CORRELATION AND MODEL UPDATING

AGENDA

- INTRODUCTION
- UPDATING STRATEGY
  - GEOMETRIC CORRELATION
  - CORRELATION
  - SENSITIVITY
  - UPDATING

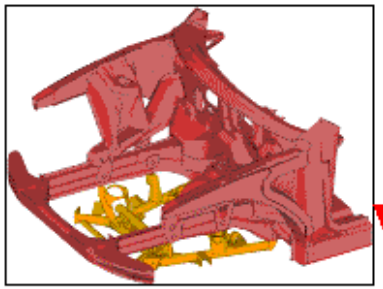
INTRODUCTION : WHY UPDATING

- WHAT IS CORRELATION UPDATING
  - Comparison between model results and physical structure
    - Model = FE / SEA / MBS / …
    - Physical structure = modes, FRFs, …

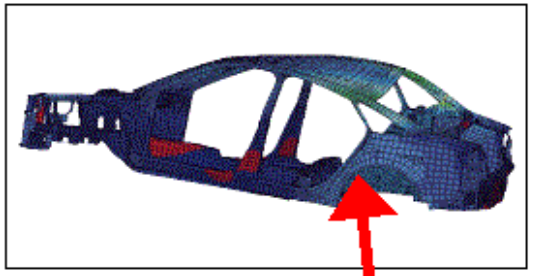
- WHY CORRELATION / UPDATING
  - Learning from accuracy / errors in previous models
  - Improving models for use in troubleshooting

- ABOUT UPDATING
  - Learning the tools is easy
  - Interpreting the results needs experience

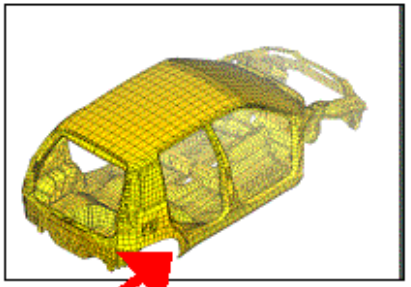
Updating in body development phases



Feasibility Phase



Concept Phase



Design/Development

ID	Task Name
1	Feasability analysis phase
8	Concept phase
16	Development phase
24	Refinement phase
31	Implementation and pre-production

TROUBLE SHOOTING

LEARNIN

Refinement Phase

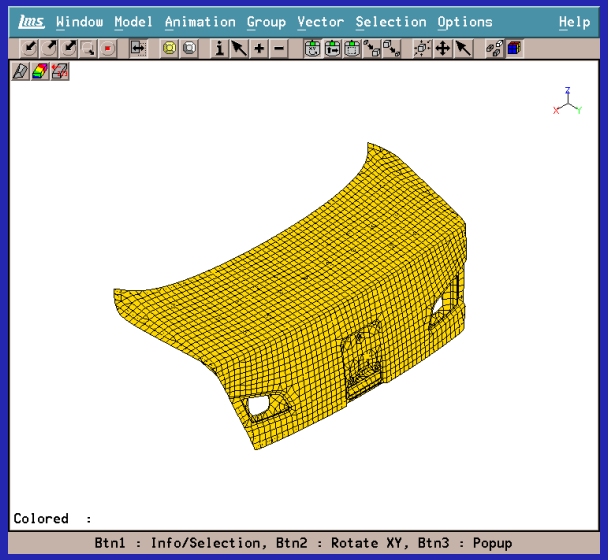
Implementation

UPDATING STRATEGY

- CORRELATION
- SENSITIVITY
- UPDATING

Correlation Software…

… allows you to examine, compare and correlate two sets of data and to obtain a qualitative assessment of the comparison



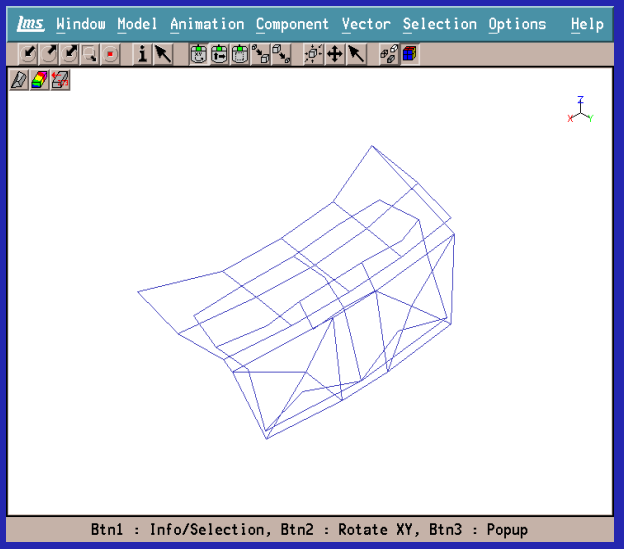
Test-Test

FE-FE

FE-Test

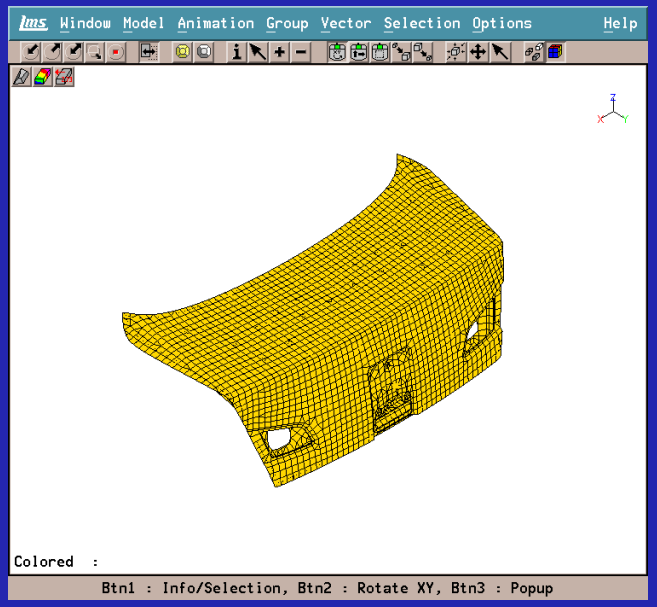
Test-FE

SESSION FILES



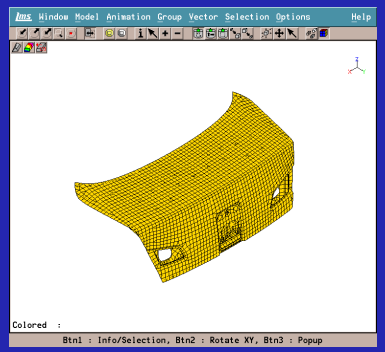
Trunk lid: test model

- Is my FE model a good representation of the real model?
- If it's not the case, how can I improve it ?

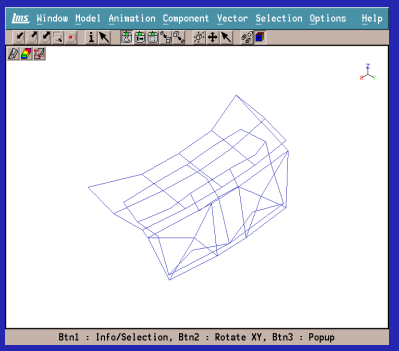


If yes, use the model without changes

Overview



Real Structure



FE model

Test model

Geometric Correlation

Dynamic Correlation ?

Not OK

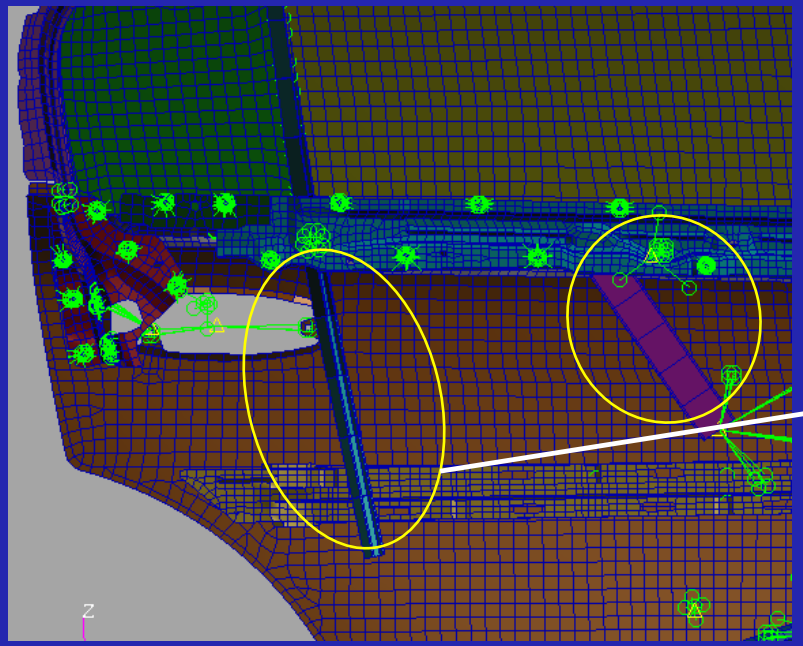
OK

Parameter Selection

Reliable FE model

Correction of the FE model

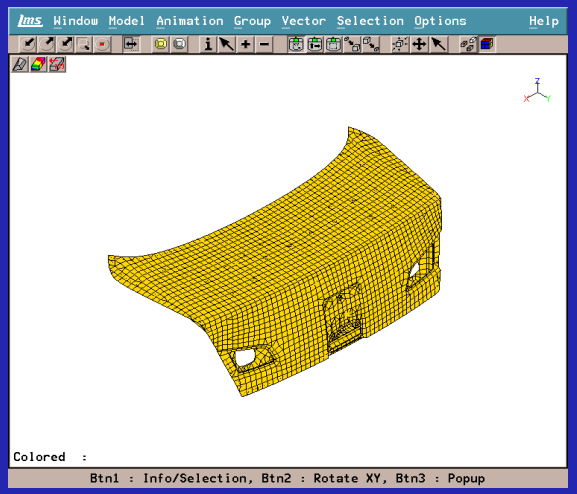
Geometric correlation TEST- FE: VISUAL

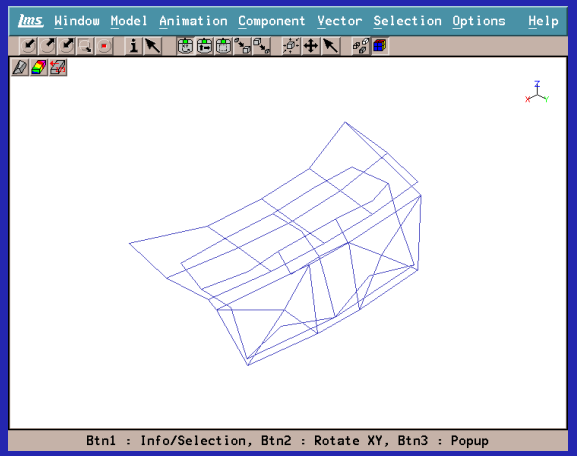


Missing parts in the original model

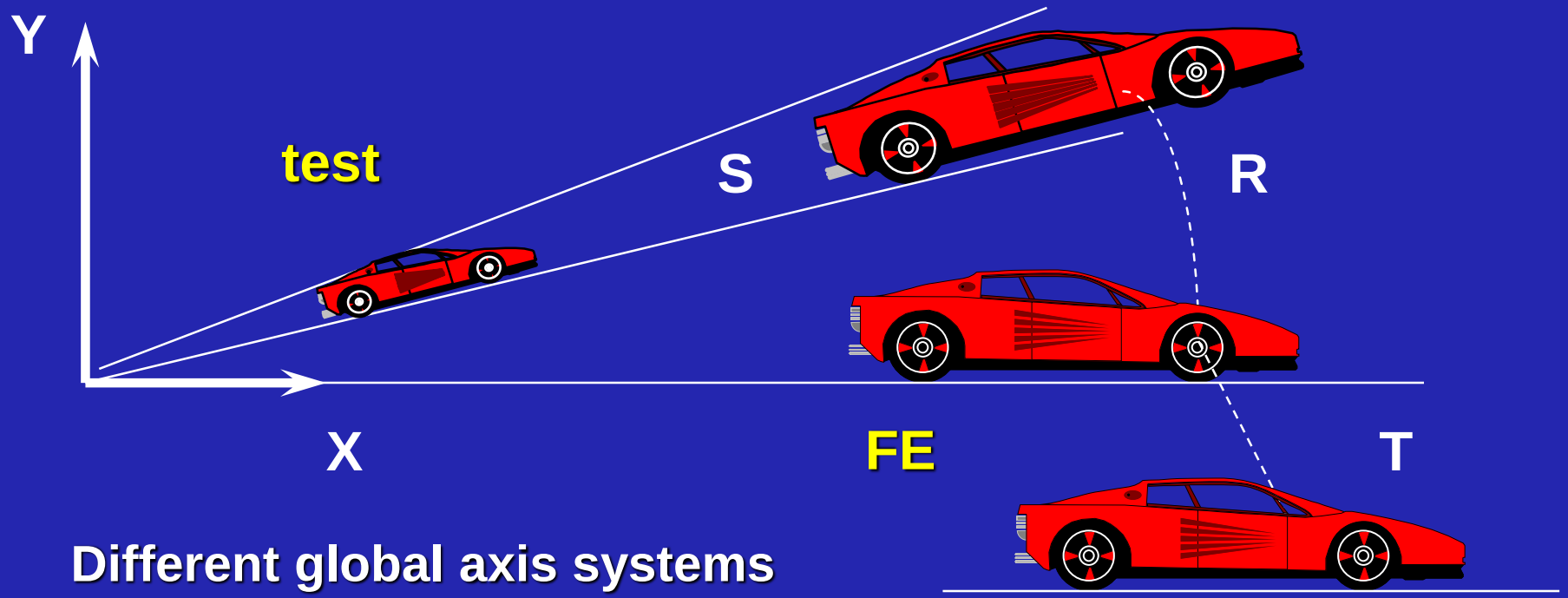
Mesh Incompatibility

- Mesh Density
- Unity Systems
- Point/Node naming
- Global orientation in space (step 1)
- Measurement directions (step 2)





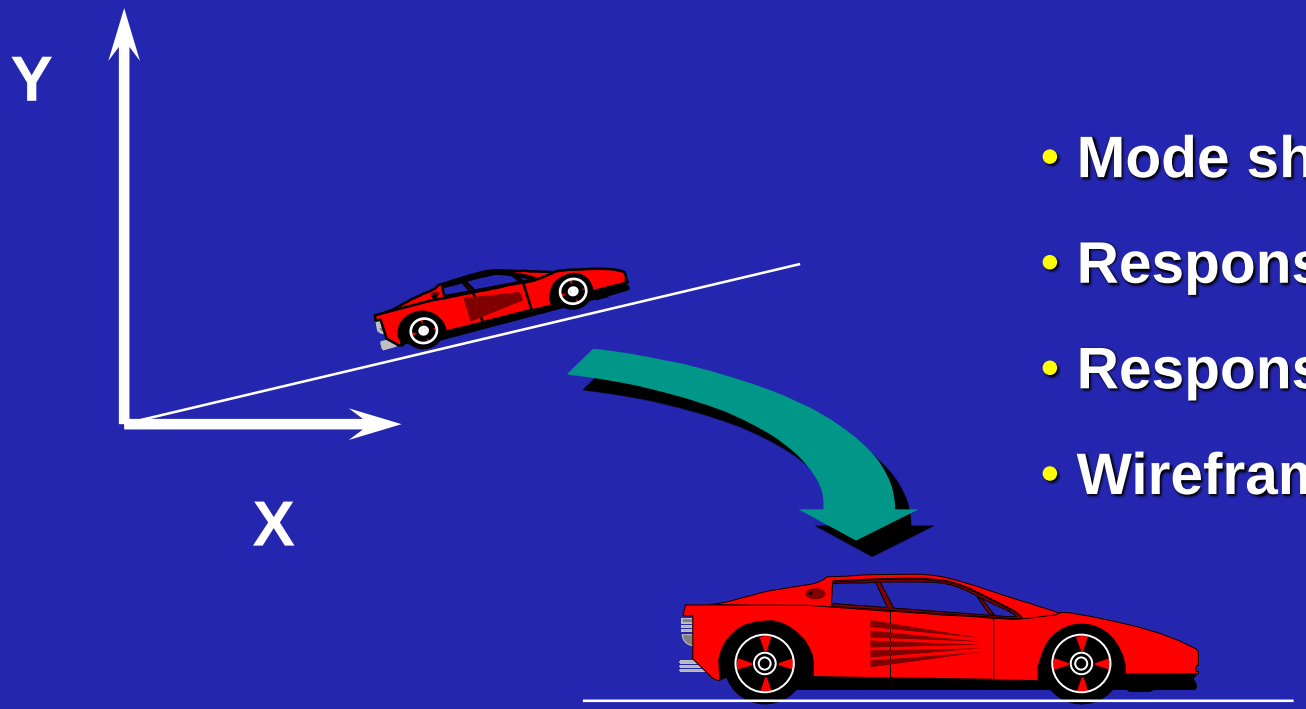
Geometric Correlation



Different global axis systems

$$\{X^{corr}\} = \{T\} + [R]S\{X^{test}\}$$

Data transfer



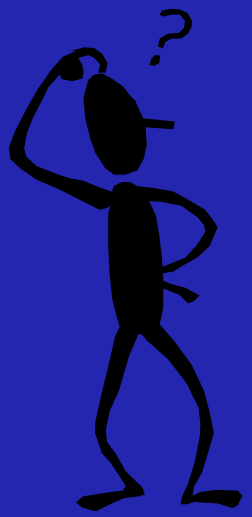
- Mode shapes
- Response vectors
- Response functions
- Wireframes ...

… from one model (test/FE) are translated to FE model

(and get the according annotations!)

Geometric/Dynamic correlation

- Geometric correlation → complete & consistent data set
- Dynamic correlation
  → evaluation of the agreement between test and FE analysis data
  → localization of the difference between the two models



How best improvements can be made ?

DYNAMIC CORRELATION: Modal Assurance Criterion

… expresses the nature of the relationship between two pair of vectors

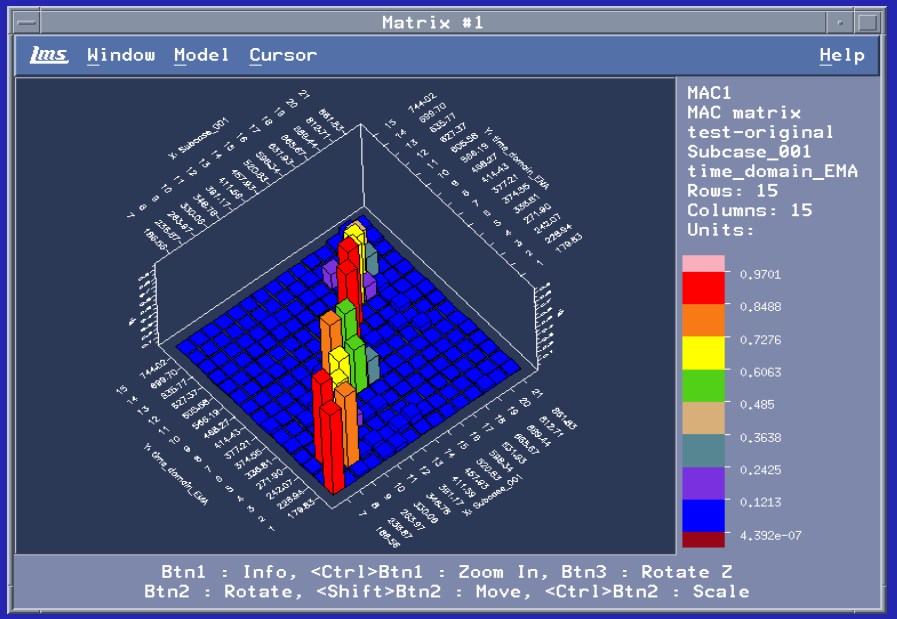
$$MAC_{rr'} = \frac{\left| \left\{\psi_r^{test}\right\} \left\{\psi_{r'}^{FE}\right\}^* \right|^2}{\left(\left\{\psi_r^{test}\right\} \left\{\psi_r^{test}\right\}^* \right) \left(\left\{\psi_{r'}^{FE}\right\} \left\{\psi_{r'}^{FE}\right\}^* \right)}$$

for 1 frequency, for all DOFs (Correlated DOFs, DOFs corresponding with a particular component)

→ Values between 0 and 1

MAC Interpretation

- Good correlation depends on the kind of structures
- Corresponding test and FE modes
- Mode switching
- Spatial aliasing !
- Missing modes



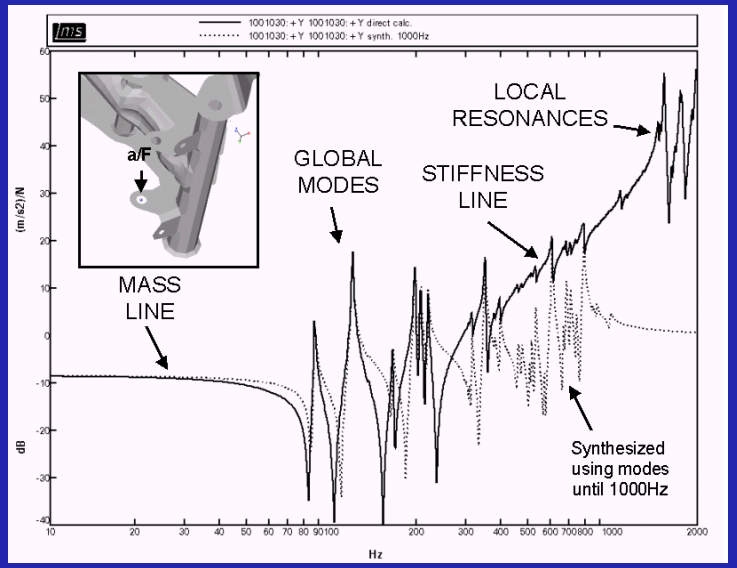
DYNAMIC CORRELATION: FRF correlation

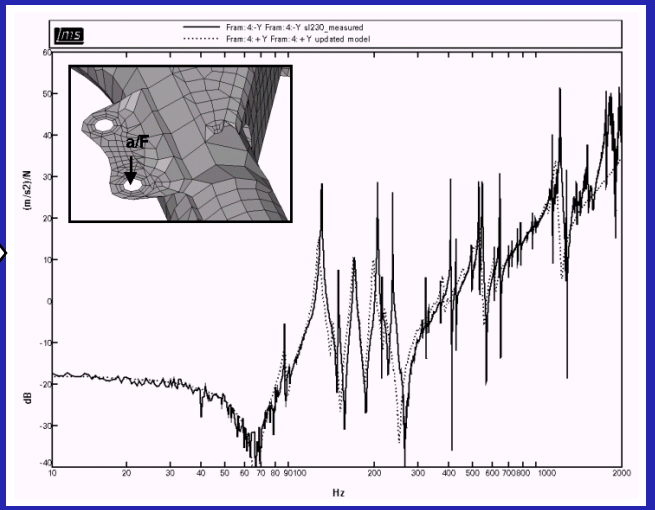
- Synthesize FRF, apply modal damping
- Correlate to Shaker and Hammer FRF from Test
  - Amplitude and Phase
- FRF in FE should have same general shape and major peaks as Test

FRF correlation

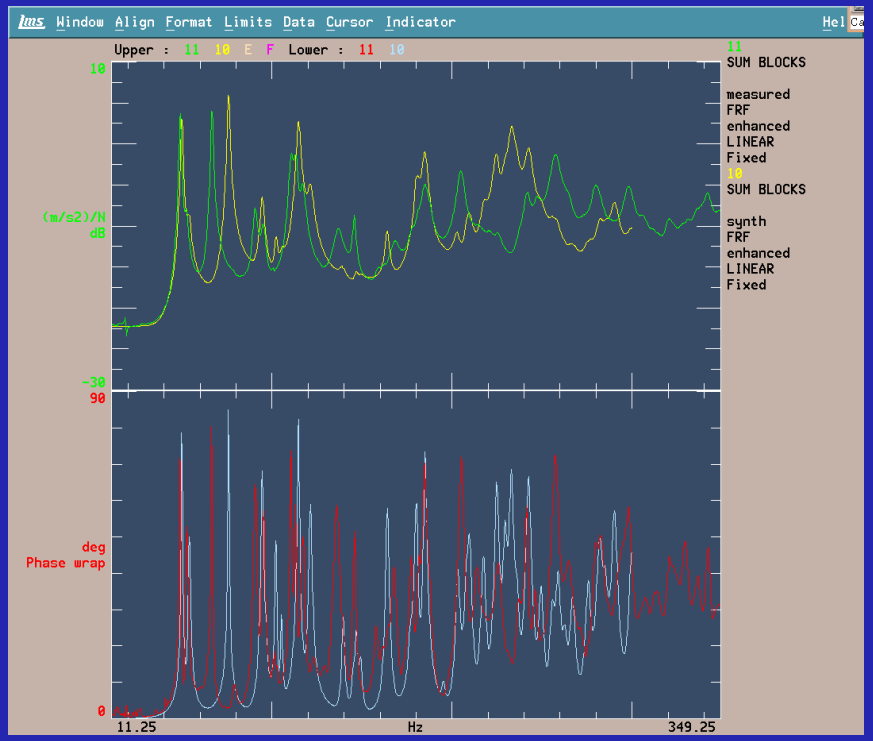
- **FRF Correlation criteria : FRAC**

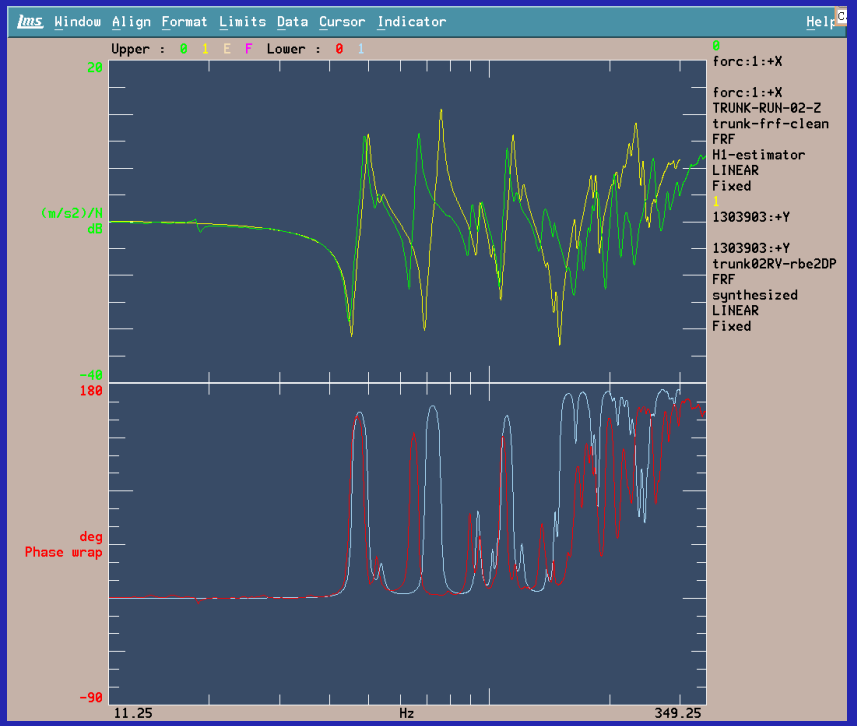
$$FRAC = \frac{\left| \{H^{test}\} \{H^{FE}\}^* \right|^2}{\left(\{H^{test}\} \{H^{test}\}^* \right) \left(\{H^{FE}\} \{H^{FE}\}^* \right)}$$



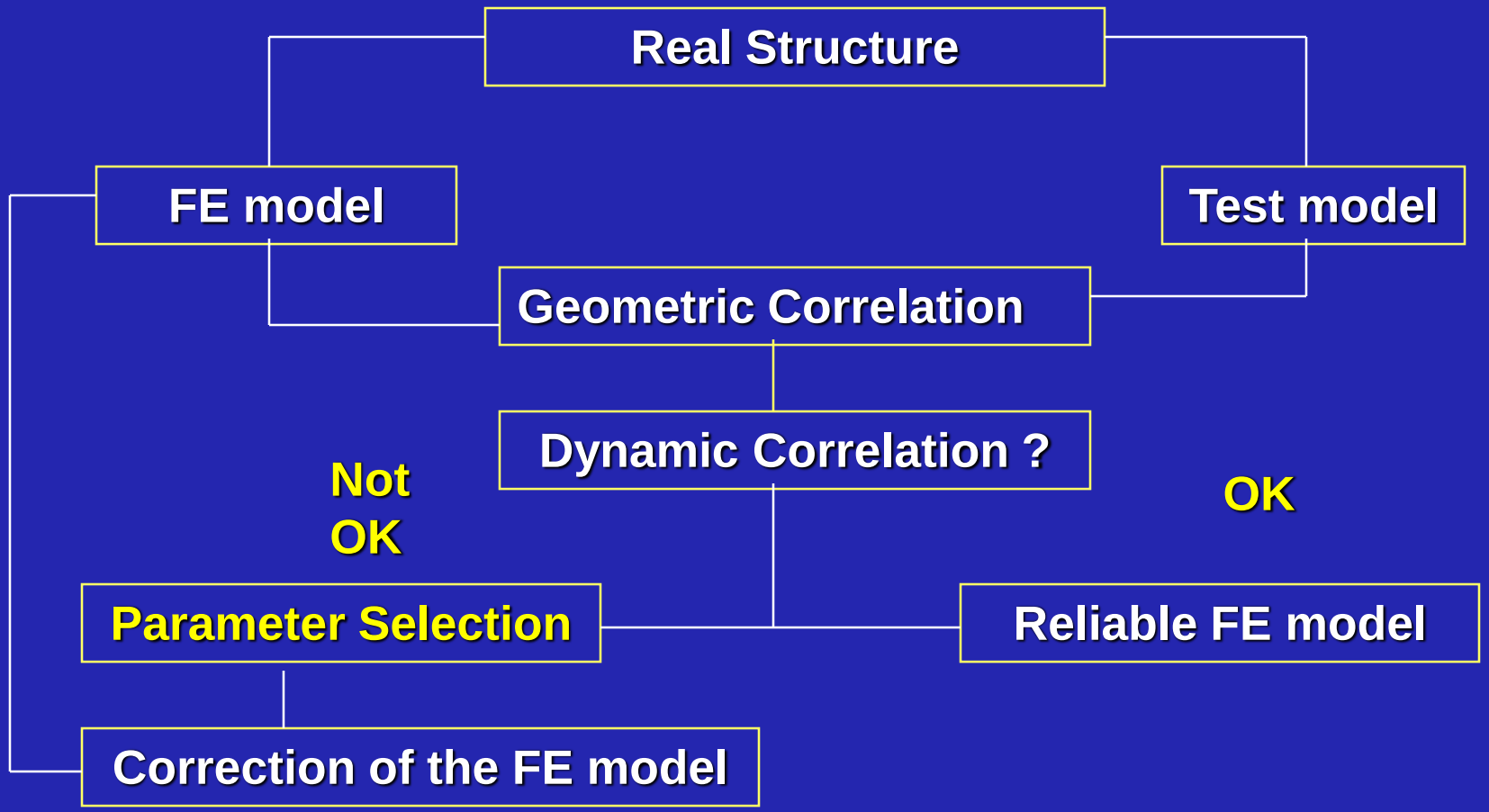


FRF correlation





Where are we ?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FE model
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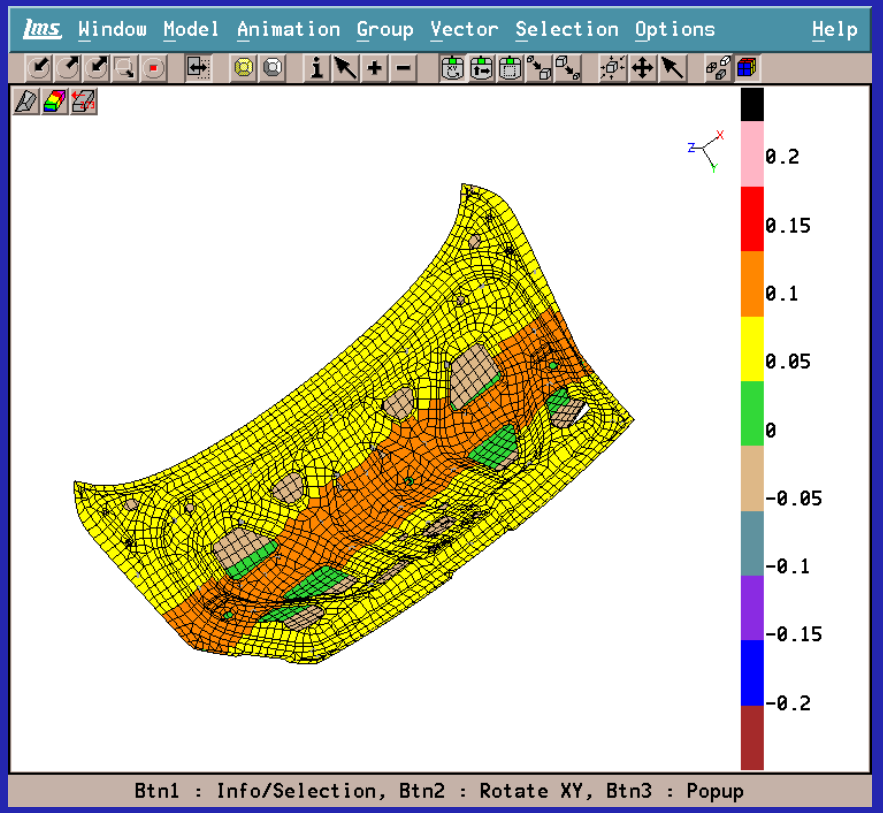
Sensitivity and Updating

Sensitivity:

Updating:



Sensitivity

… Use the quantitative results of a modal analysis to evaluate the effects of structural changes

Sensitivity can be computed for changes:

- in the structure's proportional physical properties
- within the design properties

The influence of these changes can be computed for:

- modal frequencies
- structure's total mass

How to compute sensitivity

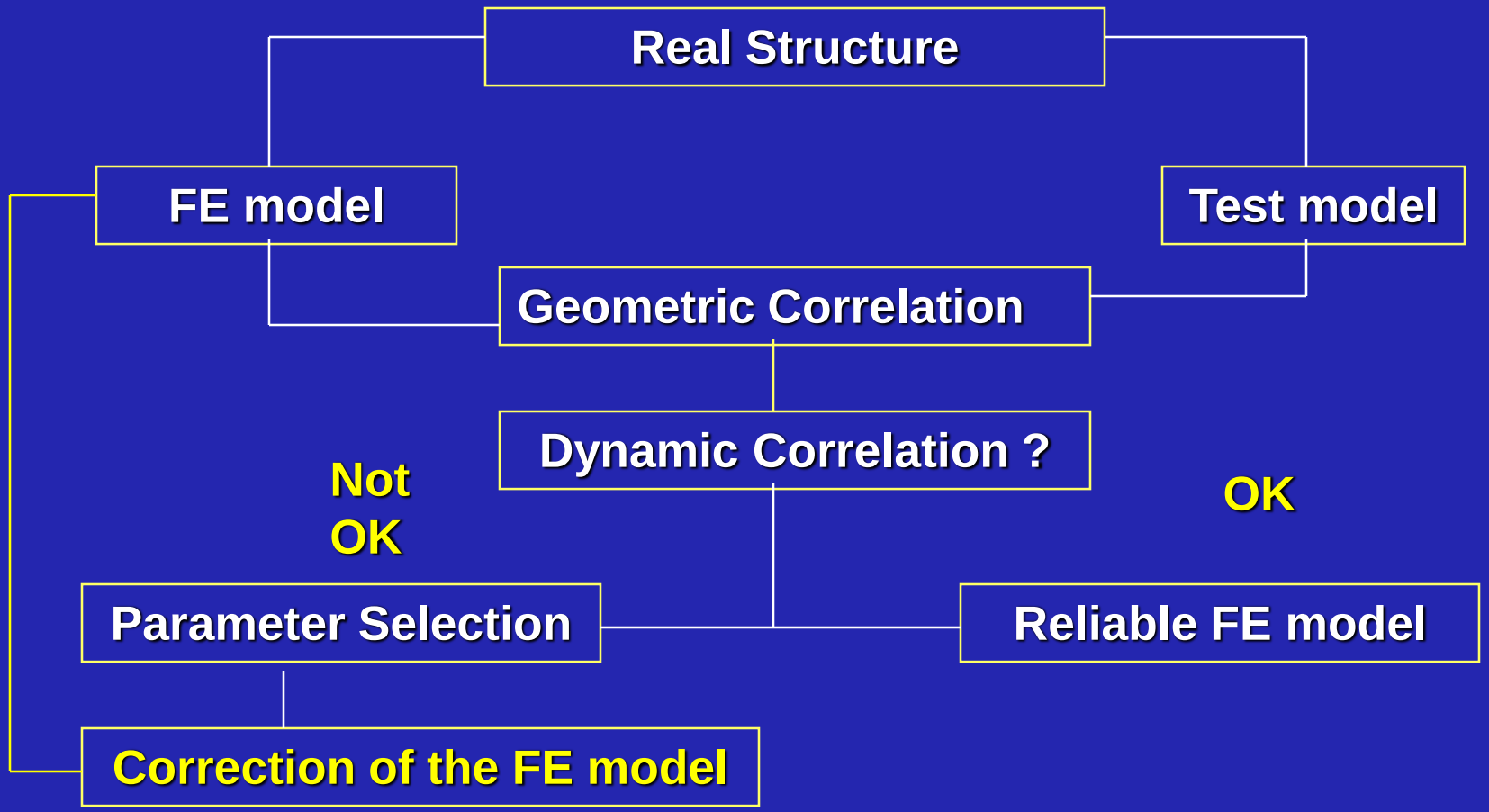
$$\left(\left[K\{p\}\right]-\omega_r^2\left[M\{p\}\right]\right)\{\psi_r\}=0$$

Where

- **[K{p}] ([M{p}]) are the assembled stiffness (mass) matrix for the current value of the design variable {p}**
- **ω_r is the eigenfrequency r for which sensitivity values are to be calculated**
- **$\{\Psi_r\}$ is the eigenvector corresponding to the eigenfrequency**
- **{p} is the set of design variable**

$$\frac{\partial \omega_r}{\partial p} \; ?$$

Where are we ?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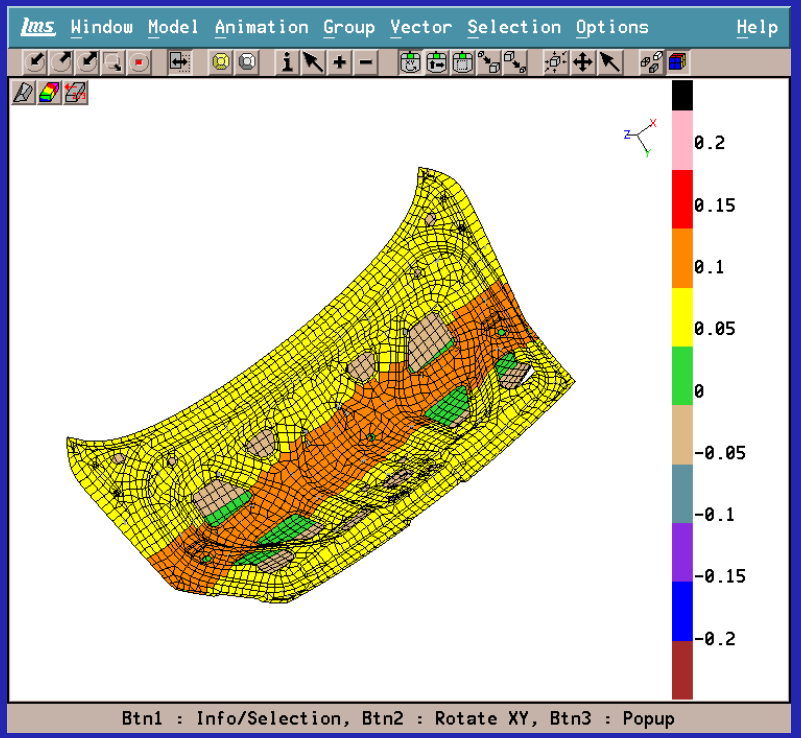


Updating problem

… is solved by minimizing the discrepancy between calculated (FE) and measured (test) response

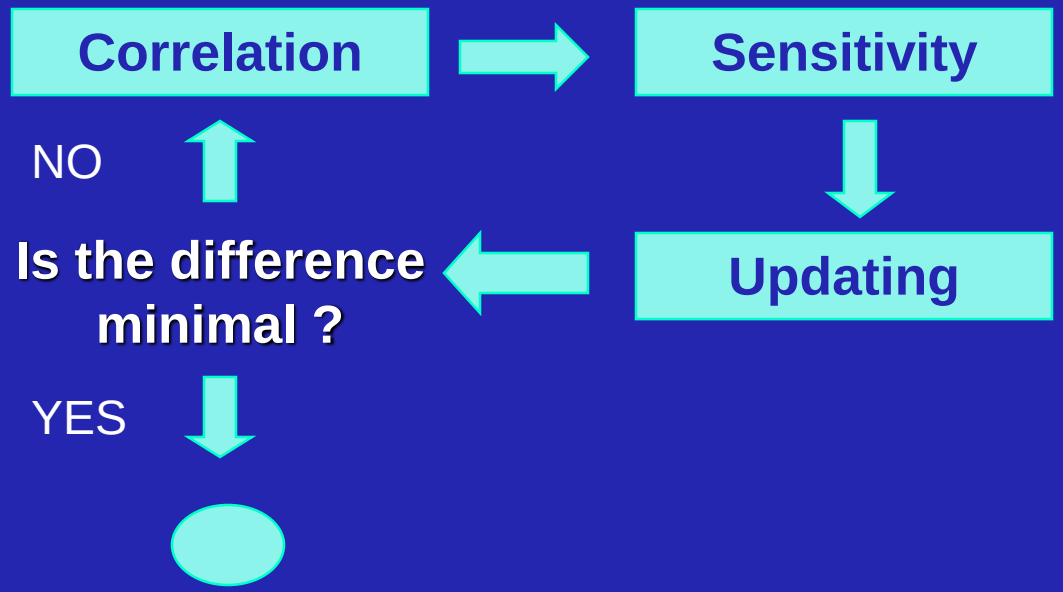
This discrepancy can be composed of the differences:

- in natural frequency
- in the structure's total mass

and expressed as the norm of a vector {e}

Updating procedure

- Step by step procedure
- Uses the results of the correlation {e} and sensitivity analysis [S]



Comparison of MAC matrices : before and after model updating