



GTEN 2019 Symposium

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Gas Turbine Component Quality Characterization

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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**

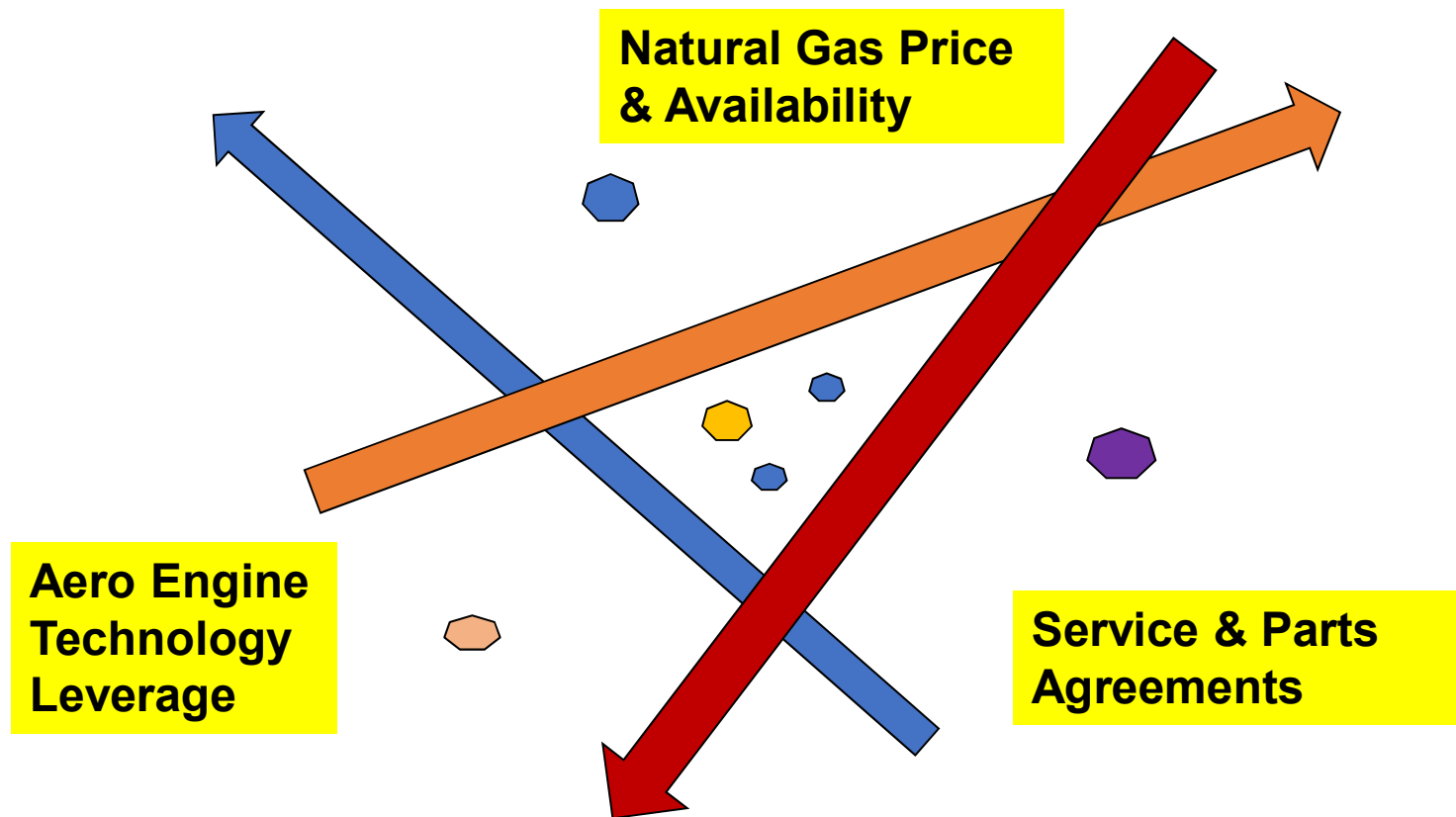
OUR MEMBERS...

- 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



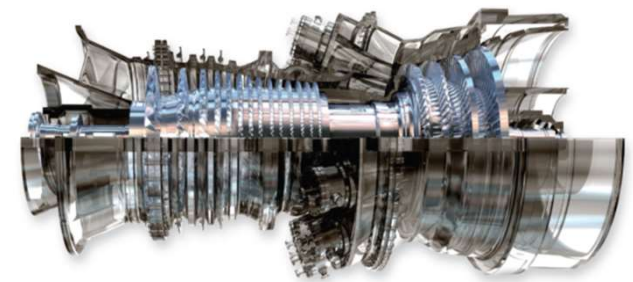


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EPRI Gas Turbine and Combined-Cycle Technical Areas

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

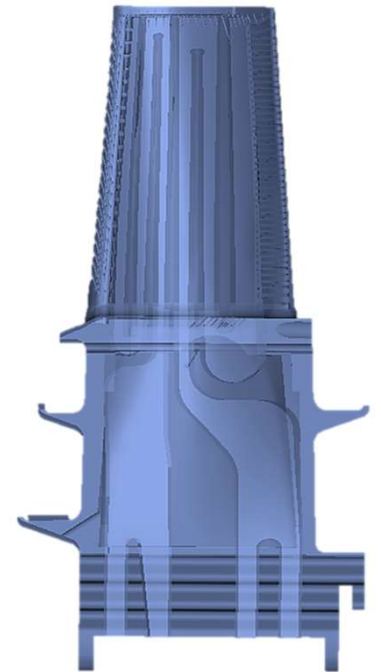
Hot-Section components are the most complicated and expensive to design, manufacture, maintain, and repair

- **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

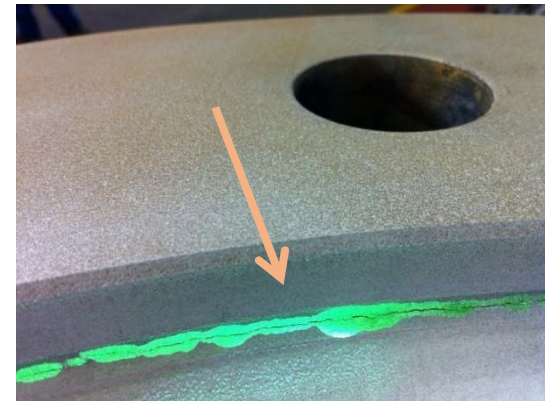
Cyclic and spinning reserve operation can cause unique issue problems in GT rotors

- **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

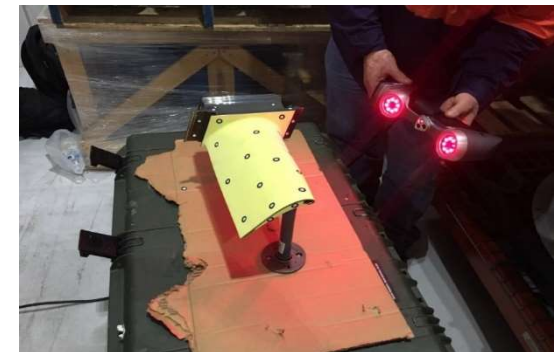


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EPRI Component Quality Testing to Date

- **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)

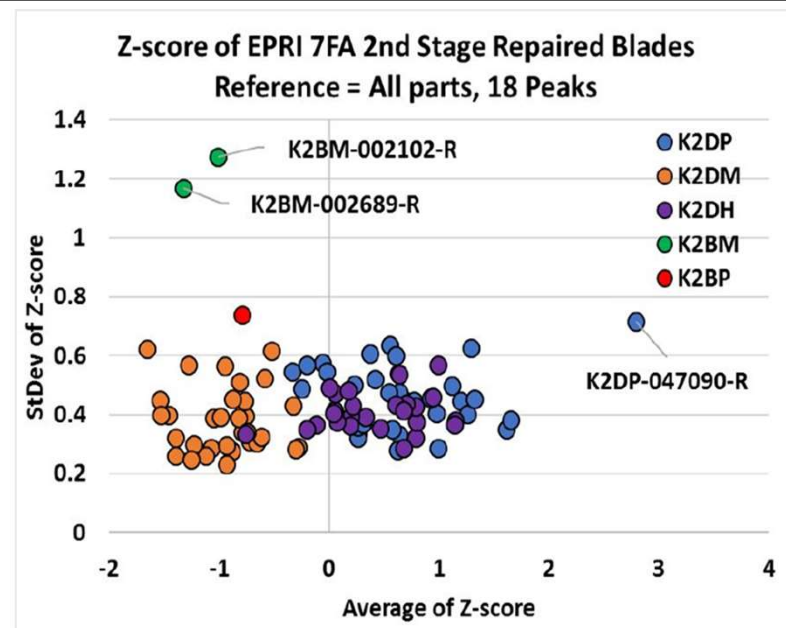


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Process Compensated Resonance Testing (PCRT) *Rapid Component Quality Screening*

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

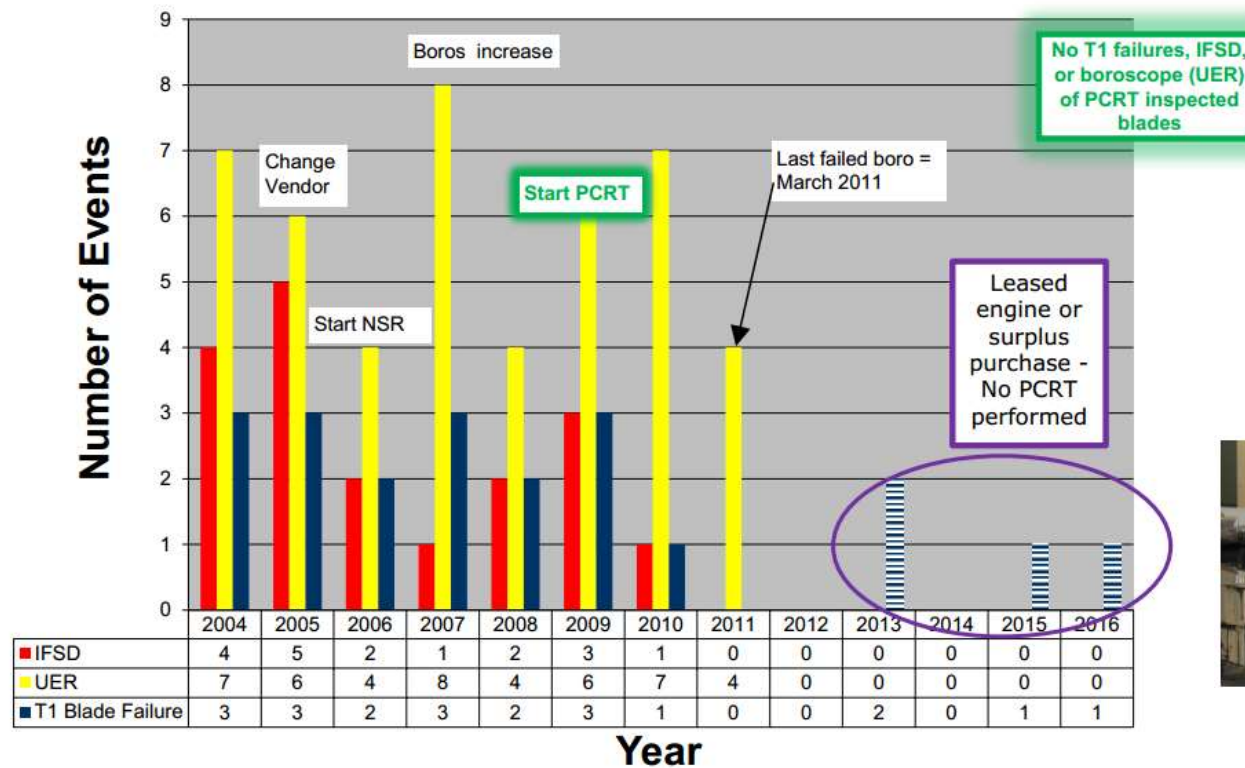




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Detecting Aircraft Gas Turbine Blade Anomalies

Operational results w/PCRT - Stellar
JT8D T1 Blade Pareto





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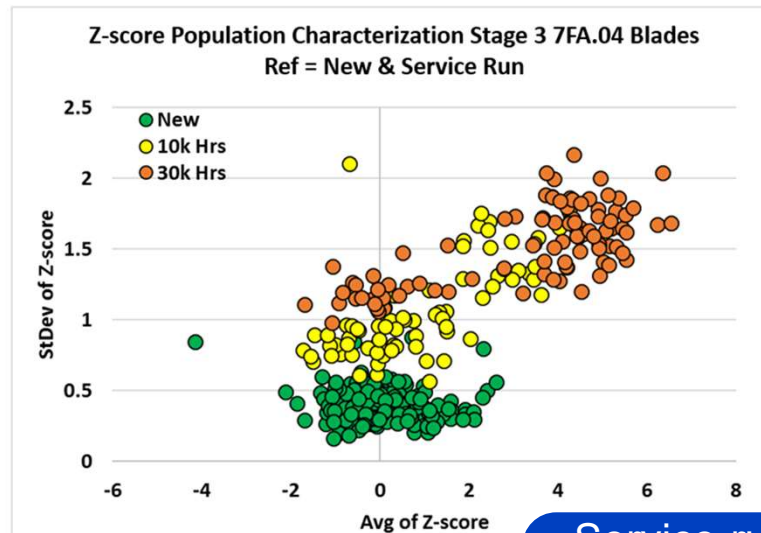
EPRI PCRT Field Testing – Industrial Blades



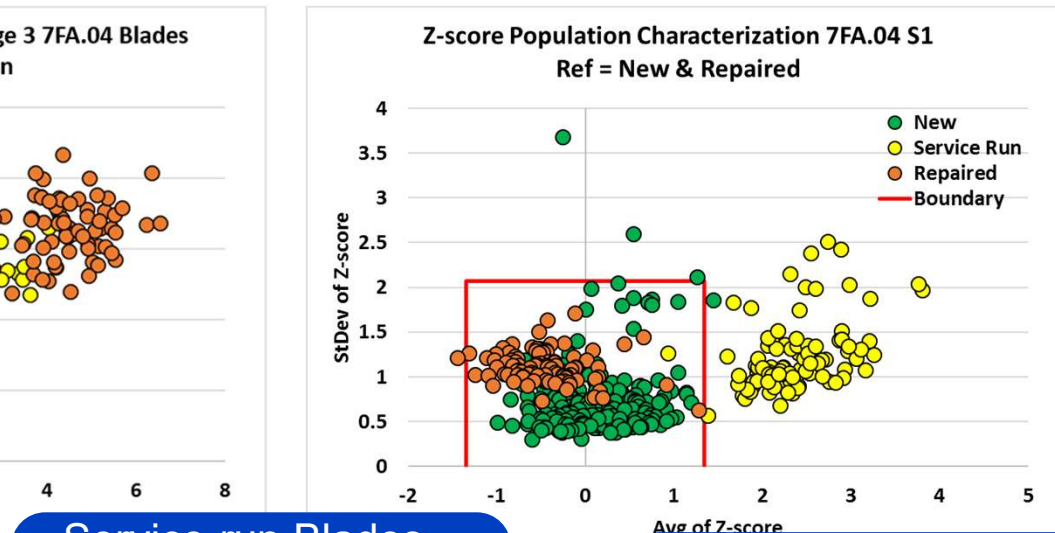


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Life-cycle of Industrial Gas Turbine Blades



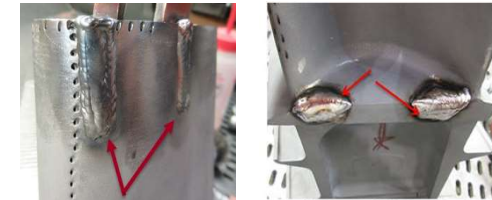
New Blades – Use
PCRT to identify
outliers



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



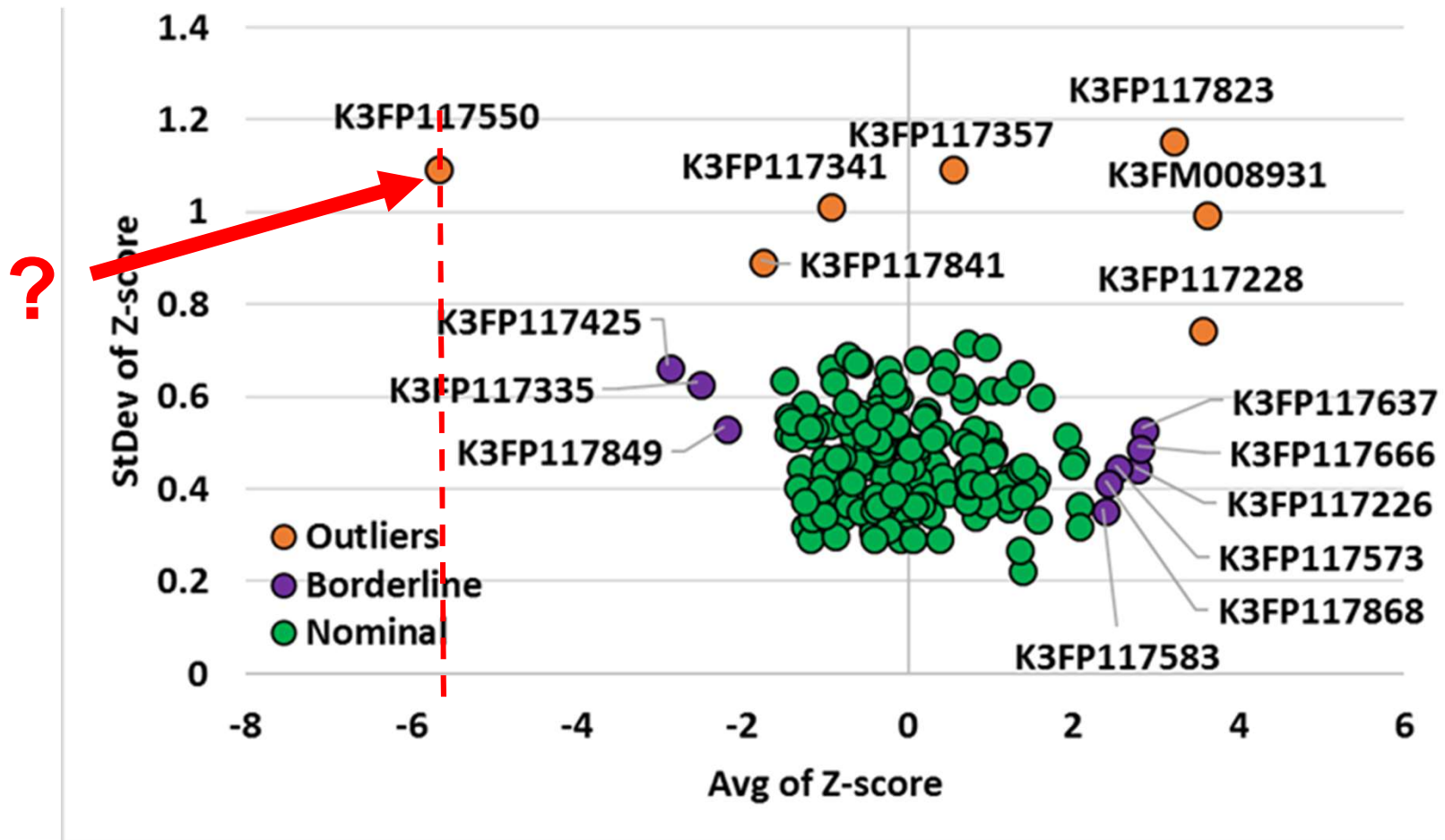
Repaired Blades – Use
PCRT to monitor
repair process





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Example Case: Analysis of New 3rd Stage GE 7FA.04 Blades

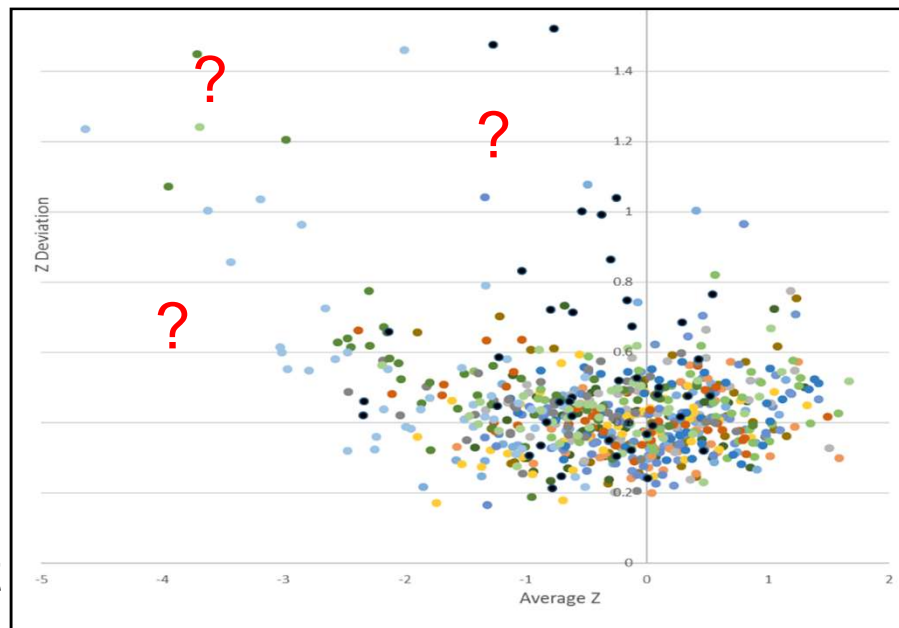




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Why is a Part an Outlier?

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

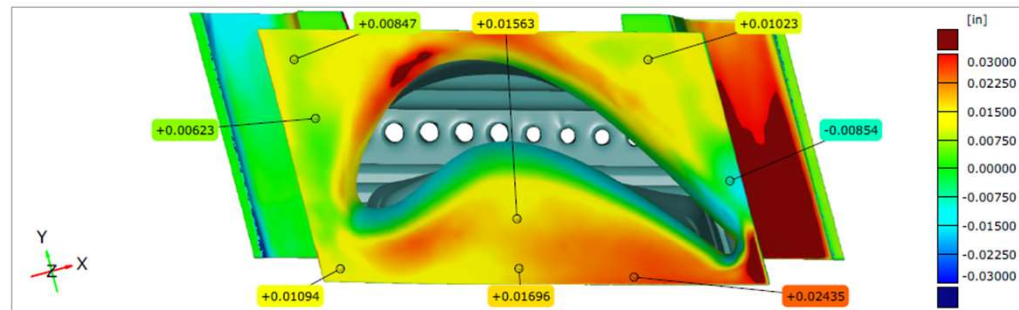
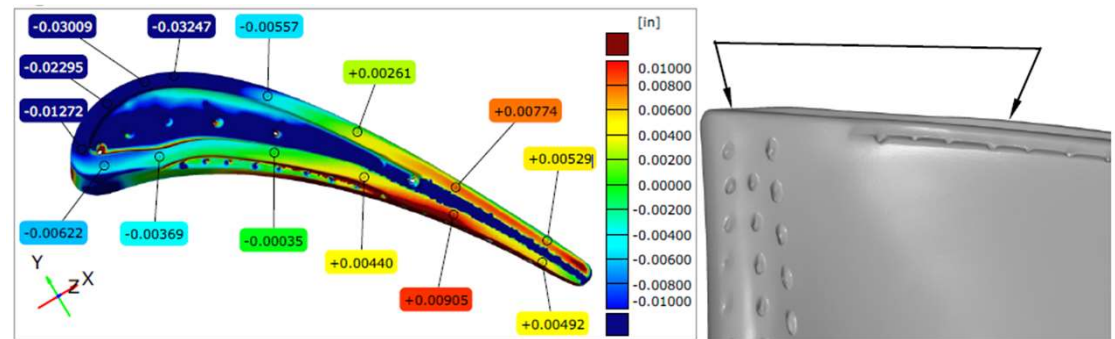
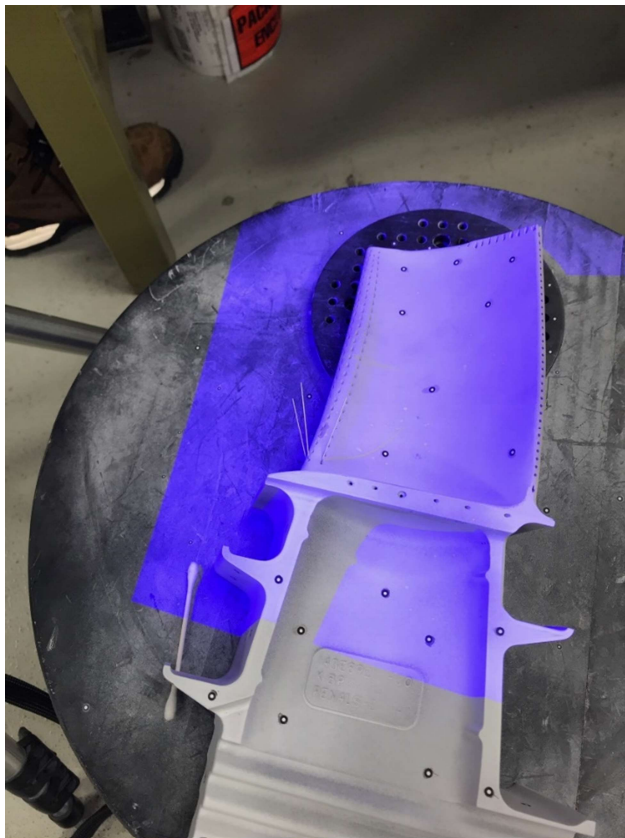


- Boiling porosity
- Creep
- Grain Angle
- Twist
- Material
- Inconsistent build parameters
- Material oxidation



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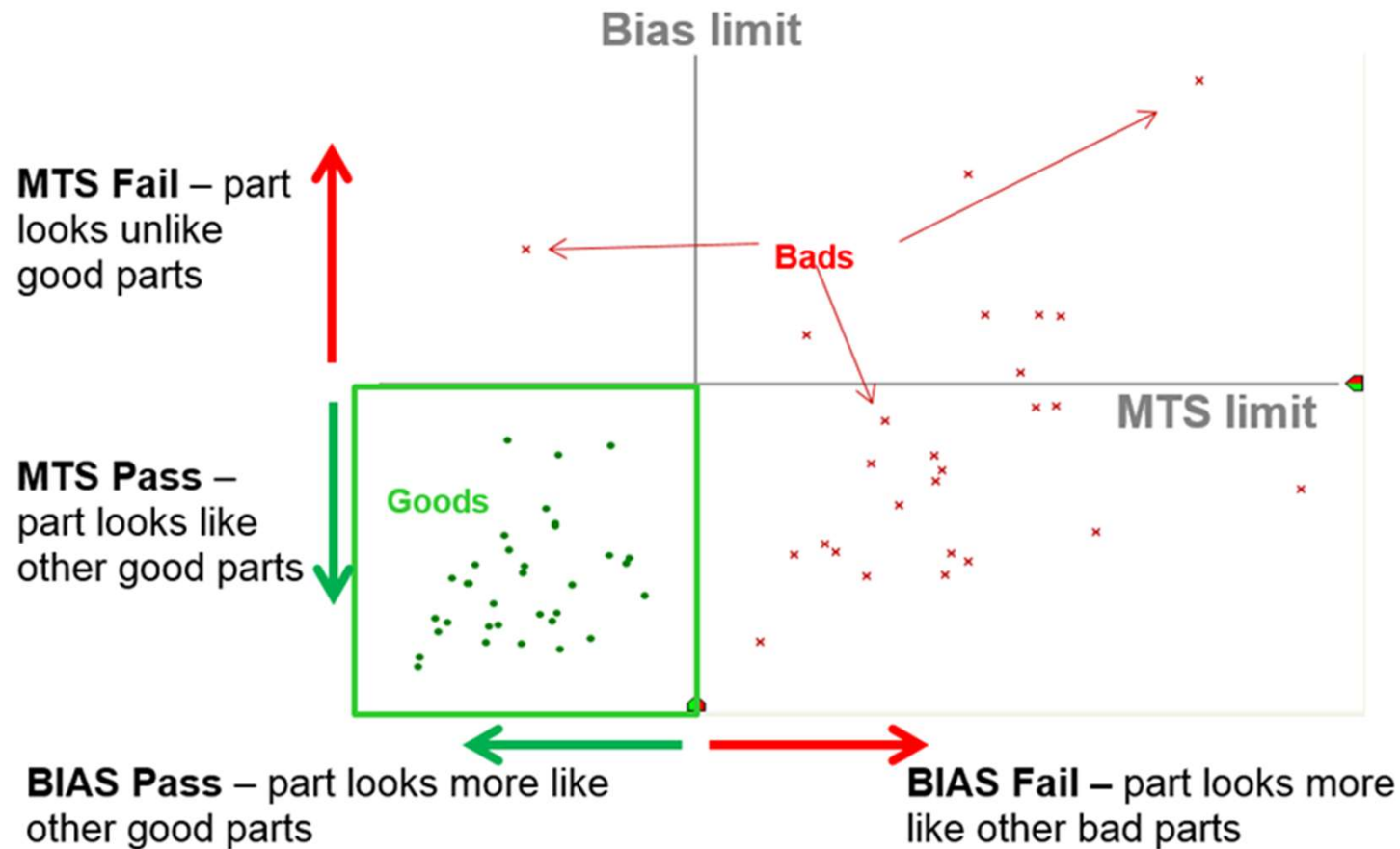
2019 Outlier Investigations





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Introduction to Targeted Defect Sort

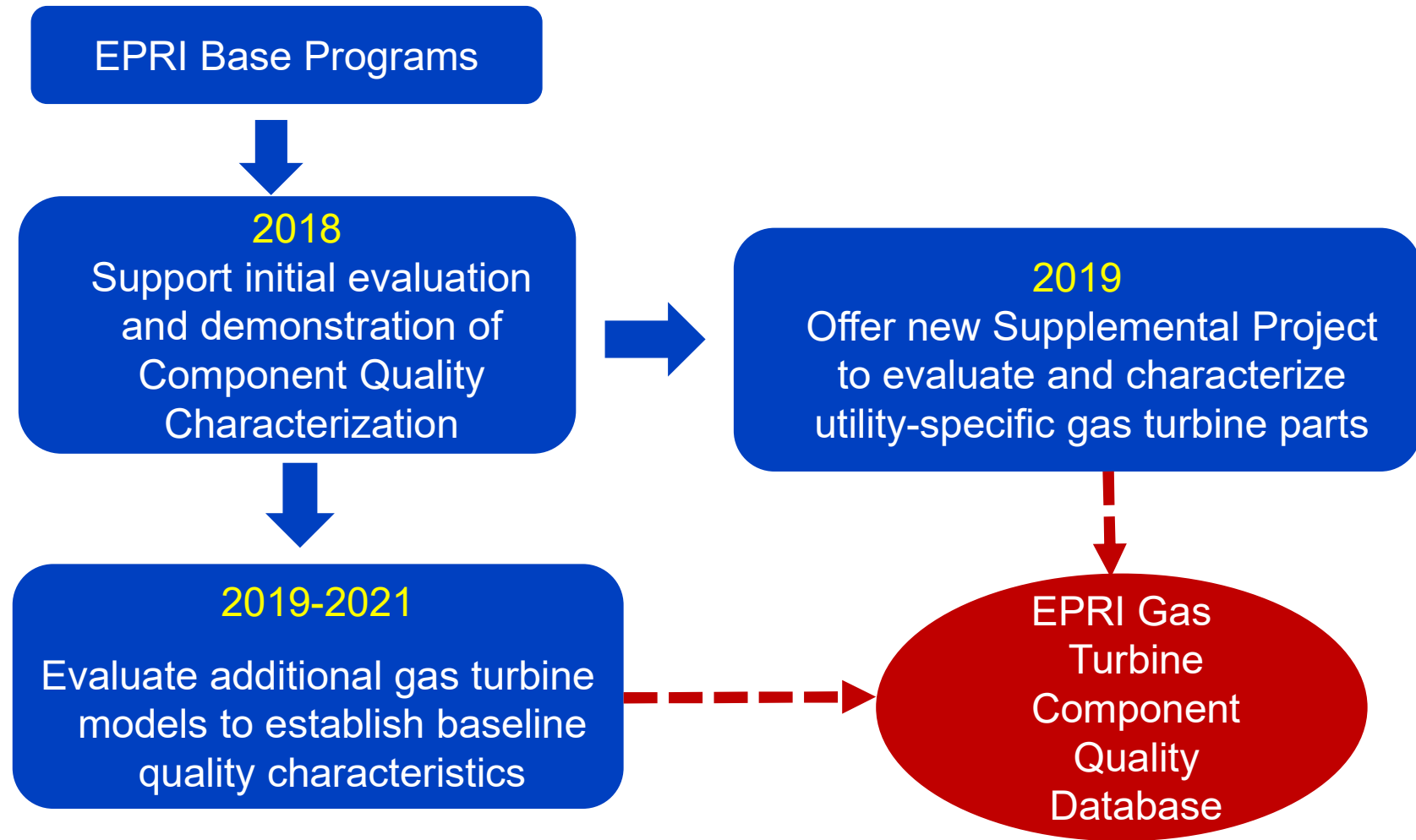


Algorithm must be trained with “good” and “bad” parts



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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

