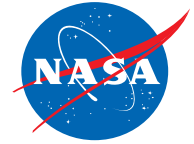
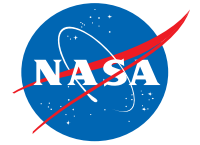


National Aeronautics and Space Administration

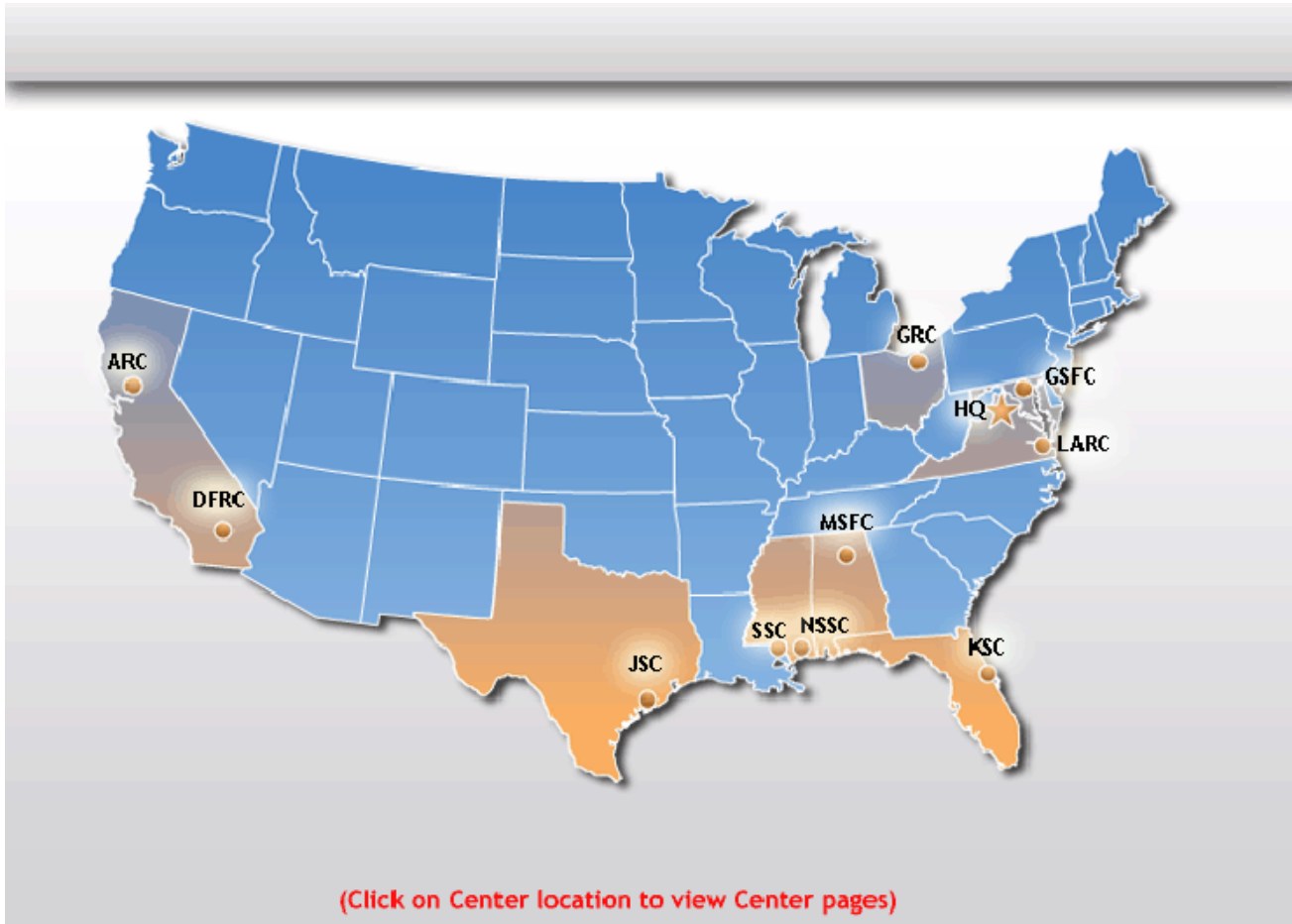


Altitude Icing Testing of Jet Engines to begin at NASA Glenn Research Center Propulsion Systems Laboratory

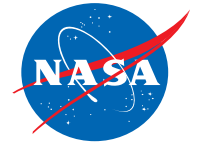
Jack Kowalewski
PSL Facility Engineer
John H. Glenn Research Center at Lewis Field



NASA Field Centers



NASA Glenn Research Center



PROPULSION SYSTEMS LABORATORY (PSL)
NASA – GLENN RESEARCH CENTER
CLEVELAND, OHIO



**JET ENGINE ICE CRYSTAL
RESEARCH TESTING
AT PSL**

Tom Hoffman, Facility Manager

Dennis Dicki, Facility Mechanical Tech. Lead

Jack Kowalewski, Facility Engineer

Paul Lizanich, Senior Electrical Engineer

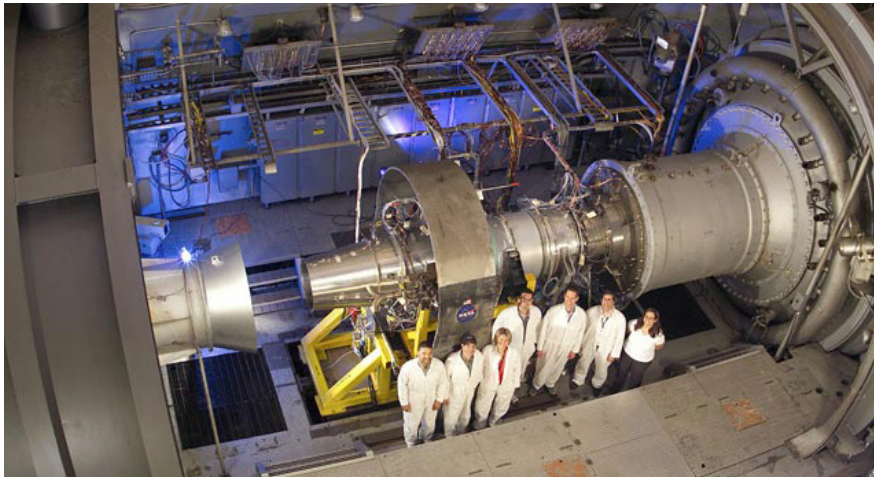
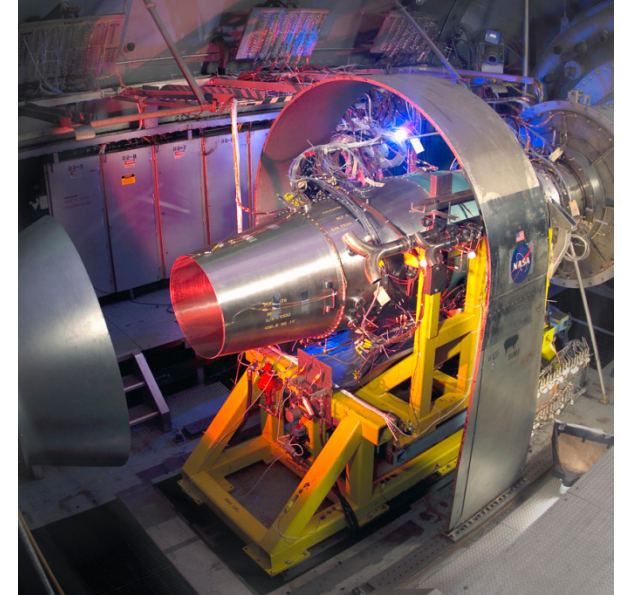
Mike Oliver, Icing Branch Research Engineer

Dr. Judy VanZante, Cloud Specialist

Tom Griffin, Icing Project Engineer

PSL Engine Testing

**National Research Facility
Commercial Development
National Defense Initiatives
Other Unique Applications**

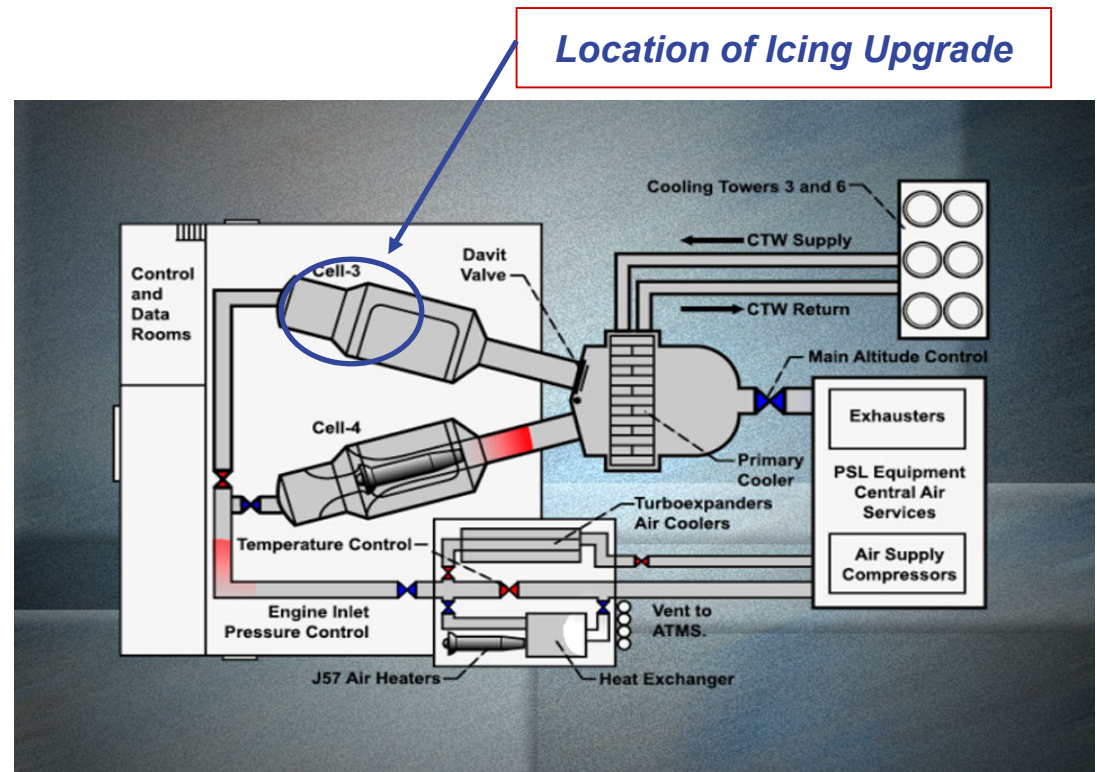


- Engine Operability and Stall Resistance
- High Altitude Performance
- General Aviation and Business Jets
- Military Fighter Engine Development
- Helicopter Turbo-shaft Engines
- UAV/Missile Engines
- **Ice Crystal Research (new)**

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**



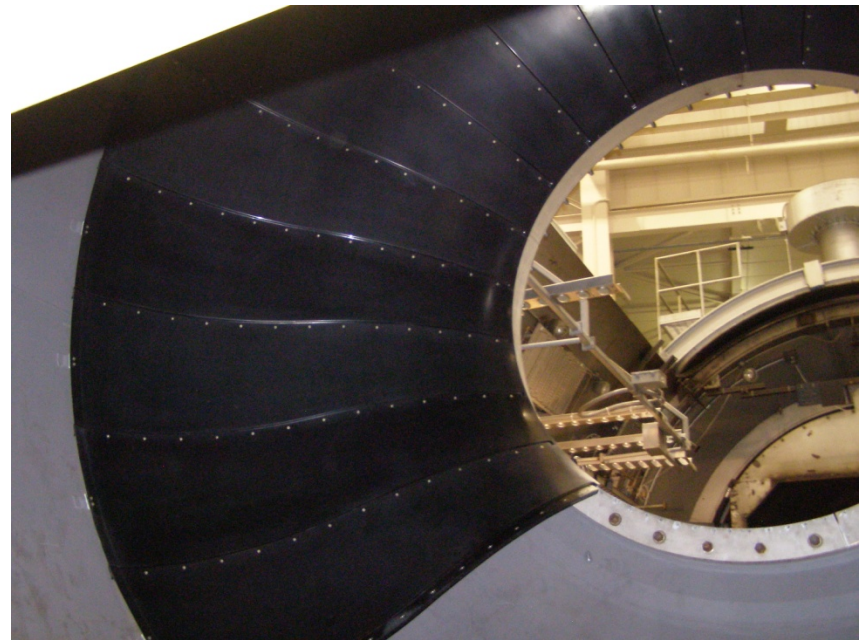
System Description

PSL Icing System



Spray Bars Installed in Plenum

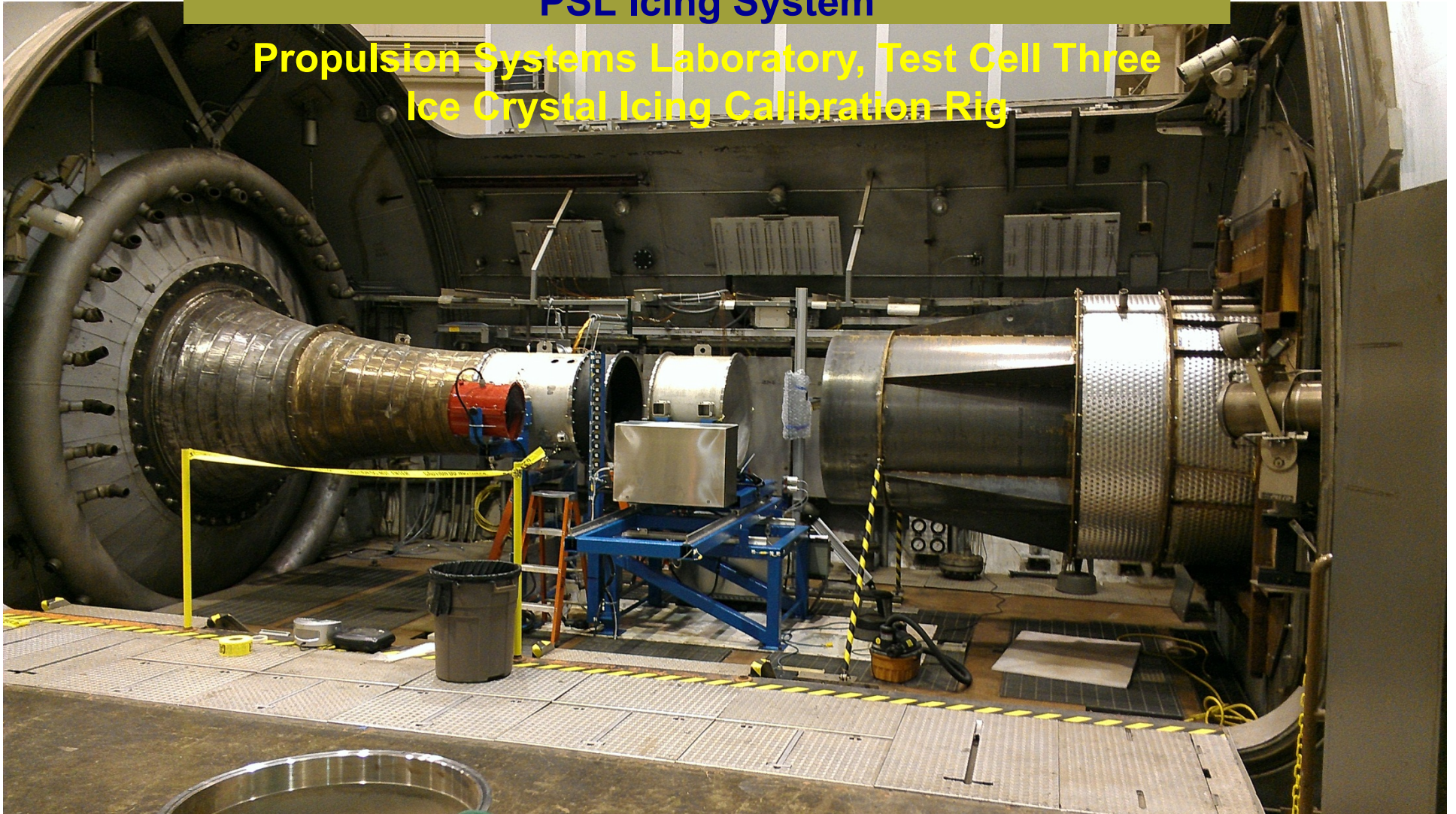
Transition Sections Installed in Plenum



System Description

PSL Icing System

Propulsion Systems Laboratory, Test Cell Three
Ice Crystal Icing Calibration Rig



Progress/Plan

PSL Icing System

- **Main Icing System Installation** (completed Q2, 2011)
- **Test Cell Hardware** (in progress)
- **Integrated Systems Test** (completed Q2, 2012)
 - System Checkouts
 - Full up Icing System Integrity and Operations Check
 - Spray Bar Vibration Survey (completed Q2, 2012)
 - Aero-thermal Calibration, Station 1 (completed Q2, 2012)
 - Spray bar systems water and ice (in progress)
- **Calibration Testing-no engine installed**
 - Scheduled to begin Q3, 2012
- **Validation Testing-engine installed**
 - Scheduled to begin Q1, 2013

Objectives

PSL Icing System

- NASA Mission: Improving Aviation Safety
- Establish a ground-based, engine altitude test facility with ice crystal cloud capability.
- Study the physics of ice crystal icing in turbofan engines.
- Development of engine test methodology in this novel facility
- Development of data sets to help validate NASA engine icing computer codes
- Engage in collaborative engine icing research with domestic and international partners.

Technical Objectives

PSL Icing System

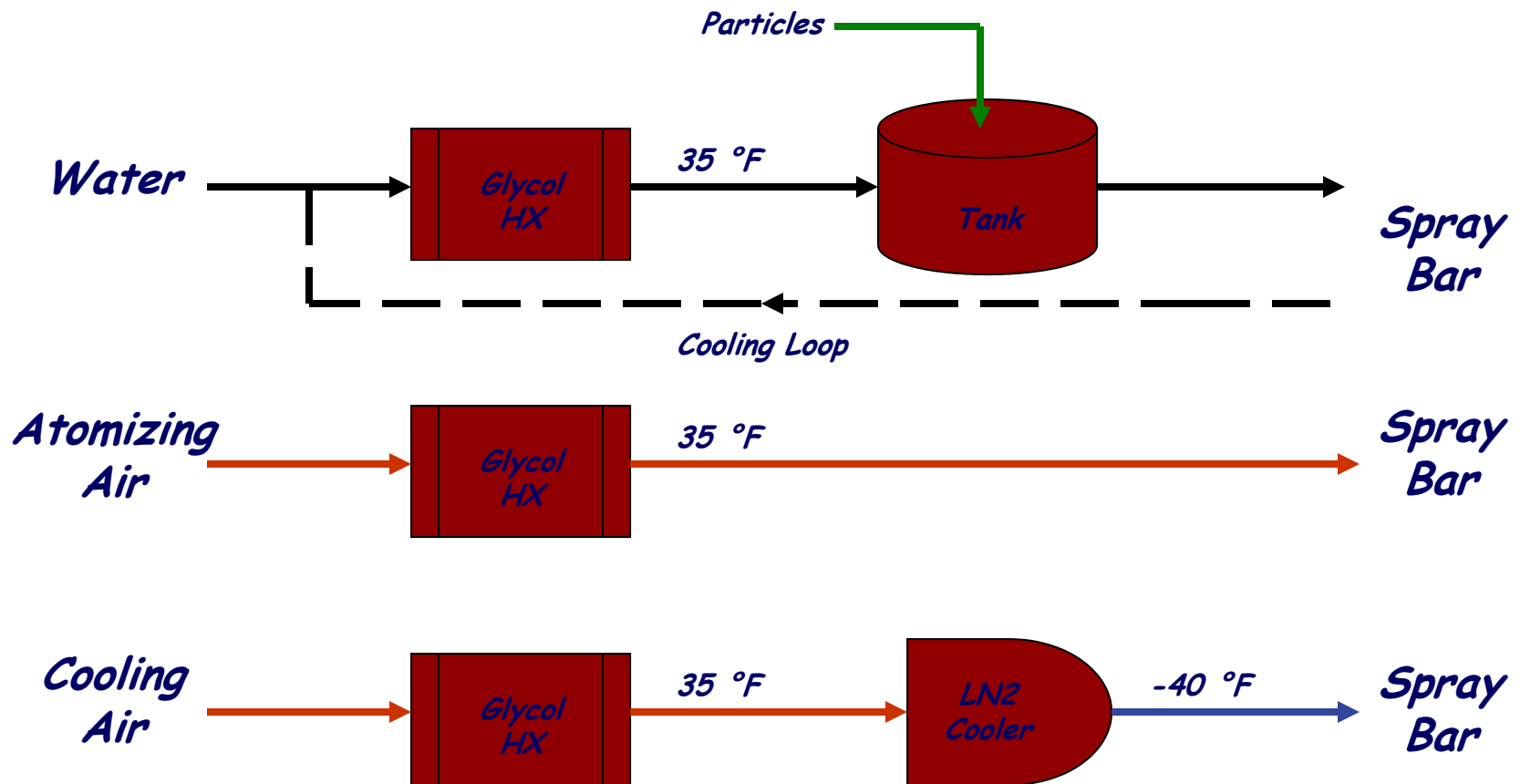
- Icing system was designed and built to requirements established through a international collaborative process between industry and government representatives

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	

System Description

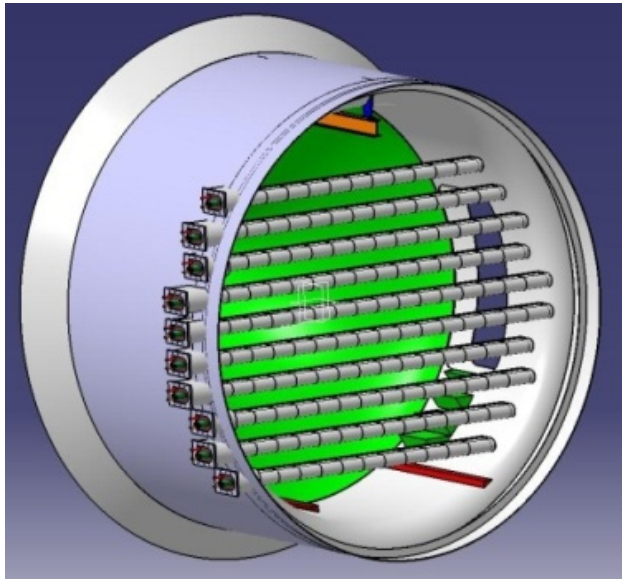
PSL Icing System

Subsystems Design Summary

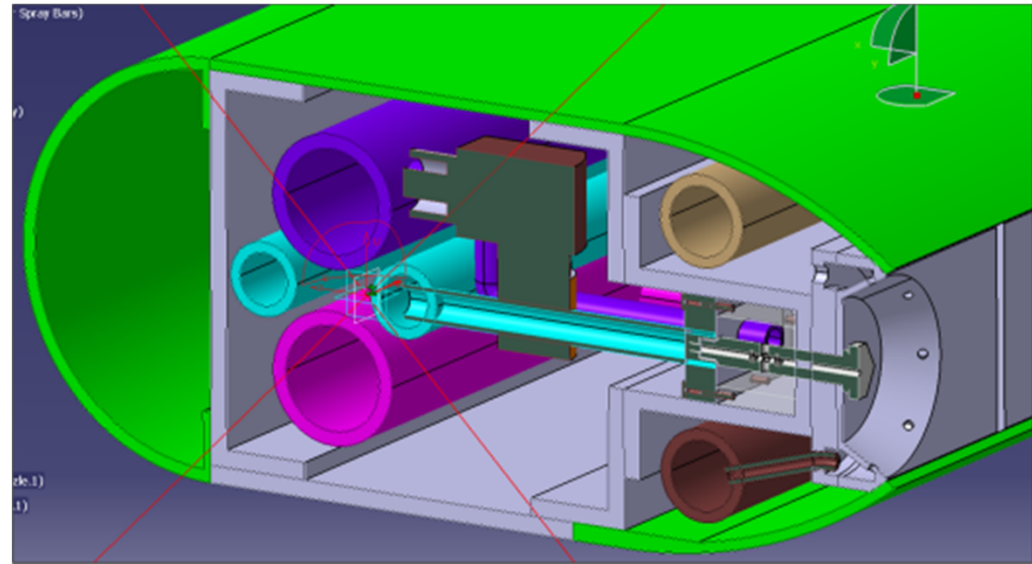


System Description

PSL Icing System



PSL 3 Plenum Spray Bars

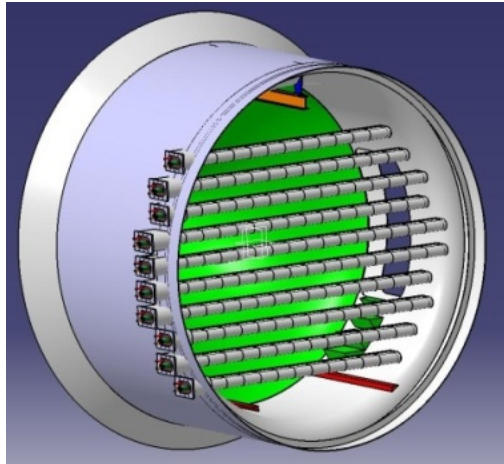


Spray Bar Detail

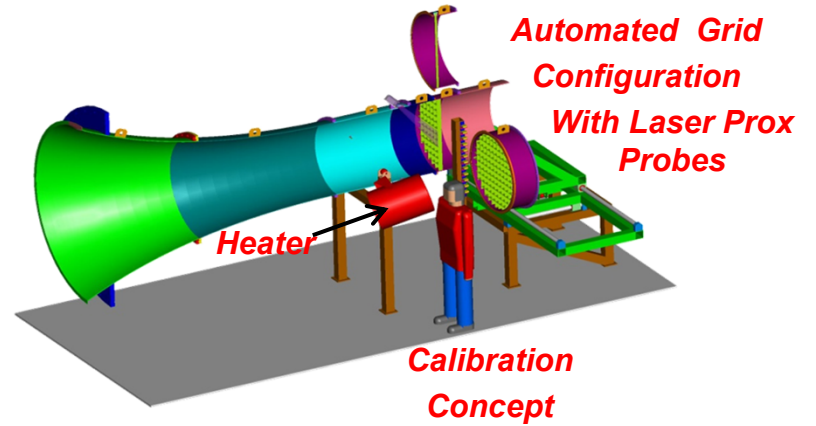
- 10 Spray Bars
- 200+ Nozzles (2 types) mounted in PSL Cell 3 plenum
- 35°F atomized water
- -40°F cooling air at nozzle exit → enhance freezing.

System Description

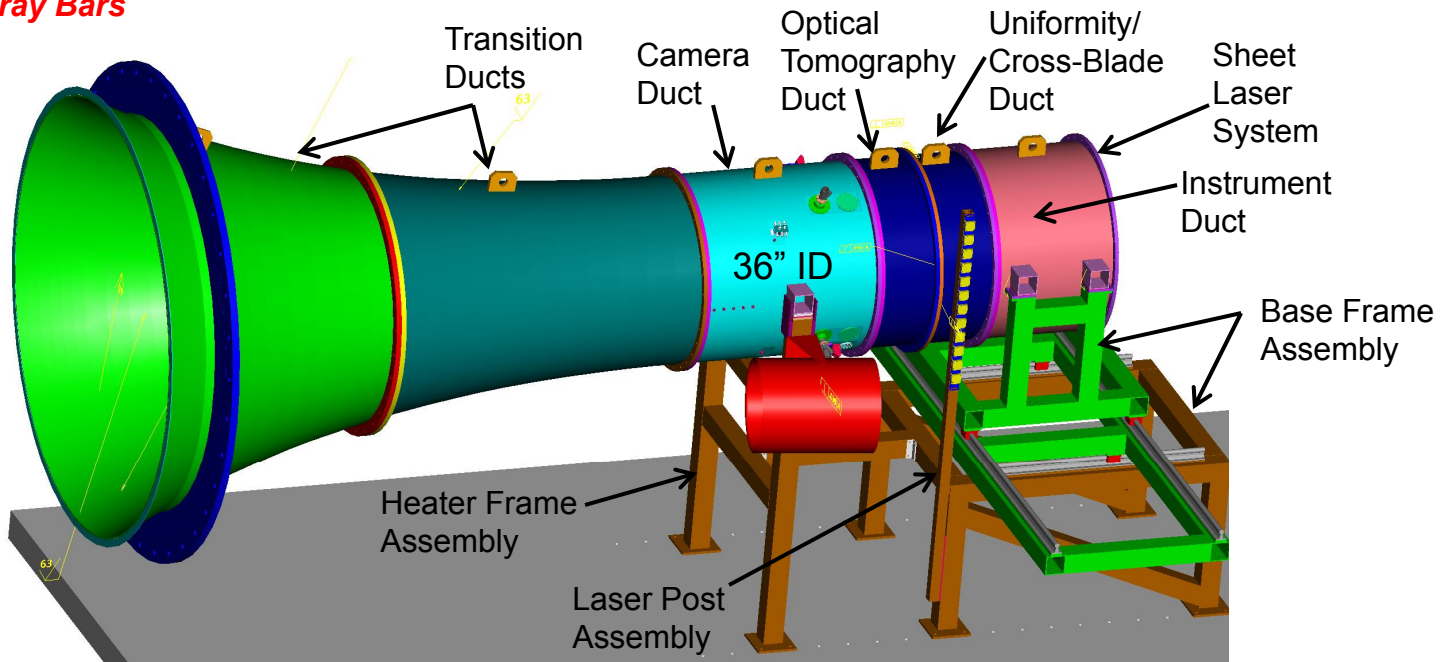
Calibration Hardware



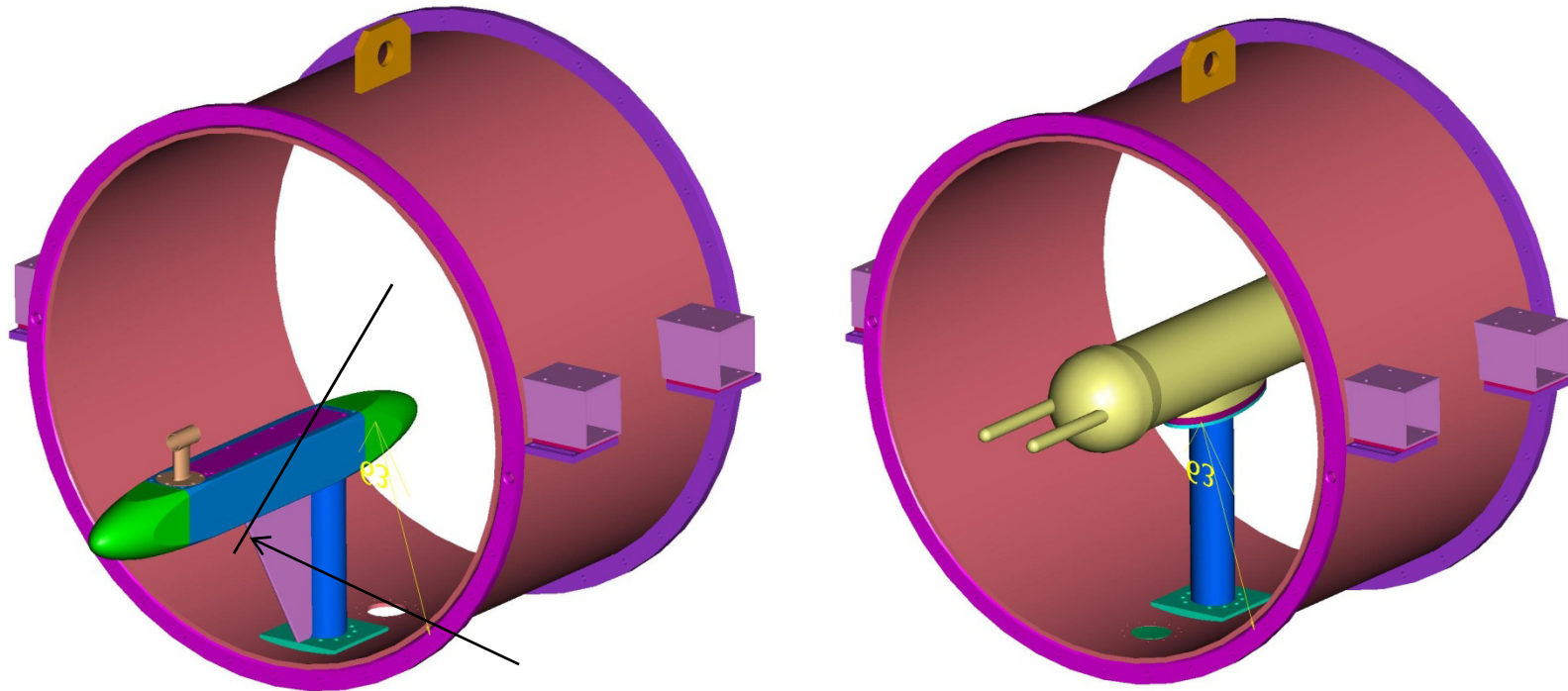
Spray Bars



Calibration Concept

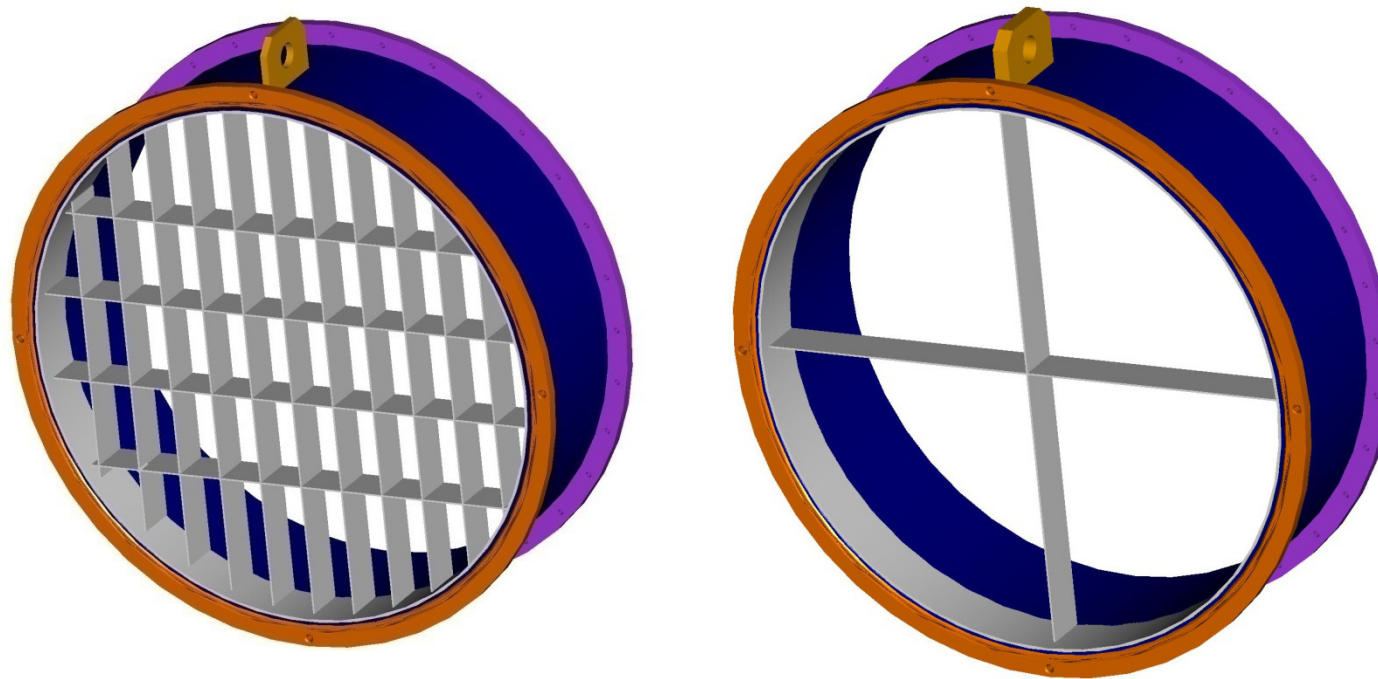


Instrument Duct

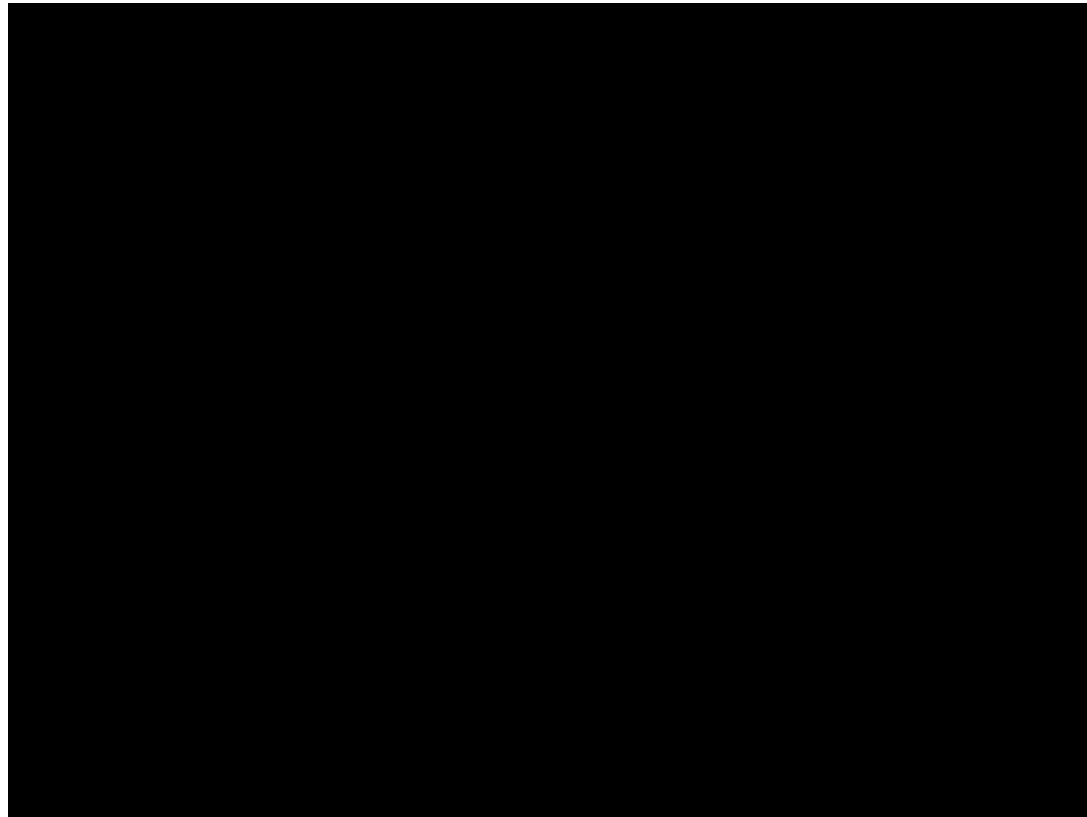


Shown with Multi-Wire (Left). CDP and CIP probes planned for particle sizing.

Uniformity/Cross Blade Duct



Articulating Table





Contact Information

Propulsion Systems Laboratory

<http://facilities.grc.nasa.gov/psl/>

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Questions?/Comments !

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