Utilizing Condemnations, Retirements and Mods to Improve the Structural risk Analysis of the T-38: Turning Trash into Treasure

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Team Members

USAF Academy Center for Aircraft Structural Life Extension (CAStLE)

- T-38 Program Office/ASIP
- USAF Academy Center for Aircraft Structural Life Extension (CAStLE)
- Southwest Research Institute
- Sabreliner Aviation

T-38 Talon

USAF Academy Center for Aircraft Structural Life Extension (CAStLE)

- Jet trainer introduced into service from 1961-1972, now entering it's **fourth** 20 year lifetime
- Over 20 different usages and numerous modification/SLEP programs
- The purpose of this presentation is to share insight on what has made the T-38 teardown program useful for risk analysis, and by extension, fleet management

T-38 Teardowns

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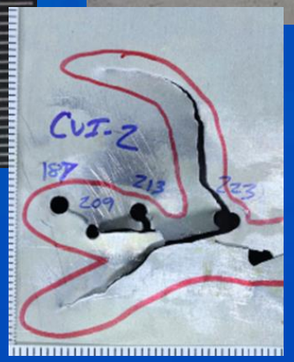
- Since 2010, the T-38 team has built a strong commitment to performing structural teardowns
  - 2 fuselages, 200 fatigue cracks
  - 30+ wings, 1,500 fatigue cracks
  - 22 landing gear
  - 100+ Additional condemned and modification components



Turning Mountains into Molehills

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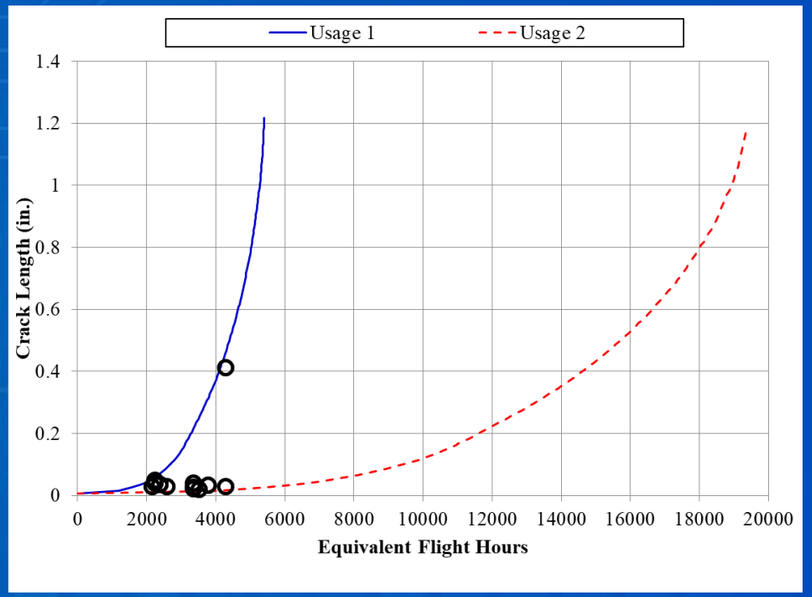
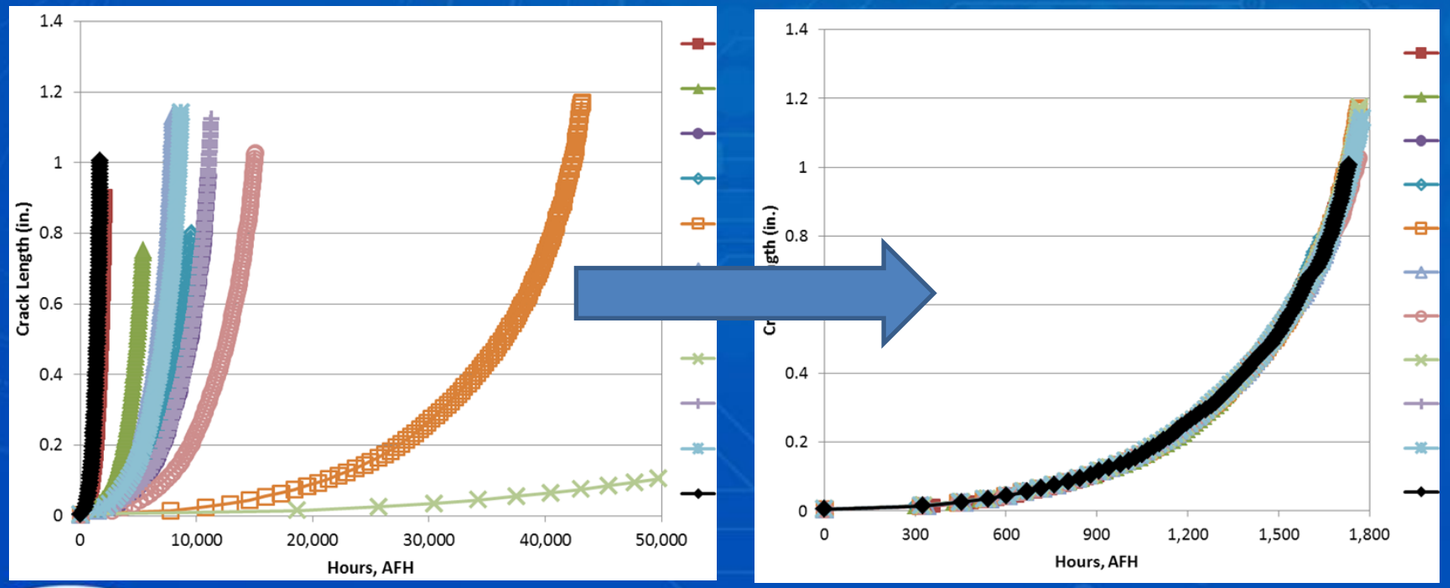
- Group like findings at each critical location
- Calculate equivalent flight hours for each finding
  - Using the history of each wing or fuselage, determine number of hours in each usage and calculate equivalent severe usage hours
- Validation of crack growth curve





EIFS Distributions

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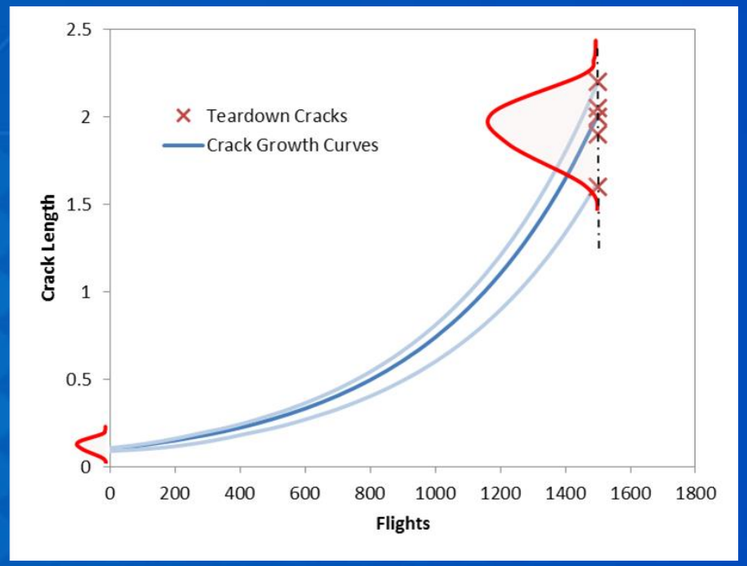
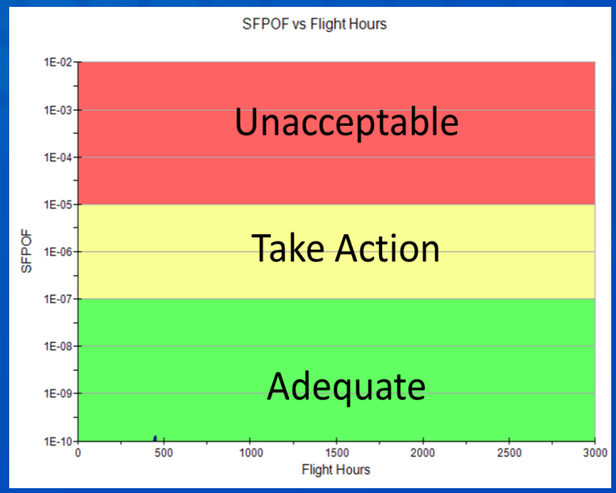
- Equivalent Initial Flaw Size (EIFS) is a hypothetical crack that results in the equivalent life to a crack that was in the structure at time zero
  - Crack is assumed to follow the durability crack growth curve
- T-38 now has location specific EIFS distributions for the highest priority wing and fuselage locations (~10 distributions)
- MIL-STD-1530D: **Structural risk analysis** – "shall be performed using the EIFS distribution" to "determine the time beyond the design service life when required safety inspections and/or modifications would result in consequences that are judged to be unacceptable"
- Risk analysis used to determine inspection intervals, replacement/retirement, modification induction schedule





10^{-5}

10^{-7}

Case Studies

Condemnations

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- Full-scale fatigue tests of two T-38 wings under different usages, presented at ICAF2017, resulted in a failure at a mechanically milled pocket in the lower wing skin.
- Updated Non-Destructive Inspection procedures resulted in numerous crack indications and condemned wings.
- Milled pocket indications were excised from the wing skin and sent for failure analysis.
- Cracks nucleated from multiple machine marks from milling process.

Condemnations

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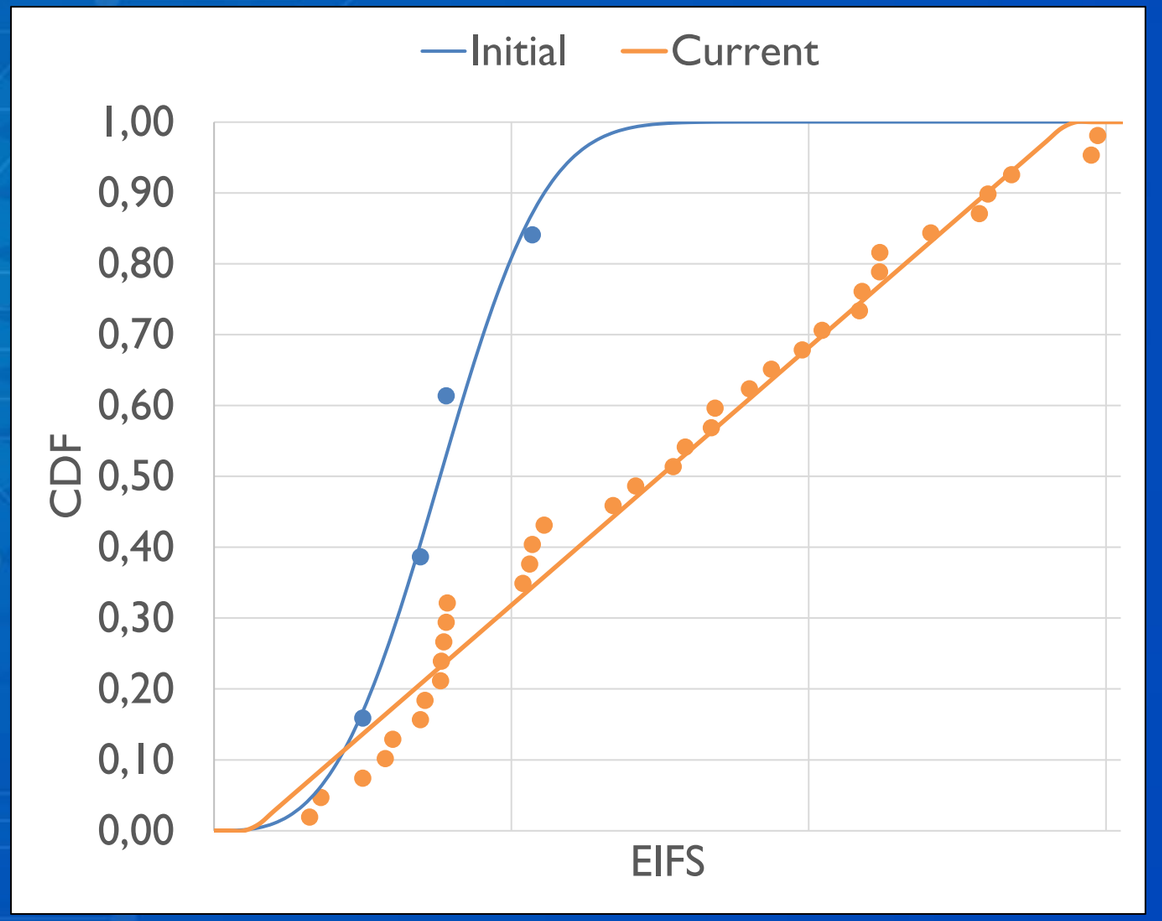
- 4 Initial EIFS points
- Assumed Weibull distribution
- 36 confirmed cracks from condemnations
- Uniform distribution
  - Arises in manufacturing where a mass-produced part gradually changes dimensions through **tool wear** and increased tool forces between setups



Condemnations

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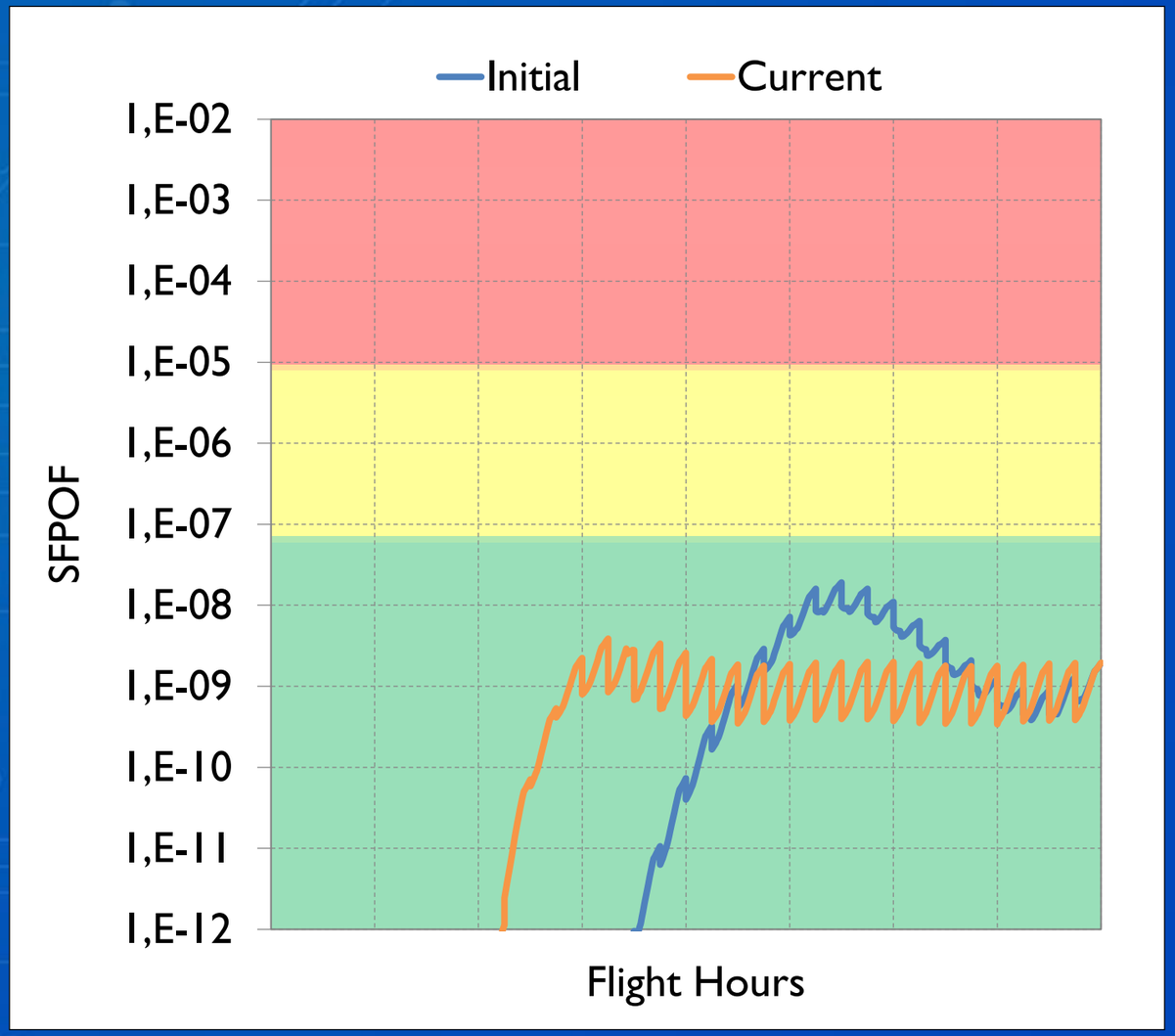
- Uniform EIFS shows an earlier increase in risk
- Weibull EIFS shows a 10x higher maximum for risk
- Expected crack findings match actual findings



Teardowns

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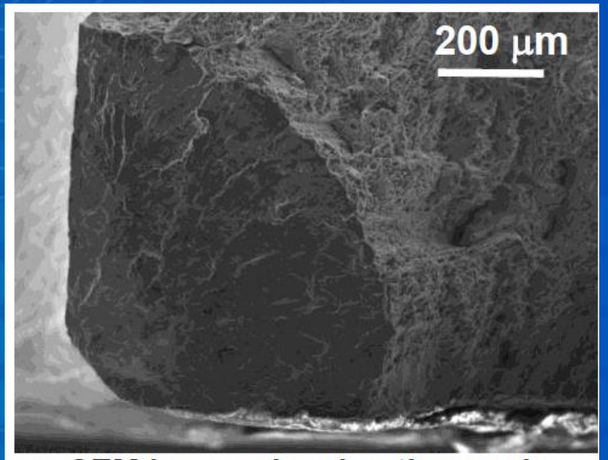
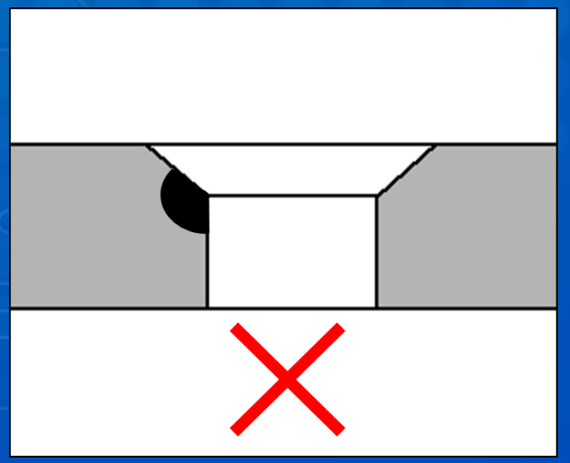
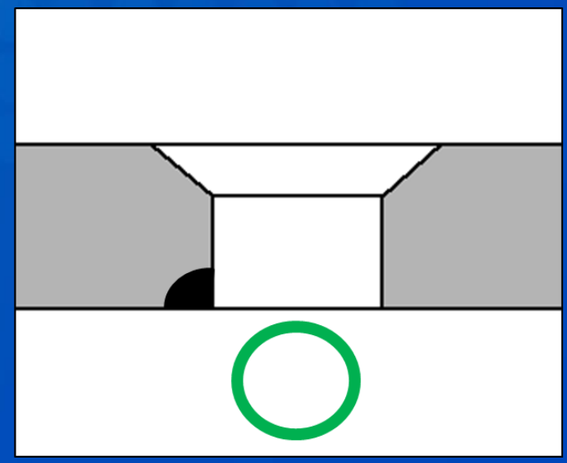
- Initial PROF analysis calculated "high risk" at a cold expanded countersunk fastener
  - No field findings to warrant "high risk"
- Teardown results provided over 30 failure analyses with sized cracks at this location
- More importantly, the FA revealed that all cracks nucleated from the faying surface of the hole, whereas the DTA assumed the crack at the countersink knee



SEM image showing the crack nucleation site at faying corner

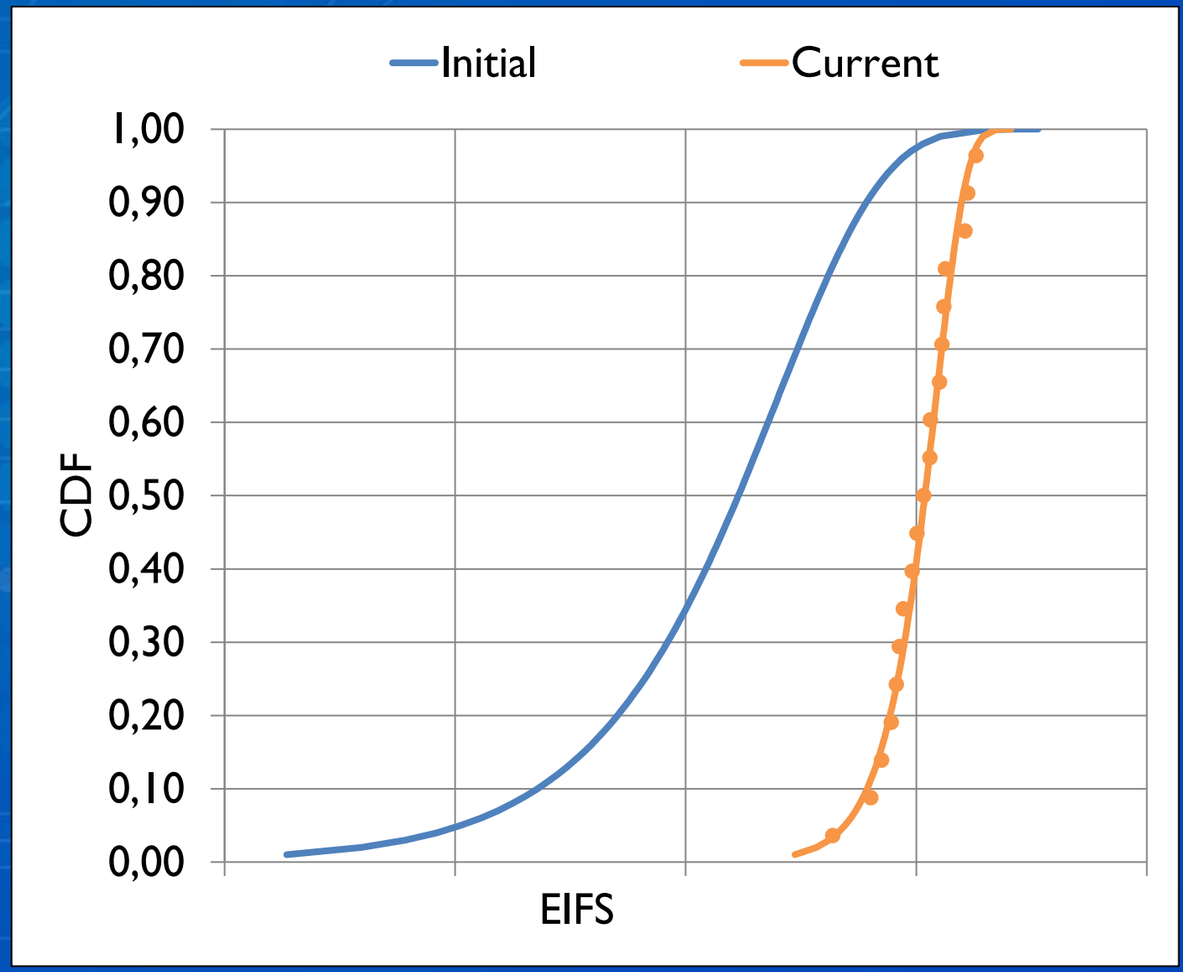




Teardowns

USAF Academy Center for Aircraft Structural Life Extension (CAStLE)

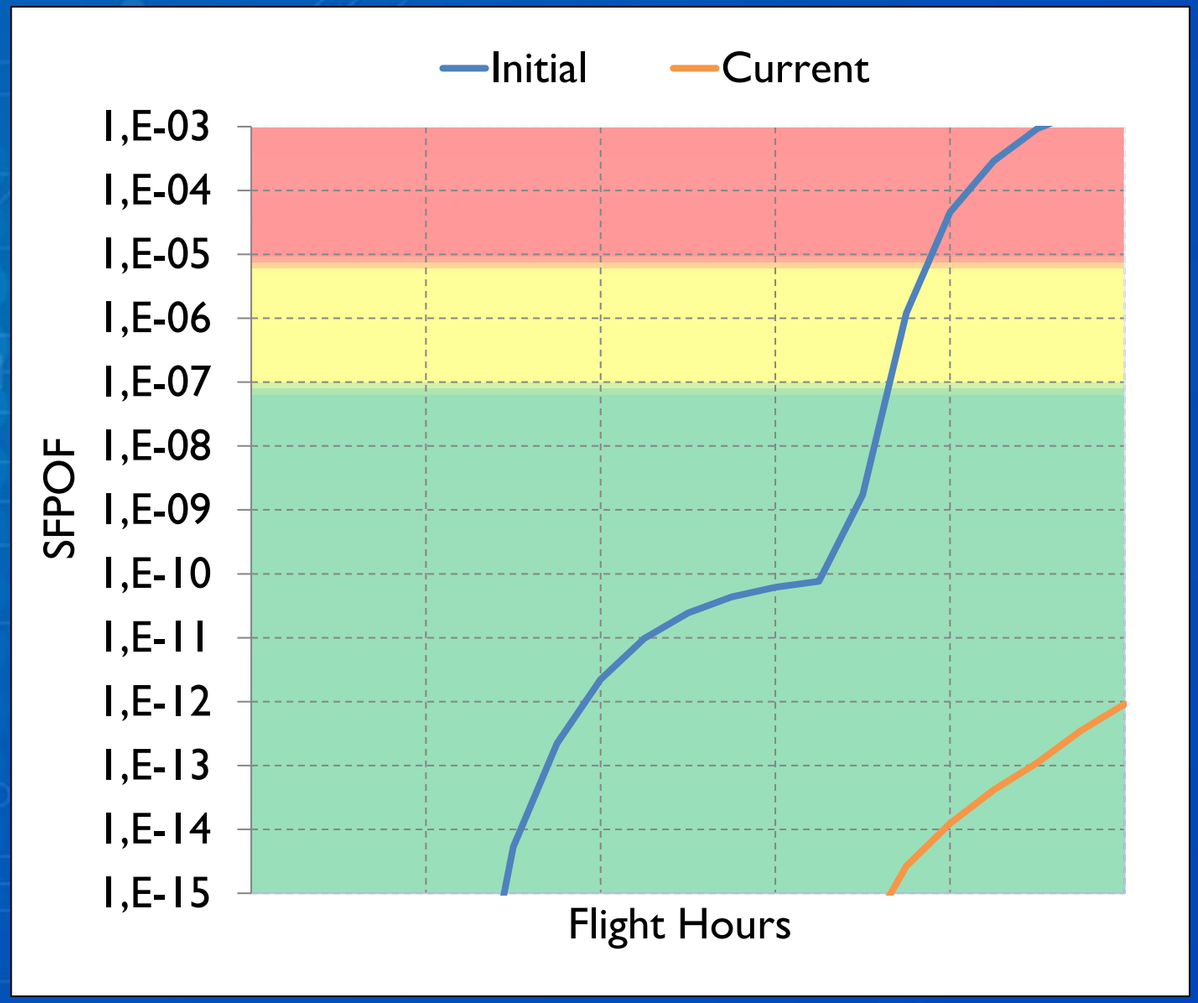
- An AFGROW model was created with the crack at the faying surface instead of the countersink knee
- The initial analysis used an EIFS distribution from a wing durability test conducted in the 1990's
- The initial EIFS distribution was not specific to one location and instead captured the variation from all cold expanded holes in the lower wing skin
- EIFS distribution was recalculated using the new crack growth life curve



Teardowns

USAF Academy Center for Aircraft Structural Life Extension (CAStLE)

- Current PROF analysis shows that risk remains below 10^{-7} for the lifetime of the wing
- Why is the risk so low when there have been numerous teardown findings?
  - Largest recorded crack was 0.07 in., critical crack size is an order of magnitude larger
  - 1.2 lifetimes between largest measured crack and CCS
- **Teardowns from retired wings, identifying true cracking location, were essential for lowering risk and preventing unwarranted extra inspections**



Modification Program

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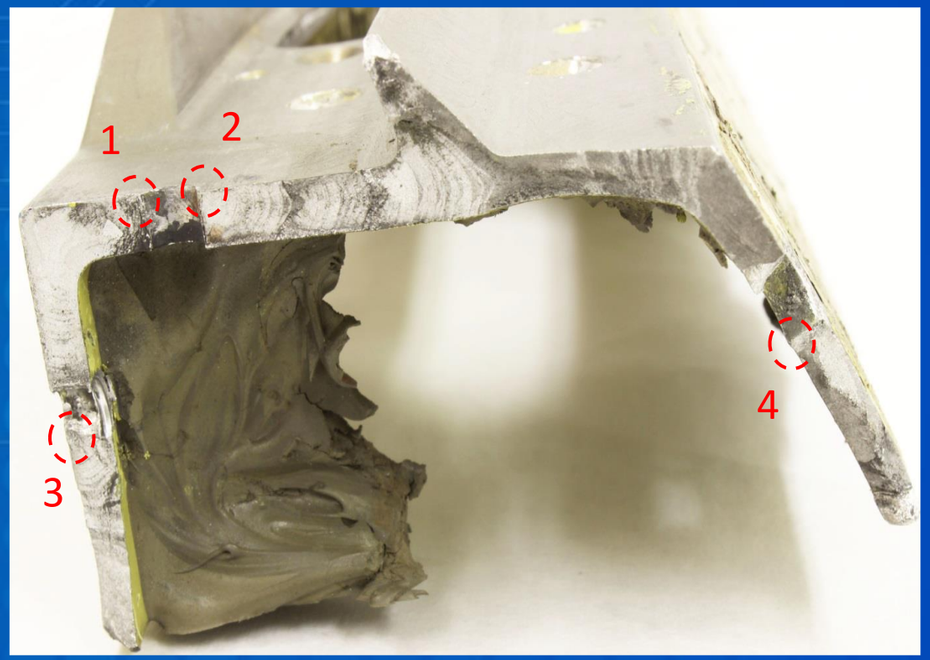
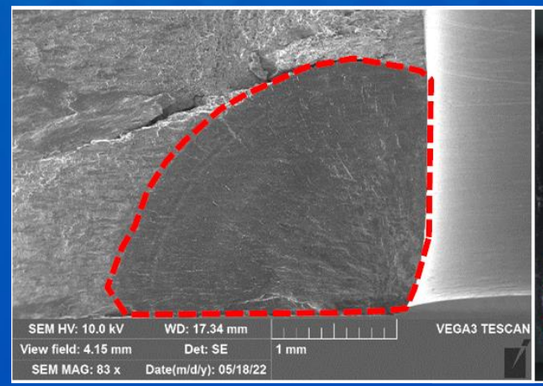
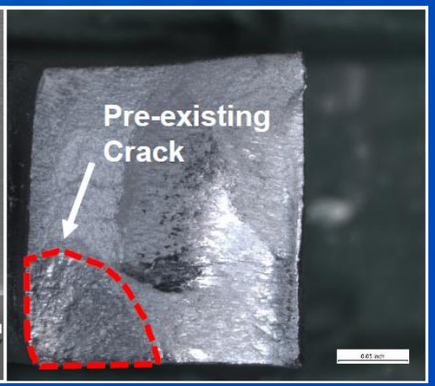
- In 2017, a previously unknown fuselage longeron was found cracked in the field
- Double-sided crack found at points 1&2, continuing damage at 3&4
- At the time, Pacer Classic III (PCIII) was ramping up
  - 3rd major modification program of the fuselage
  - Remove and replace multiple primary structure items
  - 150 longerons inspected that were headed to trash
- Old longerons were inspected and a failure analysis was performed on positive indications



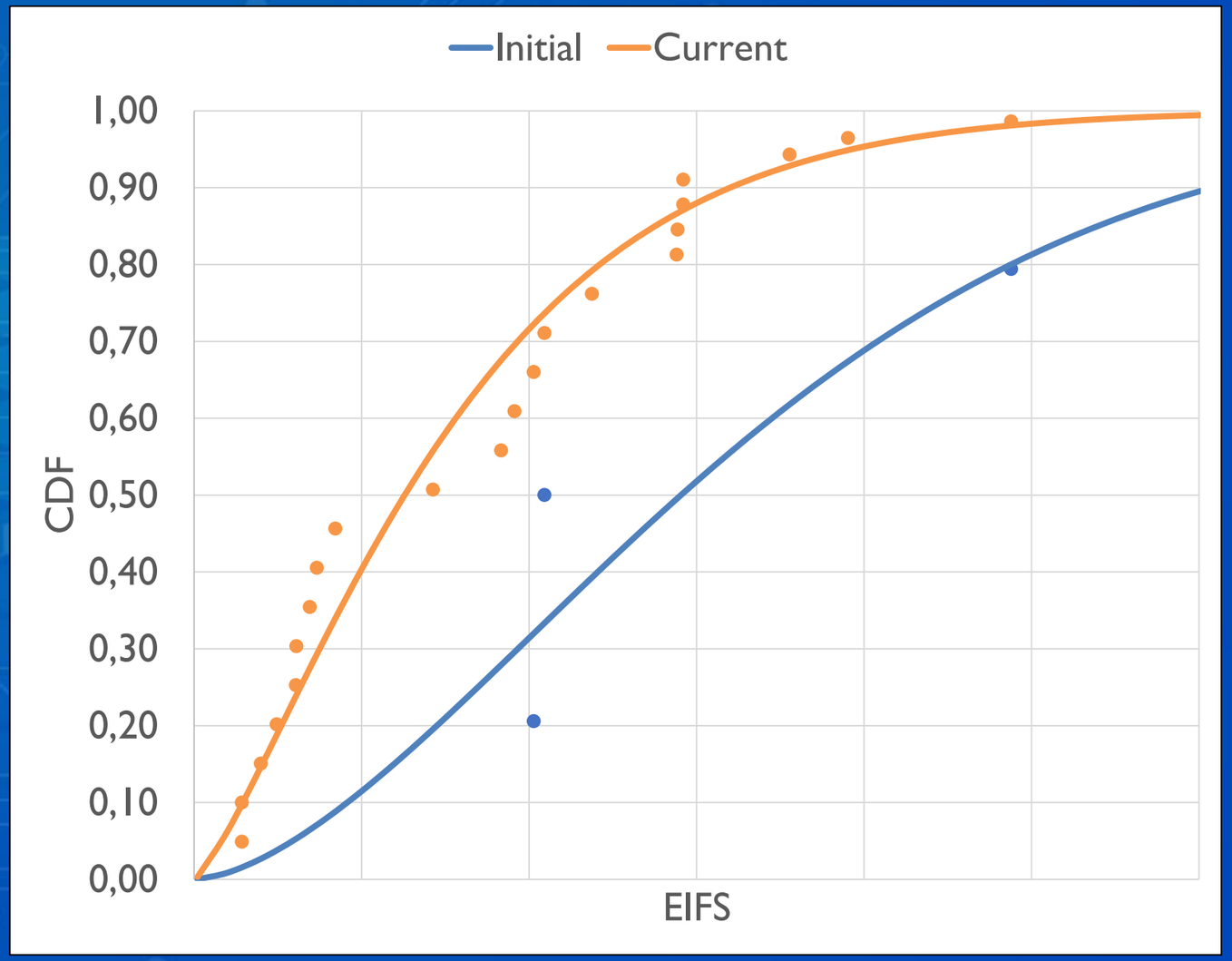




Modification Program

USAF Academy Center for Aircraft Structural Life Extension (CAStLE)

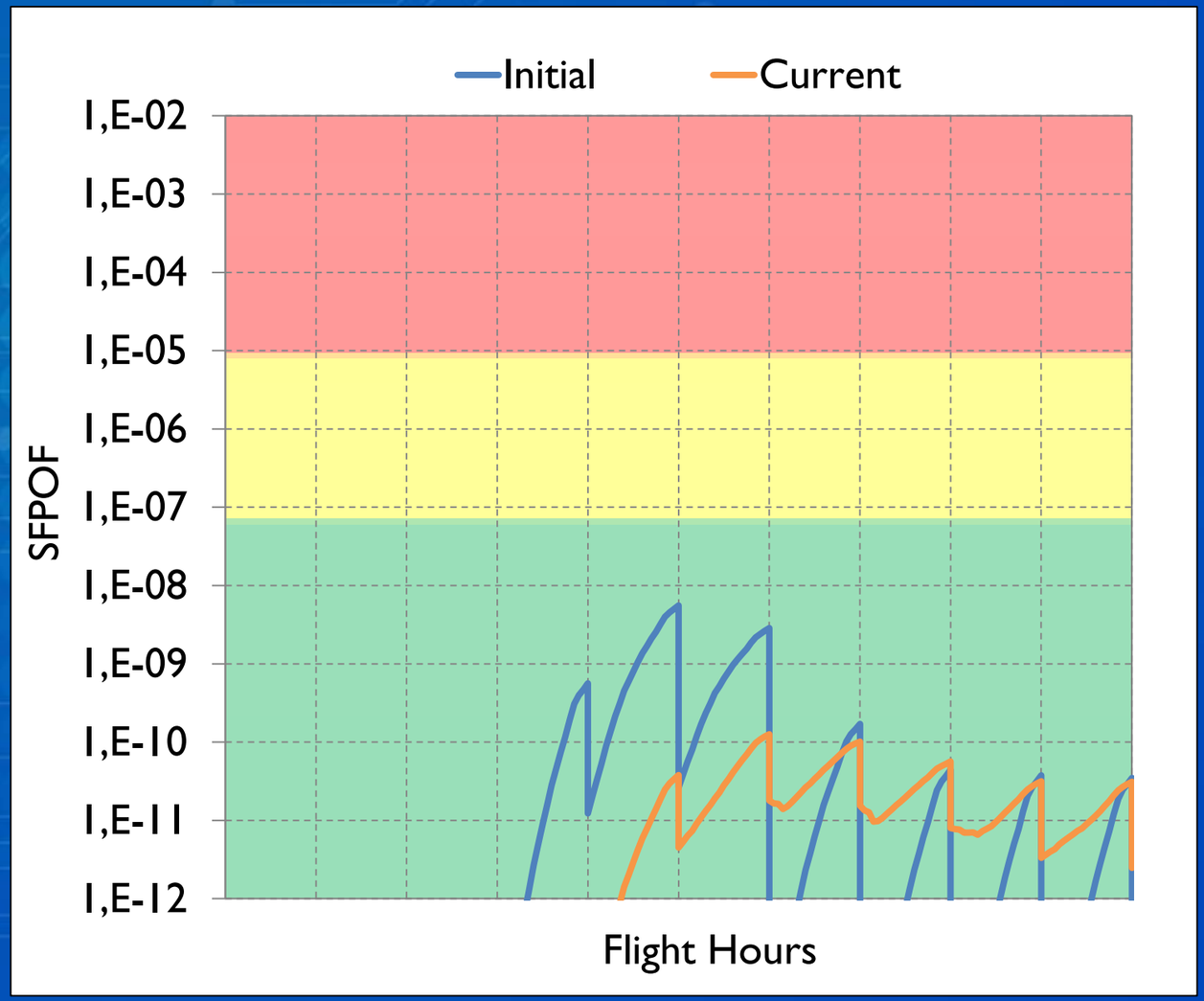
- Without PCIII inspections, EIFS dist. would be based on lone observed crack
- PCIII inspection of removed longerons revealed 24 confirmed cracks
- 10 were double cracks, 14 were single cracks
- Two DTA curves were used to create EIFS distribution based on single or double crack



Modification Program

USAF Academy Center for Aircraft Structural Life Extension (CAStLE)

- Current risk shows a lower maximum and a shift to the right
- Inspections were doubled to reduce risk to acceptable levels
- Highest risk longerons have been removed and replaced in major modification program, further mitigating risk
- **Realistic risk analysis would not have been possible without data from teardowns of opportunity**



Summary

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- MIL-STD 1530D states that EIFS/EIDS data is needed for risk analysis and should be updated regularly
- Teardowns of retired T-38 wings and fuselage parts have provided a wealth of data for initial flaw size distributions and risk assessment
- Teardowns can confirm or refute assumptions made in the analysis, leading to a more realistic risk assessment
- Quality risk assessments guide T-38 fleet management decisions on inspections, modifications, and retirements

Questions?