



Reconstruction of B-52 DTA Using AFGROW

2022 AFGROW User Group Conference

13 Sept 2022



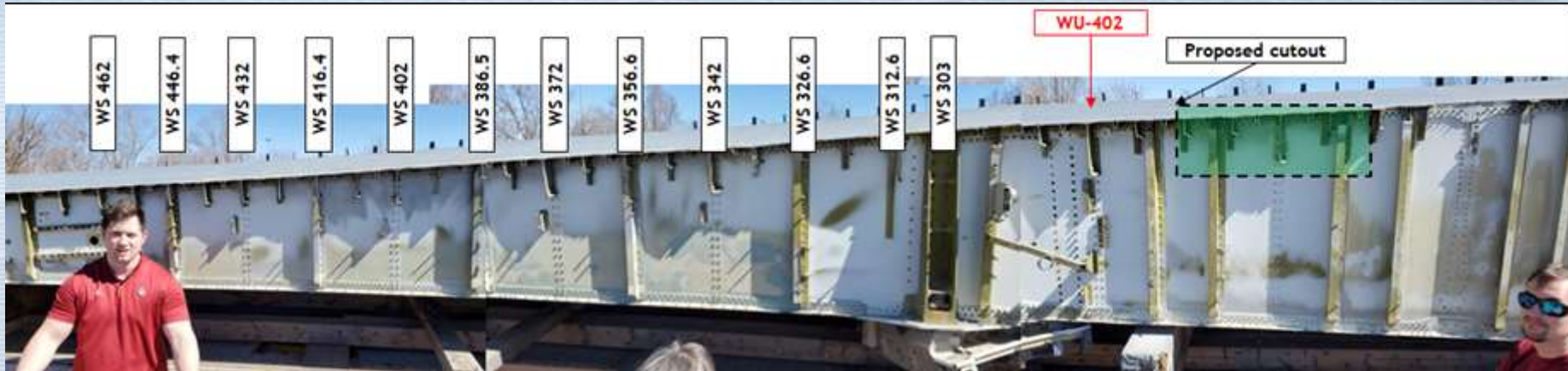
- B-52 Mission Requirements
- WU-402 Context
- WU-402 Initial Conditions
- Recreation Analysis
- Analysis Refinement



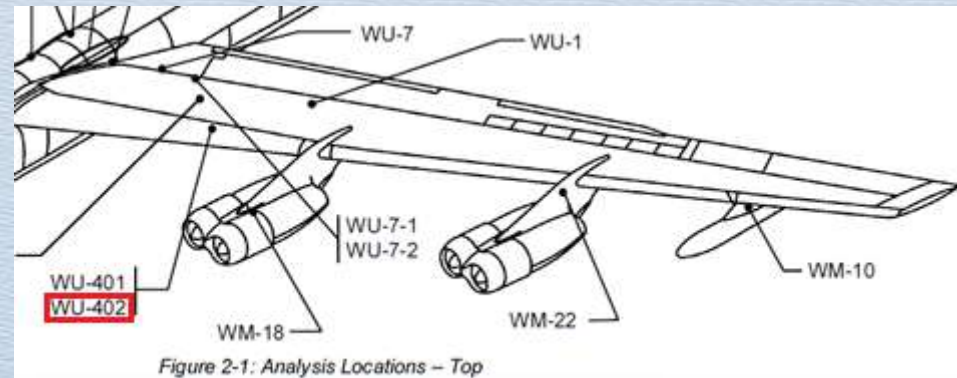


- B-52 SPO asked to keep the B-52 flying
 - Aging fleet
 - Original material prone to SCC
 - Lack of clarity on the Boeing DTA process.
- A-10 tasked to assist in progressing the B-52 ASIP efforts and DTA methods.





- Where is WU-402
 - Upper forward spar cap detail
- Why is it a problem
 - Critical location
 - Challenging inspection
 - Original inspection spanned 100s of fasteners
 - Cont. damage case with very little growth in secondary crack before critical crack length
- What is the objective
 - Explore alternative methods to determine if there is additional life/benefit not being leveraged.
 - Better understand existing DTA practice and expand internal capability

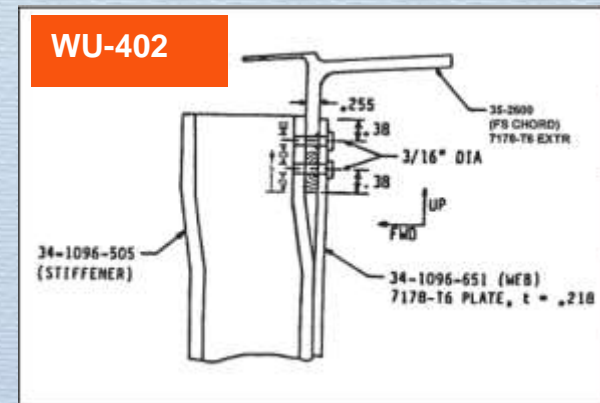




- Material: 7178-T6 Ext
 - Internally developed material tables
 - $Kc(\text{ksi} \cdot \sqrt{\text{in}}) = 31.9$
 - Fastener variation
 - Edge distance in some cases less than .38
- Model Considerations
 - Spectrum developed based on expected mission mix
 - OEM spectrum not provided
 - Wheeler retardation model used
 - $m=1$
 - Initial Flaw Size = .05in
 - Critical Crack Length provides minimal continuing damage life in 3rd phase
 - Detectable Flaw Size = .27in
 - Primary ligament length = .257in
- Modeled as hole in flat plate with .05in corner crack.

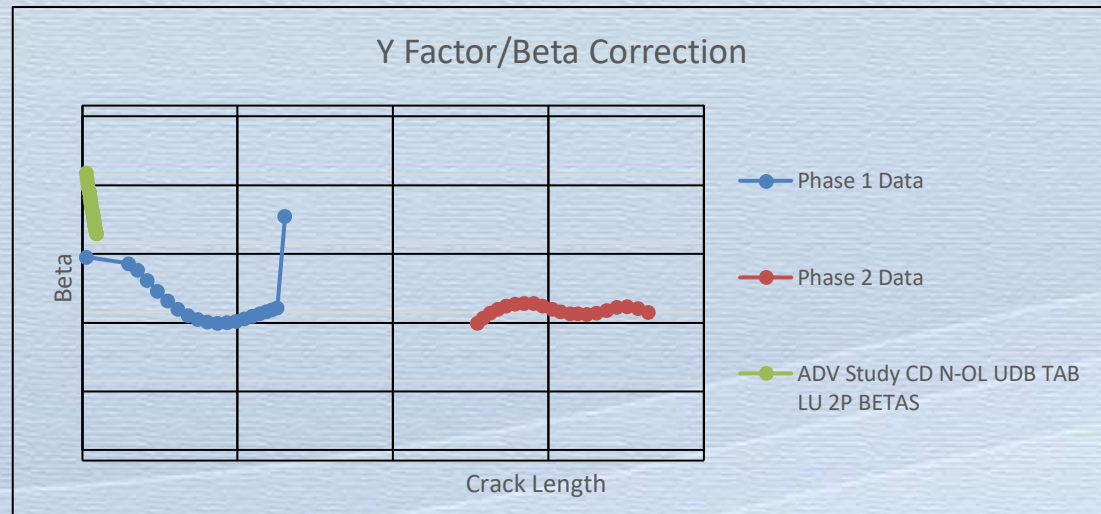
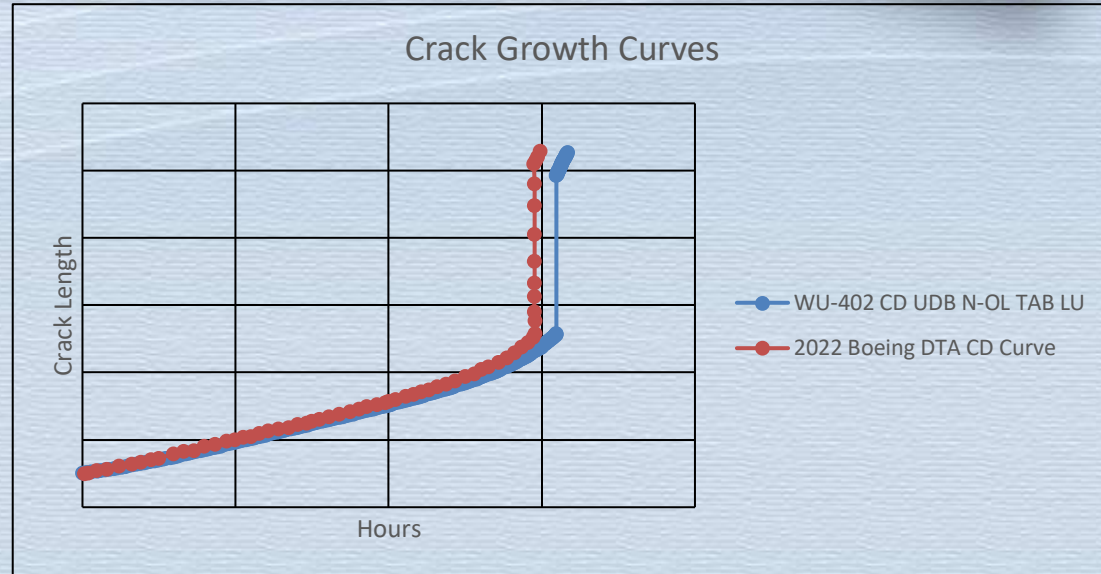


Figure 4-23. FSMP Detail WU-402 Front Spar Upper Chord to Web Attachment



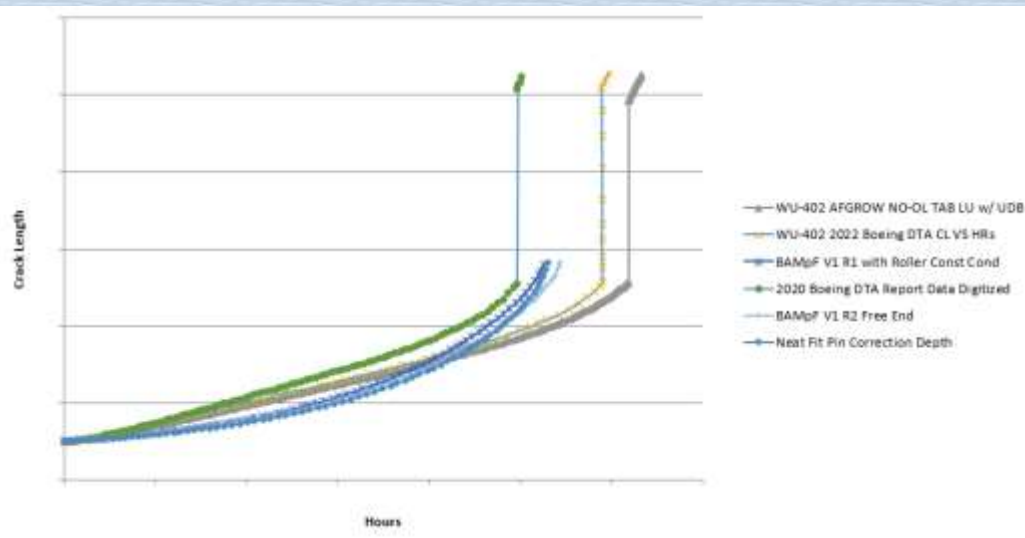
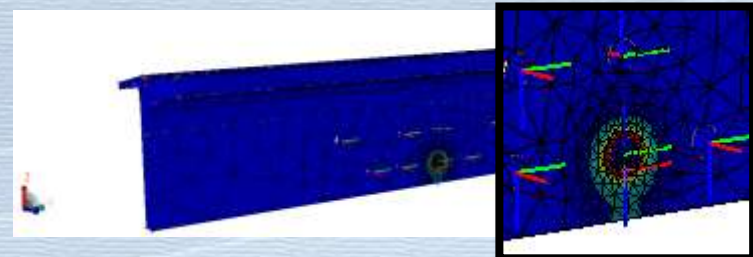
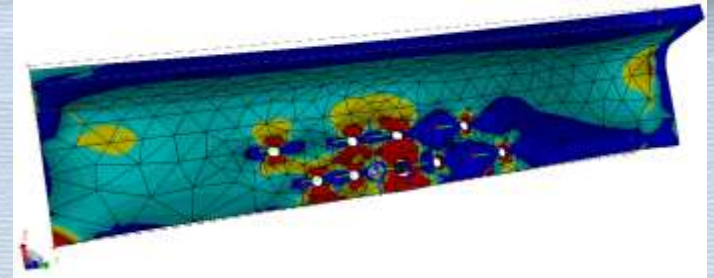


- Continuing damage study run using AFGROW
 - Advanced models were used for curve recreation
- 1st Phase CD
 - Length of primary ligament Failure = .257
- 2nd Phase CD IFS at .005in
- 3rd Phase CD has very little life from detectable flaw size to failure.
- Current inspections immanent with very frequent intervals
- Number of inspections and span are a serious fleet management issue.



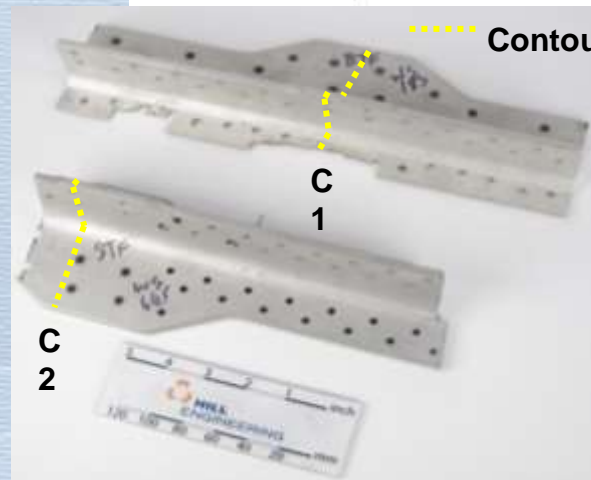
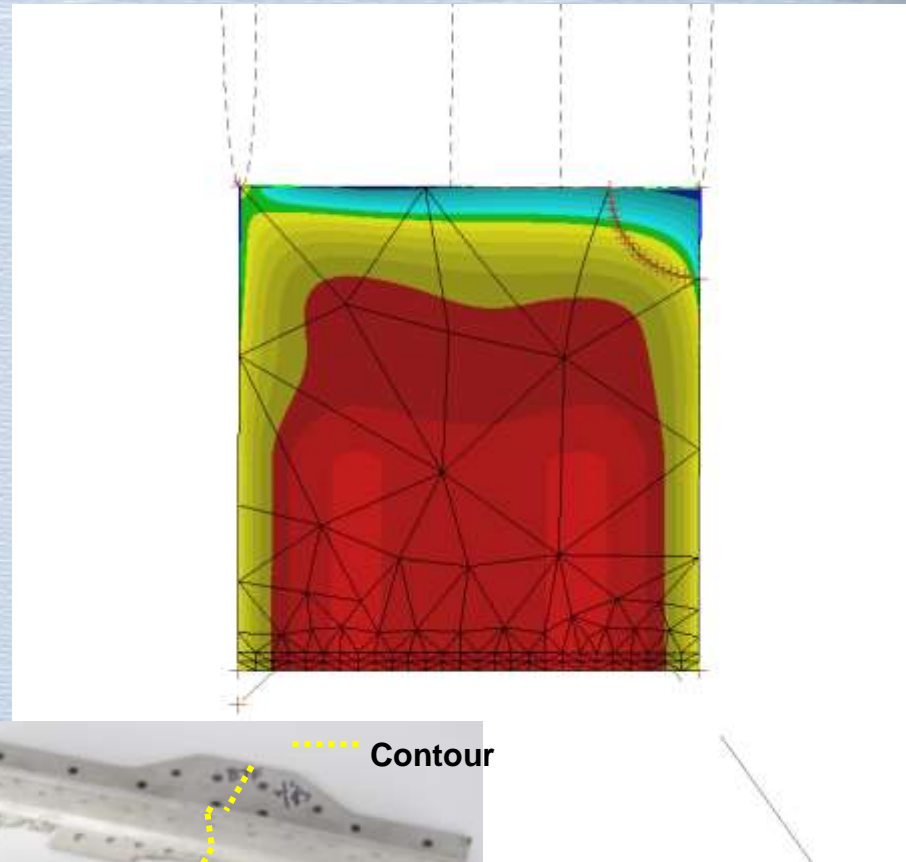


- Siemens Nastran and Stress Check used to derive more realistic constraints, loads, and meshing.
- Initial BAMpF runs correlated with standard approaches
- Open Hole and Neat Fit Pin Correction





- Residual stress measured using the contour method
- Representative RS field generated and applied using BAmP
- RS field measured was not uniform across the hole and diminished along the bore.
- Worst case orientation assumed





- Interference fit fasteners used at WU-402
- Hand calculations and FEM correlated closely.
- Contact models developed in stress check and run in BAMpF
 - 1st Phase studied only to compare growth rates more quickly.

13.3 Thick-Walled Cylinder

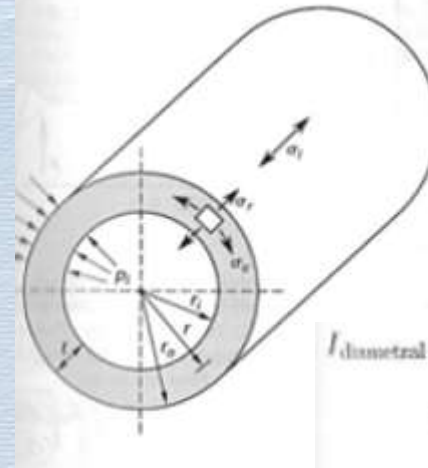


Table 53.2 Stresses in Thick-Walled Cylinders*

stress	external pressure, p_e	internal pressure, p_i
$\sigma_{r,i}$	$-\frac{(r_2^2 + r_1^2)p_e}{r_2^2 - r_1^2}$	$\frac{2r_1^2 p_i}{r_2^2 - r_1^2}$
$\sigma_{r,e}$	$-p_e$	0
$\sigma_{t,i}$	$-\frac{2r_1^2 p_e}{r_2^2 - r_1^2}$	$\frac{(r_2^2 + r_1^2)p_i}{r_2^2 - r_1^2}$
$\sigma_{t,e}$	0	$-p_e$
τ_{max}	$\frac{1}{2}\sigma_{t,i}$	$\frac{1}{2}(\sigma_{t,i} + p_i)$

*Table 53.2 can be used with thin-walled cylinders. However, in most cases it will not be necessary to do so.

$$I_{\text{diametral}} = 2I_{\text{radial}}$$

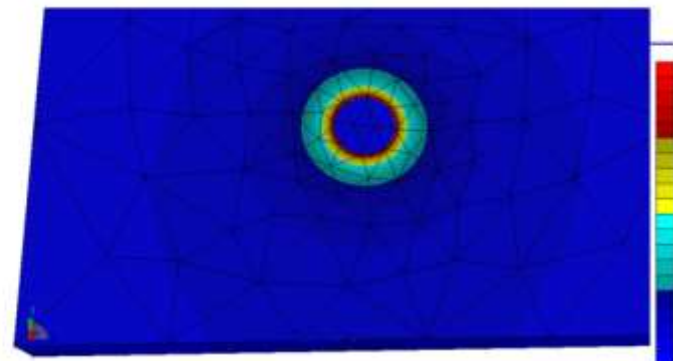
$$= \left(\frac{2pr_{o,shaft}}{E_{hub}} \right) \left(\frac{r_{o,hub}^2 + r_{o,shaft}^2}{r_{o,hub}^2 - r_{o,shaft}^2} + \nu_{hub} \right)$$

$$+ \left(\frac{2pr_{o,shaft}}{E_{shaft}} \right) \left(\frac{r_{o,shaft}^2 + r_{i,shaft}^2}{r_{o,shaft}^2 - r_{i,shaft}^2} - \nu_{shaft} \right)$$

53.28

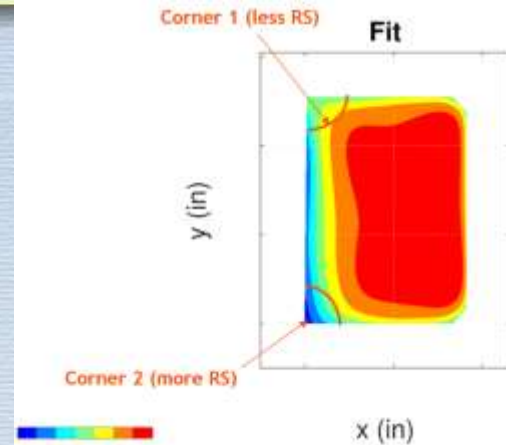
StressCheck Max Contact Pressure Error sensitivity

- Hand Calculation : 109 ksi
- Pressure error = 0.08% (contact constant = 10e6, 40 iterations)

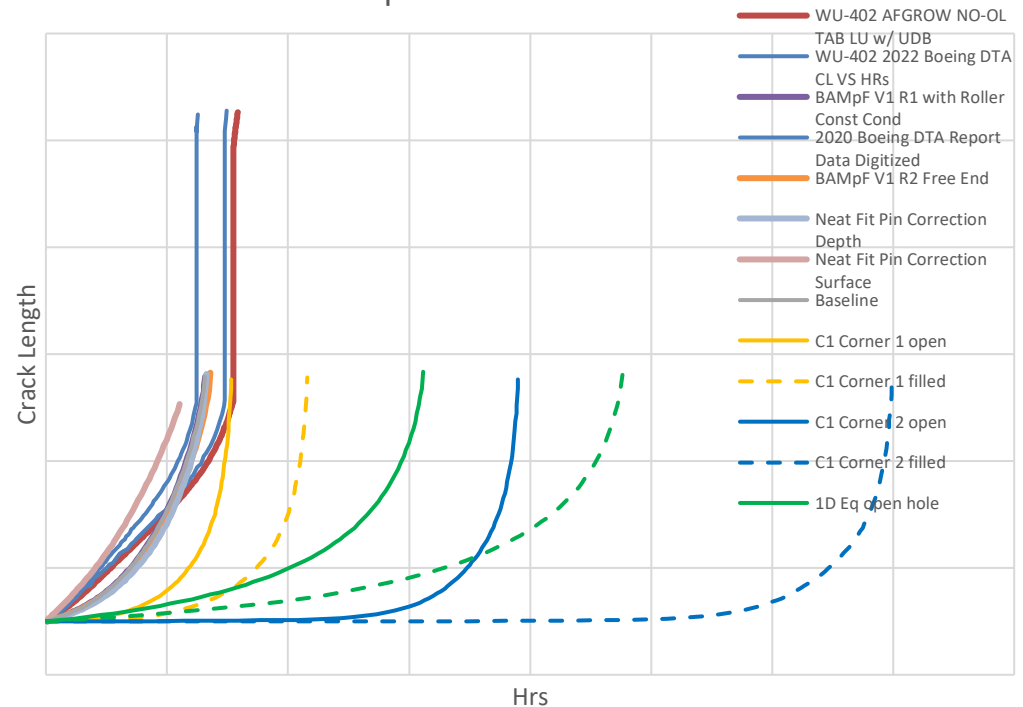




- Methods attempted
 - Flat plate approximation
 - Residual Stress
 - Open hole
 - Neat fit pin correction
 - Contact Model
 - Contact Model w/ Residual Stress
- Improvements observed WRT RS only but not enough to provide substantial relief assuming worst case RS application.
- Interaction between contact/IFF and RS field not fully representative.
 - The contact from the IFF interacts with the RS field in a way still being studied.



WU-402 BAMpF C1 RHS Crack Growth Curves





- A-10
 - Brian Boeke
 - Jake Warner
- B-52
 - Travis Reese
 - Andrew Jones
- SwRI
 - Lucky Smith
 - Jim Fieger
- Hill Engineering
 - Dallen Andrew
 - Josh Hodges
 - Bob Pilarczyk
 - Renan Ribeiro
- Boeing
 - Lee Ann McElroy



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