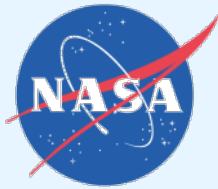


# Aero-Thermal Calibration of the NASA Glenn Icing Research Tunnel (2012 Test)

A major modification of the refrigeration plant and heat exchanger at the NASA Glenn Icing Research Tunnel (IRT) occurred in autumn of 2011. It is standard practice at NASA Glenn to perform a full aero-thermal calibration of the test section of a wind tunnel facility upon completion of major modifications. This paper will discuss the tools and techniques used to complete an aero-thermal calibration of the IRT and the results that were acquired. The goal of this test entry was to complete a flow quality survey and aero-thermal calibration measurements in the test section of the IRT. Test hardware that was used includes the 2D Resistive Temperature Detector (RTD) array, 9-ft pressure survey rake, hot wire survey rake, and the quick check survey rake. This test hardware provides a map of the velocity, Mach number, total and static pressure, total temperature, flow angle and turbulence intensity. The data acquired were then reduced to examine pressure, temperature, velocity, flow angle, and turbulence intensity. Reduced data has been evaluated to assess how the facility meets flow quality goals. No icing conditions were tested as part of the aero-thermal calibration. However, the effects of the spray bar air injections on the flow quality and aero-thermal calibration measurements were examined as part of this calibration.



# IRT 2011-12 Cooling System Upgrade

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## Aero-Thermal Calibration of the NASA Glenn Icing Research Tunnel (2012 Test)

Christine Pastor-Barsi / Sierra Lobo, Inc.

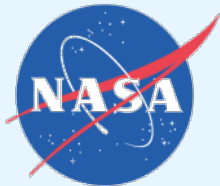
E. Allen Arrington / Sierra Lobo, Inc

Judith Foss Van Zante, Ph.D. / Sierra Lobo, Inc

4<sup>th</sup> Atmospheric and Space Environments Conference

June 26, 2012

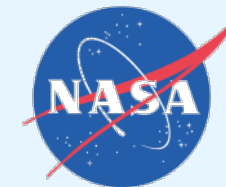




# Session Summary

Time	Topic	Presenter
0800 – 0900	IRT Upgrade and Cloud Cal	Van Zante / NASA-SLI
<b>0900 – 0930</b>	<b>IRT Test Section Aero-Thermal Cal</b>	<b>Pastor-Barsi / NASA-SLI</b>
0930 – 1000	IRT Plenum Aero-Thermal Cal	Steen / NASA-SLI
1000 – 1030	VIRT: Air Flow and Liquid Water Concentration Simulations	Clark / UVa
1030 – 1100	VIRT: Drop Concentration and Flux on Aerodynamic Surfaces	Triphahn / UIUC
1100 – 1130	3D Laser Scanner in IRT	Lee / NASA-ASRC





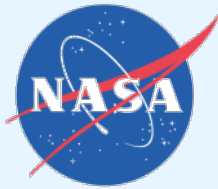
# Why Aero-Thermal?

- Calibration and Acceptance of Icing Wind Tunnels (Aerospace Recommended Practice 5905)

Parameter	Measurement Uncertainty	Test Section Spatial Uniformity	Tunnel Centerline Temporal Stability
Airspeed	$\pm 1\%$	$\pm 2\%$	$\pm 2\%$
Static air temperature, $-30$ through $+5\text{ }^{\circ}\text{C}$	$\pm 2\text{ }^{\circ}\text{C}$	$\pm 1\text{ }^{\circ}\text{C}$	$\pm 0.5\text{ }^{\circ}\text{C}$
Flow Angularity	$\pm 0.25\text{ }^{\circ}$	$\pm 2\text{ }^{\circ}$	N/A
Turbulence ( $P_{air} = 0\text{ }psi$ )	$\pm 0.25\%$	$< 2\%$	$\pm 2\%$
Turbulence ( $P_{air} = 60\text{ }psi$ )	$\pm 0.25\%$	$< 2\%$	$\pm 2\%$

- AIAA Recommended Practice (AIAA R-093-2003) Calibration of Subsonic and Transonic Wind Tunnels
- Health monitoring
- Goal – Calibration curve



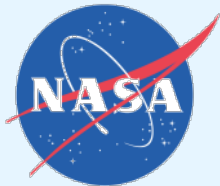


# Outline

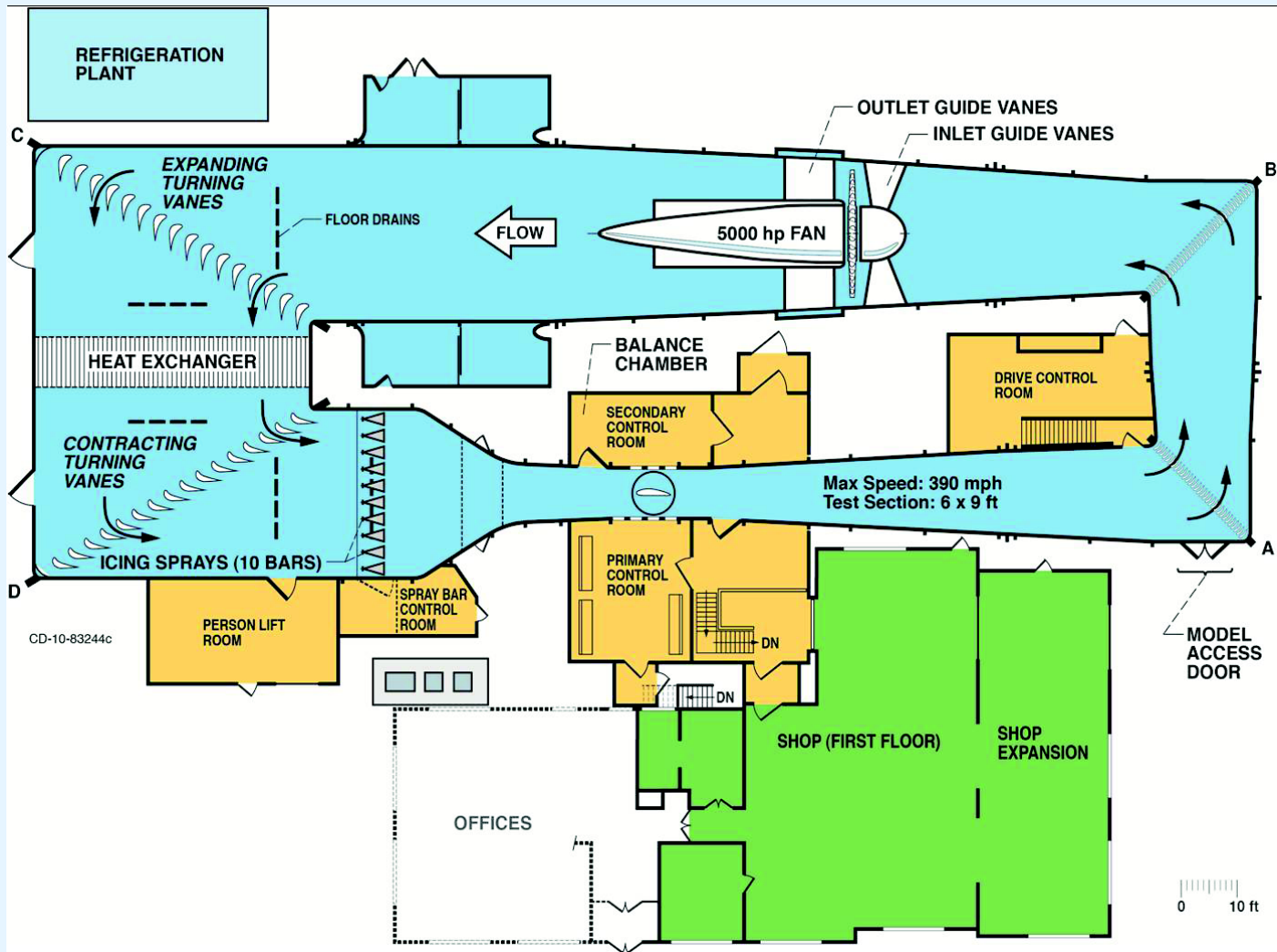
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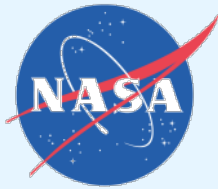
- 2012 Aero-thermal testing occurred January and May 2012 after major facility upgrade
  - Previous full Calibration January 2009
- Hardware
  - 9-ft survey rake
  - 2D RTD array
  - Hot wire/film survey rake
- Results
- Summary





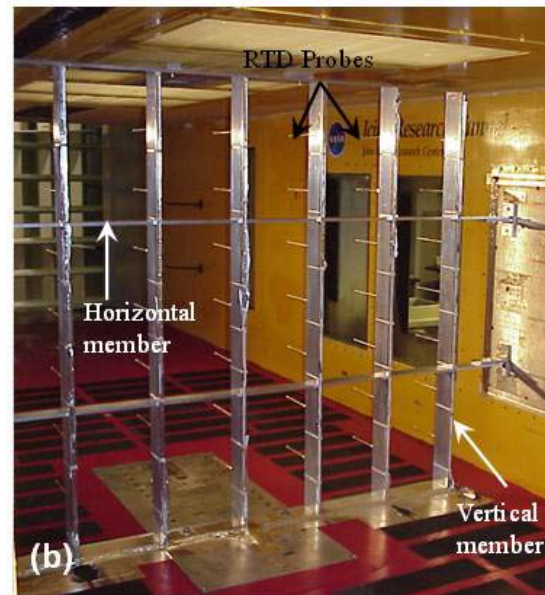
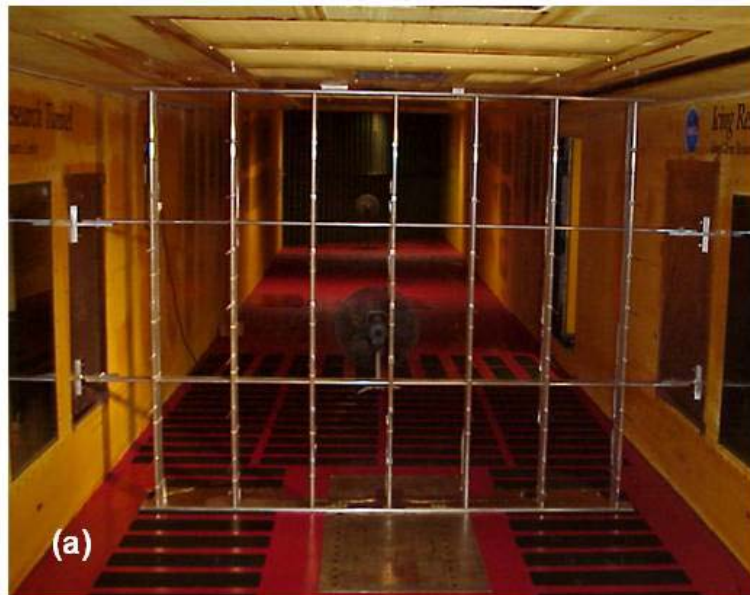
# 2012 Icing Research Tunnel



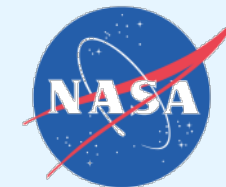


## 2D RTD Array

- 7x7 grid of RTDs (49 total)
- Probes are 4-wire RTDs with a ceramic capsule sensor
- Temperature flow recovery calibration completed in 2005 (AIAA 2005-4276)







# Test Matrix 2D RTD Array

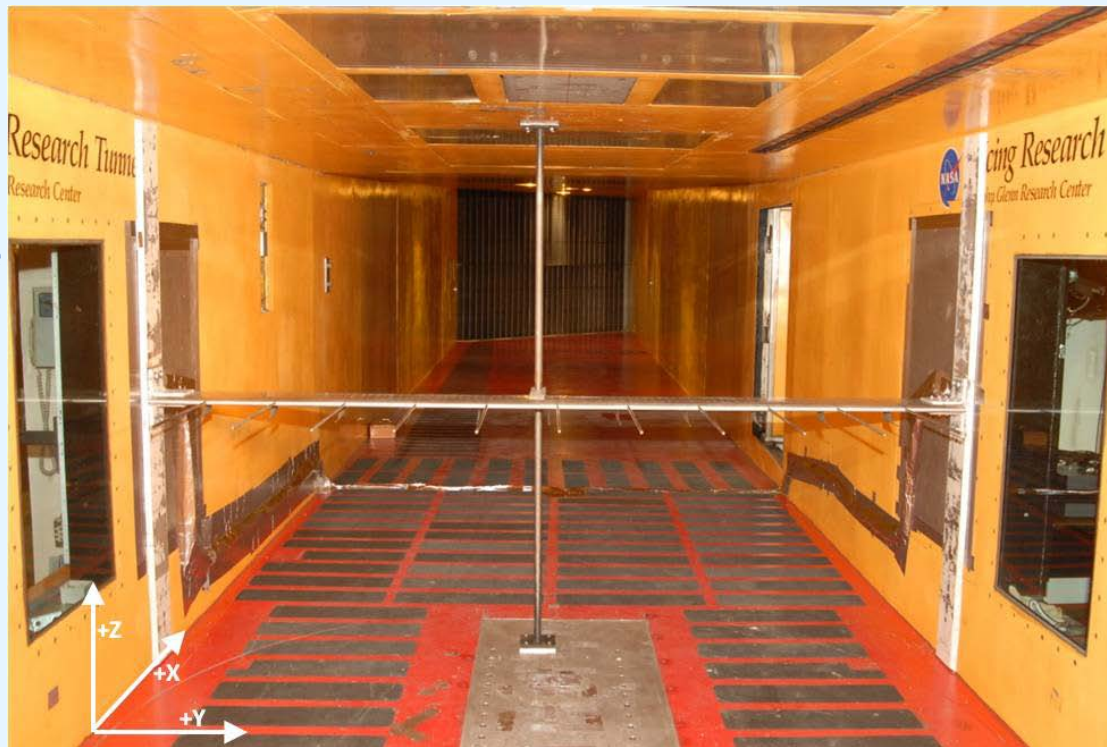
Test Section total temperature, $T_{T,ts}$ °C	Test Section Airspeed, $U_{ts}$ knots	Spraybar air pressure, $P_{air}$ , psig
-30	50,130,220,300	0,30,60
-20	50,130,220,300	0,30,60
-10	50,130,220,300	0,30,60
-3	50,130,220,300	0,30,60
-2	50,130,220,300	0,30,60
-1	50,130,220,300	0,30,60
0	50,130,220,300	0,30,60
1	50,130,220,300	0,30,60
2	50,130,220,300	0,30,60
3	50,130,220,300	0,30,60
5	50,130,220,300	0,30,60

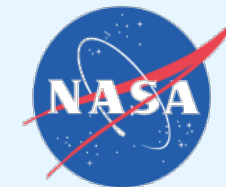




## 9-ft Survey Rake

- Positioning every 6-inches vertically
- 11 Hemispherical-head 5-hole pressure probes
  - Measures total and static pressures
- Probes calibrated in 1996 (AIAA 96-2201)

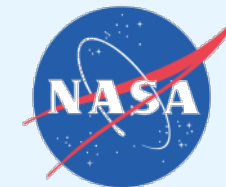




# Test Matrix 9-ft Survey Rake

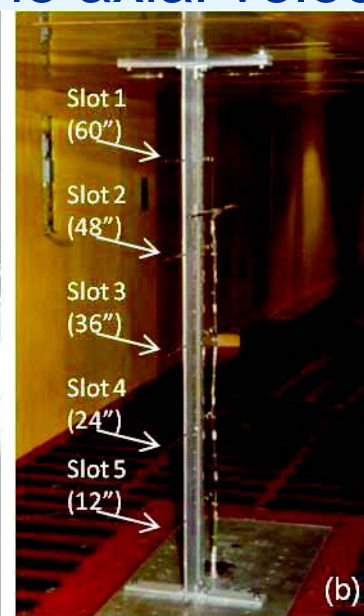
Rake Position (horizontal)	Static temperature, $T_{T,ts}$ °C	Test Section Airspeed, $U_{ts}$ knots	Spraybar air pressure, $P_{air}$ , psig
CL	4.0	50,90,120,150,170,200,250	0,30,60
CL-6"	4.0	50,90,120,150,170,200,250	0,30,60
CL+6"	4.0	50,90,120,150,170,200,250	0,30,60
CL-12"	4.0	50,90,120,150,170,200,250	0,30,60
CL+12"	4.0	50,90,120,150,170,200,250	0,30,60
CL-18"	4.0	50,90,120,150,170,200,250	0,30,60
CL+18"	4.0	50,90,120,150,170,200,250	0,30,60
CL-24"	4.0	50,90,120,150,170,200,250	0,30,60
CL+24"	4.0	50,90,120,150,170,200,250	0,30,60

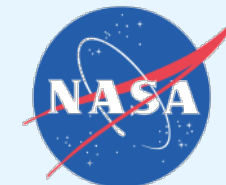




# Hot Wire Survey Rake

- Hot wire survey has 5 positions across the test section in 18-inch increments
- Testing is done in only the incompressible regime,  $M < 0.3$  (180 knots)
- Calibrations of the hot wires are performed in situ
  - Only single wires/films normal to the axial velocity are used

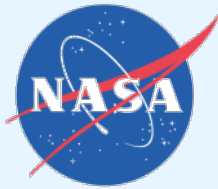




# Test Matrix Hot Wire Survey Rake

Rake Position (lateral)	Test Section total temperature, $T_{T,ts}$ °C	Test Section Airspeed, $U_{ts}$ knots	Spraybar air pressure, $P_{air}$ , psig
CL	7.8	50,90,120,150,170	0,30,60
CL-18"	7.8	50,90,120,150,170	0,30,60
CL-36"	7.8	50,90,120,150,170	0,30,60
CL+18"	7.8	50,90,120,150,170	0,30,60
CL+36"	7.8	50,90,120,150,170	0,30,60





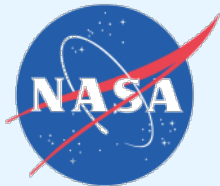
# Facility Instrumentation

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- D-corner RTD Array
  - 24-probe array, 4 rows of 6 probes
- North and South Bellmouth Pitot-Static probes
  - Measure total and delta pressure
  - Heated to prevent icing

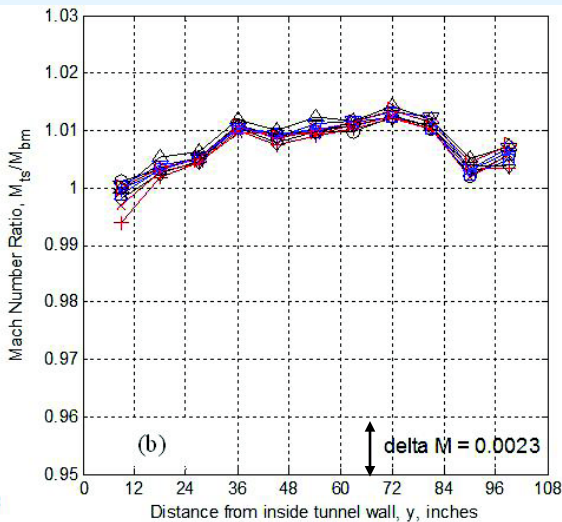
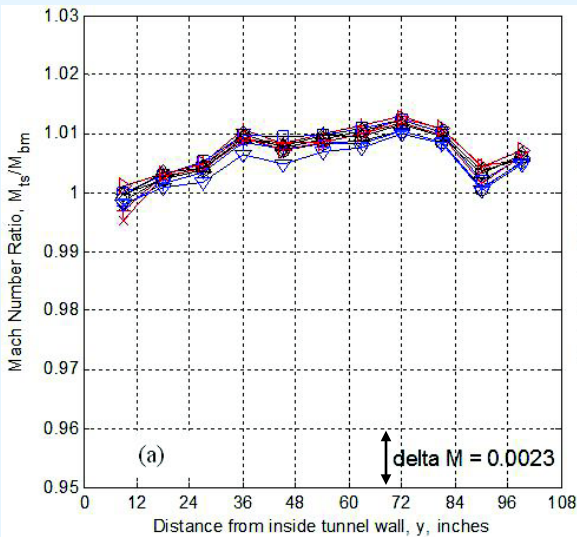




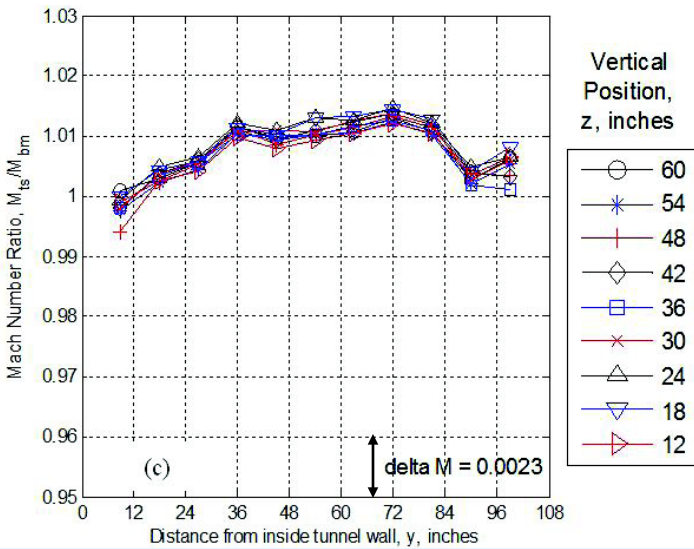


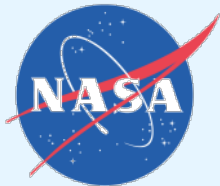
# Mach number

Target Test  
Conditions:  
150 knots,  
TSDC = 4.0°C



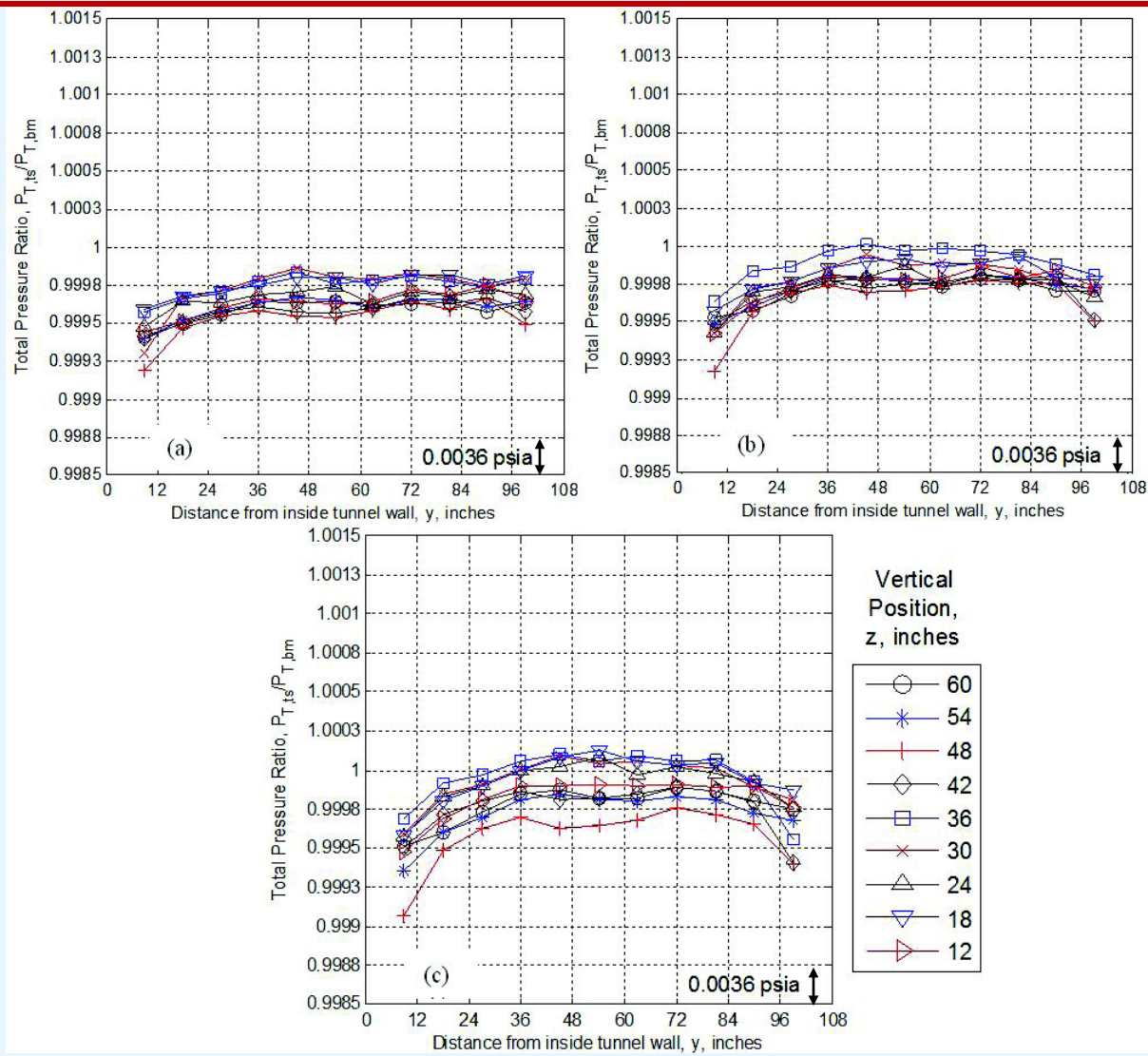
(a) 0 psig  
(b) 30 psig  
(c) 60 psig





# Total Pressure

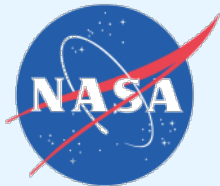
Target Test  
Conditions:  
150 knots,  
TSDC = 4.0°C



(a) 0 psig  
(b) 30 psig  
(c) 60 psig

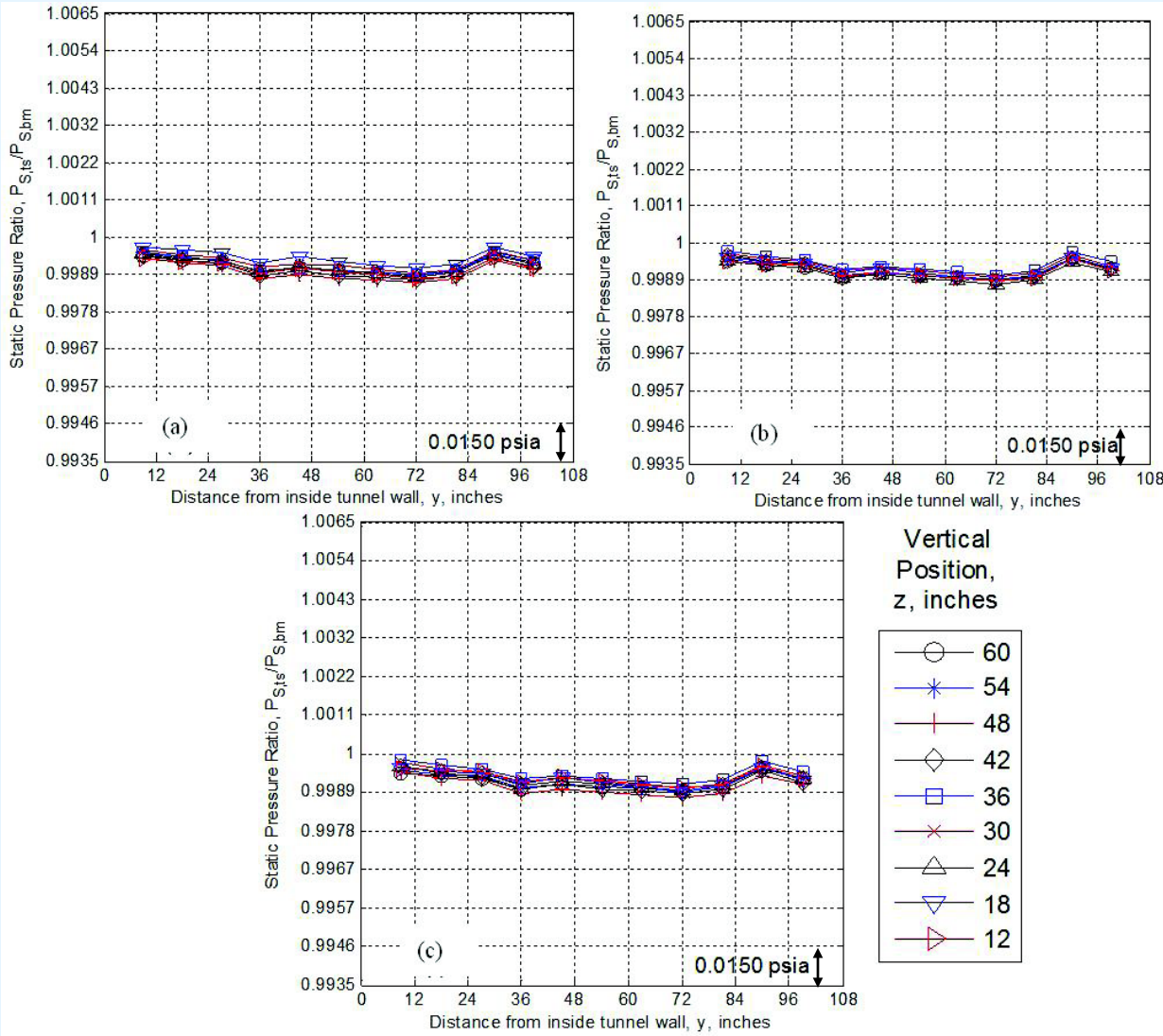






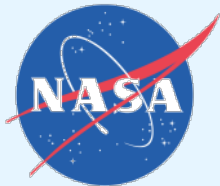
# Static Pressure

Target Test  
Conditions:  
150 knots,  
TSDC = 4.0°C



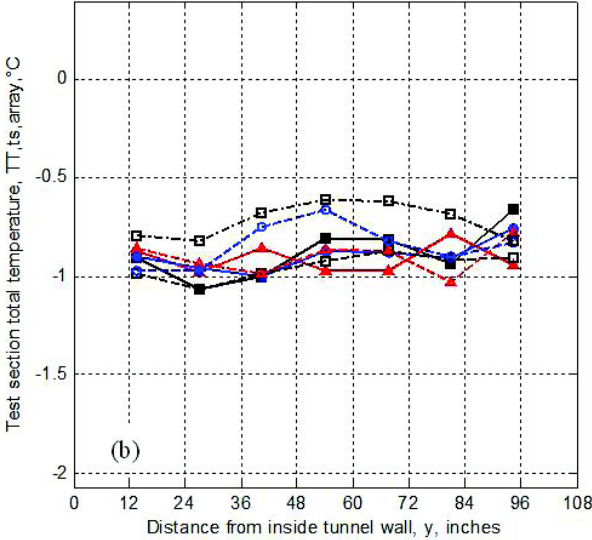
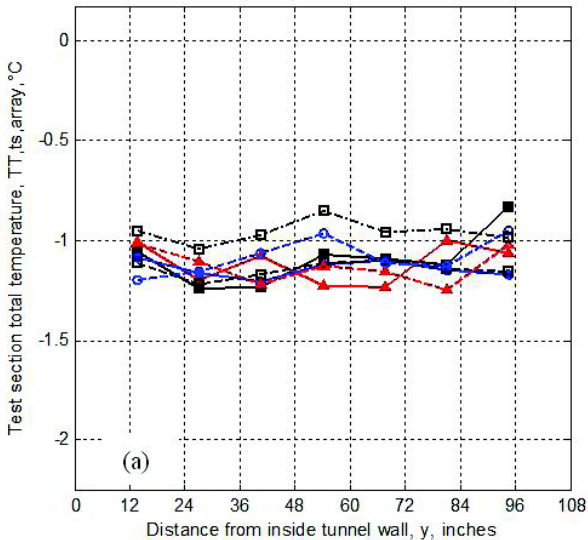
(a) 0 psig  
(b) 30 psig  
(c) 60 psig



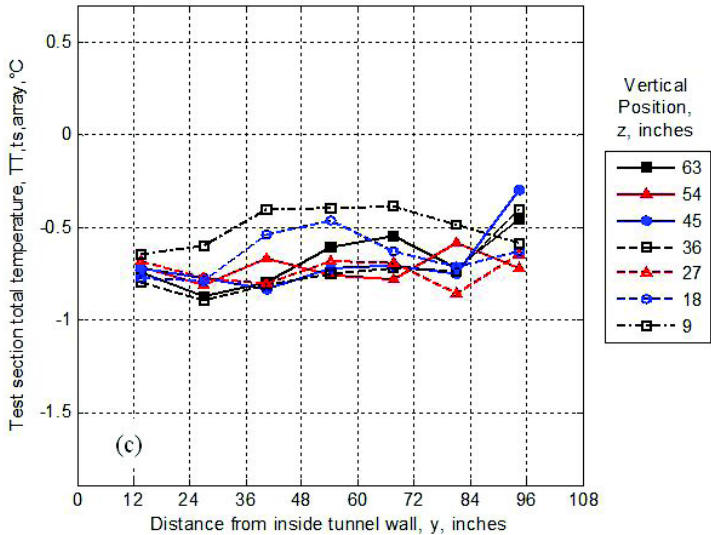


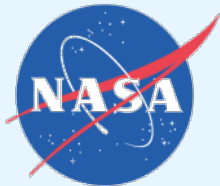
# Total Temperature

Target Test Conditions:  
130 knots,  
TTDC = -1°C



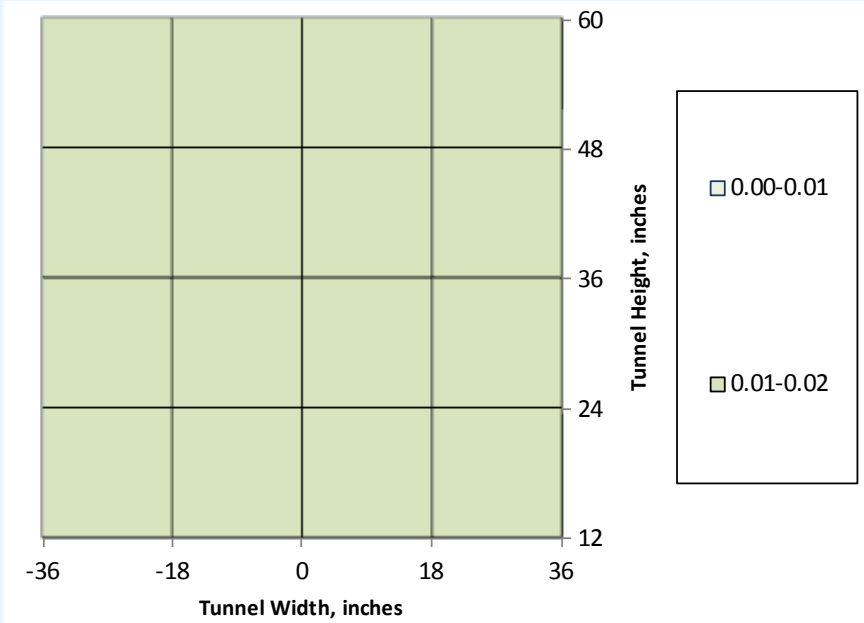
(a) 0 psig  
(b) 30 psig  
(c) 60 psig



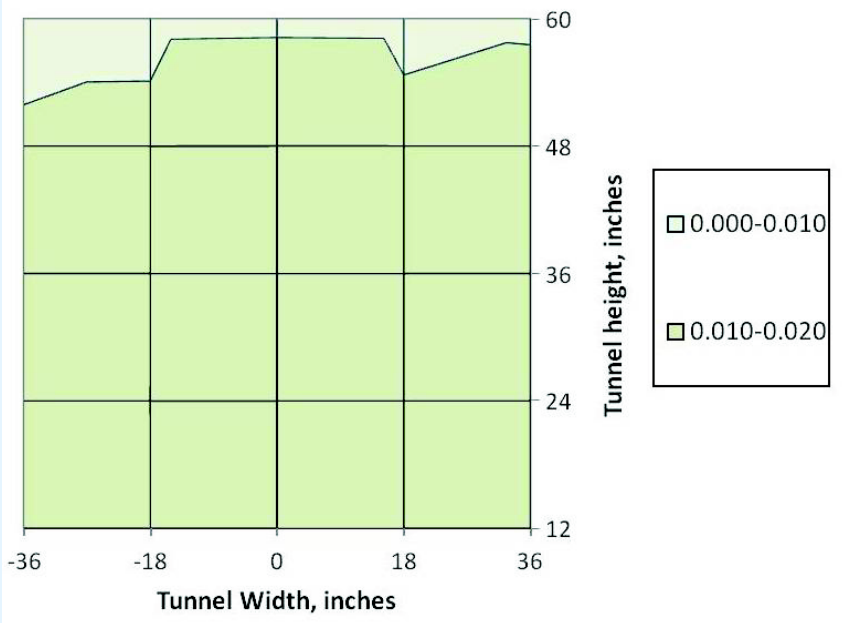


# Turbulence Intensity

2009

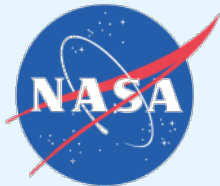


2012

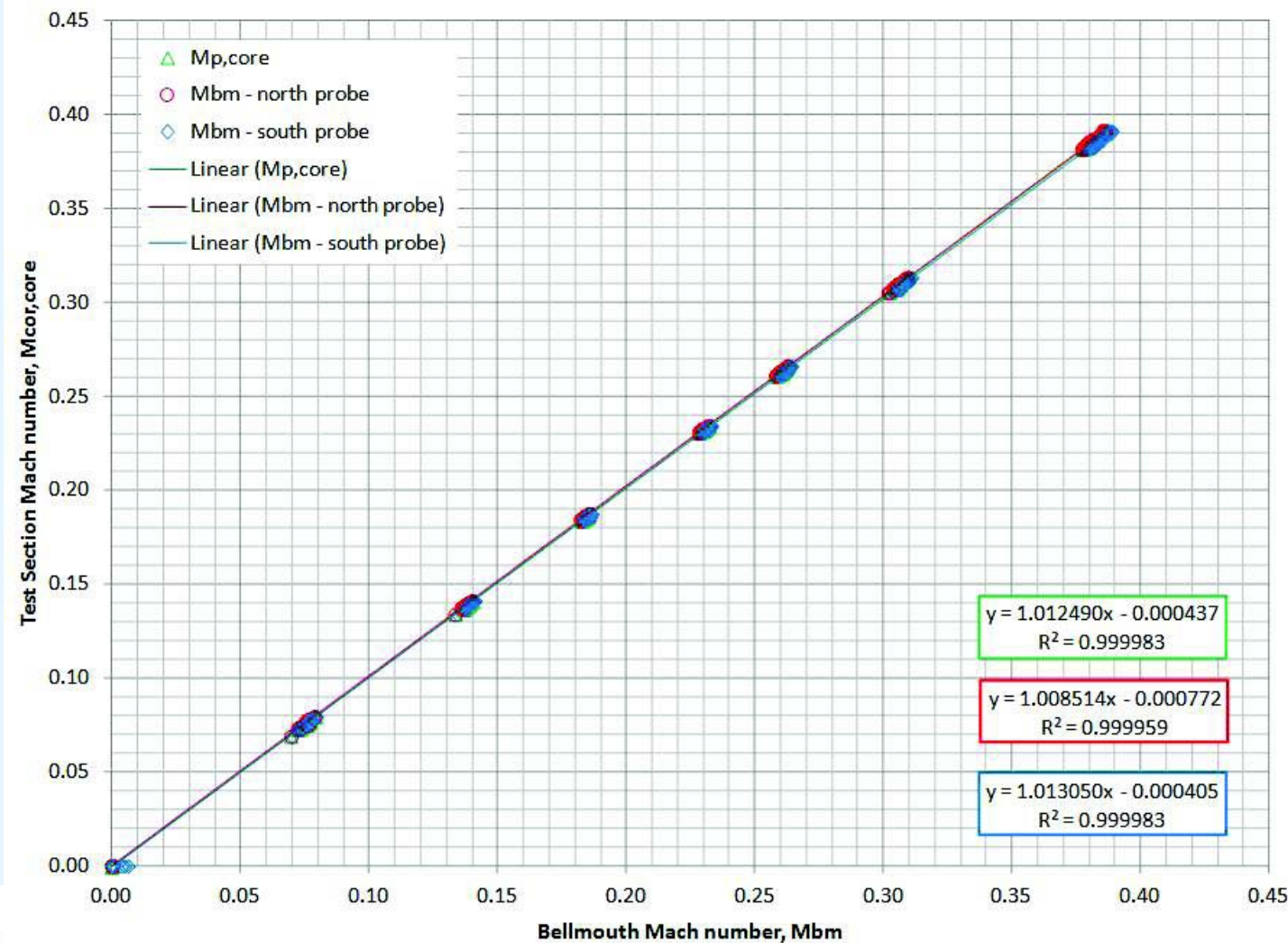


Target Test  
Conditions:  
150 knots,  
Pair = 0 psig

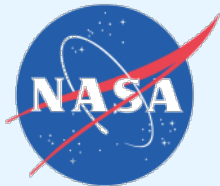




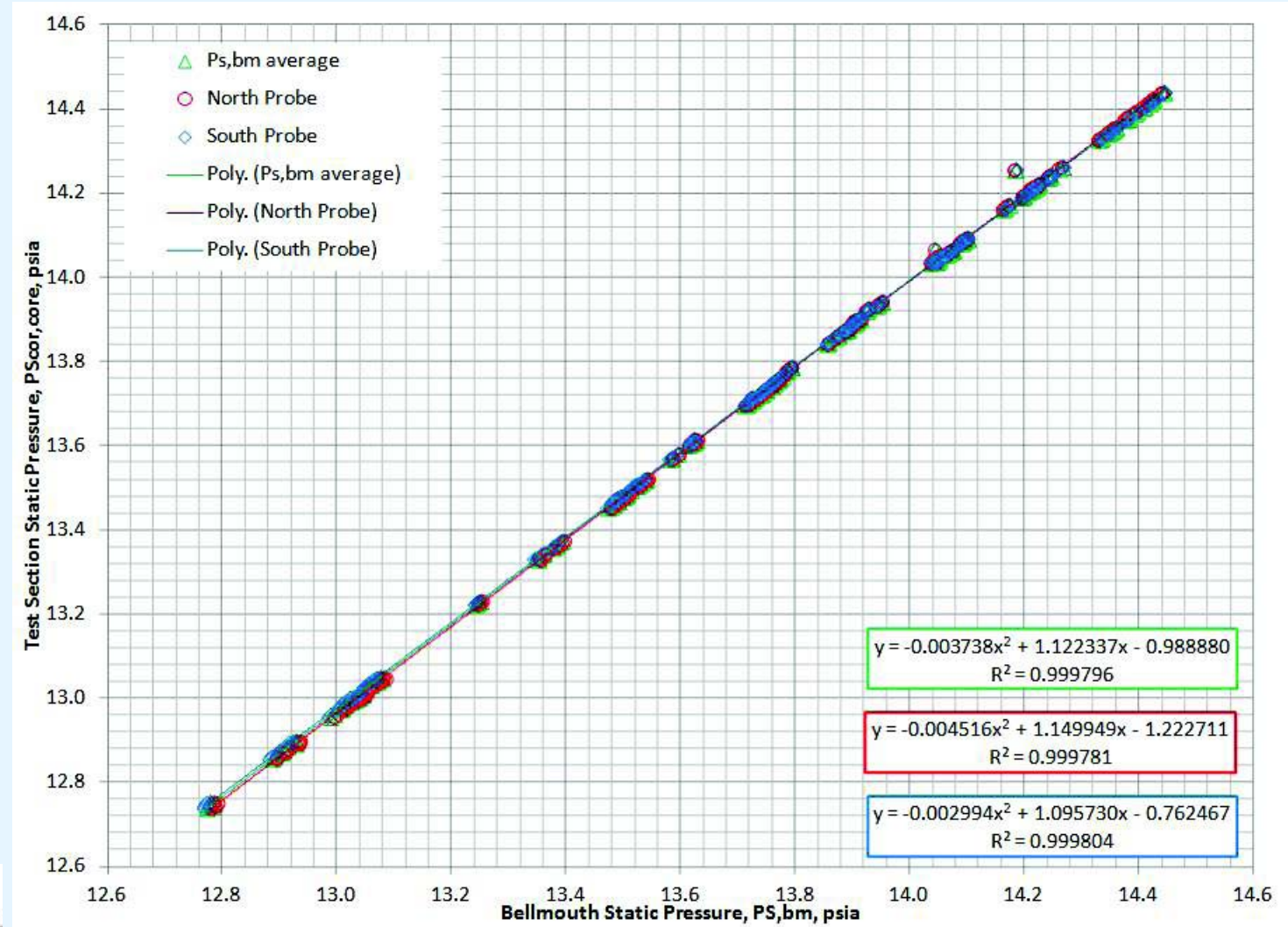
# Mach number Calibration Curve

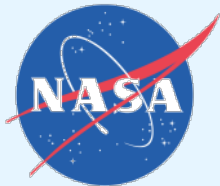




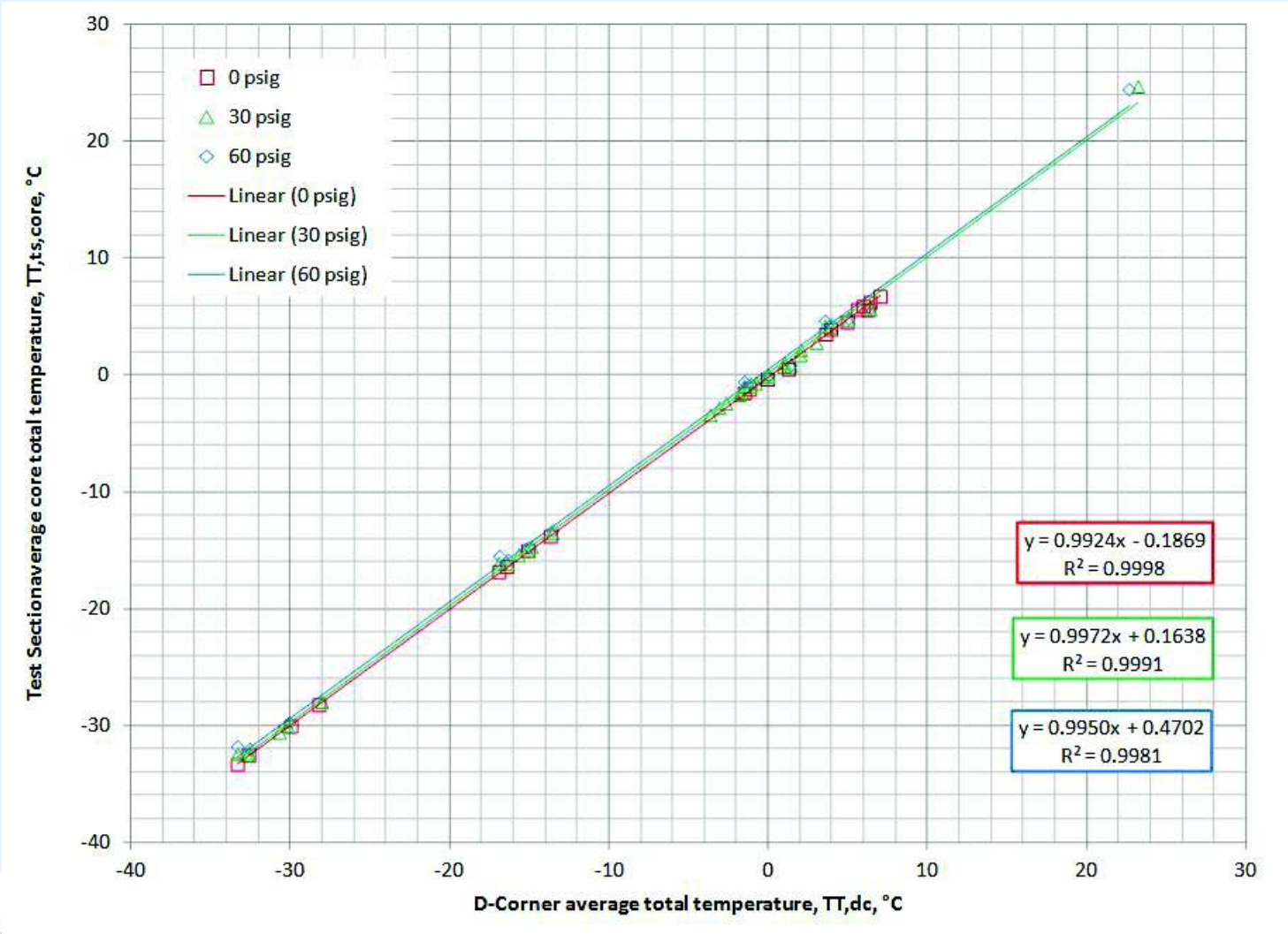


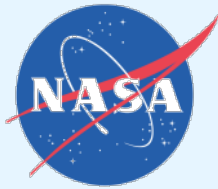
# Static Pressure Calibration Curve





# Total Temperature Calibration Curve





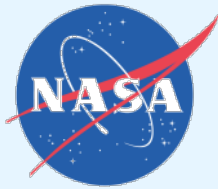
# Summary

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- Improvement in spatial temperature deviation of the heat exchanger
- New set of calibration curves have been implemented for static pressure, Mach number, and total temperature
- A facility health issue was resolved
- NASA CR will be out shortly with the full set of data.





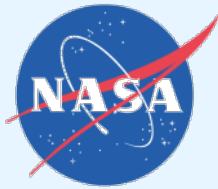


# IRT 2011-12 Cooling System Upgrade

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## Questions?



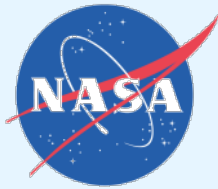


# IRT 2011-12 Cooling System Upgrade

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## Backup Slides





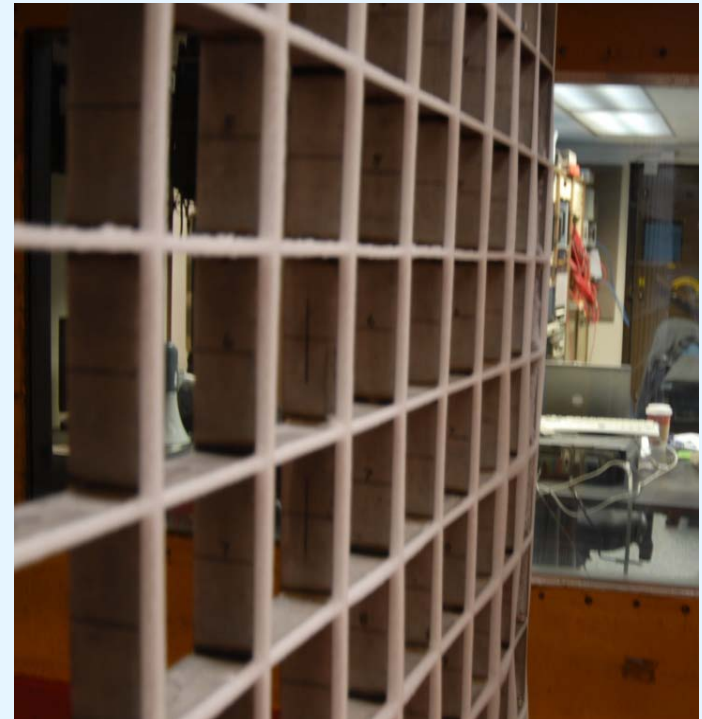
# No Struts vs. With Struts

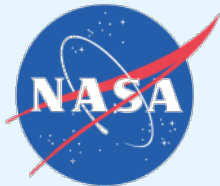
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No Struts

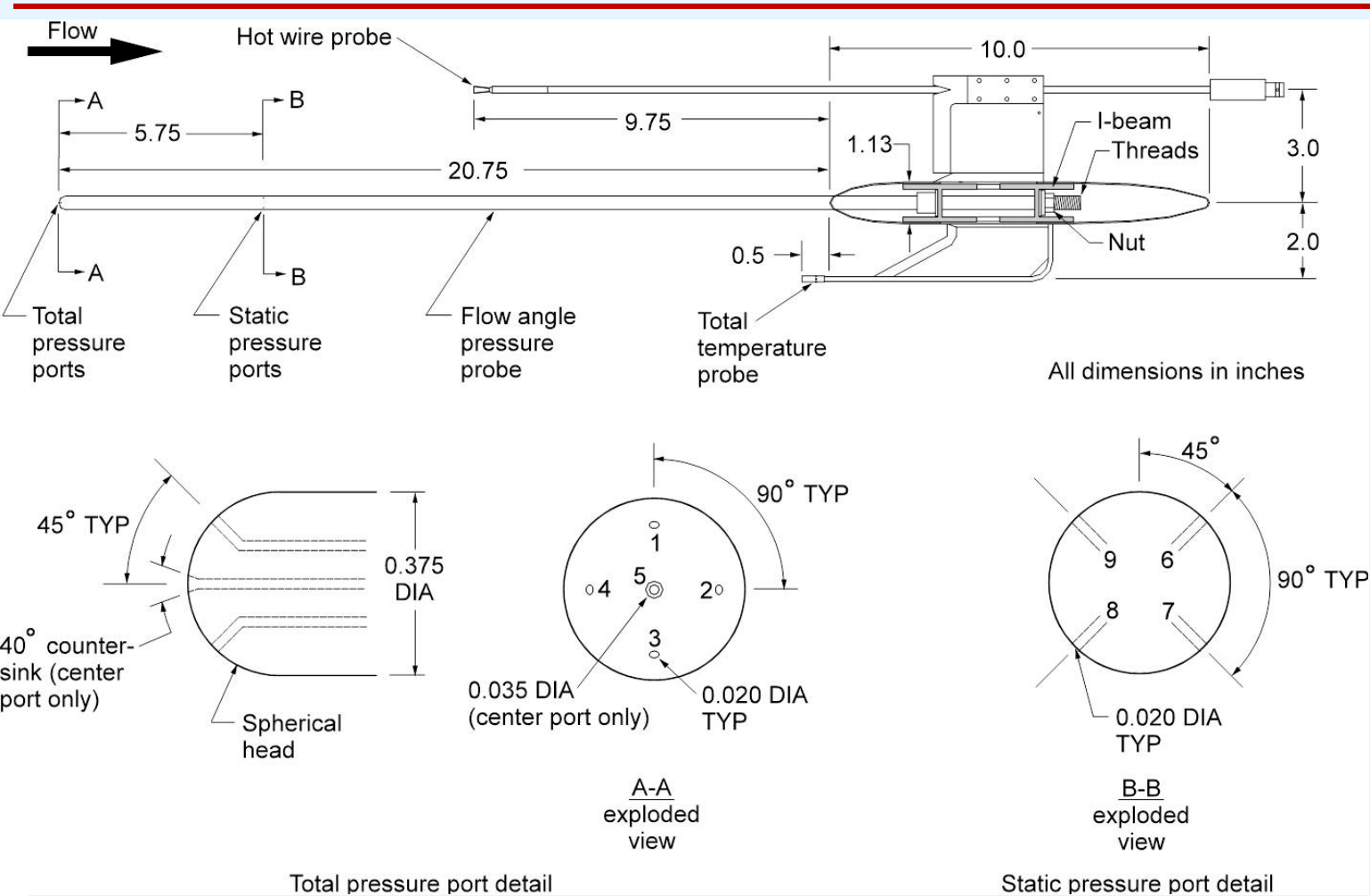


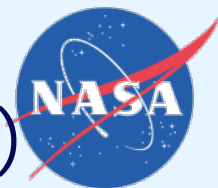
With Struts



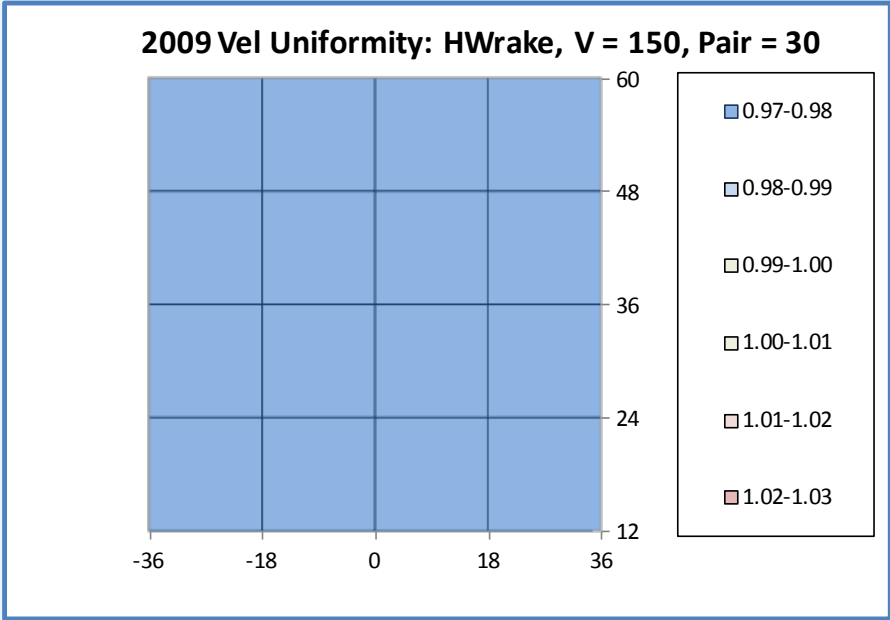
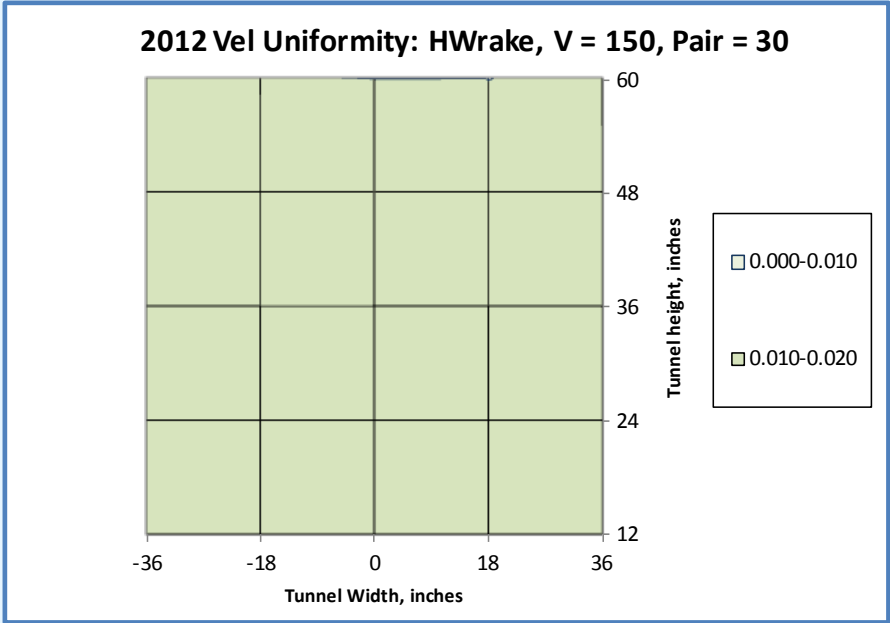


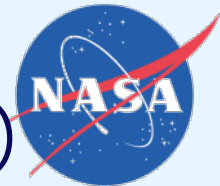
# 5-hole pressure probe detail



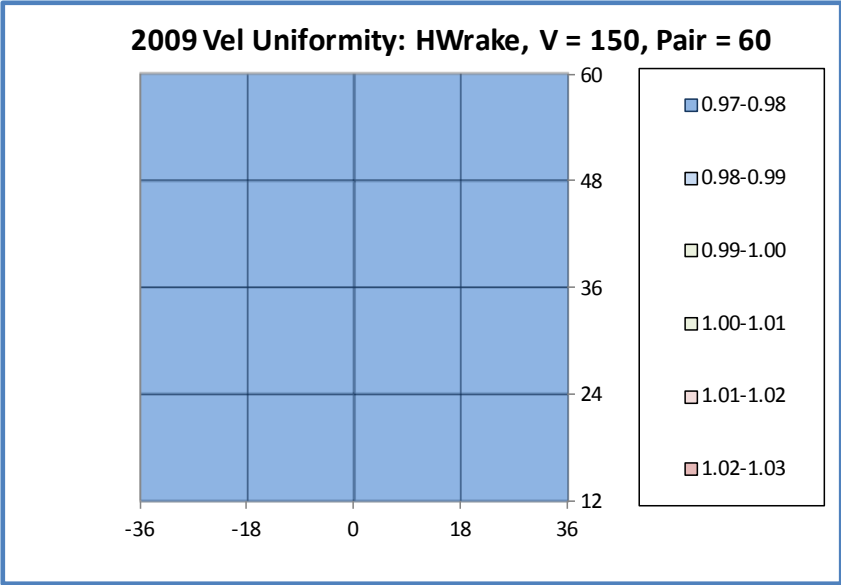
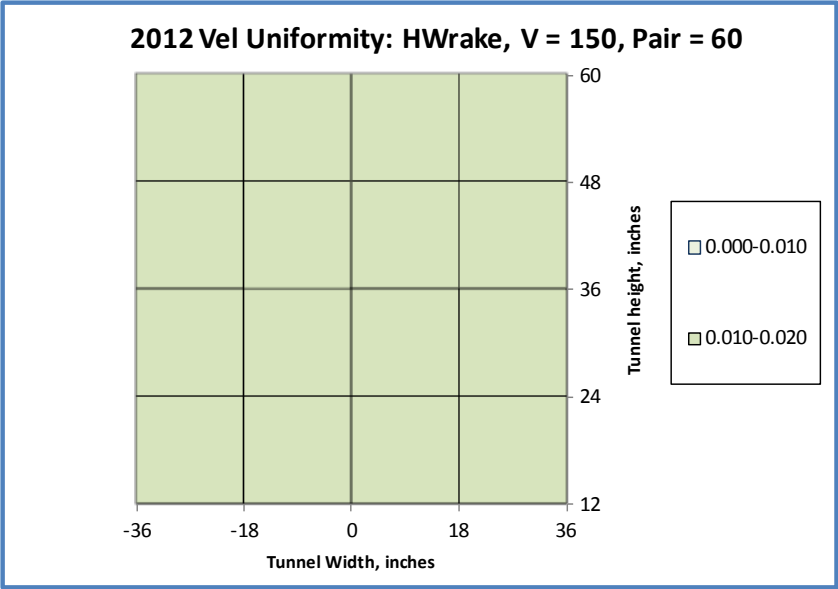


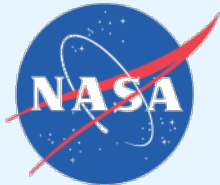
# Turbulence Intensity (150 knots, 30psig)





# Turbulence Intensity (150 knots, 60psig)





# Turbulence Intensity Historical Comparison

