I-DEAS Durability and Proving Ground Data Performance

A design study

on the

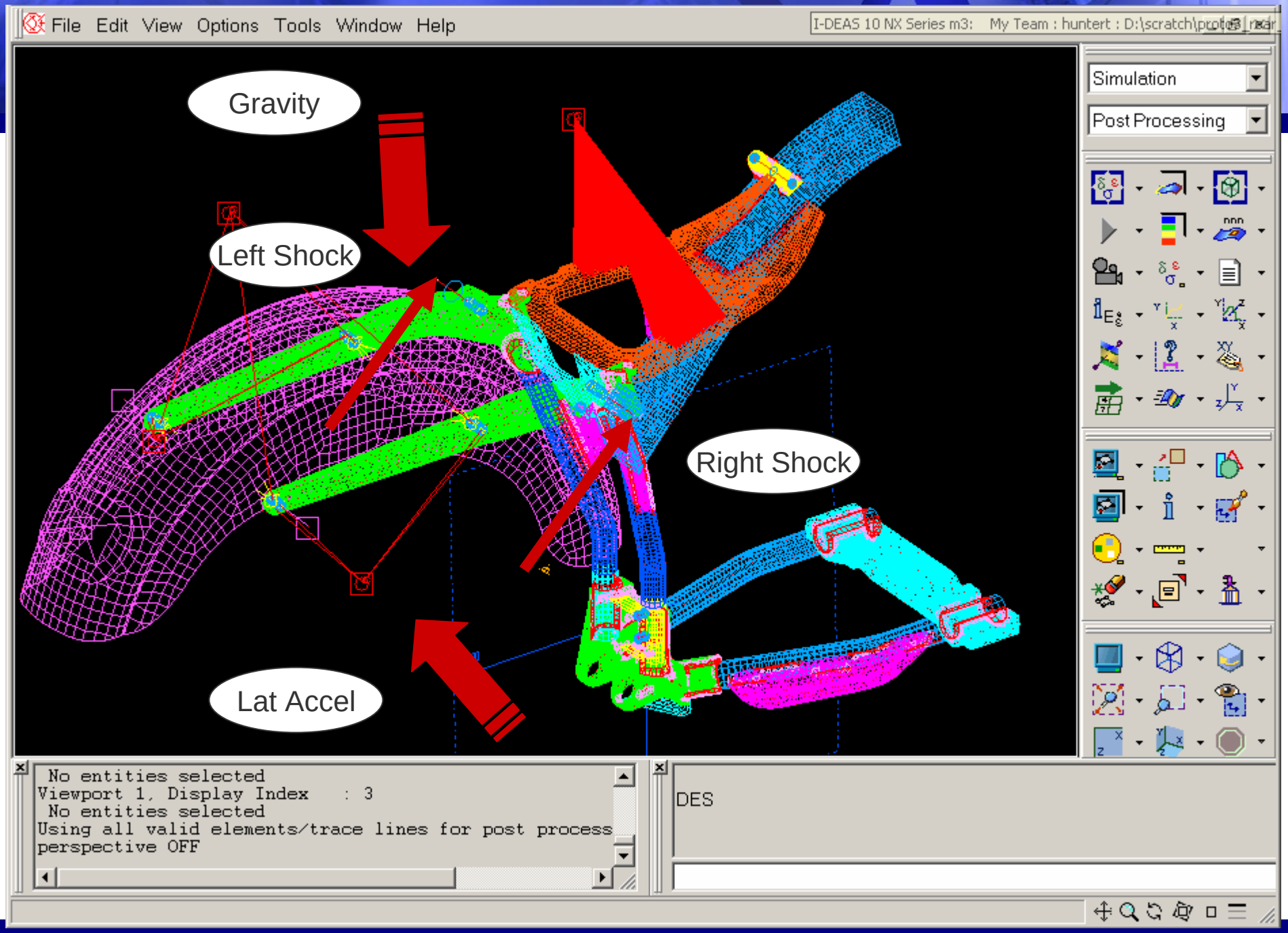
Dyna™ seatpan

Premium Partners:

MOTOR
HARLEY-DAVIDSON
COMPANY

Agenda

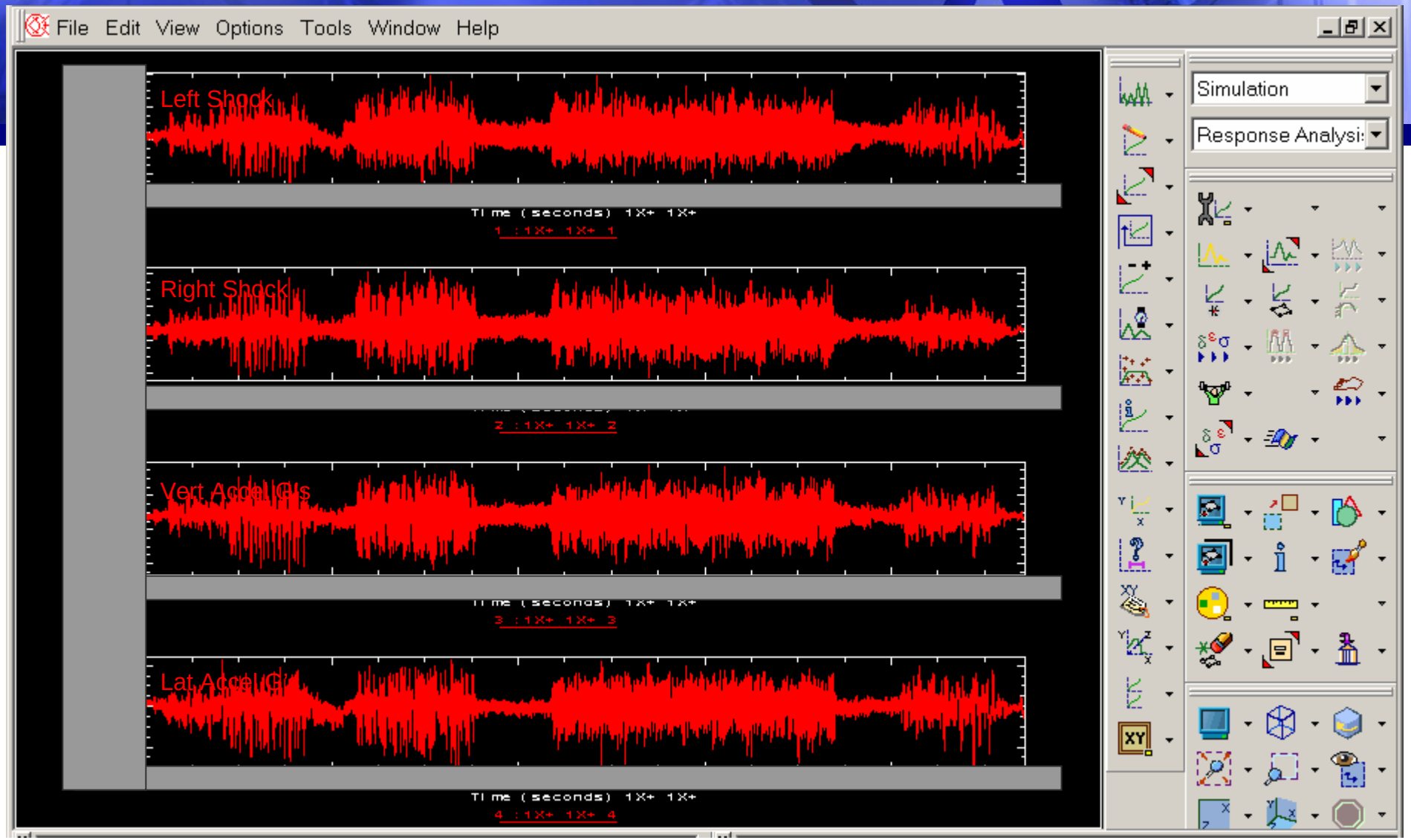
- Purpose of Analysis
- Unit Load Case
- Load Time Histories (events)
- Damage Model / Durability Settings
  - Script to automate processing
- Results


File Edit View Options Tools Window Help
I-DEAS 10 NX Series m3: My Team : huntert : D:\scratch\proto3_mar
Gravity
Left Shock
Right Shock
Lat Accel
Simulation
Post Processing
No entities selected
Viewport 1, Display Index : 3
No entities selected
Using all valid elements/trace lines for post process
perspective OFF
DES

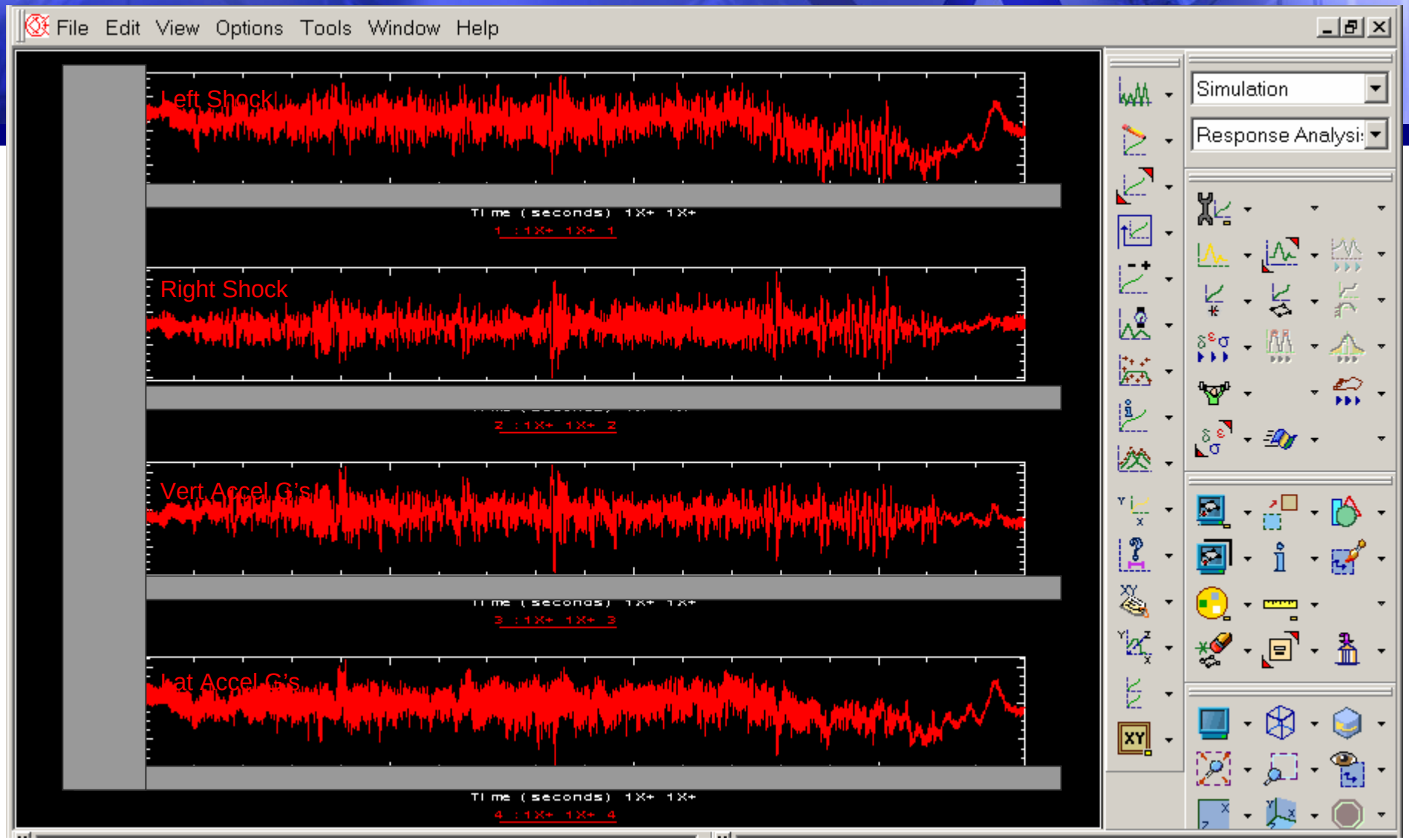
Load Time Histories

File Edit View Options Tools Window Help
Left Shock
Time (seconds) 1X+ 1X+
1 :1X+ 1X+ 1
Right Shock
2 :1X+ 1X+ 2
Vert Accel G's
3 :1X+ 1X+ 3
Lat Accel G's
Time (seconds) 1X+ 1X+
4 :1X+ 1X+ 4
Simulation
Response Analysi

Event #1


File Edit View Options Tools Window Help
Left Shock
Time (seconds) 1X+ 1X+
1 :1X+ 1X+ 1
Right Shock
2 :1X+ 1X+ 2
Vert Accel Gs
3 :1X+ 1X+ 3
Lat Accel Gs
Time (seconds) 1X+ 1X+
4 :1X+ 1X+ 4
Simulation
Response Analysis

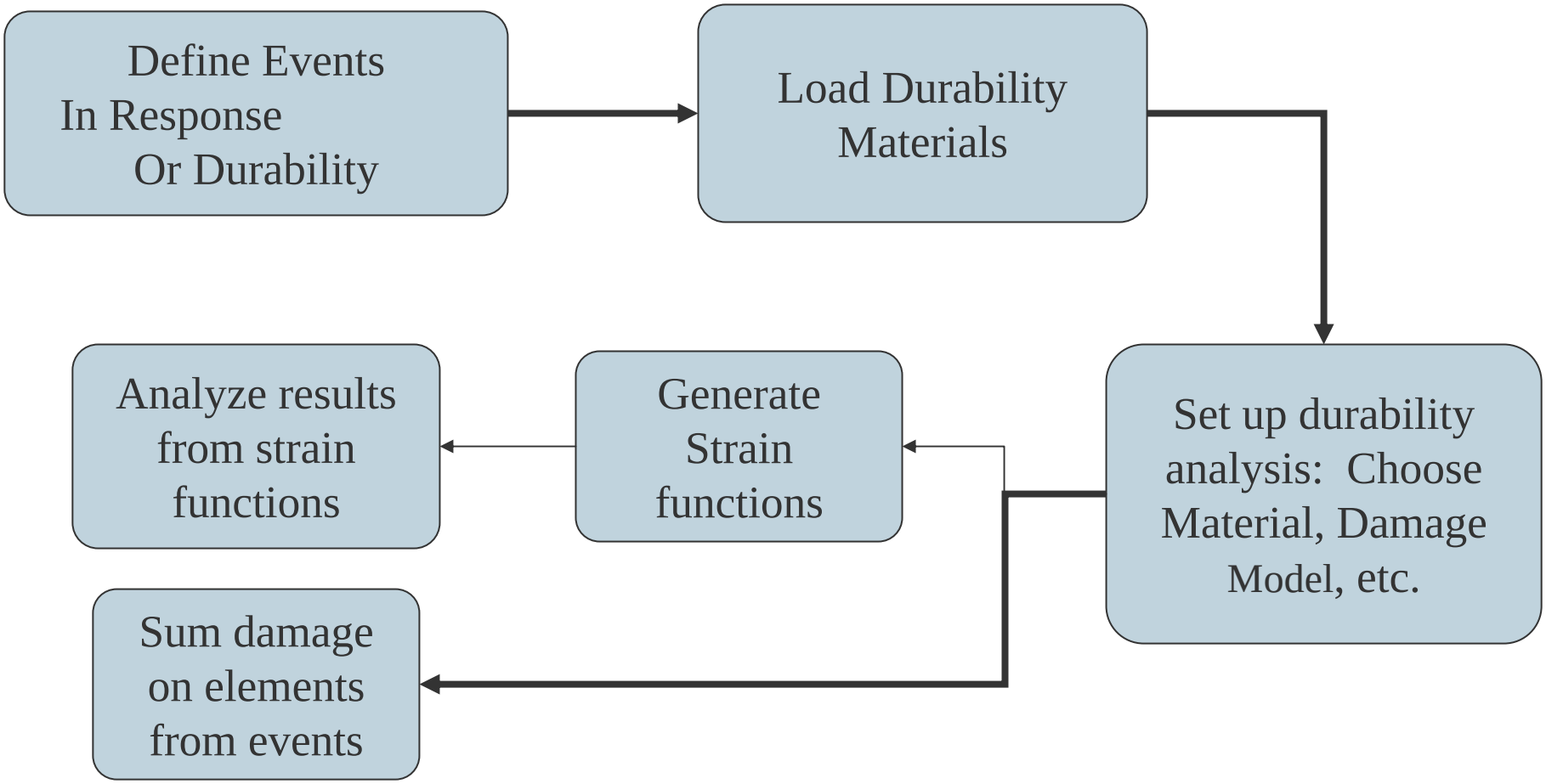
Event #2


File Edit View Options Tools Window Help
Left Shock
Time (seconds) 1X+ 1X+
1 :1X+ 1X+ 1
Right Shock
2 :1X+ 1X+ 2
Vert Accel G's
3 :1X+ 1X+ 3
Lat Accel G's
Time (seconds) 1X+ 1X+
4 :1X+ 1X+ 4
Simulation
Response Analysi:

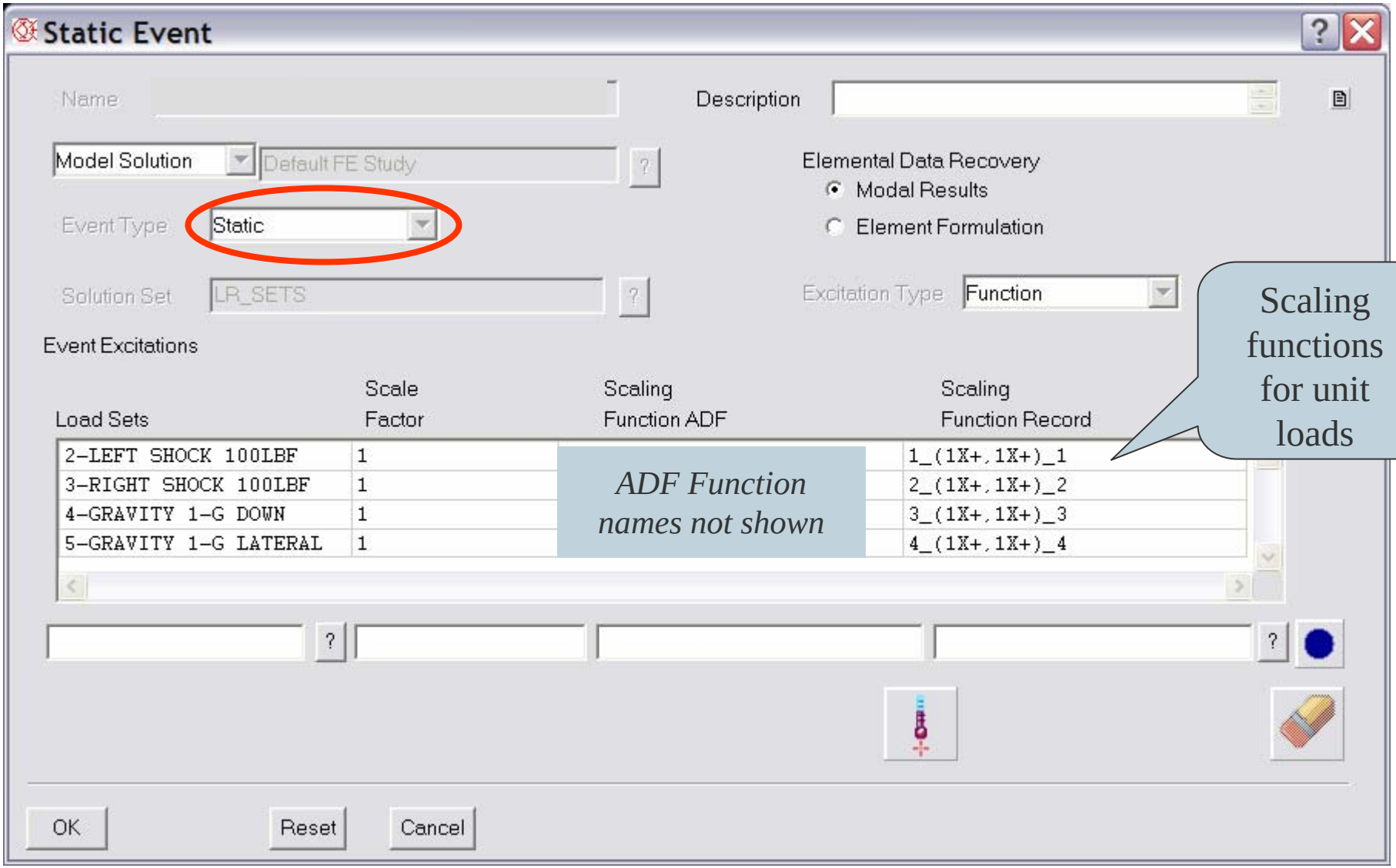
Event #3

Damage Model / Durability Settings

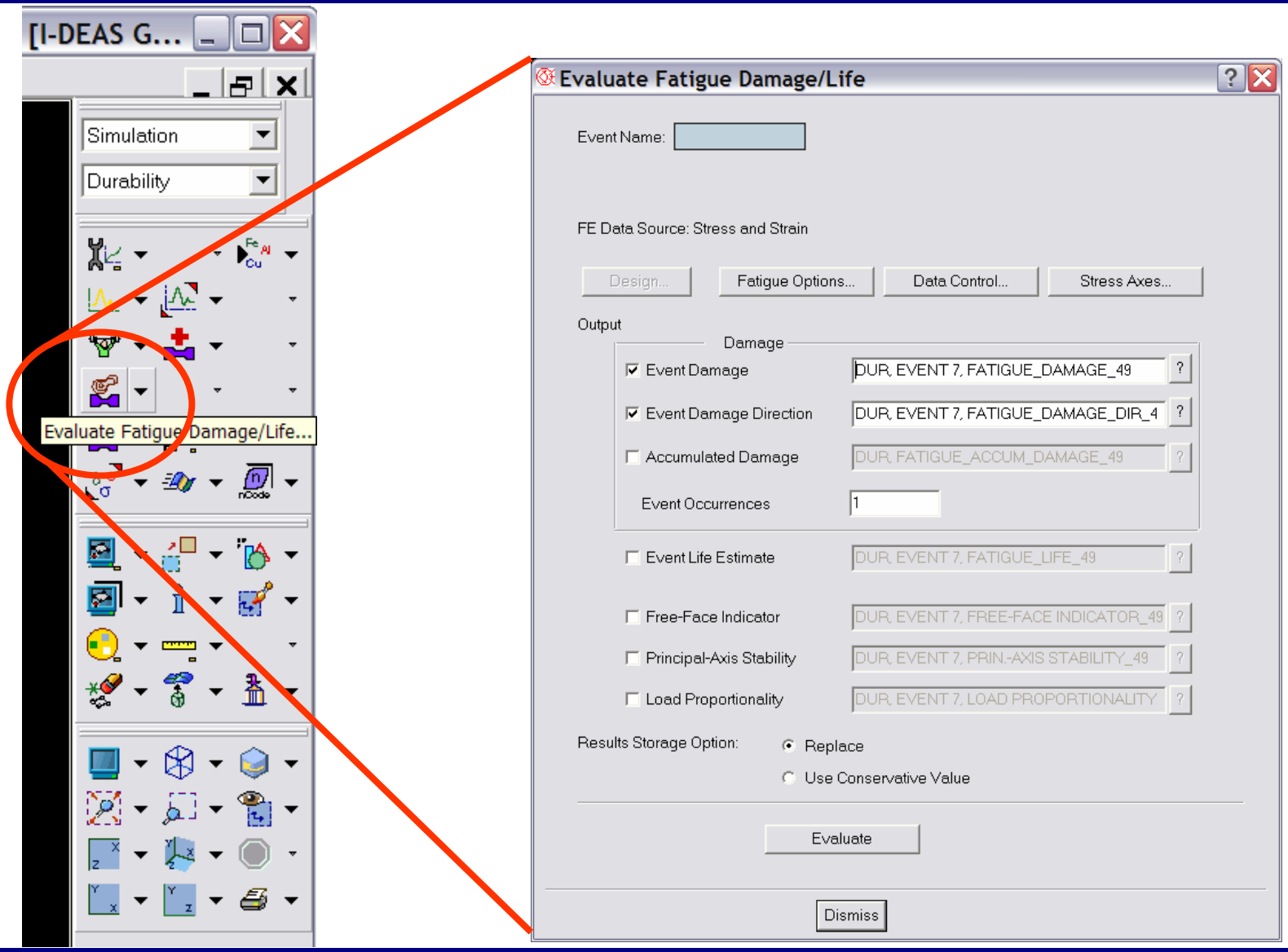
The Flow


Define Events
In Response
Or Durability
Load Durability
Materials
Set up durability
analysis: Choose
Material, Damage
Model, etc.
Generate
Strain
functions
Analyze results
from strain
functions
Sum damage
on elements
from events

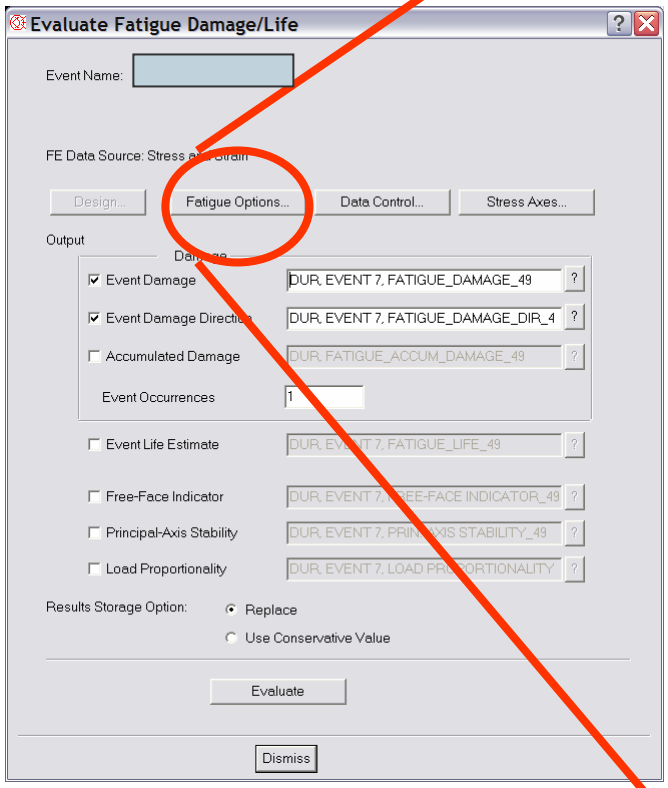
Event Definition

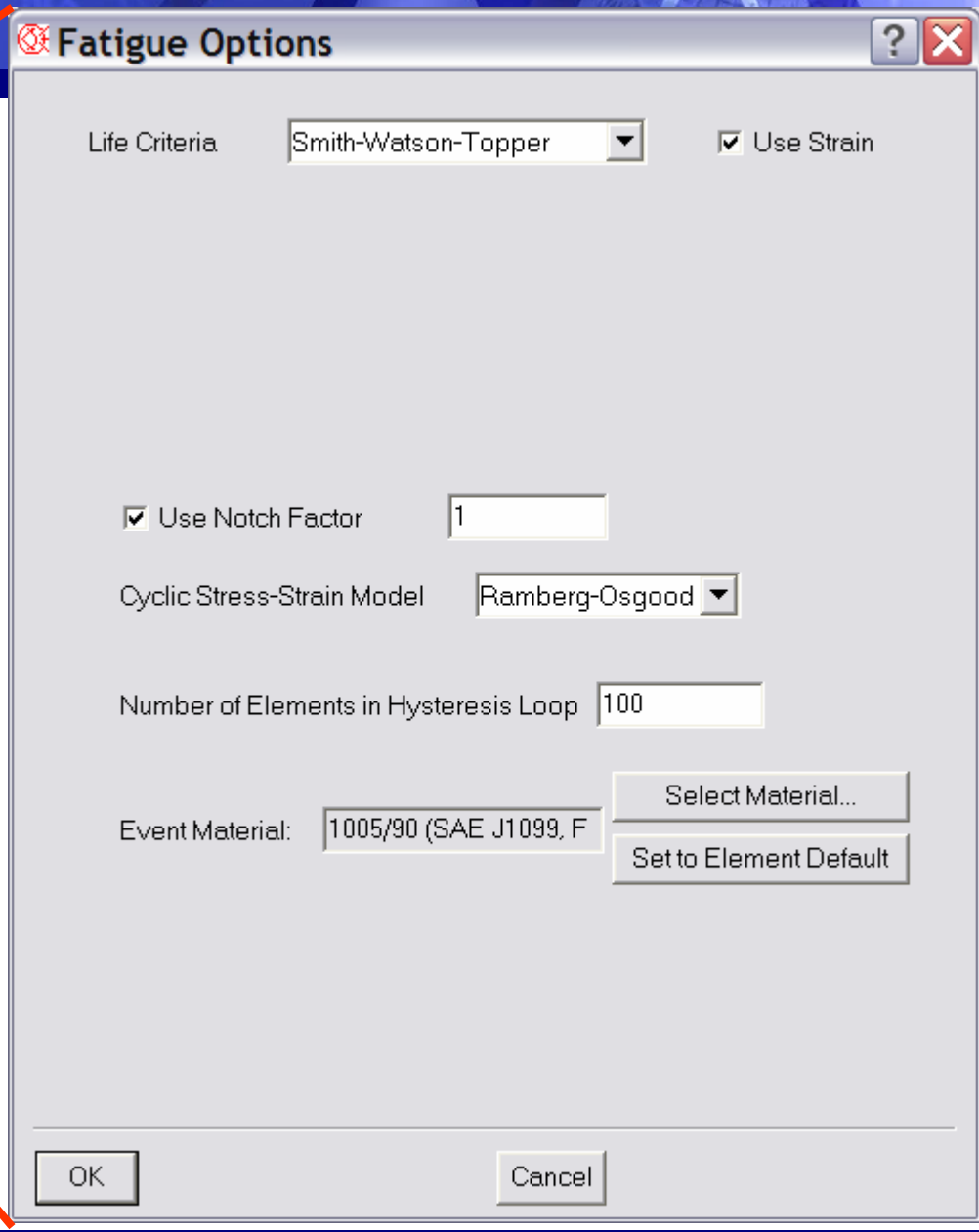


Evaluate Fatigue Damage Form

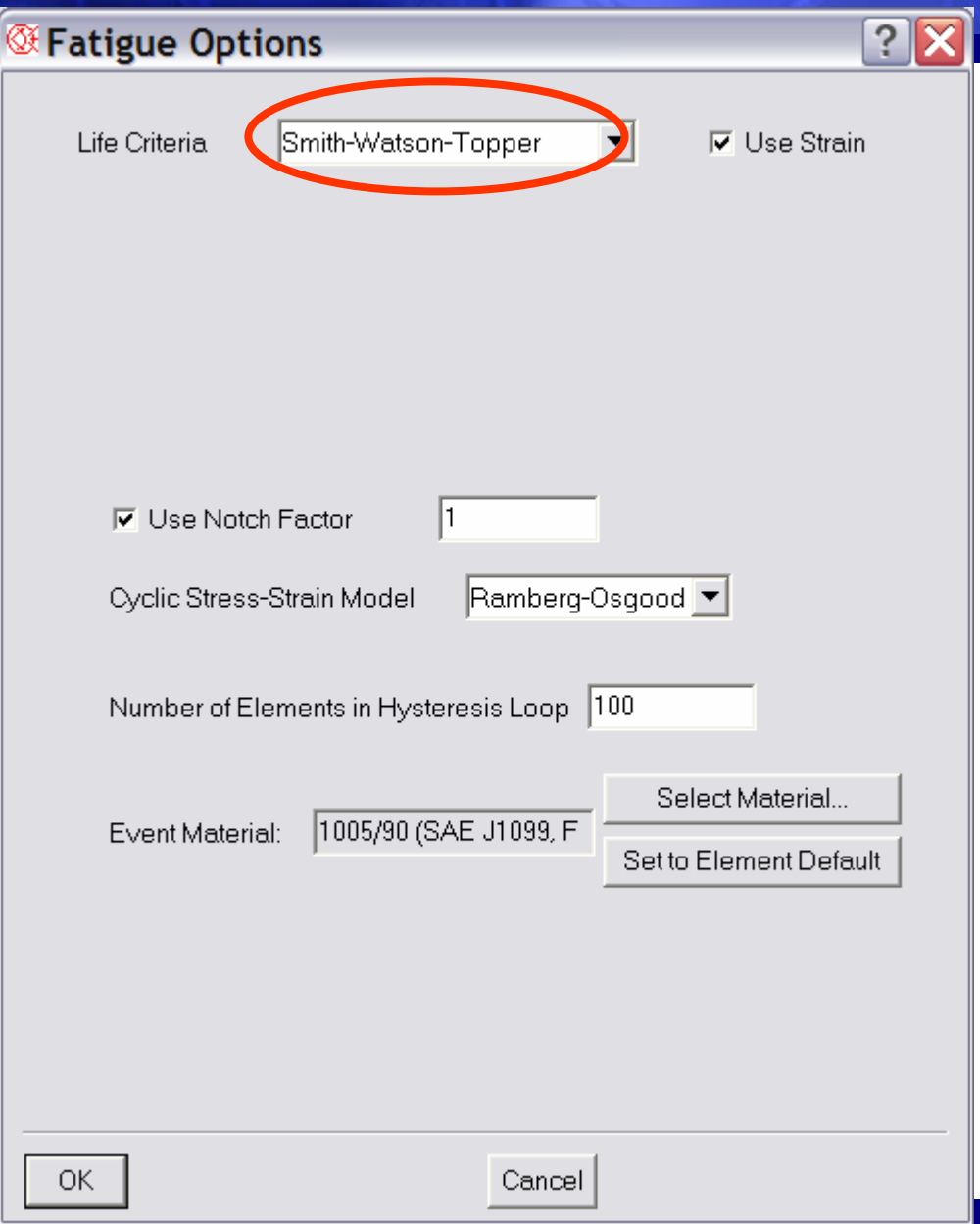


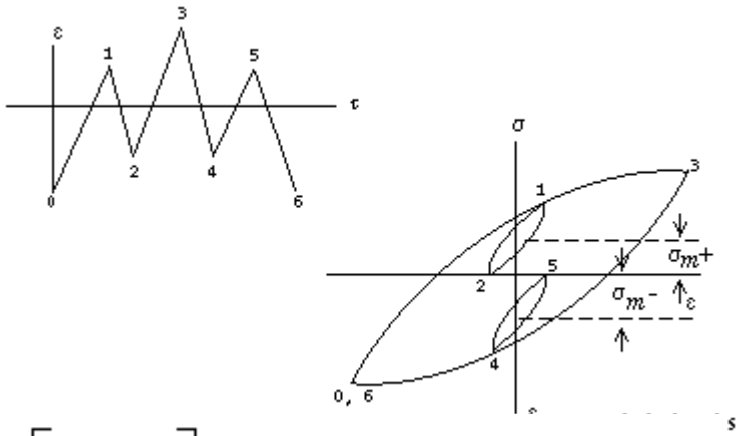
Fatigue Options





Damage Model





$$\left[\frac{\frac{\Delta\sigma}{2} + \sigma_m}{\sigma'_f (2N_f)^b}\right] \quad \frac{\Delta\varepsilon}{2} = \frac{\sigma'_f}{E}(2N_f)^b + \varepsilon'_f (2N_f)^c$$

where

$\frac{\Delta\varepsilon}{2}$ =strain amplitude

E =elastic modulus

σ'_f =Fatigue strength coefficient

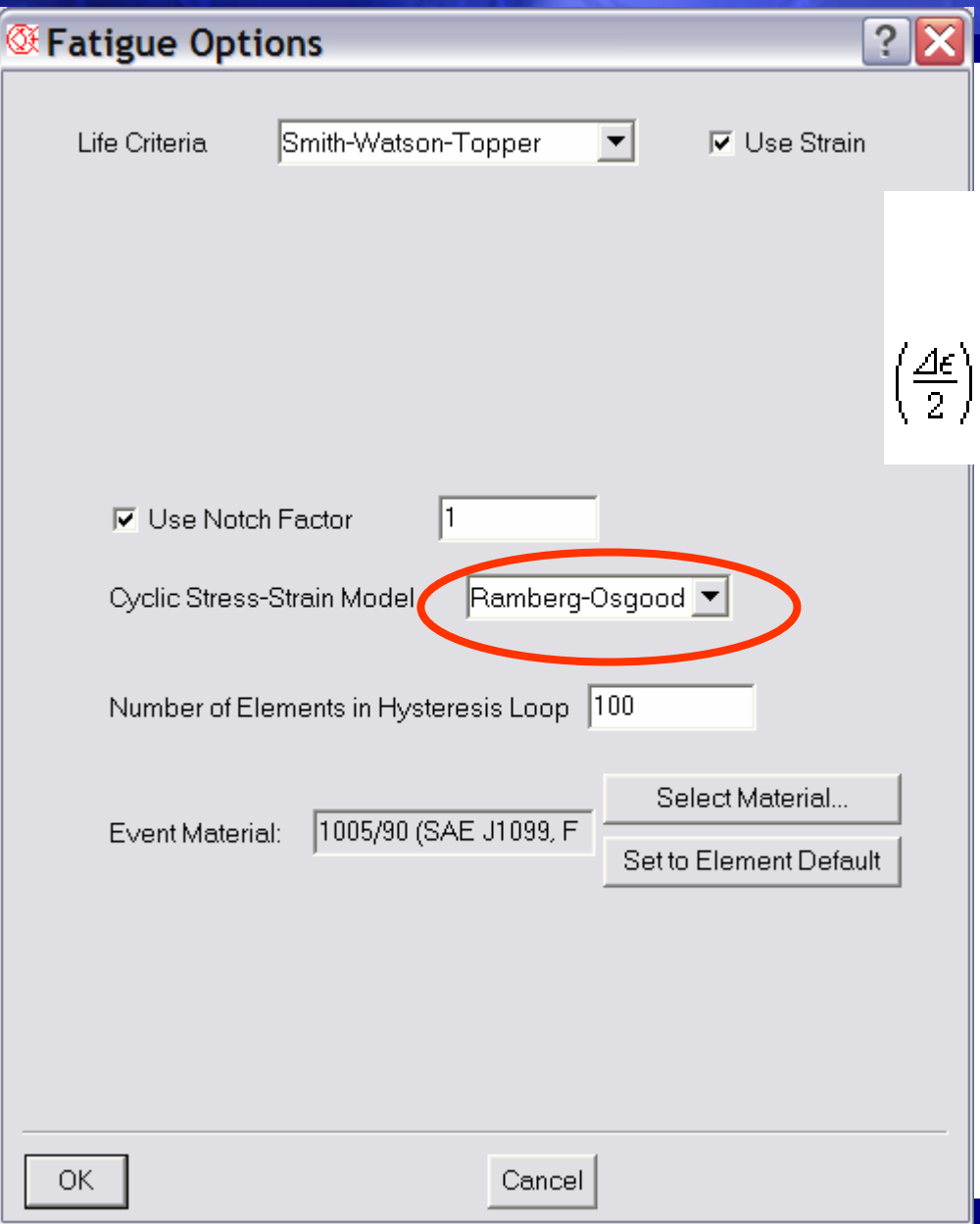
$2N_f$ =Reversals to failure

b =Fatigue strength exponent

ε'_f =Fatigue ductility coefficient

c =Fatigue ductility exponent

Cyclic Strain Model



elastic strain — plastic strain

$$\left(\frac{\Delta\epsilon}{2}\right) = (1-\upsilon\gamma)\frac{\left(\frac{\Delta\sigma}{2}\right)}{E} + (1-0.5\gamma)\left[1-\gamma+\gamma^2\right]^{1-n/2n}\left[\frac{\frac{\Delta\sigma}{2}}{H}\right]^{1/n}$$

$$\frac{\Delta\varepsilon}{2} = \frac{\Delta\sigma}{2E} + \left(\frac{\Delta\sigma}{2H}\right)^{1/n}$$

$\frac{\Delta\epsilon}{2}$ = strain amplitude

υ = Poisson's ratio

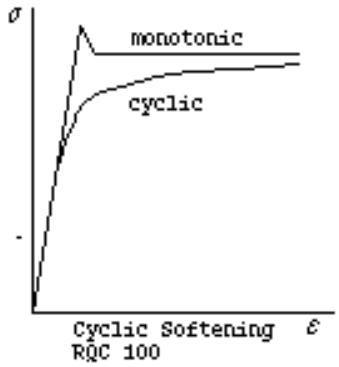
γ = stress biaxial ratio

$\frac{\Delta\sigma}{2}$ = stress amplitude

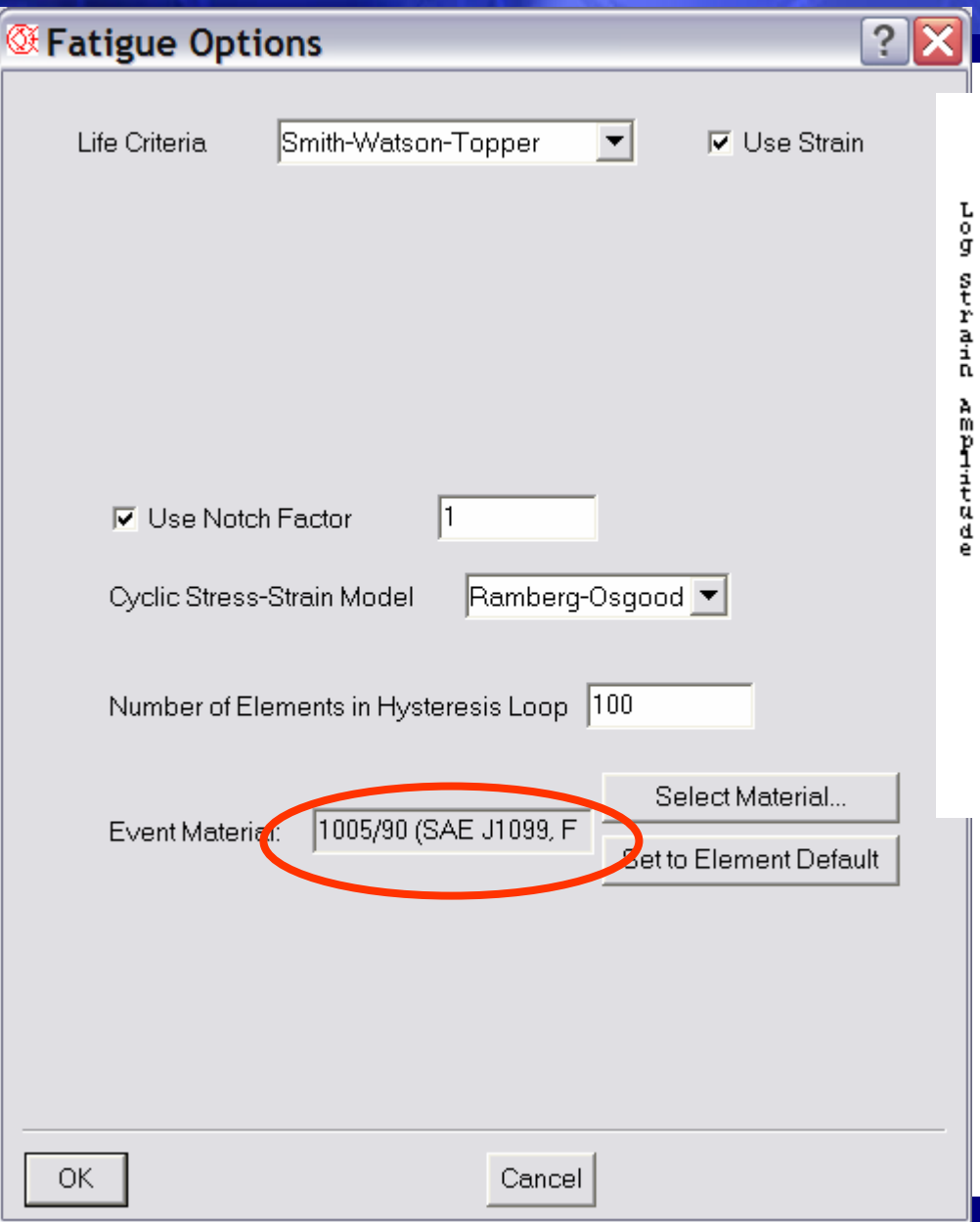
E = modulus of elasticity

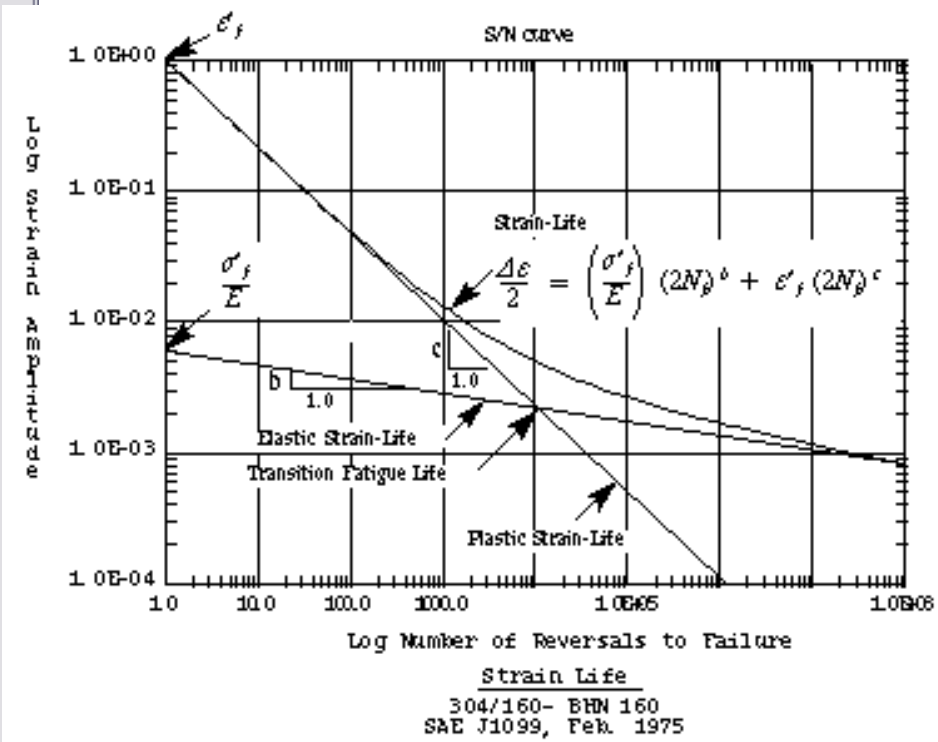
n = strain hardening coefficient

H = cyclic strength coefficient



Fatigue Material





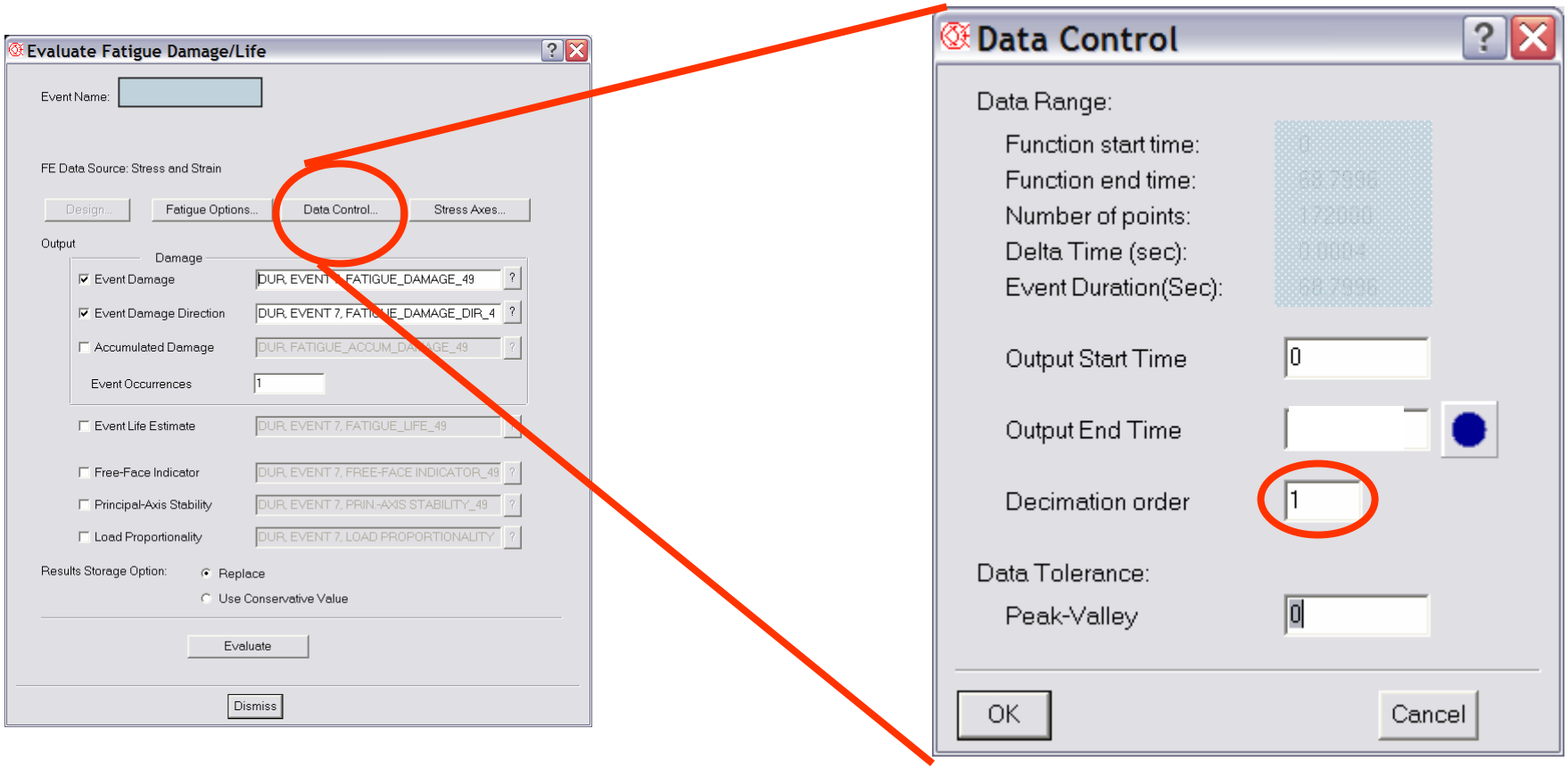
σ_f = Fatigue Strength Coefficent

b = Fatigue Strength Exponent

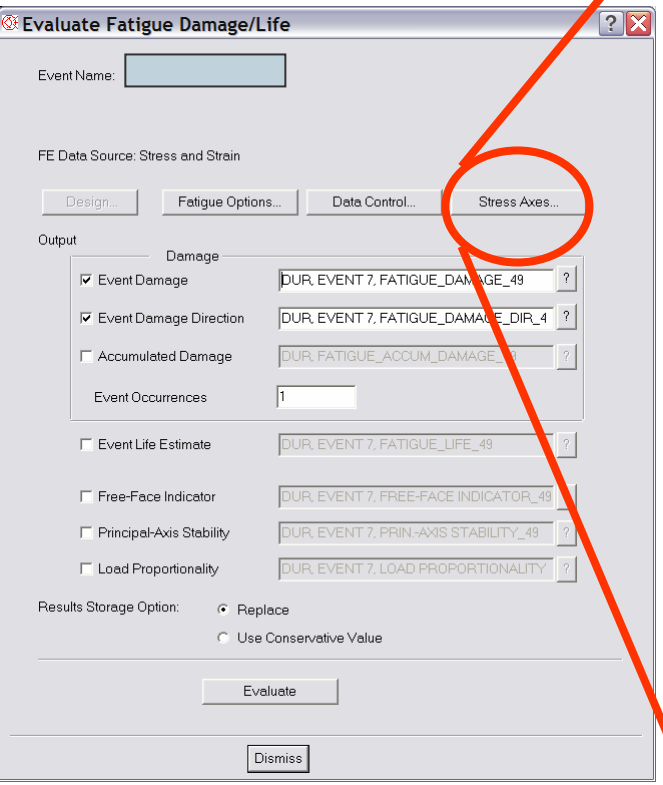
ε_f = Fatigue Ductility Coefficient

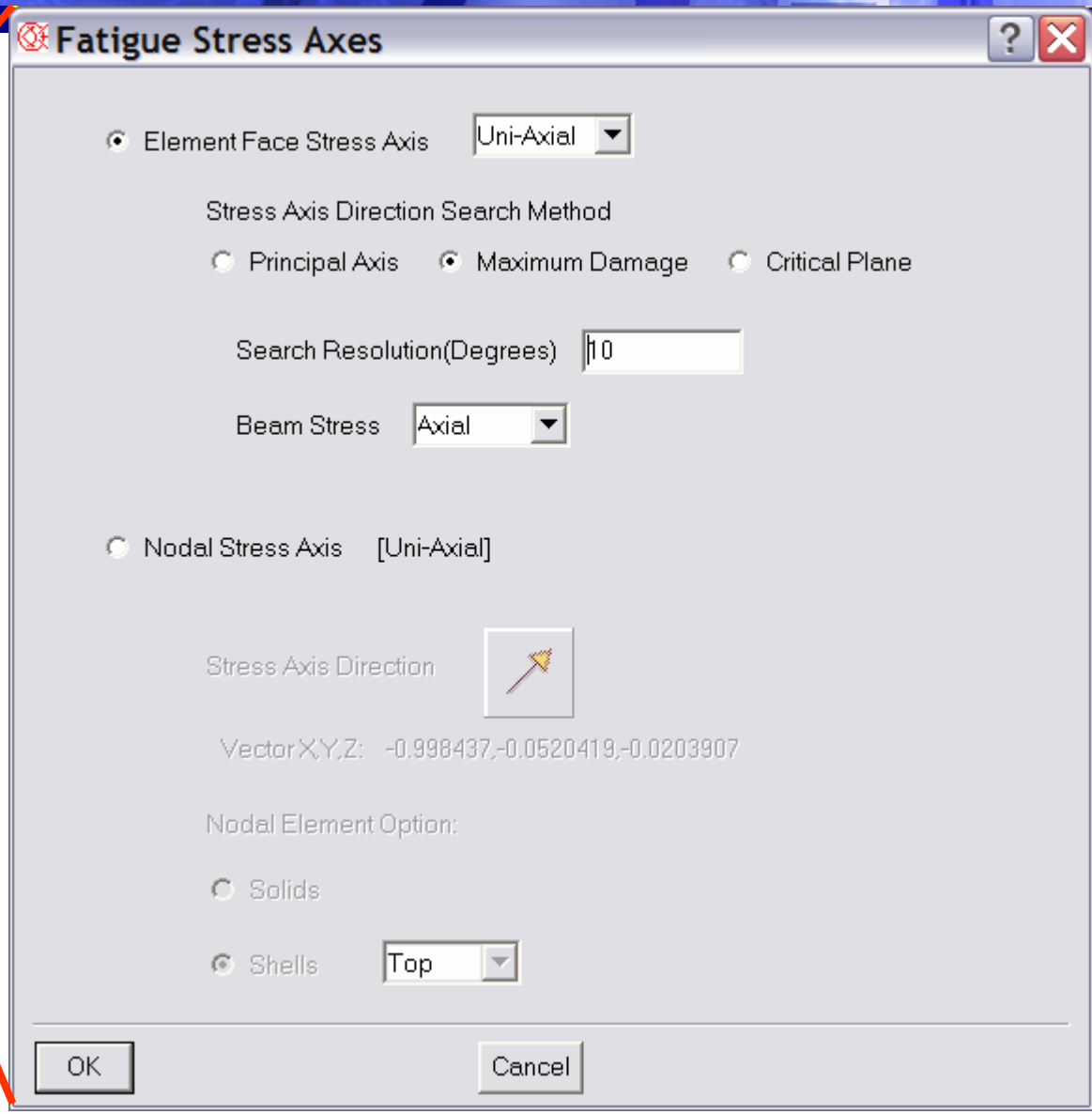
c = Fatigue Ductility Exponent

Data Control

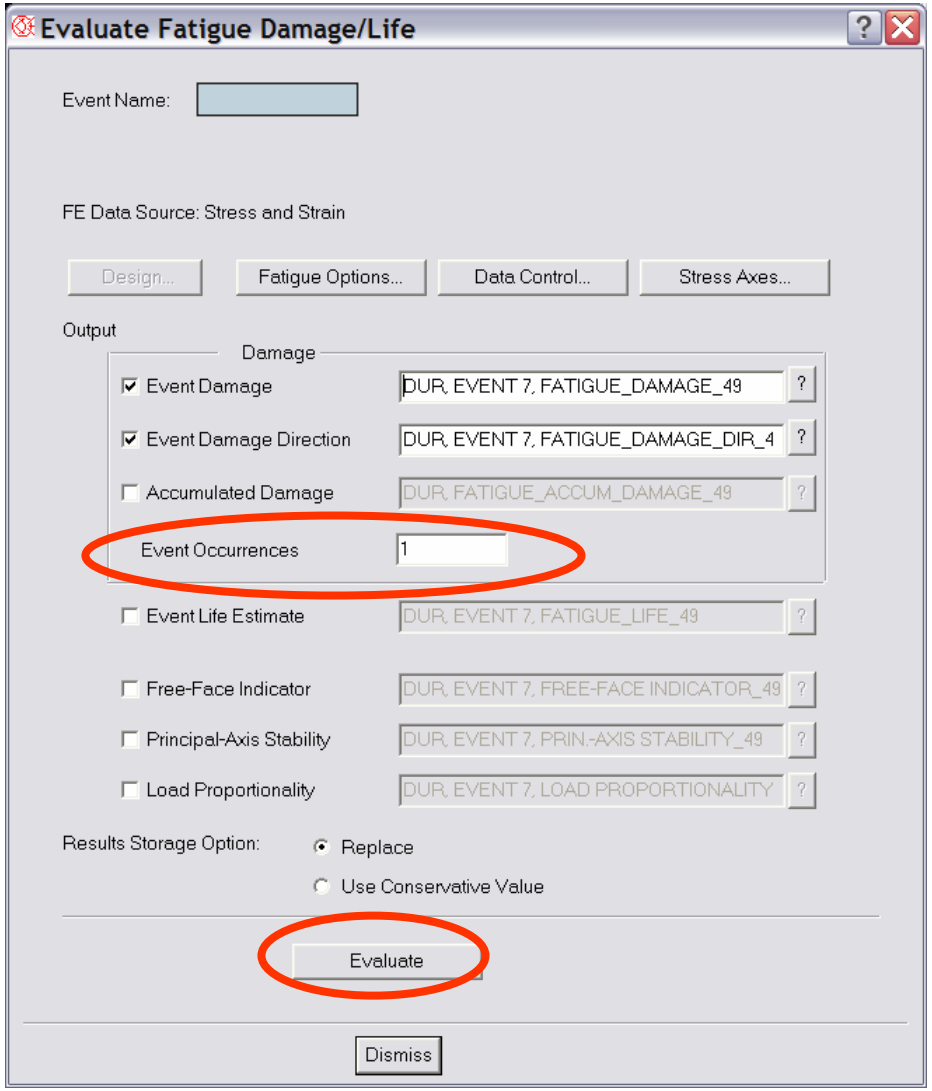


Fatigue Axes

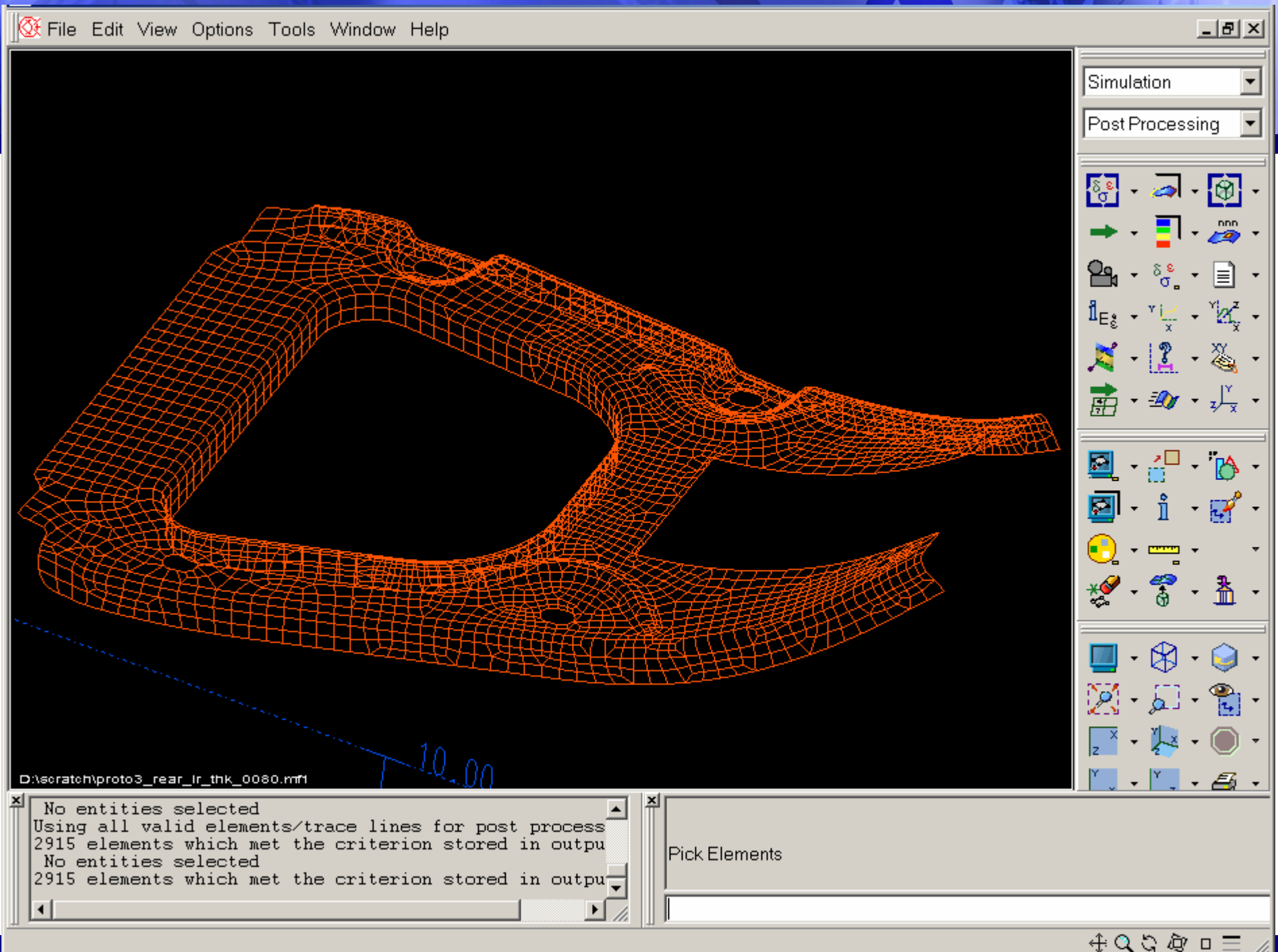


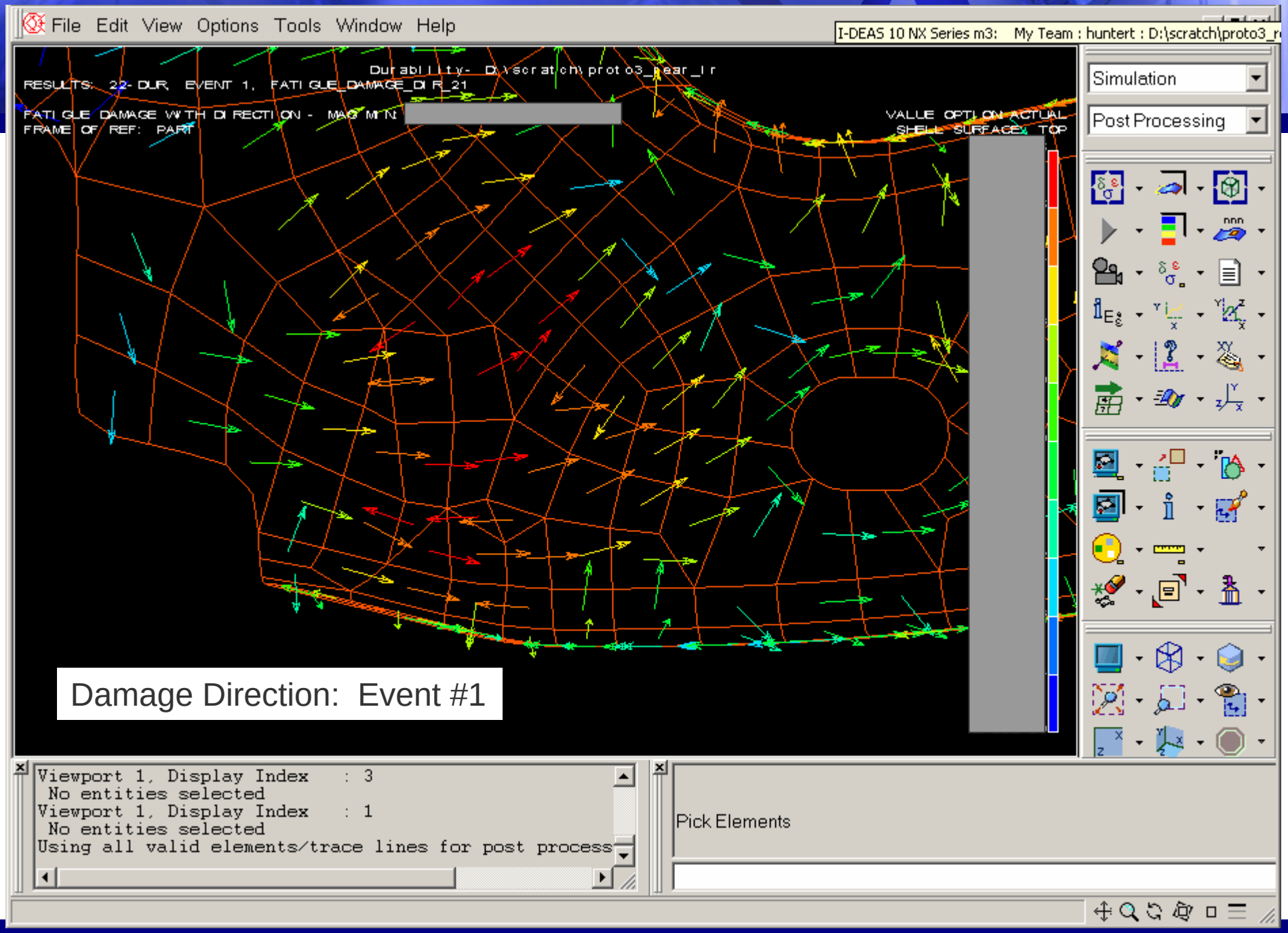


Evaluate Fatigue Damage …

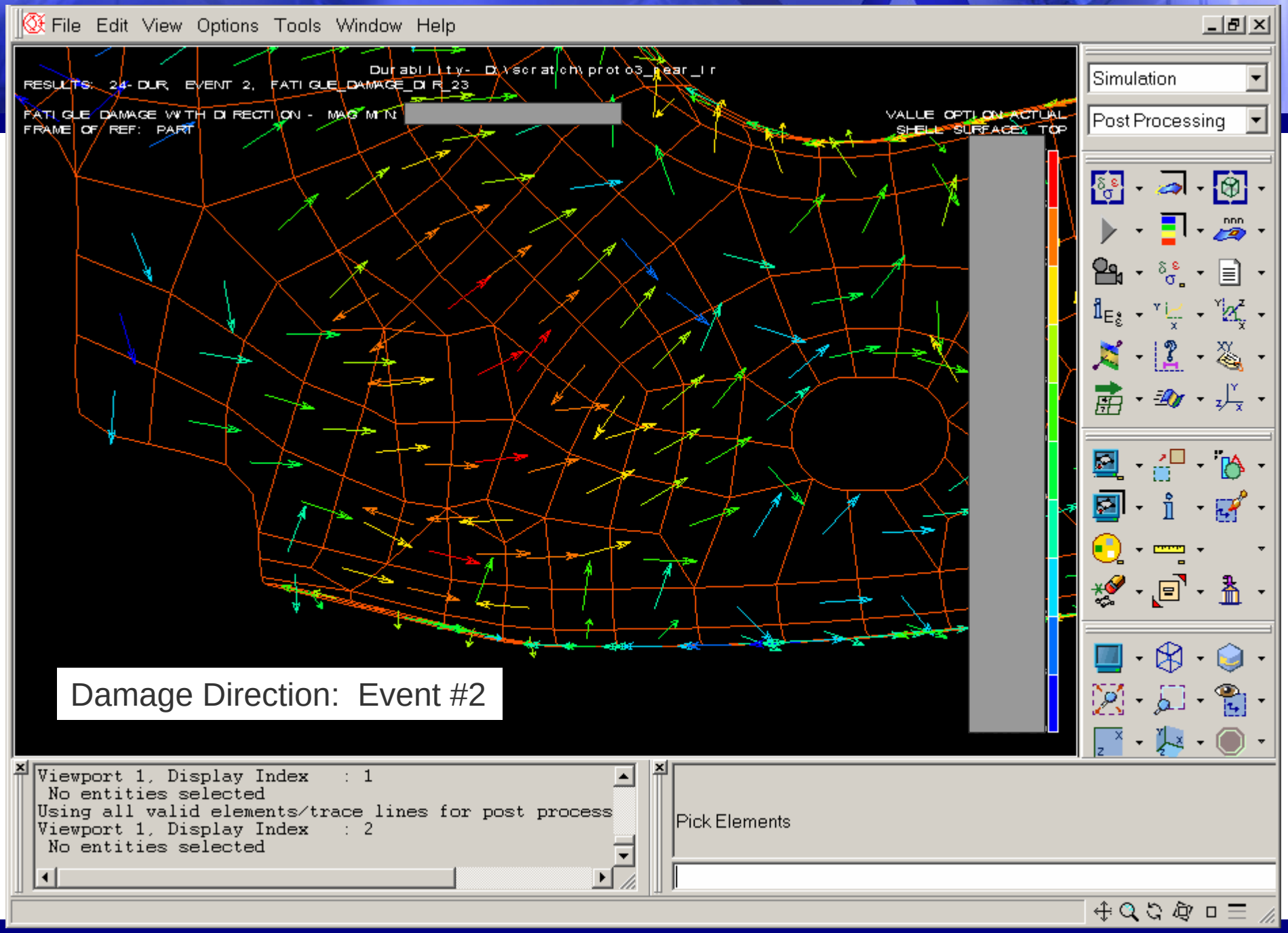


Results: Damage Directions

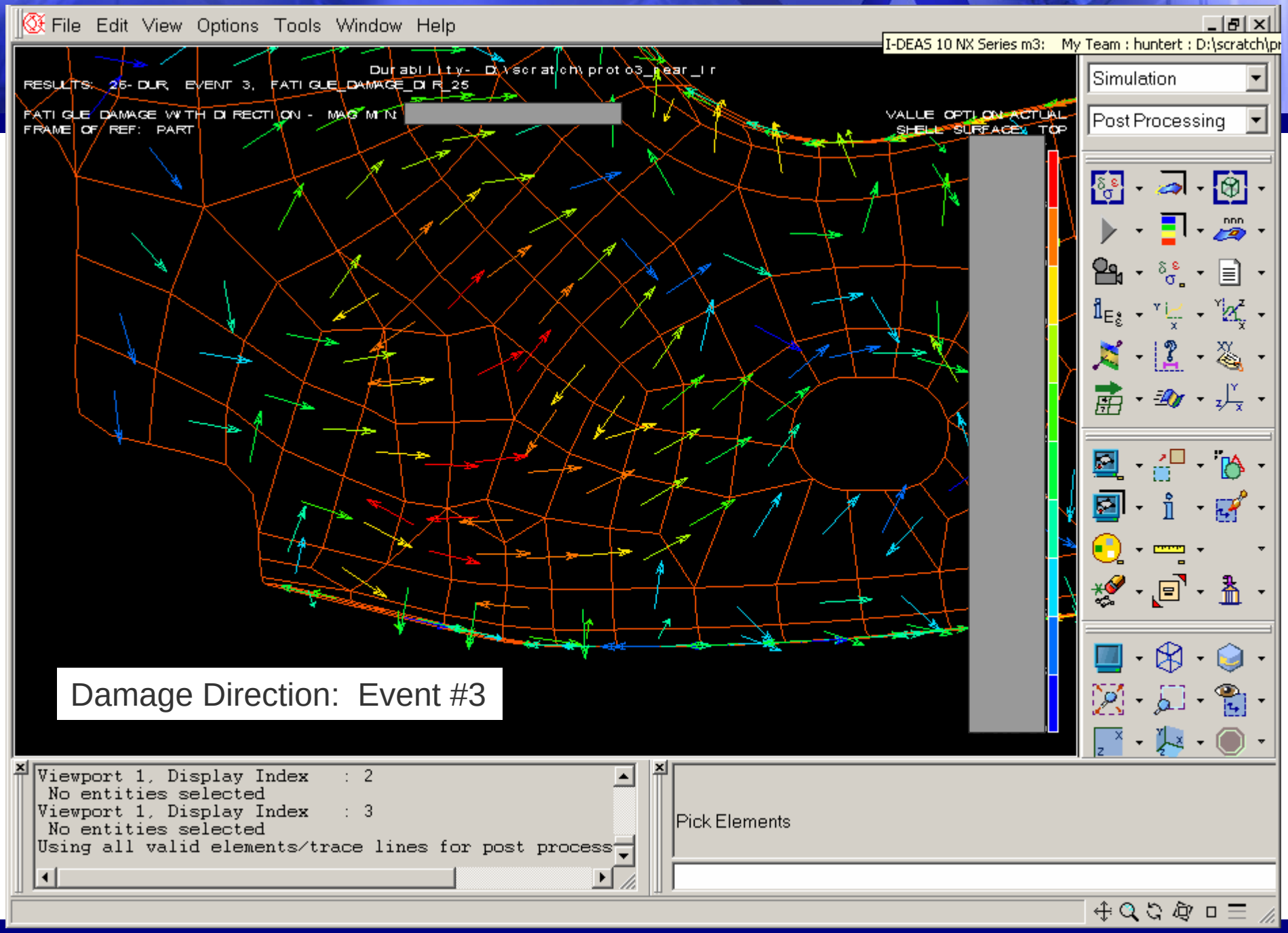

File Edit View Options Tools Window Help
Simulation
Post Processing
D:\scratch\proto3_rear_lr_thk_0080.mf1
10.00
No entities selected
Using all valid elements/trace lines for post process
2915 elements which met the criterion stored in outpu
No entities selected
2915 elements which met the criterion stored in outpu
Pick Elements



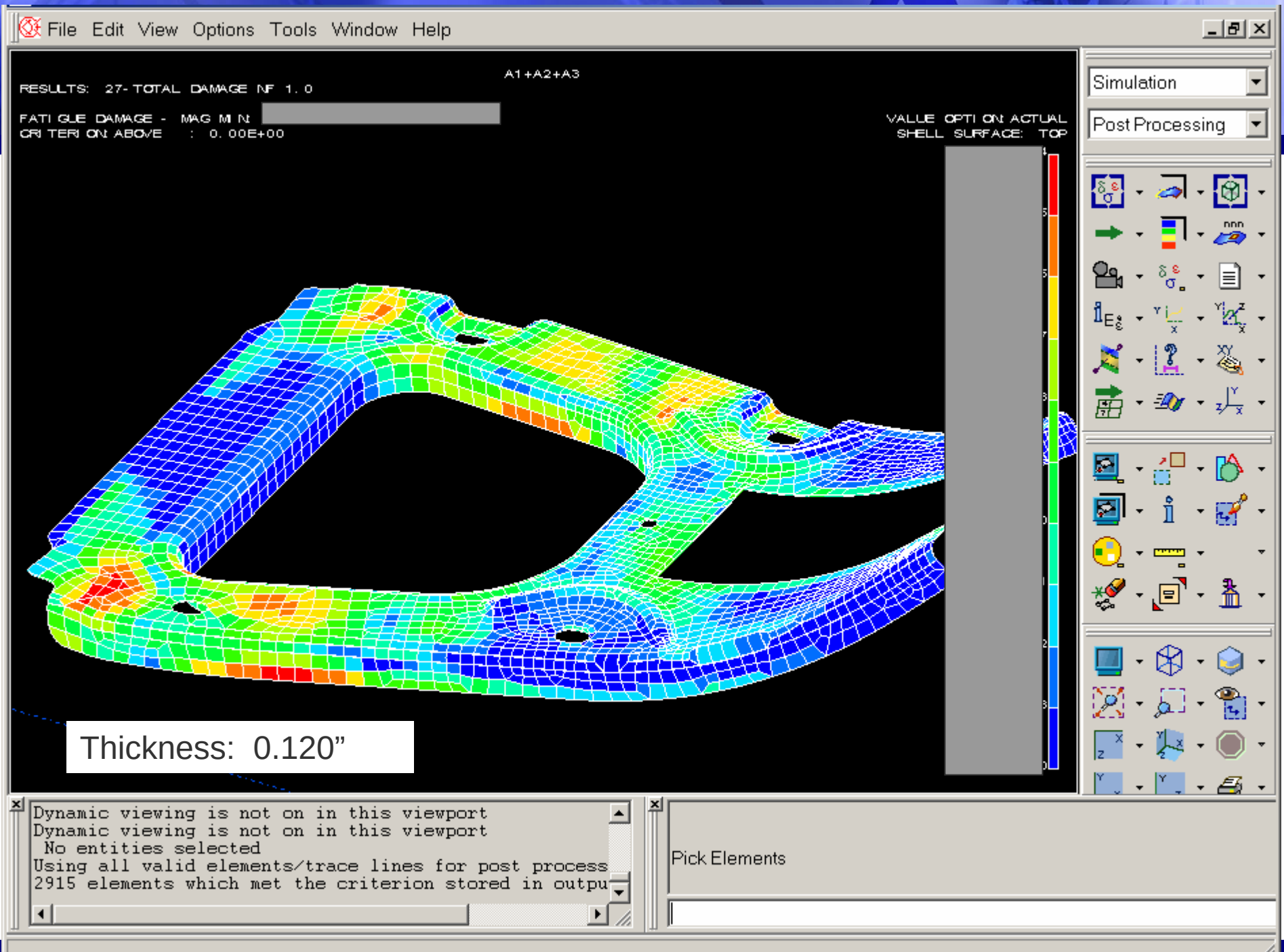
Damage Direction: Event #1

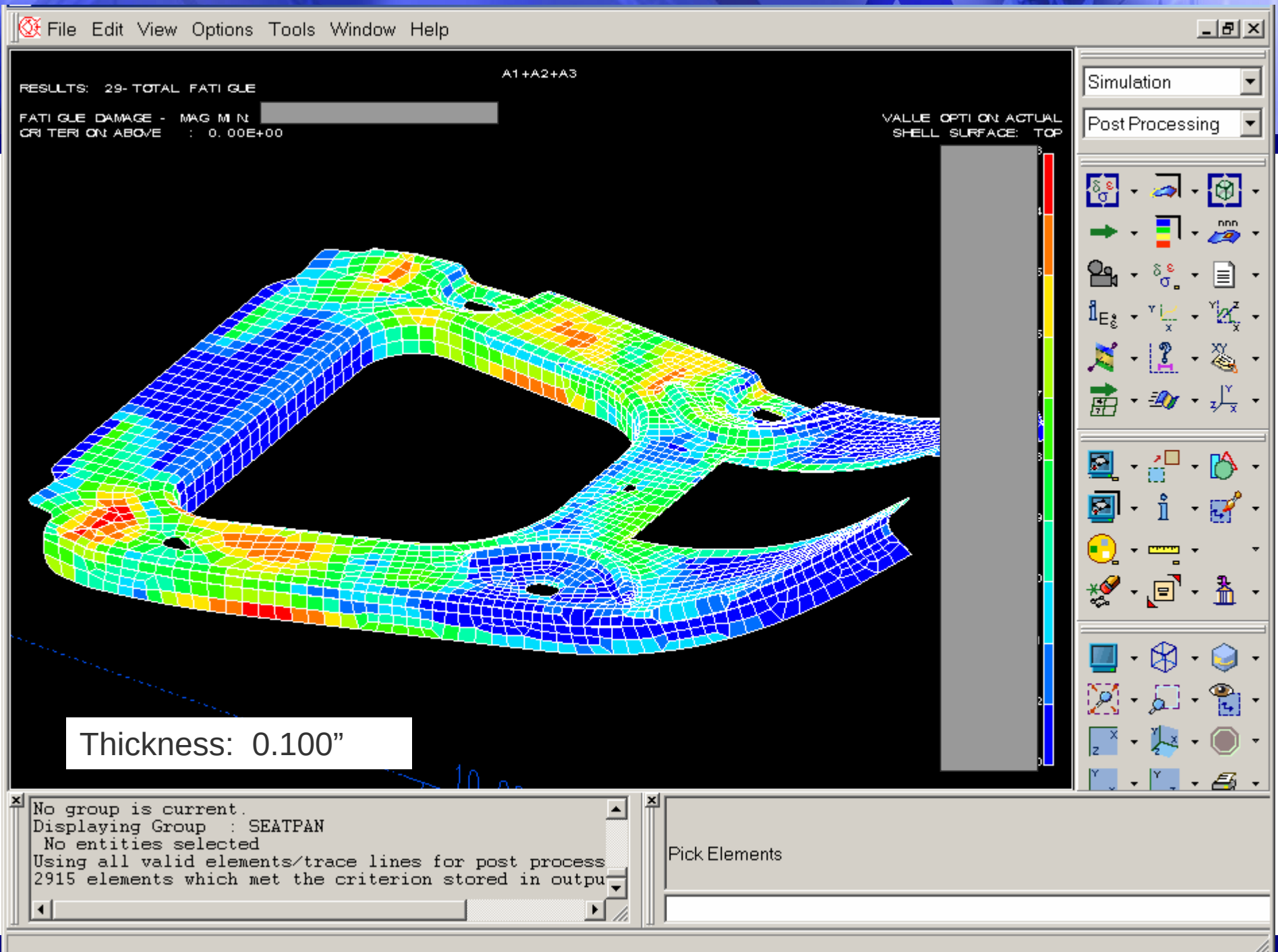


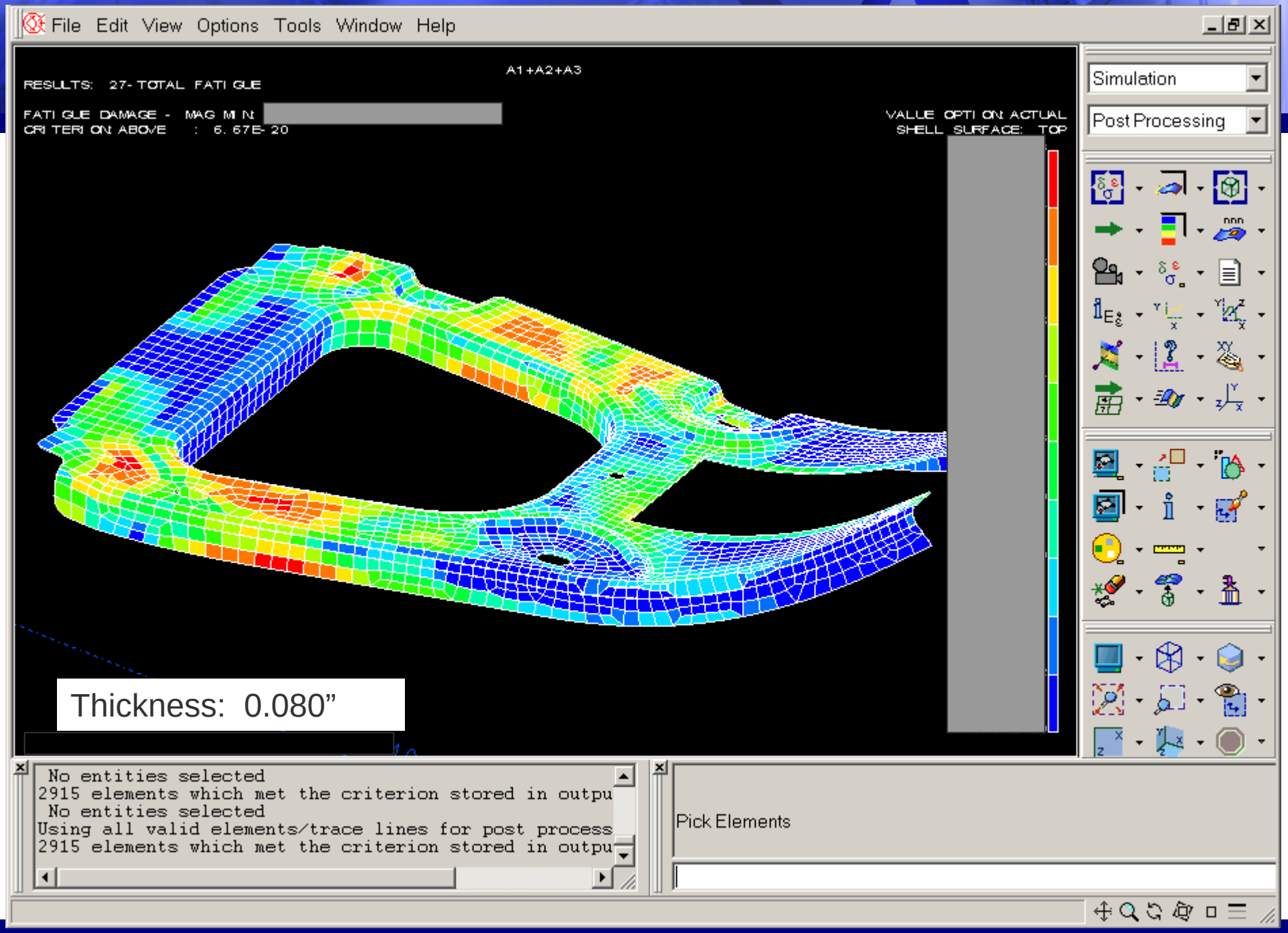
Damage Direction: Event #2


File Edit View Options Tools Window Help
I-DEAS 10 NX Series m3: My Team : huntert : D:\scratch\pr
Simulation
Post Processing
RESULTS: 25- DUR, EVENT 3, FATIGUE_DAMAGE_DIR_25
FATIGUE DAMAGE WITH DIRECTION - MAG MIN
FRAME OF REF: PART
VALUE OPTION ACTUAL
SHELL SURFACE: TOP
Damage Direction: Event #3
Viewport 1, Display Index : 2
No entities selected
Viewport 1, Display Index : 3
No entities selected
Using all valid elements/trace lines for post process
Pick Elements

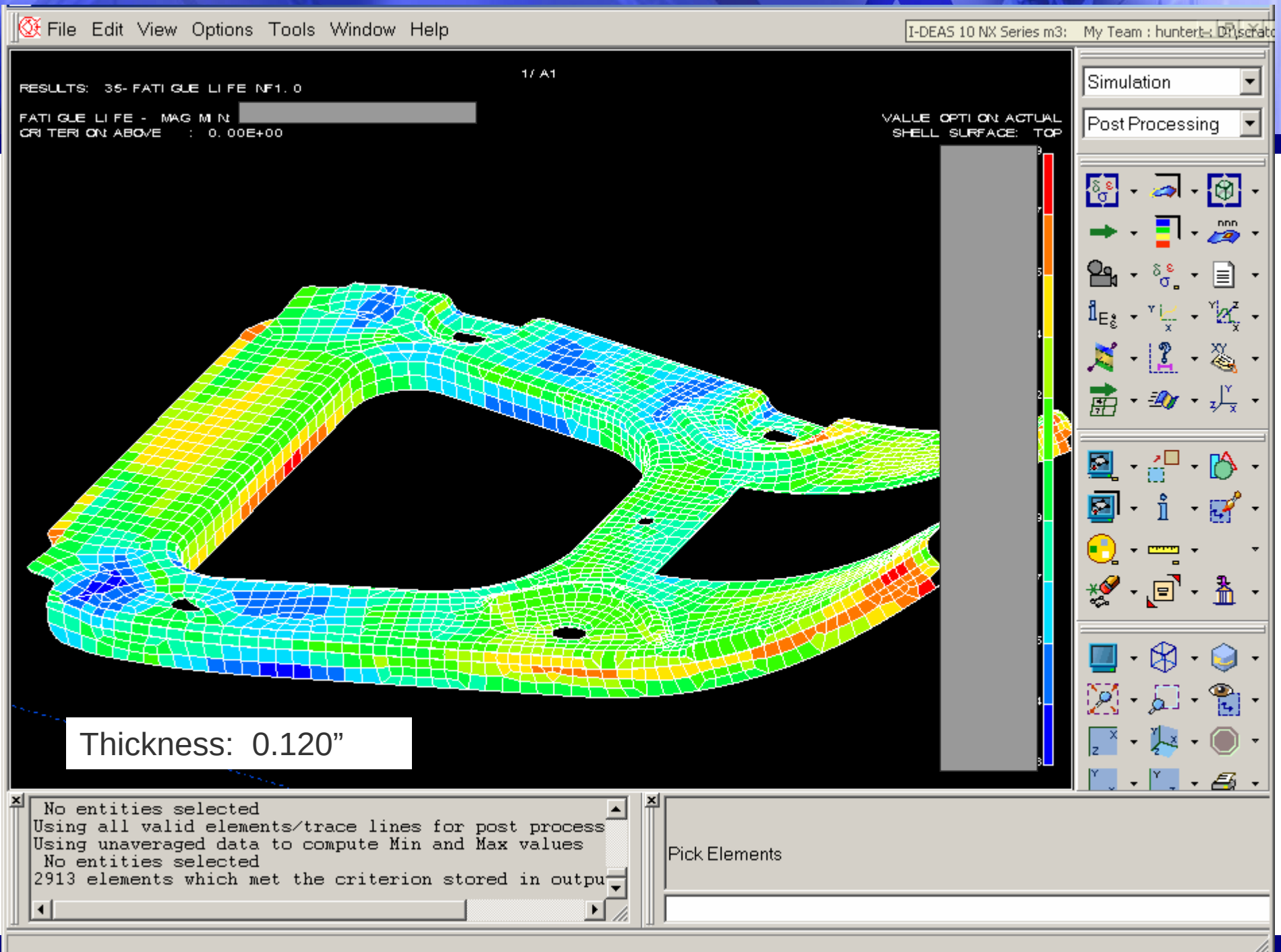
Results: Damage Plots

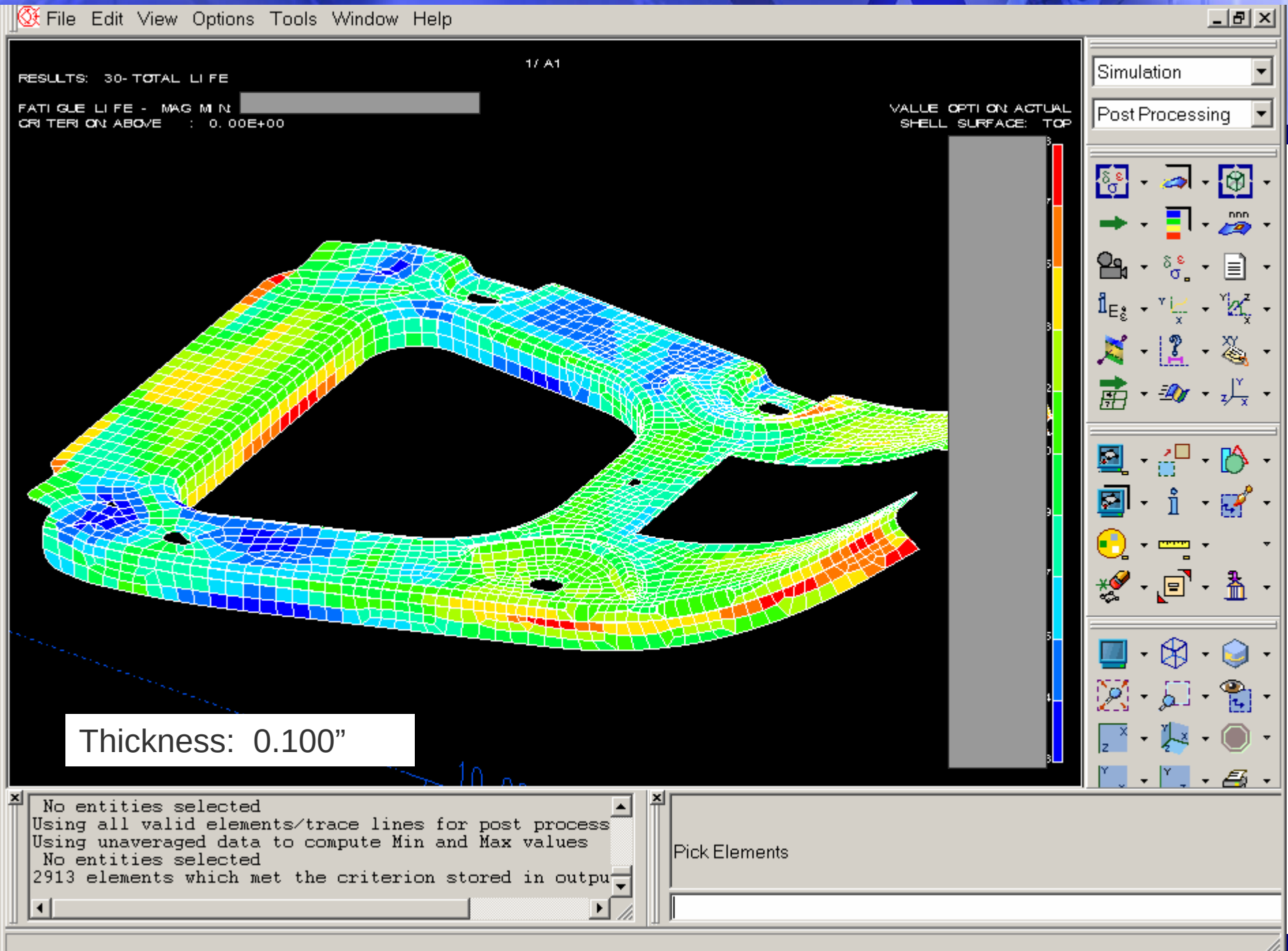

File Edit View Options Tools Window Help
A1+A2+A3
RESULTS: 27- TOTAL DAMAGE NF 1.0
FATIGUE DAMAGE - MAG MIN
CRITERION ABOVE : 0.00E+00
VALUE OPTION ACTUAL
SHELL SURFACE: TOP
Simulation
Post Processing
Thickness: 0.120”
Dynamic viewing is not on in this viewport
Dynamic viewing is not on in this viewport
No entities selected
Using all valid elements/trace lines for post process
2915 elements which met the criterion stored in outpu
Pick Elements

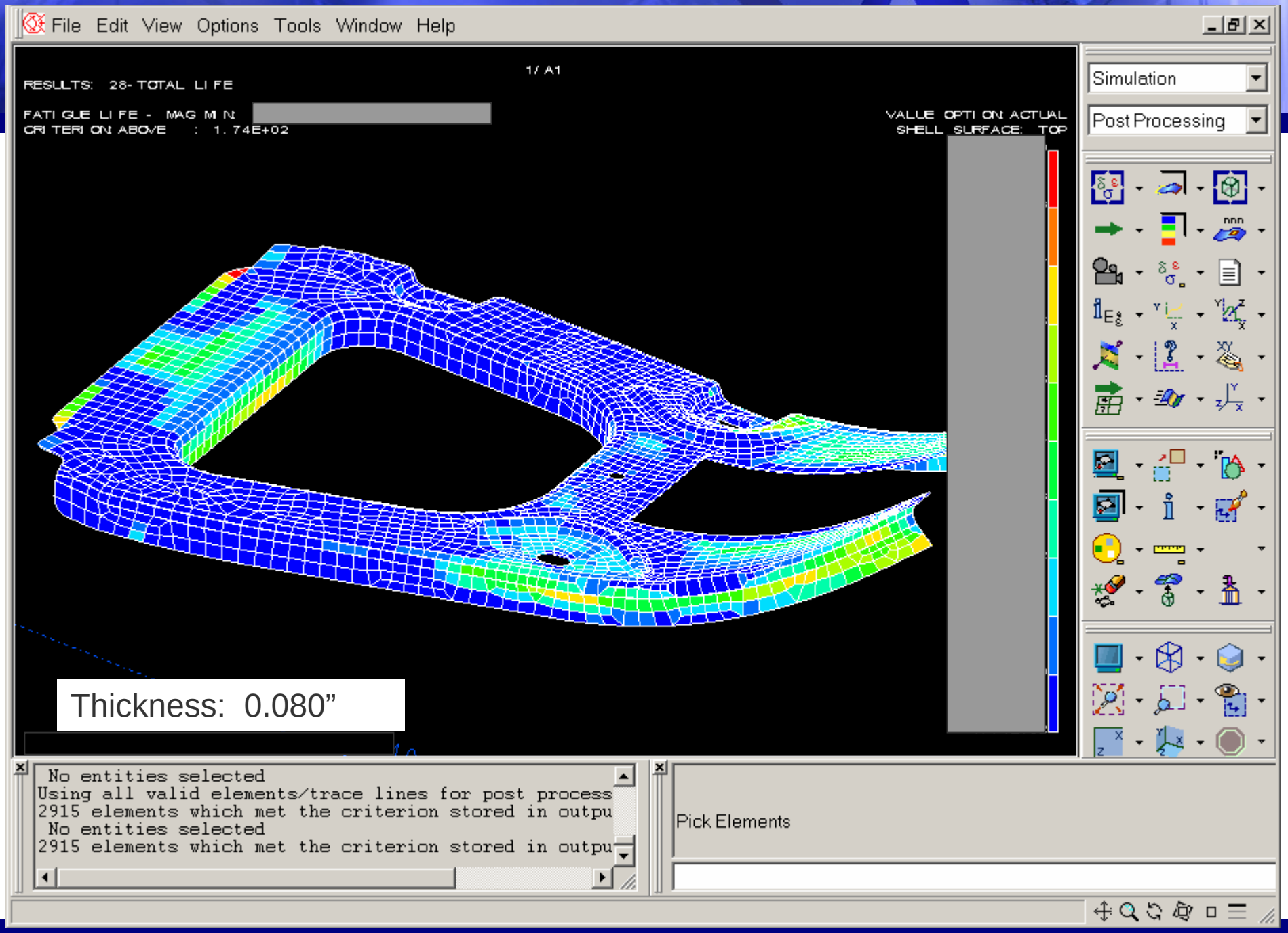

File Edit View Options Tools Window Help
A1+A2+A3
RESULTS: 29- TOTAL FATIGUE
FATIGUE DAMAGE - MAG MIN
CRITERION ABOVE : 0.00E+00
VALUE OPTION ACTUAL
SHELL SURFACE: TOP
Simulation
Post Processing
Thickness: 0.100”
No group is current.
Displaying Group : SEATPAN
No entities selected
Using all valid elements/trace lines for post process
2915 elements which met the criterion stored in outpu
Pick Elements


File Edit View Options Tools Window Help
A1+A2+A3
RESULTS: 27- TOTAL FATIGUE
FATIGUE DAMAGE - MAG MIN
CRITERION ABOVE : 6.67E-20
VALUE OPTION ACTUAL
SHELL SURFACE: TOP
Simulation
Post Processing
Thickness: 0.080”
No entities selected
2915 elements which met the criterion stored in outpu
No entities selected
Using all valid elements/trace lines for post process
2915 elements which met the criterion stored in outpu
Pick Elements

Results: Life Plots


File Edit View Options Tools Window Help
I-DEAS 10 NX Series m3: My Team : huntert
1/ A1
RESULTS: 35- FATIGUE LIFE NF1.0
FATIGUE LIFE - MAG MIN
CRITERION ABOVE : 0.00E+00
VALUE OPTION ACTUAL
SHELL SURFACE: TOP
Simulation
Post Processing
Thickness: 0.120”
No entities selected
Using all valid elements/trace lines for post process
Using unaveraged data to compute Min and Max values
No entities selected
2913 elements which met the criterion stored in outpu
Pick Elements


File Edit View Options Tools Window Help
1/ A1
RESULTS: 30- TOTAL LI FE
FATI GUE LI FE - MAG M N:
CRI TERI ON ABOVE : 0. 00E+00
VALUE OPTI ON ACTUAL
SHELL SURFACE: TOP
Simulation
Post Processing
Thickness: 0.100”
No entities selected
Using all valid elements/trace lines for post process
Using unaveraged data to compute Min and Max values
No entities selected
2913 elements which met the criterion stored in outpu
Pick Elements


File Edit View Options Tools Window Help
1/ A1
RESULTS: 28- TOTAL LI FE
FATI GUE LI FE - MAG M N
CRI TERI ON ABOVE : 1. 74E+02
VALUE OPTI ON: ACTUAL
SHELL SURFACE: TOP
Simulation
Post Processing
Thickness: 0.080”
No entities selected
Using all valid elements/trace lines for post process
2915 elements which met the criterion stored in outpu
No entities selected
2915 elements which met the criterion stored in outpu
Pick Elements

Script to automate the process

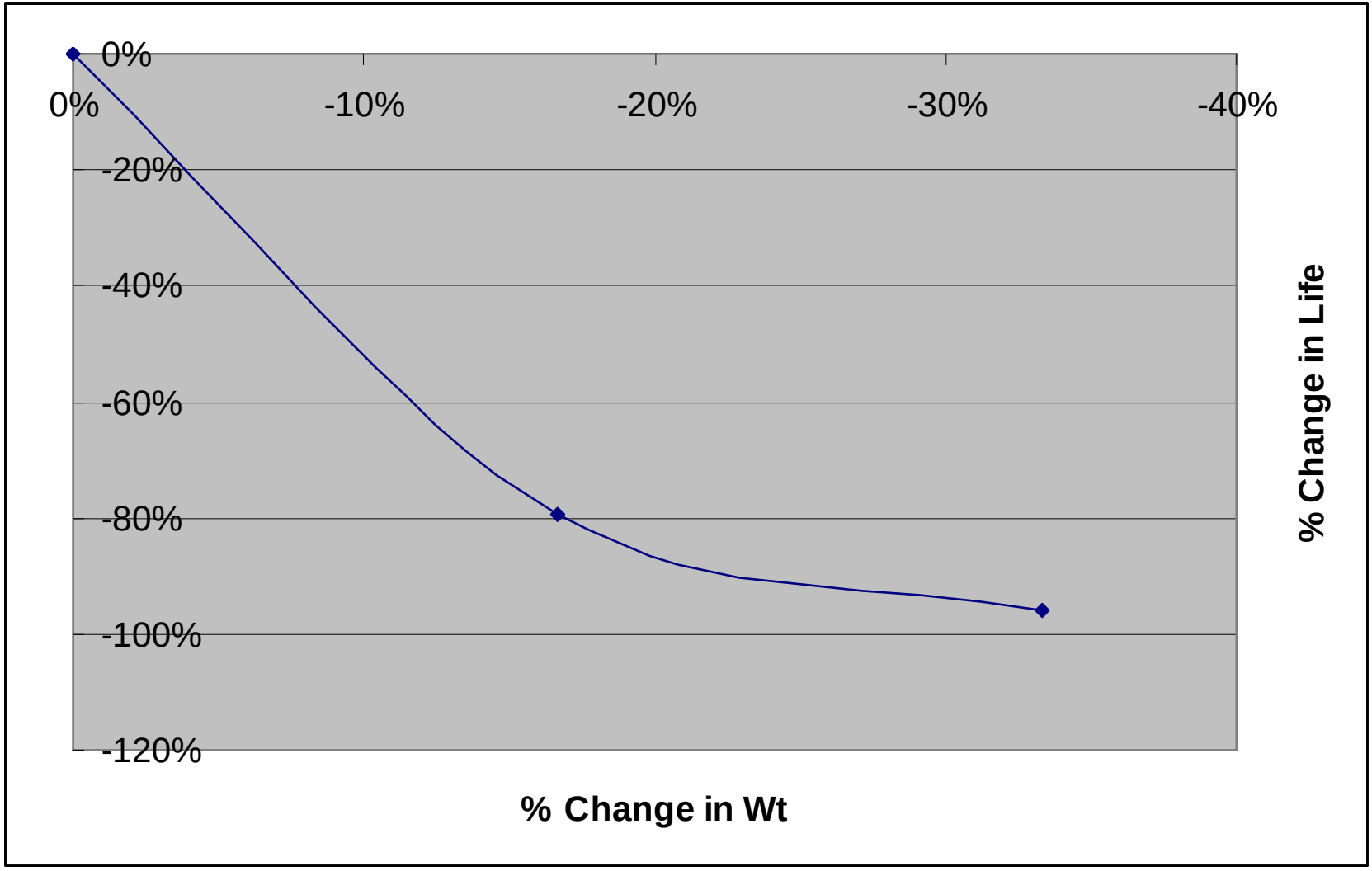
```
C : File:  Durab.prg
C :
C : Purpose:  String a series of events together into a dutycycle
C :                for durability
C :
==============================================
C :
C :   Number of events
C :
K : #n_event = 3
K : #delete occur
K : #declare occur(n_event)
C :
C :   Number of occurence of each event
C :
K : #occur(1) = 1
K : #occur(2) = 4
K : #occur(3) = 1
C :
C :  Decimation Order
C :
K : #dec_ord = 10
C :
C : Timer
K : #execute "tic.bat Start_big_loop"
C :
C :  Initialize the Durabilty Form
C :
K : /ma ev
K : dmn
K : 2;
K :
K : canc
K : no
K : dmn 2 ;;;
K :
K : canc
K : canc
K :
K : $
C :
```

```
C :   This is the big loop
C :
K : #ktr1 = 0
K : #loop1:
K : #ktr1 = ktr1+1
K : #if(ktr1 gt n_event) then goto endlp1
C : Timer
K : #execute "tic.bat Start_event_"+ktr1
K : /ma ev
K : dmn
K : ktr1 ;
K :
K : canc
K :
K :  /FE
C :  ============
C :  Data Control
C :  ============
K :  dc
C :    Desimation Order
K :    do
K :    dec_ord
K :    okay
C :  ===============
C :  Fatigue Options
C :  ===============
K :  OP
C :    Life criterion : Smith Watson Topper
C :    ----------------------------------
K : #execute "tic.bat End_big_loop"
K :    LI SWT
C :
C :    Notch Factor : On
C :    ----------------
K :    NF ON
C :
C :    Notch Factor Value: xxx
C :    ----------------------
K :    NFV 1.0
C :
C :    Use Strain : On
C :    --------------
K :    US ON
K :    OKAY
C :  ===========
c :  Stress Axes
C :  ===========
K :  AX
C :    Element Face Axis : Uniaxial
K :    EF UN
C :    Direction Search Method : Maximum Damage
K :    DS MD
K :    OKAY
```

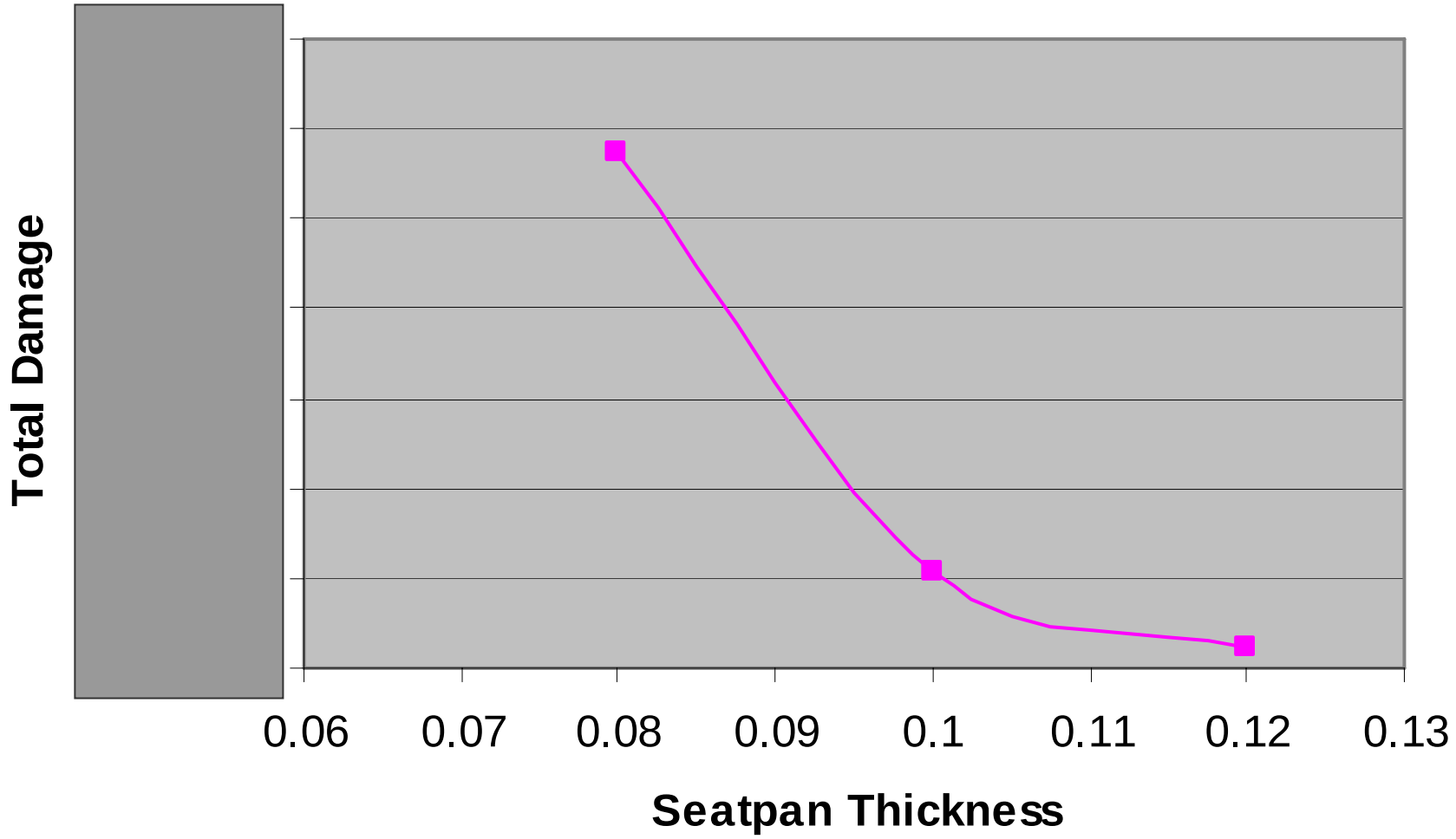
```
C :  Event Damage , Damage Toggle, On / Off
C :  ---------------------------------------
K :   DA DA On !
C :
C :  Event Damage Dir , Damage Dir Toggle, On / Off
C :  ----------------------------------------------
K :   DD DD On !
C :
C :  Accum Damage , Accum Damage Toggle, On / Off
C :  ------------------------------------------------
K :   AD AD off  !
C :
C :  Event Life , Life Toggle, On / Off
C :  ----------------------------------
K :   LI LI off !
C :
C :  Free Face , Free Face toggle, On / Off
C :  ---------------------------------------
K :   FF FF off !
C :
C :  Prin Axis, Prin axis Toggle, On / Off
C :  ---------------------------------------
k :   PA PA off !
C :
C :  Load Proportionality , Load Proportionality Toggle, On / Off
C :  ------------------------------------------------------------
K :   LP LP Off !
C :
c :  Number of occurences
C :  --------------------
K :   nu
K :   occur(ktr1)
C :
C :  This Closes the form
C :
K : CANC
C :
C :
C :
C :
C :  This process elements on the preselect list
C :
K : /fe
K :  EV
K :
K : canc
K : #goto loop1
K : #endlp1:
```

Results: Trade-Off Curves

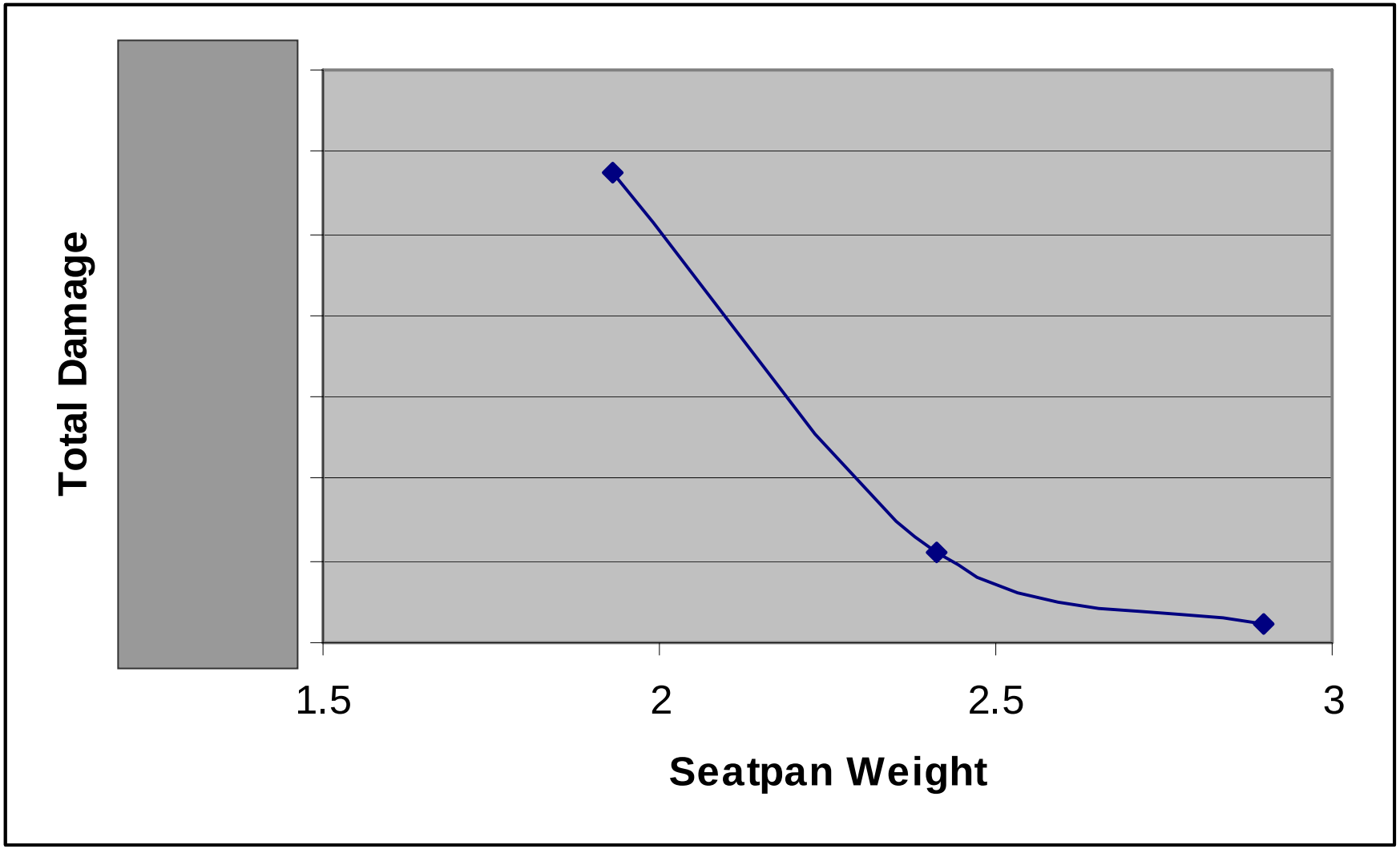
%Change in Life vs. Wt



Total Damage vs. Thickness



Total Damage vs. Wt



Summary

- Quick evaluation of durability on multiple designs can be achieved with:
  - Accurate loading time histories
  - FEA Model of structure
  - Prudent application of I-DEAS Durabilty analsysis procedures

The End