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# Model Preparation Area for High Reynolds Number Propulsion Airframe Integration Testing at the National Transonic Facility

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# Outline

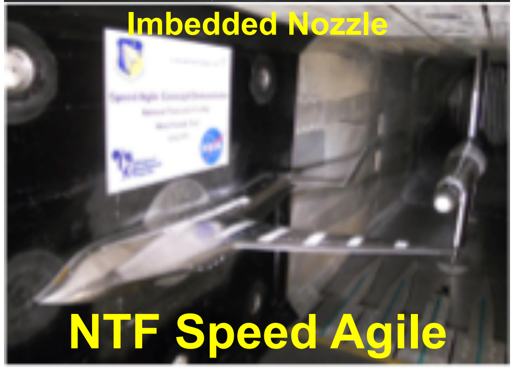
- Introduction and Problem Statements
  - Background
  - The National Transonic Facility (NTF) Operations
  - Challenges with powered semi-span testing in a transonic cryogenic environment
- Model Preparation Area (MPA) Requirements
  - Jet Exit (Nozzle Performance)
  - Semi-Span using Side Mounted Support System (SMSS)
    - Flow Thru Nacelles
    - Turbine Powered Simulator (TPS)
    - Ejectors
    - Open Rotors
- Layout of MPA-4
- Concluding Remarks

*AERIAL VIEW OF NTF COMPLEX*

# Background – LaRC PAI facilities

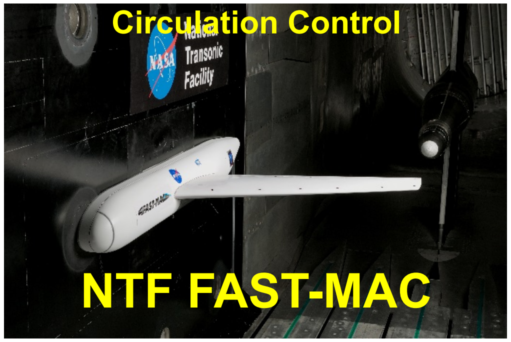
- Examples of Propulsion Airframe Integration (PAI) facilities
  - LaRC 16-Foot Transonic Tunnel (Demolished)
  - LaRC Jet Exit (Demolished)
  - LaRC 14- by 22-Foot Subsonic Tunnel (14x22)


- High Reynolds number Propulsion Airframe Integration
  - NTF (Common Research Model)
  - NTF (Speed Agile – AFRL/LM)
  - NTF (HWB - AFRL/LM)



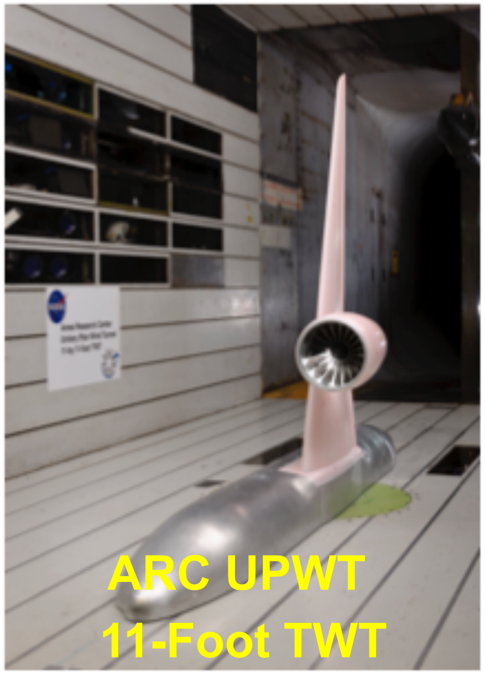

- High Reynolds number Active Flow Control (AFC)
  - NTF FAST-MAC

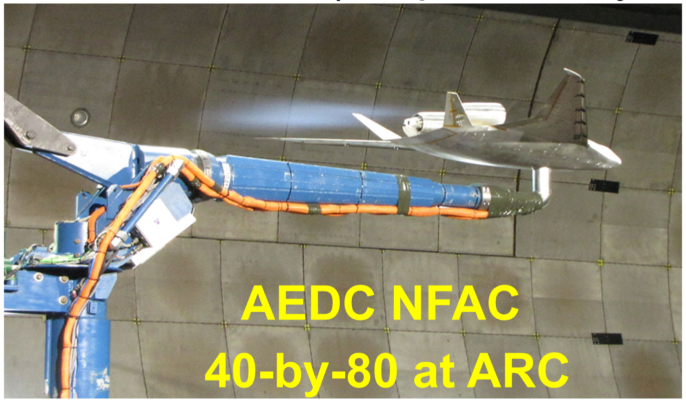
**(Fundamental Aerodynamic Subsonic Transonic - Modular Active Control)**



# Background – Other NASA PAI facilities

- NASA ARC Propulsion Airframe Integration
  - ARC Propulsion Simulator Calibration Lab (Demolished)
  - ARC Unitary Plan Wind Tunnel 11- by 11-foot Transonic Test Section (11-Foot TWT)
  - AEDC National Full-Scale Aerodynamics Complex (NFAC) 40-by-80 Foot Test Section (40-by-80)
- NASA GRC Propulsion Airframe Integration
  - GRC 9- by 15-Foot Low Speed Wind Tunnel (9x15 LSWT)
  - GRC (Propulsion System Laboratory)

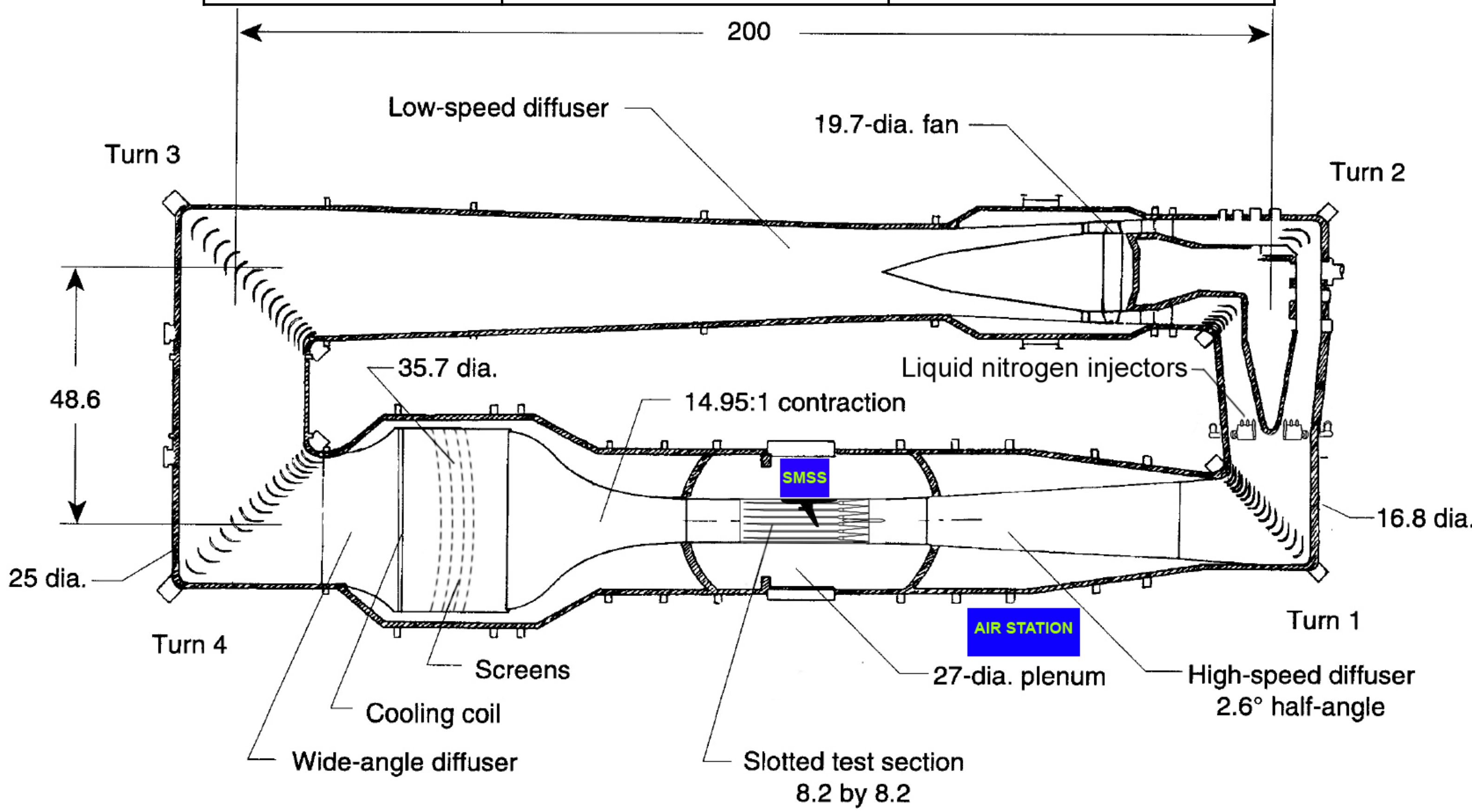




# National Transonic Facility – NTF

| | | |
|---|---|---|
| *Test Section* | 8.2 x 8.2 x 25 Feet ( 2.5 x 2.5 x 7.6 meters) | |
| *Pressure* | 14.7 to 133 psia; 1 to 9.0 atm.; 1.01 to 9.1 bar | |
| | Air Operations | $N_2$ Operations |
| *Mach No.* | 0.2 to 1.05 | 0.2 to 1.20 |
| *Reynolds No. Max* | $20 \times 10^6$ / ft ($65 \times 10^6$ / m) | $145 \times 10^6$ / ft ($475 \times 10^6$ / m) |
| *Temperature* | 90° to 150°F (32° to 65°C) | -50° to -250°F (-45° to -157°C) |



# NTF MPA 4 Requirements for Thrust Calibrations and Momentum Tares

- Dedicated facility (or location within existing facility) with necessary equipment/utilities
  - High-pressure air (1800/5000 psi and up to 30 lbm/sec delivery)
  - Temperature control (compensate for Joule Thompson effects)
  - Accurate and well-maintained mass flow measurement capability
  - Force measurements

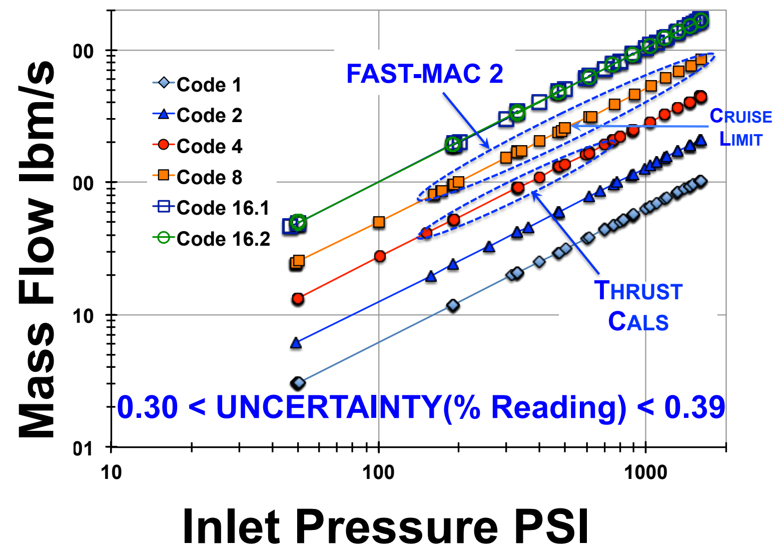
- Ability to vary ambient pressure is desirable but may not be a firm requirement

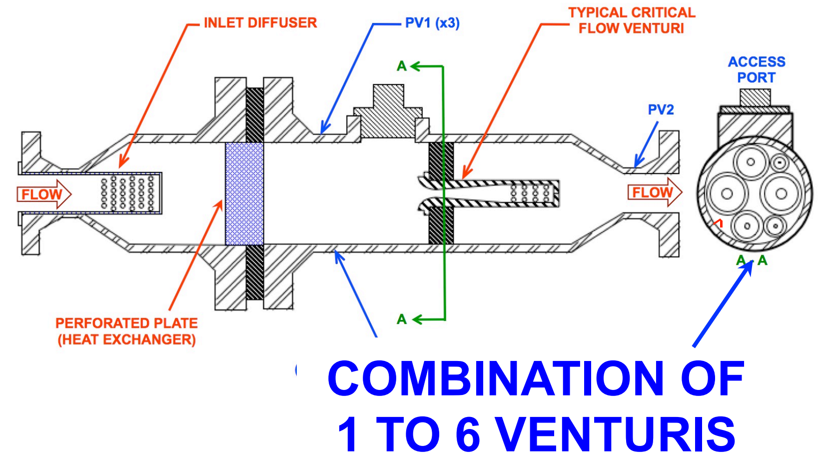
- Staff should be available for calibrations and tares but won't be a full-time activity
  - Maintain continuity with staff assigned to this task to keep high level of expertise

# Unique challenges with powered semi-span testing in a transonic cryogenic environment

- Data repeatability is dependent on NTF 117 balance and Multiple Critical Venturi (MCV)
- Large dynamic pressure may require custom fan set for TPS and Open Rotor testing
- Operations vary with tunnel temperature
  - Cooling requires less power to operate motor
  - Cooling reduces fan tip speed
- Mechanical stability of motor system
  - Lubrication is challenging
- Safety
  - Risk associated with blade failure condition

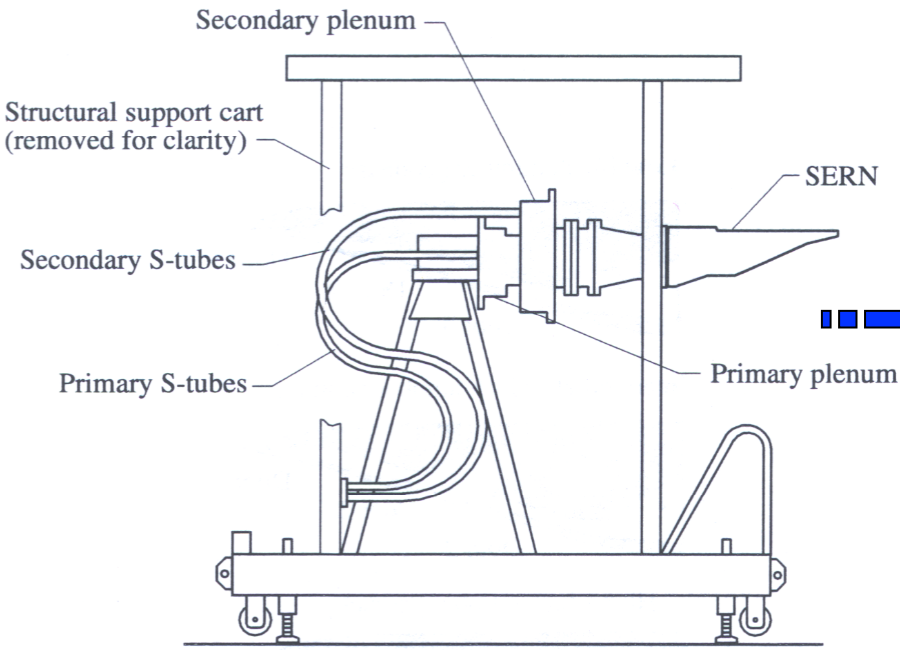
## MCV Operating Envelope

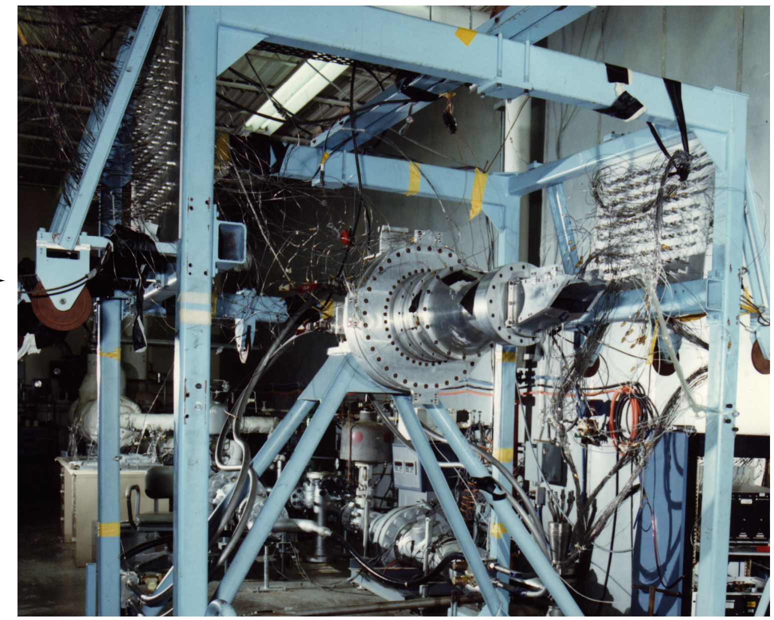


# Nozzle Testing

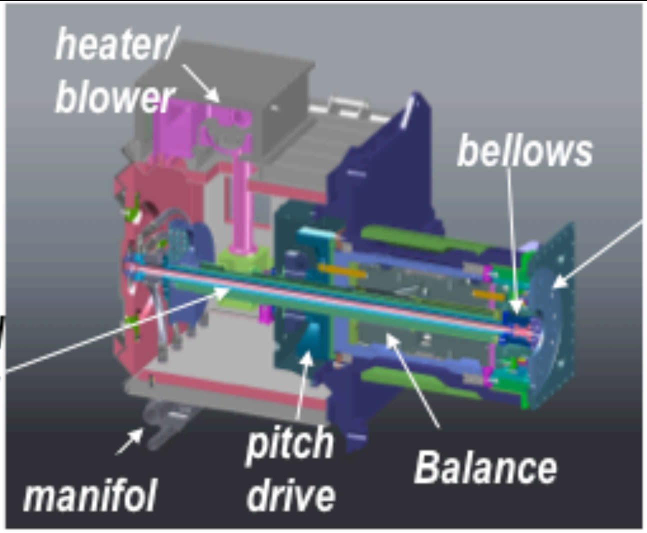
## Re-purpose LaRC Jet Exit test stand



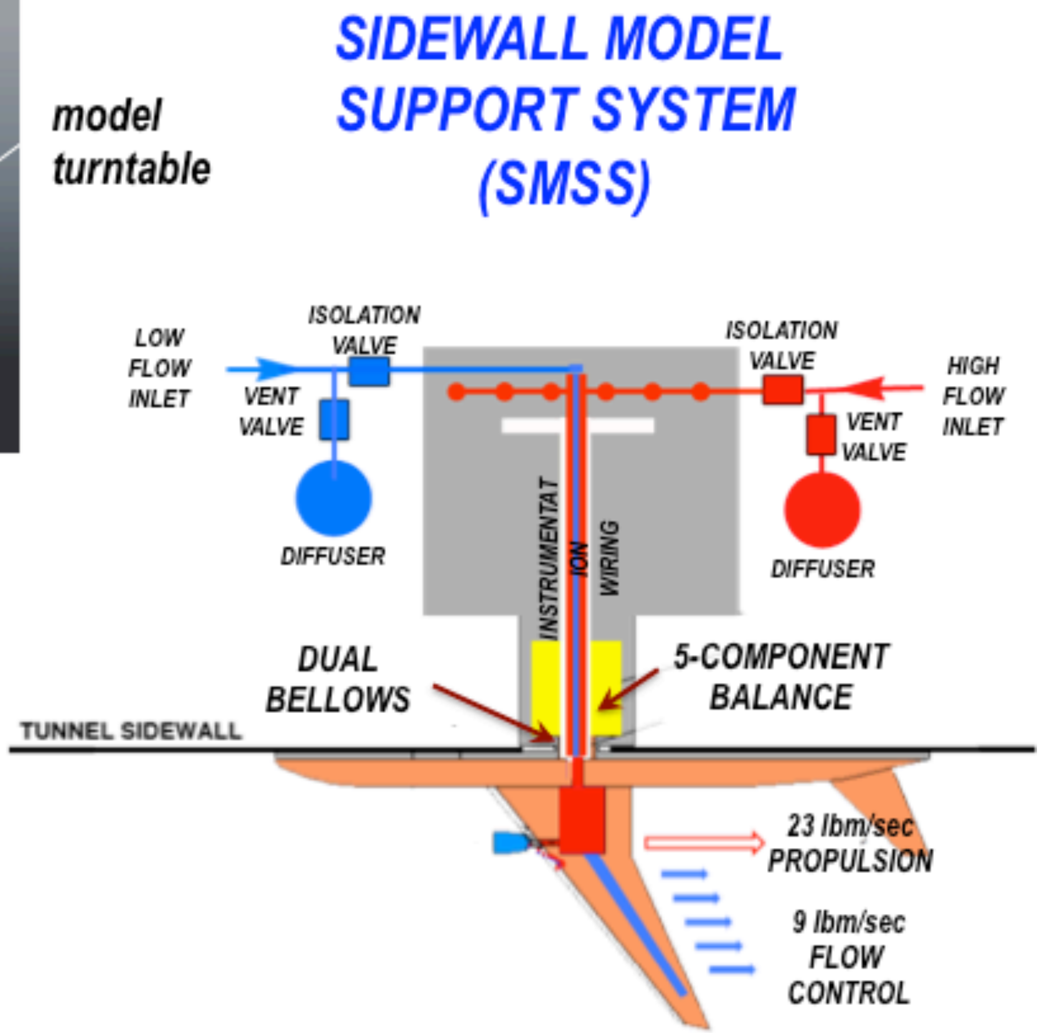



**Dual Flow Test Stand/S-Tubes**

# SMSS (2 Independent flow paths)



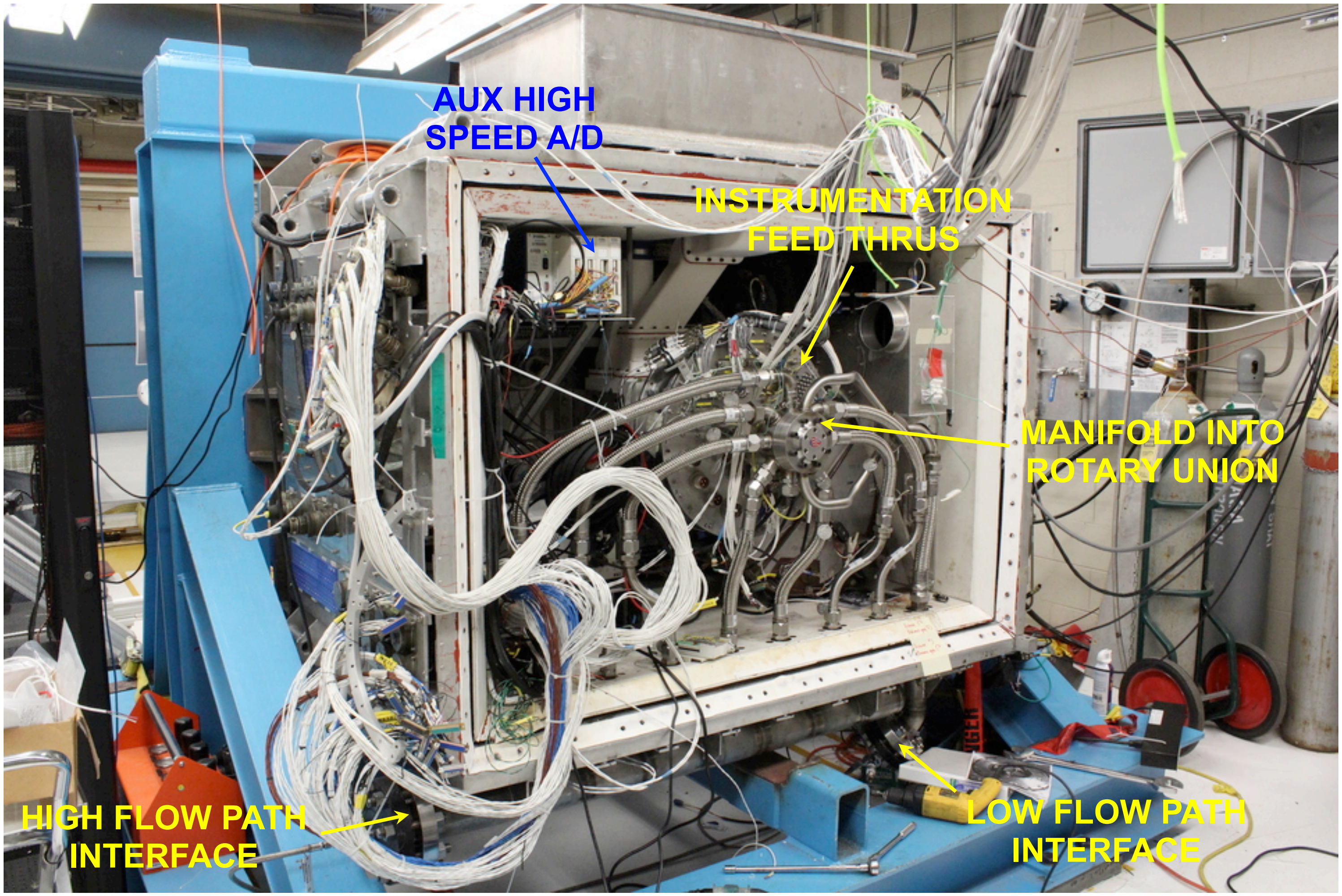

model
turntable




**The current temperature limit of -50º F is based on the operational limits of the vent and isolation valves associated with the SMSS safety system**

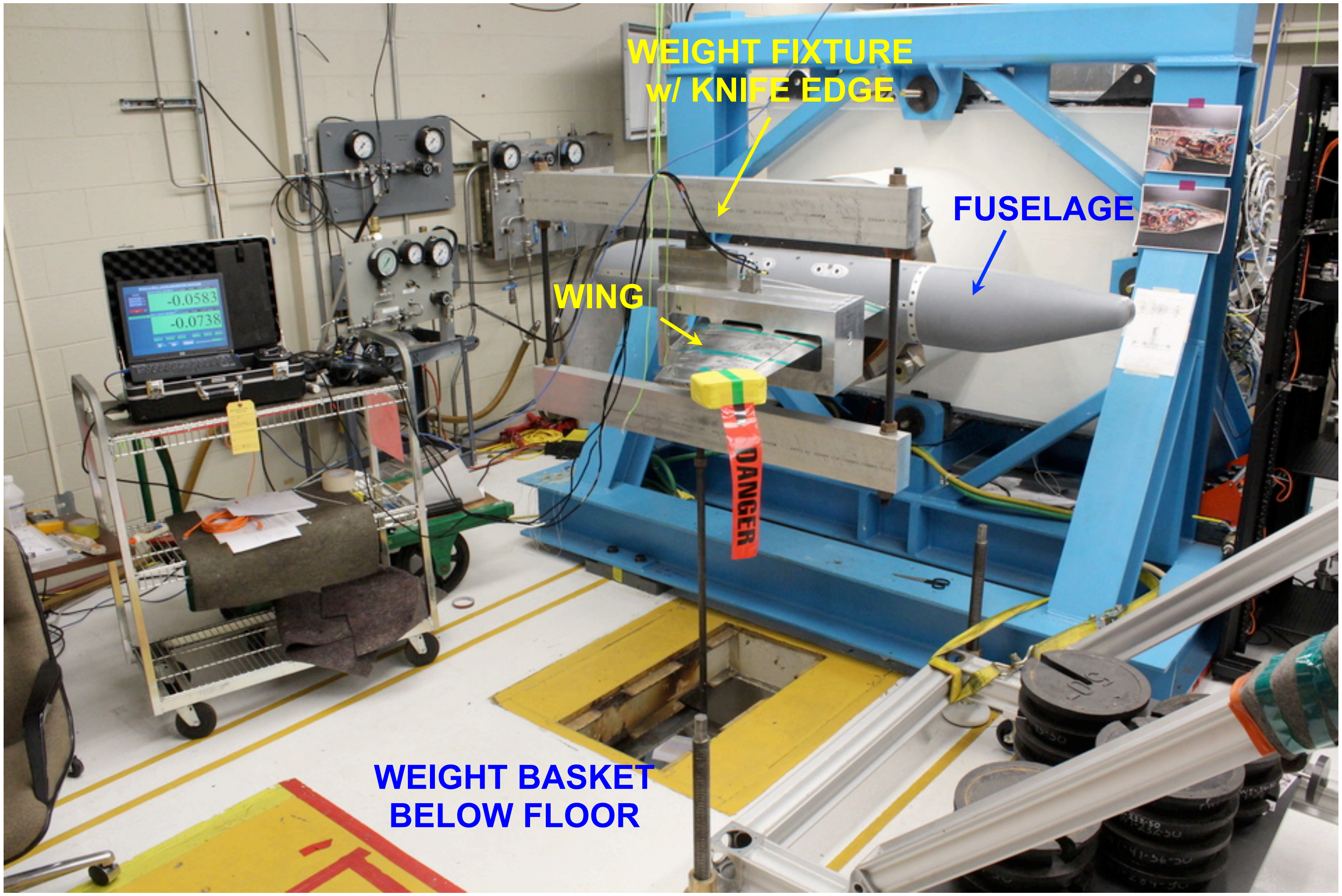
# MPA 1 (Instrumentation checks)

**REAR VIEW OF SMSS w/ DOOR REMOVED**
**BOX TEMPERATURE MAINTAINED AT 100 F**



# MPA 1 (SMSS balance calibration configuration)

**NORMAL FORCE LOADING - EVALUATE FOULING (w/ PRESSURE INFLUENCES)**
**ROTATED 0º (DOWN FORCE)**

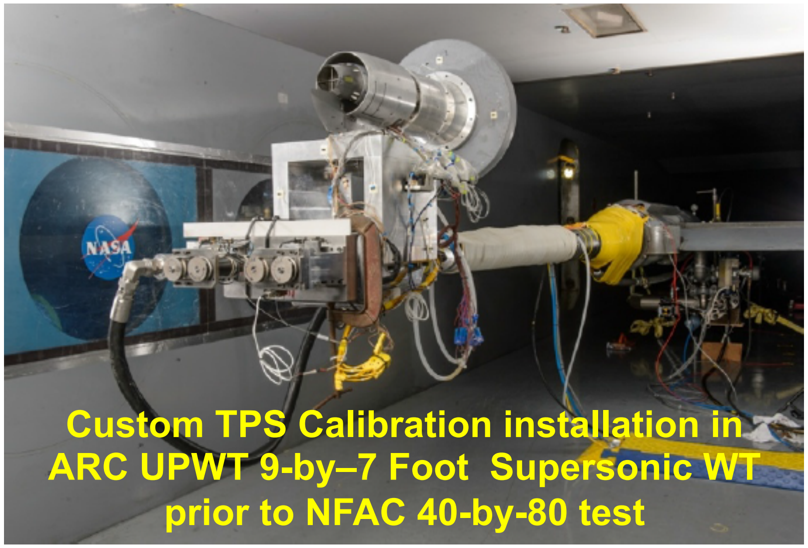


# MPA 4 Safety

- High Noise environment
- Blade Failure for Open Rotor and TPS testing
- High Pressure system (1800 psig)
- High Flow systems (30 lbm/sec)
- Nozzle Pressure Ratio
  - (typical: 1.0 < NPR < 6)
  - (max : 1.0 < NPR < 25)
- Temperature Control (Steam Heat)


# TPS Calibration in Tunnel

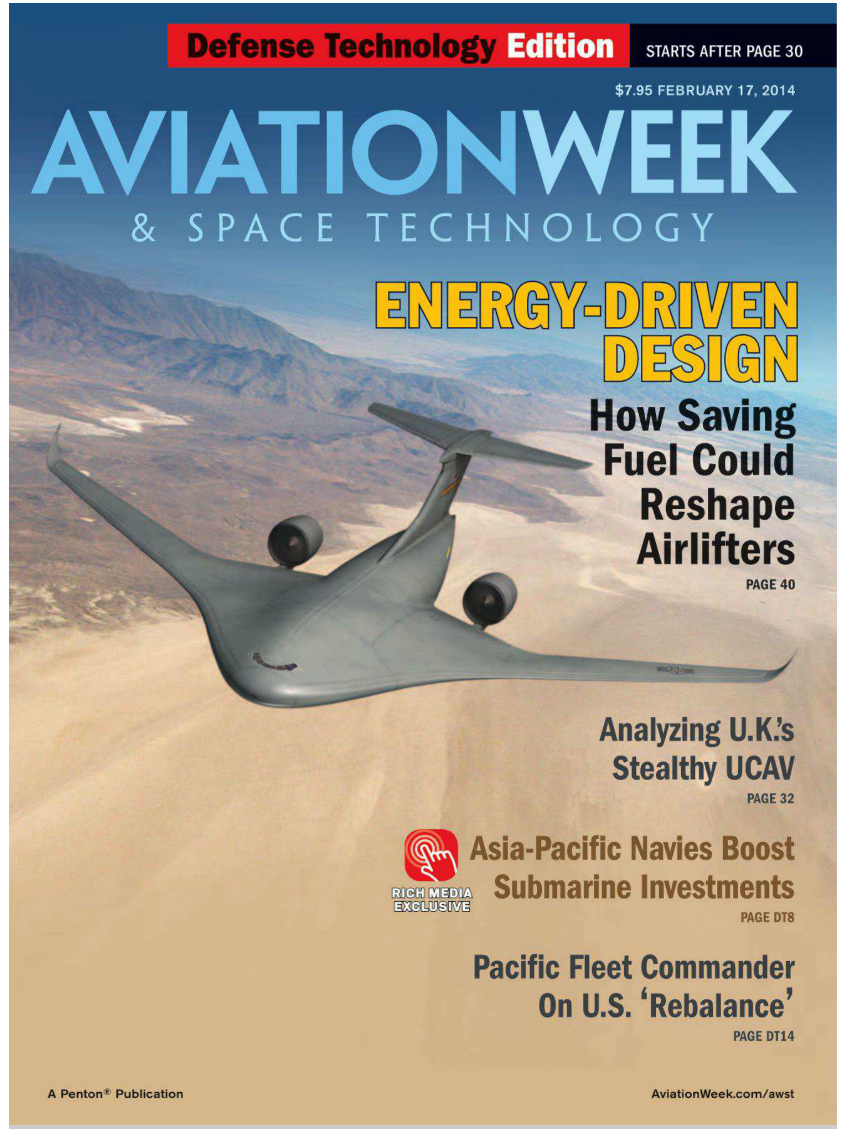
- Specialty hardware
- Occupies tunnel (potentially interferes with other testing)
- Very costly even with reduced tunnel occupancy charges
- Does not check for fouling of final test configuration


# Recent Semi-Span Testing

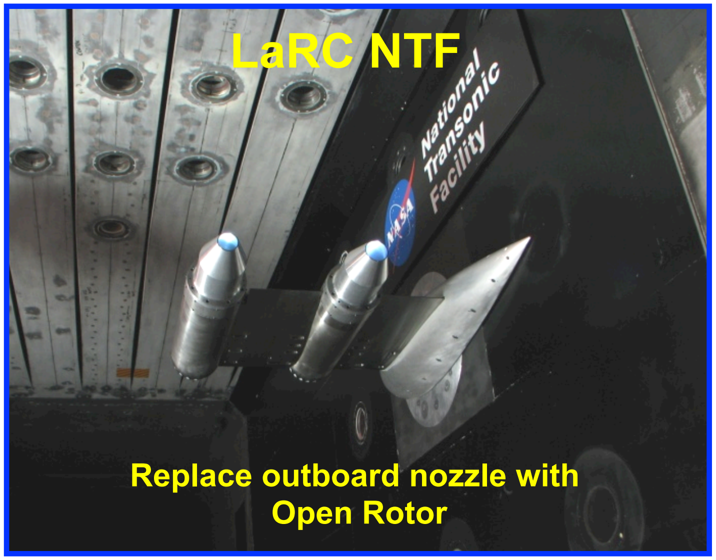
- Hybrid Wing Body with Flow Thru Nacelles
  - Improvements made to SMSS balance heating system
    - Resulted in a repeatability of 1 drag count for baseline
  - AFRL/LM Planning follow-on test
    - Evaluate Open Rotor Configuration)

**Collaborative Effort**

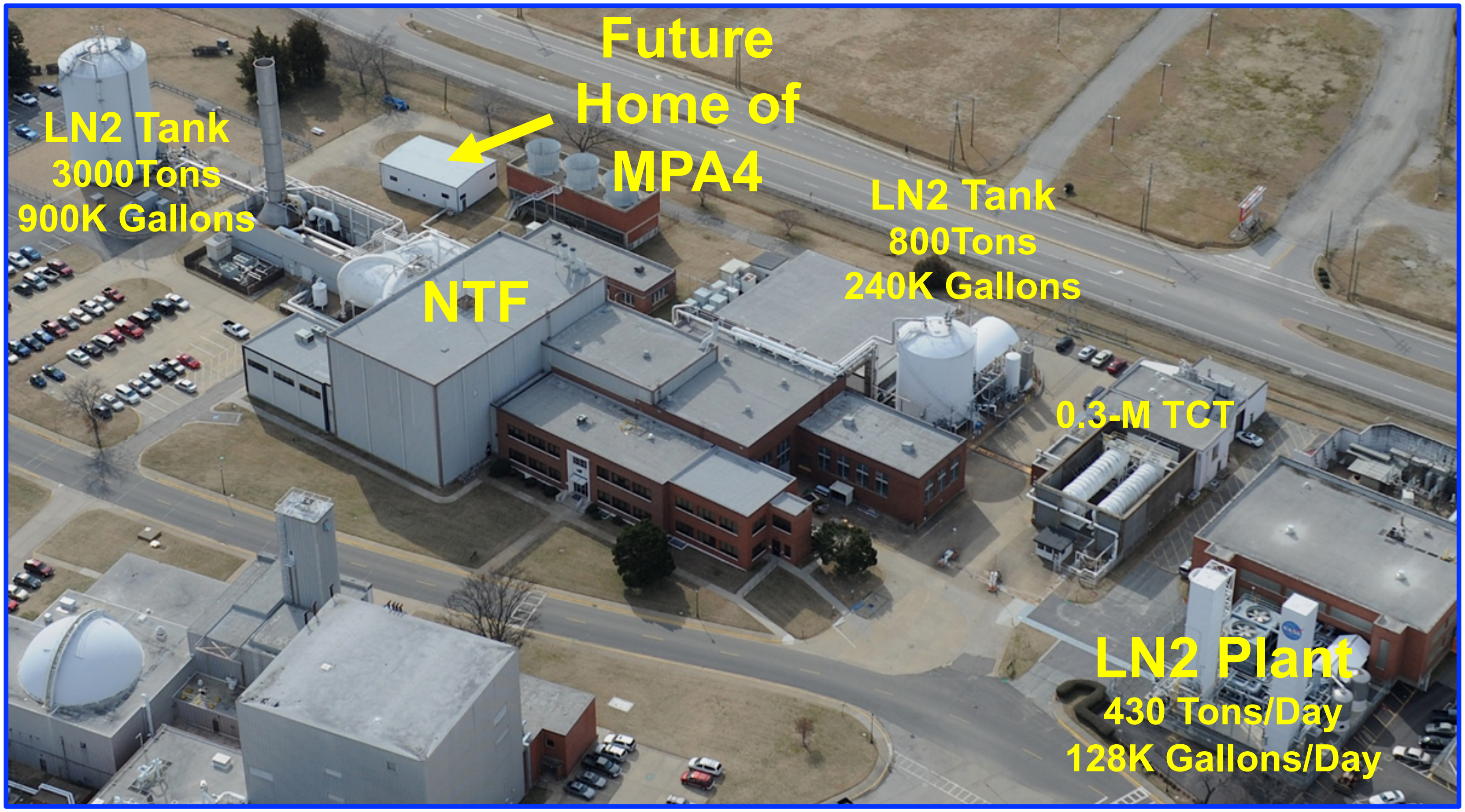


# Risk Reduction Semi-Span Open Rotor Testing

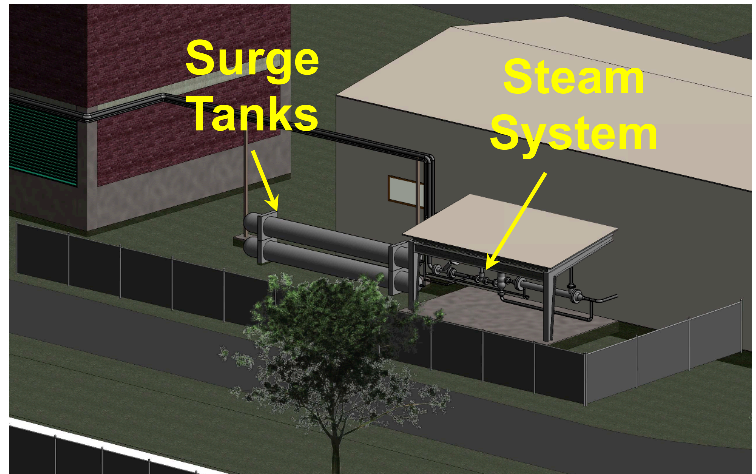
- Open rotor would be mounted to SMSS
  - Modified Dual Aerodynamic Nozzle model
  - Two independently controllable high pressure air lines (1275 psig)
    - High: 0.1 - 20.0 lbm/sec
    - Low: 0.1 - 8.0 lbm/sec
    - Equipped with calibrated Stratford nozzles
    - Air system (valves) limited to -50°F ops
  - SMSS incorporates 5-component balance
    - Determine the risk to SMSS balance due to open rotor catastrophic failure

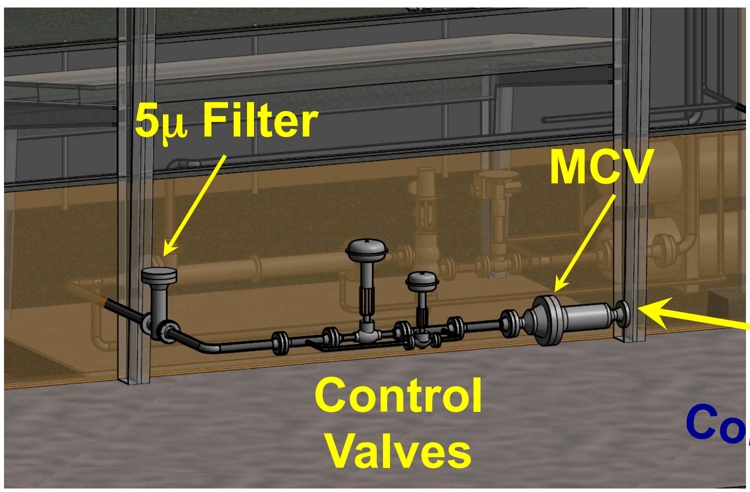


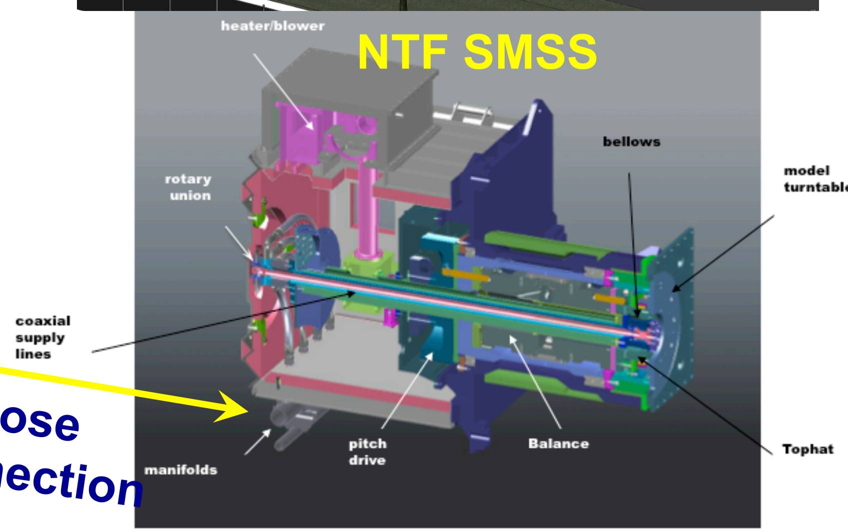

# MPA 4 located next to NTF Complex



# NTF MPA 4 (Location is part of the NTF complex)

# Concluding Remarks

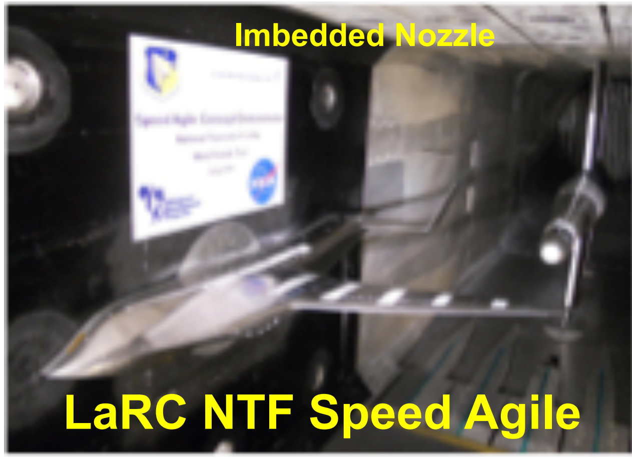
- Work with Industry, DOD, and University partners to develop a Model Preparation Area that supports high Reynolds number PAI testing
  - This supports the need to have a dedicated setup area for pretesting and calibration prior to entering the tunnel (avoiding costly calibrations in the test section)

- Develop high Reynolds number testing techniques for flow physics based research in active flow control and Propulsion Airframe Integration configurations

- Improve data accuracy and repeatability related to Propulsion Airframe Integration calibrations and momentum tares

- Evaluate different AFC techniques to improve aircraft performance with optimized Propulsion Airframe Integration

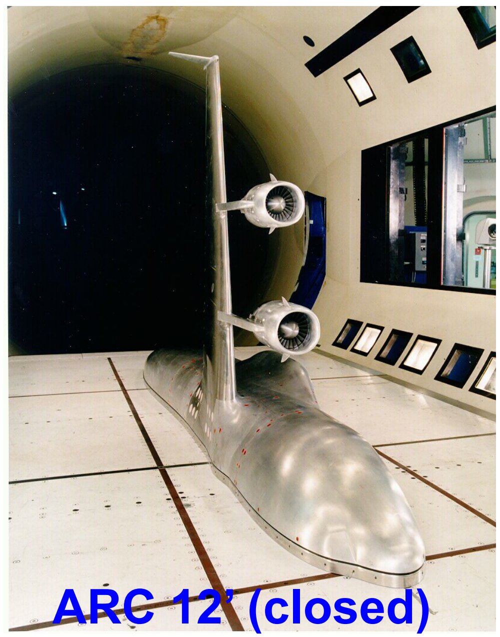
# Questions?


Imbedded Nozzle
LaRC NTF Speed Agile


Truss Braced Wing
LaRC 14x22
Image – artistic representation of upcoming TBW test


MIT Double-bubble
LaRC 14x22


ARC
NFAC 80-by-120

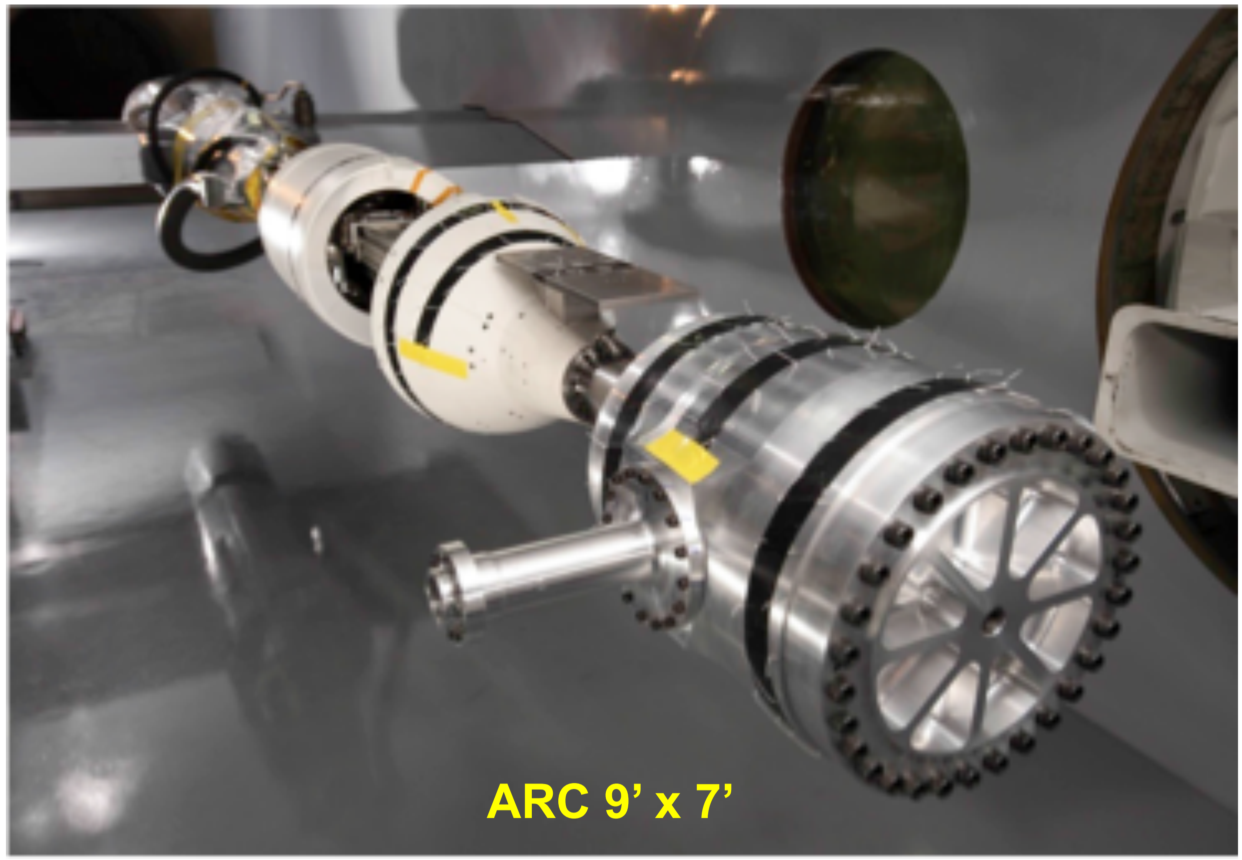

ARC 12' (closed)


AEDC
NFAC 40-by-80

# BACKUP

# Orion Ascent Abort Test
# Momentum Tares

- Custom setup in Ames 9x7 to perform momentum tares
- Costly occupancy (even at special rate negotiated for tares) and custom hardware required for test Section
- May not have been best internal flow path to establish momentum tares



# MPA 1 (SMSS balance calibration configuration)

AXIAL FORCE LOADING
ROTATED 90º (THRUST)