Pratt & Whitney Canada

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NDT Technology Readiness

A P&WC Case Study

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A P&WC CASE STUDY

14th. Annual NDT Better Way Award Winners

Airlines for America®
We Connect the World

SAE INTERNATIONAL™

P&WC

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Content

- Pratt & Whitney Canada (P&WC)
- NDT in the value stream
- Technology Readiness (TR)
- Case study
- Turbine blade re-design PCRT activity
- Statistical Process Control (SPC) using PCRT
- Summary

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Pratt & Whitney Canada (P&WC) - 1928

The six men who originally came to work for Canadian Pratt & Whitney Aircraft Limited in 1928. The company was founded by James Young (3rd from right), a Montreal businessman.

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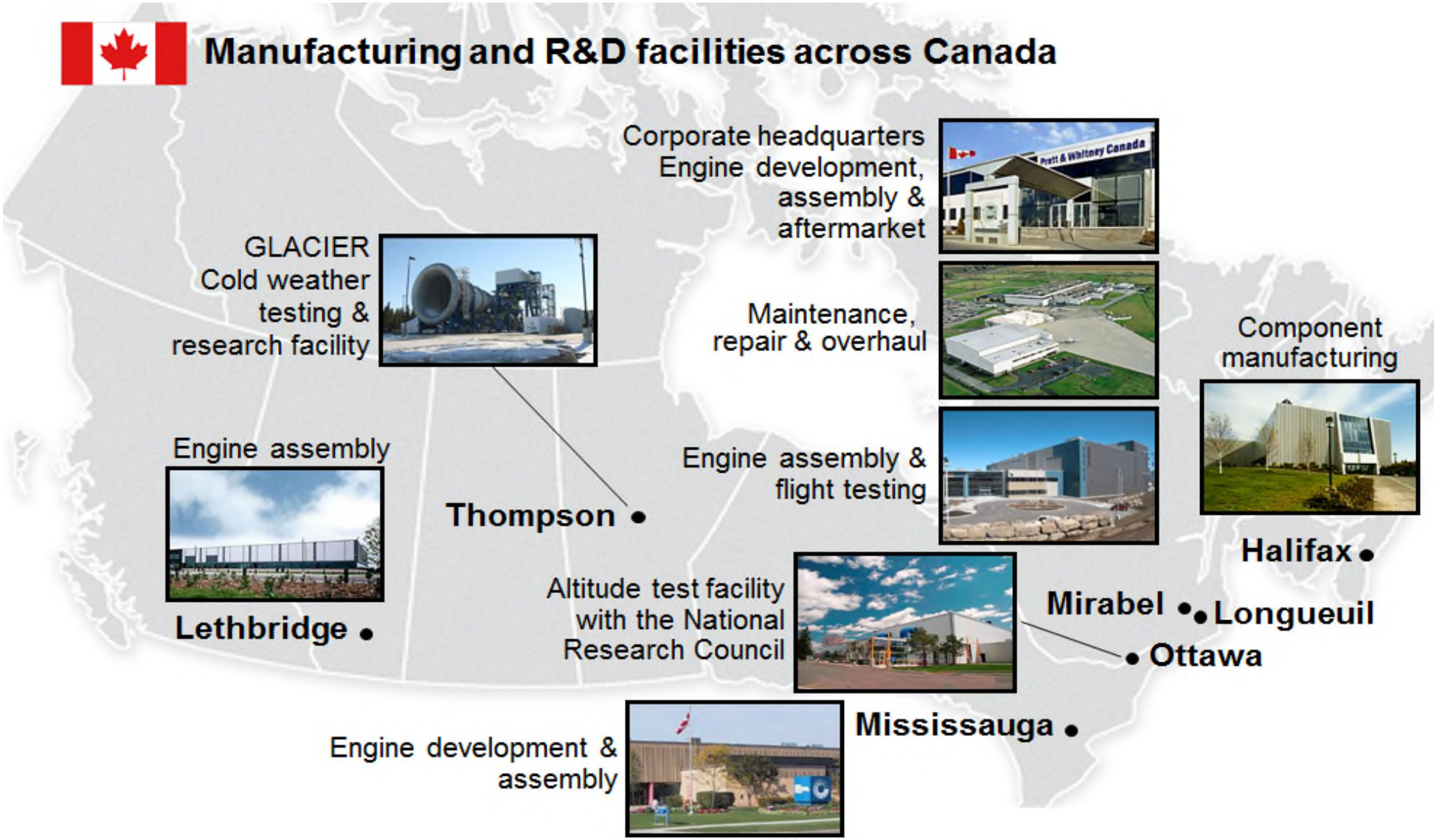
P&WC Canadian Facilities



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P&WC Employment World-Wide

Canada	**6,165**
Québec	~5,000
Ontario	~700
Nova Scotia	~315
Alberta	~150
International	**2,950**
Poland	~1,400
United States	~850
Others (India, China, etc.)	~700
	Total 9,115

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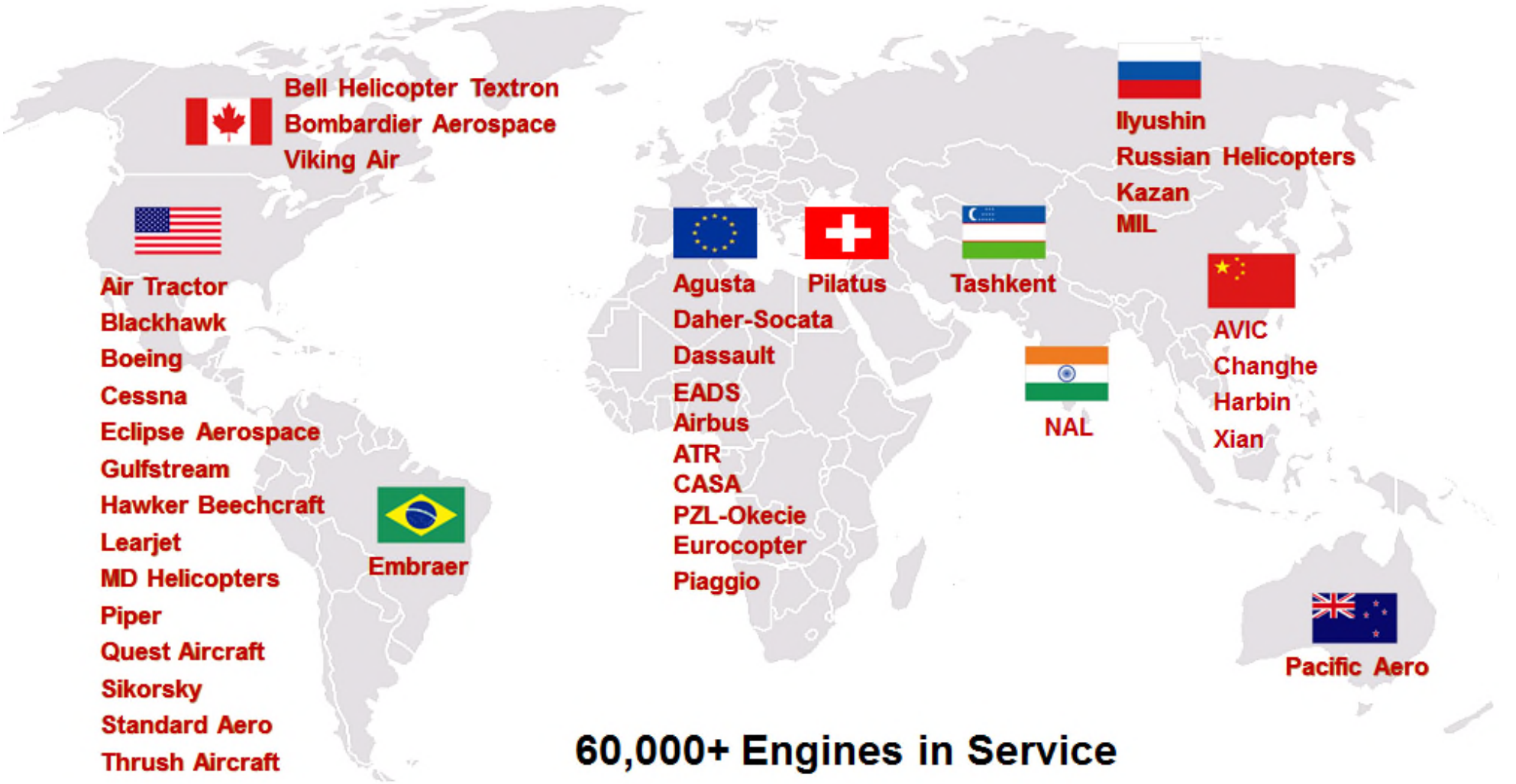
Global Customer Base



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Six Key Business Segments

Corporate

Cessna Citation XLS

Dassault F7X

General Aviation

King Air C90GT

Pilatus PC-12

Regional

ATR 72

Bombardier Q400

Civil Helicopters

AgustaWestland AW139

Sikorsky S76D

Military

Embraer Super Tucano

CASA C295

Aftermarket

Customer First Centre

Repair & Overhaul

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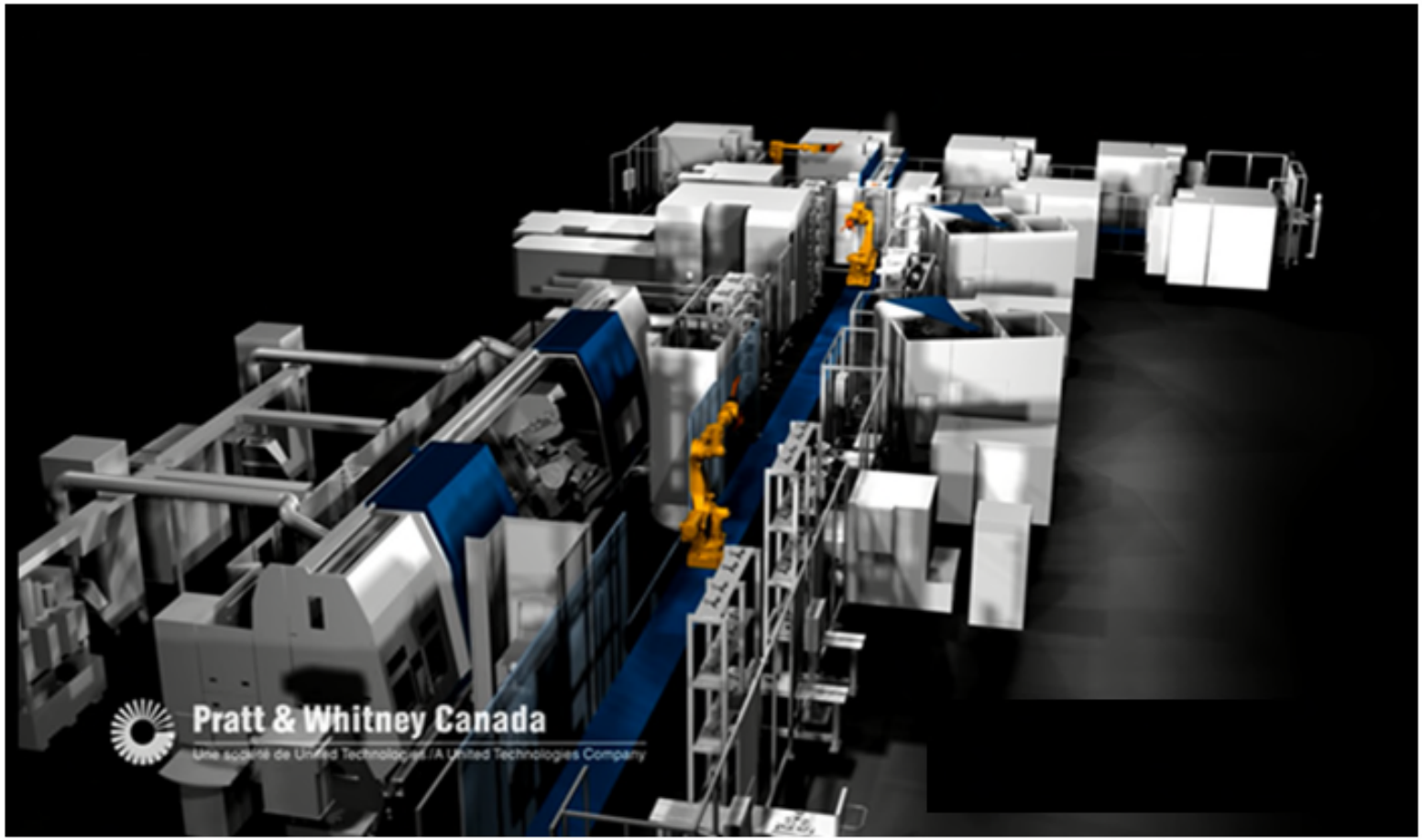
Pratt & Whitney Canada (P&WC) – 2016

Three Advanced Manufacturing Intelligent Cells $275M Cdn. investment



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NDT in the Value Stream

P&WC Value Stream Video

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NDT in the Value Stream

- The 2016 NDT Better Way Award Team -
  - Chief Engineers Office
  - Turbine Rotating Structures
  - Customer Management
  - Procurement – account manager
  - X-ray Computed Tomography (CT) technician and NDT

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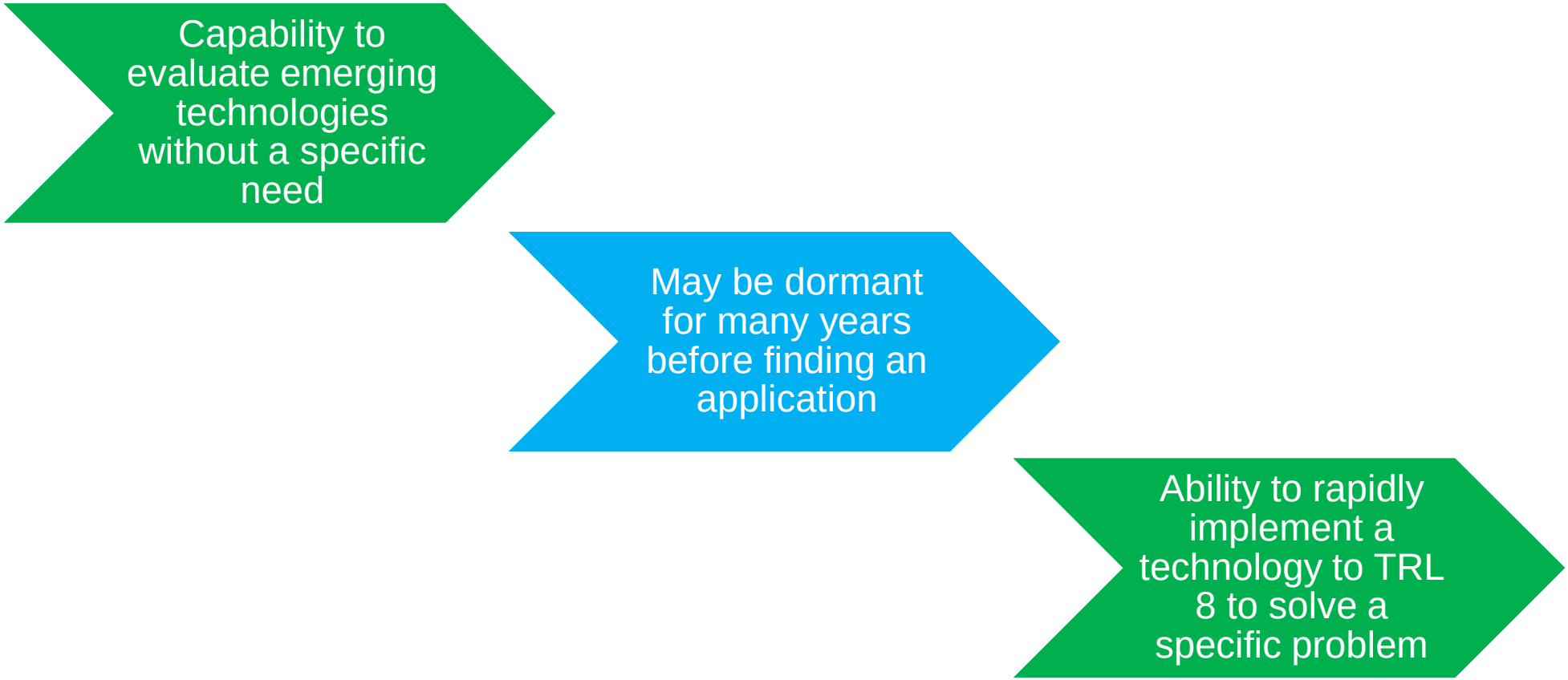
Technology Readiness



- X-ray Computed Tomography (CT). First CT scanner installed at P&WC over 20 years ago.

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Technology Readiness (TR)

- Some other NDT technologies evaluated over the years….
  - Remote Acoustic Impact Doppler (RAID)
  - ***Resonant Ultrasonic Spectroscopy (RUS) (1994)***
  - Alternative Current Potential Drop (ACPD)
  - Sonic IR / Thermosonics / Vibrothermography
  - …..

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PRODUCT | COLLABORATION | PROCESS

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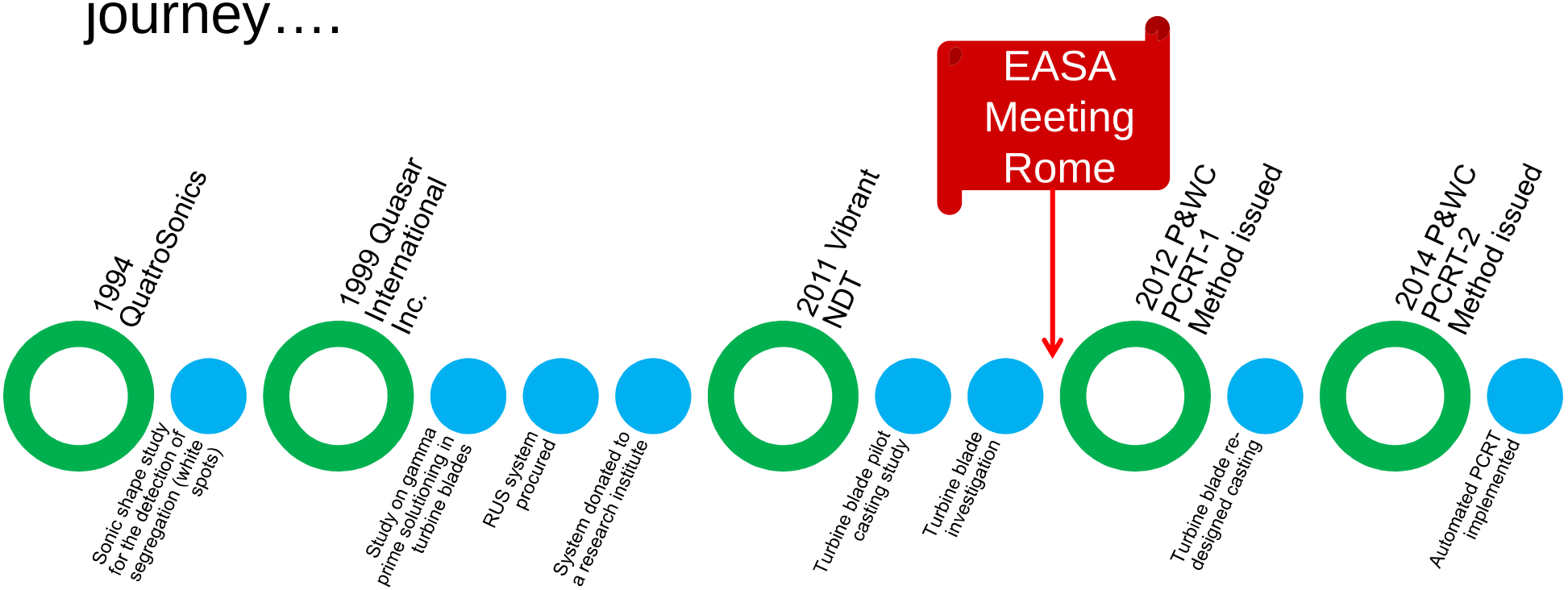
Technology Readiness (TR)

- Resonant Ultrasonic Spectroscopy (RUS) / Process Compensated Resonance Testing (PCRT) a 22 year journey….



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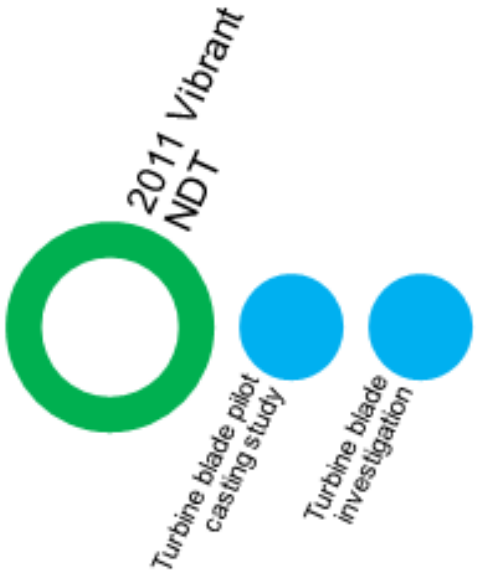
Case Study…initial mandate…



- Systemic issue with turbine blades related to various casting flaws
- Eliminate unique casting flaws that are not detected by current inspection methods that result in quality escapes. These include, but are not limited to, cold shots, non-metallic inclusions, non-homogeneous material, under min. wall thickness, aluminum rich layer, etc.

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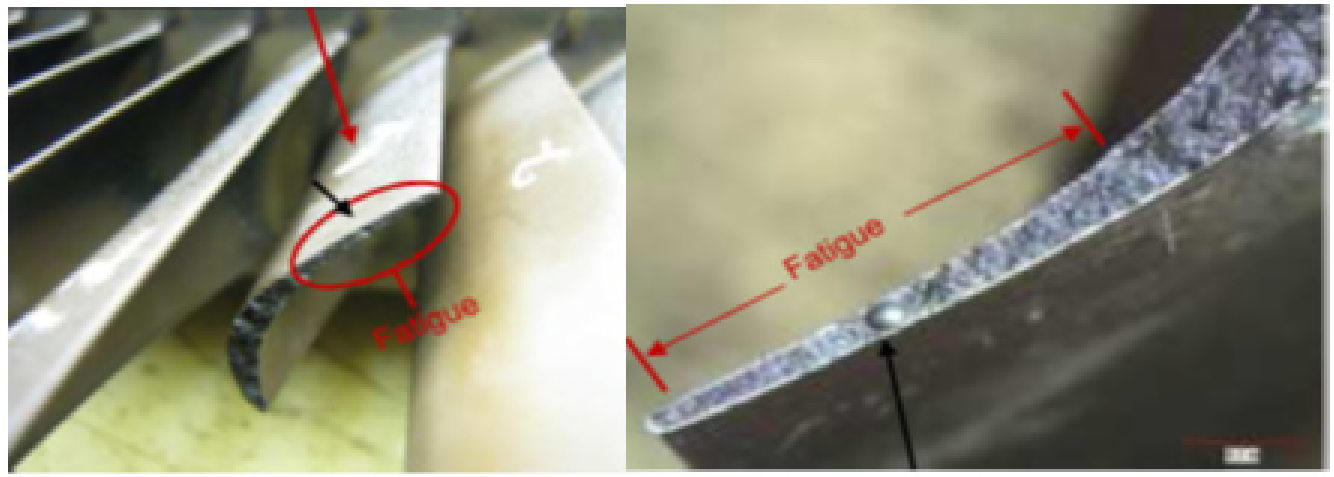
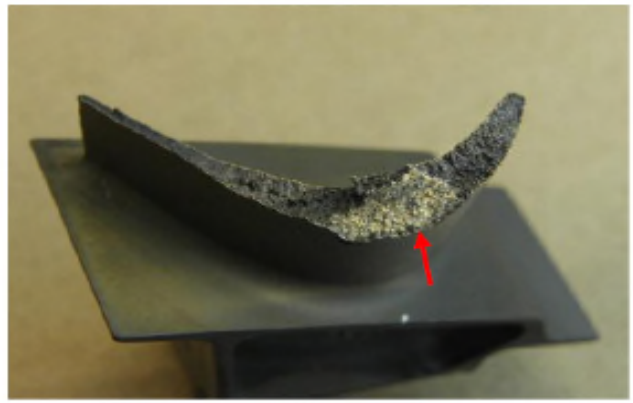
Typical casting anomalies



Cold Shot



Non-metallic inclusion

Sinuous interdendritic casting anomaly

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TR link…

- Connection made back to the early 90's RUS work – full part inspection, quick, sensitive to material flaws, etc.

- Vibrant contacted and technology had matured significantly to Process Compensated Resonance Testing (PCRT)

  - Allows for normal process variation while still detecting target defects
  - Population characterization identifies outlier parts with singular defect conditions
  - Quantifiable output monitors part flow over time to show process or component drift outside of the norm

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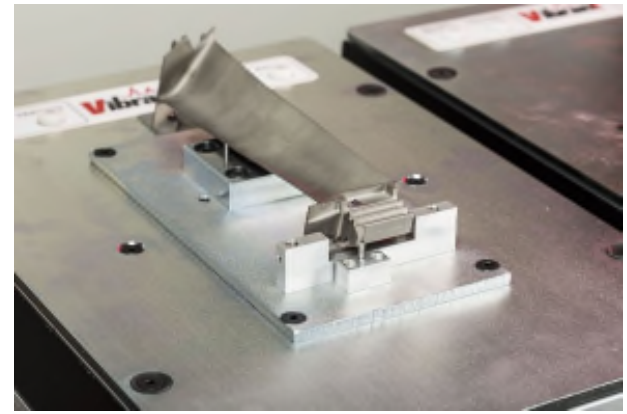
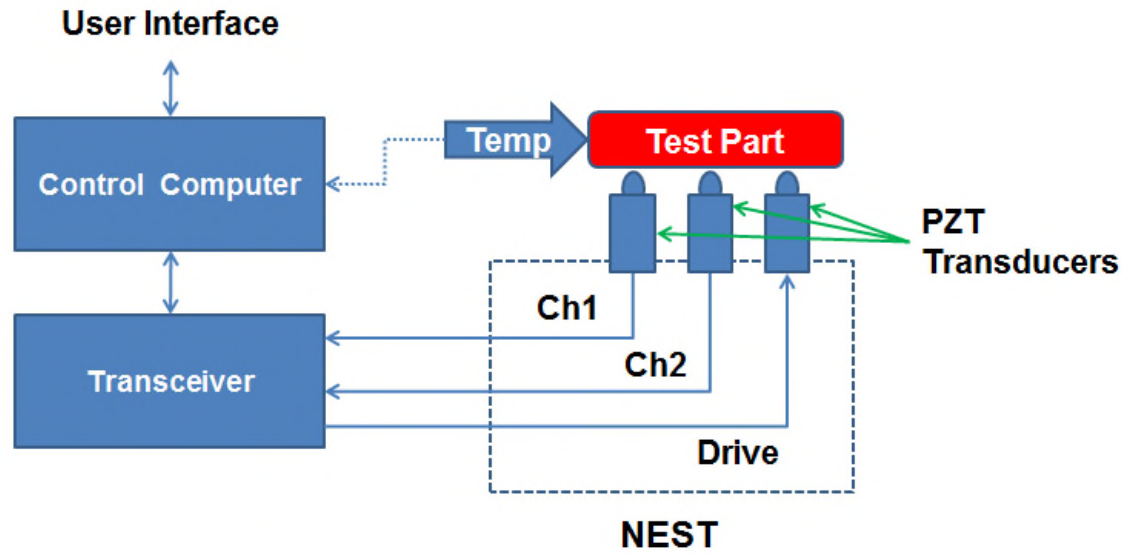
PCRT system





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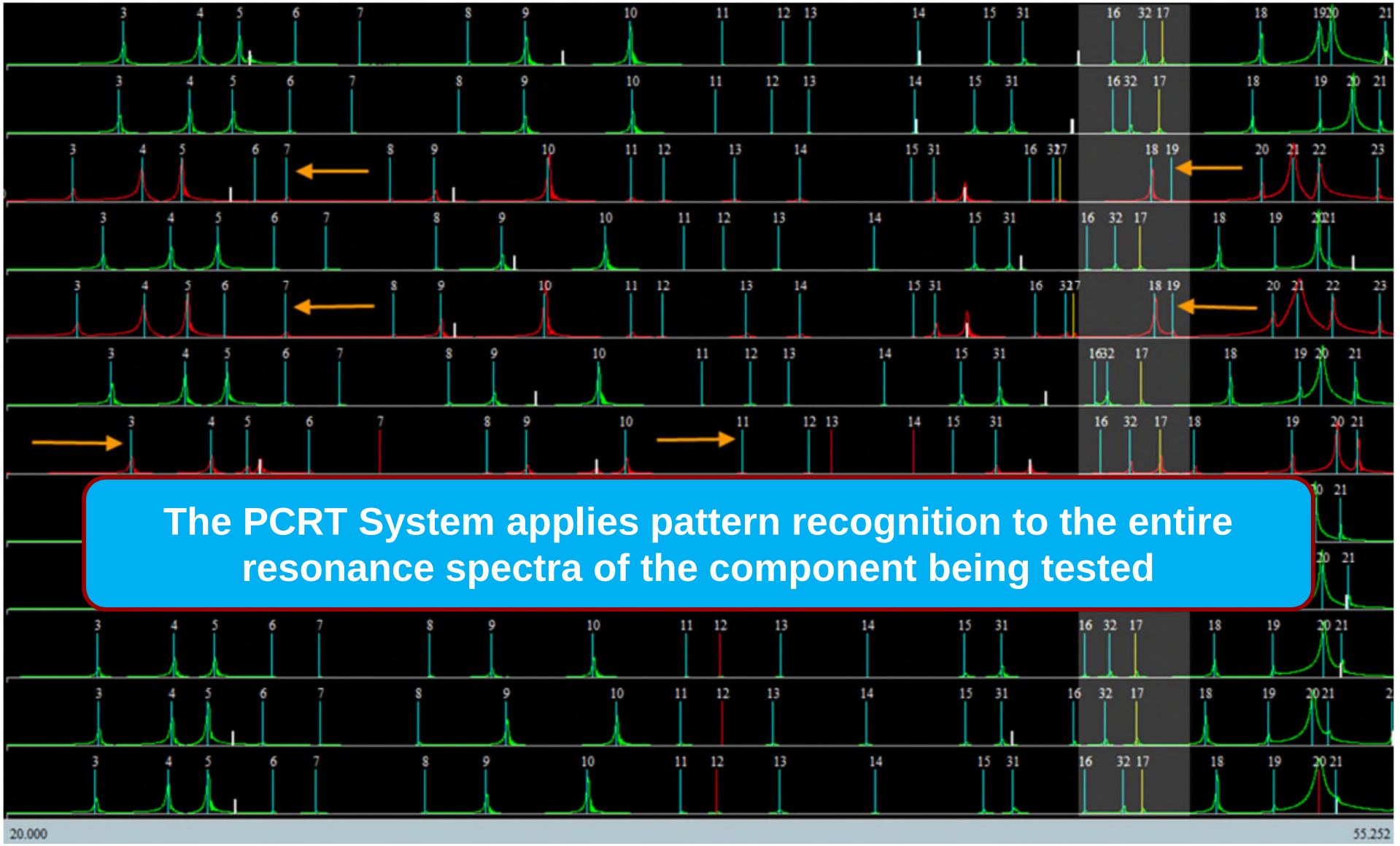
Typical resonance spectra



The PCRT System applies pattern recognition to the entire resonance spectra of the component being tested

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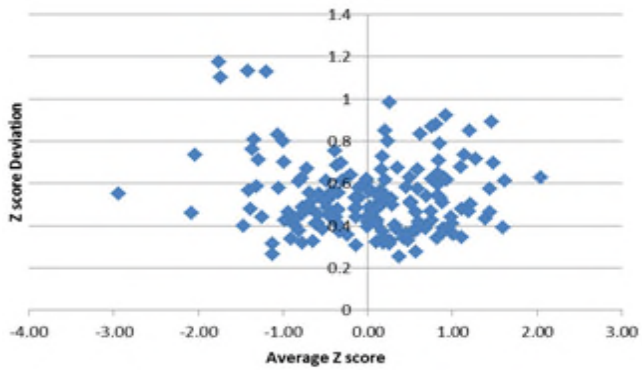
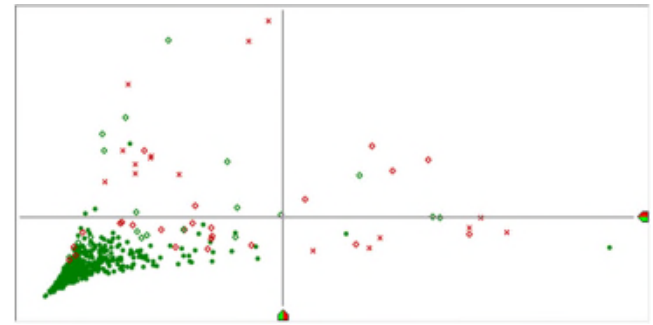
PCRT
Analysis Tools

Z-Score
Method
Outlier Screening / Process Monitoring



VIPR
Method
(Targeted Defect)



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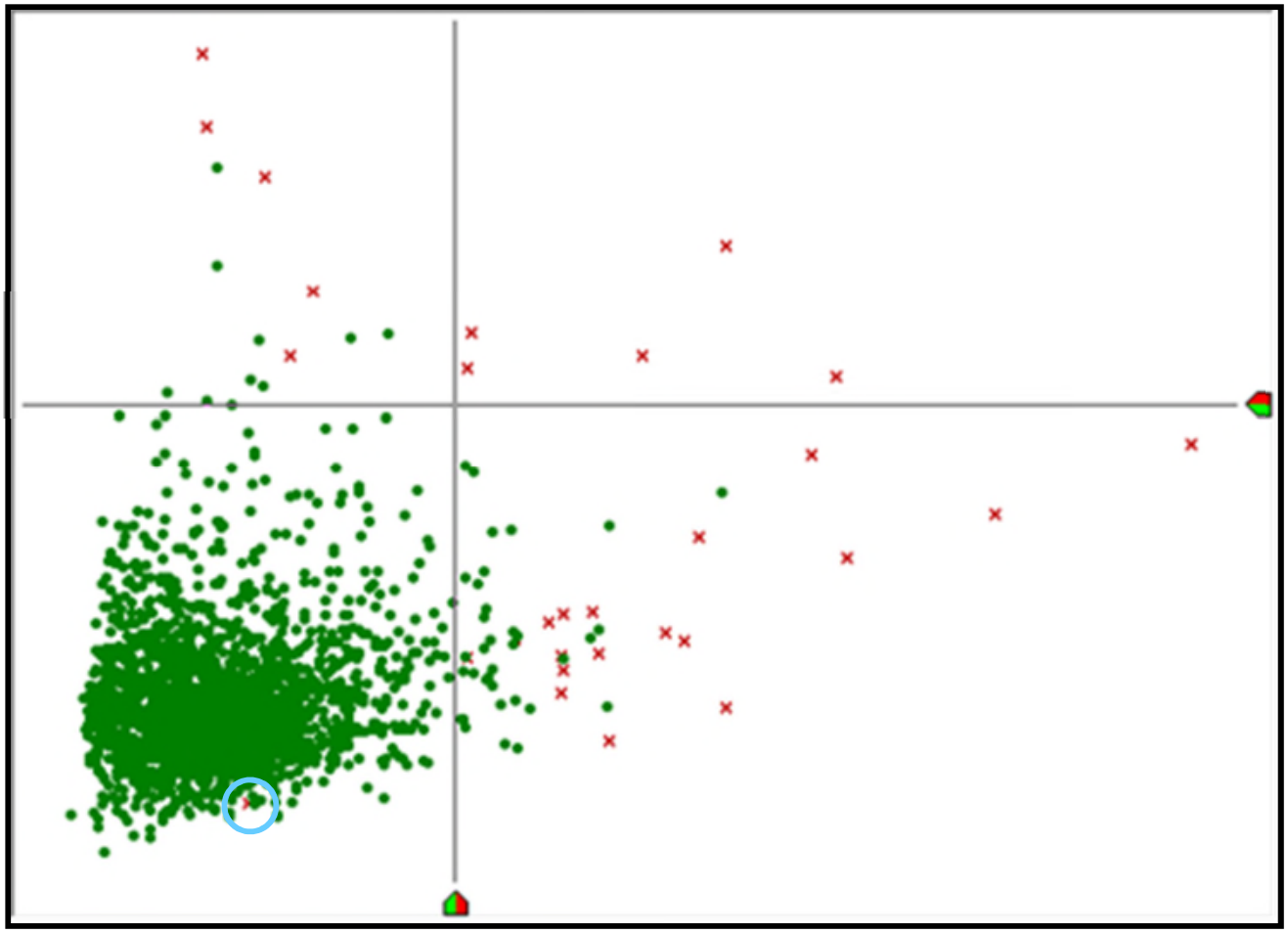
Casting pilot study

- 2400+ castings inspected
- VIPR sort had relatively good correlation with x-ray inspection data
- < 10 second inspection per casting



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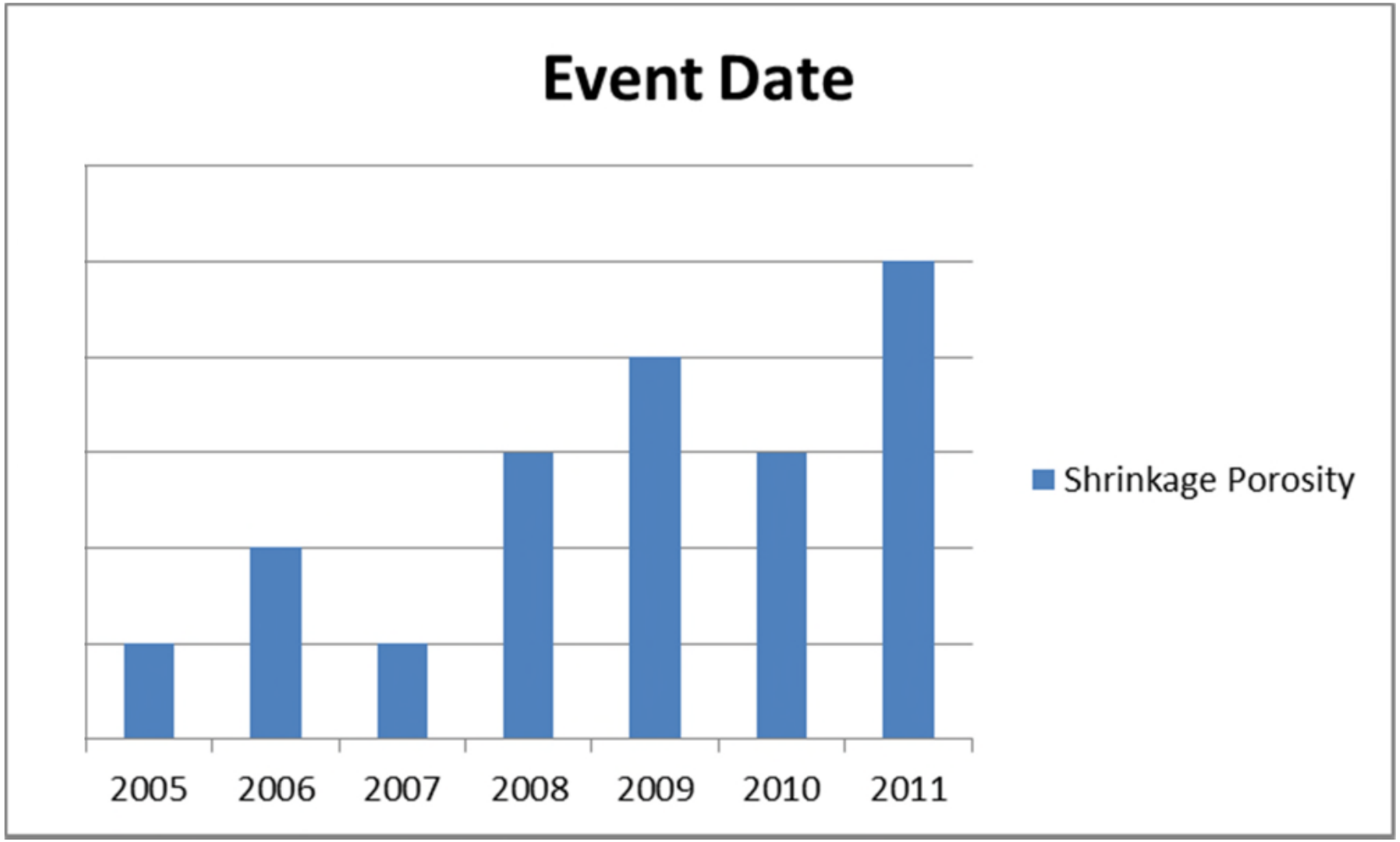
Quality issue attributed to shrinkage porosity



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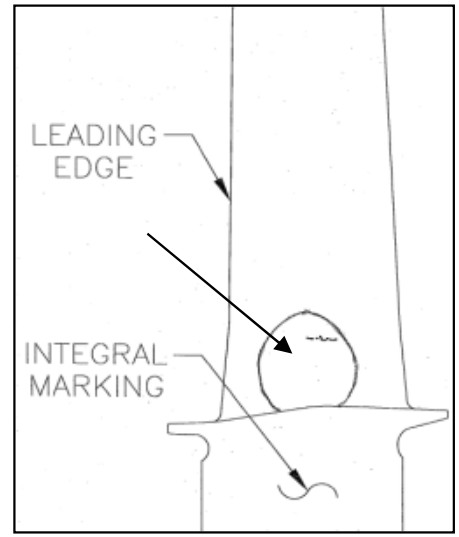
X-ray film review

- Review of production x-ray film (where available) of the casting revealed two issues –
- Shrinkage porosity in the vicinity of the blade pocket not detected during x-ray inspection
- Shrinkage porosity indication on the x-ray film but missed by the inspector
- 40% / 60% ratio



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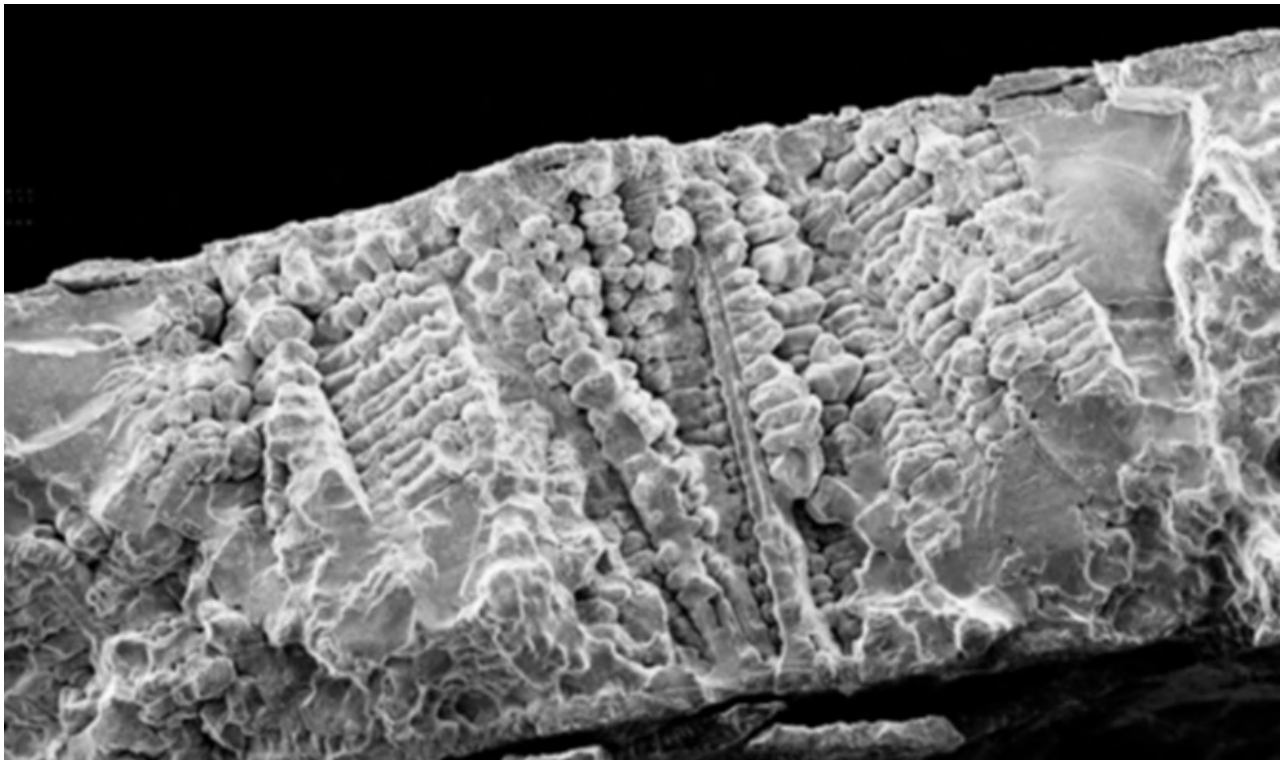
Shrinkage porosity



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Shrinkage porosity

- Equiaxed casting
- Shrinkage porosity difficult to detect and interpret using conventional film (orientation, grain diffraction (mottling), etc.)
- Digital Radiography (DR) and X-ray Computed Tomography (CT) utilized to select blades for VIPR training

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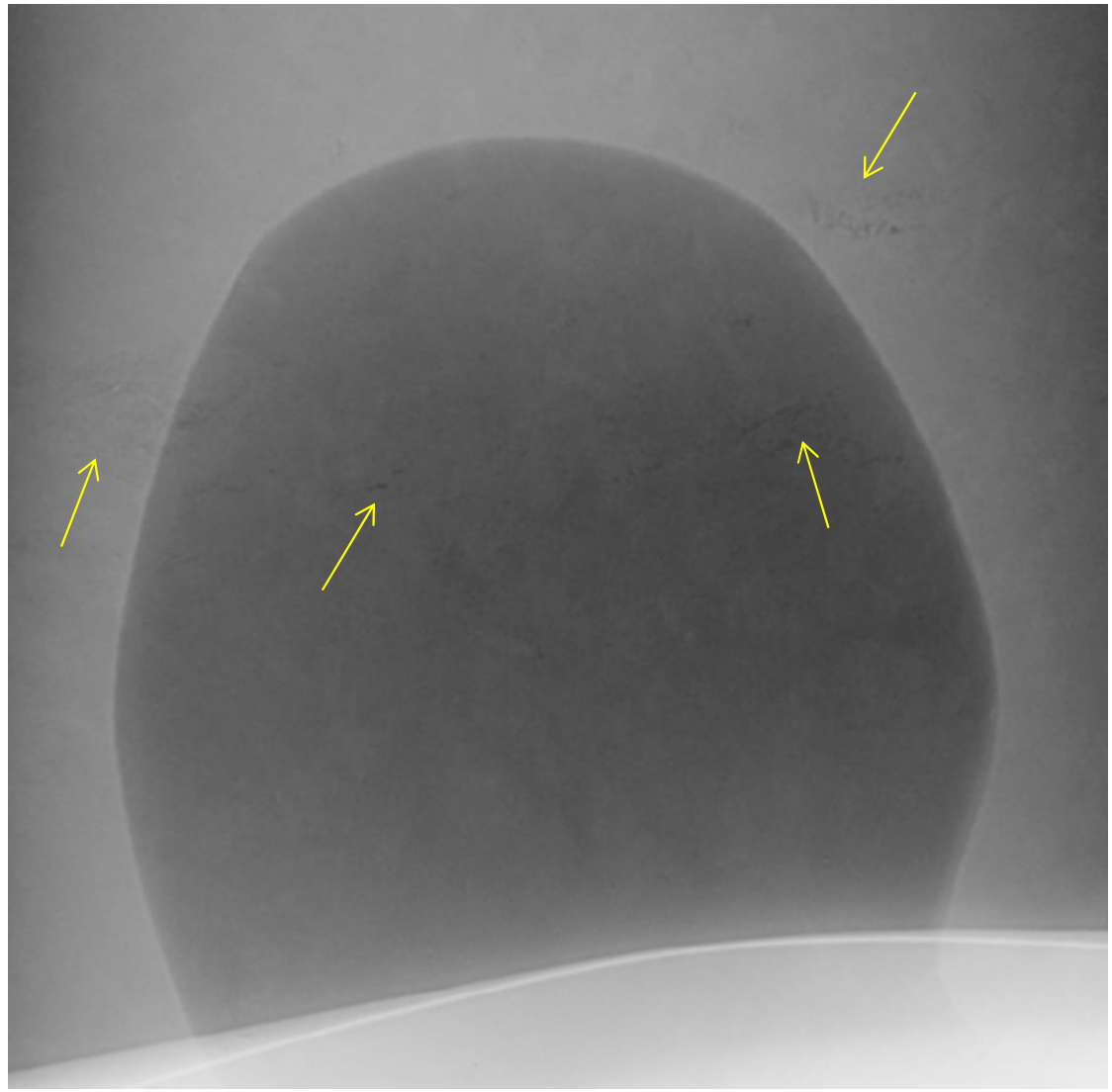
Shrinkage porosity

- DR Image



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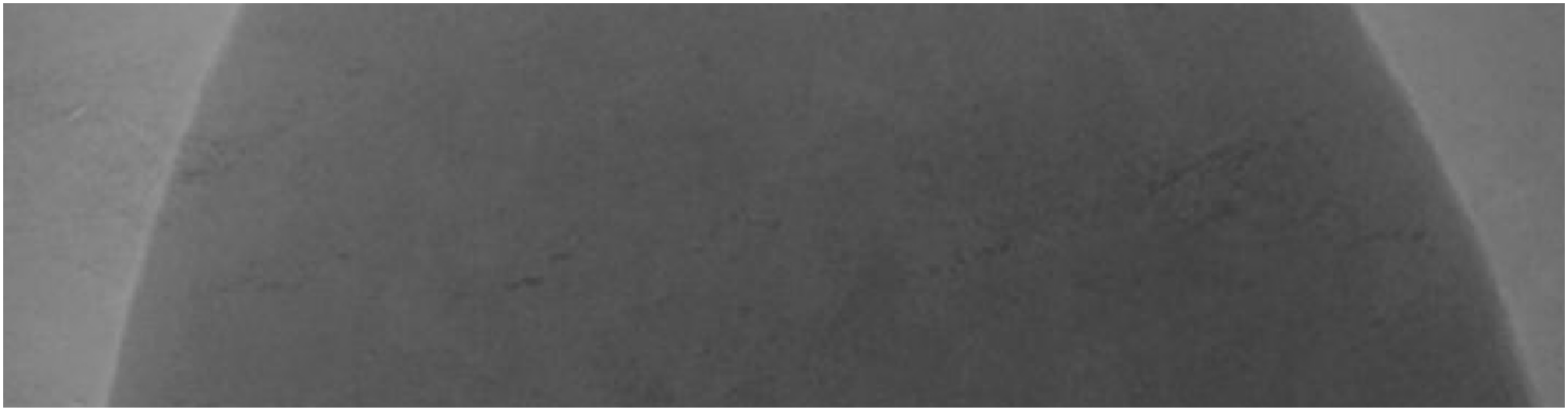
Shrinkage porosity

- DR Image



- Classified as “heavy” shrinkage porosity

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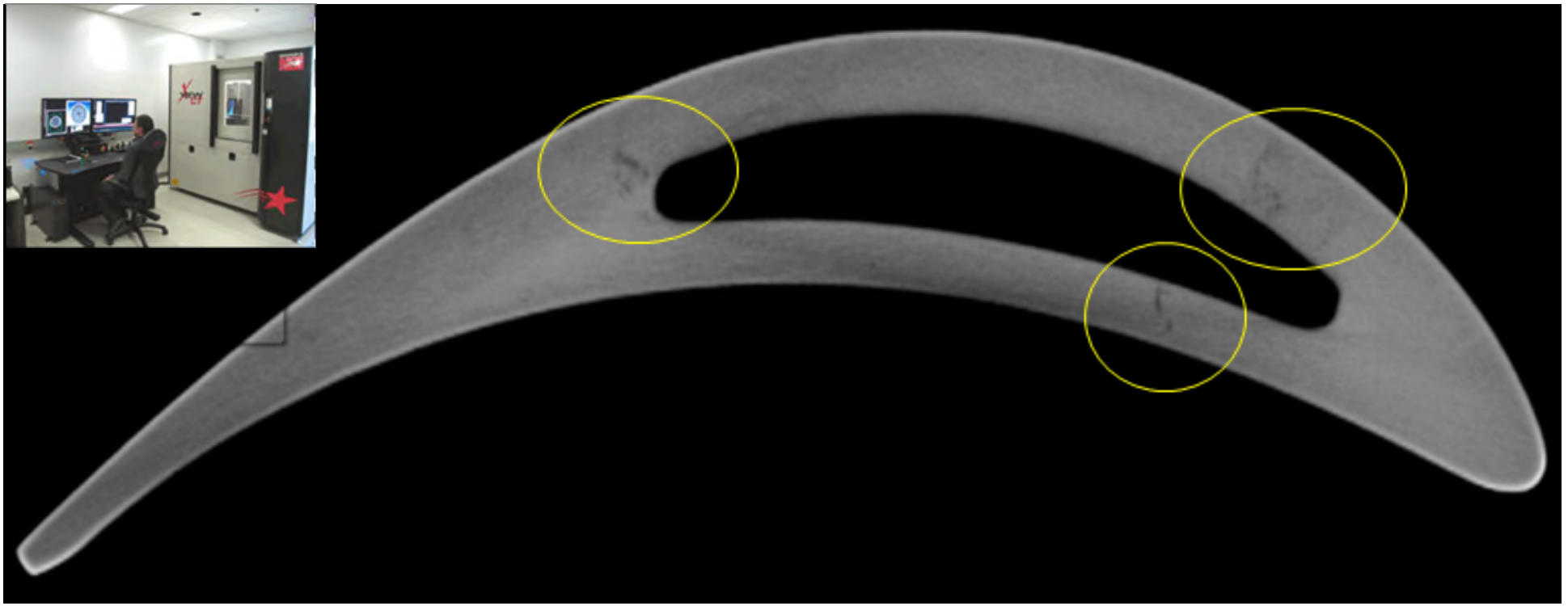
Shrinkage porosity

- CT slice



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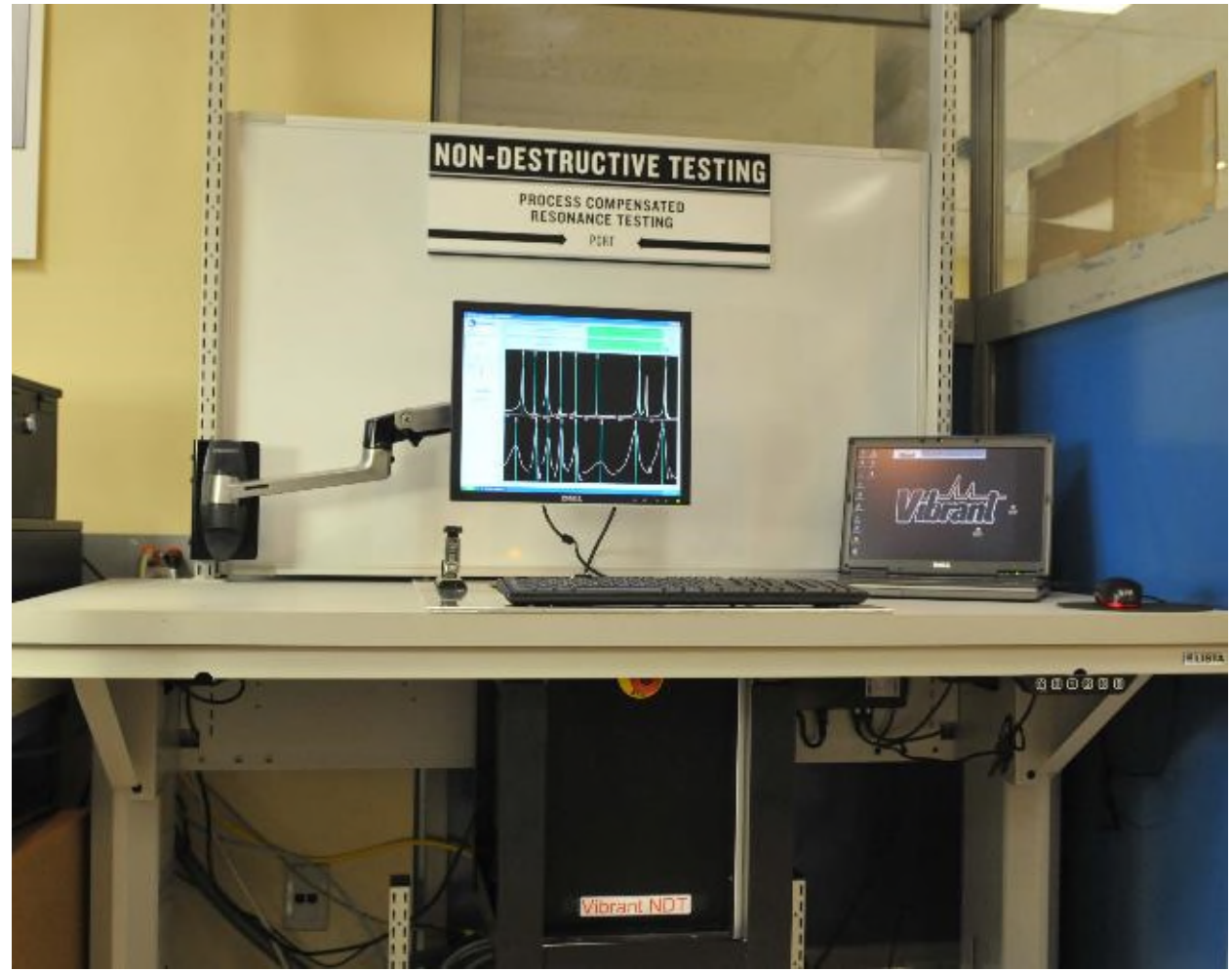
PCRT inspection booth

- P&WC PCRT production inspection set-up
- Inspection service P&WC / Vibrant
- >140,000 blades inspected to VIPR



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VIPR progression (6 off)

- VIPR progression (6 off)

VIPR Rev 1-4

- Train to small number of confirmed defects
- Use conservative limits with lower yield to immediately quarantine suspect blades
- Yield 70-90%

VIPR Rev 5-6

- Further examine severity of defects relative to population
- Align targets with engine field performance data
- Re-test quarantined components
- Yield 95+%
- 7000 blades scrapped

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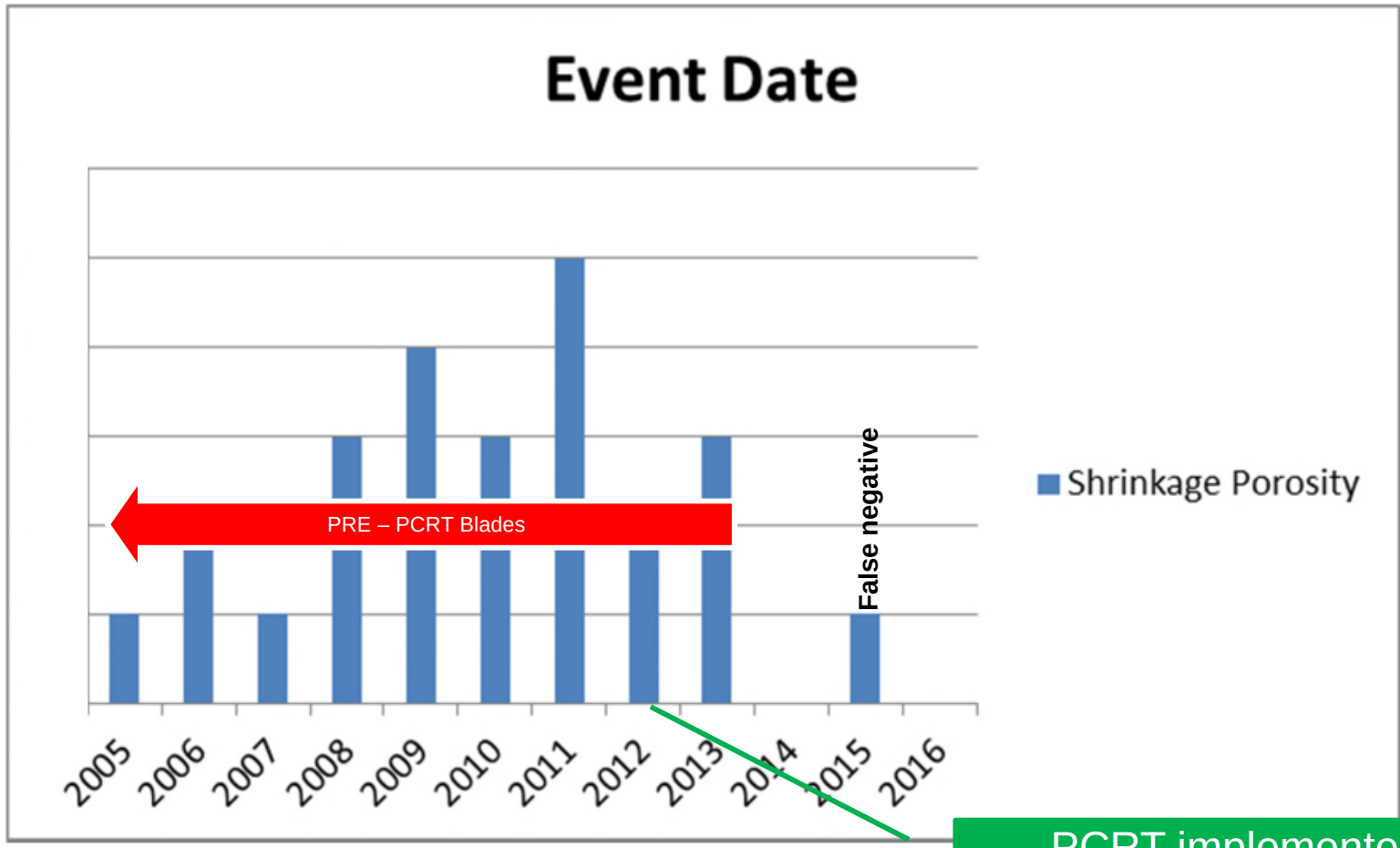
Event rate reduction

- Latest field data attributed to shrinkage porosity – 1 false negative (Rev 1 VIPR). Two post PCRT lead-the-fleet engines at over 6000hrs



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Casting re-design

- In conjunction with the inspection activity, Engineering initiated a re-design of the casting

- Result: Improved creep life in the airfoil

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Statistical Process Control (SPC) using PCRT

- Since re-design: Automated production process monitoring of castings
- Z-score
- Incorporates a vision system for reading of the casting S/N (reduced human factor)
- Approx. 51,000 castings tested to-date
- Reject rate < 1.0%

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Statistical Process Control (SPC) using PCRT

Vibrant Robotic System Video

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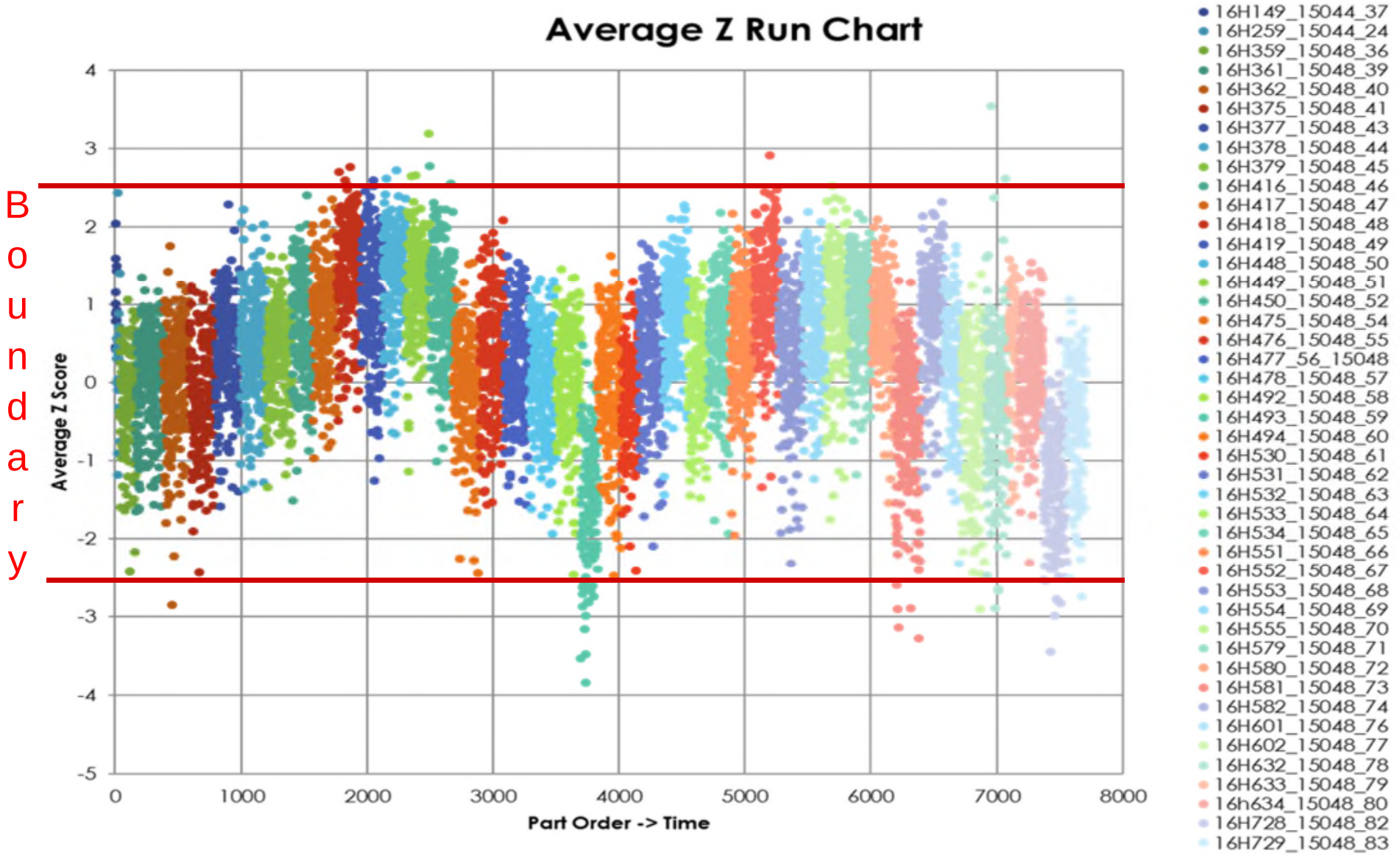
Statistical Process Control (SPC) using PCRT



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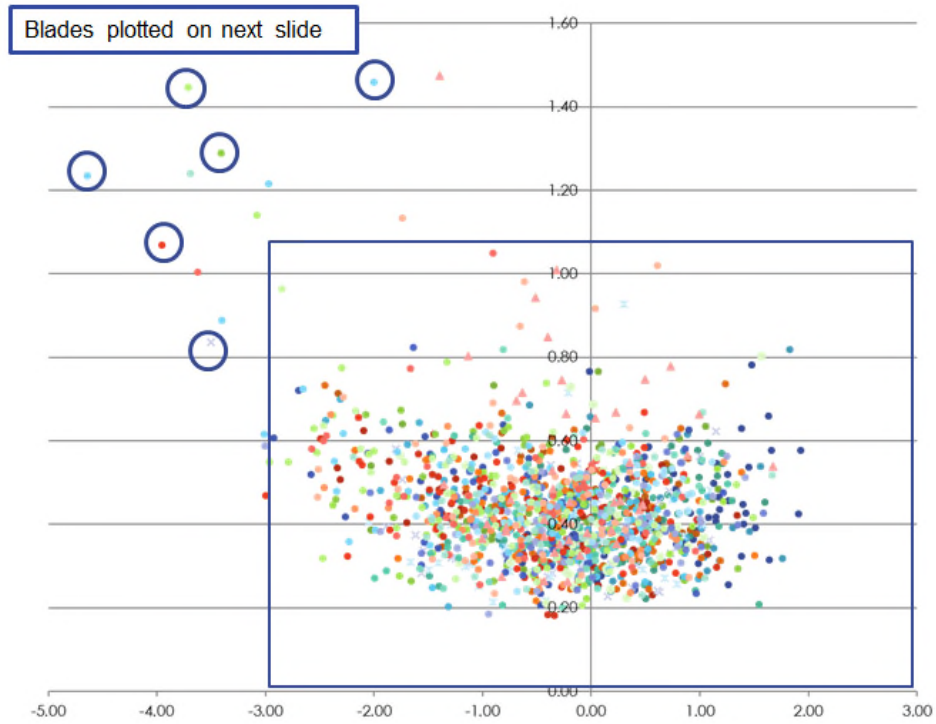
PCRT – emerging trend related to dimensional variations in blade castings

- Other limited studies are trending towards a dimensional variation in the blade profile of PCRT Outliers



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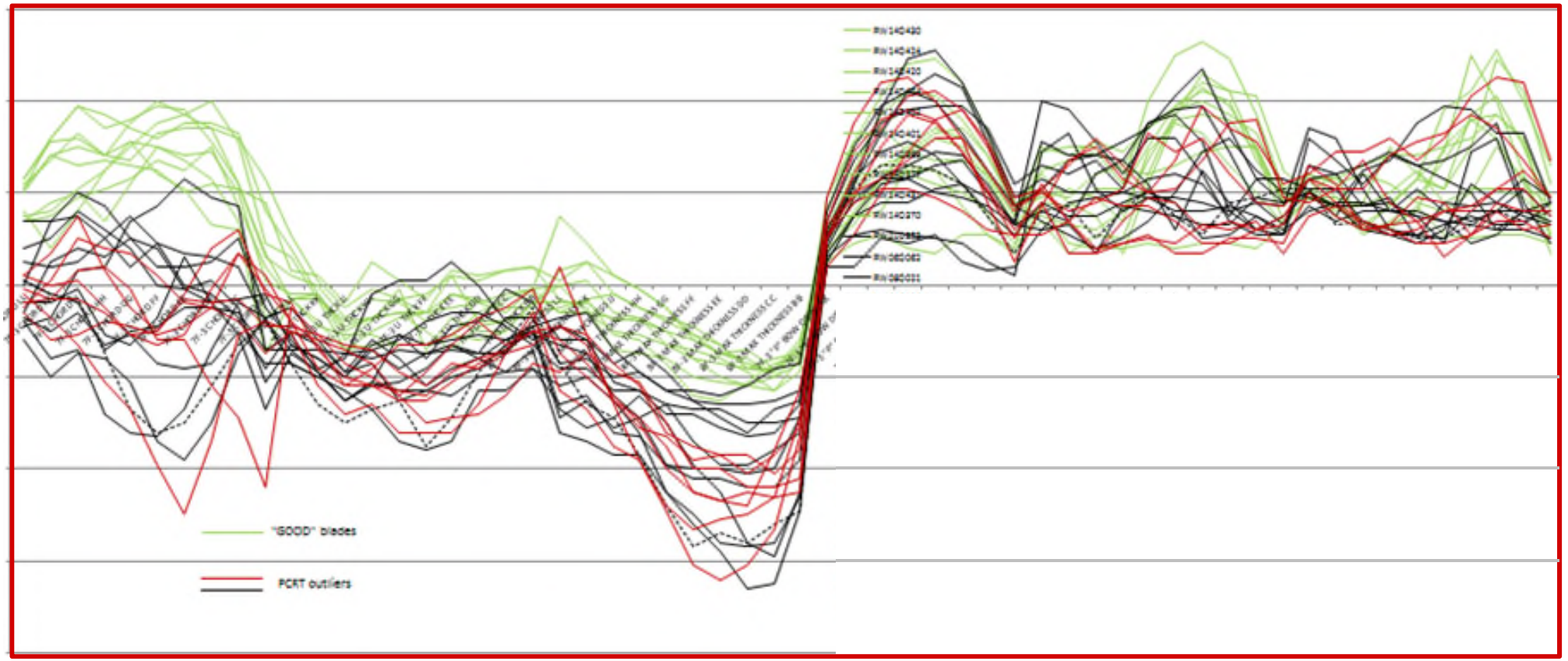
PCRT – emerging trend related to dimensional variations in blade castings



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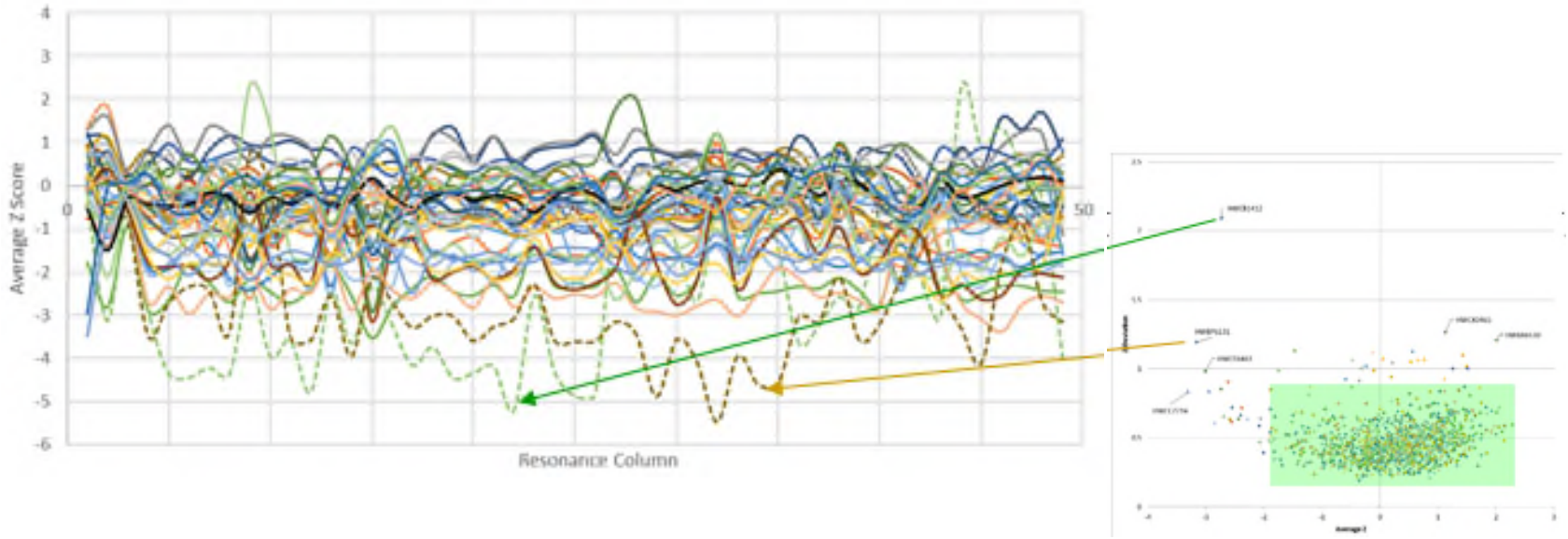
PCRT – the dilemma, quandary, predicament or impasse….



- In some cases, cause of resonance Outlier signal cannot be conclusively identified
- Relate this resonance difference to blade performance in an engine

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The TR Advantage

TRL 1-6

- Initial evaluation of technology in development mode
- 3222 casting study - showed sensitivity to X-ray indications

TRL 6

- Testing on real parts
- Additional inspection gate quickly established to protect the field
- VIPR 1

TRL 7

- First engine to test
- VIPR 6 established to better align with performance data

TRL 8

- Production implementation
- Z-score SPC on re-designed casting

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Summary

- Need to be pro-active and evaluate emerging NDT technologies in a controlled manner away from the extreme pressure of a production or field inspection need – Technology Readiness

- Using Technology Readiness history P&WC was able to rapidly implement a PCRT inspection process that met the expectation of the various aviation regulatory bodies thus allowing the fleet to continue flying

- NDT is no longer just an inspect tool. It contributes significantly to the value stream and life cycle management of gas turbine aircraft engines on a daily basis

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