JAGUAR LAND ROVER

Delivering Multi-Platform and Attribute Differential Mounting System Design through Optimisation, Engineering and Collaboration

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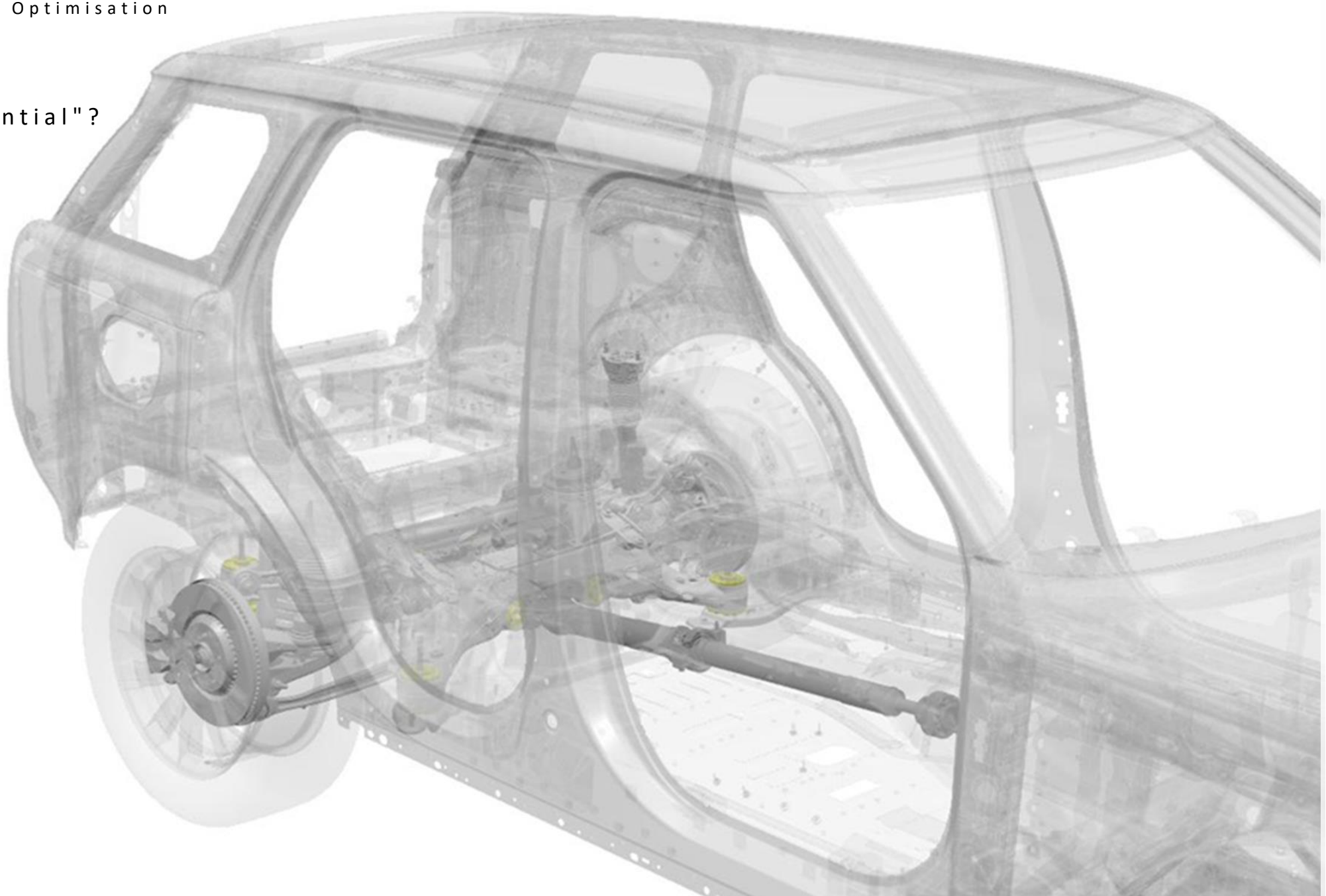
Over 50 years of evolution has seen the Range Rover not only keep at the forefront of offroad capability but become the epitome of comfort with class-leading ride and refinement.

The intent for the latest generation of the vehicle line was to retain the offroad leadership and move the create a significant step forward in the customer experience as part of defining "Modern Luxury“ in most exclusive market segment....

What is a "Differential"?



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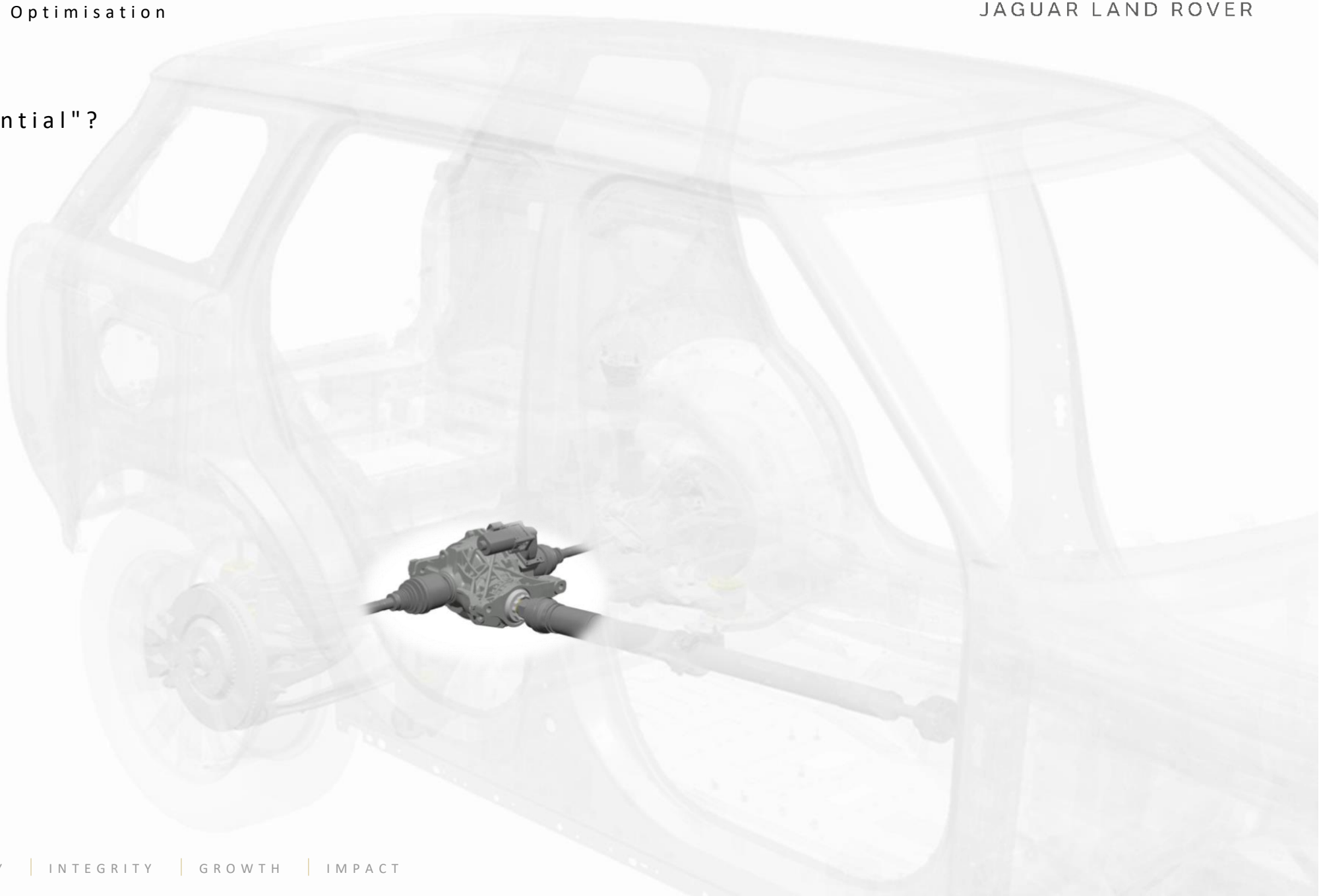

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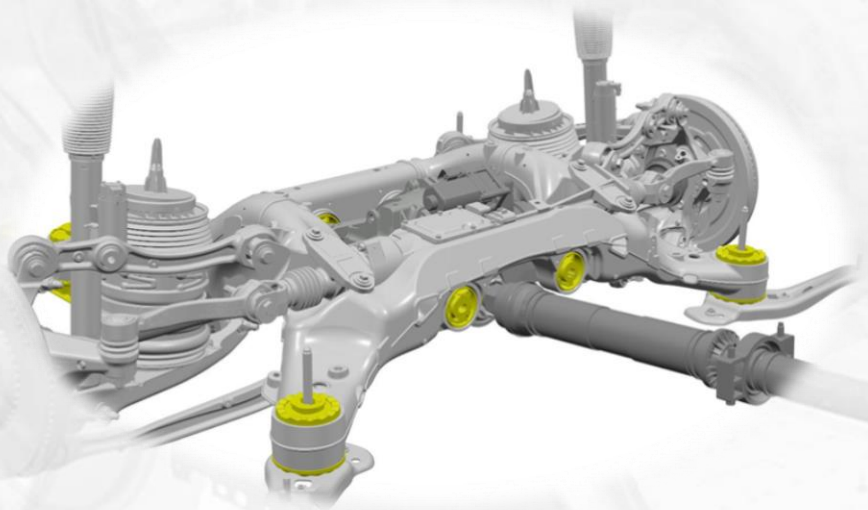
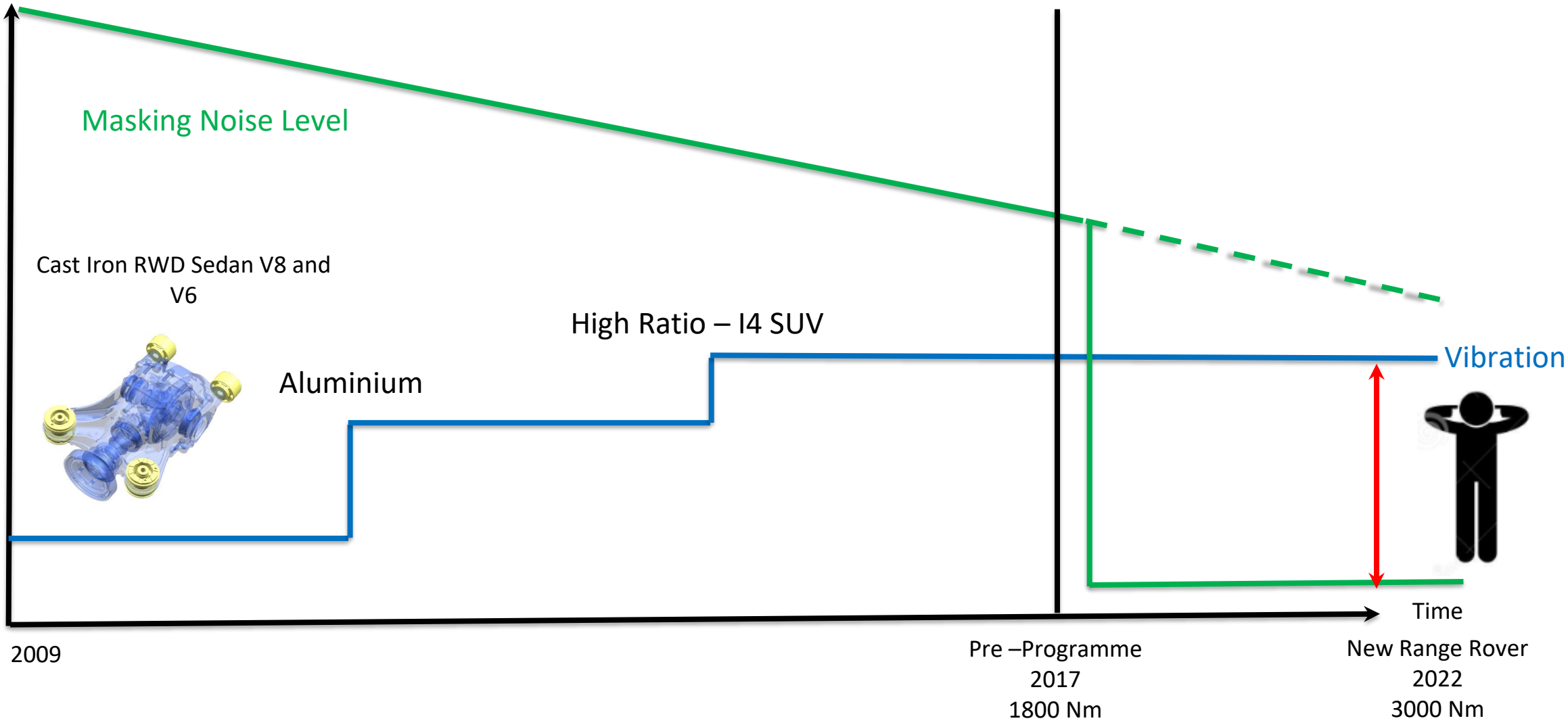


The need for change



Assemble the Team

Vehicle Refinement

Driveline Refinement Attribute

Driveline CAE

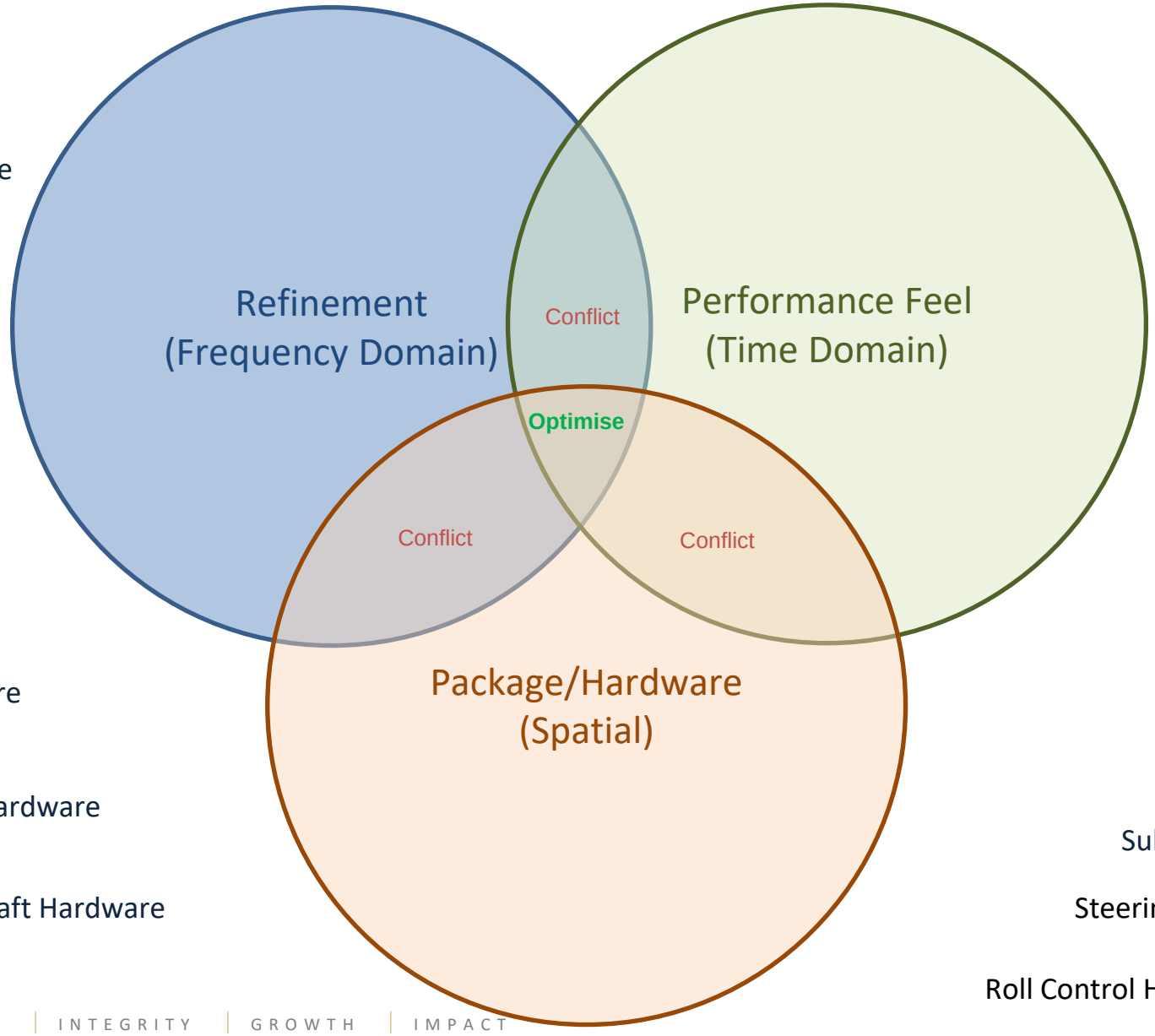
Driveline System TS

Hardware

Differential Hardware

Propshaft Hardware

Driveshaft Hardware



Performance Feel

Performance Feel Attribute

Performance Feel CAE

Mounting System TS

Hardware

Chassis Integration

Mounting System

Mounting Hardware

Subframe Hardware

Steering Hardware

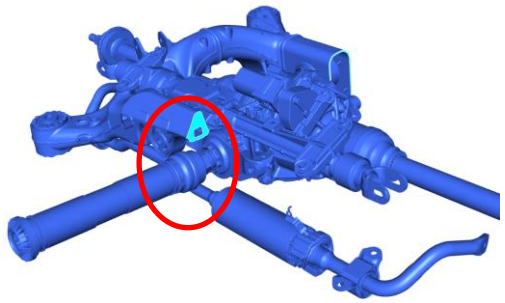
Roll Control Hardware

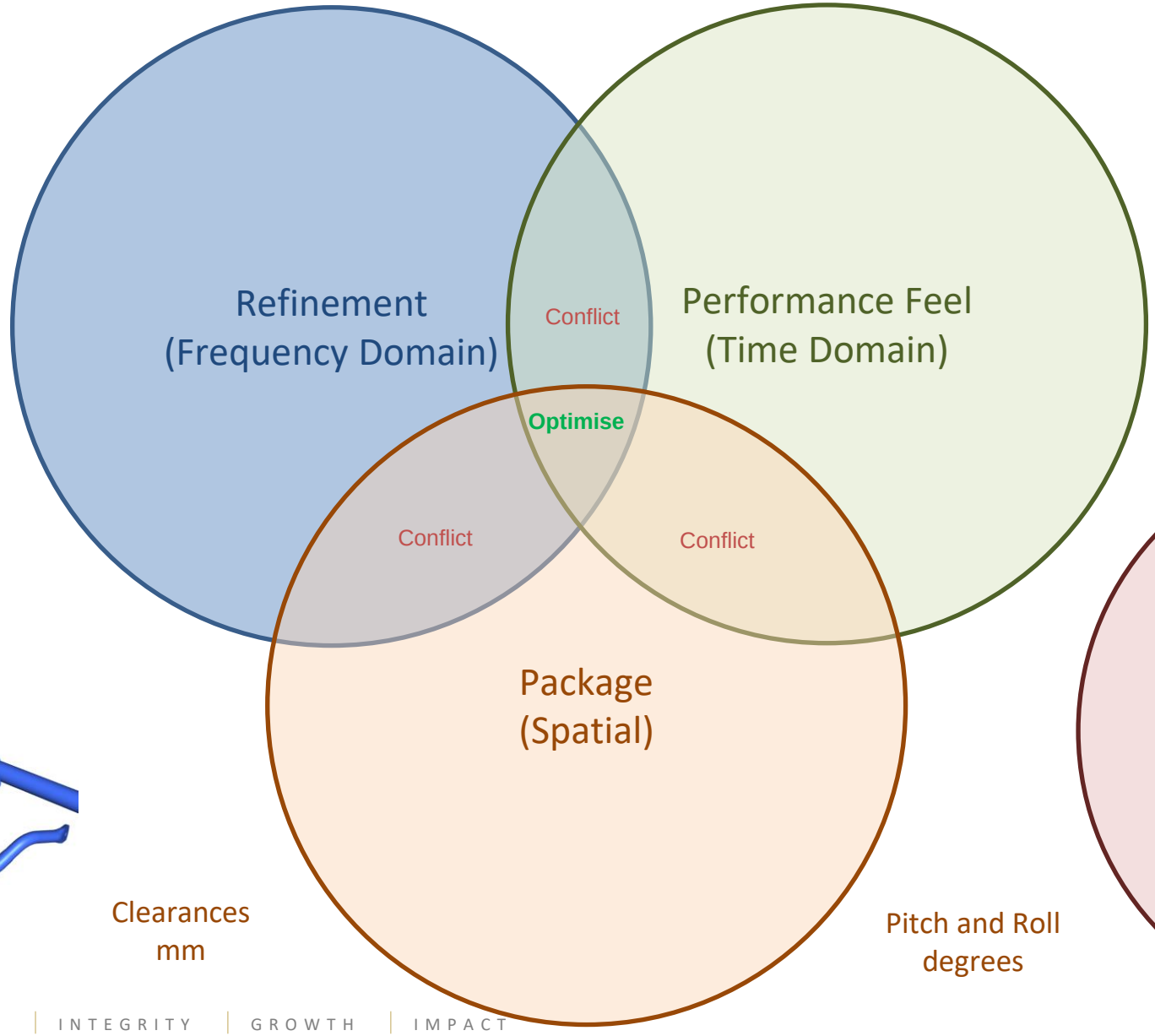
The Challenge

Propshaft Imbalance
100 Hz
(Boom)

Combustion Forcing
400 Hz
(Transitional Noise)

Gear Mesh Forcing
1000 Hz
(Axle Whine)





Vehicle Longitudinal Response
seconds

Vehicle Acceleration
m/s/s

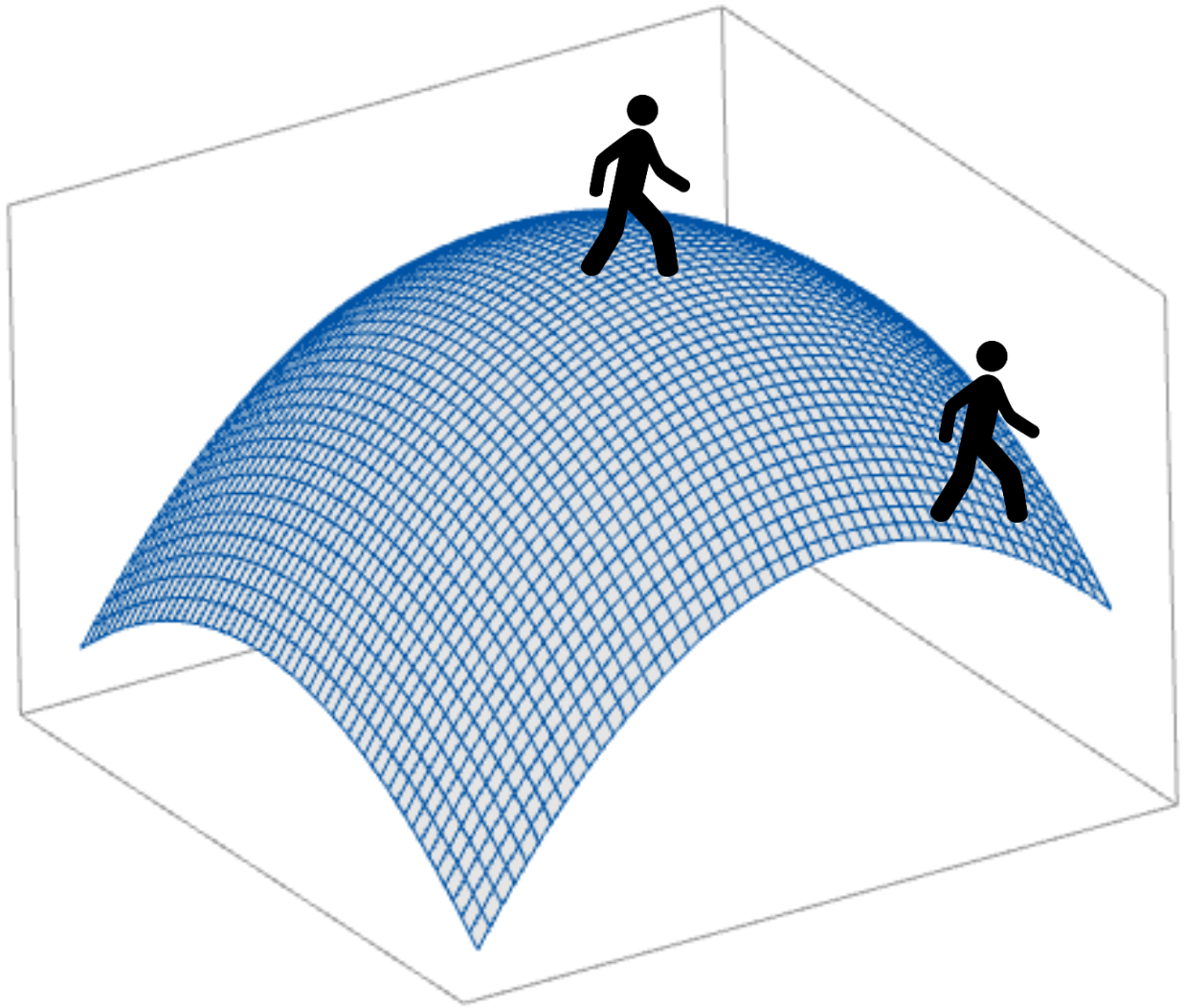
Clearances
mm

Pitch and Roll
degrees

Error States

Thumps/Thuds
“Shuffle”

Which Optimiser – Response Optimisation or Gradient Solver



It was clear an optimisation strategy was required but which one?

8 potential outputs with 5 final drive unit ratios – 40 load cases to assess!!!

Each load case has multiple data points (e.g. 10 – 2000 Hz in 10 Hz steps)

Too big for a regression equation!!!

Response Optimisation – works well if you have a limited design space and a strategy and is good for guaranteeing finding solutions within your constraints, but, requires a huge amount of data and post processing.

Gradient Solver – outputs an answer but doesn't always guarantee the best answer – may need iteration from different start points.

Team decision was to investigate an automatic "gradient" based solution – question is "which one to use?"

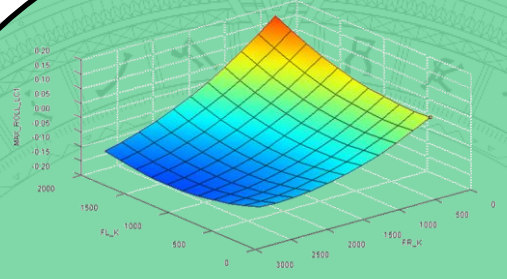
JLR Research

MBS

Dynamic Transfer Stiffness

Torque Transfer Stiffness

Pedal Tip-In Response



High stiffness = min roll and pitch

Axle Whine

Dynamic Mount Stiffness

CONFLICT

CONFLICT

X-OPT

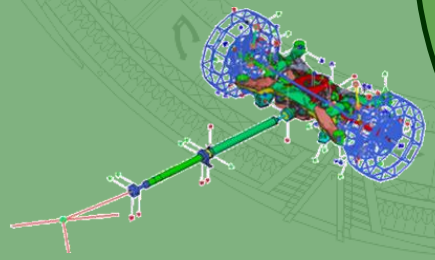
Engine Excitation

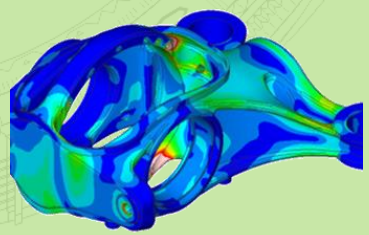
Static Abuse

Low stiffness
Min vibration

CONFLICT

High stiffness
Low stress





Prop Out of Balance

Static Mount Stiffness

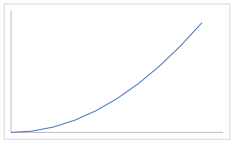
FEA Dynamic

FEA Static

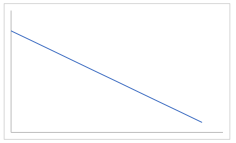
Simplify and Localise, with Robustness!

Wants a Low Stiffness → CONFLICT ← *Wants a High Stiffness*

Force at Mounts

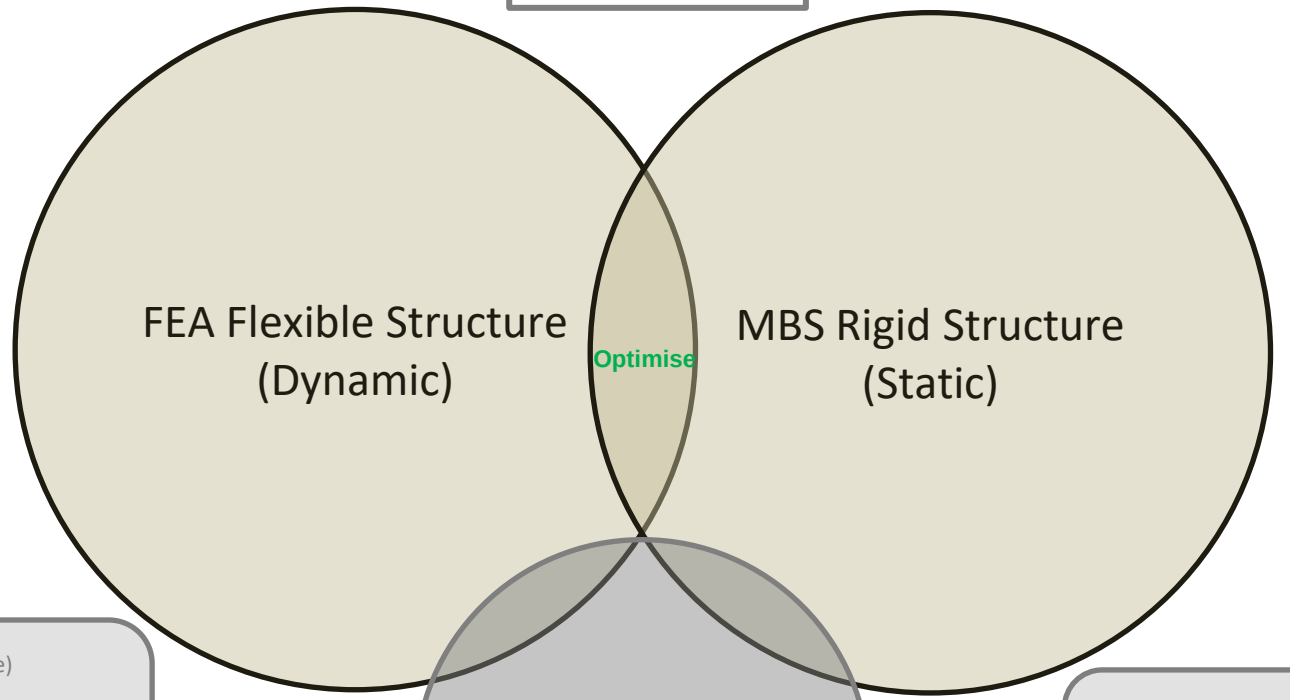


Prop OOB



Combustion Torsional

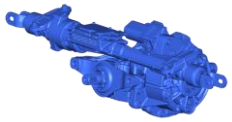
Gear Meshing



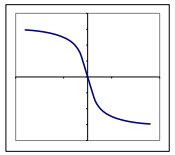
Pitch Angle < 4 Degrees

Roll Angle < 1 Degree

Movement < 3mm



"Smooth Response"
Torque Vs Displacement



Mount Span (increase)

Increases Pitch/Roll Stiffness ✓
Decreases Mount Stiffness ✓
Increases RDU Mass ✗✓
Decreases RDU Stiffness ✗
Increases Rigid Body Rotational Vibration ✗

Mount Stiffness

Low is good for axle whine
High is good for pitch stiffness, package
Mixed for prop imbalance, Combustion Forcing

Interactions

Mount Position

Balances Pitch Vs Roll
Balances Load Distribution in Mounts

Number of Mounts (Cost)

3 works for a limited drive ratio range
4 can be robust to a wide range of ratios

Pitch Stiffness

Noise Factors

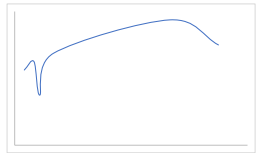
FDR 2.2 to 4.3
3000 NM Prop Torque
Torque Rise Rate 35 KNm/s

Single, linearised, Tool Set Analysis

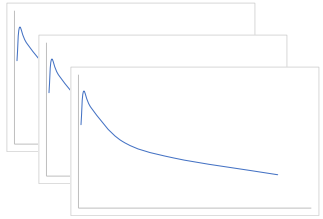
Targets

Prop OOB Response

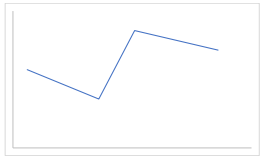
65,895 Constraints



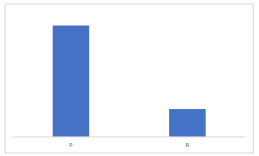
Combustion Response (X5)



Gear Response

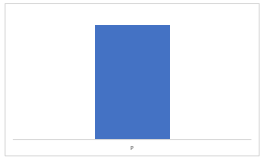


Pitch Angle



Pitch to Roll Ratio

Package Displacement



Control Factors

Bush Stiffness X, Y Z

Bush Position in X,Y (Z)

16 Design Variables

GENESIS

FEA Flexible Structure Including Suspension (Dynamic)

FEA Rigid Model (Static)

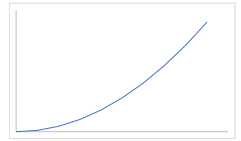
10 concurrent FEA Models Optimised

Noise Factors

5 Final Drive Ratios

Load Cases

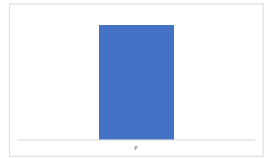
Prop OOB Forcing



Combustion Forcing

Gear Forcing

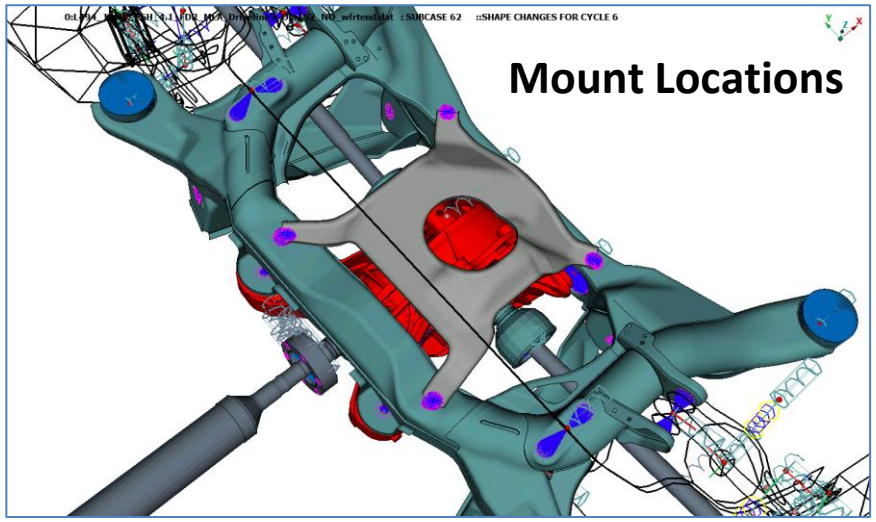
Propshaft Torque



4 load Cases

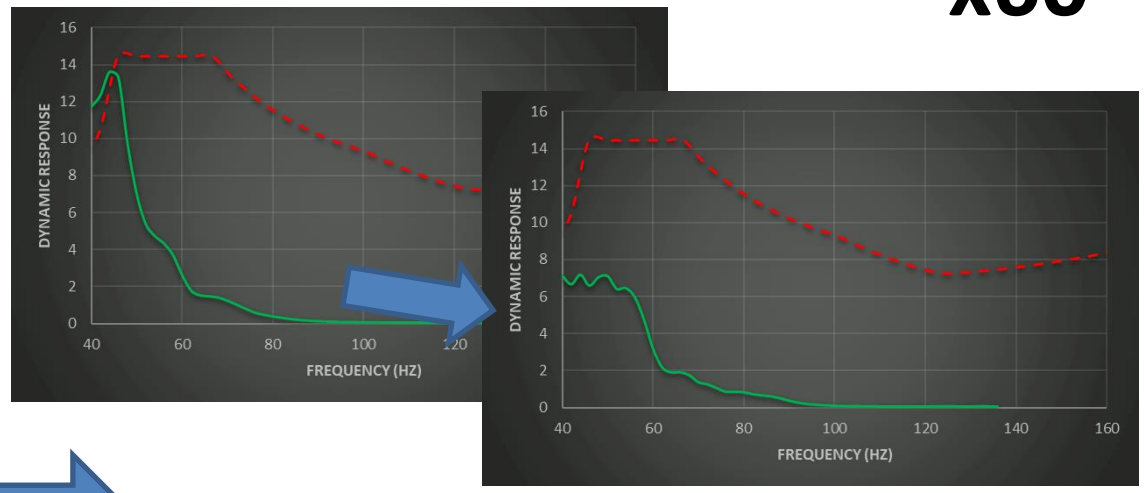
MBS Overcheck for High Torque

Optimisation in Action- The Results

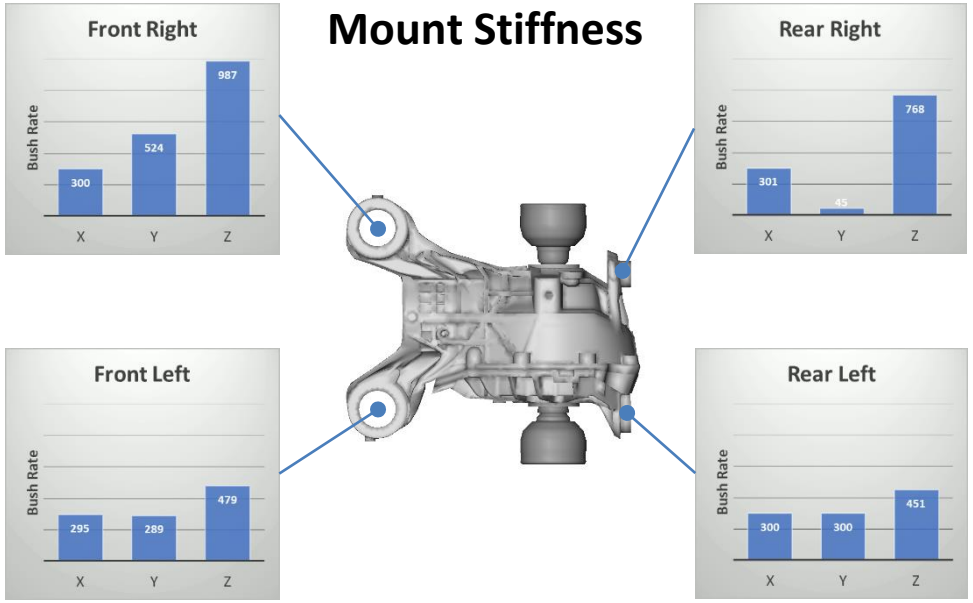


Dynamic Constraints

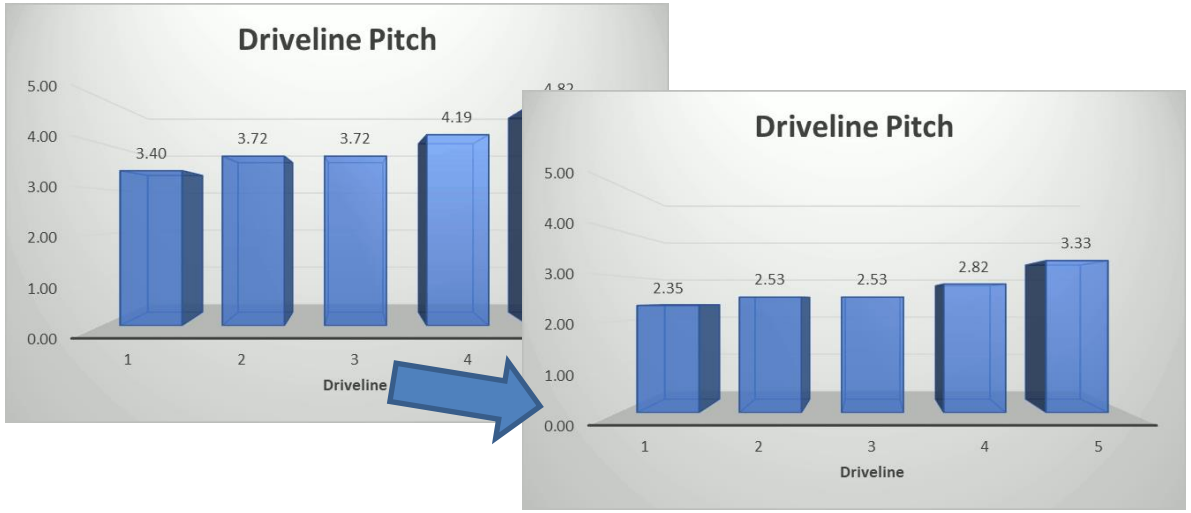
x60

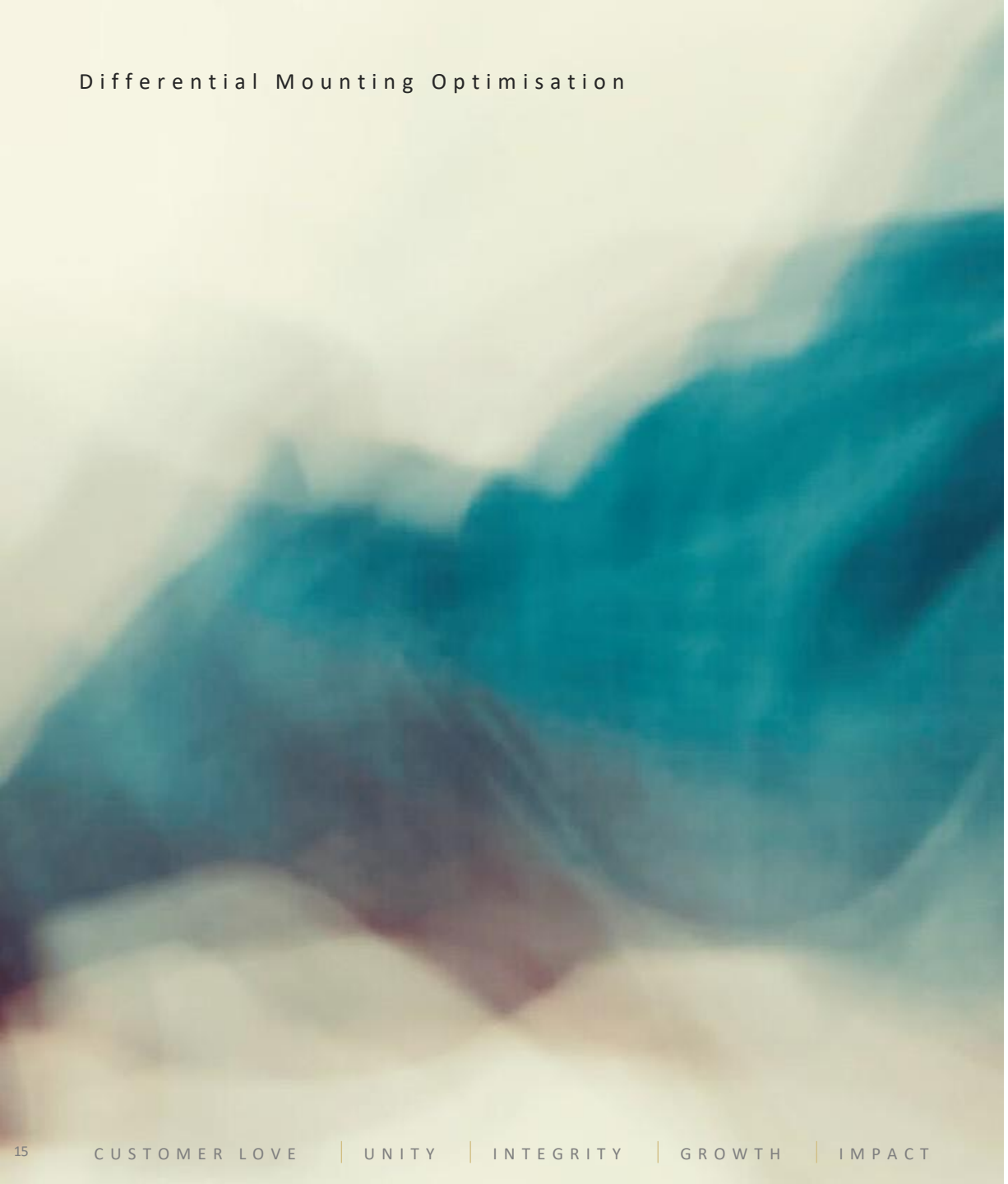


Mount Stiffness



Multi-Platform Objectives



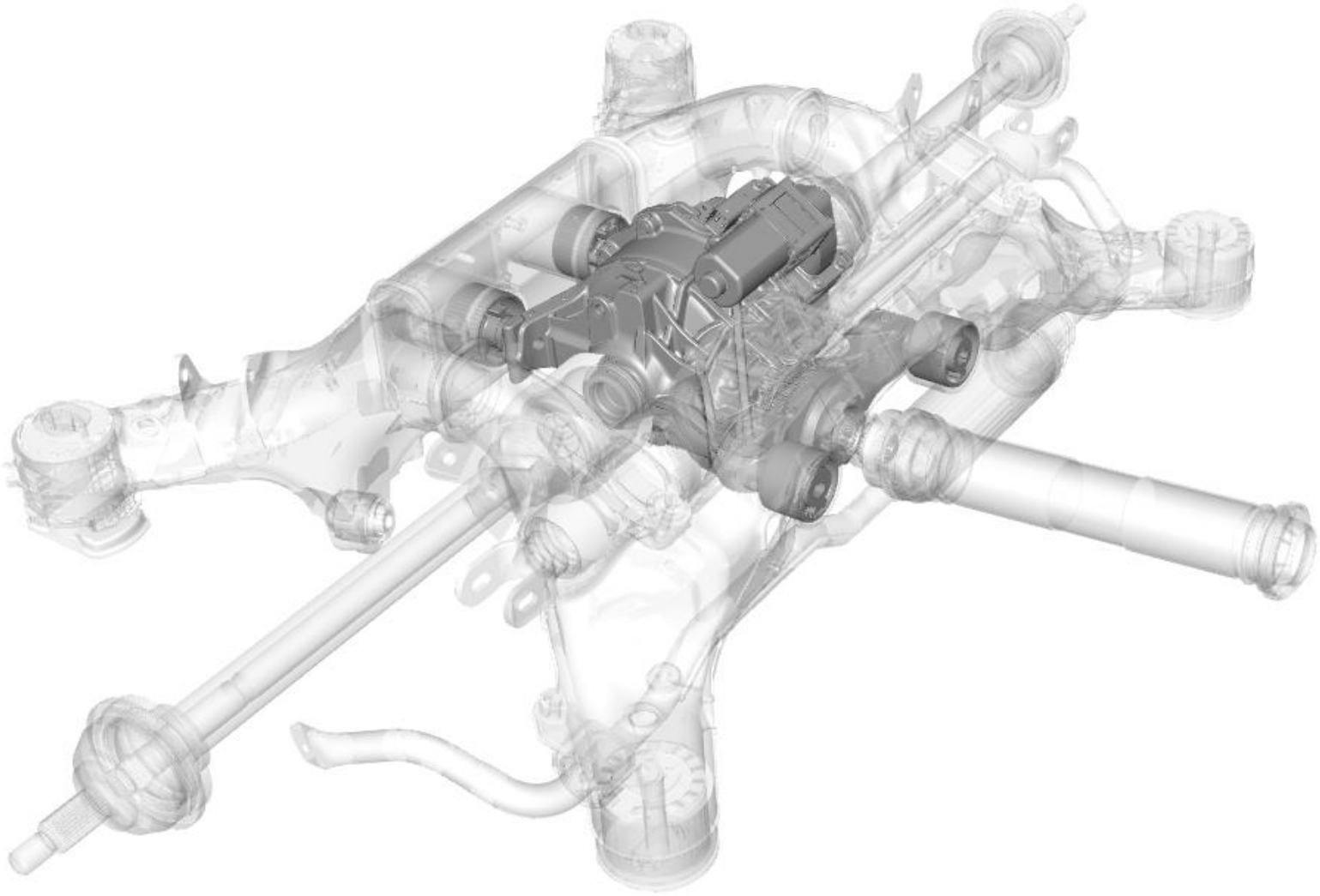


What this means for the products

- From the complexity of the optimisation, we can distil the results down to:
  - 4 differential mounts with
    - The defined rates
    - The positions chosen
  - A solution that works across 5 vehicle powertrains

- The success is in requiring zero rework… did we do it?

Implemented Design



So how did we do?

https://www.bbc.co.uk/iplayer/episode/m001f8hm/top-gear-series-33-episode-3#t=44m55s

https://www.bbc.co.uk/iplayer/episode/m001f8hm/top-gear-series-33-episode-3#t=53m15s

https://www.bbc.co.uk/iplayer/episode/m001f8hm/top-gear-series-33-episode-3#t=38m24s

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