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PragTic in Application

Fatigue in Riveted Joints

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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

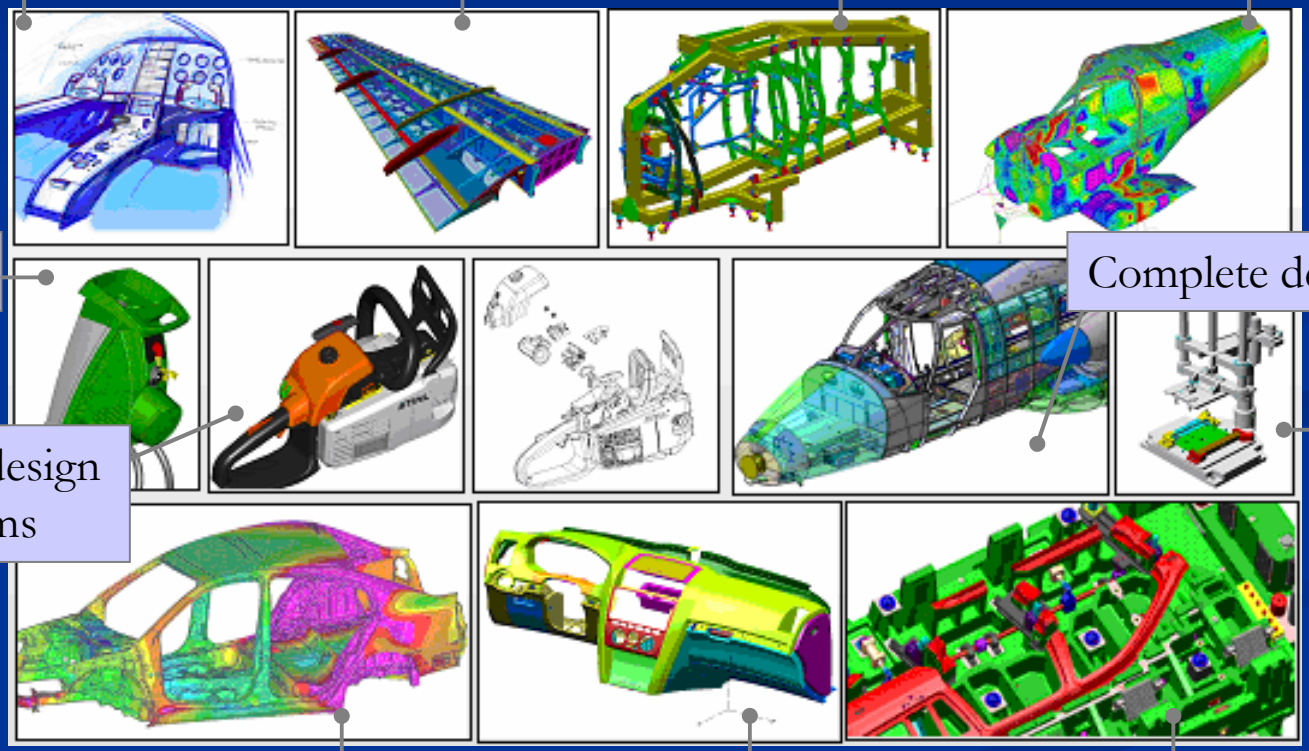
Scope of Projects

Design studio

Design of components

Design of jigs, fixtures

Stress analysis



Plastic parts

Complete development

Preliminary design of mechanisms

Prototype tooling

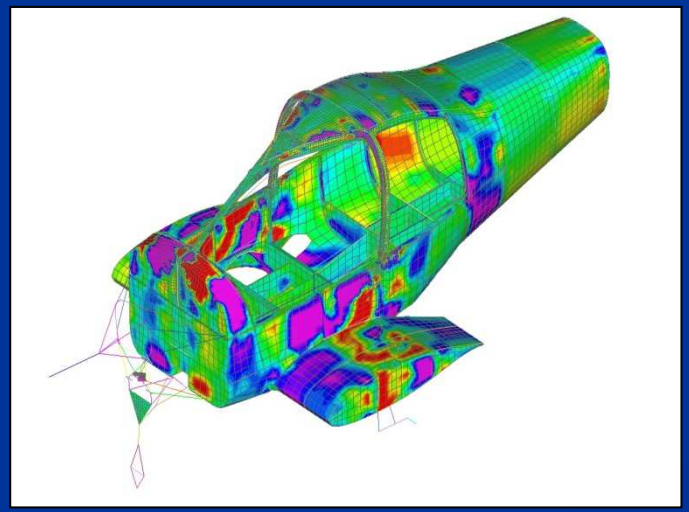
FE-analysis including crashes

Interiors design

Stamping tools

Aircraft structures

VUT 100



EV-55

IMPERJA Project

- **Imp**roving the Fatigue Performance of **R**iveted **J**oints in **A**irframes
- 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

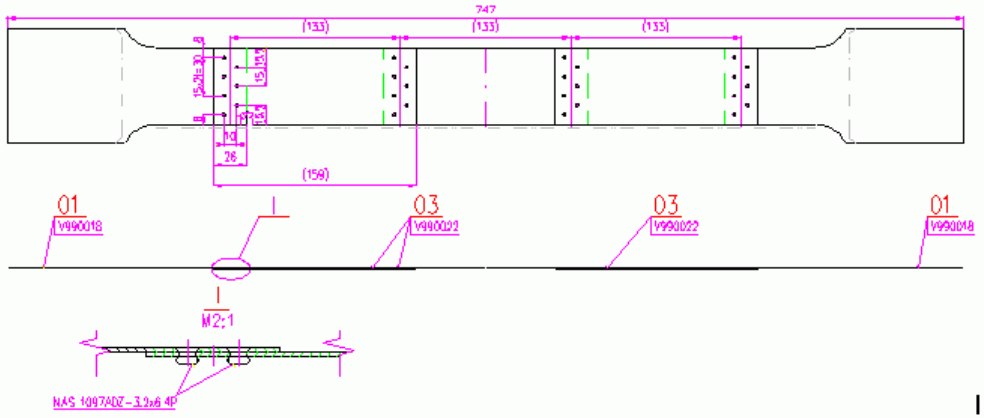
- EVE1
  - R=0.1
  - 4 results at four load levels

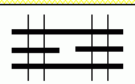
EVE1	σ_u [MPa]	N [-]
LR1	160.7	3 631
LR2	108.475	16 093
LR3	64.675	134 453
LR4	37.575	733 014

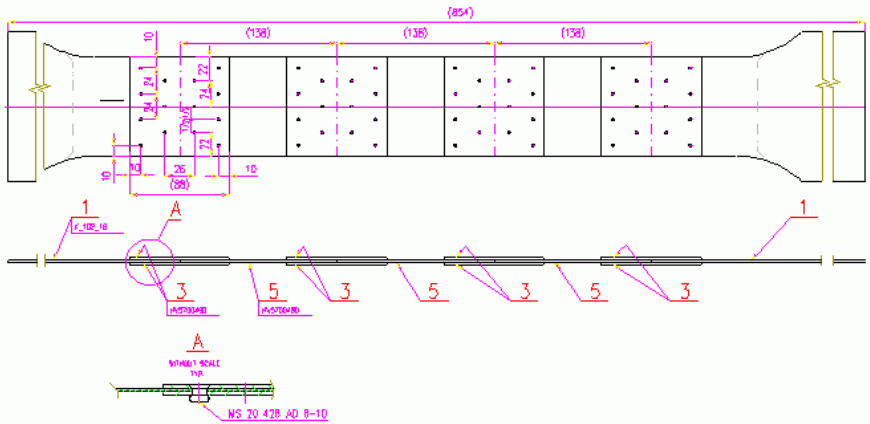
- EVE2
  - R=0
  - 4 results at four load levels

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

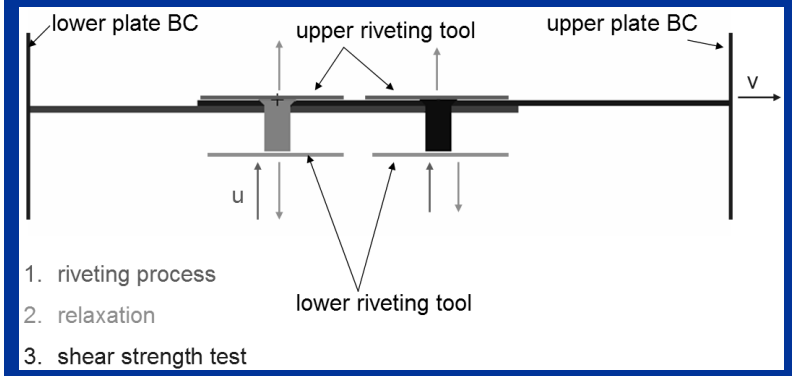


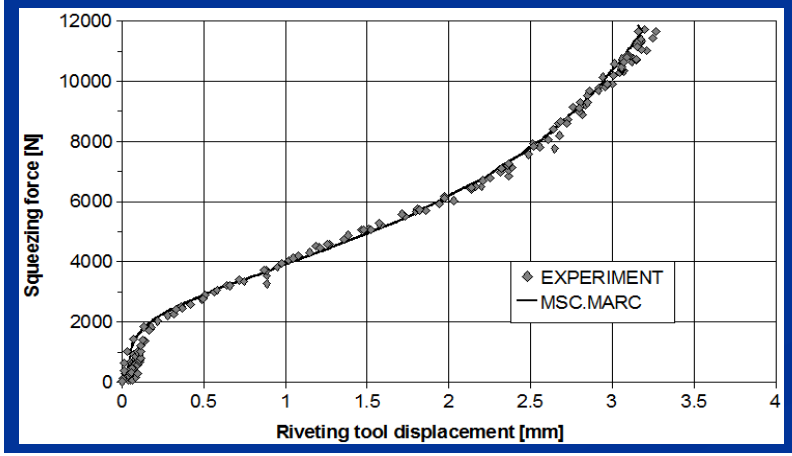
Name of specimen	Type of riveted joint	Joint figure	Glue	Rivet holes	Sheet		
					Material	Thermal processing	Thickness
MMDHS 4,8U (for IMPERJA EVE2,č.v. K-102-17)	Riveted joint with underlay, double shear – solid countersunk rivet MS20426 AD Ø4.8		Putty: TM1 in according with AEN 5471 (PR1770C12)	Reamed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

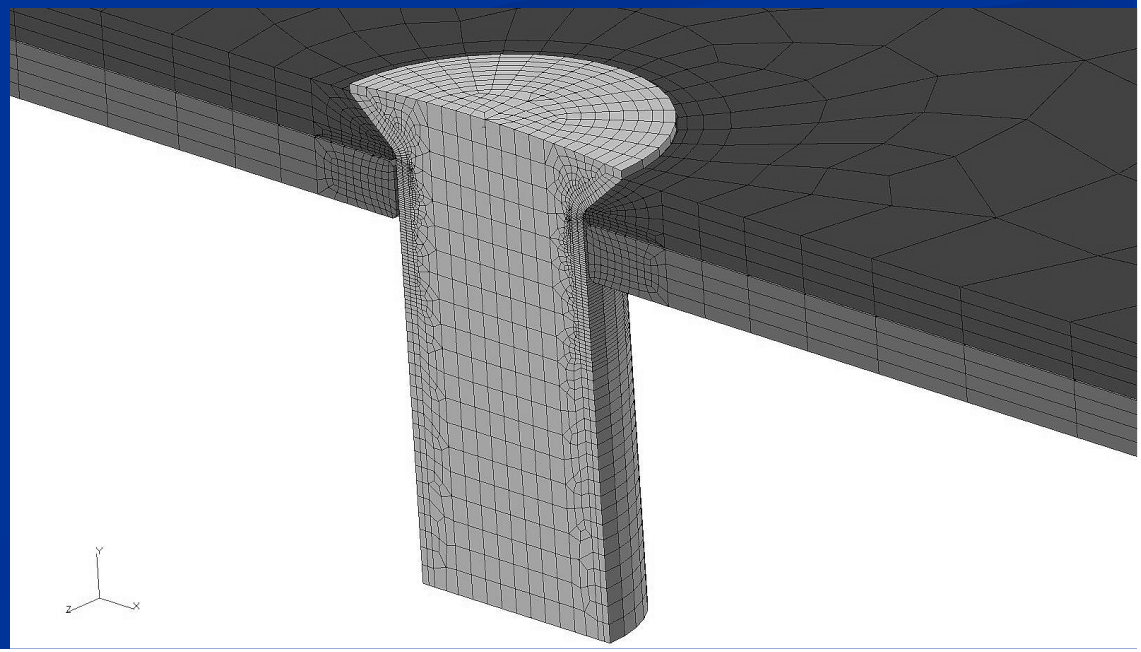


FEA Analyses

- 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

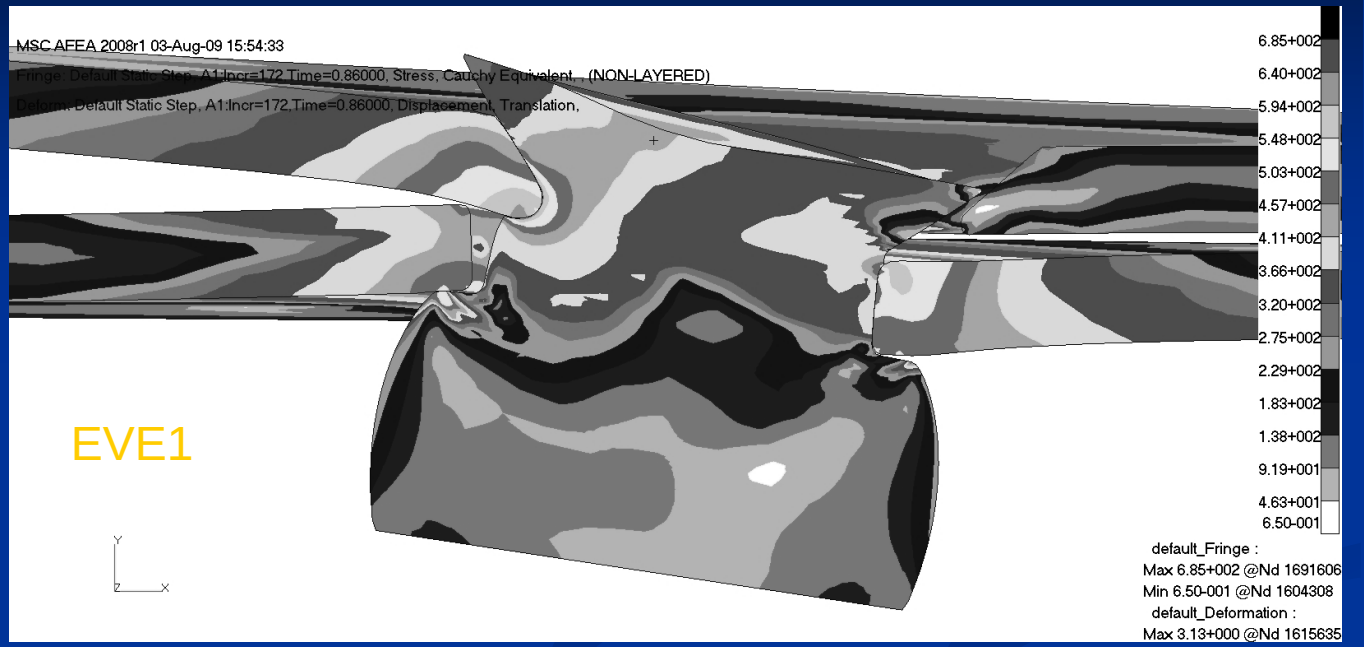


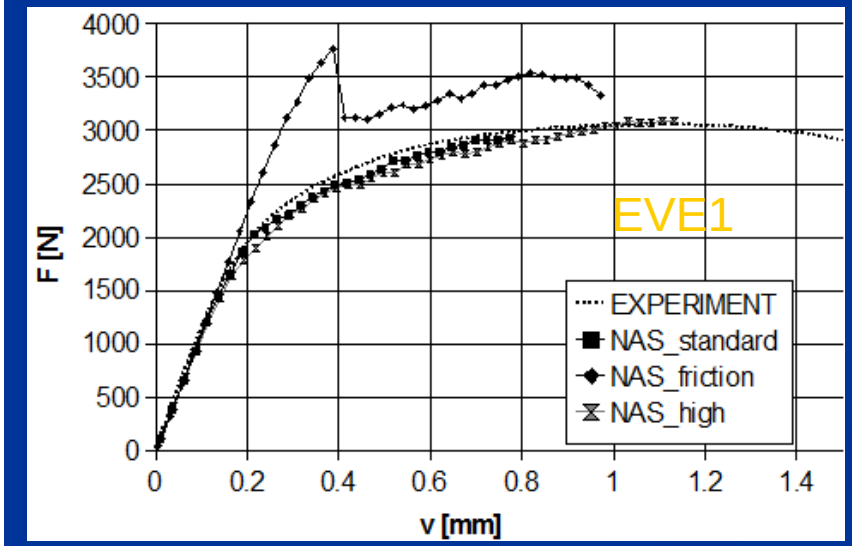


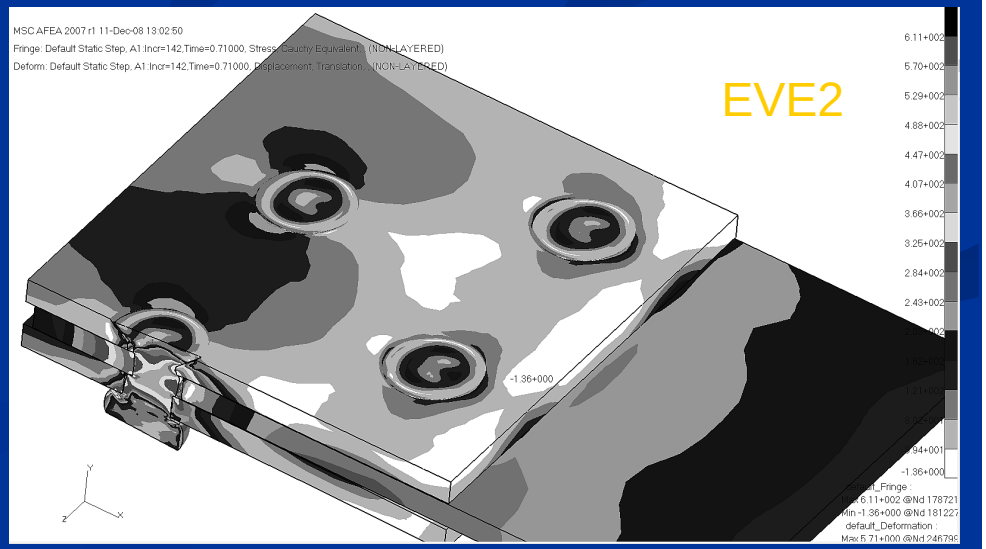


FEA Analyses II

- 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

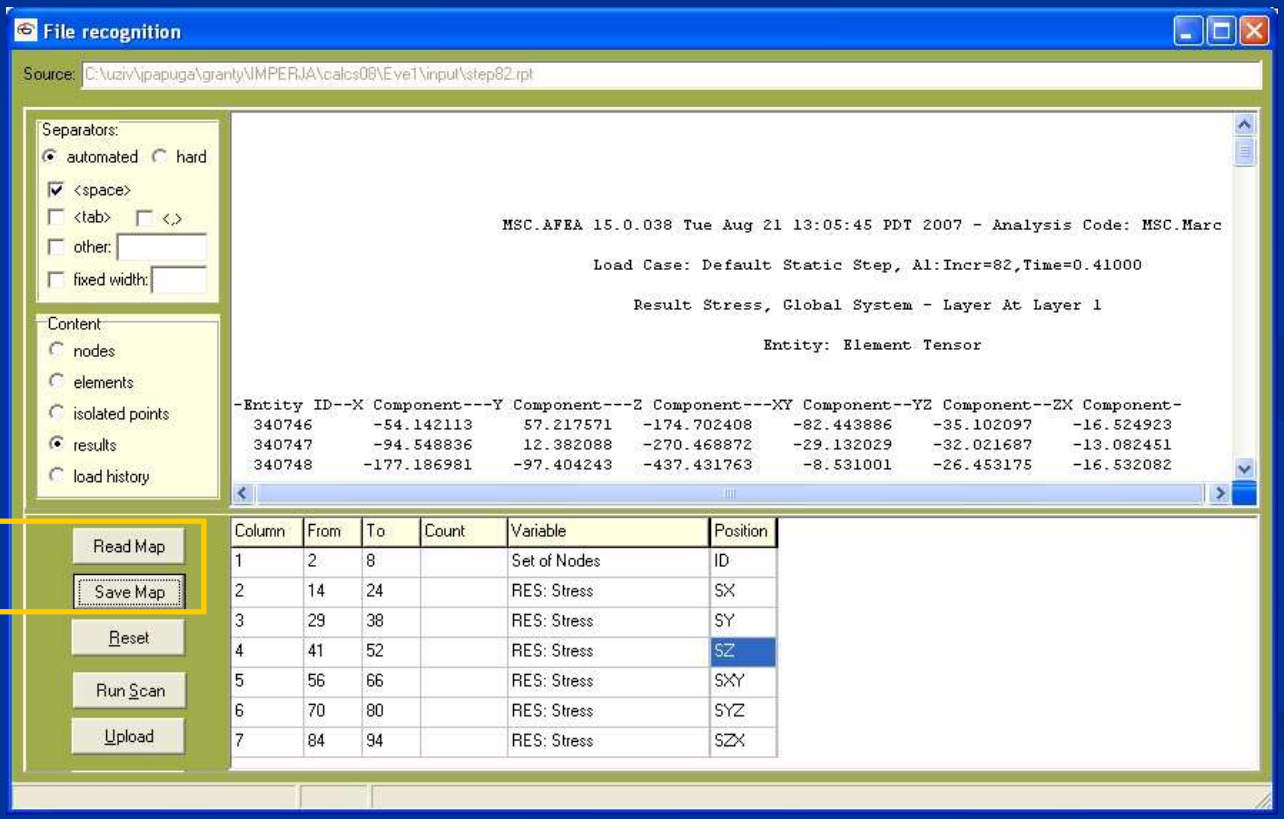
- Import of *.nas file

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

PragTic in Application III

Import of Result Files – Make Map

- Preparation of map file for FEA results import

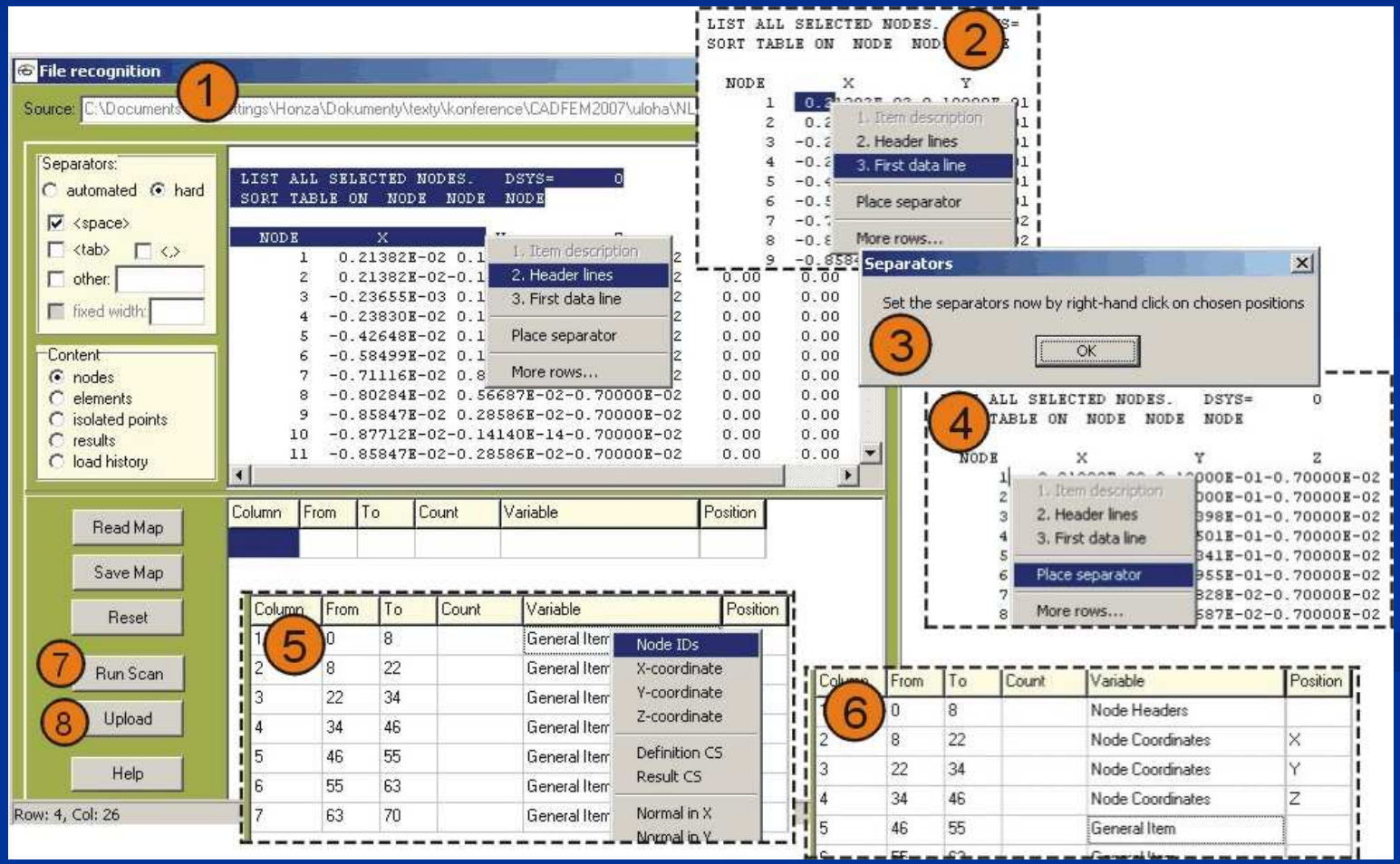


Here

PragTic in Application IIIbis

- General input of FE-data in formatted records

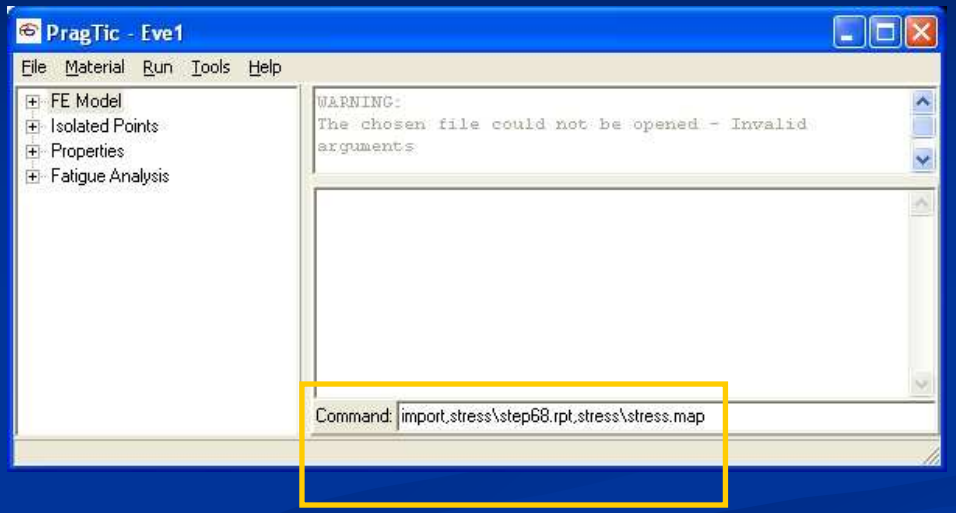
See Help for PragTic

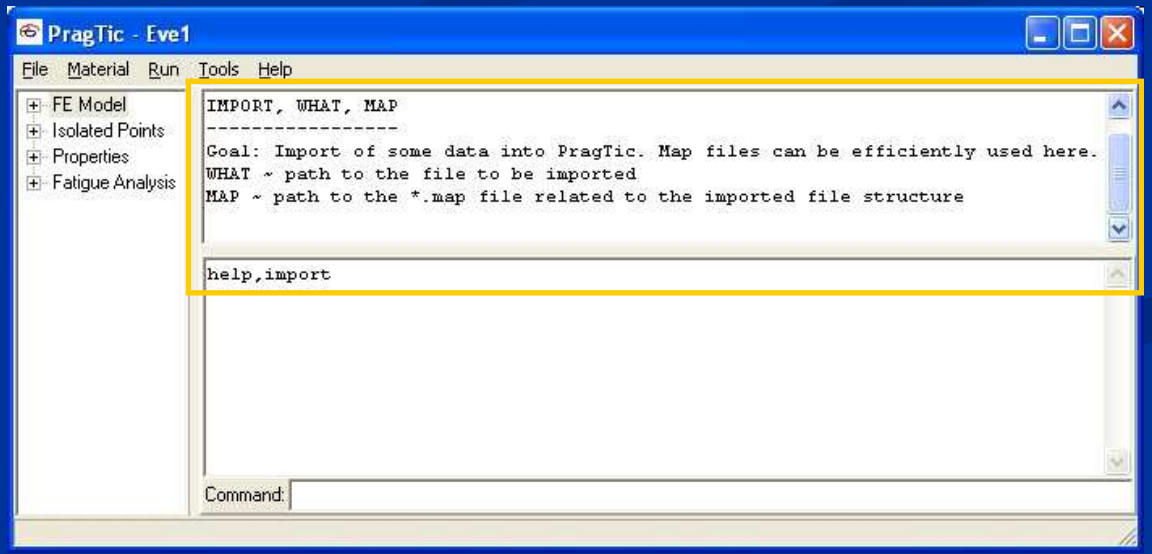


PragTic in Application IV

Import of Result Files – Command Line

- Input of further result files from the **command line**





PragTic in Application V

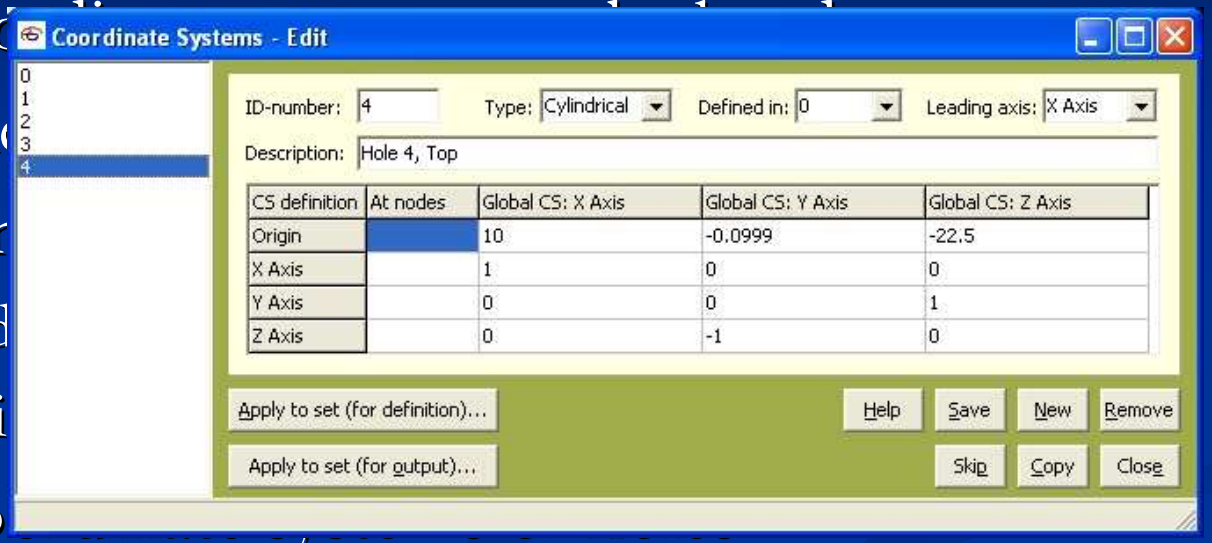
Decrease of the Task Size

- 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

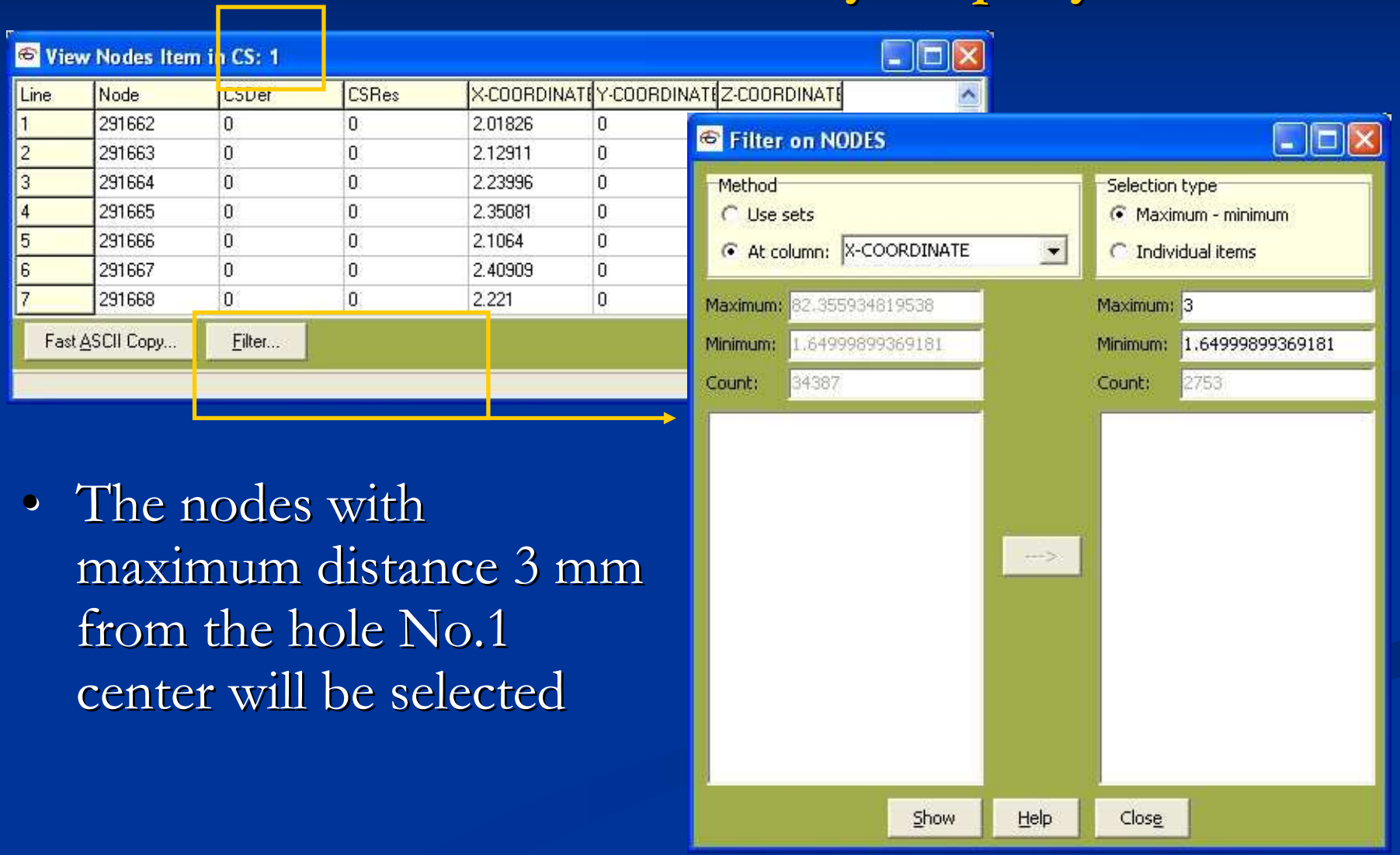
Coordinate Systems

- Use of other coo
- Nodes, result file
- C.S. can be defir
  - cartesian, cylind
  - C.S. can be defi
- Definition of co
  - 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

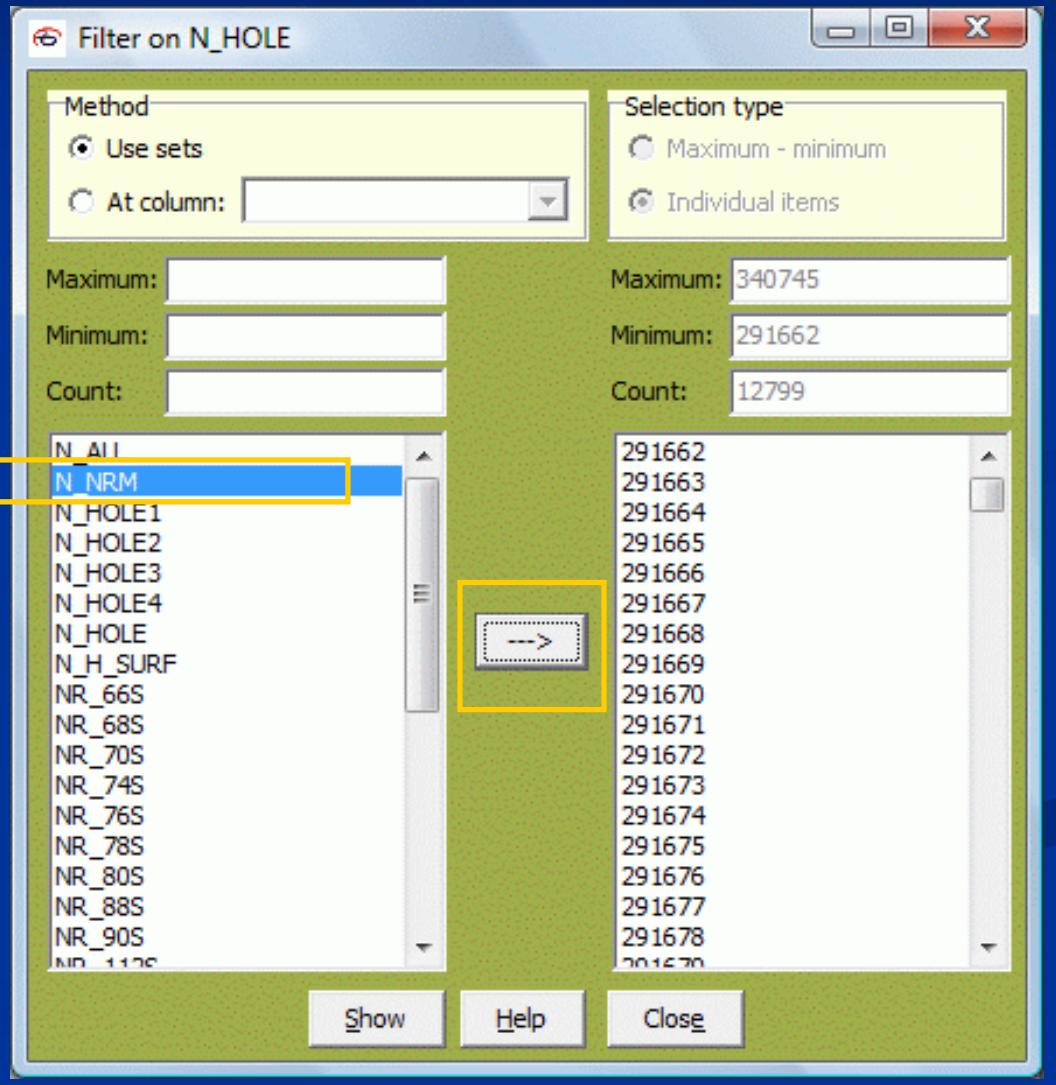


- The nodes with maximum distance 3 mm from the hole No.1 center will be selected

PragTic in Application VIII

Filter Tool – Selection by Set

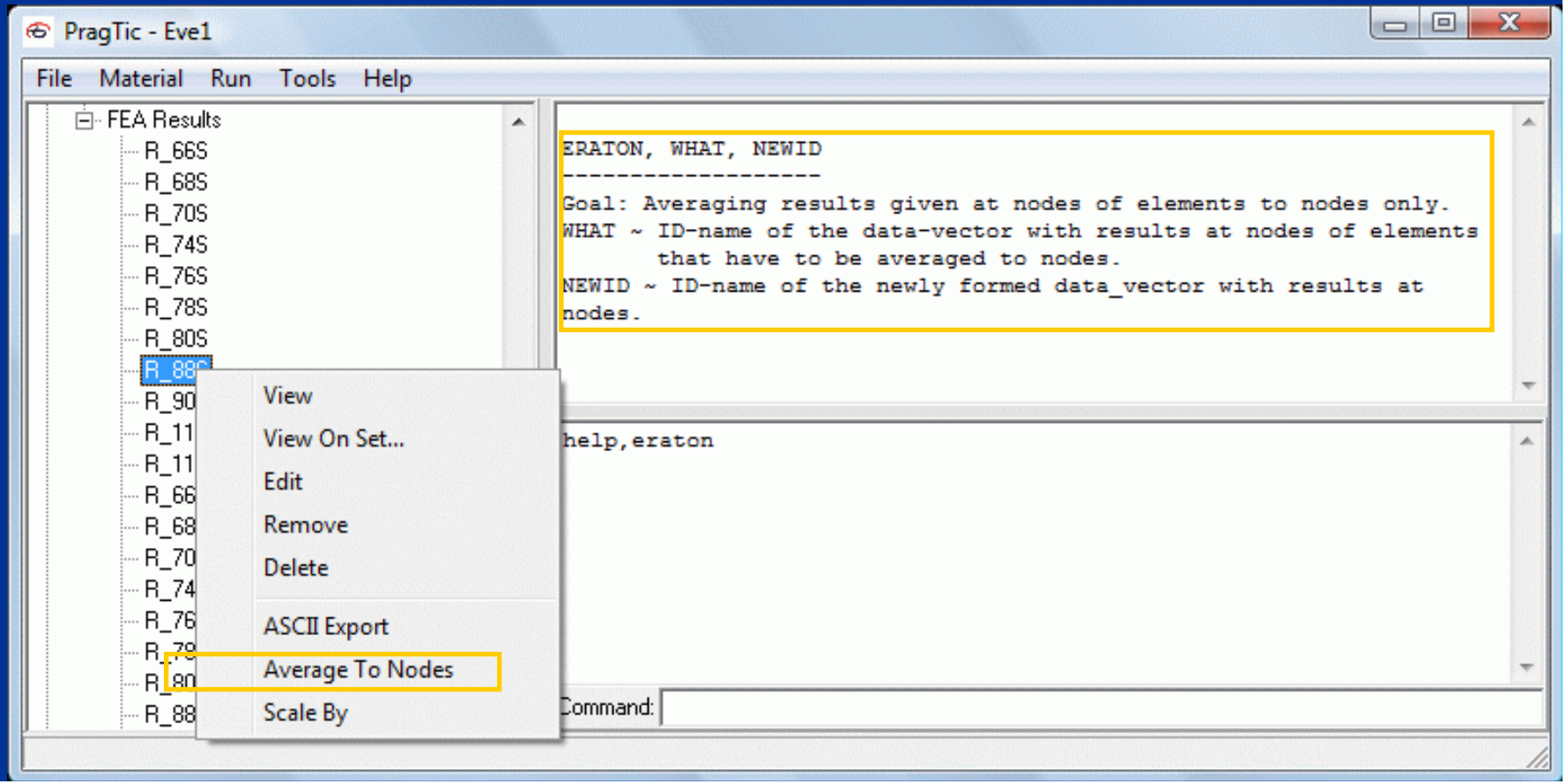
- Nodes from the area of interest (N_HOLE), but lying on the surface of components only (N_NRM set), will be selected



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

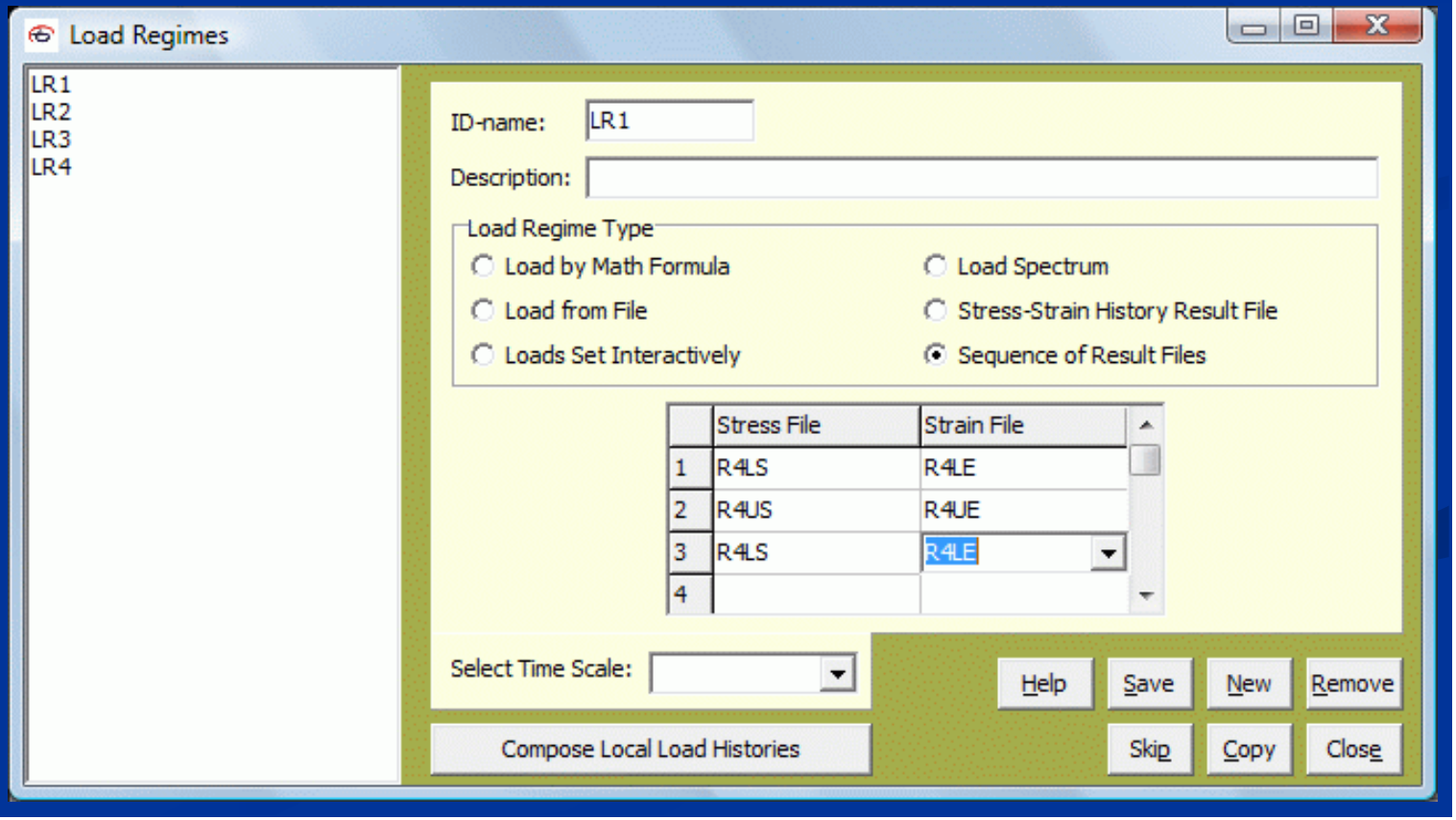
- result file sequence
- transient local load history

Elastic-plastic solution

PragTic in Application XIbis

Load Regime Definition – Transient Load History

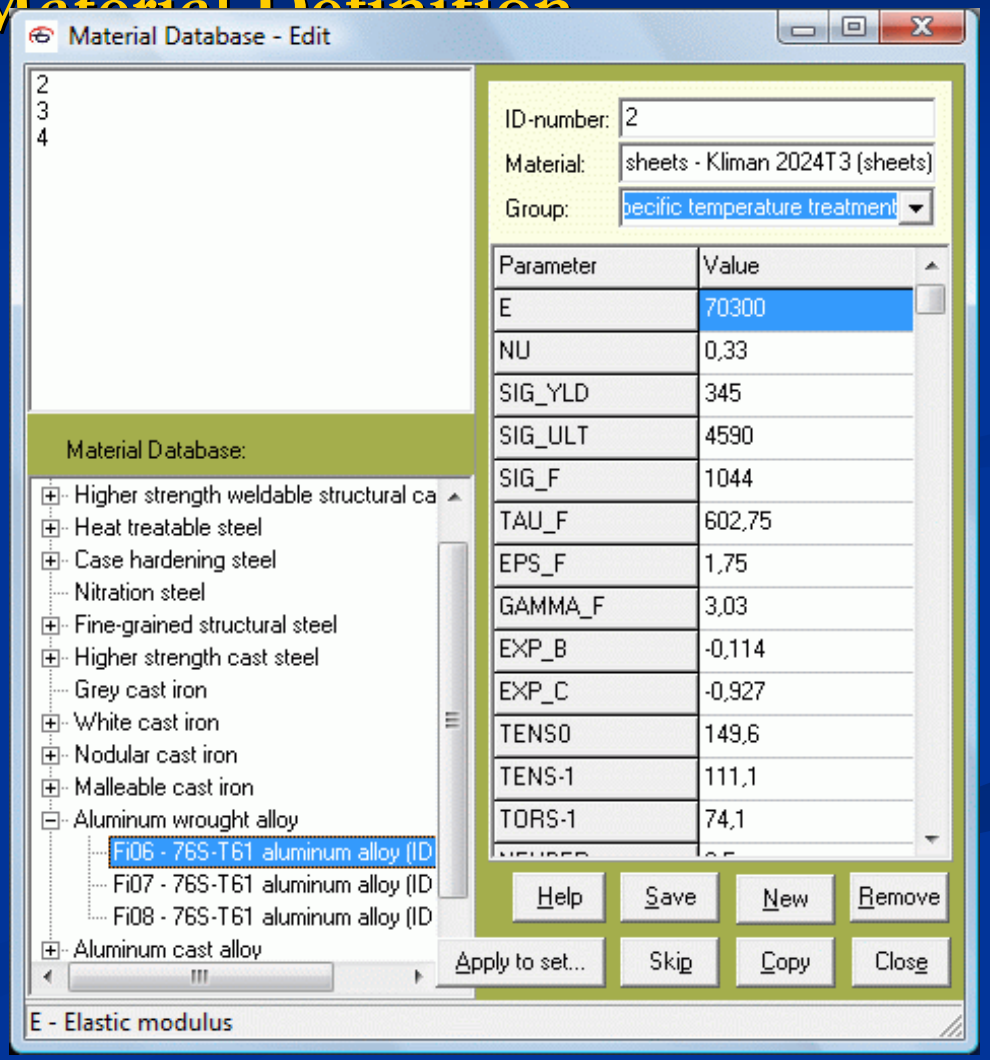
- Its preparation is a necessary condition to run the analysis
- LR definition as a result file sequence cannot be used in fatigue analysis yet



PragTic in Application XII

Material Definition

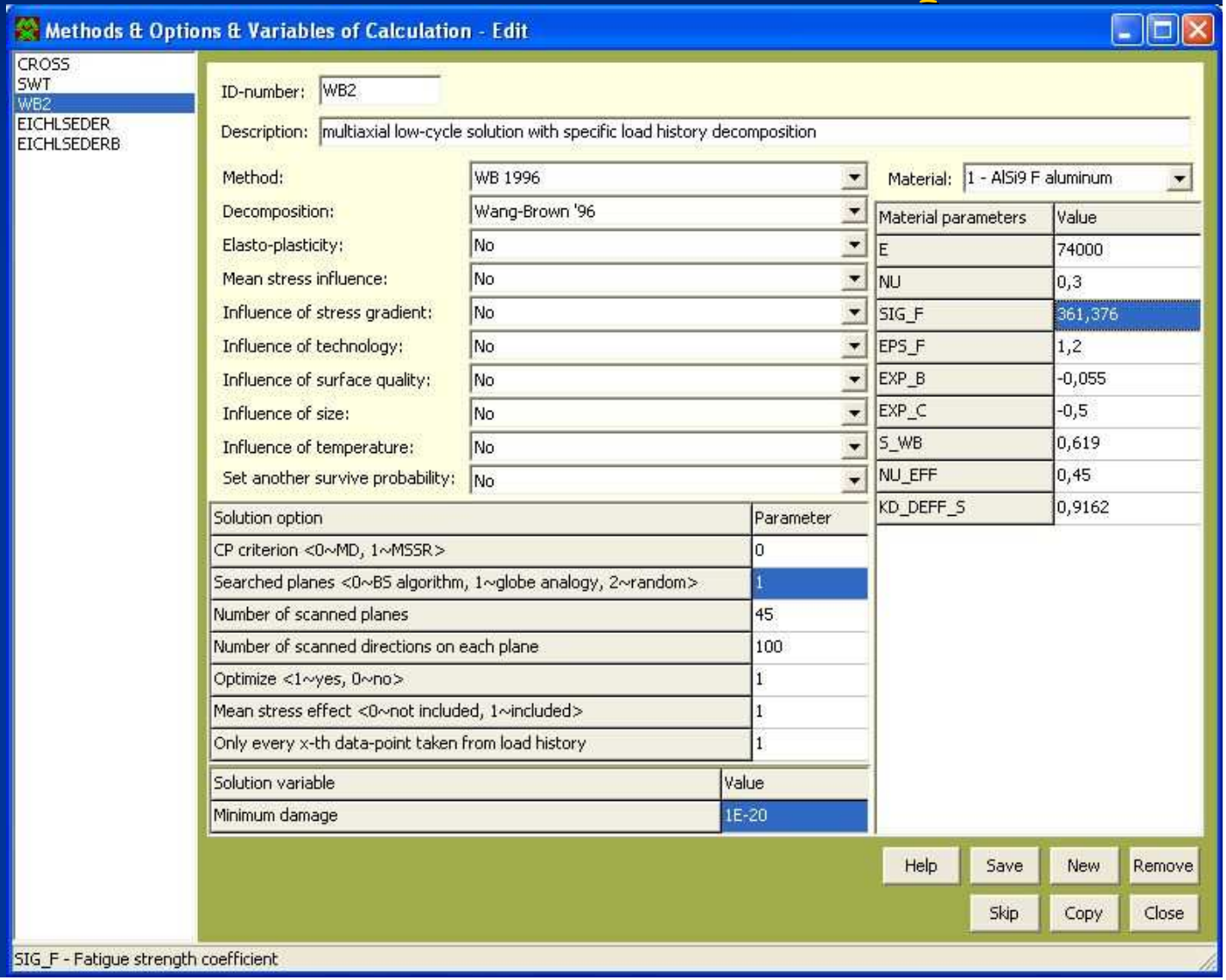
1. Import from an older analysis
2. Direct creation
3. Using data from the material database



PragTic in Application XIII

Calculation Methods Selection and Setup

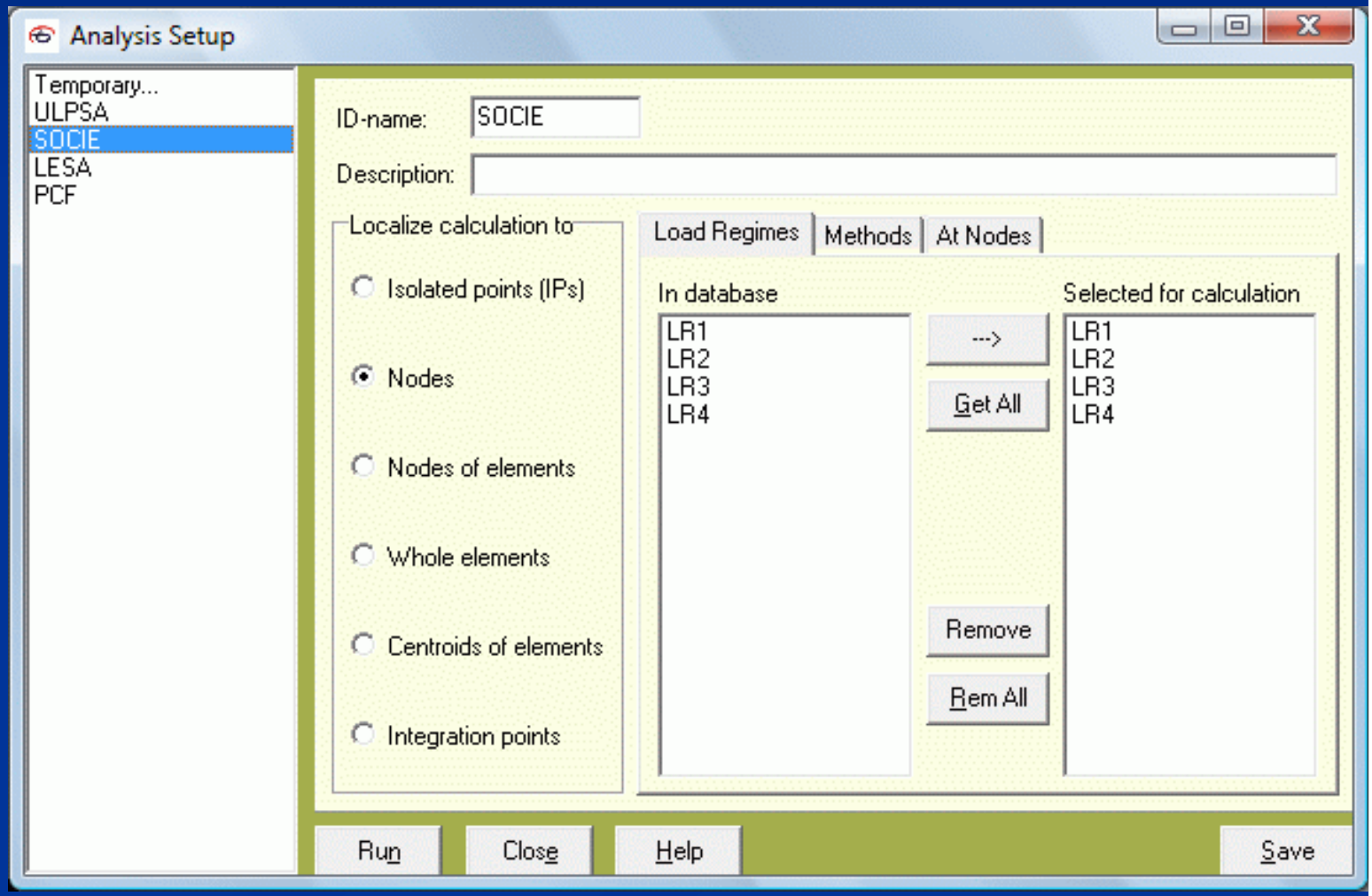
- Default values proposed
- Check existence of all necessary material data



PragTic in Application XIV

Calculation Run (Analysis Setup)

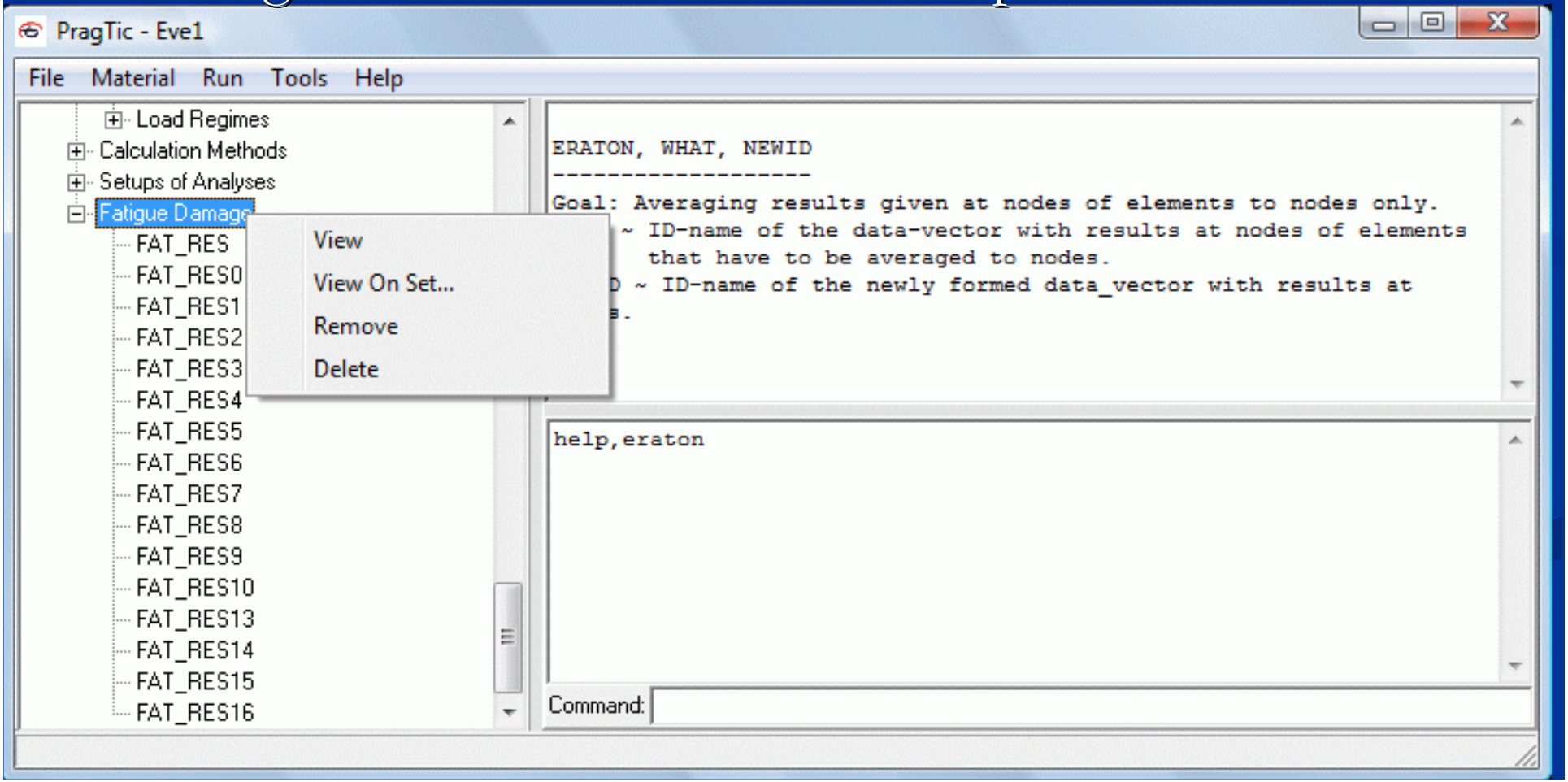
- The Analysis Setup can be saved



PragTic in Application XV

Fatigue Results Viewing

- All fatigue results can be viewed or exported

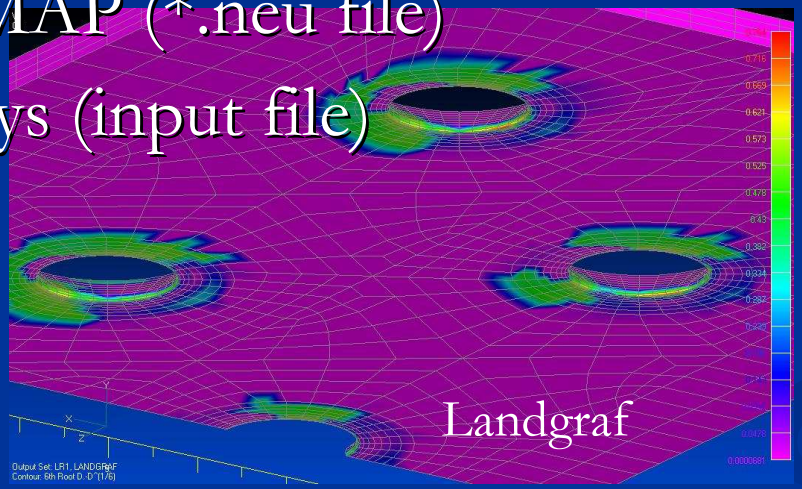


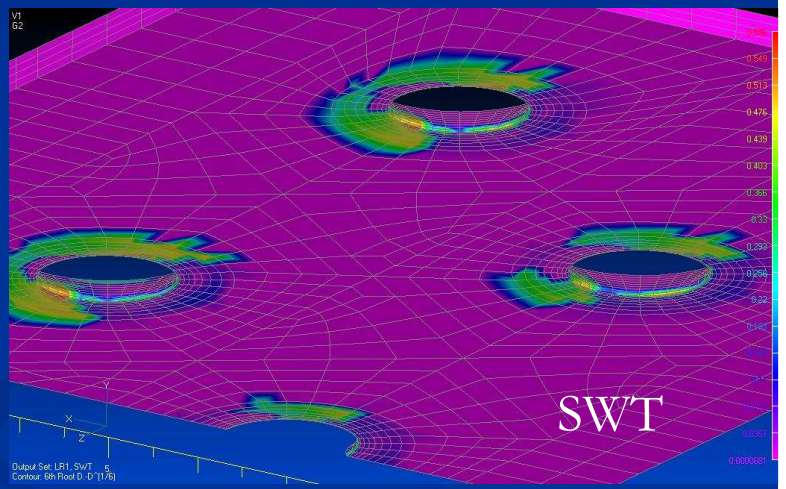
PragTic in Application XVI

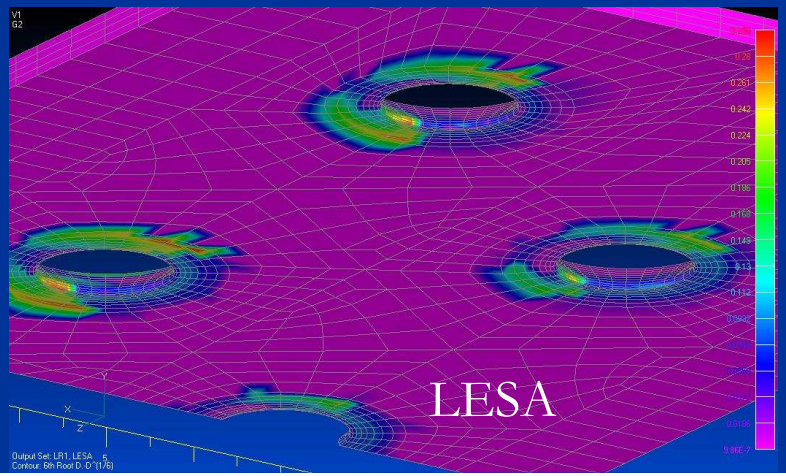
Fatigue Results Export

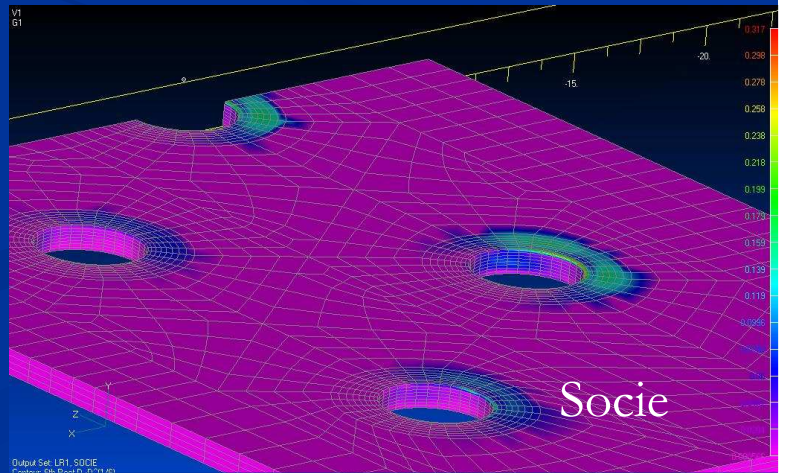
- Two options currently
  - FEMAP (*.neu file)
  - Ansys (input file)

EVE1
LR1
(maximum
load)









PragTic in Application XVIbis

Fatigue Results