# The Integration Of Analysis And Test For Full Vehicle Structural Durability

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# Who & What is Deere?

- **De-Centralized Company evolving to global manufacturing of products.**
- **Mid-sized company - $13B.**
- **Improved communication & time compression forcing change in processes. Collaboration not an option - rather a requirement.**
- **Most of products are specialized vehicles operated in a range of off-road conditions at high-power levels for long periods of time.**
- **Mature products with customer expectations of high durability and availability**

# The Challenge - Global Sharing of Technology & Techniques

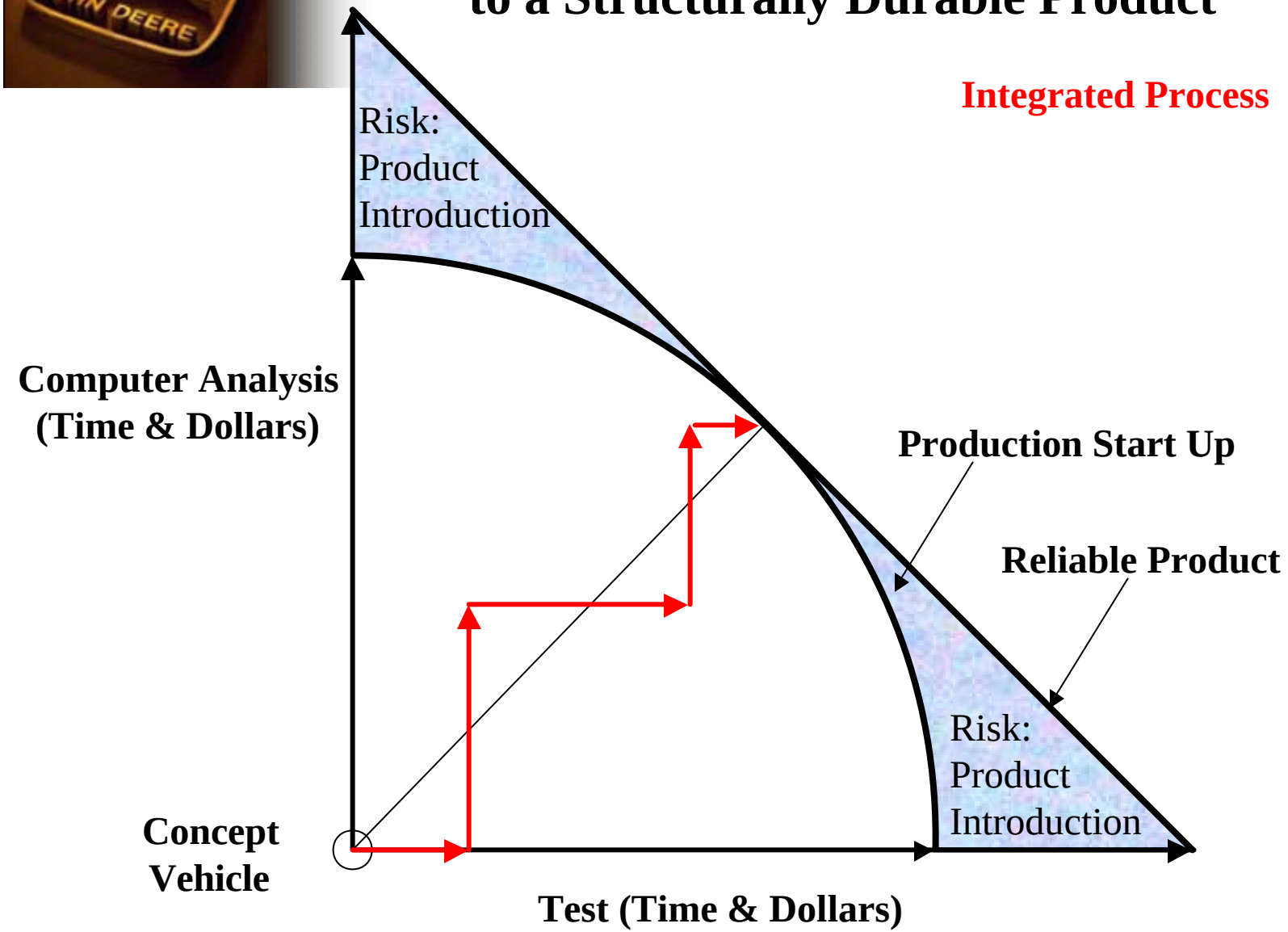
- Design Anywhere - Manufacture Anywhere
- About 40 Engineering Locations - Depending on Definition of Product Engineering
- Diverse Products - Tractors, Combines, Forage Harvesters, Log Skidders, Dozers, Backhoes, Road Graders, Balers, Lawn & Garden Tractors, Mowers, Chain Saws, Etc.
- Increased Competition
- Faster Pace => More simulation & analysis.

# Structural Durability Development Through Integration Of Analysis And Full Vehicle Test

**What & Why:**

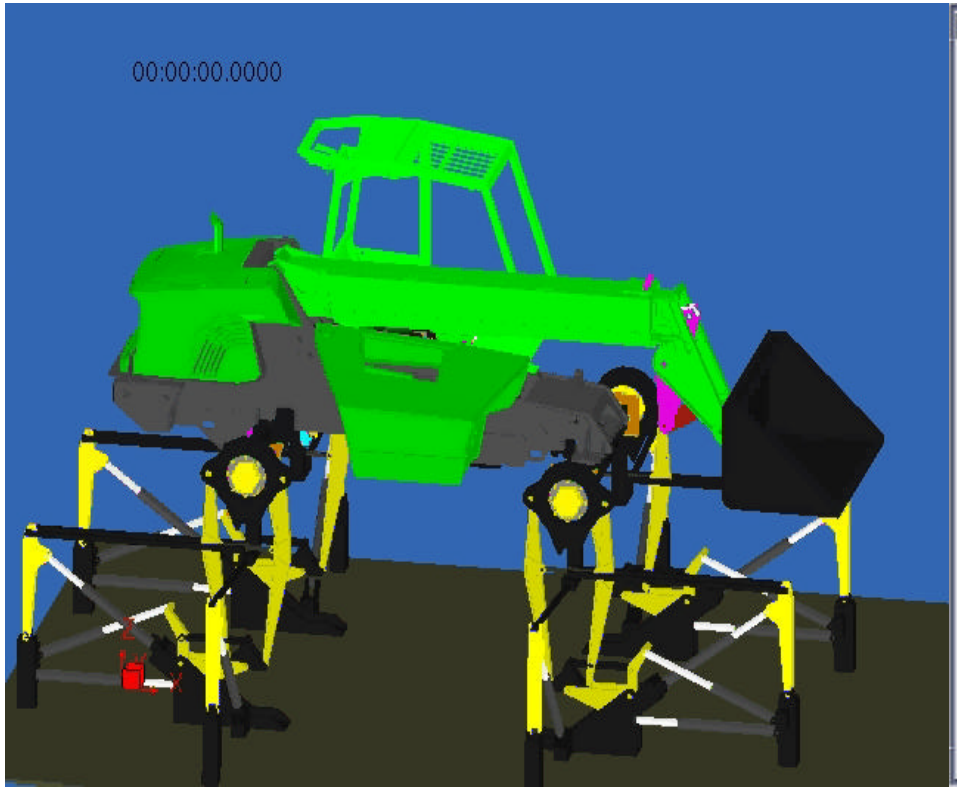
- Correlate Fatigue/Finite Element/Dynamic Analysis to the Lab (Field) Test
- "Field Test" the Structural Design in the Computer Before Building the Hardware
- Establish Confidence in Fatigue Predictions By Comparing to Actual Test Fatigue Lives
- Define Subsystem Load Information from the Dynamic Model/Lab Test Load Histories
- Obtain Fatigue Life Contours for Multiple Load Inputs for the Composite Duty Cycle

# Optimal Computer Analysis/Test Path to a Structurally Durable Product

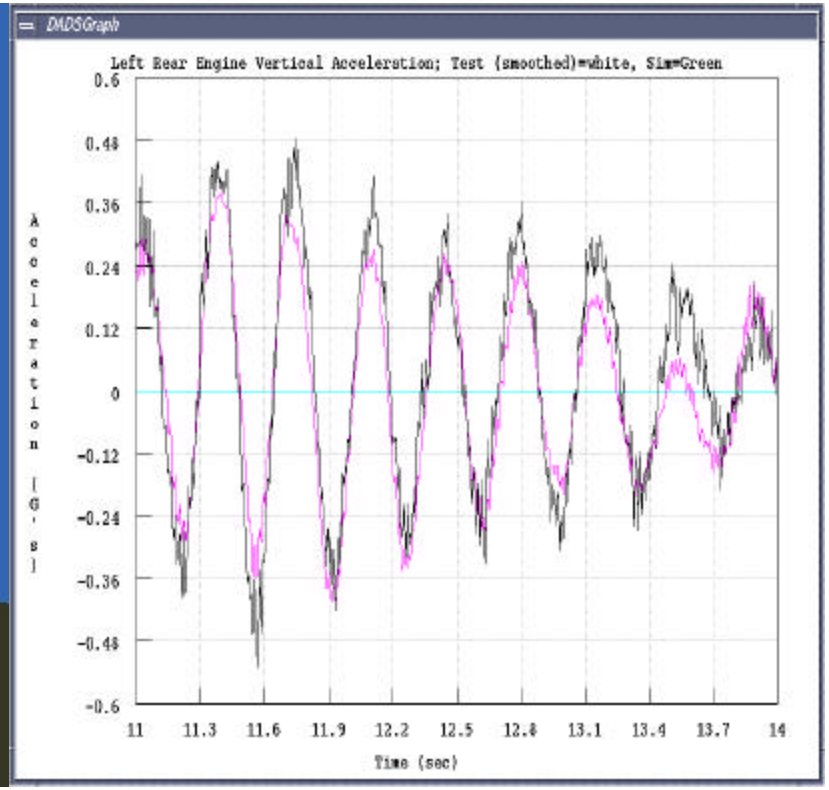


# Dynamic Model of Telehandler and Correlation with the Lab Test

Dynamic Model
Rough Transport Empty

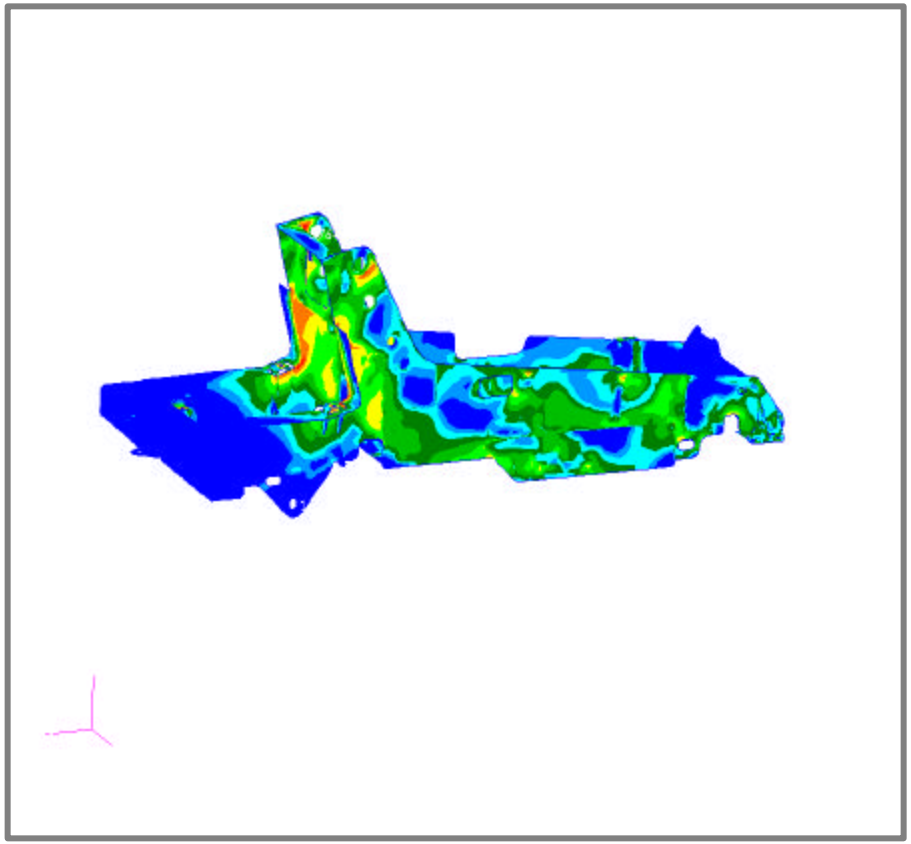



Left Rear Engine Vertical Acceleration Correlation between Dynamic Model and Lab test

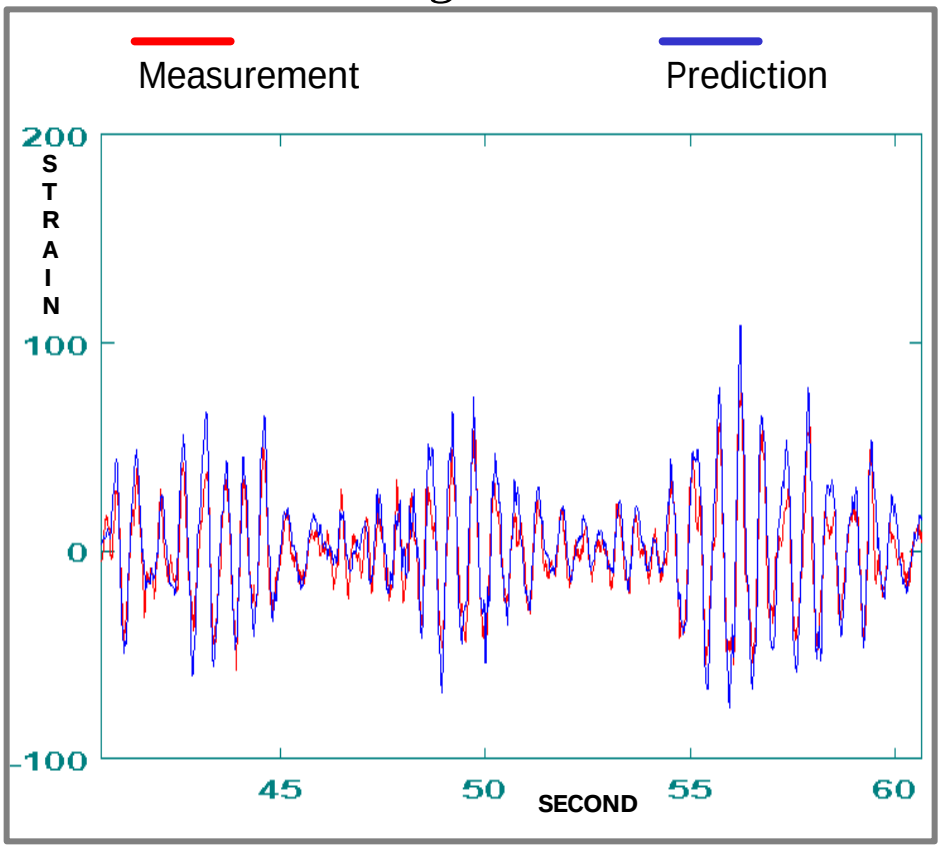


# Finite Element Model of Telehandler Chassis and Correlation with Strain Gage Measurement from a Lab Test

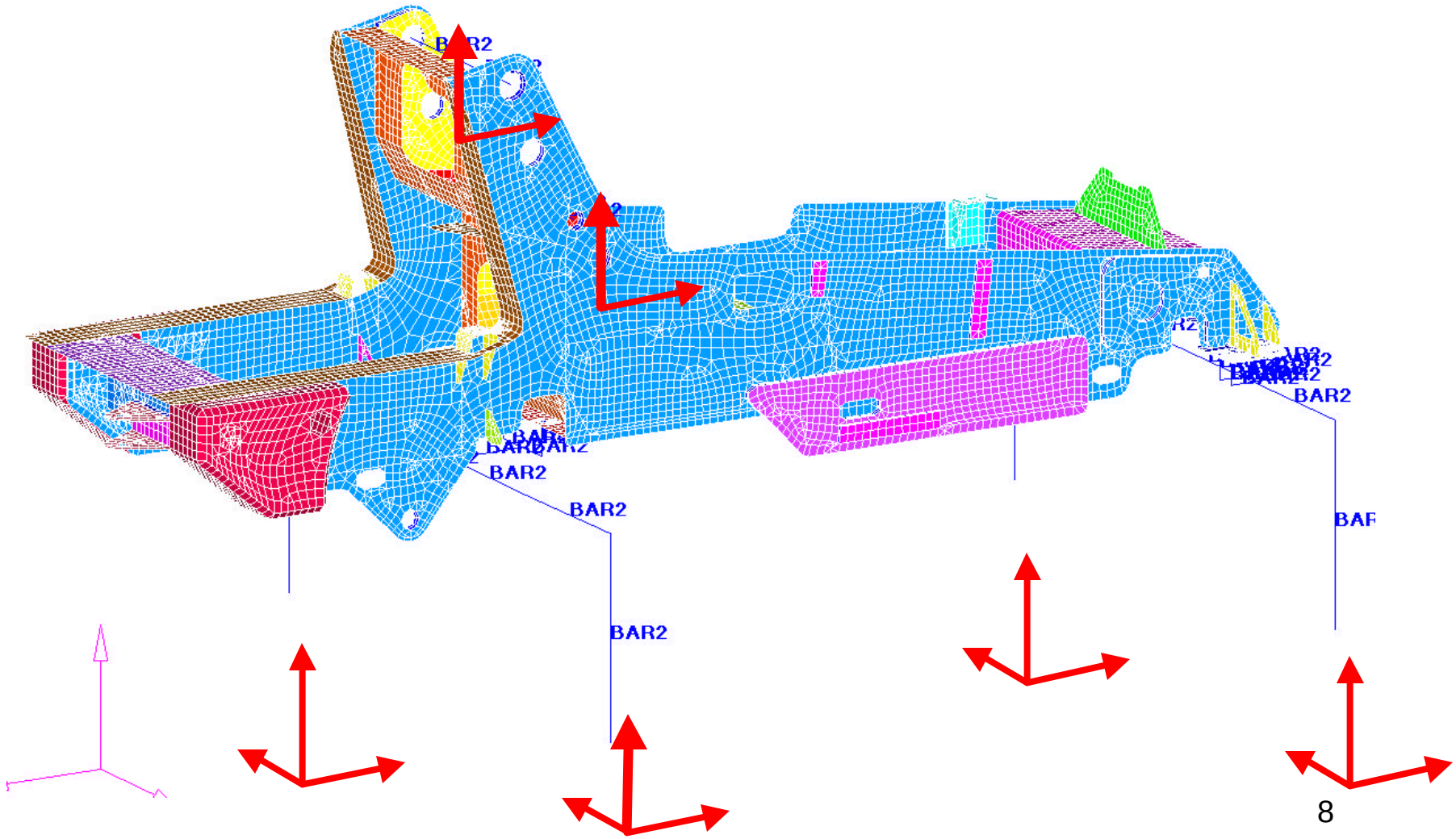
Strain Contour of the Finite Element Model



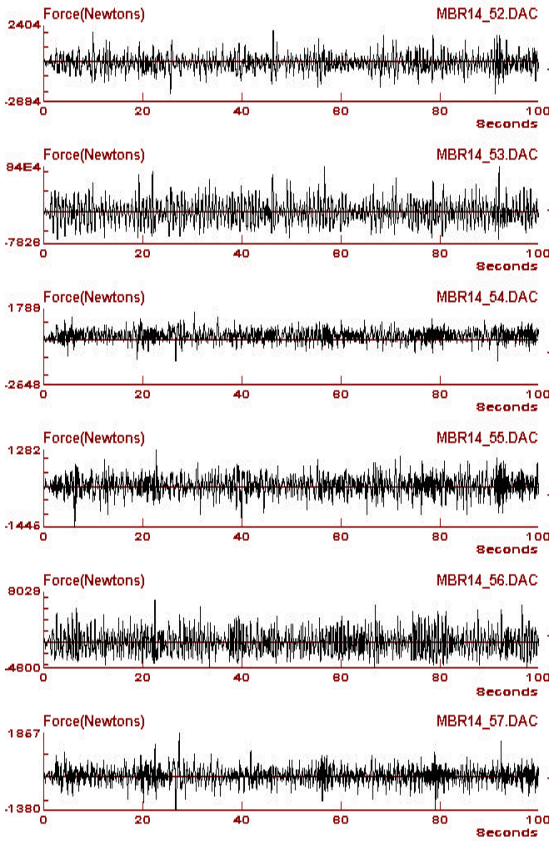
Strain Correlation between Finite Element/Fatigue Model and Lab test

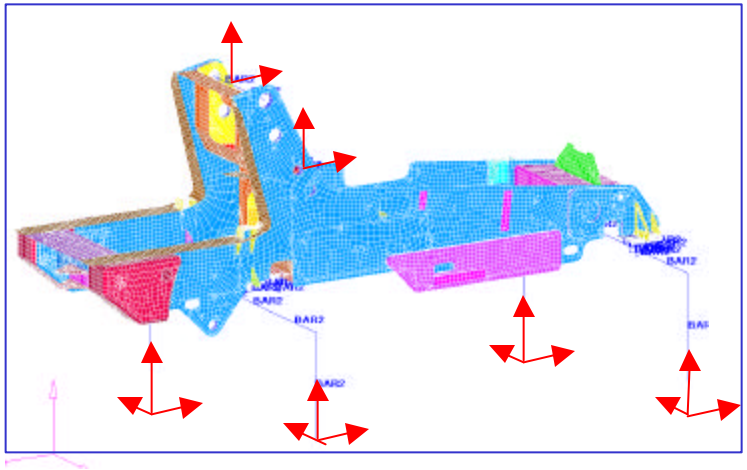


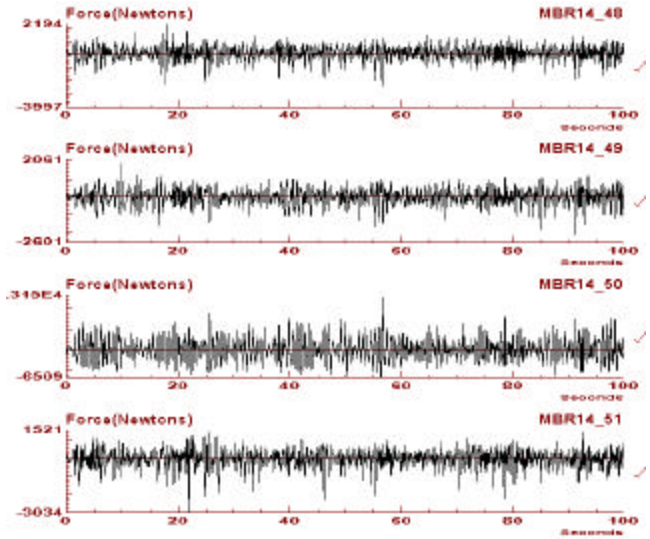
# Finite Element Model of Telehandler Chassis and Multiple Load Inputs

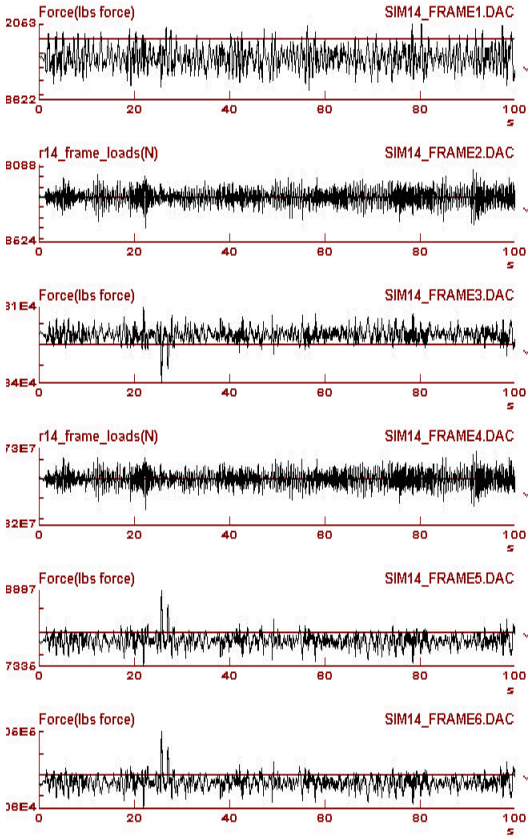


# Time Histories Associated with the Multiple Load Inputs

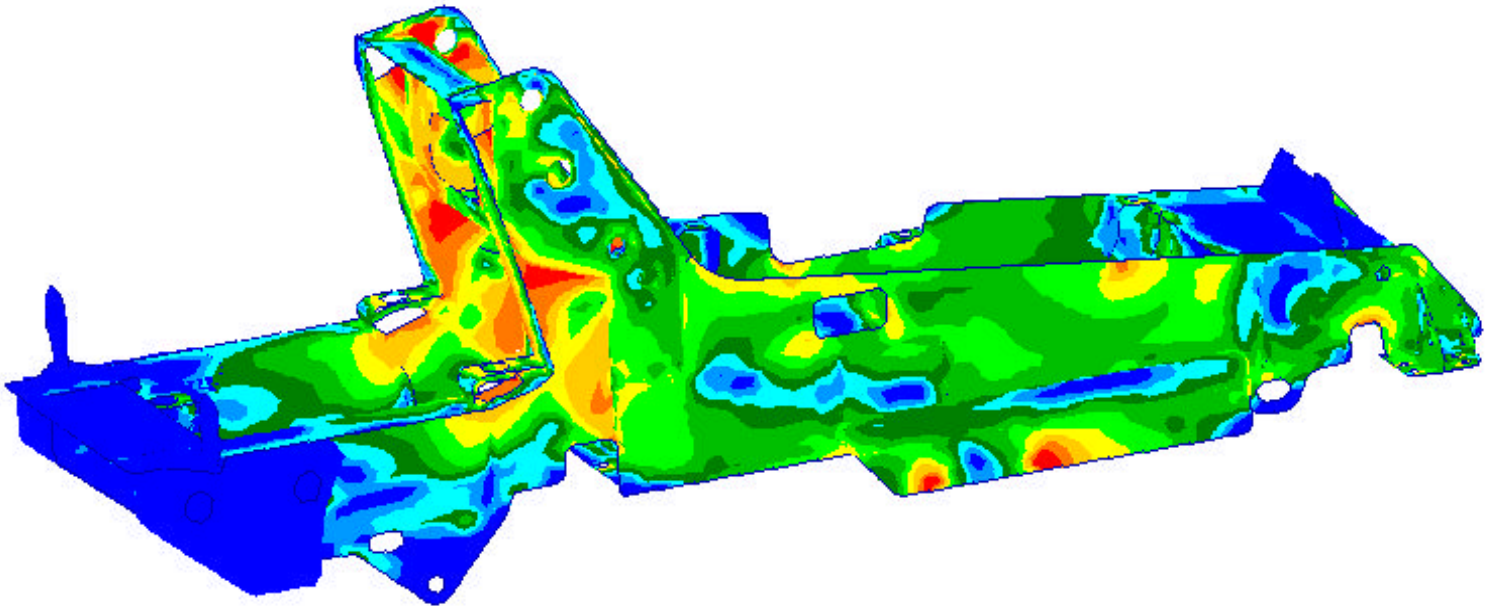


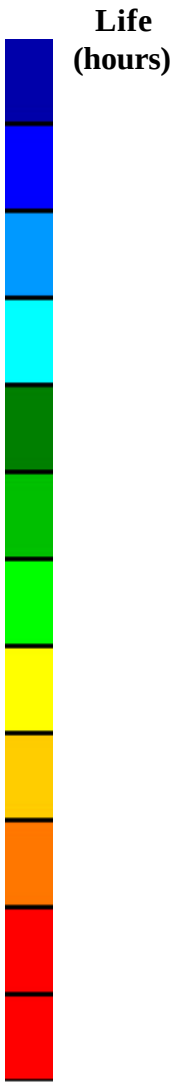





# Fatigue Life Contours of Chassis for Truck Load Lime Operation

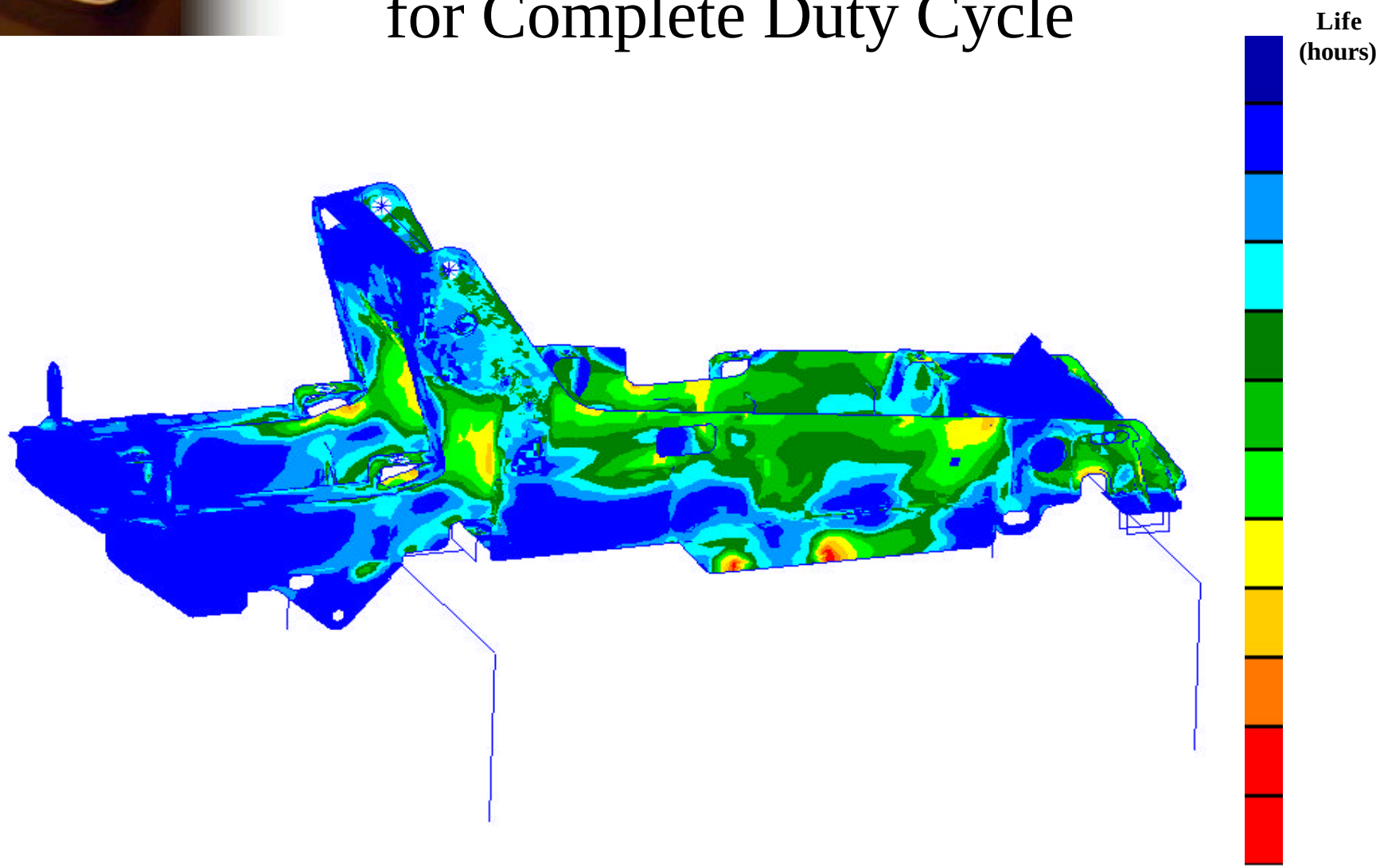




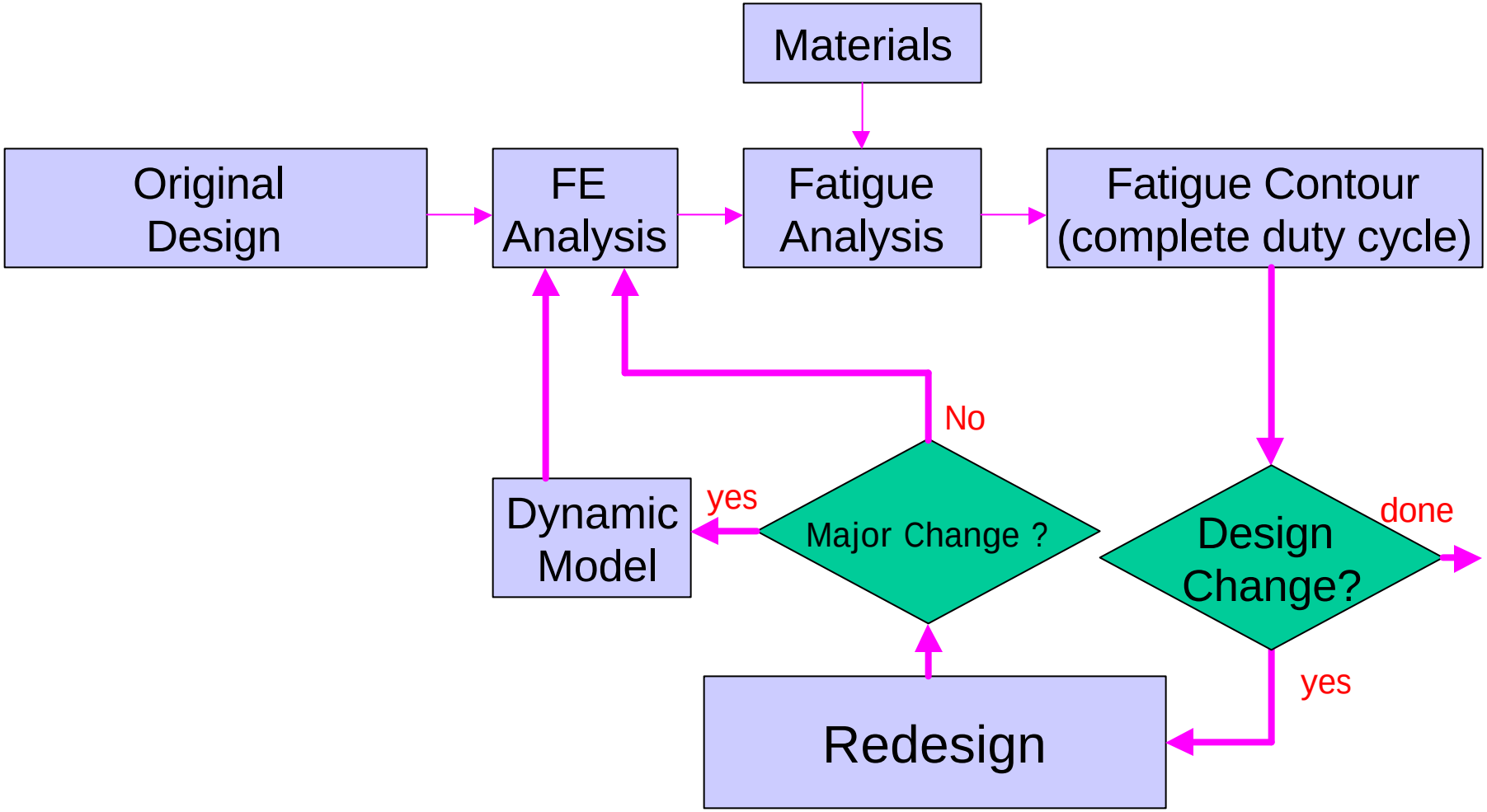
# Lab Rig Operations - Need Percentages of Test Time

| | |
|---|---|
| • Normal Transport Loaded | xx% |
| • Figure 8's Empty | xx% |
| • Push Up Silage and Compact | xx% |
| • Truck Load Lime | xx% |
| • Muck Out Pit | xx% |
| • Truck Load Gravel | xx% |
| • ... | xx% |
| • ... | xx% |
| • ... | xx% |

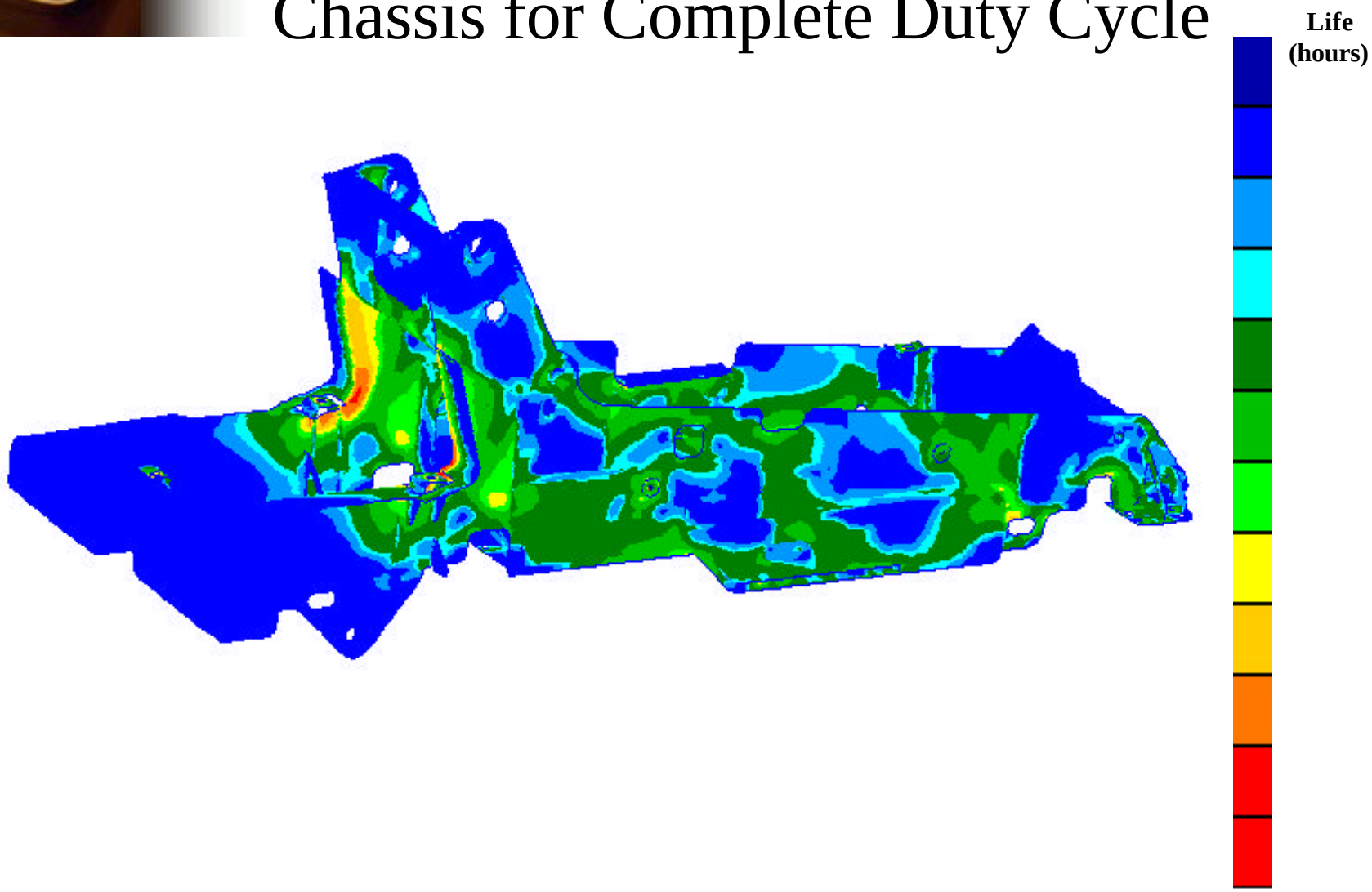
# Fatigue Life Contours of Chassis for Complete Duty Cycle



# Structural Design Iteration Process

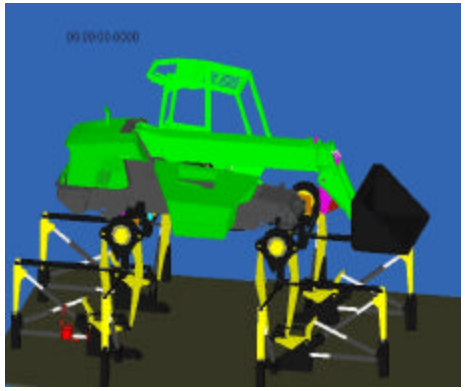


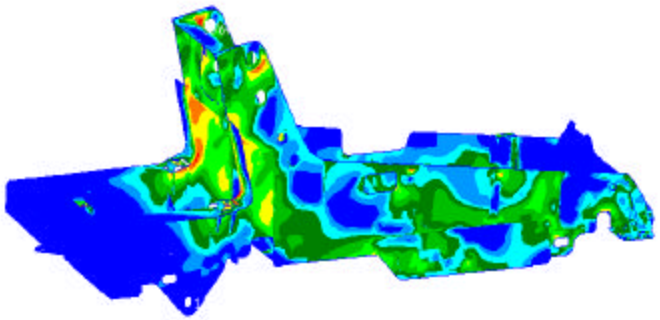
# Fatigue Life of Second Re-Designed Chassis for Complete Duty Cycle



# From Competitor Evaluation to Final Build

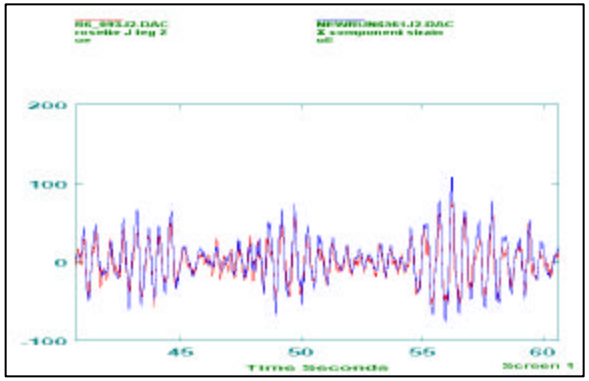
- **Competitor Evaluation**
  - Field Data Acquisition
  - Lab Test
  - Dynamic Model - Validate
  - Finite Element & Fatigue Analysis - Validate
- **Current Production**
  - Field Data acquisition
  - Lab Test
  - Dynamic Model - Validate
  - Finite Element & Fatigue Analysis - Validate
- **Initial Design**
  - Dynamic Model
  - Finite Element & Fatigue Analysis
  - Prototype Build (for durability evaluation)
- **Design Iterations**
  - Finite Element & Fatigue Analysis
- **Final Design**
  - Lab Test (validation - 3rd production vehicle)





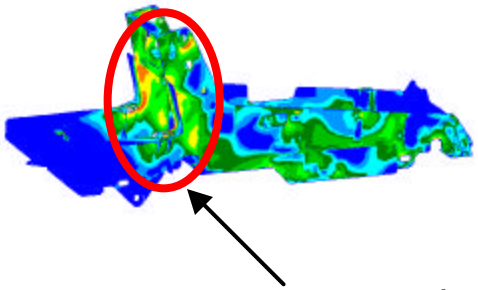
# Analysis Highlights

- **Confidence in the Process**
  Excellent correlation between measured (Lab Test) and predicted (Dynamic-FEA-Fatigue) strains.




- **Analysis before Prototype Build**
  Fatigue analysis of initial Deere design highlighted problem areas, enabling re-design before first prototype build.

- **Development of Analysis Process**
  - Dynamic Model - DADS
  - Finite Element Model - Hypermesh
  - Finite Element Analysis - Abaqus (unit load cases)
  - Fatigue Analysis - MSC/Fatigue



Primary Re-Design Focus Area

- **Enhancement of Analysis Process**
  - Frame : 3 major designs iterations in 6 months
  - Inner Boom : 6 major design iterations in 2 months
  - Outer Boom : 2 major design iterations in 1 month

# Lessons Learned

- It’s not easy!
- Requires experienced personnel.
- Both test and analysis have equal weight and value in the design iteration effort.
- Acceptance is comparable to any new technology - requires proof and then becomes part of the routine process.

# Conclusions

- Full Vehicle Structural Durability Behavior Is Predictable
- Prediction of Full Vehicle Structural Durability Behavior Is Fast Enough to Be Practical
- Prediction of Full Vehicle Structural Durability Behavior Is Cost-Effective
- The Durability of a Structure Can Be Optimized Using Computer Models Before Production