



WCFA'09 & PUM3
VÍLANEC, CZECH REP.
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EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
INVESTMENT IN YOUR FUTURE



PragTic in Application

Fatigue in Riveted Joints

Jan Papuga

The organisation of the meeting is partially financed from OPPI programme
Czech Technology Airspace Platform, reg. number SPTP 01/004

Evektor, spol. s r.o.

Founded in 1991

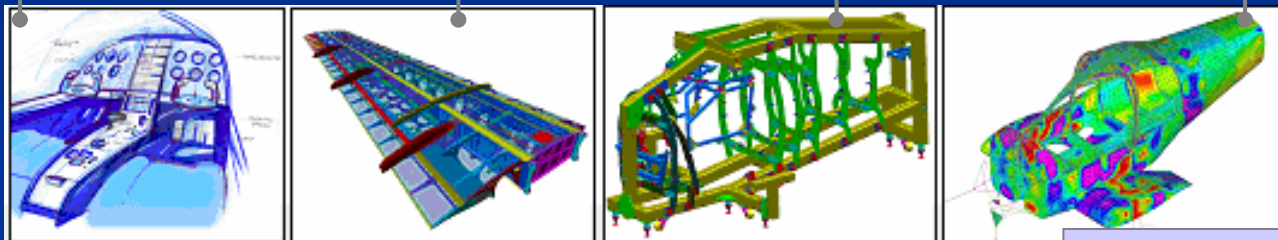
Design activities from 1992

Fully private owned
company

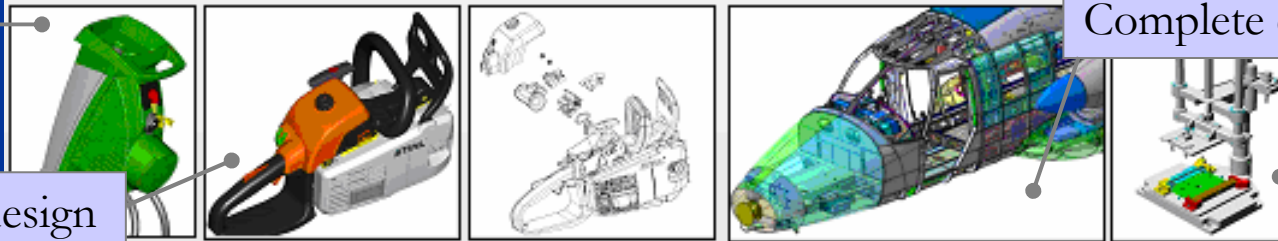


Scope of Projects

Design studio Design of components Design of jigs, fixtures Stress analysis



Plastic parts Complete development



Preliminary design of mechanisms



FE-analysis including crashes Interiors design Stamping tools

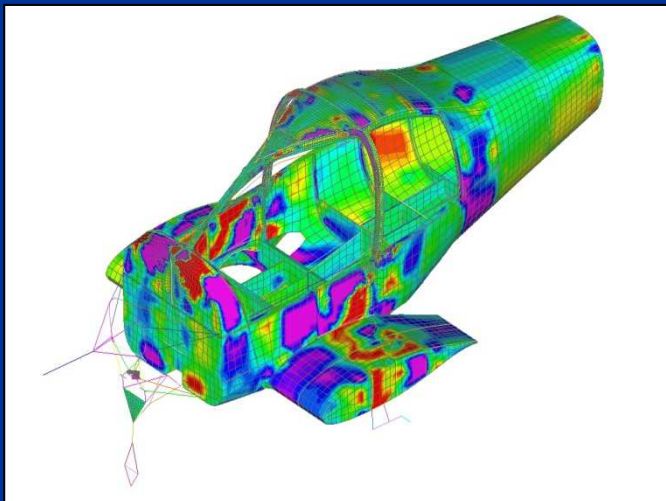
Prototype tooling

Aircraft structures

VUT 100



EV-55



IMPERJA Project

- Improving the Fatigue Performance of Riveted Joints in Airframes
- EUREKA programme of EU
- International project with partners mainly from Poland
 - Institute of Aviation, Warszawa, Poland - coordinator
 - AGH University of Science and Technology, Krakow, Poland
 - ATR University of Technology and Agriculture in Bydgoszcz, Poland
 - WAT Military University of Technology, Warszawa, Poland
 - PZL Mielec, Mielec, Poland
 - Stresstech Oy, Vaajakoski, Finland

Evektor Participation

- WP12: Experimental analysis of riveted specimens
- WP13: FEM-based analysis of riveted specimens
- WP14: Fatigue analysis of riveted specimens based on WP13 results

Experiments

□ EVE1

□ R=0.1

□ 4 results at four load levels

EVE1	σ_u [MPa]	N [-]
LR1	160.7	3 631
LR2	108.475	16 093
LR3	64.675	134 453
LR4	37.575	733 014

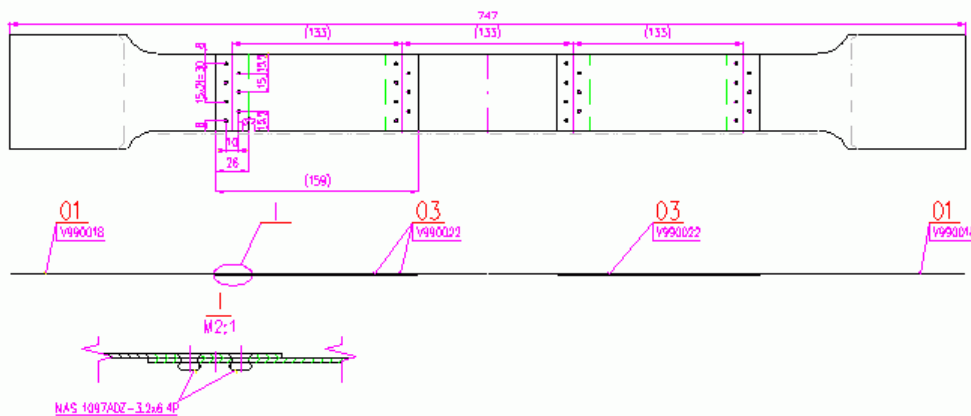
□ EVE2

□ R=0

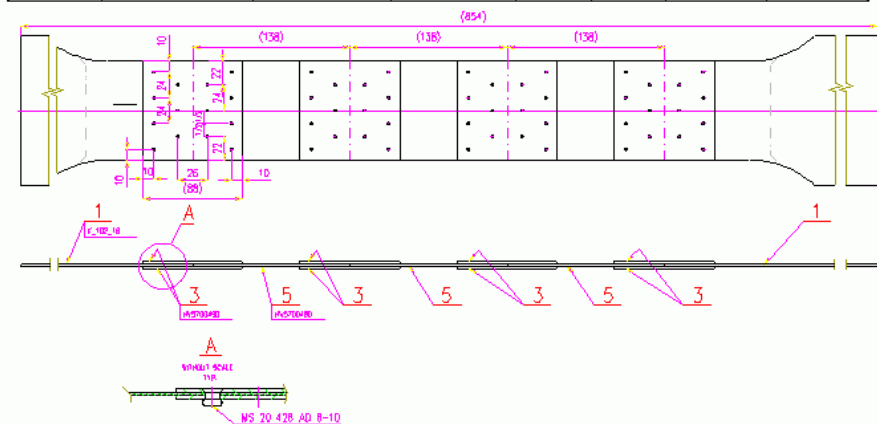
□ 4 results at four load levels

EVE2	σ_u [MPa]	N [-]
LR1	190	11 808
LR2	140	57 003
LR3	100	573 116
LR4	80	1 857 551

Name of specimen	Type of riveted joint	Joint figure	Glue	Rivet holes	Sheet		
					Material	Thermal processing	Thickness (mm)
NNPL (for IMPERJA EVE1, č.v. V990006)	Cladding- countersunk solid rivet Ø3.2 NAS 1097AD		Emfimastic	Bored holes	D16 Č	ATV	0.8 x 0.8

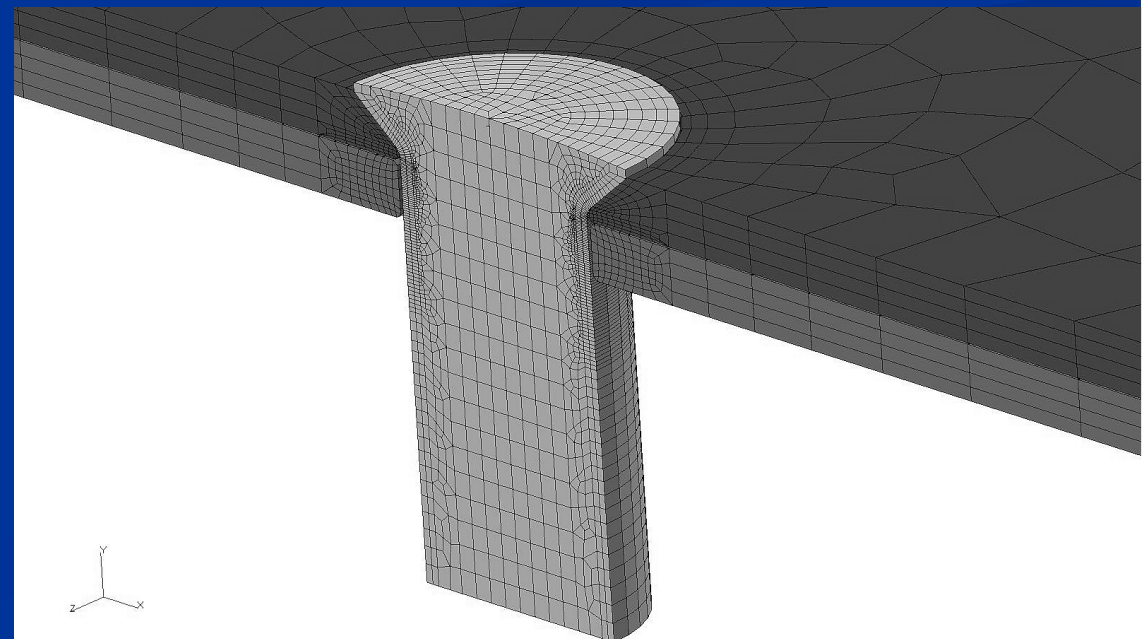
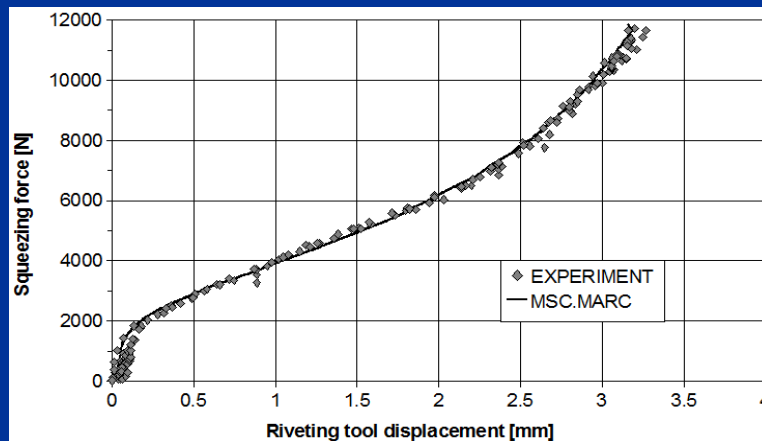
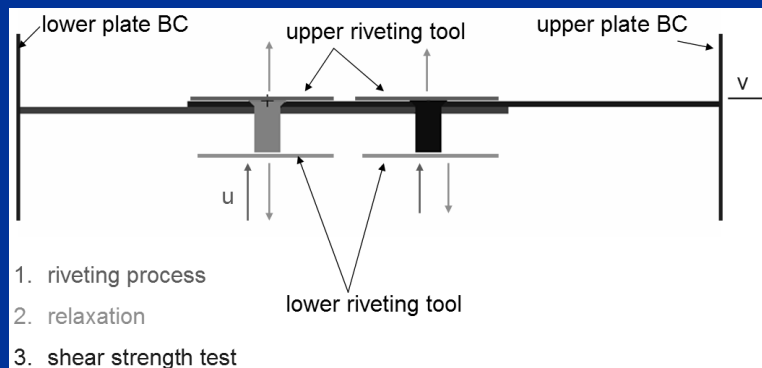


Name of specimen	Type of riveted joint	Joint figure	Glue	Rivet holes	Sheet		
					Material	Thermal processing	Thickness
MMDHS 4,8U (for IMPERJA EVE2, č.v. K-102-17)	Riveted joint with underlay, double shear – solid countersunk rivet MS20426 AD Ø4.8		Putty: TM1 in according with AEN 5471 (PR1770C12)	Reamed holes	Clad 2024	T3	2.5x2.5x2.5



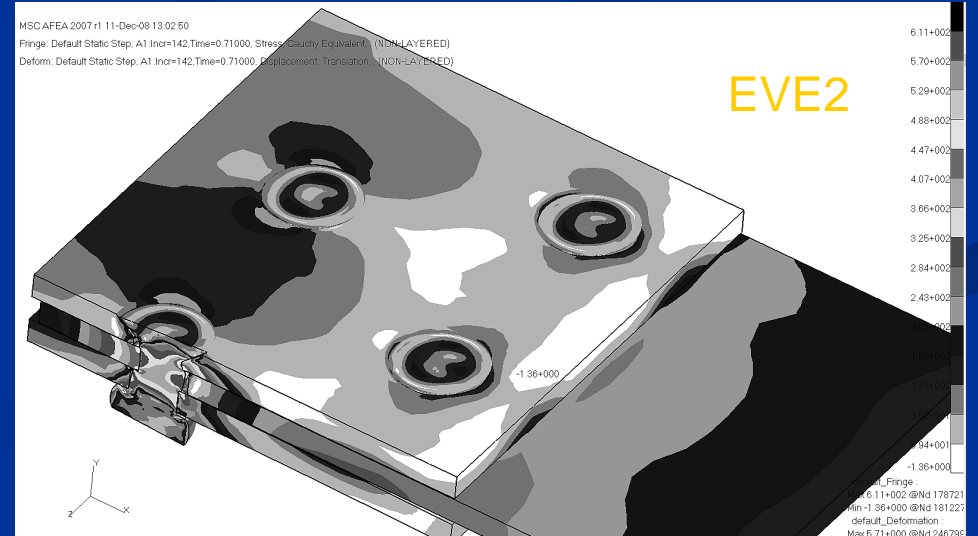
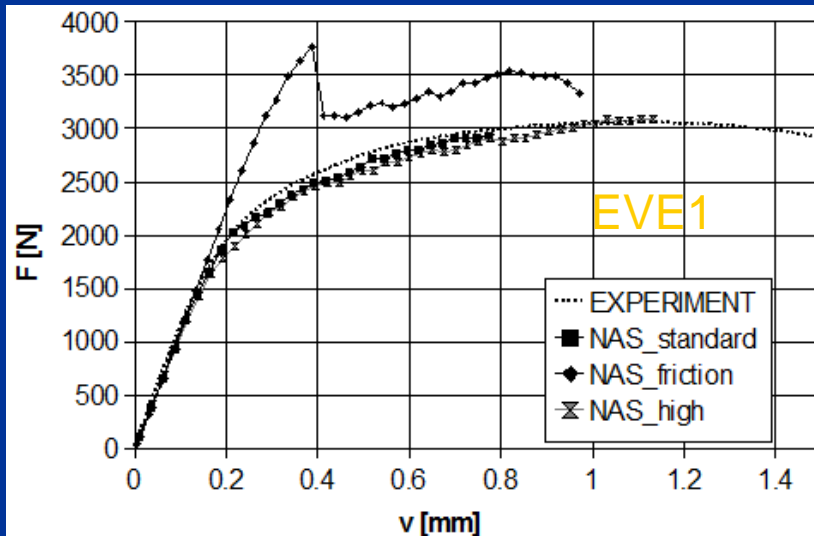
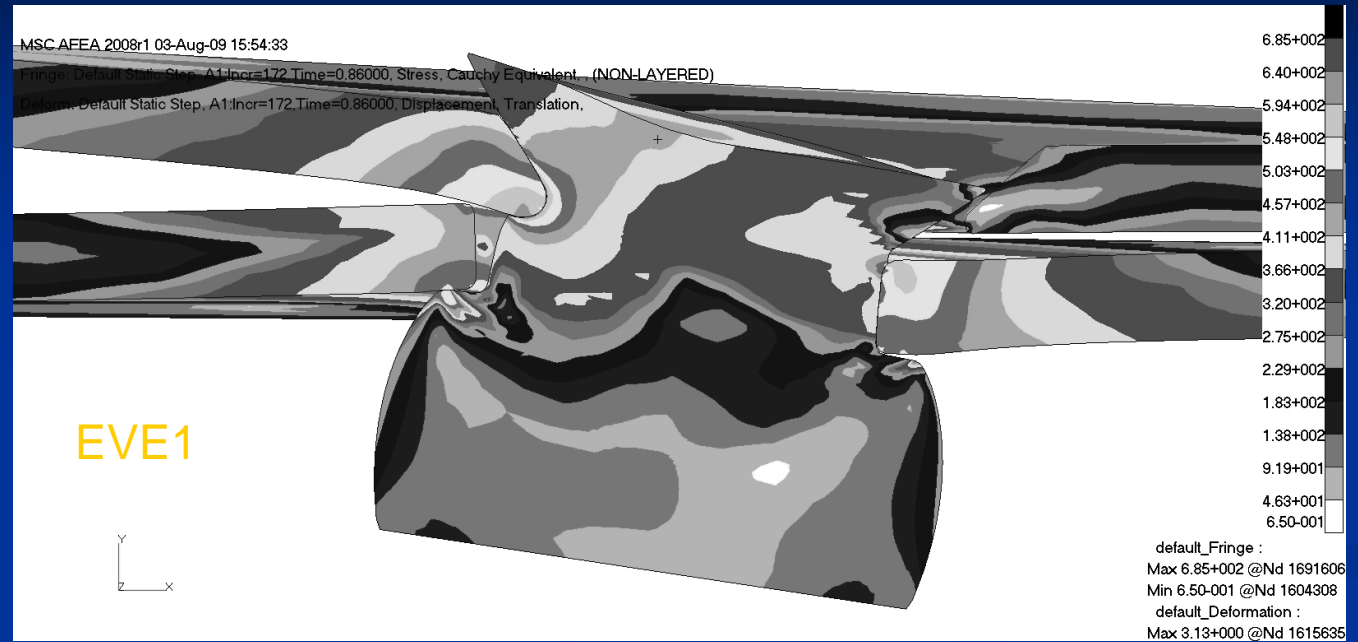
FEA Analyses

- Problems above all with EVE1
 - very thin cylindrical part below the countersunk head
 - pronounced changes of elements shape at this region
 - remeshing would be suitable



FEA Analyses II

Shear tests:



Inputs for Fatigue Analysis

- FEA Model
 - built in MSC.Patran => *.nas file exists
 - outputs from MSC.Marc
 - can be read back to Patran
 - local stress and strain tensors at various load increments
- Experimental data
 - final lifetimes (just for comparison with fatigue prediction)
 - material properties – derived from available referenced data
 - load data

PragTic in Application I

First Run

- Registration to <http://www.pragtic.com>
- Download
- Unzip to desired location – example C:\Test\PragTic\
- Edit of WinPragTic.ini file – renaming the paths:

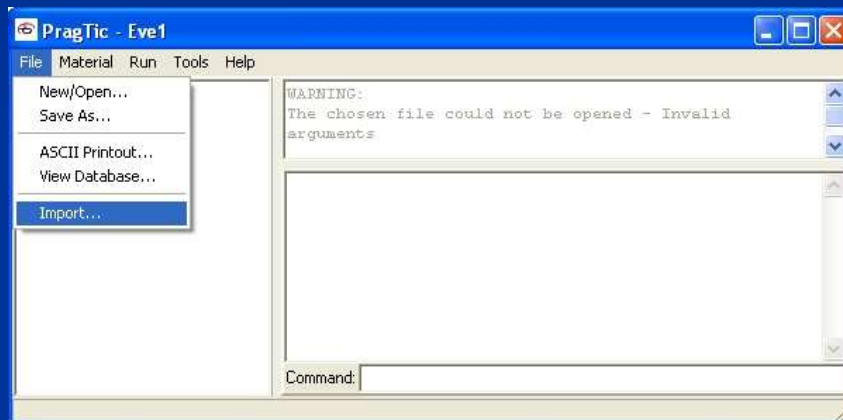
```
DIR C:\Test\PragTic\  
HOME C:\Test\PragTic\  
IMAGES C:\Test\PragTic\  
MPORT C:\Test\PragTic\  
XPORT C:\Test\PragTic\  
MDB C:\Test\PragTic\PragTic_MDb.mat  
ERROR 1e-10  
EM_BUFF 100000
```

- Run of the executable

PragTic in Application II

Import of FE-Model Topology

- Import of *.nas file



- Let the normals to be calculated
 - It does not take so long
 - It is useful for detection of surfaces of individual parts

PragTic in Application III

Import of Result Files – Make Map

- Preparation of map file for FEA results import

Source: C:\uziv\ipapuga\granty\IMPERJA\calcs08NE ve1\input\step82.rpt

Separators:
 automated hard
 <space>
 <tab> <>
 other:
 fixed width:

Content:
 nodes
 elements
 isolated points
 results
 load history

MSC.AFEA 15.0.038 Tue Aug 21 13:05:45 PDT 2007 - Analysis Code: MSC.Marc
Load Case: Default Static Step, A1:Incr=82,Time=0.41000
Result Stress, Global System - Layer At Layer 1
Entity: Element Tensor

Entity ID	X Component	Y Component	Z Component	XY Component	YZ Component	ZX Component
340746	-54.142113	57.217571	-174.702408	-82.443886	-35.102097	-16.524923
340747	-94.548836	12.382088	-270.468872	-29.132029	-32.021687	-13.082451
340748	-177.186981	-97.404243	-437.431763	-8.531001	-26.453175	-16.532082

Column	From	To	Count	Variable	Position
1	2	8		Set of Nodes	ID
2	14	24		RES: Stress	SX
3	29	38		RES: Stress	SY
4	41	52		RES: Stress	SZ
5	56	66		RES: Stress	SXY
6	70	80		RES: Stress	SYZ
7	84	94		RES: Stress	SZX

Read Map
Save Map
Reset
Run Scan
Upload

Here

PragTic in Application IIIbis

- General input of FE-data in formatted records

The screenshot illustrates the PragTic application interface for handling FE data. It features a 'File recognition' panel on the left, a central data input area, and several context menus and dialog boxes for formatting the data.

1. File recognition: The 'Source' field is set to 'C:\Documents and Settings\Honza\Dokumenty\texty\konference\CAD\FEM2007\uloha\NL'. The 'Separators' section has 'automated' selected and '<space>' checked. The 'Content' section has 'nodes' selected.

2. Data Input: The main window displays a table of node coordinates. The input text is:


```
LIST ALL SELECTED NODES. DSYS= 0
SORT TABLE ON NODE NODE NODE
```

 The table has columns: NODE, X, Y.

NODE	X	Y
1	0.21382E-02	0.11111E-02
2	0.21382E-02	-0.11111E-02
3	-0.23655E-03	0.11111E-02
4	-0.23830E-02	0.11111E-02
5	-0.42648E-02	0.11111E-02
6	-0.58499E-02	0.11111E-02
7	-0.71116E-02	0.81111E-02
8	-0.80284E-02	0.56687E-02-0.70000E-02
9	-0.85847E-02	0.28586E-02-0.70000E-02
10	-0.87712E-02-0.14140E-14	0.70000E-02
11	-0.85847E-02-0.28586E-02-0.70000E-02	0.00

3. Context Menu: A context menu is shown over the data table with options: '1. Item description', '2. Header lines', '3. First data line', 'Place separator', and 'More rows...'. A 'Separators' dialog box is open, prompting to 'Set the separators now by right-hand click on chosen positions'.

4. Data Input (Z-axis): The input text is:


```
ALL SELECTED NODES. DSYS= 0
TABLE ON NODE NODE NODE
```

 The table has columns: NODE, X, Y, Z.

NODE	X	Y	Z
1	0.0000E-01	0.70000E-02	0.0000E-02
2	0.0000E-01	0.70000E-02	0.0000E-02
3	998E-01	0.70000E-02	0.0000E-02
4	501E-01	0.70000E-02	0.0000E-02
5	841E-01	0.70000E-02	0.0000E-02
6	955E-01	0.70000E-02	0.0000E-02
7	828E-02	0.70000E-02	0.0000E-02
8	587E-02	0.70000E-02	0.0000E-02

5. Column Mapping Table:

Column	From	To	Count	Variable	Position
1	0	8		General Item	Node IDs
2	8	22		General Item	X-coordinate
3	22	34		General Item	Y-coordinate
4	34	46		General Item	Z-coordinate
5	46	55		General Item	Definition CS
6	55	63		General Item	Result CS
7	63	70		General Item	Normal in X
					Normal in Y

6. Column Mapping Table:

Column	From	To	Count	Variable	Position
1	0	8		Node Headers	
2	8	22		Node Coordinates	X
3	22	34		Node Coordinates	Y
4	34	46		Node Coordinates	Z
5	46	55		General Item	
6	55	63		General Item	

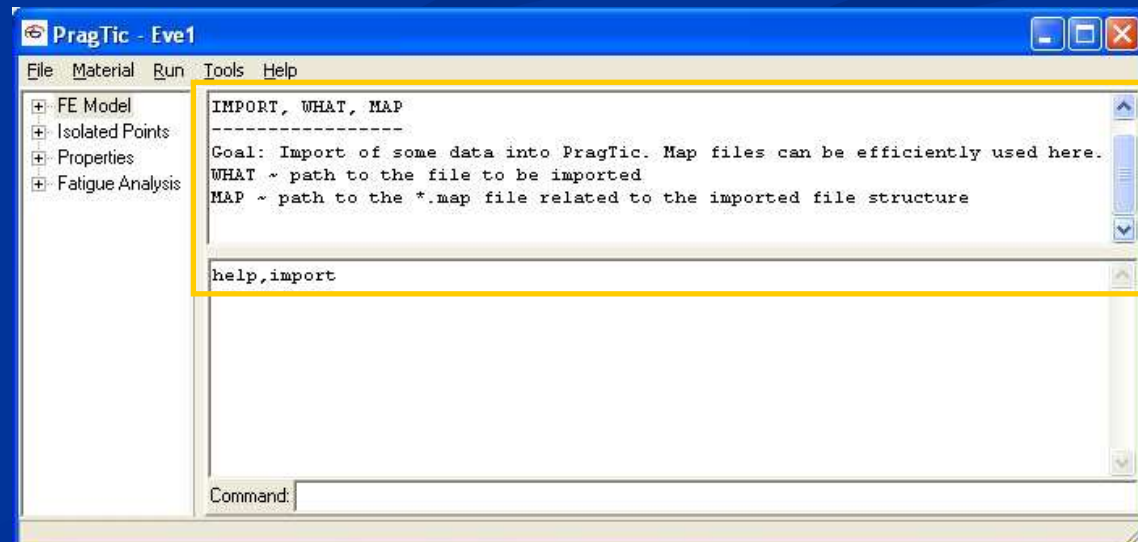
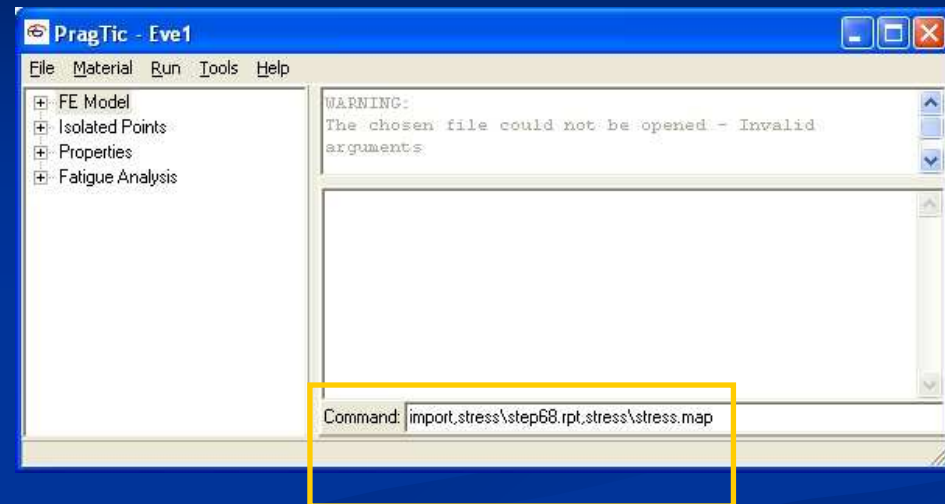
7. Run Scan and **8. Upload** buttons are visible in the bottom left.

See Help
for
PragTic

PragTic in Application IV

Import of Result Files – Command Line

- Input of further result files from the command line



PragTic in Application V

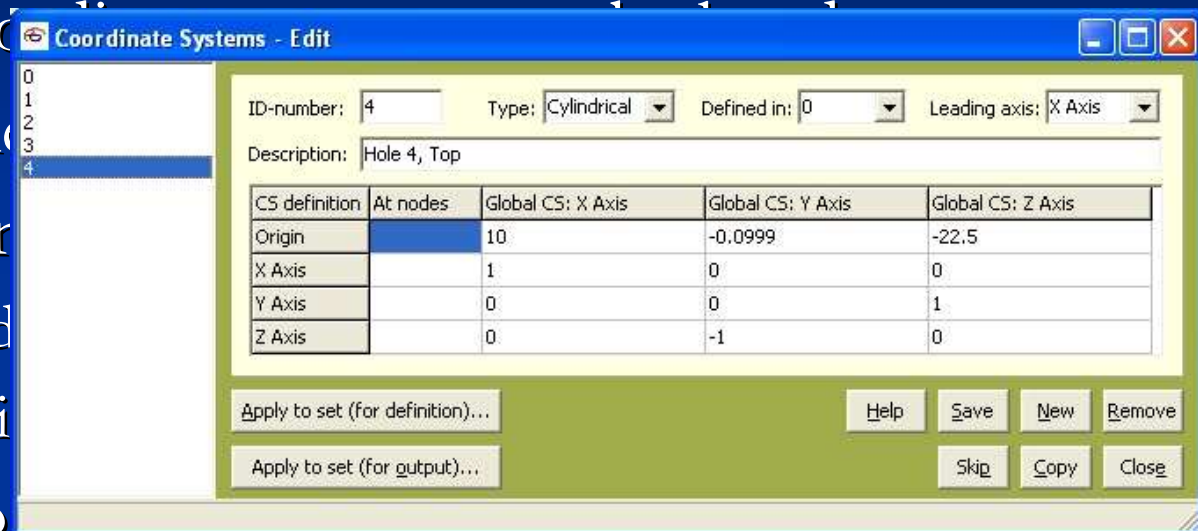
Decrease of the Task Size

- Only critical localities should be evaluated
- PragTic is not a commercial SW
- You are the one who has to optimize the computation time
 - Focus on surface nodes (N_NRM node set)
 - Check the nodes with highest loading (Tools->Results->Tensors – you can get Mises stress, principal stresses...)
 - Select nodes around expected notches (Filter tool)

PragTic in Application VI

Coordinate Systems

- Use of other coordinate systems
- Nodes, result files
- C.S. can be defined
 - cartesian, cylindrical
 - C.S. can be defined by
- Definition of coordinate system
 - two vectors and the origin have to be input
 - leading axis
 - the only vector, which represents the real axis of the new coordinate system
 - the other vector serves just for a definition of the plane to which the third axis is found as perpendicular



PragTic in Application VII

Filter Tool – Selection by Property

The screenshot displays two windows from the PragTic software. The 'View Nodes Item in CS: 1' window shows a table of node data:

Line	Node	CSDer	CSRes	X-COORDINATE	Y-COORDINATE	Z-COORDINATE
1	291662	0	0	2.01826	0	
2	291663	0	0	2.12911	0	
3	291664	0	0	2.23996	0	
4	291665	0	0	2.35081	0	
5	291666	0	0	2.1064	0	
6	291667	0	0	2.40909	0	
7	291668	0	0	2.221	0	

The 'Filter on NODES' dialog box is open, showing the following settings:

- Method: At column: X-COORDINATE
- Selection type: Maximum - minimum
- Maximum: 82.355934819538
- Minimum: 1.64999899369181
- Count: 34387
- Maximum: 3
- Minimum: 1.64999899369181
- Count: 2753

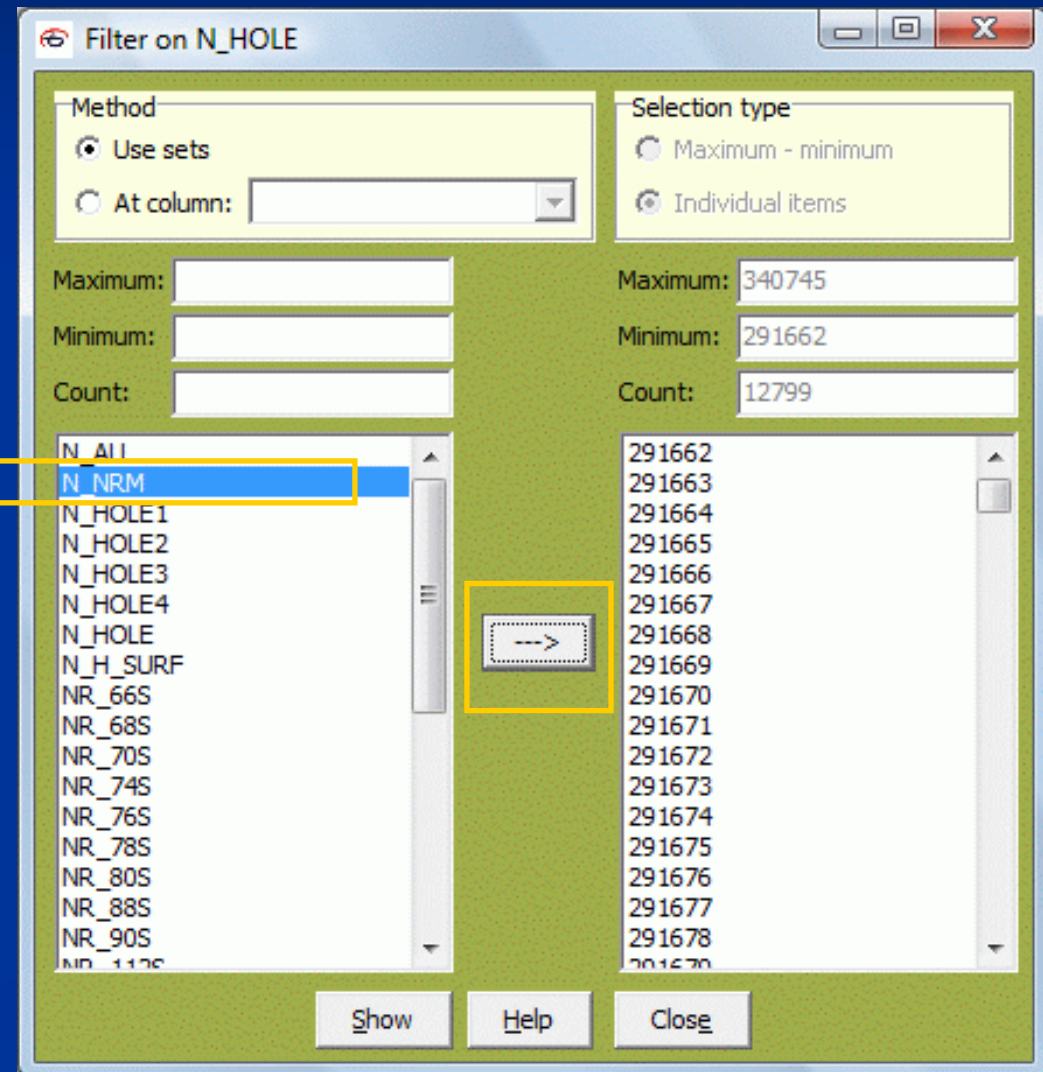
Buttons at the bottom of the dialog include 'Show', 'Help', and 'Close'. A yellow box highlights the 'Filter...' button in the table window, and an arrow points from it to the dialog box.

- The nodes with maximum distance 3 mm from the hole No.1 center will be selected

PragTic in Application VIII

Filter Tool – Selection by Set

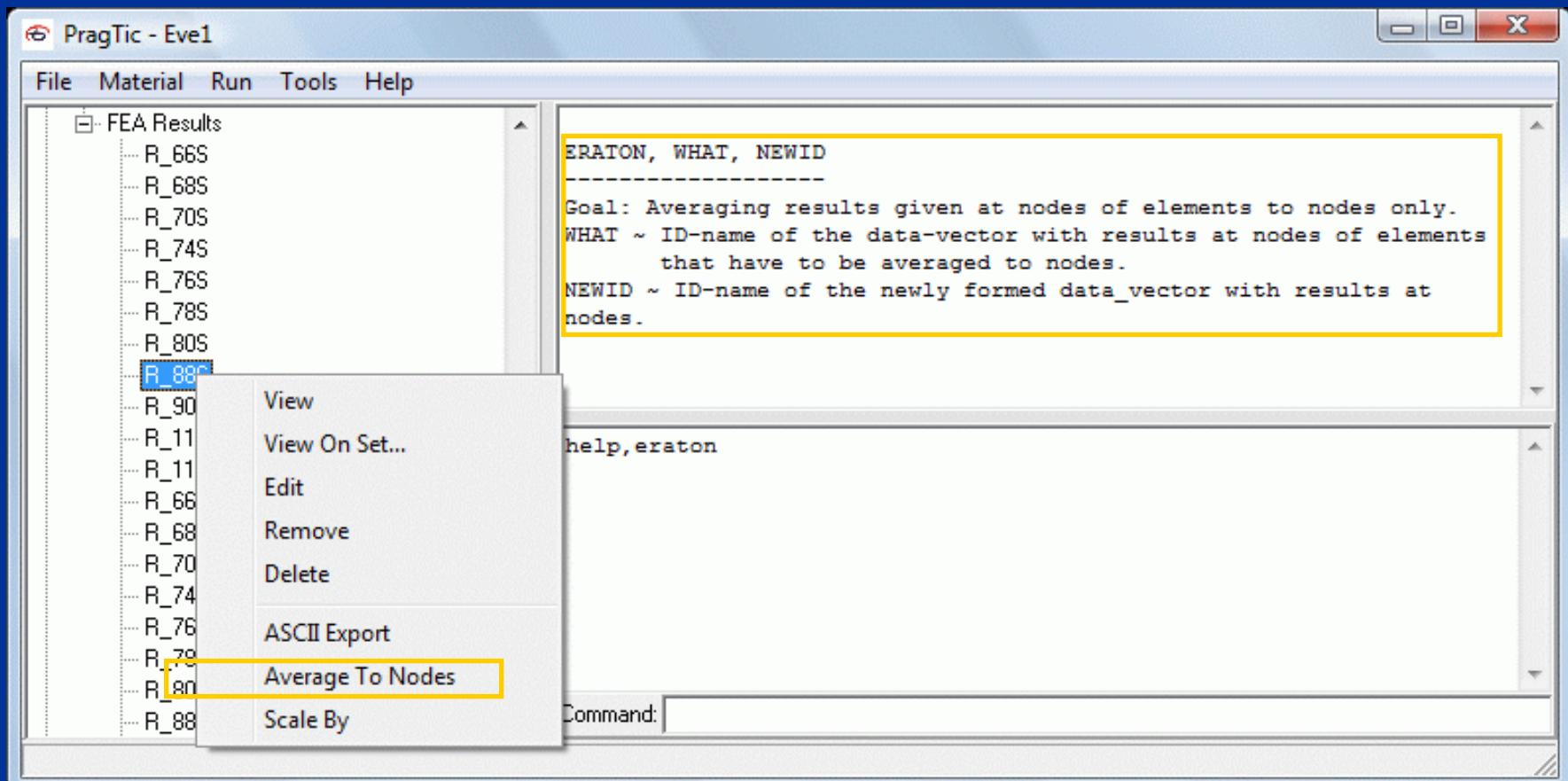
- Nodes from the area of interest (N_HOLE), but lying on the surface of components only (N_NRM set), will be selected



PragTic in Application IX

Results – Averaging to Nodes (ERATON)

- Results read into PragTic as printed out at nodes of elements, have to be averaged to nodes
- Decrease of the task size



PragTic in Application X

Results – Superposition

Increment No.	FEA force [N]	total force [N]	nominal stress [MPa]
60	2 652	-5 305	-23,1
62	971	-1 942	-8,4
64	-2 974	5 948	25,9
66	-6 815	13 629	59,3
68	-10 113	20 227	87,9
70	-12 969	25 939	112,8
72	-15 306	30 611	133,1
74	-17 067	34 135	148,4
76	-18 271	36 542	158,9
78	-18 987	37 973	165,1
80	-19 564	39 128	170,1
82	-20 043	40 085	174,3
84	-20 405	40 810	177,4
86	-20 519	41 037	178,4
88	-20 822	41 644	181,1
90	-21 115	42 230	183,6
92	-21 369	42 738	185,8
94	-21 556	43 113	187,4
96	-21 666	43 332	188,4
98	-21 819	43 638	189,7
100	-21 984	43 968	191,2

σ_x - Nominal stress in experiments [N]	σ_1 [MPa]	σ_2 [MPa]	coeff. a	coeff. b
0	-8,4	25,9	0,7539	0,2461
80	59,3	87,9	0,2769	0,7231
100	87,9	112,8	0,5145	0,4855
140	133,1	148,4	0,5491	0,4509
190	189,7	191,2	0,8131	0,1869

$$F_x = a \cdot F_1 + b \cdot F_2$$

$$\Sigma_x = a \cdot \Sigma_1 + b \cdot \Sigma_2$$

- Tools->Arrays->Superpose
 - two data_vectors of similar length but different weight coefficient, can be superposed
- Another adept for command line

PragTic in Application XI

Load Regime Definition

- Load Regime is a compound of

- FEA result files
- coefficients to get them to adequate load level
- load histories

Elastic solution

- FEA result files at different load level

Elastic-plastic solution

- The local load history can be defined on basis of

- mathematical formula
- load sequence

Elastic solution

- result file sequence
- transient local load history

Elastic-plastic solution

PragTic in Application XIbis

Load Regime Definition – Transient Load History

- Its preparation is a necessary condition to run the analysis
- LR definition as a result file sequence cannot be used in fatigue analysis yet

Load Regimes

LR1
LR2
LR3
LR4

ID-name: LR1

Description:

Load Regime Type

Load by Math Formula Load Spectrum

Load from File Stress-Strain History Result File

Loads Set Interactively Sequence of Result Files

	Stress File	Strain File
1	R4LS	R4LE
2	R4JS	R4JE
3	R4LS	R4LE
4		

Select Time Scale:

Help Save New Remove

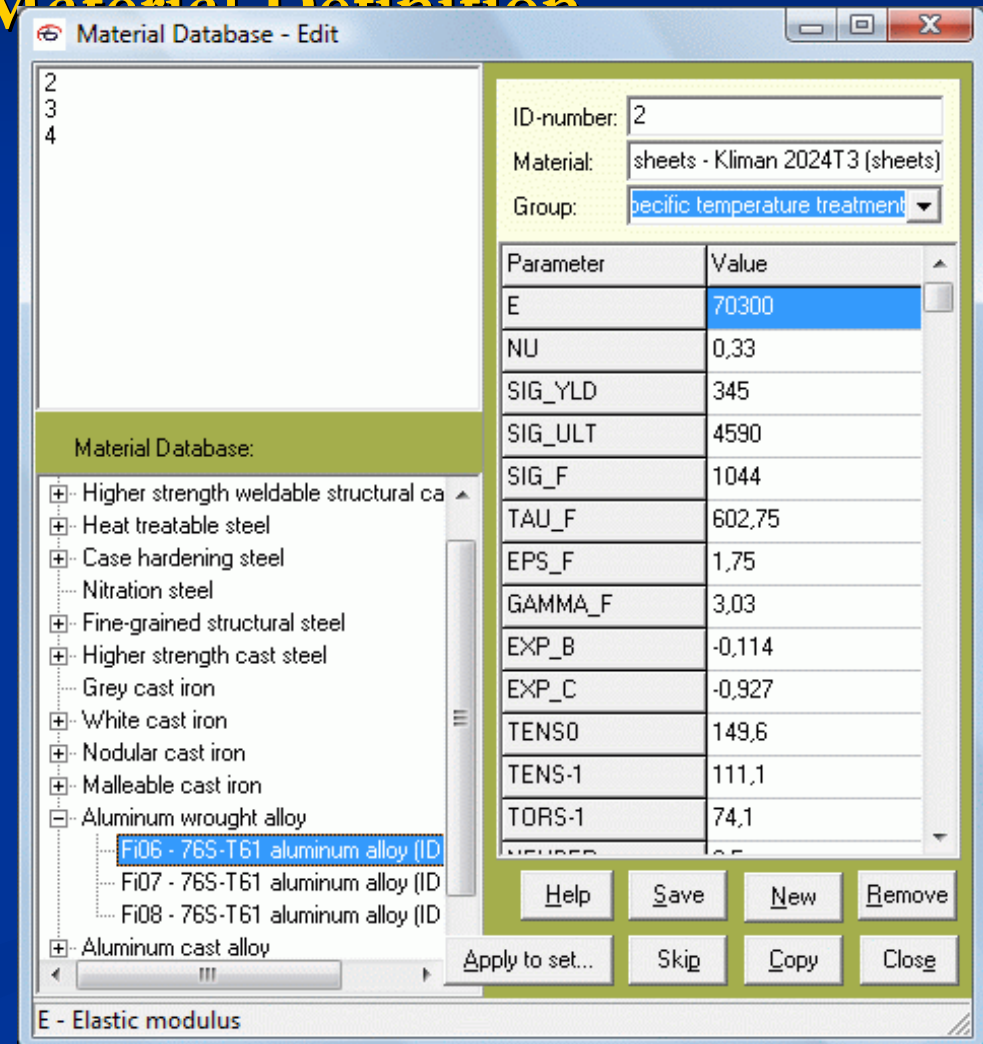
Compose Local Load Histories Skip Copy Close

PragTic in Application

XII

Material Definition

1. Import from an older analysis
2. Direct creation
3. Using data from the material database



PragTic in Application XIII

Calculation Methods Selection and Setup

- Default values proposed
- Check existence of all necessary material data

Methods & Options & Variables of Calculation - Edit

CROSS
SWT
WB2
EICHLSEDER
EICHLSEDERB

ID-number: WB2

Description: multiaxial low-cycle solution with specific load history decomposition

Method: WB 1996

Decomposition: Wang-Brown '96

Elasto-plasticity: No

Mean stress influence: No

Influence of stress gradient: No

Influence of technology: No

Influence of surface quality: No

Influence of size: No

Influence of temperature: No

Set another survive probability: No

Material: 1 - AISI9 F aluminum

Material parameters	Value
E	74000
NU	0,3
SIG_F	361,376
EPS_F	1,2
EXP_B	-0,055
EXP_C	-0,5
S_WB	0,619
NU_EFF	0,45
KD_DEFF_S	0,9162

Solution option	Parameter
CP criterion <0~MD, 1~M5SR>	0
Searched planes <0~BS algorithm, 1~globe analogy, 2~random>	1
Number of scanned planes	45
Number of scanned directions on each plane	100
Optimize <1~yes, 0~no>	1
Mean stress effect <0~not included, 1~included>	1
Only every x-th data-point taken from load history	1

Solution variable	Value
Minimum damage	1E-20

Help Save New Remove

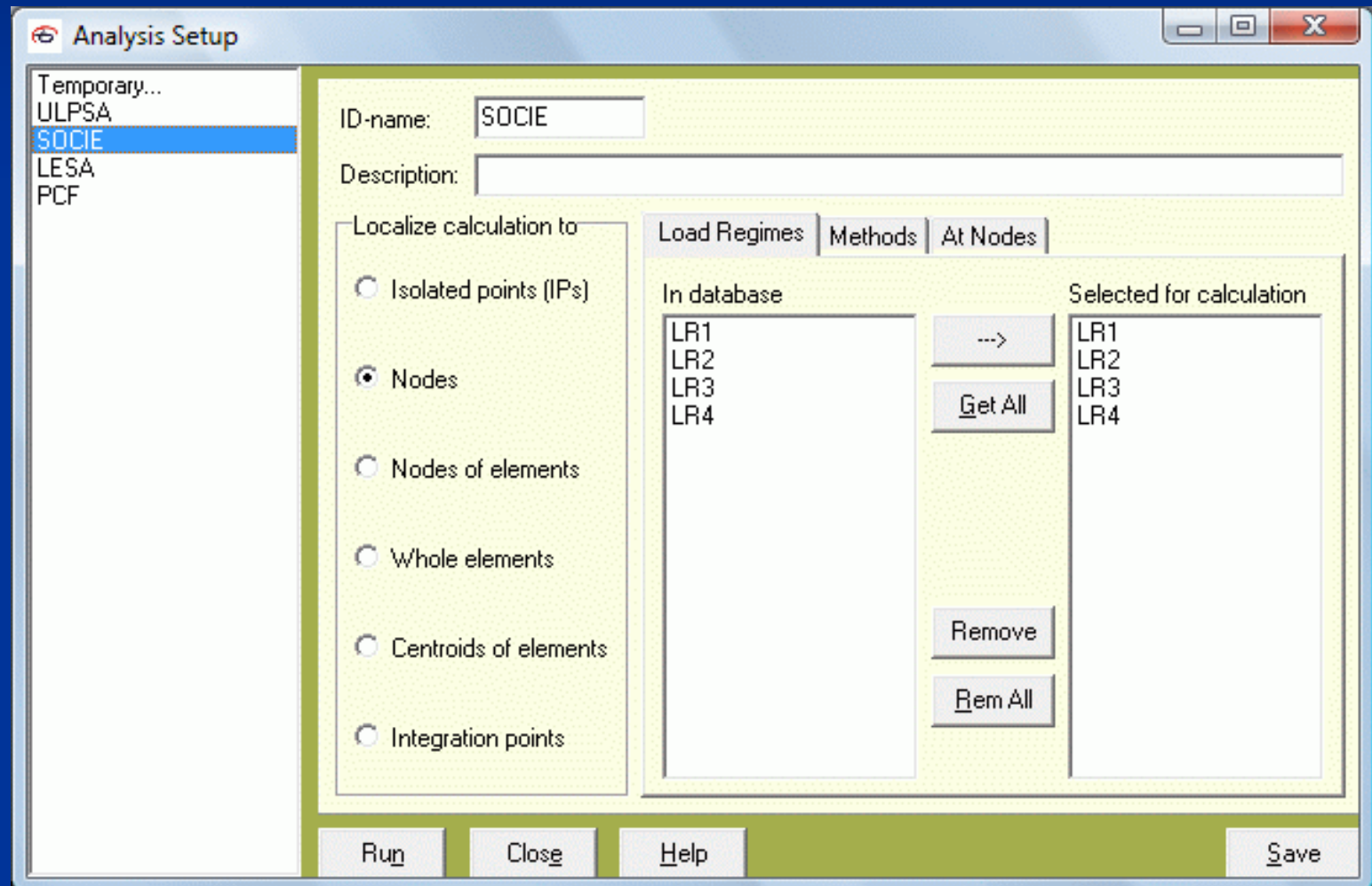
Skip Copy Close

SIG_F - Fatigue strength coefficient

PragTic in Application XIV

Calculation Run (Analysis Setup)

- The Analysis Setup can be saved

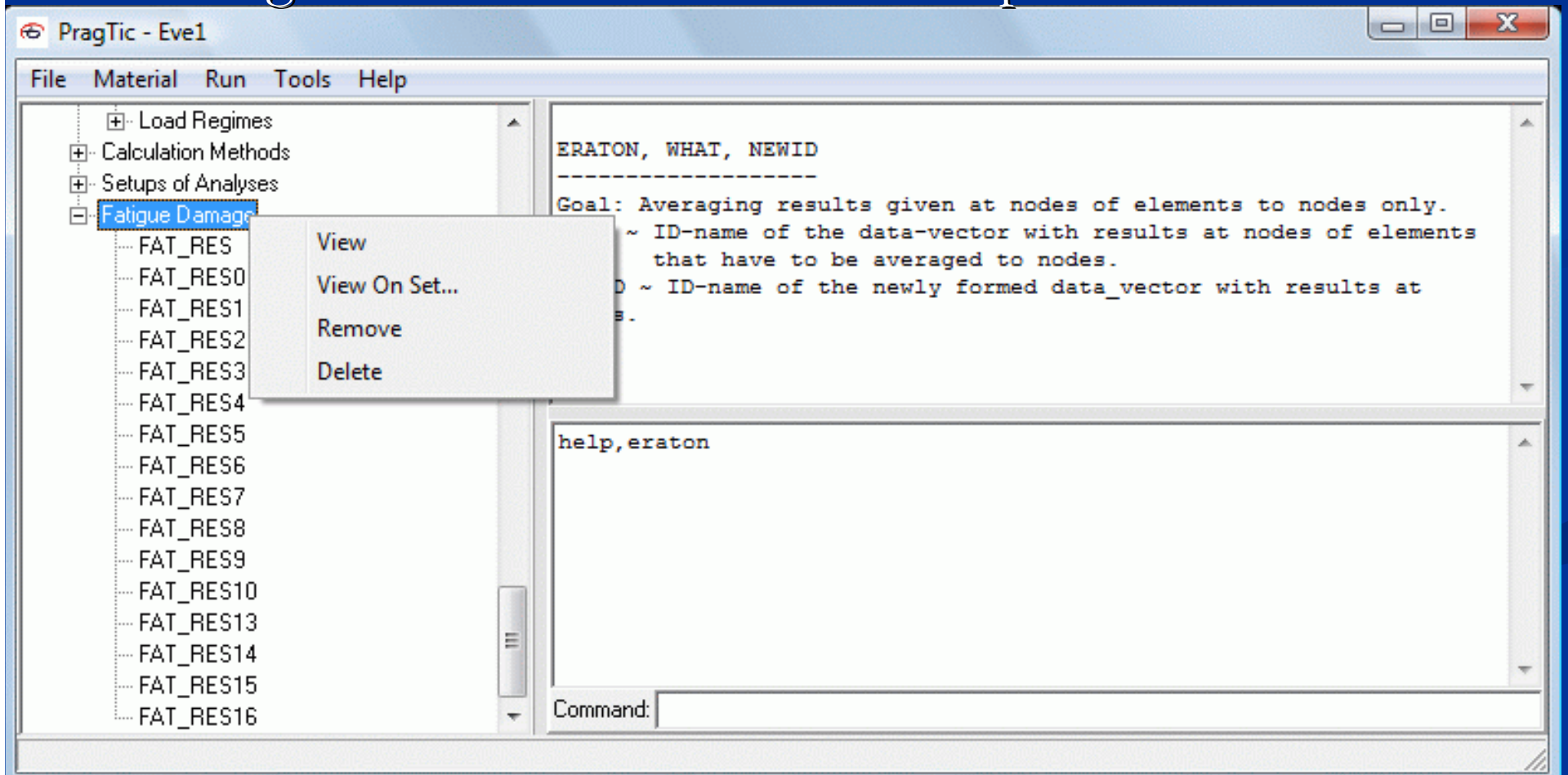


PragTic in Application

XV

Fatigue Results Viewing

- All fatigue results can be viewed or exported

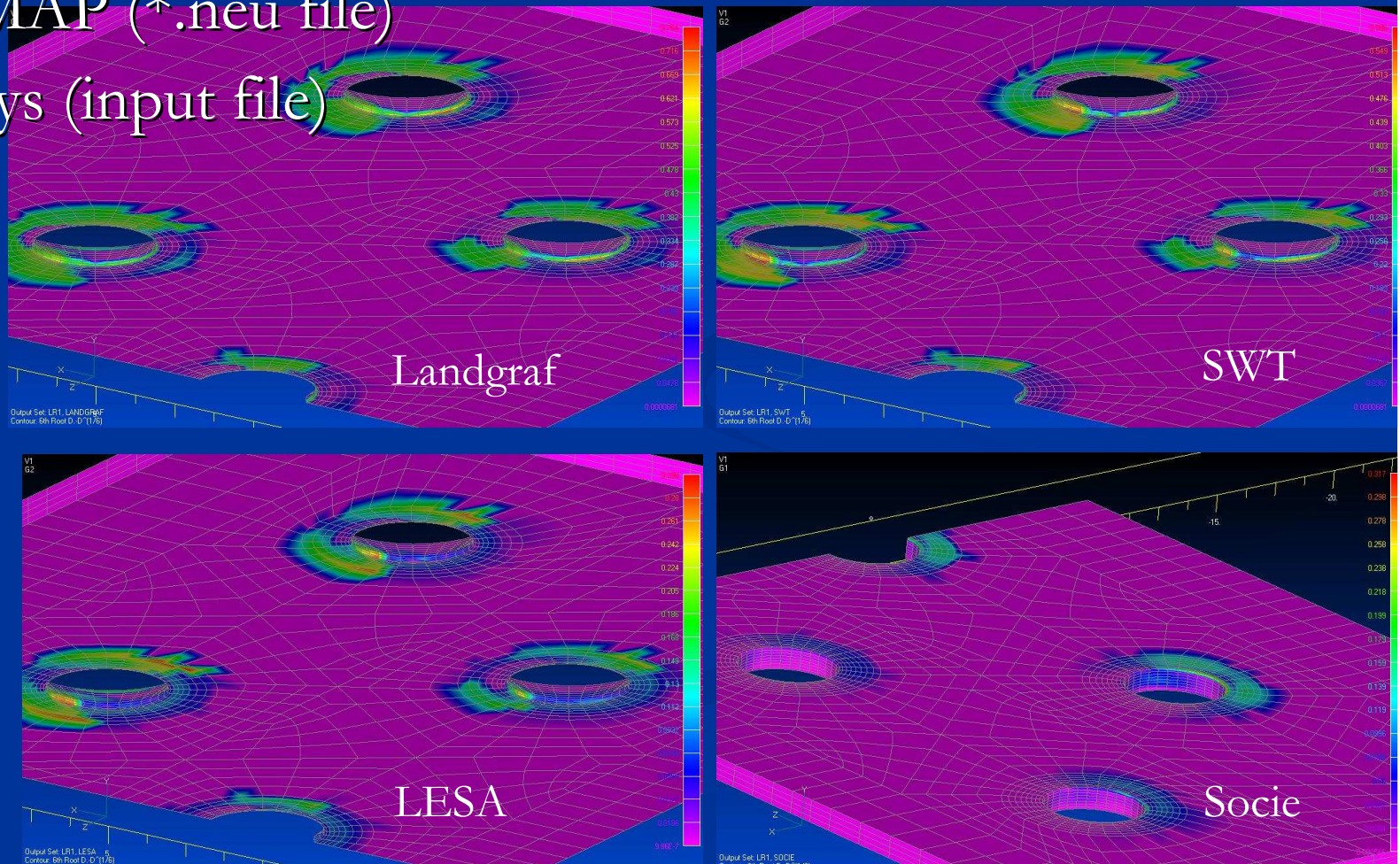


PragTic in Application

XVI

- Two options currently **Fatigue Results Export**
 - FEMAP (*.neu file)
 - Ansys (input file)

EVE1
LR1
(maximum
load)



Pragmatic in Application

XVIbis

Fatigue Results

