



# GTEN 2019 Symposium

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## Gas Turbine Component Quality Characterization

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# GTEN 2019 Symposium

## Electric Power Research Institute?

### BORN IN A BLACKOUT

Founded in 1972 as an independent, nonprofit center for public interest energy and environmental research

*New York City, The Great Northeastern Blackout 1965*

### EPRI'S VALUE

To provide value to the public, our members, and the electricity sector

**THOUGHT LEADERSHIP**  
**INDUSTRY EXPERTISE**  
**COLLABORATIVE MODEL**

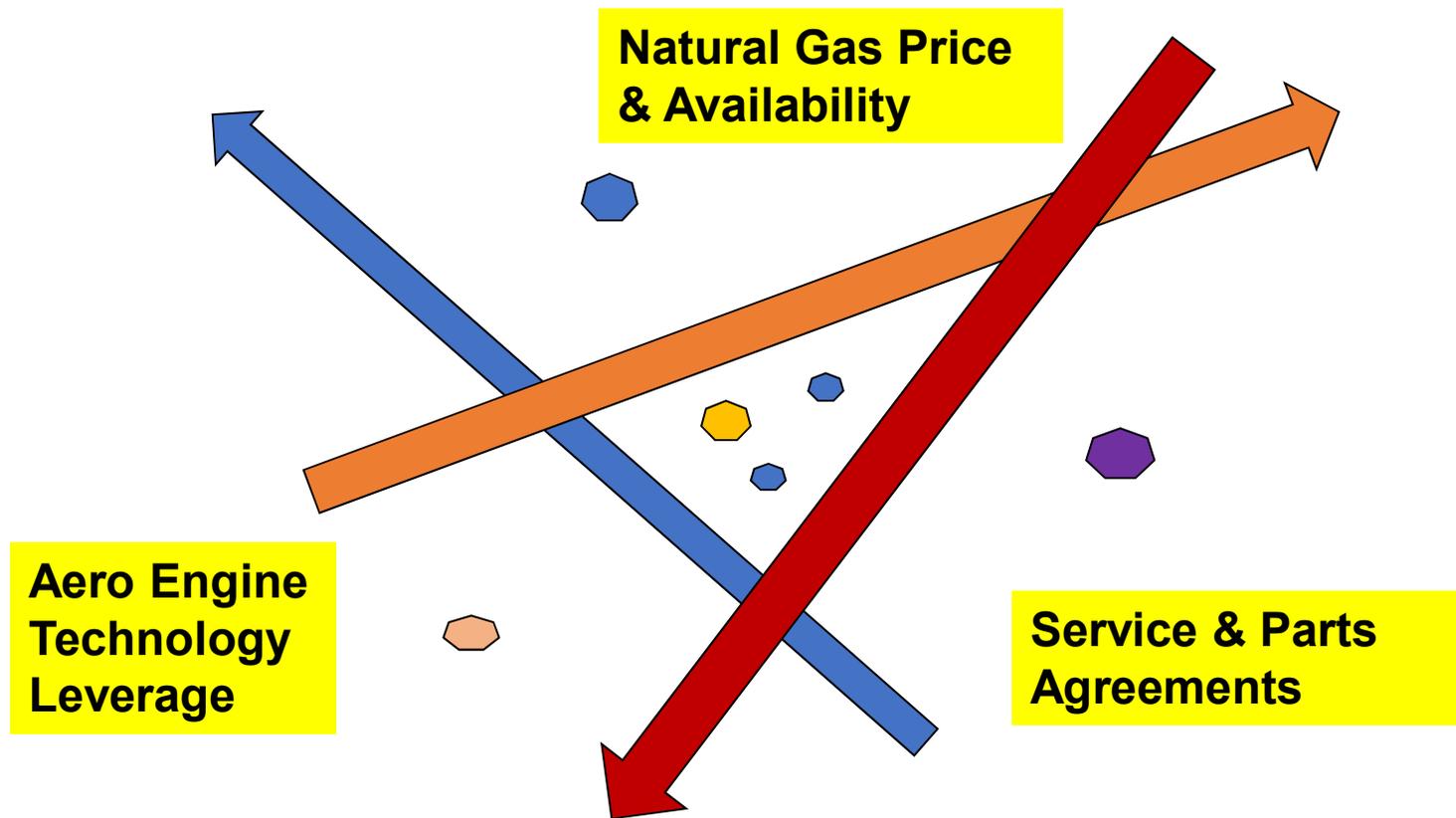
### OUR MEMBERS...

- 450+ participants in more than 40 countries
- EPRI members generate approximately 90% of the electricity in the U.S.
- International funding – nearly 30% of EPRI's research, development, and demonstrations



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# Strategic Plan Crossroads for Gas Turbine Industry



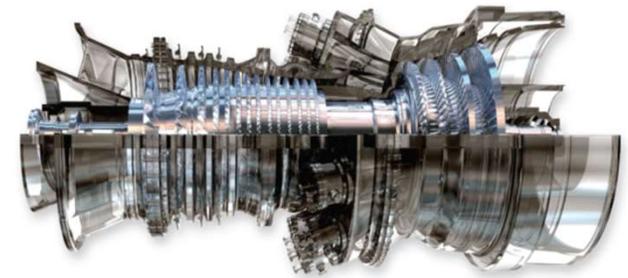


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# EPRI Gas Turbine and Combined-Cycle Technical Areas

**Issues and challenges to integrating combined-cycle assets, with particular focus on operating and maintaining gas turbines**

- **Improvements** in plant-wide operational flexibility and thermal efficiency
- **Evaluation and Optimization** of GT, HRSG, and ST-Gen interaction and interdependence
- **Design evolution** of new turbomachinery
- **Maintenance** and component life assessment
- **Root-cause analyses** of failures and durability shortfalls
- **Monitoring and Inspection techniques** to safeguard critical components



**Tools to manage component life assessment and risk; make operational and maintenance improvements; evaluate technology advancements**



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### *Success Story # 1*

Evaluates New Techniques for Diagnostic Monitoring of GT Compressors

**Failure of compressor blades or vanes can result in equipment damages exceeding 10 million USD**

- **Approach**

- Demonstrate effectiveness of advanced instrumentation and associated diagnostic monitoring techniques on operating gas turbine

- **Results**

- Successful field demonstration and evaluation of vibration monitoring, blade tip deflection, dynamic pressure, acoustic emissions



**Increase reliability, operational flexibility, and reduce risk**



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### *Success Story #2*

#### Increase Life and Reduce Cost of F-Class Components

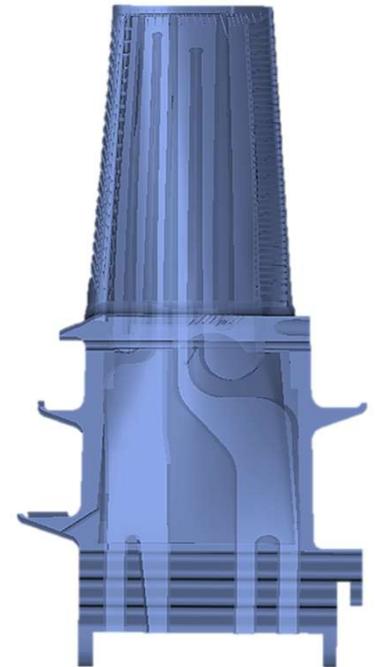
**Hot-Section components are the most complicated and expensive to design, manufacture, maintain, and repair**

- **Approach**

- Conduct durability analyses including aerothermal/structural simulations, material testing of service-aged components
- Establish criteria for extending operation intervals

- **Results**

- Increase overall useful life by 50%
- Determine optimal maintenance intervals for hours and starts-based operations



**Financial savings of tens of millions USD**



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### *Success Story #3*

#### Extend Rotor Life of GT in High-Cycle Operation

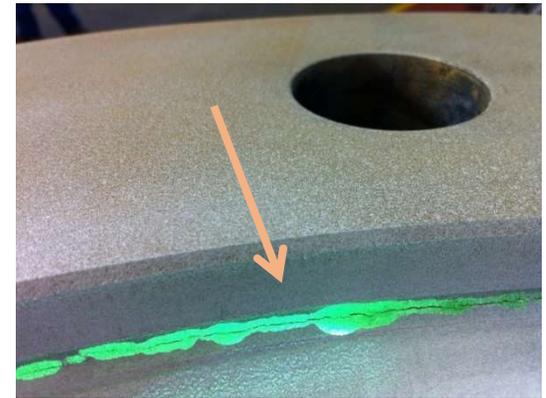
**Cyclic and spinning reserve operation can cause unique issue problems in GT rotors**

- **Approach**

- Develop condition-based live management approach to continue safe operation beyond OEM nominal starts limit for rotor
- Establish non-destructive test method of rotor without de-stacking

- **Results**

- Successfully extended safe operation from 5000 to 8000 starts
- Applicable to all GTs in highly cyclic operation



**Reduce outage costs and time by eliminating rotor de-stacking**



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# **Gas Turbine Component Quality Characterization**



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## Gas Turbine Quality

### Complex International Supply Chain

6 Sigma Quality Standards

Low Production

Increasing Supplier Deviation Reports

**TRUST**



### Service/Parts Agreements

Widely Spread and Growing

Risk vs. Quality Balance

### New and Innovative Quality?

Quality standards for custom single crystal alloys and additively manufactured parts are trailing

**... BUT VERIFY**

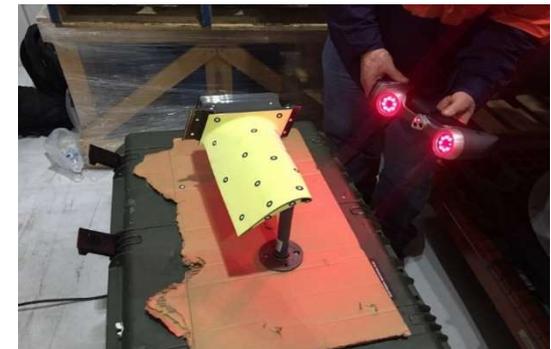


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# EPRI Component Quality Testing to Date

### • Number of Blades Tested

- M501G – 590
- M501J – 748
- M501F – 334
- GE7FA.05 – 276
- GE7HA.02 – 150
- GE7EA – 184
- W501FC – 307
- V84.2 – 354
- V84.3\* - 256
- GE6B – 368
- GE7EA – 368
- GT8 – 239 Blades
- GE7FA.04 – 1104



**EPRI has evaluated > 8800 Blades (2018-2019)**

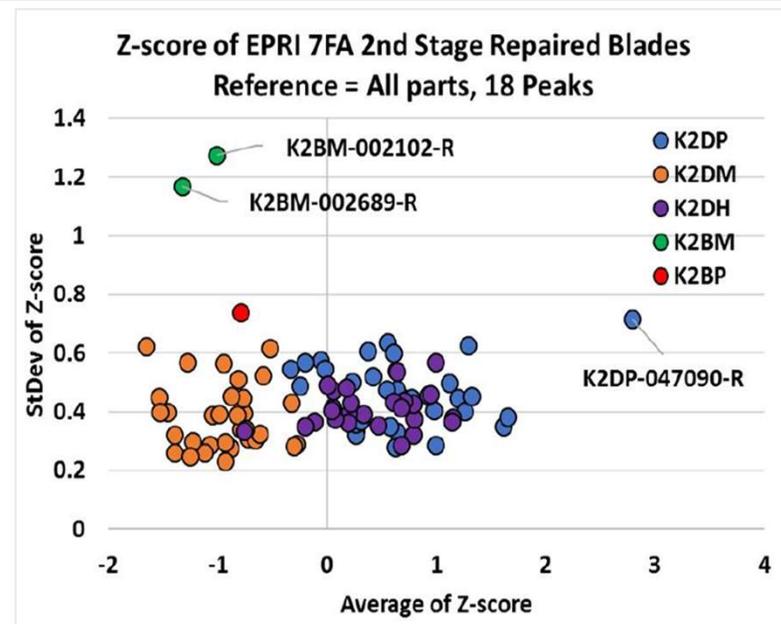


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# Process Compensated Resonance Testing (PCRT) ..... *Rapid Component Quality Screening*

### Adopting Quality Verification from Other Industry

- General new and refurbished component quality concerns
- Adapt PCRT used on aircraft engines to industrial gas turbine components
- Test sets of components and material specimens with controlled defects

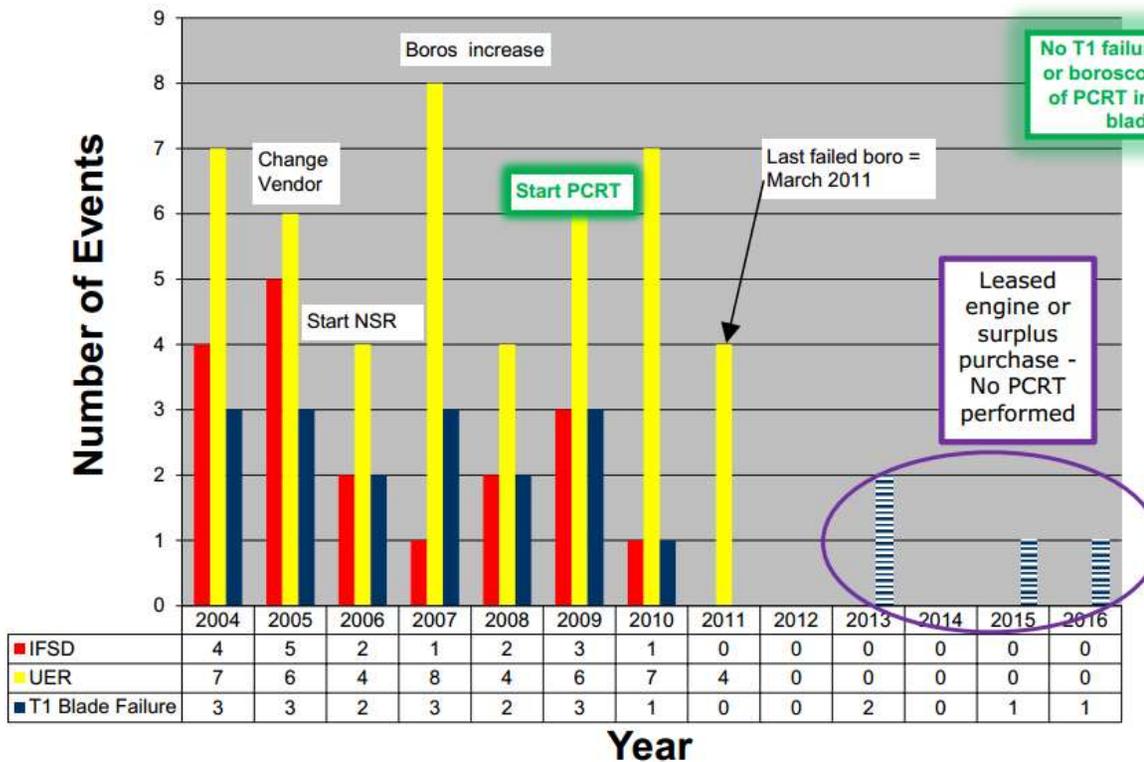




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## Detecting Aircraft Gas Turbine Blade Anomalies

Operational results w/PCRT - Stellar  
JT8D T1 Blade Pareto





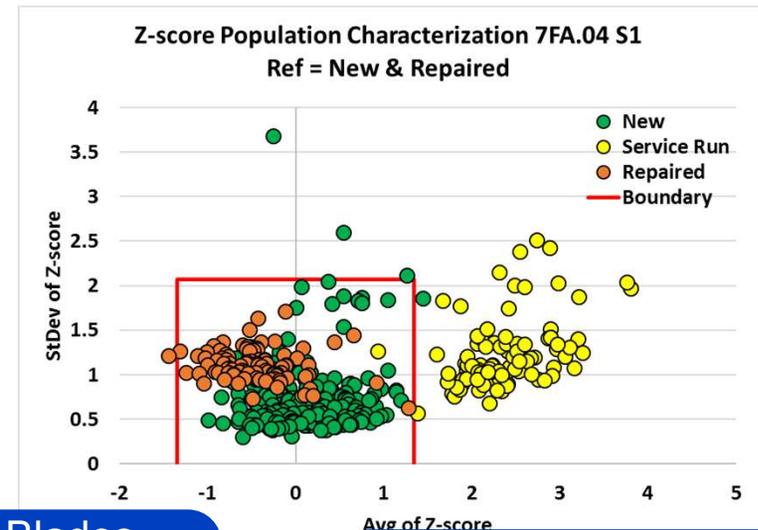
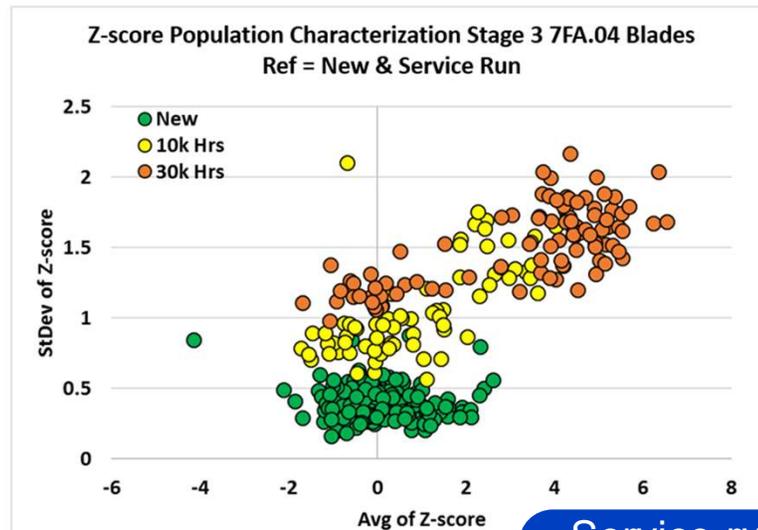
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## EPRI PCRT Field Testing – Industrial Blades





## Life-cycle of Industrial Gas Turbine Blades



New Blades – Use PCRT to identify outliers

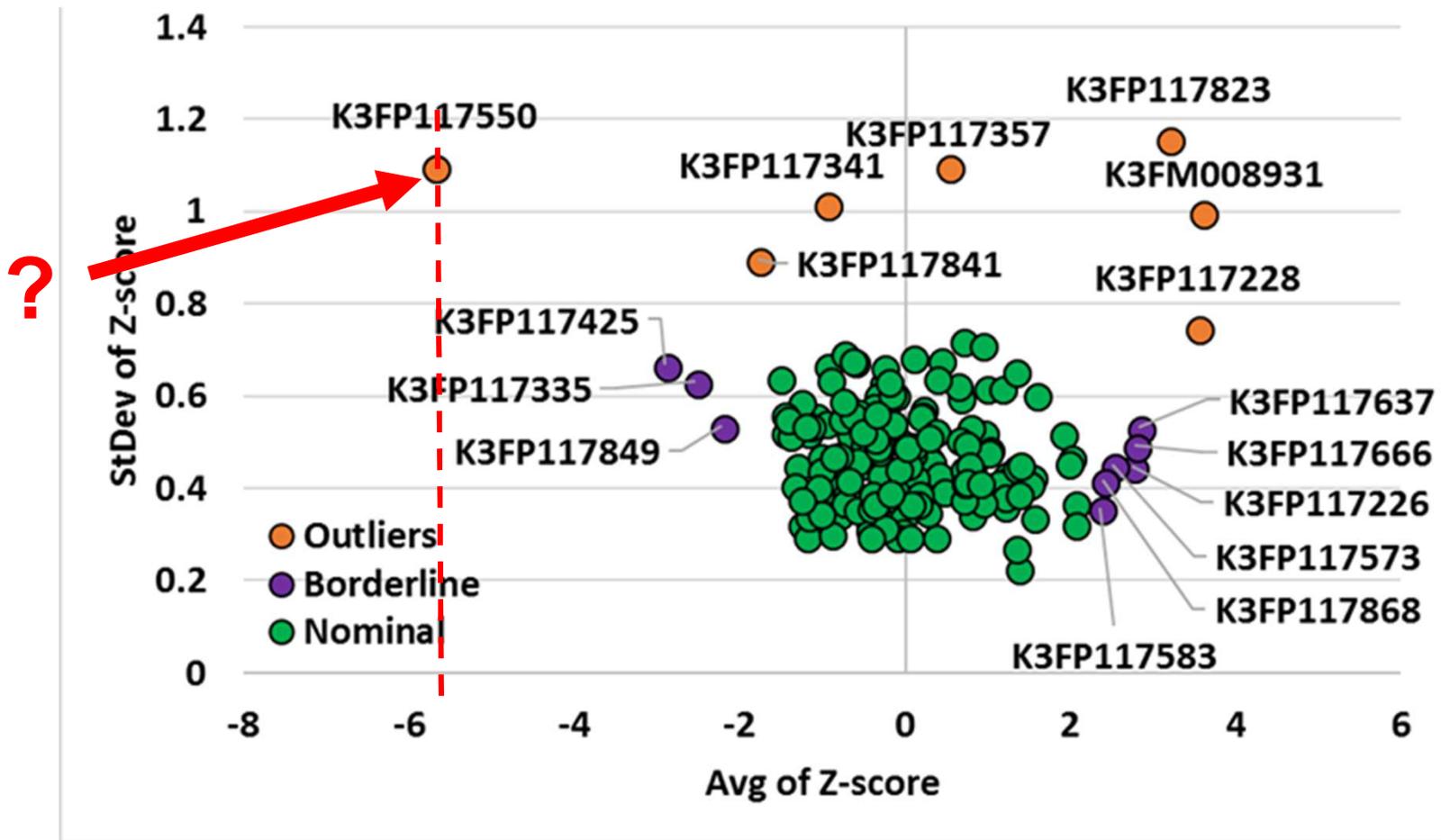
Service-run Blades – Use PCRT to identify candidates to repair or replace

Repaired Blades – Use PCRT to monitor repair process





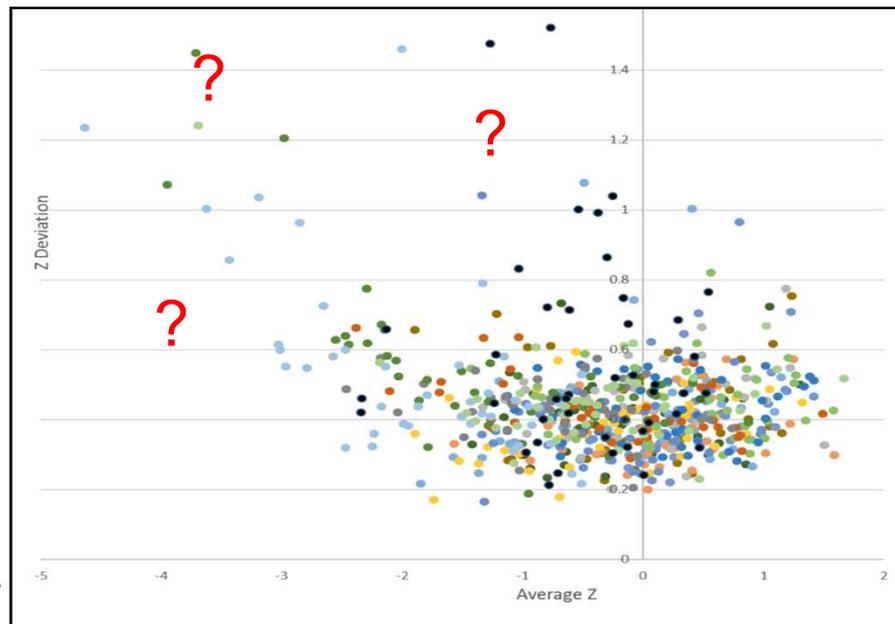
## Example Case: Analysis of New 3<sup>rd</sup> Stage GE 7FA.04 Blades





## Why is a Part an Outlier?

- Shrink
- Crack
- Dimensions
- Core Shift
- Inclusion
- Lack-of-fusion
- Heat treatment

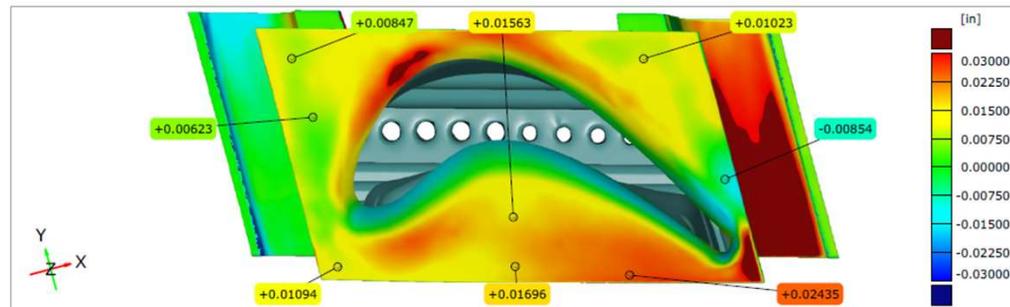
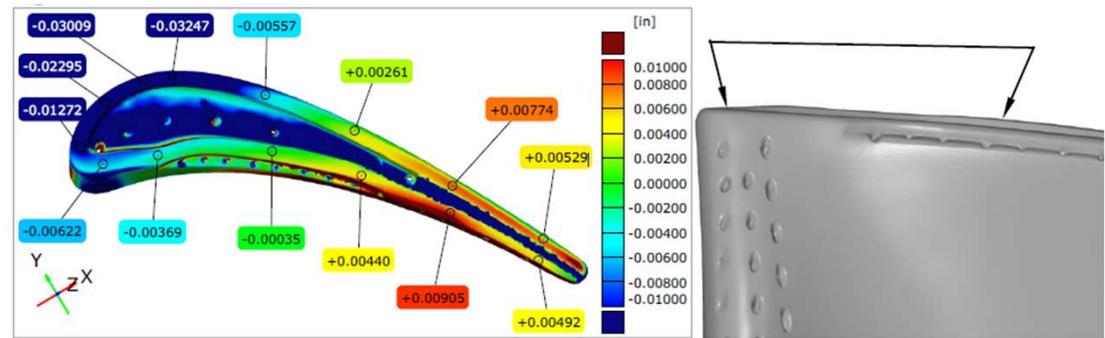
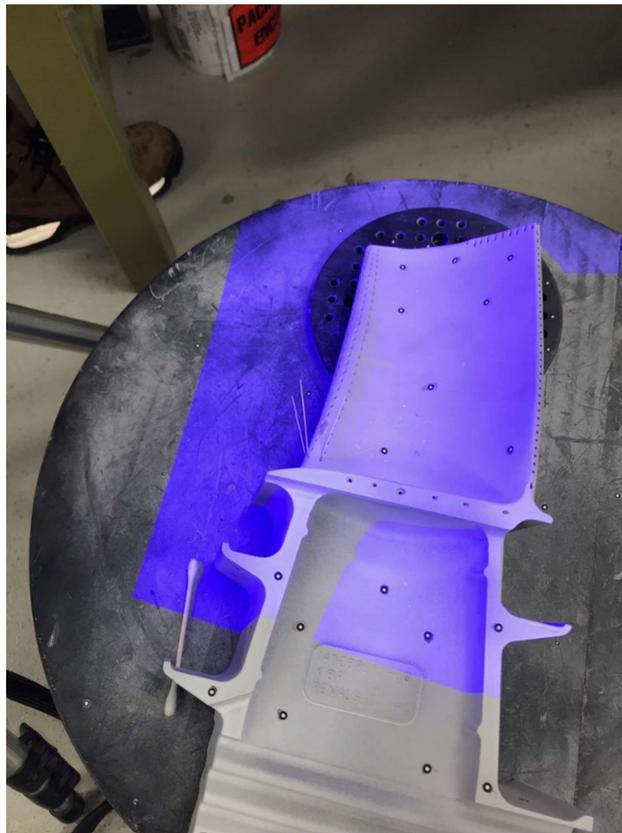


- Boiling porosity
- Creep
- Grain Angle
- Twist
- Material
- Inconsistent build parameters
- Material oxidation



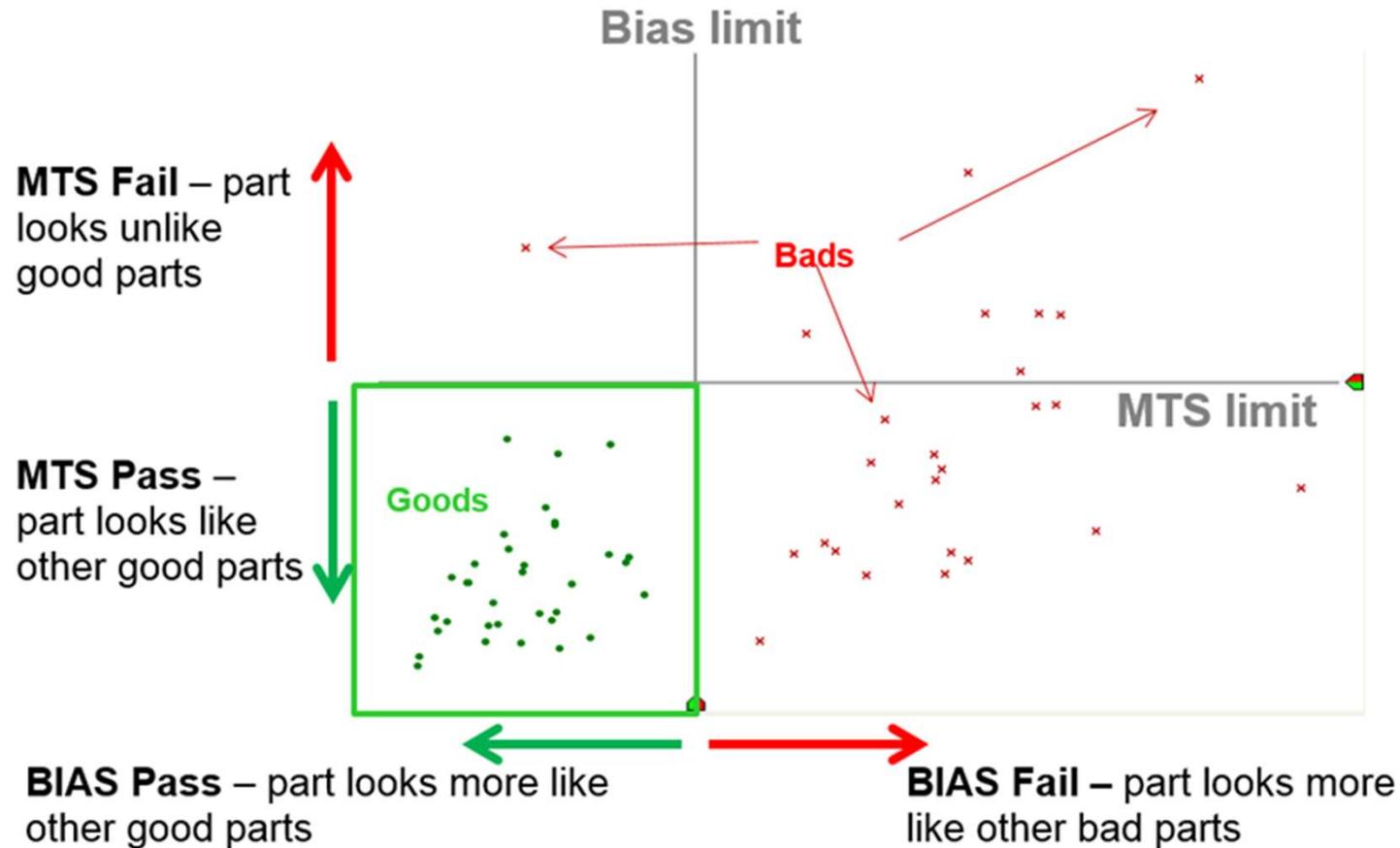
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## 2019 Outlier Investigations





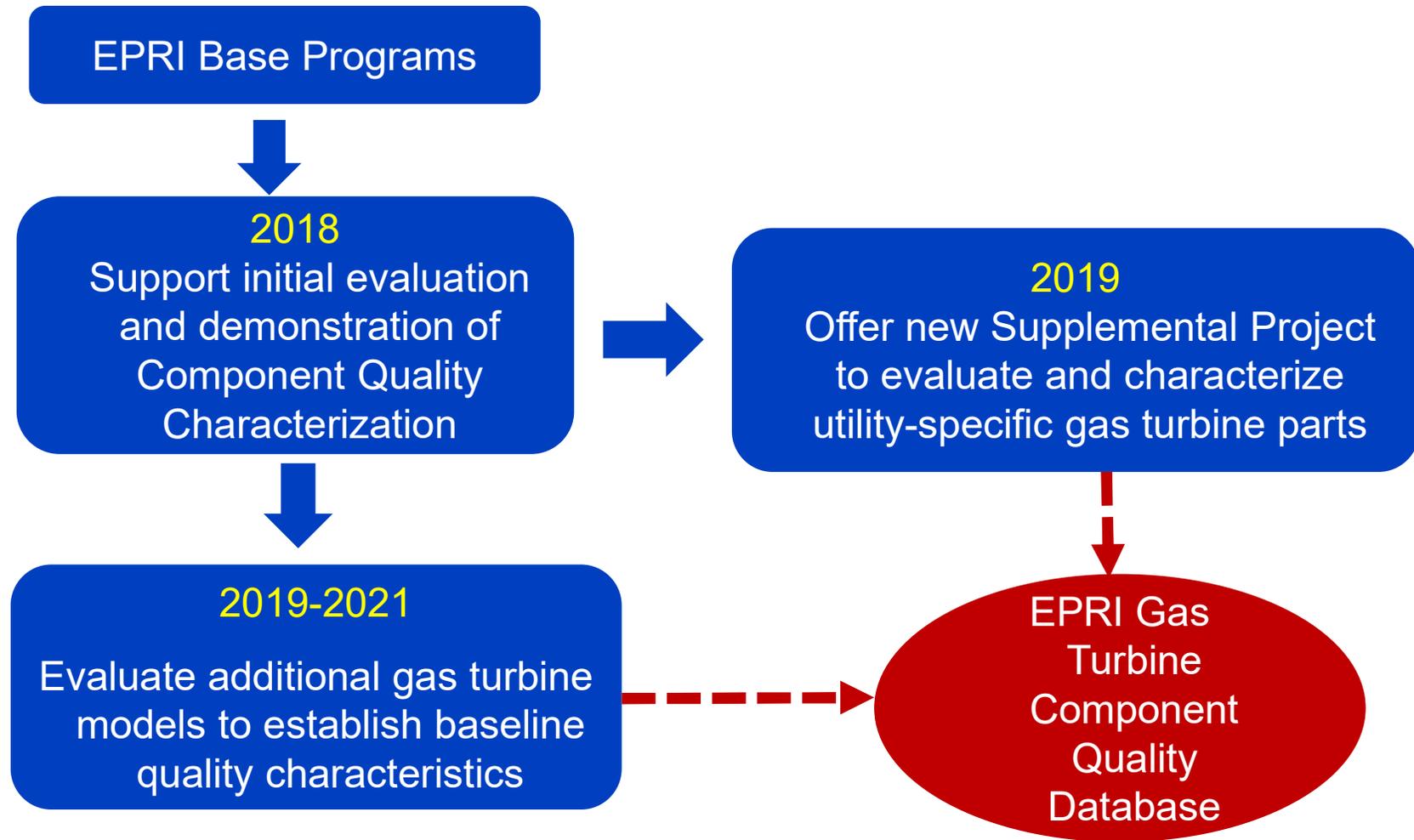
## Introduction to Targeted Defect Sort



**Algorithm must be trained with “good” and “bad” parts**



## EPRI Approach to Implementing PCRT





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# Gas Turbine Hardware Needed

P79 Base Program



Currently Seek PCRT Data:

- GE 6B, 7FA.05
- GE GT24/26, 7/9 HA
- Siemens V84/94
- Siemens SGT 5/6
- MHPS 701G
- GE LM 6000
- Other gas turbines of interest

New Supplemental Project



Ready to Evaluate Your Gas Turbines:

- GE 7FA (.03/.04)
- GE 7HA.02
- GE 7EA
- All 501F models
- MHPS 501G & J

**PCRT approach should also work for small Industrial Gas Turbines**



# Summary

- Gas turbine owners and operators seek further verification of quality and overall condition of hot section blades
- PCRT has been FAA certified for aircraft gas turbines
- EPRI is evaluating the effectiveness of PCRT for industrial gas turbine hot section blades
  - > 8800 blades scanned to date (2018-2019)
  - Blades were scanned in 13 different site locations
- Every indication shows that PCRT is a useful technique for identifying non-conformities in manufactured and repaired hot section blades



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Together...Shaping the Future of Electricity

