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Multi-stage Analysis Approach to Low-Speed Vehicle Impacts using the *SENSOR Keywords

14th European LS-DYNA Conference

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18th October 2023

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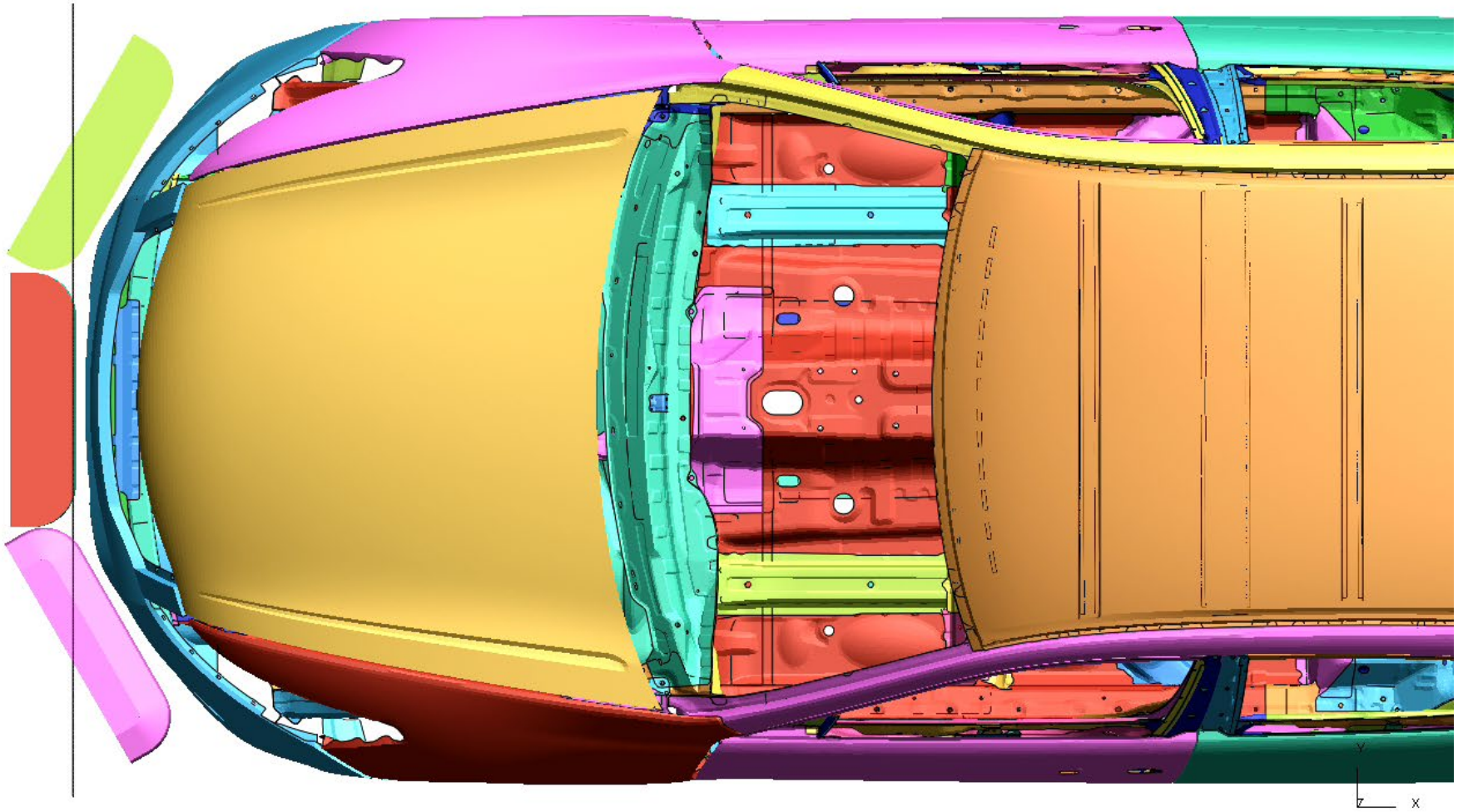
Low-Speed Vehicle Impacts Analysis



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Bumper Regulations

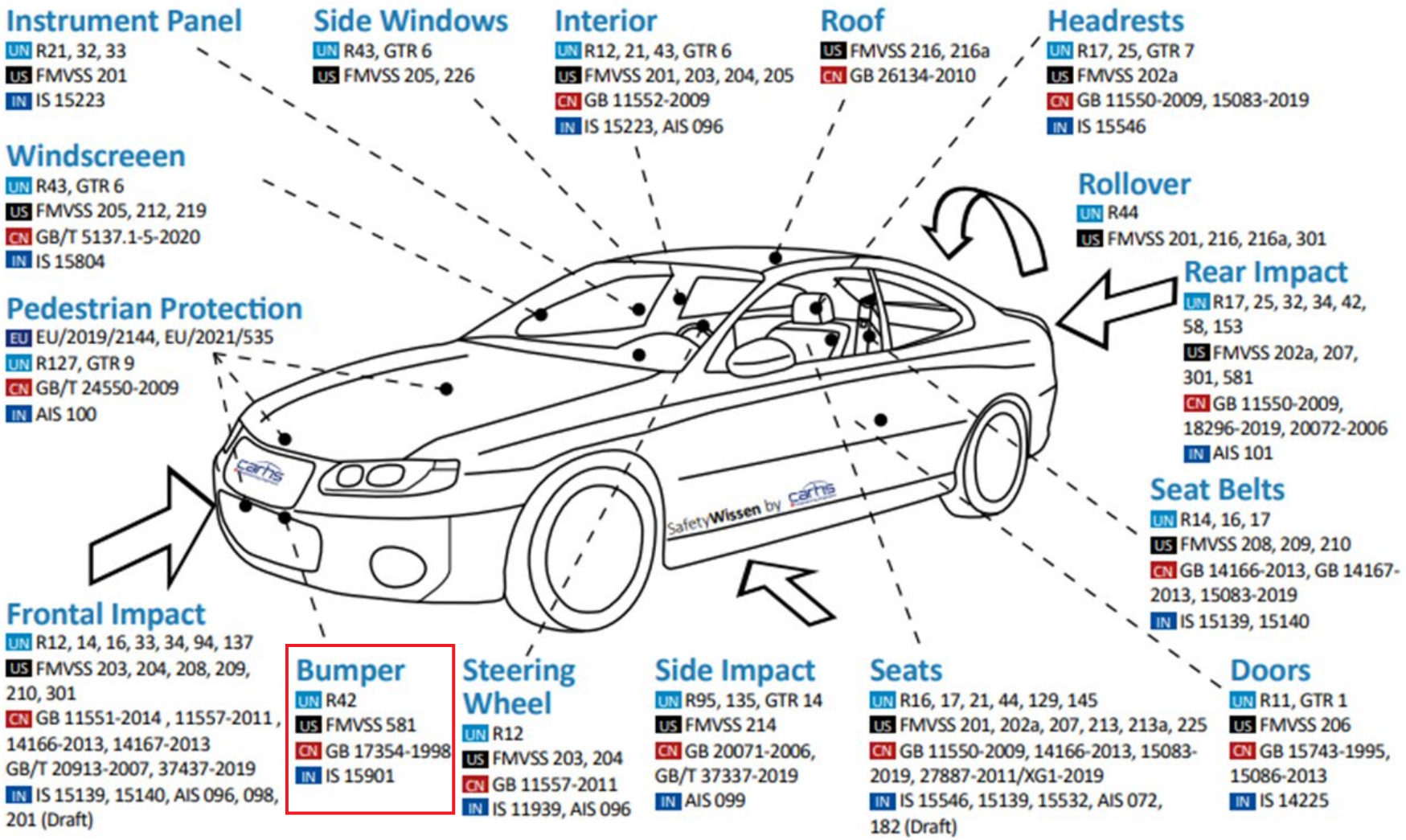

Image taken from Carhs Safety Companion 2023 (page 21)

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Bumper Regulations

Purpose

Minimise vulnerability to damage and reduce repair costs resulting from low-speed front and rear collisions.

Image taken from https://www.autodeal.com.ph/articles/car-features/how-repair-bumper-dent

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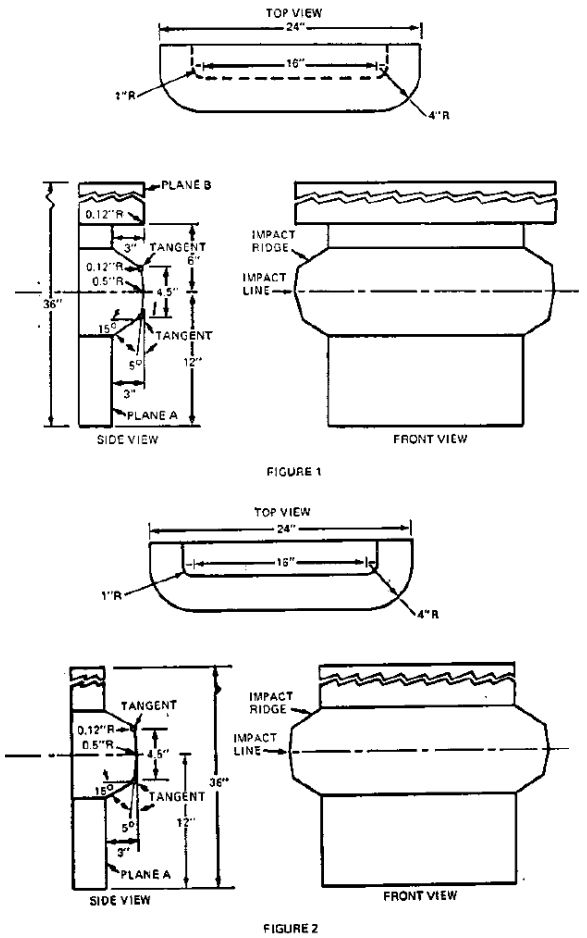
Bumper Regulations

FMVSS CFR 581

Successive impacts are performed on the same vehicle. The bumper and supporting structure cannot be replaced or repaired between impacts.

1. Right-hand corner impact – 1.5 mph
2. Left-hand corner impact – 1.5 mph
3. Longitudinal impact – 2.5 mph
4. Longitudinal impact – 2.5 mph
5. Flat wall impact – 2.5 mph

Test Rig



Pendulum Drawings
a.) double ridge b.) single ridge

Images taken from:
http://www.concept-tech.com/files/291_2082_/PDS_A4_Bumper+Pendulum_200416.pdf
U.S. DEPARTMENT OF TRANSPORTATION, Laboratory Test Procedure for Regulation Part 581, Bumper Standard I, 1990

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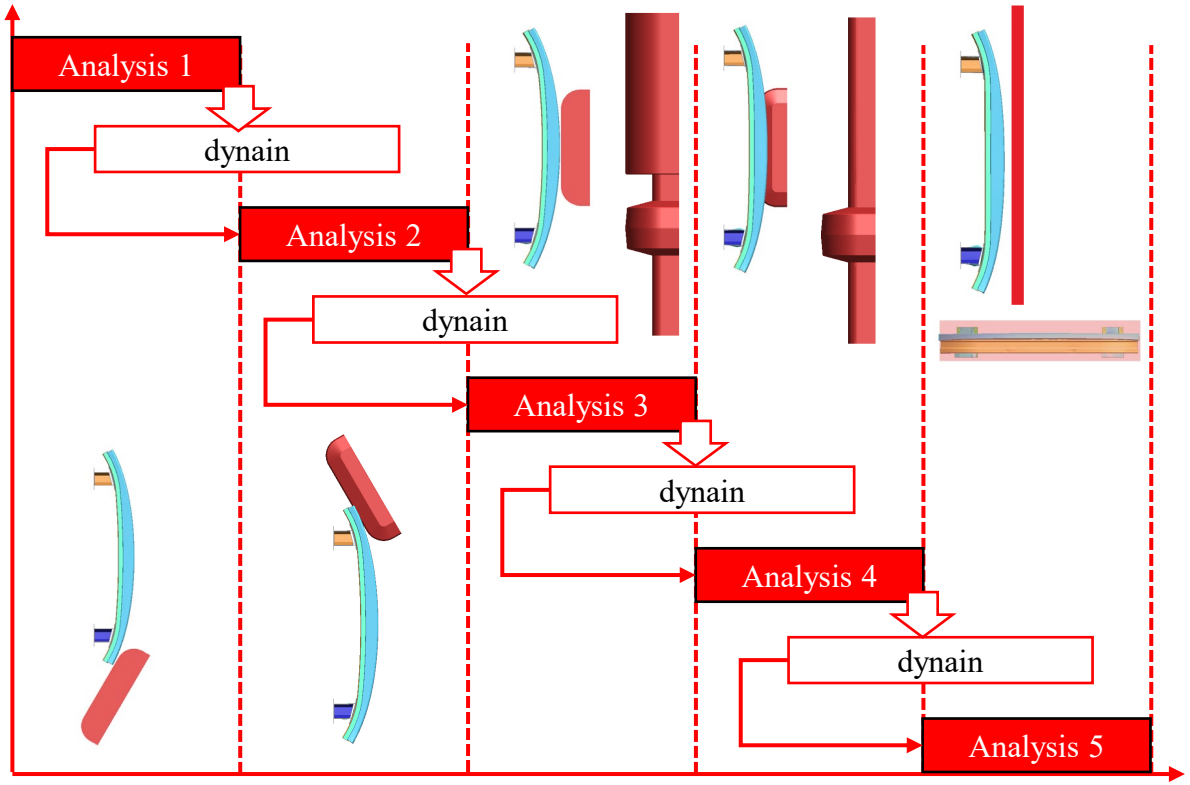
CAE Analysis Approach

Legacy Methodology

Run each analysis individually with necessary information transferred to the next impact.



Limitations

- Transfer (‘dynain’) files can be large
- Requires modification of master model to remove data included within transfer file
- Intermediate model modification steps

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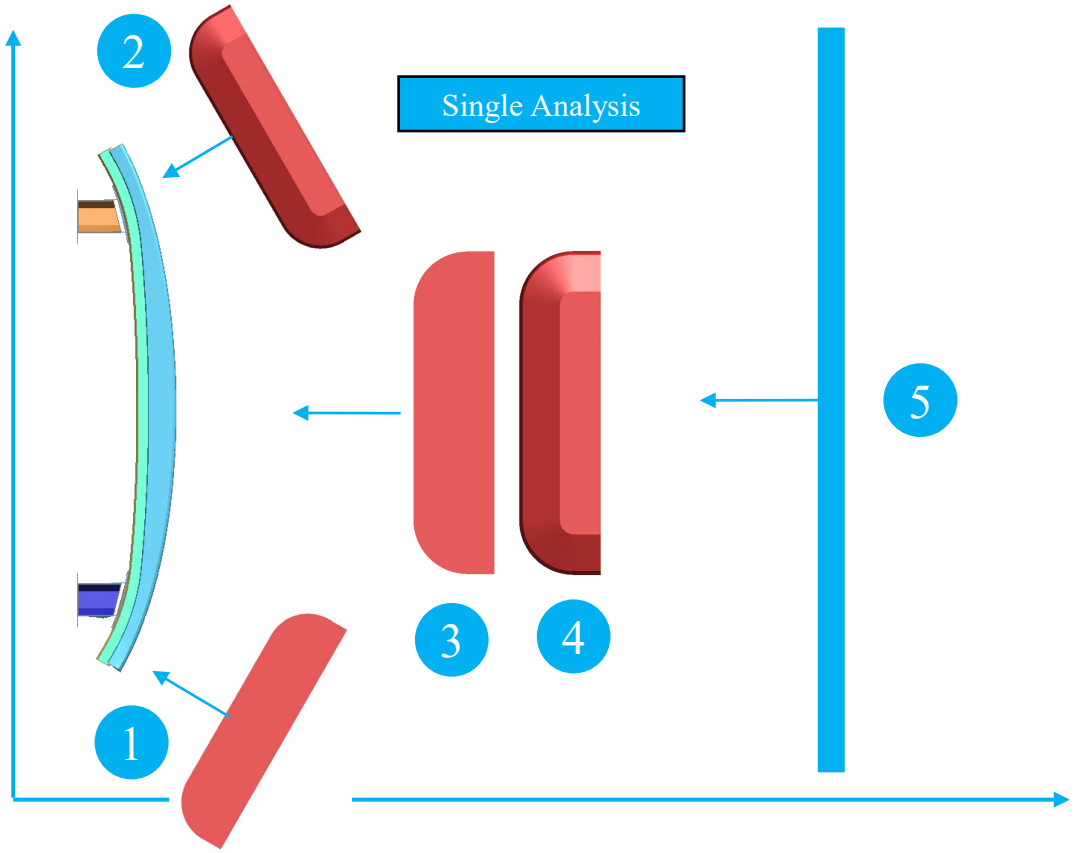
CAE Analysis Approach

Improved Methodology

Combine the sequential analysis into a single analysis with the following functionality:

1. Detect when one impact is over
2. Slow the vehicle down and bring it to a full stop
3. Initiating the next impact in the sequence
4. Terminate analysis once all impacts have taken place



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Sensors

What is a sensor?

Devices that respond to a physical input and transmit a resulting output

Image taken from https://www.techadvisor.com/article/723047/hive-thermostat-mini-review.html

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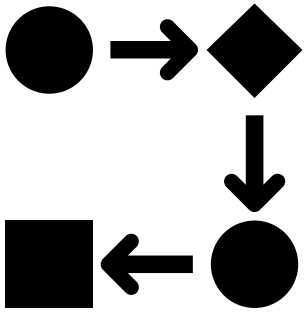
Sensors

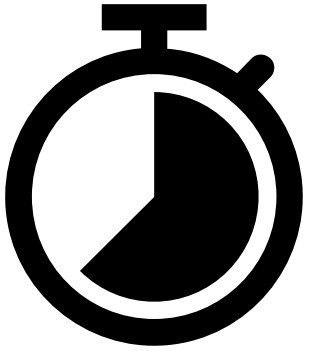
Sensors in LS-DYNA

In LS-DYNA, the **`*SENSOR`** keywords provides a convenient way of activating and deactivating other keywords based on model responses.

Possible applications:



Multi-staged analyses



Termination control

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Sensors

*SENSOR Keywords

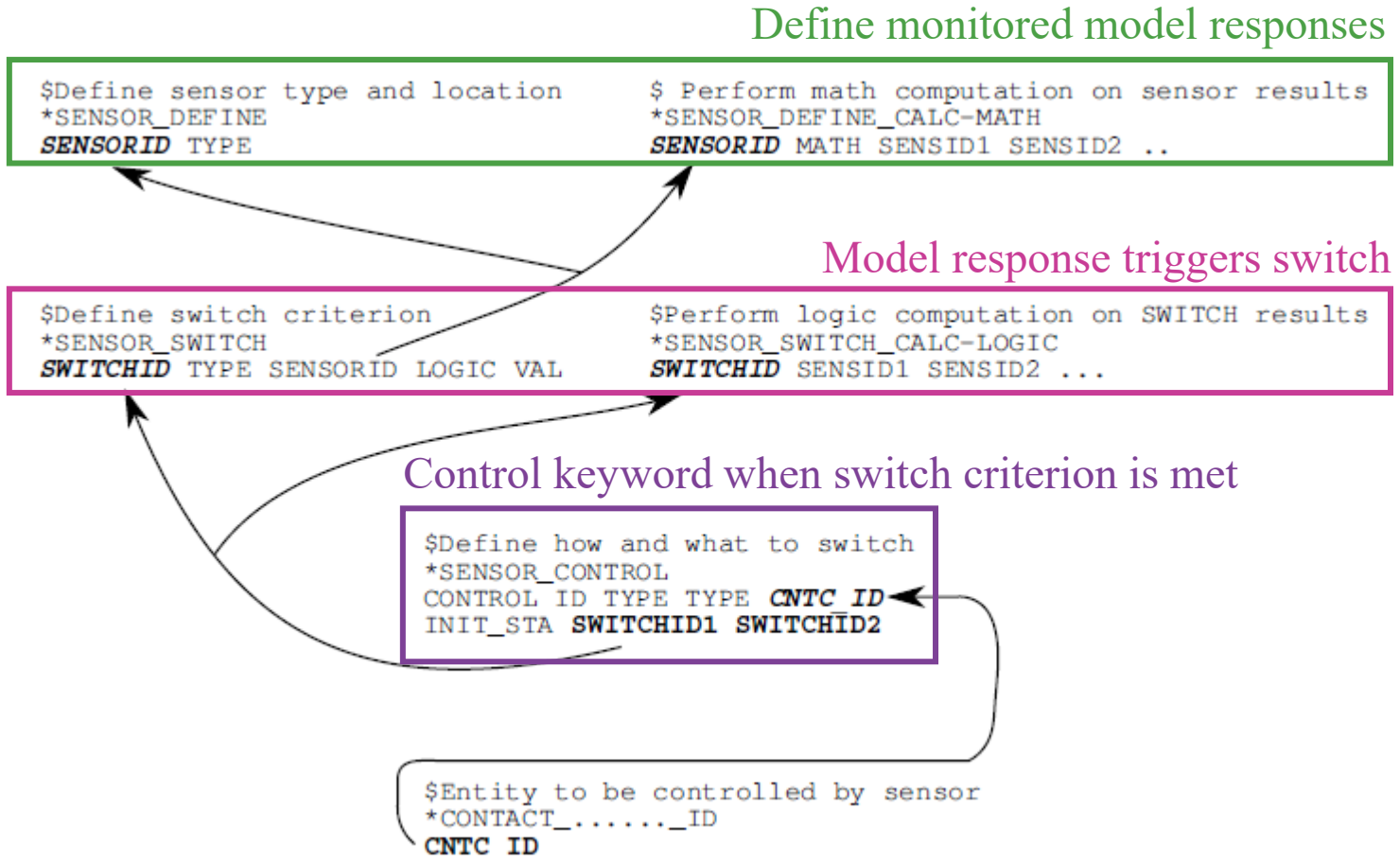
3 definitions are required to define and utilise a sensor:

*SENSOR_DEFINE

*SENSOR_SWITCH

*SENSOR_CONTROL

*TERMINATION_SENSOR



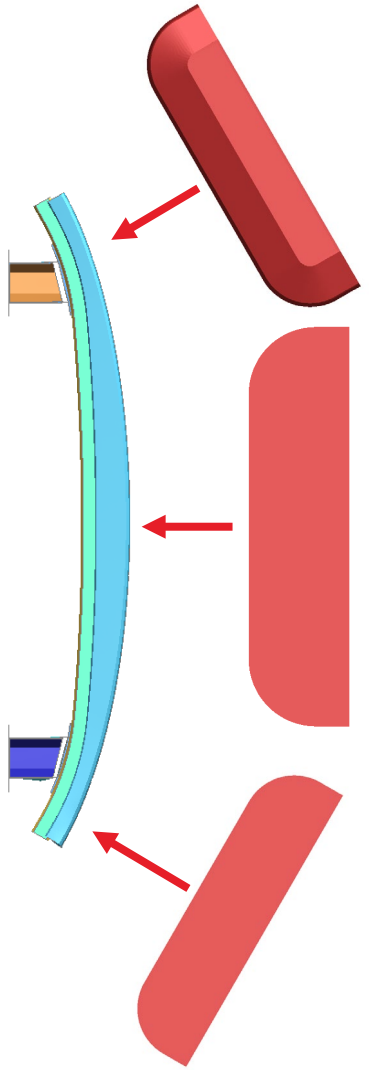
Sensors

Triggering Switches

Often the most difficult aspect of using sensors is ensuring switches trigger at the right time.

Three key methods are utilised to manage this issue, which can be used individually or in combination:

- Delays
- Combining switches with AND/OR gates
- Ordering switches



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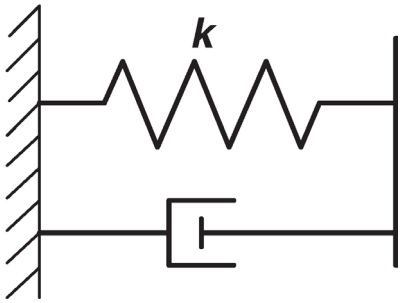
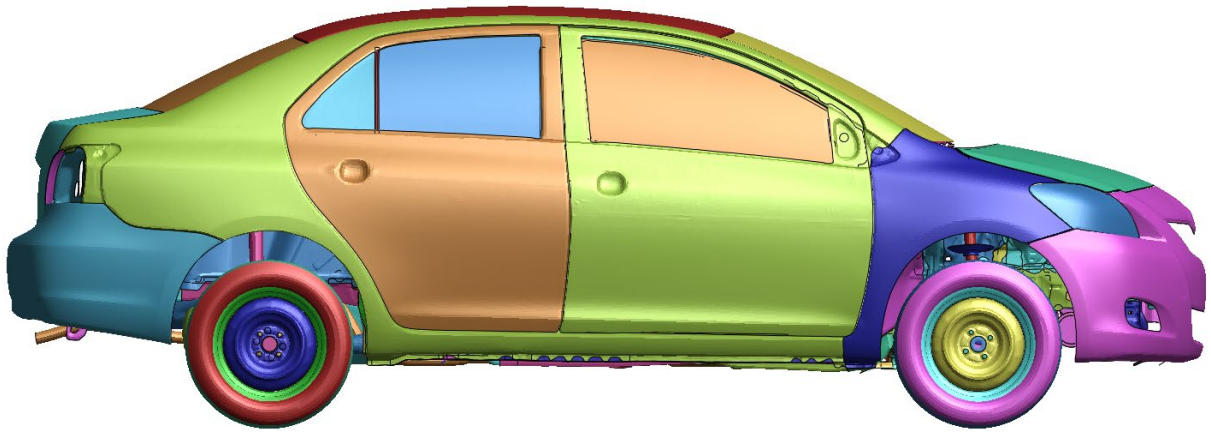
Analysis Steps

Spring Damper System

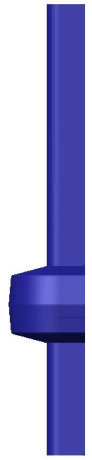


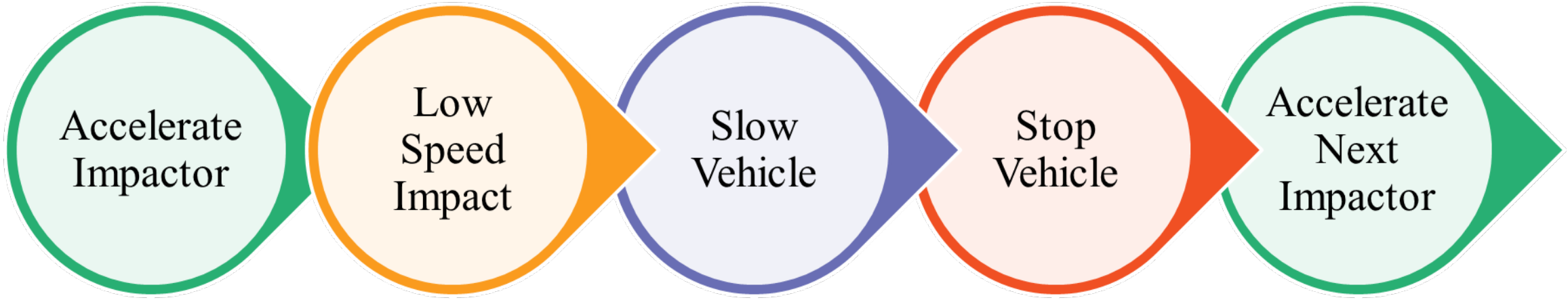
Vehicle



Impactor 1

Impactor 2





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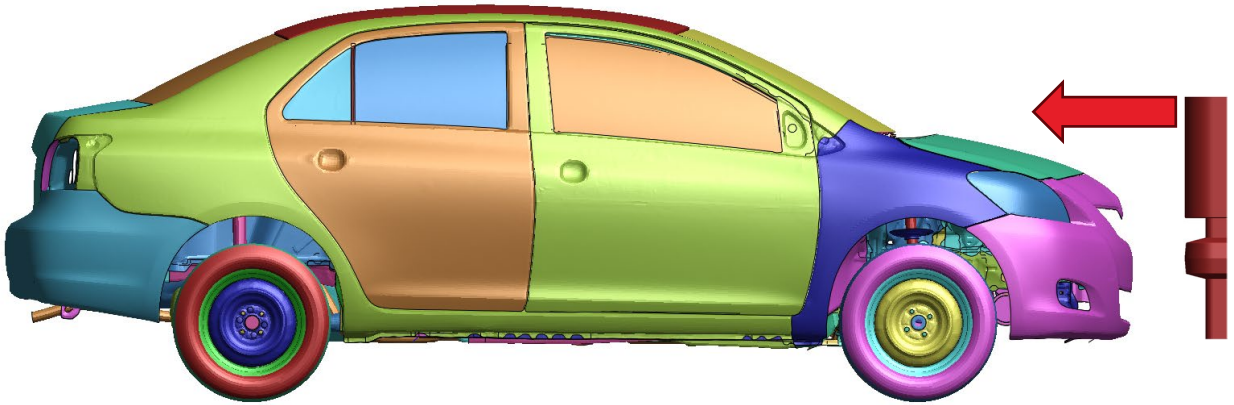
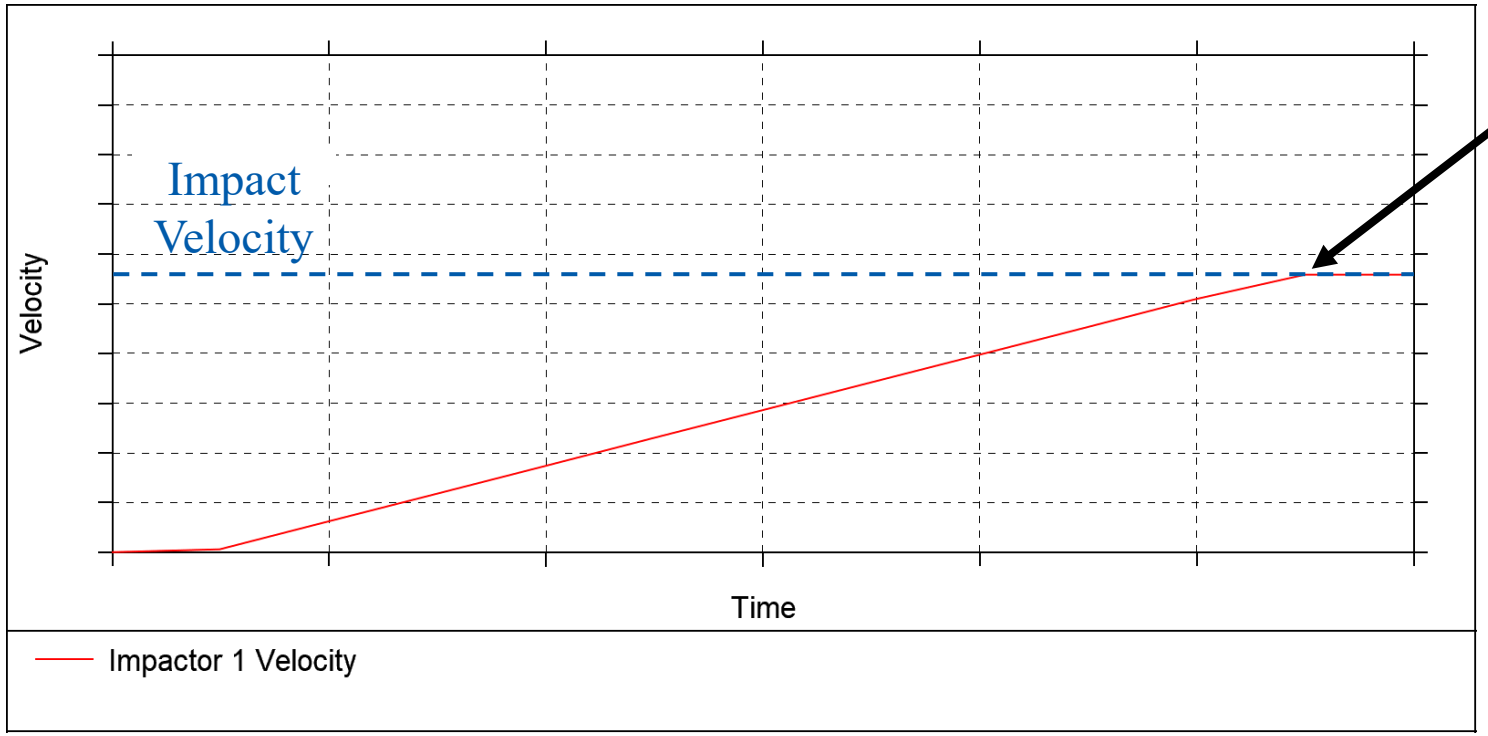
Analysis Steps

Accelerate Impactor



Accelerate Impactor



Turn off impactor acceleration

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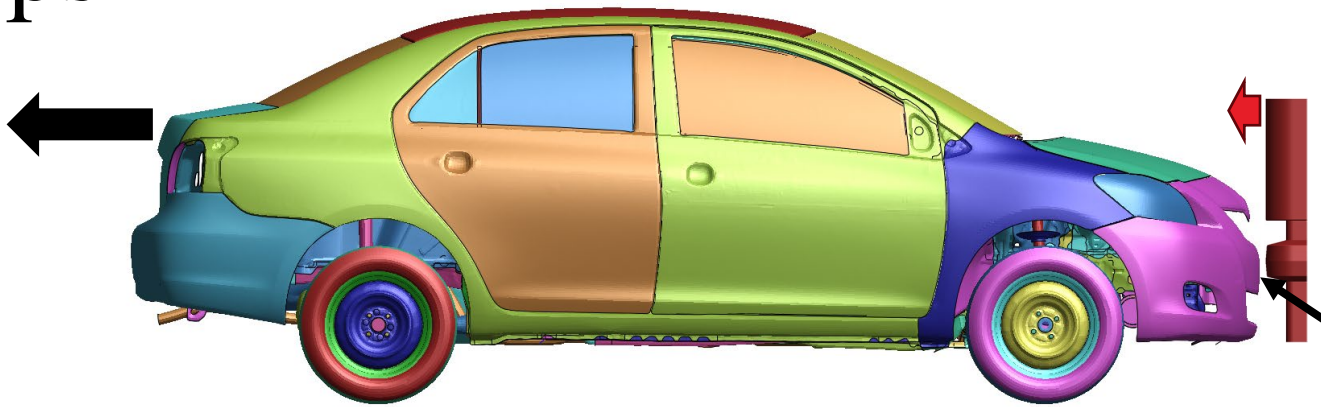
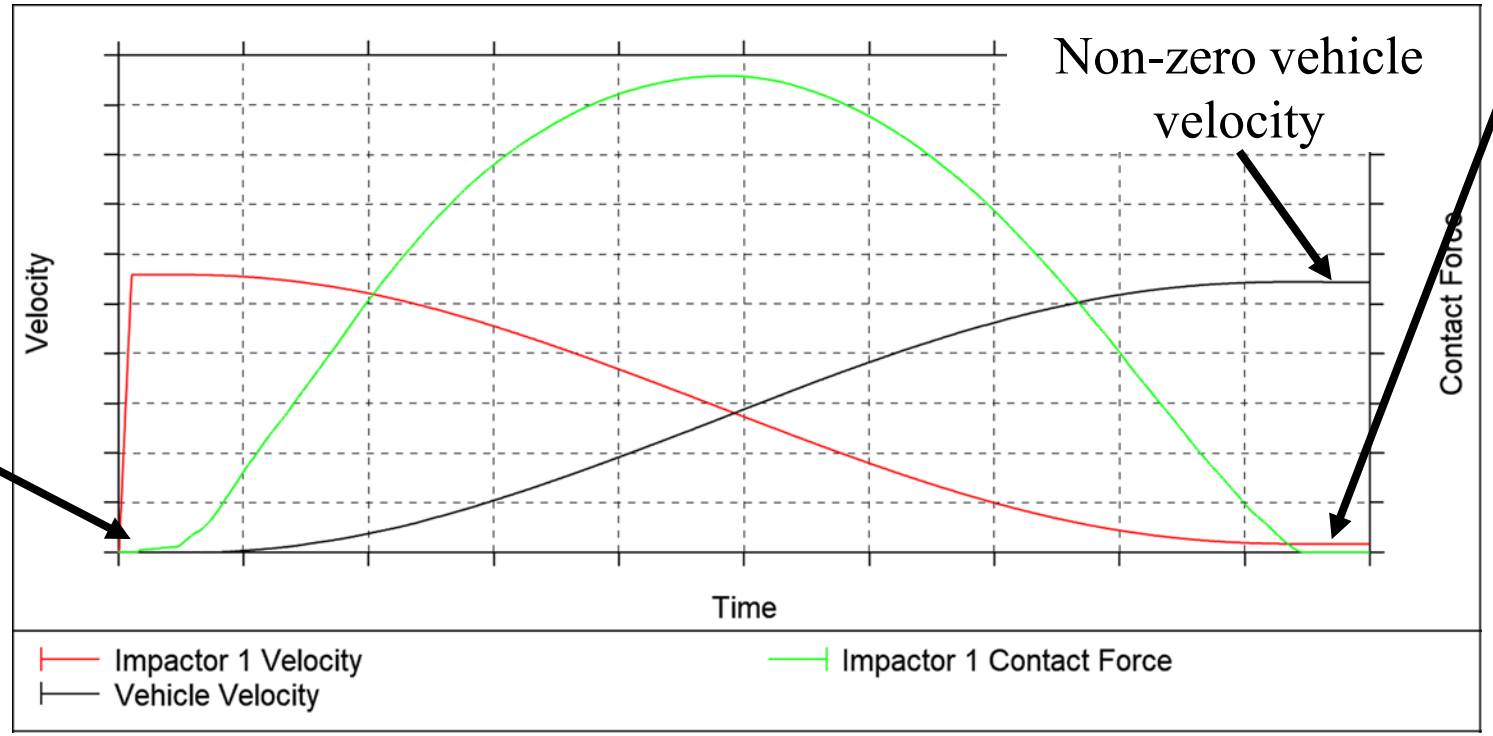
Analysis Steps

Low Speed Impact



Low Speed Impact



Zero contact force before impact

Impactor loses contact signalling the end of the impact

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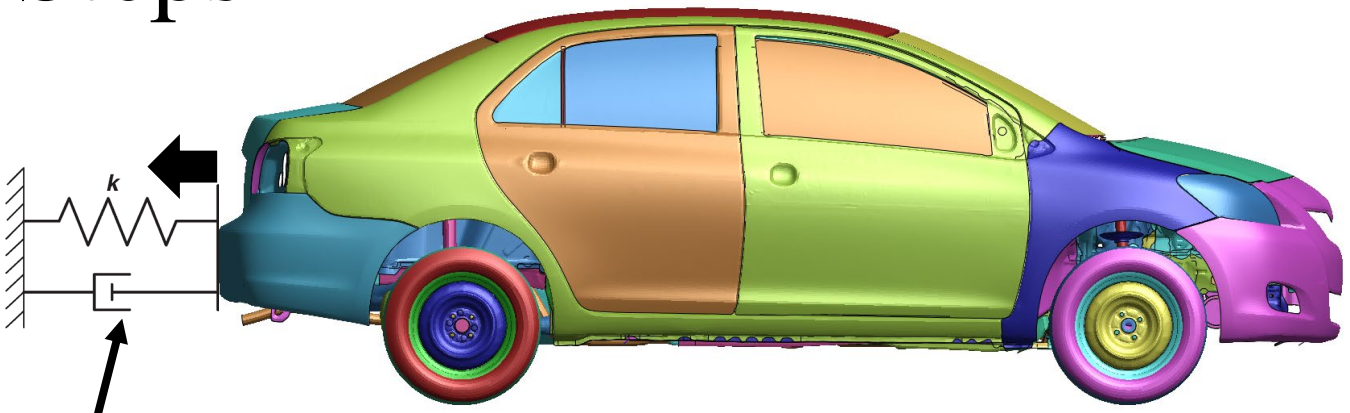
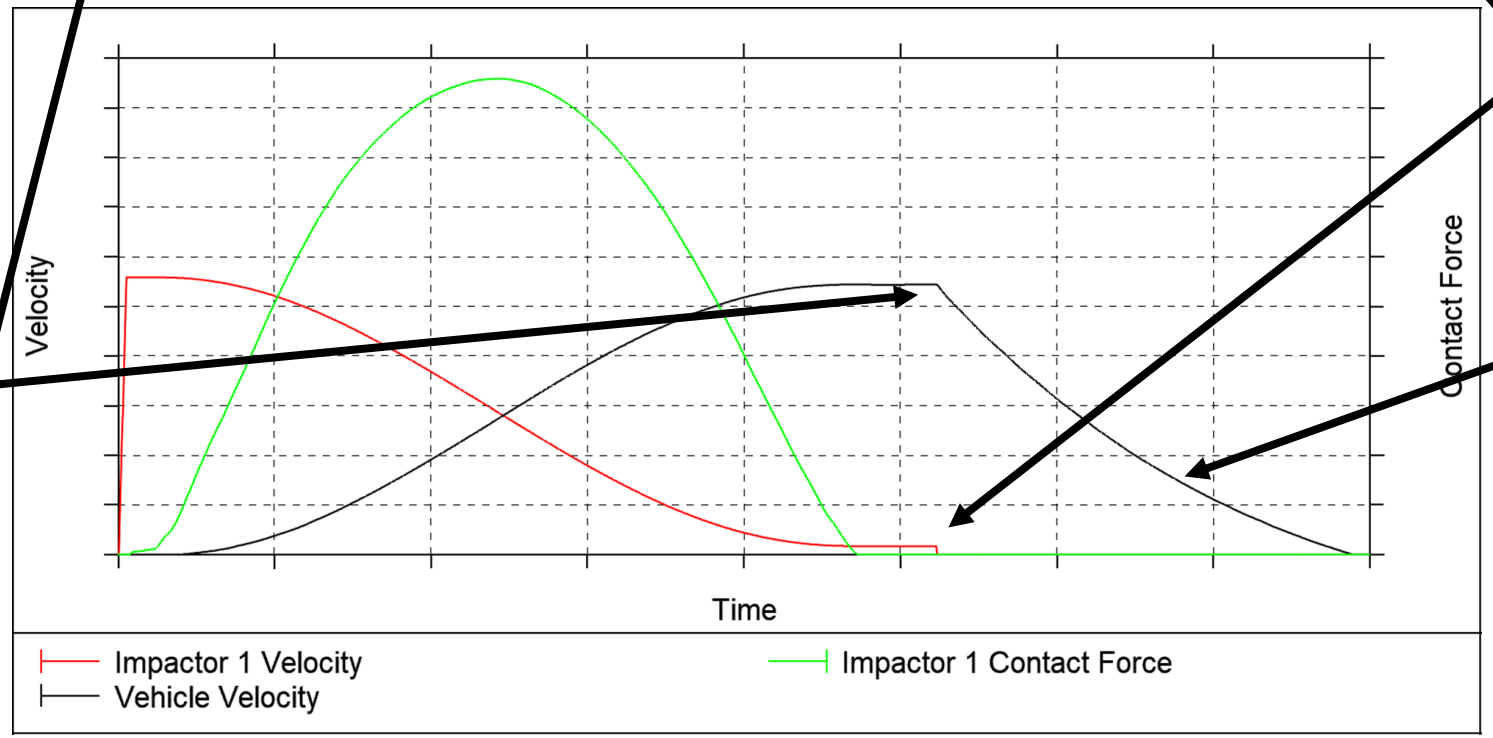
Analysis Steps

Slow Vehicle



Slow Vehicle

Engage spring damper system



Impactor brought to stop to avoid second impact with vehicle

Critically damped slowing of vehicle

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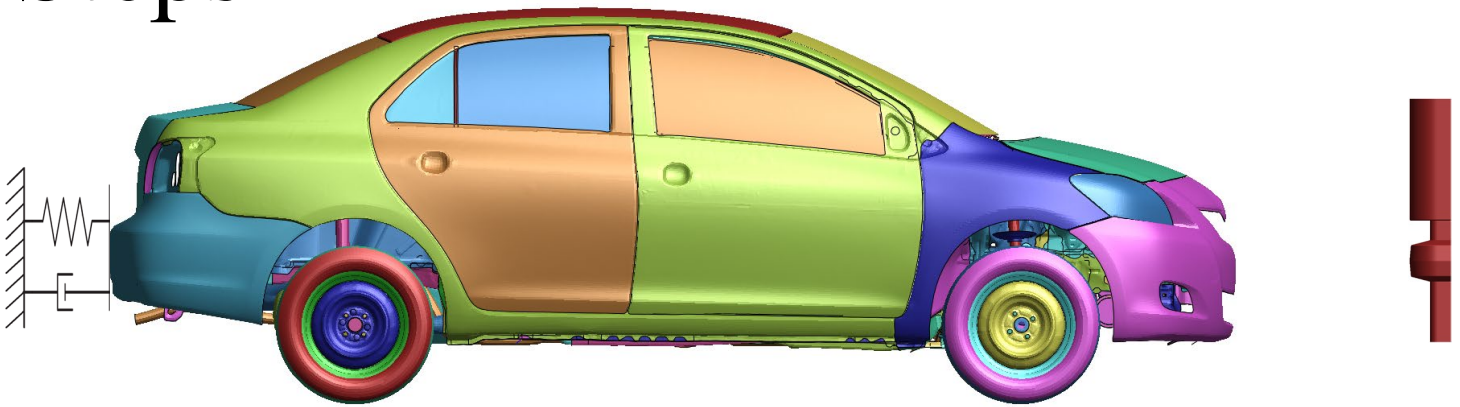
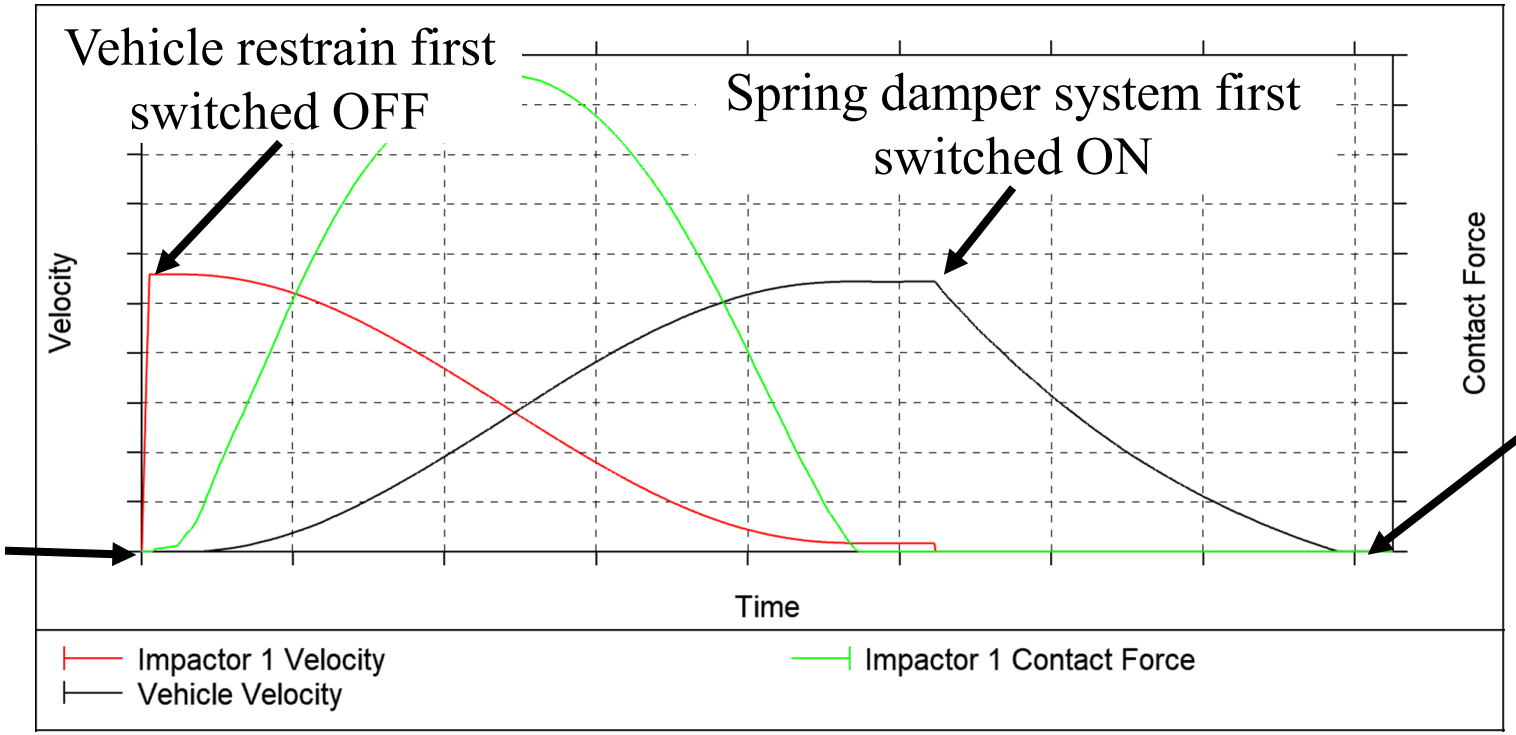
Analysis Steps

Stop Vehicle



Stop Vehicle



Vehicle and impactor at a complete stop for an instant

Vehicle and impactor at a complete stop for prolonged period

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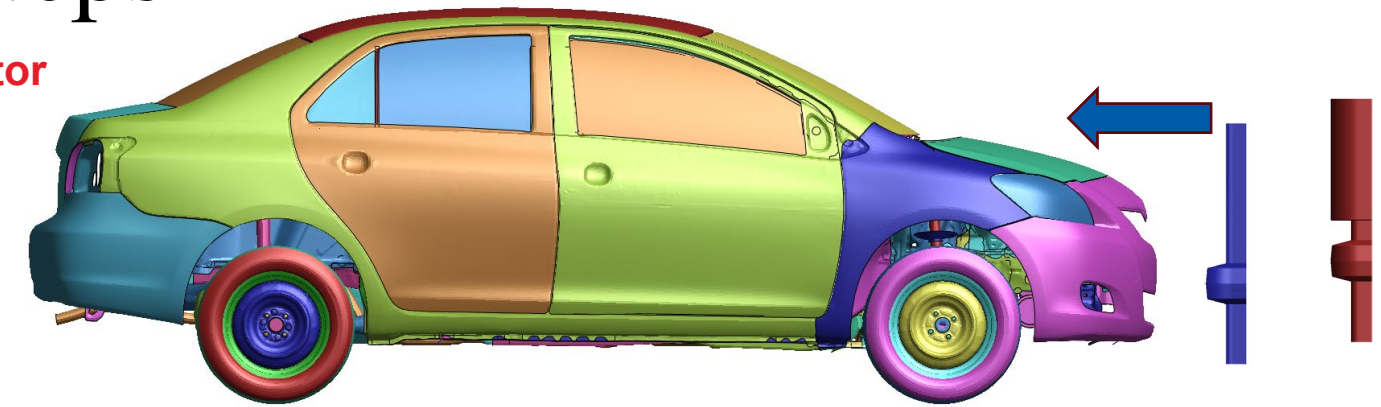
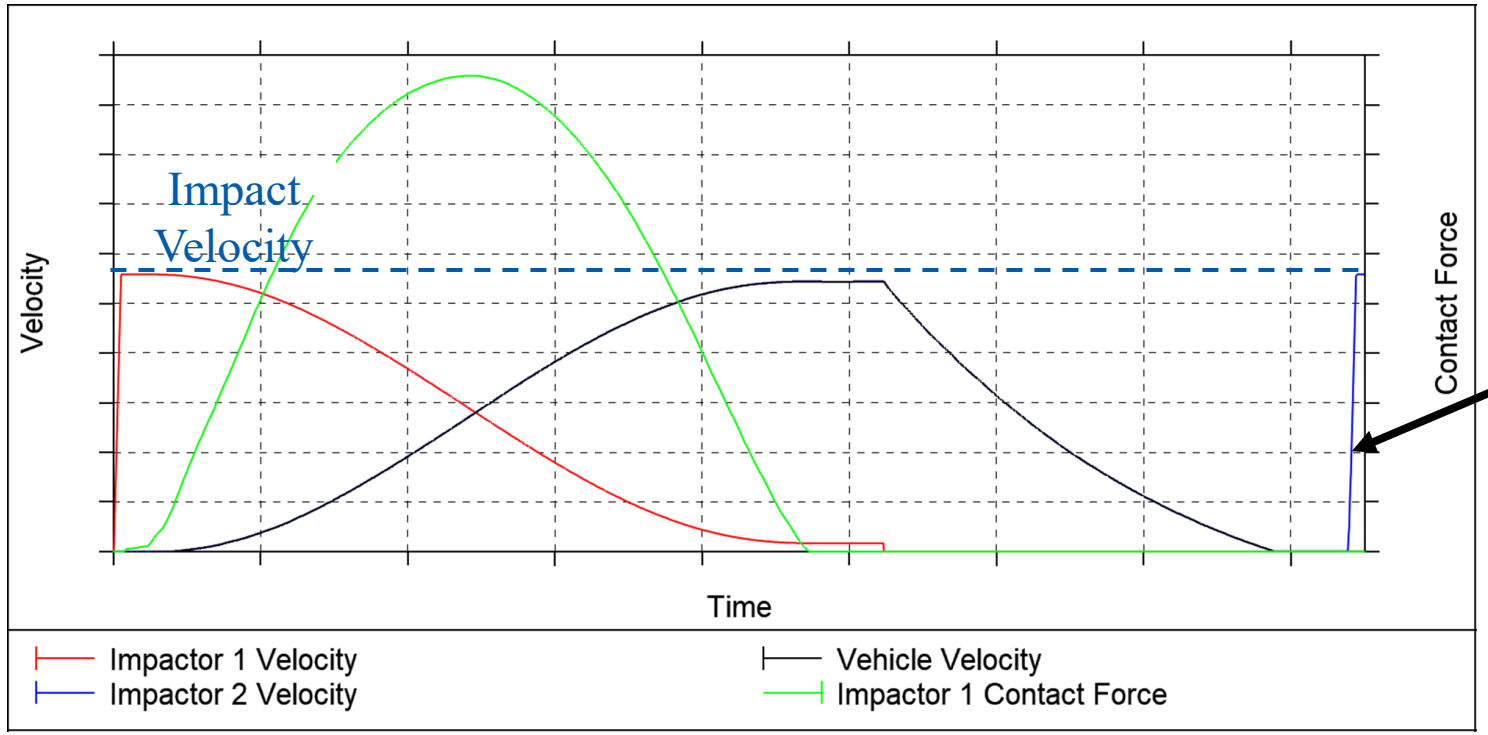
Analysis Steps

Accelerate Next Impactor



Accelerate Next Impactor



Second impactor accelerated to impact velocity

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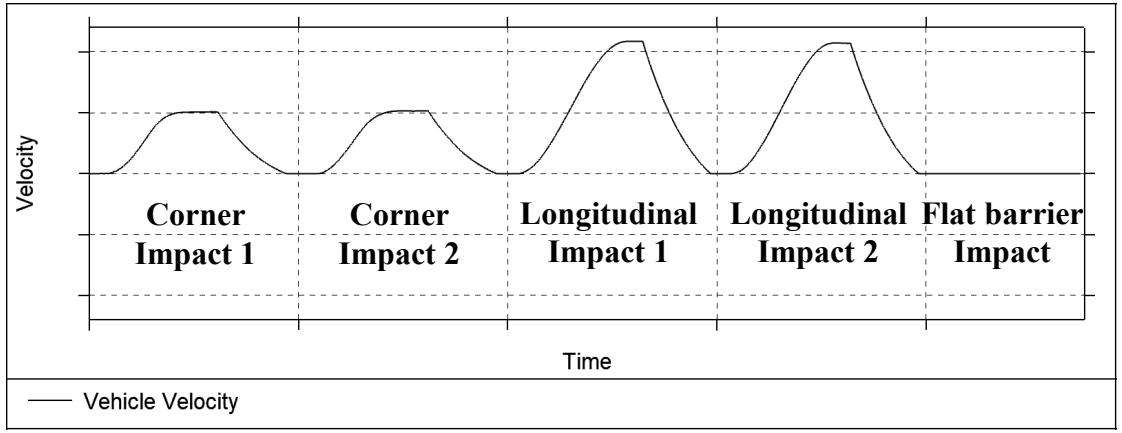
Impactor Positioning

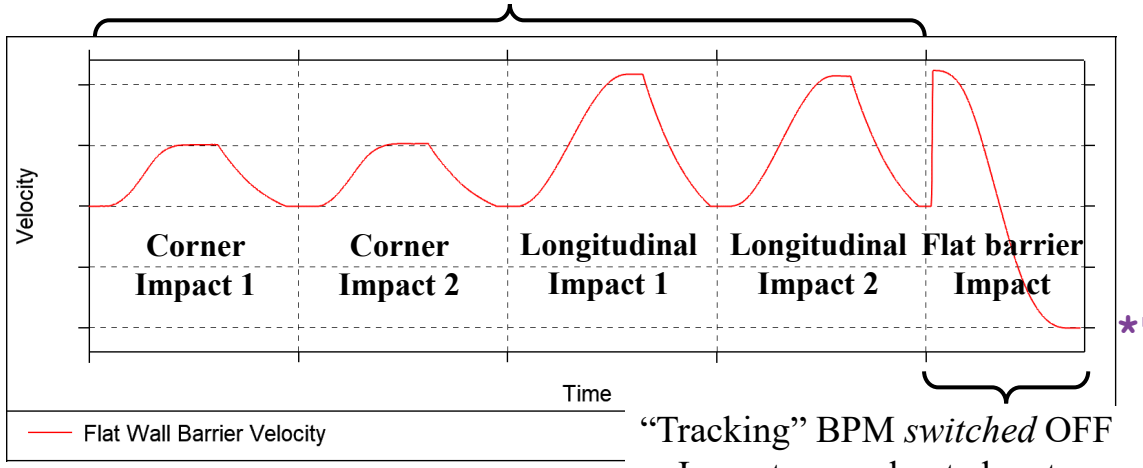
***SENSOR_DEFINE**
Monitors vehicle X velocity

***DEFINE_CURVE_FUNCTION**
Plots monitored response

***BOUNDARY_PRESCRIBED_MOTION**
controls flat barrier velocity prior to impact



"Tracking" BPM ON
Impactor velocity = Vehicle velocity



***TERMINATION_SENSOR**

"Tracking" BPM *switched* OFF
Impactor accelerated up to impact velocity

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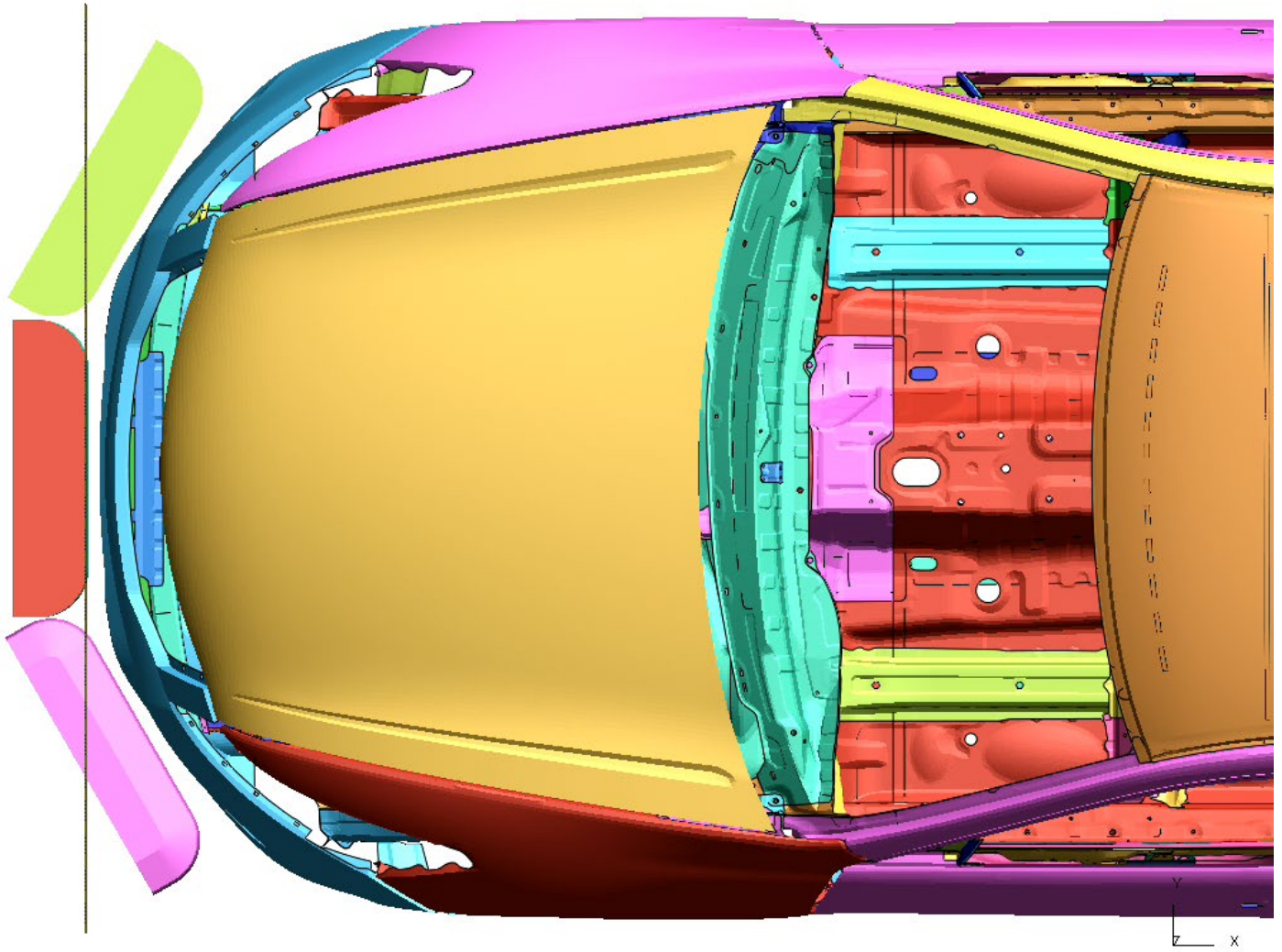
Final Result

- Single integrated analysis
- Eliminated large transfer files
- Easier file management and set-up
- Removed intermediate post-processing and model modification stages
- Analyses can be run overnight or over a weekend



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Contact

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Thank You

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