National Aeronautics and Space Administration

Propulsion Systems Laboratory Engine Icing Modifications

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Propulsion Systems Laboratory

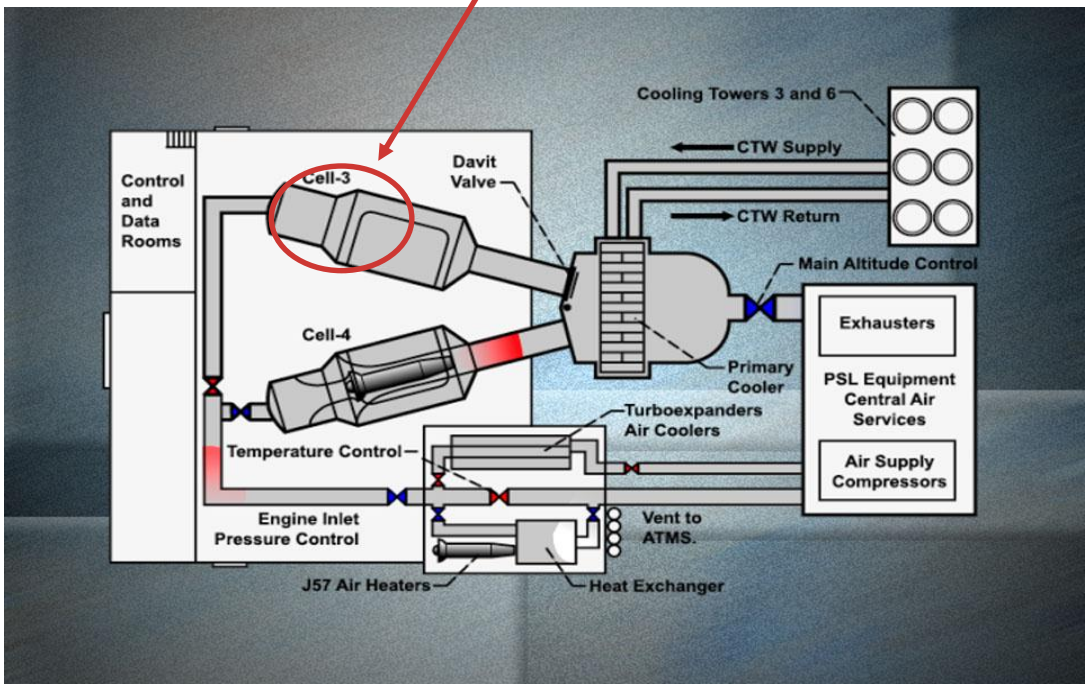
NASA Glenn's Propulsion Systems Lab (PSL) is one of the Nation's Premier Direct Connect Altitude Simulation Facilities for Full-Scale Gas Turbine Engines and Propulsion System Research

- **Two test sections share common inlet and exhaust**
- **Continuous Operation at high air flow rates**

  Altitude 90,000 ft (-90 deg F)

  PSL-3 Mach 3.0 (600 deg F)

  PSL-4 Mach 4.0 (1000 deg F)
- **Six component thrust system (50,000 lbf)**
- **Real time, high speed data acquisition and display**



Progress/Plan

PSL Icing System

- **Main Icing System Installation** (complete 6/2011)
  - Construction at 90% complete
  - Spray bar installation nearly complete
- **Test Cell Calibration/Engine Transition Hardware** (complete 11/2011)
  - Fabrication set to begin
  - Includes instrumentation, camera systems
- **Integrated Systems Test** (complete 1/2012)
  - System Checkouts
  - Full up Icing System Integrity and Check
- **Calibration Test** (complete 6/2012)
  - Verify Requirements are met and easily achievable
  - Document System Capabilities
- **Validation Test** (start 10/2012)
  - Seeking a cooperative test with engine manufacturer
  - Validate Against Existing Flight Data

Objectives
PSL Icing System

- Establishment of a ground-based, ice-crystal environment, engine test capability that includes altitude effects.
- Better understanding on how ice accretes inside an engine and how it effects engine performance and operability.
- Investigation and development of test methods and techniques that enable the effective and efficient study of engine icing due to ice-crystals along the path of airflow through the core of an engine.
- Development of validation data sets required to enable the creation of a system of computer codes that can be specifically applied to assess engine icing susceptibility as well as engine performance and operability effects.
- Collaboration with industry partners to utilize system to meet above objectives and facility utilization goals.

Technical Challenges

PSL Icing System

- Design and build an icing system that is versatile so it can be refined to meet developing engine icing requirements.
- An assessment of PSL's capability to simulate conditions that lead to engine core icing events.
- The establishment of conditions inside the engine under which ice can accrete, both before and after accretion occurs at a given point in the simulated flight trajectory (altitude).
- Test methods for conducting pertinent engine core icing tests in PSL.
- The creation of methods and techniques needed to measure/monitor engine core ice accretions.
- A complete set of validation data sets including engine design geometry and operating conditions as well as atmospheric conditions for simulation of engine core icing events.
- A knowledgebase of engine core icing from which engineering tools to address the problem can be further developed.

Technical Approach
PSL Icing System

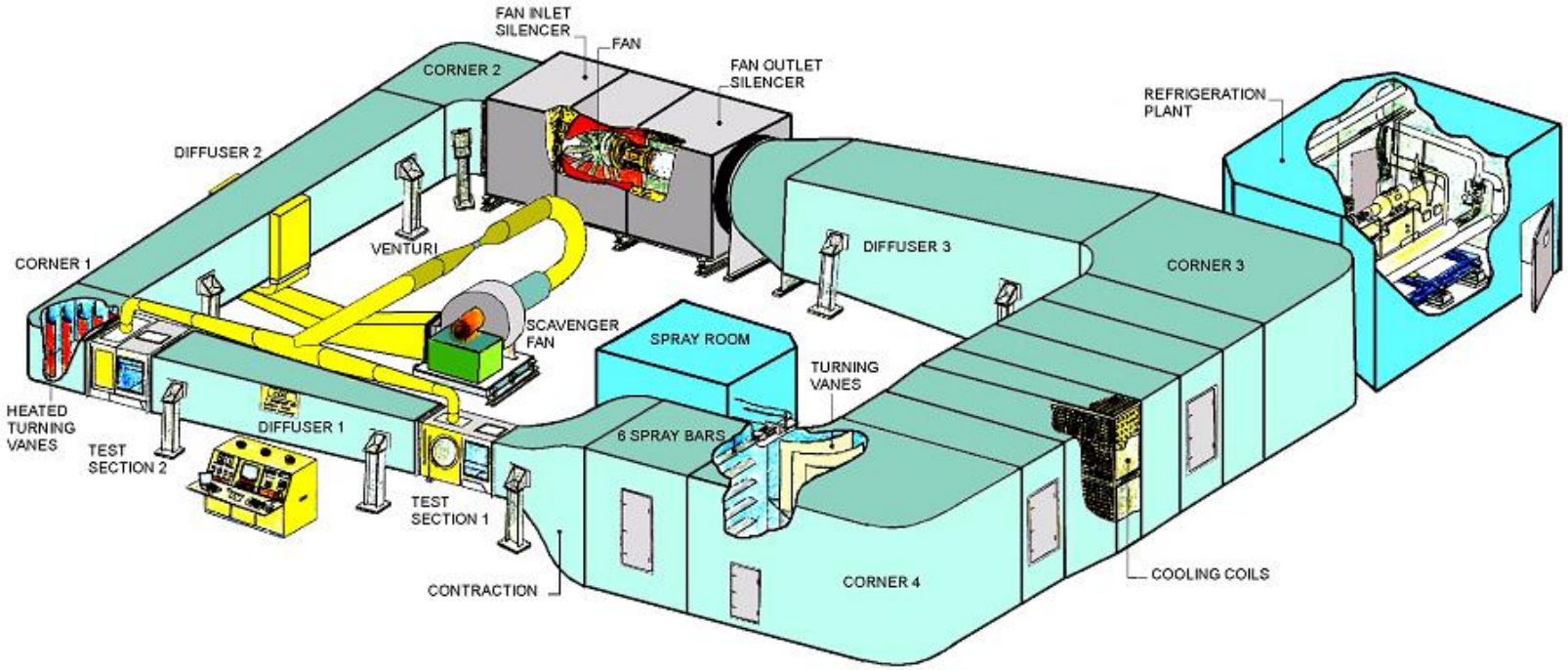
- Icing system was designed and built to requirements established by collaboration with industry and government experts

Specified Requirement		
Specification	**Minimum**	**Maximum**
Altitude (pressure)	4000 ft	40,000 ft
Inlet Total Temperature	-60°F	15°F
Mach Number	0.15	0.80
Air Flow Rate	10 lbm/sec	330 lbm/sec
IWC (icing water content)	0.5 g/m^3	9.0 g/m^3
MVD (median volumetric diameter)	40µ	60µ
Run Time	Continuous up to 45 minutes	

Analysis

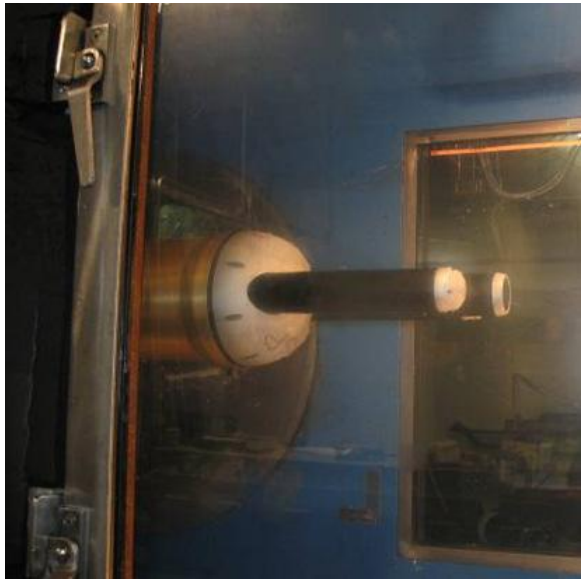
PSL Icing System

- Proof of concept tests, instrumentation evaluation and PSL simulation and computer simulation were performed by NASA and Cox & Co.
- Schematic of Cox and Co. Icing facility.

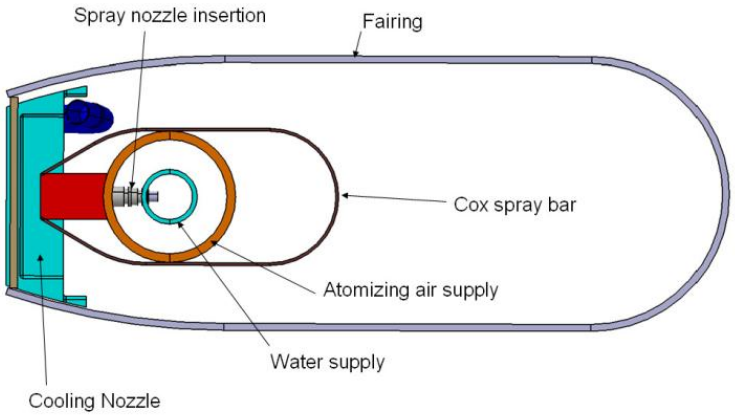


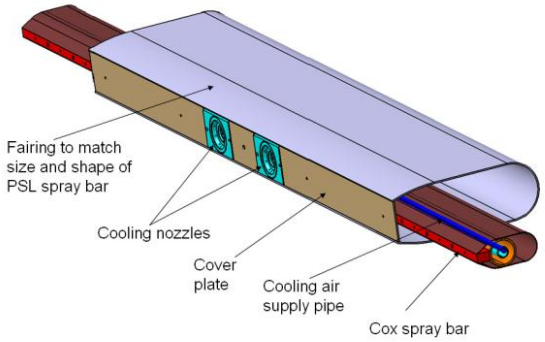
Analysis

PSL Icing System



- Parametrics include tunnel speed and temperature, nozzle type, cooling air pressure and temperature, spray bar atomizing air and water pressures and temperatures.
- FSSP and OAP used to determine median volume droplet size (MVD) and distribution
- Multi-wire probe used to determine liquid and total water content (LWC, TWC) and freeze fraction.



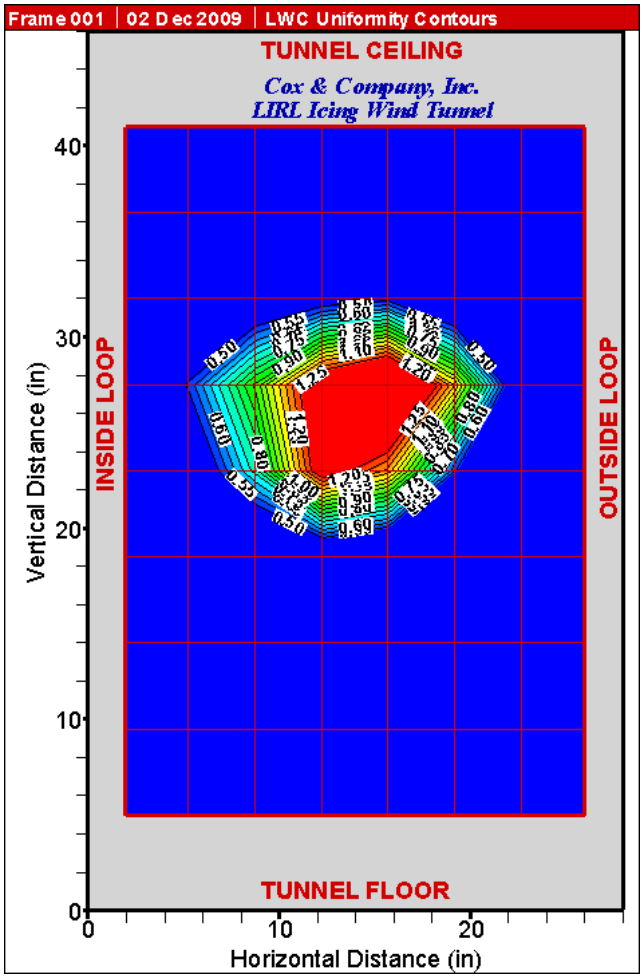


Prototype Spraybar

Analysis

PSL Icing System

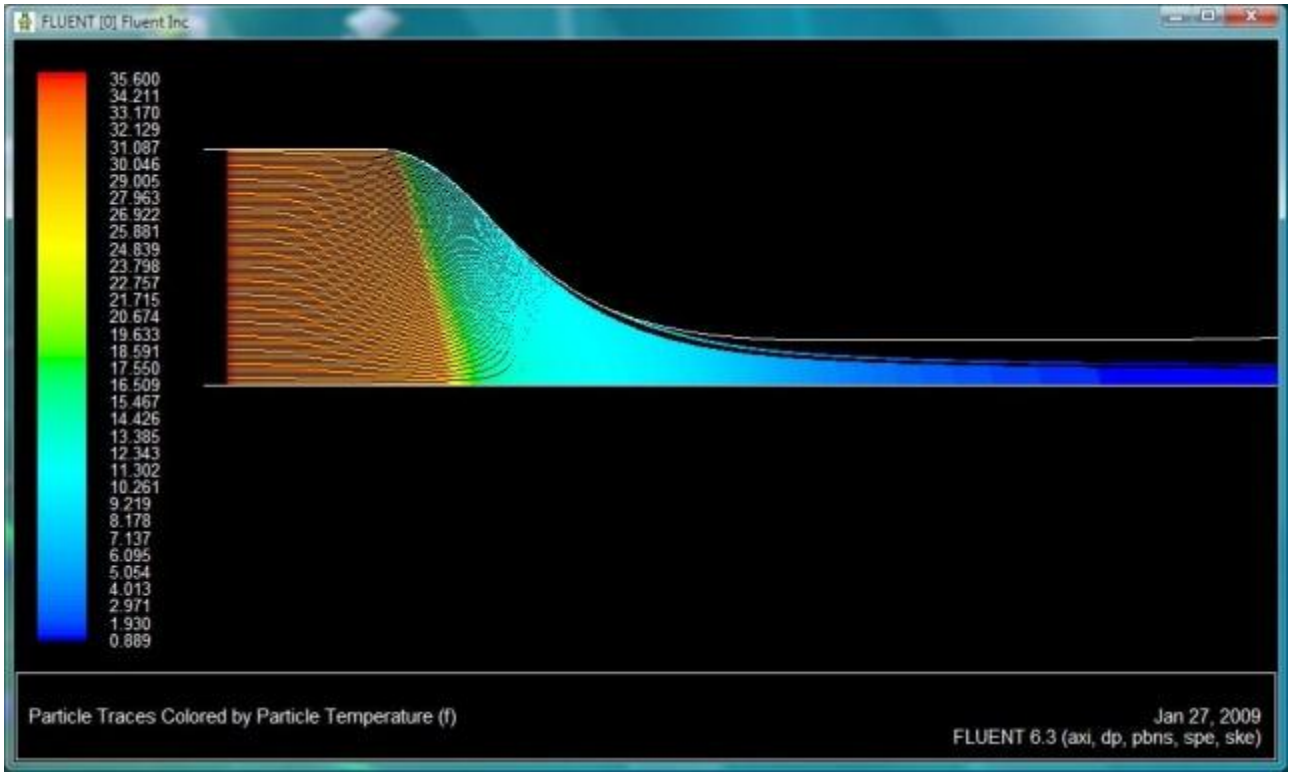
- Grid establishes cloud size, uniformity and center for instrument placement.



Analysis

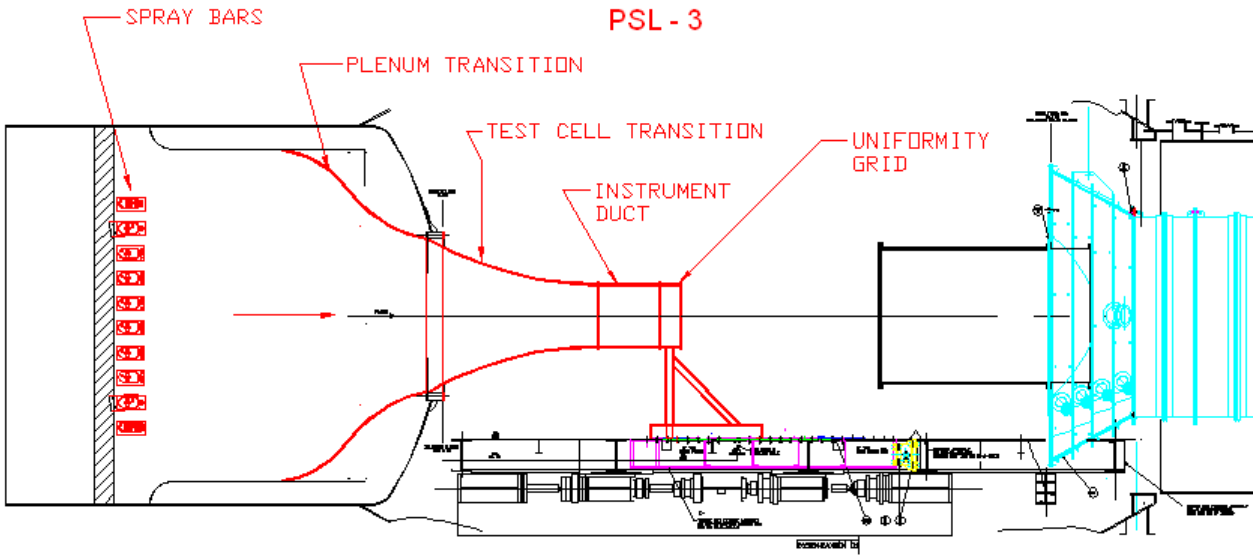
PSL Icing System

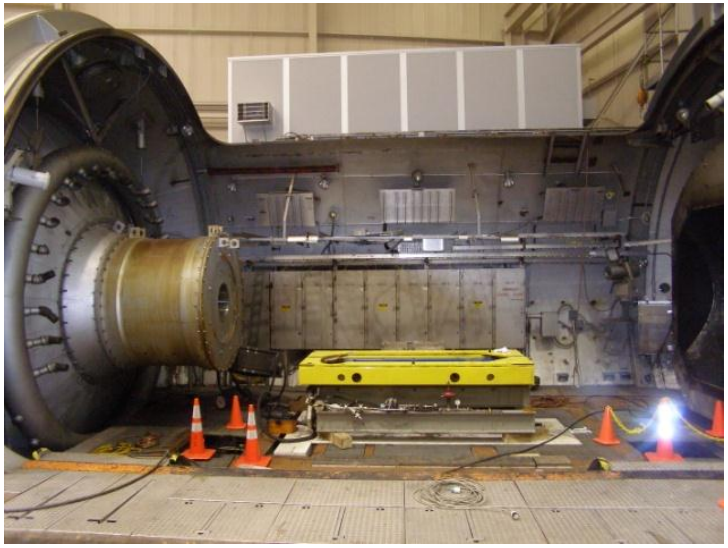
- Computer simulations with Fluent Software were performed and evaluated by NASA and Cox & Co.



System Description

Icing Configuration

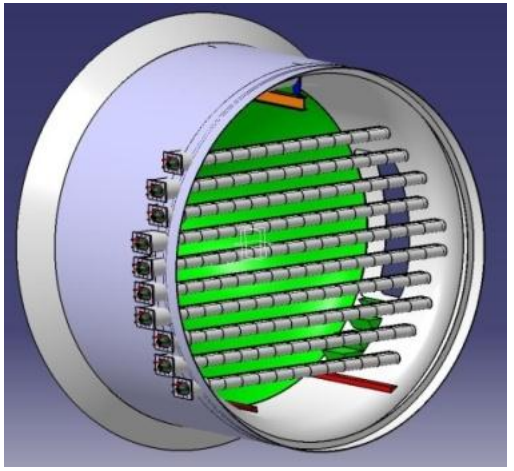




Test Cell 3

System Description

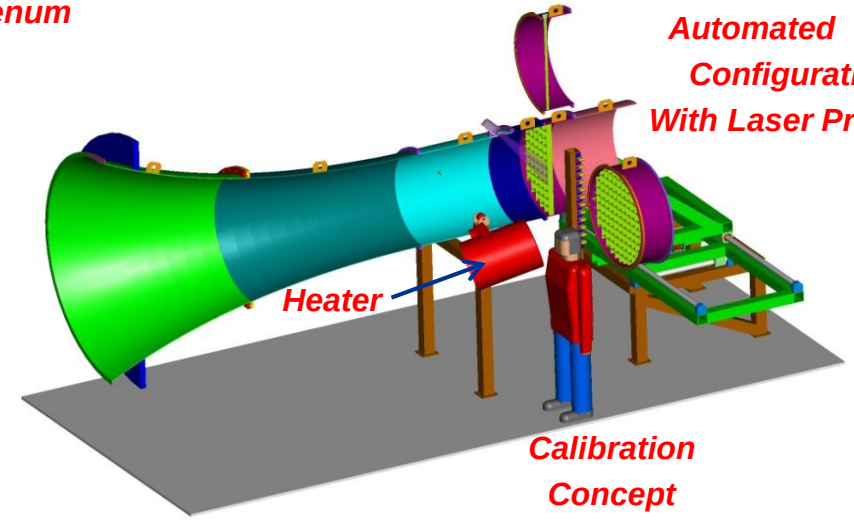
PSL Icing System



Plenum

Spray Bars

Automated Grid Configuration With Laser Prox Probes

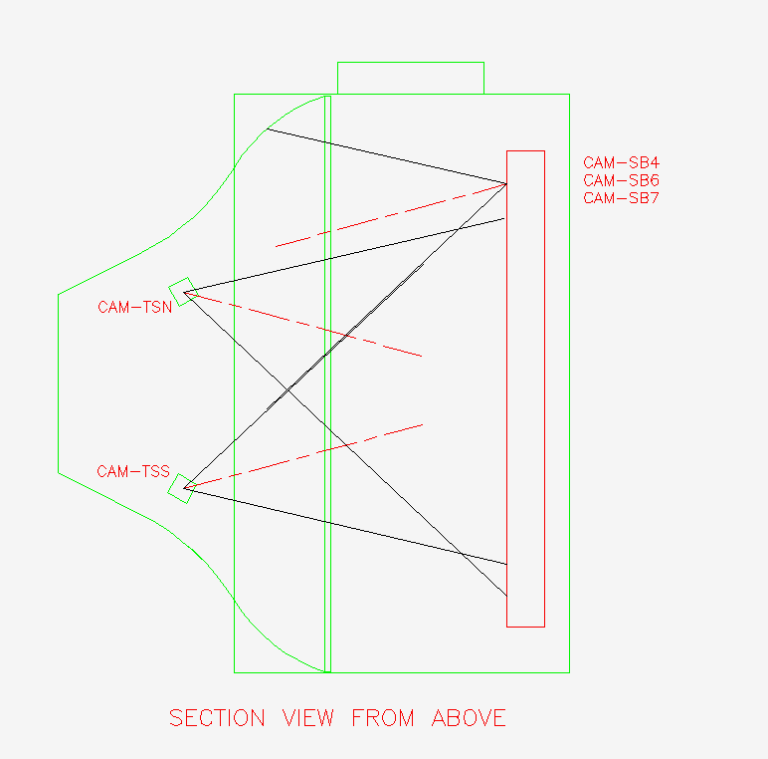


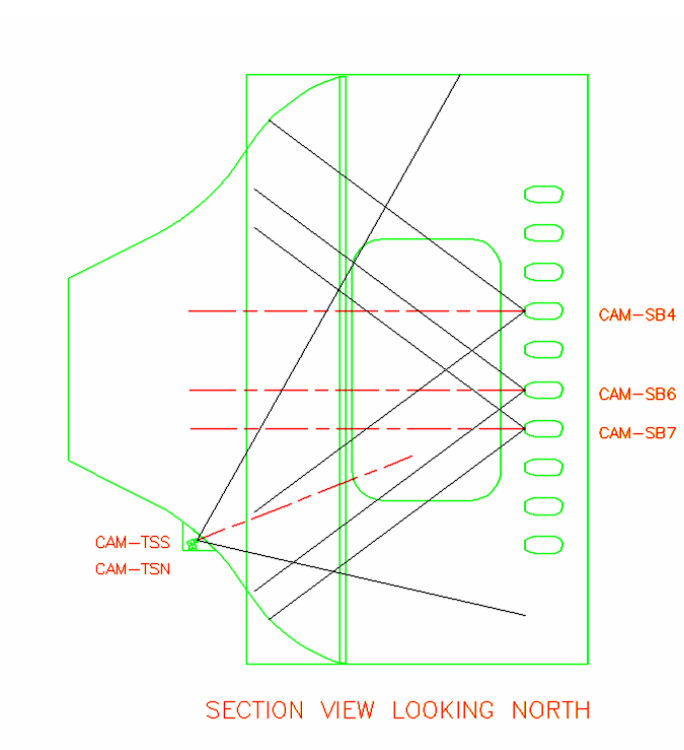
Calibration Concept

System Description

PSL Icing System

- 5 cameras inside the plenum will provide a wide angle view of the spray bars, nozzles, plenum surfaces and ice cloud.
- To be displayed and recorded in control room for system integrity and ice cloud documentation.

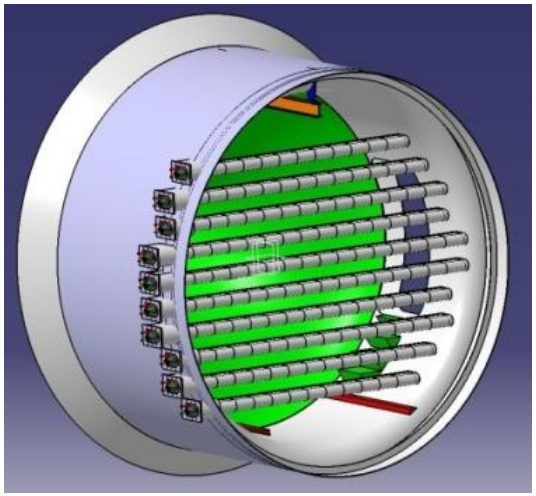




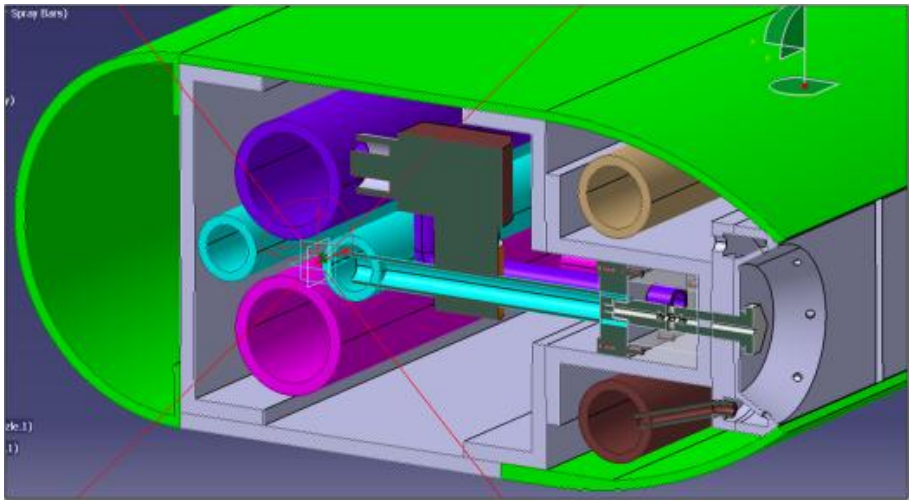
System Description

PSL Icing System

- 10 Spray Bars of 200+ Nozzles (2 types) mounted in PSL Cell 3 plenum that spray 35°F atomized water. Spray is cooled with -40°F air at nozzle exit to enhance freezing.
- System to be operated and controlled by the PSL Facility Control System from the Control Room.
- System emphasizes versatility, flexibility and portability. Spray bars are removable.



PSL 3 Plenum Spray Bars



Spray Bar Detail

System Description

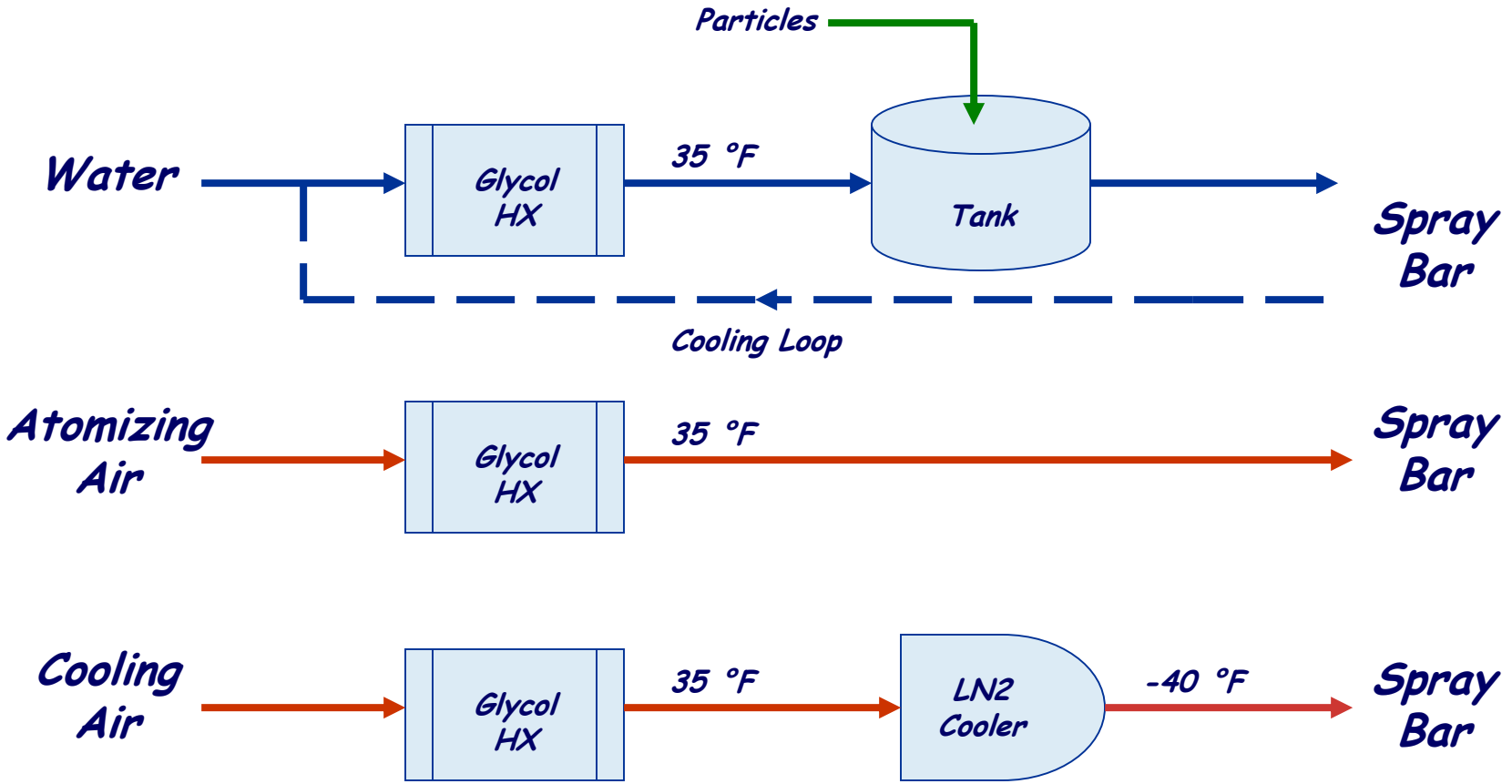
PSL Icing System

Spray Bars being fabricated

System Description

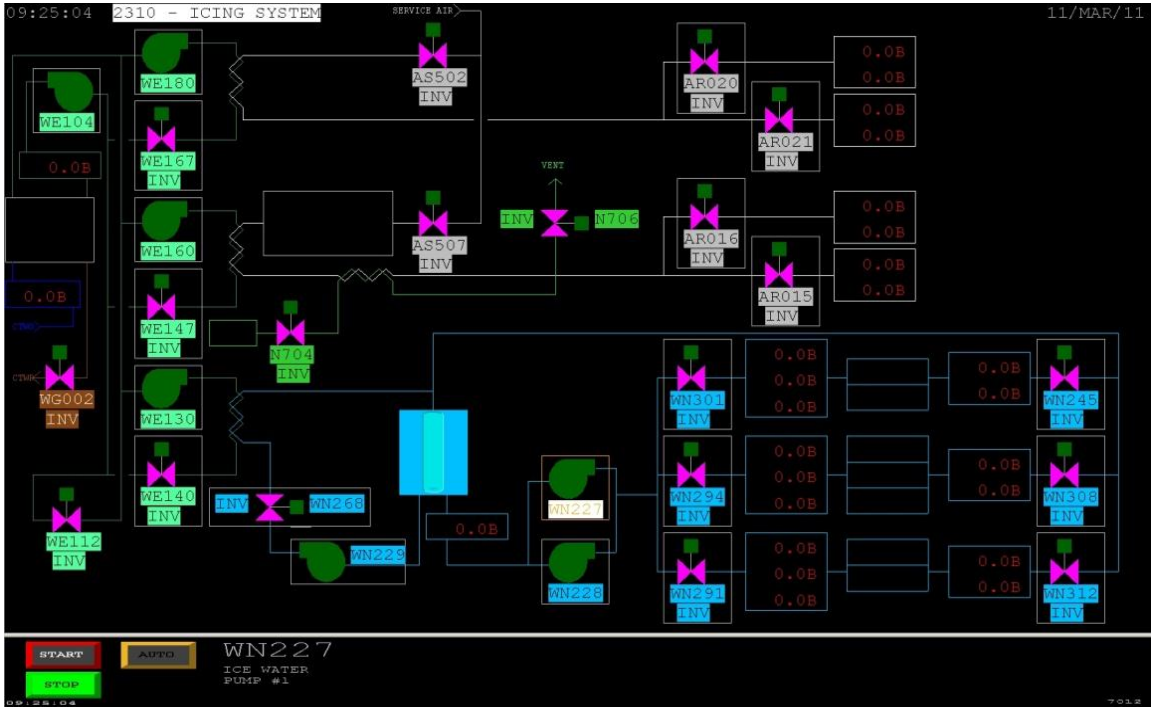
PSL Icing System

Subsystems Design Summary



System Controls
PSL Icing System

- Icing system control pages allow one operator to set desired conditions.



Icing System Control

Spray Bar Nozzle Pattern Control

Spray Bar Control

Questions?/Comments !

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Backup Slides

Contact Tom Hoffman, PSL Facility Manager
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System Description

PSL Icing System

Water Tank

Air Dryer

Glycol Chiller

Outside Test Cell
Water Supply and Return Pipe
Atomizing and Cooling Air Supply

Controls

Cooling/Atomizing Air HX