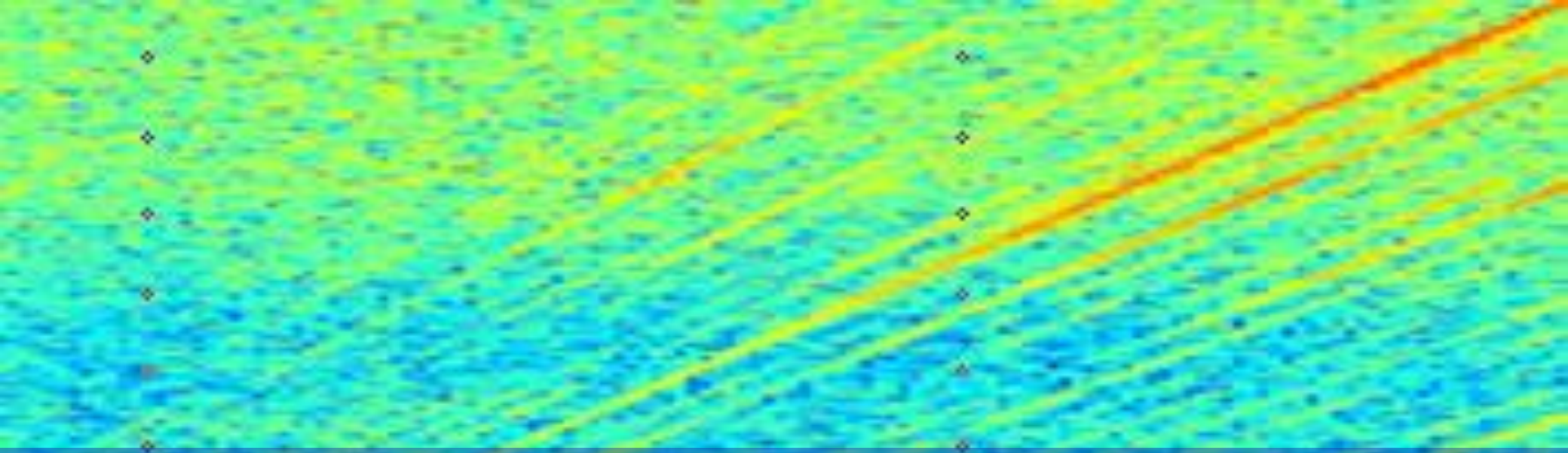


Orders-based Validating and Updating of Rotating Machinery FE Models

E. Dascotte

Dynamic Design Solutions (DDS) NV

IMAC XLI

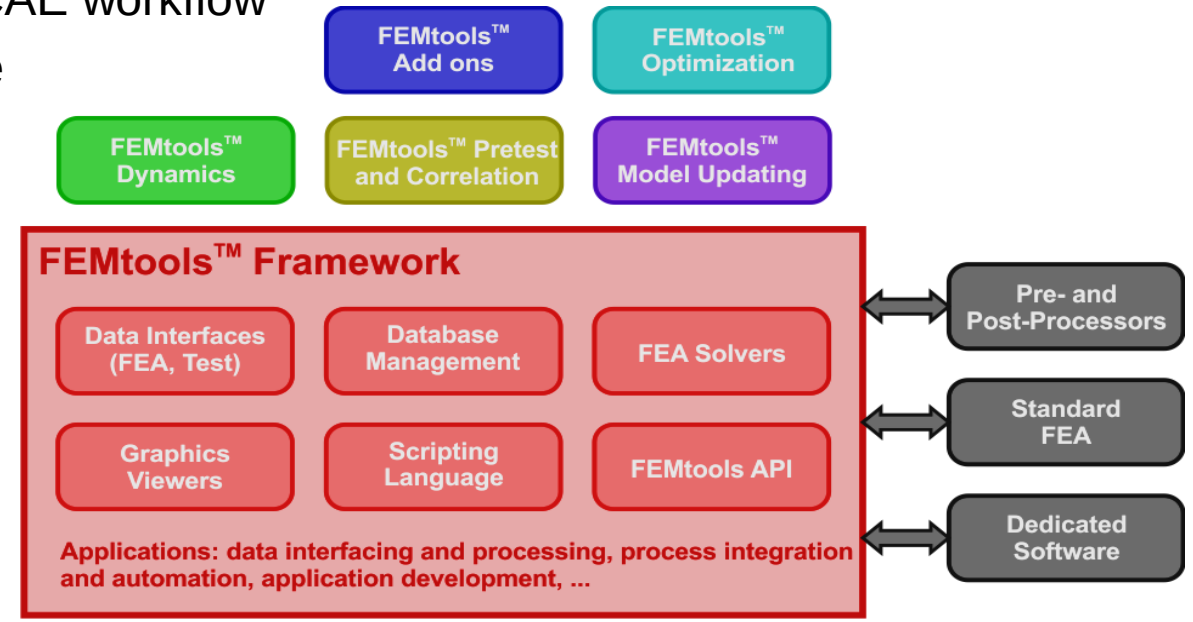
Austin, TX, Feb. 13-16, 2023

Dynamic Design Solutions

FEMtools simulate › validate › update › optimize

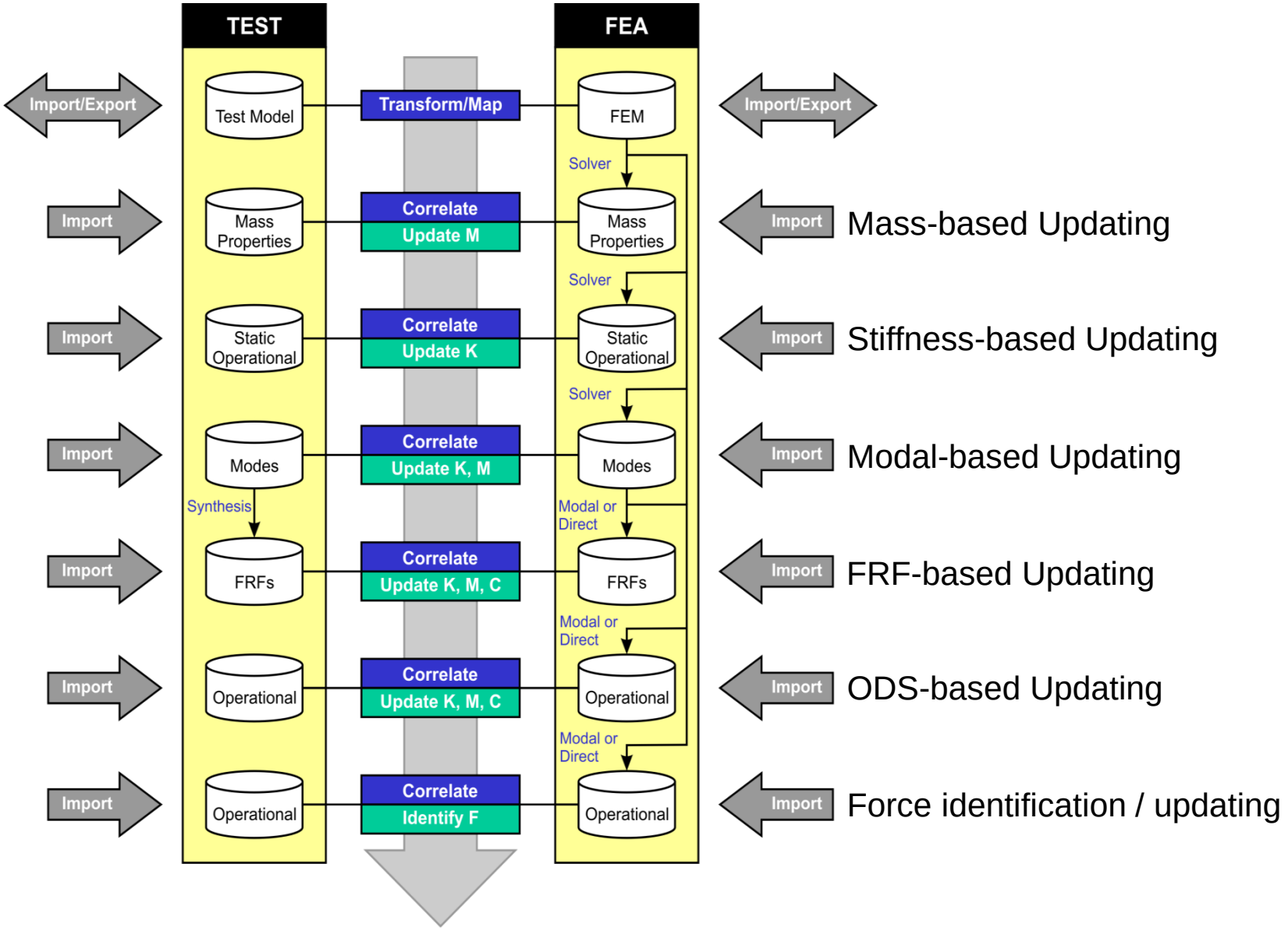
Dynamic Design Solutions – Company Profile

- CAE software development and services
- Specializing in structural dynamics, integration of FEA with testing, validation and updating of finite element models
- Main product is “FEMtools”
  - multi-functional, cross-platform and solver-independent CAE software suite providing analysis and scripting solutions
  - Neutral, open database combining FE and test data
  - Easy integration in any CAE workflow
  - Customizable, extensible

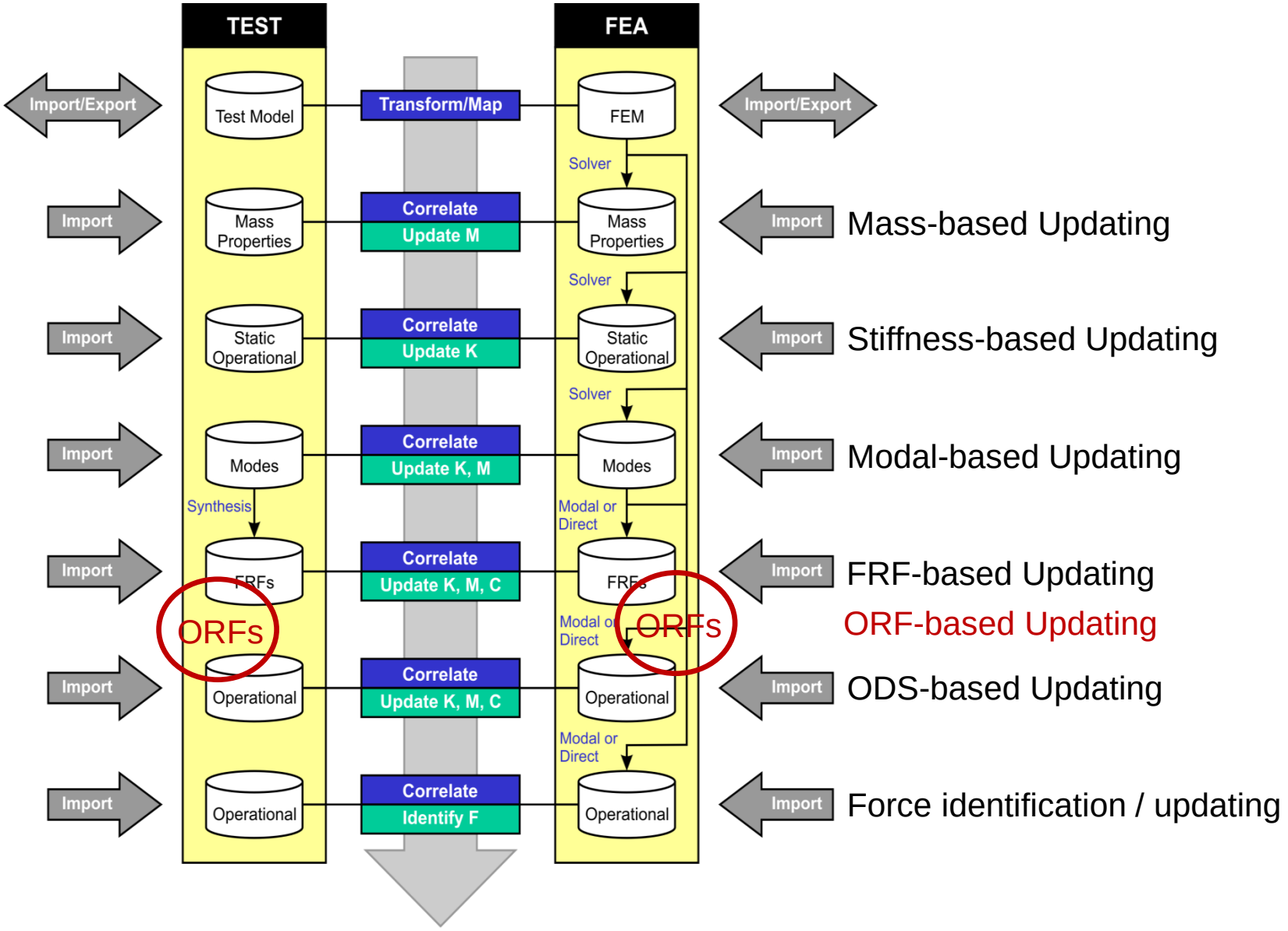


FEMtools
simulate › validate › update › optimize

Different Types of FE Model Validation and Updating

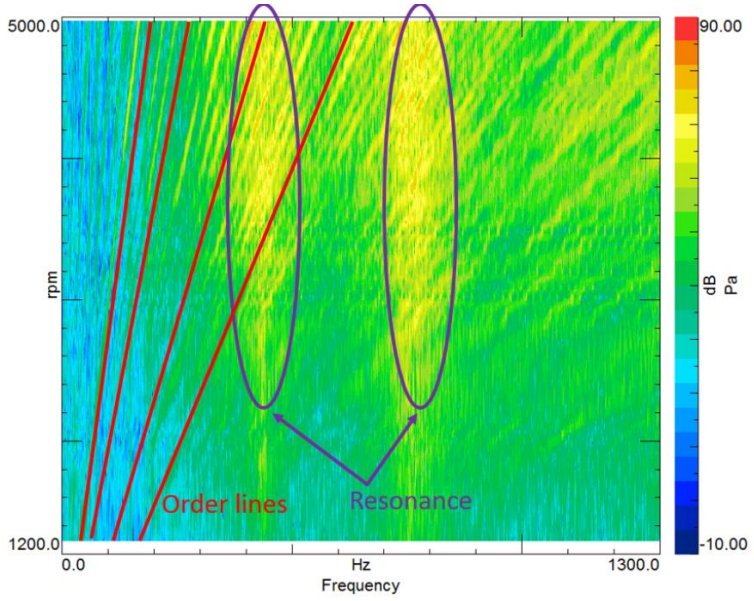


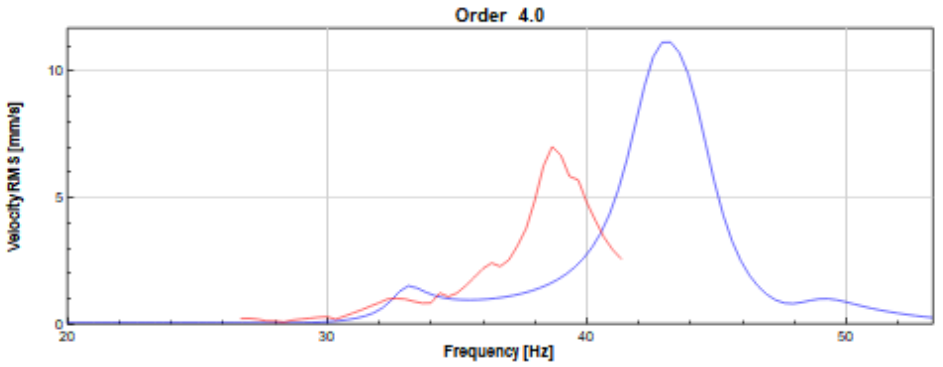
Different Types of FE Model Validation and Updating



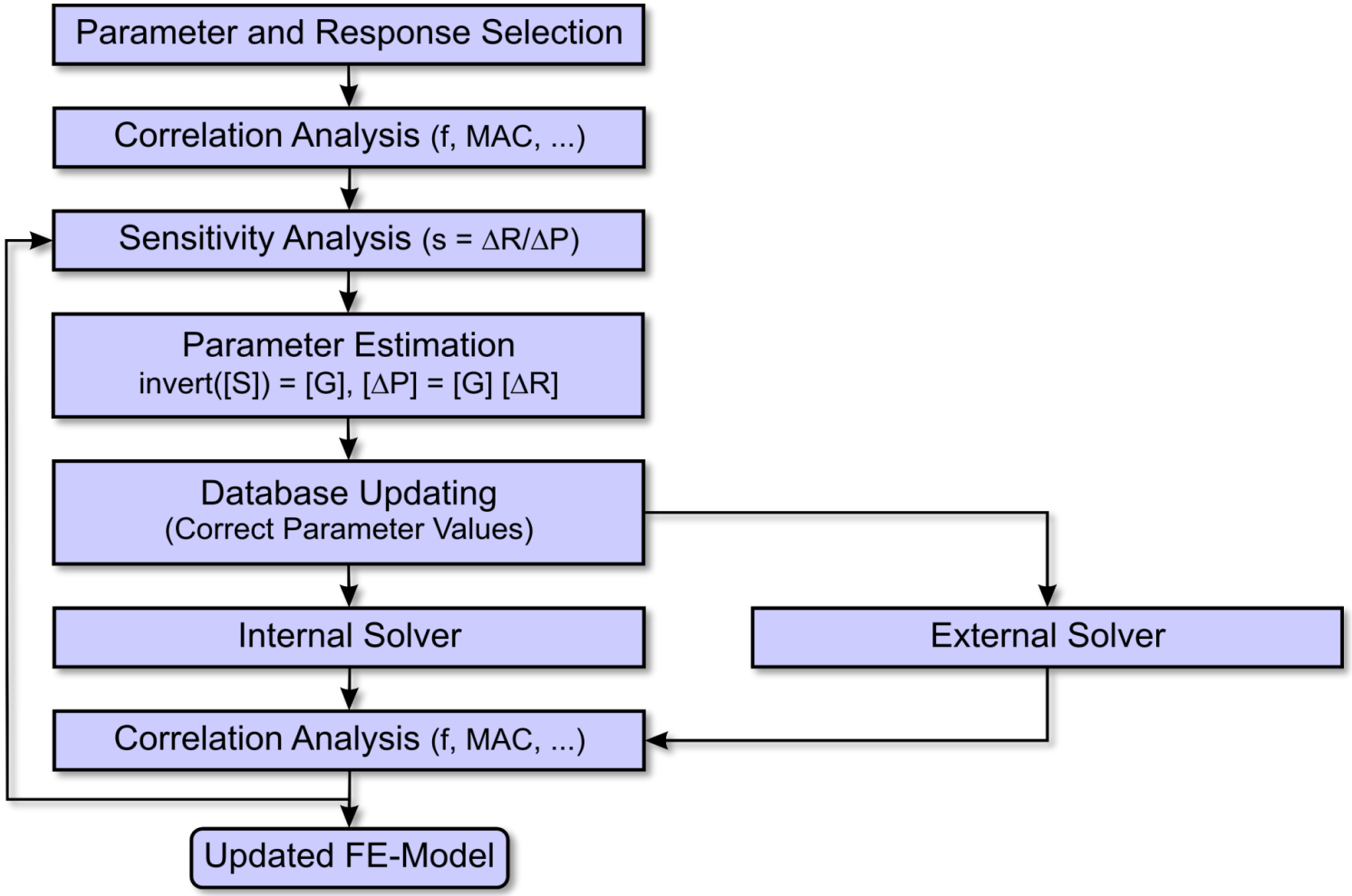
What are orders? What are Order Response Functions

- Order number is the ratio of the events per revolution relative to the first order.
- Orders Response Functions are the vibration amplitude as a function of RPM (or Hz)
- Test ORF can be obtained from run-up/down vibration testing and order tracking.
- Simulation ORF are obtained using modal-based response analysis with excitation functions per order.



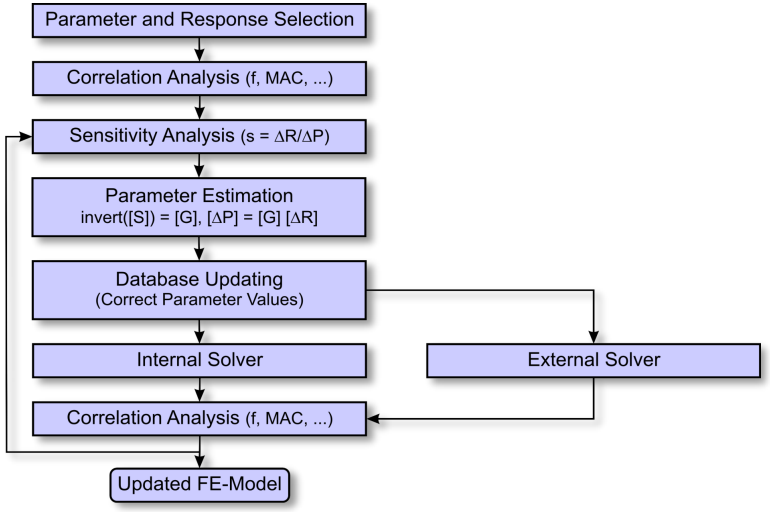


Model Updating Challenges



ORF-Based Correlation and Updating (FEMtools OCU)

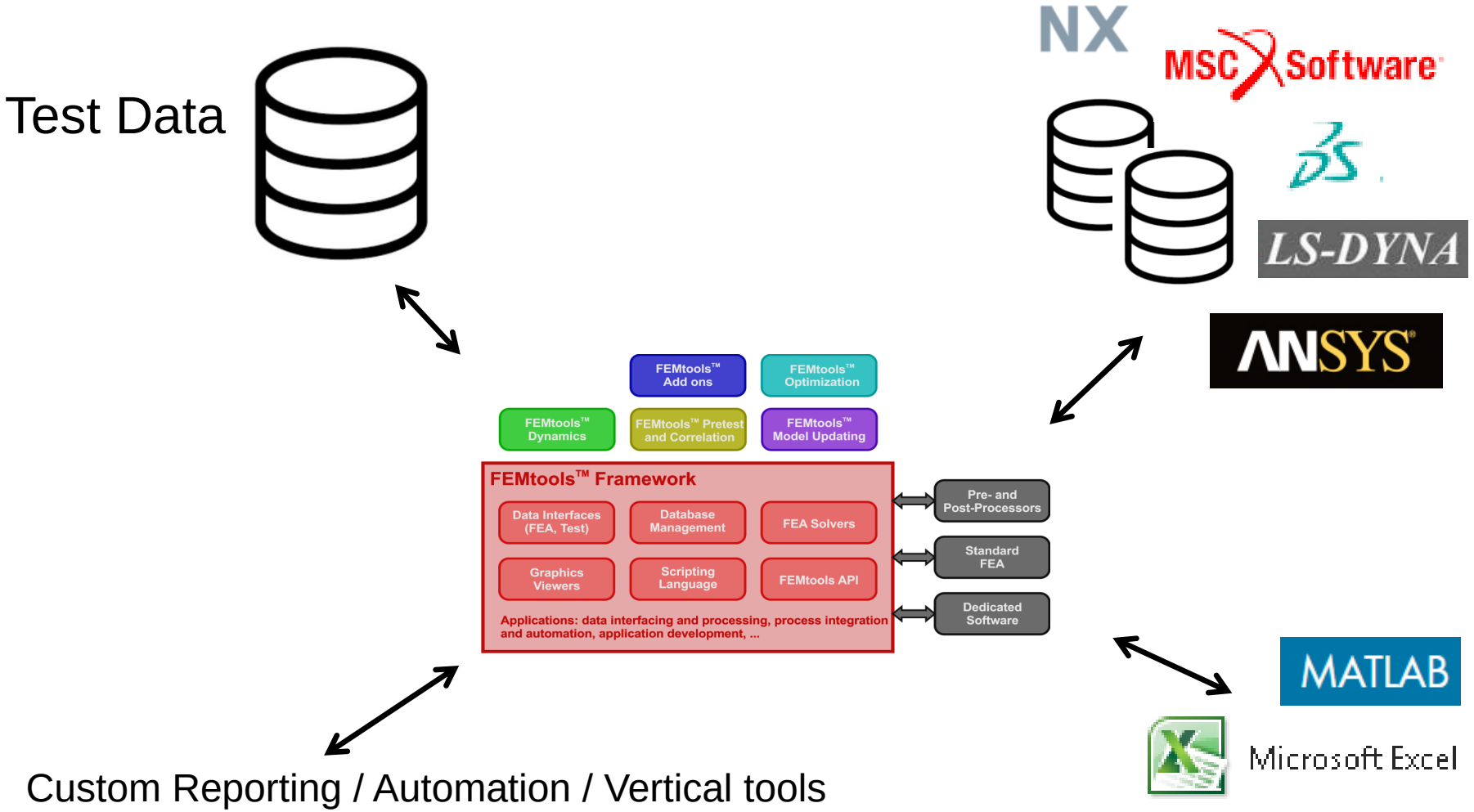
- Step 1: Updating the modal model
  - Generate FE model and compute mode shapes
  - Import test model and pair FE and test model (identify DOF pairs)
  - Create crop model from FE model and mode shapes at DOF pairs (truncation)
  - Use OCU to update the crop modal base (+ forces)
- Step 2: Updating the FE model
  - Use generic FE model updating using modal-based approach with the updated crop modal base as targets



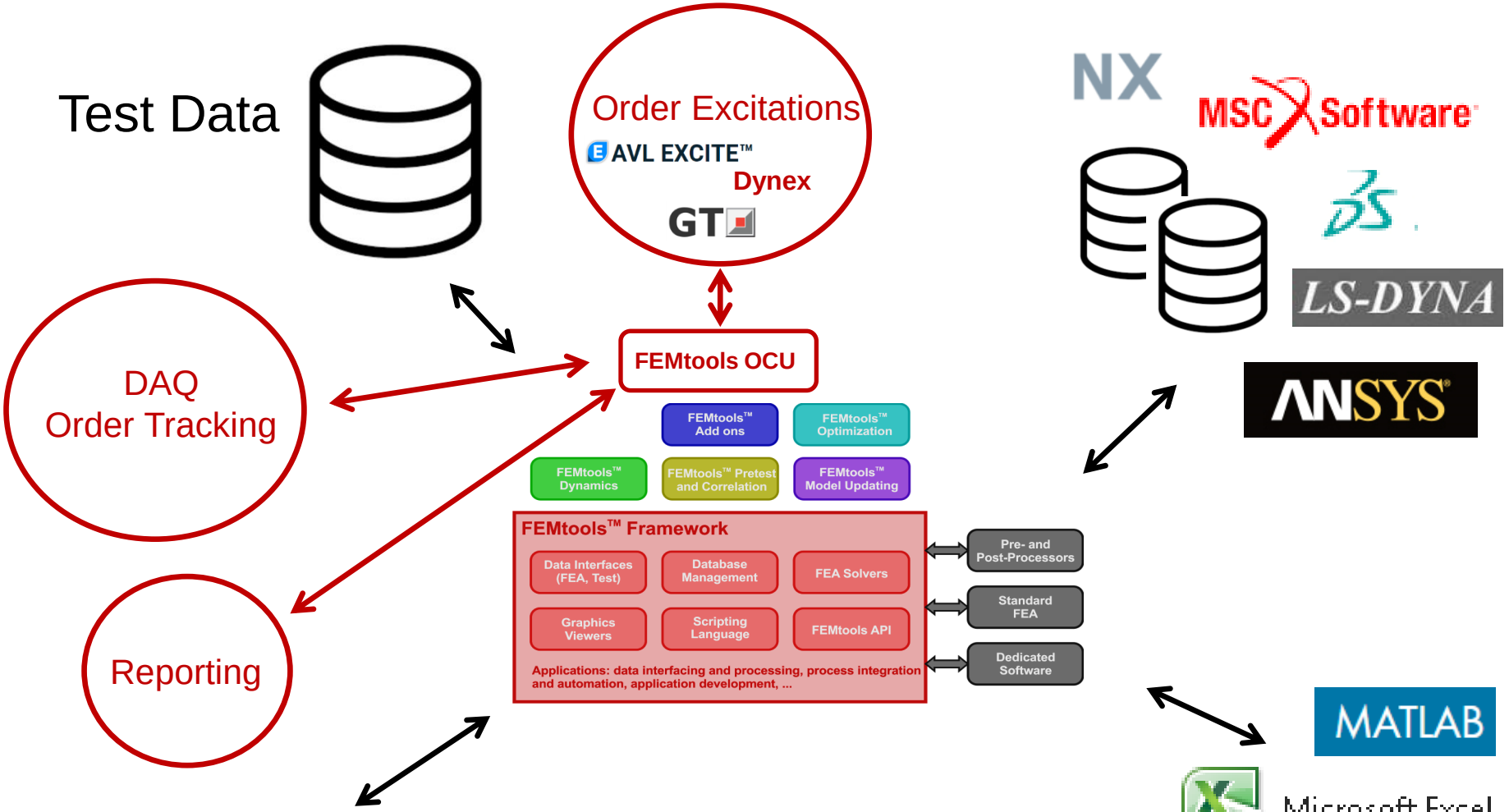
FEMtools OCU – Overview

- A dedicated applet developed in FEMtools Script to work with ORFs from test and simulation.
- Developed in collaboration with engine development specialists.
- A new “Orders Response Analysis” solver optimized for speed. For example: re-analysis reduced from ~5s to ~0.5s enabling near real-time updating of ORFs when modifying parameter like frequency, damping, mode amplitude and force amplitude.
- Order Response Functions (ORF) are selected as the reference responses if excitation is due to the rotation of the system (EMA, OMA, ODS do not apply).
- The main goal is to obtain the changes needed to the FE modal base and forces to fit simulation with test. The modified FE modal base can be used as the target test modal base for FE model updating (2-step approach).
- FEMtools OCU combines all data in a single interactive app.

FEMtools as an Integration Tool



FEMtools as an Integration Tool



Custom Reporting / Automation / Vertical tools
(Digital Twins, SHM, Material identification)

FEMtools OCU – Workflow

- Data preparation
  - Create or import a “cropped” FE data. This is an FE model and modal base truncated using FEMtools Framework commands to the load and response nodes.
  - Import loads.
  - Import the test model (~ as cropped FEM).
  - Import measured order responses.
  - Import the configuration file to specify load and response locations, labels, mapping between FE and test, speed setting, color settings.
  - (import measured ODS) *optional*
  - (import modal parameter changes file) *optional*
- Launch interactive OCU panel
  - Automatically computes the ORFs for given loads and settings.
  - Scripts can be launched for loading data, saving modal parameters, saving graphics and text files for reporting.

FEMtools OCU – Workflow

Angular domain Excitation

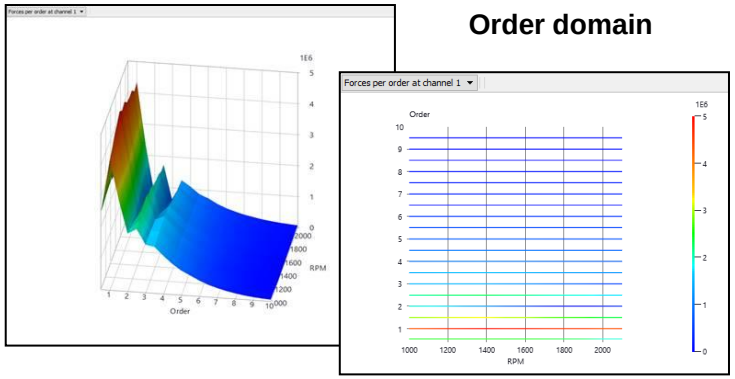
GT

FFT

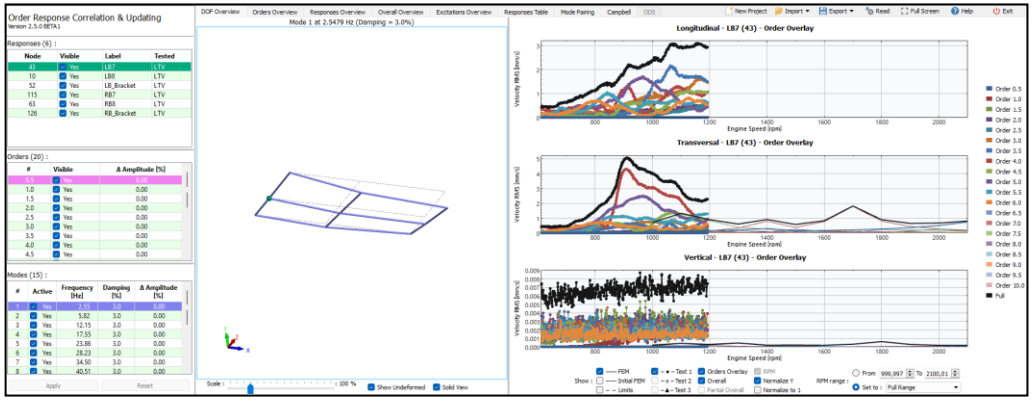
Cropped FE Model

Measured Order Responses (Order Tracking)

Order domain



FEMtools OCU

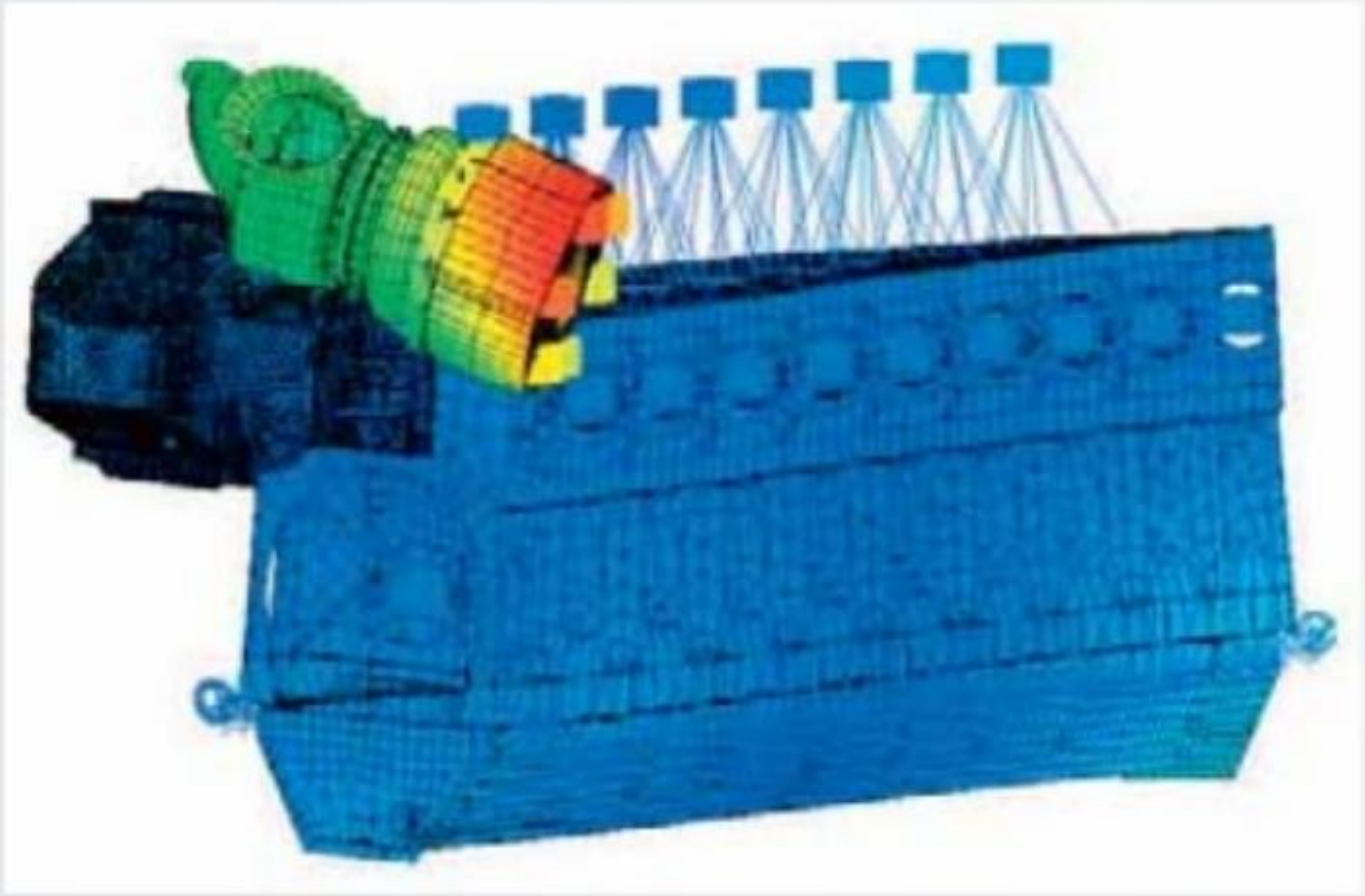


Test and Analytical data shown for different RPM ranges. (Demo purposes only)

Marine Diesel Engine Example Case

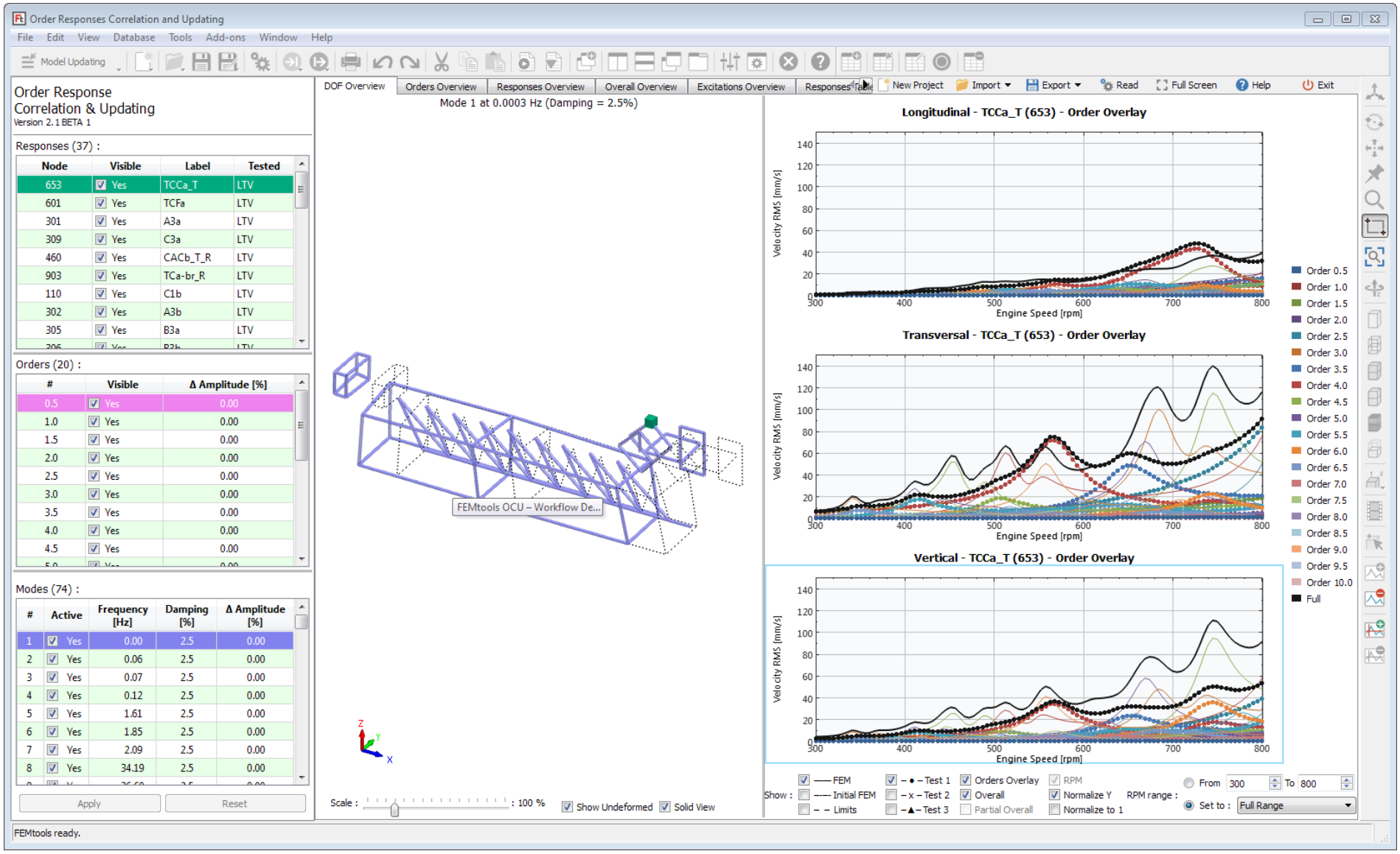
Wärtsilä 8L46 engine with ABB TPL Turbocharger

Marine Diesel Engine Example Case (FE Model)

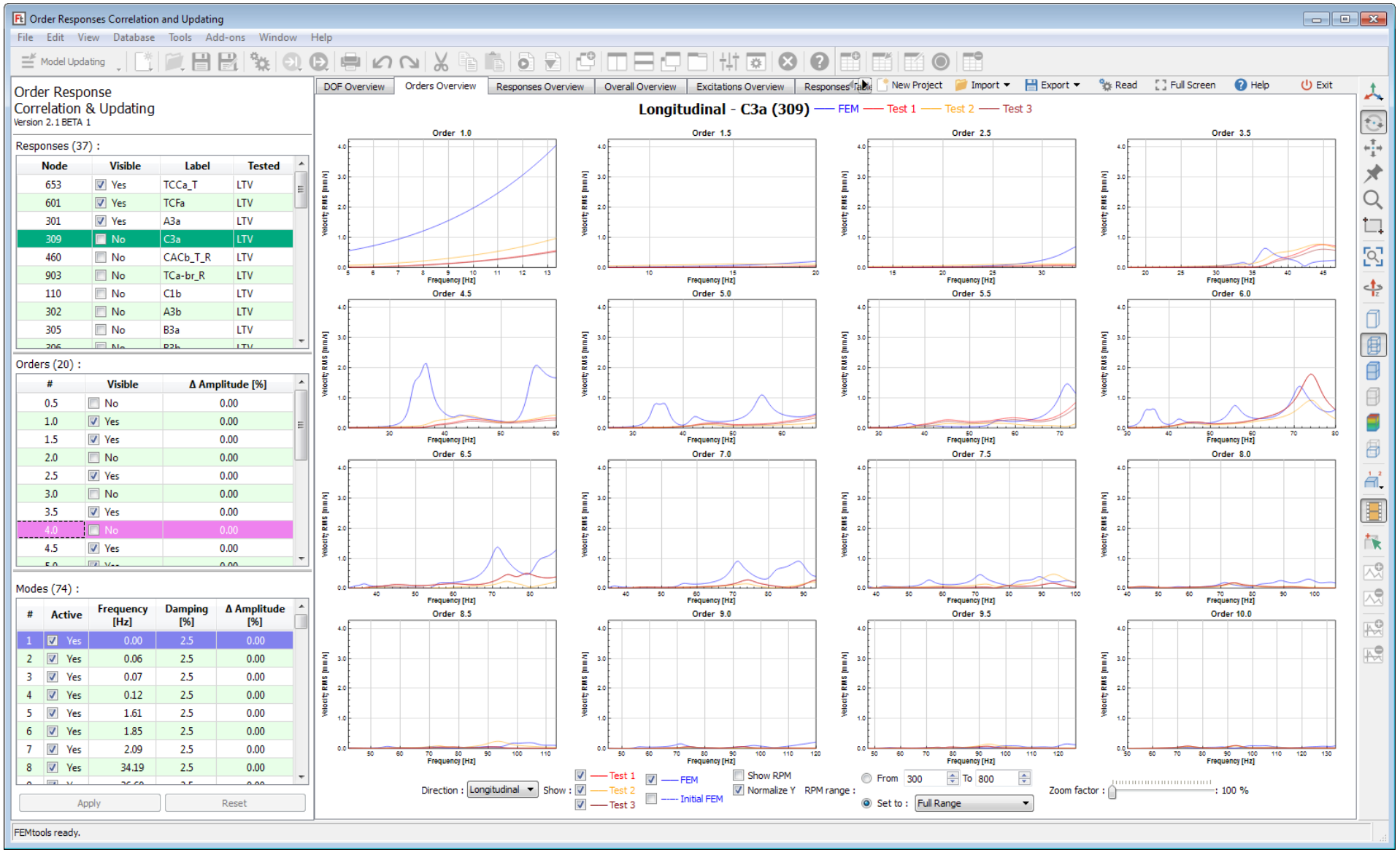


Typical torsion mode marine diesel engine (image provided by Wärtsilä Finland Oy)

DOF Overview



Orders Responses Overview



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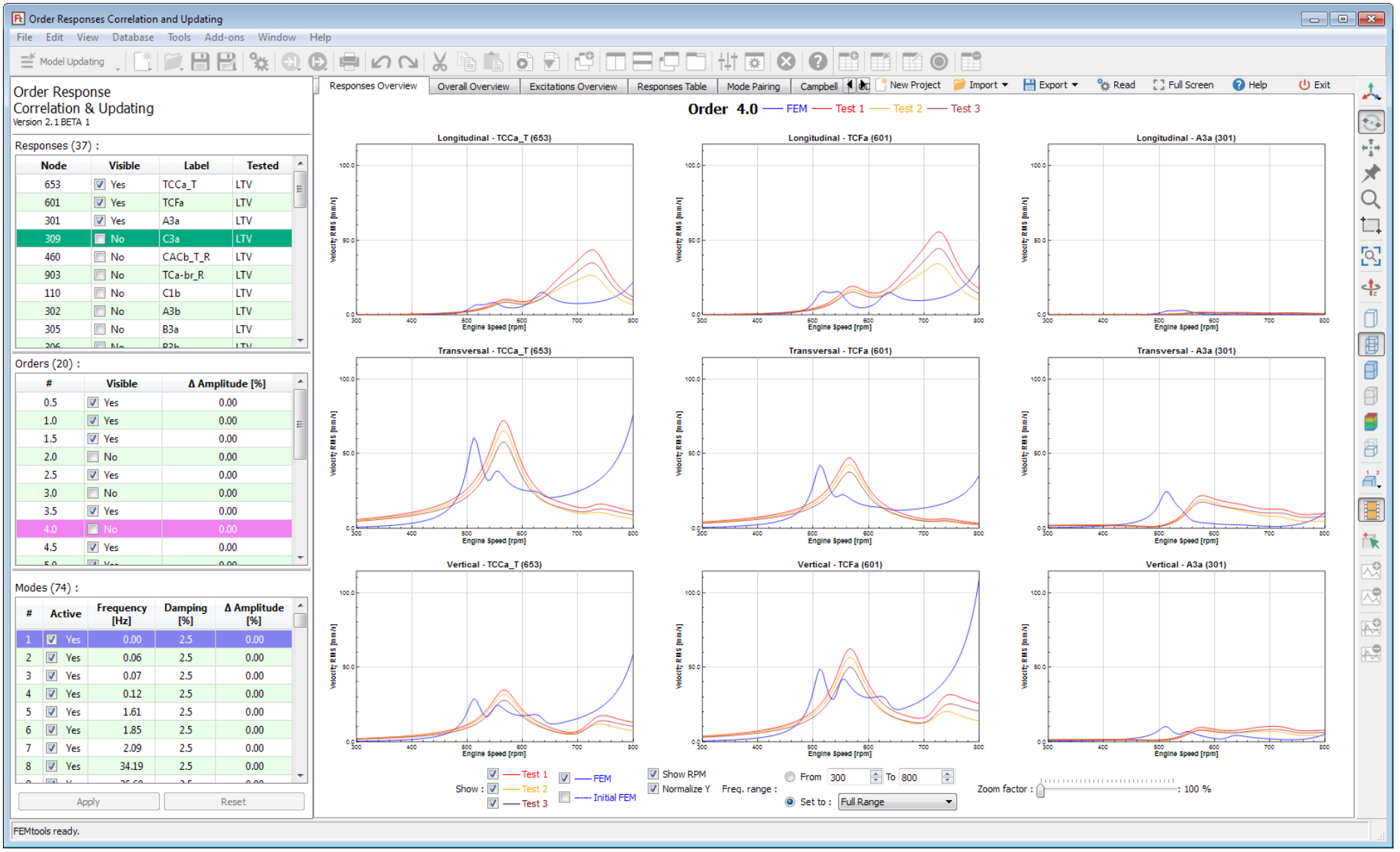
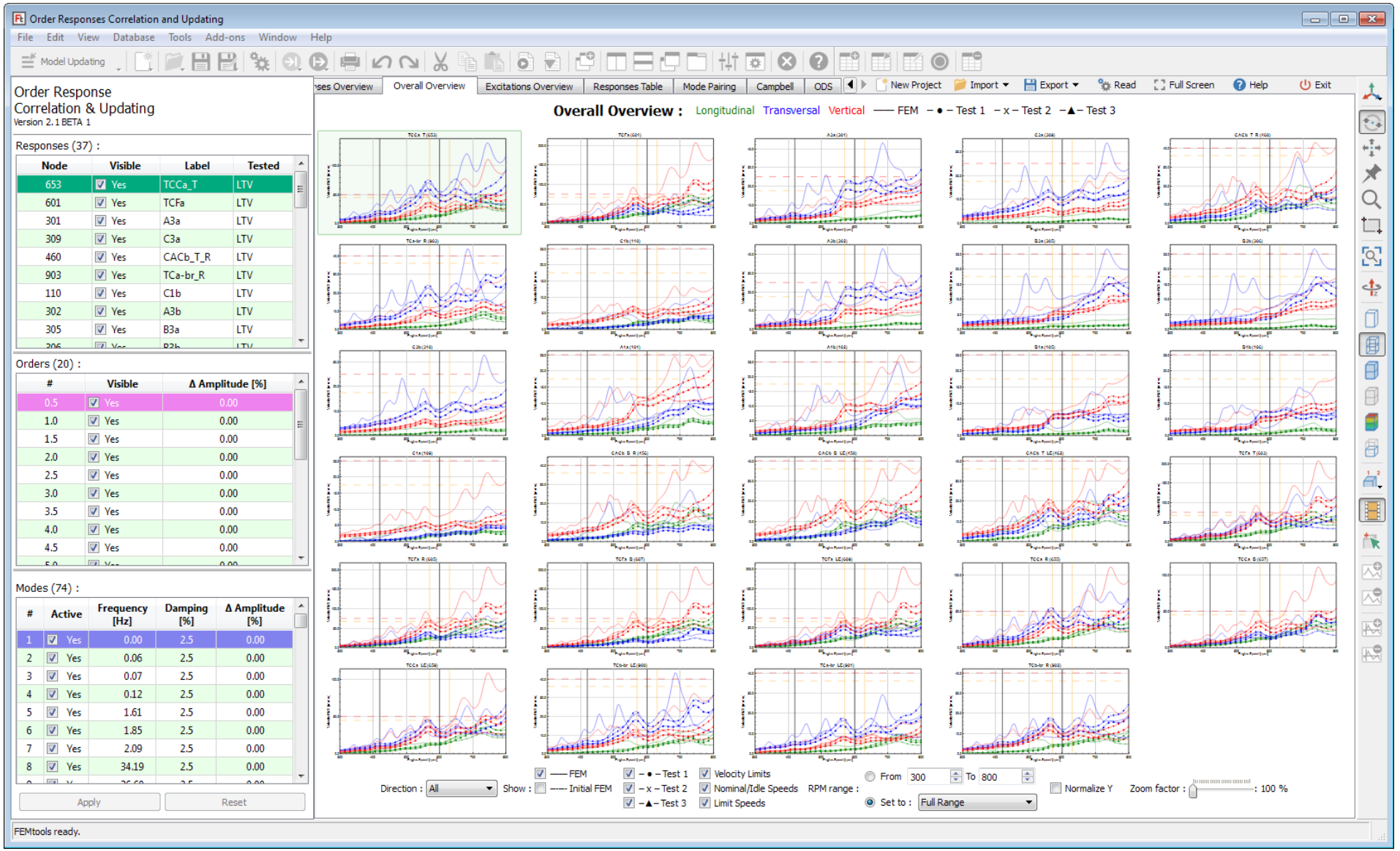
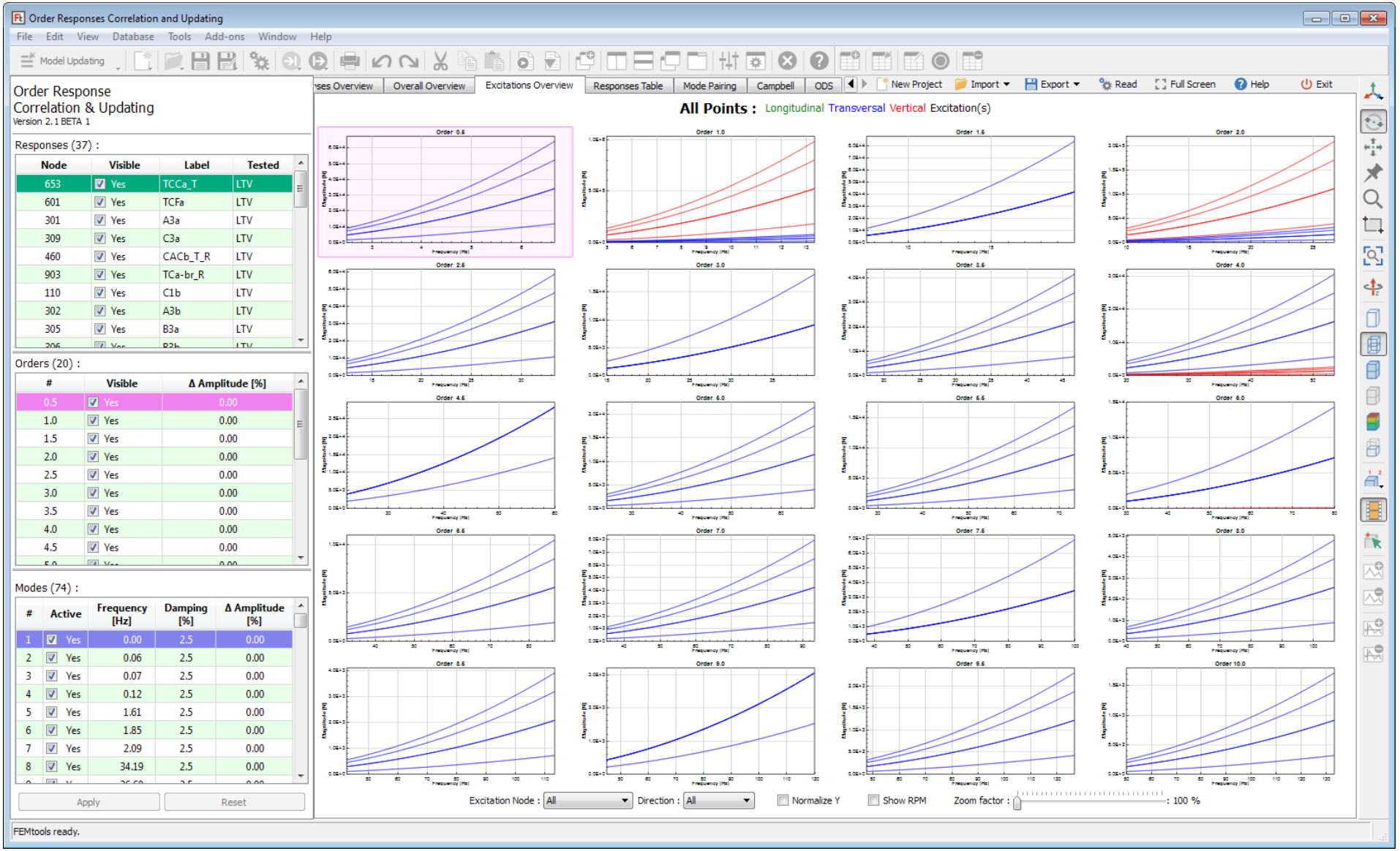


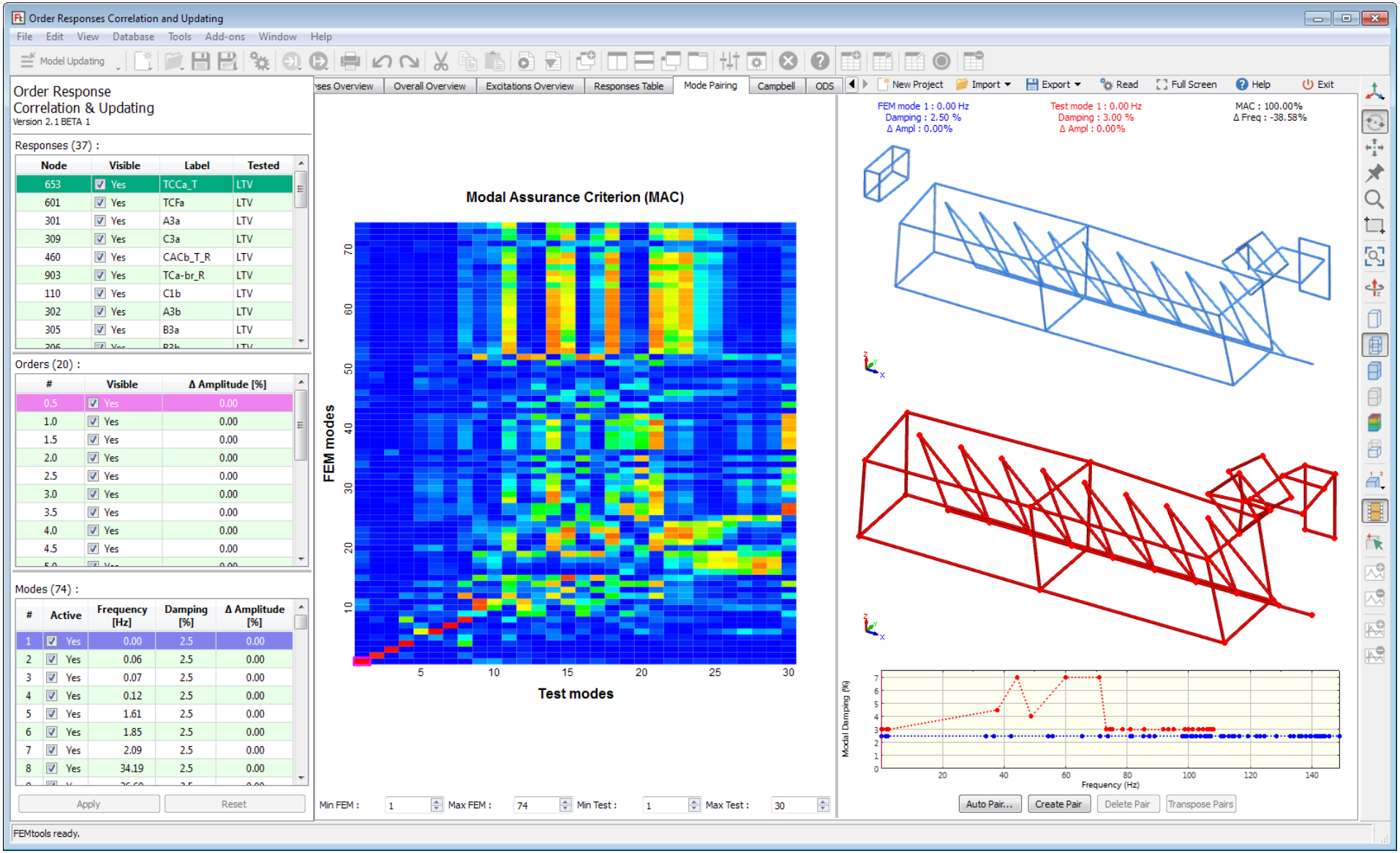
Overall Overview



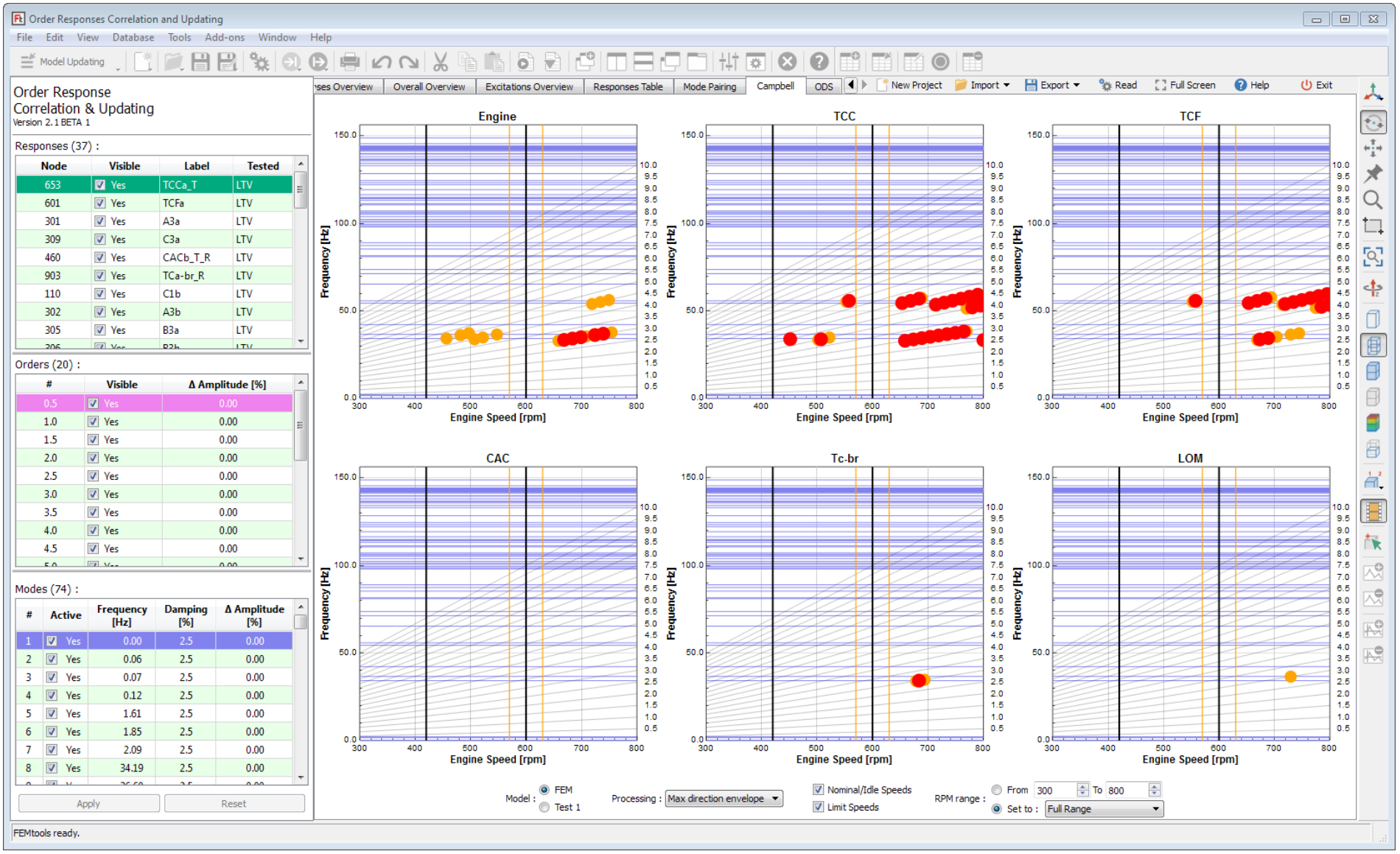
Excitations Overview



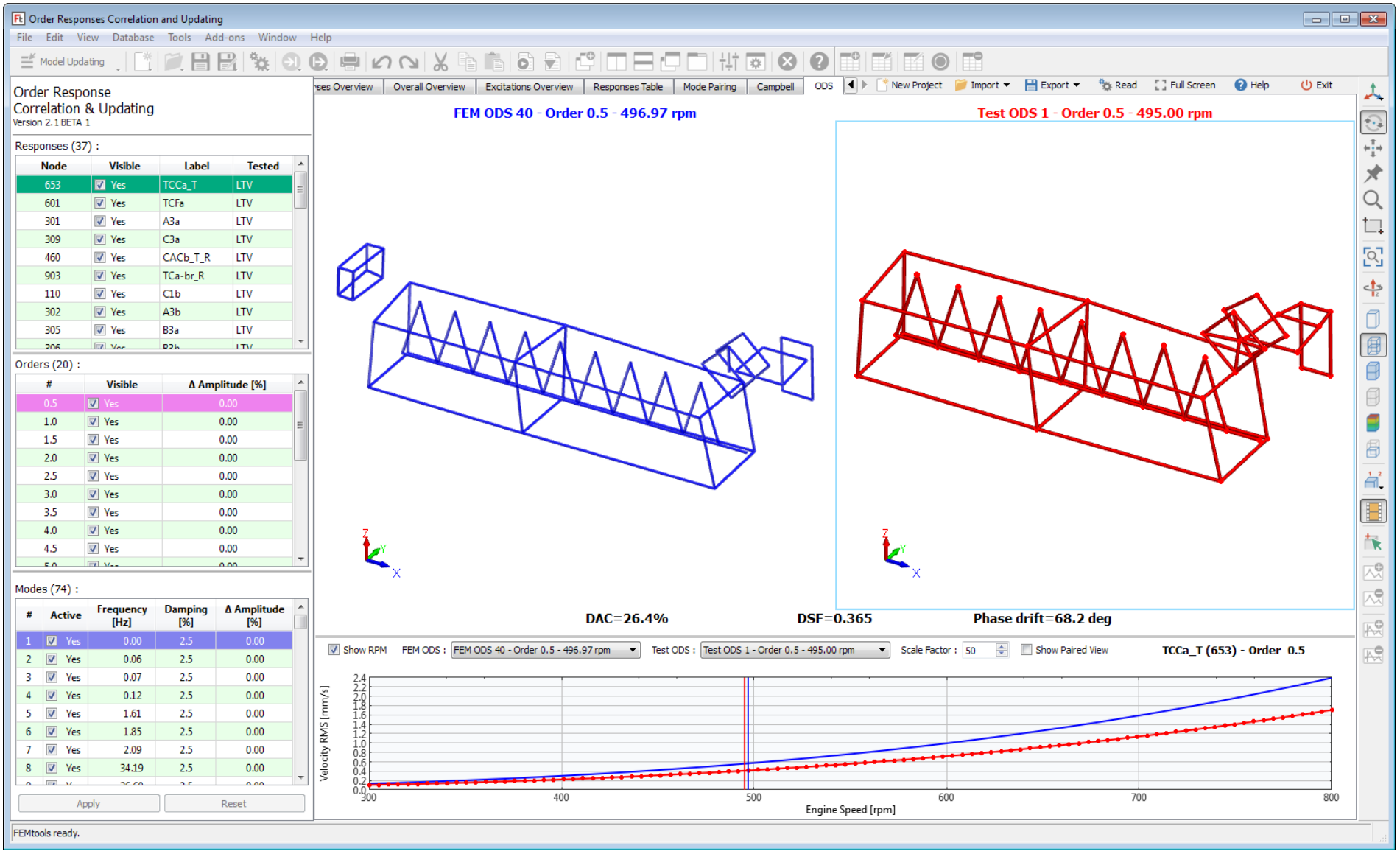
Mode Pairing



Campbell Diagram



ODS Correlation



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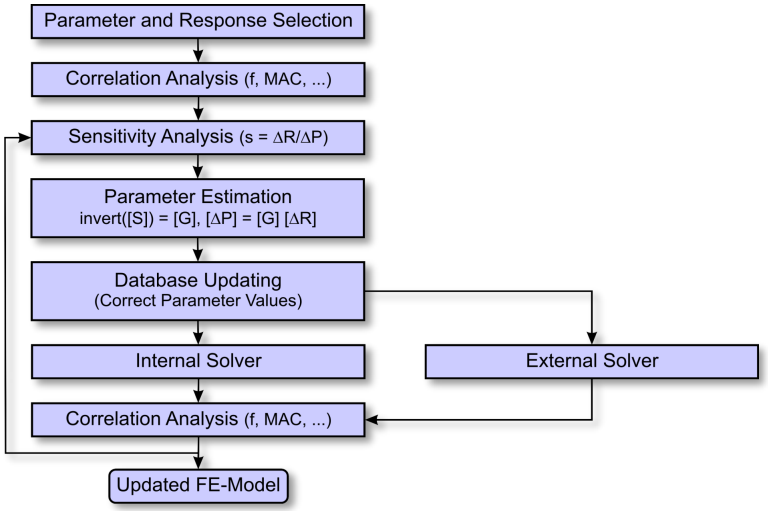
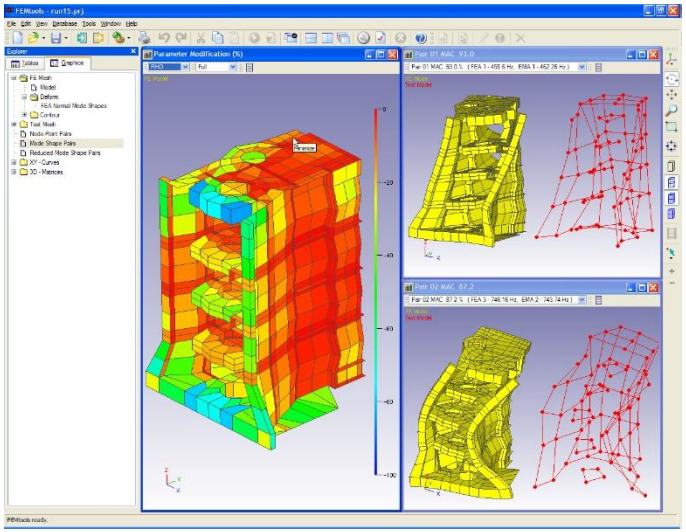




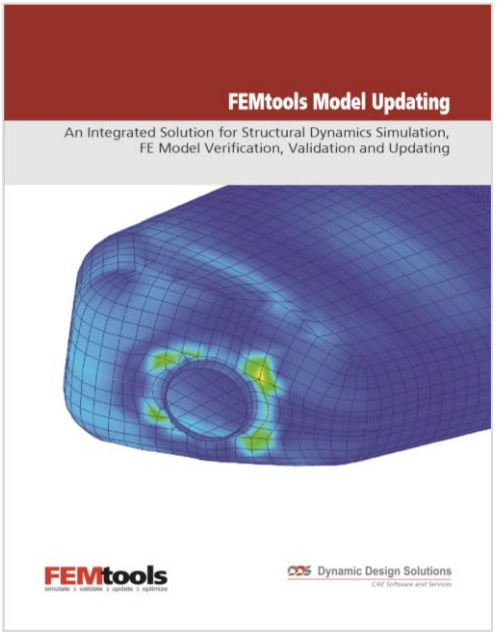
Next Steps

- Review workflow with potential users
  - Test and simulation processes
  - Validation requirements
  - Reporting needs
  - …
- Pilot installations for trial and evaluation
- Interface development for excitations (GT-suite, AVL Excite,…)
- Extended interactive configuration and customization
- Data management and file repository (HDF5?)
- Integrate complementary tools
  - Order tracking
  - Automated parameter optimization (DOE/RSM, genetic algorithm, gradient,…); possibility to loop back to FE parameter updating

Contact Me!

For More Information…

- Exhibition hall, booth 503
- Technical papers
  - http://www.femtools.com/products/papers.htm
- Webinars
  - www.femtools.com/webinars
- Technology course
  - http://www.femtools.com/courses
  - Next course
    - March 29-31, 2023 (Leuven, Belgium)
  - For courses on Modal Testing and Analysis, see www.navcon.com
- E-mail
  - info@femtools.com



www.femtools.com