

Load Measurement And Linear Dynamics



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Integrated Solutions from
Wolf Star Technologies

The Tools

Abaqus/CAE plug-ins



True-Load™

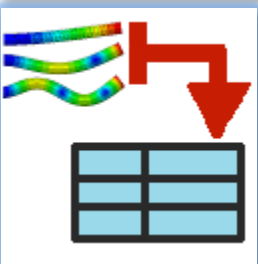
Turns Components into load transducers



True-QSE™

Quasi-Static Events

Linearly Superimpose results via user defined functions



True-LDE™

Linear Dynamic Events

Post-Process Abaqus linear dynamic solutions

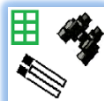
**MODAL DYNAMIC, *STEADY STATE, *RANDOM RESPONSE*

fe-safe®

FEA based fatigue



True-QSE™



True-Load™



True-LDE™

True-Load™



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Overview ...

Motivation

- What's the load?
- True-Load provides
 - Strain correlated loading
 - Full field knowledge from a handful of strain gauges
 - Easy interface to fe-safe®
- First to market solution



Traditional Methods

Load Transducers

- ✗ Expensive
- ✗ Requires changes to components / systems
- ✗ Changes stiffnesses
- ✗ Changes load paths
- ✗ Not aligned to analysis

Strain Gauges

- ✗ Heuristic Placement
- ✗ Complex loading → Complex strains
- ✗ Impossible to correlate to FEA
- ✗ Unique loading recipe at every point in time

GIGO → Doomed to repeat design / analyze / build / test

The True-Load™ Solution

- In-situ load measurement
- Turns complex components into multi-channel load cells for recording load histories
- Leverages FEA Model and Test Data
- Works with Abaqus CAE
- Optimal placement of Strain Gauges
- Direct interface to fe-safe®



True-QSE™

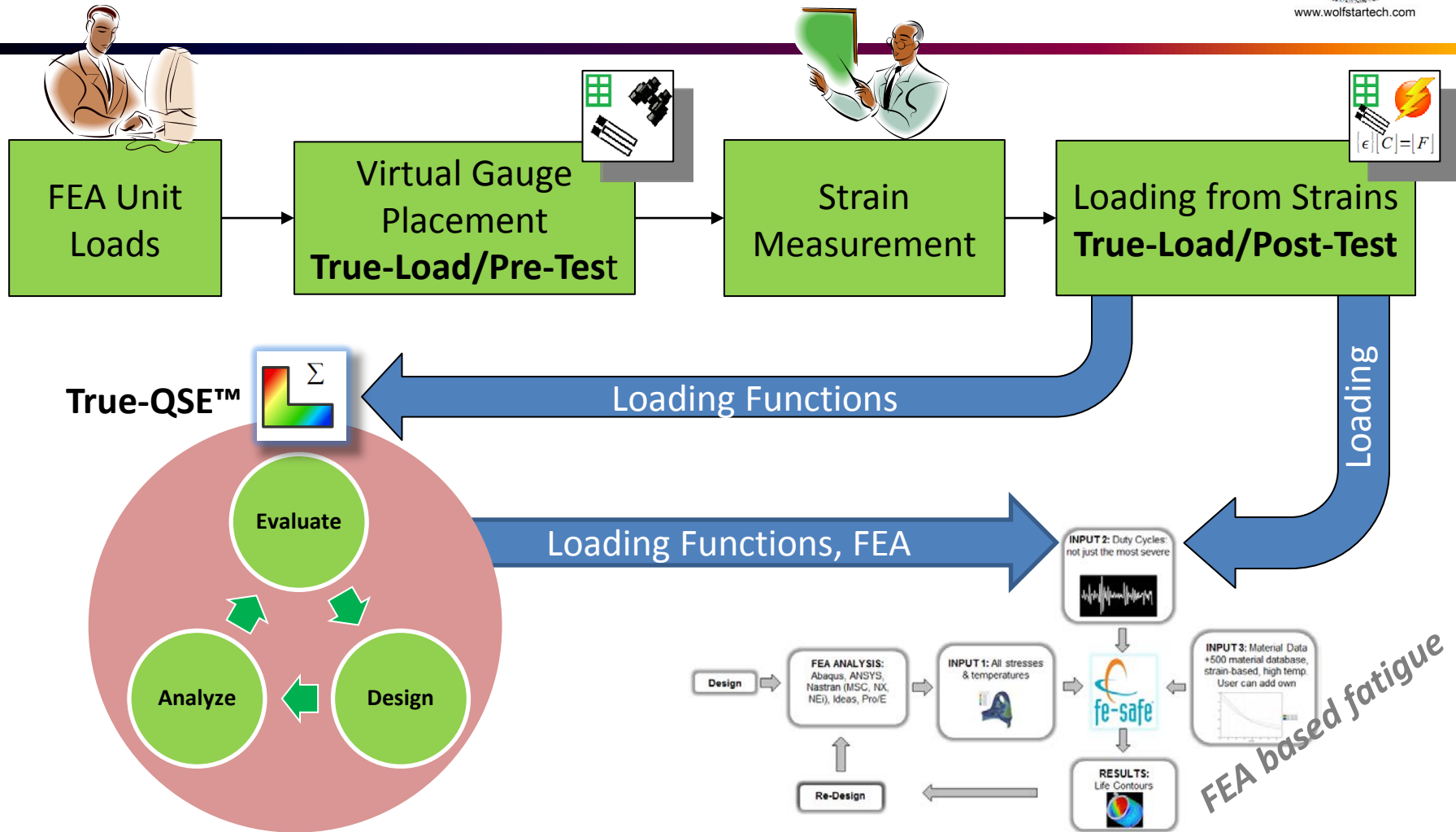


True-Load™

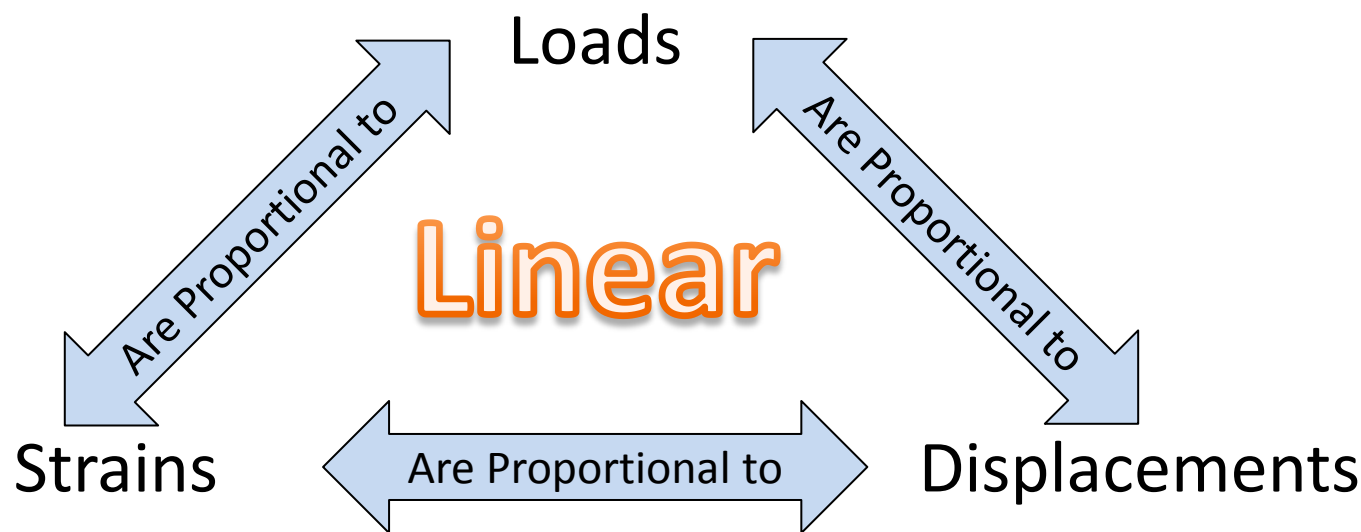


True-LDE™

The True-Load™ Workflow



Linear Systems and Loads



In other words

$$F = Kx$$

and

$$\epsilon C = F$$

From Test

From FEA

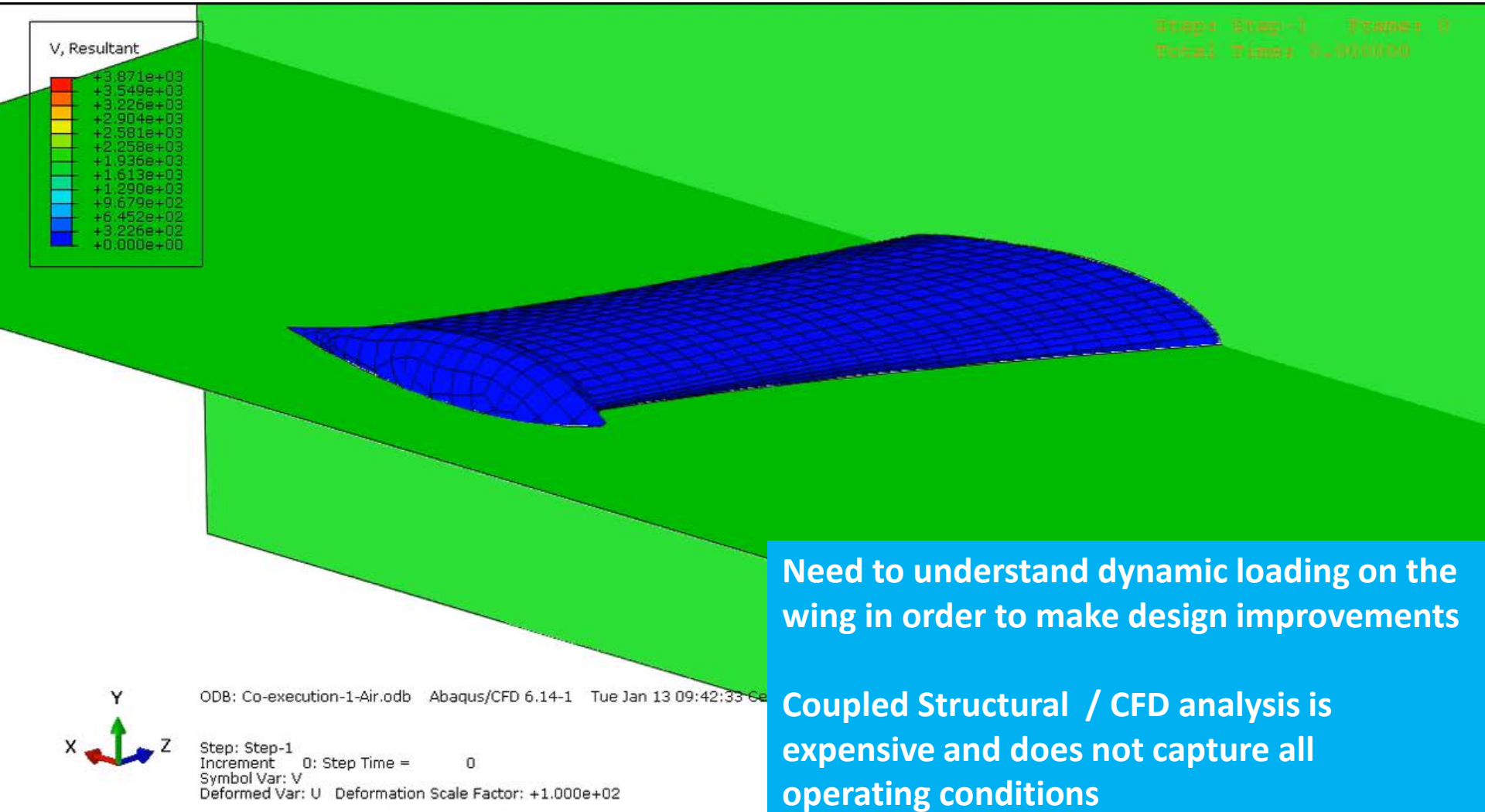
$$F = \epsilon C$$

Forces from strains

F, Load vector
K, Stiffness matrix
 ϵ , Strain matrix
C, Correlation Matrix

Problem Statement

Airplane Wing Dynamic Loading

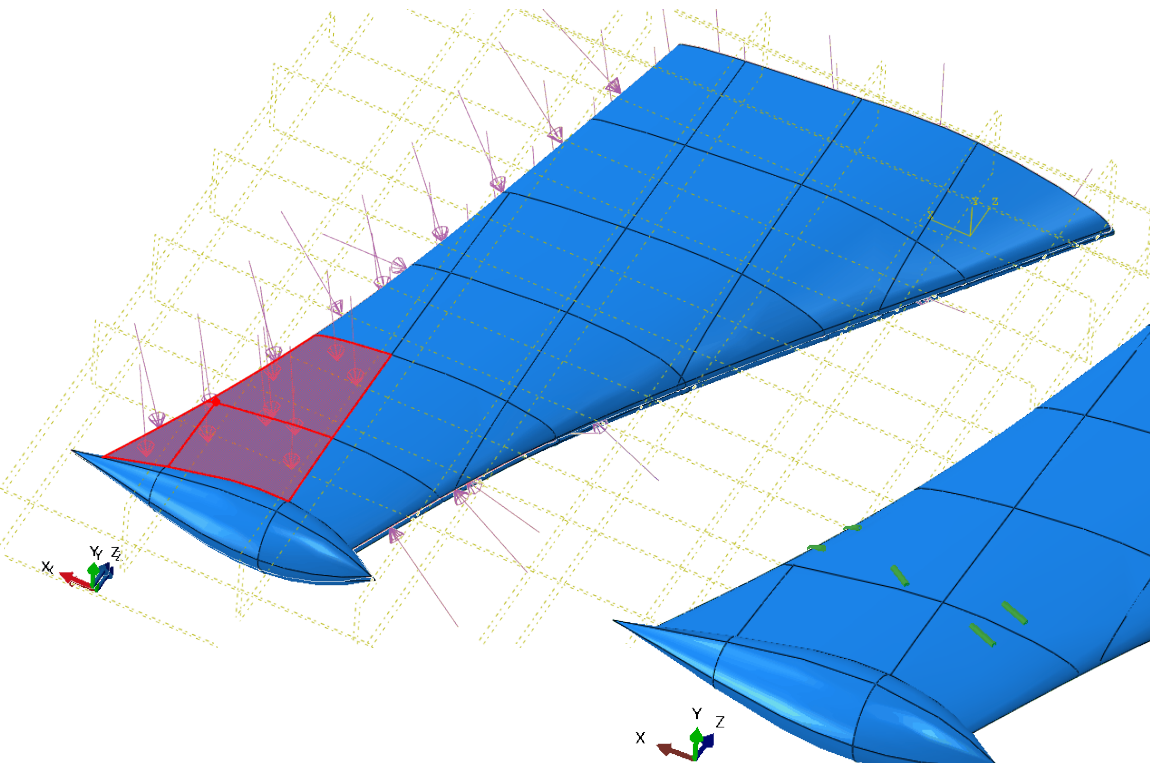


Need to understand dynamic loading on the wing in order to make design improvements

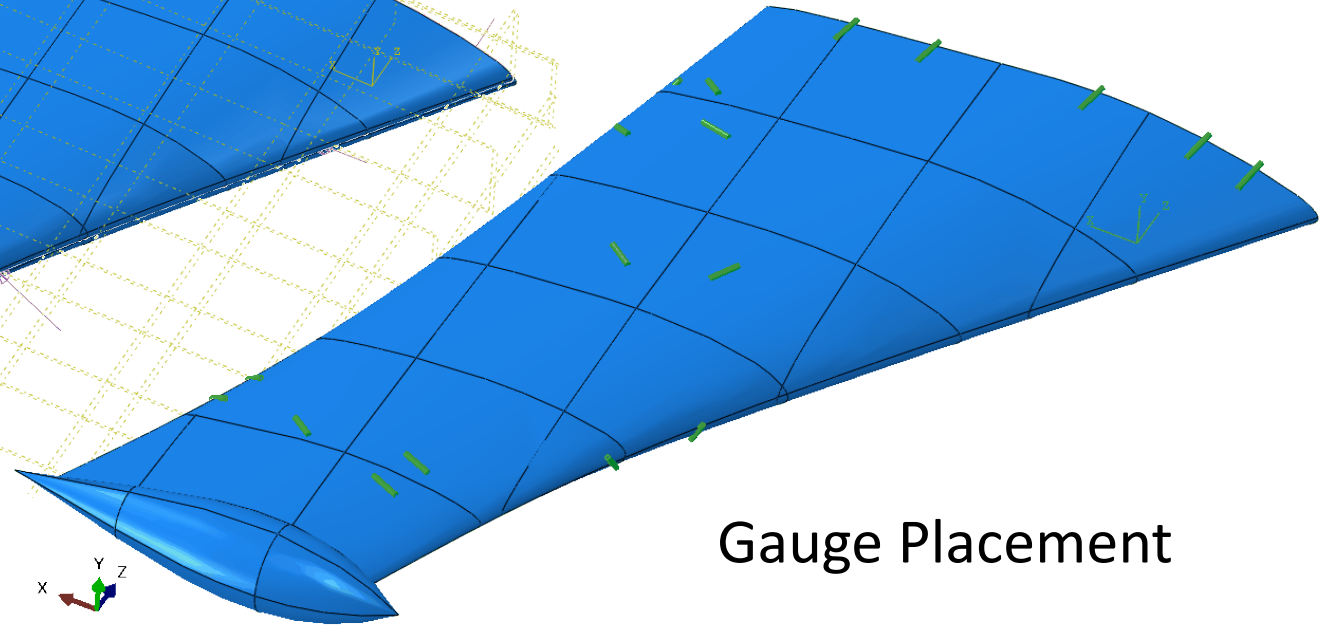
Coupled Structural / CFD analysis is expensive and does not capture all operating conditions

Unit Loads / Gauges

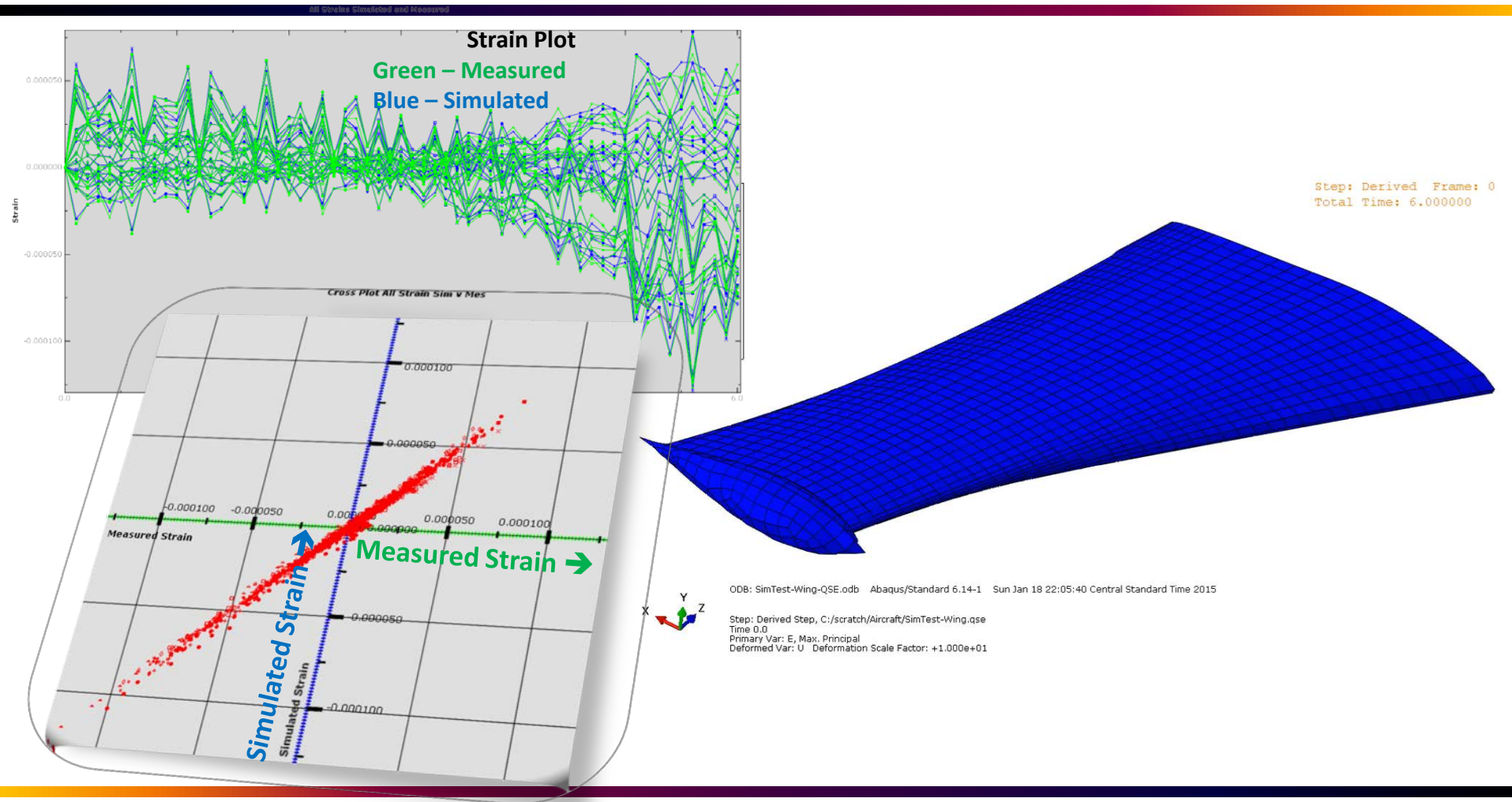
Unit Loads



Gauge Placement



Correlation / Loads / Results



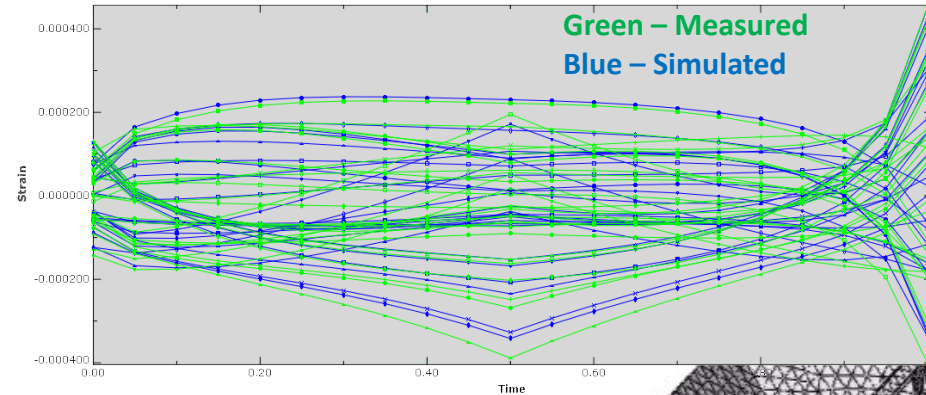
Front End Loader



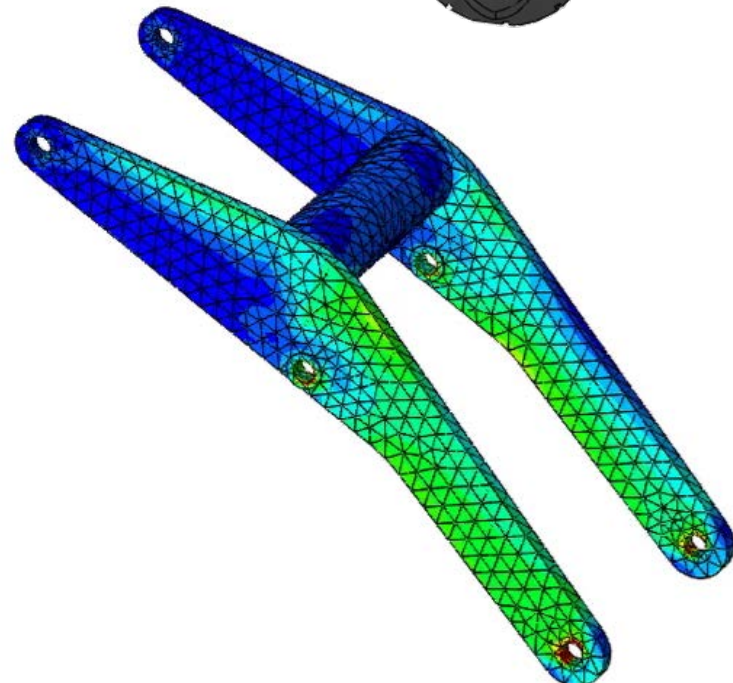
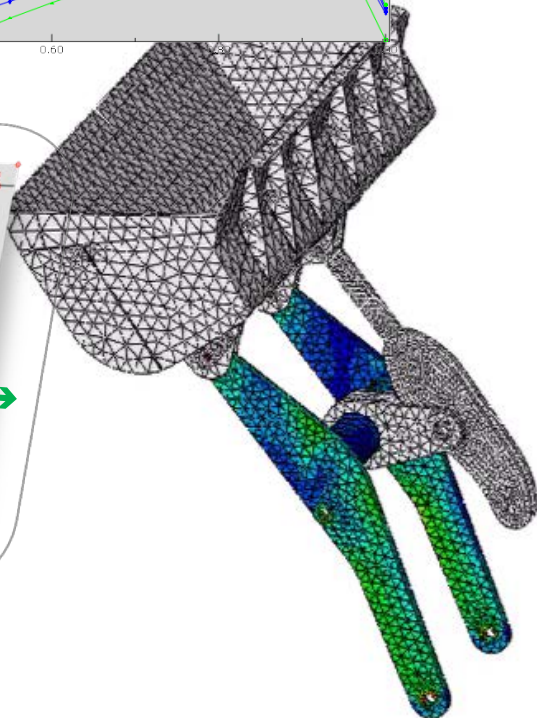
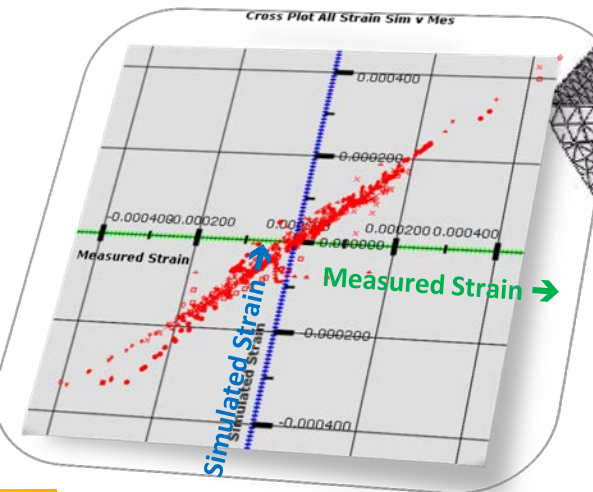
All Strains Simulated and Measured

Strain Plot

Green – Measured
Blue – Simulated



Cross Plot All Strain Sim v Mes



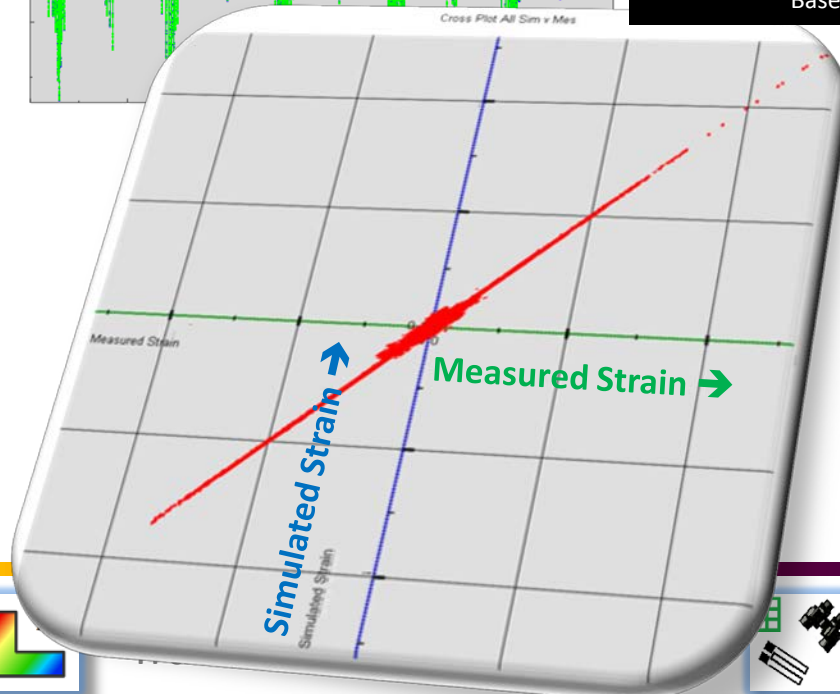
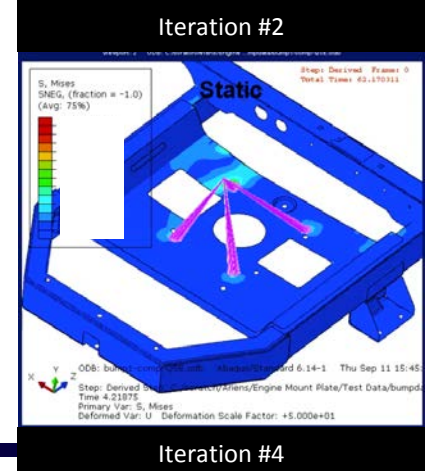
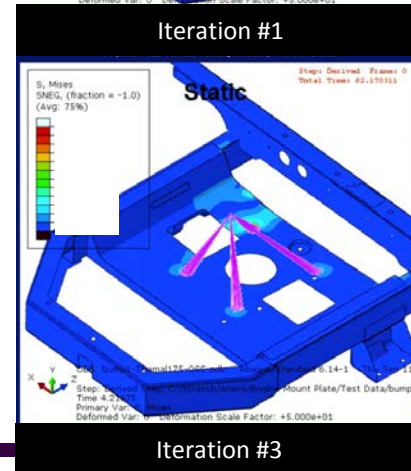
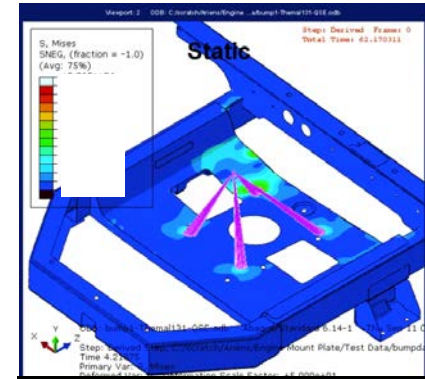
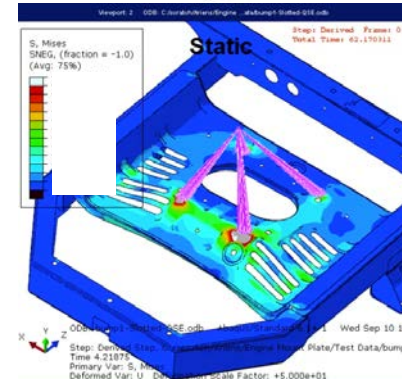
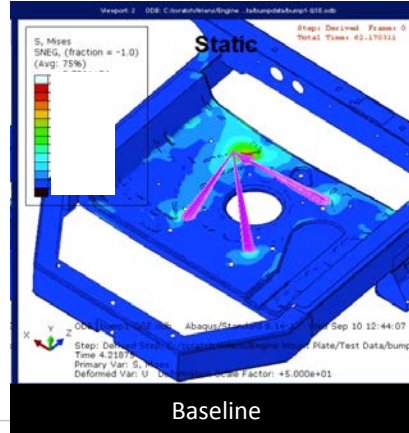
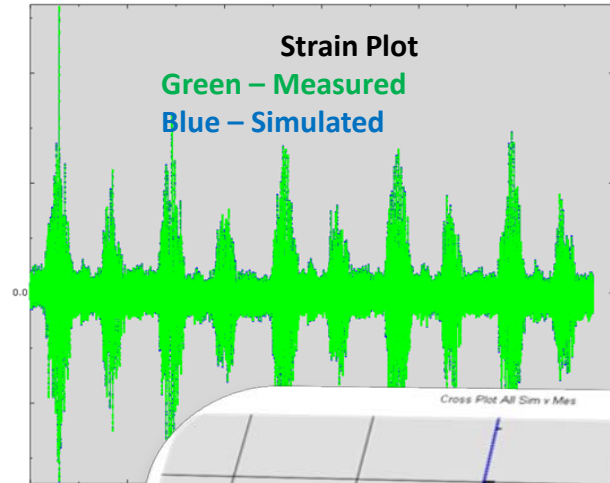
Commercial ZTR Tractor



All Strains Simulated and Measured

Strain Plot

Green – Measured
Blue – Simulated

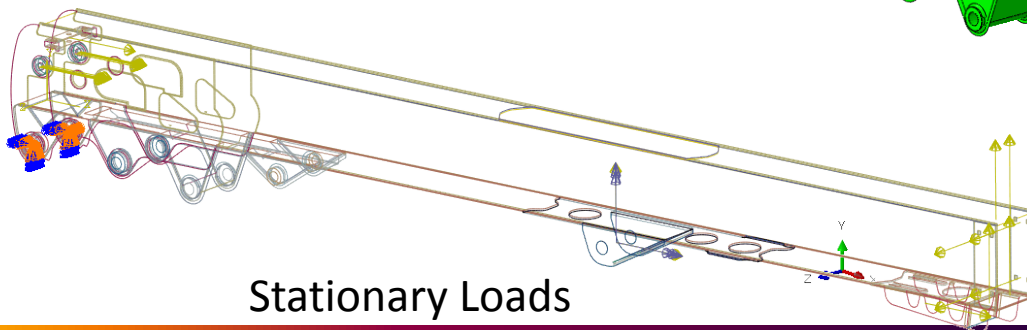
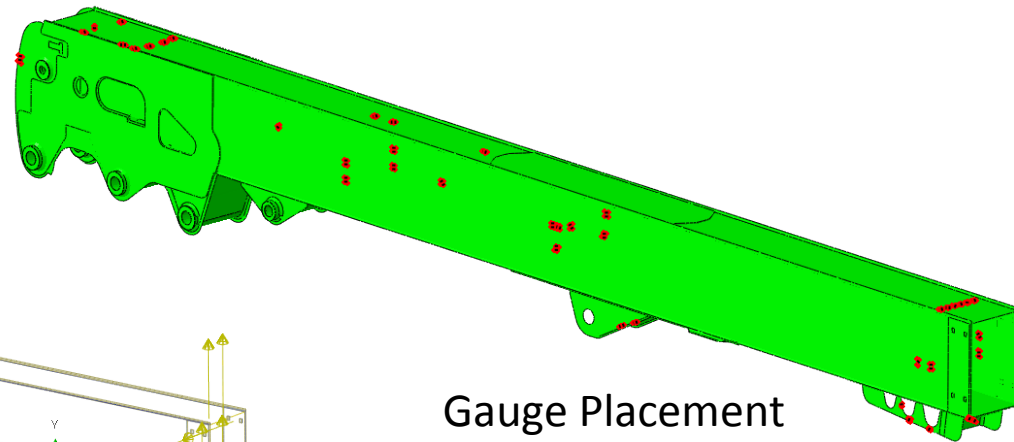
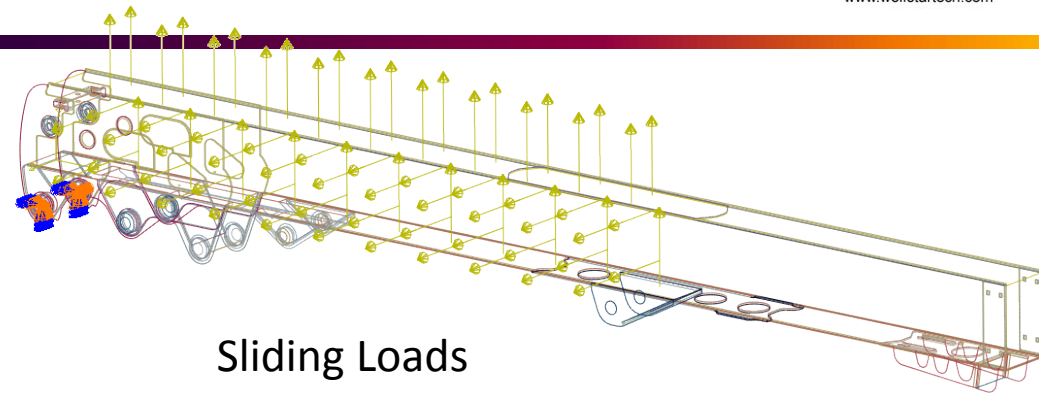


True-Load™

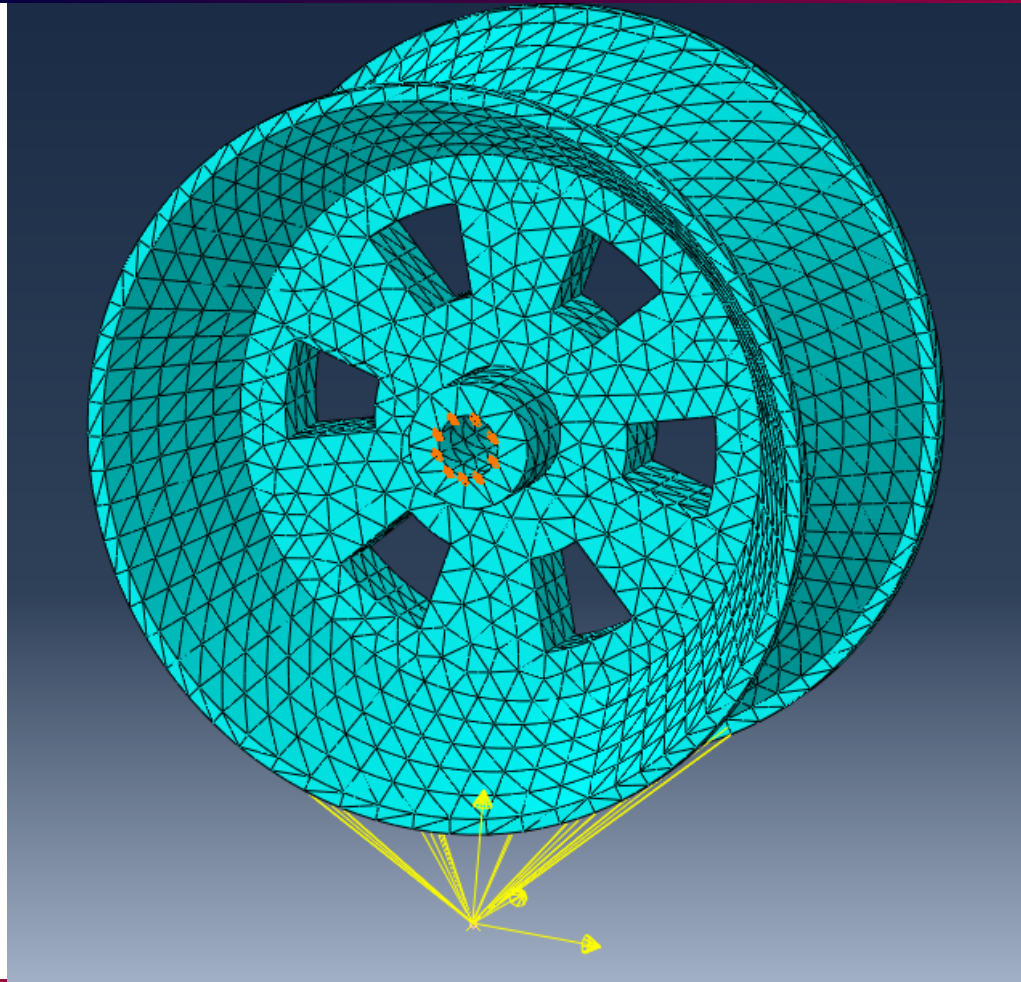


True-LDE™

Sliding Load Application



Wheel Load Transducer Concept



True-QSE™



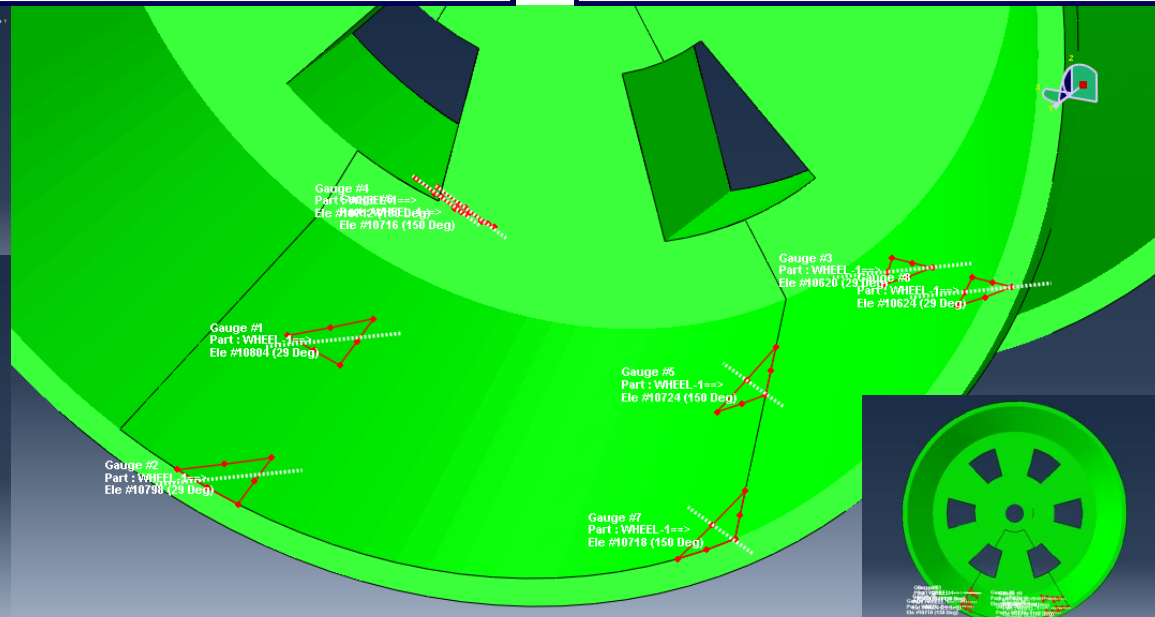
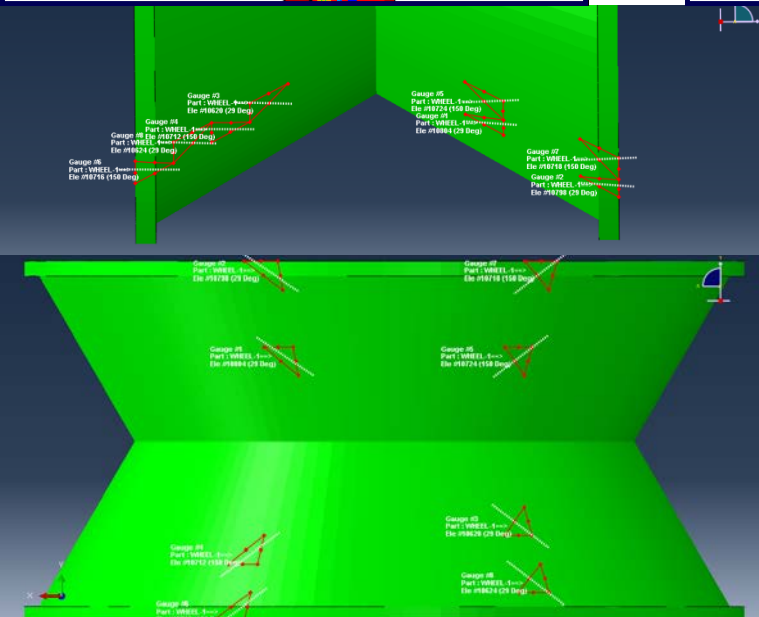
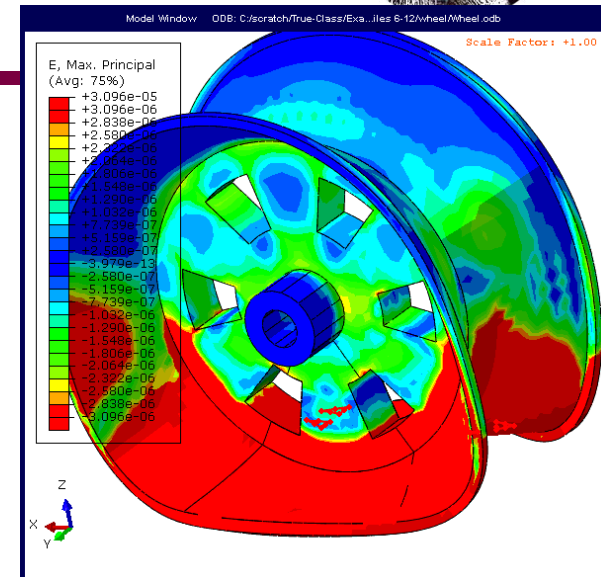
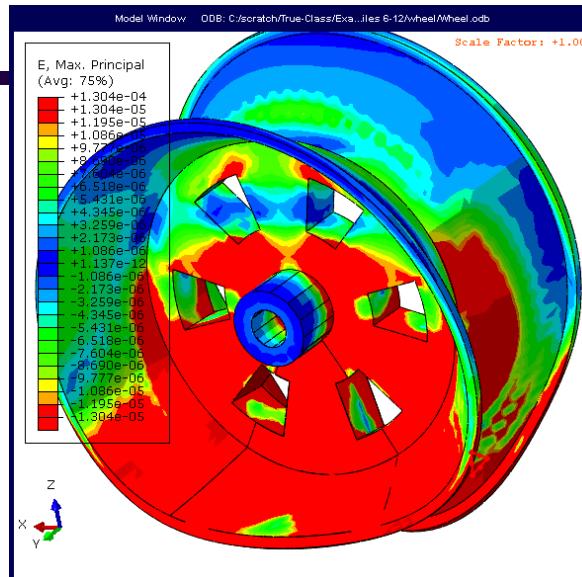
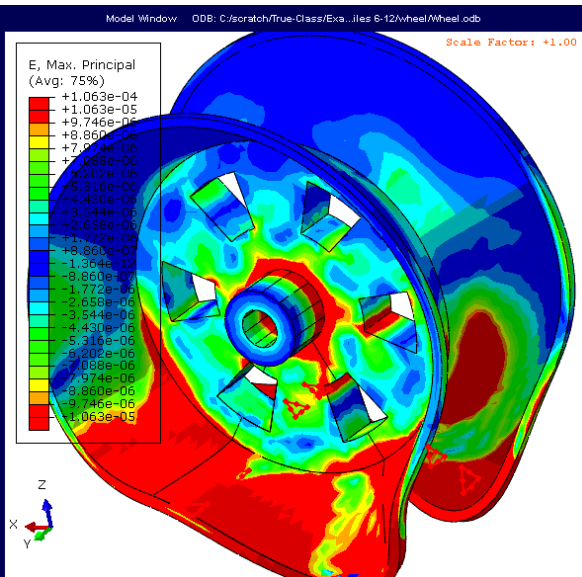
True-Load™



True-LDE™



Wheel Load Transducer Concept



True-Load™ Summary

True-Load™ will revolutionize your product development through:

- Optimal Strain Gauge placement based on FEA unit loads
- Unprecedented Strain Correlation on all strain channels
- Strain Correlated Load histories
- Reduced test and analysis time correlating loads
- Reduced test costs (transducers, testing, labour)
- Knowledge of the True Loading on structure
- Saving \$\$\$ by eliminating iteration cycles



True-QSE™



True-Load™



True-LDE™

True-LDE™



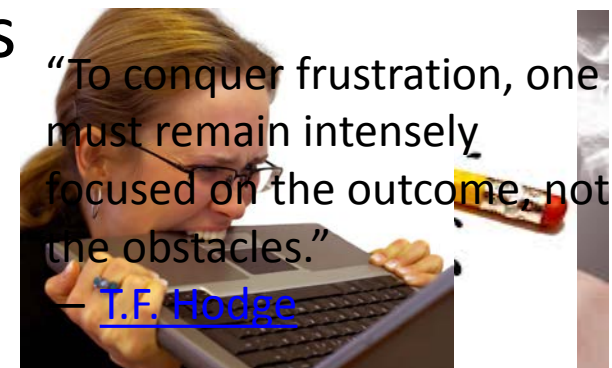
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Linear Dynamic Events

Overview ...

Traditional Linear Dynamics w/ Abaqus → True-LDE Motivation

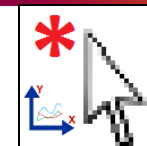
- ✗ Large storage requirements for field data
- ✗ Need to know nodes & elements for generating
*HISTORY requests apriori
- ✗ Solution times can be slow (due to storage)
- ✗ New XY plots require resubmitting the deck
- ✗ Modal mass participation not obvious
- ✗ Pre-Load not considered in results
- ✗ Not intuitive
- ✗ Batch mode oriented



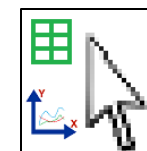


True-LDE™ - Basic Concept

Modes



Nodal Functions



Elemental Functions



Operating Deflection Shapes

$\Sigma \Rightarrow \Rightarrow$

fe-safe® FEA Based Fatigue

MPF
(Generalized Displacements)



True-QSE™



True-Load™



True-LDE™

True-LDE™ - Important Features

- Include Pre-Load
- No field results stored in the event step
 - Only Generalized Displacements
- Supports
 - *MODAL DYNAMIC (time domain)
 - *STEADY STATE DYNAMIC (frequency domain)
 - *RANDOM RESPONSE (PSD domain)
- Interface to fe-safe
 - All in time domain
 - Ready-to-run

A recent benchmark

	Original File	Prep for True-LDE™	
	freq_time_orig.inp	freq_time_LDE.inp	
Start Time	11:18:19 AM	12:05:35 PM	
End Time	11:32:26 AM	12:06:12 PM	
Elapsed Time	14.12 min	0.62 min	95.63% Faster
ODB Size	13,010,626,864 bytes	35,081,624 bytes	99.73% Smaller

True-LDE™ to fe-safe®

- Strategy:
 - Represent fatigue problem in time domain
 - Create Loading Definitions in time to scale results on modes
- *Modal Dynamics

GUs(t) in Abaqus → LDFs in fe-safe®
- *Steady State Dynamics

GUs(ω), GPU(ω) in Abaqus →

$$GU(t) = \sum GU(\omega) * \sin(\omega t + GPU(\omega))$$

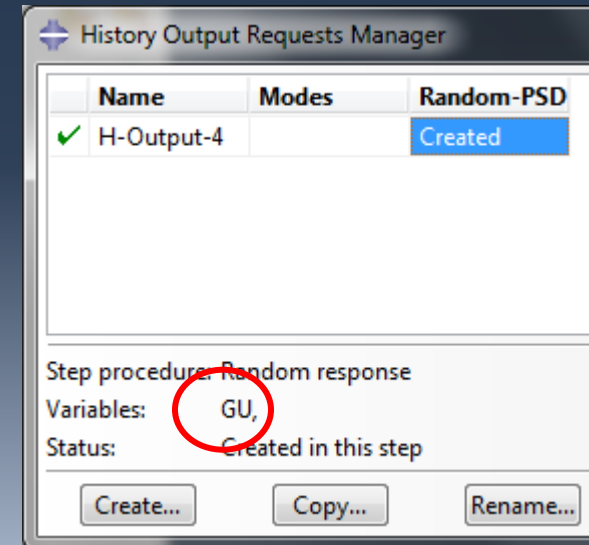
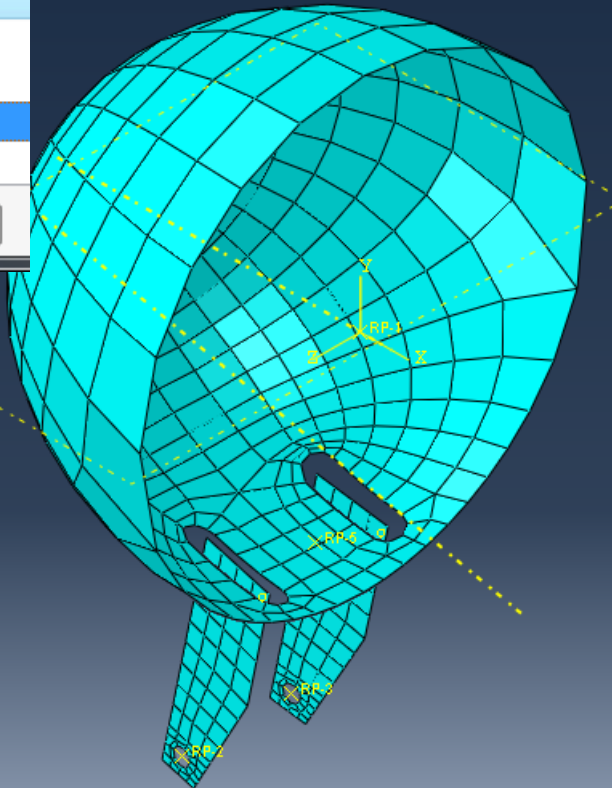
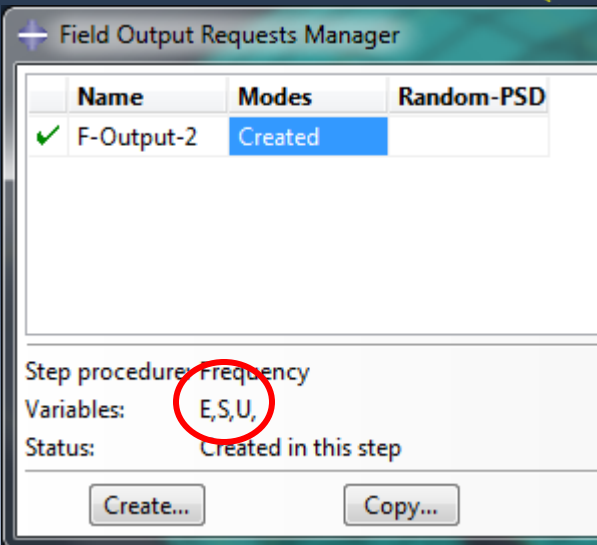
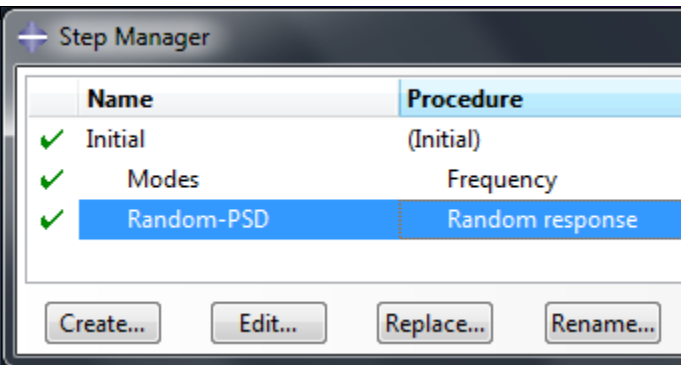
→ LDFs in fe-safe®
- *Random Response

GUs(ω) in Abaqus →

$$GU(t) = \sum GU(\omega) * \sin(\omega t + Rand(\omega))$$

→ LDFs in fe-safe®

True-LDE Solution Set Up



A session snapshot

WST/Linear Dynamic Events

Event File: C:/scratch/True-Class/Example Files 6-12/

Modal ODB
Modal ODB: C:/scratch/True-Class/Example Files 6-12/headlamp/headlamp-psd-resp.odb Modal Step: Modes

Dynamic Event ODB
Event ODB: C:/scratch/True-Class/Example Files 6-12/headlamp/headlamp-psd-resp.odb Event Step: Random-PSD

Linear Dynamics Event Definition

	Active	Freq (hz)	%X Mass	%Y Mass	%Z Mass	%RX Mass	%RY Mass	%RZ Mass	MPF Range	GU
1	☒	53.06	0.009%	0.000%	95.643%	0.575%	0.214%	0.000%	3.1e-09	GU-1
2	☒	59.56	76.453%	17.286%	0.008%	0.000%	0.000%	1.328%	1.72e-09	GU-2
3	☒	257.41	0.374%	1.236%	2.638%	0.008%	94.340%	0.001%	2.51e-13	GU-3
4	☒	265.91	19.938%	64.205%	0.030%	0.018%	1.779%	0.003%	1.08e-12	GU-4
5	☒	511.29	0.004%	0.009%	1.239%	63.064%	0.005%	0.000%	1.26e-14	GU-5
6	☒	953.43	0.000%	0.012%	0.058%	18.060%	0.688%	0.003%	1.49e-18	GU-6

Number of Modes: 10

Results Generation
☒ Include Pre-Load
☒ PSD Repeats 10

GU / Session Options
☒ Mode Plotting
 Mode Number: 1

Mode Filtering

Pre-Load

PSD Repeats



True-QSE™

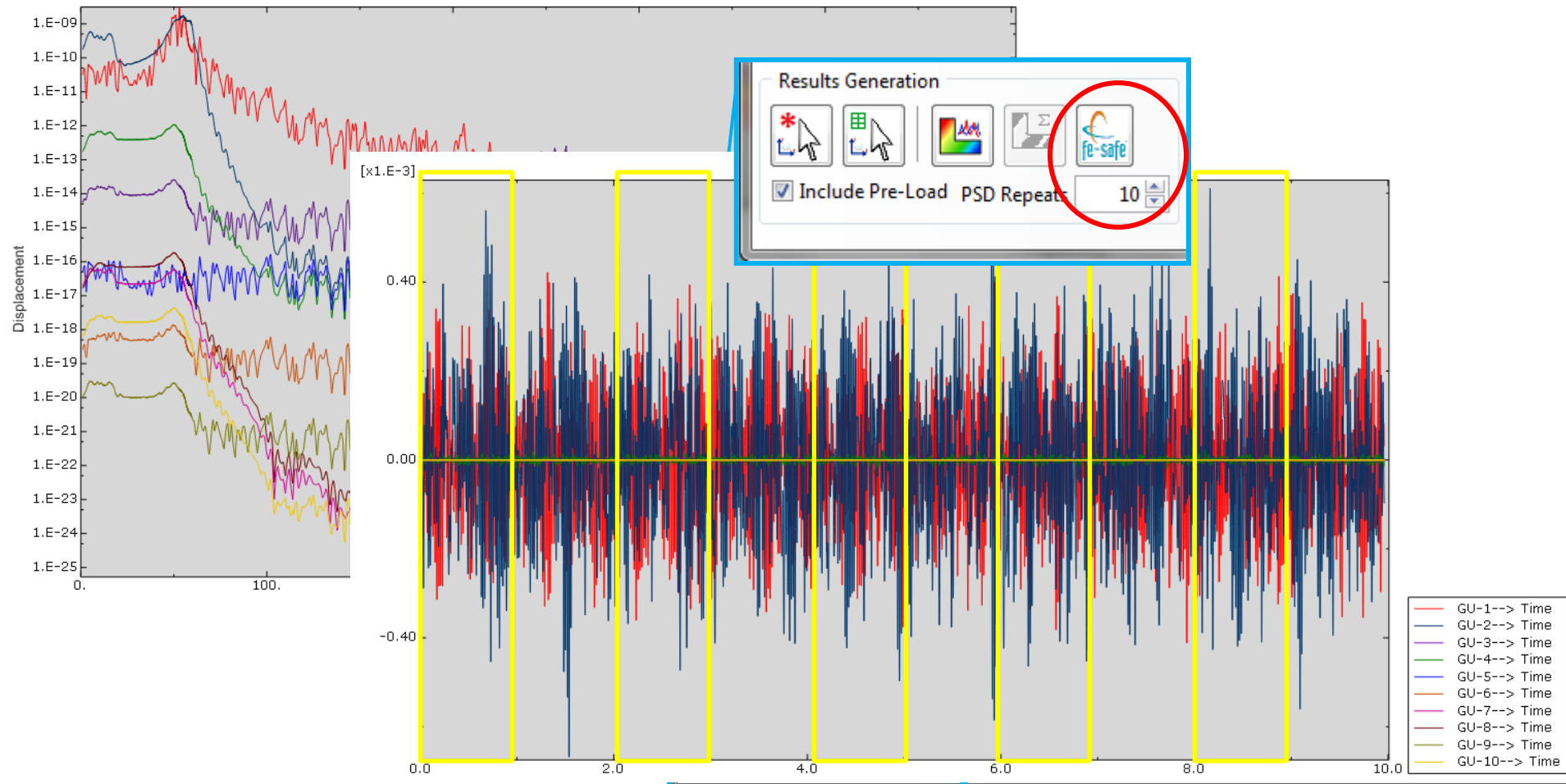


True-Load™



True-LDE™

Export to FEA fatigue



The Tools

Abaqus/CAE plug-ins



True-Load™

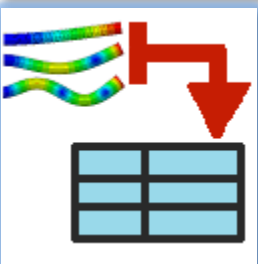
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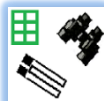
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Wolf Star Technologies

True-Load™, True-QSE™, True-LDE™



Thank you!

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True-QSE™



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