The Future of NDT and the Upcoming Paradigm Shift

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Purpose

- New technologies => Innovative , “game-changing” with amazing sensitivities, archiving ability.
- Material properties – Bossi (2012)
  - Overtemp microstructure in turbine blades.
  - Grinding burns through chrome.
  - Bond strength.
- Technology is easy part; Persuasion difficult. WHY?
- Comfort-zone mindset.
- Traditional, established NDT protocols don’t fit new technologies (i.e., ‘box’).
  - Defect definition.
  - Calibration.
  - Validation (POD).
  - Training & Qualification.
  - Guidance issues.
  - Ownership of problems.

- We must adapt our protocols in order to utilize the next generation of NDT.

We must alter our thinking to move forward.

Comfort-zone Mindset

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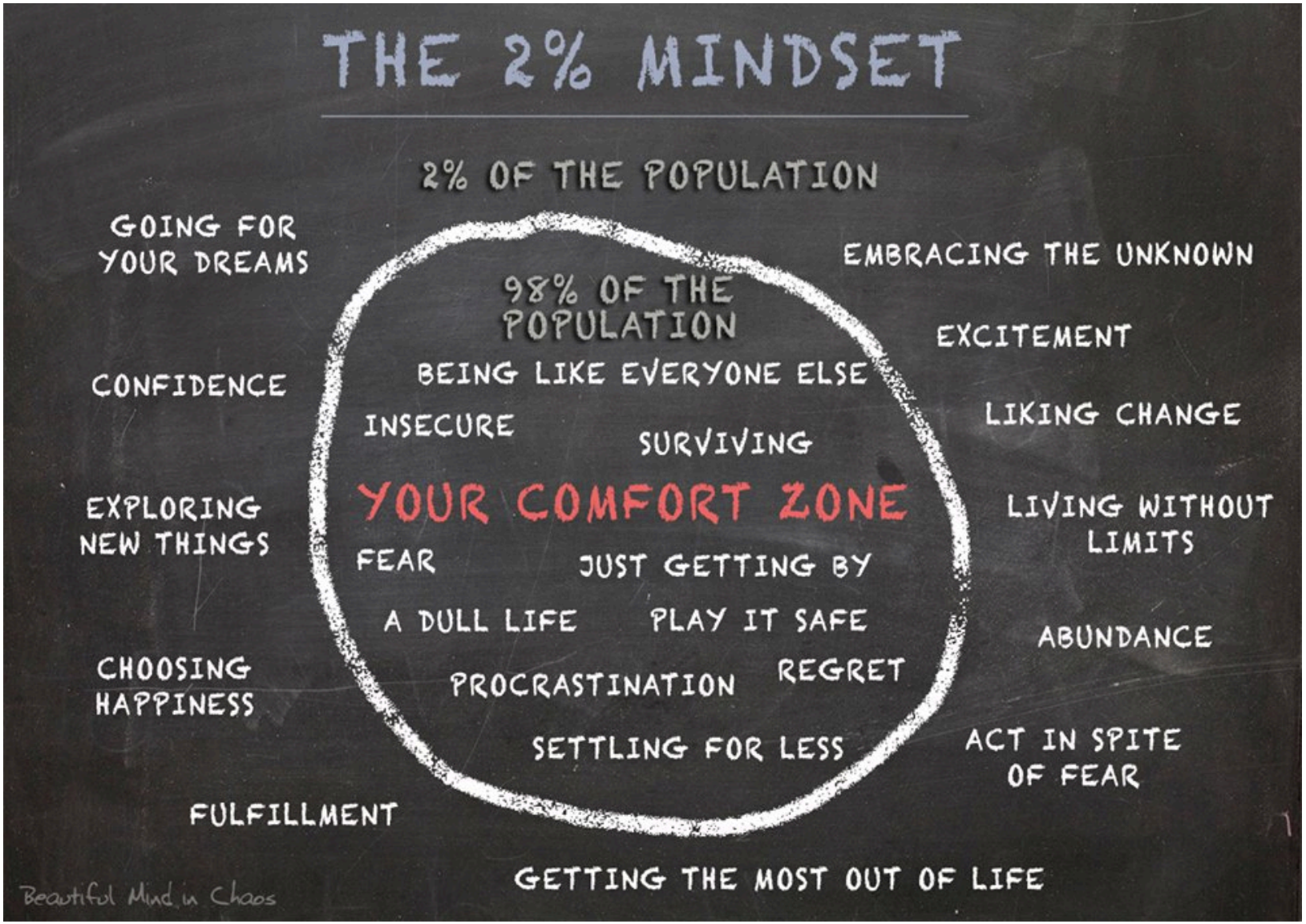


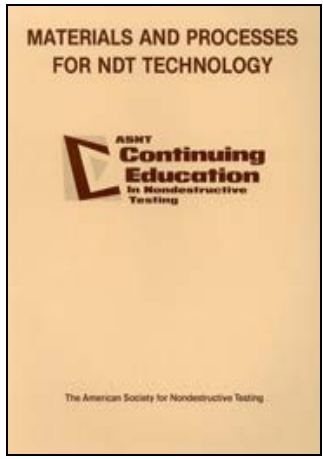
Courtesy: imgur.com

Issue #1 – Defect Definition

- Hypnotized into traditional defect definitions => crack, corrosion, etc..

– Increased use of composites brings new defect types.
  – Industry effort to educate, inform community.

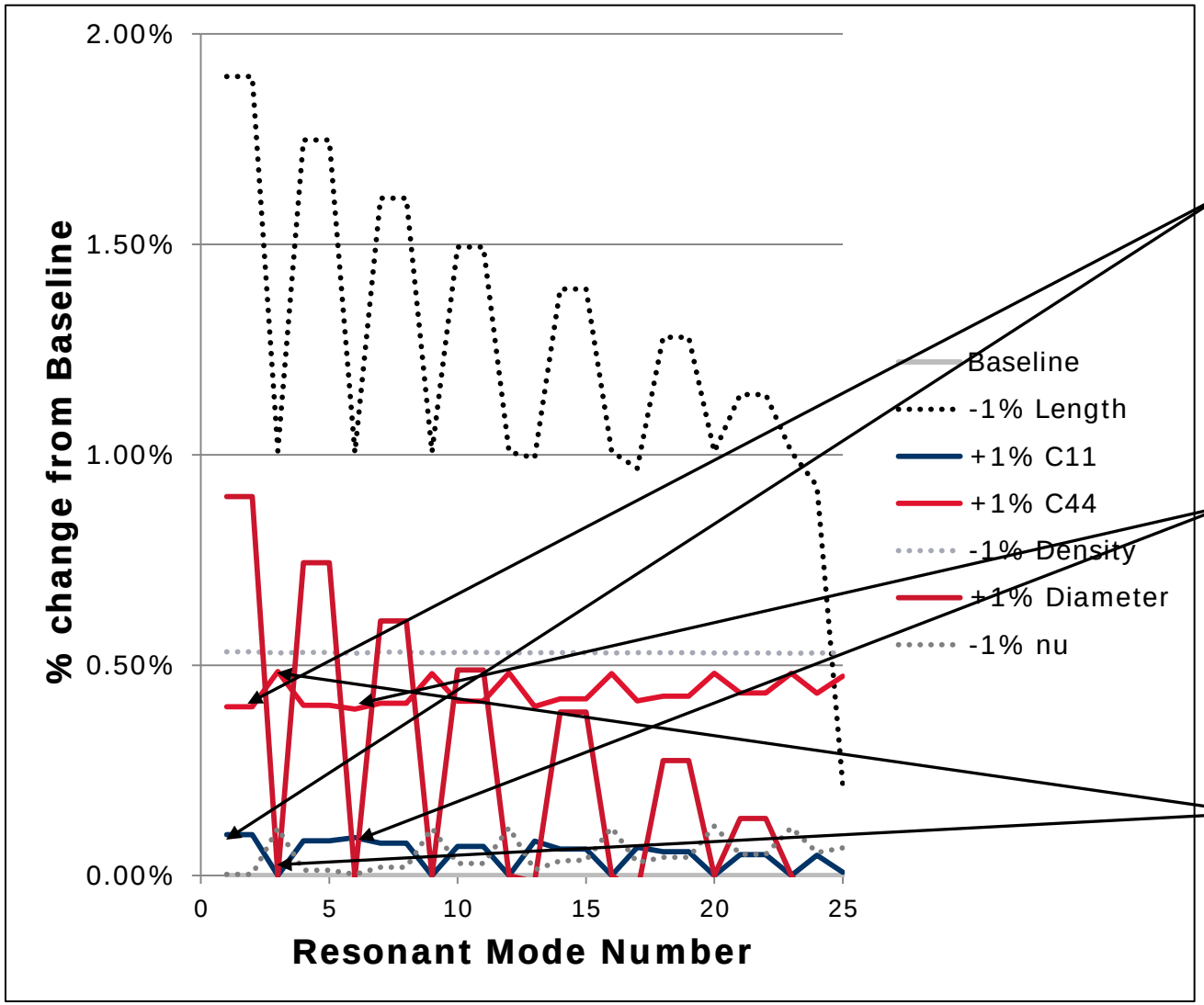
- Strive for fuel-efficiency drives increased need for vigilance.
  – Hotter engines, thinner materials.
  – Heat damage in composites, landing gear parts.
  – OEM designs assume ability for quality.

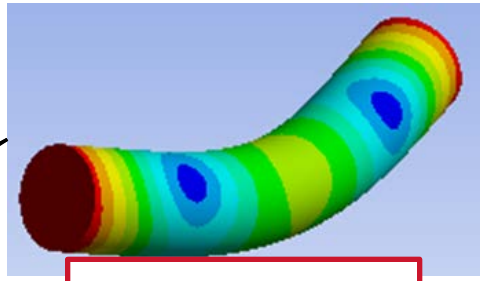


- Desire for MTC savings means part 'out' longer.
- PMA parts = meet dimensional, visual = good to go.
- Now defects include 'overtemp' microstructure, disoriented grains (Directionally solidified alloys), grinding burns, carbide precipitate clustering, resonance modes.
- New technologies capable of finding of finding these defects (Barkhausen Noise, PCRT, etc.).
- Fly 'excrement' in pepper?

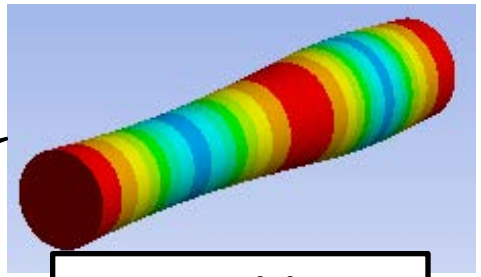
Industry now can go after non-traditional defects.

Resonant Modes - Important

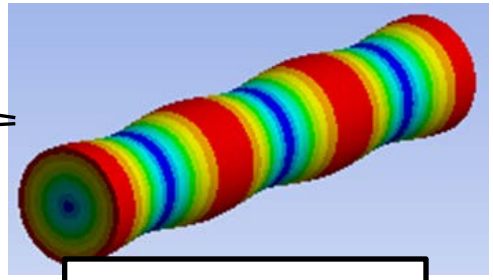




Bending



Breathing

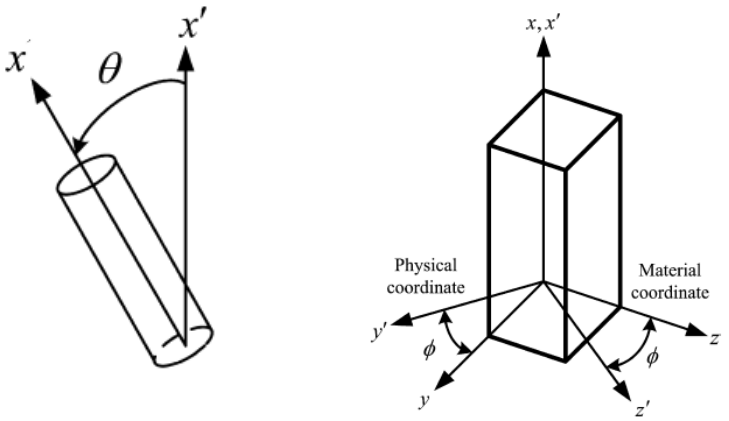


Torsional

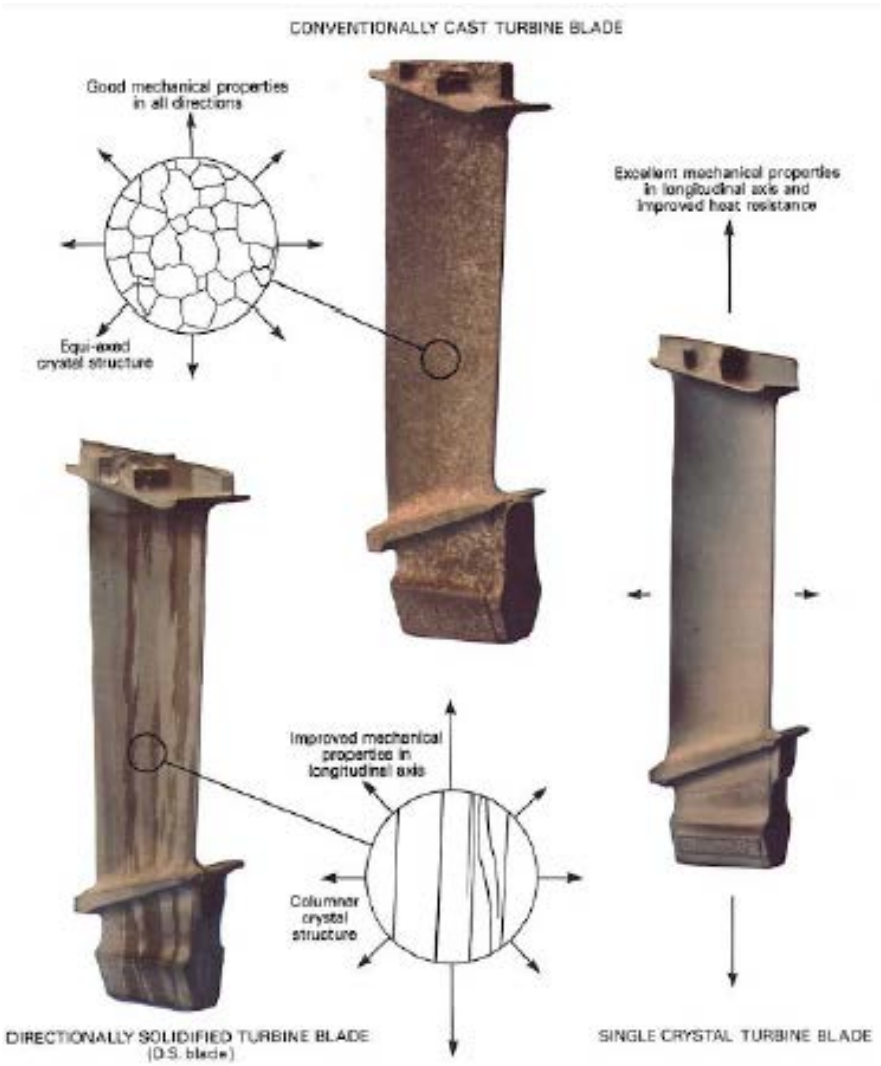
PMA parts ‘pick and choose’ resonant mode verification.

Superalloys – microstructure defects

- UCSB – Modeling work
  - Estimate elastic constants
- Affects Modulus
  - Can be detected with PCRT
- Recent finding of single crystal turbine blade with issues
  - Solidification flowlines



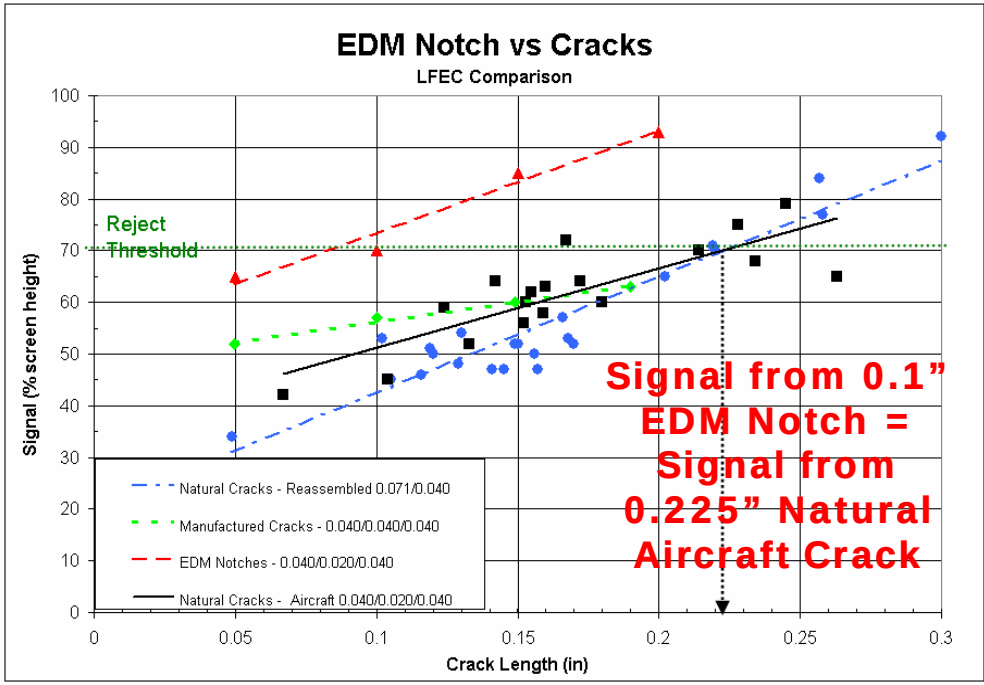
*C-M Kuo, “Effects of Disoriented Grains on the Elastic Constants of Directionally Solidified Superalloys”, 2007



Microstructure ‘errors’ can affect part life.

Issue #2 - Calibration

- Years of “false calibration” ingrained into industry protocol.
  - FBH/EDM notch not representative of actual defect you are looking for.
  - 2006 Bode/Piotrowski paper – EDM Notch/Manufactured crack/Real crack.
    - Detectability difference!

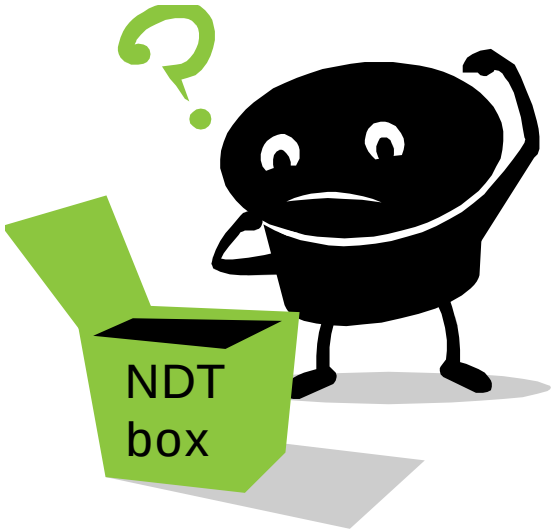


- OEM Guidance is key =>
  - What do we need to find?
- OEM proprietary or “sole source”
  - Faux cost hurdle.
- EX: CVM Sensors => “Continuity check” vs “calibration with known defect”.
- EX: Barkhausen Noise for heat damage through chrome.
  - Slow implementation due to lack of ref. std. (Conflict between Boeing and SAE document).
    - Now in Boeing NDT Manuals.

What do we need to find?

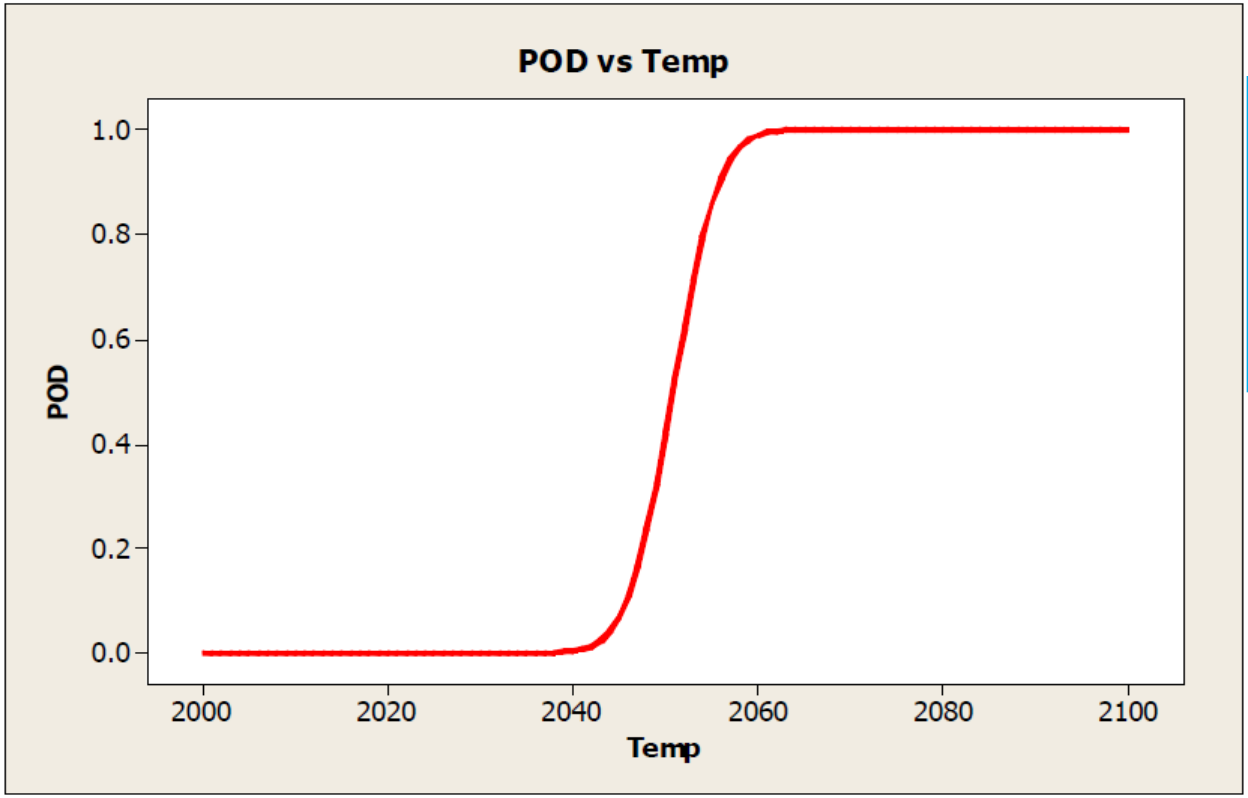
Issue #3 – Validation/POD

- How to apply validation criteria developed for legacy methods to novel methods?
- Sonic IR work (Sandia/Wayne State/Siemens/FTT).
- Remote vision – high resolution borescopes using traditional optics standards; how to reconcile?
- Barkhausen Noise – Grinding burns, but not yet cracked?
- MAPOD (Model Assisted Probability of Detection) efforts may help.
- Not crack length, but 'affected area'?
- Signal-to-Noise is the key!



Capable of finding defects – what now?

PCRT – POD for Overtemp



NM Small Business Admin – Validation of Process Compensated Resonance Testing (PCRT) for Detection of Overtemperature Condition in Jet Engine Fan and Turbine blades
Final Report
January 7, 2011

Table 1. Gage R&R Results for PCRT of JT8D T1 Blades for Over Temperature Condition.

Source of Measurement Variation	Variance	%Contribution of Variance
Total Gage R&R	0.00757	0.33
Repeatability (System)	0.00717	0.31
Reproducibility (Operator)	0.00040	0.02
Part-to-Part	2.31303	99.67
Total Variation	2.32060	100.00

Sandia attempted POD, Gage R&R study for OT.

Issue #4 – Personnel/Training

- Legacy Training and qualification schemes may not adequately address emerging, novel methods.
- Traditional organizational hierarchies were developed with six principal methods (ET, MT, PT, UT, RT & IR/TIR) in mind.
  - Inspection vs Mtc vs Unskilled.
  - Level I Special, Level I, Level II.
- Divergent skill requirements => No skill or 'expert'.
  - Direct reading vs 'blip on screen' vs 'Phased Array scan evaluation'.
  - Workforce computer proficiency.
- How does something like PCRT fit into the scheme (Operator's see only red/green, lots of behind the curtain detail & engineering rigor)?
- ATA 105 has some language around "Emerging NDT" – but aimed at Level III qualification.
- NAS 410 has clear 'Direct read guidance', but this guidance was written in the context of traditional methods with simplified instruments in mind.
- Human Factor mitigation; More automation; Recognition Software.

Training, quals may need to be overhauled.

Drones for visual inspections?

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easyJet develops flying robots to inspect aircraft (BBC, 5/7/14)

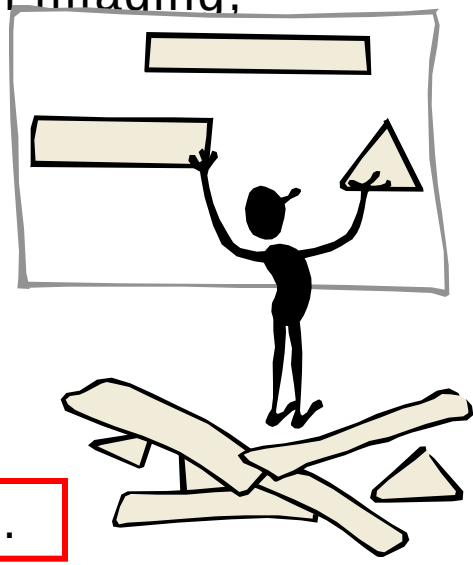
easyJet is developing drones to inspect its fleet of Airbus aircraft, and may introduce the flying maintenance robots as early as next year.

easyJet Head of Engineering:
The drones are fitted with high definition video cameras, but can also use lasers to scan the outside of the aircraft.
"We could zoom [the laser scanner] up and down the aircraft and map the surface," he said. "If we've mapped the aeroplane we can have a complete history of its full life."

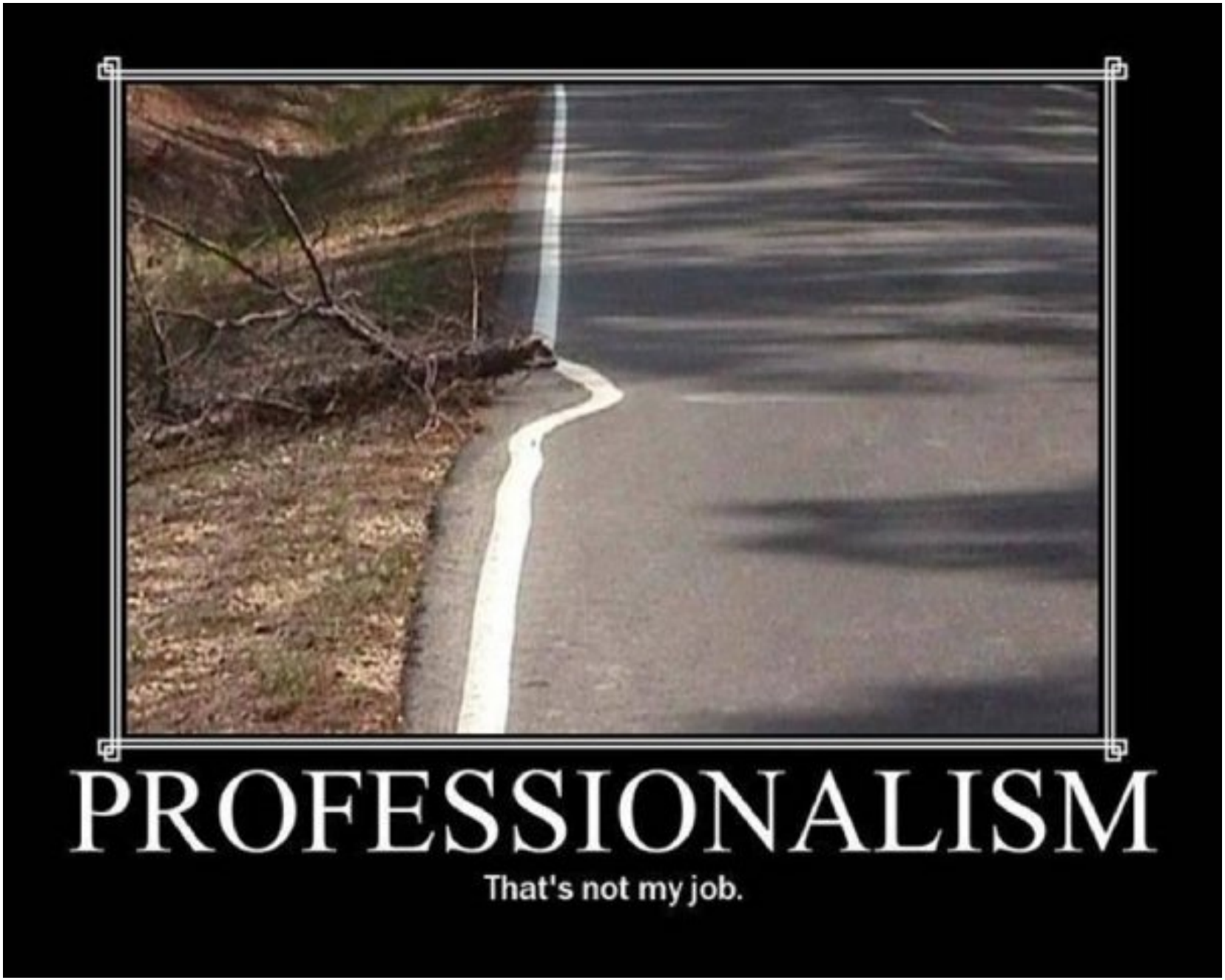
Issue #5 – Guidance

- FAA SHM program/SAE SHM working group/ Committee K.
- Decrease in OEM participation in industry committees.
  - Intellectual Property (IP) concerns or "sole source" from OEM.
  - PP OEM Participation in NDT Forum.
  - Reduction in collaboration.
    - Aloha, SUX, PNS events all promoted industry collaboration on common challenges; NOW = "I'LL DO MY THING YOU DO YOURS".

- Conflicts in industry => How do we resolve disagreements?
  - Resource constraints often lead to technology racing ahead of guidance.
- Records management & Data Archiving (ET/UT C-Scan imaging, Radiography, IR, etc.).
  - How do we leverage the capabilities?
  - How do we handle the limitations, liabilities?
  - Previous scans reviewed against current scans.
    - easyJet visual drones.
    - MAUS C-scan/ Resonance/Array Scans.
    - Process Compensated Resonance Testing (PCRT).
- OEM/FAA typically lead efforts – but not exclusive.



Path must be paved in order to progress.


PROFESSIONALISM
That's not my job.

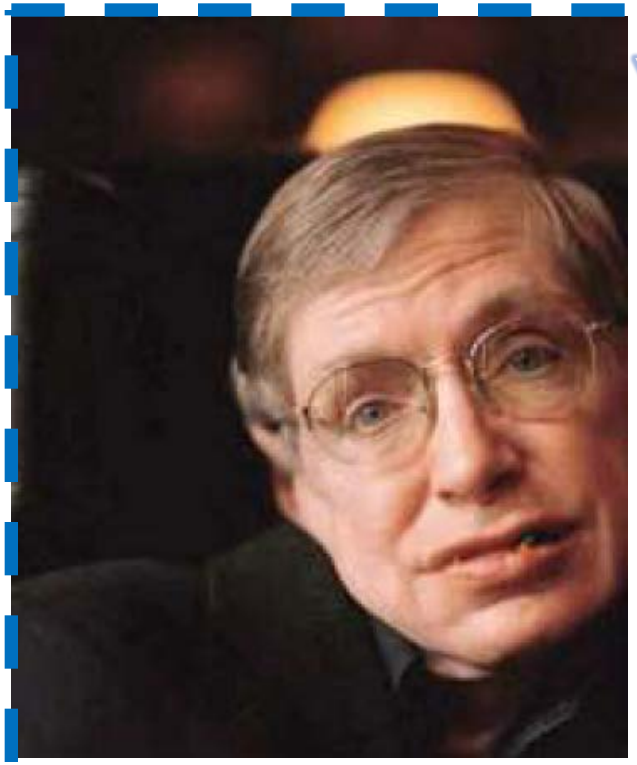
Issue #6 Ownership of Problems

- Power plant OEM's seeking greater share of life cycle product support (e.g. GE, Pratt, RR MRO's & Partner MRO's) leaving operators with limited options and increased cost.
  - Less willingness to partner, even participate in Industry Meetings.
  - Customer vs Competitor quandary.
  - Sign support contract at initial purchase or else.
- Airframe less pronounced, but Airbus, Boeing, and others are entering into strategic commercial partnerships with select MRO's.
- Airlines are stuck with 'events' and 'consequences' both financially, and technically (ATB, UER, ODI etc.).
- Airframe vs Engine philosophy.
- Components now being examined.
- Casting house issues = > before machining and OEM assembly!
- How to deal with increasingly fragmented product support environment via Sub- contractors, sub to sub etc..
  - STC issues
  - Second and third tier suppliers

United we stand, divided we fall?

Summary

- Future is here! Innovative, “game-changing” technologies.
- Comfort-zone mindset.
- Traditional, established NDT protocols don’t fit new technologies.
  - Defect definition/Calibration/Validation (POD)Training & Qualification.
  - Guidance issues/Ownership of problems.
- We must adapt or be left behind.



“Intelligence is the ability to adapt to change.”

Stephen Hawking

Questions?

KEEP CLIMBING

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