C-130J-30 Wing Fatigue Test - Test Interpretation

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July 2018

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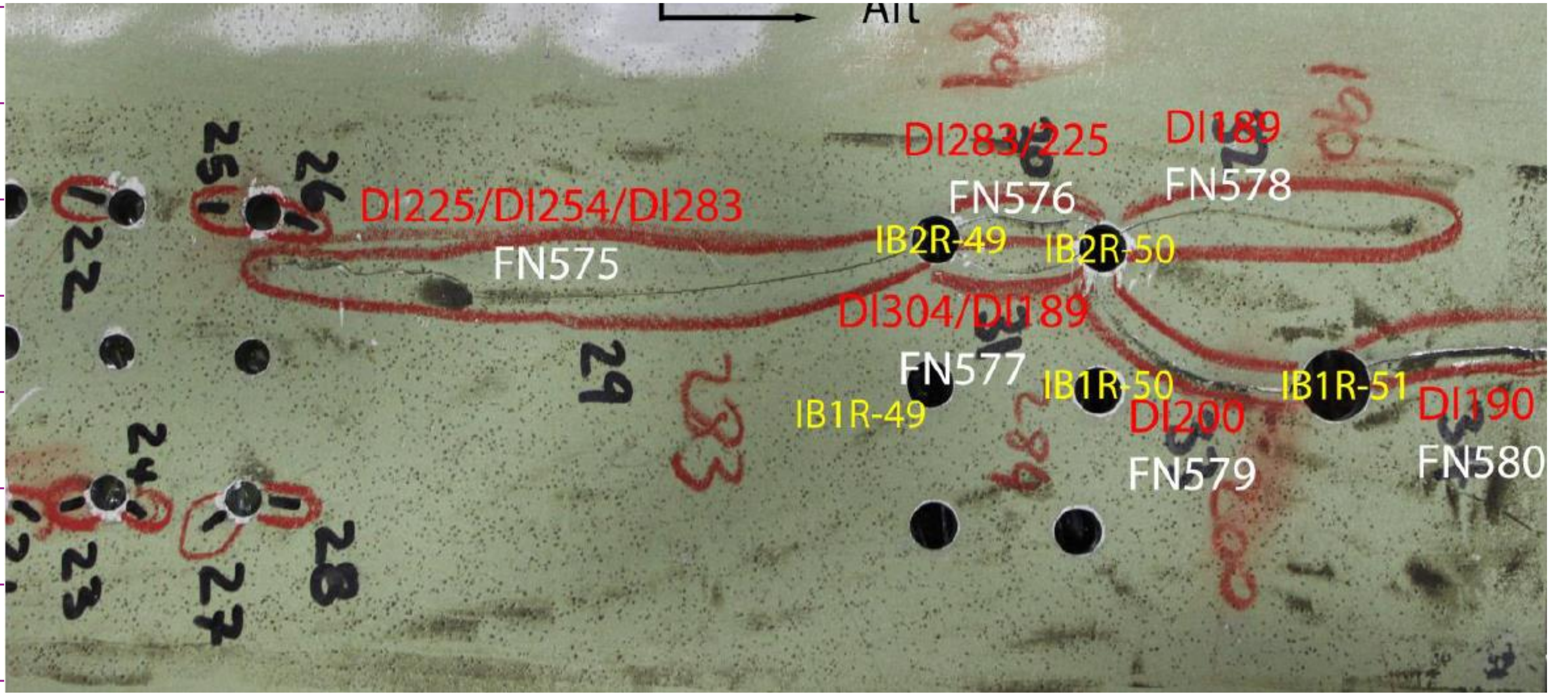


History of C-130J WFT

- The WFT primary objective was to:
  - Maximise the Structural Life of Type (SLOT) of primary wing structure
  - Maximise aircraft availability throughout the defined SLOT
- Combined RAAF and RAF test
  - Test at MA in UK
  - Teardown by AIRBUS at Richmond
  - Separate Test Interpretation (TI)
- Test Spectrum OLM based
  - Selection of RAF and RAAF flights
  - Super block 1500 flights (3100 flying hours)
  - 5 x standard block 250 flights
  - 1 x 250 flights with higher amplitude cycles
    - i.e. few more severe flights

History of C-130J WFT

- Test at MA in UK
- Test article
  - Centre and outer wings
    - No TE or LE
  - Fuselage support structure
  - Nacelle structure
- Loading
  - 40 actuators
  - Vertical, lateral and torque loads applied to each engine
  - Airbag for Fuselage pressurisation
  - 600 gauges to assist TI, confirm loads and compare to OLM

History of C-130J WFT

- Damage tolerance testing
  - 9 cracks introduced cracks late in test
- Reached durability goal
- Residual Strength Test (RST)
  - 1.2 DLL
- Accelerated testing + additional RST
- Failed past limit load on 6th RST
  - Wing root
  - Failure location expected
- Teardown
  - By AIRBUS at Richmond
  - CW
  - 1 OW
  - 2nd OW past engines

Type Certification Basis (TCB)

- For C-130J-30 Service Entry - MIL-S-5700 series standards supplemented by
  - Aeroelasticity requirements of MIL-A-8870
  - Durability guidelines of AFGS 87221A
  - Damage tolerance requirements of MIL-A-83444
  - Gust requirements of DEF-STAN 00-970
- For WFT TI
  - JSSG 2006
  - EN-SB-08-001 and EN-SB-08-002
  - Interpretation by Authority
    - Convert specifcation into suitable requirements
    - Diffcility in retrospectivly applying these to a designed aircraft

AIR FORCE STRUCTURES

Structures Bulletin

ASC/EN
Bldg 28, 2145 Monahan Way
WPAFB, OH 45433-7017
Phone 937-255-5312

Number: EN-SB-08-002, Revision A

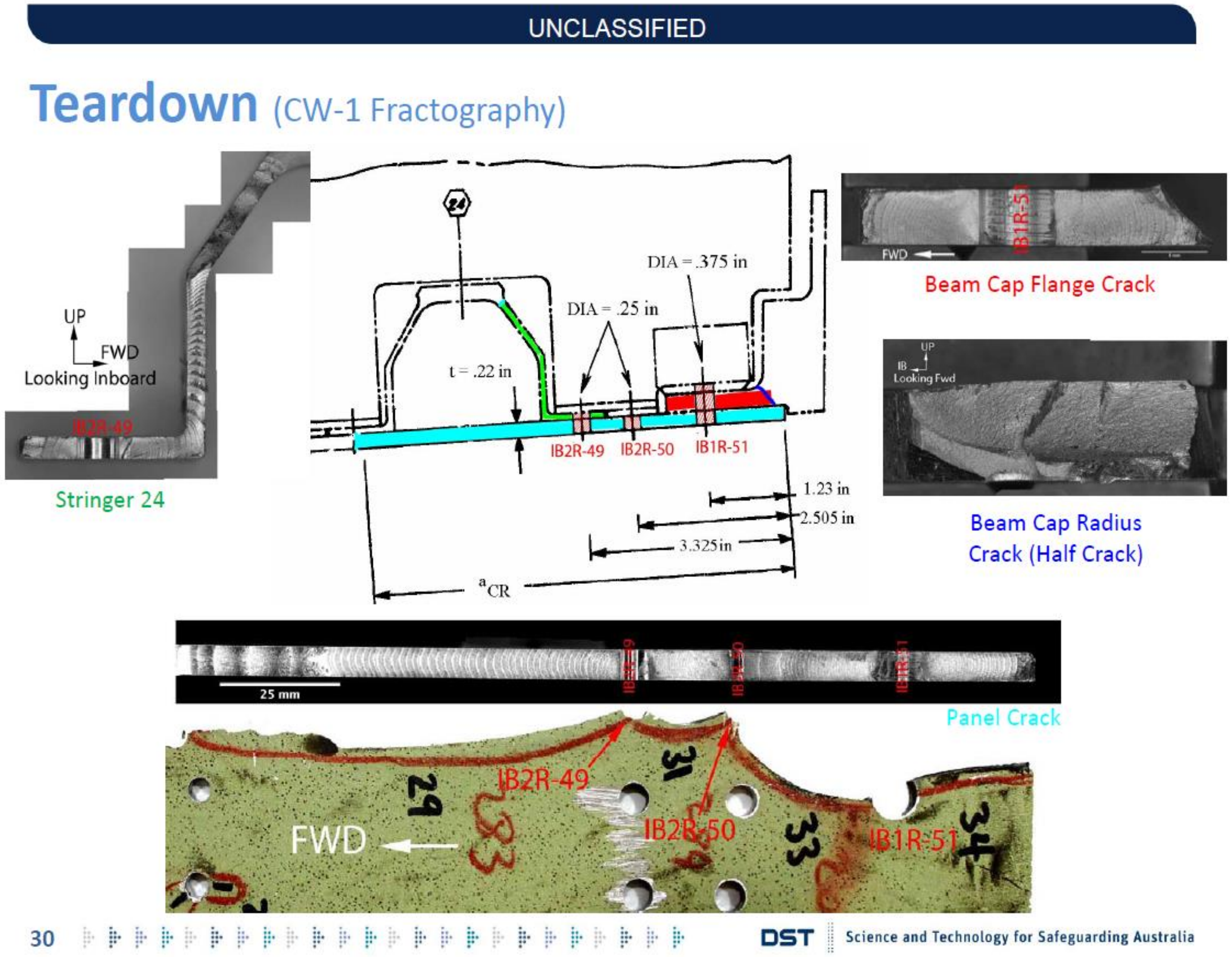
Date: 18 March 2011

Subject: Revised Damage Tolerance Requirements and Determination of Operational Life Limits for Slow Crack Growth Metallic Structures

QINETIQ

Test Interpretation

- TI undertaken by QinetiQ and DST Group
  - QinetiQ - Standard locations
  - DST Group – Some complex MSD/MED locations
- QinetiQ Part 21 Designs
  - ICA
  - ASIMP Vol 2 Updates
    - ADF MAwL and ICA
  - Implementation impact considered
    - Fleet status compared to ICA
    - Time for implementation
    - Alignment with major servicing's
- LOT
  - Preliminary estimates for individual TI locations
  - TDLL
  - Probability Risk Assessments later TI stages



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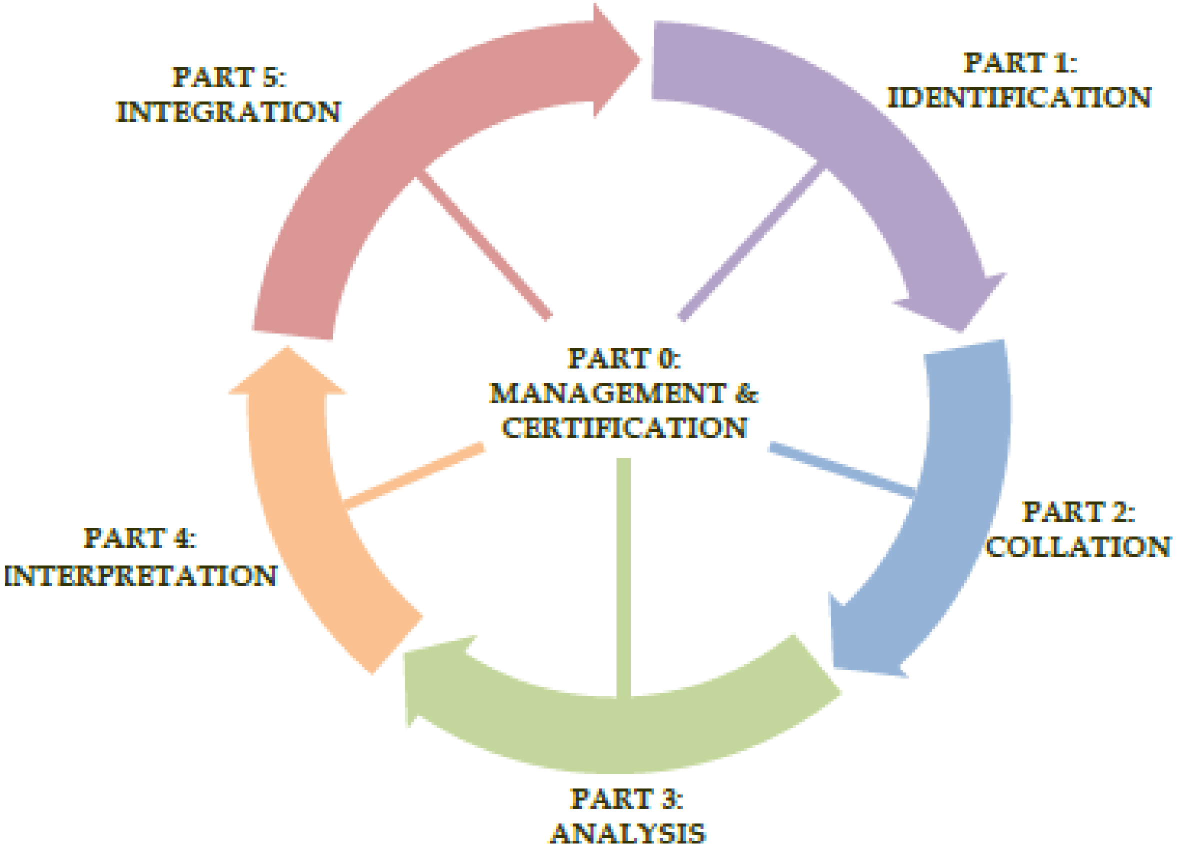
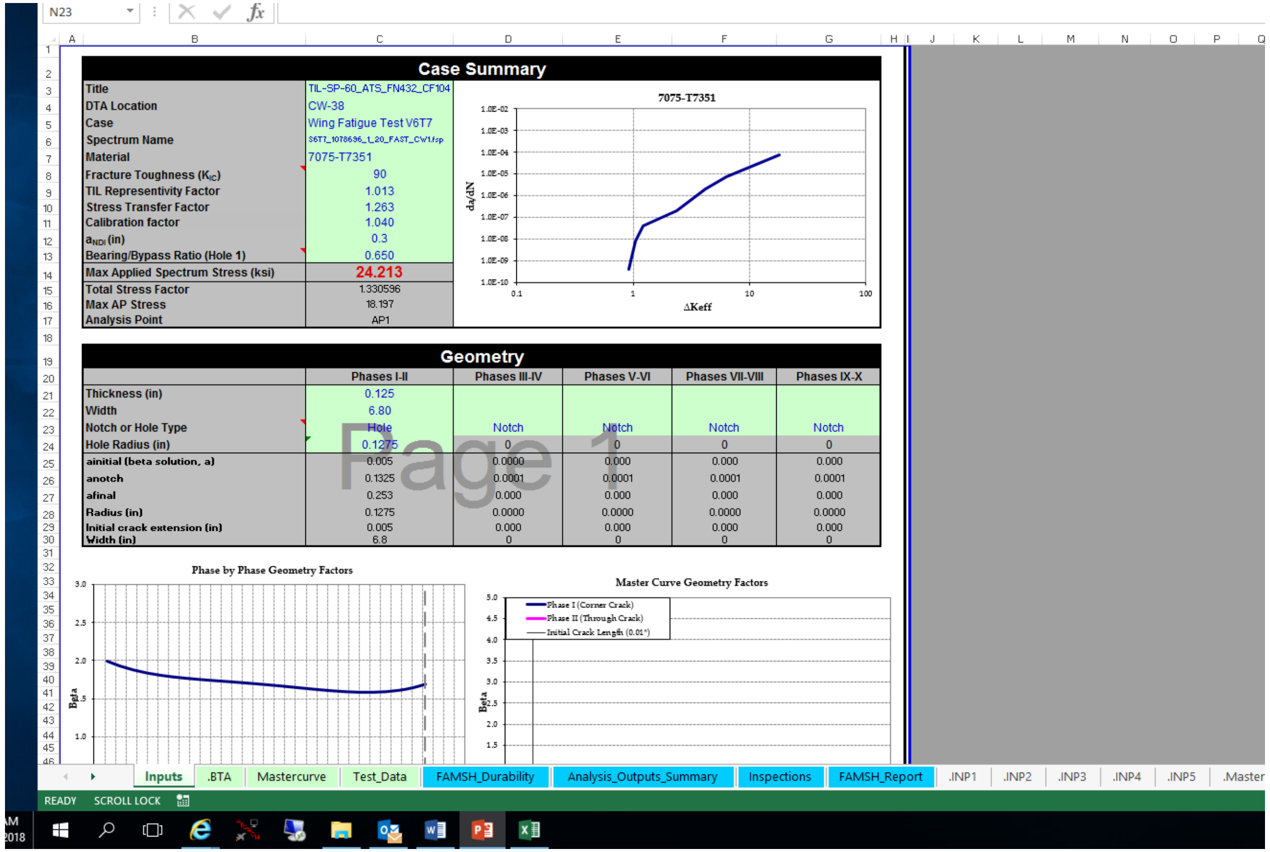
Test Interpretation

- Replace current ICA
  - OEM based ASIMP Vol 2
- TI Process documented within guides
- Specific Tools / data developed
- V&V of Data, tools and process
  - TCB
  - Data integrity
  - Robust
  - Process documentation
- Authority approval before process starts



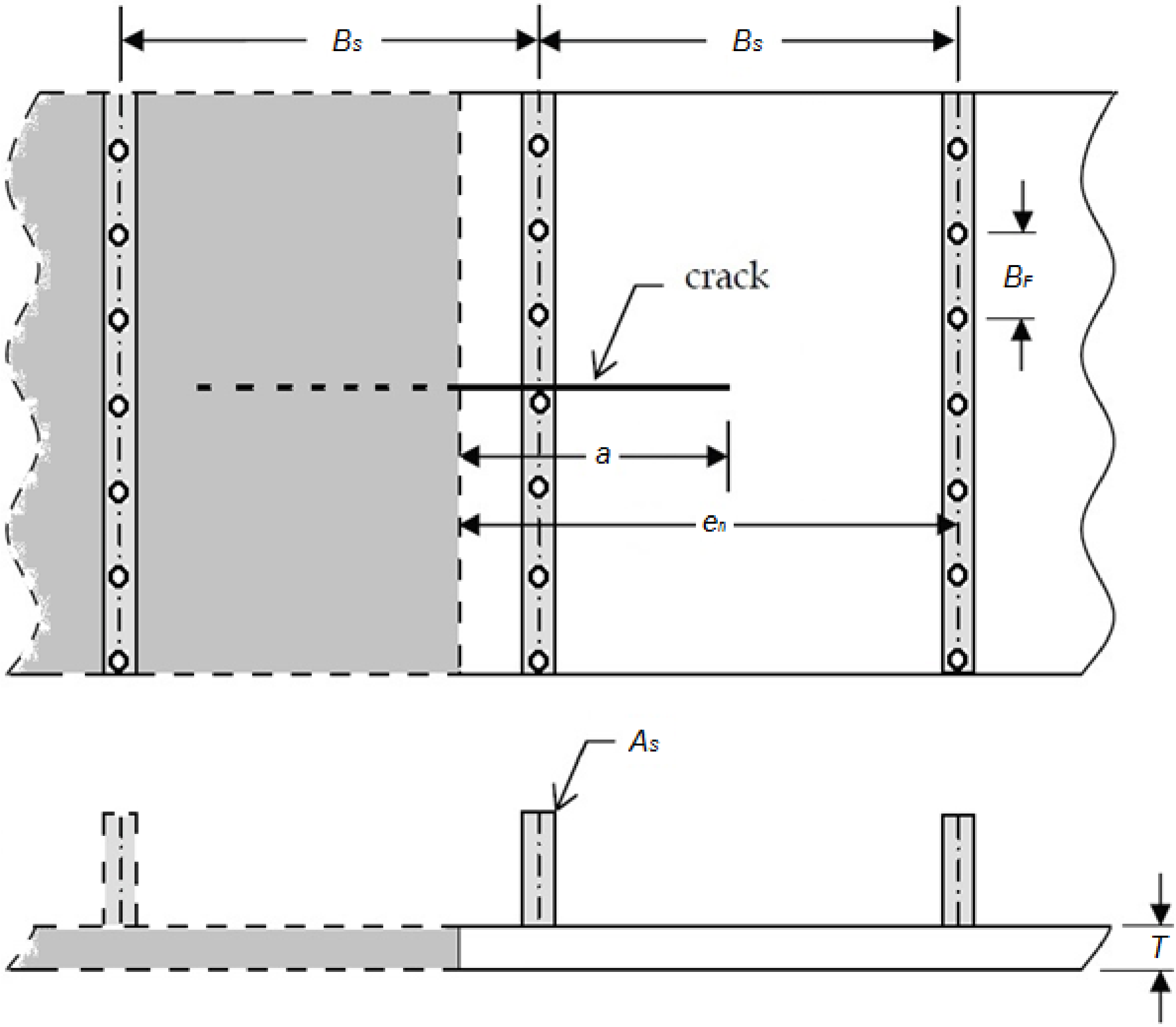
TI Tools/ Data

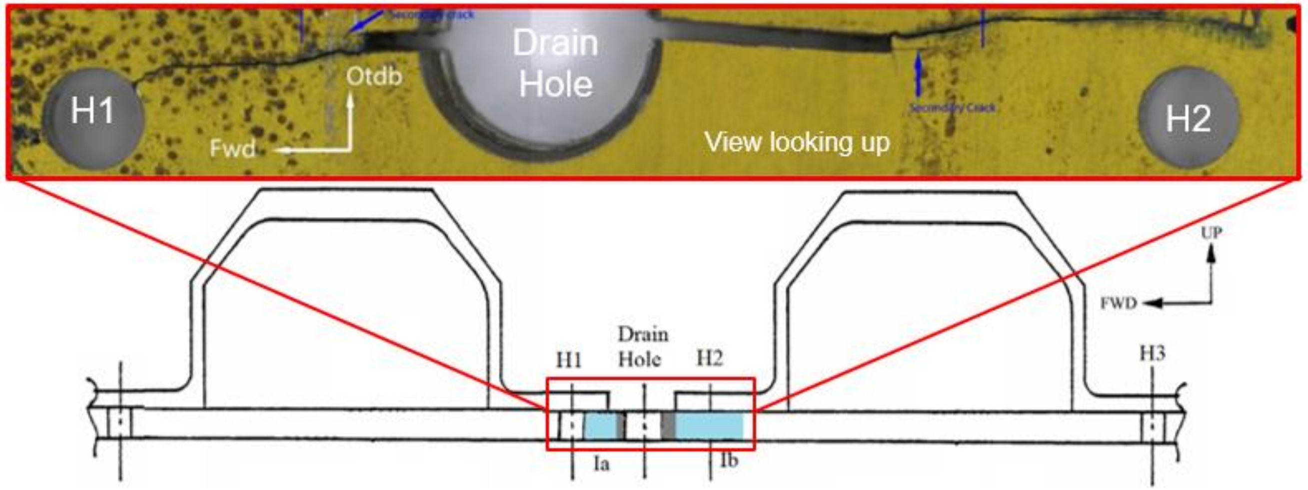
- DADTA template
  - FASTRAN
    - Retardation crack growth model
  - FAMS
    - Strain life model
  - Generates crack growth curve
  - Calculates Intervals
  - Includes
    - Spectra
    - Material data
  - Accounts for multiple phase crack growth
    - Continuing damage



TI Tools/ Data

- Geometry Factors
  - Stress check & classical solutions into generic tabulated data
  - Allows build up of locations
  - Developed for each situation
  - Significant compounding to develop solutions
  - Up to 12 crack phases for some locations

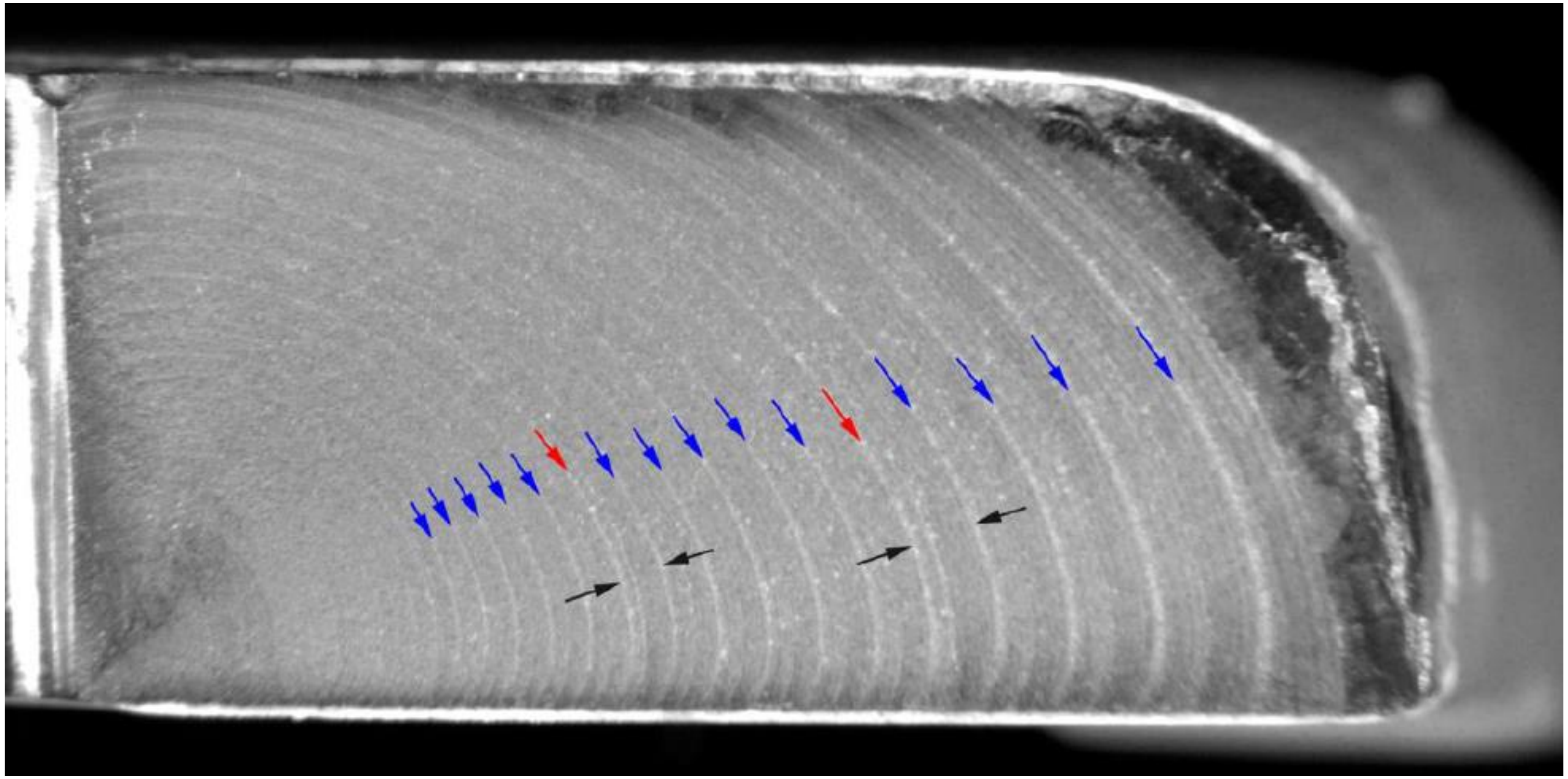




TI Tools/ Data

- Geometry Factors
  - For calibration
    - Beta at fractographic recorded point
      - Same point on the crack face
      - Not at 5 and 80 degrees
    - Crack aspect ratio
    - Test crack progression
      - Crack interaction

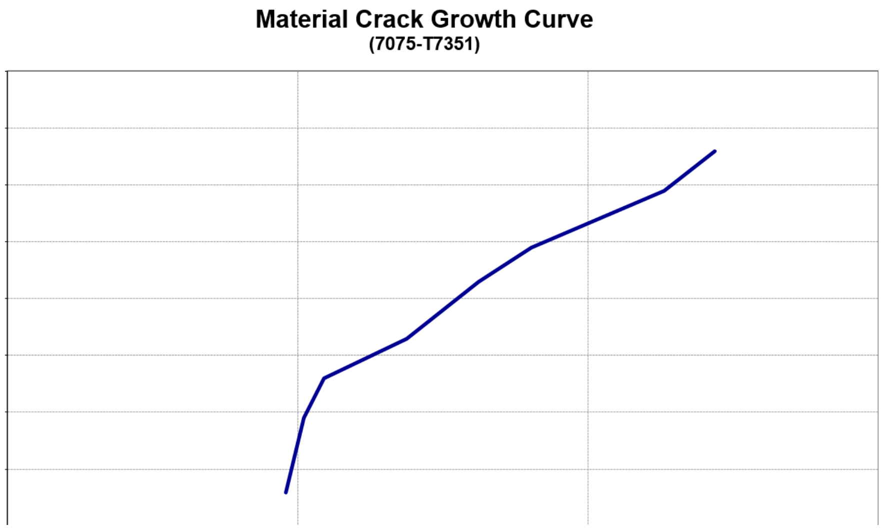
  - For DTA
    - Fixed aspect ratio a/c = 1.00
    - Nominal blueprint geometry
    - DTA crack progression
    - Consistent with calibration Beta

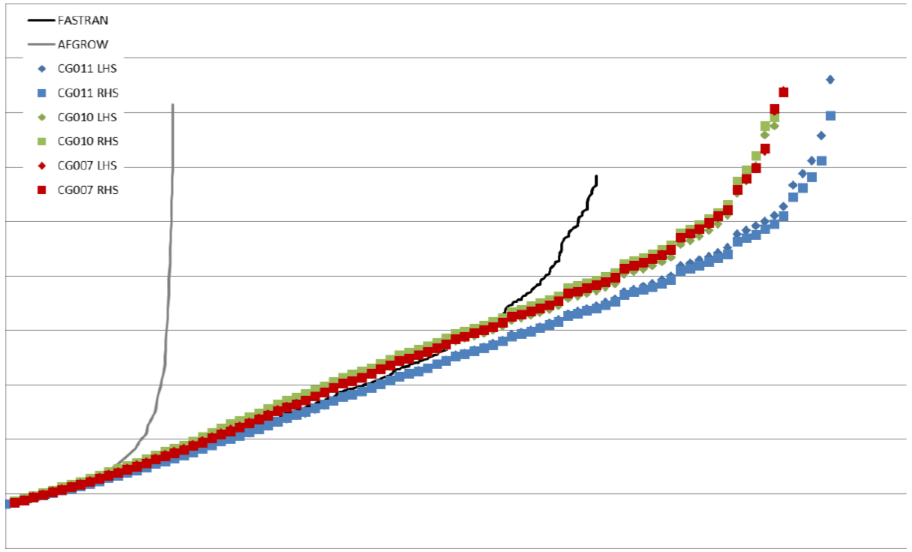


TI Tools/Data

- Coupon testing
  - Da/DN data
    - short and long crack lengths
  - Fatigue test spectrum clipping

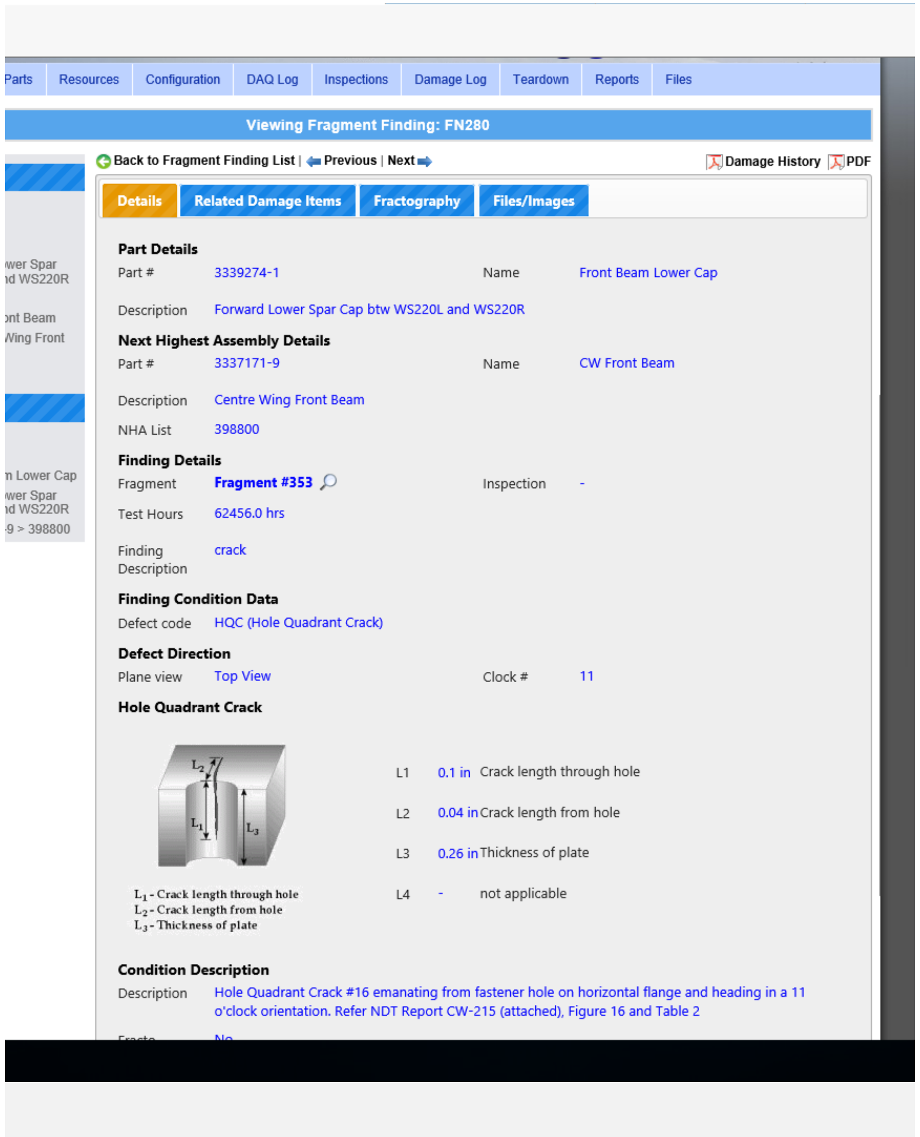
- OEM Fracture toughness
- Handbook yield strength





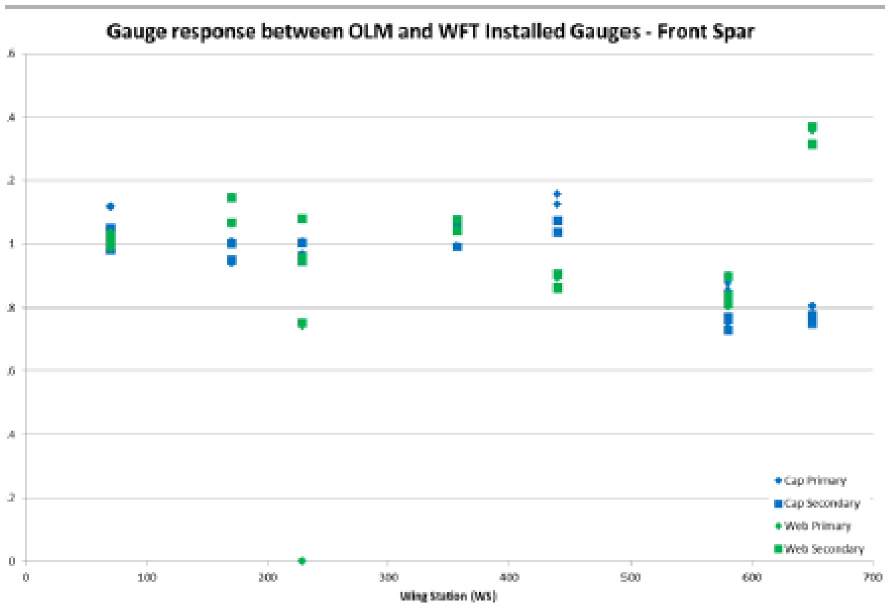
TI Tools/ Data

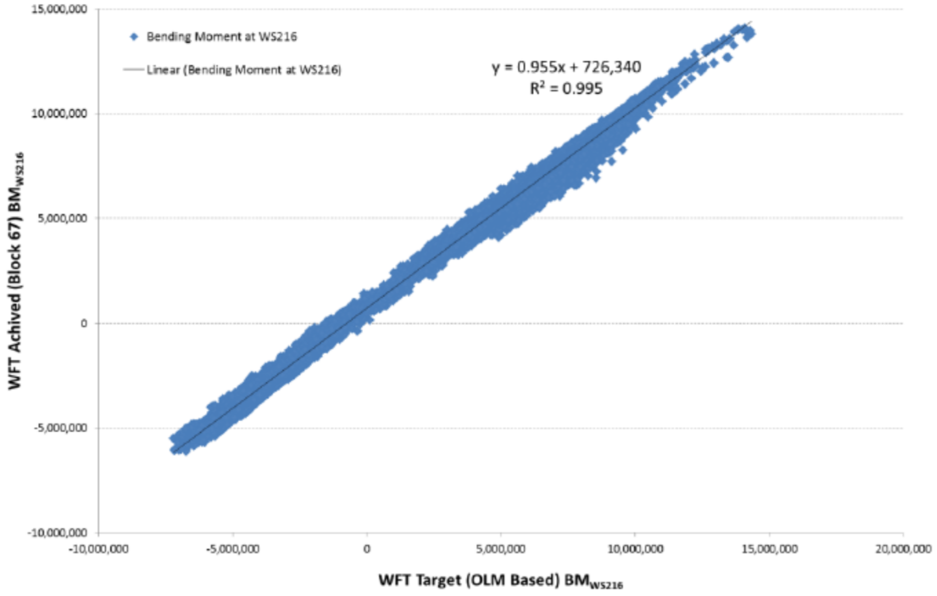
- IMSst
- Data repository
  - Test defects
  - Fragments
  - Findings
  - All test reports
    - NDI
    - Fracto
    - Repair decisions
    - Defect reports
- Assists in data quality
- Web based



Verification and Validation

- DADTA template
  - FASTRAN
  - FAMS
  - Outputs comply with TCB
    - In particular continuing damage
- Confirm TIRS
- Material
  - Da/DN data
  - Other data
- Transfer factors
  - TIRS to EFH
  - Converting outputs to match individual tracking program (IATP)





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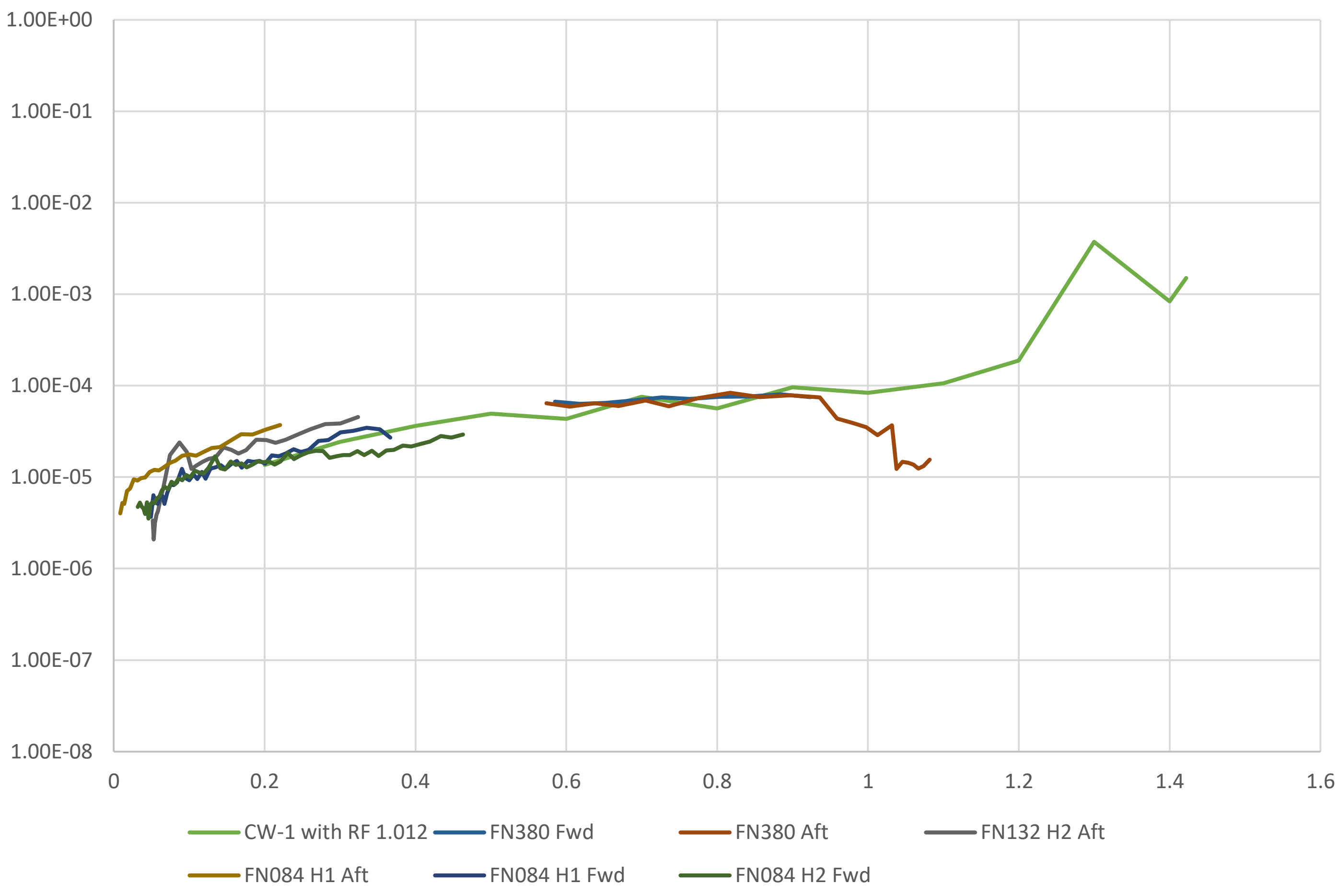
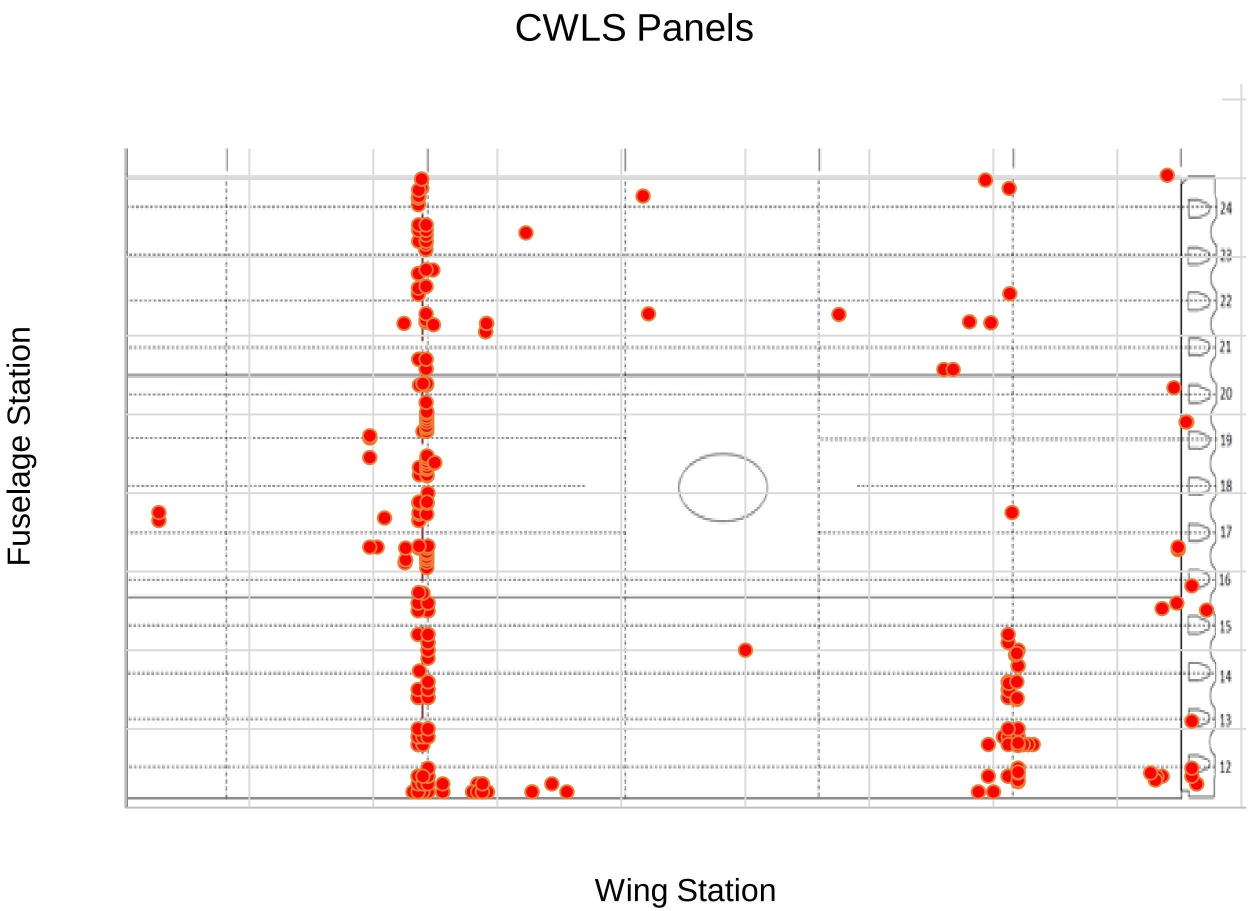
Verification and Validation

- WFT loading
  - OLM to WFT gauge results
  - Along / across the span
  - Over time
    - Ensure loading remains constant
- Comparison of WFT cracking with DTA
- Authority sign off
  - When DaDTA tools used correctly ICA will be compliant with TCB



Selection of Locations

- 1400 findings
  - Most findings will not undergo fractography and DTA
- Extant SSI from LM Aero
- Critical test cracking
  - Size and density of findings
  - Criticality of failure
- Priority
  - Test crack size
  - Time of cracking
  - Extant maintenance program impacts



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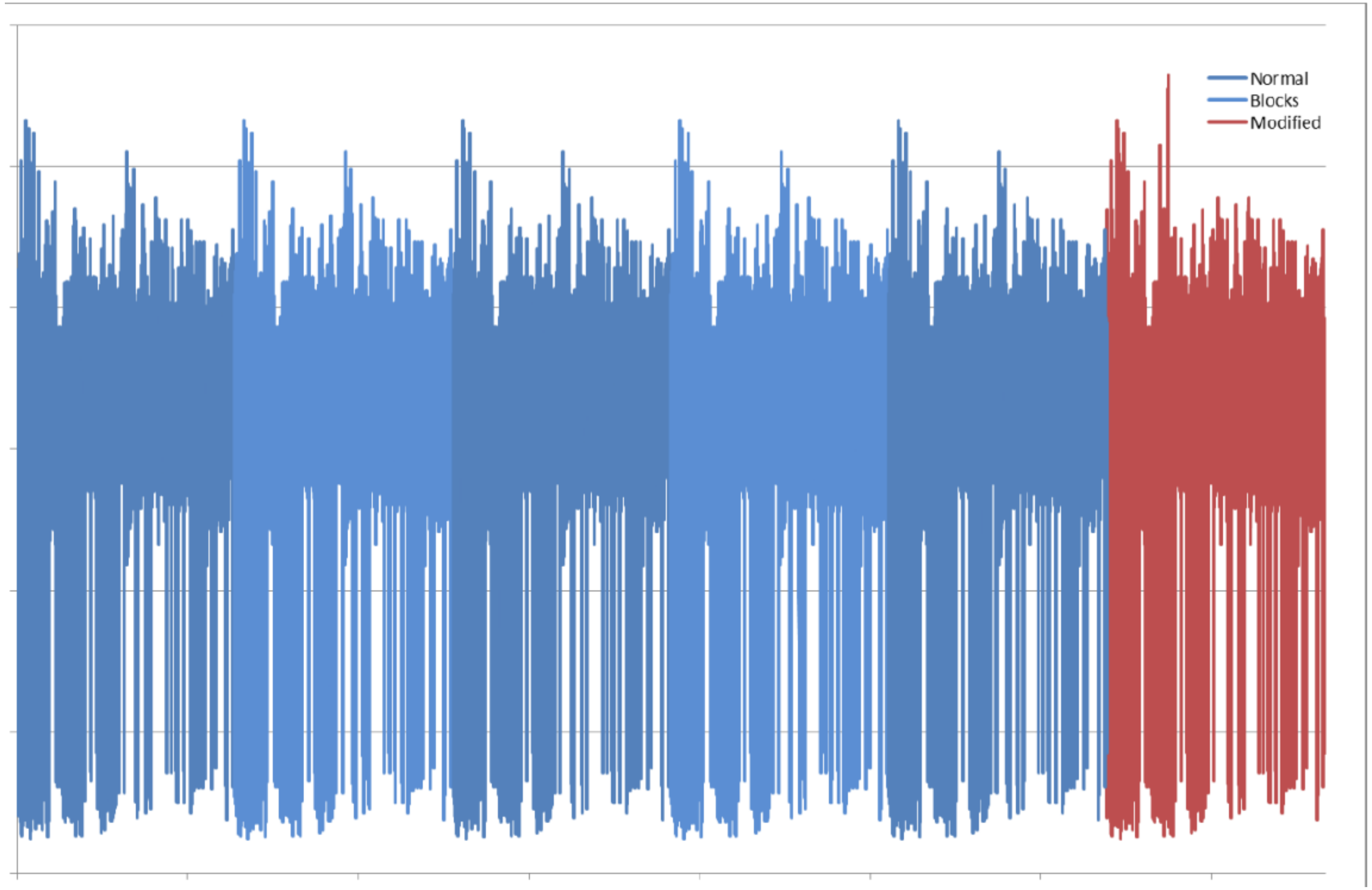
Spectrum

- Seven AP spectra
  - ATS & TIRS
- Stress Transfer Factor (STF)
  - Strain gauge
  - OEM data
  - FEM
- Test Representivity Factor (RF)
- Applied Test Spectrum
  - ATS = AP ATS x STF x RF
  - For fatigue test cracking
- Calibration Factor (CF)
- Test Interpretation Spectrum
  - TIRS = AP TIRS x STF x CF



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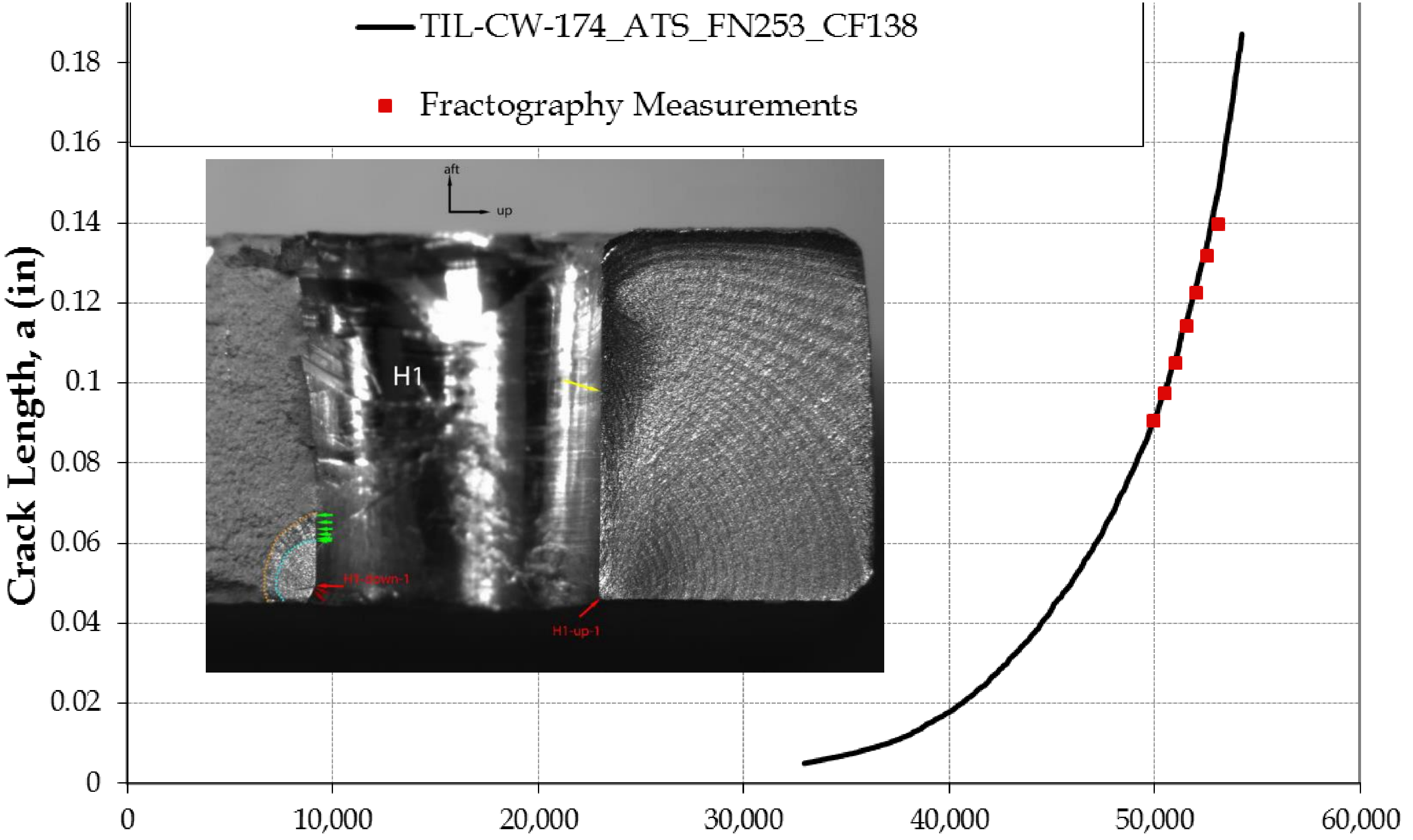
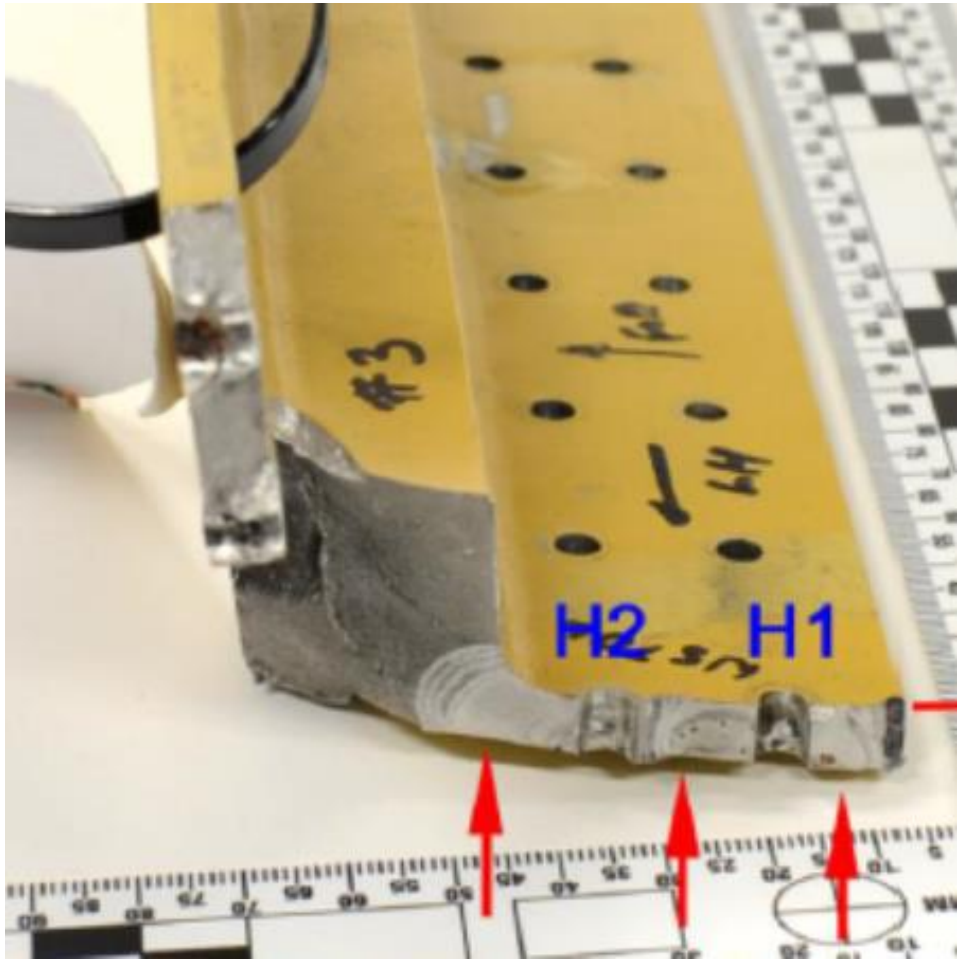
Calibration Factor

- Factor on overall stress
  - CF x ATS
- DTA of cracking
- Compare with qualitative Fractography results
- Overcomes deficiencies
  - STF
  - Beta



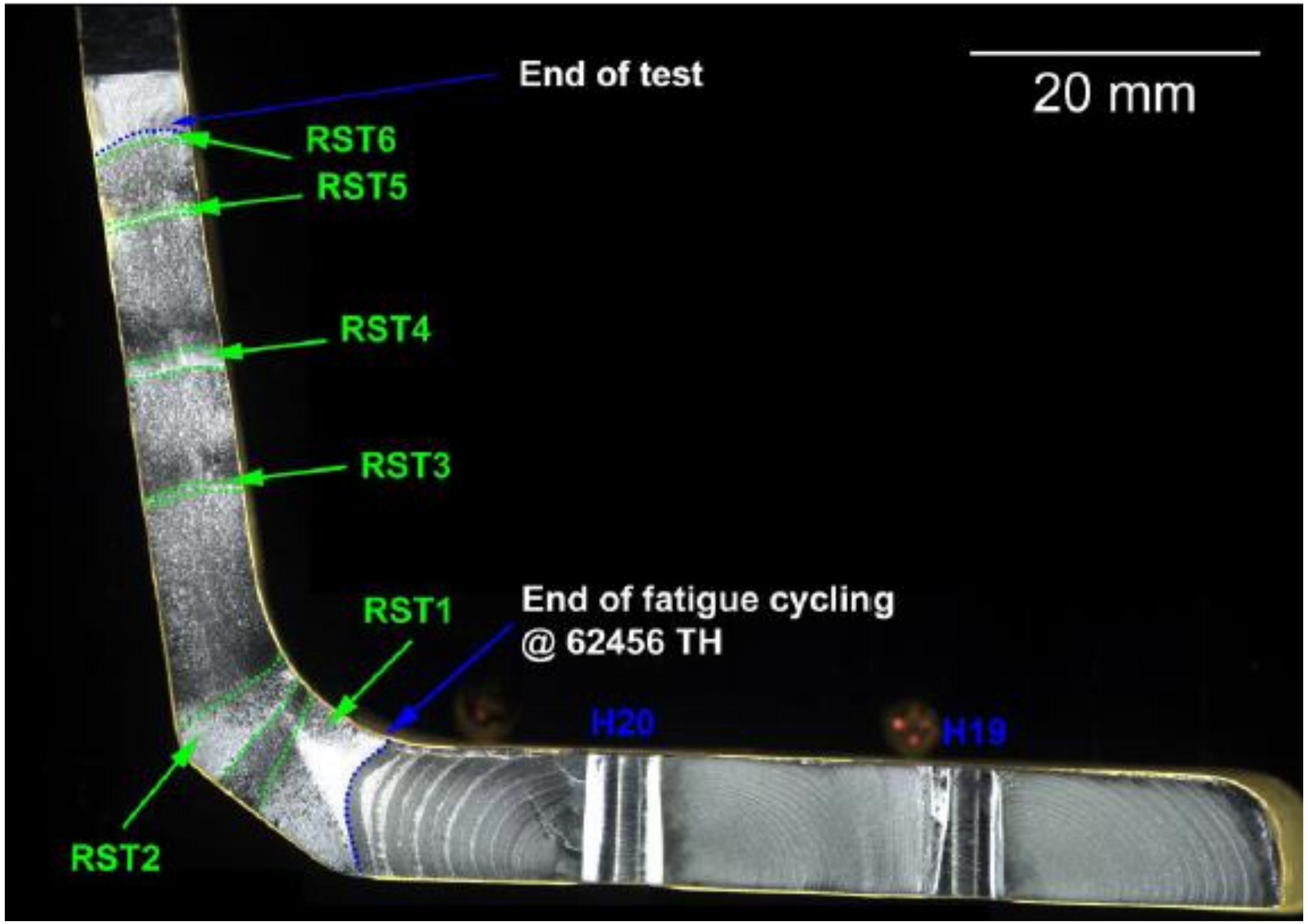
Calibration Factor

- Iterative process
- Simple beta
  - Refined if required
    - Account for other geometry
    - Account for crack interaction
    - Load redistribution
- Similar CF for adjacent cracks
- May have multiple CFs if local failure allowed
  - Accounts for local stress transfer



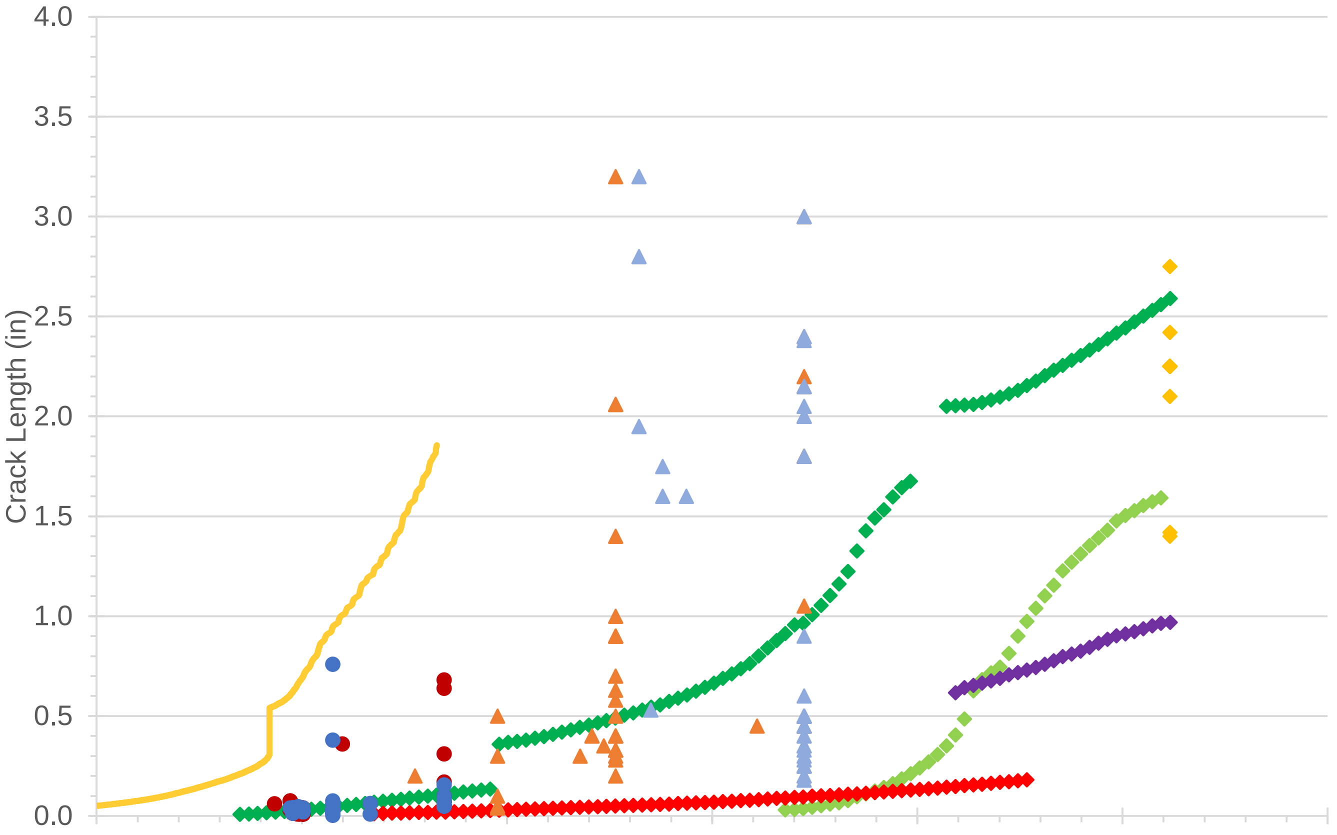
DTA

- Cracking Scenario
  - Worst of test cracking
  - LM DTA
  - Or other?
- Multiple test cracks not necessarily the worst case
  - TCB requires only a single 0.05” flaw
  - TCB continuation damage flaw
- Multi phase crack growth
- Intervals derived from crack growth curve as per TCB



Interpretation

- TIRS intervals converted to EFH
- EFH intervals for ICA
  - Allows IATP
- Configuration differences between the test article and the fleet
- Comparison of derived crack growth curves with relevant in-service and test cracking data
  - Account for all findings in control area
- Sense checks for comparable programs
- Implementation urgency



Interpretation

- Need for modifications
  - Low recurring interval
  - High access cost
  - Planned change vs Repair when found
- Suitability of NDI procedures
  - Extant OEM procedures
  - Would service cracks be found
  - Alter a_{ndi} or alter NDI type

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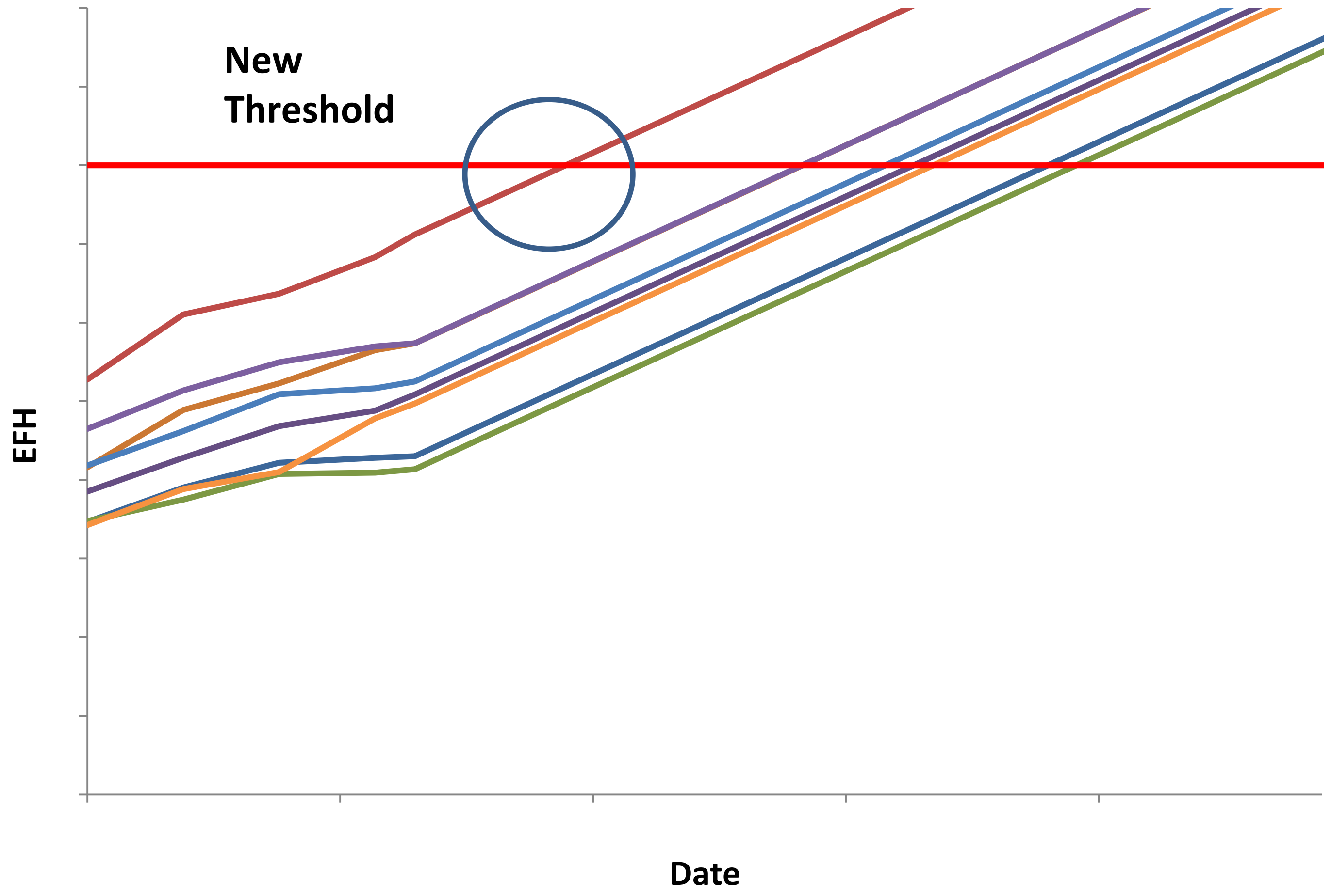
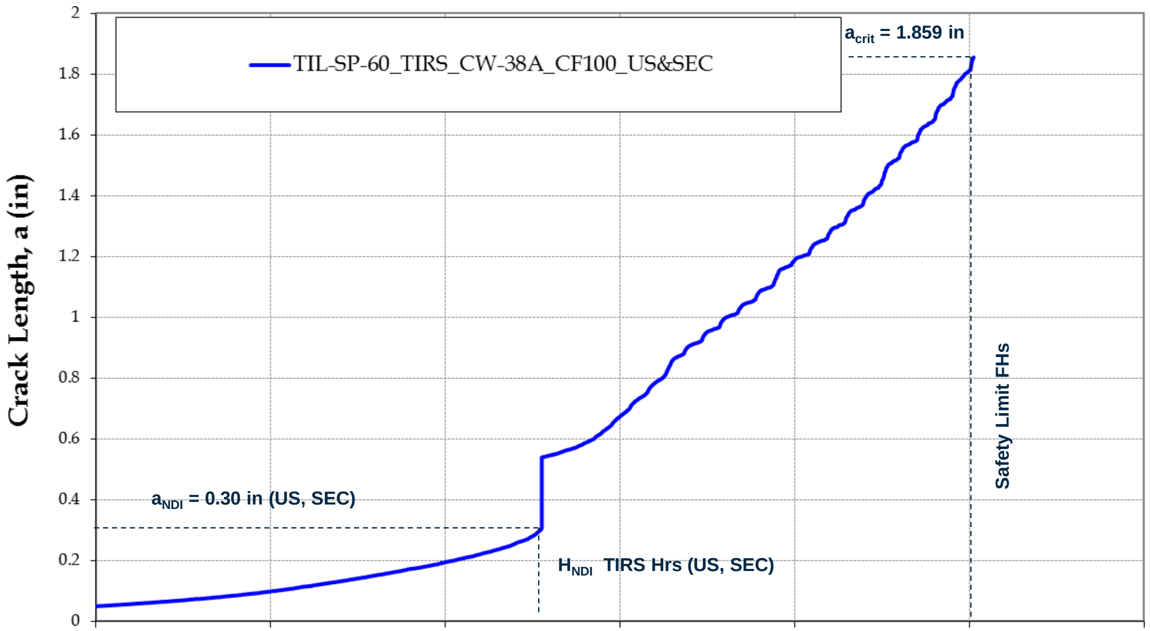
Implementation

- EFH intervals tracked by IATP
- ASIMP Vol 2 updates
- Ensure adequate time for implementation
  - Escalate if any immediate safety issue present
    - Reduced Threshold Interval
    - Reduced Recurring Interval
- Provide aircraft specific ICA if needed
- Aim to align with major routine servicing's
- All may need refinement of analysis (not 100% on what this is)
- Suggestions for CAMO



Summary

- By end of TI
  - 1400+ findings
  - 55+ Fractography reports will be required
  - 46 CF curves
  - 57 DTAs
  - 91 Locations
    - locations covered DTA at more critical points
  - 11 areas were MSD
    - Just started to well advanced
  - 6 locations with developed MED
  - 4 locations for PRA
- Currently Completed
  - 22 locations
  - 13 DTAs
  - 19 CF curves



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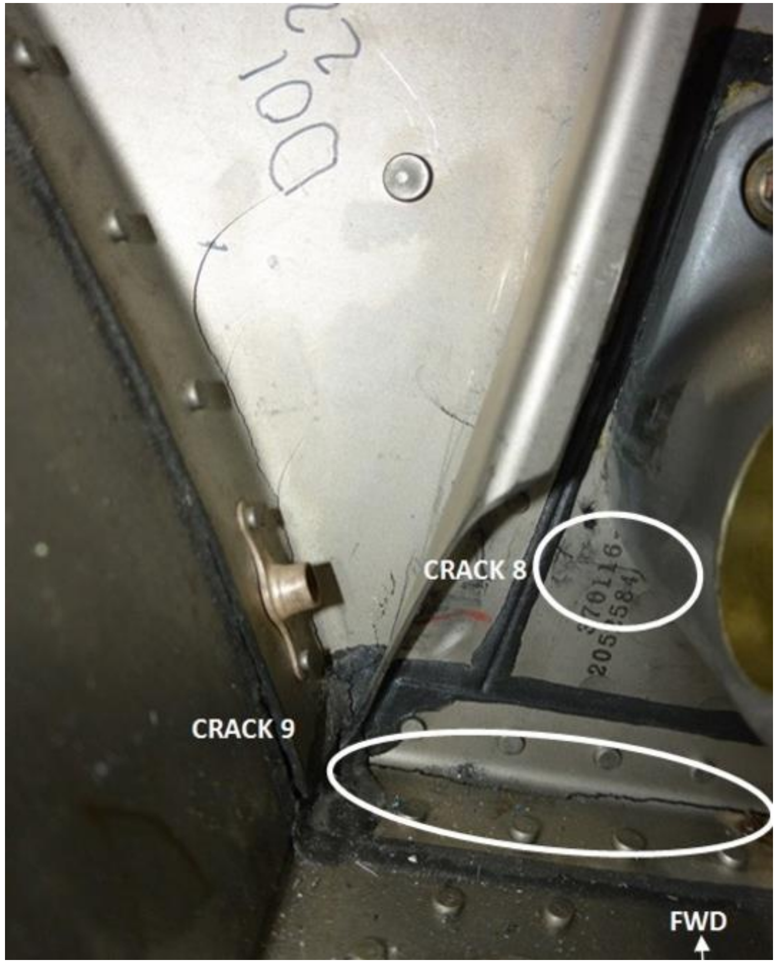
Summary

- Increase in thresholds and recurring intervals
  - Can be aligned with routine servicing's
  - Increased aircraft availability
  - Less chance of inspection damage

- Improvements believed to be due to more advanced tools

Lessons Learned

- Fracto excellent
  - used to account for load changes due to crack interaction
  - Provides confidence
- Usefulness of strain gauge locations
  - Not ideal for STF (local strain effects)
  - Great for OLM comparisons
  - Identify if load redistributes during course of testing
- Confidence in TI Process is dependent on V&V at multiple stages of development
- Full understanding of Test outcome gives confidence in ICA outcome
- Next stage LOT
  - Probabilistic Risk Assessments



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