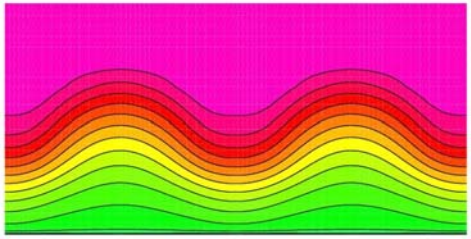

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