

# Perspective on R&D Needs for Gas Turbine Power Generation

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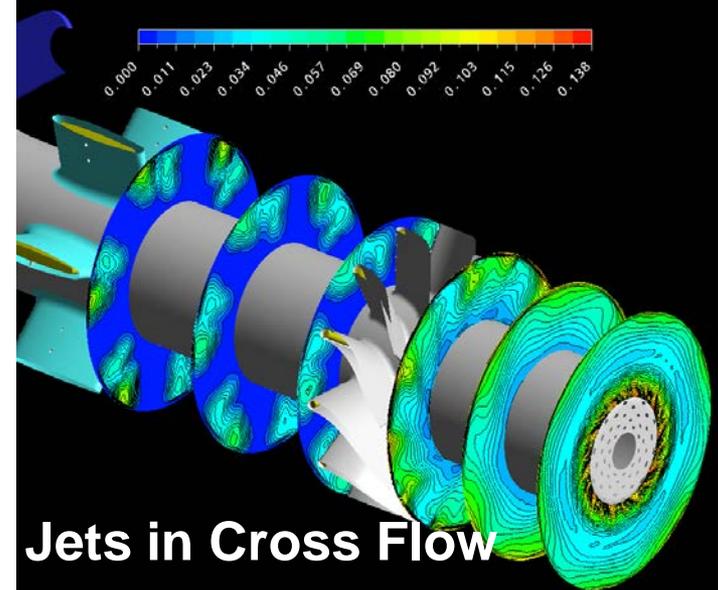
## Perspective on R&D Needs for Gas Turbine Power Generation – **Combustion**

- Challenge to Provide Better Understanding of Fuel Composition's Impact on Combustion System Performance
  - Alternative Fuels Have Lower Wobbe Index Due to Higher  $H_2$ ,  $CO$ ,  $CO_2$ ,  $H_2S$
- Critical Needs:
  - Improve Understanding of LEL; High  $H_2$  (Syngas) Fuels Pose Safety Risks
  - Improve Understanding of Oscillations
  - Evaluate Lean Extinction Limits
  - Evaluate Impact of High  $H_2S$  on Auto-ignition and Flame Speed
  - Perform Jet-stirred Reactor Testing
  - Improve Simulation of Jet Mixing in Cross Flow; Higher Fuel Volume Flow Rate

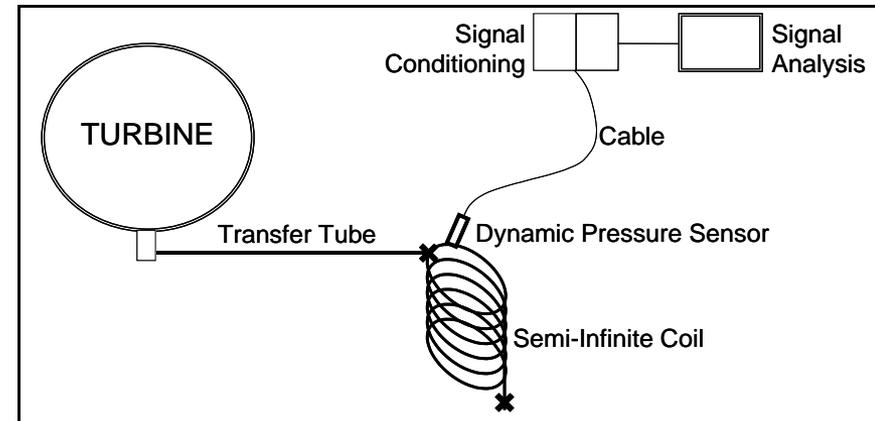
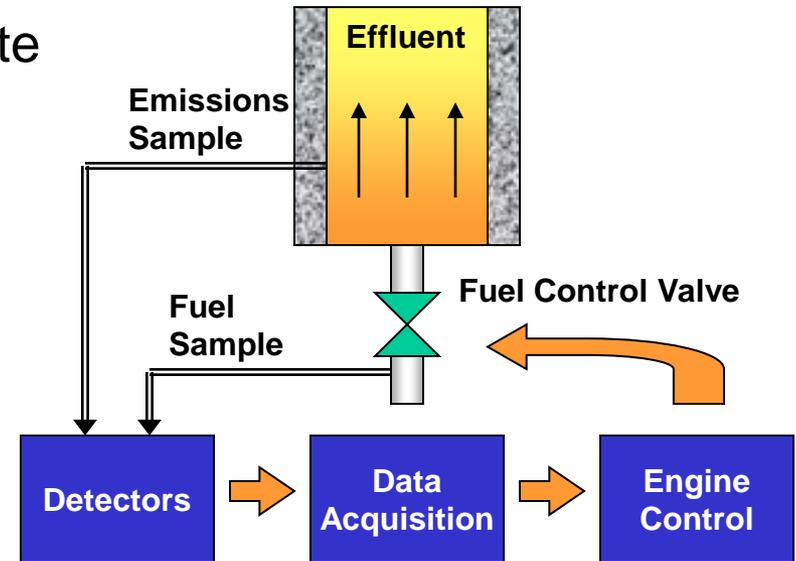
## Flat Flame Burner



CH4 Molar Fraction



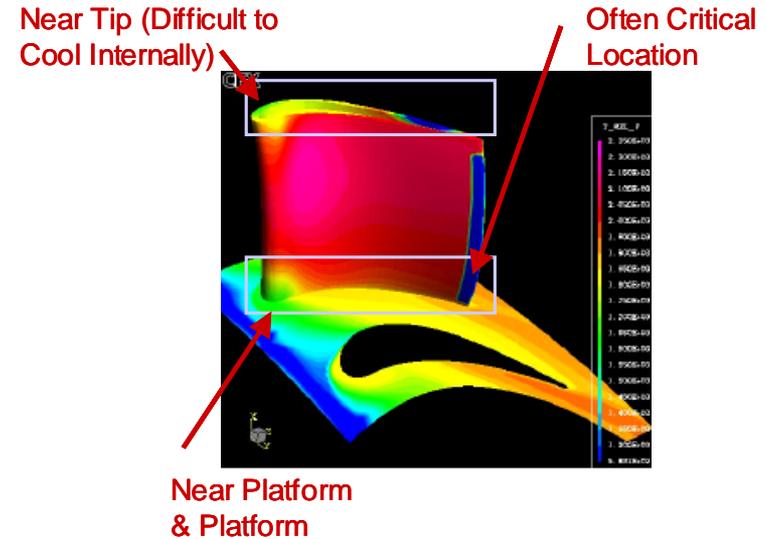
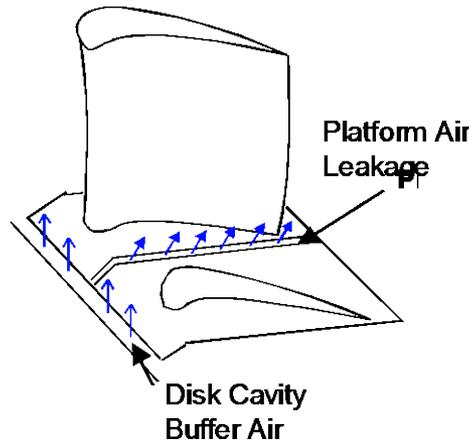
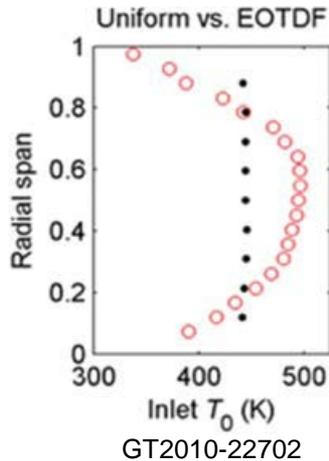
- Improve Gas Turbine's Ability to Operate on Alternative Fuels
- Respond to Rapidly Changing Fuel Composition
- Specific Needs:
  - Develop Fast Acting Online Composition Detection
  - Optimize Emissions Measurement Techniques for Ultra-low NOx
  - Improve Reliability of Dynamic Pressure Measurement Devices



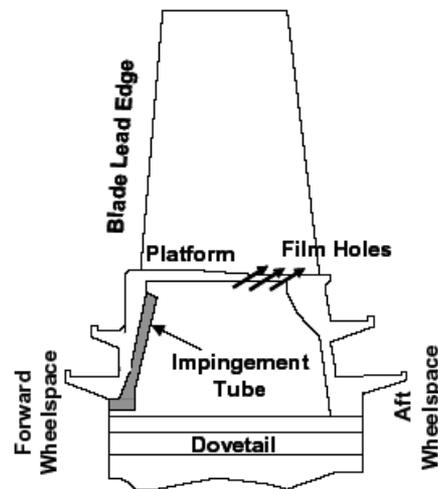
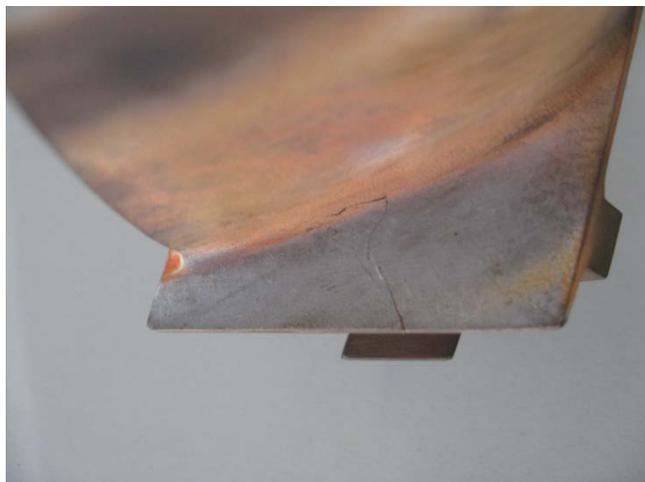
- Issues
  - Challenge to Improve Gas Turbine's Reliability on Alternative Fuels
  - Alternative Fuels Can Present New Design Challenges
- Critical Needs:
  - Study Fuel Composition Effects on Fouling of Internal Passages, External Surfaces
  - Study Impact of Surface Chemistry on Fouling with Different Materials



## Perspective on R&D Needs for Gas Turbine Power Generation – **Aero/Thermal**



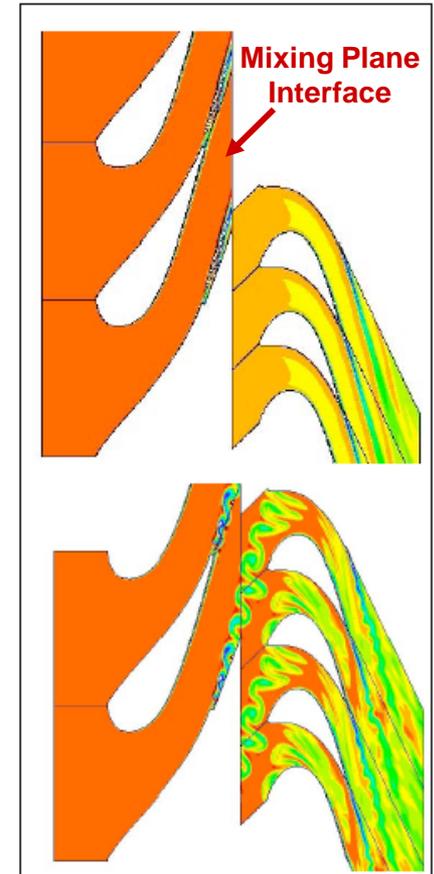
- Challenge to Predict Adiabatic Wall Temperature and Heat Transfer Coefficient Accounting for
  - Inlet Temperature Profile
  - Buffer/Leakage Air Effects
  - Hot Streaks etc.
- Requires
  - Models to Account for Effects Early in Design Cycle
  - CFD Based Modeling for Detailed Design
  - Experimental Validation/Calibration



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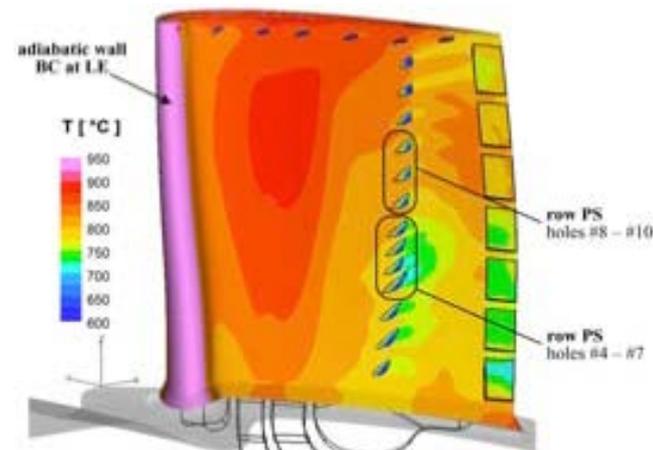
- Design Challenges
  - Large Heat Load Variation
  - Few Papers Related to the Platform Heat Transfer (External/Internal)
  - Casting Process
- Requires
  - Rig Testing
  - Practical Computational Analysis
  - Innovation

- Challenge: Design Environment vs. Research Environment
- Current CFD Options
  - Steady RANS (Mixing Plane)
    - Flow Assumed Mixed Out Circumferentially
    - Computational Time Acceptable
  - Unsteady RANS (Sliding Mesh)
    - High Fidelity Modeling
    - Requires Full Model
    - Unacceptable Computational Time for Iterative Design Environment
- Need Improved, Verified Steady State “Mixing Plane” Model - Open Documentation for Application
  - Flux Conservation
  - Indifference to Local Flow Direction
  - Robust
- Test Validation/Calibration

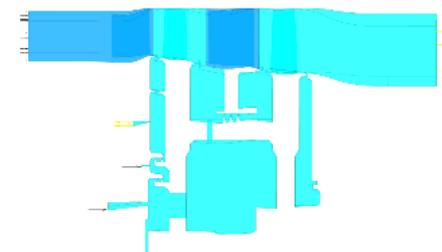


Comparison of Entropy with Mixing Plane & Unsteady Calculations  
(Denton GT2010-22540)

- Challenge – Temperature Prediction  
Error of 10 to 20°F is Significant
- Requires
  - Efficient Modeling
  - Experimental Validation
- Conjugate HT Analysis of Airfoils
  - Pure Convective Analysis (Decoupled)  
No Longer Good Enough
  - HT Affected by Local Phenomena & Lateral Conduction
- Disk Cavity
  - Ingress/Egress/Mixing
  - Seal Effectiveness for Various Configurations
  - High Swirl (Seal, Windage Effect)
  - Disk Pumping



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(a) Fluid domain

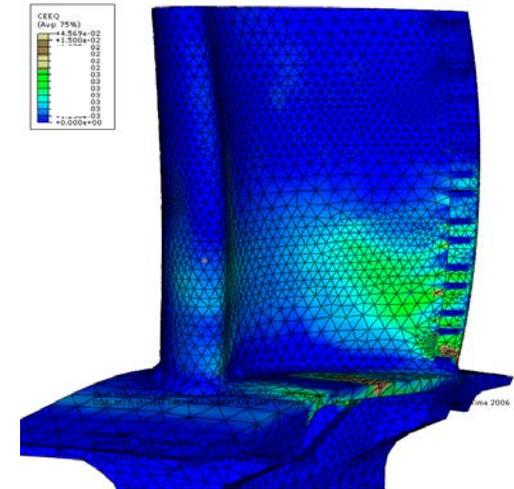


(b) Solid domain

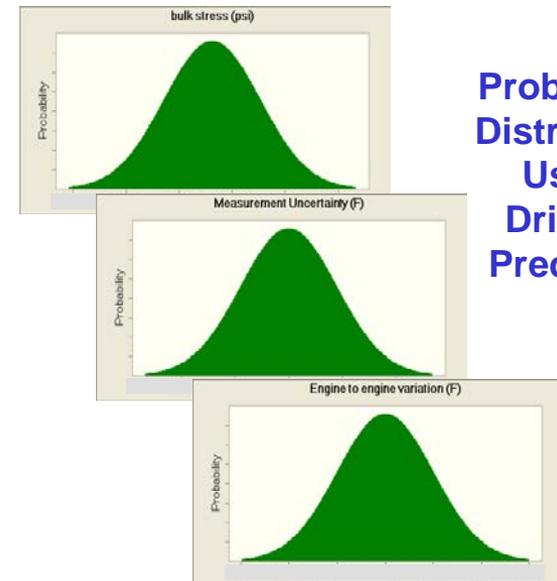
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## Perspective on R&D Needs for Gas Turbine Power Generation – **Materials**

- Challenge
  - Creep Damage Accumulation in a Component Can Lead to Deformation and Rupture with Catastrophic Results
  - Often Creep Damage Difficult to Monitor During Operation and Difficult to Predict Accurately
  - Creep-Fatigue Interaction
  
- Requirements
  - More Accurate Creep Damage Models
    - Damage Initiation
    - Progression in Single Crystal Materials
  - Faster More Cost Effective Methods for Developing Creep Material Data
    - Virtual Test Rigs
  - Improved Data Driven Probabilistic Lifting Models



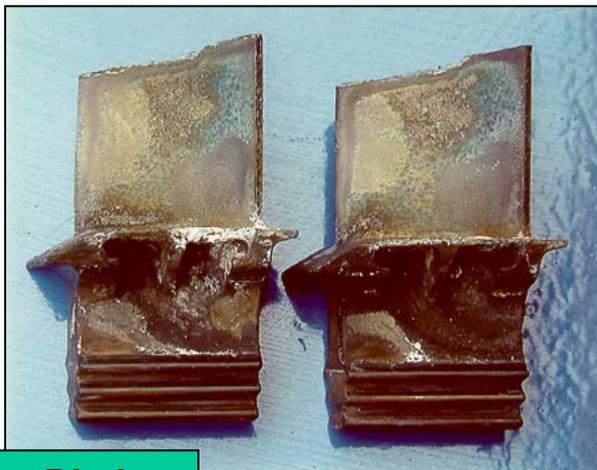
**Creep Accumulation  
Pressure Side, Cooled Airfoil**



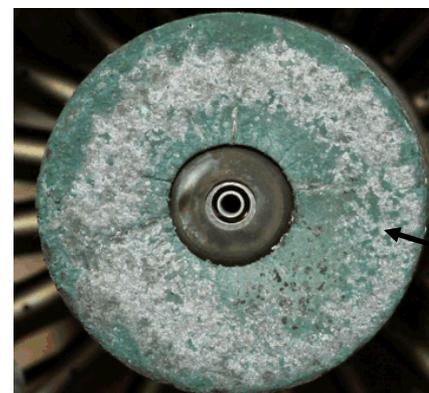
**Probabilistic  
Distributions  
Used to  
Drive Life  
Predictions**

## Fuel Related Challenge

- Material Durability when Exposed to Various Operating Fuel Environments
  - $H_2S$  / S /  $H_2$
  - Coke Oven Gas
- Degradation Mechanisms
  - Hydrogen Embrittlement
  - Fouling
  - High Temperature Oxidation
  - Hot Corrosion and Sulfidation



Turbine Blade  
Hot Corrosion



Injector Tip  
Degradation

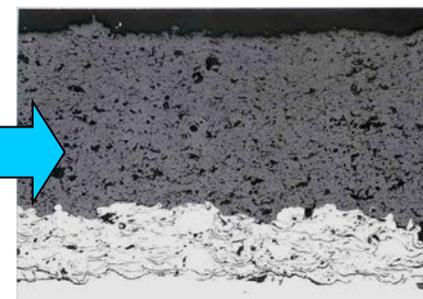
- Requirements
  - Corrosion Resistant Alloys (with Necessary Mechanical Properties)
  - Coatings
    - Resistant to Environmental Attack
    - Strain-Tolerant
    - Thermal Protection
  - Improved Testing Systems
    - Rig Tests that Demonstrate Engine Environment



## Thermal Barrier Coating (TBC)



## TBC Microstructure



**Thanks**