PCRT

PROCESS COMPENSATED RESONANCE TESTING

A Resonance-Based Approach for Life Monitoring of Fan Blades

-Leanne Jauriqui, Lem Hunter, Greg Weaver, Thomas Köhler

What does **Vibrant** do?

Vibrant Corporation uses its proven **PCRT services** to:

- Help reduce field failures by screening population outliers
- Support Big Data Analytics
  - Quantitatively monitor part streams, via 100% NDE, to evaluate correlation to manufacturing and operational variables, aid in process control, and provide quantitative life-monitoring feedback.

CERTIFIED:
AS9100 Rev D and ISO 9001:2015

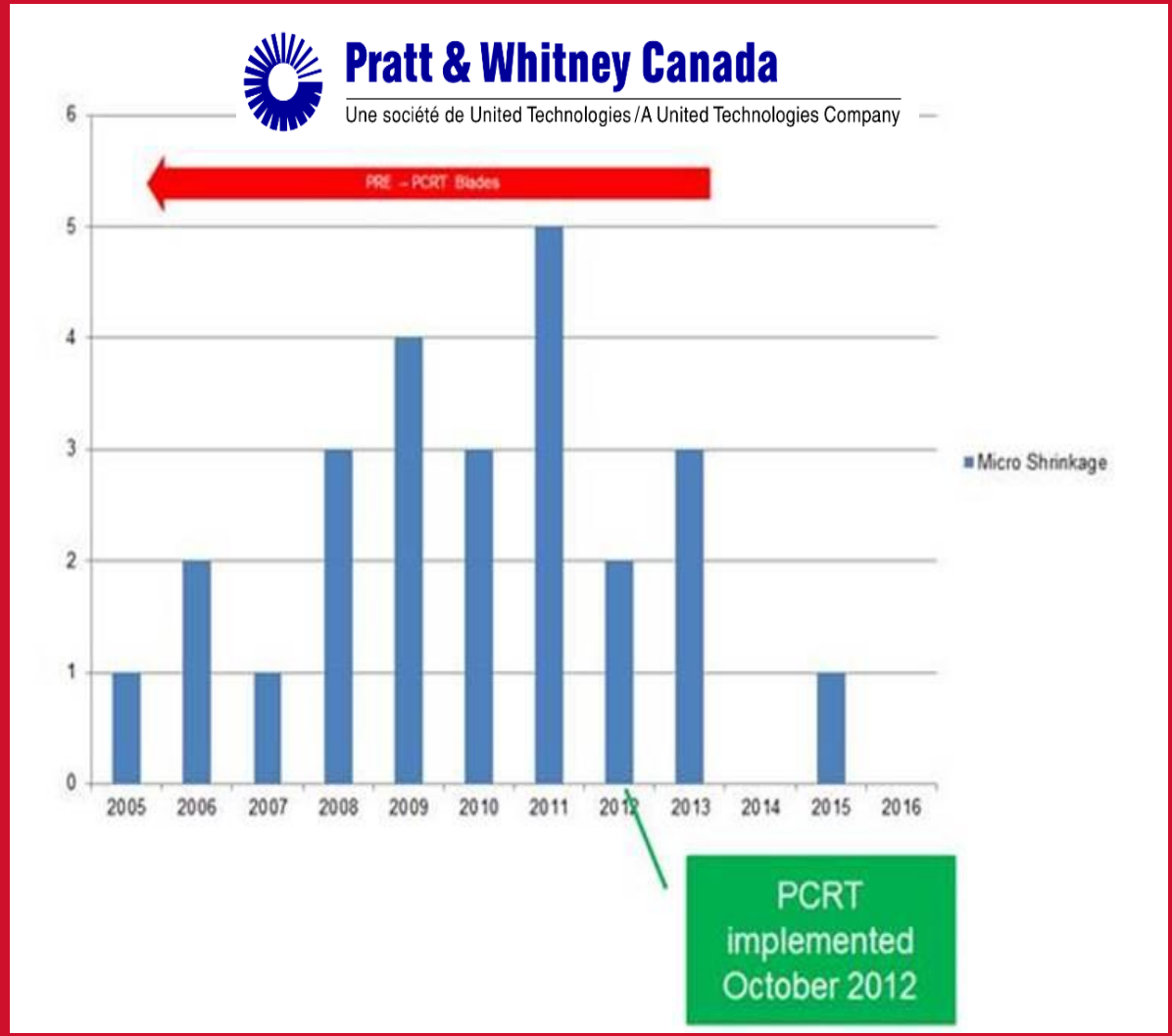
Resonant Ultrasound Spectroscopy (RUS) and PCRT application are described by ASTM Standard Guide E2001-13 and ASTM Standard Practice E2534-10.

PCRT is FAA-approved for gas turbine engine blade inspection.

PWC presents PCRT Success
Sep 18

A4A 2016 - Better Way Award
Sep 18

Aug | Nov | Feb | May



https://www.ntsb.gov/investigations/Pages/DCA18MA142.aspx

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Delta TechOps updates PCRT Success

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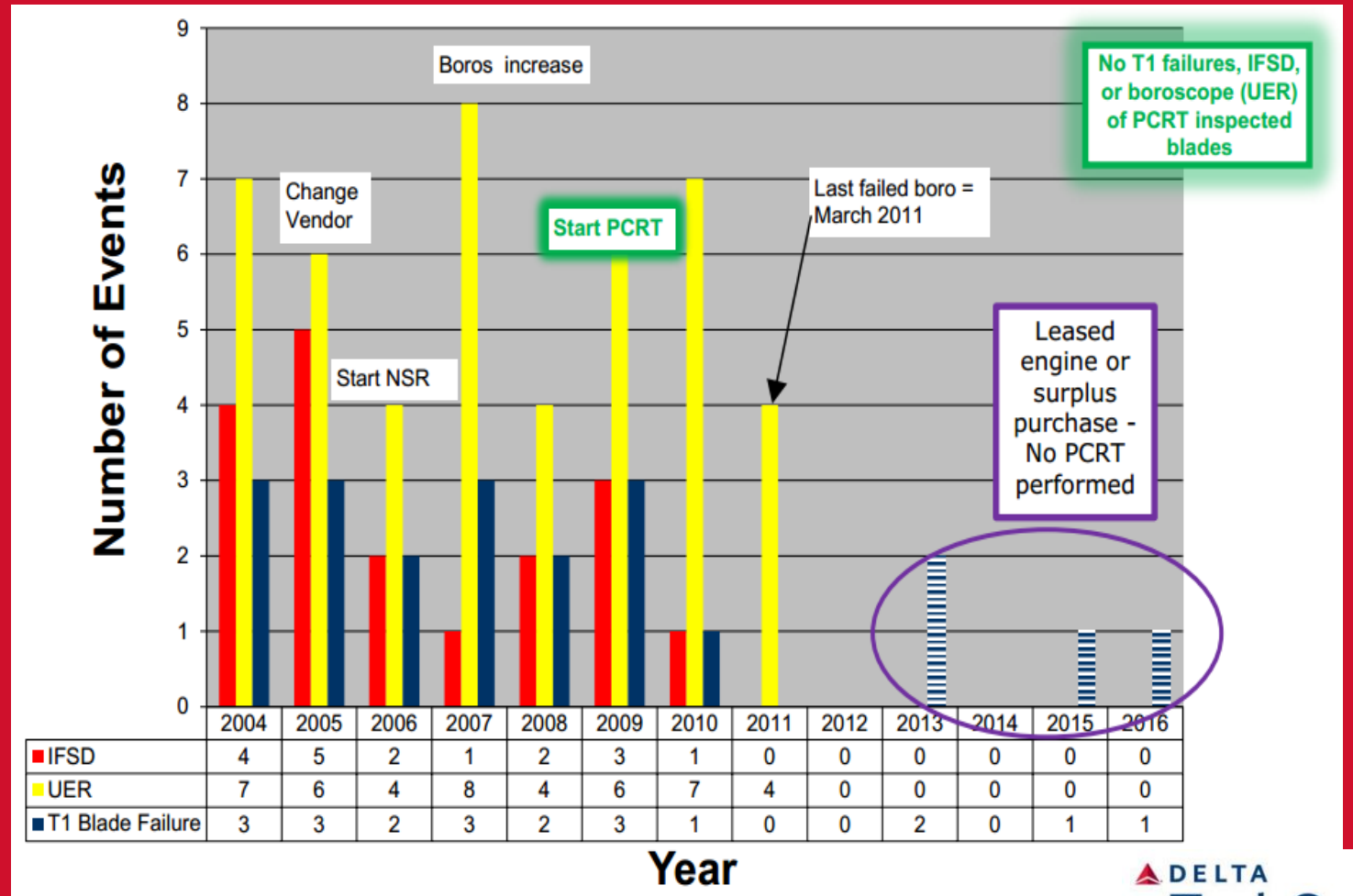

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
IFSD	4	5	2	1	2	3	1	0	0	0	0	0	0
UER	7	6	4	8	4	6	7	4	0	0	0	0	0
T1 Blade Failure	3	3	2	3	2	3	1	0	0	2	0	1	1

DELTA TechOps

https://www.ntsb.gov/investigations/Pages/DCA18MA142.aspx

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CFM56-7 Fan Blade Failure
Aug 27

Delta TechOps updates PCRT Success
Sep 18

PWC presents PCRT Success
Sep 18

A4A 2016 - Better Way Award
Sep 18

2nd CFM56-7 Fan Blade Failure - Passenger Killed
Apr 17

Pending AD
Oct 1

Aug | Nov | Feb | May | Aug | Nov | Feb | May | Aug

Today

Jan 15
OEM develops inspection in response to failure, incorporates into Repair

Jun 13
OEM recommends inspection of ALL fan blades

Apr 20
OEM issues SB requiring inspection of fan blades older than 20,000 cycles, every 3000 cycles

FAA issues emergency AD requiring inspection of fan blades older than 30,000 cycles

https://www.ntsb.gov/investigations/Pages/DCA18MA142.aspx

Meeting AD Requirements…

Is a SCRAMBLE!

- Purchase new equipment
- Train/Hire new NDT personnel
- Modify maintenance schedules
- Manage replacement part inventory
- Update Programs/Documentation
- Manage PR
- Get ready to do it again real soon…

How does this happen?

Best Industry Practice Design

Risk-Based Inspection

FAA Oversight

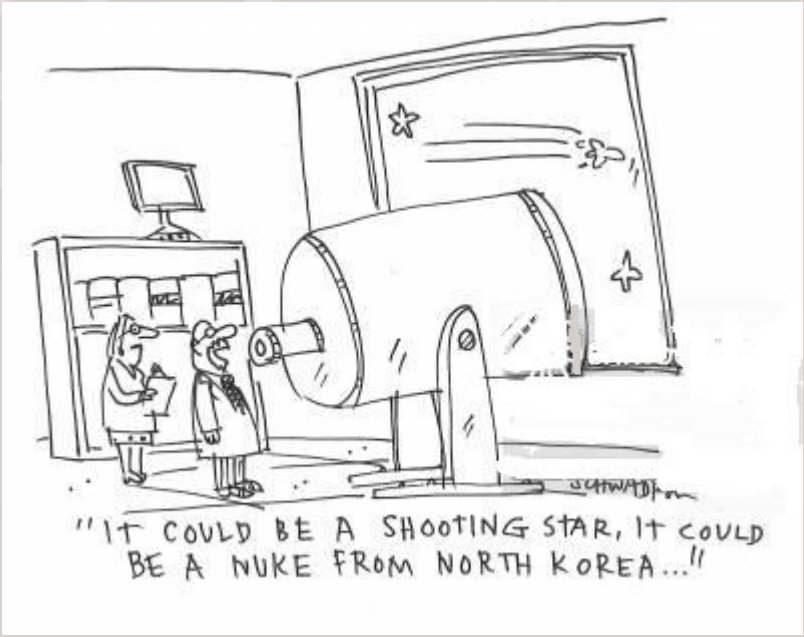
That shouldn't have happened …

It must have been …

It could be …

Uncertainty

Uncertainty in Life … and Work



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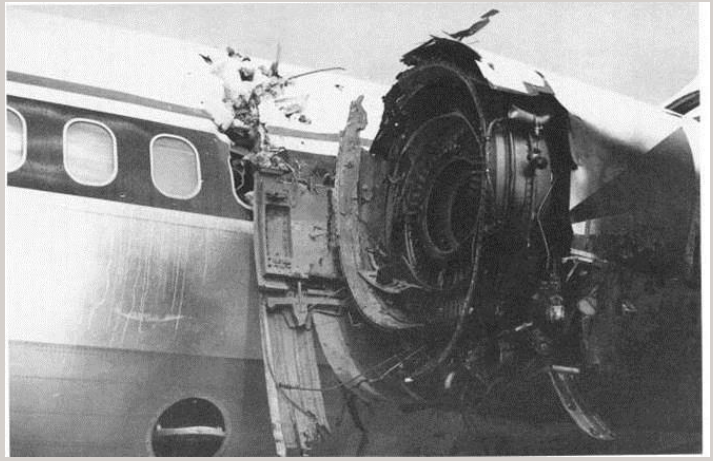
What did all of these have in common?



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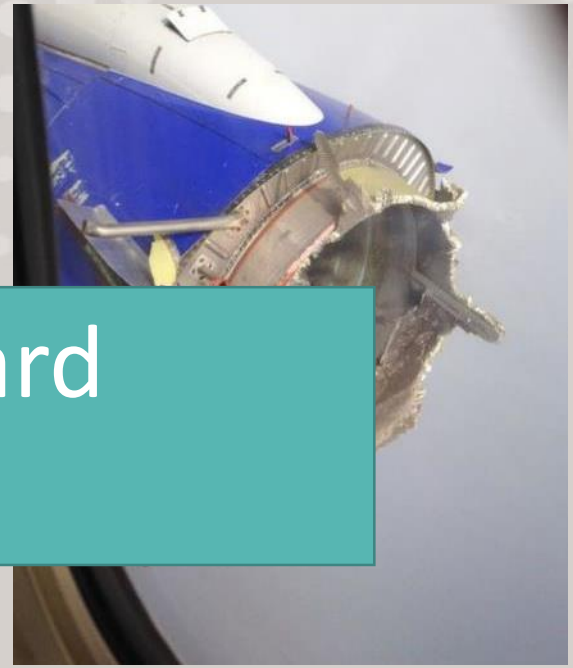

They all received industry-standard inspections prior to failure.

Are we doing everything we could?

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Sources of Uncertainty

In Part Models, which are used to predict risk:

- "Normal" Service Conditions
- Extreme Service Conditions
- Material Properties
- Best Manufacturing Control Scenarios
- Repair Processes
- Post-Processing Effectiveness – HT, SP, HIP

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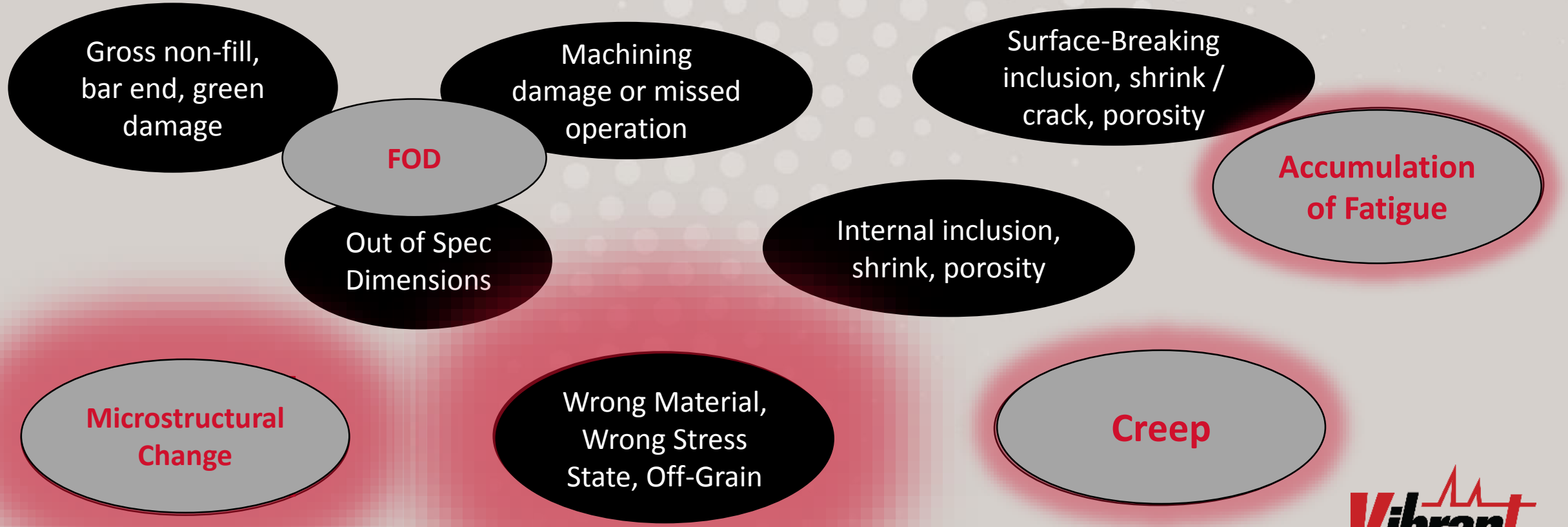
Mitigating Uncertainty

Inspections to reduce risk:



Mitigating Uncertainty

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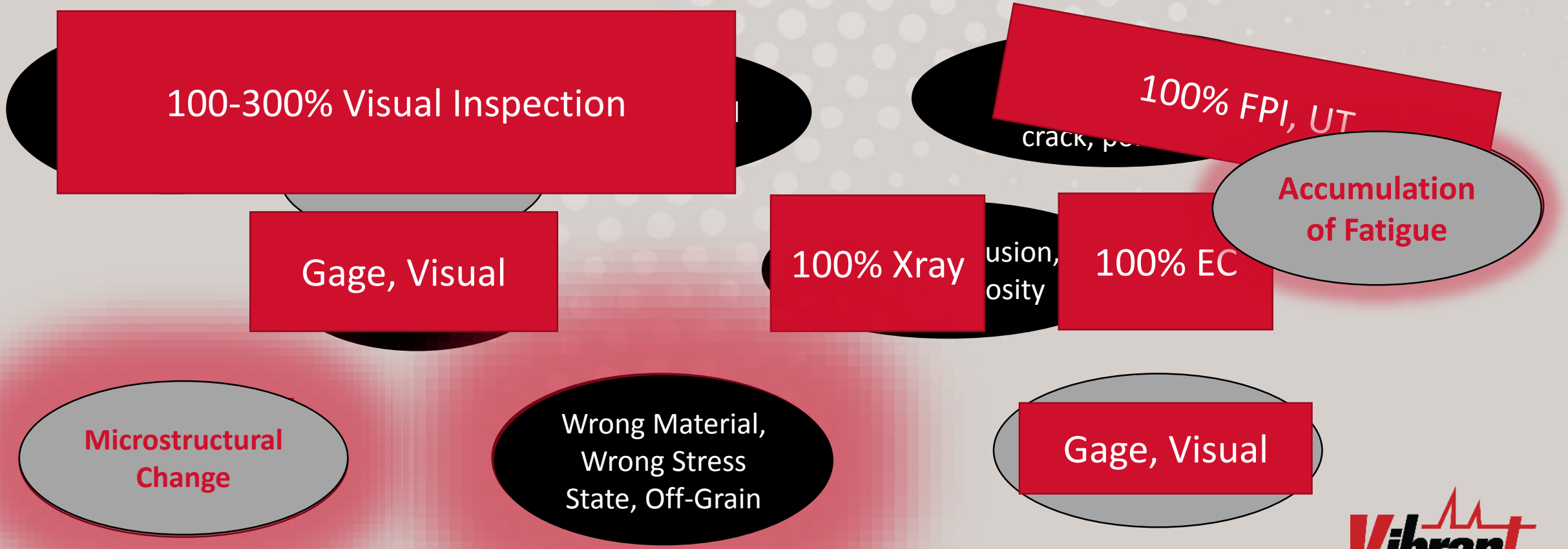

Mitigating Uncertainty

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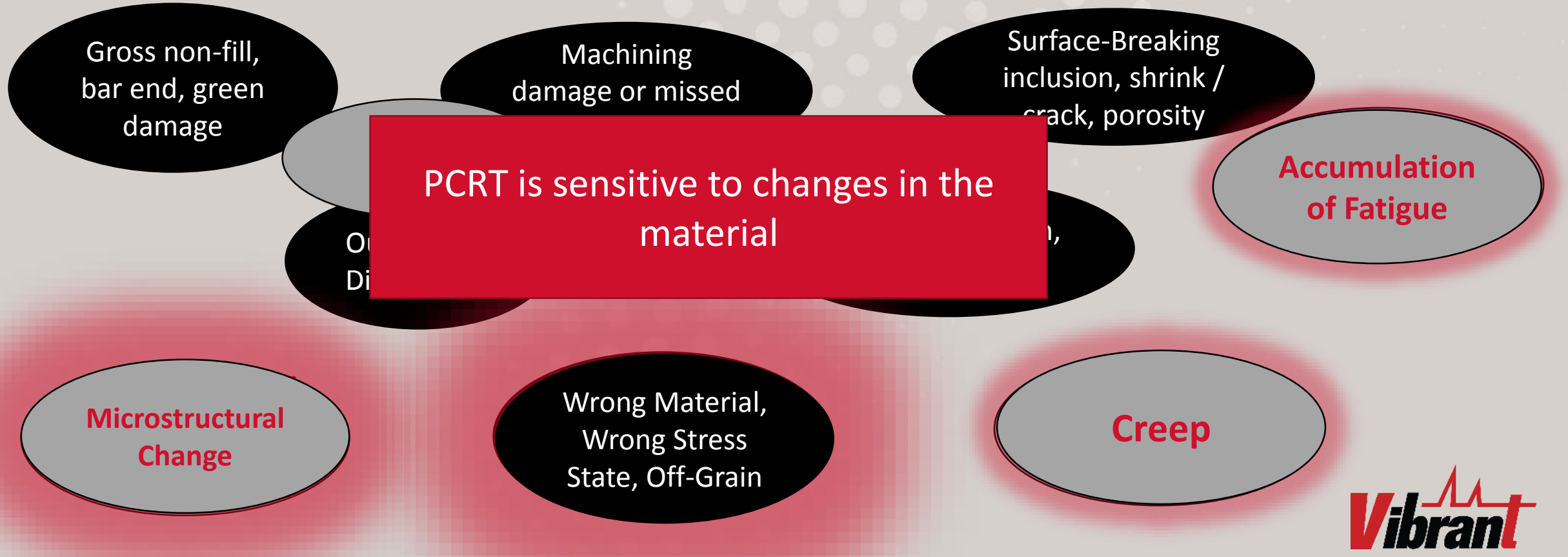

For the Fan Blades

- Was the Design model wrong? Was the Operational model wrong? Are the stresses different? Do cracks form sooner? Propagate faster?
  - Should we inspect more frequently? Start earlier?
  - Which parts are at the most risk?
  - How should we change the model? Are other parts at risk as well?
- Was the inspection done? Was it done correctly?
  - Should we do it again?
  - Should someone else do it?

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For the Fan Blades

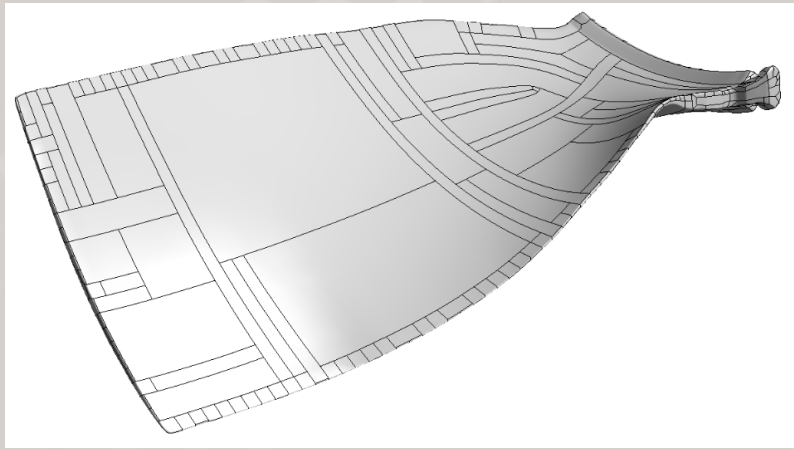
- Why did “theirs” fail? Are “ours” different?
  - How critical are operating conditions?
  - How different are they?
- Should we replace them all?
  - With new parts of the same Design?
  - Or is a new design required?
- What if another one fails?
  - What if is fails differently?

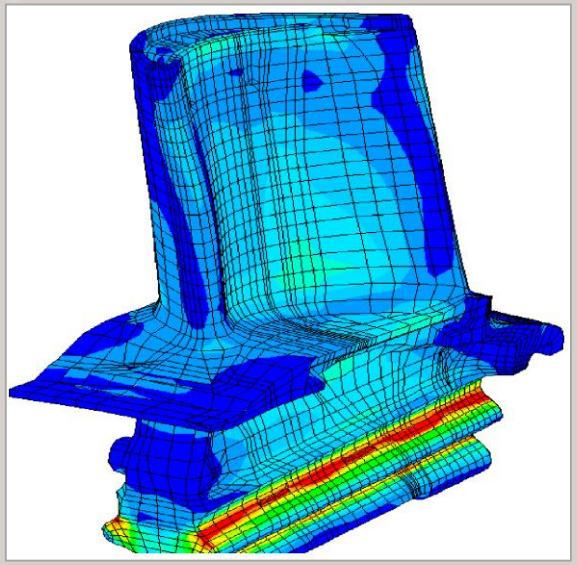
Let's Reduce Uncertainty

Is our part what we modeled?

PCRT data can:

- Help validate models AND parts
  - Material properties are not invisible, and ARE reflected in resonance measurements.
  - Get smarter about material properties, material variation, and the effects of aging and damage.





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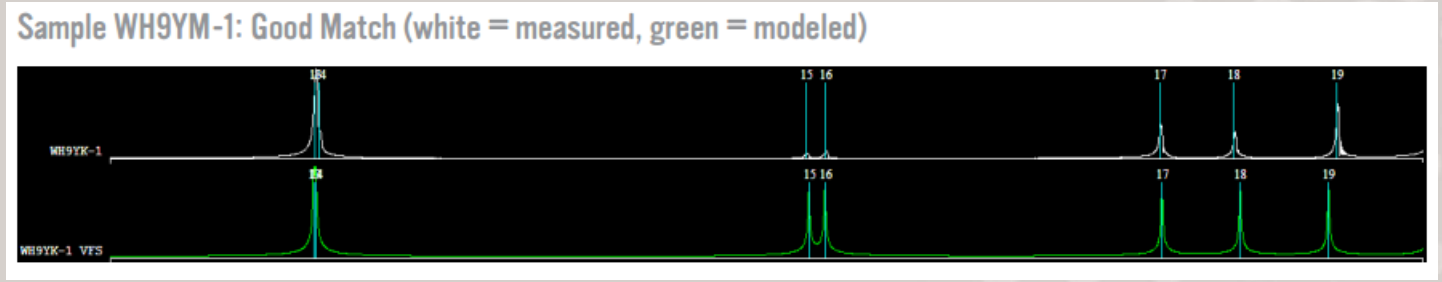
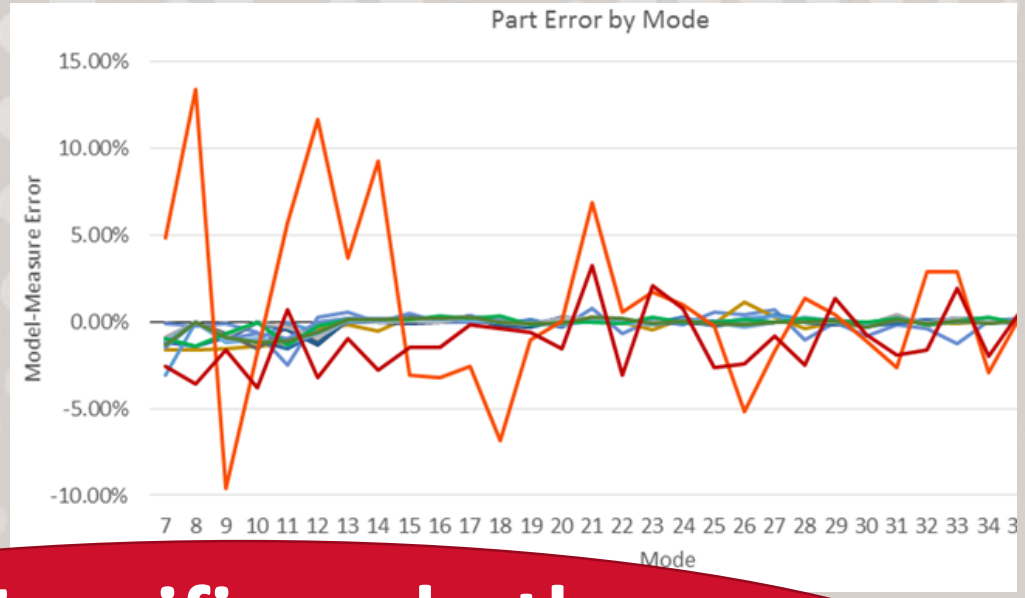
Validating Models





PCRT verifies whether material properties match the model

Part	Cast Bar Laue	Inversion	Re-Laue Side A	Re-Laue Side B
WH9YC-2 (6)	37.9°	37.0°	37.0°	30.4°
WH9YG-1 (13)	8.7°	13.3°	13.3°	14.1°
YB2WN-1 (53)	6.6°	6.0°	7.7°	14.1°
YB2YF-2 (66)	0.9°	0.0°	0.5°	0.6°

Let's Reduce Uncertainty

Are we (still) making the part we qualified?

PCRT data can:

- Help validate models
- Evaluate the Part Stream over time
  - Assure supply is consistent with qualification parts
  - Identify/Correct process drift
  - Assure suppliers are making the same part
  - Combine part data with manufacturing data to improve process control

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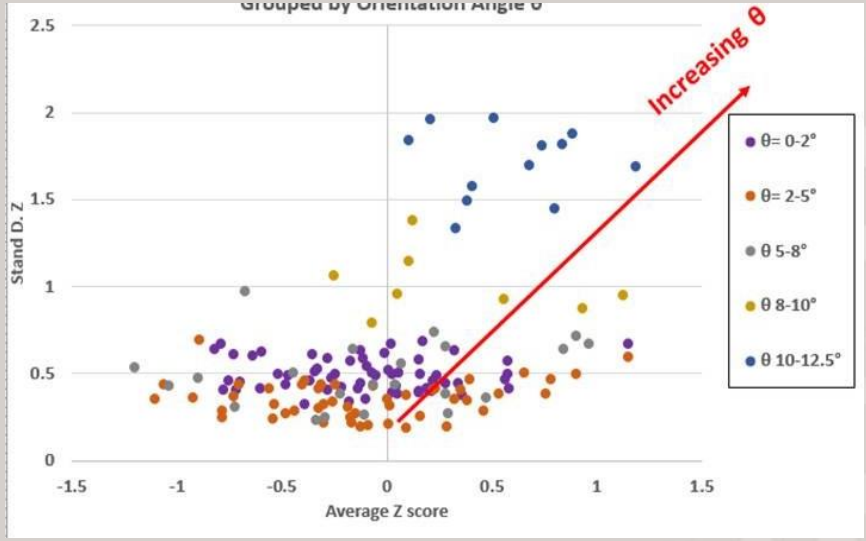
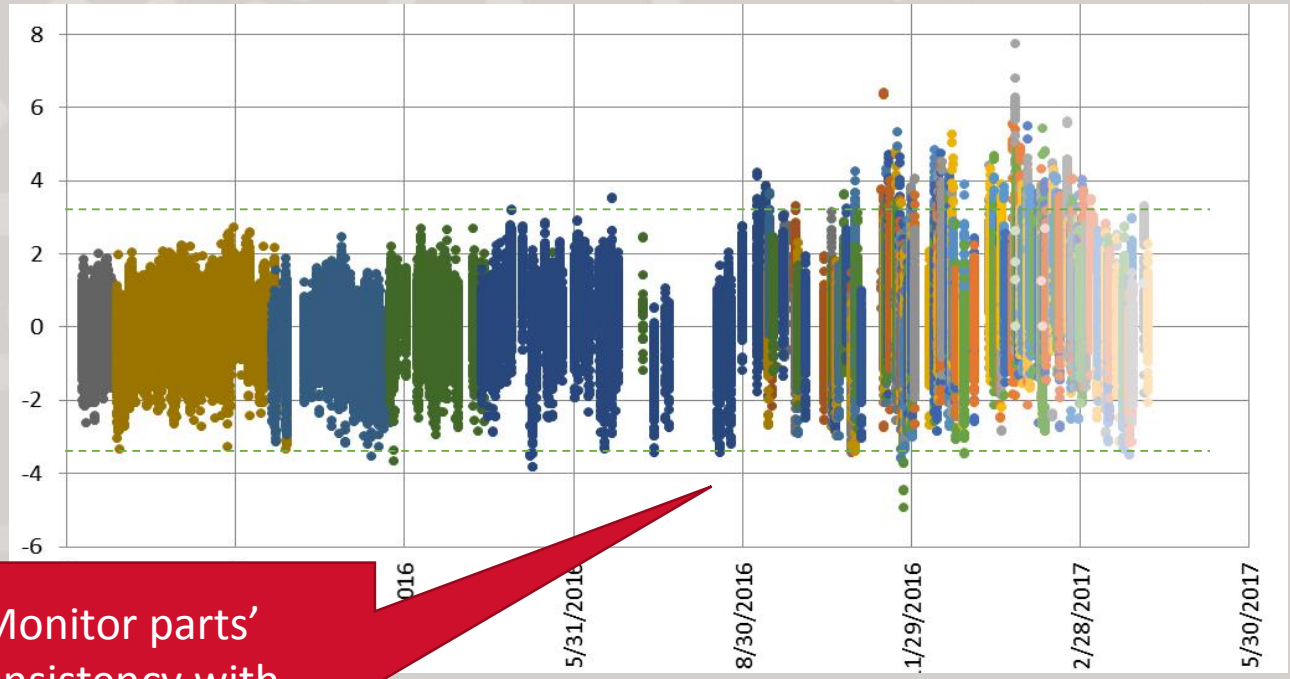
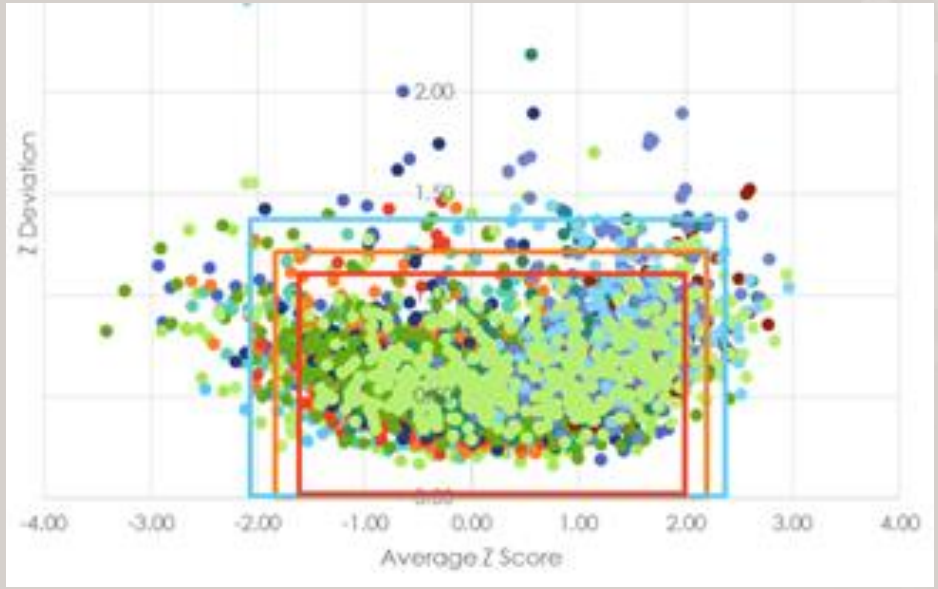
Process Control for Part Supply







Monitor parts' consistency with qualification parts. Detect Process Drift!

Let's Reduce Uncertainty

Are we getting the improvement that we want?

PCRT data can:

- Help validate models
- Correlate to manufacturing control points
- Verify post-processing operations 100%
  - Consistent Heat Treat, regardless of furnace position
  - Quantify how much HIP changes part density

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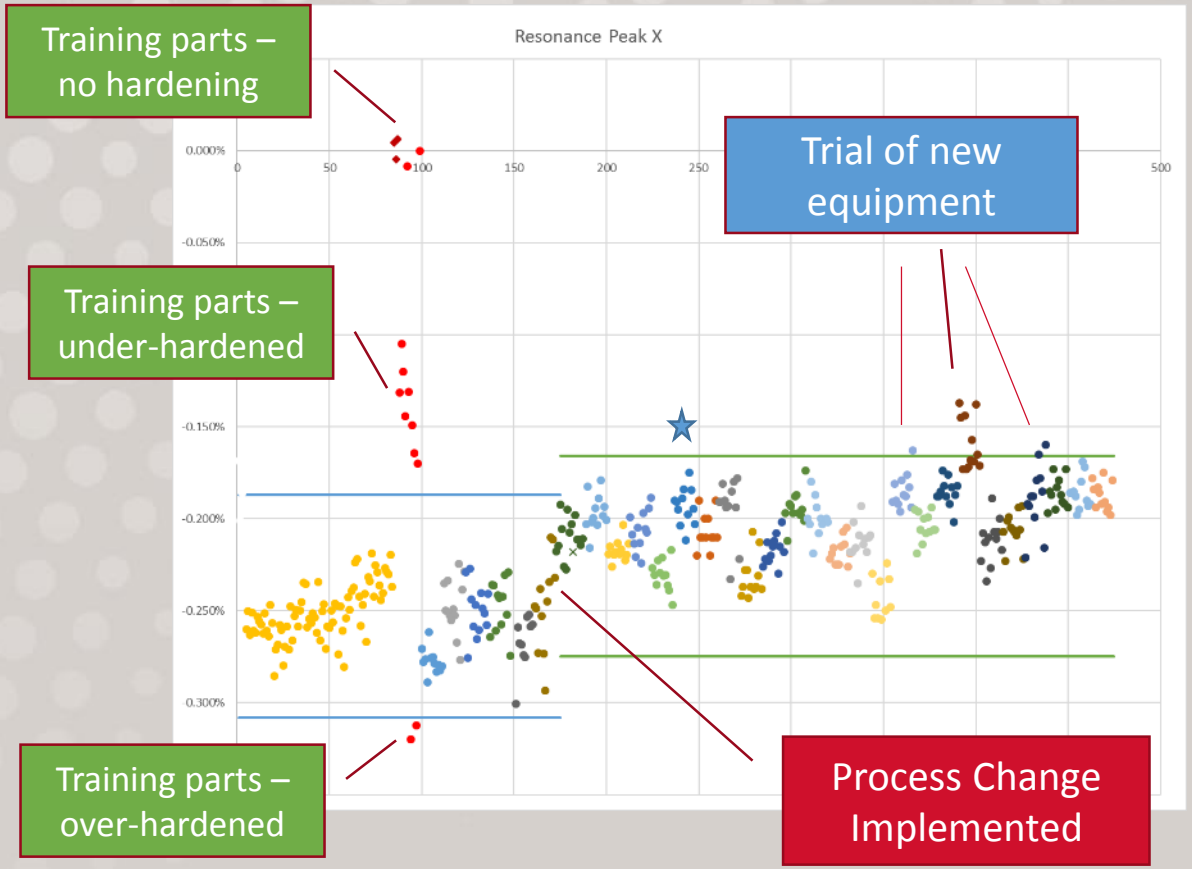
Verification of Critical Processing

Resonance Data is:

- Highly repeatable gage data
- Easily tracked like other SPC data sources
- Able to correlate with production settings to facilitate better control



Let's Reduce Uncertainty

Are parts changing the way we expected?

PCRT data can:

- Help validate models
- Correlate to manufacturing control points
- Verify post-processing operations
- Monitor changes in parts, by serial number, over time
  - Measure HOW parts change
  - Detect changes in stress due to material change or crack propagation
  - Detect changes in parts that other NDT methods don't see
  - Combine part data with operational data and other NDT data to better understand aging and damage mechanisms

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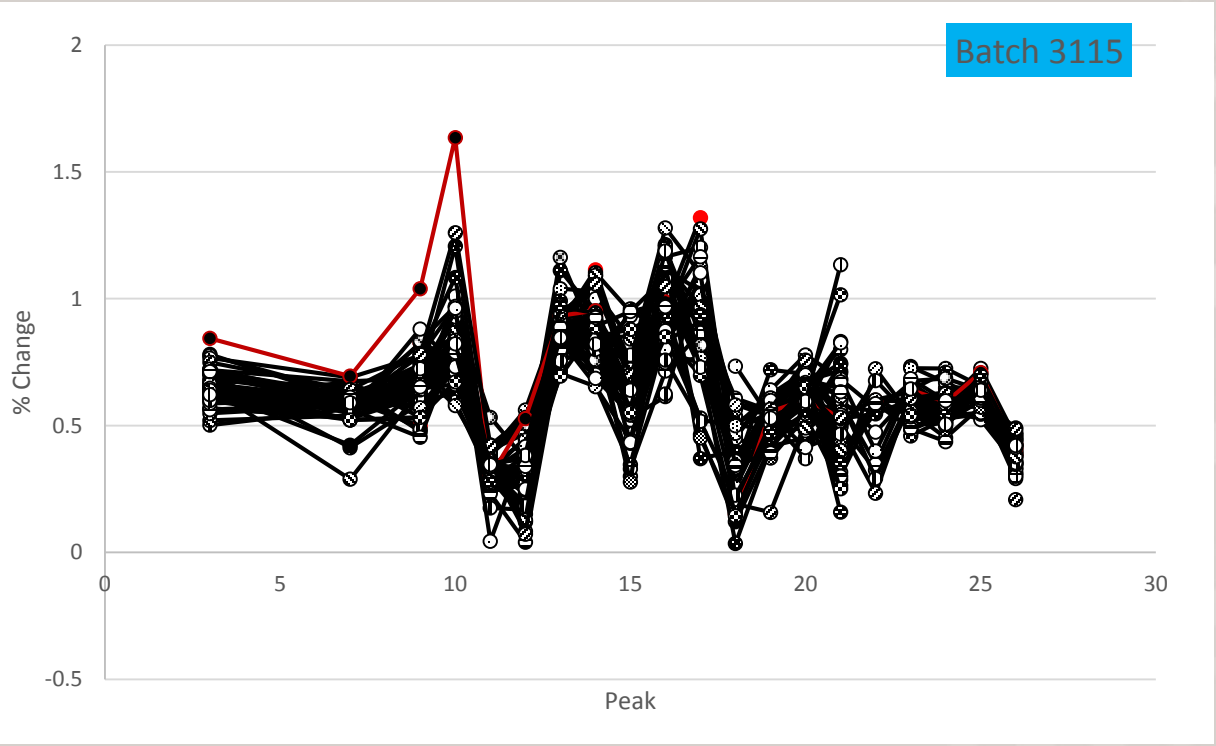
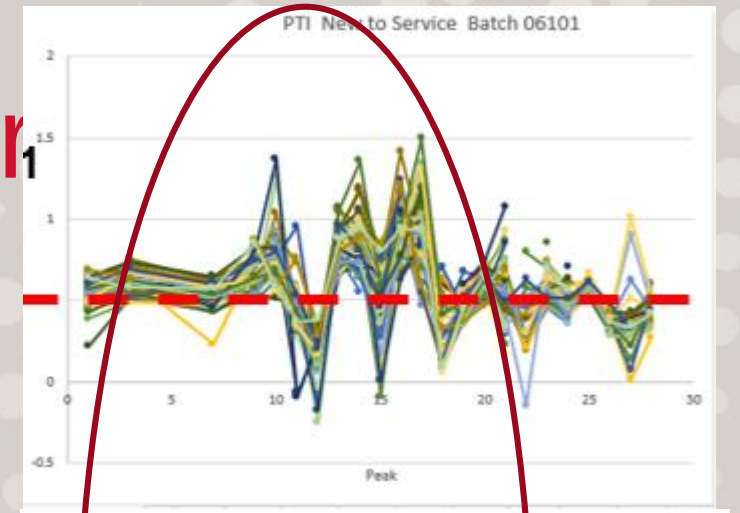
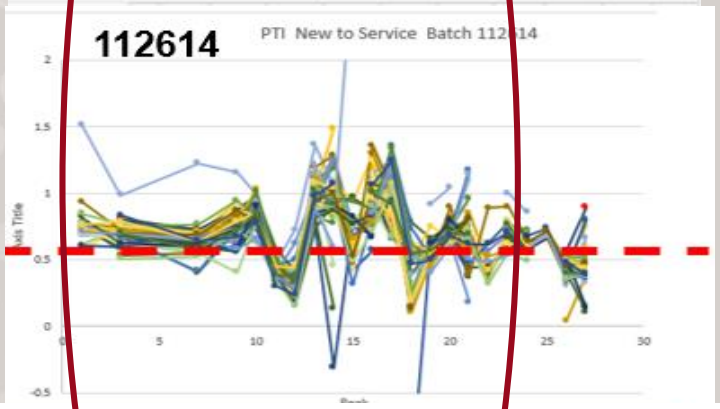
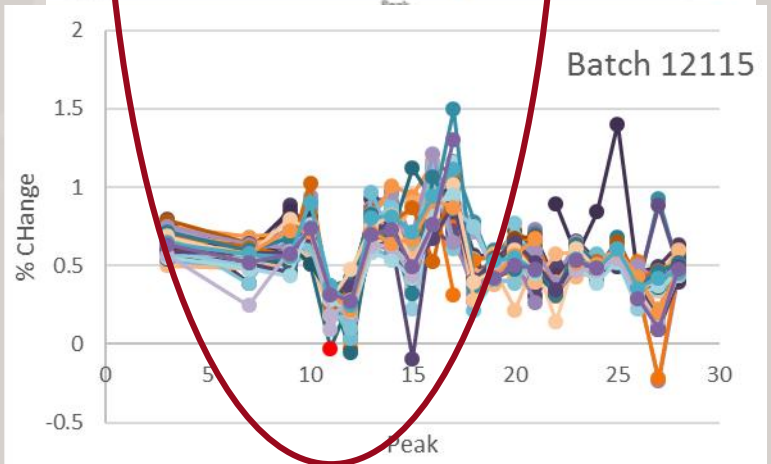
Monitoring Parts over

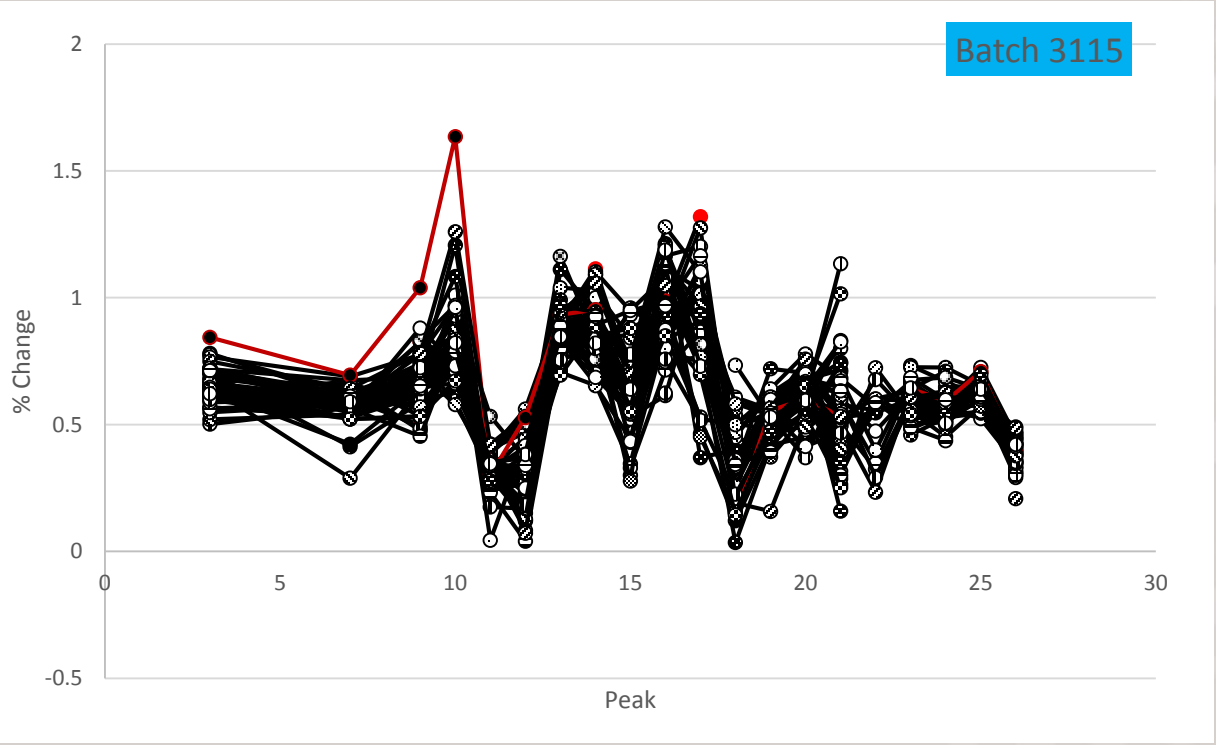


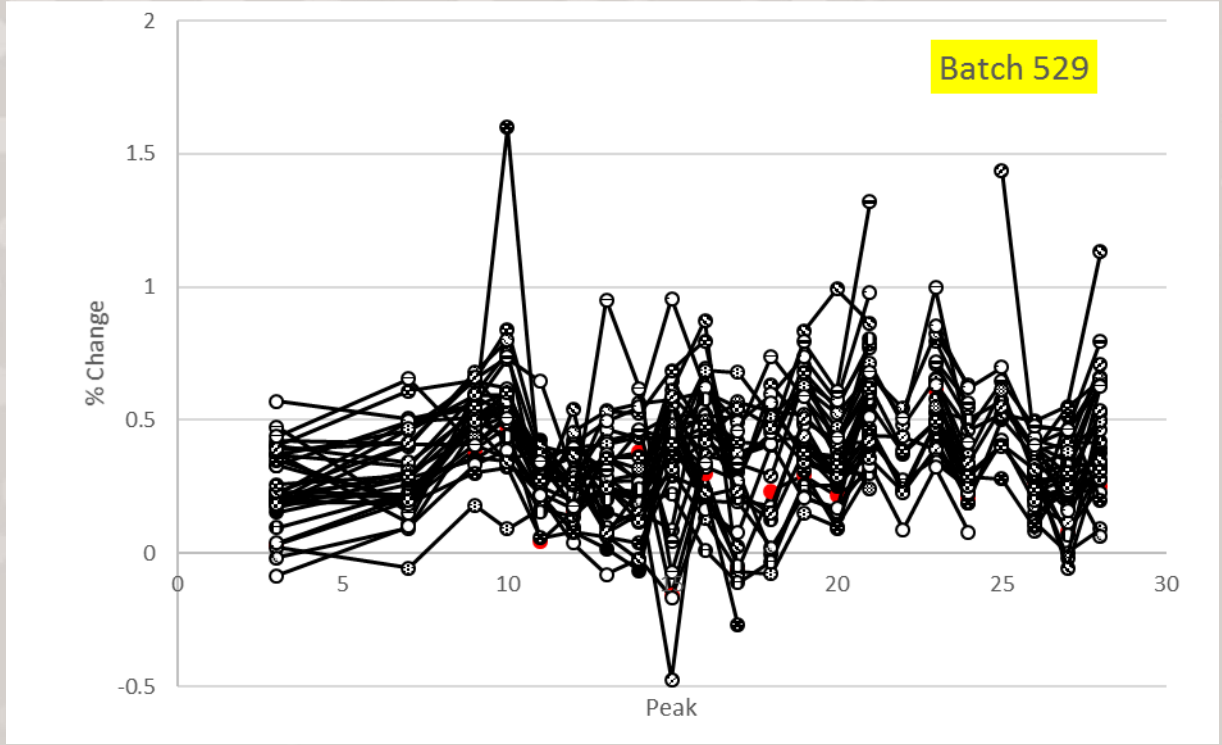


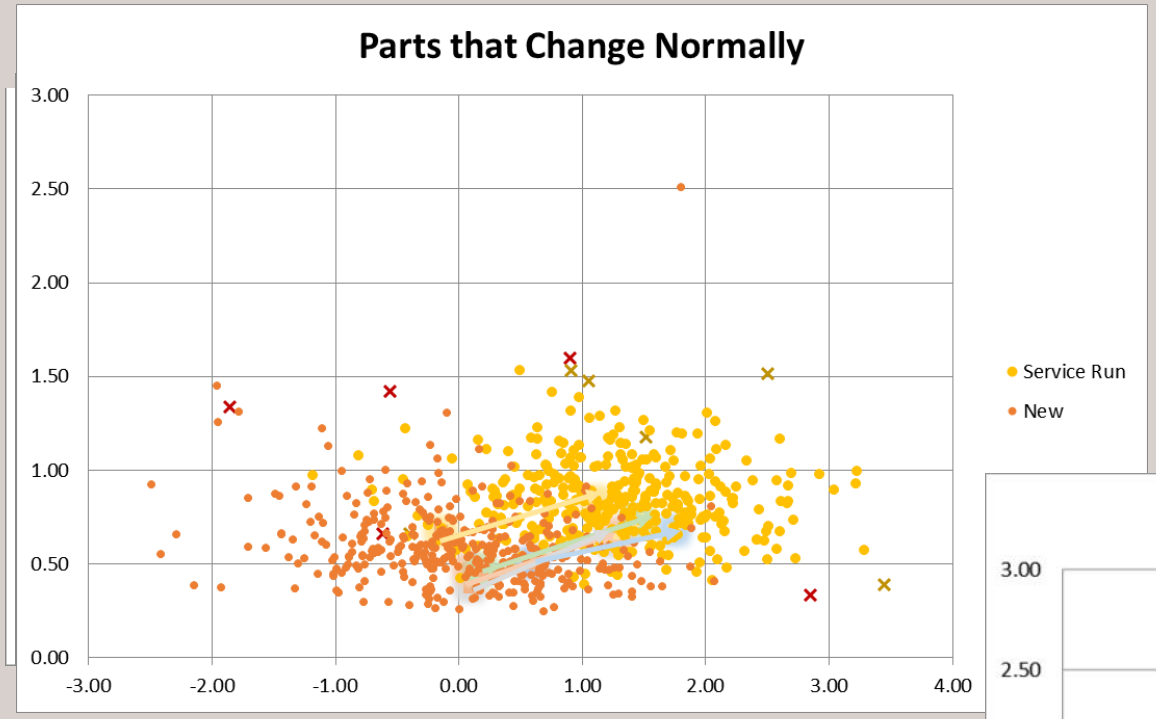


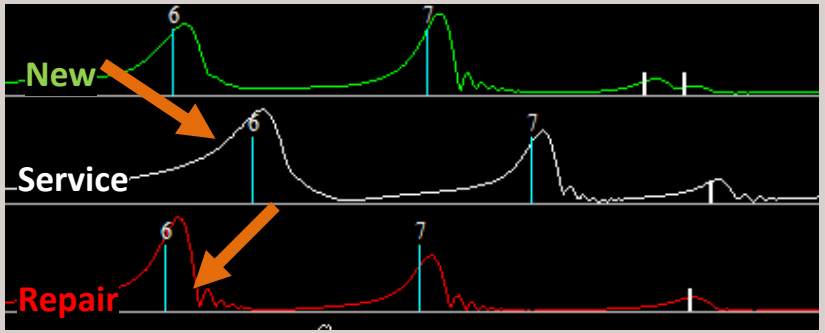


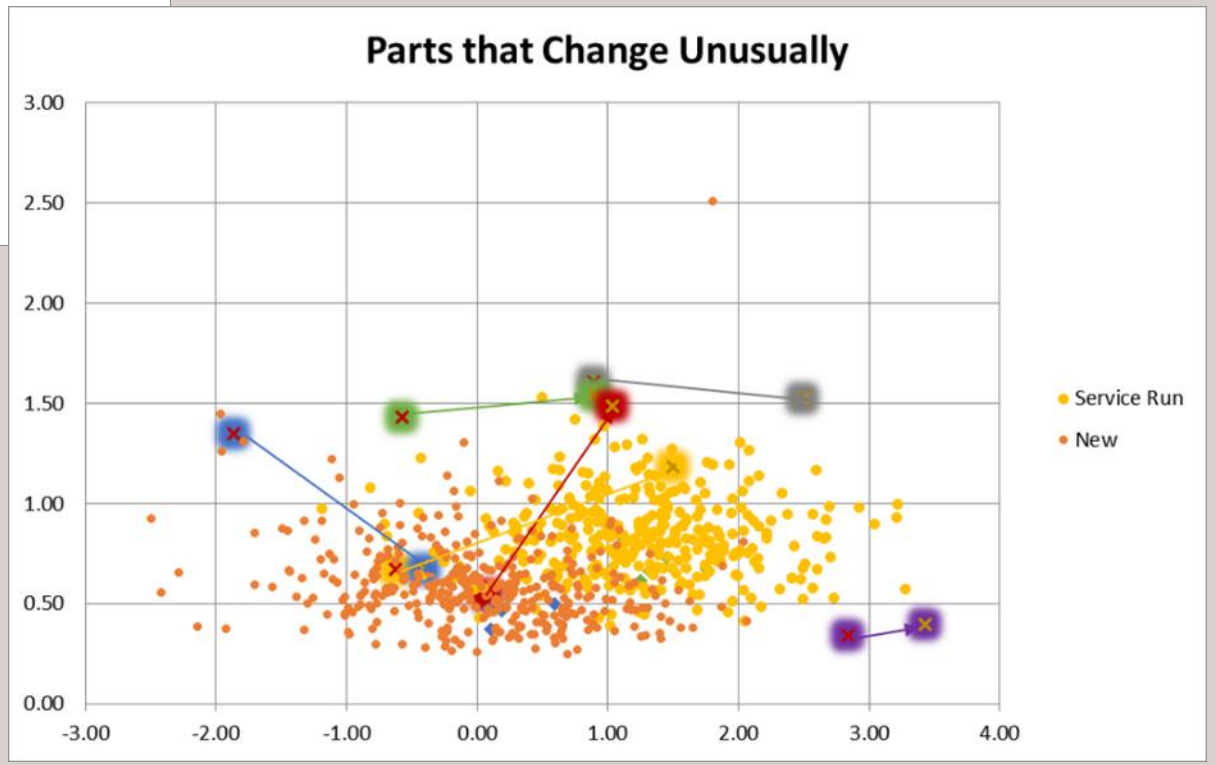
Monitoring Parts over their Life






Parts that Change Normally
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
Service Run
New


New
Service
Repair
6
7


Parts that Change Unusually
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
Service Run
New

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Let's Reduce Uncertainty

Where can we take this next?

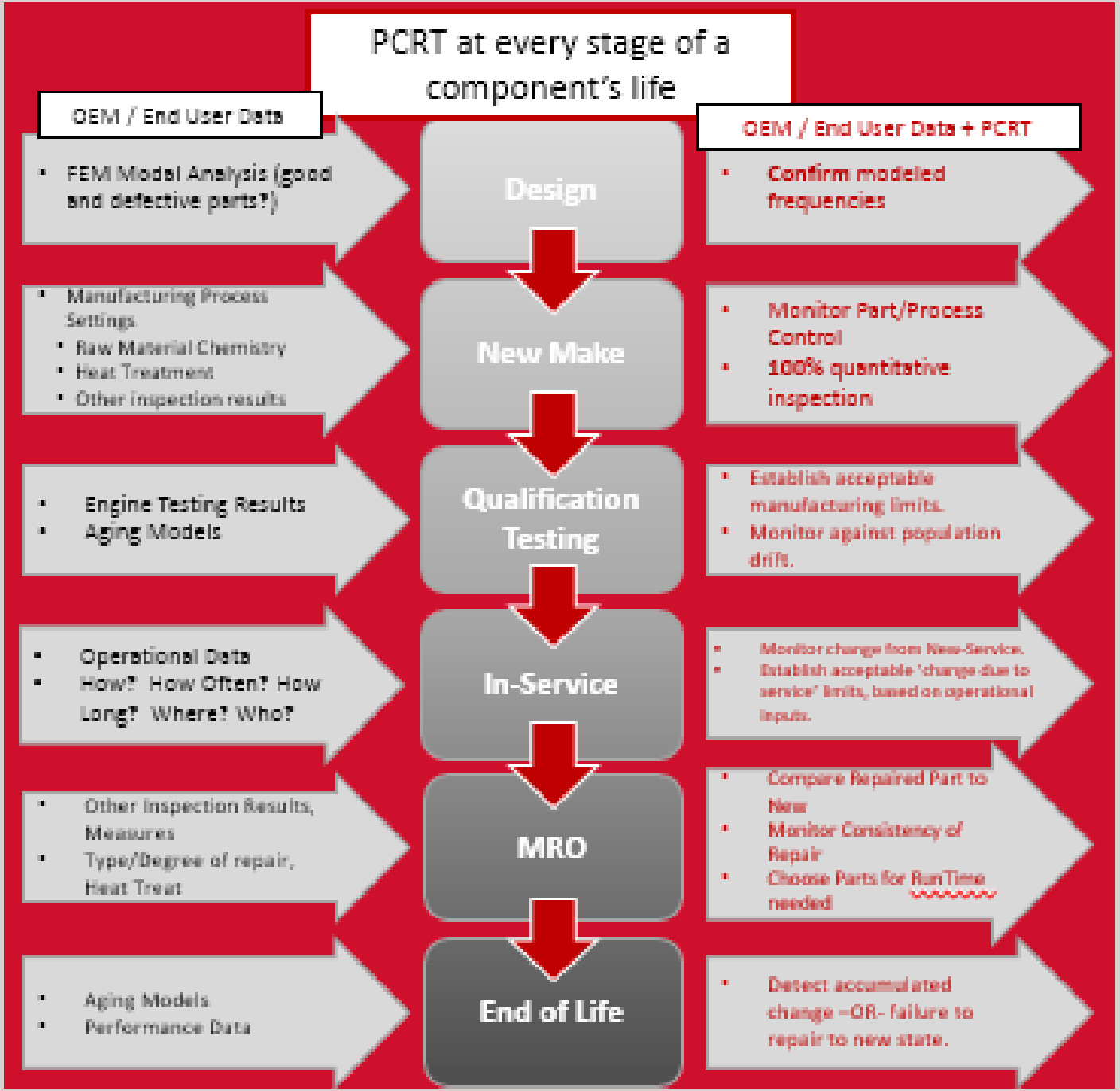
PCRT data can:

- Help validate models
- Correlate to manufacturing control points
- Verify post-processing operations
- Monitor changes in parts, by serial number, over time
- Combine with other data sources and inspection results for better risk management

Combine Forces

Combine PCRT part data with:

- Design intent and model inputs
- Manufacturing data to improve process control
- Operational data and other NDE data to better understand aging and damage mechanisms
- Other NDE results to identify when one result can help better interpret the other



Where do we start?

Fan Blades are a great opportunity.

- Identify and Quarantine outlying components → Reduce risk!
- Collect data at lube visit, every 1600 cycles.
- Evaluate changes in parts over time, identify parts that are changing more (or less?), evaluate further.
  - Many wheels/LG have friendlier inspection intervals as well.


THANK YOU.
Vibram