TURBINE BLADE TIP, ENDWALL AND PLATFORM HEAT TRANSFER, INCLUDING ROTATIONAL EFFECTS

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PROBLEM

- Blade Tip and Platform Over-Temperature Problems Have Resulted from Relatively Flat Radial Temperature Profiles Produced by Low Emission Combustors

OBJECTIVES

- The primary objective is to quantify airfoil tip and platform heat transfer and aerodynamics
- This study will include the effects of film cooling, tip geometry, seal flows, and rotation

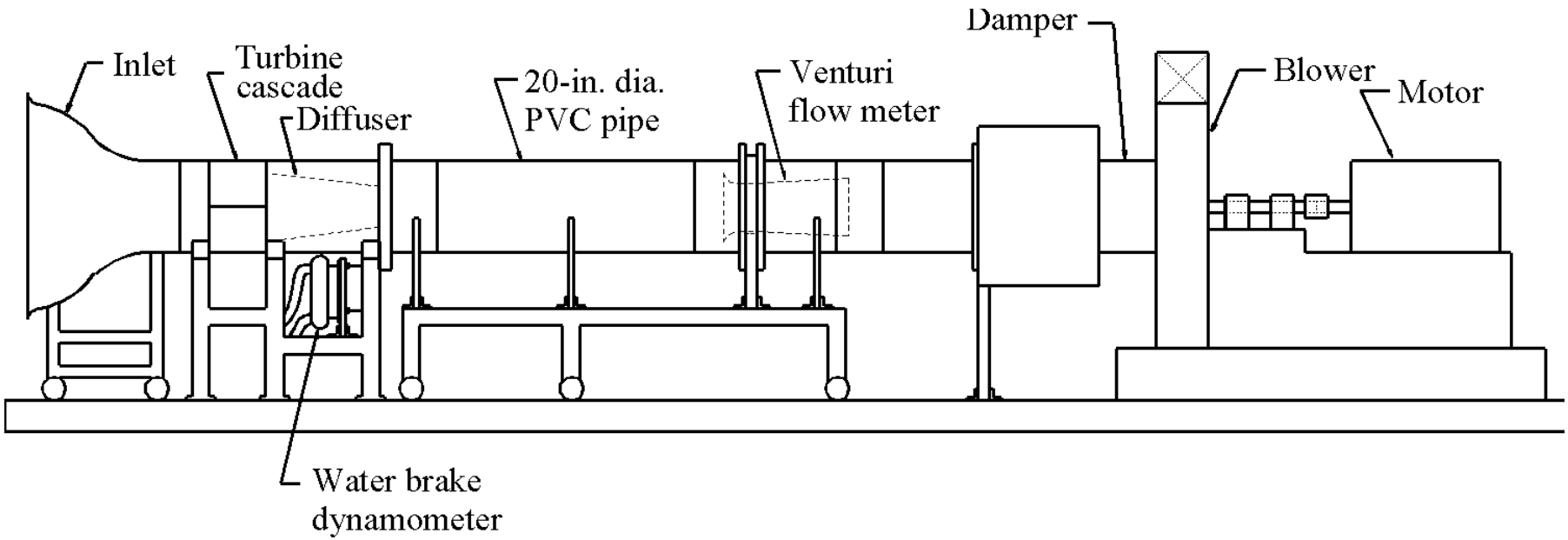
Specific Objectives include:

- Characterize the tip flow and heat transfer of a film cooled rotor, including the effects of hollow “squealer” tips

- Investigate the role of vane blade seal purge flow on platform heat transfer

- Analyze the research turbine flow field with CFD for comparison to experimental data

FACILITY LAYOUT

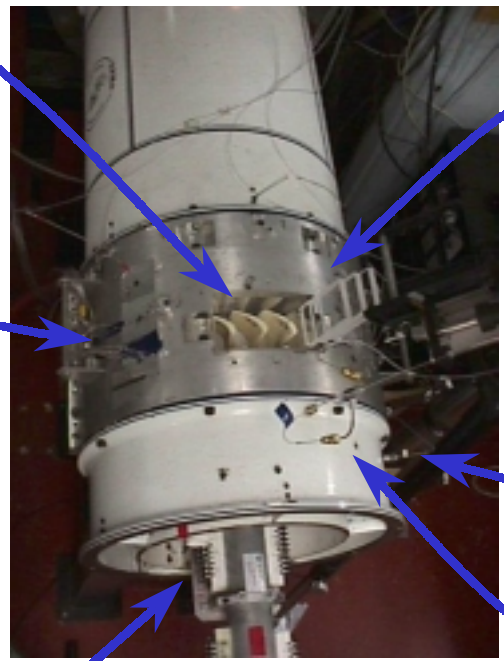


- Two Stage, Low Speed Research Turbine
- Advanced, Forced Vortex Blading Designed by Rolls Royce / Allison

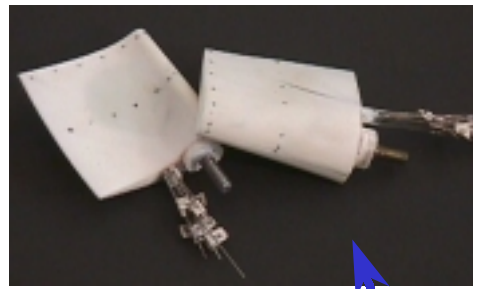
EXPERMIMENTAL SET-UP

Optical Access Spans Axially Mid Chord of IGV to Vane 2 Leading Edge & Covers 4 Rotor Passages

Array of case static pressure taps



Corrective Optics for Skewed PIV Perspective



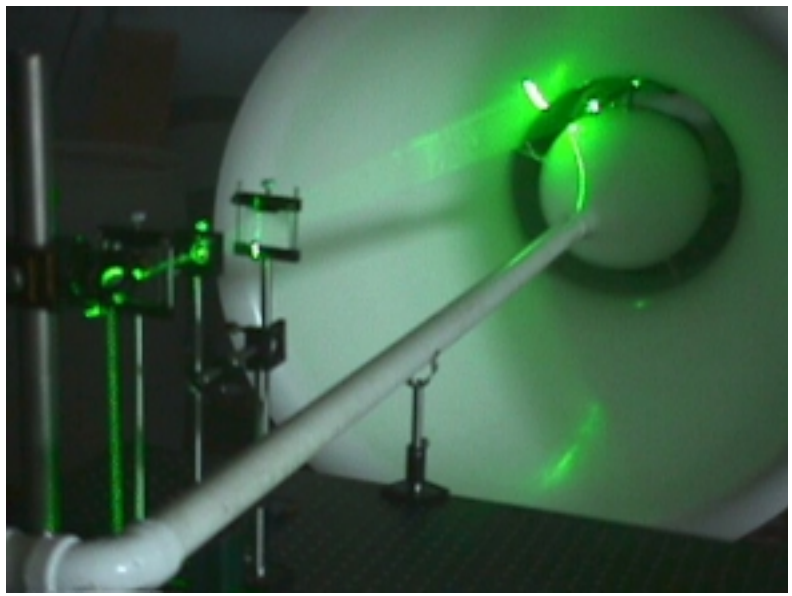
Strategically Placed Total Pressure Probes, Thermistors, Pitot Probes, and Blade Mounted Static Pressure Ports.

Electric Slip Ring Allows Rotating Frame Instrumentation Such as Bleed Air Metering, Electrical Heaters, and Thin Film Heat Flux Gages.

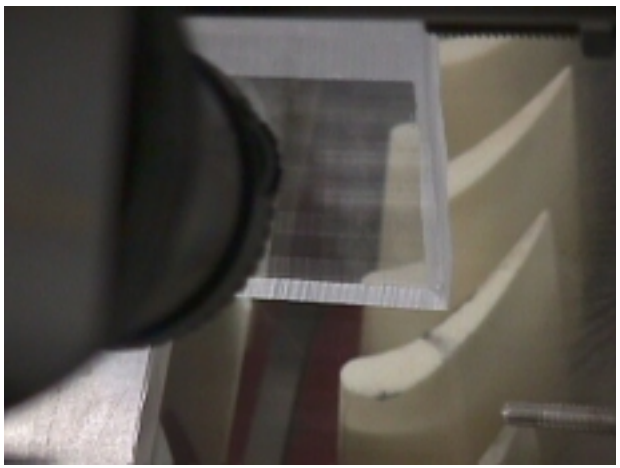
Recent Progress….

Hub Seal Experiments

A Nose-Cone Supply Line Delivers Seed Particles, and Serves as a Metering Location for Hub Flow Rate



Turbine Inlet with a Light Sheet for PIV



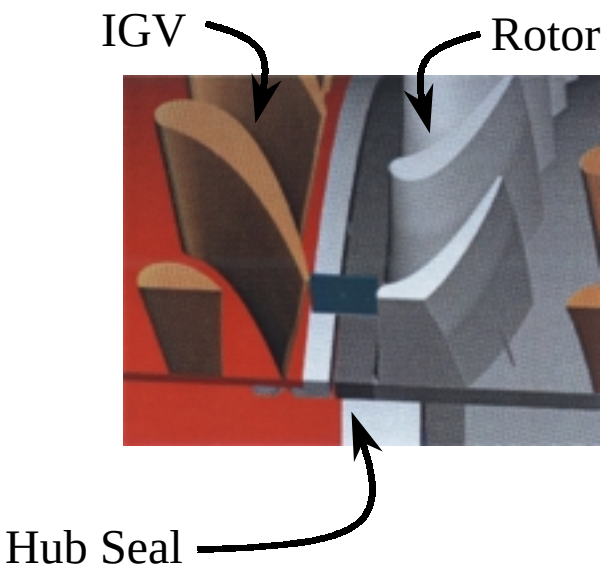
Camera and Case Window

A Perspective on the Hub Seal, with Camera at Left and Rotor 1 to the Right

Recent Progress….

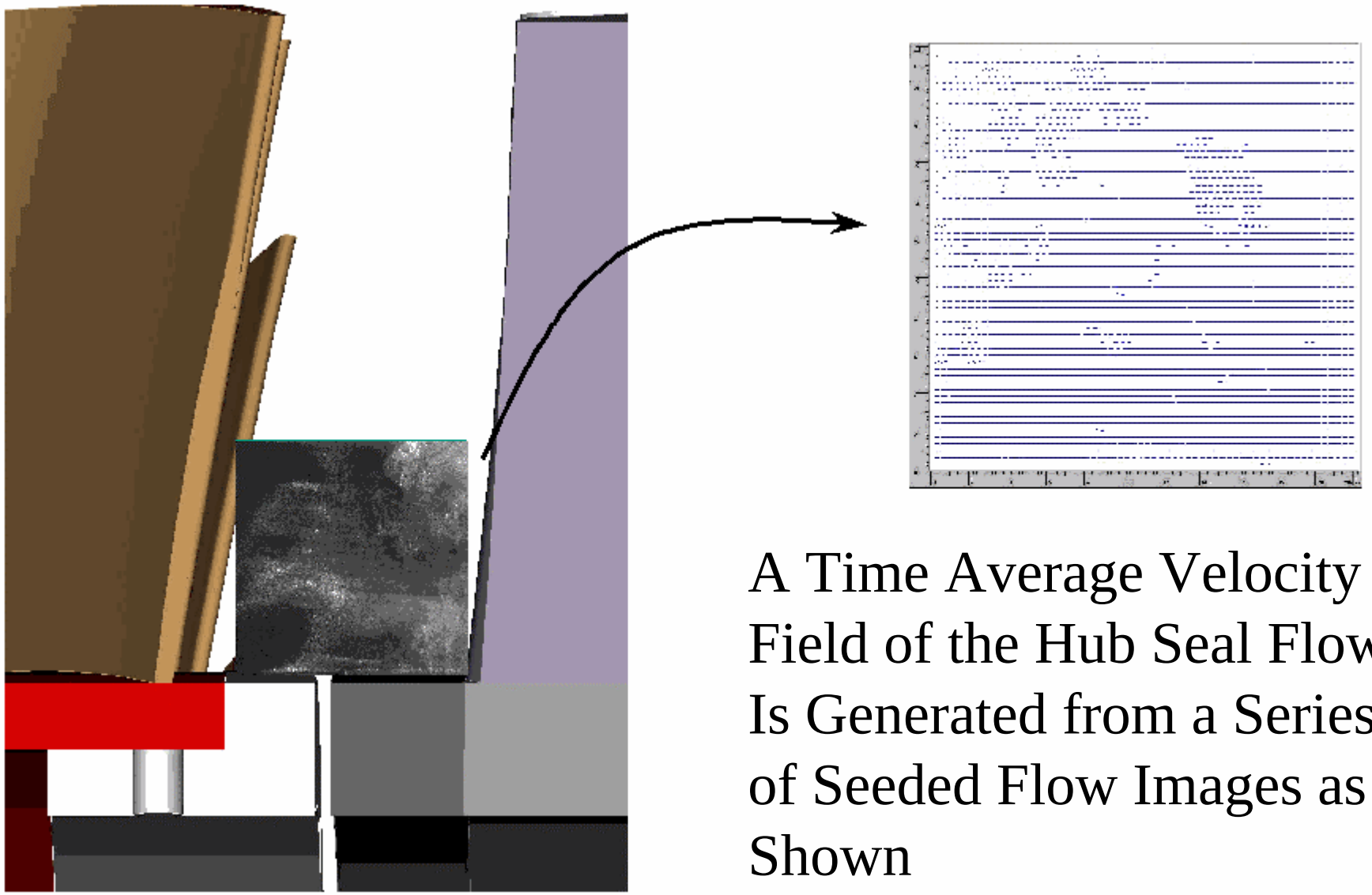
PIV Hardware Layout

Case Window Astigmatic Corrective Optics is Shown in the Sight Line of the Camera



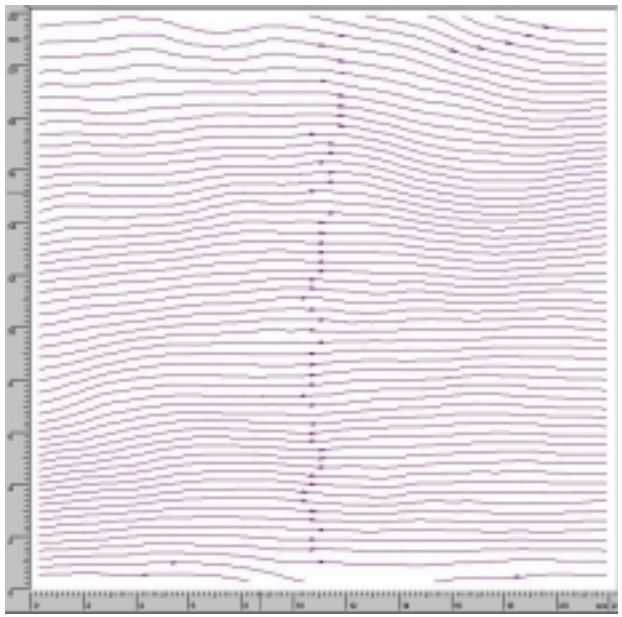
The Object Plane for Current PIV Data Spans Seal Gap

PIV DATA

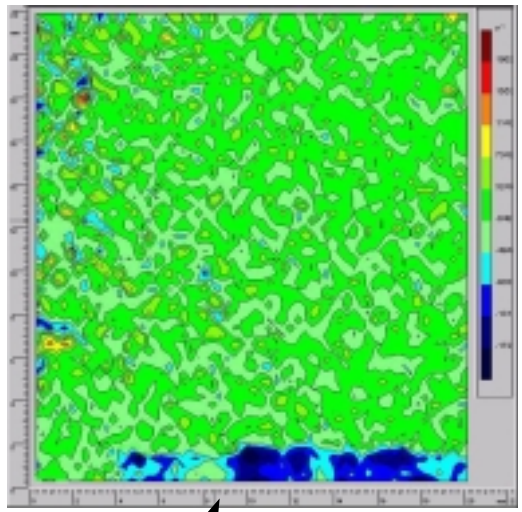


A Time Average Velocity Field of the Hub Seal Flow Is Generated from a Series of Seeded Flow Images as Shown

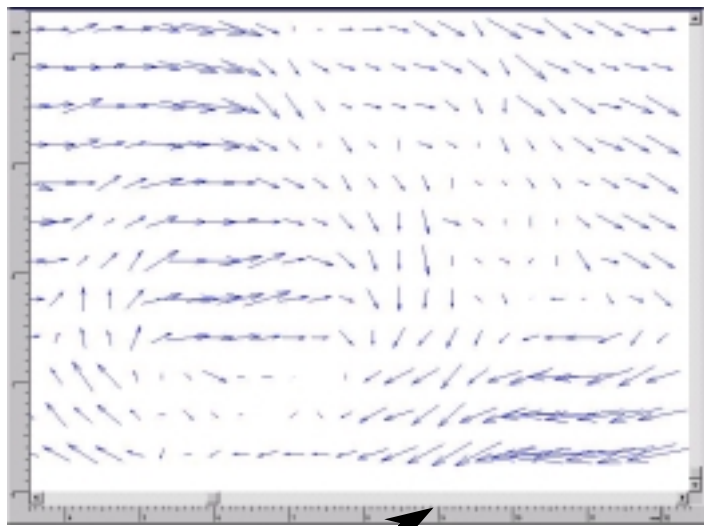
PIV DATA



Streamlines, Vorticity and Perturbation Velocity Maps Are Generated from the Time Average Velocity Statistics



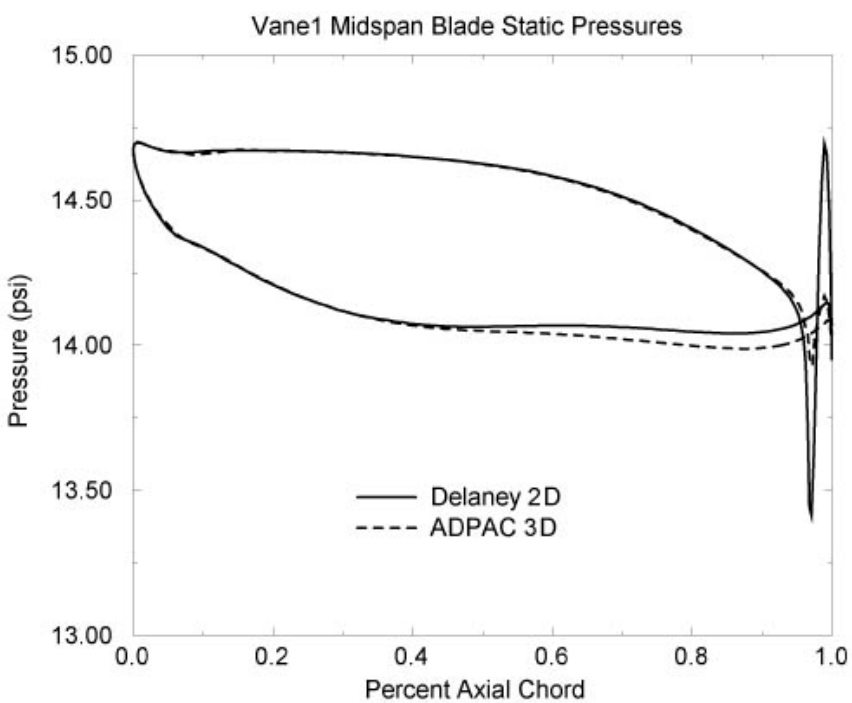
Both Near-Seal Streamlines and Perturbation Velocity Maps Suggestion Local Seal Ingestion

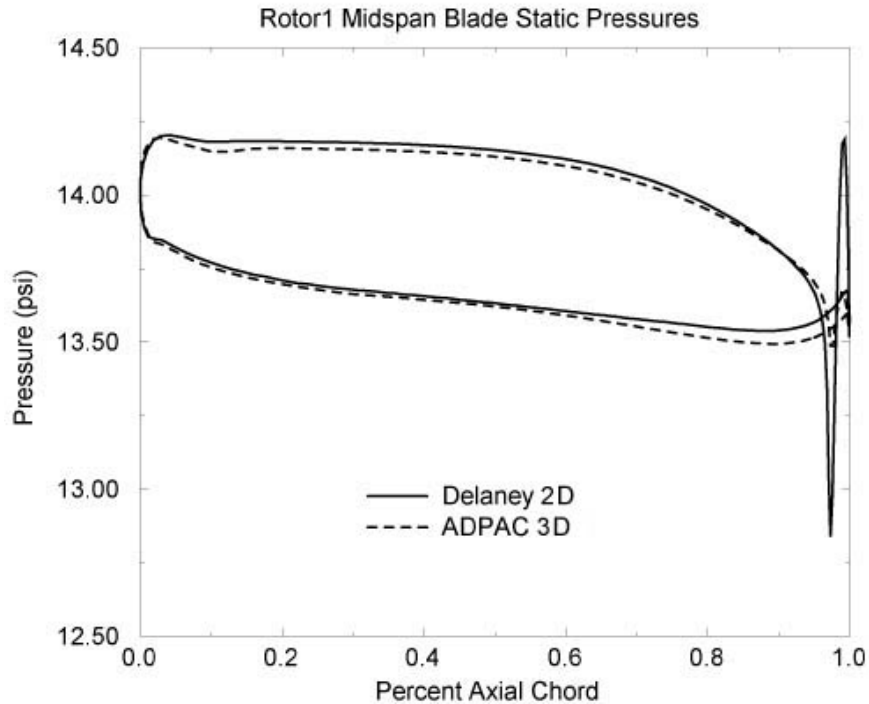


Seal Location

Recent Progress….

Computational Predictions

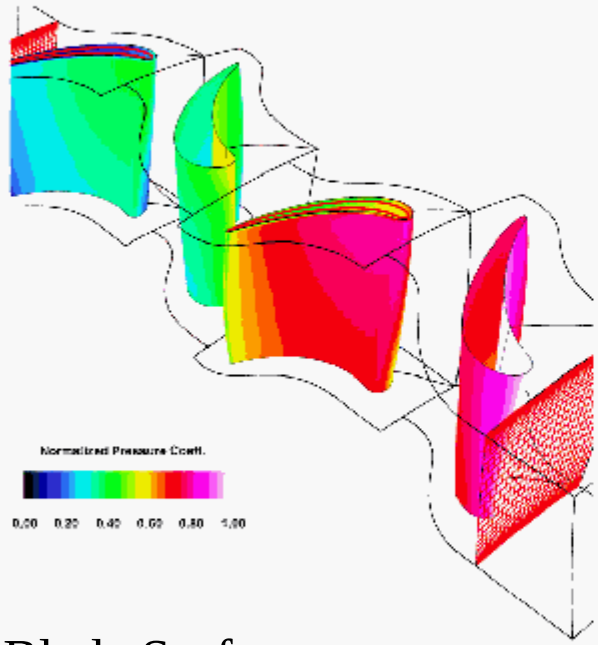




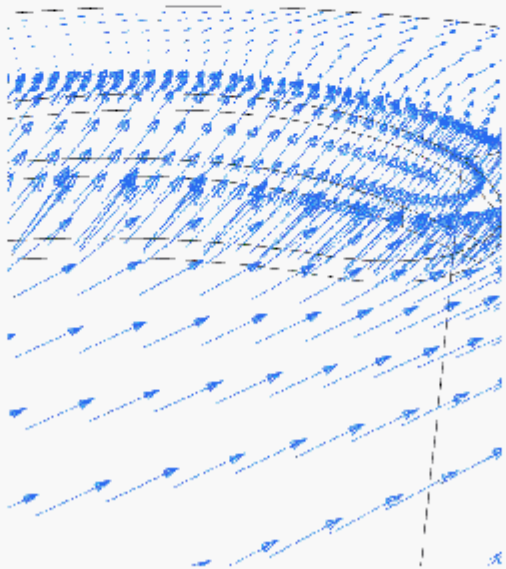
ADPAC-3D Unsteady N-S Solution of the 2 Stage Turbine with ATS Blading

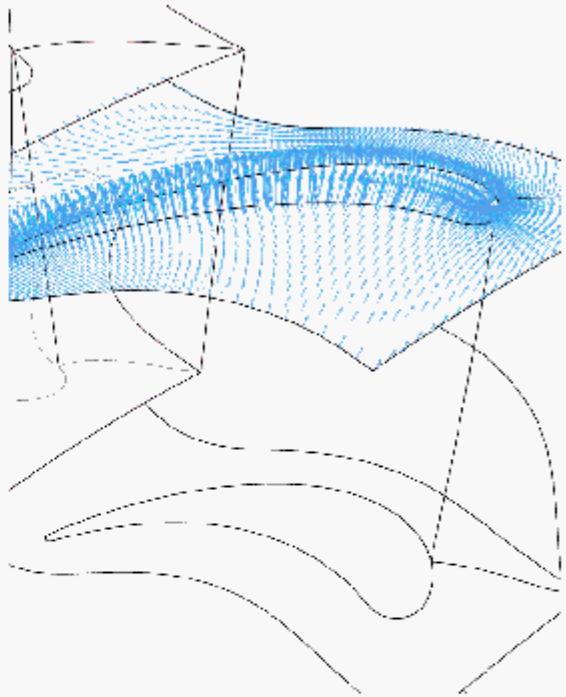
Recent Progress….

Computational Predictions



Blade Surface
Pressure Coefficient



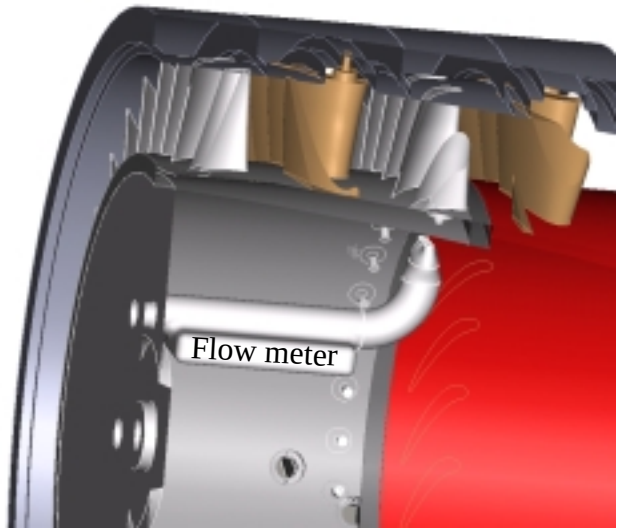


Tip Clearance Vector
Field Prediction

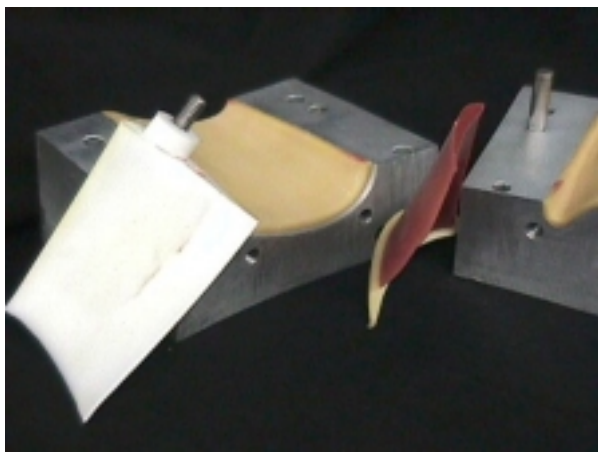
ADPAC-3D Unsteady N-S Solution of
the 2 Stage Turbine with ATS Blading

Film Cooled Rotor Tip

Rotor Blades for Tip Film Cooling were Fabricated using a Lost-Wax Molding Process.



Hub Mounted Coolant Delivery Line with integral flow meter

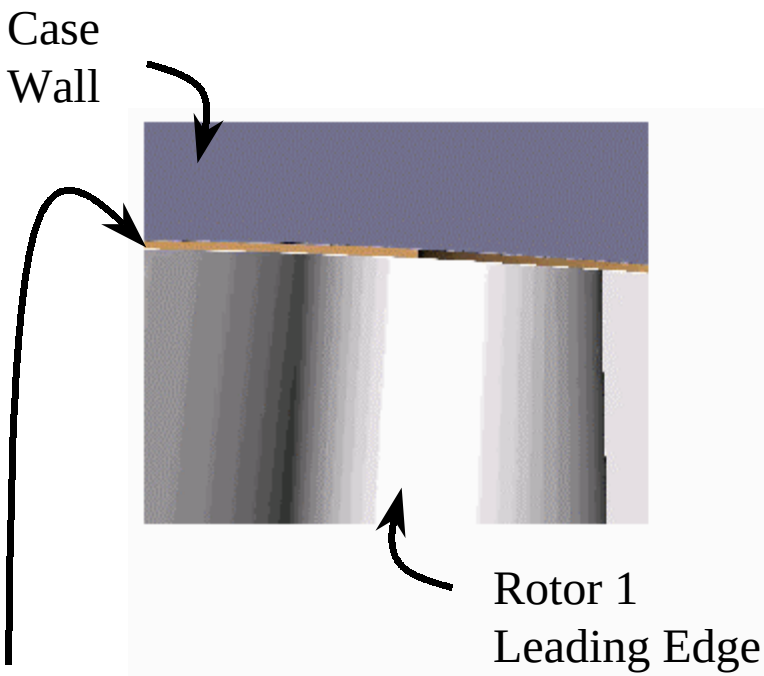


Blade molding hardware

Cooling Air is Metered with a Drum-Mounted, Hot-Film Based, TSI Flow Meter.

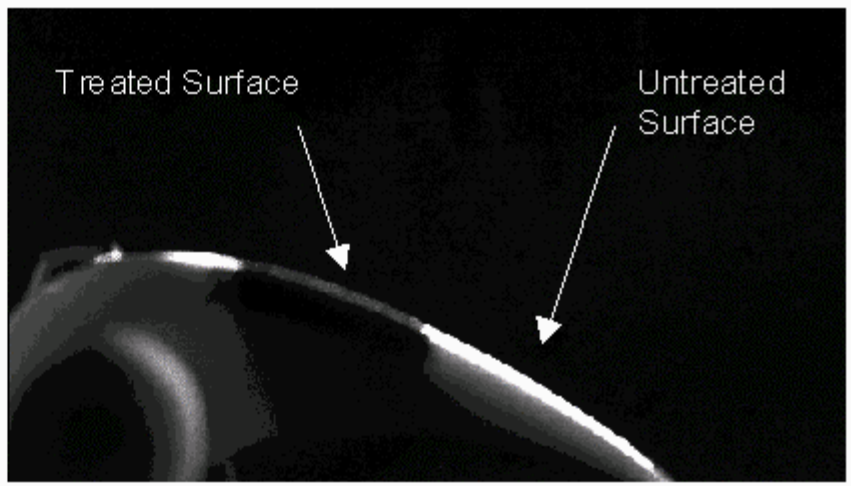
FUTURE WORK….

TIP REGION EXPERIMENTS



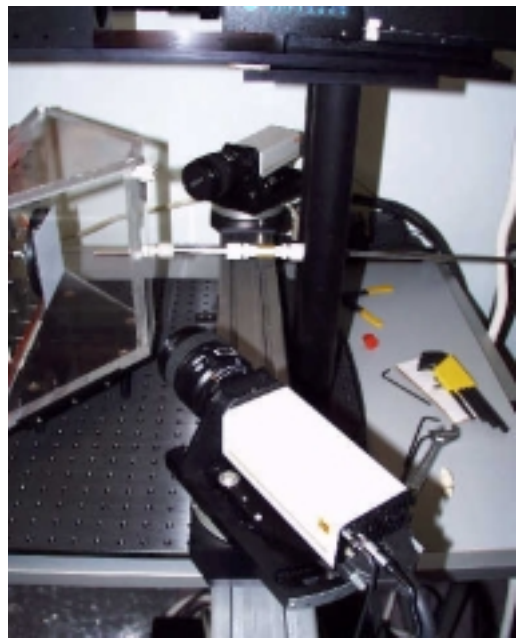
Anti-Reflection Coatings have been Tested for the Purpose of Tip Region PIV

Tip Gap Set to 1% of Blade Height
Utilizes Typical Engine Geometry & Provides Space for 3+ PIV Light Sheets



Future Work

- Purge Flow Interrogation via Tangential Sweep passing through an IGV wake.



- Tip Region Planar PIV
- Tip Region 3D-PIV
- Tip Heat Transfer Using Full Area Heat Flux Gage Derived from Temperature Sensitive Paints