

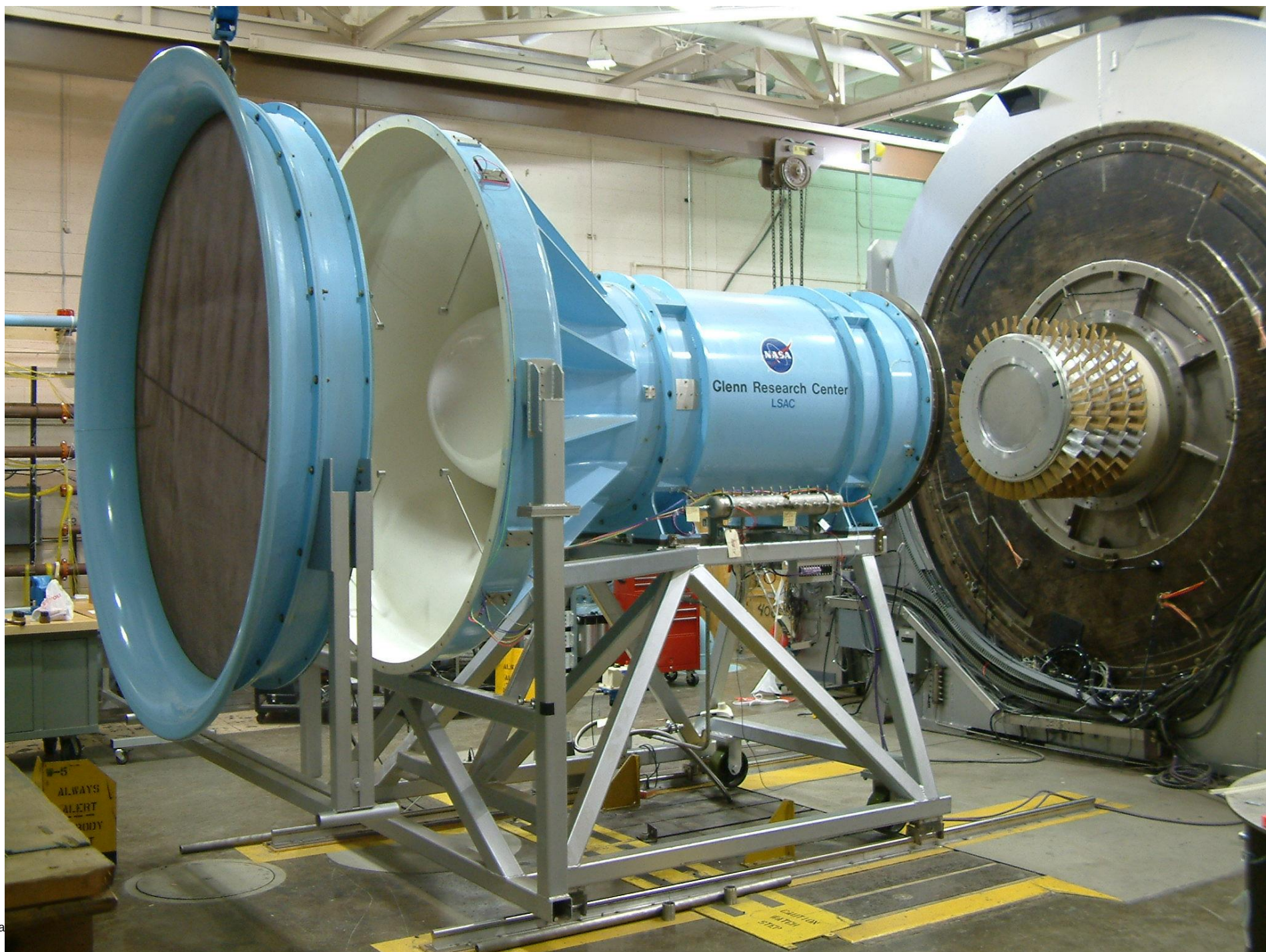
W-1A Low Speed Axial Compressor (LSAC) Facility

NASA-Rolls Royce Technical Interchange Meeting

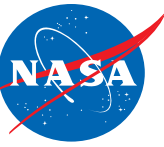
21 March 2024

GRC-LTE/Mike Borghi

GRC-LTE/Sameer Kulkarni



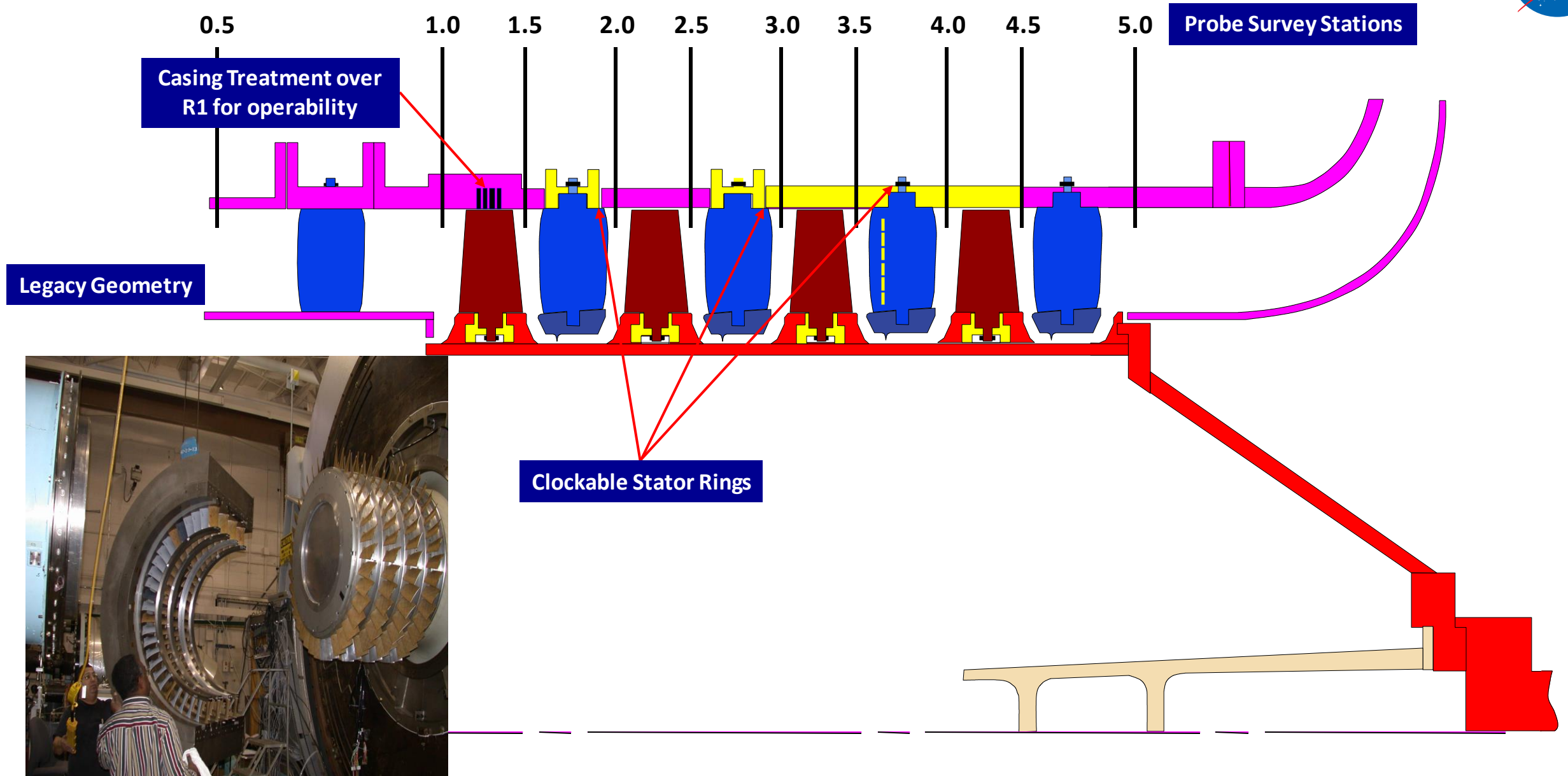
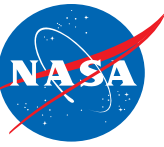
Facility Capabilities

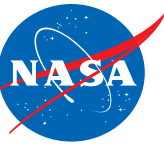


Parameter	Operating Value
Inlet air pressure	Atmospheric
Inlet air temperature	Ambient
Inlet airflow (centrif/ax)	66/32 lb/s
Atmospheric exhaust	0.8 psid blowers
Altitude exhaust	20-26 in hg
Rotor speed (centrif/ax)	1920/1050 rpm
Rotor diameter (centrif/ax)	60/48 in
Drive motor	1500hp

System	Number and Type
ESP (steady state pressures) → transitioning to Netscanner	384 Ports of +/- 1 PSID Barometric Ref
Escort (steady data system) → transitioning to COBRA	128 Analog Channels 112 Available to the Customer
Dewetron (dynamic data system)	32 channels @ 1-200 kHz
Dynamic Pressures	16 Transducers +/- 5 PSID
Thermocouples	96 Type E/K

Legacy LSAC Cross Section

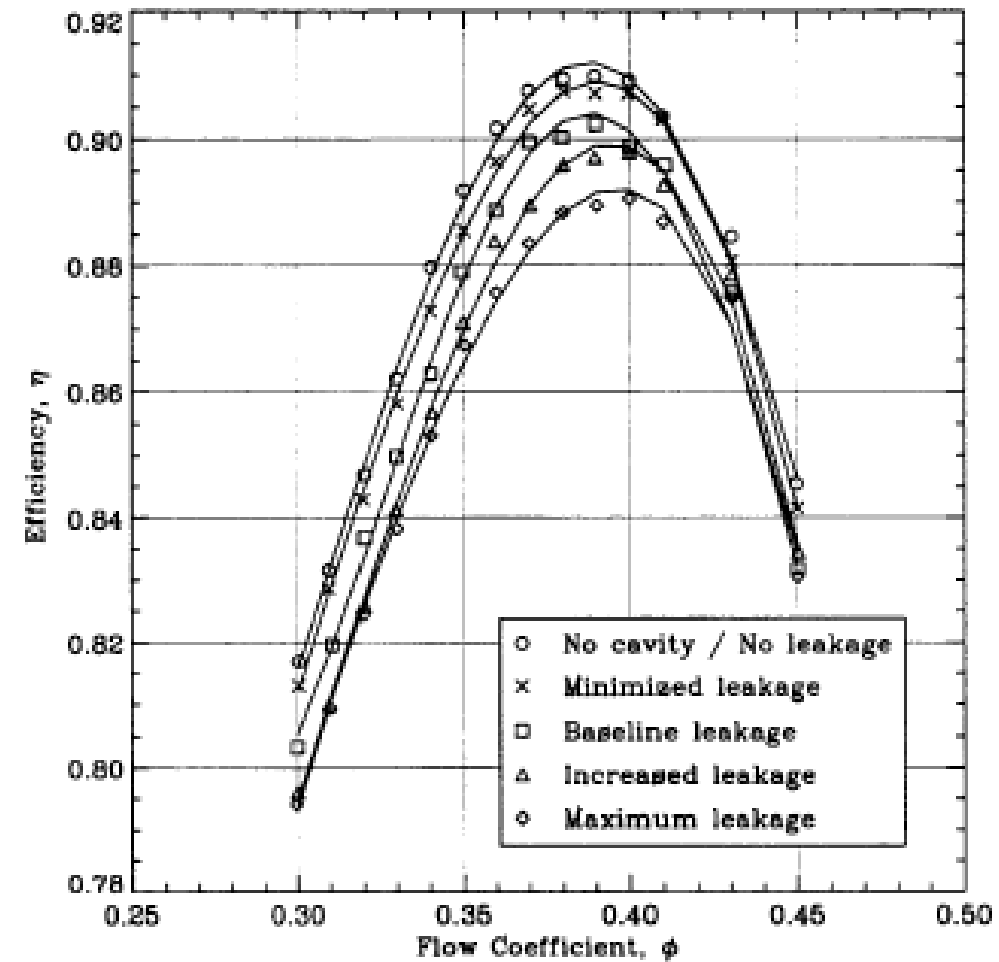
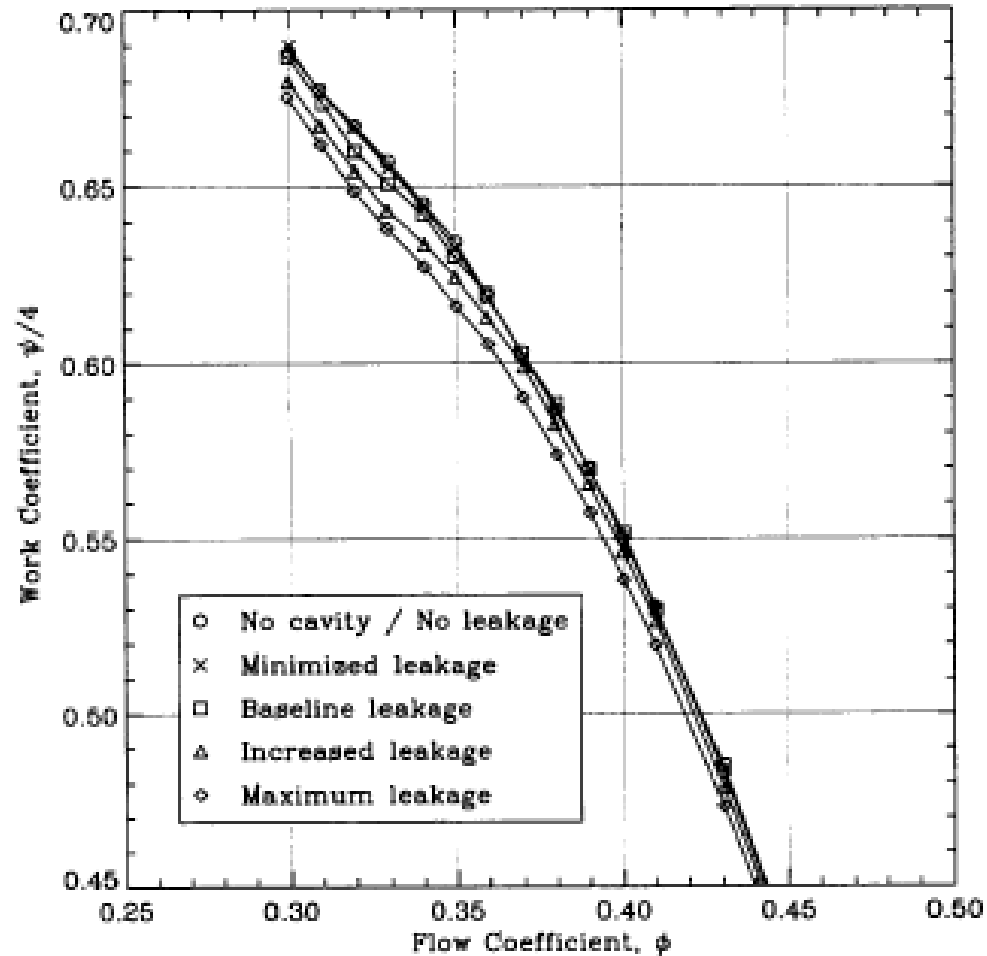
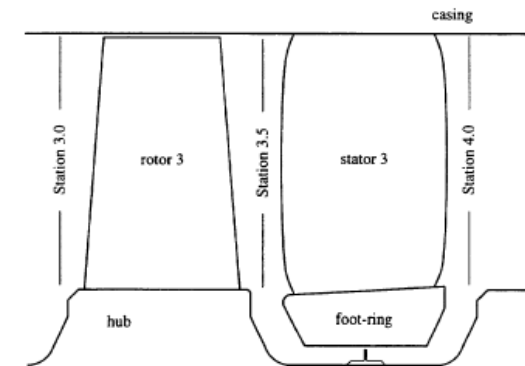




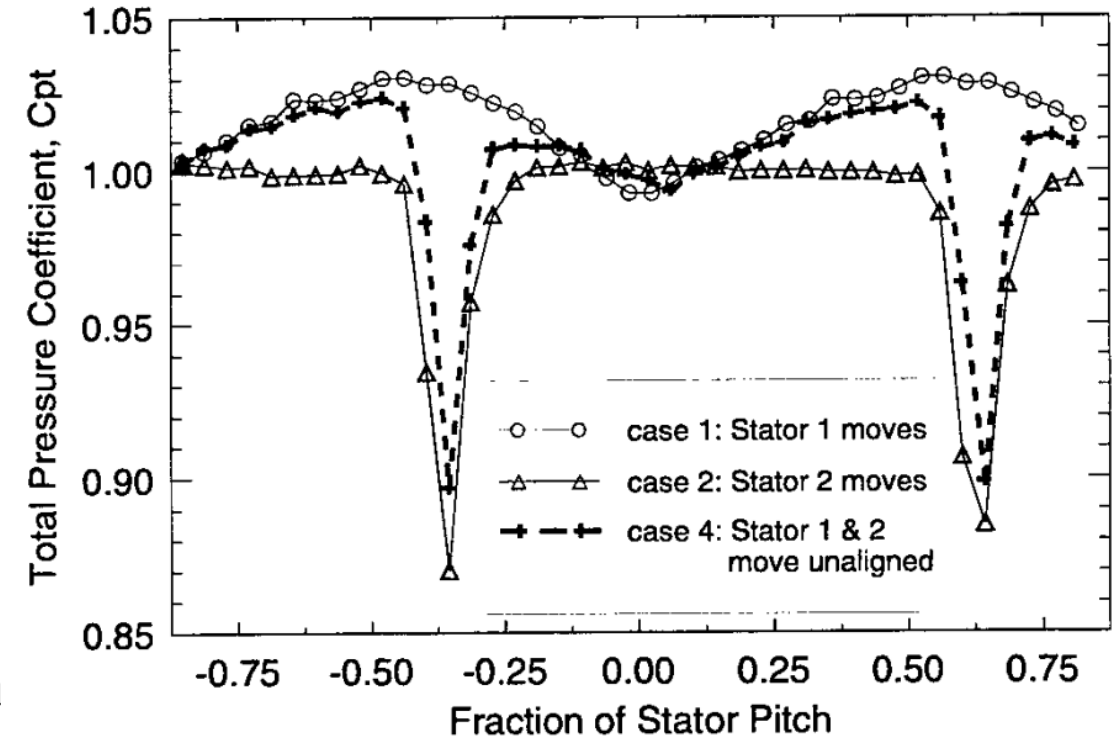
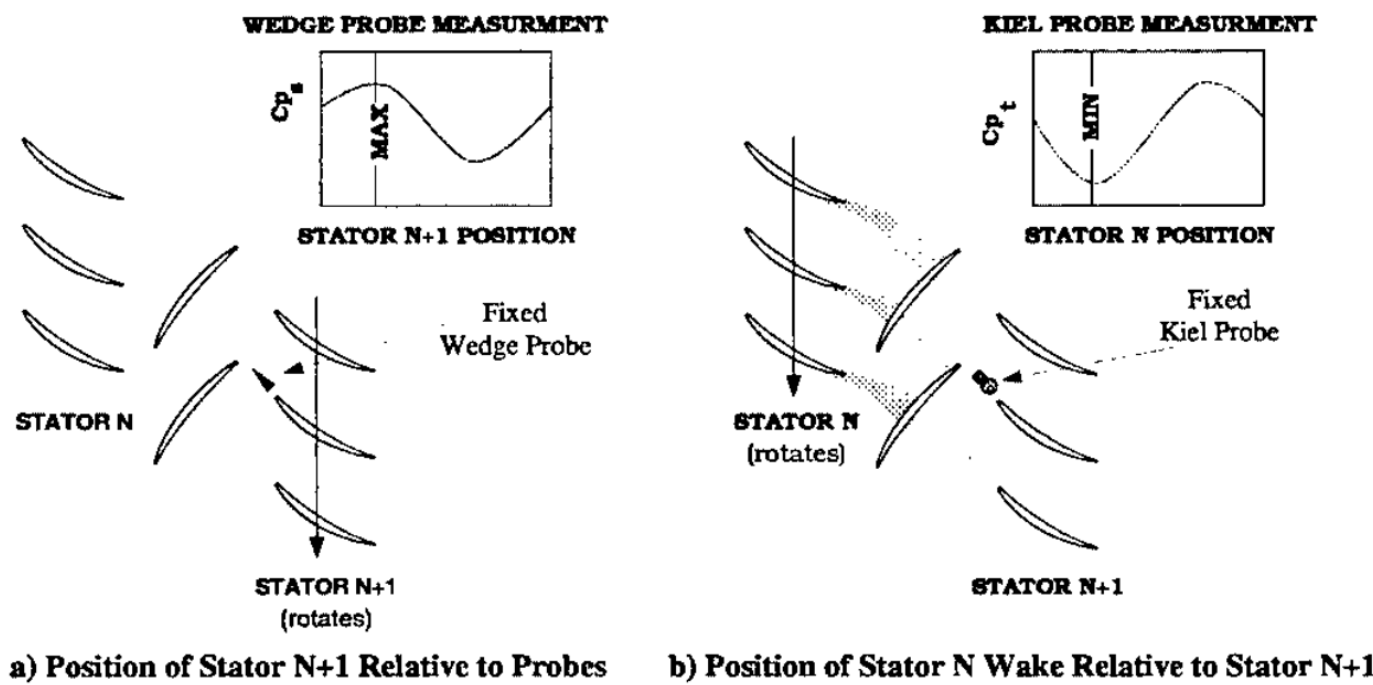
Past Work

- **Investigation of shrouded stator leakage**
 - Varying leakage gap under stator shroud cavity
 - Varying axial extent of stator hub leakage gap
- **Stator vane surface separation control**
 - Steady (slots, holes)
 - Active external & fluidic injectors embedded in vane
 - Closed loop detection and feedback control
 - Impulsive surface injection
- **Investigation of rotor 1 instability**
 - Characterization of tip clearance flow using PIV
 - Measurement of rotating stall
 - CG parametric study (CFD based on LSAC geometry)

EFFECTS OF SHROUDED STATOR CAVITY FLOW ON MULTISTAGE AXIAL COMPRESSOR PERFORMANCE

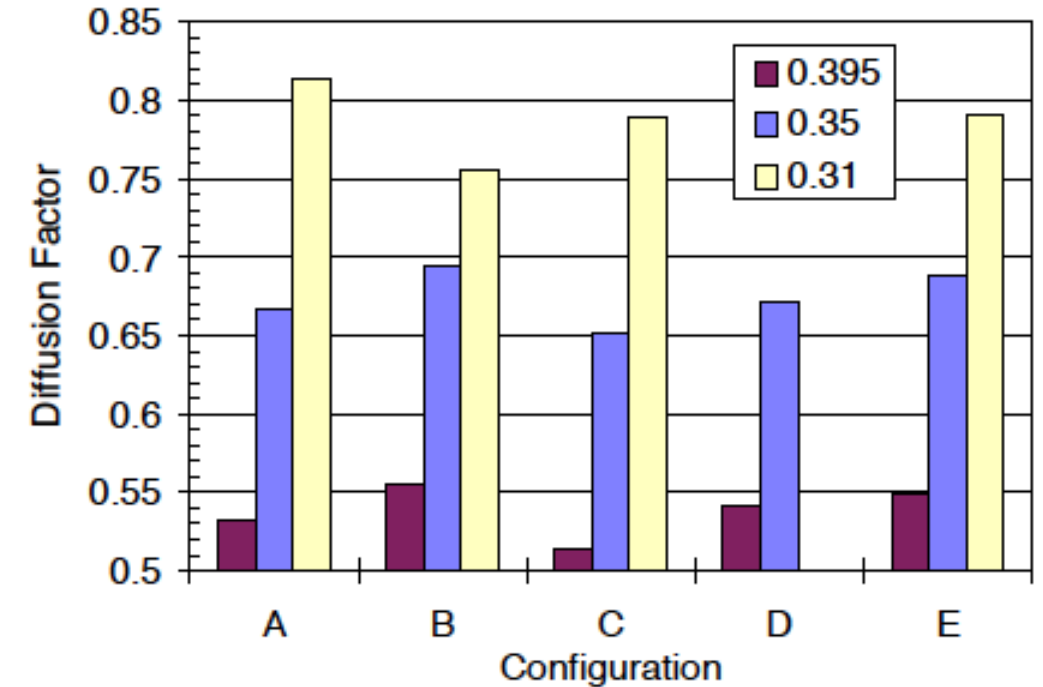
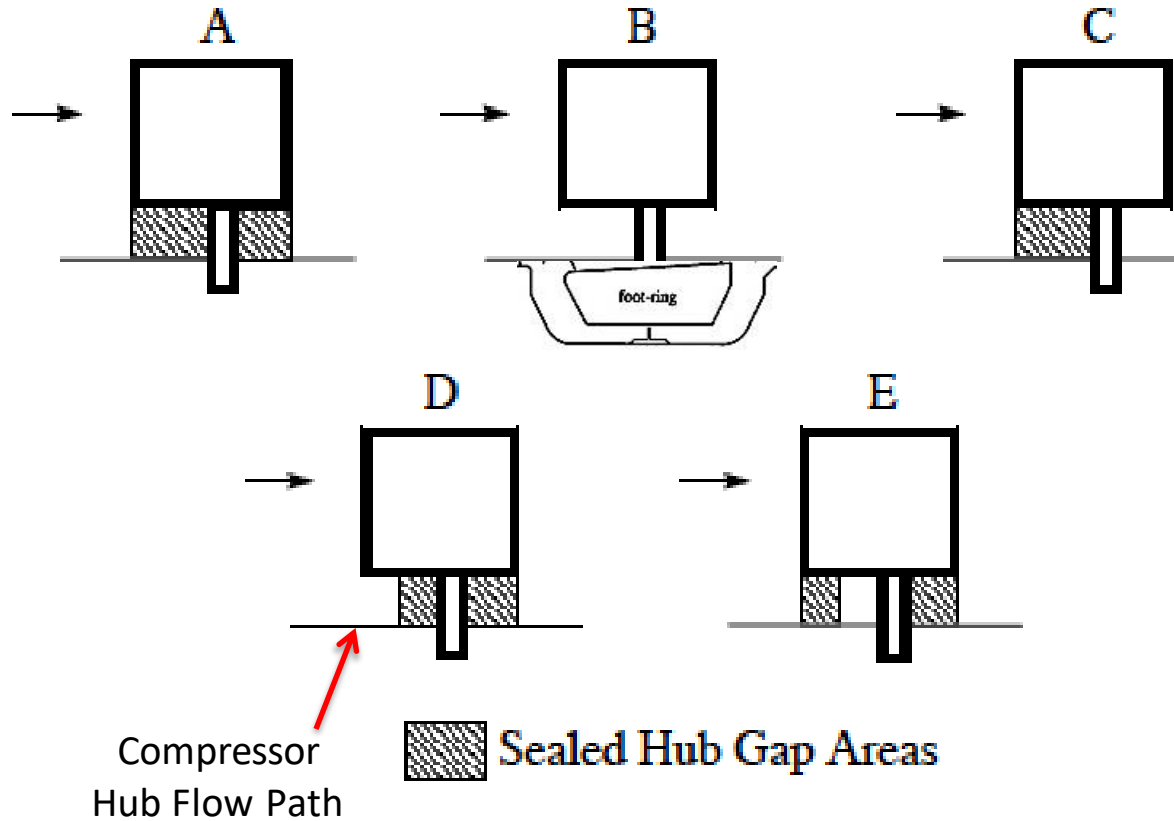


EFFECTS OF STATOR INDEXING ON MULTISTAGE COMPRESSOR PERFORMANCE



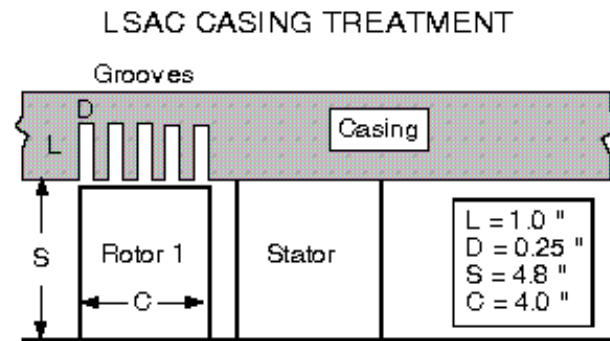
a) Stator 2 exit / Rotor 3 inlet

IMPACT OF VARIABLE-GEOMETRY STATOR HUB LEAKAGE ON MULTISTAGE COMPRESSOR PERFORMANCE

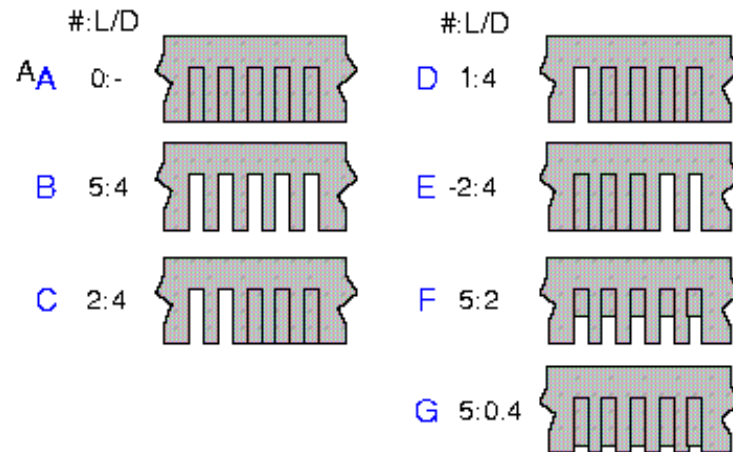


NUMERICAL STUDY ON VARYING GEOMETRY OF R1 CIRCUMFERENTIAL GROOVE CASING TREATMENT

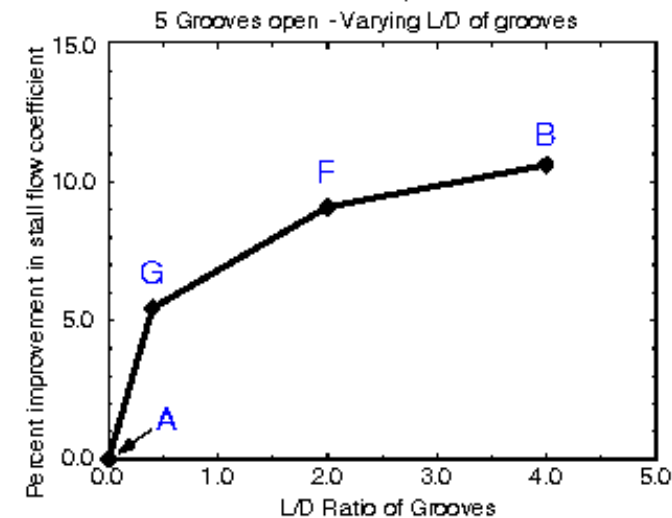
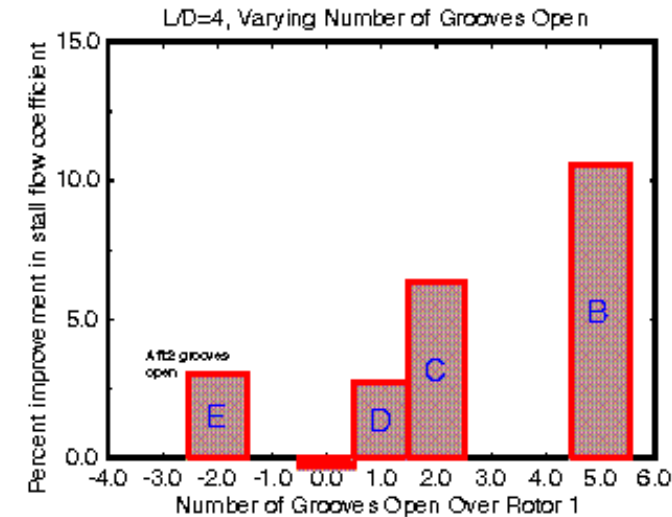
DATA FOR APNASA CASING TREATMENT MODELING



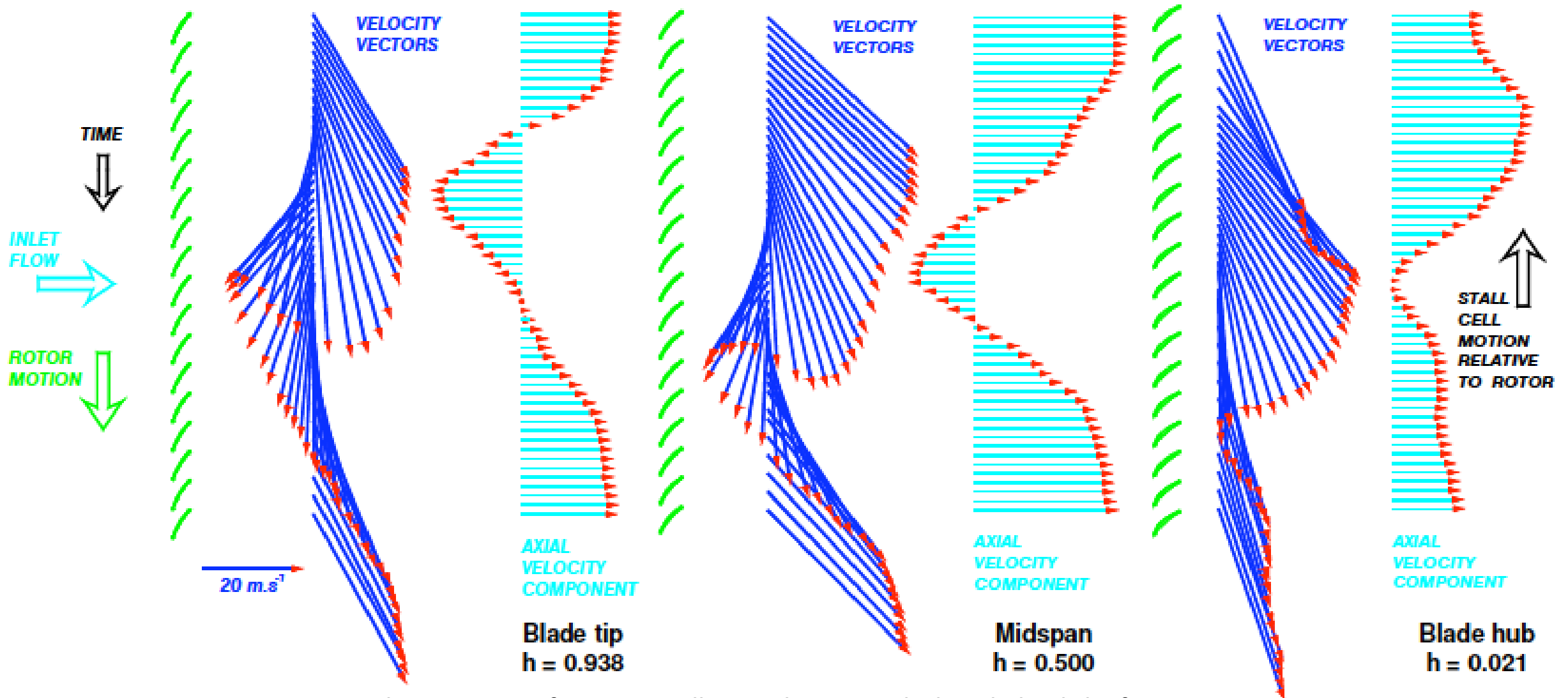
CONFIGURATIONS TESTED



mauddib/tninjadwgs/
 FPM_FY99/ppm_ty99_10.dwg

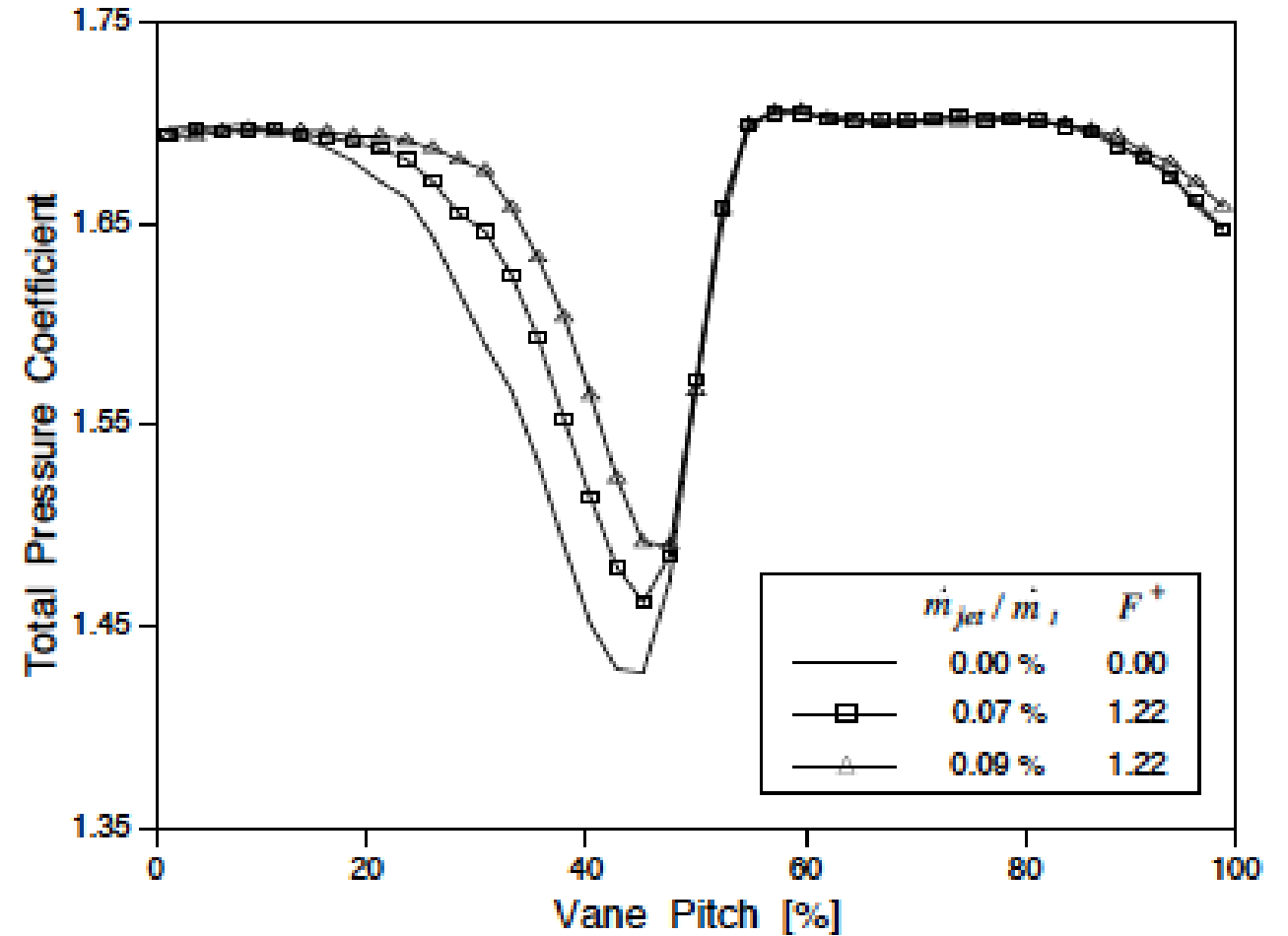
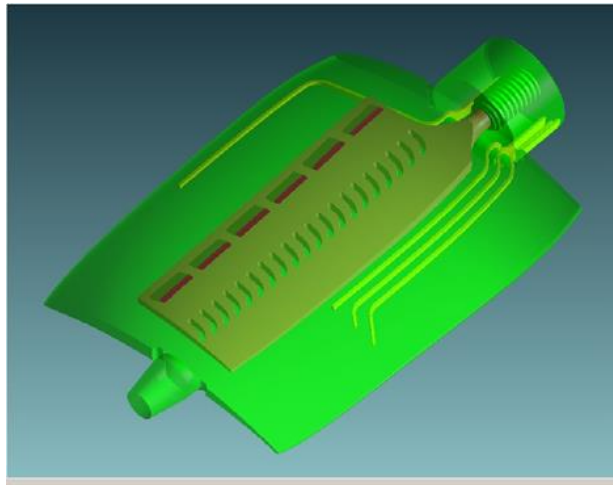
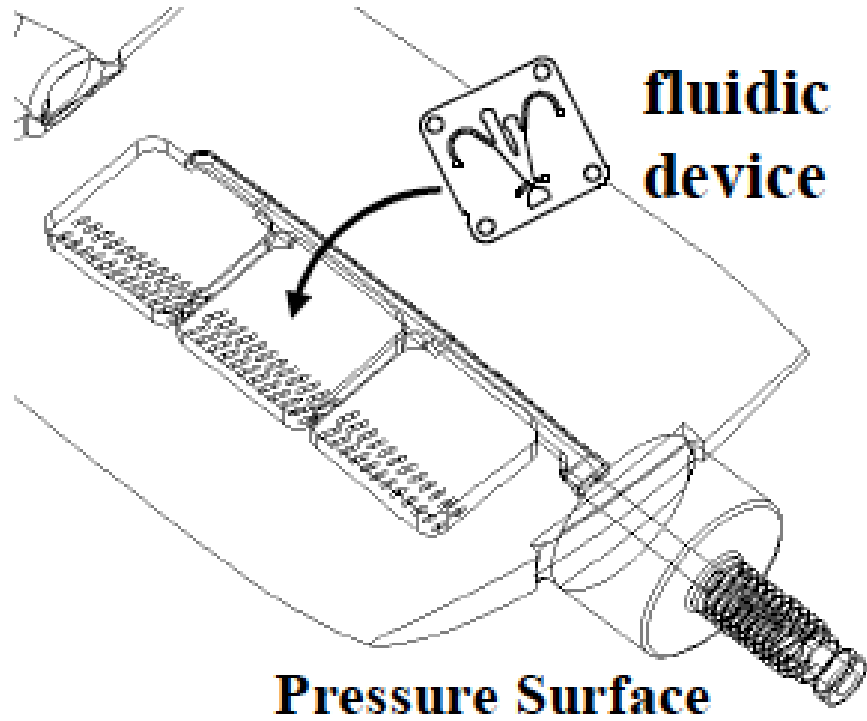


INVESTIGATION OF ROTATING STALL BEHIND ROTOR 1



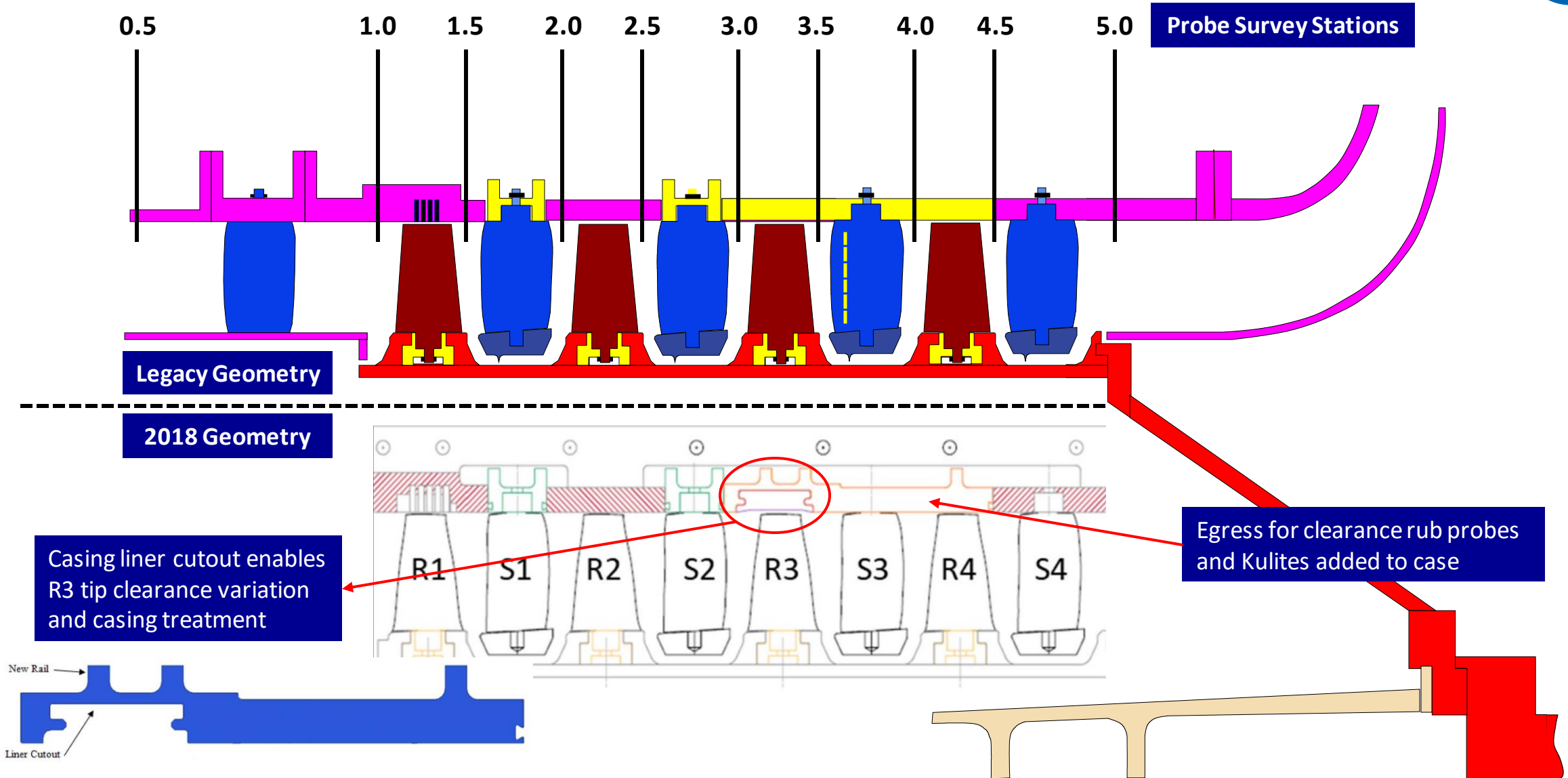
Flow patterns of rotating stall in axial-tangential plane behind the first stage rotor measured at three span locations (blade tip, mid-span, and blade hub)

SEPARATION CONTROL USING IMPULSIVE SURFACE INJECTION



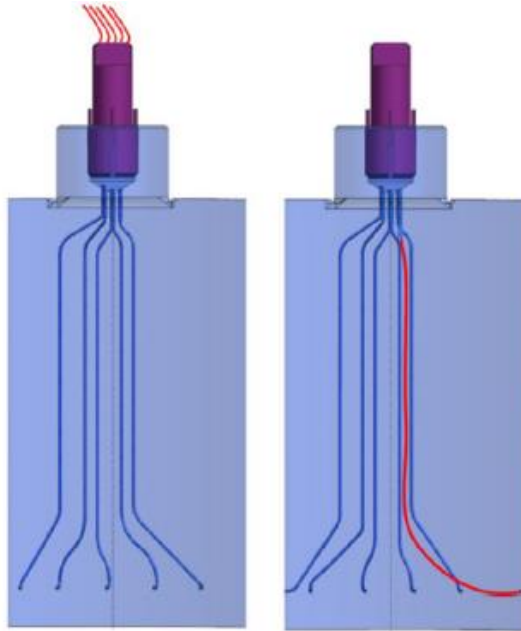
- Culley, et al "Active Flow Separation Control", 2003
- Bright, et al, "Closed Loop Active Flow Separation Detection and Control in a Multistage Compressor", 2005
- Culley, et al, "Impulsive Injection for Compressor Stator Surface Separation Control", 2005

Legacy vs New 2018 Hardware

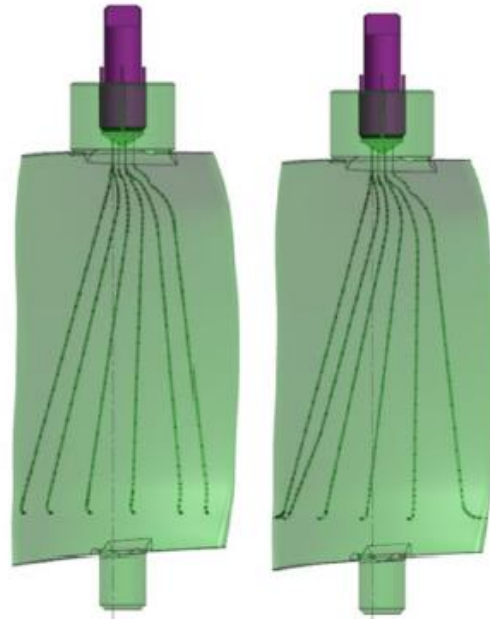


New LSAC Airfoils

- Instrumented stators (IGV, S2, S3) contain axial pressure arrays at 90%, 50%, or 10% span on suction or pressure surface
- These baseline airfoil geometries are unrestricted / unlimited rights



Instrumented IGVs



Instrumented Stators



IGV

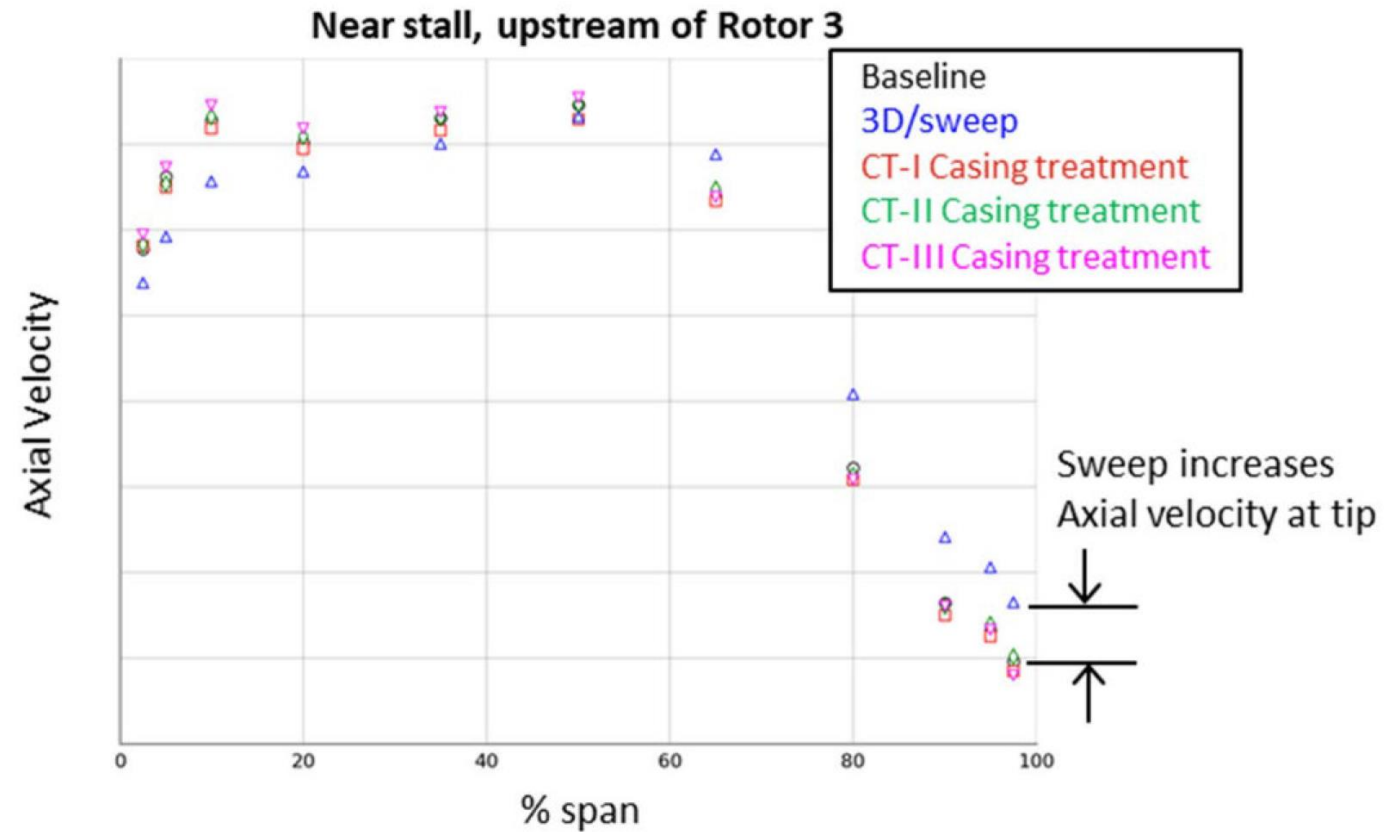
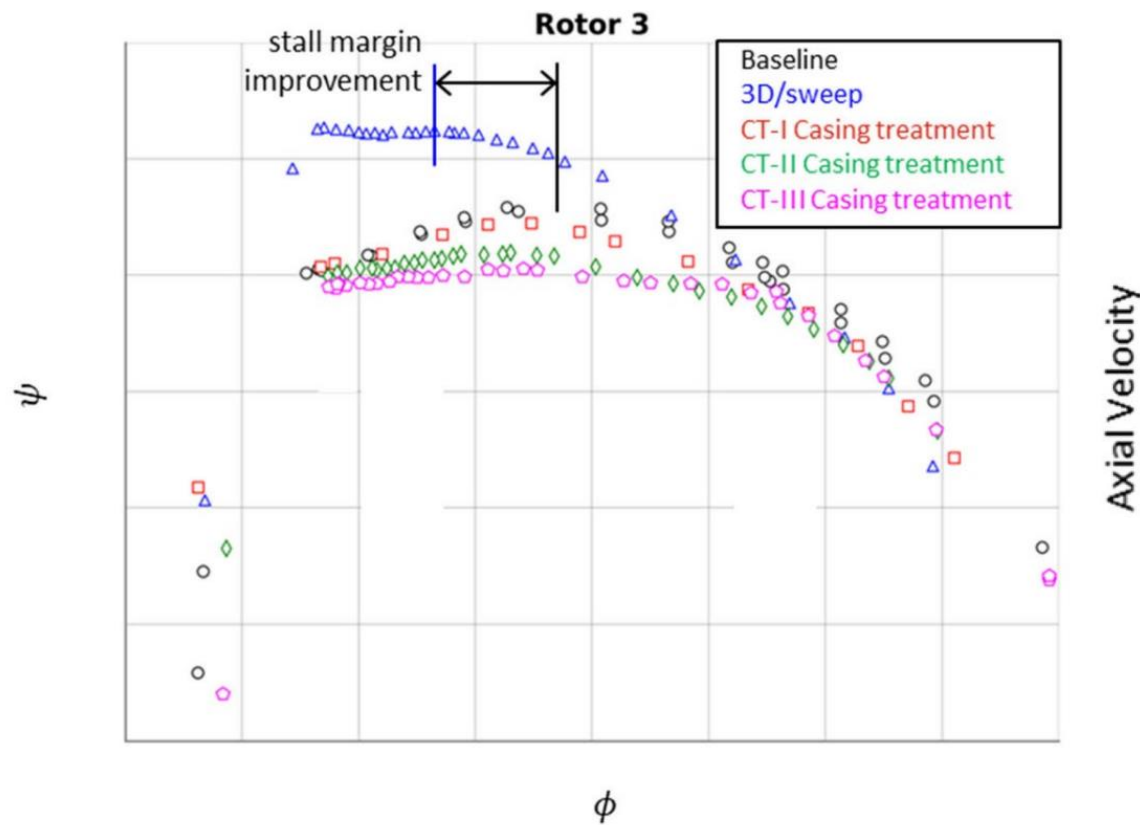
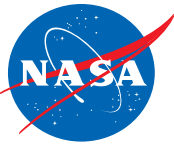


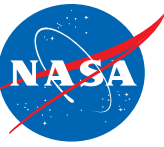
Rotor



Stator

Recent Work (2018-2020): Effect of Sweep and Casing Treatment





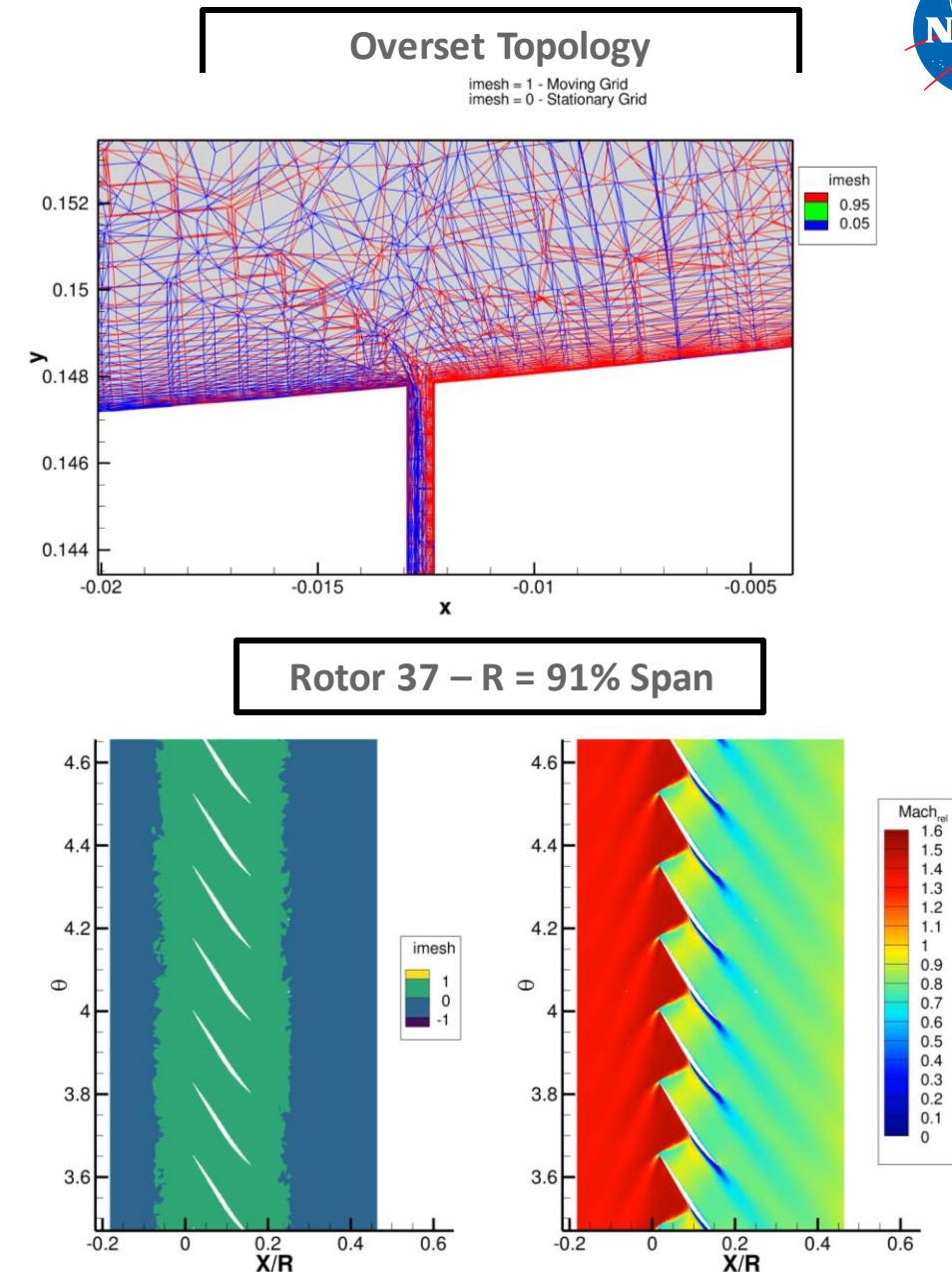
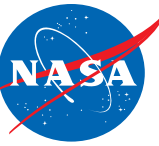
Future/Proposed Work (FY25+)

Acquiring Turbulence Data in an Axial Compressor

- There is a need for detailed CFD-validation quality dataset(s) for axial compressors with and without advanced casing treatments.
- Turbulence quantities are rarely examined in detail within turbomachinery CFD studies. This is in part due to the lack of high-quality validation datasets.
- As modern compressor geometries have become more complex, unstructured CFD approaches have become necessary to simplify the grid generation process and improve the fidelity of the simulations through the inclusion of more geometry features.
Transformational Tools and Technologies (TTT) has supported this effort through the development of turbomachinery capabilities in GFR and FUN3D.
- LSAC is currently configured as an unlimited rights multistage axial compressor with modern 2018 blade design and capability for additively-manufactured advanced casing treatment liners. The rig has optical access windows as well as other measurement ports.
- The proposed test would collect mean-flow and turbulent data using multiple techniques such as: traversing Kiel and wedge probes, hot-wire velocimetry, Fast-Response Aerodynamic Probes (FRAP), and Laser Doppler Velocimetry (LDV).

FUN3D for Turbomachinery

- Developed by NASA Langley
- Fully unstructured node-based finite volume implementation
 - Second order in time and space
- Range of Turbulence models from SA to full Reynolds Stress models to SRSs
 - Current work done with SA
- Overset and dynamic grids supported
 - Rigid motion
 - 6 DOF
 - Aeroelastic coupling
 - Full air-gap required between moving bodies
- Two overset assemblers
 - Yoga – LaRC developed (on hold for now)
 - Sugar++
- Adjoint optimization
- Dynamically loaded boundary condition library allows for the application of radially varying flow conditions
- Work ongoing to add features to FUN3D simplify simulations
 - Pitchwise periodic
 - Sliding interfaces



Rotor 37 imesh contours. imesh = 1 is the Rotor grid; imesh = 0 is the stationary mesh

Rotor 37 relative Mach number



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3. Barankiewicz, W. S., and Hathaway, M. D., "Effects of Stator Indexing on Performance in a Low Speed Multistage Axial Compressor", ASME Paper 97-GT-496, June 1997
4. Barankiewicz, W. S., Hathaway, M. D., "Impact Of Variable-Geometry Stator Hub Leakage In A Low Speed Axial Compressor", 98-GT-194, ASME International Gas Turbine and Aeroengine Congress and Exposition, Volume 1: Turbomachinery, Stockholm, Sweden, June 2-5, 1998
5. Culley, D. E., Bright, M. M., Prahst, P. S., Strazisar, A. J., "Active Flow Separation Control of a Stator Vane Using Surface Injection in a Multistage Compressor Experiment", NASA TM-2003-212356, GT2003-38863, 2003
6. Bright, M. M., Culley, D. E., Braunscheidel, E. P., "Closed Loop Active Flow Separation Detection and Control in a Multistage Compressor", NASA TM 2005-213553, AIAA-2005-0849, May 2005
7. Culley, D. E., Braunscheidel, E. P., Bright, M. M., "Impulsive Injection for Compressor Stator Surface Separation Control", AIAA 2005-3633, 41st AIAA/ASME/SAE/ASEE Joint Propulsion Conference, Tucson, AZ, 10-13 July 2005
8. Shabbir, A., Adamczyk, J. J., "Flow Mechanism for Stall Margin Improvement due to Circumferential Casing Grooves on Axial Compressors", ASME Journal of Turbomachinery, Vol. 127, pp. 708-717, October 2005
9. Wundrow, D. W., Braunscheidel, E. P., Culley, D. F., Bright, M. M., "Separation Control in a Multistage Compressor Using Impulsive Injection", NASA TM-2006-214361, July 2006
10. Lepicovsky, J., Braunscheidel, E. P., Welch, G. E., "Experimental Investigation of Rotating Stall in a Research Multistage Axial Compressor", ISABE-2007-1263, 2007
11. Botros, B., Evans, S., Dong, Y., Rose, B., Murphy, A., Zukowski M., "NASA High Efficiency, High OPR Capable Small Core Compressor", NASA FR-29184-2, Contract NNC16AA01A, 2021
12. Evans, S., Yi, J., Nolan, S., Joseph, L., Ni, M., Kulkarni, S., "Modeling of Axial Compressor With Large Tip Clearances", ASME Journal of Turbomachinery, 143(6): 061007, Jun 2021

