Integrating Virtual and Physical Simulation to Improve the Validation Process

Integrated
analytical
physical
virtual
Simulation

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Trends - Platform Commonality

- Broader end-product range developed off small numbers of basic design platforms
- Increased evaluation on basic platform required to confirm performance in entire design envelope
- Increased product evaluation based on “Design of Experiment” principles required to validate core set of interacting product options
  - Limited manufacturing validation testing can be done inside current accelerated development programs.

Trends - Design Process Activities

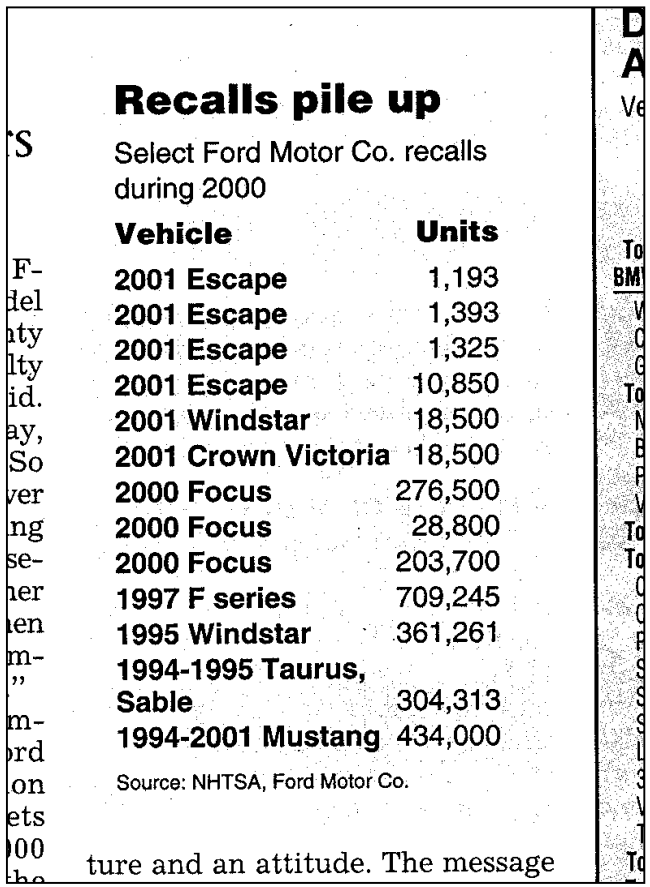
- Improve the Analytical Design Process
  - Move from Design, Build, Test, Analyze . . .
  - To Design, Test, Build, Validate
- Utilize more predictive methods based on hybrid models
- Utilize Design of Experiments based on mathematical models
- Build more confidence (less risk) in earlier in design

- Reduce Cost
- Reduce Time to Market
- Improve Quality

Quality & Engineering Related Recalls

- "One problem with the product development process is that initial component design parameters are established by 'designers' (drafting staff) where the average experience level has dropped from 15 years to 18 months. A lot of effort is therefore being spent getting even the initial design correct"

- North America - In 2000, 19 million vehicles were recalled vs. 17.9 million built



Recalls pile up

Select Ford Motor Co. recalls during 2000

Vehicle	Units
2001 Escape	1,193
2001 Escape	1,393
2001 Escape	1,325
2001 Escape	10,850
2001 Windstar	18,500
2001 Crown Victoria	18,500
2000 Focus	276,500
2000 Focus	28,800
2000 Focus	203,700
1997 F series	709,245
1995 Windstar	361,261
1994-1995 Taurus, Sable	304,313
1994-2001 Mustang	434,000

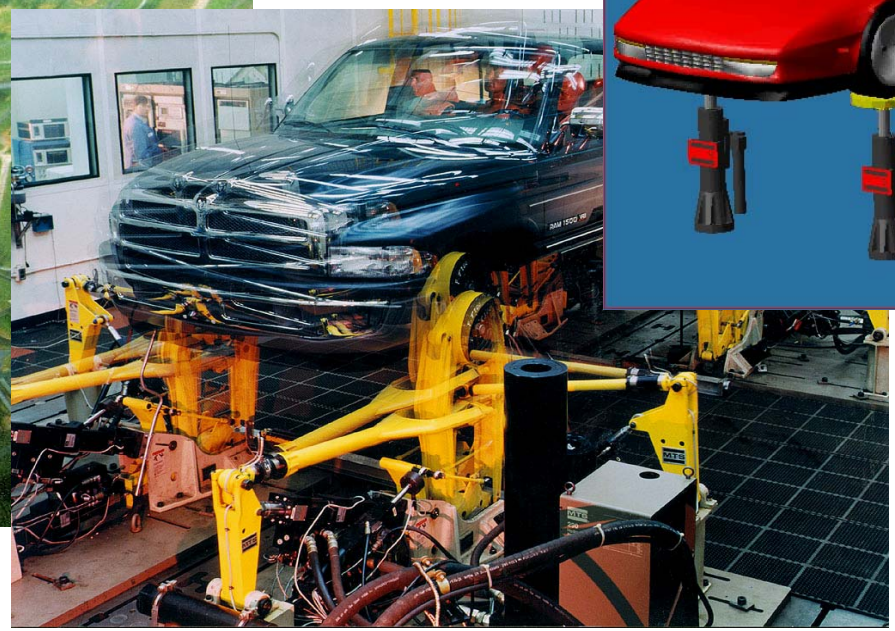
Source: NHTSA, Ford Motor Co.

ture and an attitude. The message

Quality & Engineering Related Problems

- J.D. Power and Associates' Initial Quality Study indicates that less than 30 percent of problems identified by consumers after 90 days of ownership can be traced back to manufacturing-related causes. A much greater share of initial quality problems, 65 percent, can be traced to the vehicle design stage and approximately five percent are due to dealership sales and service functions

Take Your Design Validation...



From the Real World...

To the Test Lab...

Into the Virtual Test Lab

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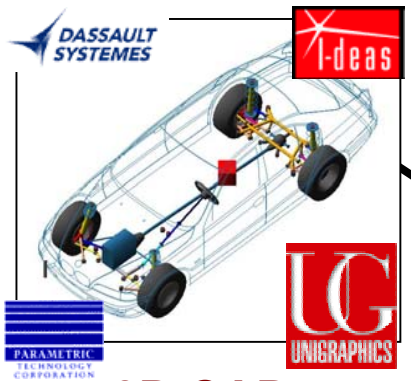
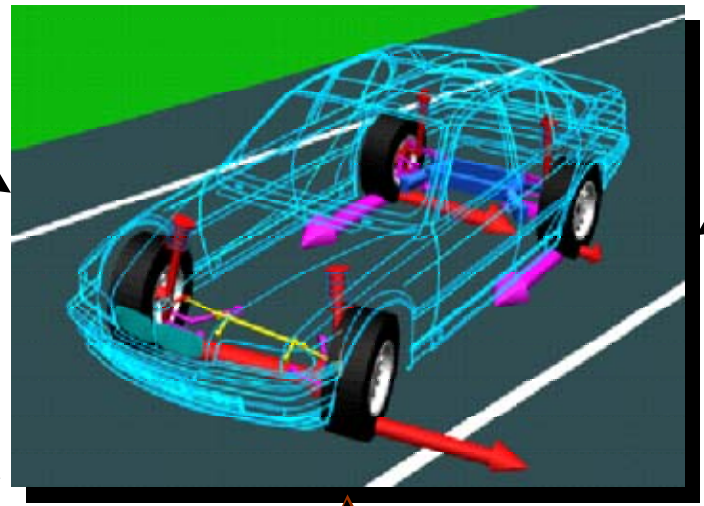
Achieving Analytical Design Processes

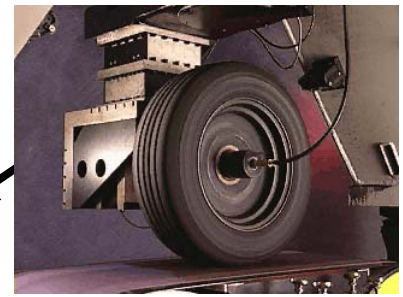
- Build a more accurate model – Concept or Design Model
  - Empirical Dynamics Models (EDM) integrated with ADAMS
    - Shock absorber, elastomer, suspension, tires
    - Dynamic non-linear behavior
    - Characterizes frequency and amplitude dependencies
    - "Property Driven Development"
- Test "Concept" and "Design" model using *virtual tools* – More predictive analysis
- Validate the model using the physical tools – Use the same analysis methods as the predictive process
- Modify the model to improve future processes

Building a More Accurate Model

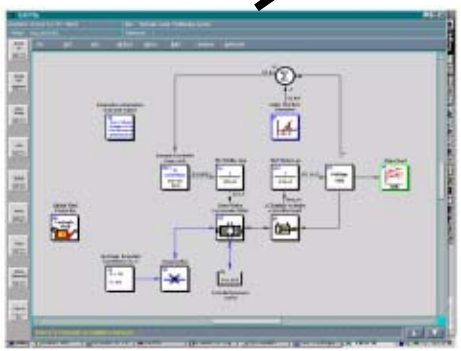


3D CAD

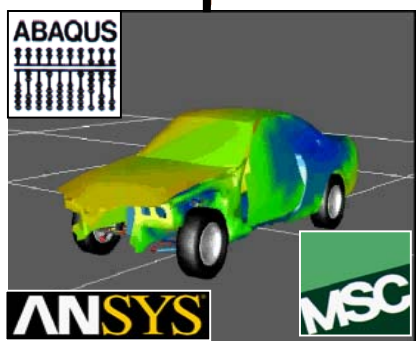




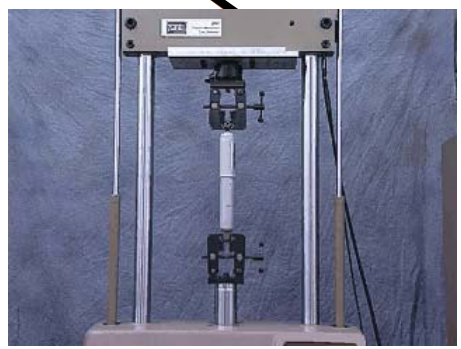
EDM Tire Model



Controls and Hydraulics



Flexibility



EDM Shock Absorber and Elastomers Models

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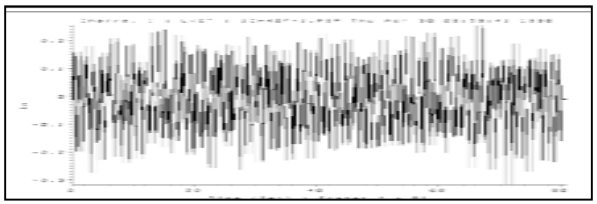
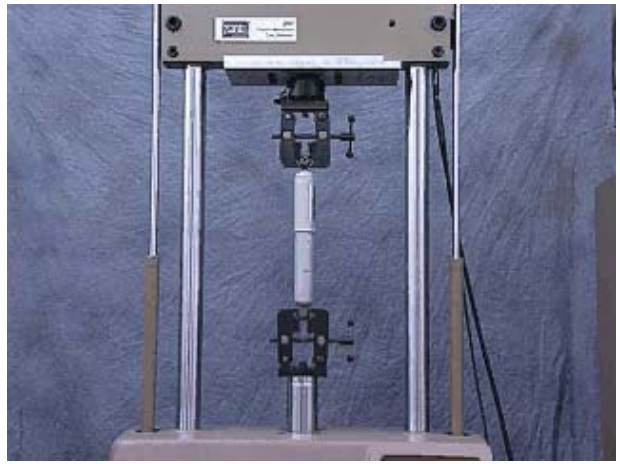
Empirical Dynamics Models for Shock Absorbers

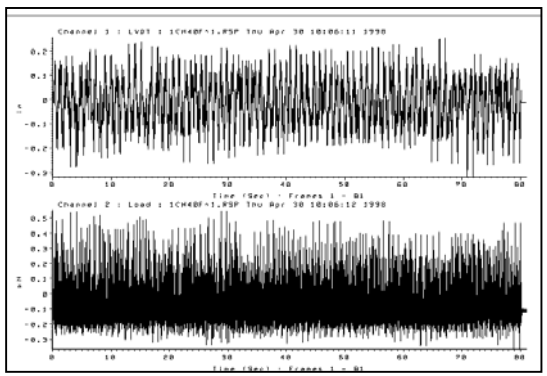
EDM Shock Absorber Example



Random Displacement Command

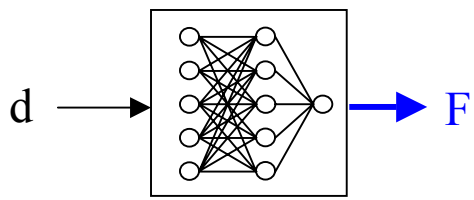
Test
cEDM





Measured Force and Displacement

cEDM
Process



Model Build - Training

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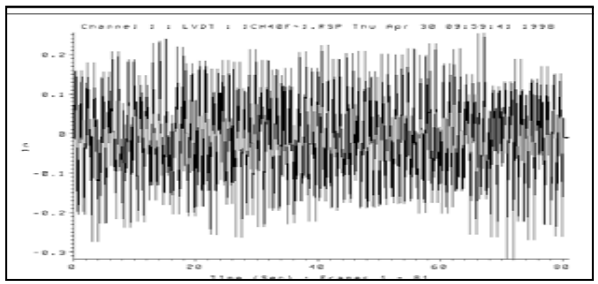
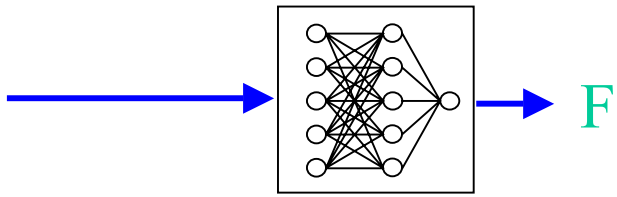
EDM "What if" Scenario

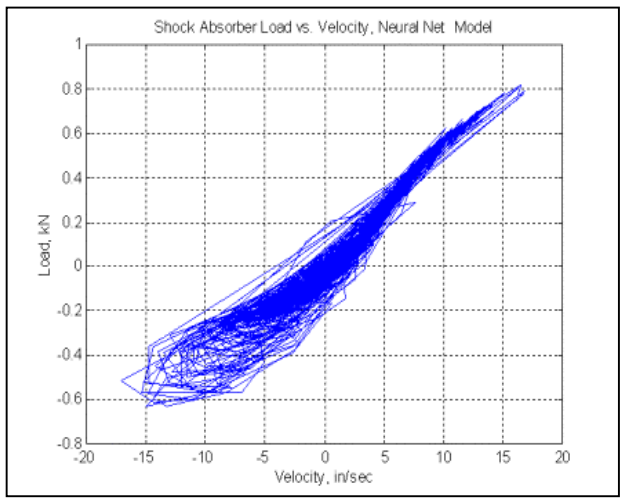


Random Displacement Command



EDM Model

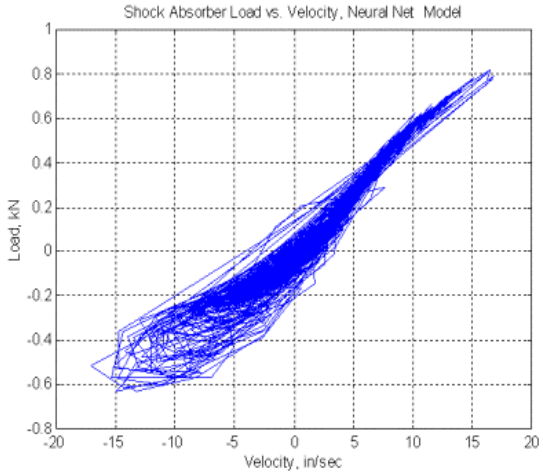
Typical Results



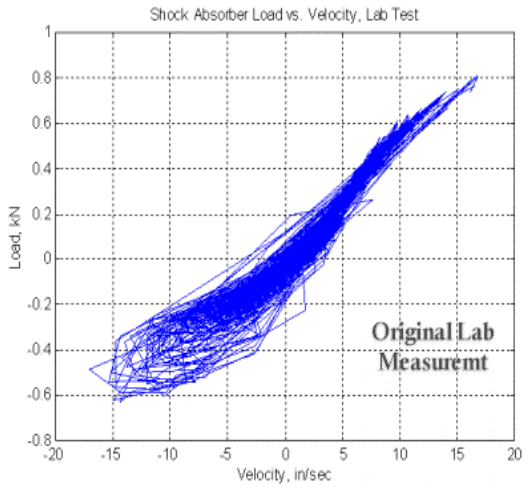
Predicted Results

Non-linear, Dynamic Validation Result

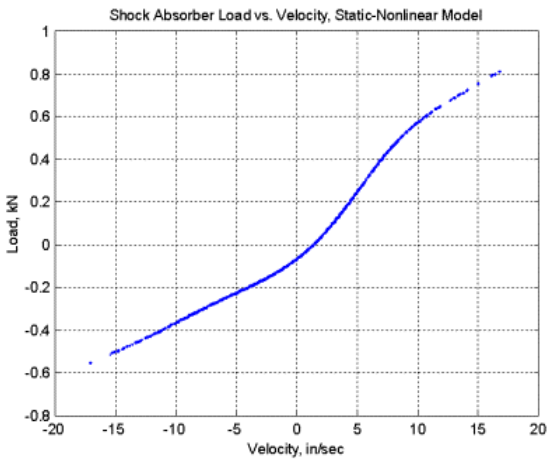
EDM™ Model Prediction



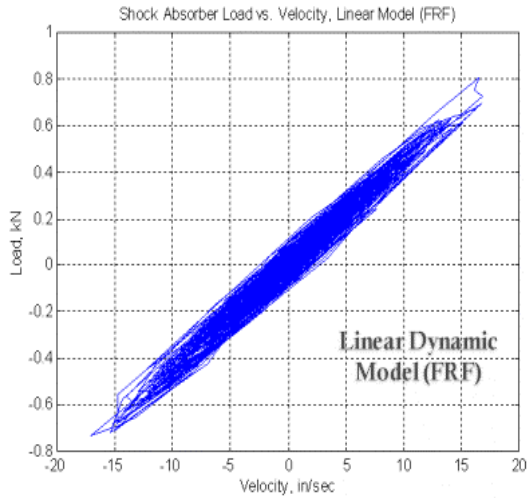
Measured Load versus Velocity



Polynomial Model Prediction



FRF Model Prediction



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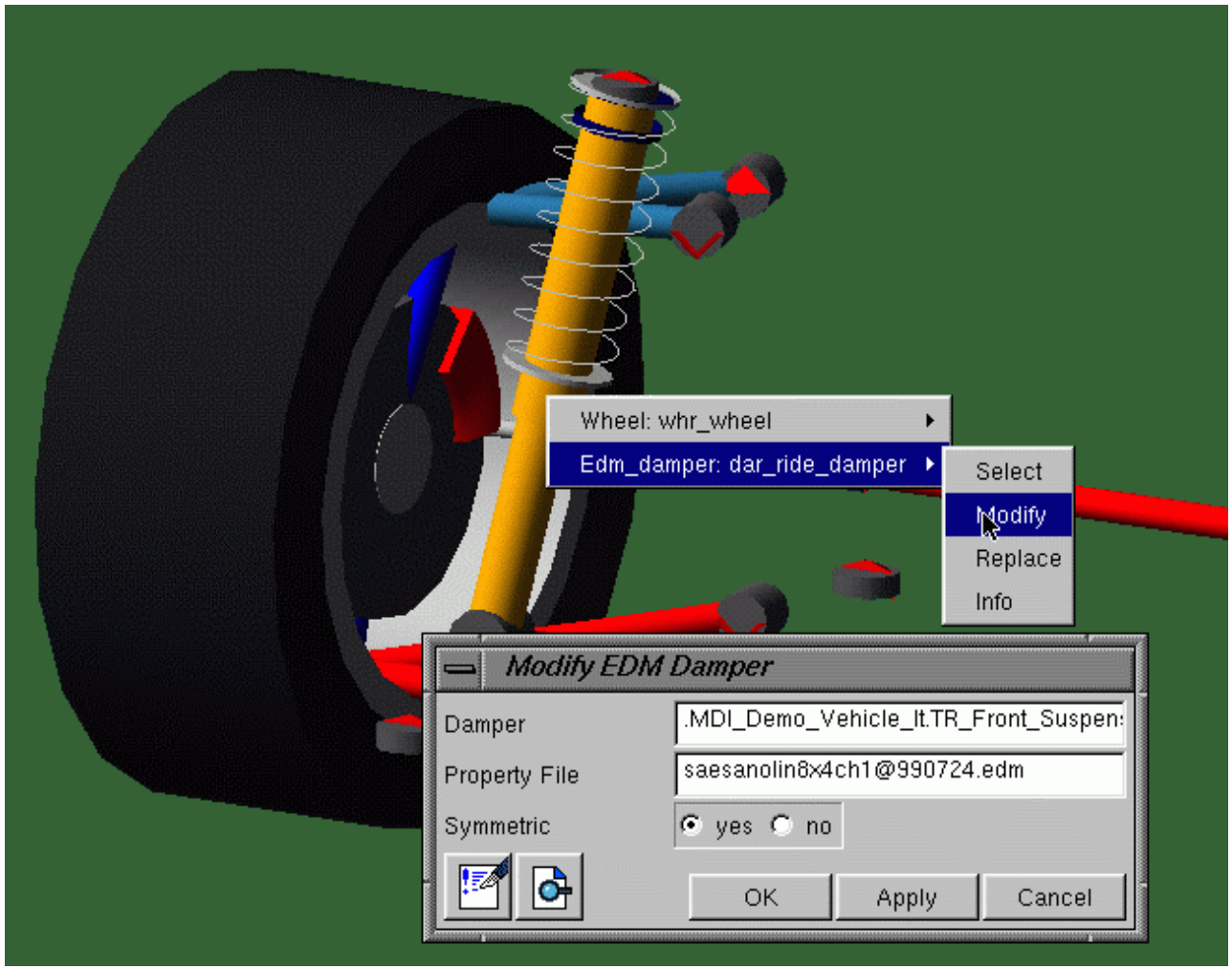
Using Empirical Dynamic™ Models



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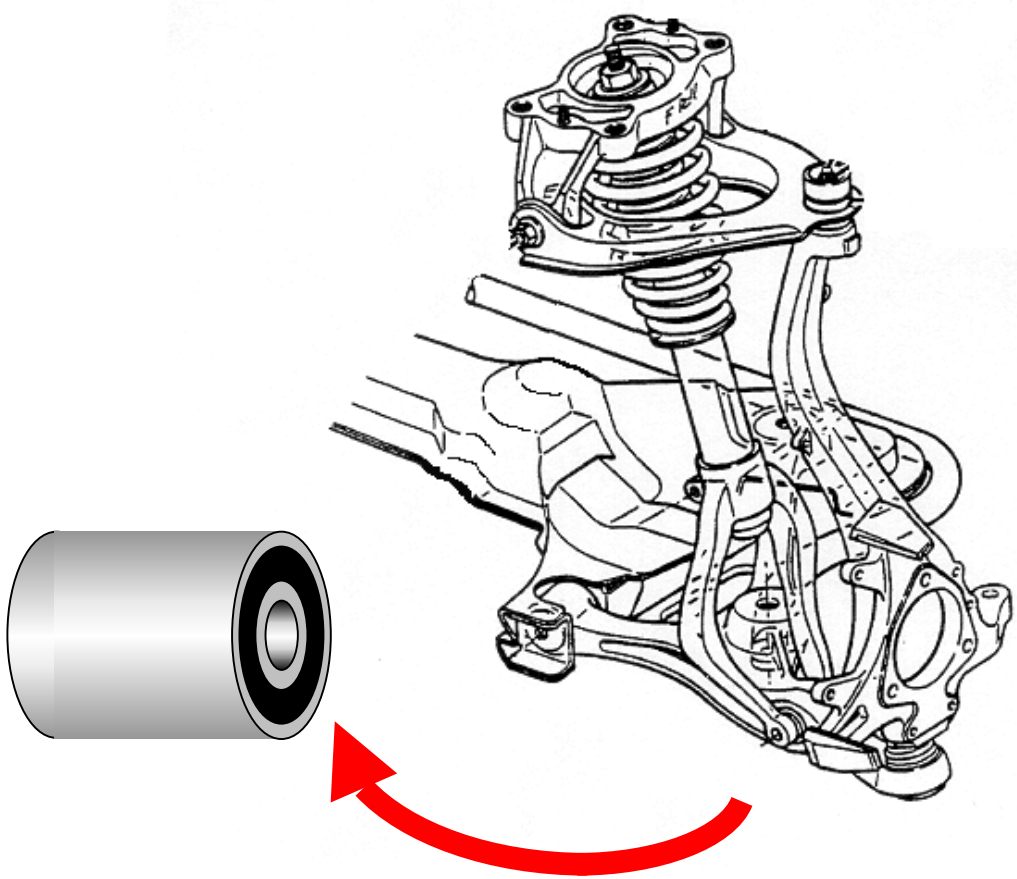
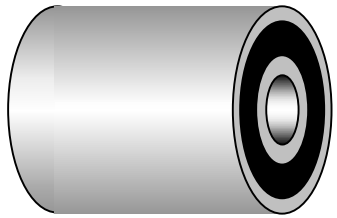
Empirical Dynamics Models for Multi-axis Bushings

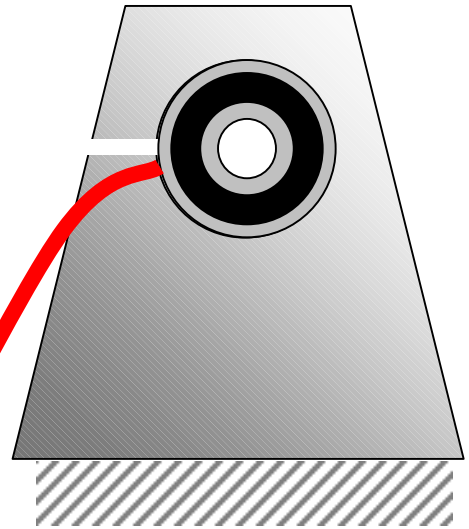
Suspension Bushing

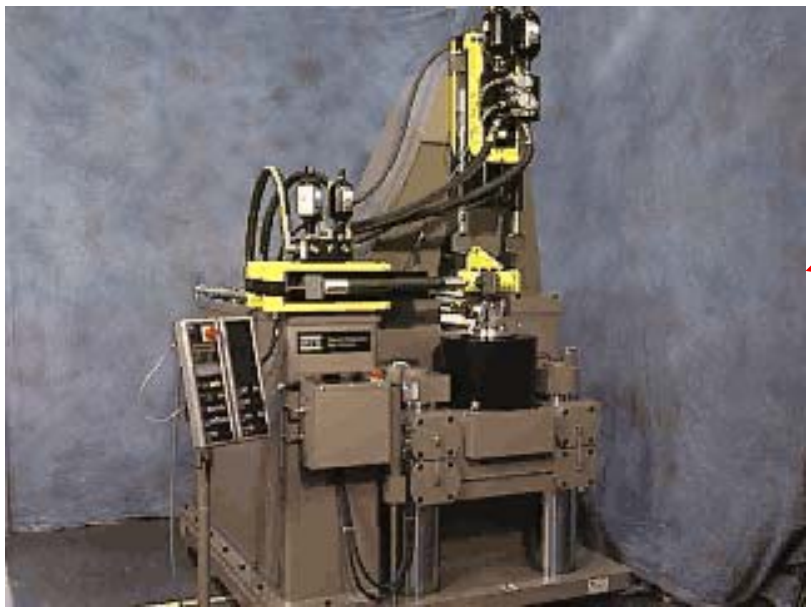


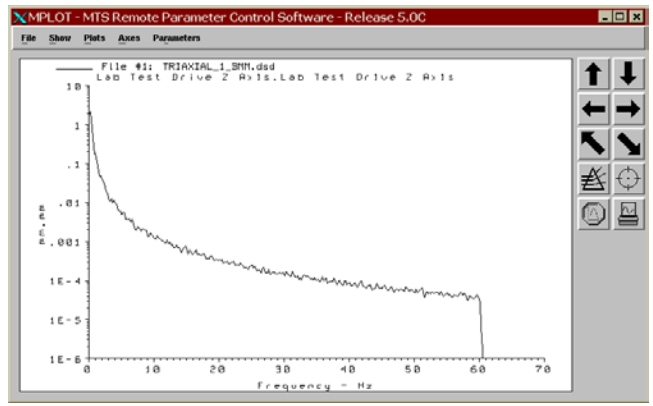
Suspension Bushing Lab Test



- Clamp bushing into rigid fixture







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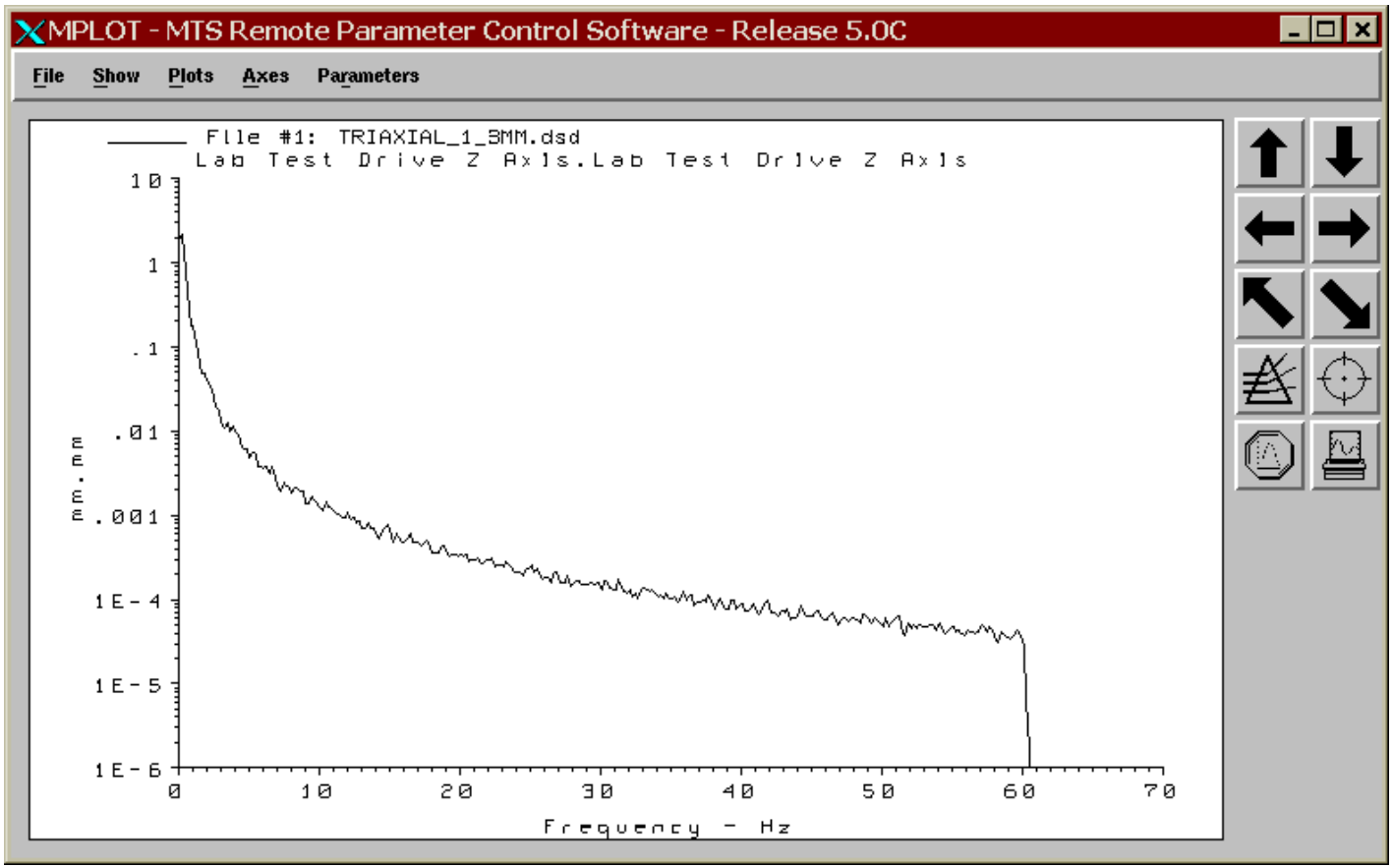
Command Channel Frequency Shape



Measured Predicted

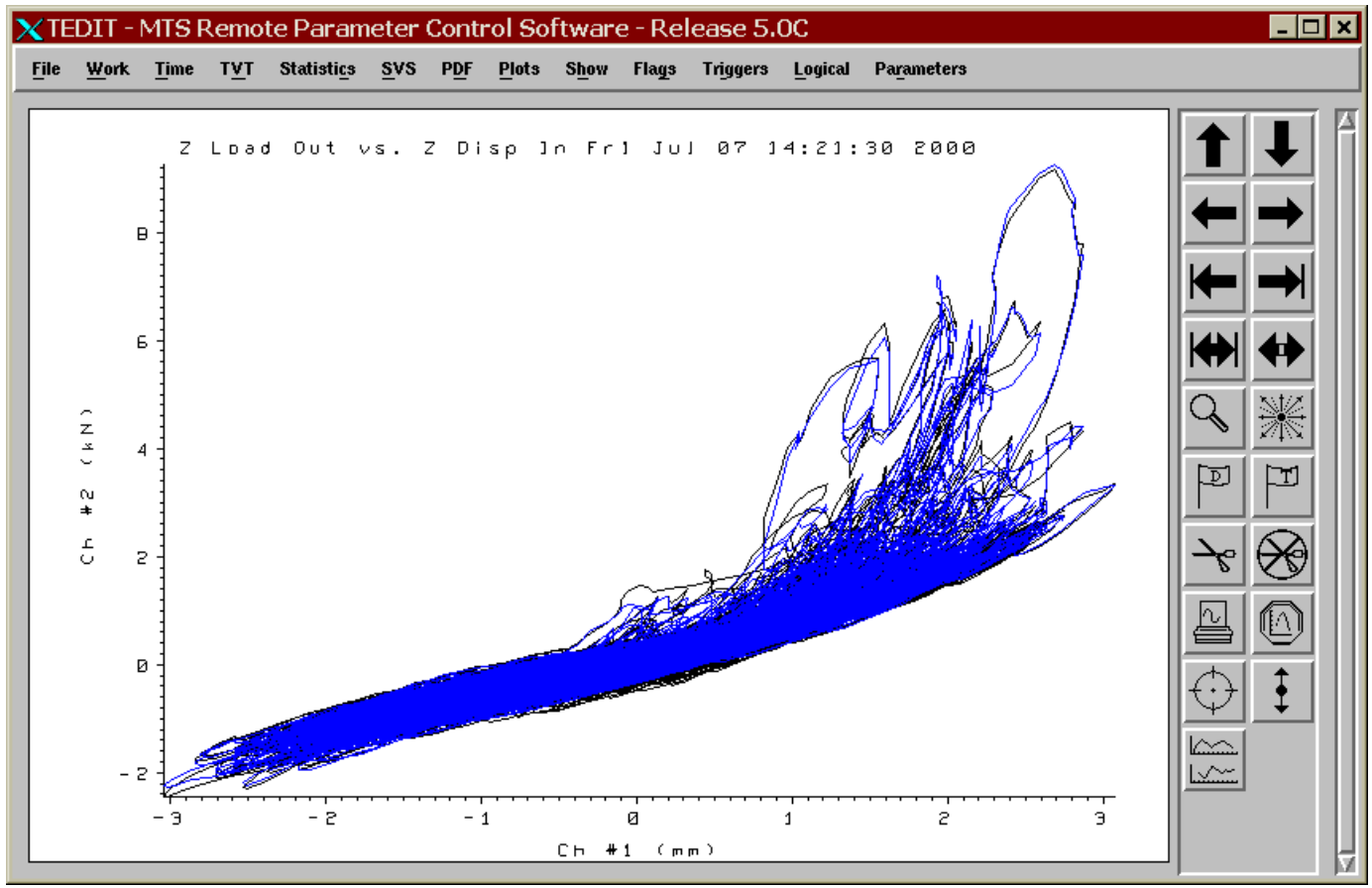
Developed an EDM Model

- Developed a multi-axial model
- Including cross coupled information
  - This can be done currently with specialized subroutines in ADAMS
  - Comes “free” with the EDM MIMO capability

- Input to the model a typical road profile drive signal to predict the bushing response
- Input the same drive signal into the triaxial test rig to validate the response

Bushing Response vs. Model Prediction

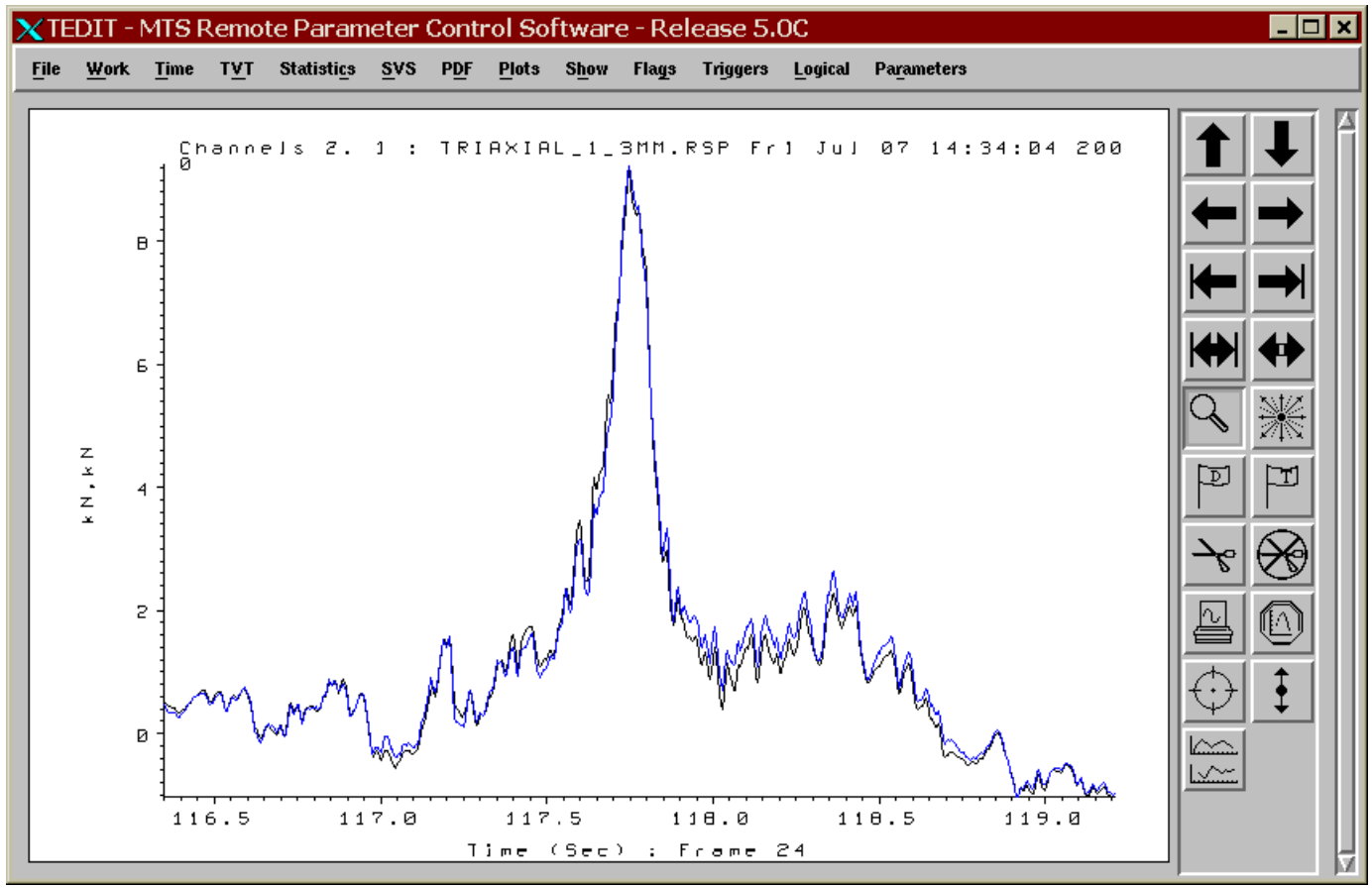
Z Axis (Force) with 100 Epochs



Measured — Predicted

Bushing Response vs. Model Prediction

Z Axis (Force) with 100 Epochs

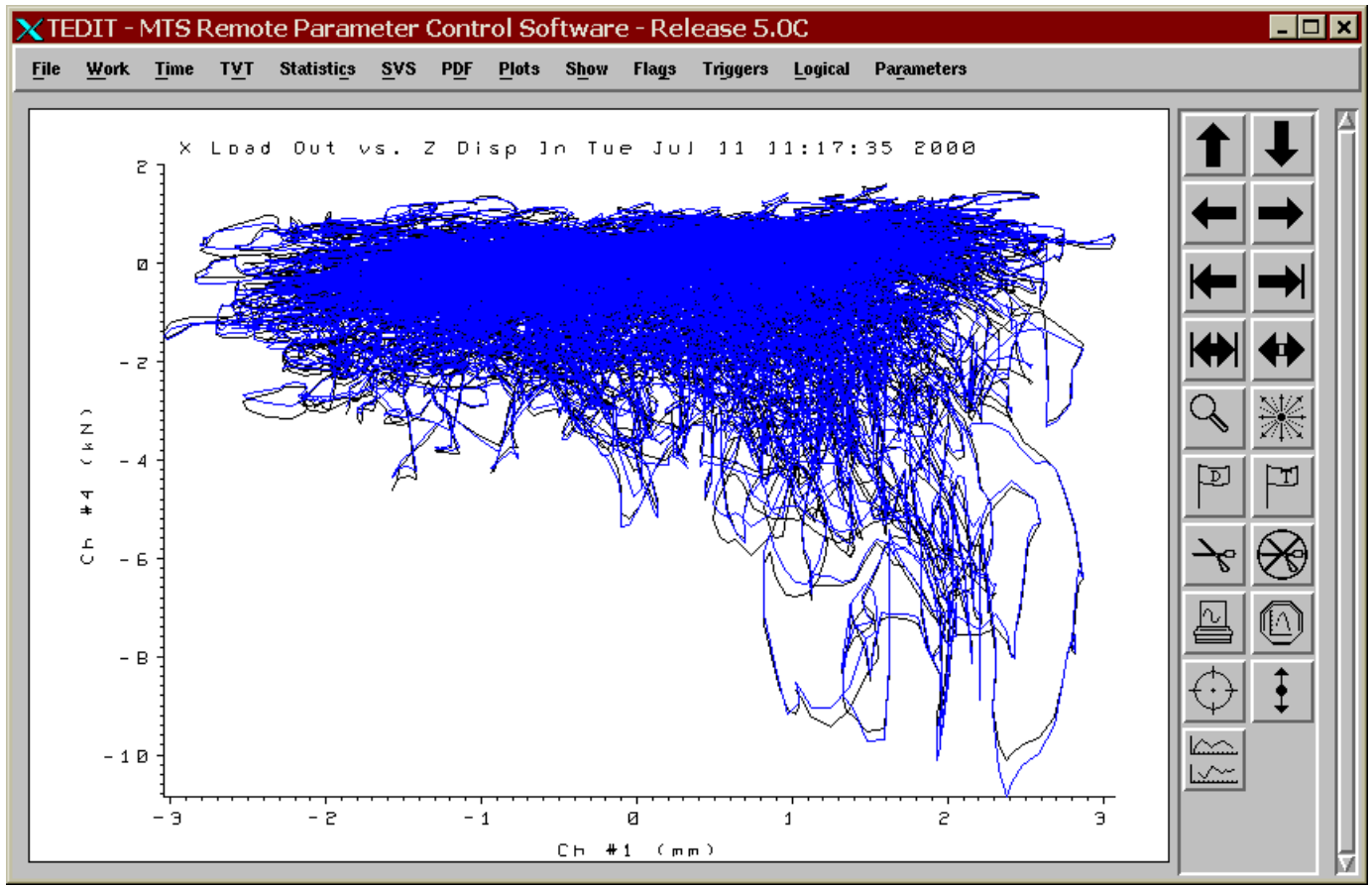


Measured

Predicted

Cross Correlation

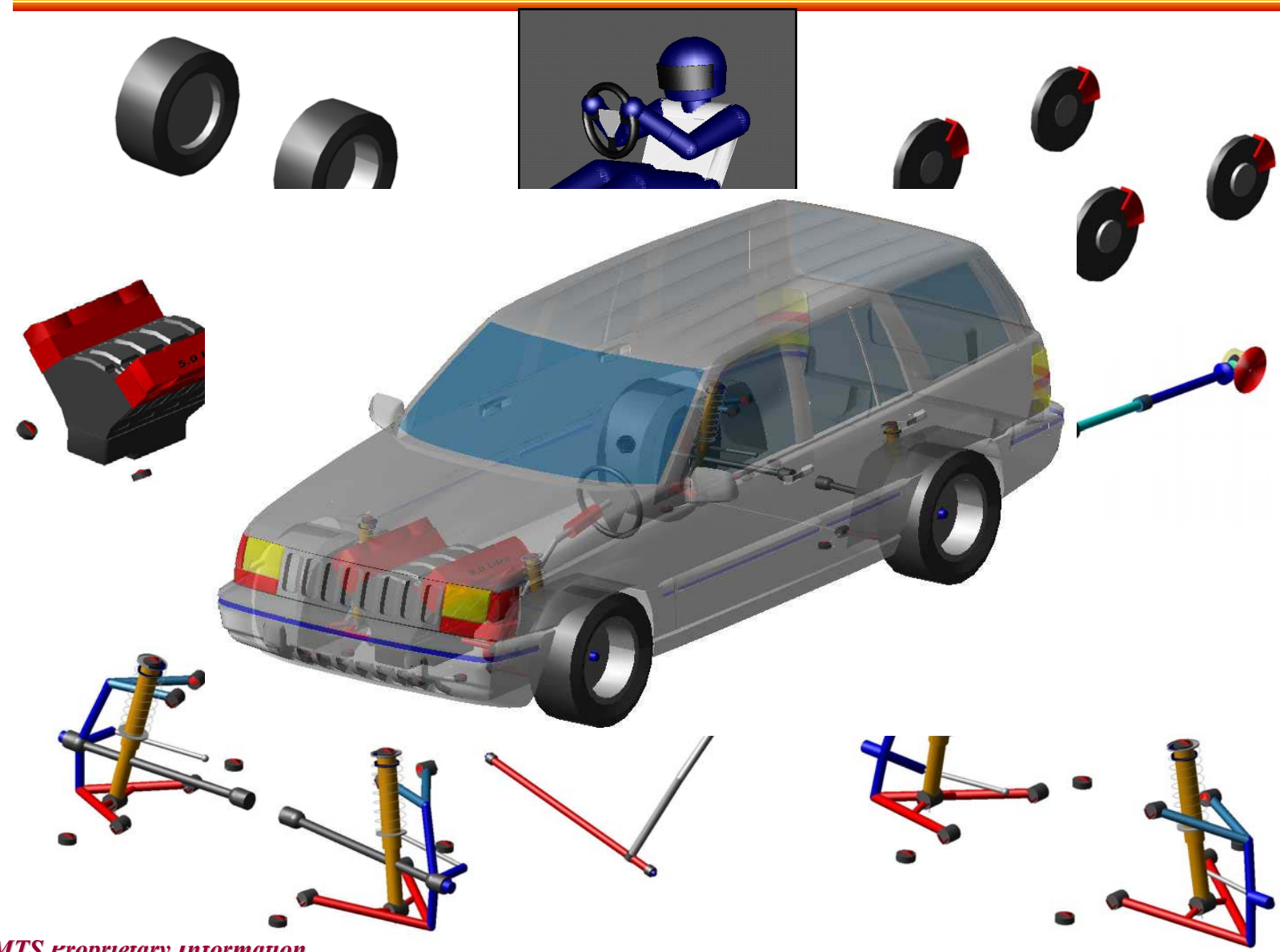
Z Displacement Input vs. X Force Output



Measured Predicted

Development Time Reductions with Virtual Test Lab

ADAMS/Car Creates Vehicle Model



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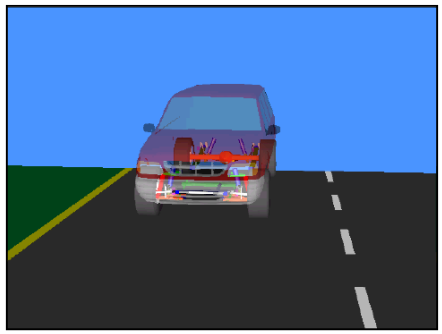
Virtual & Physical Testing Integrated



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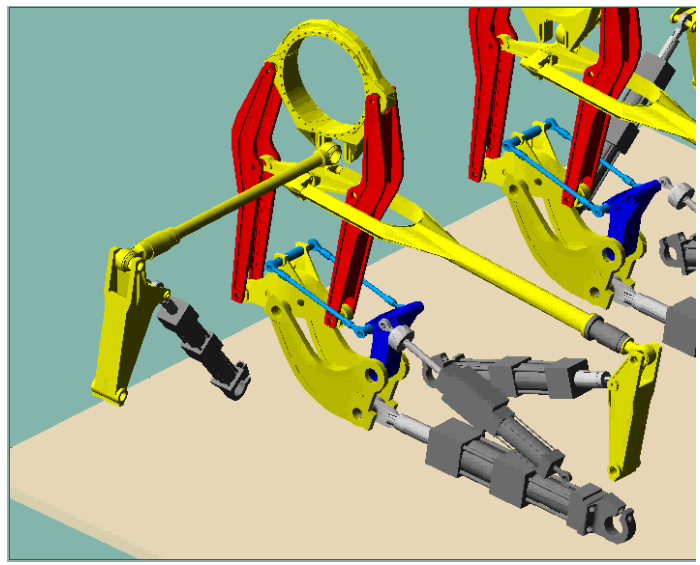
Virtual & Physical Testing Integrated



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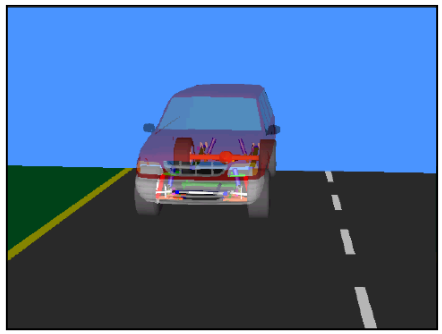
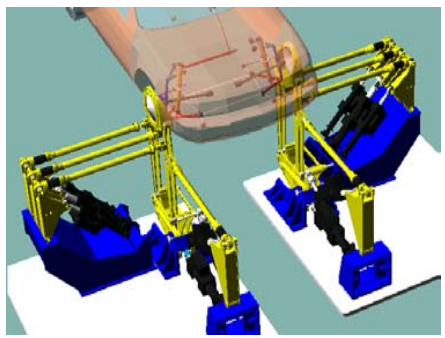
Virtual & Physical Testing Integrated





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Best of Both

Boundary Conditions
Understand Constraints
Faster Correlation
Cheaper - No Track

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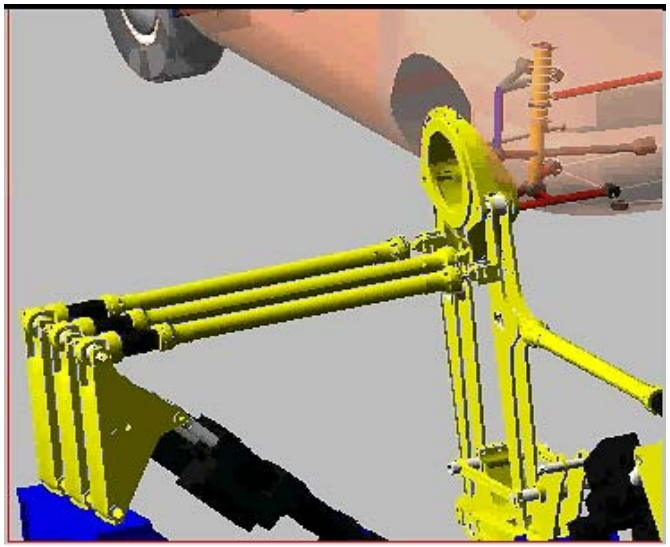
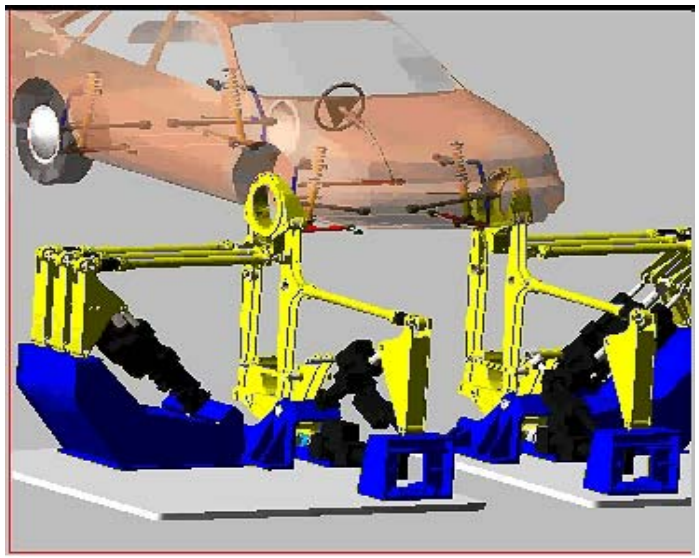
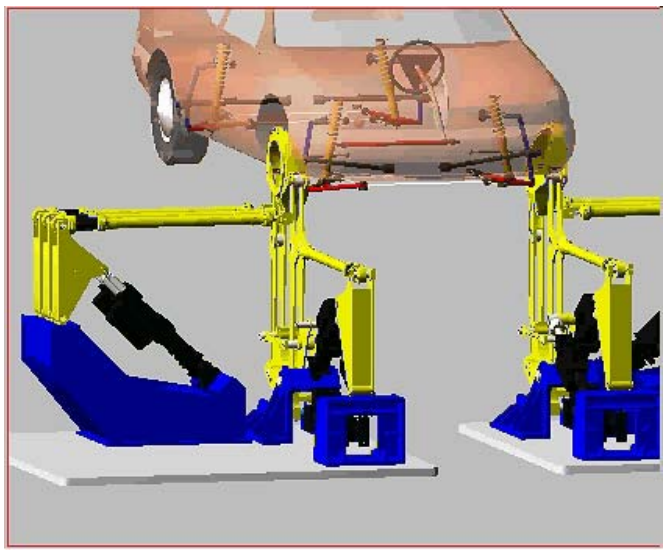
Virtual TestLab™







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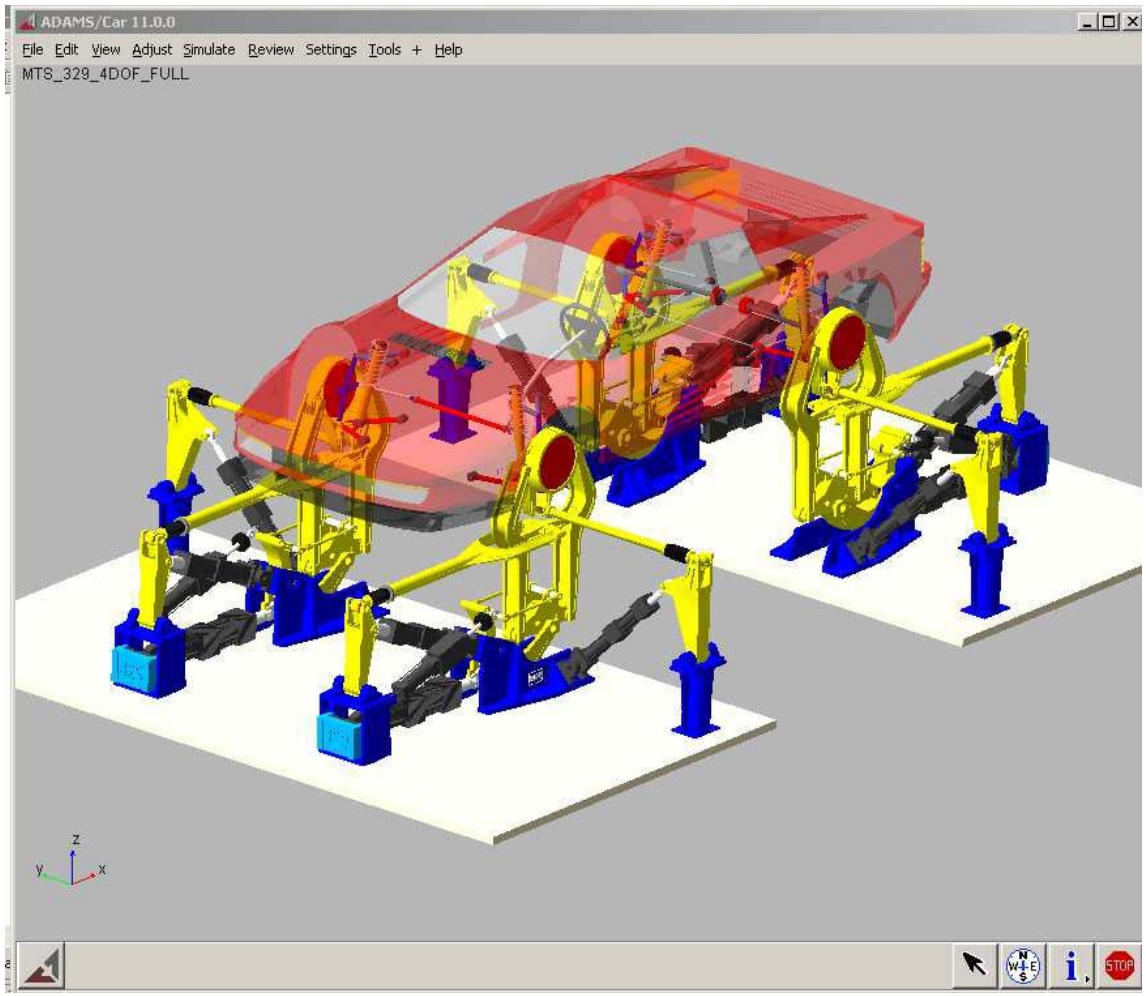
Full Vehicle VTL Customer Case Study



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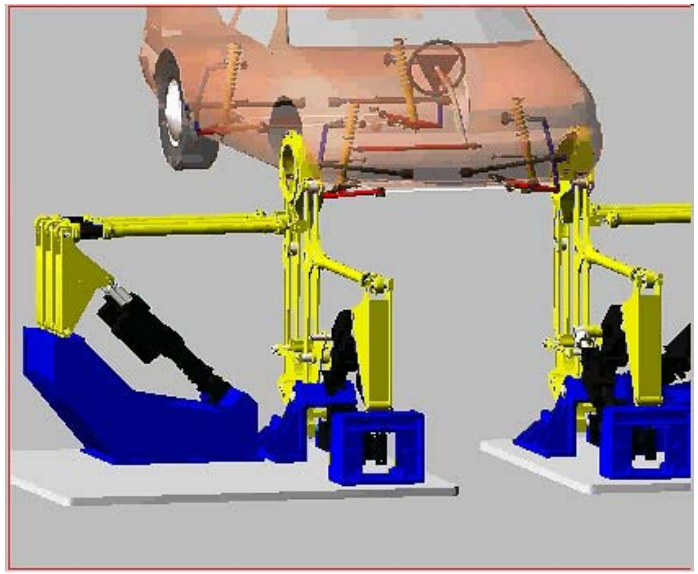
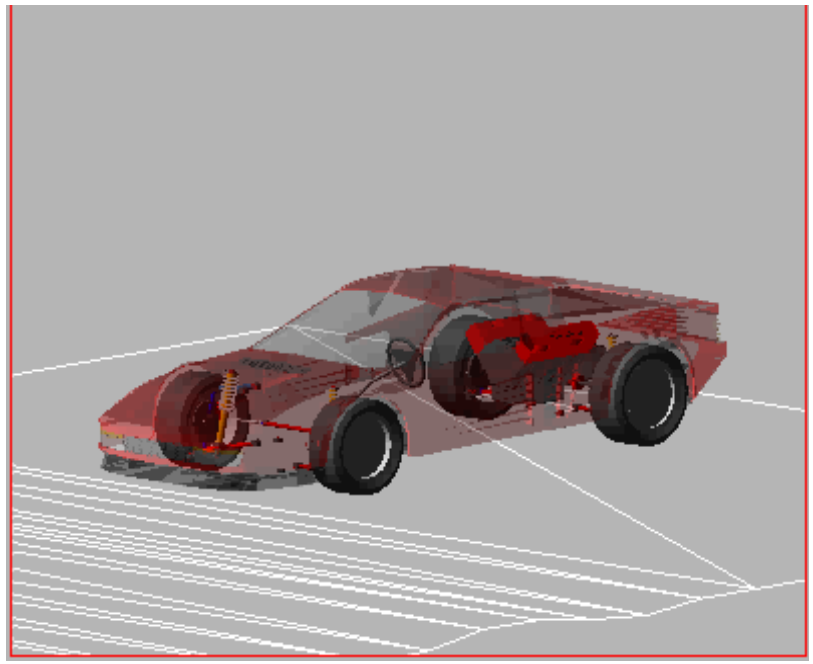
Run the Durability Event





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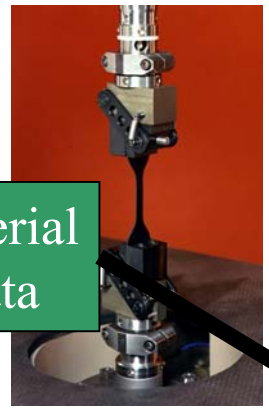
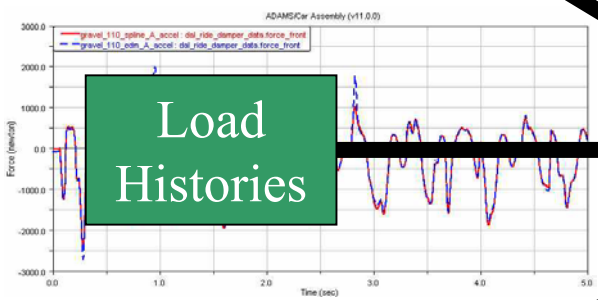
Fatigue - "the 5 Box Trick"



Material Data



Load Histories

Geometry

Fatigue Analysis

Fatigue Life

Traditional fatigue analysis for a single location

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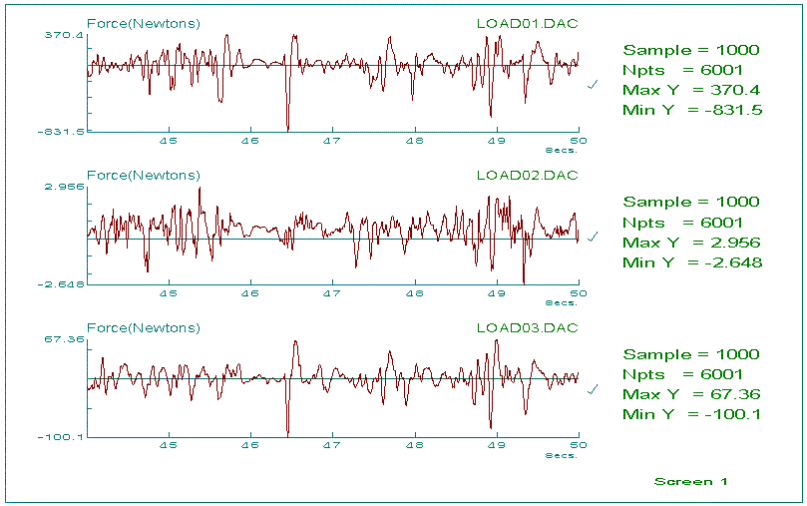
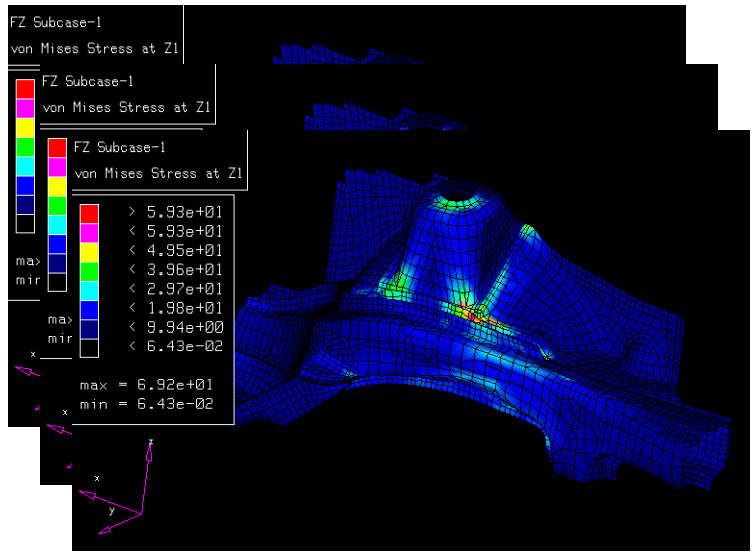
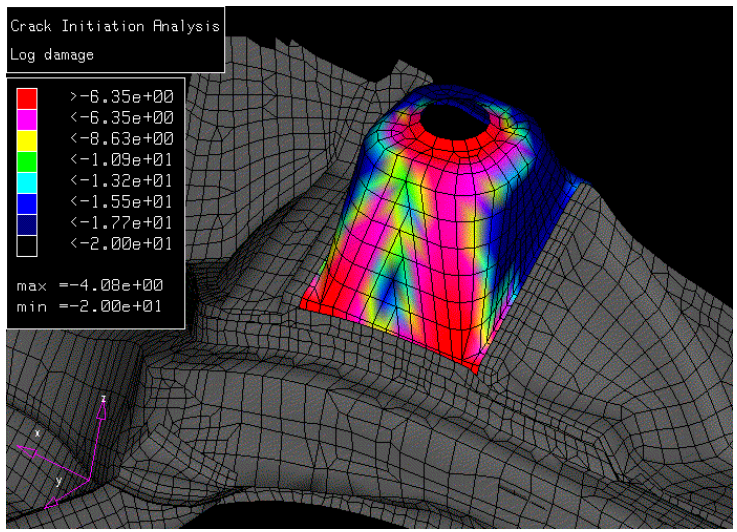
Perform Durability Analysis - nCode

Component Loading Histories



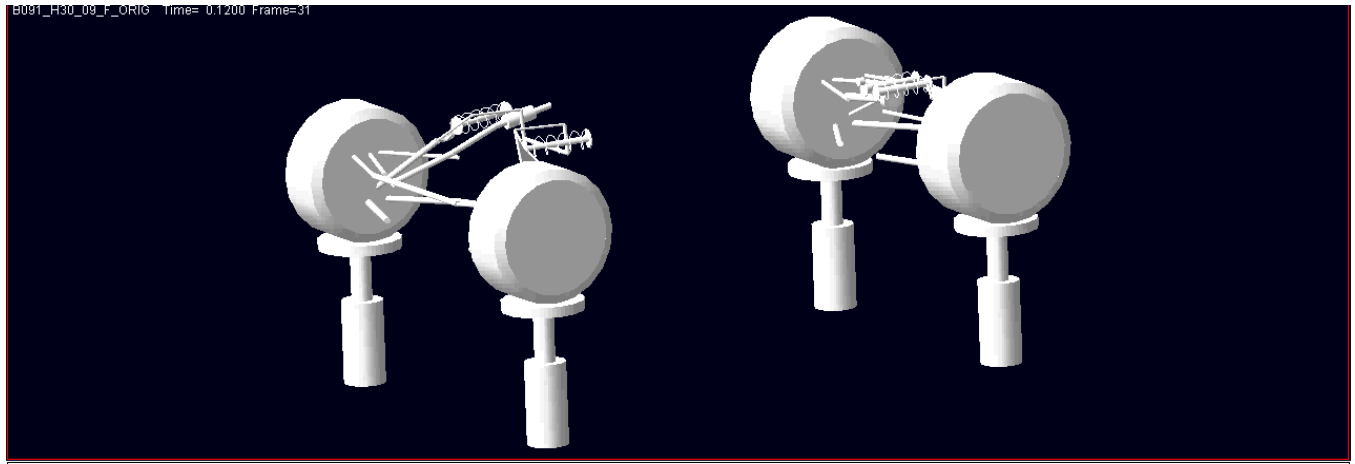
Unit Load Cases

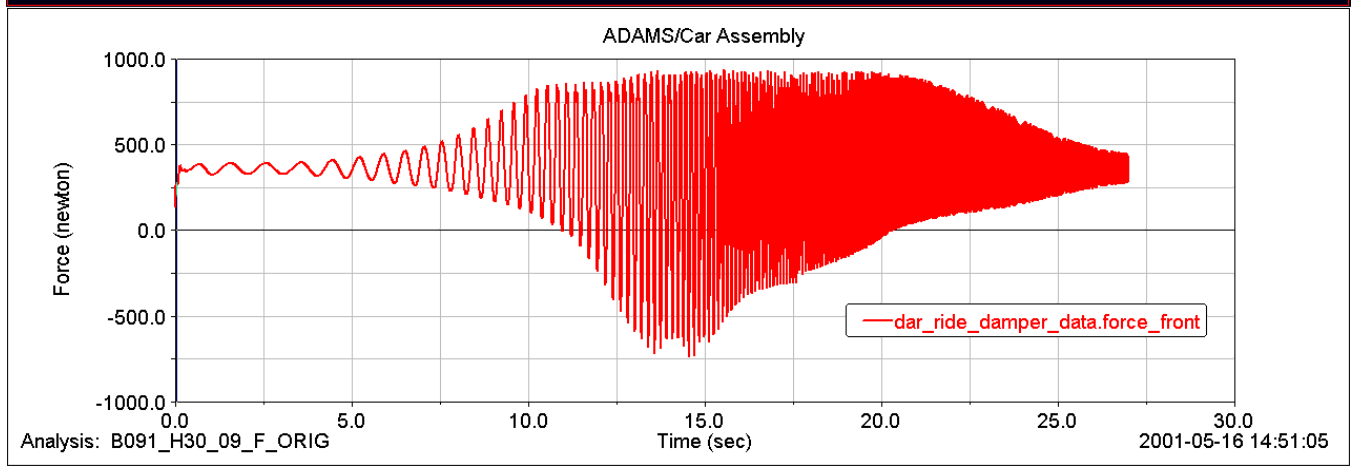




Damage Distribution in Critical Locations

NVH Applications





Uses of Data from the Model

Departments

- Ride
- Handling
- Suspension
- Durability
- NVH
- XYZ Dept.

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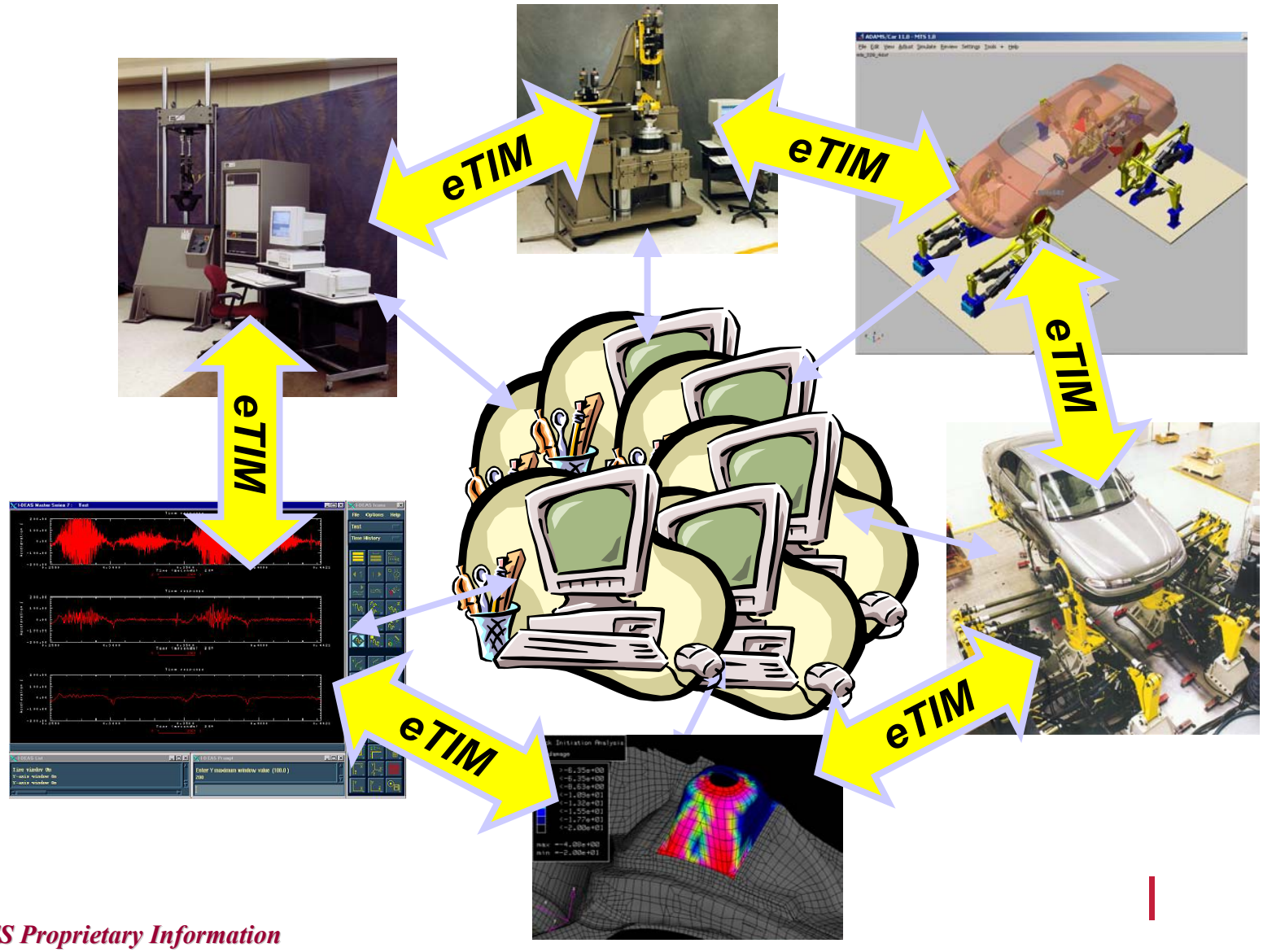
Managing the Information with eTIM



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Test Virtually or Physically?

- Trade-off's in timeliness and quality of results
  - Development front end virtual simulation
  - Development back end physical validation
- Trade-off's in cost
  - Sometimes physical tests are faster and cheaper
    - Prototypes are required
    - Test Equipment is required

Complete Integrated Solutions

- Predictive design and analysis tools integrated with CAD & FEA models
  - ADAMS for multi-body dynamic simulation and evaluation, design of experiment, ride and handling
  - MTS Virtual Test Lab for virtual simulations in a parallel process
  - nSoft for fatigue analysis from predicted or measured loads
  - MTS NVH tools and analysis from predicted or measured results
- Validation systems and methods
  - Creation of empirically created models
  - MTS' physical testing solutions for component, sub-system and complete vehicle validation
- Information Management for the design process - eTIM
- Professional Services to help integrate the complete solution

MTS

Mechanical Dynamics

nCode