Using simulation to gain competitive advantage

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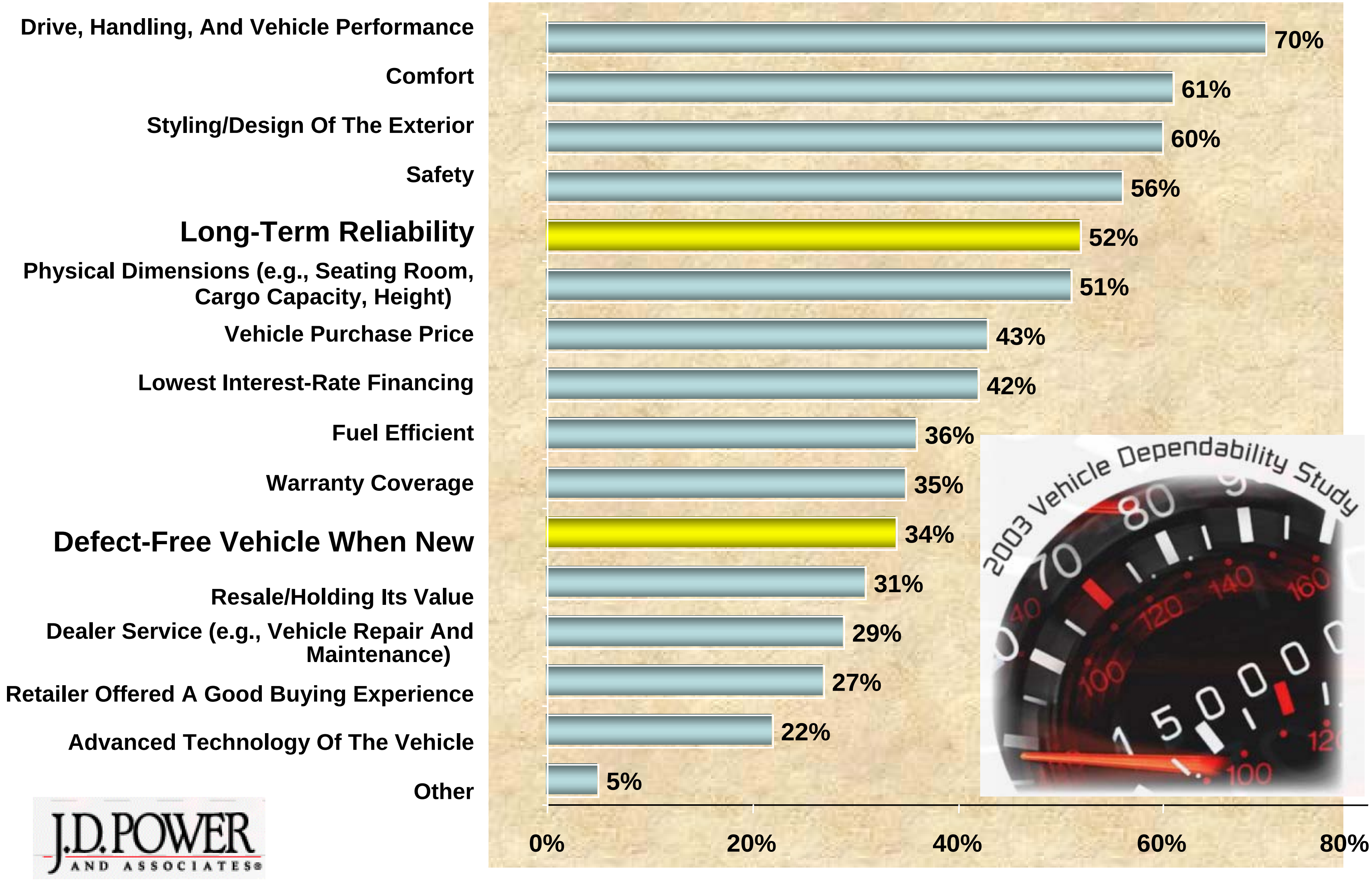
Jaguar & Land Rover

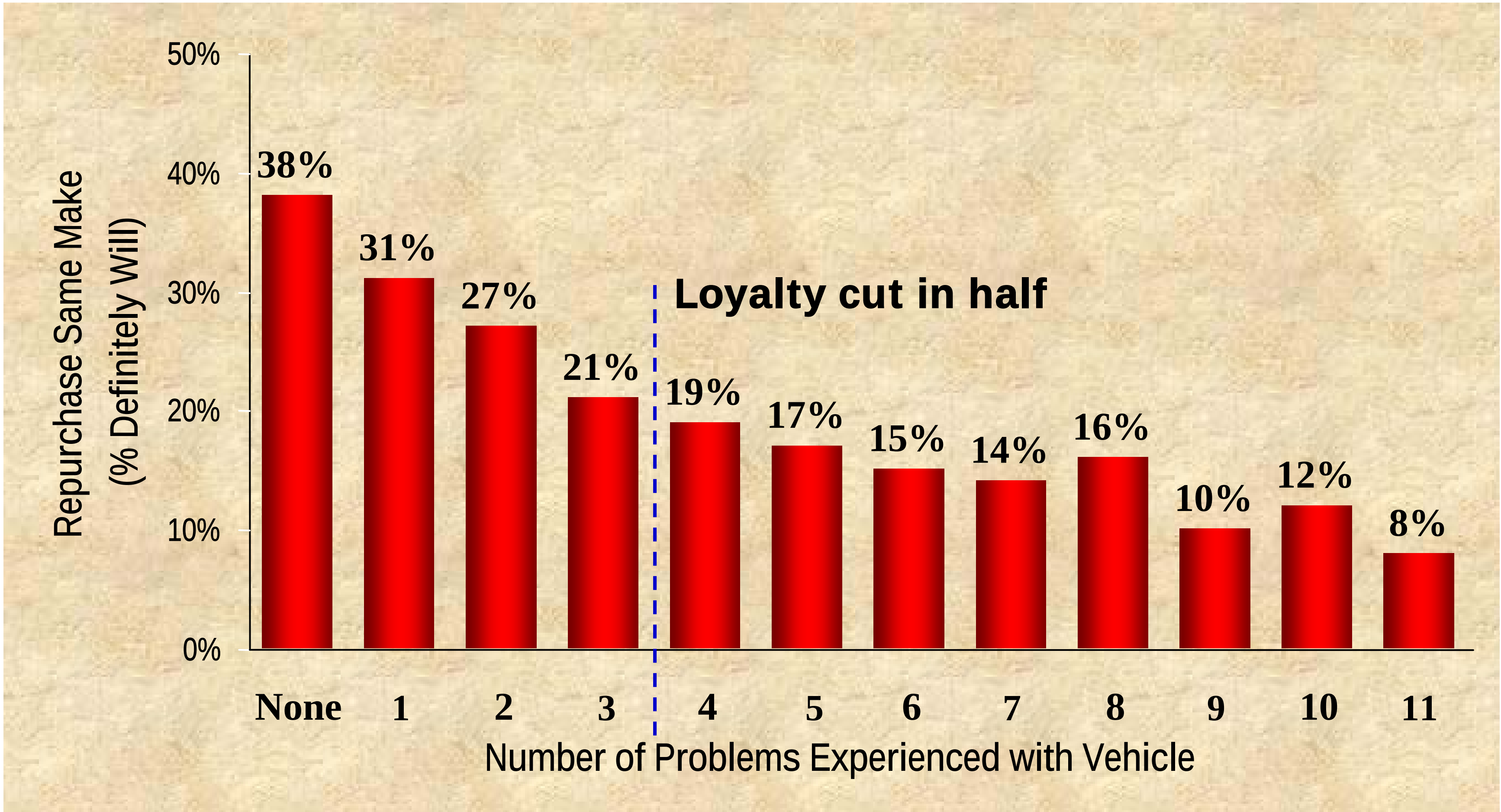
Contents

Things demanded from us by our customers attributes with the most impact on purchase decision.



2003 Vehicle Dependability Study

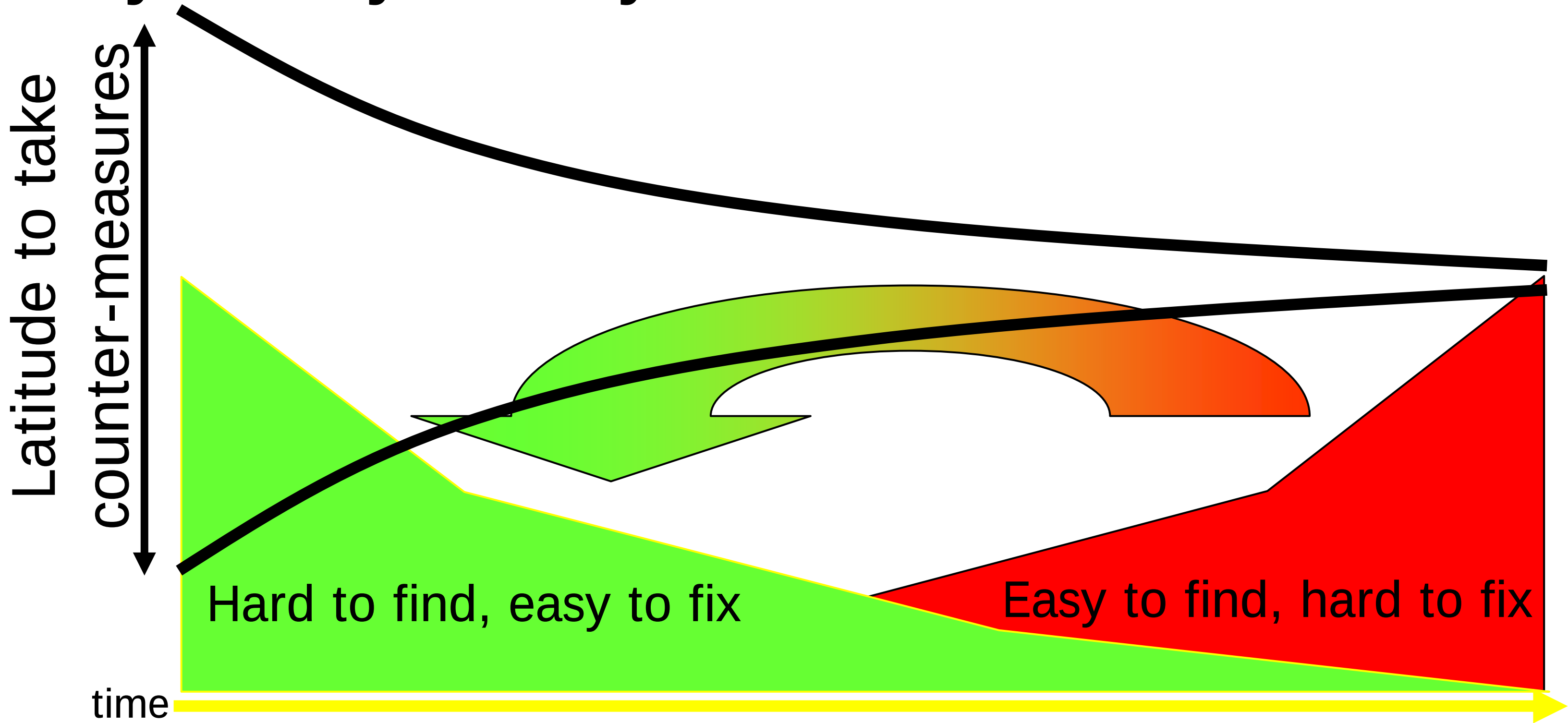
A significant drop in vehicle repurchase intent is due to customers finding failure modes on our behalf.



J.D. POWER AND ASSOCIATES

* 2003 Vehicle Dependability Study

The symmetry of early detection of failure modes



- There is a conservation principle underlying the basic idea of finding failure modes early, illustrated above.
- The failure mode can be seen as the fundamental quantity in engineering (like electrons in chemistry, or energy in physics).
- If all the failure modes are found early, the design in production will look the same as on the drawing – symmetry.

High Level Failure Mode Determination

Identify Failure Modes

AIMS
FMEA
DVP
Peer Review
Thought Experiments
Brain Storms (Thought Shower)
Quality History
Warranty
Competitor Benchmarking
BSAQ
PVT's

→

Identify Detection Events/Tools

CAE
CAD
Physical Test
Jury
Assessment of Benchmarks

→

Publish Plan for Failure Mode Detection.

- Root cause
- Load cases
- Suggested countermeasures
- Quantify programme risk
- Estimate cost of failure to programme

Determination of CAE Failure Mode Activities

- The High Level Tracker and judgement on the failure modes that CAE can detect is carried out:
  - NOW – with a high level of confidence
  - NOW – but with some current methods development (potentially ‘new’ CAE activity using known codes)
  - NOW – Low level of confidence using current techniques
  - Enablers
    - What methods need developing in order to improve detection
    - What new tools need procuring and/or developing to enable detection on future programmes.

Enablers

- CAE engineers
- Batch Meshing
- Material database
- Auto Assembly
- CAE Wrapping Process and morphing
- Auto Post
- CPUs….
- CAE PIM

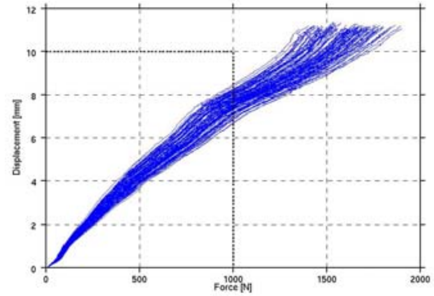
ISCAE Front Doortrim SDS 6

Assessment:
Armrest uniformly distributed

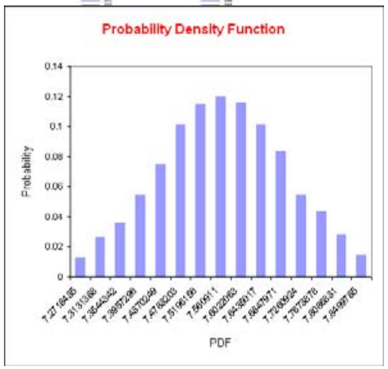
Results :

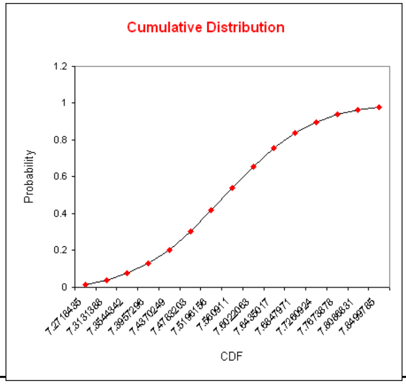
Risk : Comply

Detailed results of all analyses in Doc No: ISCAE-1055



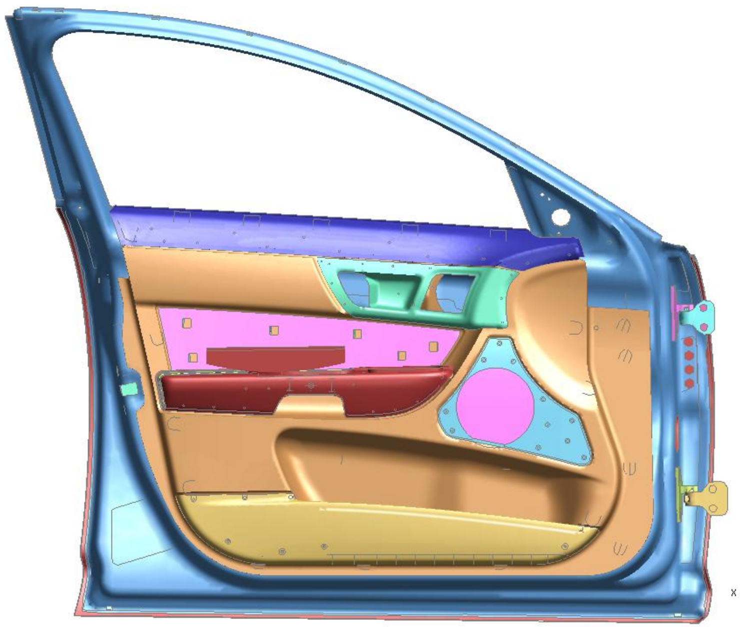
Probability density and cumulative distribution





Objectives / Issue addressed :

Robustness run with +/-10% variability on the following parameters: **Material Young's Modulus** (ABS, Dylark, PP, Steel), **Scale factor on stress strain curves** (ABS, Dylark, PP, Steel) and **thickness** (armrest substrate, armrest heatstake pegs, armrest pull cup, main moulding, door closer panel, dog houses and door inner panel). 15 variables in all. DOE of 100 runs set up and carried out.



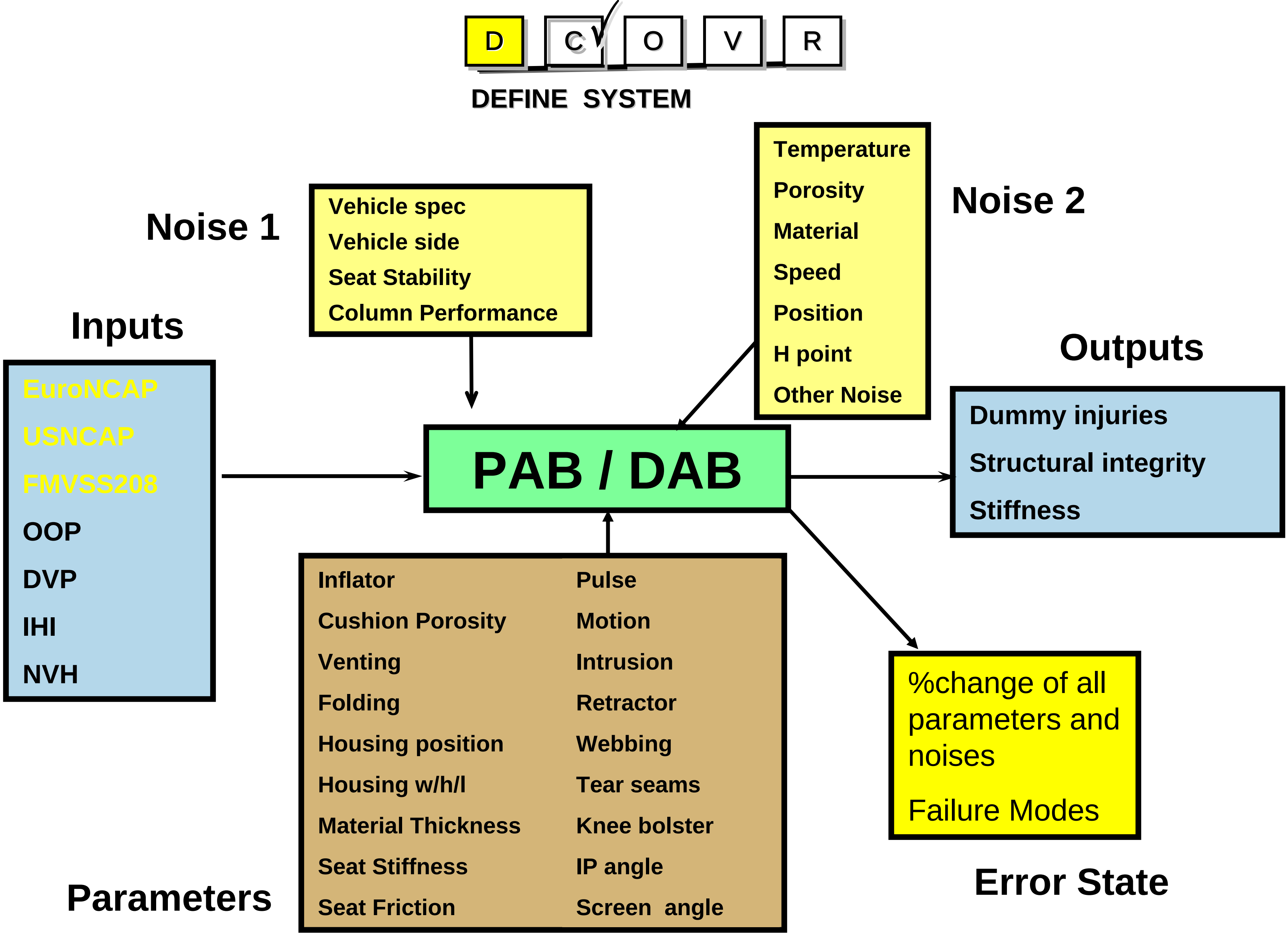
Conclusions / Recommendations :
All runs meet requirement.

Next Steps:	**Owner**	**Date**

Target :
React 1000N load without displacing more than 10mm

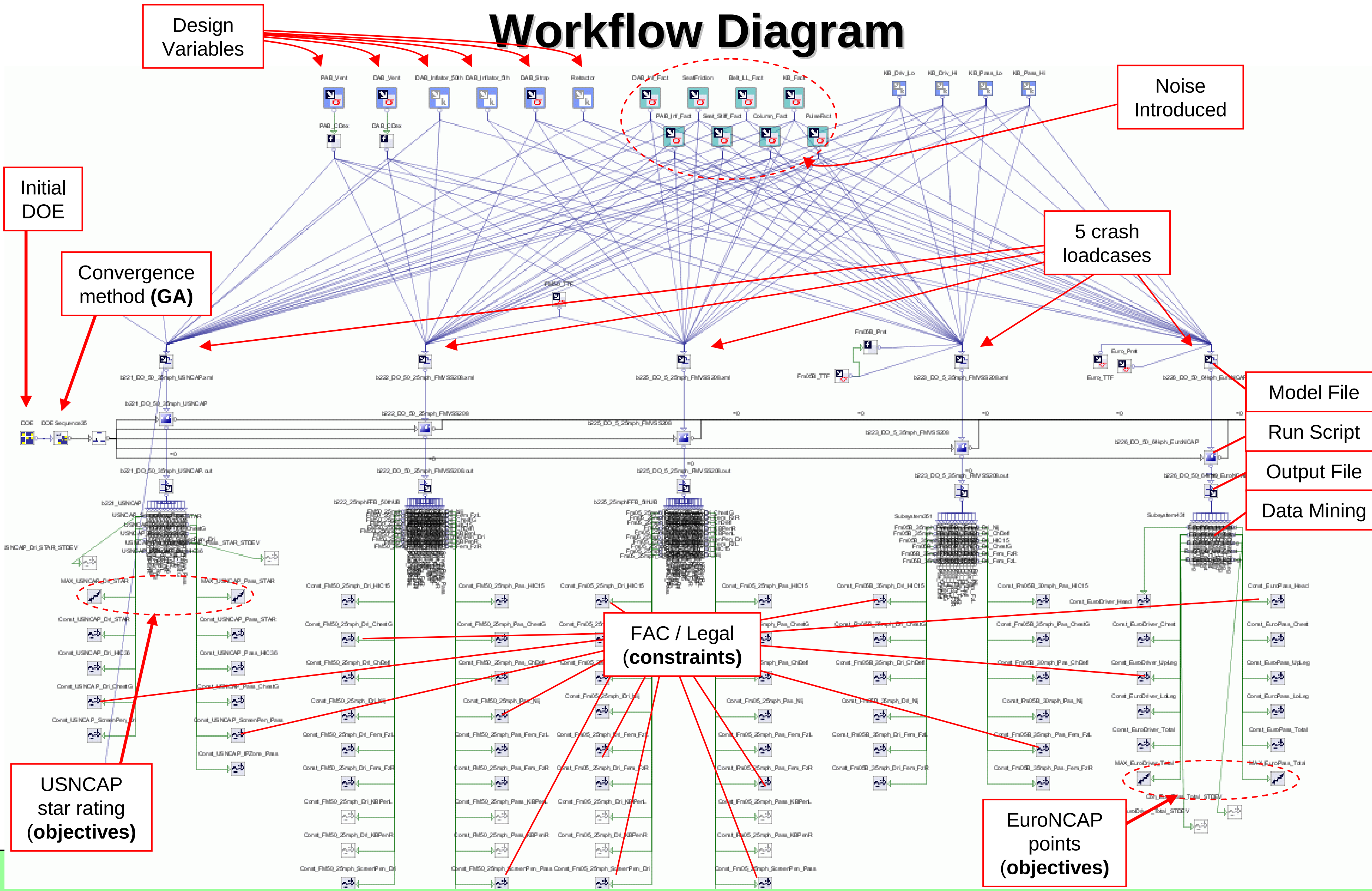
Prepared by:

Robustness Studies Using DFSS


D
C
O
V
R
DEFINE SYSTEM
Noise 1
Vehicle spec
Vehicle side
Seat Stability
Column Performance
Temperature
Porosity
Material
Speed
Position
H point
Other Noise
Noise 2
Inputs
EuroNCAP
USNCAP
FMVSS208
OOP
DVP
IHI
NVH
PAB / DAB
Outputs
Dummy injuries
Structural integrity
Stiffness
Inflator
Cushion Porosity
Venting
Folding
Housing position
Housing w/h/l
Material Thickness
Seat Stiffness
Seat Friction
Pulse
Motion
Intrusion
Retractor
Webbing
Tear seams
Knee bolster
IP angle
Screen angle
Parameters
%change of all parameters and noises
Failure Modes
Error State

Pure Optimisation Progress

Workflow Diagram



Optimisation Model Setup

1. Initially a Genetic Algorithm (GA) was used to control a pure optimisation run
   - Searching over 20 generations for solutions which met all FAC/ legal requirements and optimised USNCAP and EuroNCAP performance. The optimised solution was then to be used as a seed for a subsequent robustness analysis. Low robustness was found for all optimised points

2. GA was then used with a Multi Objective Robust Design (MORDO) option to search for the most optimum **robust** solution.
   - Rather than applying the pass/ fail criteria to injuries from individual model runs, it assesses the cloud generated by running a suite of models with noise applied around the nominal model. 15 models were run around each setup and the mean and standard deviation for each injury parameter was considered

Design Variable Setup

- DAB vents size 2x23mm – 2x33mm
- PAB vent size 2x44mm – 2x56 (Later increased to 2x55mm – 2x70mm)
- DAB inflator selection for 50th%ile Dual stage Dt5ms v Dt10ms
- DAB inflator selection for 5th%ile Single 1 v Dual stage Dt10ms
- DAB tether length 300mm – 380mm
- All airbag fire times (TTF)

Responses – Characterisation Study

USNCAP

Driver HIC36
Driver ChestG 3ms
Driver STARS

Passenger HIC36
Passenger ChestG 3ms
Passenger STARS

Euro NCAP

Driver Head
Driver Chest
Driver Upper leg
Driver Lower leg
Driver Total Frontal Points

Passenger Head
Passenger Chest
Passenger Upper leg
Passenger Lower leg
Passenger Total Frontal Points

FMVSS208

50th %ile UB 25mph

5th %ile UB 25mph

5th %ile Belted 35mph

25mph Driver HIC15
25mph Driver ChestG 3ms
25mph Driver Nij
25mph Driver Neck FzT
25mph Driver Femur FzL
25mph Driver Femur FzR
25mph Driver Ch Deflection

25mph Passenger HIC15
25mph Passenger ChestG 3ms
25mph Passenger Nij
25mph Passenger Neck FzT
25mph Passenger Femur FzL
25mph Passenger Femur FzR
25mph Passenger Ch Delflection

History Chart

1. A useful way to chart the progress and trends of input / output variables over generations (design Id)
    - The chart shows the trends throughout the genetic search and allows the user to see the direction it is taking

2. Shows if convergence of an input variable is occurring towards a value as the analysis progresses
    - If this value is also the limit of the range then the process may be restarted with modifications to the input ranges (PAB vent size in next slide)

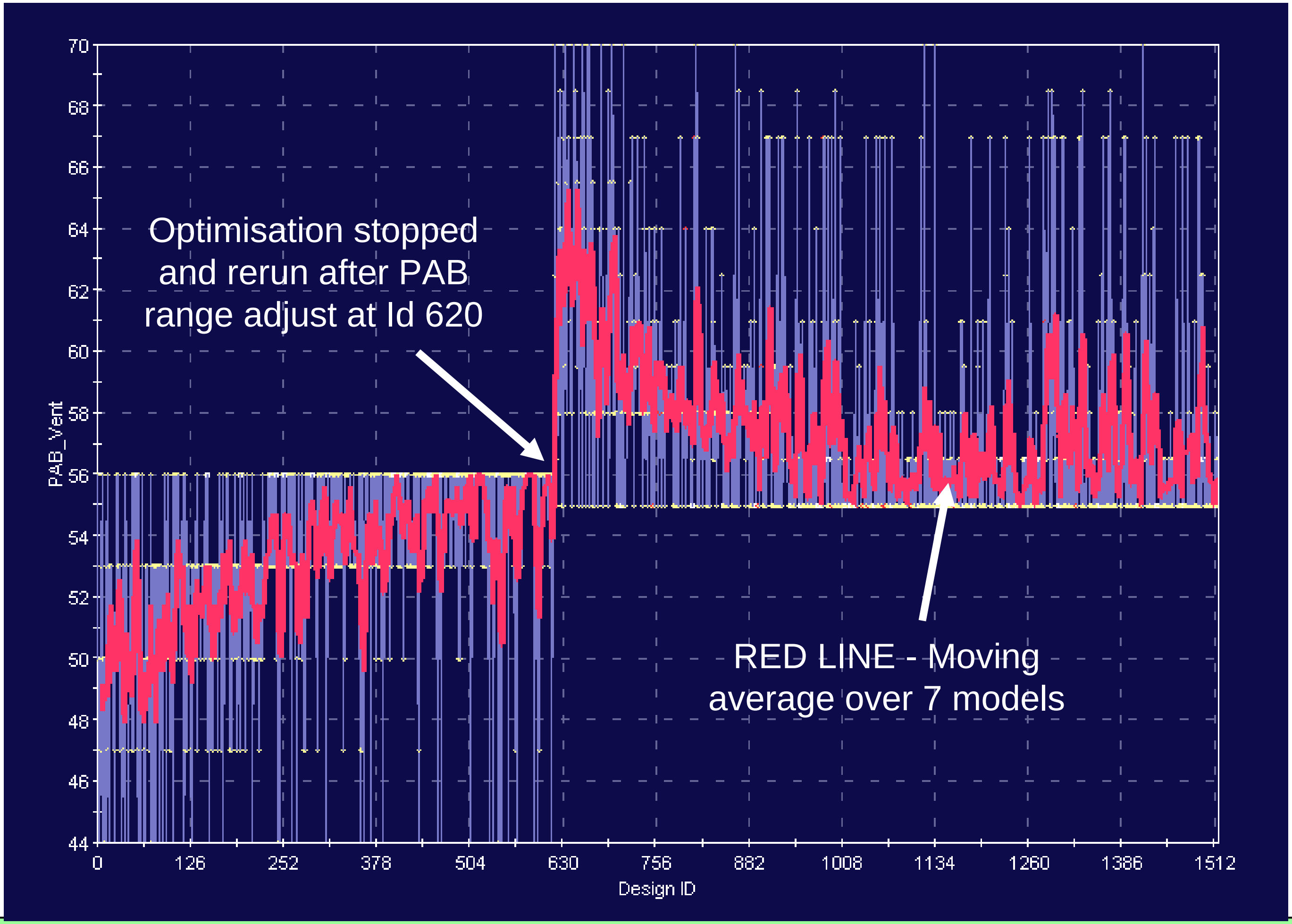
3. Shows if convergence of an output variable is occurring towards a particular value

4. A moving average is used to emphasise the trends within the genetic search for solutions

Pure Optimisation Progress

PAB Vent size convergence

PAB vent input range was altered at Run Id 620 due to convergence towards a limit

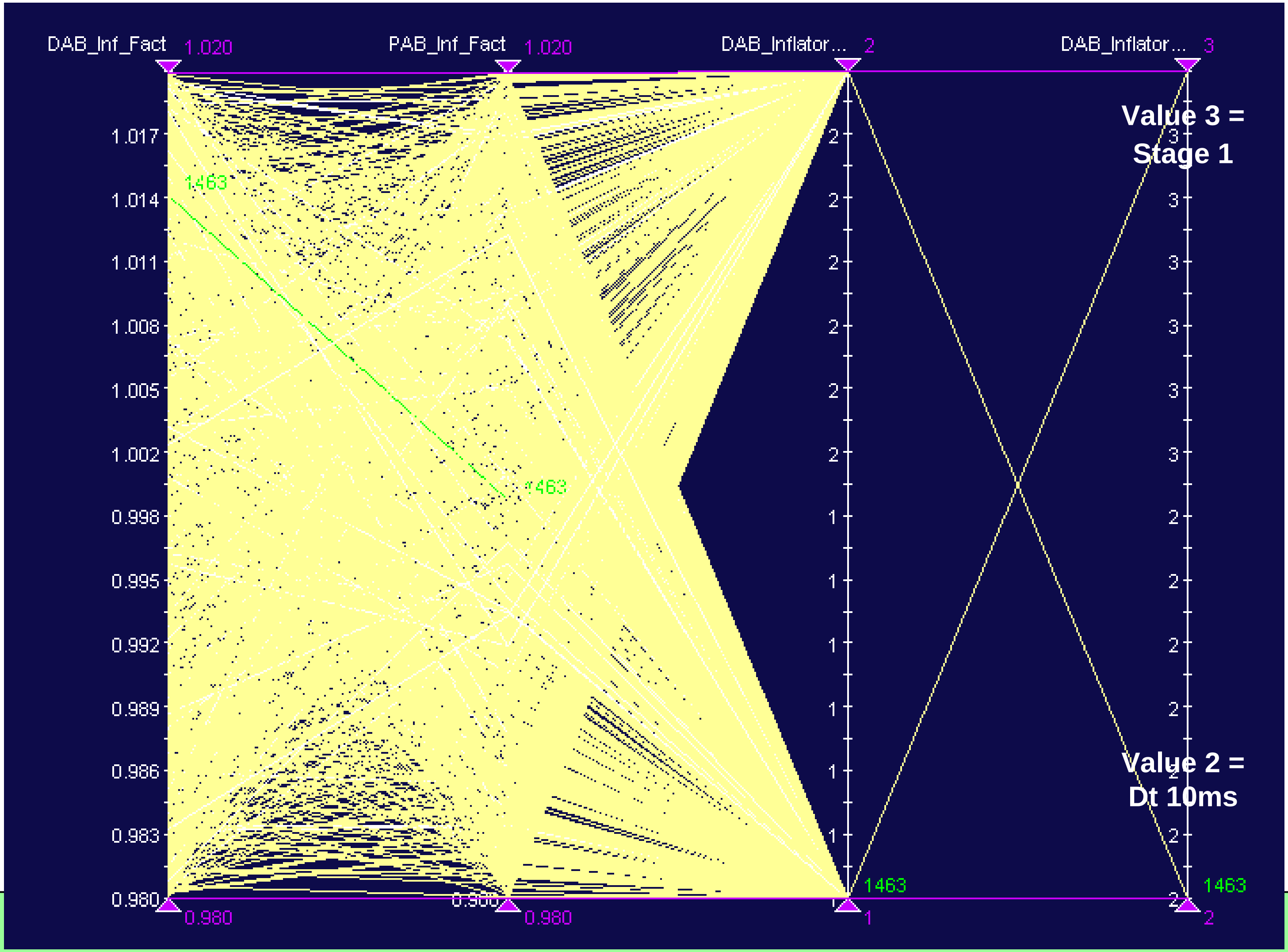


Parallel Chart

1. A very useful way to understand relationships between input-input, input-output and output-output in the data table
2. Each axes represent an input/ output variable, showing the full valid range it could take
3. Coloured lines represent models; plotted across the various axis at the particular values for that model
4. Dynamic filtering by input/output value is used to retain models which fulfil certain criteria
5. Models (coloured lines) can also be turned on or off according to rules such as model status (feasible, unfeasible, error, marked, group, etc)
6. **By removing unfeasible (yellow) and error (red) models, it is possible to clearly see the range of inputs which leads to feasible (white) models**

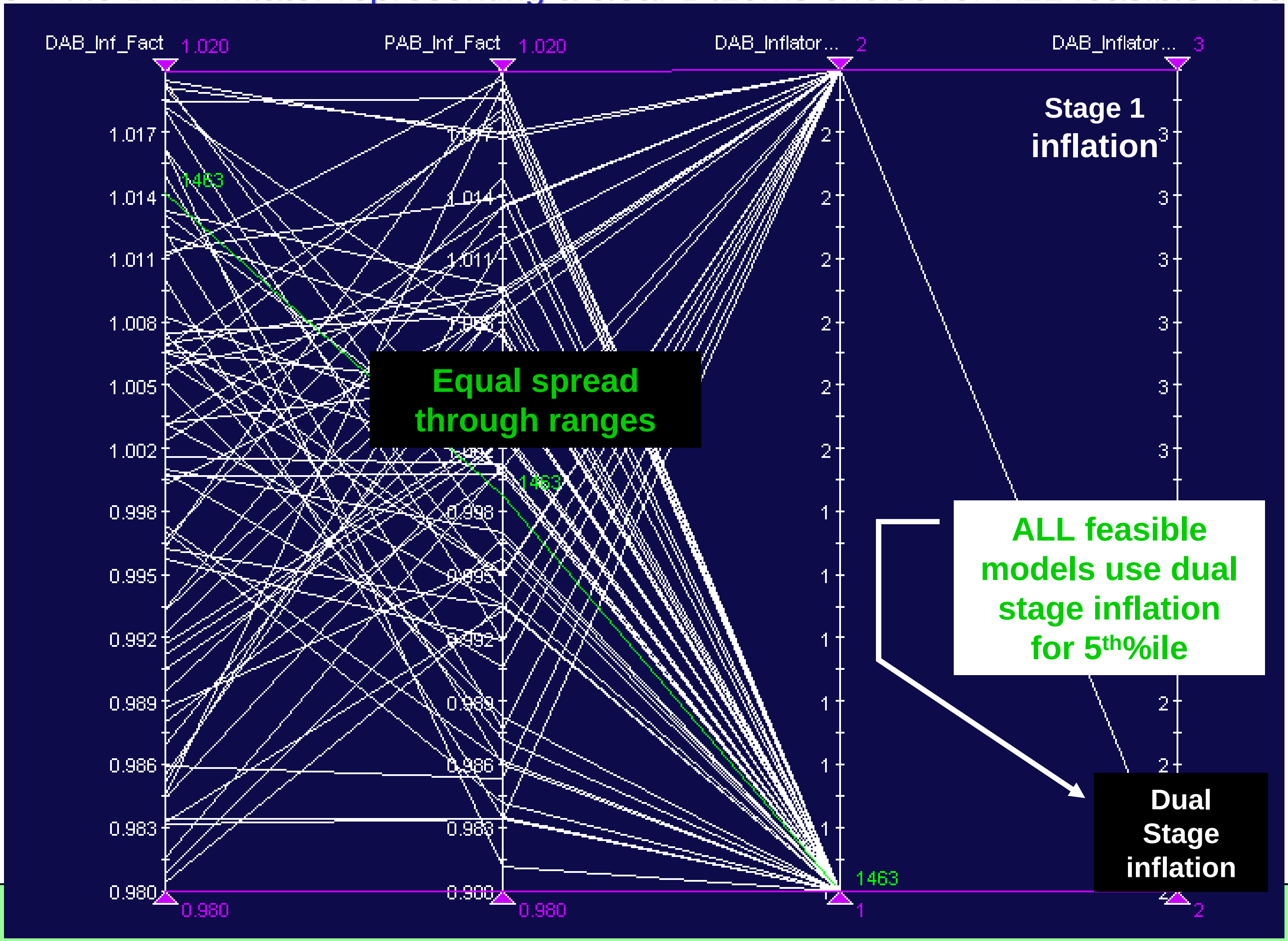
DAB inflator selection for 5th%ile

All models shown – very little can be concluded as coloured lines are equally distributed through input combinations



Only feasible models shown

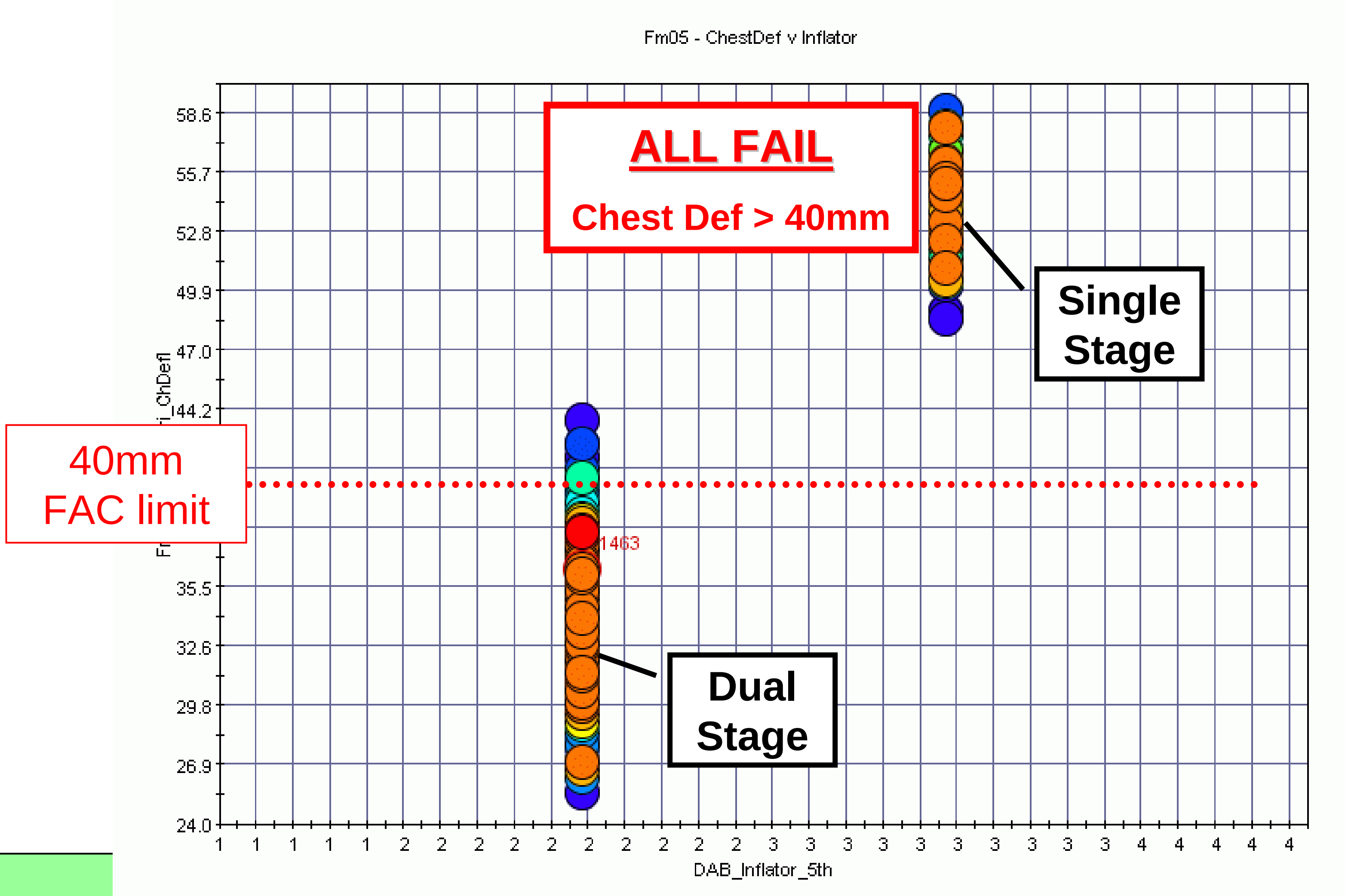
The system is insensitive to inflator power variations and 50th DAB inflator as shown by the even spread of models though the input parameters. ALL lines go through the lower point for the 5th%ile DAB inflator representing a clear Dt10ms choice for ALL feasible models



Pure Optimisation Progress

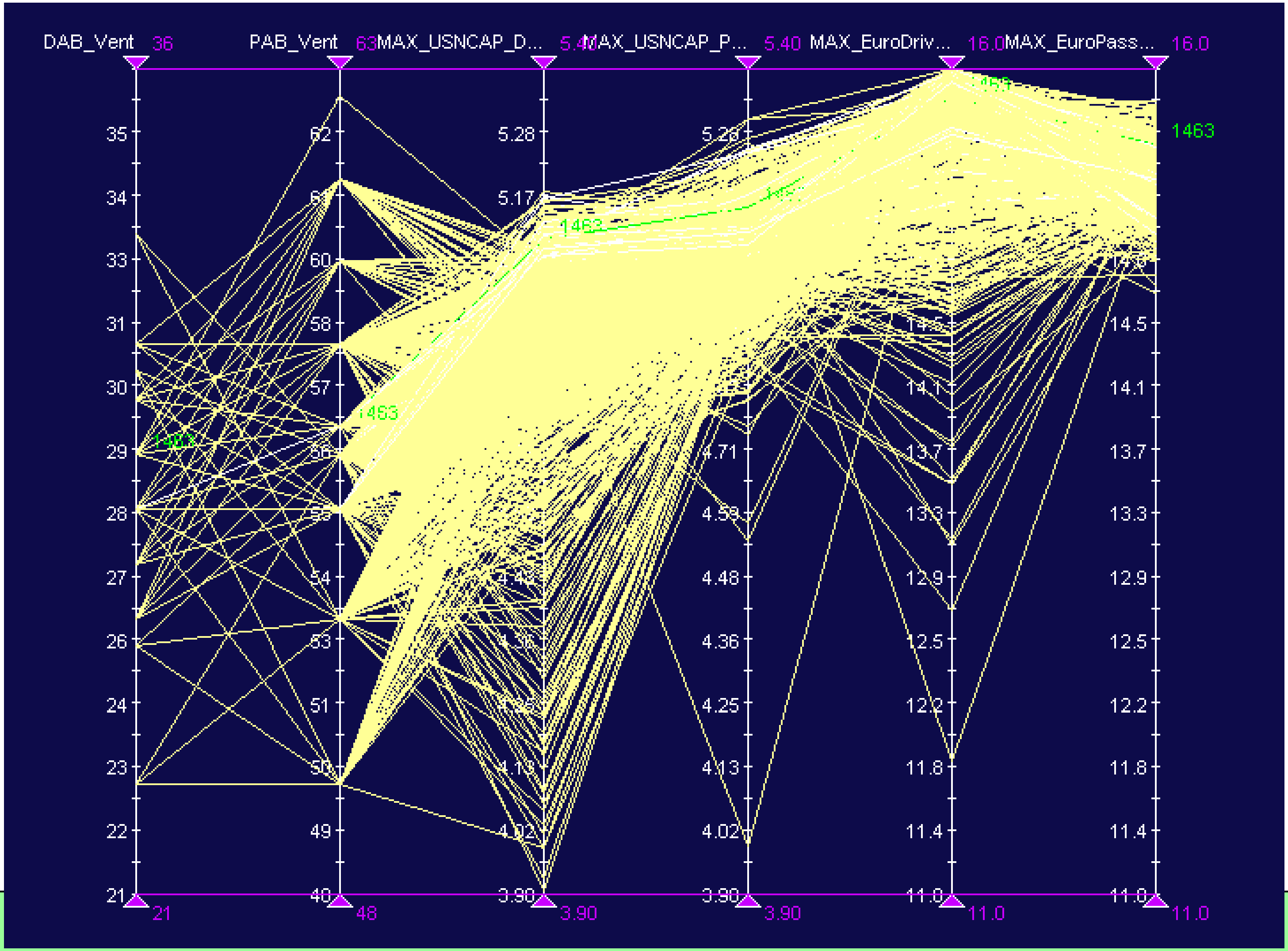
5th%ile UB Chest Deflection

No feasible models with a single stage inflator



Airbag vent sizes

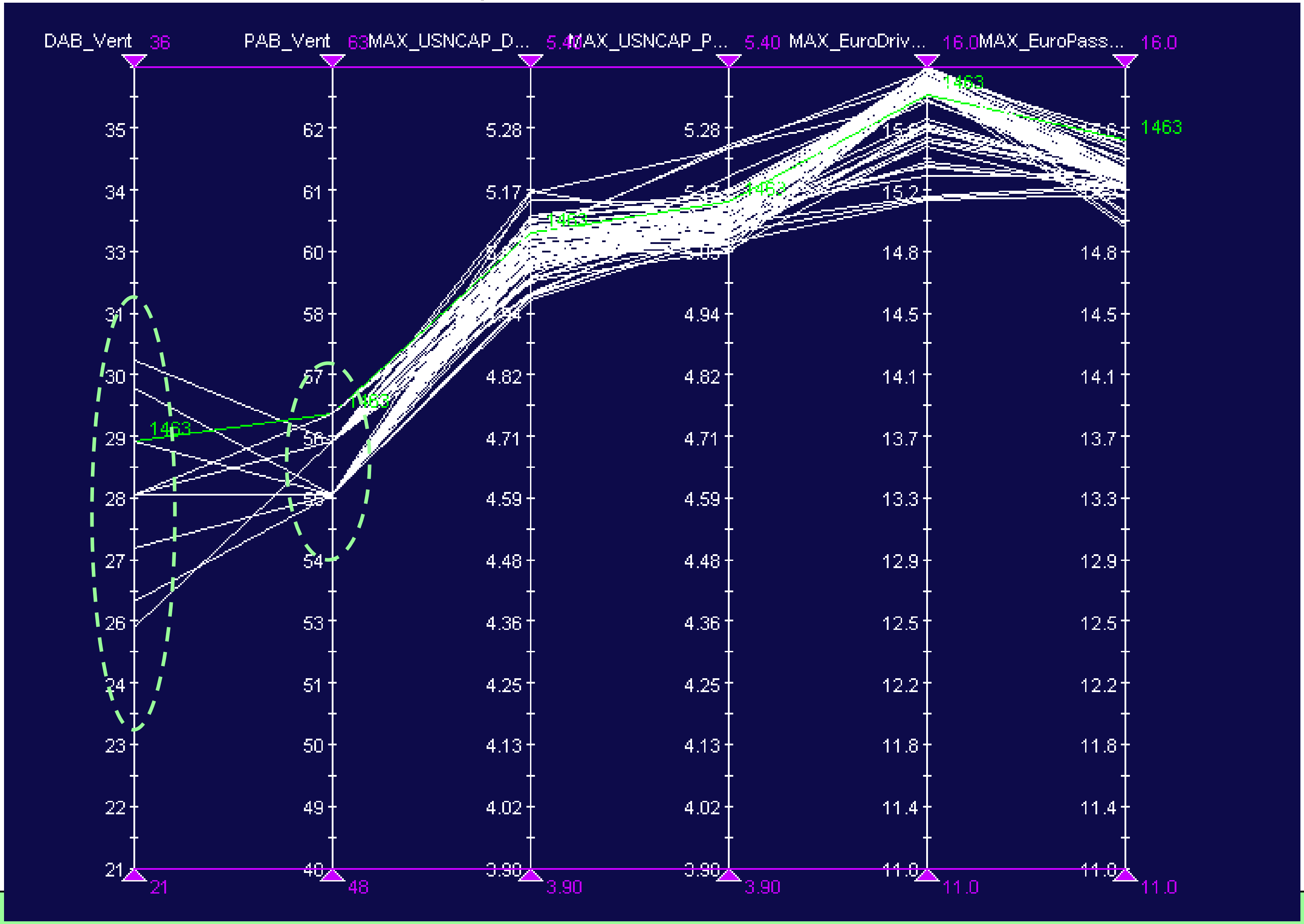
All models shown – very little can be concluded as coloured lines are equally distributed through input combinations



Only feasible models now shown

These all meet legal and FAC requirements and obtain highest NCAP ratings.

It is clear that the valid vents for the DAB lie in the range 26-30mm whilst the larger PAB vent specifically requires a size of 55-56mm.



MORDO

Multi Objective Robust Design Optimisation

1. This functionality is provided by modeFRONTIER and is used to find the optimum of all ***robust*** solutions

2. Rather than running a conventional optimisation and following with a subsequent robustness run, MORDO optimises only within the solutions marked as robust (based on standard deviation of a set)

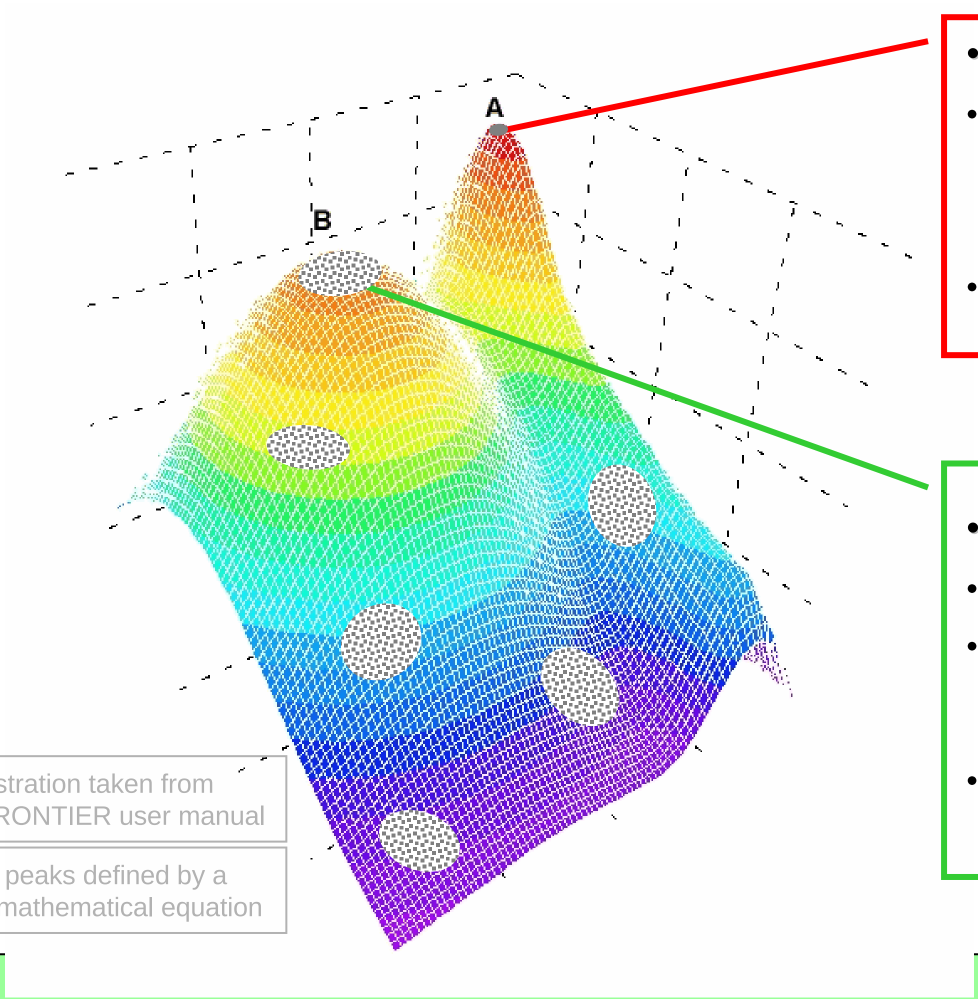
3. Robustness is defined by the standard deviation of the set around a nominal model (vent cutting tolerances, pulse severity, TTF variation, inflator output, seat stiffness and friction, etc)

4. Further generations are created to improve the **mean** value of the sets rather than absolute value of any one model

GA using MORDO

Submits sets of 'noise' models around the nominal model

Assesses the SPREAD and MEAN value of each model cloud



- **SIMPLE OPTIMUM POINT**
- Absolute highest peak ignored due to sharp gradients surrounding it, reflecting the non-robust nature of the solution
- A small change in input (X or Y) will result in a rapid change in output (Z)

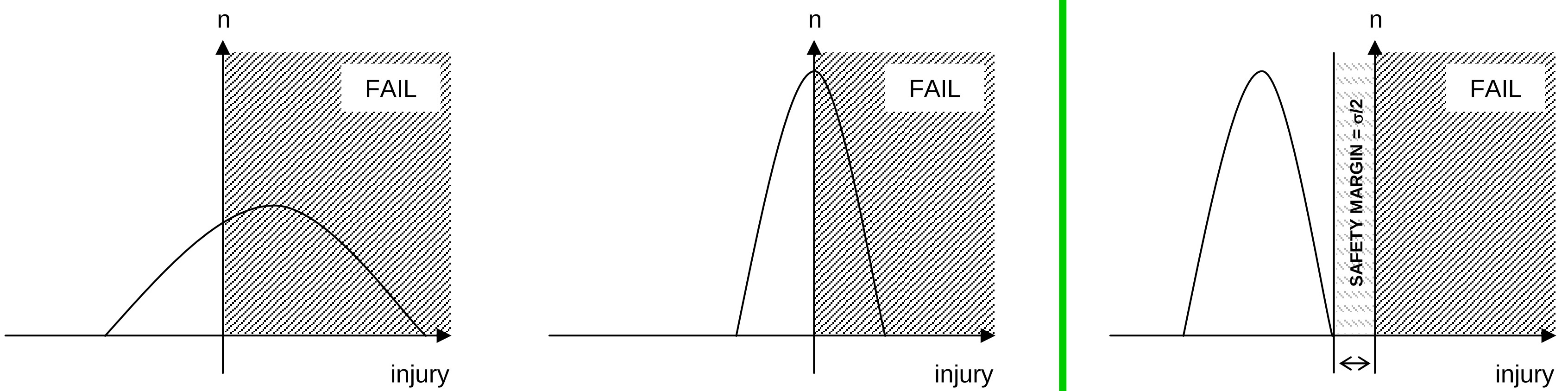
- **ROBUST OPTIMUM CLOUD**
- Peak B has value lower than Peak A
- The flatter landscape in the region of the peak results in more robust solutions in that area
- The output (Z) will not be highly sensitive to small changes X or Y

Illustration taken from modeFRONTIER user manual

Two peaks defined by a simple mathematical equation

MORDO

Robust optimisation

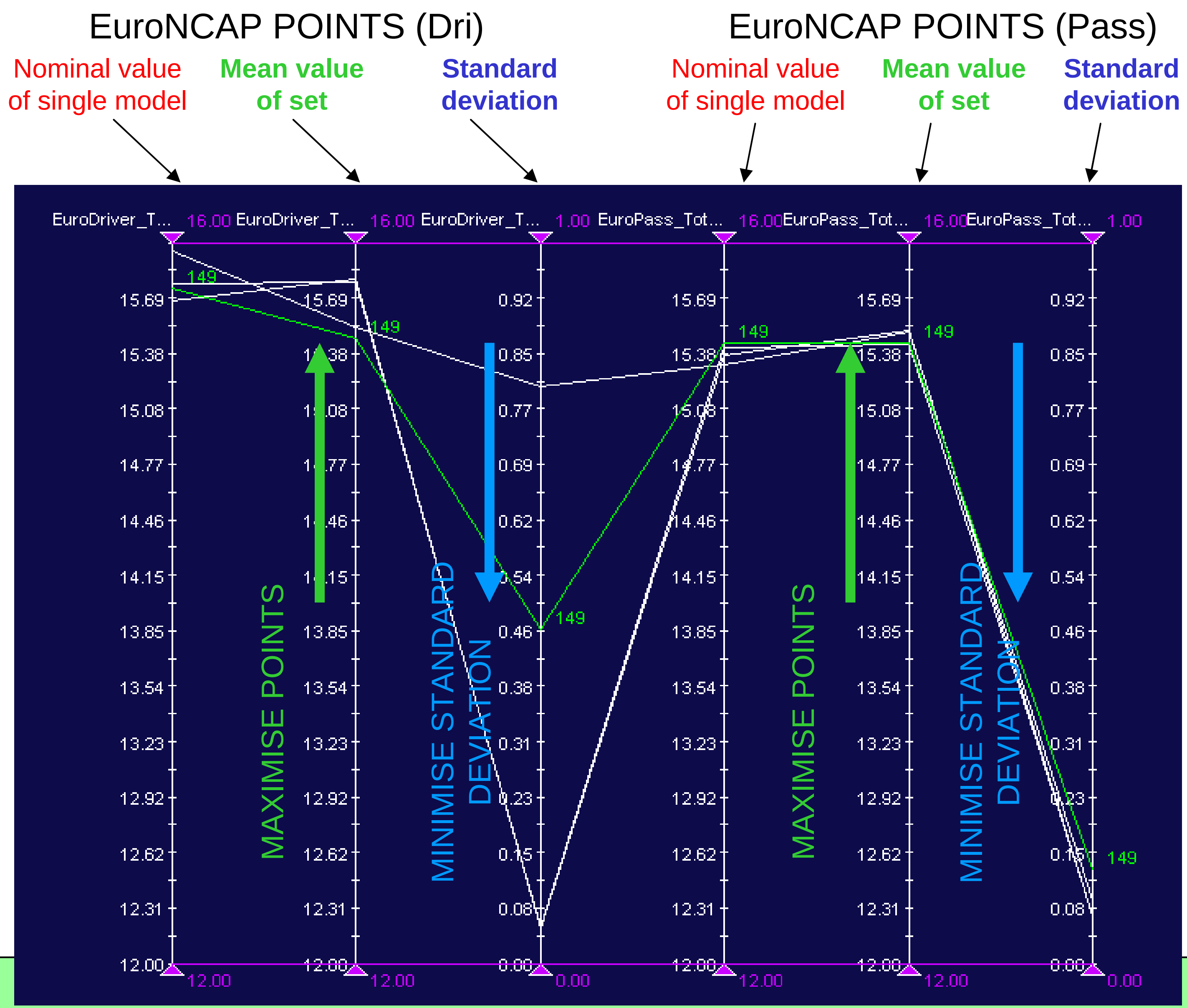


Non Robust with many failures	Robust with 50% failures	Robust with minimised failures
•Applying constraint to nominal value	•Applying constraint to mean value of cloud •Minimising cloud spread (standard deviation)	•Applying constraint (with margin) to mean value of distribution •Minimising standard deviation

Build Tolerance and Noise Setup

- Mean injury level should be half standard deviation (σ) away from the FAC/legal limit to ensure robust passes
- Airbag vent sizes ±1mm : DAB tether length ±10mm
- Airbag TTFs ±1ms : DAB and PAB inflator power ±4%
- Retractor load limitting behaviour ±10%
- Column stroke, kneebolster crush and seatpan deformation loading behaviour ±4%
- Crash pulse variations ±2%

MORDO Analysis



Robustness

After Multi Objective Robust Design Optimisation

1. The optimised robust solution selected through the MORDO analysis is now put through a thorough robustness run

2. An aggressive distribution is applied to the models by using UNIFORM distributions for each input variable as this maximises the number of models with variables at the extremes of the tolerance ranges. Other distibutions (normal, Cauchy, etc) would create a suite of models with a bias towards the nominal value

3. Many models (>200) are run with distribution around the nominal point.

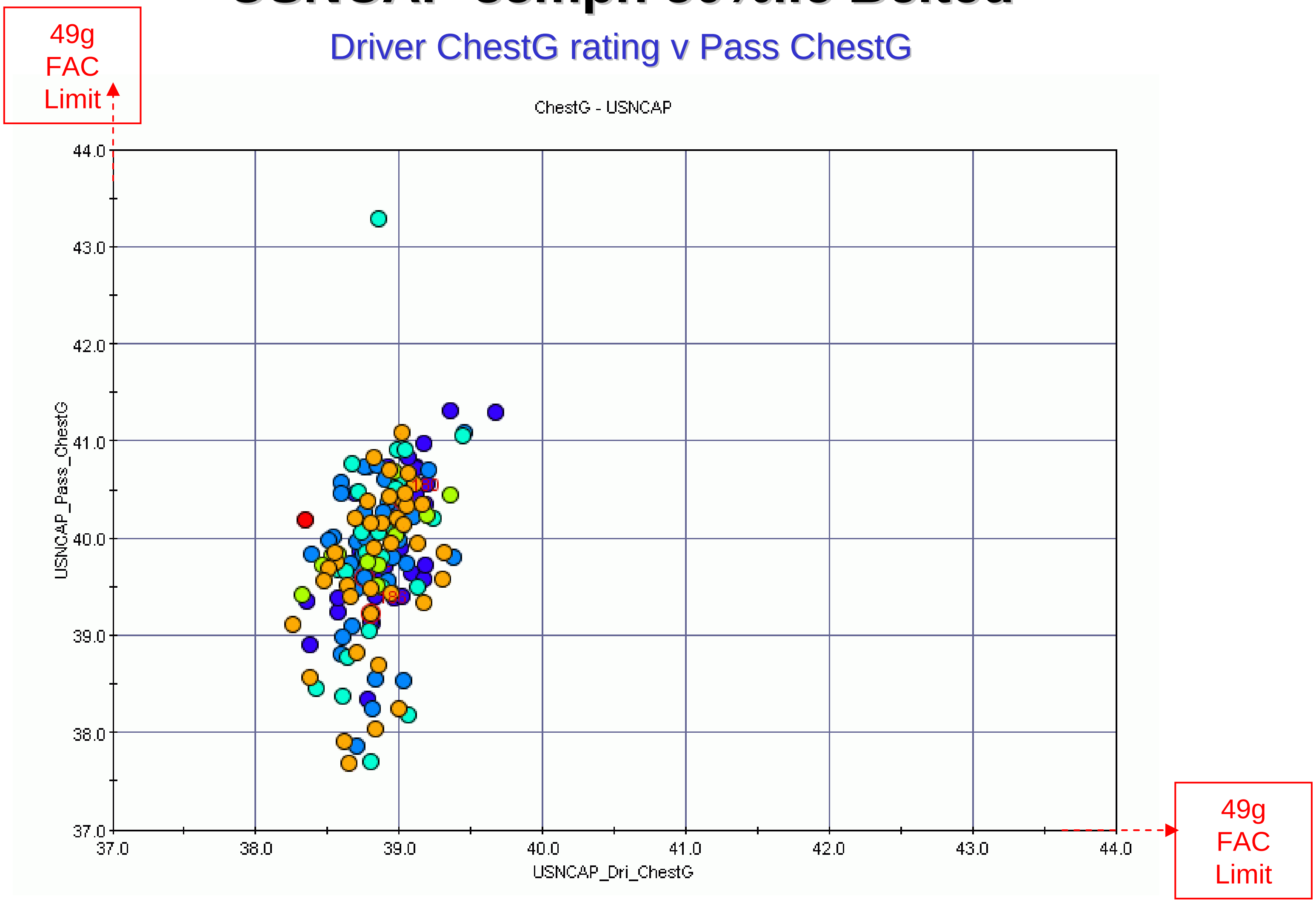
4. Of these runs, the number of models which pass all requirements (feasible) and the number of models which fail any (unfeasible) are used to create a ‘pass/fail ratio’

5. The ‘pass/fail’ ratio is a simple measure of robustness. A high ratio is desirable as this indicates a robust setup

Robustness Over-Check

USNCAP 35mph 50%ile Belted

Driver ChestG rating v Pass ChestG



Conclusions

- The failure mode can be seen as the fundamental quantity in engineering (like electrons in chemistry, or energy in physics).

- If all the failure modes are found early, the design in production will look the same as on the drawing – symmetry

- While Surface Response Methods (RSMs) are available in modeFRONTIER, the highly non-linear crash environment requires the stochastic processing techniques which are also provided in the software …. SDI….