The Use of Fatigue Calculations in the Durability Engineering Process

Presenter :

Dr. Peter Heyes

nCode International Ltd

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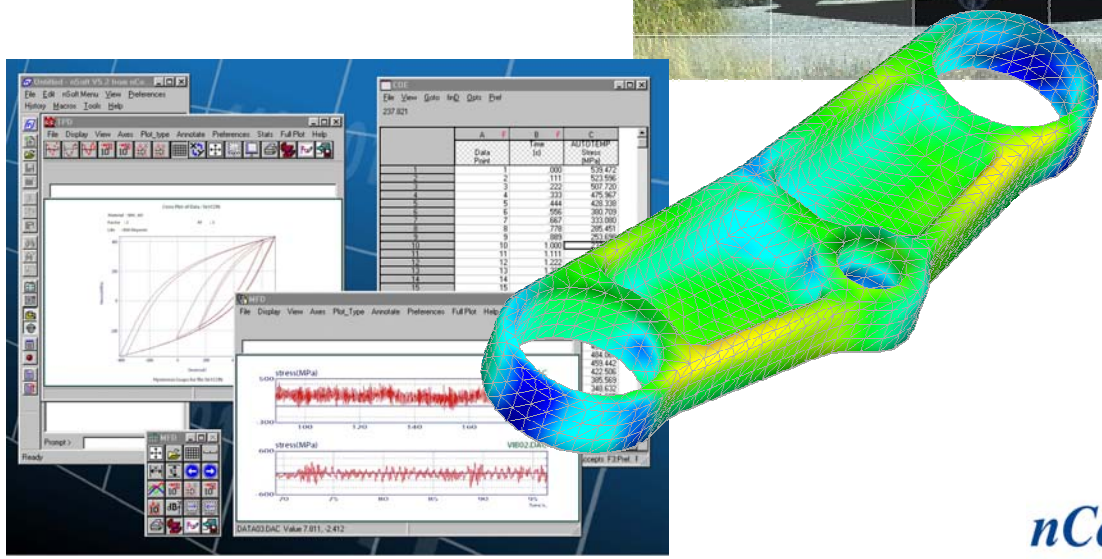
Mechanical Dynamics

nCode Managing Durability

nCode International

Accelerating and streamlining durability processes



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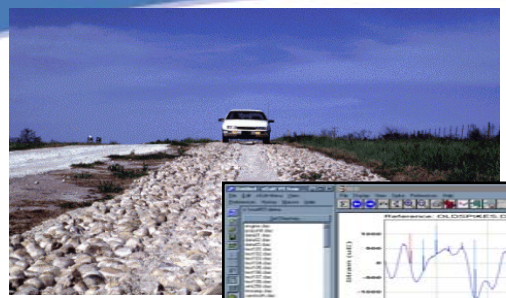
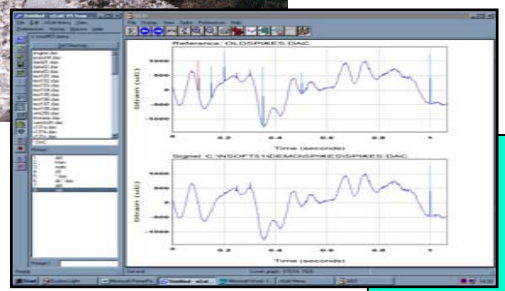
The durability process
nCode alliances and solutions…





MTS

Physical Life

Test Durability

FATIMAS

Measured or Predicted Loads

Data Processing

nSoft

Correlation

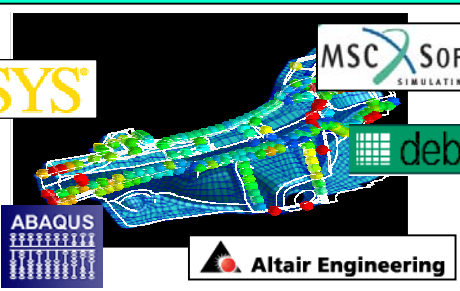
FE-Fatigue

CAE Durability

Integrated Durability Solutions

Virtual Life

Mechanical Dynamics



ANSYS

MSC SOFTWARE SIMULATING REALITY

debis

ABAQUS

Altair Engineering

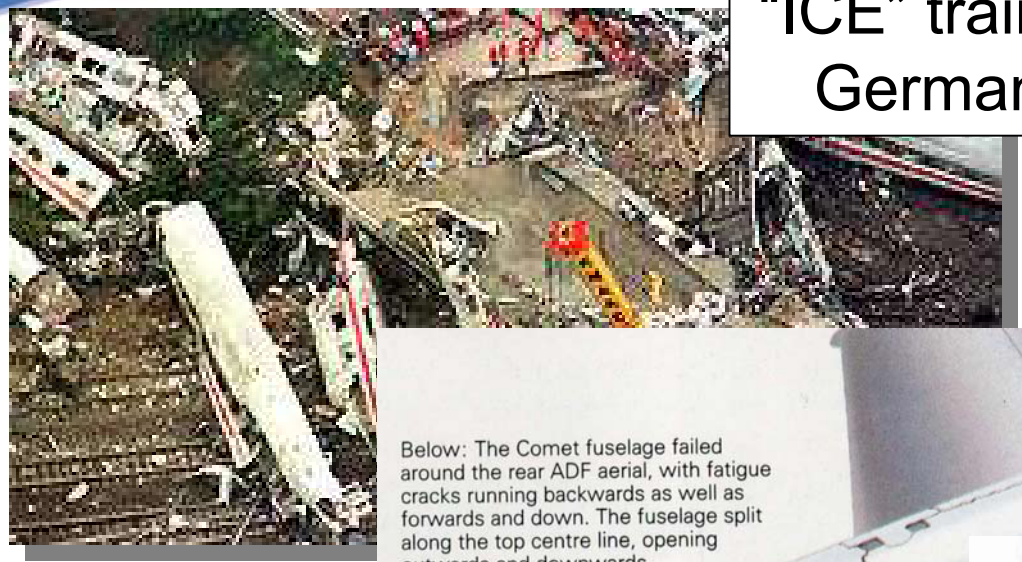
nCode Managing Durability

Outline of Presentation

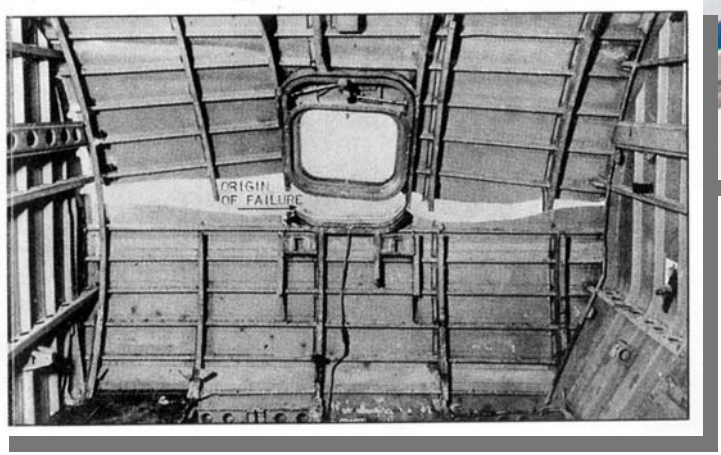
- The durability engineering process
- FE-based fatigue calculations
- Synergy between ADAMS and FE-Fatigue
- Application
- Concluding remarks

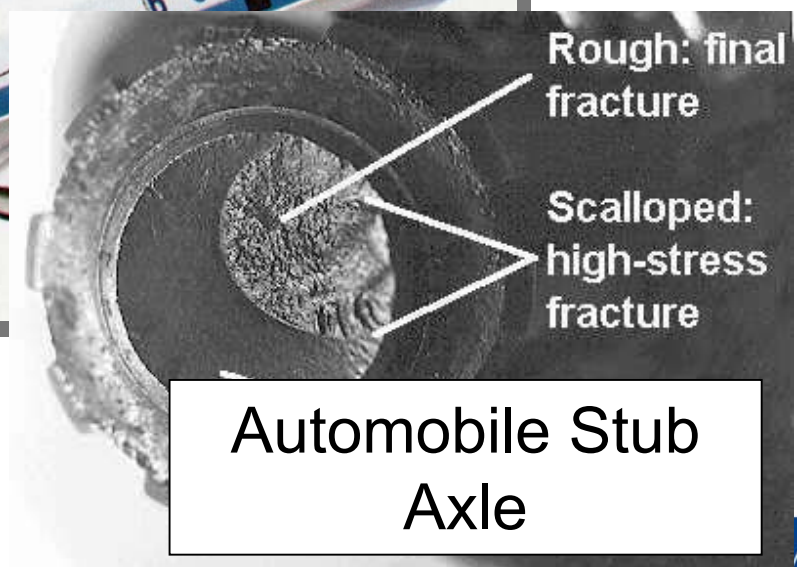
Fatigue Failures in Industry

"ICE" train disaster
Germany 1998



De-Havilland
Comet





Automobile Stub
Axle

Durability Engineering in the Past

Durability Through Testing

Customer Usage

Test

Life

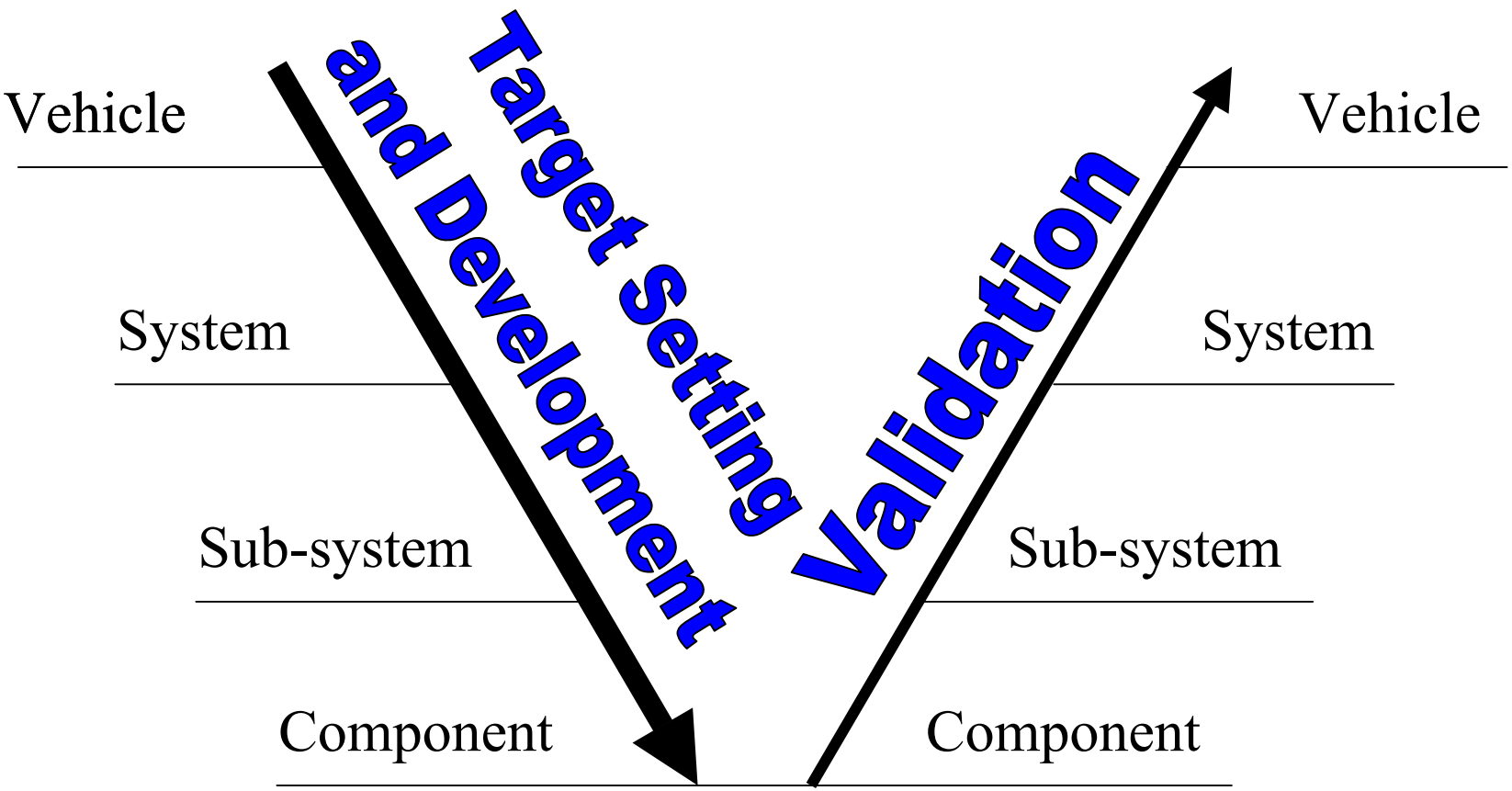
Re-design

Requirements for Durability Process

- Reduce development time/cost
- Distribute development
- More variants and complexity
- Optimize product cost/performance
- Avoid recalls

- NOT POSSIBLE BY SIMPLY TESTING A SERIES OF PROTOTYPES
- REQUIRES AN INTEGRATED SYSTEMS APPROACH BASED ON CAE METHODS

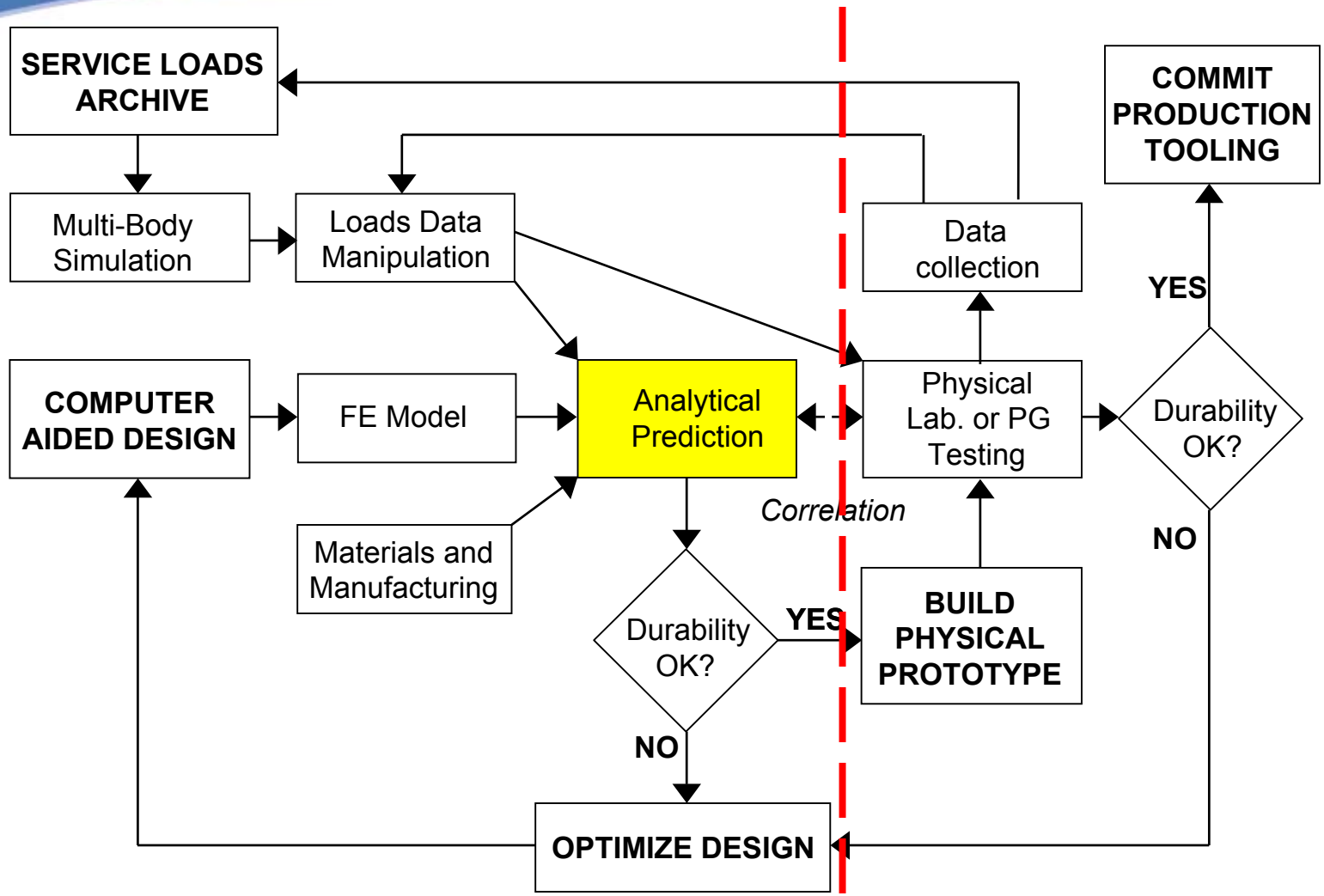
Systems Approach to Durability



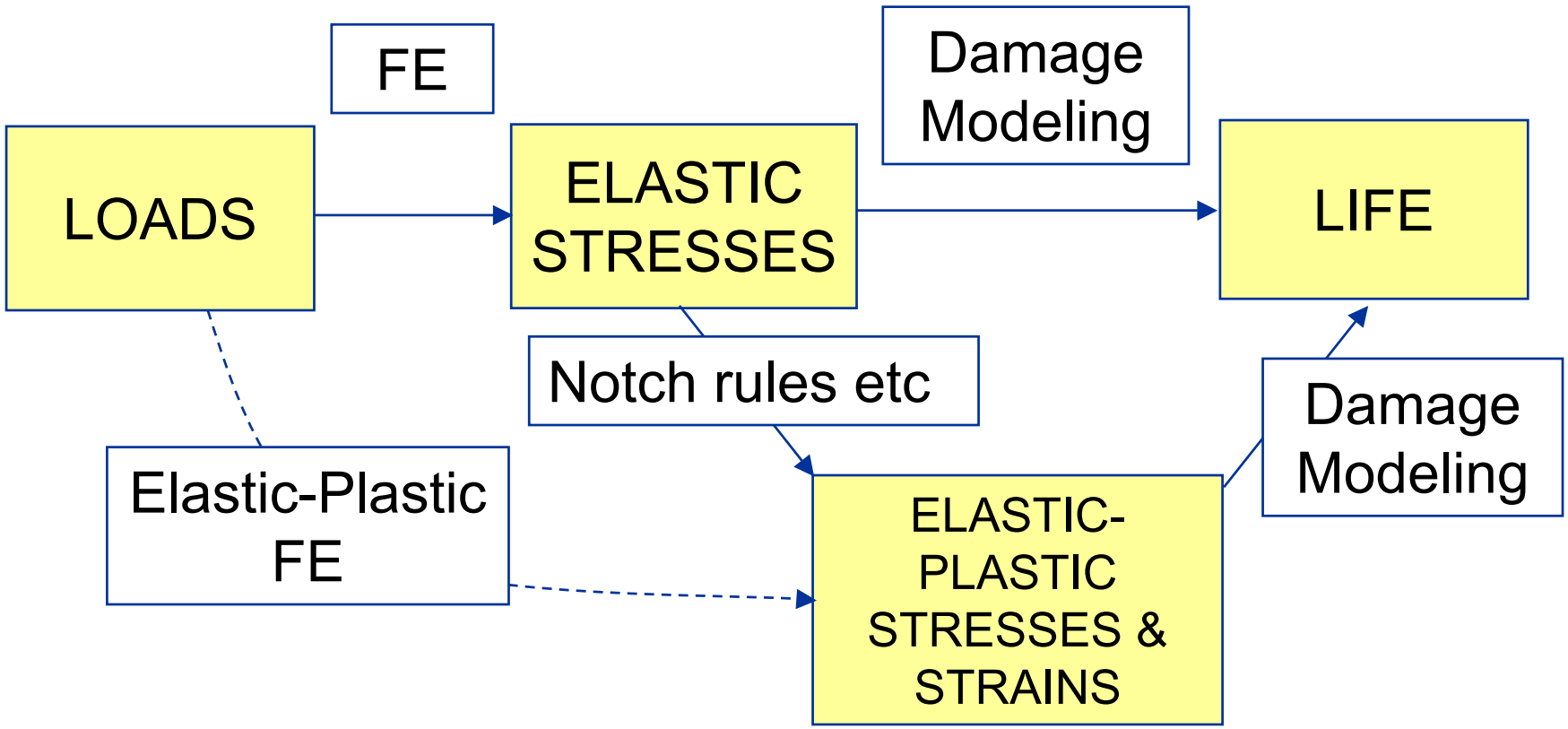
Durability Target Setting (Automotive)

- Typical target – 250 000 km of public road driving by “90%” customer
- Equivalenced to a combination of road surfaces and events on the proving ground (e.g. using nCode CORRELATION)
- Measurements of wheel forces
- Target cascaded to give system, subsystem and component loads using ADAMS analysis
- Analytical development and validation mainly carried out at component level

Integrated Durability Process

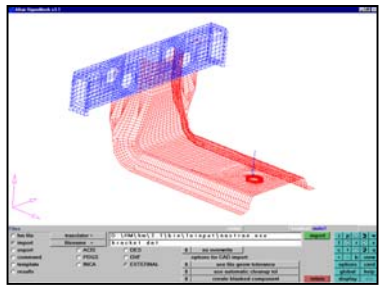


The Fatigue Analysis Process



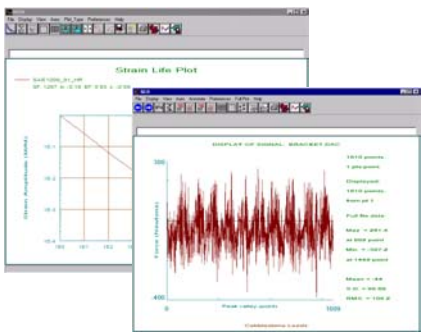
FE-Fatigue Overview

FE stress/strains

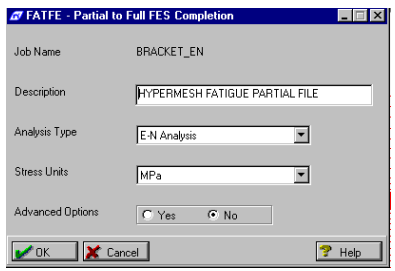


View model and stress/strains in Pre/Post Processor

From:
ANSYS I-DEAS Hypermesh
Medina Pro-Mechanica
NASTRAN ABAQUS UNV



Load and Material information



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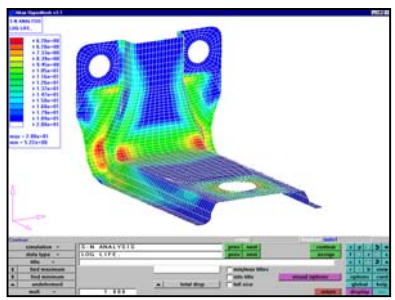
FE-Fatigue



Post process fatigue results

In:
ANSYS I-DEAS Hypermesh
Medina Pro-Mechanica PATRAN

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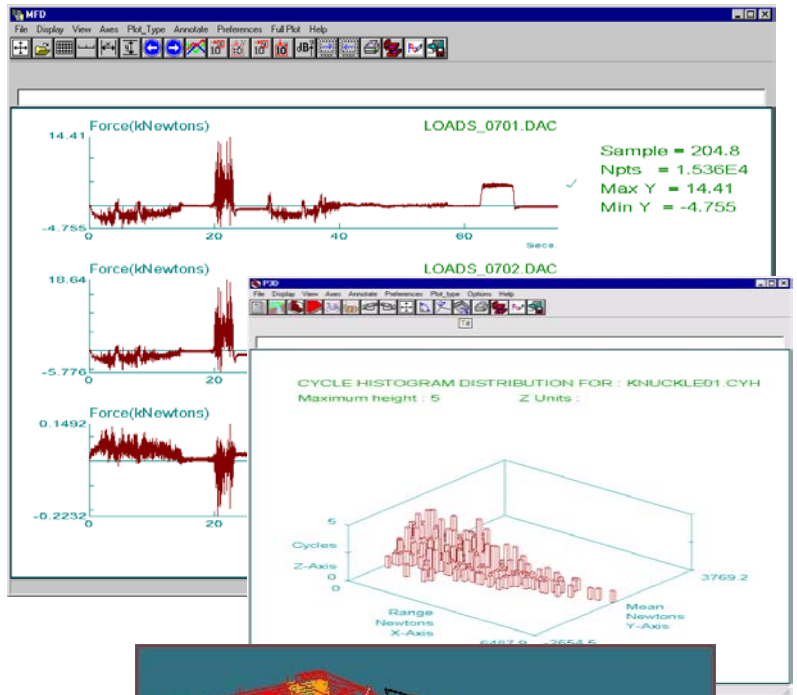
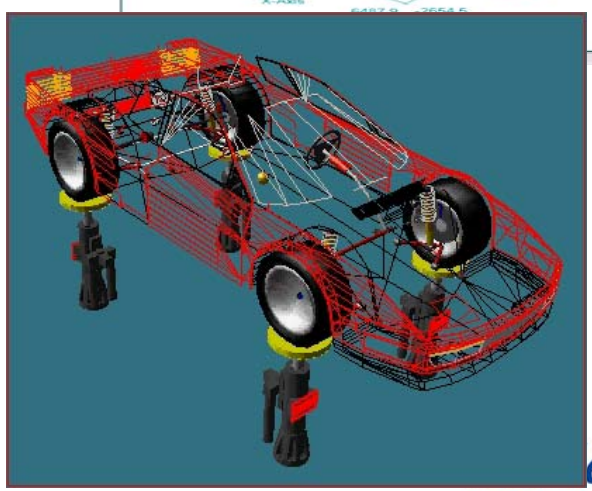
Loading Information

- Loading history or rainflow input
- Measured or calculated loads
- Up to 500 loading cases
- Unlimited time-steps
- Loading histories in DAC or RPCIII format
- ADAMS 11.0 new Durability option to read / write DAC and RPC III files – component loads or modal displacements
- Duty cycle manager for multiple event analysis

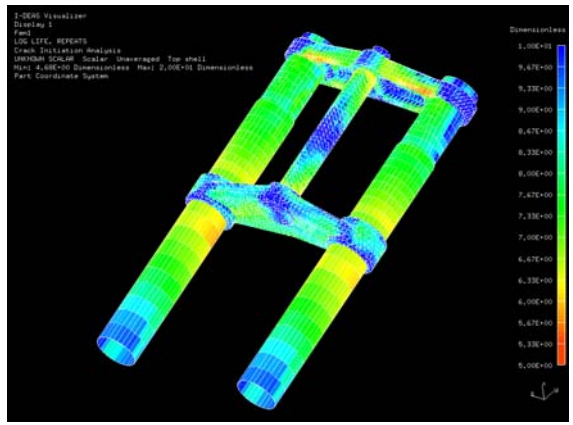


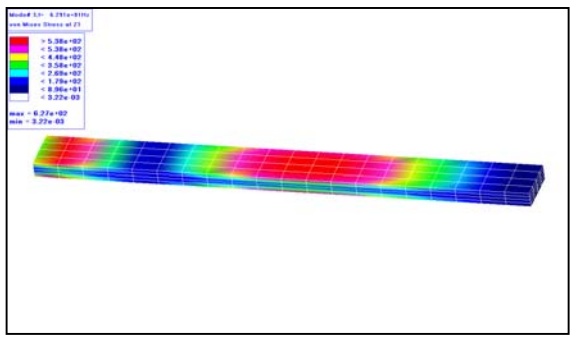


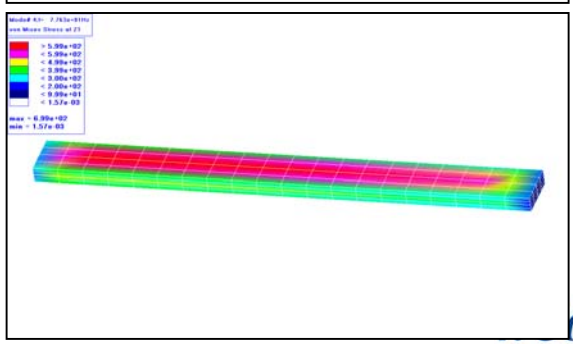
Managing Durability

Connection to FE

- Connects to most common FE analysis codes and interfaces
- Node or element centroid results from shells or solids
- NASTRAN CBARs for spot welds
- Stress histories by:
  - Linear superposition (quasi-static method)
  - Transient results
  - Modal superposition
  - Non-linear time-step

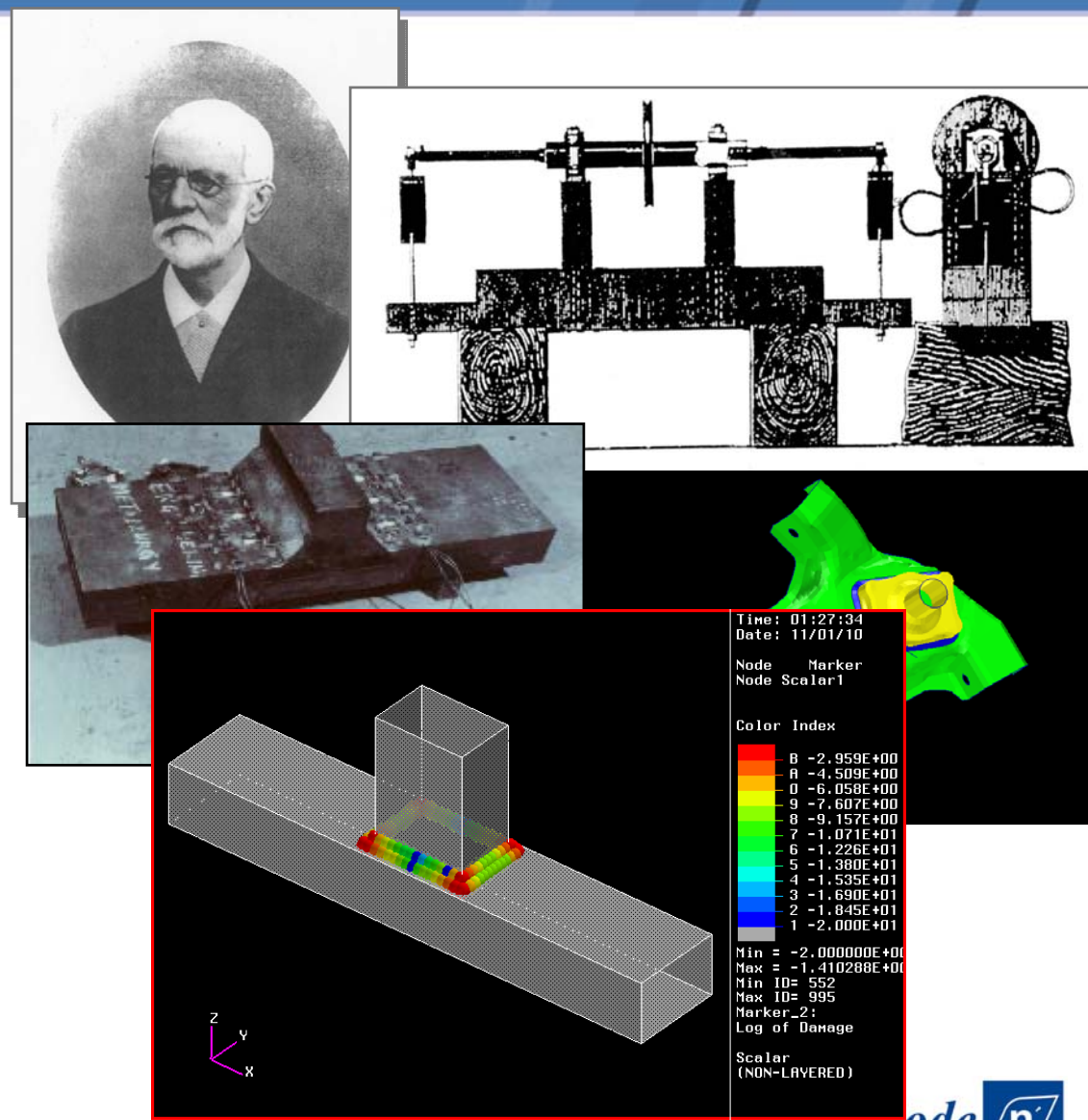






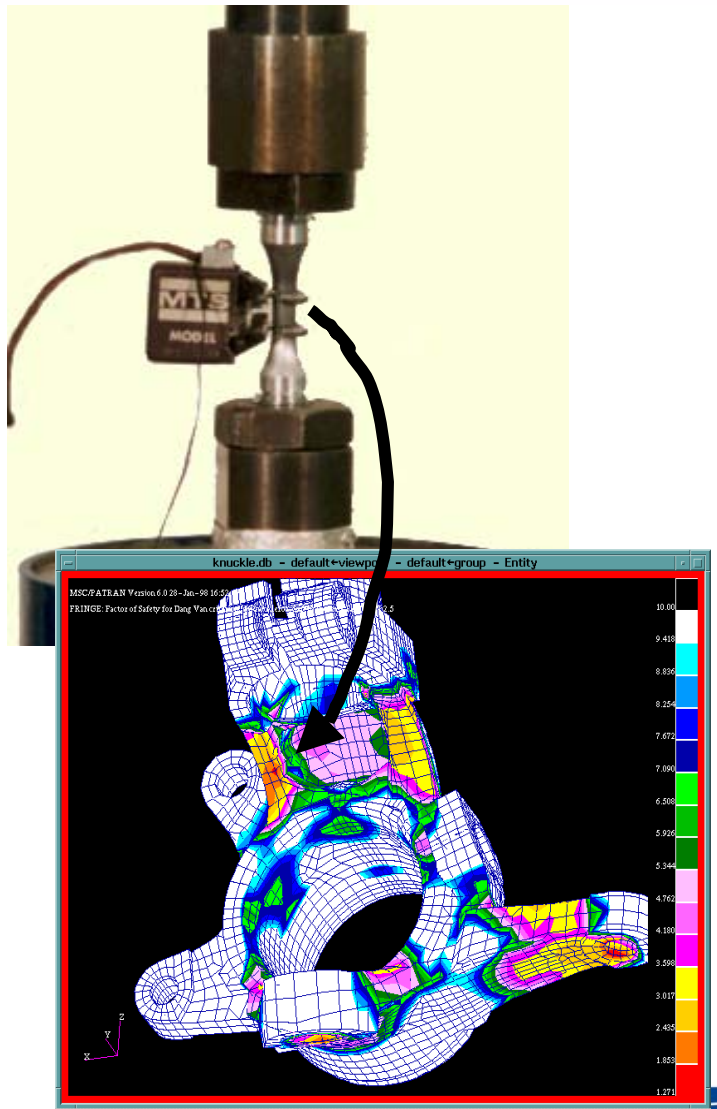
Damage Modelling – S-N method

- S-N approach based on work of August Wöhler
- Relates nominal stress to fatigue life
- Uses rainflow counting, damage summation etc
- Often used in aerospace industry
- Very suitable for analysis of welded structures



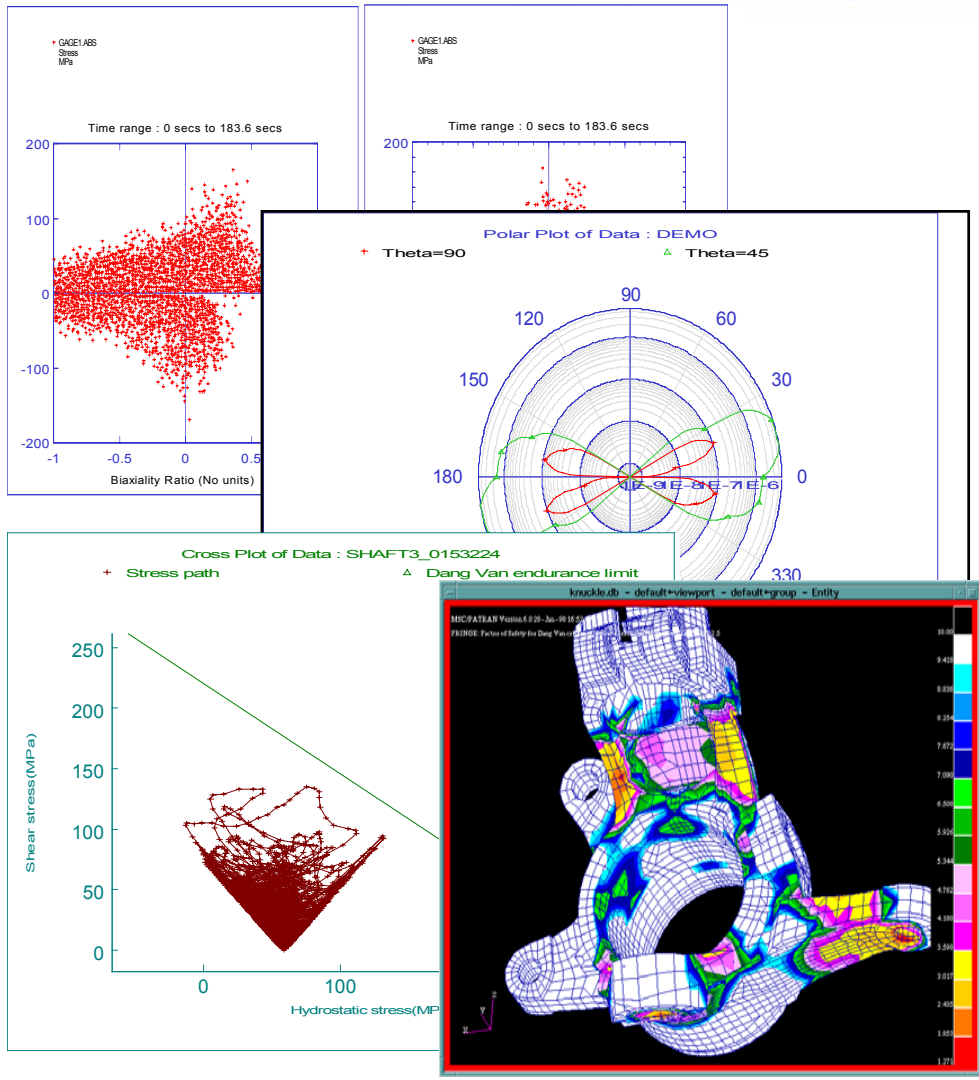
Damage Modelling – Local Strain Method

- Relates local strain to crack initiation life
- Uses approximate methods (e.g. Neuber method) to estimate plastic strains
- Rainflow cycle counting and damage summation
- Highly suitable for many sheet and solid metal applications
- Not so good for structural joints



Damage Modelling – Multiaxial Methods

- Many components experience multiaxial external loadings
- Some of these have multiaxial stress states
- Multiaxial assessment tools
- Multiaxial Neuber method and damage models
- Multiaxial safety factor calculations (Dang Van method)



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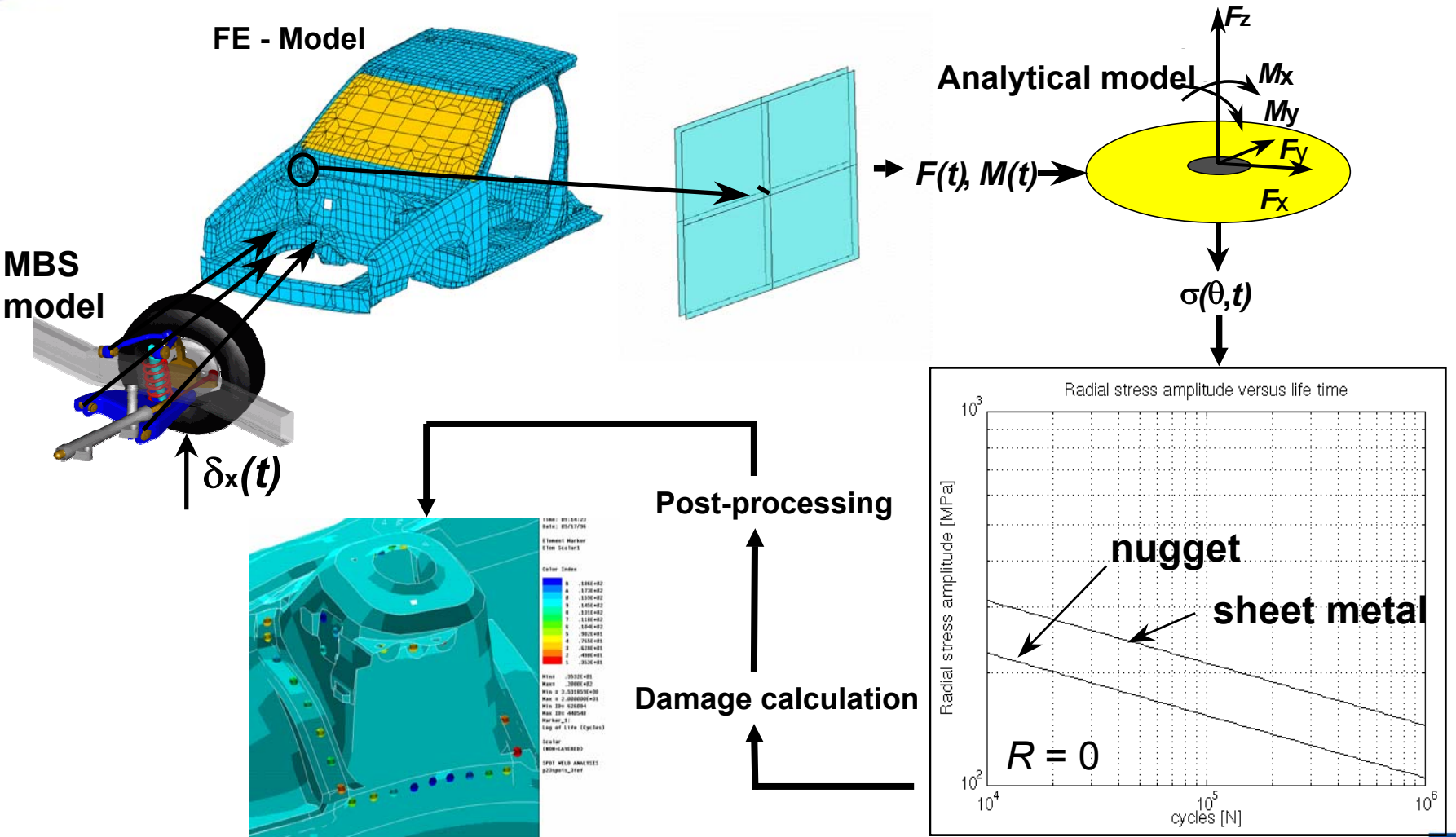
Life Prediction of Spot Welded Structures



Volvo S-80

Mission:
Increase fatigue life

- Analytical Life Prediction
  - Case study covers the first 3 design iterations
  - Loads from physical spring and damper measurements made on proving ground
- Physical Testing
  - Lab based simulation of the equivalent proving ground event
  - Target Life is 12000 repeats of loading event

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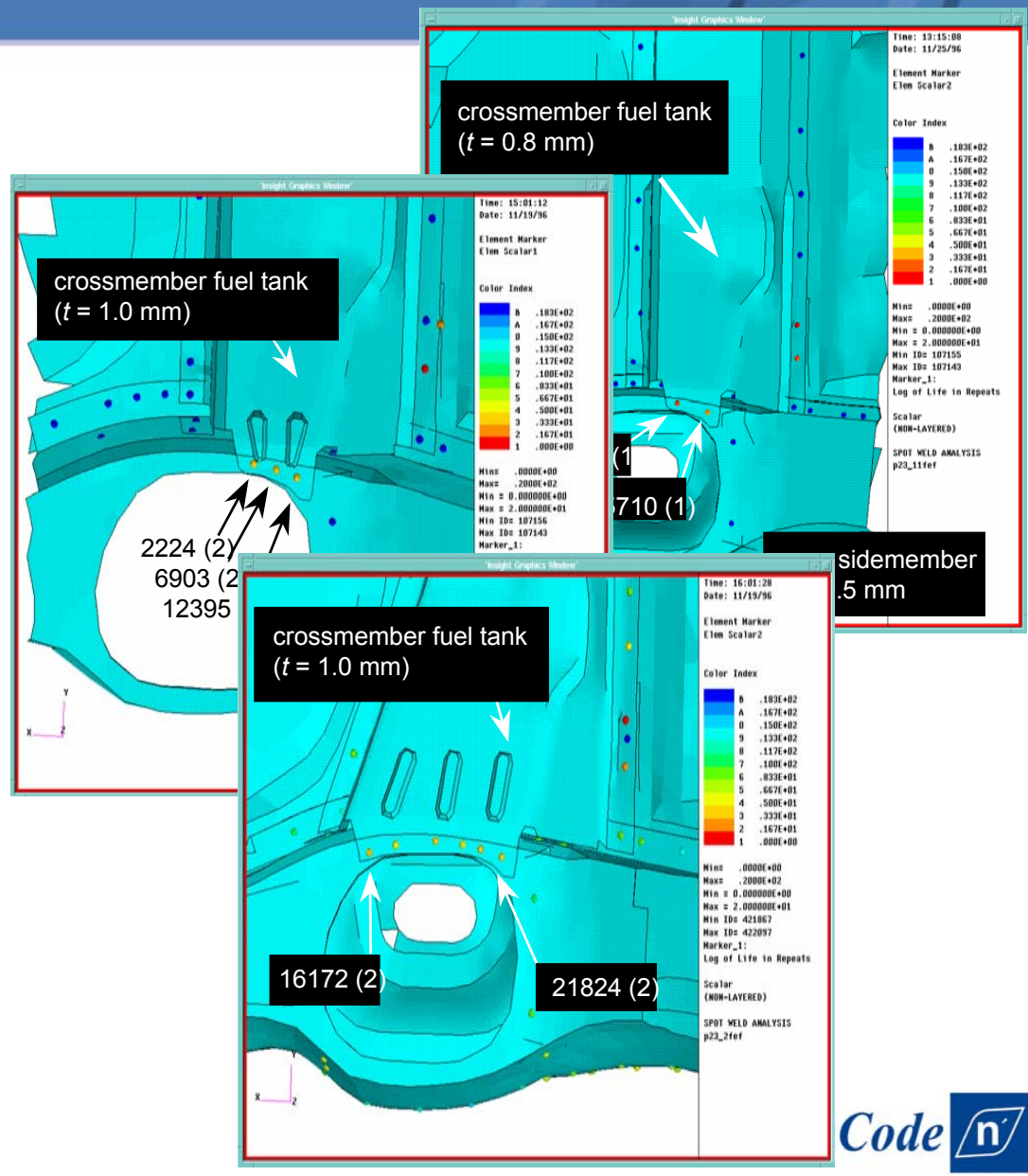
Volvo S-80

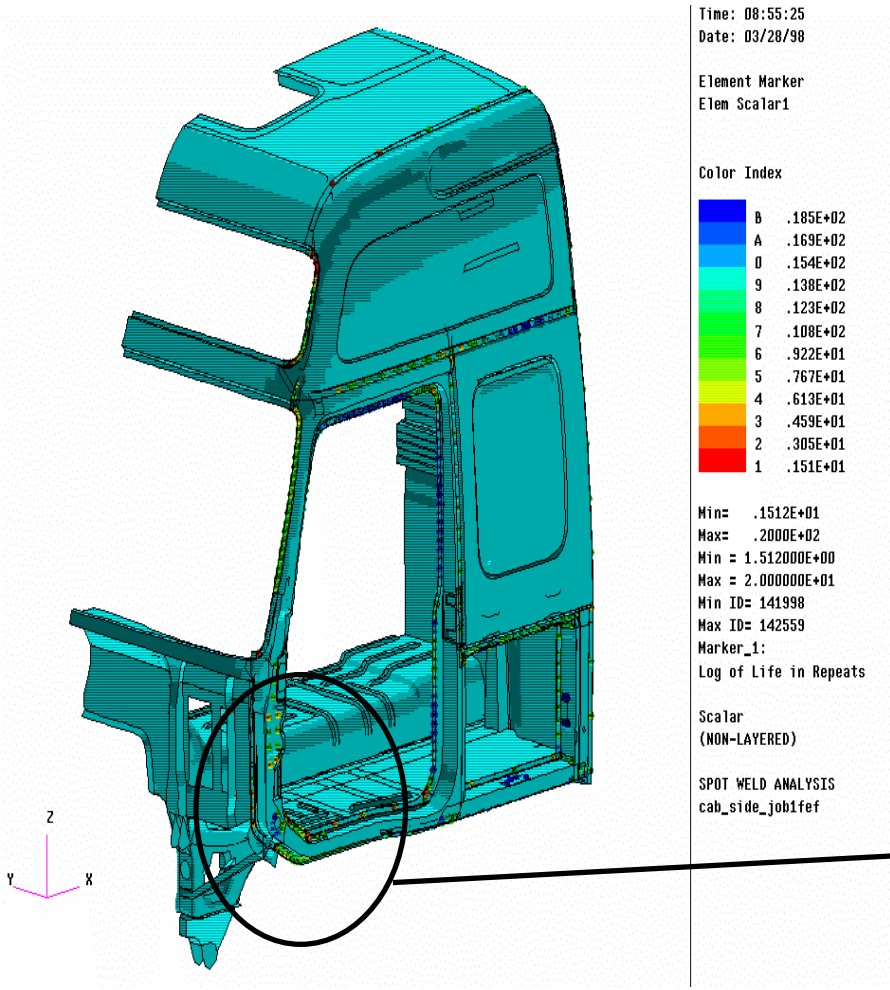
- Results of analysis matched test very closely through 3 design iterations, predicting:
  - failed spotwelds
  - life
  - crack location
- Results gave confidence in method



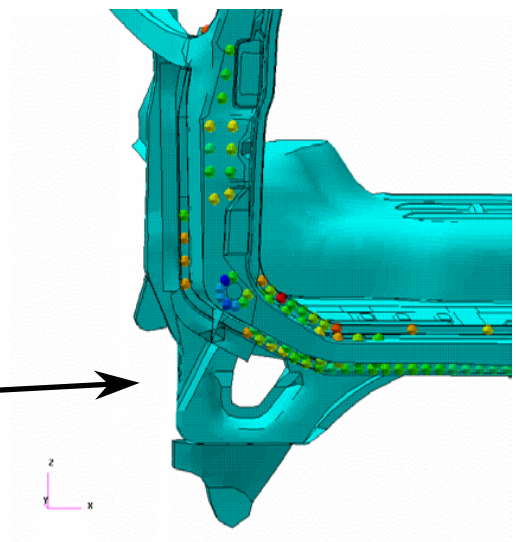
S-80 Bi-Fuel Version Development

- Floor pan of Volvo S-80 was extensively modified to accommodate an extra gas tank for the bi-fuel version
- ADAMS based loads from previous S-80 used, with some modifications
- Durability was analysed and optimised virtually before manufacture of final prototype
- Structure verified on shake-rig test
- No fatigue failures on floor pan

Truck Cab Production Cost Optimisation



Mission:
Speed up cab production by reducing total number of spot welds by 10%



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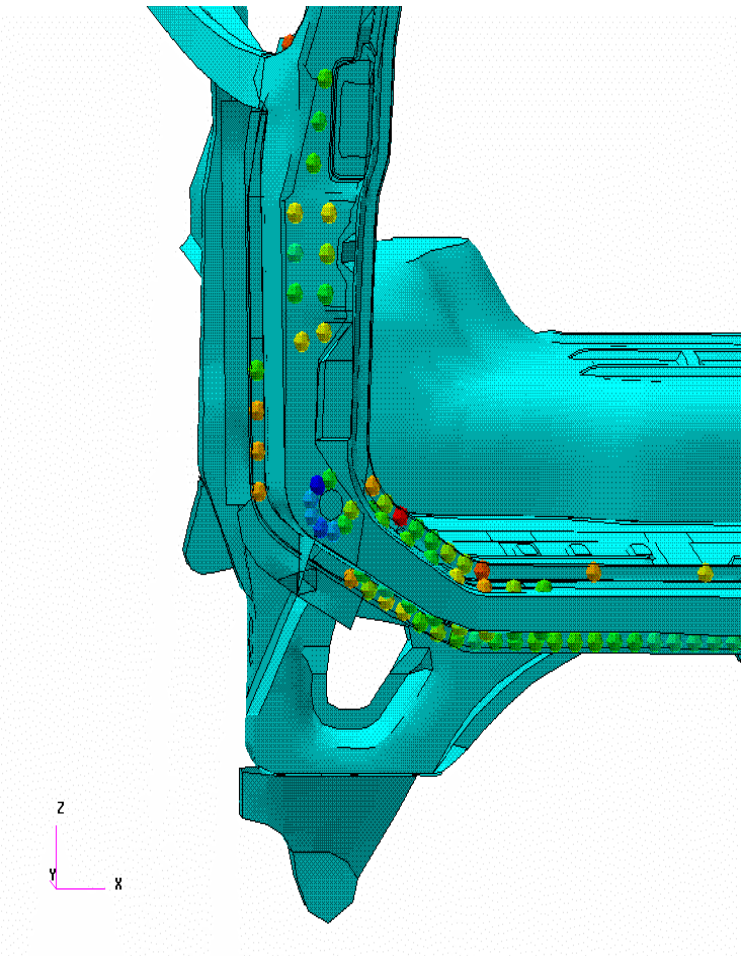
Truck Cab Production Cost Optimisation



- Analytical approach
  - Perform fatigue calculation on truck cab exposed to signals measured on endurance track
  - Exclude spot welds in crush zones from fatigue calculation
  - Remove some of the spot welds with longest fatigue life and perform new FE and fatigue calculation

Truck Cab Production Cost Optimisation

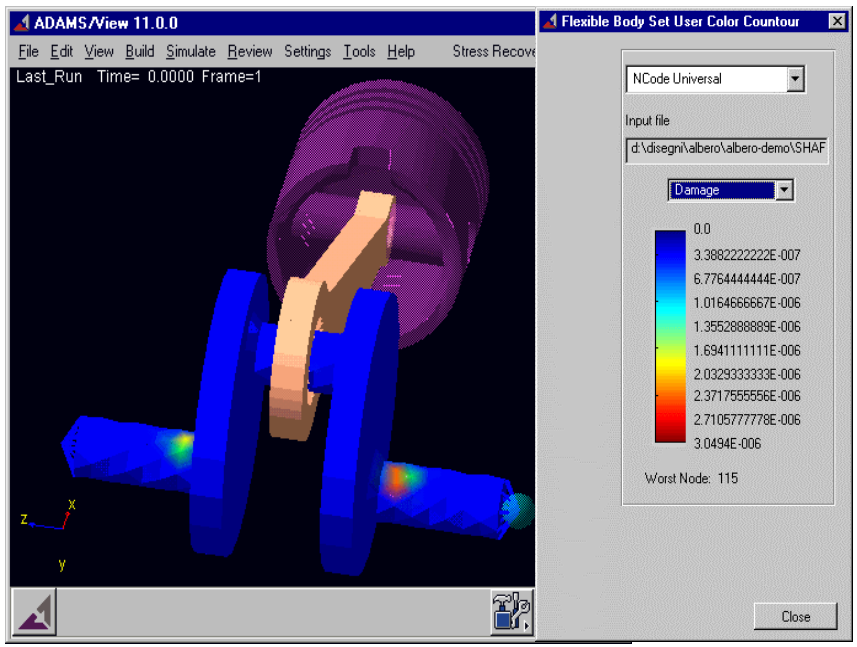
- Simulation test
  - Run durability test on cab using laboratory simulation of service loading
- Result of exercise
  - Analysis indicates it is possible to remove 400 spot welds
  - Test demonstrates that the structural durability of the design is not compromised

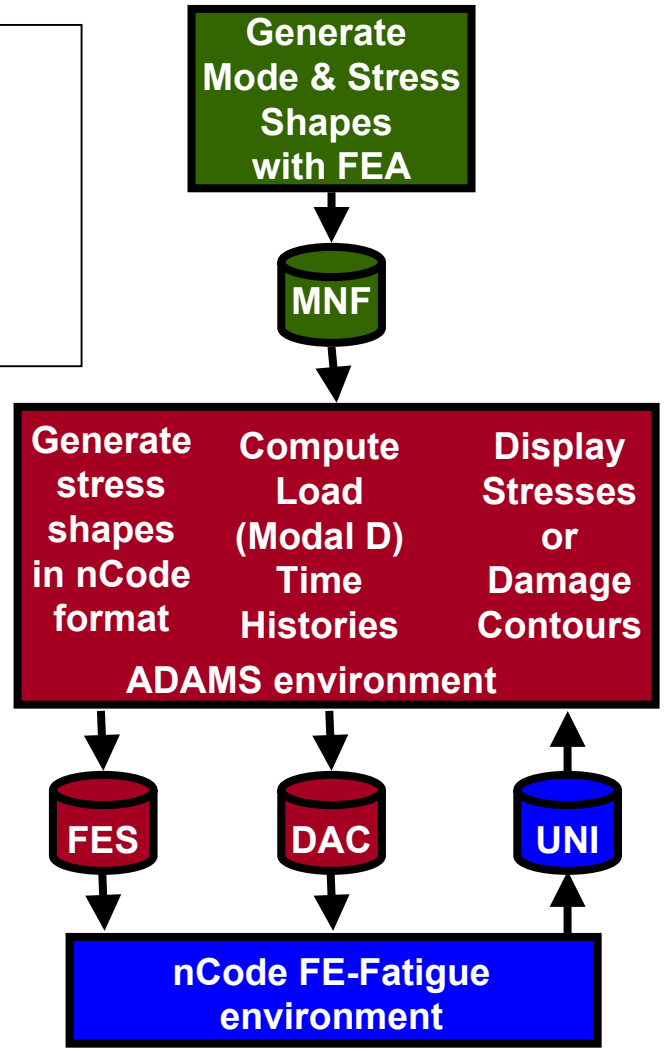
❖ **Consequences:**

↗ Time savings of about 30 minutes for each cab (3 - 5 seconds/weld)!

Links between ADAMS and FE-Fatigue

Fatigue analysis process streamlined with MSR-Fatigue toolkit
- Minimise data transfer
- Avoid unnecessary steps
- Postprocess results on flexible bodies





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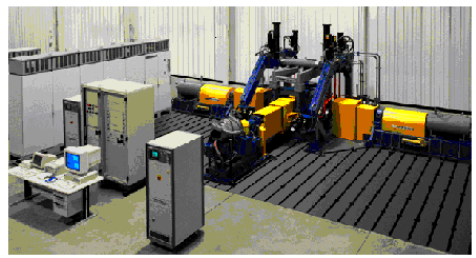
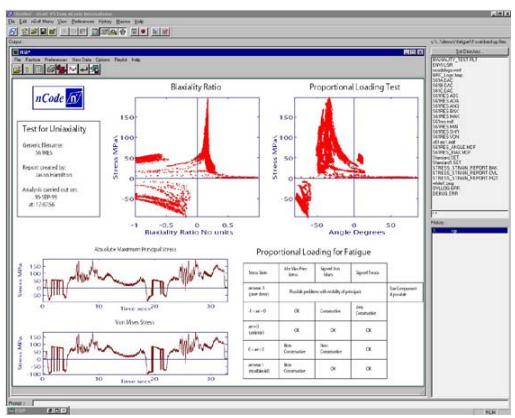
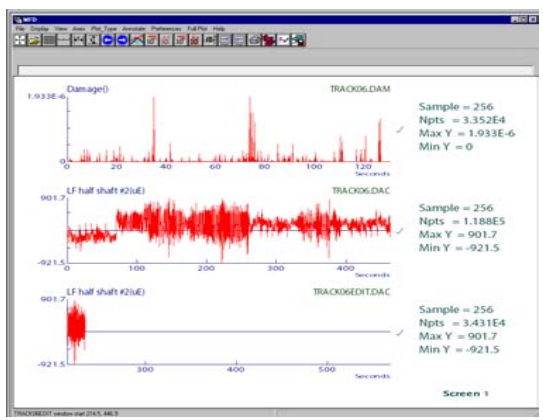
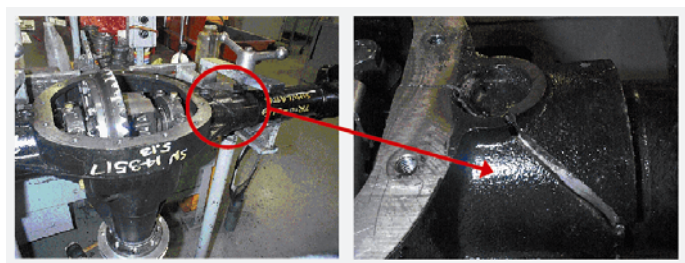
Application of Fatigue Analysis to Testing

- Visteon – test acceleration through fatigue editing
- Duplicated Proving Ground Incidents on test rig
- Accelerated overall rig test by 5:1
- More test studies in less time
- Estimated savings, over $1M









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Concluding Remarks

- Fatigue calculations are a central part of the durability engineering process
- Use of fatigue calculation is essential for fast development of optimised products
- Obtaining accurate component loads is essential for good results and Multi-Body-Simulation is very important in this respect
- FE-Fatigue and ADAMS provide an effective integrated solution for durability analysis
- Testing is still important too!

Presented by

Dr Peter Heyes
Email peter.heyes@ncode.com

nCode
Managing Durability

nCode International Ltd
230 Woodbourn Road,
Sheffield, S9 3LQ
England

Tel: +44 (0)114 275 5292

www.ncode.com

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