From 6 months to 6 weeks "Multi Disciplinary Optimisation MDO" (Crash - NVH - Restraints)

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Jaguar Landrover

Summary:

The traditional new-vehicle design cycle is very time consuming due to the sequential approach used. The need to reduce time to market for new vehicles as well as the increased affordability of high-performance computing, which can process hundreds of simulations concurrently, has led to the increased adoption of MDO processes.

The goal of an MDO is to provide a more consistent, formalized process for complex system design than that found in traditional approaches, as well as to impact the design cycle through timely, performance-based direction. In essence, MDO aids in the management of the design process workflow itself.

The MDO principle allows engineers and analysts to address multiple vehicle attributes such as safety performance, refinement and failure modes e.g. full frontal, offset, side and rear impacts, occupant restraints and total vehicle level NVH.

This paper provides a formal and structured approach in the use of MDO at JaguarLandover to address complex and often conflicting requirements; arriving at better quality designs in a faster and more cost- effective manner.

The use of MDO solutions increases the efficiency of the simulation processes by the following:
Automation of many manual simulation processes to save time.

Linking multiple simulation such as Crash, NVH and restrain to perform trade-off analyses
Minimizing vehicle weight and meeting all vehicles attribute requirements.
Find optimal designs and develop better products

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JLR Multi Disciplinary Optimisation

(NVH - Crash - Restraints)

From 6 months to 6 weeks

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CAE Challenges in support for **more great product faster**

Development cycle must be reduced ? → Failure modes have to be found and resolved earlier → **CAE Enablers**:

- Faster model creation
- CPU
- Automation
- Material database
- CAE engineers
- Robustness
- Optimisation
- Validation
- Auto Assembly
- Morphing
- CAE PIM

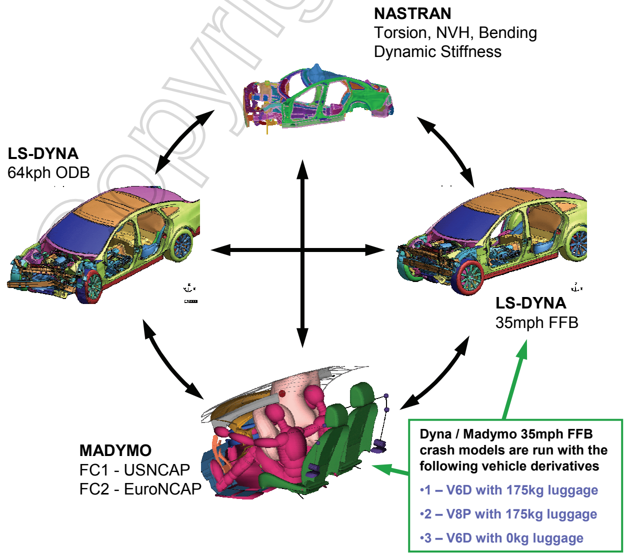
CAE future competitive position

- Model Auto Assembly
- Target Setting
- MDO multi disciplinary optimisation
- One model, One code for all Body Engineering attributes

CAE Models

Following models are created for each design iteration

Extracted results are constrained or optimised



Design Objectives

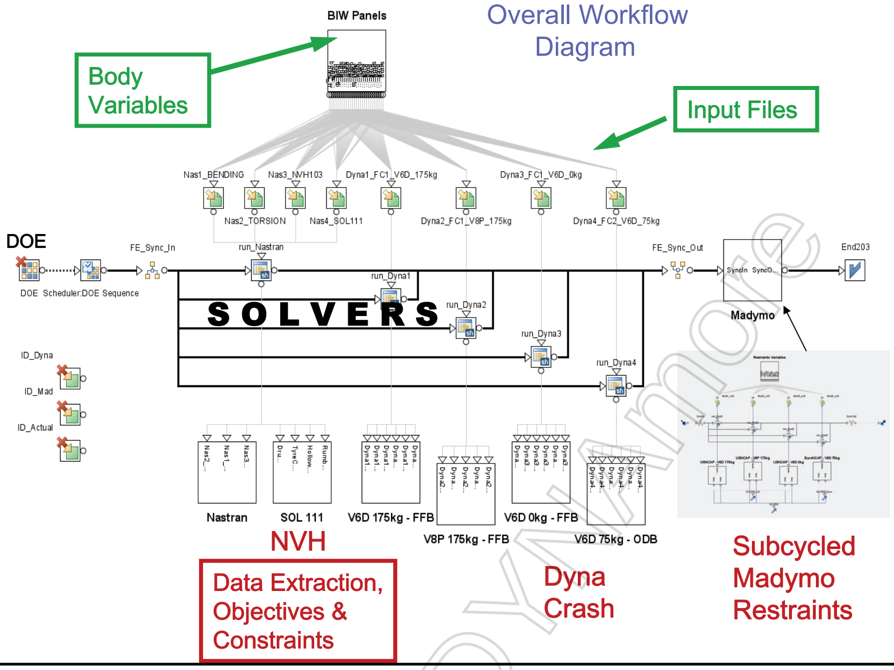
- Minimise Mass
- Maximise US/ EuroNCAP star rating

Design Constraints

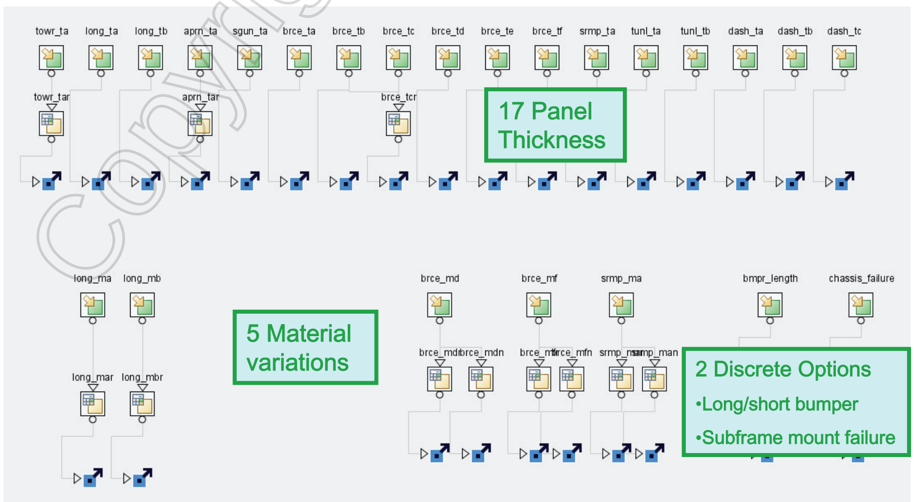
Meet all attribute targets and FAC constraints, eg:-

- Vehicle pulse and intrusion
- Occupant injuries
- Bending/ torsional stiffness
- Point dynamic stiffness
- Body natural frequencies

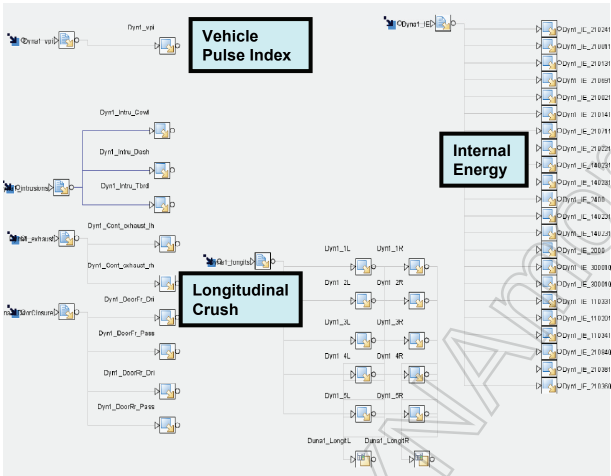
Overall Workflow Diagram



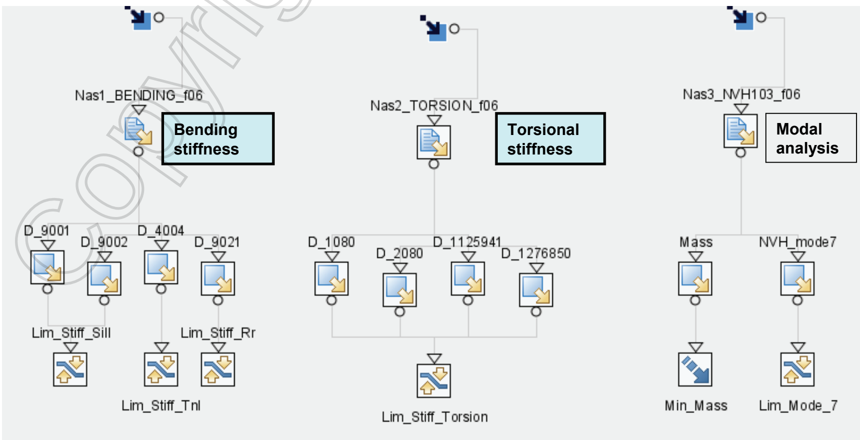
24 Variables used in Crash / NVH models



Outputs Extracted from DYNA crash model



Outputs Extracted from Nastran NVH model



Dynamic stiffness (mobility) at chassis loading points was also calculated at 10 points through 4 frequency bands

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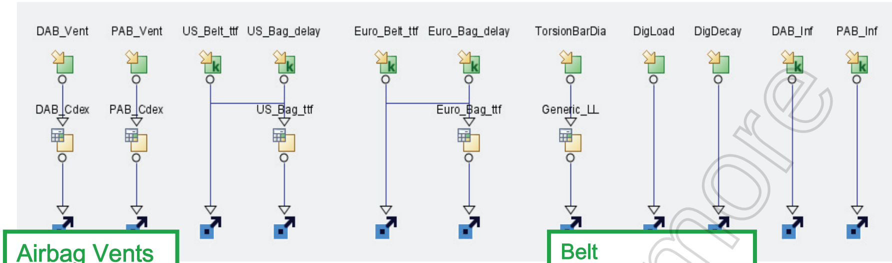
Variables used for Restraints models



Airbag Vents

TTF and inflator choice were kept constant (denoted by 'k') to reduce the required number of restraint models

Belt
- Torsion Bar choice
- Load used for digressive loadlimiter
- Duration for Dig LL

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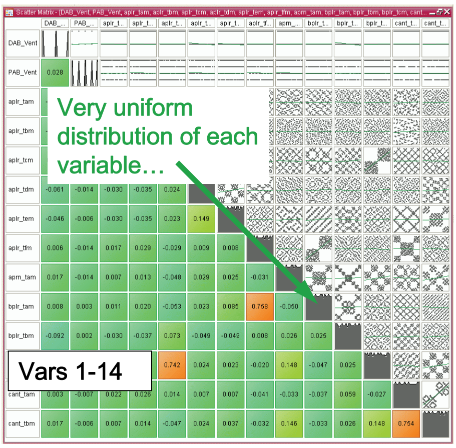
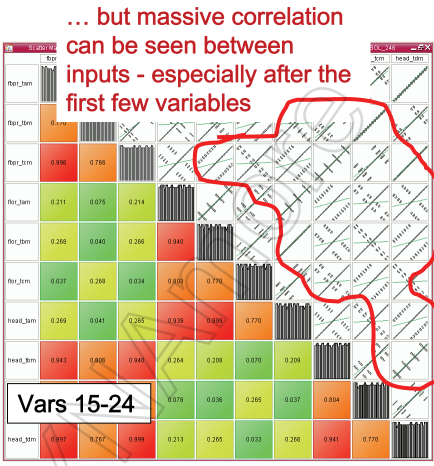
Initial DOE

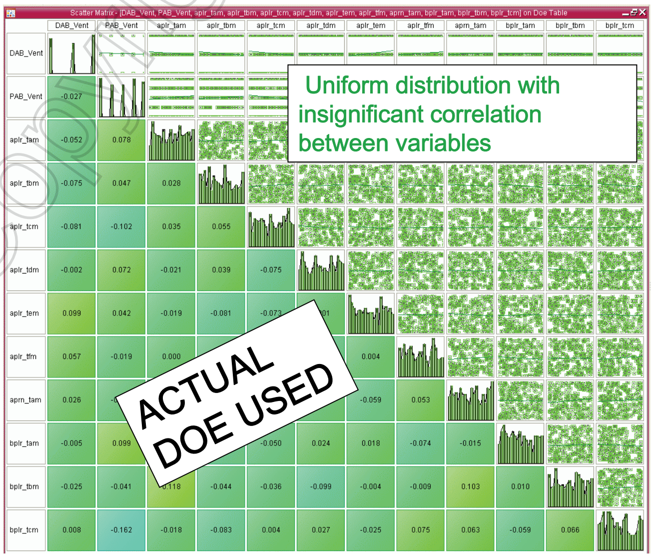
- Combining disciplines into such a study results in a large number of independent variables (n=82 in this first run).
- Even the simplest two level Full Factorial DOE would result in massive 5e24 runs!
- **Assuming very good distribution, a useful approximation for the number required is 3xn = 246.**
- Selecting 246 well distributed points from this vast design space is a challenge. Many options were investigated; the best being adopted.

Poor input correlation

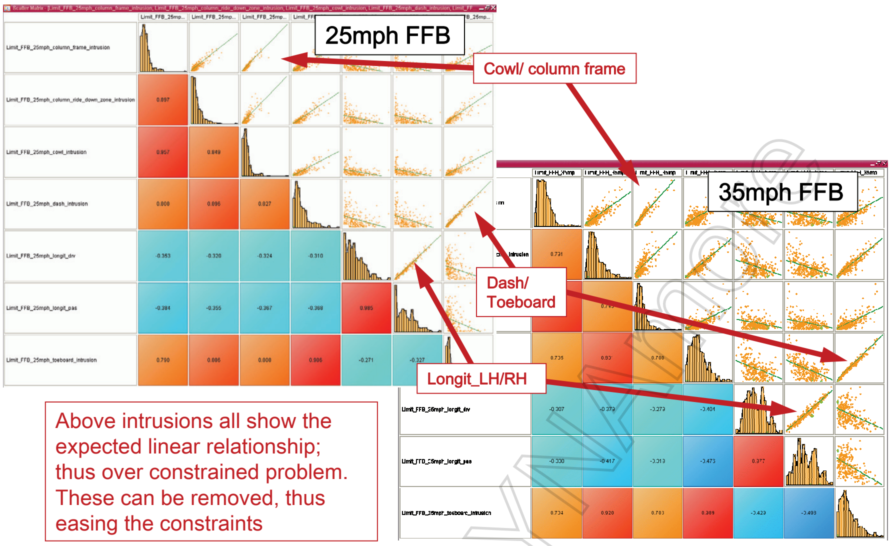




Using D-Optimal criterion from a large random set

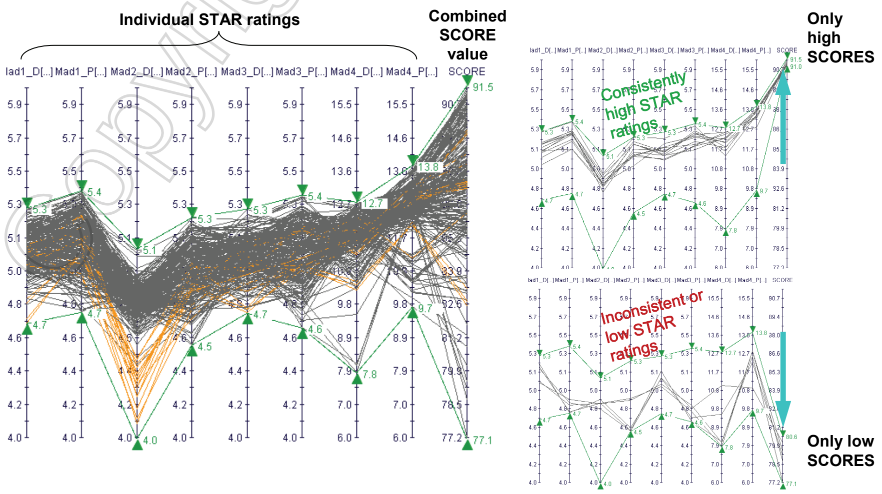


Example of direct correlation between constraints

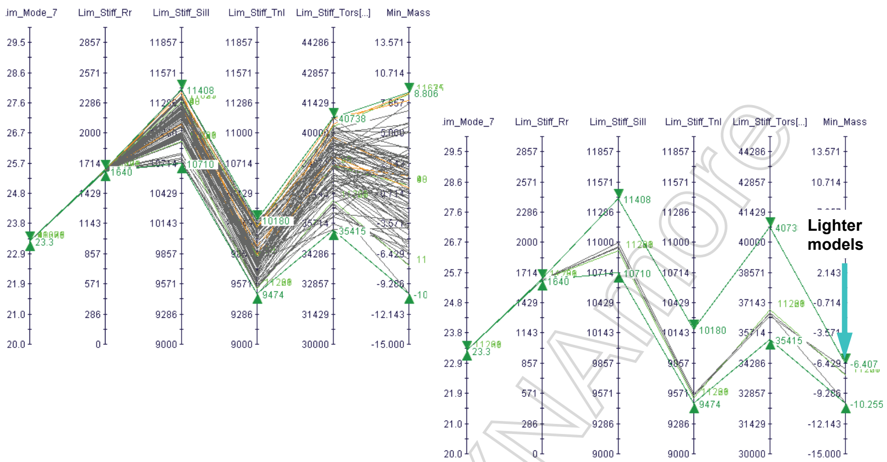


Calculation of SCORE

For assessment of results and rating of 'best' variant



Nastran results overview



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Restraints performance v VPI

Vehicle Pulse Index as a measure of body performance

- VPI is a measure of the pulse severity.
- The target value of 63g should not be exceeded during the crash.
- VPI can not be used for EuroNCAP as these injuries are intrusion related.

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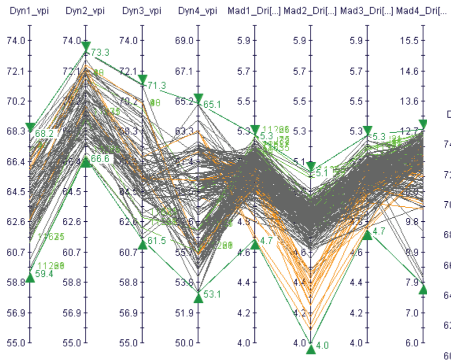
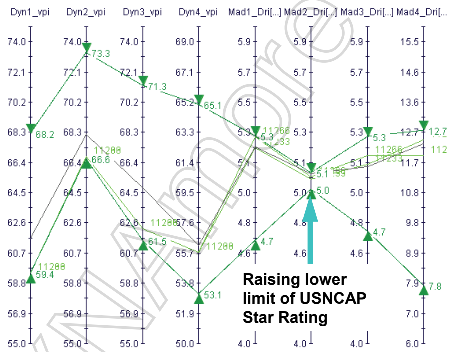
VPI Index is a valid measure of body crash performance



By filtering individual star ratings, it is clear that low vpi results in high star rating and vice versa



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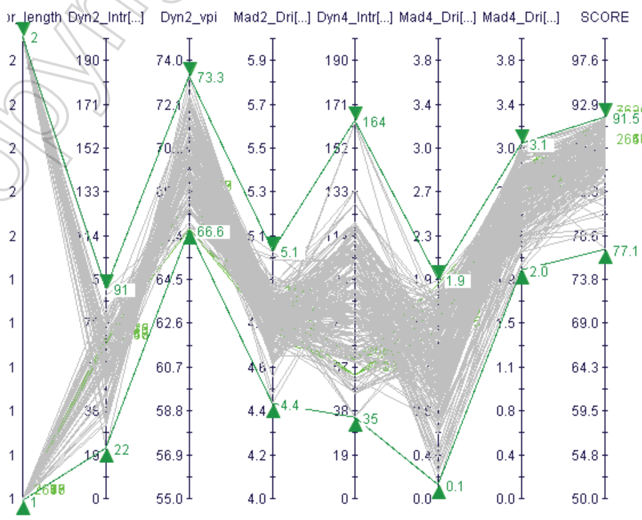
V8P on USNCAP & V6D for EuroNCAP



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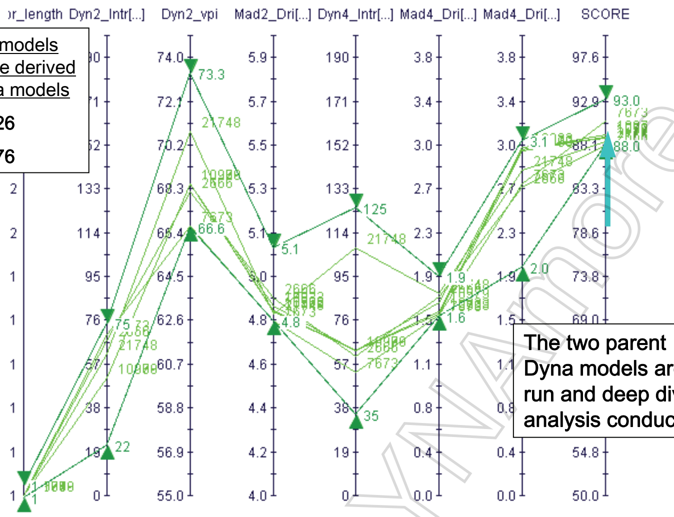
Final filtering by SCORE and highlighting resulting models



The final two models highlighted are derived from two dyna models

02666	026
07673	076

The two parent Dyna models are run and deep dive analysis conducted

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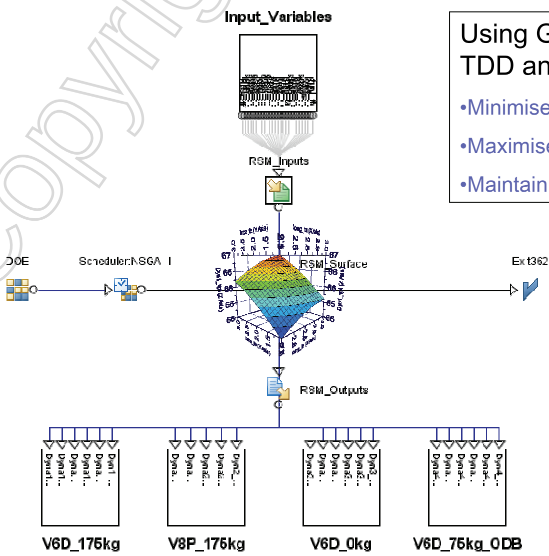
RSM methods applied to find better solution



Using GA to optimise for TDD and vpi on RSM

- Minimise vpi
- Maximise TDD
- Maintain all previous constraints

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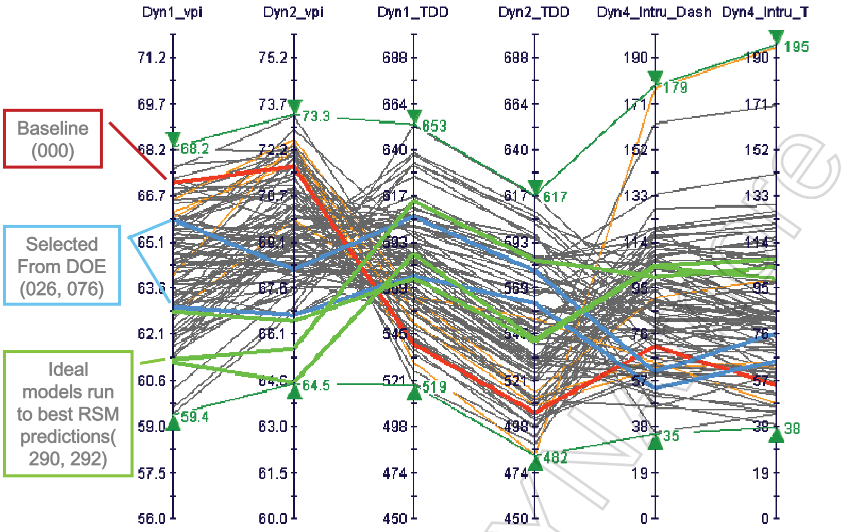
Overview using vpi, TDD and ODB intrusions

Baseline, best of the DOE and actual DYNA models run to RSM best predictions



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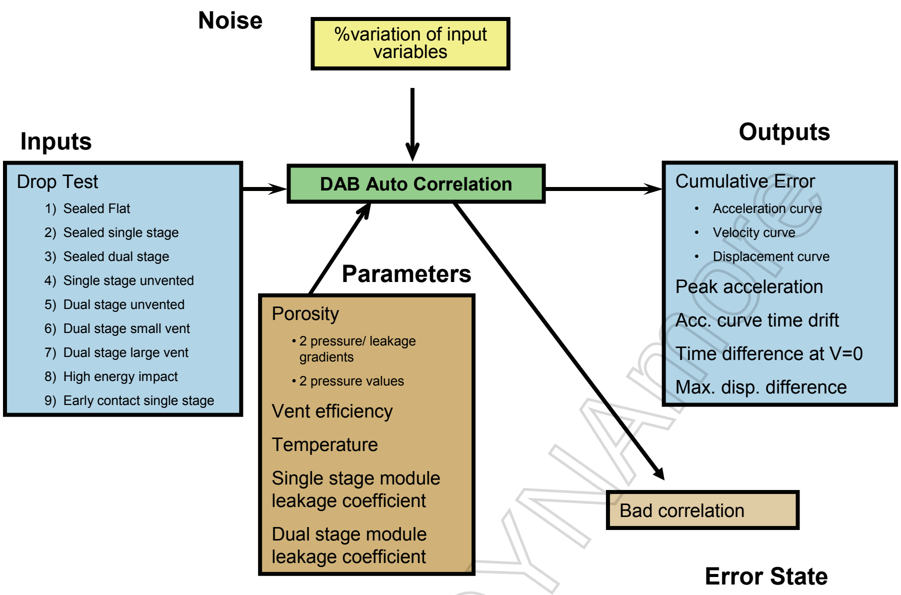
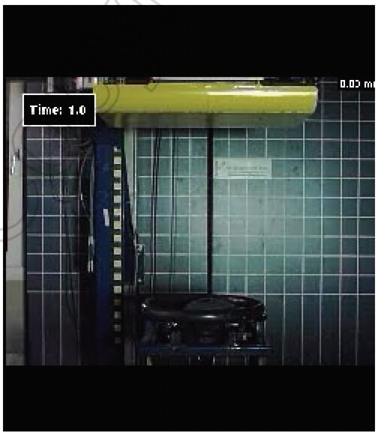
While the MDO is running , CAE enabler can be developed

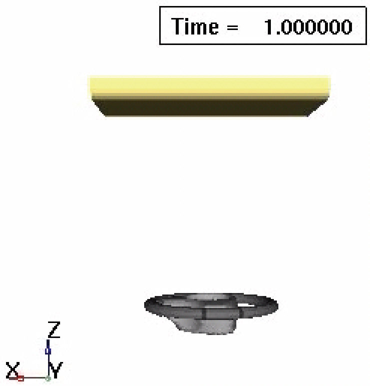
From 6 weeks to 2 hours
Auto correlation on airbags

Process



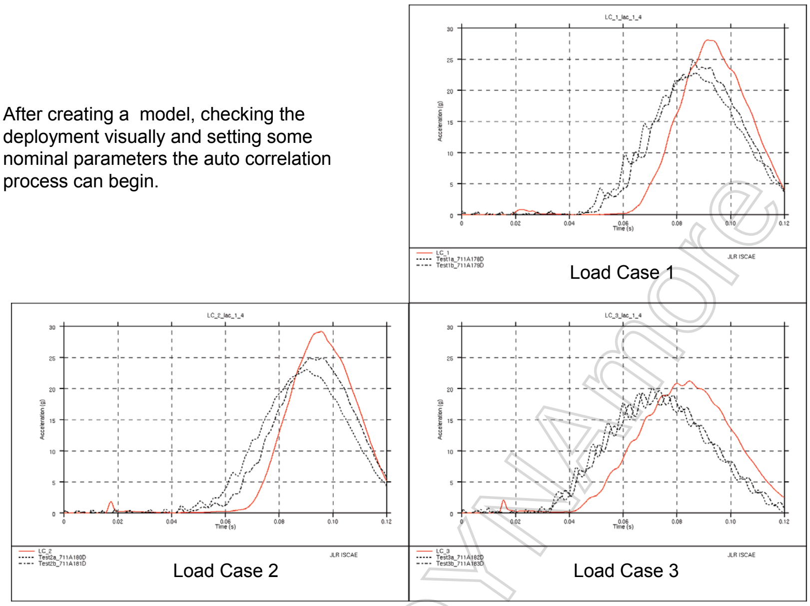
Auto Correlation – Test & CAE





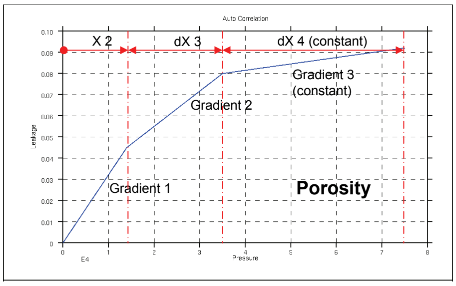
Auto Correlation – Initial Values

After creating a model, checking the deployment visually and setting some nominal parameters the auto correlation process can begin.



Parameters

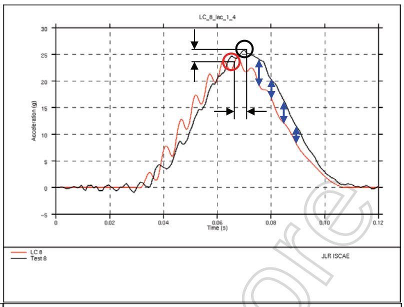
Parameter	Lower Bound	Upper Bound
Temperature coefficient	0.6	1.0
Vent efficiency	0.6	1.0
Single stage module leakage	0.001	0.500
Dual stage module leakage	0.001	0.500
Porosity X2	0.01	0.06
Porosity dX3	0.01	0.03
Porosity gradient 1	0.5	5.0
Porosity gradient 2	0.5	5.0

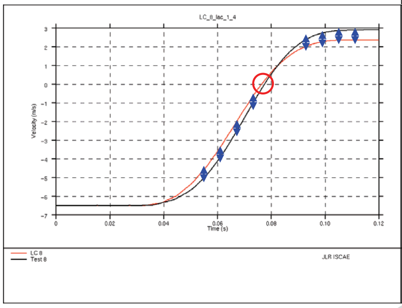


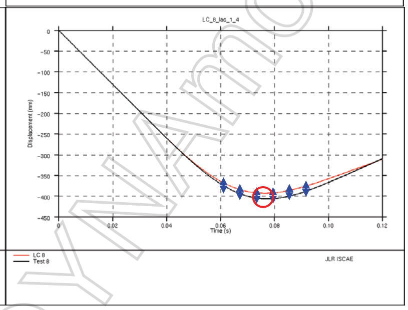
Porosity verses pressure curve defined by two gradients and 2 pressure values. A constant gradient tail is used to limit excessive gas los at the high pressures created in the airbag unfolding and so reduce the number of variables in the DOE.

Objectives And Constraints

Peak values, time velocity equals zero and times of peaks are also used as constraints to control acceptable limits.





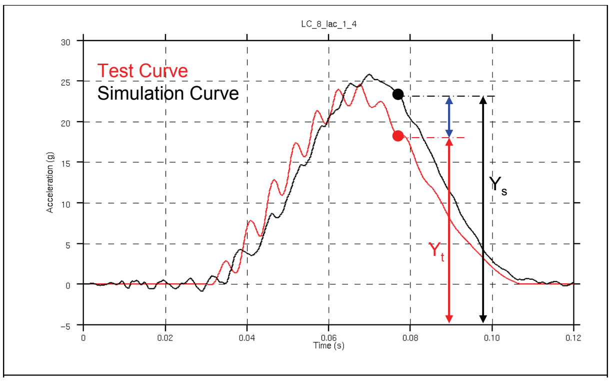


Objective Function

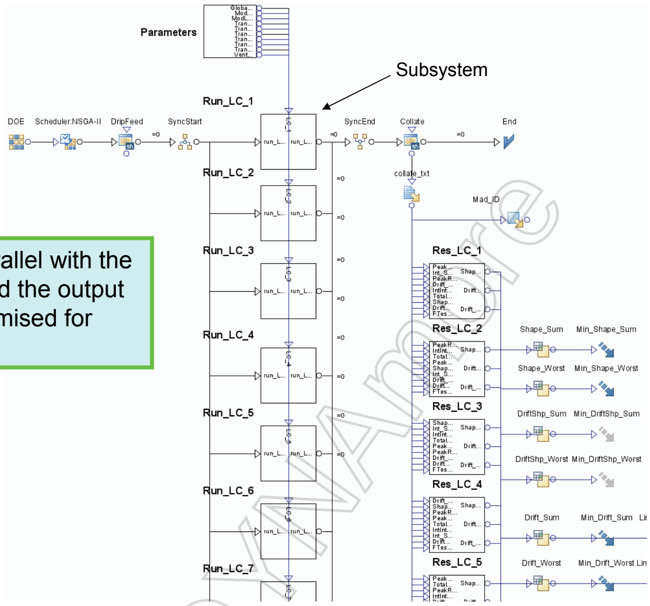
Cumulative error function:

A modified least squares function normalised over the common range of the curves to give a total error score for the correlation of the test and simulation curve. No correlation gives a score of 1 while a perfect correlation gives a score of 0.

$$\xi = \frac{\sum_{i=1}^{N} (y_t - y_s)^2}{\sum_{i=1}^{N} y_t^2 + \sum_{i=1}^{N} y_s^2}$$



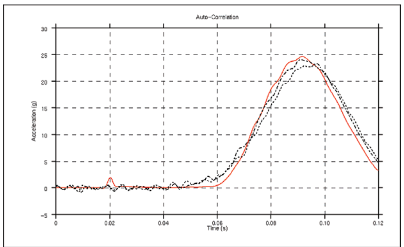
Auto Correlation with multiple load cases



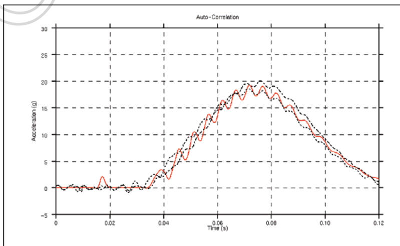
All load cases run in parallel with the same values of input and the output cumulative is then minimised for each load case.

Auto Correlation –Results

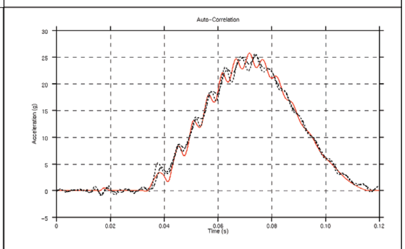
Excellent correlation against original test curves.



Load Case 4



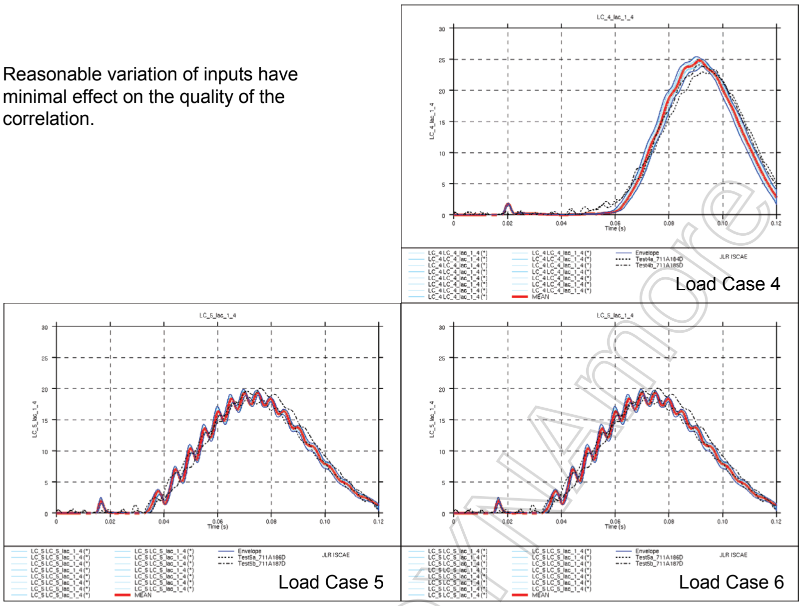
Load Case 5



Load Case 6

Robustness Check

Reasonable variation of inputs have minimal effect on the quality of the correlation.



Conclusions

- *MDO is a design by objective approach that is faster than traditional CAE that uses trial and error analysis to find satisfactory design.*
- While MDO is running an auto correlate for a complex load cases was developed in a very short time from 6 weeks to 2 hours using the same MDO principle including robustness assessments.
- MDO has been successfully applied for Crash, NVH and Restraints in a very short time from 6 months to 6 weeks

Conclusion

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- Modefrontier has been successfully applied to auto correlate a complex load cases in a very short time from 6 weeks to 2 hours.

- Robustness assessment procedure has been included for the auto correlation.