

Simultaneous Updating of FE Models for Different Structure Configurations

Eddy Dascotte

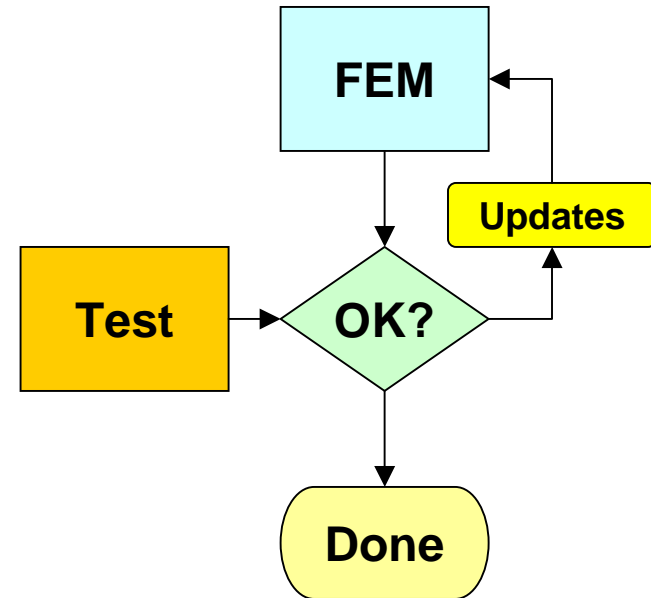
Dynamic Design Solutions nv.

Dynamic Design Solutions

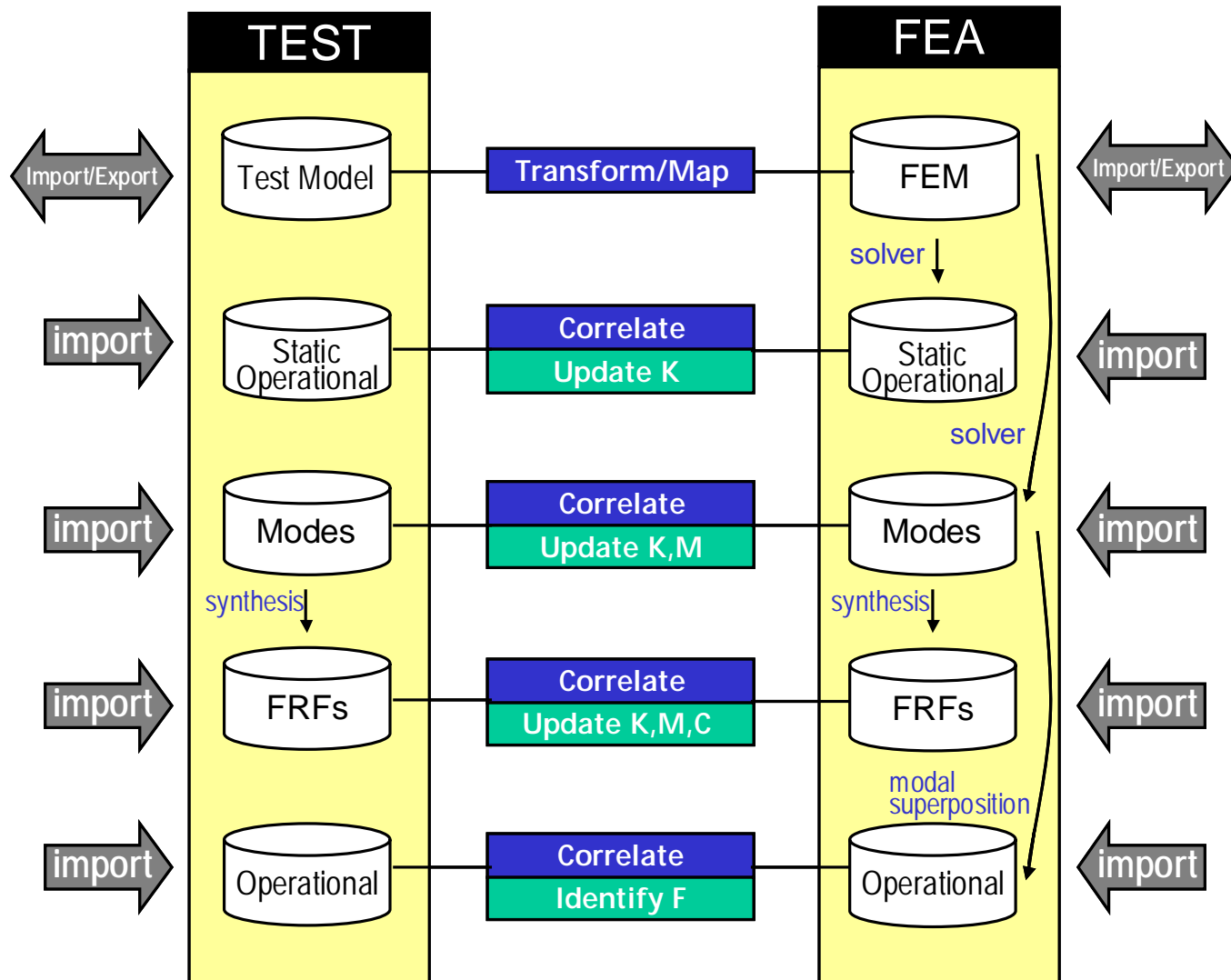
- Located Leuven, Belgium
- Independent, privately owned CAE software development
- Pioneer in FE model updating technology
- Products
 - FEMtools Application Platform – Programming platform for CAE application development (FBScript)
 - FEMtools Modules (FEA-Test correlation, pretest, sensitivity, model updating, ...)
- Services
 - Software related services (support, training, custom-development,...)
 - Consulting (FE analysis, FE model validation, data file translation,...)
 - Project research

FE Model Validation and Updating

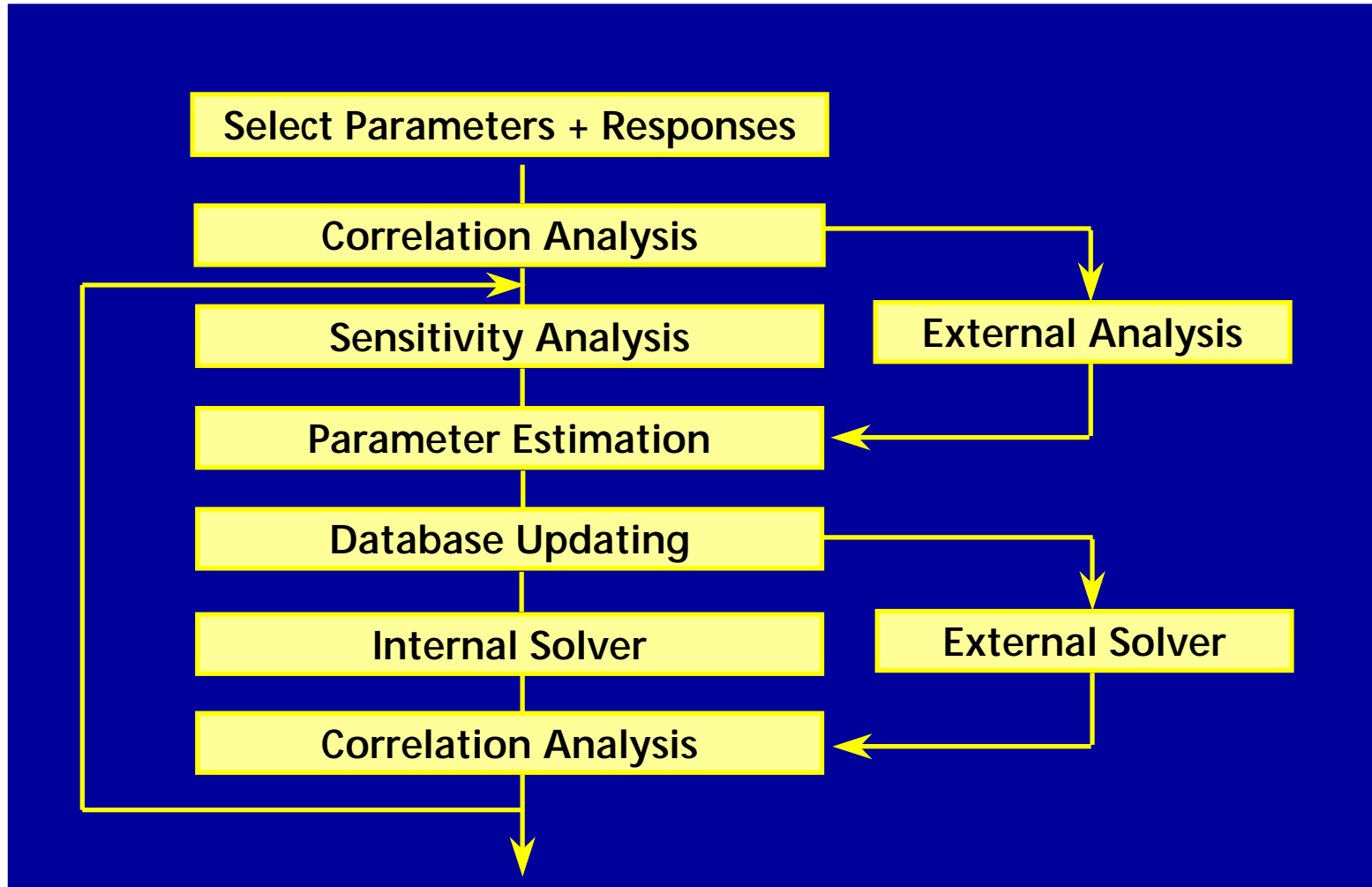
- Why?
 - Uncertainty
 - Simplification
 - Missing information
 - Errors
- How?
 - Trial-and-error
 - FEM matrix updating
 - FEM property updating
- Benefits
 - Learn how to model
 - Identify materials and physical properties
 - Gain expertise for future FE modeling



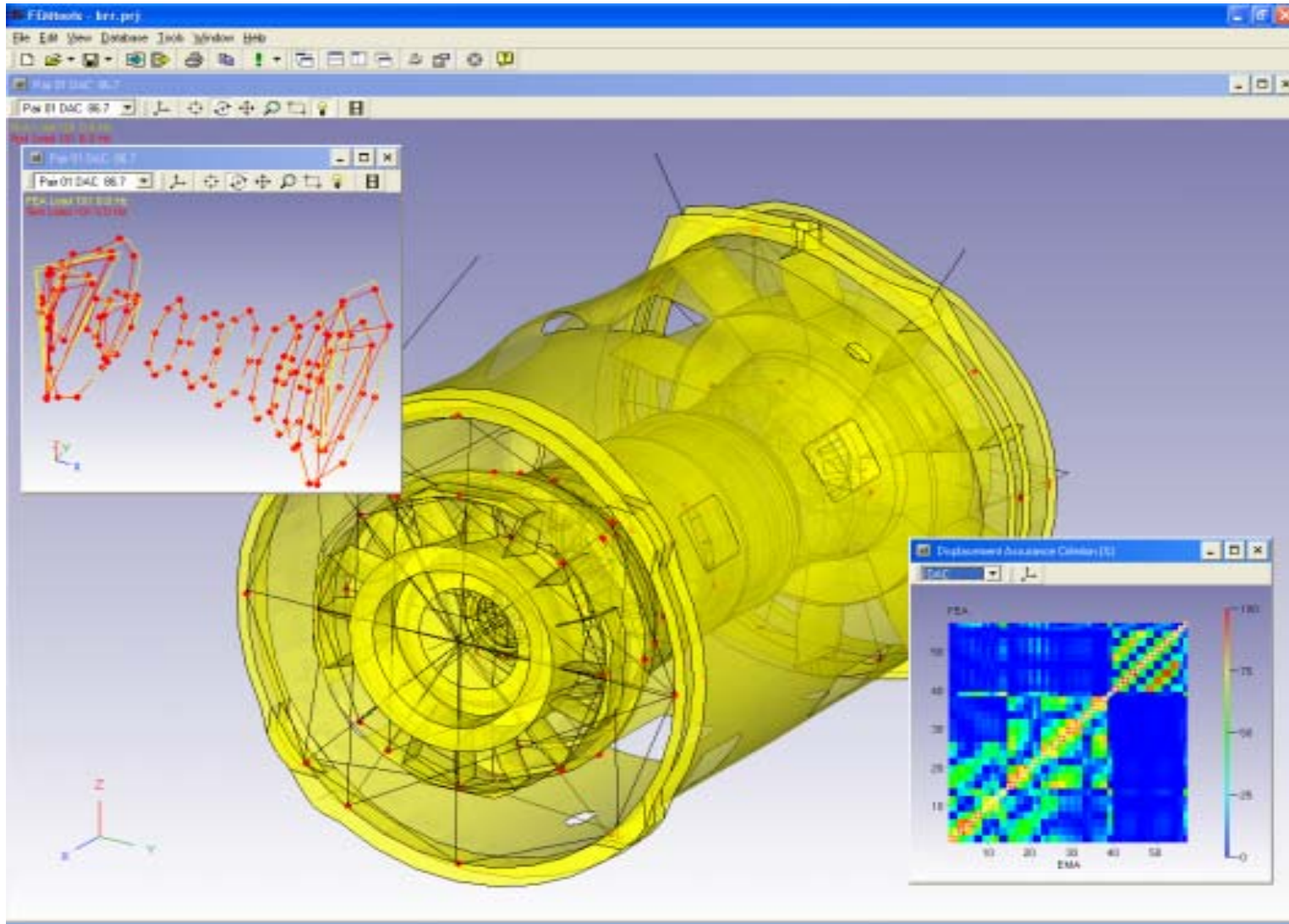
Updating Structural Analysis Models



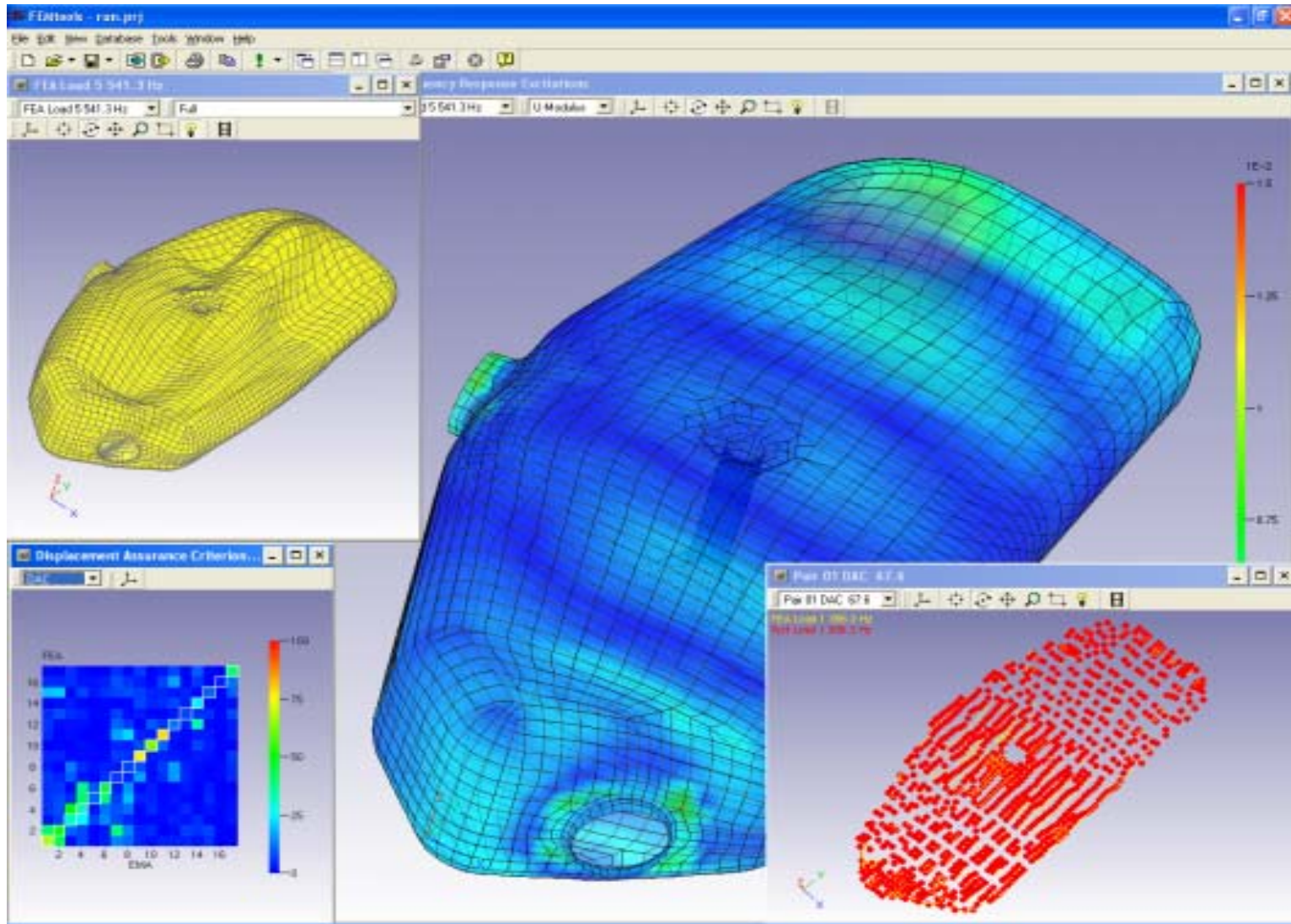
Automated FE Model Updating



Industrial Examples



Industrial Examples



Multi-Model Updating

- What and How
 - Create and exploit a richer database by testing and modeling different variations of a structure, then update parameters that are common to all models.
- Possible FE model variations
 - perturbed boundary conditions
 - adding/removing (lumped) masses
 - variations in shape
 - variations in configuration
- Examples
 - Launch vehicle tested with different levels of fuel
 - Solar panels tested at different stages of deployment
 - Firefighter boom with/without water
 - Elastic properties of layered materials

Multi-Model Updating Algorithm

1) Computation of the sensitivity matrices for each model

$$\{\Delta R_i^n\} = [S_{ij}^n] \{\Delta P_j\}$$

2) Assemblage of a global sensitivity matrix

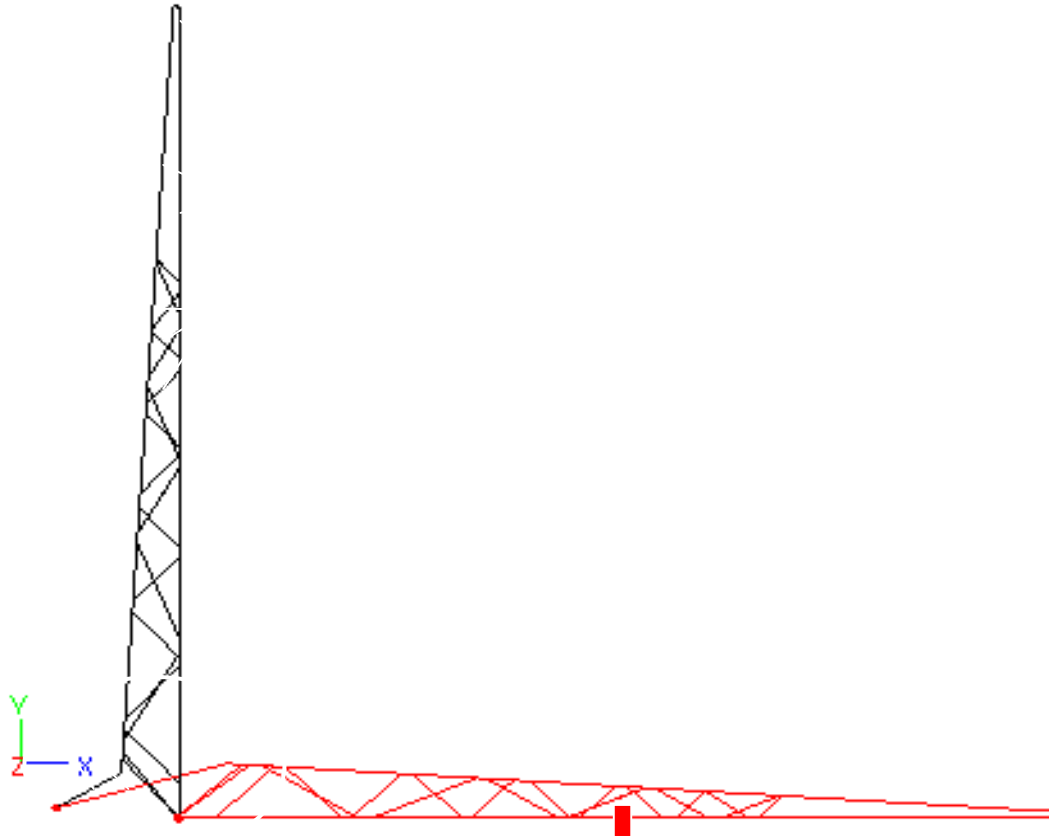
$$\begin{Bmatrix} \Delta R_i^1 \\ \Delta R_i^2 \\ \vdots \\ \Delta R_i^k \end{Bmatrix} = \begin{bmatrix} S_{ij}^1 \\ S_{ij}^2 \\ \vdots \\ S_{ij}^k \end{bmatrix} \{\Delta P_j\}$$

3) Computation of the improved model parameters

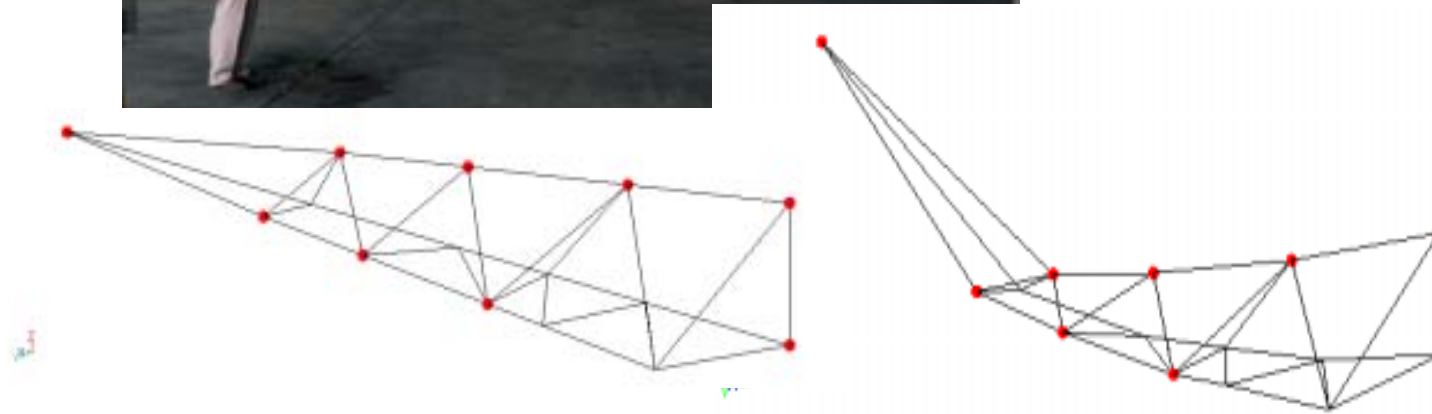
Example 1: MI 17 Fire Fighting Helicopter Boom



FE-model



Experimental modal Analysis

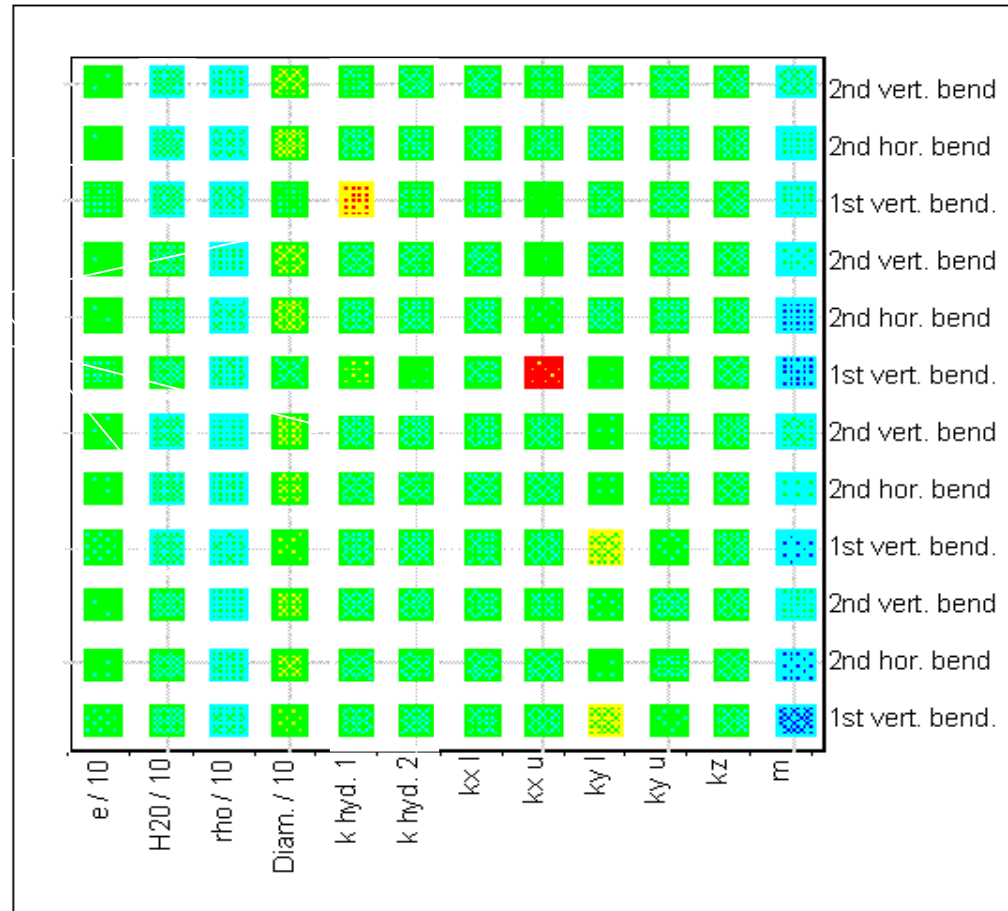


Error average of 50 % !!!
Resonance of 2nd bending mode!!!

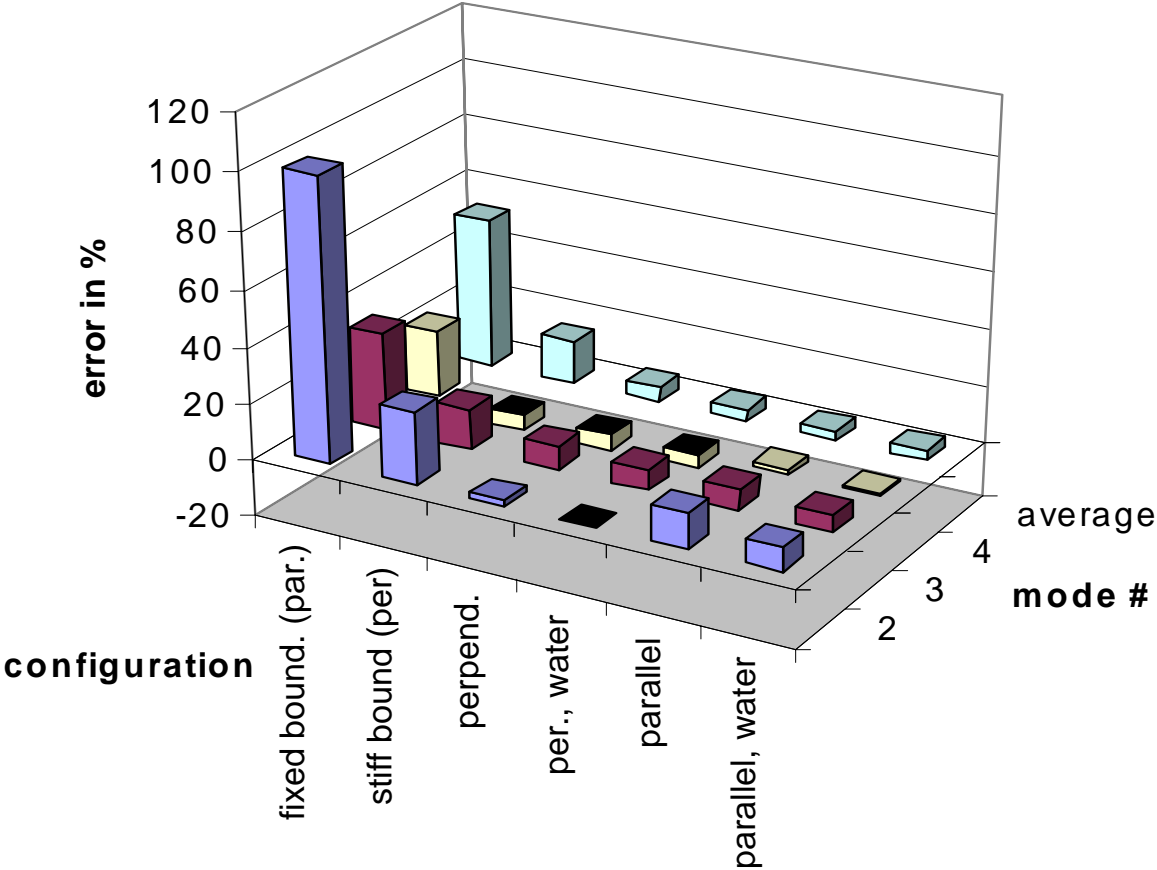
Rigid boundaries?



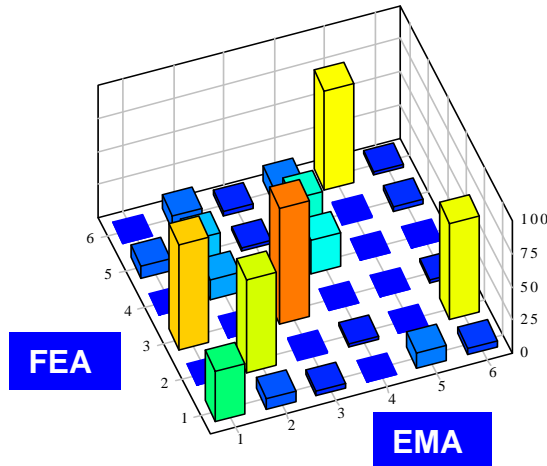
MMU Sensitivity Matrix



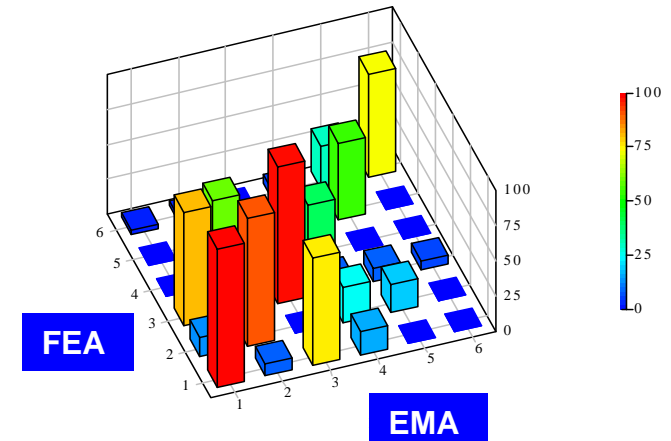
Results: error of eigenfrequencies



Updating Results: MAC



Initial model, fixed boundaries



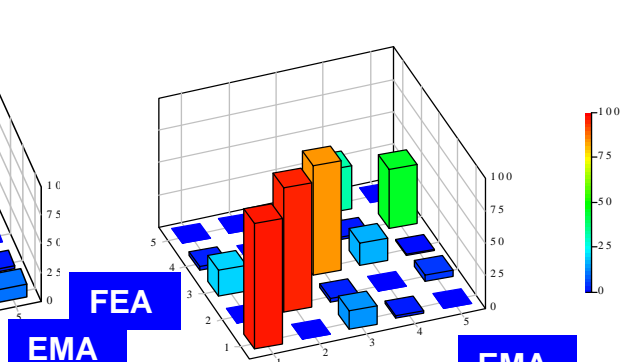
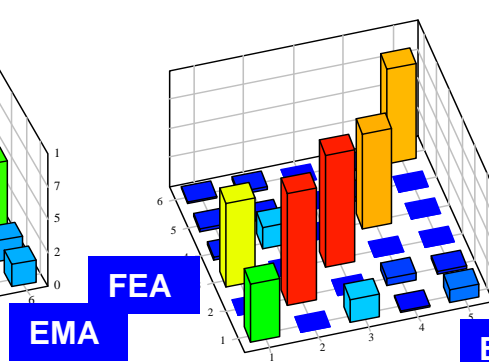
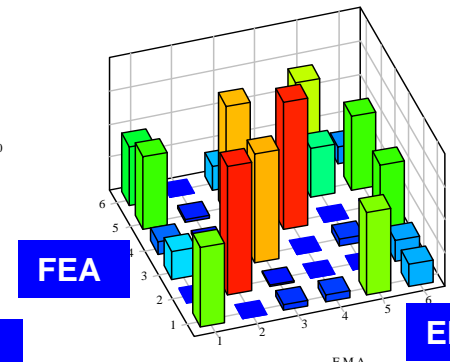
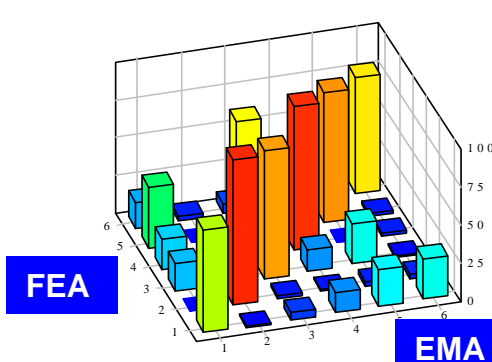
Initial model, stiff boundaries

Modal Assurance Criterion

Modal Assurance Criterion

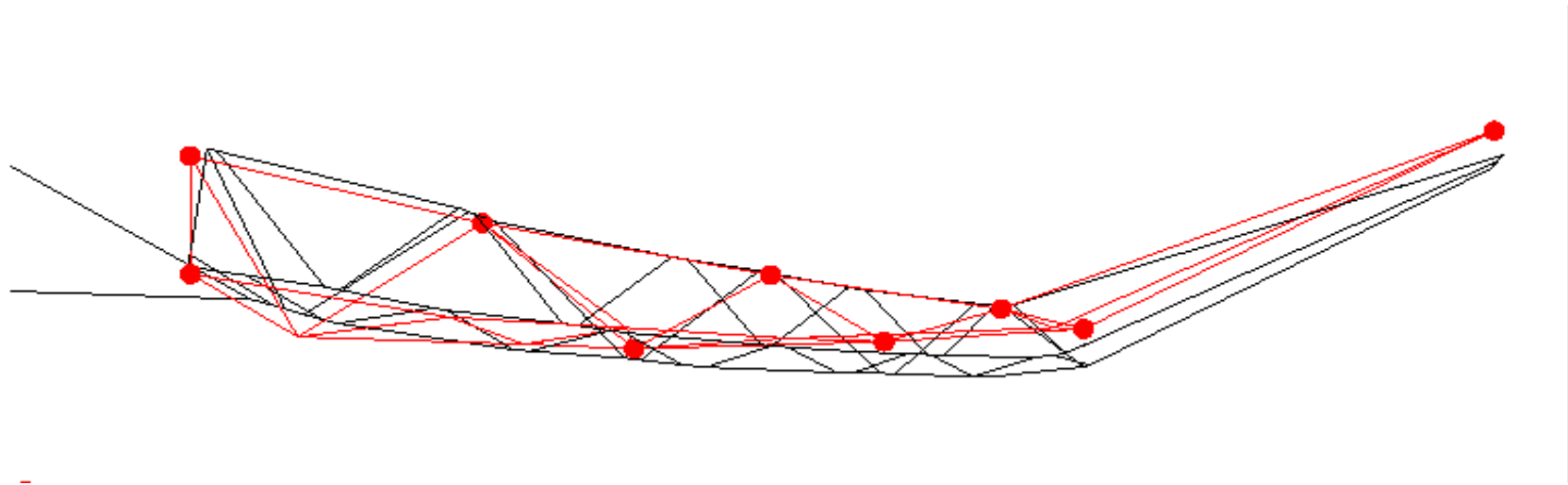
Modal Assurance Criterion

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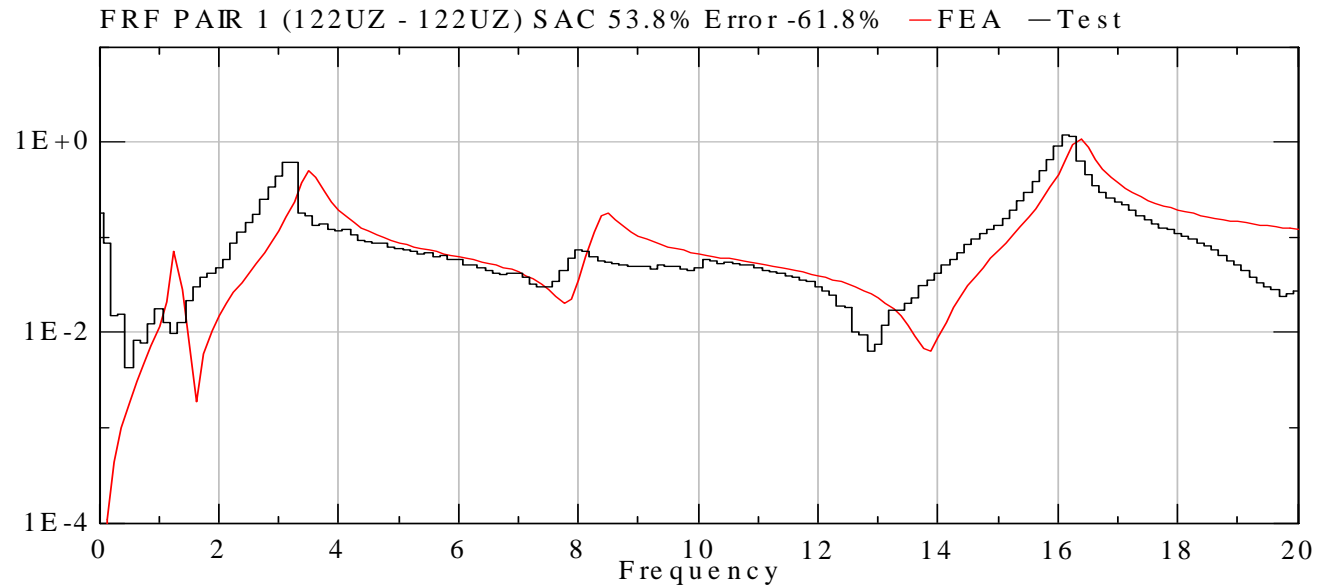


updated models: perpend. / perpend. water / parallel / parallel water

2nd vertical bending mode

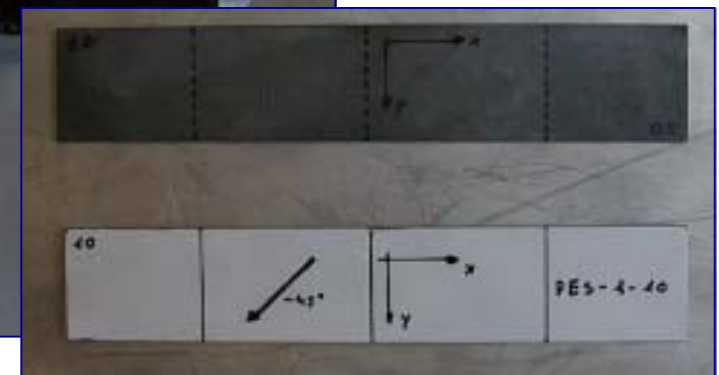
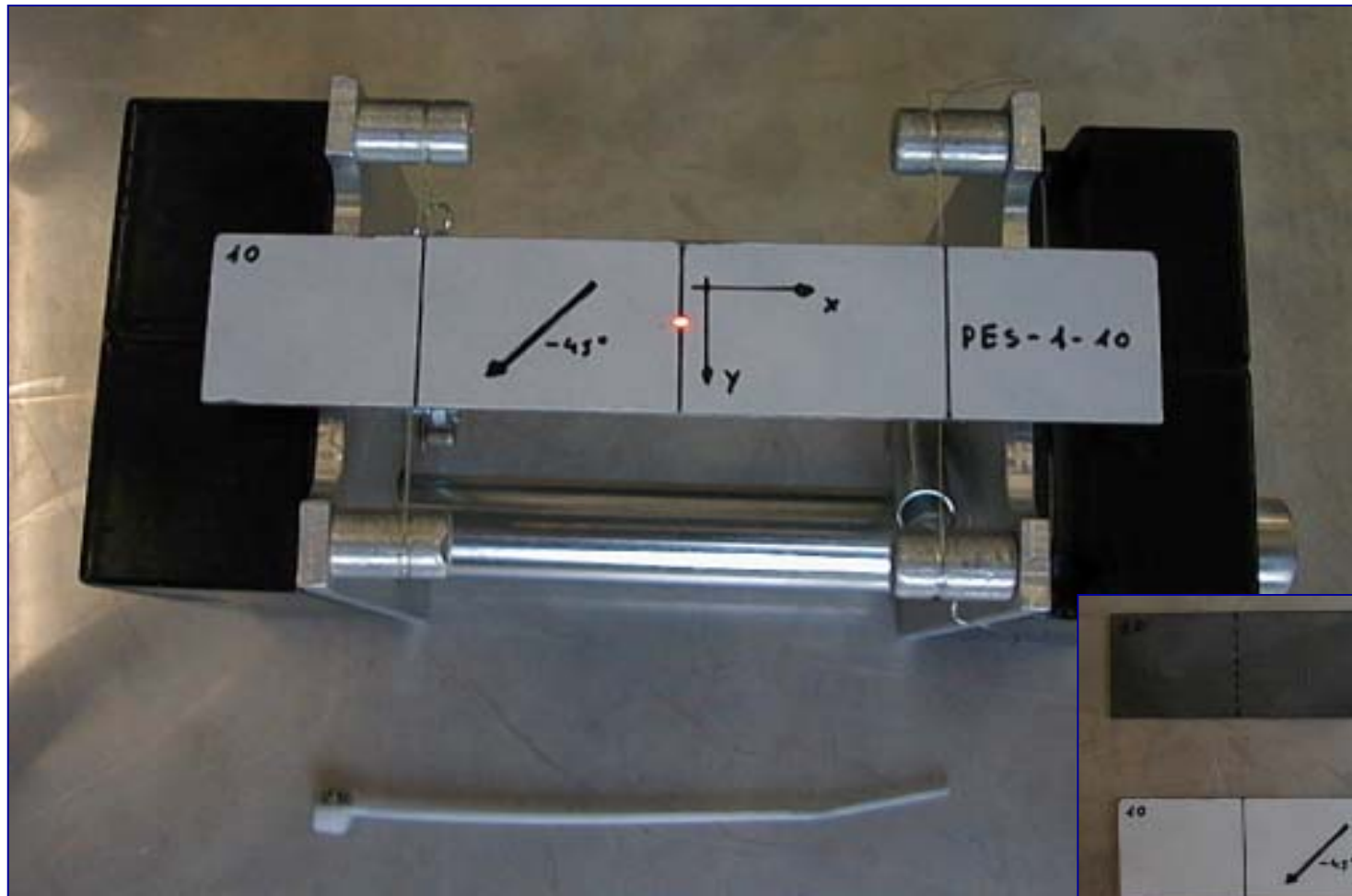


FRF-based updating



$$CSAC(i) = \frac{\sum_{k=1}^N \left(|u_{ki} w_{ki}| \right)^2}{\sum_{k=1}^N u_{ki}^2 \sum_{k=1}^N w_{ki}^2}$$

Example 2: Layered Material Identification



Material Identification using MMU

- Identifying longitudinal Young's modulus of a non-symmetric coated (email) steel plate
- 3 Materials \Rightarrow 3 test samples



- Fundamental bending frequency of each sample
- Simultaneous updating of 3 FE-models

Need for Multi-Model Updating

- Columns sensitivity matrix are linearly dependent \Rightarrow no unique solution
- Modal parameters: only sensitive to the integrated through thickness stiffness
- Removing linear dependency by
 - changing the layer stacking
 - changing the layer thickness
- Only solution is to use multi-model updating routine

Identification Results

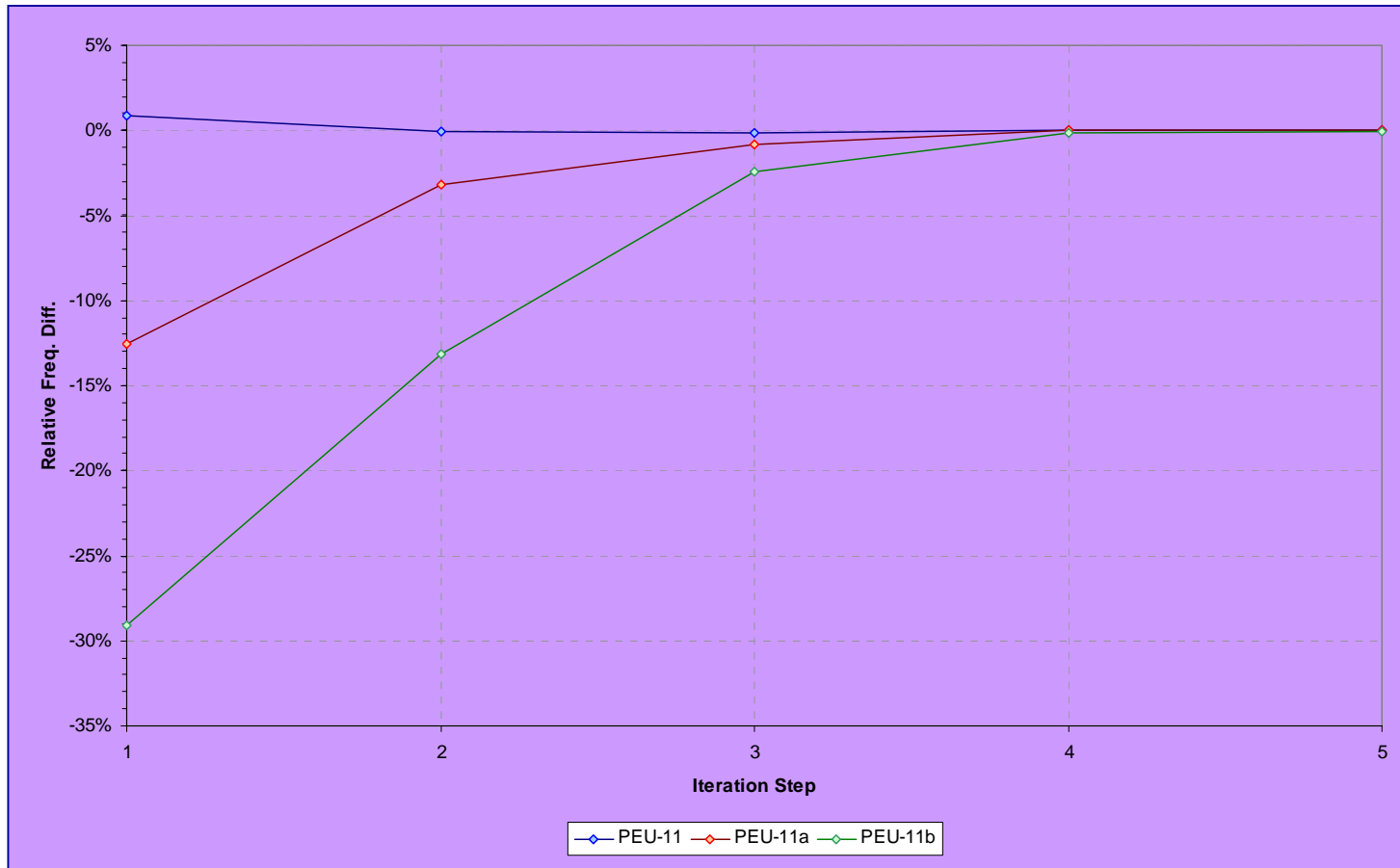
- Obtained frequency match

Sample Id	Freq. Num. (Hz)	Freq. Diff. (%)
Sample-1	496.06	-0.0001
Sample-2	436.47	-0.0001
Sample-3	361.10	-0.0002

- Obtained material properties

Layer	Ex
Top Coating	71.13 GPa
Steel substrate	198.85 GPa
Bottom Coating	70.84 GPa

Convergence



Conclusion

- Model Updating is a Process

- FEM-Test mapping

- Database expansion and reduction

- Pre-test planning

- Global shape correlation analysis

- Local correlation analysis (error localization)

- Transfer function correlation

- Updating variable selection

- Cost function definition

- Design space exploration

- Sensitivity analysis

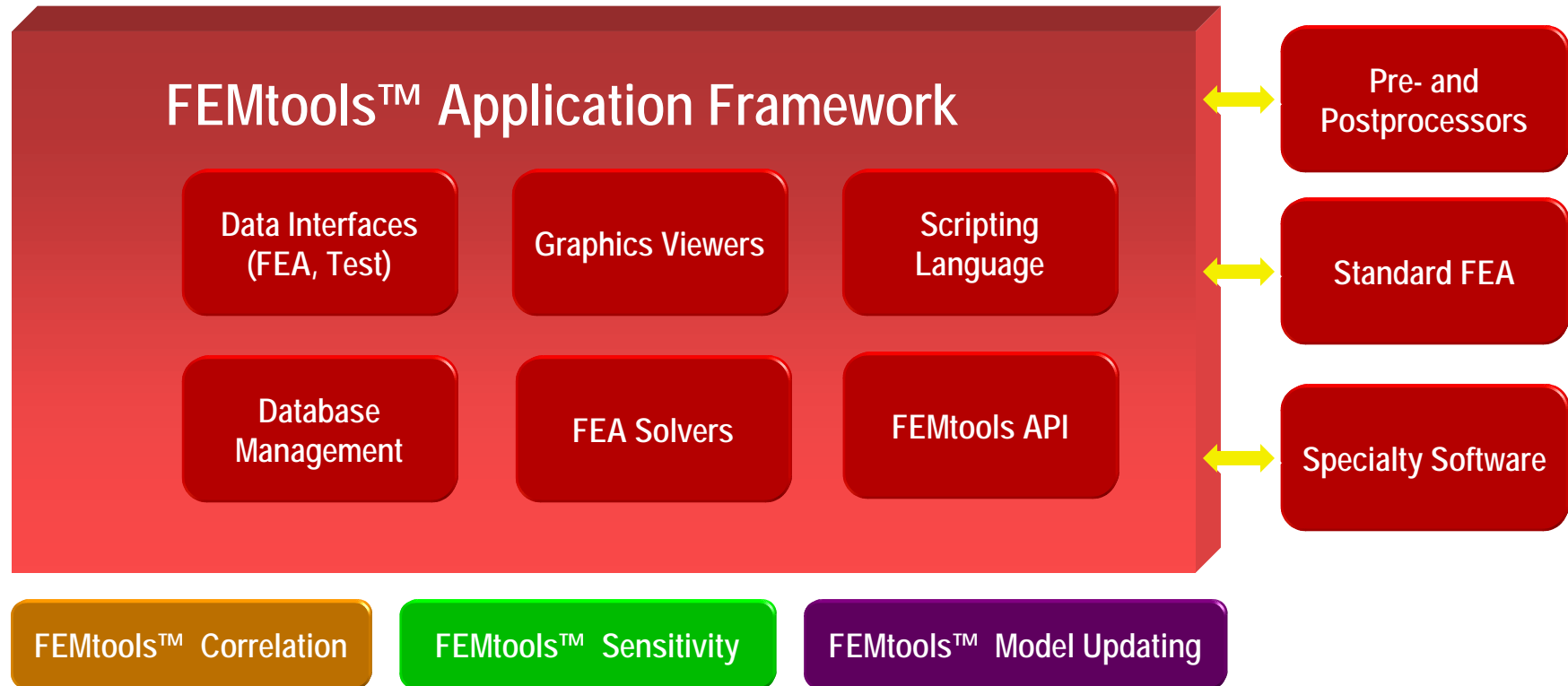
- FEA re-analysis

- Result visualization and interpretation

- ...

Requiring dedicated software

FEMtools Overview



For More Information...

- FEMtools Website

<http://www.femtools.com/products>

<http://www.femtools.com/products/papers.htm>

- E-mail:

eddy.dascotte@dds.be