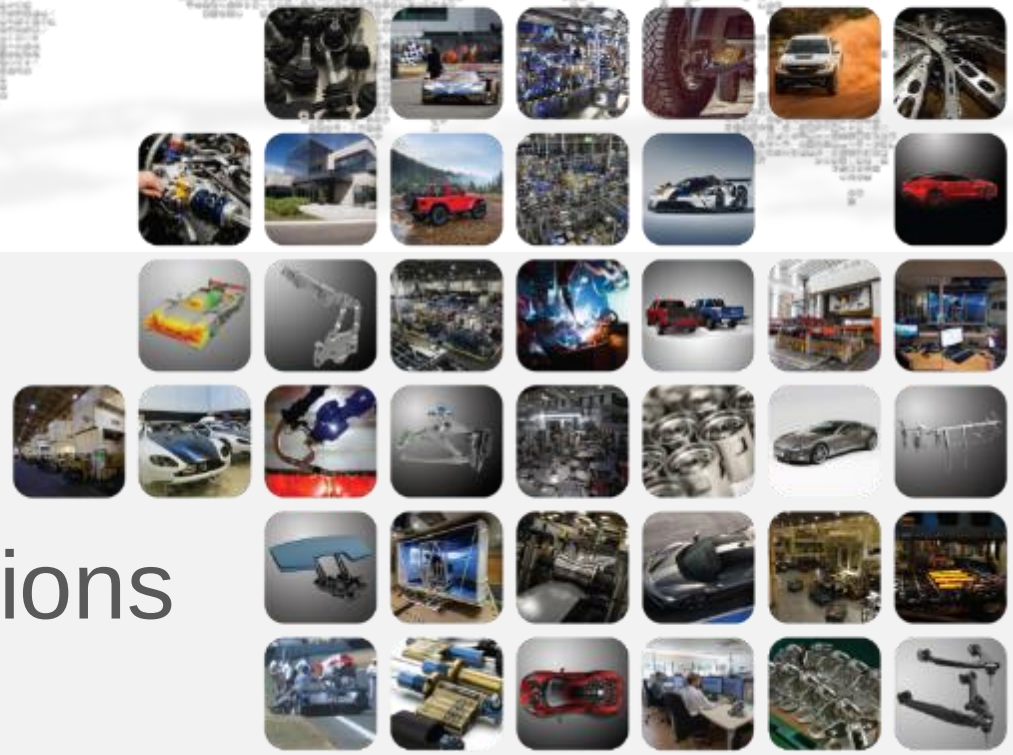
Multimatic



Development of a Jounce Damper for Off-Road Applications

2023 Zero Prototypes Summit

May 24th-25th, 2023 – Udine, Italy

Robert Teseo
Andre Alvarez

Overview

- Multimatic Background
- Integrated Development Process
- Design Brief
- Vehicle Level Objectives
- Model Overview
- Component Synthesis
- Component Optimization
- Objective Performance Development
- Summary

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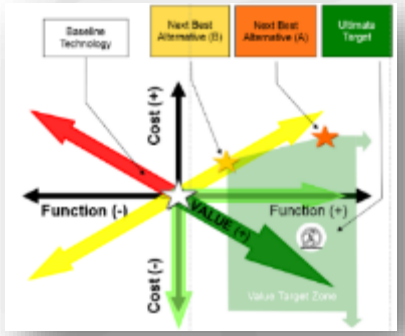
Corporate Overview

- A trusted supplier of manufactured products and engineering services to the global automotive industry
- A privately held global corporation founded in 1984
- Headquartered in Toronto, Canada with facilities in North America, Europe and Asia
- Engineering driven, with strong emphasis on design, development and production of differentiated products
- Successful and sustainable, with annual sales in excess of $1.5 billion

Multimatic is decentralized with five operating groups:

- Multimatic Mechanisms
- Multimatic Structures & Suspension
- Multimatic Engineering
- Multimatic Niche Vehicles
- Multimatic Special Vehicle Operations

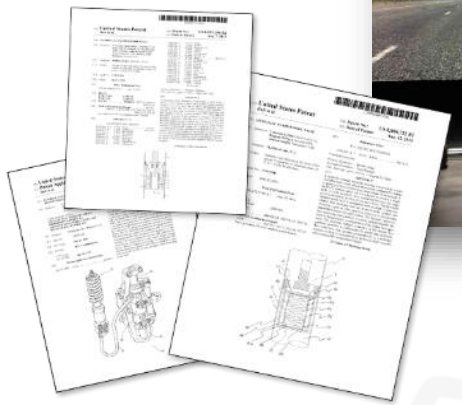


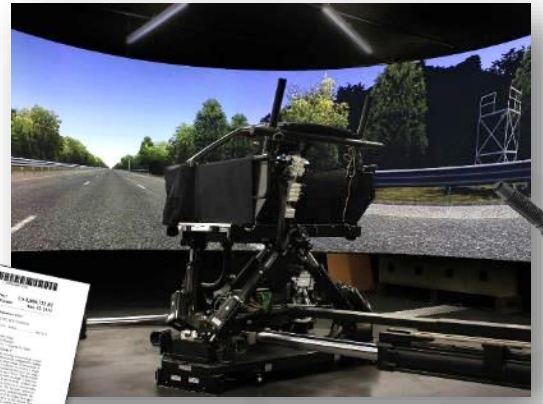
Multimatic Engineering

Transforms ideas into reality

- Multimatic Engineering delivers integrated design, analysis, prototyping, testing, validation and R&D activities for production-intended products
- Services range from stand-alone finite element analysis to comprehensive “art to part” development programs to electronic systems development

Research and Development

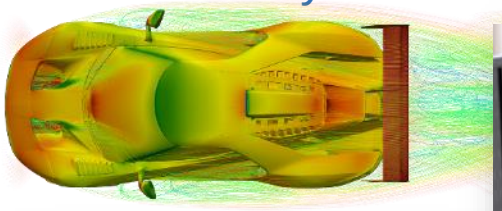




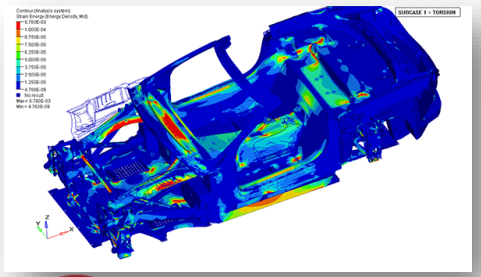
Vehicle Dynamics

Testing

Component and system engineering



Advanced simulation



VI-GRADE

Multimatic

Production at Any Scale

Multimatic delivers manufactured products and engineering services to the global automotive industry… at any volume level.

Low Volume Production → **High Volume Production**

Suspension Products

Structural Products

Mechanism Products

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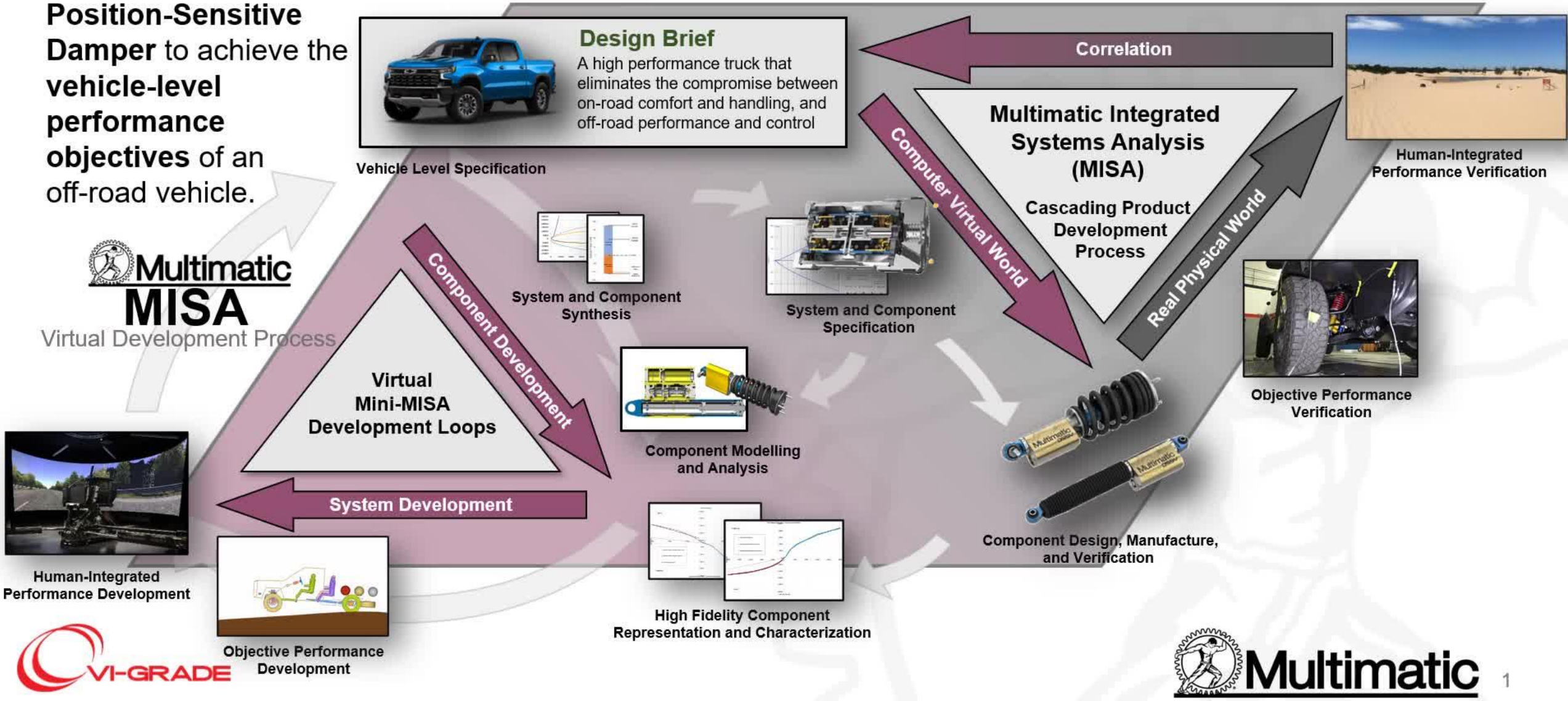
Integrated Development

The following slide demonstrates how Multimatic used its proven **MISA** development process to design a **Position-Sensitive Damper** to achieve the **vehicle-level performance objectives** of an off-road vehicle.

Multimatic
MISA
Virtual Development Process



VI-GRADE

Multimatic

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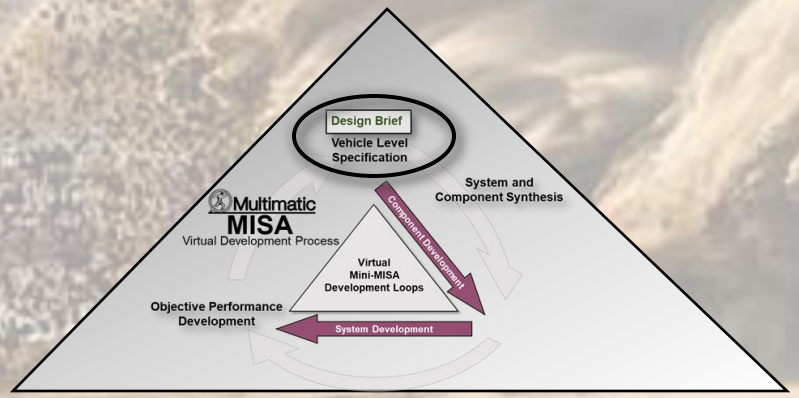
Design Brief

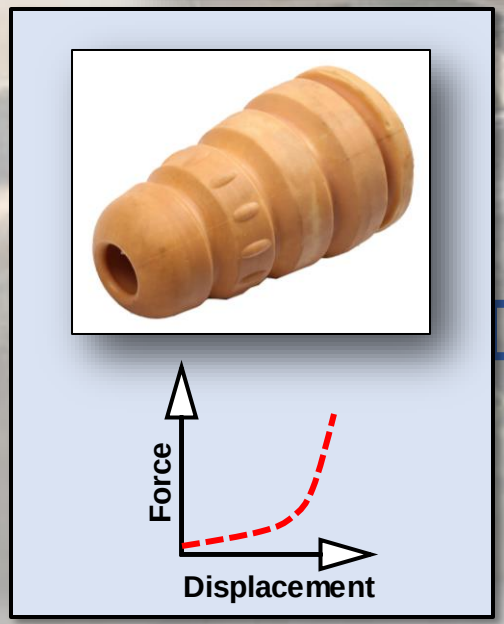
Multimatic designed, developed and manufactured a hydraulic jounce damper in order to achieve the vehicle level objectives of a high-performance off-road vehicle.

The following presentation outlines the **Integrated Systems Analysis (MISA)** approach that was taken to define the design direction.

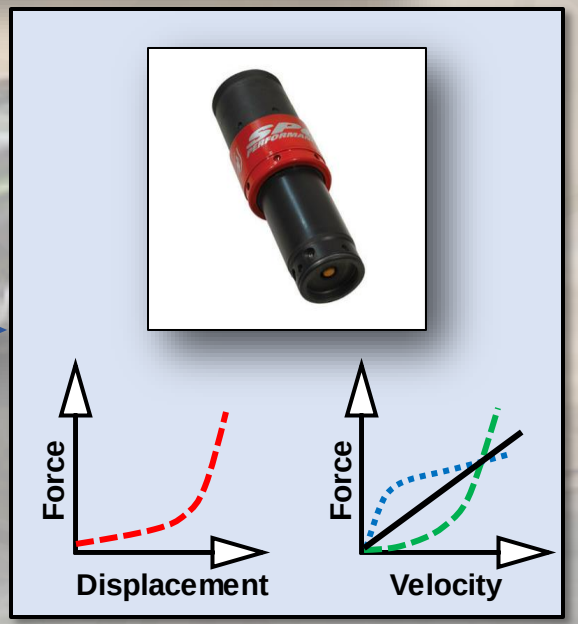


Vehicle Level Design Brief

A high performance truck that can withstand and remain controllable throughout severe off road events without compromising on-road comfort or handling



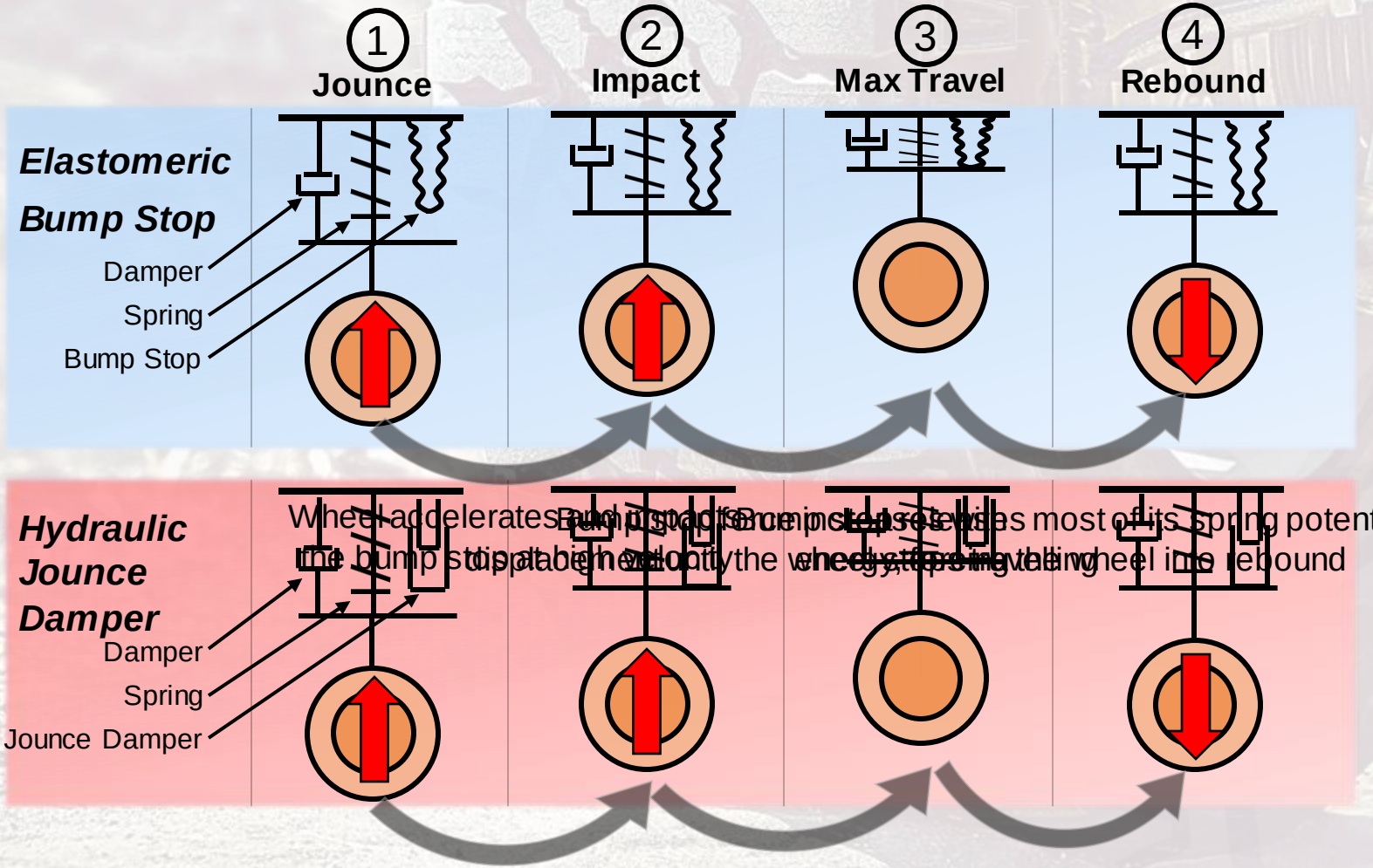
Elastomeric Jounce Bumper

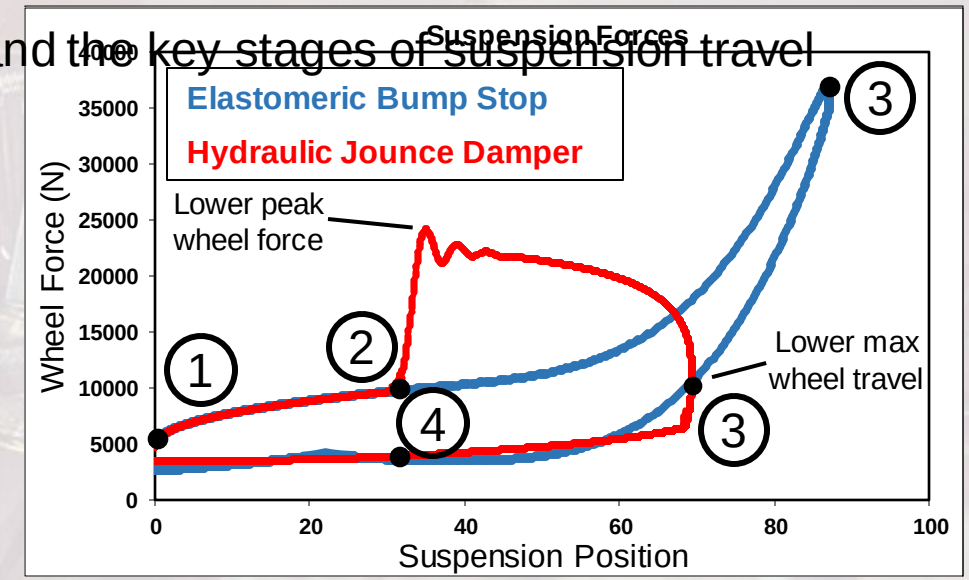


Hydraulic Jounce Damper

Why use a Jounce damper?

Now let's look at how a hydraulic jounce damper and elastomeric bump stop work together to understand the key stages of suspension travel





Benefits of a Jounce Damper

- Increased energy dissipation during large off-road events
- Energy dissipation during rebound reduces peak rebound forces and improves platform control
- More efficient utilization of wheel travel
- Reduced peak frame and tire forces

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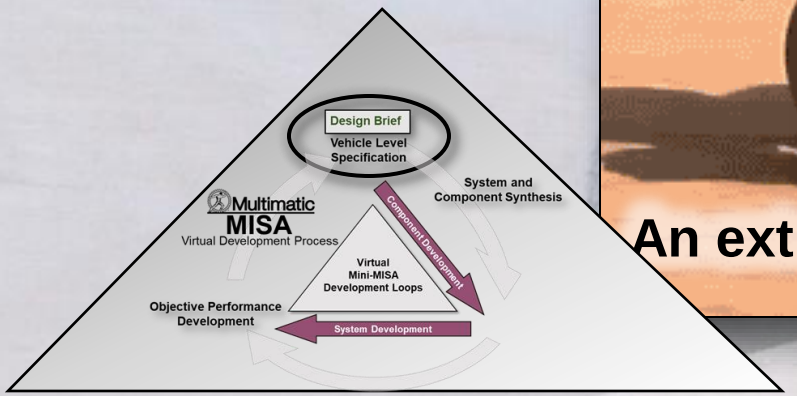
Vehicle Level Objectives

From the vehicle level design brief, three key performance objectives were determined.

These objectives will be assessed for aggressive off-road driving conditions



Vehicle Level Design Brief

A high performance truck that can withstand and remain controllable throughout severe off-road events without compromising on-road comfort or handling

Minimize Body Motion:

- Heave Acceleration
- Pitch Velocity
- Pitch Amplitude

Allows the driver to control the vehicle during off-road events

Reduced Wheel Travel

Allows for more efficient utilization of the design package space.

More of the wheel travel can be dedicated to on-road behavior without compromising off-road performance

Reduced Peak Tire and Frame Loads

Allows for lighter and less expensive component designs

An extreme example of aggressive off road driving

Achieved through the increased and more evenly distributed dissipation of energy

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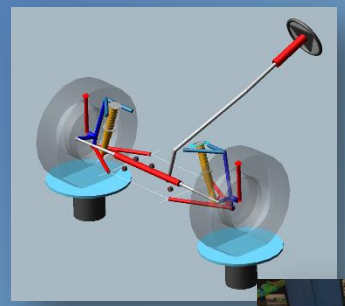
Modelling

A comprehensive model was used to define the design problem and establish sensitivities

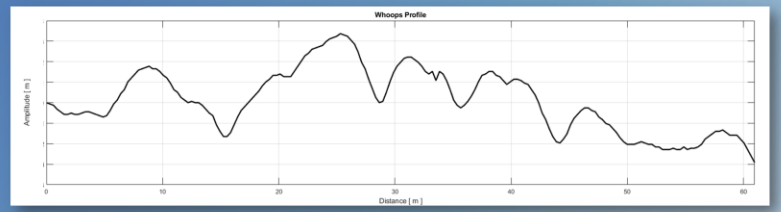
Correlated Vehicle Model

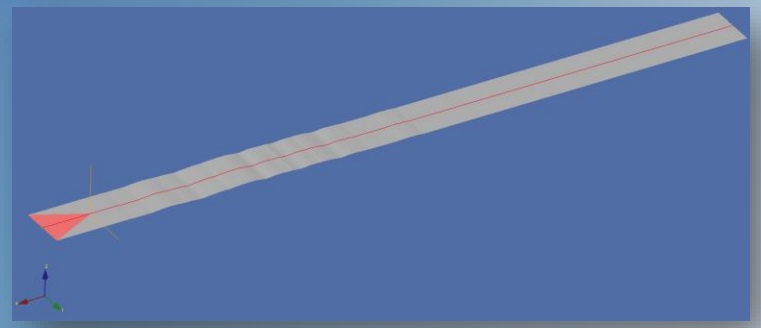
- Kinematic and Compliance behaviour was modelled in ADAMS/Car and correlated to test data
- Vertical dynamics were correlated to the vehicle using Multimatic's multi-post test rig



Road Model

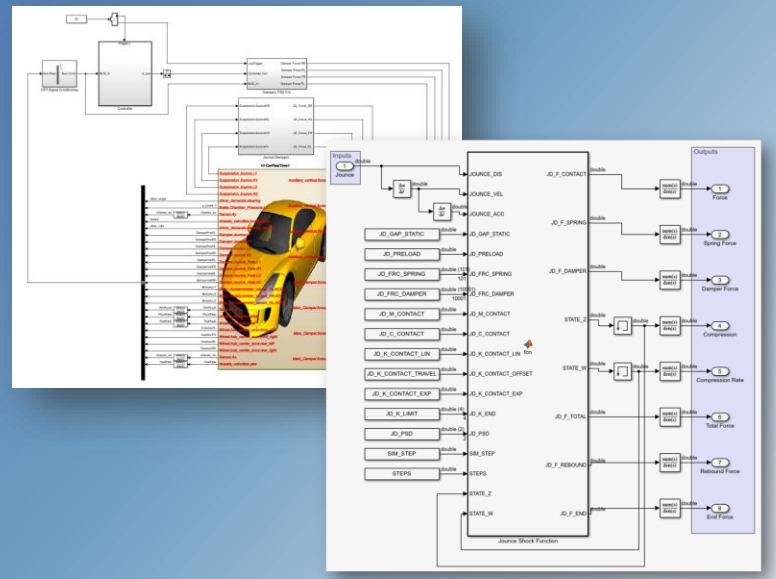
- A narrow, bumpy road profile (whoops) was used to assess aggressive off-road driving conditions





Jounce Damper Model

- The jounce damper was represented by a Matlab Simulink model, along with main dampers and friction
- The model was run in Co-Simulation with VI-CarRealTime



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System and Component Synthesis

During the early stages of the program, a wide variety of system-level behaviours can be quickly synthesized, and their vehicle-level benefits can be compared. The open exploration of different concepts allowed for a design direction to be chosen.

Spring Rate?

Linear Spring?
Non-Linear Spring?

Will the jounce damper have significant preload?

Amount of wheel travel?

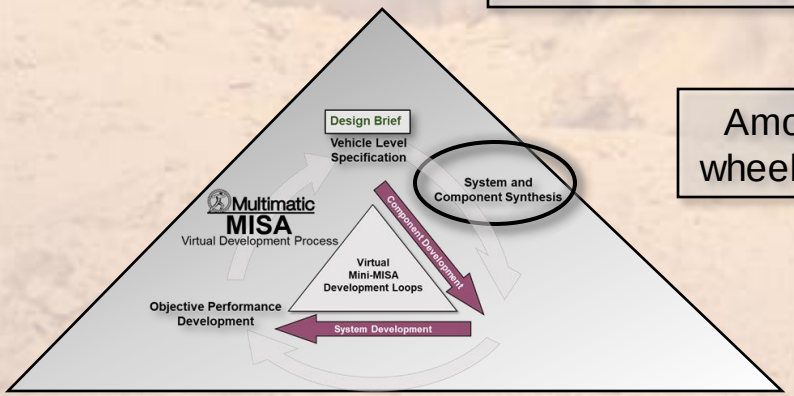
How is the jounce damper mounted to the frame?

How much damping is required?

What type of damping is best? (digressive, linear, progressive)

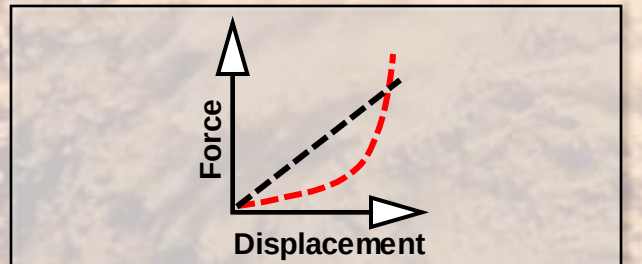
Is position-sensitive damping required?

How will the jounce damper contact the suspension?

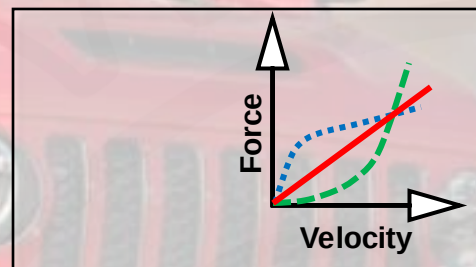


System and Component Synthesis

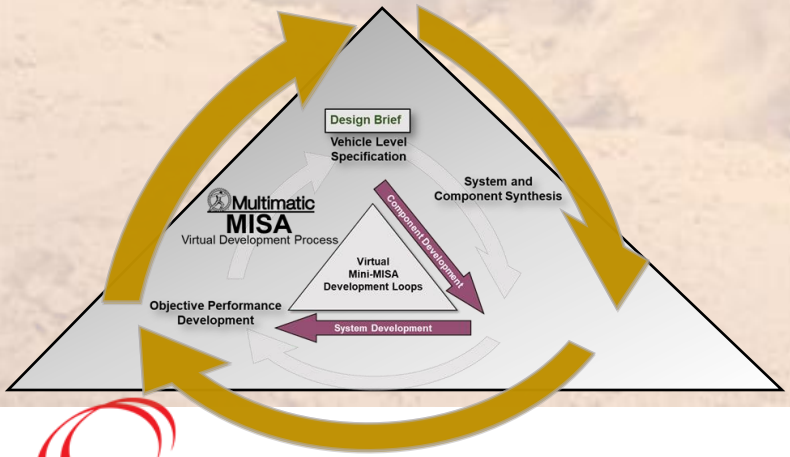
Using simple representations of component behaviour, a preliminary loop of the development cycle was done to establish the design direction



Spring rate can be represented by a linear or progressive rate



Damper can be represented by a digressive, linear or progressive rate



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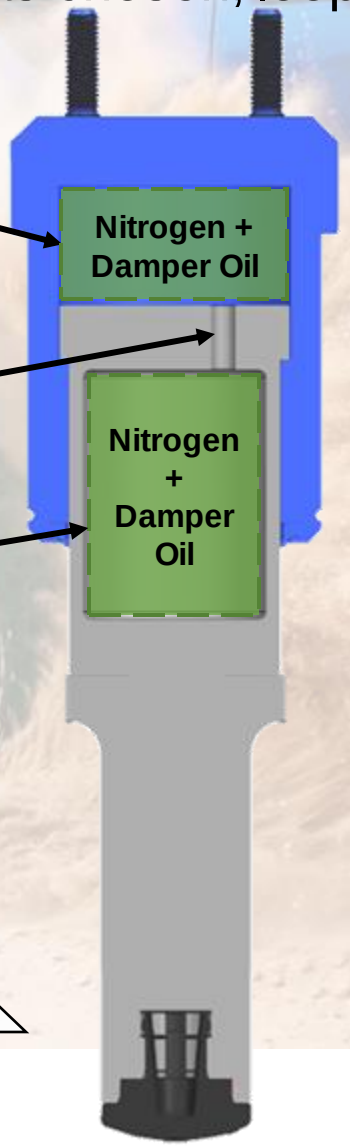
Component Level Specifications

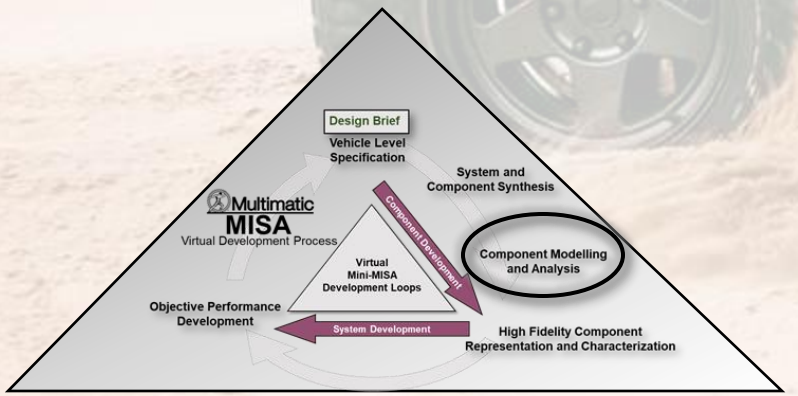
Once the design direction was chosen, loop of the development cycle was completed with additional component detail

Upper Chamber
Mixture of charged nitrogen and damper oil

Damping Orifice
Can be a bleed hole, shim stack or spool valve

Lower Chamber
Mixture of charged nitrogen and damper oil





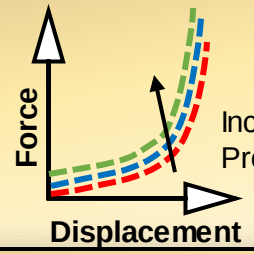
Design Challenges

- Minimize Cost
- Tight Package Space and Travel Requirements
- Strength and Durability Requirements
- Thermal Effects

Nitrogen Charge Pressure

Pressure of the Nitrogen determines the preload of the jounce damper.

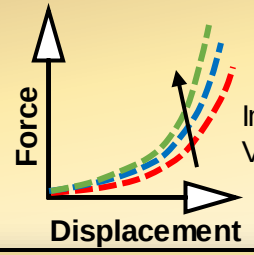
Increasing preload increases the force at impact and decreases total travel.



Damper Oil Fill Volume

The upper and lower chambers consist of a mixture of nitrogen and damper oil

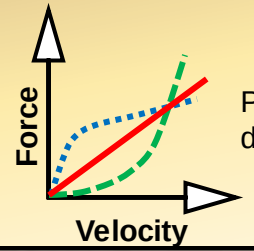
Increasing oil fill volume makes the spring curve more progressive.



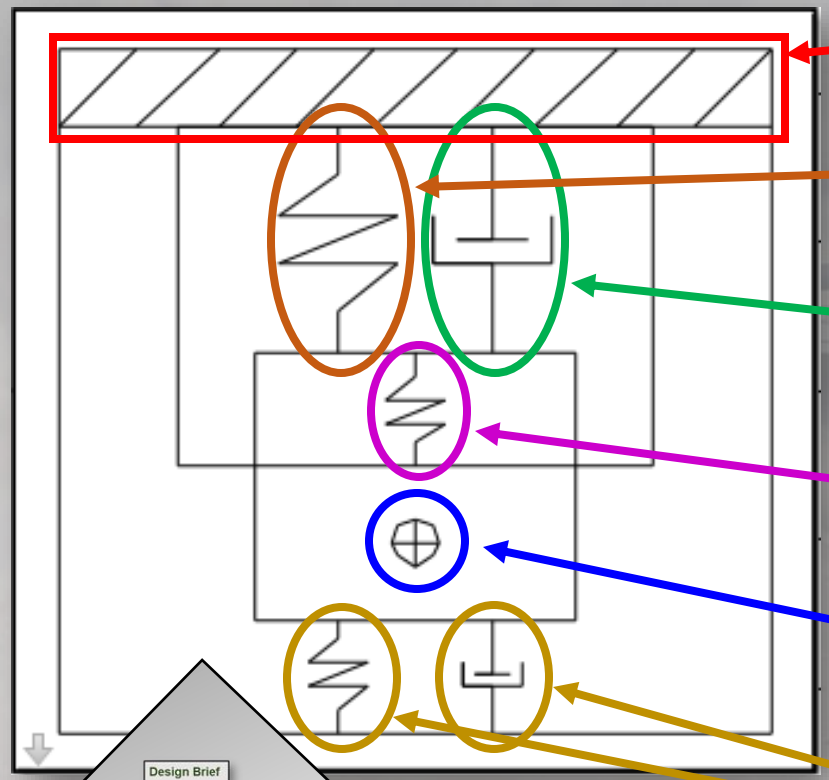
Damper Curve Shape and Rate

Damping can be achieved through a bleed orifice, a shim stack, or a spool valve.

Several damping curve shapes and rates can be achieved (progressive, linear, digressive)



Component Modelling



Connection to Chassis

Nitrogen gas in mixture modelled as non-linear spring

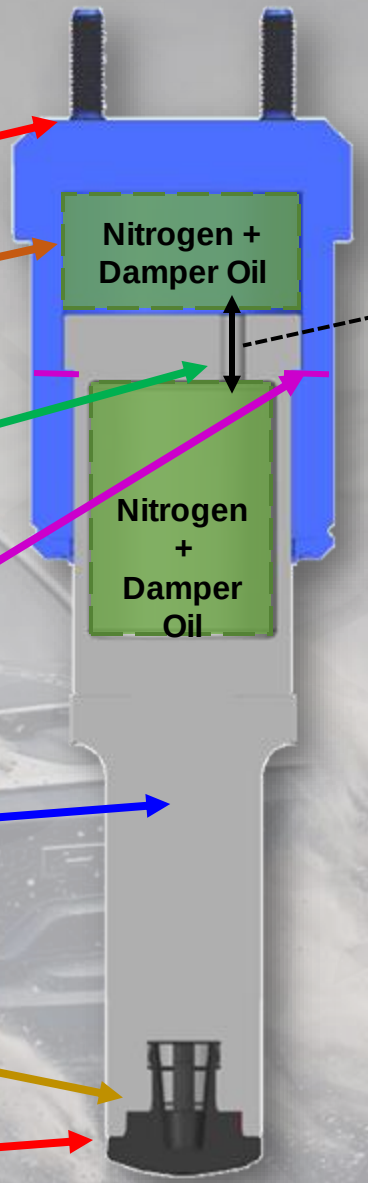
Damping orifice can be modelled as progressive, linear or digressive

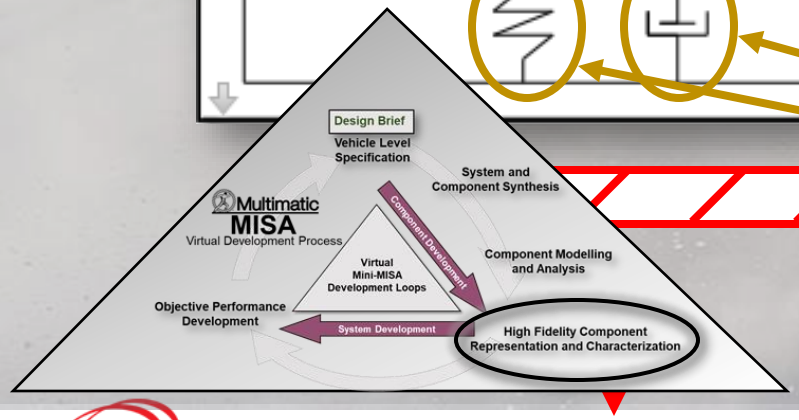
Rebound contact surfaces modelled as a spring

Mass of the jounce damper is considered

Stiffness and damping of the contact pad are considered

Suspension Contact Point





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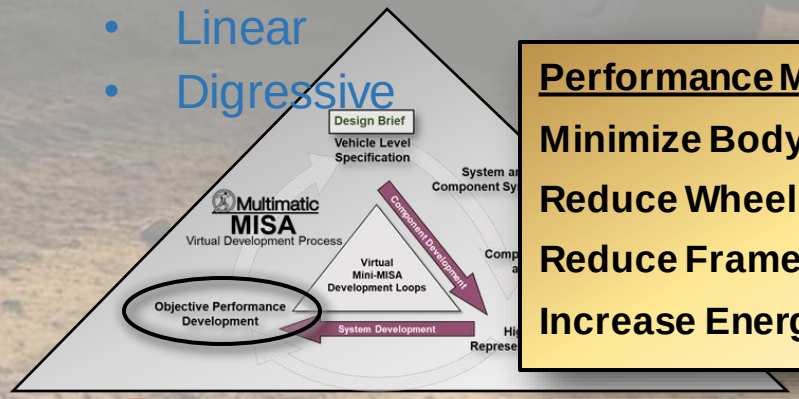
Objective Performance Development

Digressive Damping
Linear Damping
Progressive Damping

Using VI-CarRealTime, offline simulations can be run and comparisons made based on key vehicle-level performance metrics. The data below is for the first significant front wheel impact during a whoops event

Several sensitivities can be investigated:

- Charge Pressure
- Fill Volume
- Damping Architecture
  - Progressive
  - Linear
  - Digressive



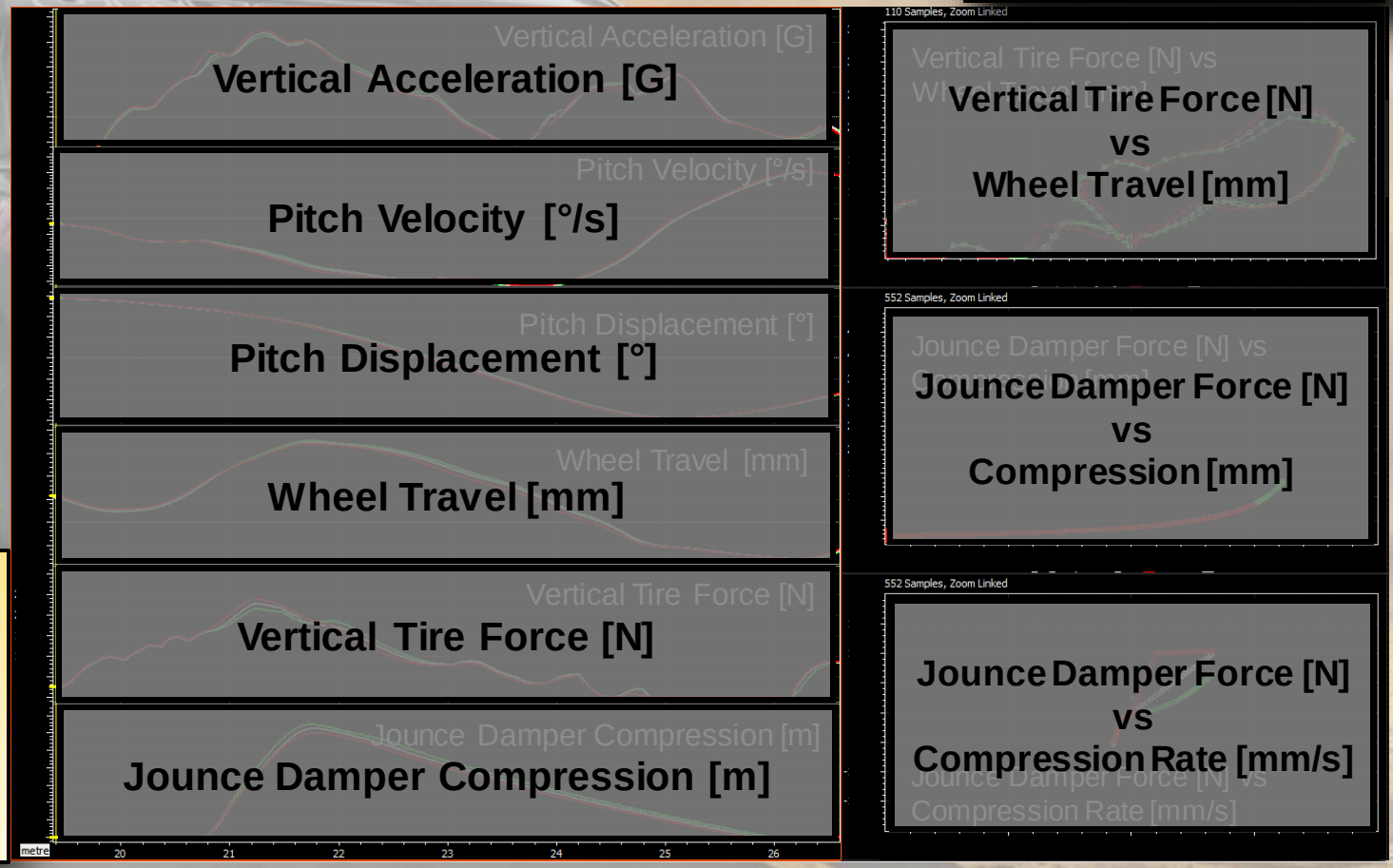
Performance Metrics:

Minimize Body Motion

Reduce Wheel Travel

Reduce Frame and Tire Loads

Increase Energy Dissipation



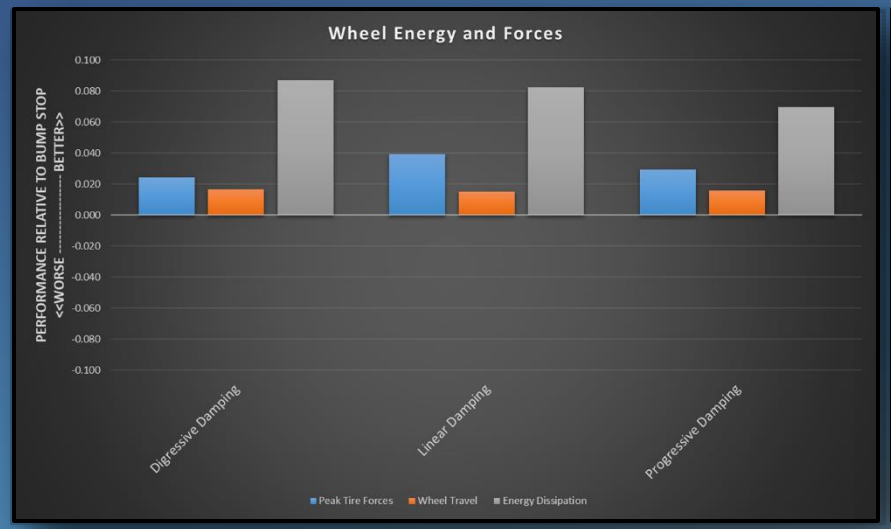
Objective Performance Development

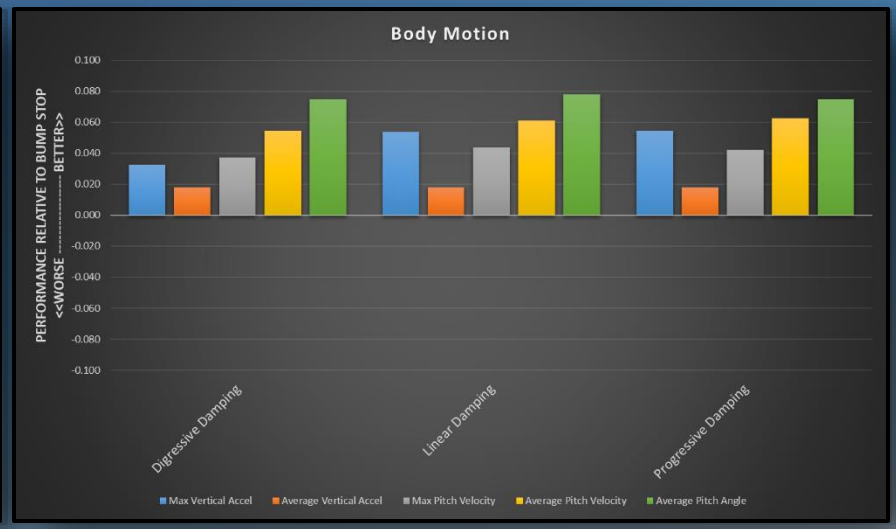
The key performance metrics can also be calculated from simulation results and compared throughout the entire off-road event

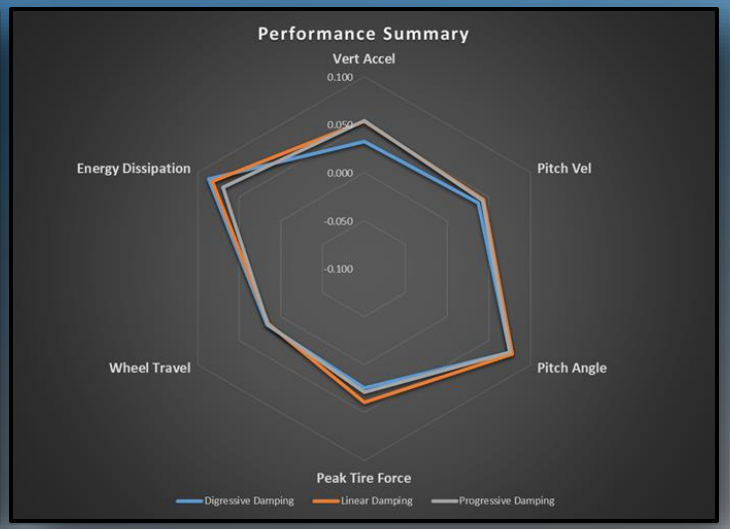
Performance Metrics:

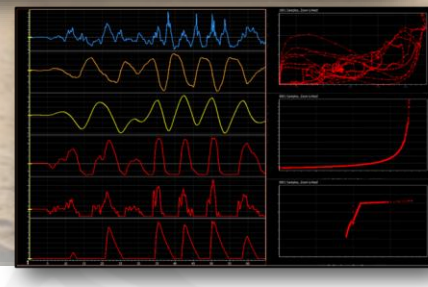
- **Minimize Body Motion**
- **Reduce Wheel Travel**
- **Reduce Frame and Tire Loads**
- **Increase Energy Dissipation**

Damper Curve Study







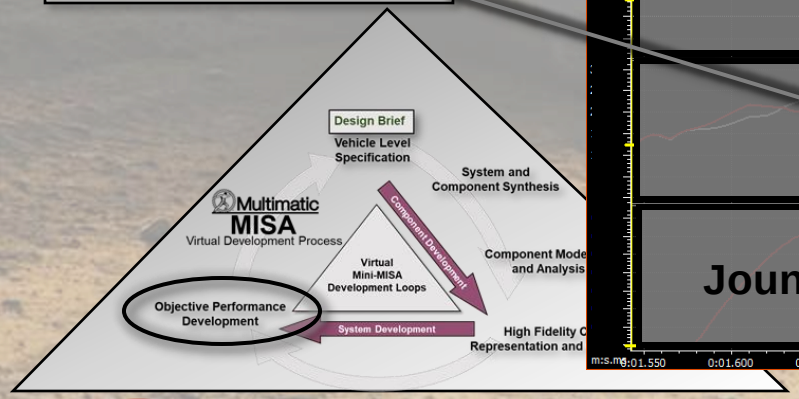


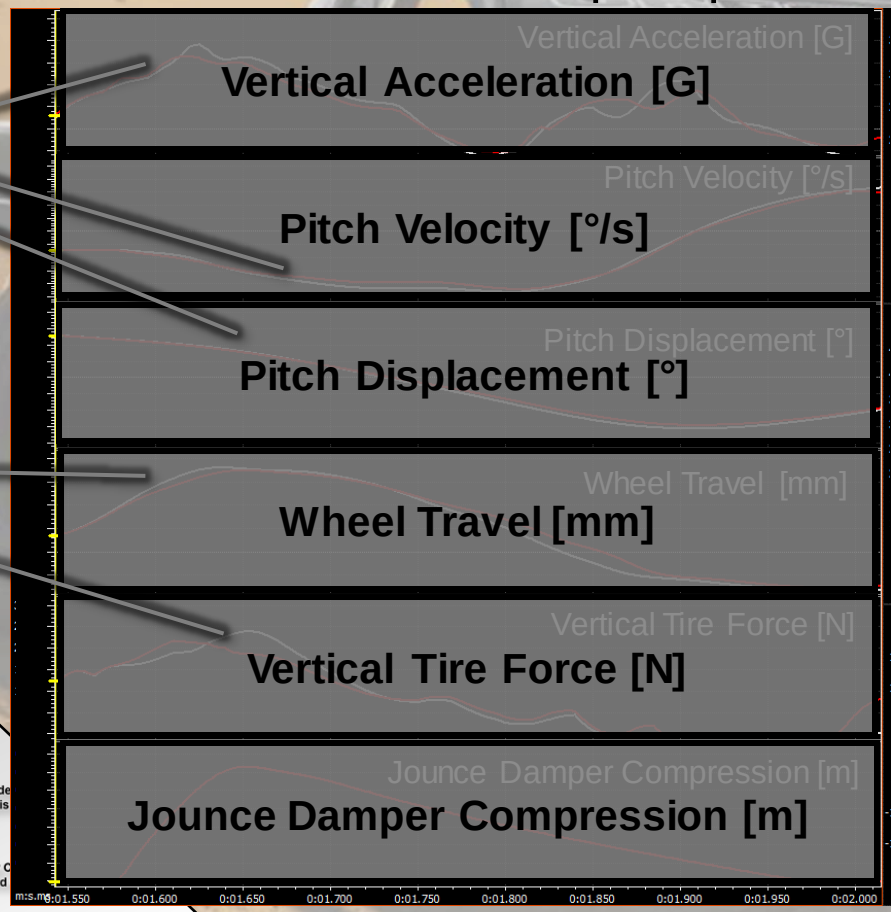
Objective Performance Comparison

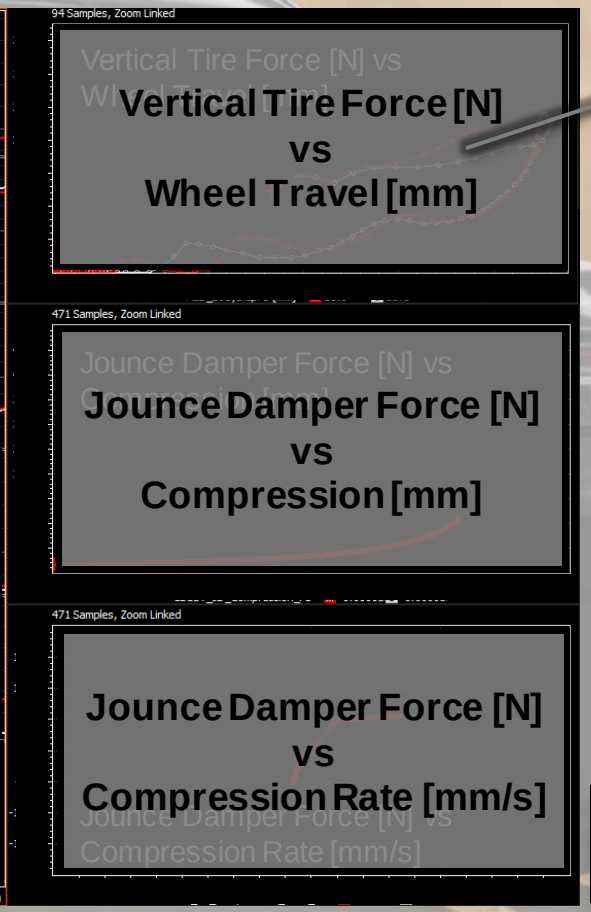
The following slide outlines the benefits in performance that can be achieved using a hydraulic jounce damper instead of an elastomeric bump stop

Reduced peak body motions
- Vertical Acceleration
- Pitch Velocity
- Pitch Angle

Reduced peak wheel travel and wheel force







More wheel energy is dissipated when jounce damper is engaged

Hydraulic Jounce Damper

Elastomeric Bump Stop

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Summary

Multimatic used the Integrated Systems Analysis **(MISA)** approach to develop a jounce damper for a high-performance off-road vehicle. A correlated vehicle model was coupled with a detailed component model of the jounce damper to cascade vehicle level performance objectives to component specifications.

The use of VI-Grade simulation tools has allowed Multimatic designers to quickly explore vastly different design concepts and understand the effects of component design parameters on vehicle performance.

Jounce dampers and tuning parts have been designed and manufactured, and are now being used on test vehicles for subjective evaluation