

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

AASC
Mr Ross Stewart

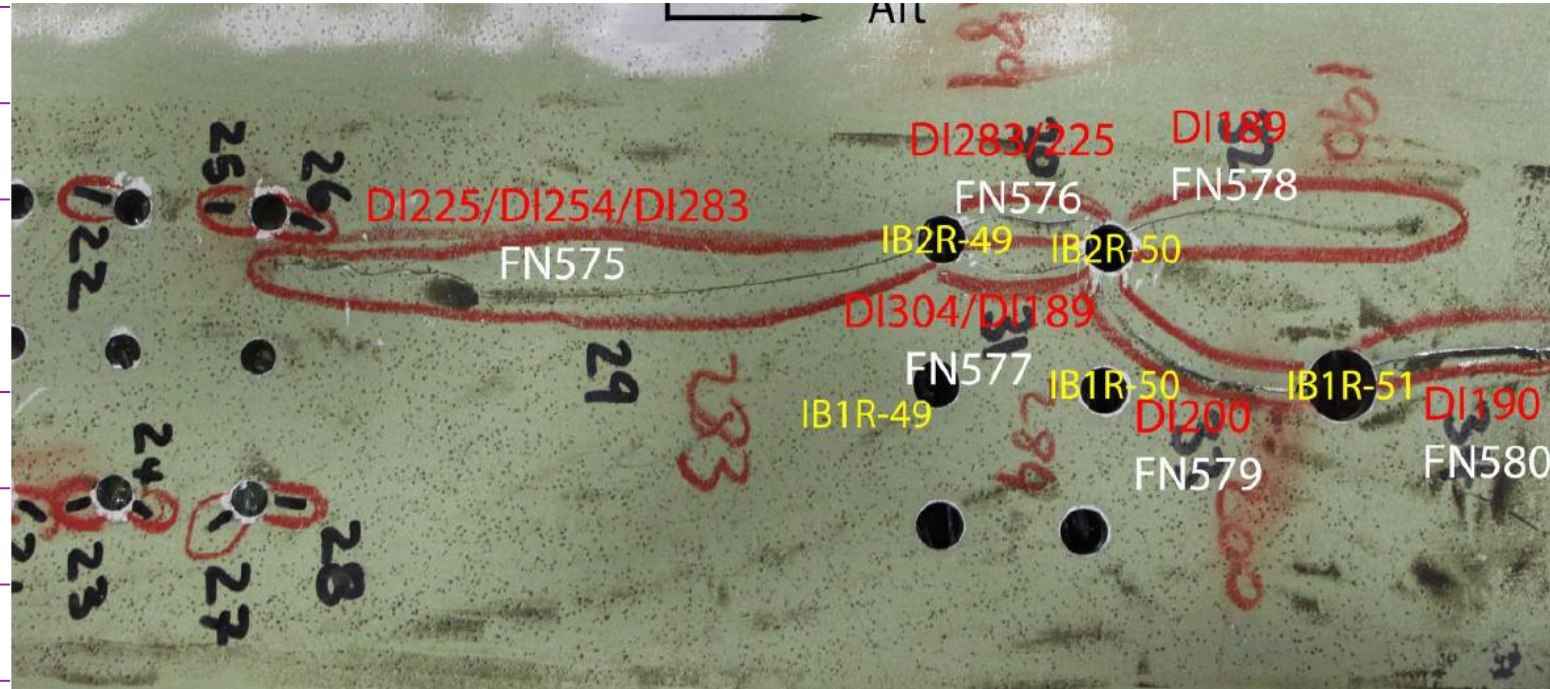
July 2018



QINETIQ

Agenda

- 1 History of C-130J WFT
- 2 Type Certification Basis (TCB)
- 3 Test Interpretation
- 4 TI Tools/ Data
- 5 Verification and Validation
- 6 Selection of Locations
- 7 Spectrum
- 8 Spectrum
- 9 Section
- 10 Section



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 specification into suitable requirements
 - Difficulty in retrospectively applying these to a designed aircraft



Structures Bulletin

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

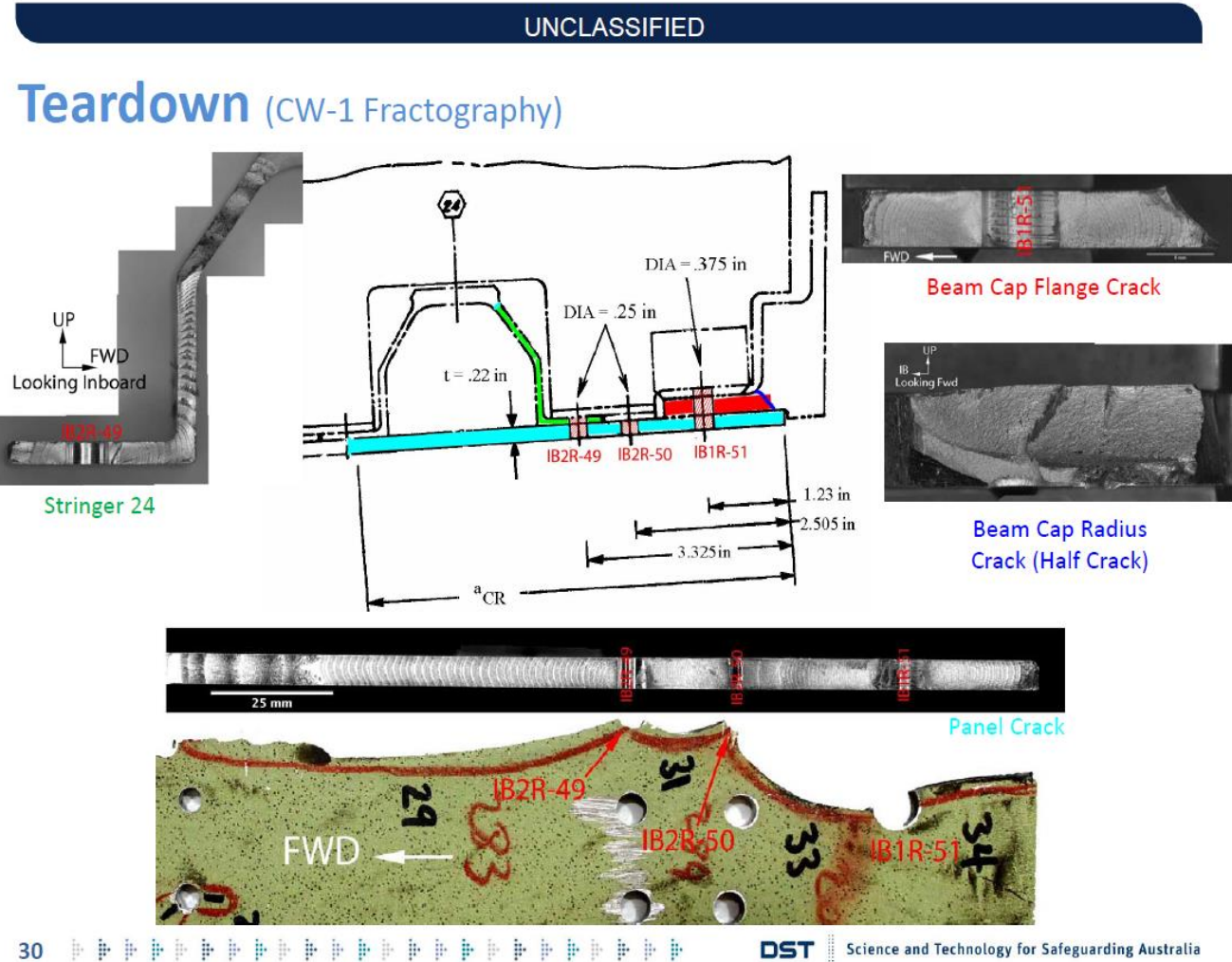
Number: EN-SB-08-002, Revision A

Date: 18 March 2011

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

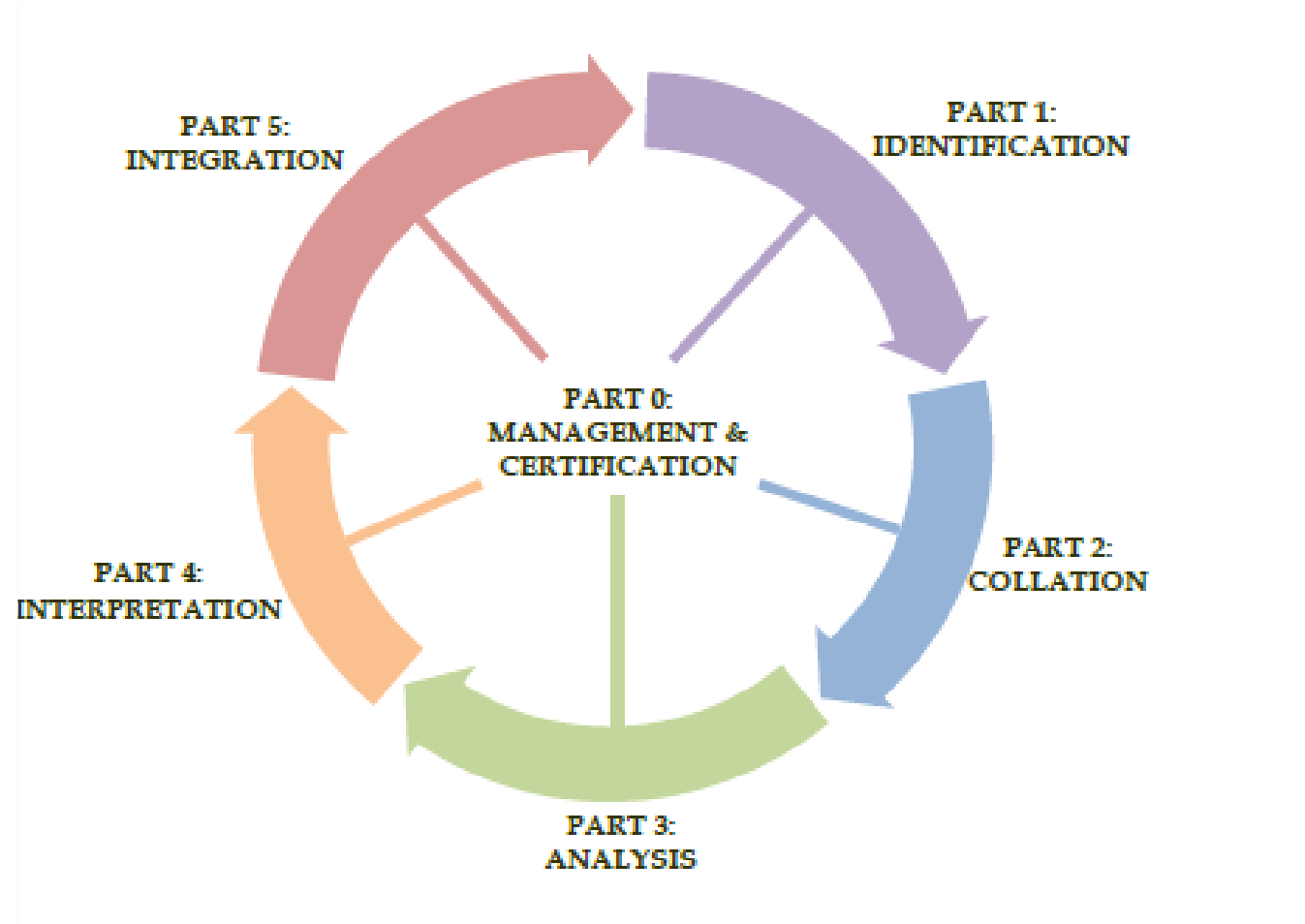
Test Interpretation

- 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



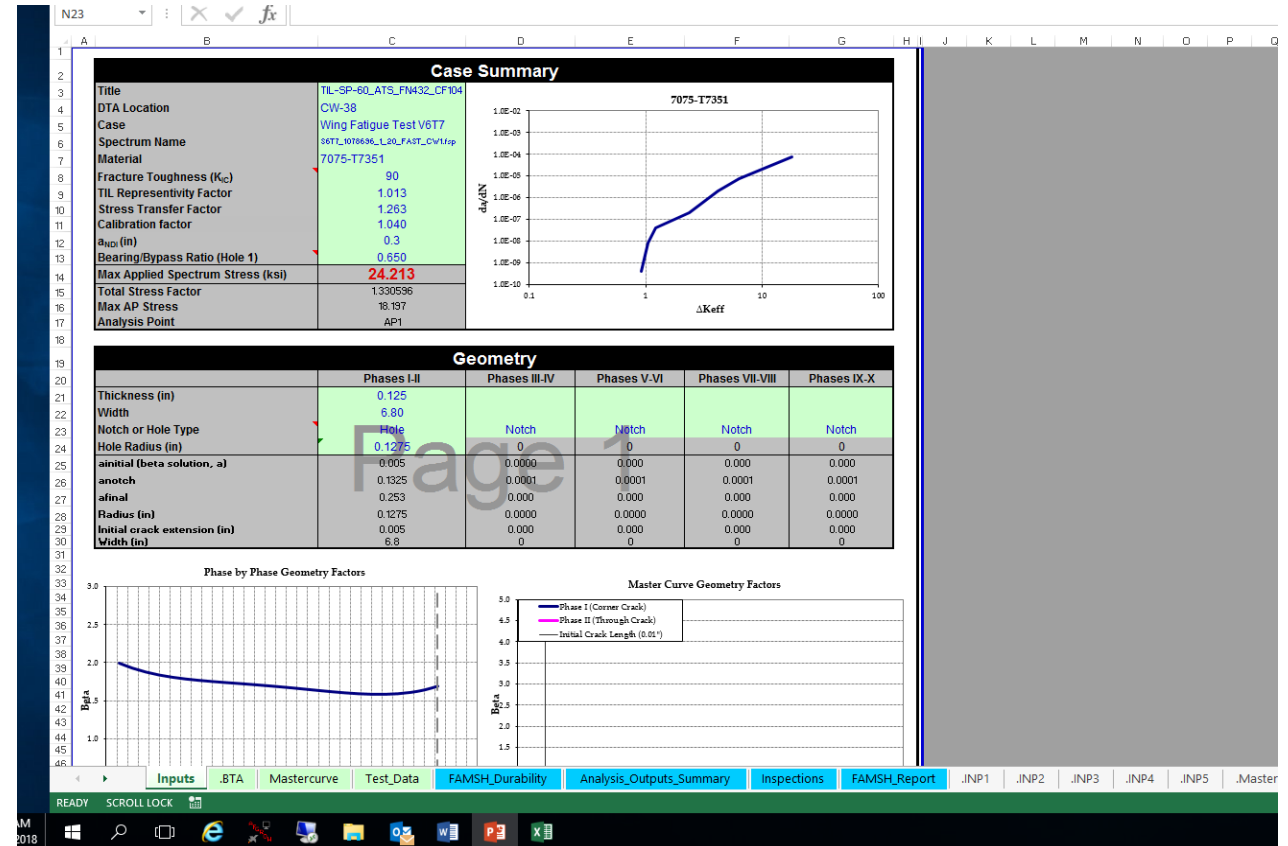
Test Interpretation

- 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

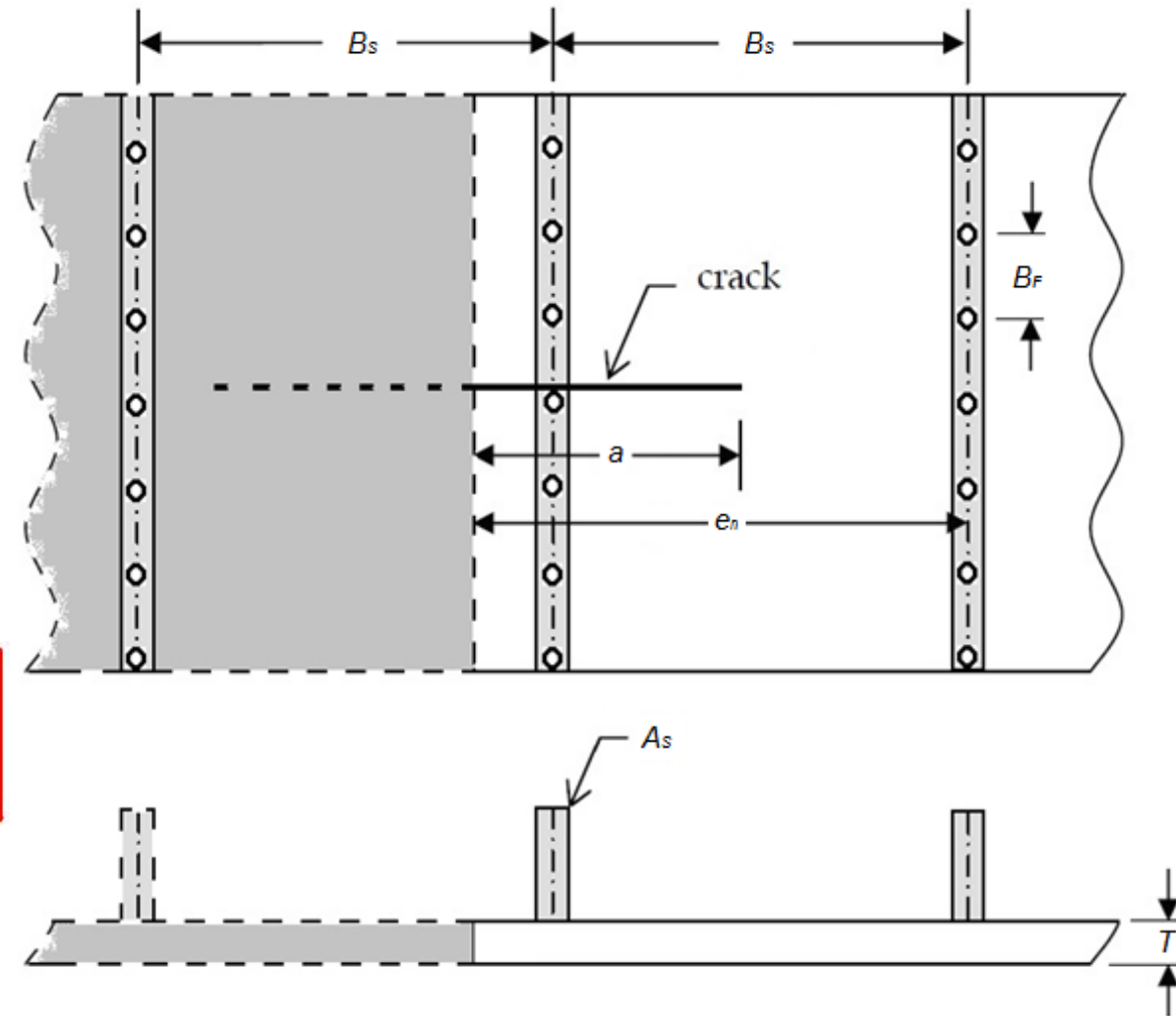
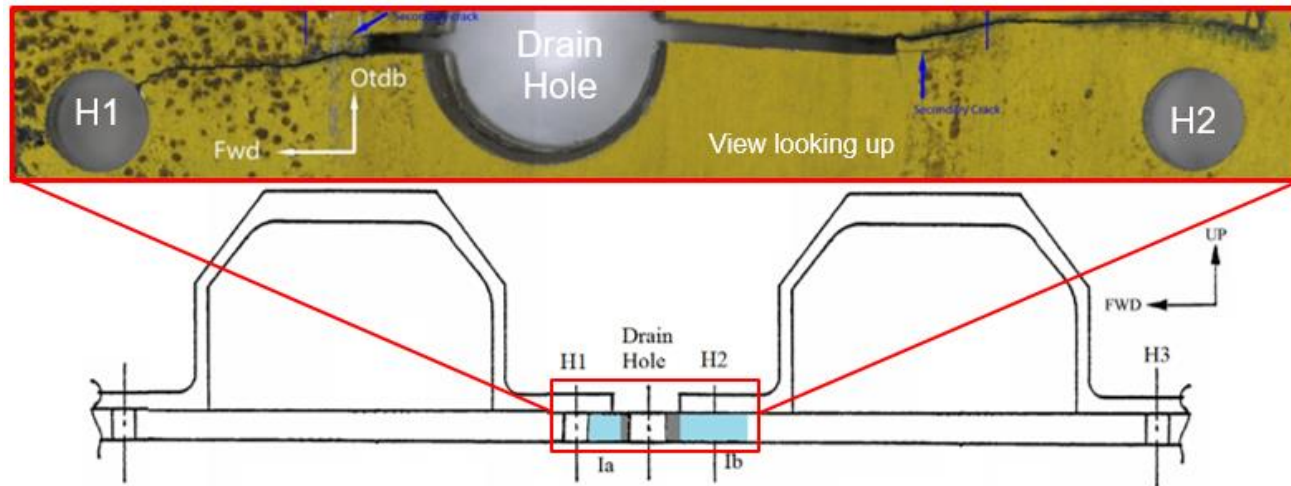
- DADTA template
 - FASTRAN
 - Retardation crack growth model
 - FAMS
 - Strain life model
 - Generates crack growth curve
 - Calculates Intervals
 - Includes
 - Spectra
 - Material data
 - Accounts for multiple phase crack growth
 - Continuing damage



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

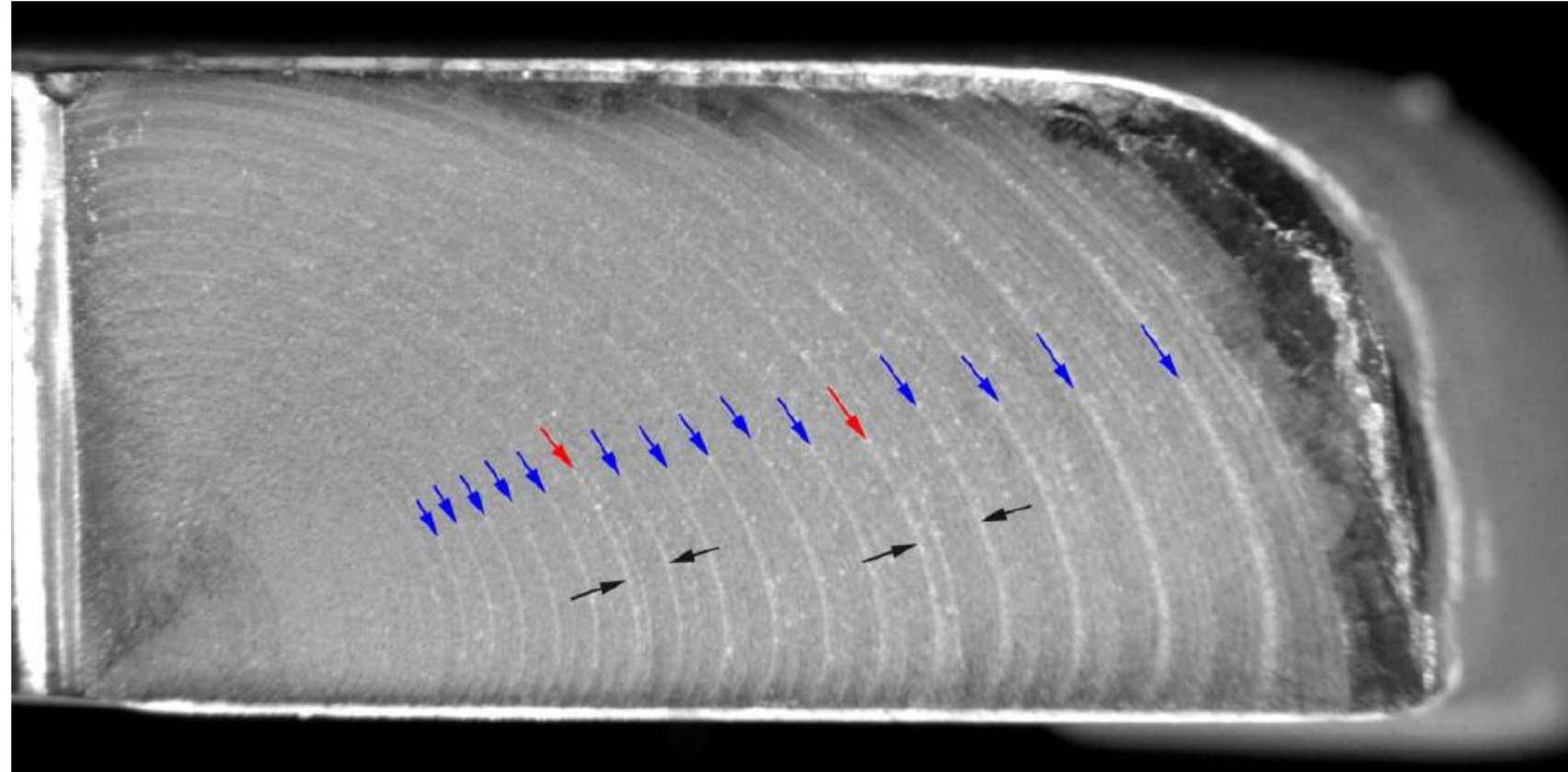
- Geometry Factors

- 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

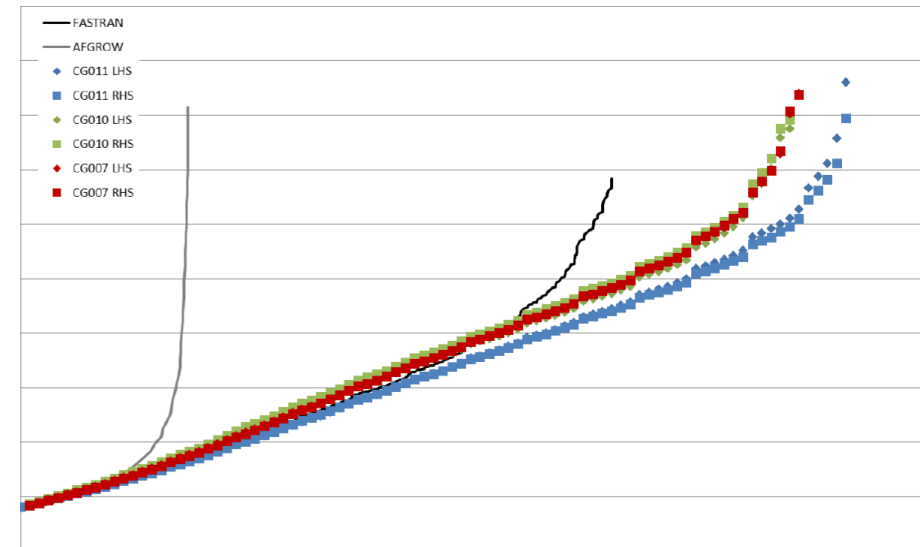
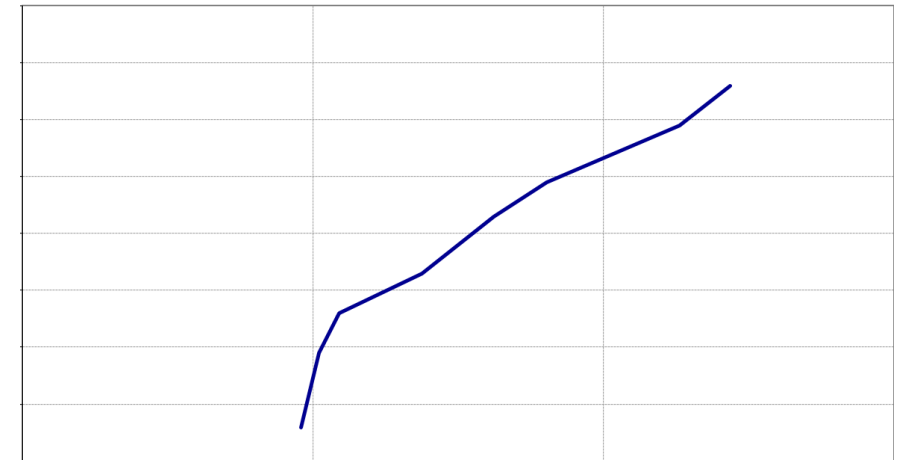
- Fixed aspect ratio $a/c = 1.00$
 - Nominal blueprint geometry
 - DTA crack progression
 - Consistent with calibration Beta



TI Tools/Data

- Coupon testing
 - Da/DN data
 - short and long crack lengths
 - Fatigue test spectrum clipping
- OEM Fracture toughness
- Handbook yield strength

Material Crack Growth Curve
(7075-T7351)



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

Parts Resources Configuration DAQ Log Inspections Damage Log Teardown Reports Files

Viewing Fragment Finding: FN280

Back to Fragment Finding List Previous Next Damage History PDF

Details Related Damage Items Fractography Files/Images

Part Details

Part # 3339274-1 Name Front Beam Lower Cap

Description Forward Lower Spar Cap btw WS220L and WS220R

Next Highest Assembly Details

Part # 3337171-9 Name CW Front Beam

Description Centre Wing Front Beam

NHA List 398800

Finding Details

Fragment **Fragment #353** Inspection -

Test Hours 62456.0 hrs

Finding Description crack

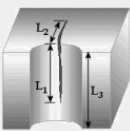
Finding Condition Data

Defect code HQC (Hole Quadrant Crack)

Defect Direction

Plane view Top View Clock # 11

Hole Quadrant Crack



L1 0.1 in Crack length through hole

L2 0.04 in Crack length from hole

L3 0.26 in Thickness of plate

L4 - not applicable

Condition Description

Description Hole Quadrant Crack #16 emanating from fastener hole on horizontal flange and heading in a 11 o'clock orientation. Refer NDT Report CW-215 (attached), Figure 16 and Table 2

Home | QinetiQ Global Portal Annex B - All Documents Quality

Options

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IMSst

Tests Loads Parts Resources Configuration DAQ Log Inspections Damage Log Teardown Reports Files

Login successful

Welcome to IMSst

IMSst is a structured Information Management System for Structural Test programs that has been designed and is operated by the Australian Government Department of Defence, Defence Science and Technology Organisation (DSTO).

This site has been optimized for viewing using [Mozilla Firefox](#) (v3.6.15 or later) and requires [Adobe Flash Player](#) to be installed and javascript enabled.

You can navigate through the relevant information sections using the menubar above.

You are currently viewing information related to the C-130J Wing Fatigue Test.

Current test status

Latest DAQ Session #4

Session: Block120_4_300715 Block#: 120

Session End:

Instruction#: 250 Step#: 1148

Test Hours: 62456.0

Date/Time: 2015-08-01 05:30:50

Latest Configurations

Test Rig Configuration Version: 2

DAS Configuration Version: 1

DAS Configuration Version: 1

Latest New DI

Issue Report #4 for DI337 created @ 2016-01-30 10:09:05

Issue Report #10 for DI258 created @ 2016-01-30 09:58:11

Issue Report #10 for DI257 created @ 2016-01-30 09:51:06

Issue Report #2 for DI372 created @ 2016-01-30 09:40:29

Issue Report #5 for DI311 created @ 2016-01-30 09:25:51

Issue Report #5 for DI312 updated @ 2016-02-23 15:01:48

Issue Report #4 for DI311 updated @ 2016-02-23 15:00:29

Issue Report #3 for DI345 updated @ 2016-02-23 14:58:33

Issue Report #14 for DI266 updated @ 2016-02-23 14:56:31

Issue Report #10 for DI281 updated @ 2016-02-23 14:53:55

Latest New Finding

FN1424 created @ 2018-05-08 03:45:14

FN1423 created @ 2018-05-07 22:56:23

FN1422 created @ 2018-05-07 22:37:58

FN1421 created @ 2018-05-07 21:13:17

FN1420 created @ 2018-05-07 04:53:59

Latest Updated Finding

FN1397 updated @ 2018-05-29 03:59:22

FN1396 updated @ 2018-05-29 03:56:54

FN1395 updated @ 2018-05-29 03:55:54

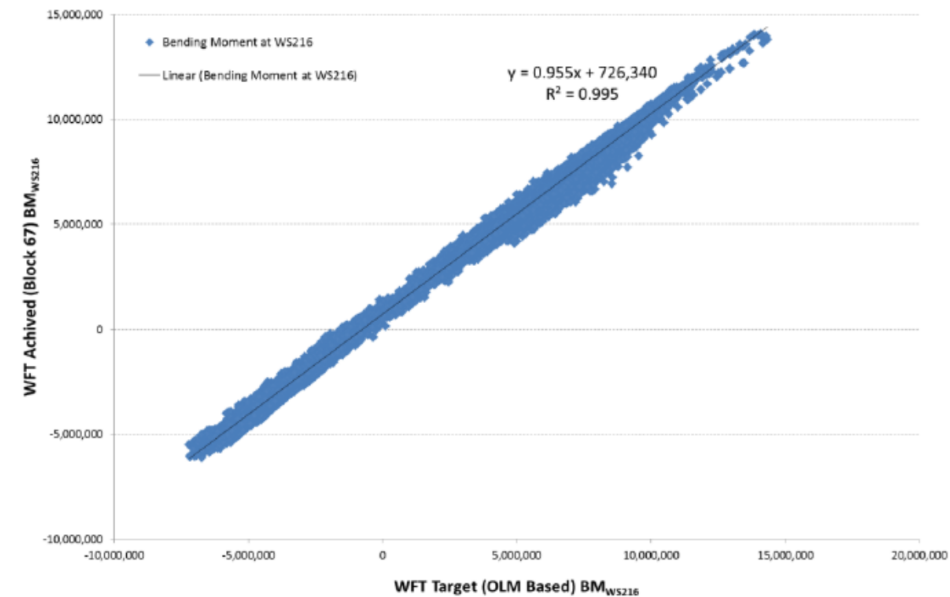
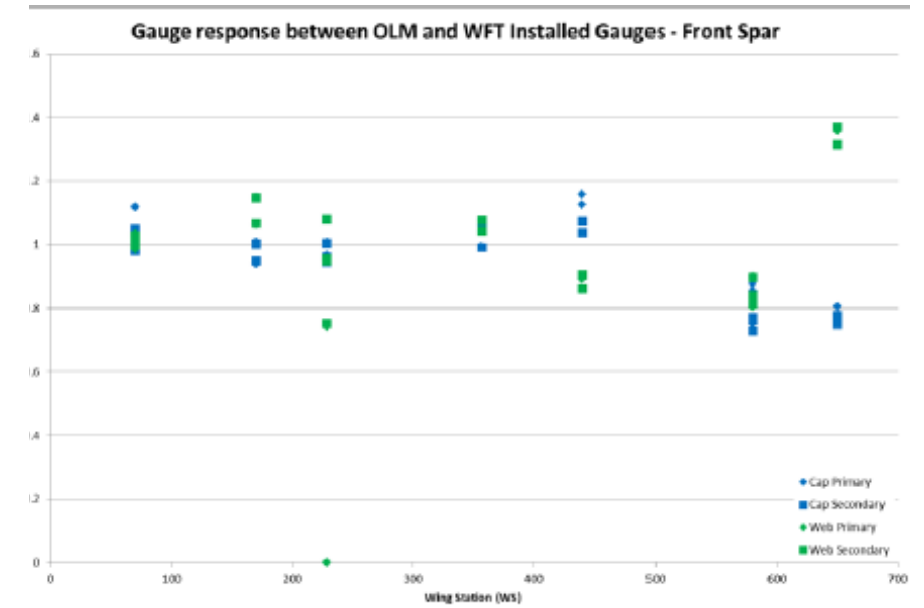
FN1394 updated @ 2018-05-29 03:53:21

FN1393 updated @ 2018-05-29 03:51:42

View changes since your last login (Coming soon!)

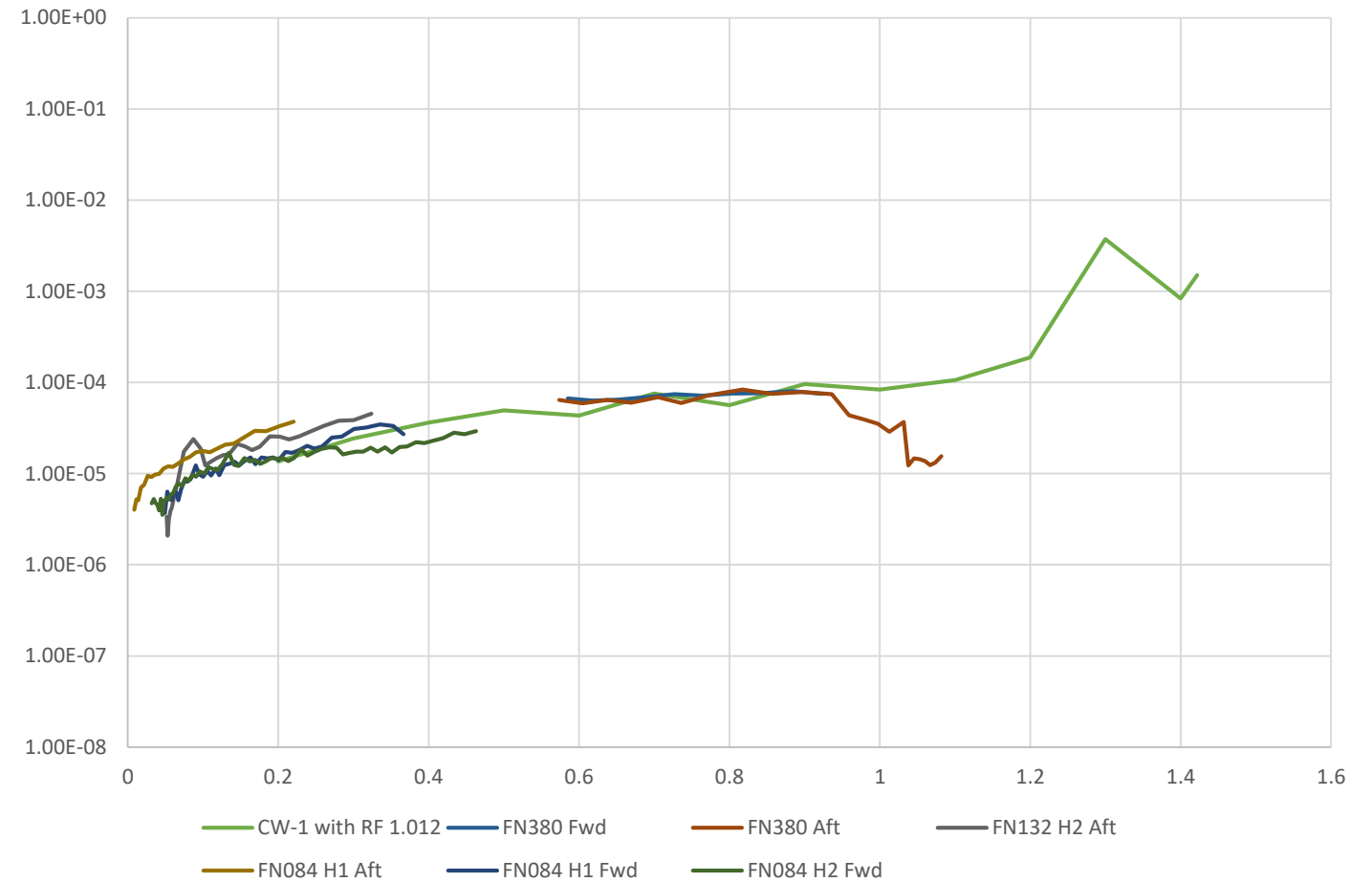
Verification and Validation

- 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)



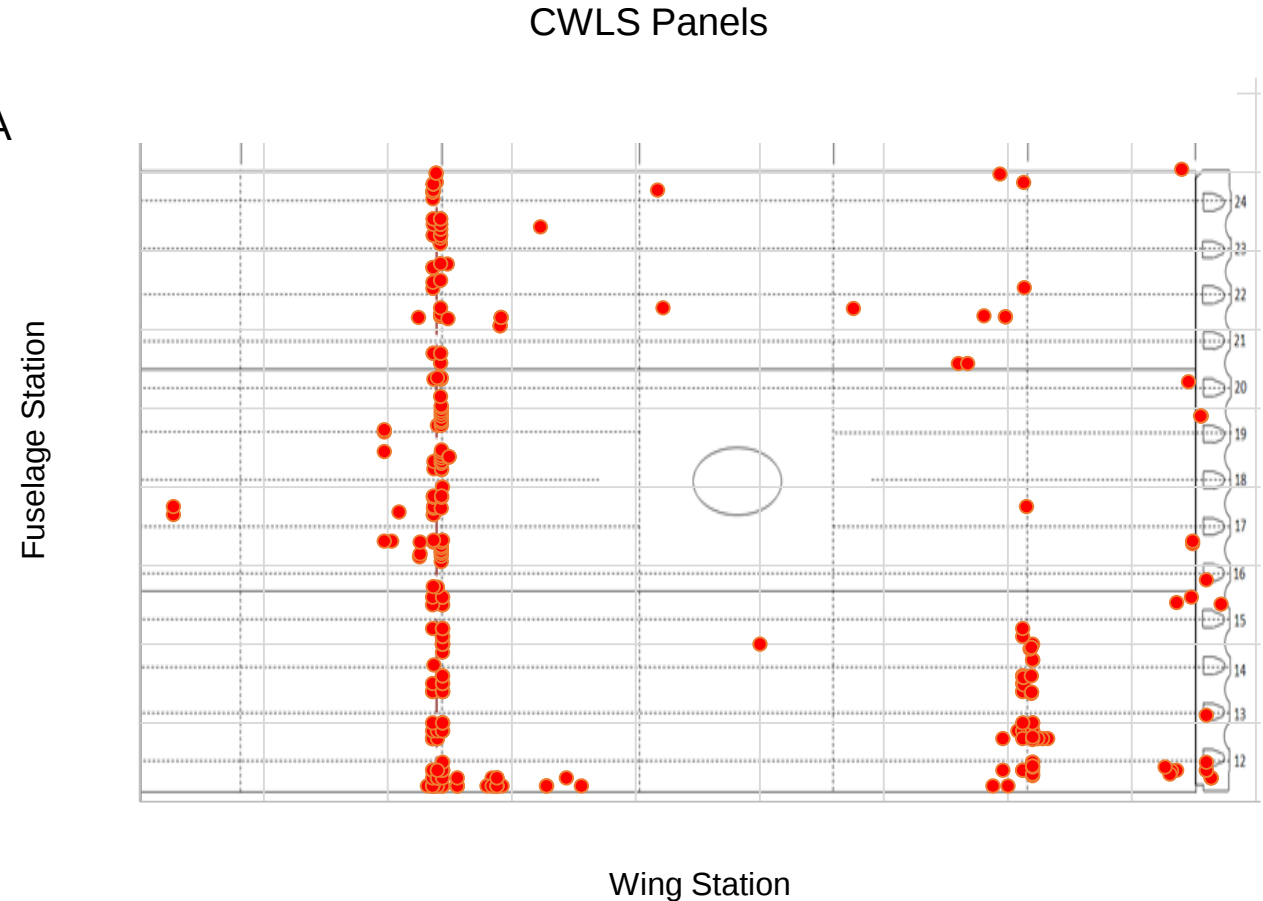
Verification and Validation

- 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



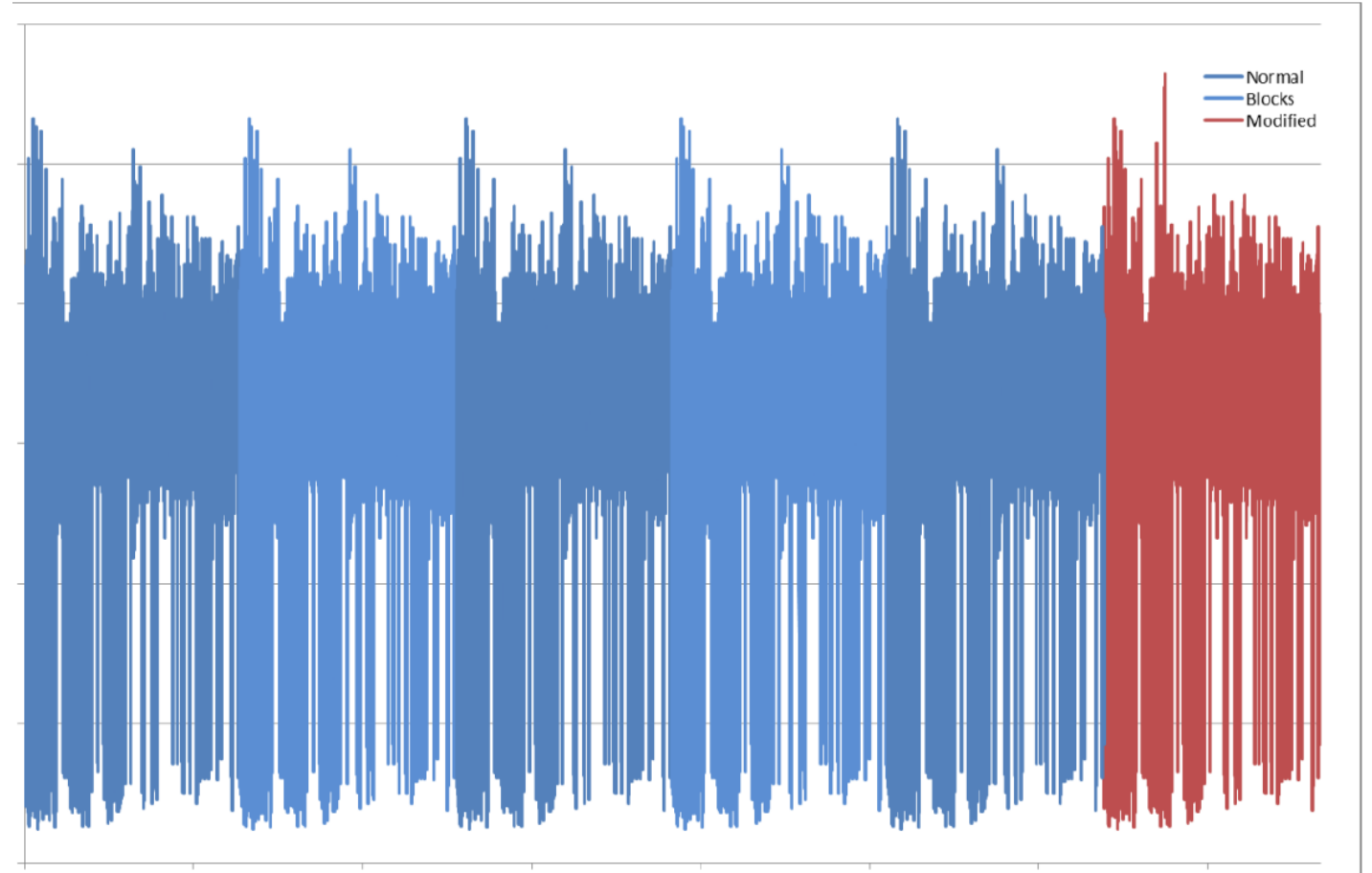
Selection of Locations

- 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



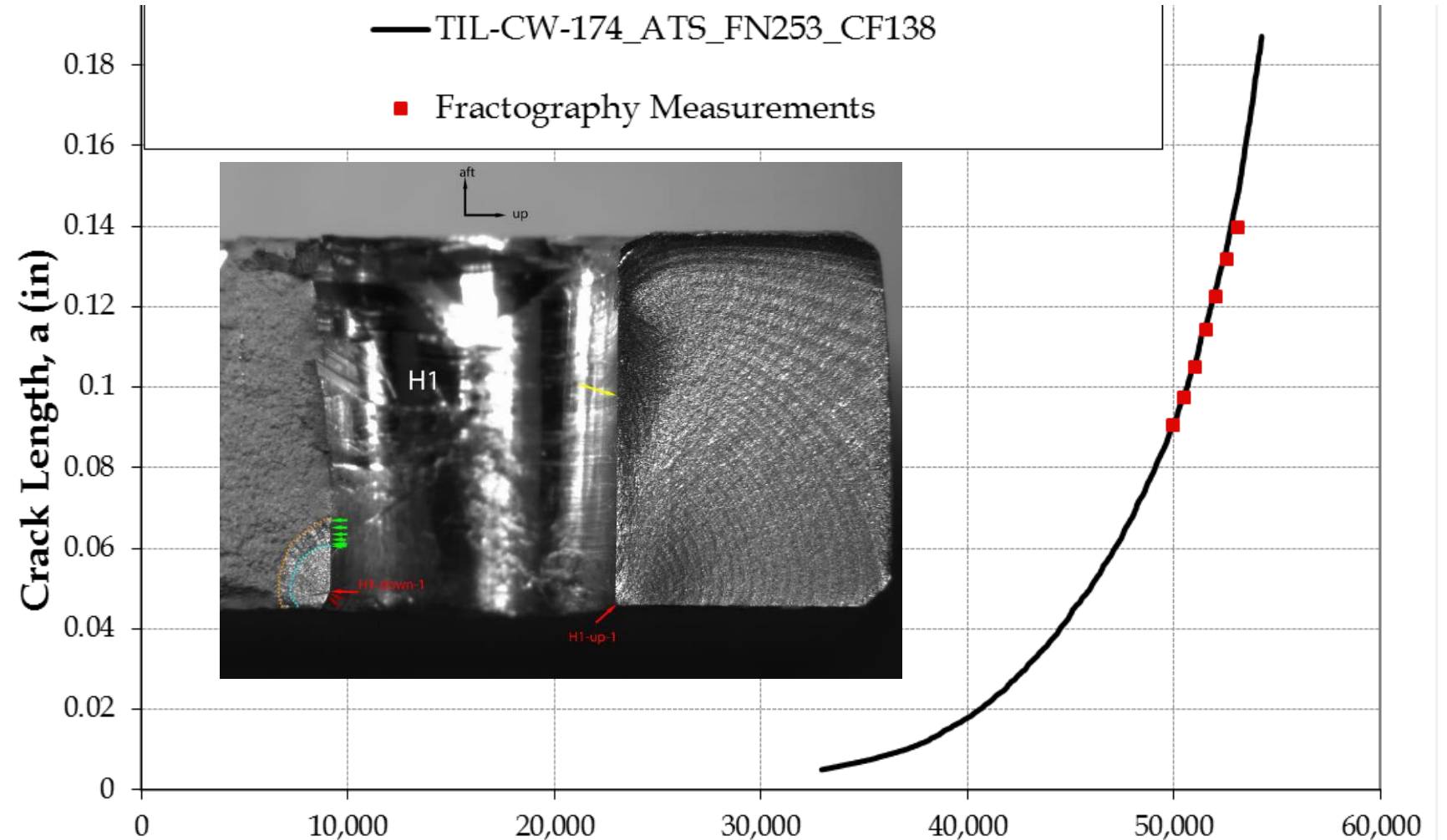
Spectrum

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



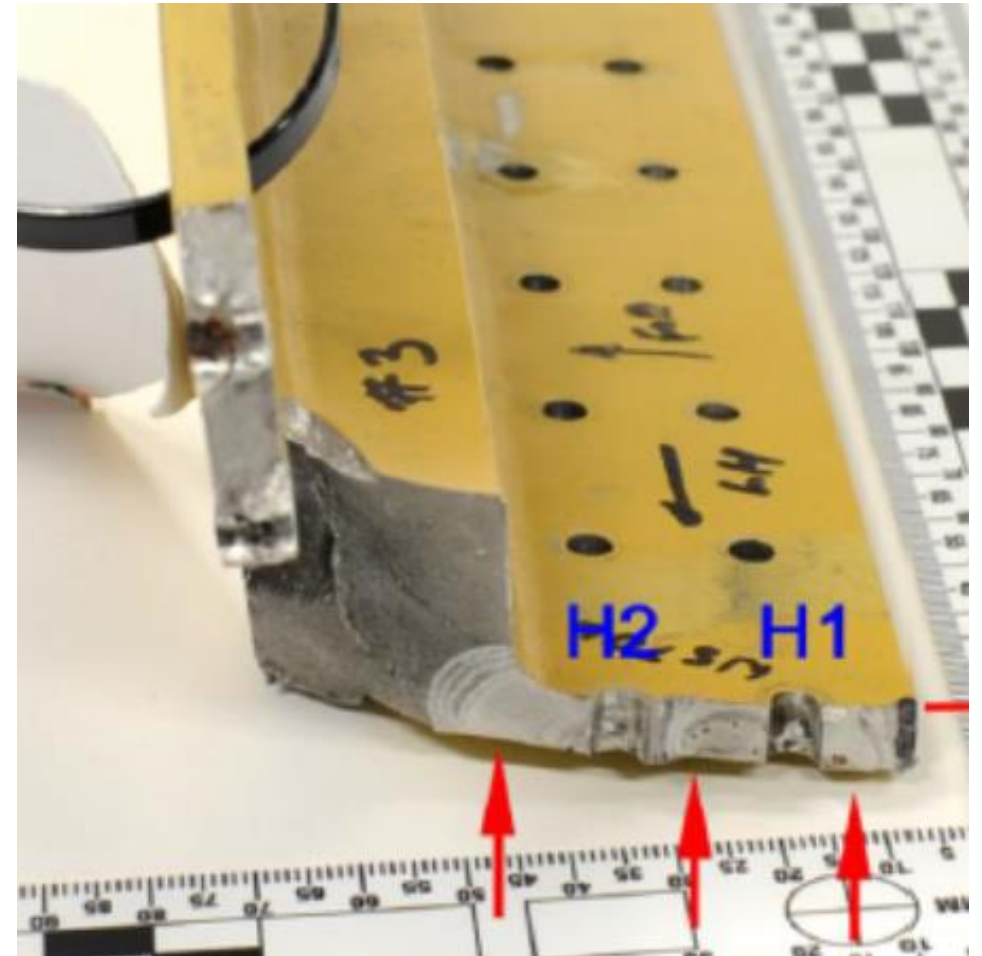
Calibration Factor

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



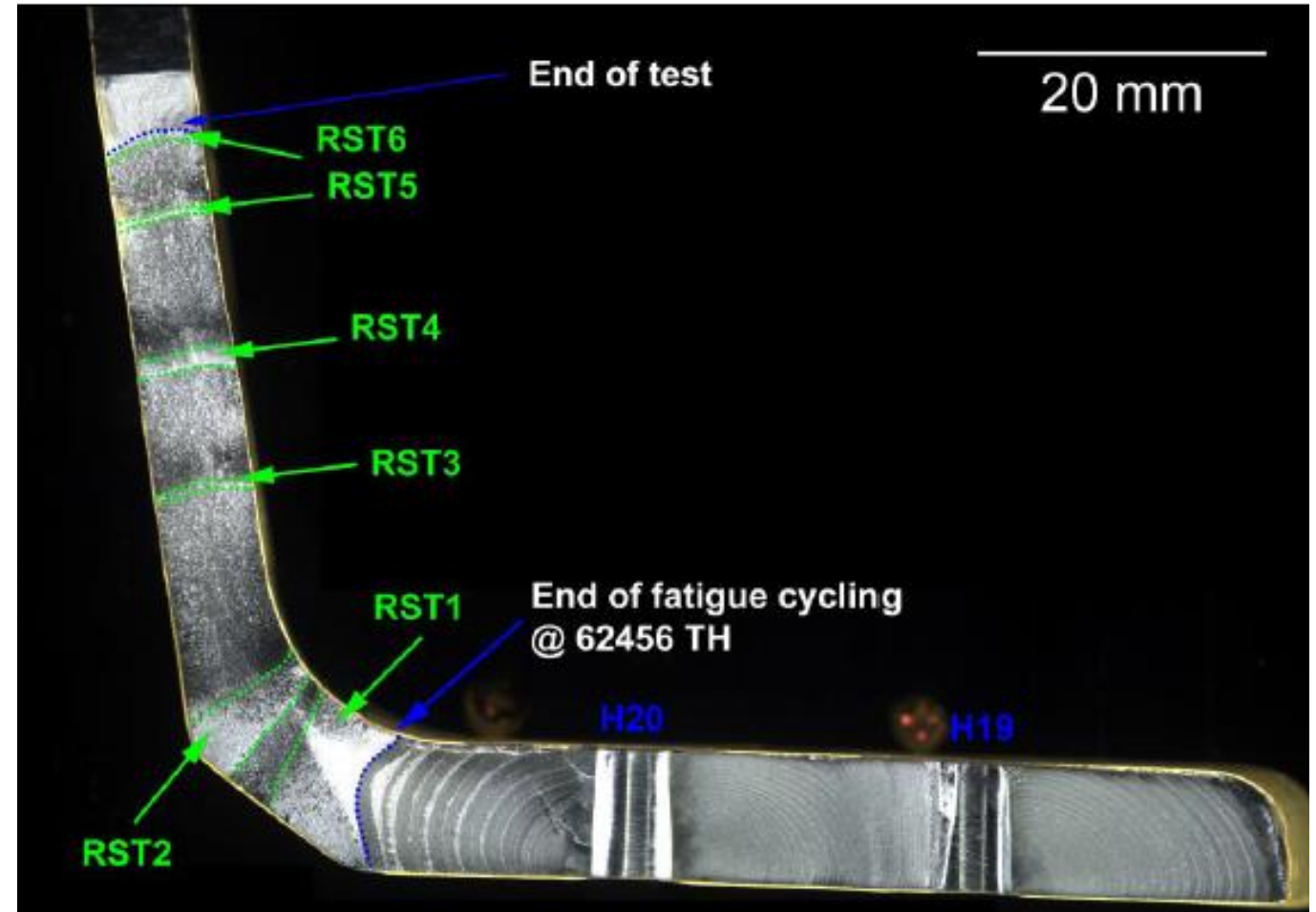
Calibration Factor

- 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



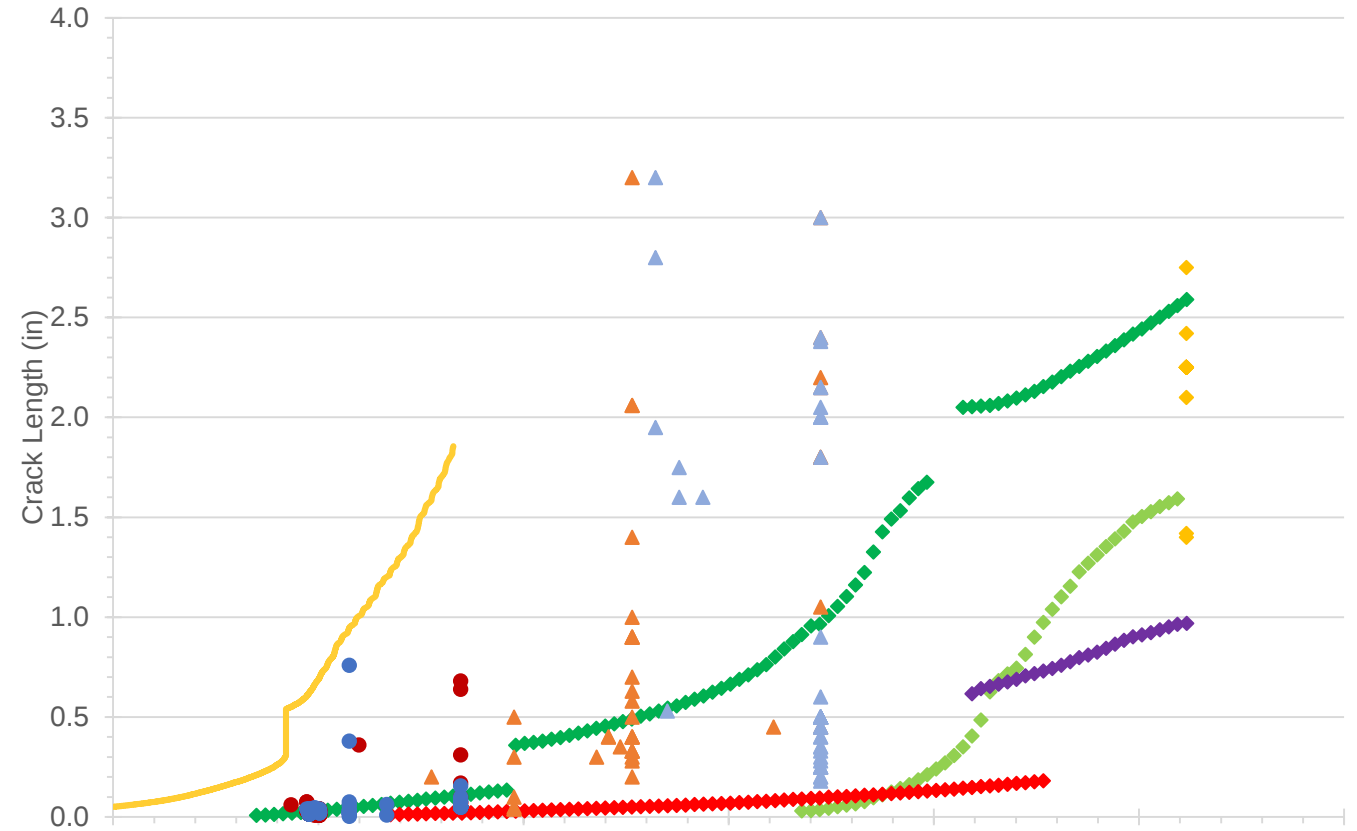
DTA

- 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



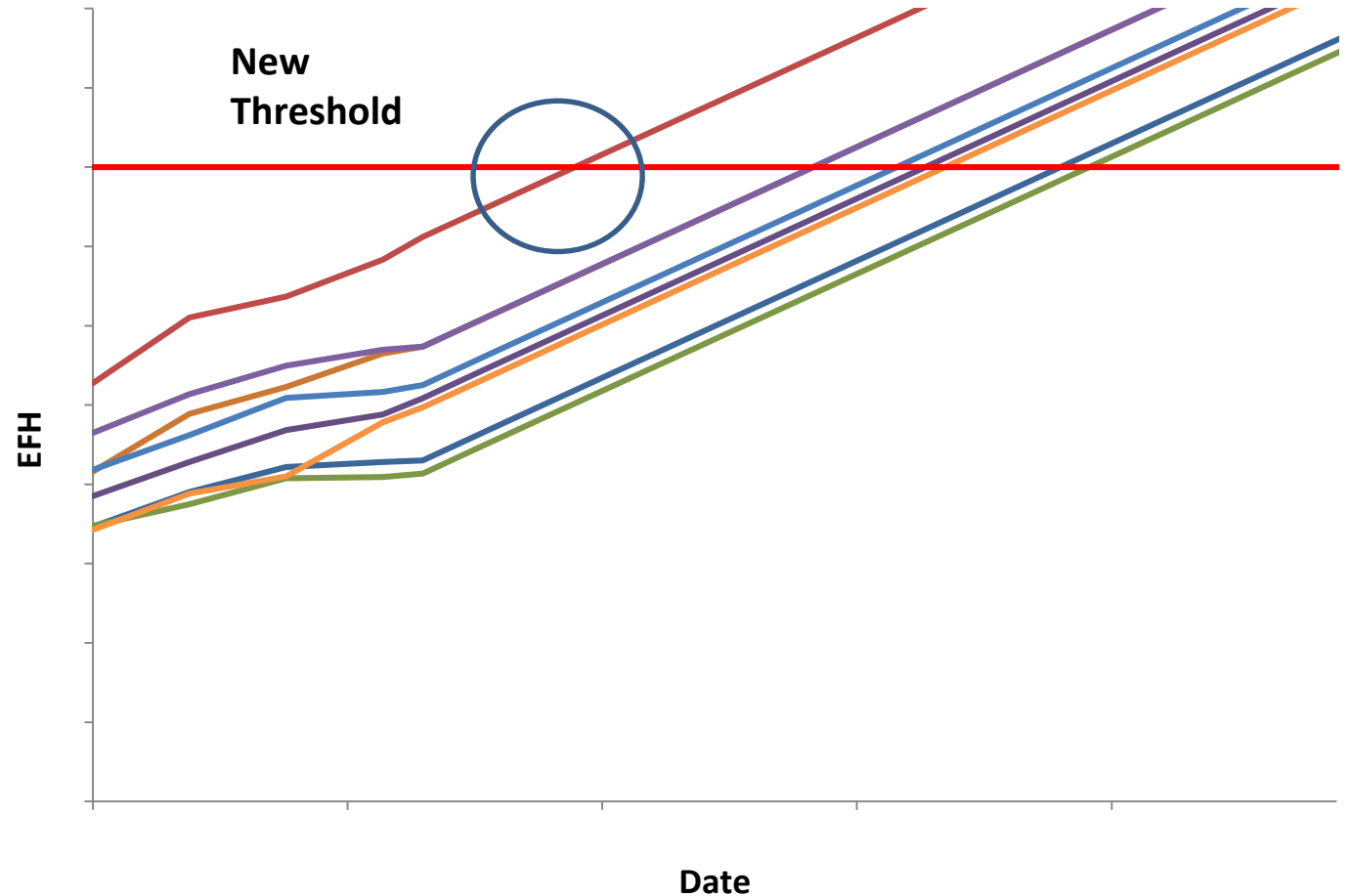
Interpretation

- 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



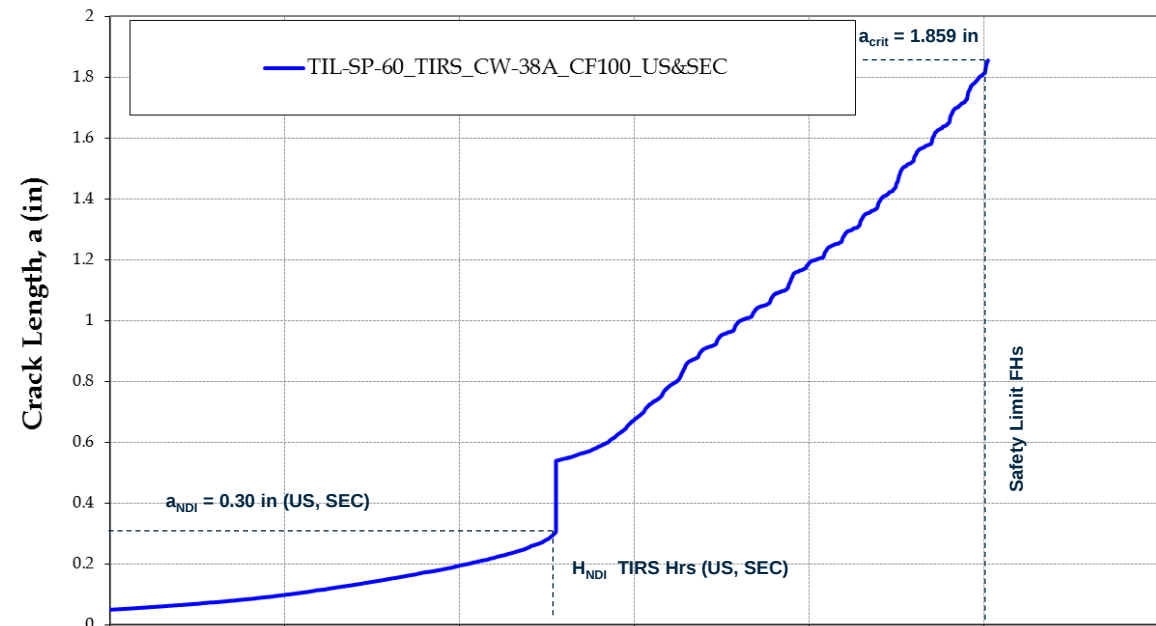
Implementation

- 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



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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