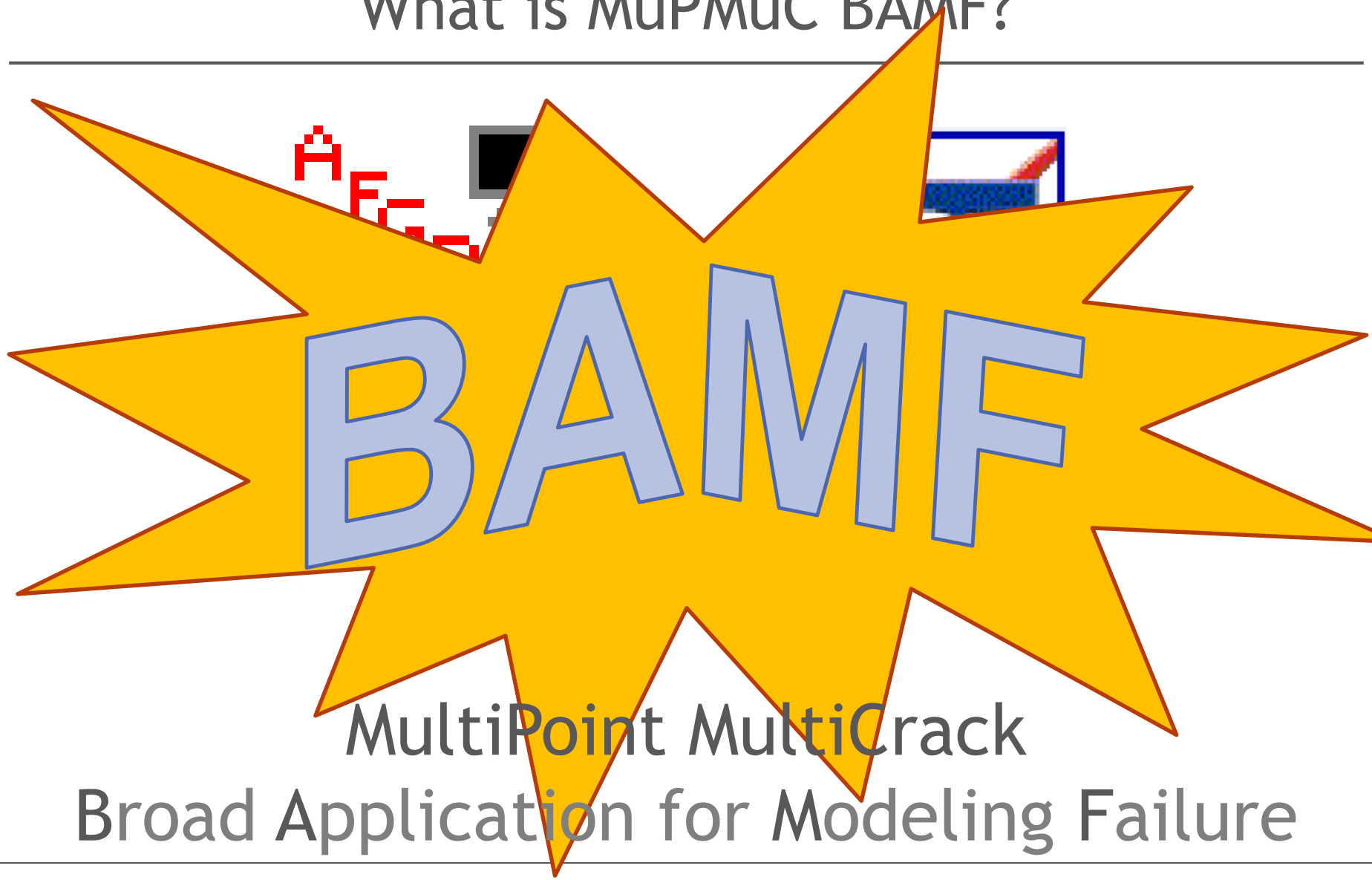
HILL ENGINEERING
Predict. Test. Perform.

The Future of BAMF

Sept 20, 2017

What is MuPMuC BAMF?



MultiPoint MultiCrack

Broad Application for Modeling Failure

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BAMF Background

Broad Application for Modeling Failure (BAMF)

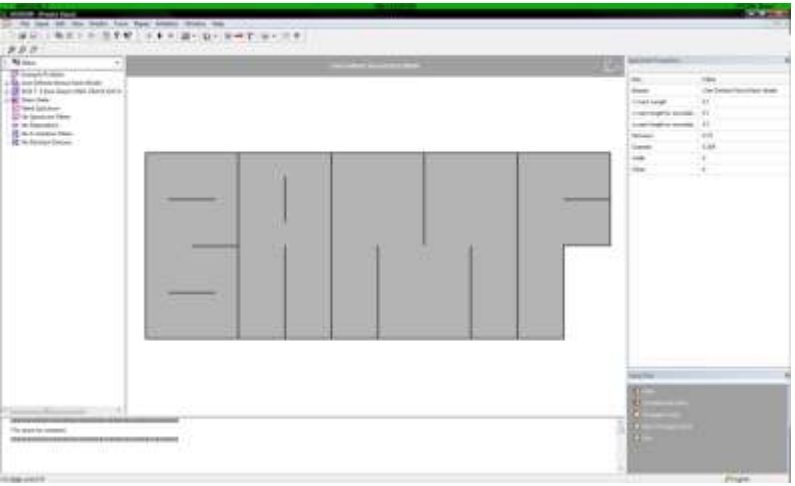
Overview:

- BAMF is a software plug-in that couples FEA stress intensity calculations (StressCheck) with a crack growth engine (AFGROW)
- Originally developed by USAF (T-38 & A-10)

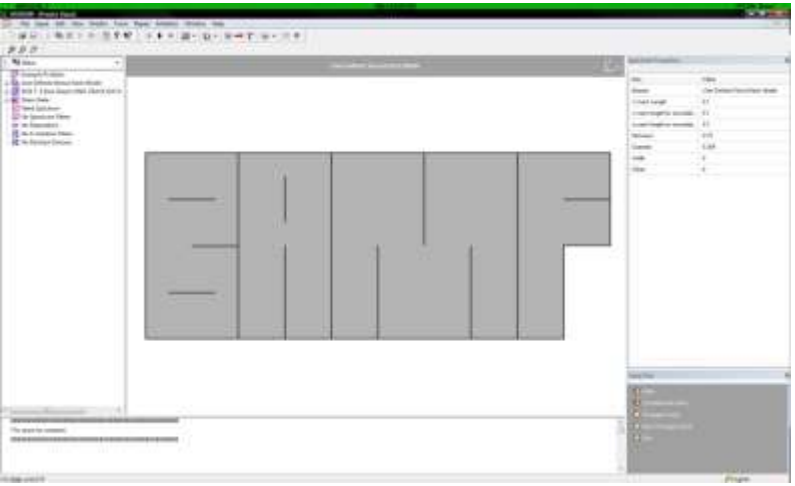
Motivation:

- Need tool for addressing non-handbook-type configurations

What does MuPMuC do for you?



What does MuPMuC do for you?



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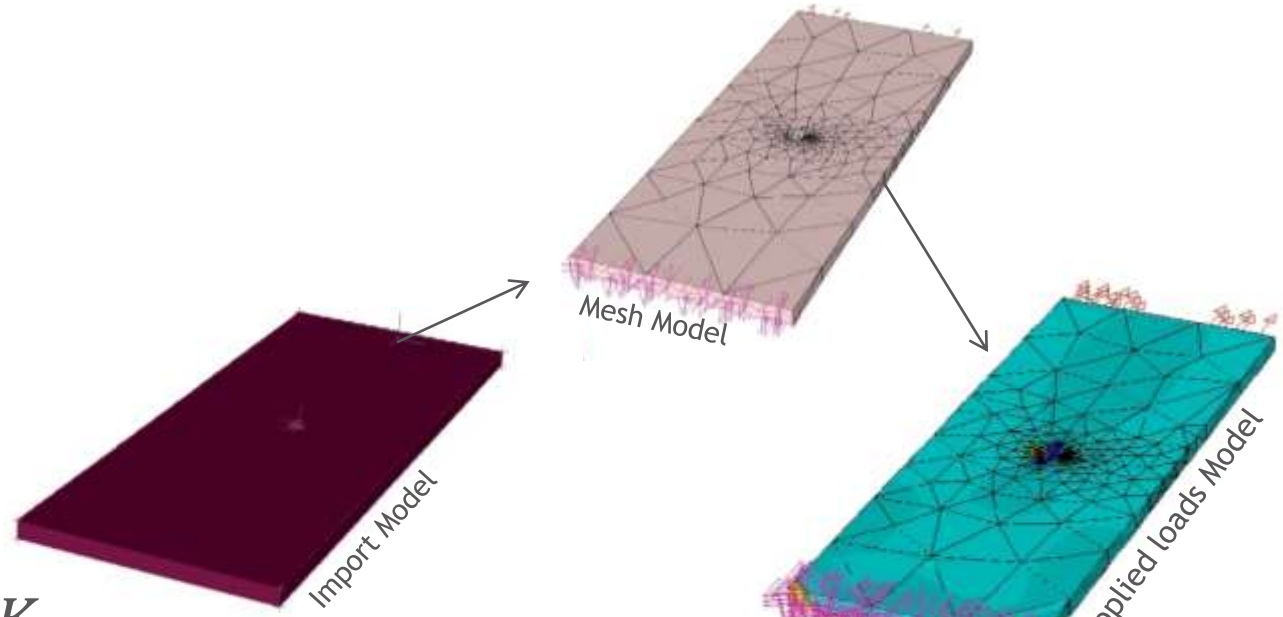
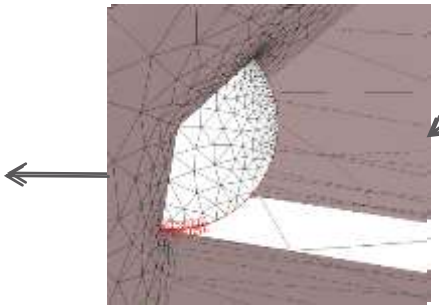


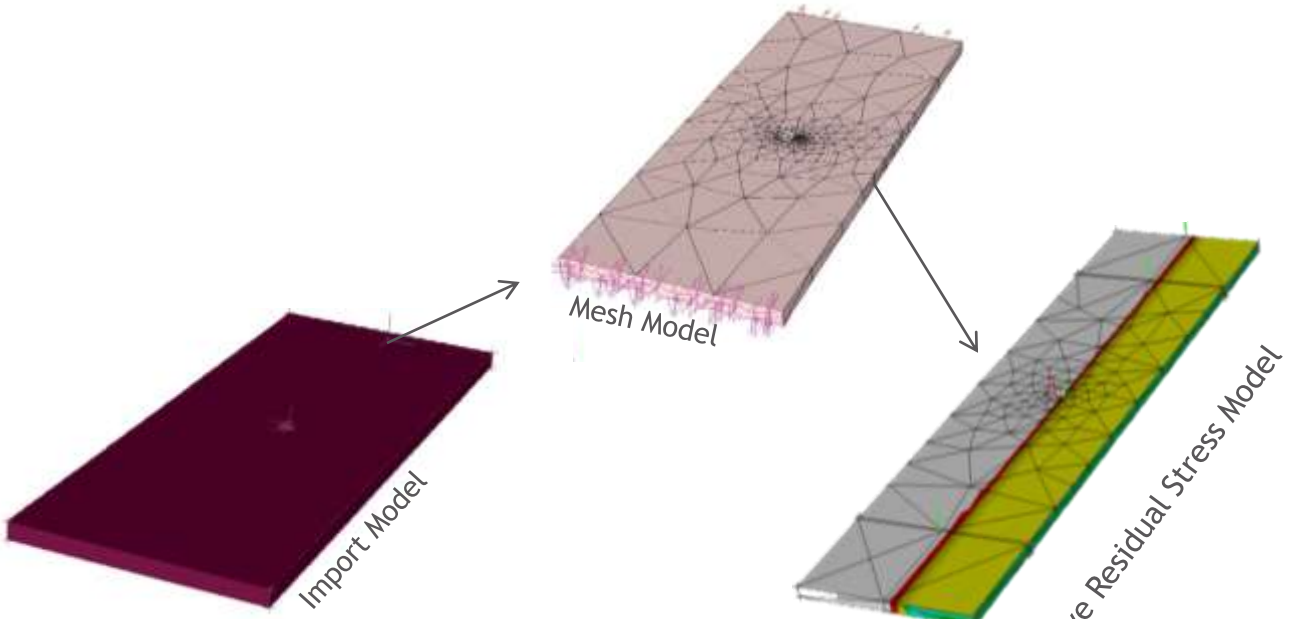
$$a_{app_{CN}} = \frac{K_{app_{CN}}}{\sigma}$$

Far field stress from StressCheck



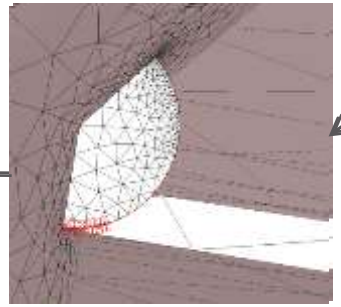
Extract Stress Intensities K_{app}
For each crack in the model

What does MuPMuC do for you?



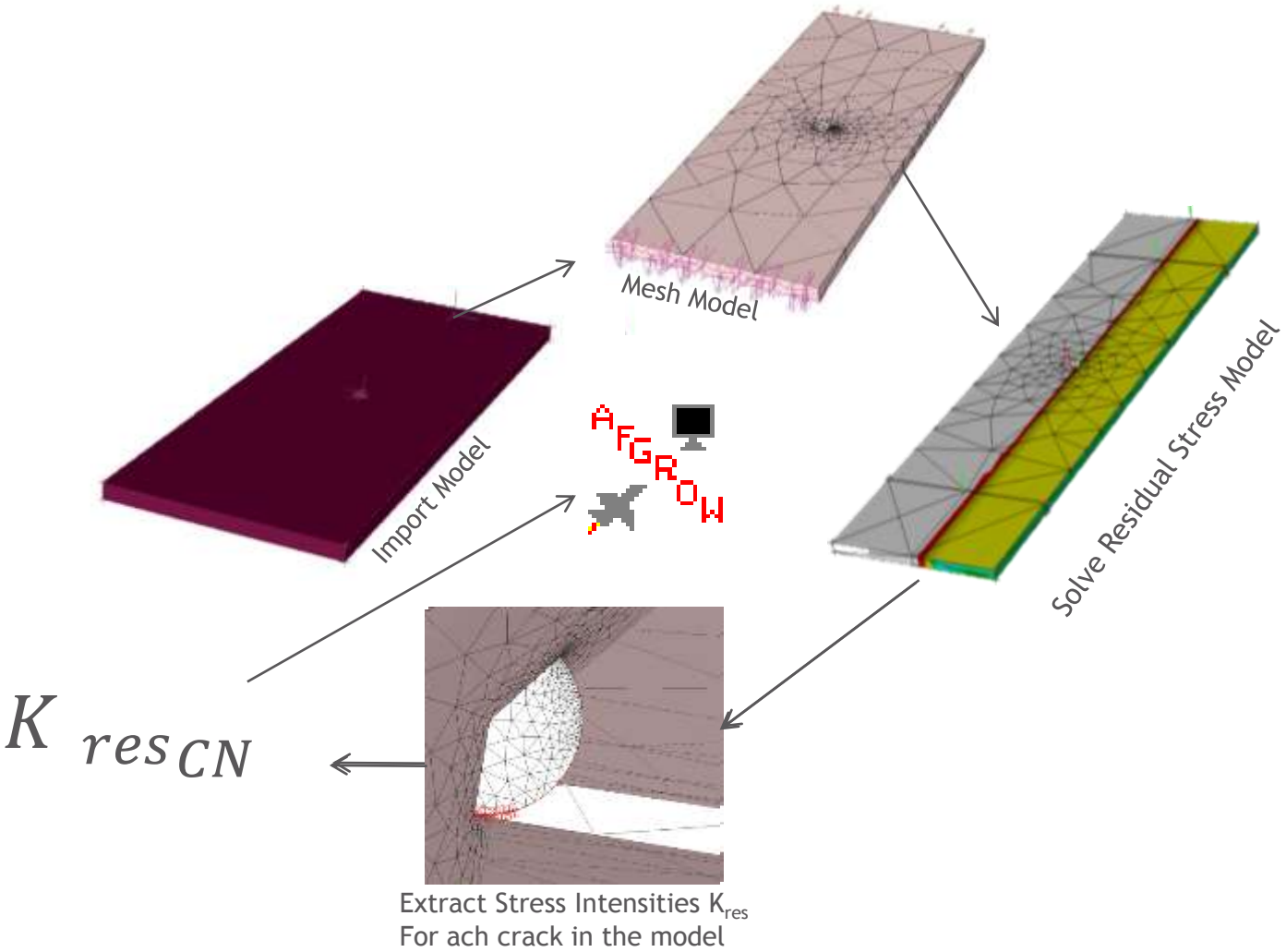
$$a_{app_{CN}} = \frac{K_{app_{CN}}}{\sigma}$$

$$K_{res_{CN}}$$



Extract Stress Intensities K_{res}
For ach crack in the model

What does MuPMuC do for you?



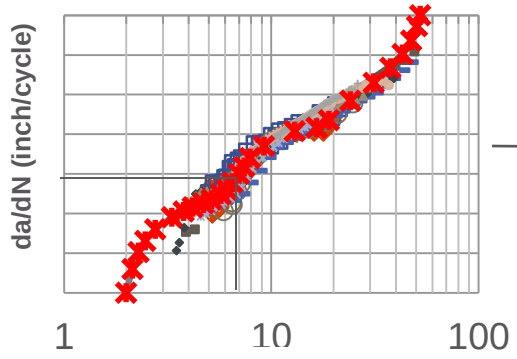
What does BAMF do for you?

$$K_{min_{CN}} = a_{app_{CN}} \sigma_{min} + K_{res_{CN}}$$

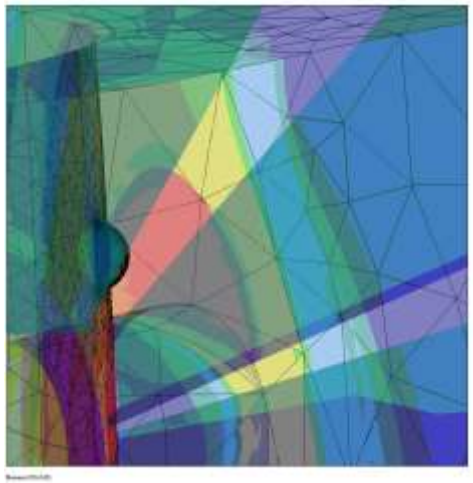
$$K_{max_{CN}} = a_{app_{CN}} \sigma_{max} + K_{res_{CN}}$$

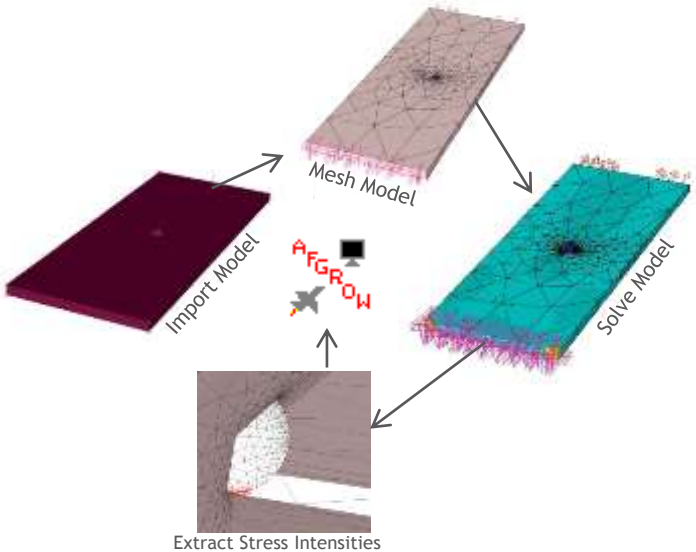
Where $\sigma_{min/max}$ is the AFGROW spectrum stress

$$R_{CN} = K_{min_{CN}} / K_{max_{CN}}$$



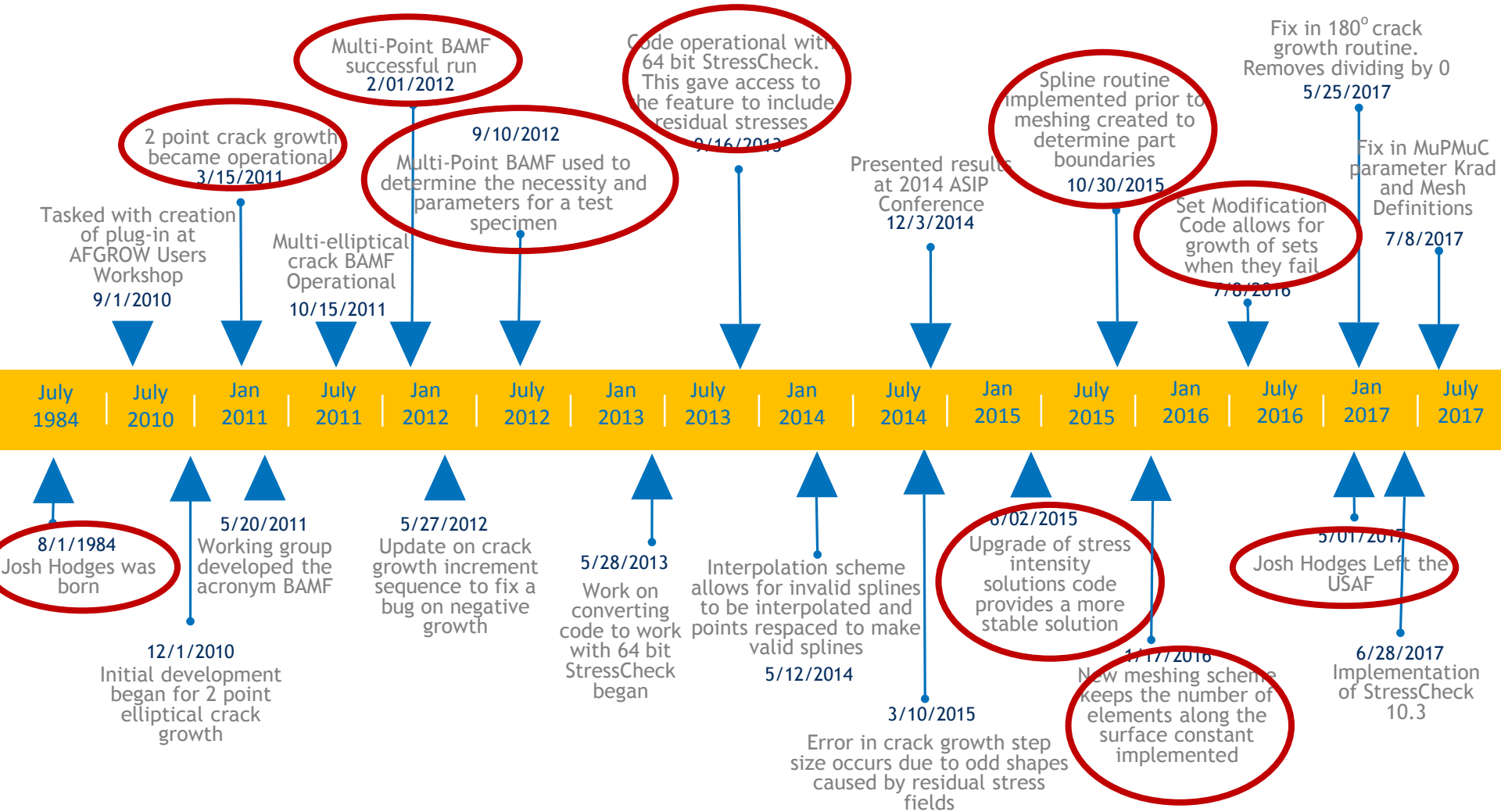
New Crack Lengths





Extract Stress Intensities
For each crack number

The Complete History of BAMF



BAMF Transition

BAMF was primarily developed by Josh Hodges while at T-38 USAF

- Josh recently moved from the USAF to Hill Engineering

To facilitate the continued viability of BAMF for use by USAF (and others) Hill Engineering plans to continue to update and maintain the software

- We are currently developing a plan that specifies the project details
- We are actively looking for input from the user community

Near-Term Plan

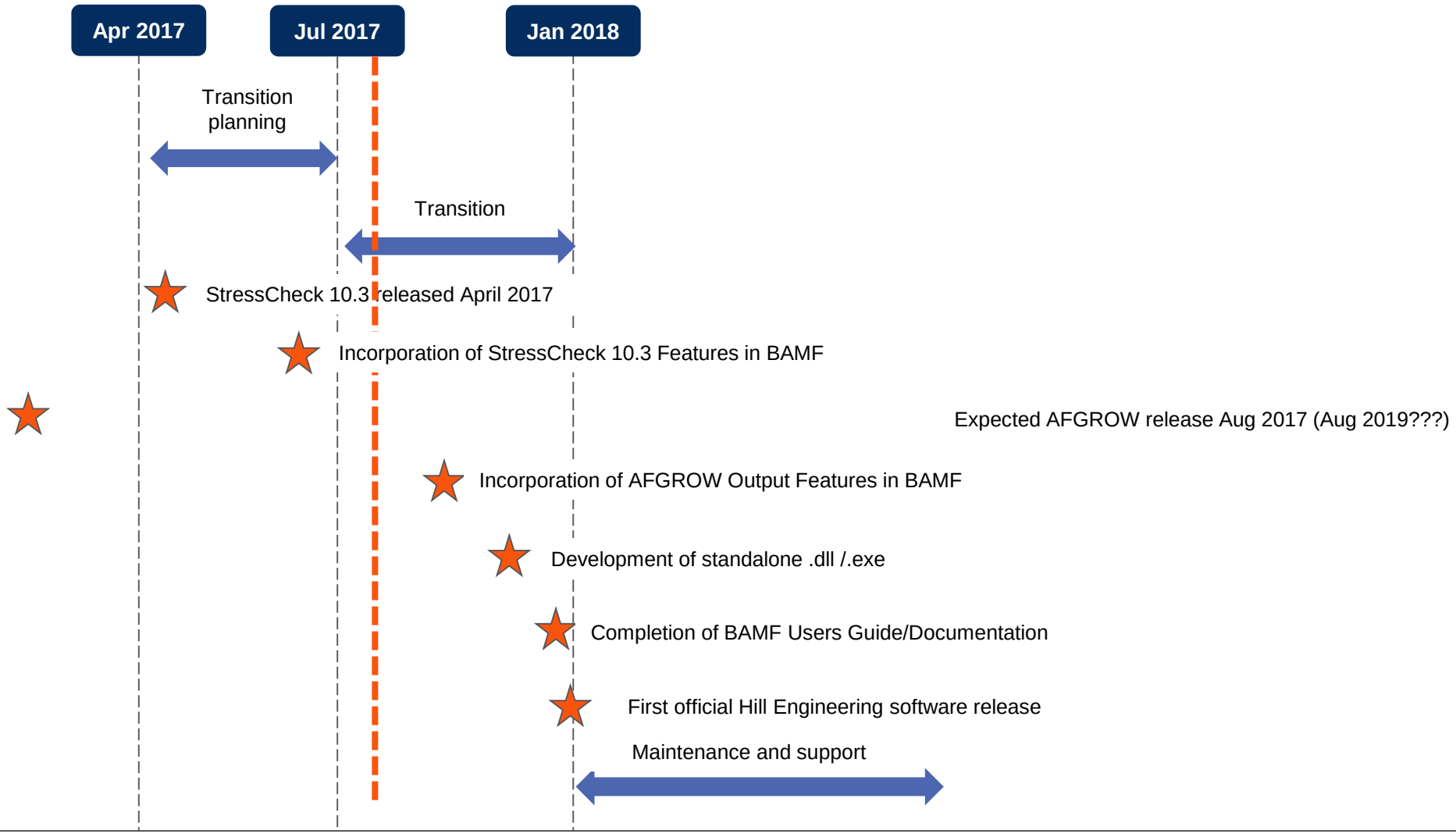
Phase 1: Transition (Target completion: January 2018)

- Prepare updated software for release and distribution
  - Users Guide
  - Standalone .dll files
  - Handbook Models
- Provide interim releases to maintain compatibility with new StressCheck/AFGROW releases that occur in 2017
- Develop project funding

Phase 2: Maintenance and support

- Release regular software updates to maintain compatibility with new StressCheck/AFGROW releases on an ongoing basis
- Provide software technical support, as available
- Identify opportunities for improvement/enhancement

Near-Term Schedule



BAMF Consortium

Hill Engineering will organize a software consortium to provide input and support of BAMF development

- Provides a mechanism for Hill Engineering to interact with core user group
- Provides a stable and ongoing revenue source
- Mimics AFGROW business plan

Consortium benefits

- Connect with BAMF developers
- Receive priority support
- Invitation to participate in annual BAMF consortium meeting
- Ability to identify and prioritize desired new BAMF capabilities

User Questionnaire

How frequently are you currently using BAMF

- How do you see your usage changing in the future
- How many others in your organization use BAMF
- What are some current limitations that prevent you from using BAMF more frequently

What is your most typical BAMF application

- What is your most typical BAMF analysis (Multi-site damage, contact, residual stress, primary/secondary crack growth, etc…)

What improvements would you like to see made to BAMF

- What would be the benefits of these improvements
- What type of complex analysis would you like to see improved on (Multi-site damage, contact, residual stress, primary/secondary crack growth, etc…)

Are you interested to be a member of the consortium

- What is your process/timeline for funding

Do you know any others who we should contact about introducing BAMF

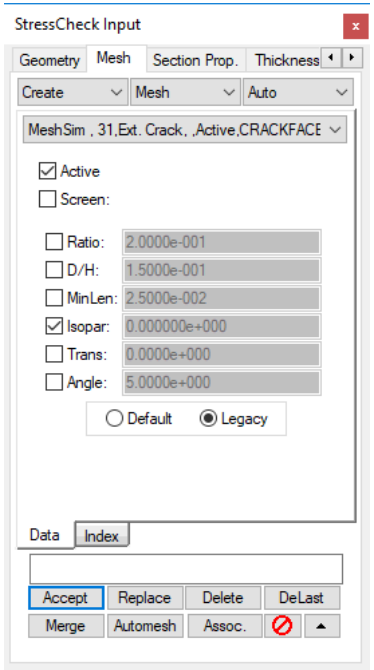
Recent Updates

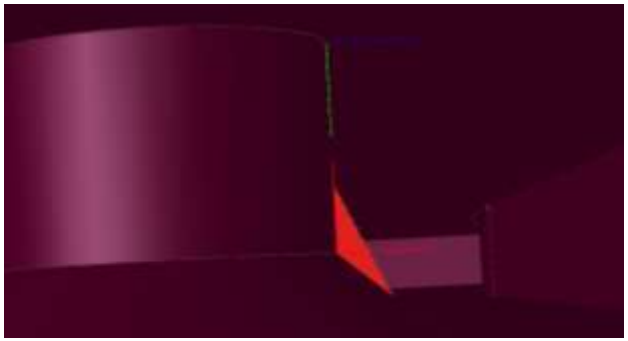
StressCheck 10.3 Implementation

- StressCheck 10.3 has a new automesh
  - Option for legacy automesh still exists (Use Legacy until next SC Update)

Set Creation

- StressCheck 10.3 allows for creation of sets programmatically using local coordinate system
- Sets can be created programmatically using the Nucleation set
- This feature will replace the need to build CRACKFRONT and CRACKFACE sets
  - Nucleation set and boundary condition sets will still required
- The feature is currently under testing to help understand the stability and effectiveness of set creation prior to full implementation.





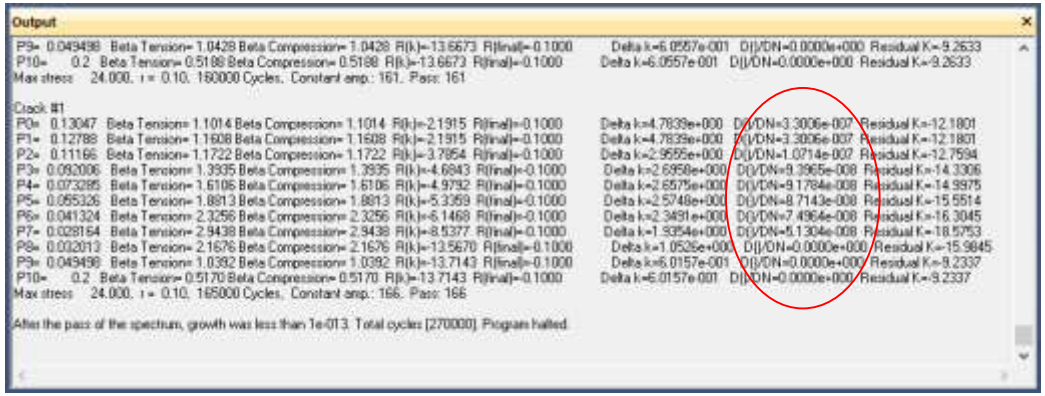
Recent Updates

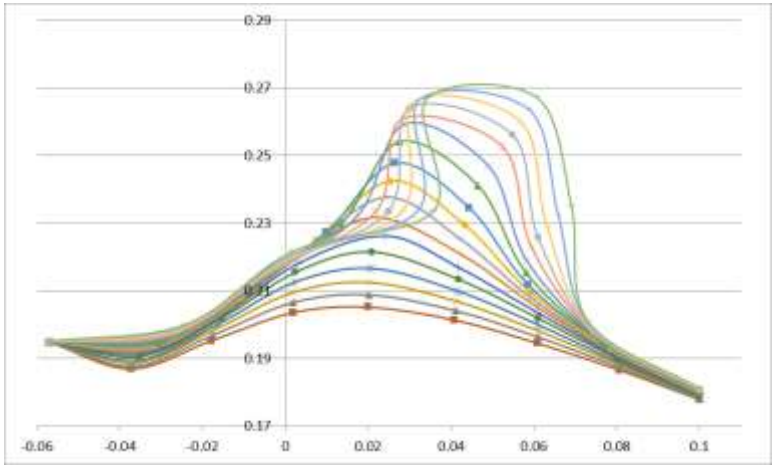
180° Crack Growth Bug Fix

- Crack growth was halting during crack growth of countersunk fasteners.
  - Occurs when a crack point was being divided by 0.

Py(Count + 1, k, i) = Py(Count, k, i) - deltaP(i, k) / Sqrt(SlopeP(i) ^ 2 + 1) * (Py(Count, k, i) / Math.Abs(Py(Count, k, i)))

  - Removed (Py(Count, k, i) / Math.Abs(Py(Count, k, i))) and replaced with an if statement looking at the direction of the slope.
- X-direction crack growth with unique shapes was also providing negative growth
  - Added check for negative X step
  - Added check for a negative Y value

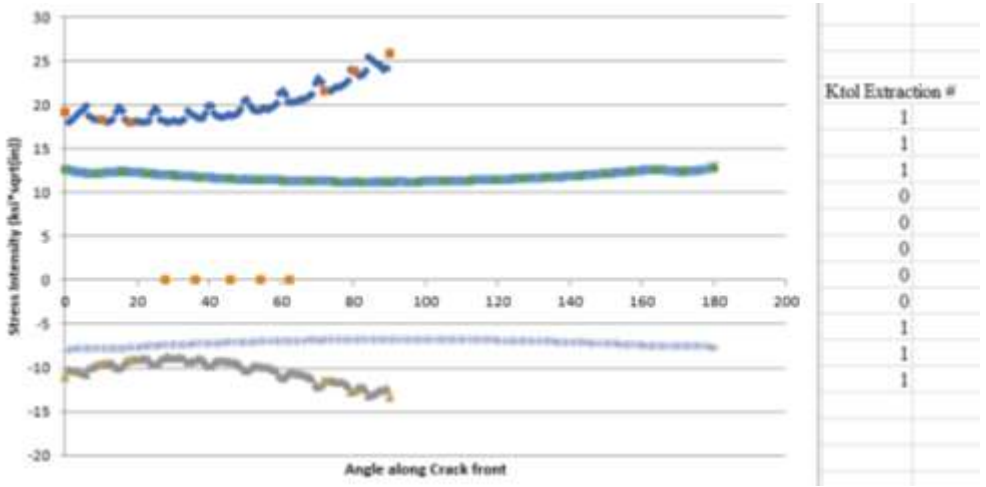




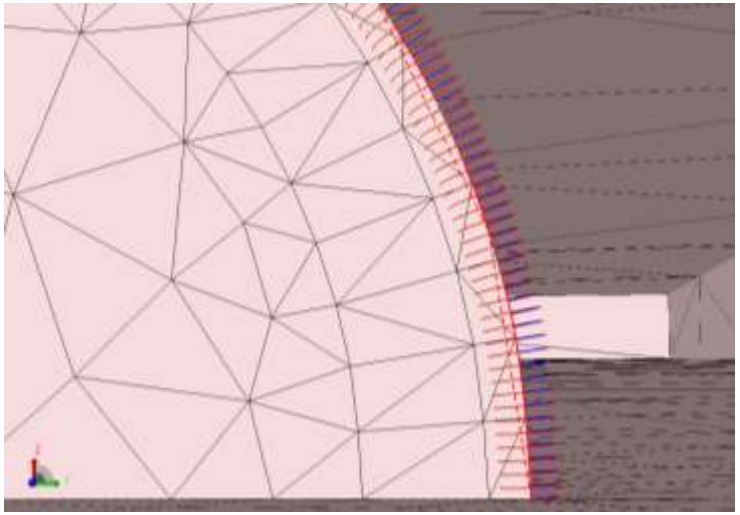
Recent Updates

MuPMuC mesh and K-extraction not working properly

- K_tol and K_rad were not vectors and were redefined using the dimensions of the secondary crack
- Two issues combined here to cause issues
  - K_rad was too small causing extractions to be within the sacrificial elements
  - K_tol was too small that for some points there was no K assigned
- Vectorizing parameters based on crack number solved the issue



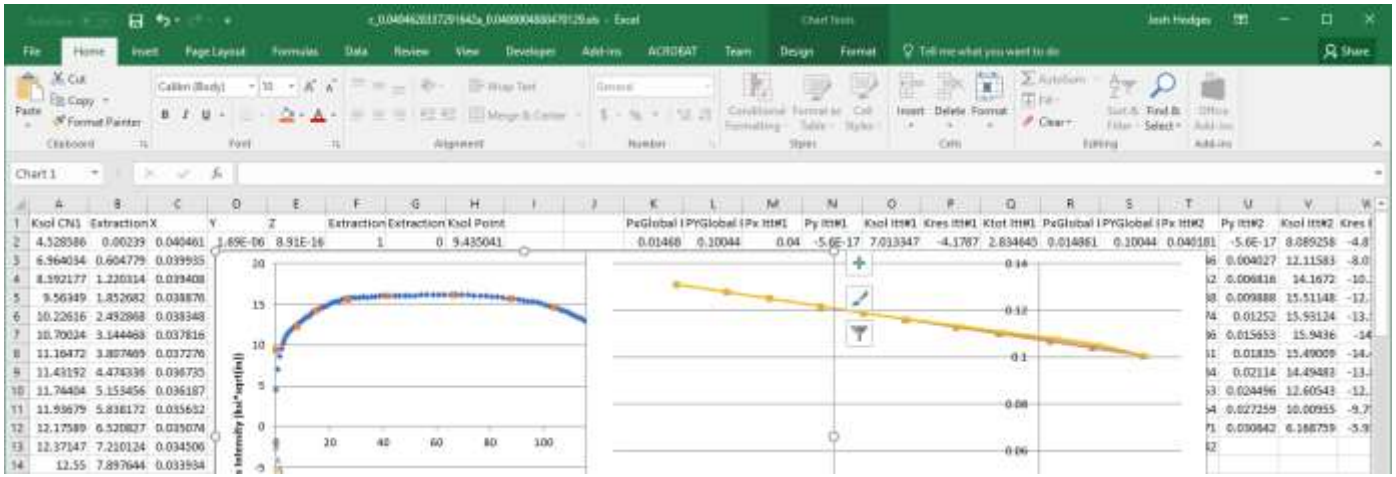
Ktol Extraction #
1
1
1
0
0
0
0
0
1
1
1

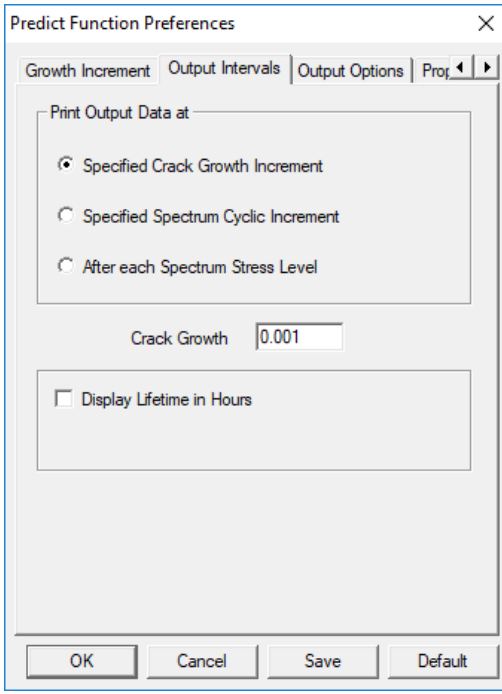


Recent Updates

Post Processing

- Labels!!!
- Until next AFGROW release output every 0.001” to allow for comparisons of BAMF output/AFGROW output
  - New AFGROW Output will be at same crack length of BAMF output

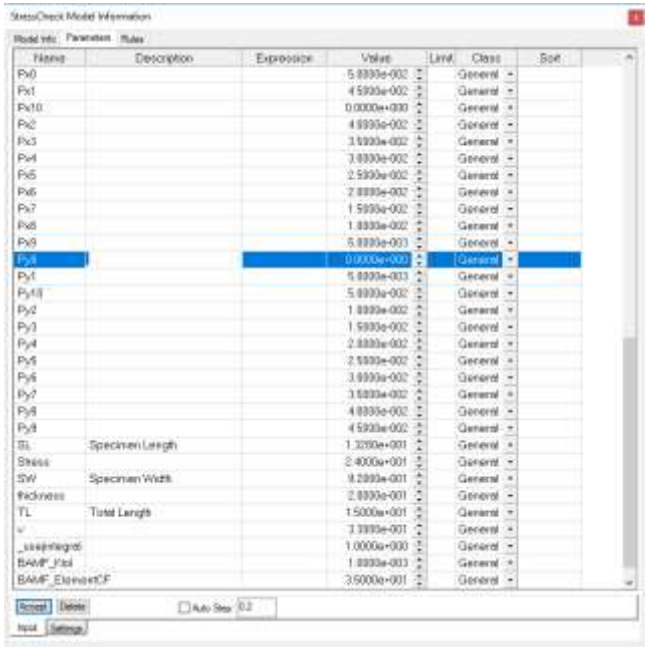




Recent Updates

USAF unable to load Visual Studio express on their computers

- Need a way to change parameters in code without having the code available
- Currently modifiable parameters
  - Number of elements along the crack front-BAMF_ElementCF (18)
  - Tolerance of K-selection-BAMF_Ktol (0.001)
  - Number of extraction points along the crack front-BAMF_ExtractionPoints (45)
- Other default parameters to change?



Summary

Hill Engineering intends to provide maintenance and support for BAMF

- Effective immediately and extending into the future

We are currently working to formulate a transition plan and would appreciate input from users of the software

- Engage current users to understand their needs and priorities

In the near-term Hill Engineering will use IR&D funding to update and maintain BAMF to be compatible with new StressCheck and AFGROW releases

Hill Engineering will develop a users document and handbook models for use with the program

Hill Engineering is forming a software consortium to provide direction/input and a stable funding source

First Hill Engineering BAMF release planned for Jan 2018

Awesome things are happening

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Thank You

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Backup Slides

The following slides are included for possible backup support:

BAMF Features

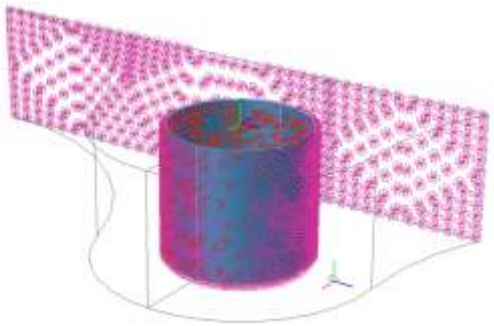
Key features:

- 2-D planar growth
- Arbitrary crack shape evolution
- Many analysis points along crack front
- Full suite of AFGROW capabilities
  - Materials, spectra, retardation, etc.
- Multiple crack front support
- Surface based application of crack face traction

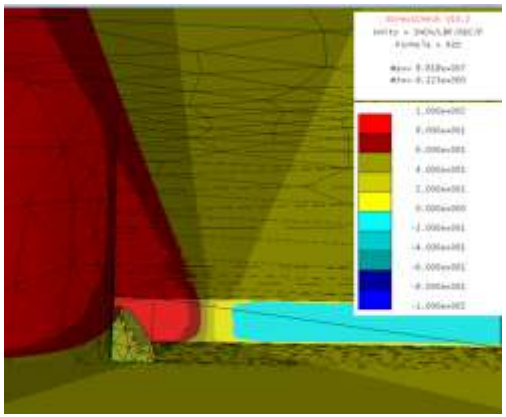
BAMF Geometry, Loading, and Mesh

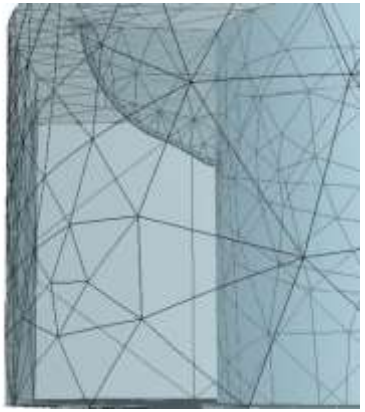
Modeling capability:

- Full utilization of StressCheck™
  - Contact Solutions
  - Residual Stresses via CIM-LC



Fully automated mesh updating and refinement





Example Crack Front Estimate

Multi-Point Multi-Crack shape evolution

- 1-5 Cracks
- 2-45 points defining the crack front
  - Points grow normal to the surface
  - Growth defined by local stress intensity