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Frontal Compatibility Analysis With Option 2 LTV's and Over Ride Barrier Design For SEAS Evaluation: Preliminary Analysis

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16. Abstract

This report summarizes the work activity related to compatibility analysis in frontal collisions between passenger car and option 2 LTVs. This work involved both an overview analysis of structural interaction in frontal collisions between passenger cars and option 2 LTVs and the design of an over ride barrier for evaluating the secondary energy absorbing structure (SEAS) of the option 2 LTVs.

Vehicle-to-vehicle frontal finite element simulations were conducted between compact passenger car (Neon) and option 2 LTV's (Ford F250 and Chevy Silverado). The Ford F250 has a cross-member type SEAS and the Chevy Silverado has a non cross-member type SEAS. The simulations were conducted with and without the SEAS. The effect of the SEAS on structural interaction between the two vehicles is evaluated based on the energy absorption and intrusions in the vulnerable vehicle.

A parametric study was conducted with the option 2 LTV FE models to identify impact velocity, width and height of the ORB and the relevant assessment metrics to evaluate the strength of SEAS. Based on this study, an impact velocity of 25 mph was identified as an appropriate speed for the ORB test. A 1250 mm wide barrier with a top height aligned with the top of the Part 581 zone (508 mm) was identified as an appropriate barrier. Potentially, Kw400 could be used as an assessment metric for determining the strength of the SEAS structure.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2002)

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1 Introduction

As part of the planned research activities under the FHWA/NHTSA/NCAC co-operative agreement DTFH61-02-X-00076 and in consultation with NHTSA research staff, NCAC has conducted initial frontal compatibility studies between passenger car and LTVs. In addition, an over ride barrier design was evaluated based on the current Secondary Energy Absorbing Structure (SEAS) designs to evaluate the strength of the SEAS to promote improved structural interaction in frontal collisions. This report provides a summary and documentation for these two activities and identifies opportunities for further research.

Crash compatibility has attracted a lot of attention in recent years due to the proliferation of bigger, taller, and heavier SUV's. The inherent issue is the safety of the occupants in a smaller vehicle when involved in a collision with a larger vehicle. The three factors that contribute to crash incompatibilities are the differences in **mass, stiffness** and **geometry** between the colliding vehicles. Mass is difficult to control due to customer need for different class of vehicles ranging from small sub-compact cars to large pick-up trucks. Any proposal to control front-end stiffness should ensure that today's self-protection levels are not sacrificed to improve partner-protection. Though these three factors are increasingly difficult to define objectively, controlling front-end geometry presents a possible first step to improve the crash compatibility between passenger vehicles.

A first step toward improving geometrical compatibility was taken by the Alliance of Automobile Manufacturers (AAM) in the USA. The purpose of the voluntary agreement is to "align" the primary structural components for improved engagement in front-to-front crashes and to reduce the occurrence of underride and over-ride. The voluntary commitment was signed by all member manufacturers to begin designing light trucks in accordance with one of the following two geometric alignment alternatives (Figure 1-1), with the light truck at unloaded vehicle weight [1], no later than September 2009:

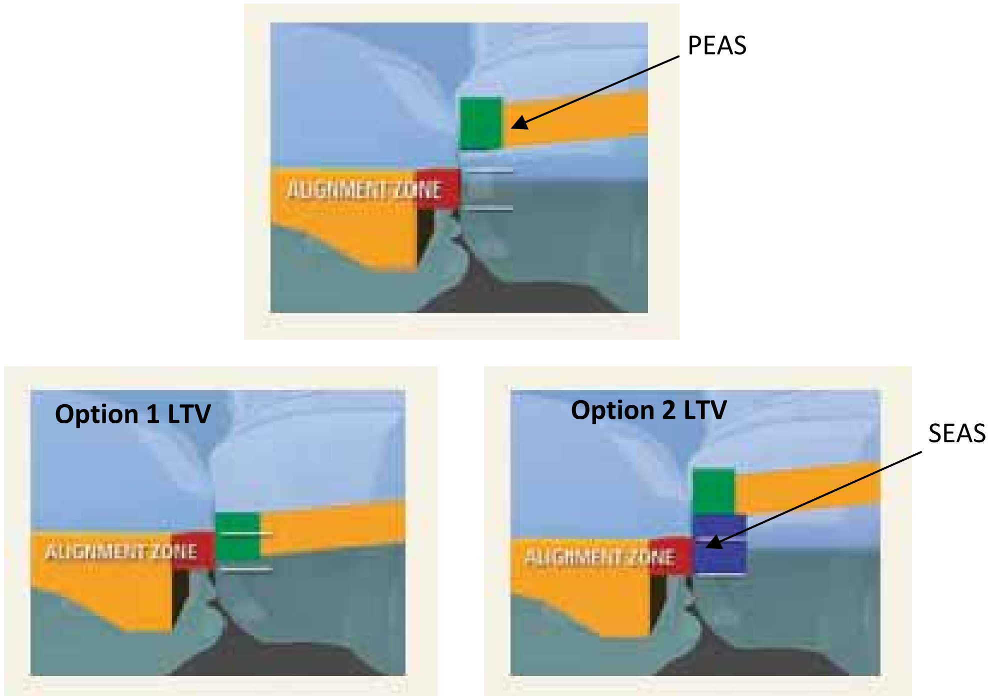

Figure 1-1: Structural Alignment, AAM Voluntary Commitment [1]

Option 1: The light truck's primary frontal energy absorbing structure (PEAS) shall overlap at least 50% of the Part 581 zone (as defined in 49 CFR 571.3 [2]) AND at least 50% of the light truck's PEAS shall overlap the Part 581 zone (if the primary frontal energy-absorbing structure of the light truck is greater than 8 inches tall, engagement with the entire Part 581 zone is required) [1].

Option 2: If a light truck does not meet the criteria of Option 1, there must be a SEAS, connected to the primary structure whose lower edge shall be no higher than the bottom of the Part 581 zone. This secondary structure shall withstand a load of at least 100 KN exerted by a loading device, before this loading device travels 400 mm as measured from a vertical plane at the forward-most point of the significant structure of the vehicle [1].

The objective of this study was to characterize the structural interaction between passenger cars and option 2 LTV's in frontal crashes[1]. NCAC/GWU has developed a fleet of virtual vehicles which are used to evaluate the effectiveness of static geometric alignment on structural interaction. The following vehicle pairs are used in this study:

- 1996 Neon – 2006 Ford F250 (Option 2 LTV, cross-member type SEAS)
- 1996 Neon – 2007 Chevy Silverado (Option 2 LTV, SEAS without a cross-member)

[1] Under this contract, the Structural Interaction between passenger cars and option 1 LTV's was also investigated. The results from this study have been documented in a Doctoral Dissertation titled "Development of Objective Metrics to Improve Compatibility in Frontal Crashes" by Pradeep Mohan at the NCAC/GWU [3].

In addition, a laboratory test method was developed to evaluate the strength of the SEAS. An over ride barrier (ORB) was developed based on a test conducted at VRTC and optimized for the SEAS designs of the 2006 Ford F250 and 2007 Chevy Silverado LTV models.

2 Vehicle Models

NCAC/GWU has been developing a fleet of virtual vehicles which could be used in studies of this nature to gain further insight into structural interaction in many impact scenarios. The vehicle FE models range from a small sub-compact car (1997 Geo Metro) to a full size pick-up truck (2006 Ford F250). The vehicle models chosen for this study are based on the 1996 Dodge Neon, 2006 Ford F250 and the 2007 Chevy Silverado (Figure 2-1). These models have been validated to a full frontal NCAP test [Appendix A].

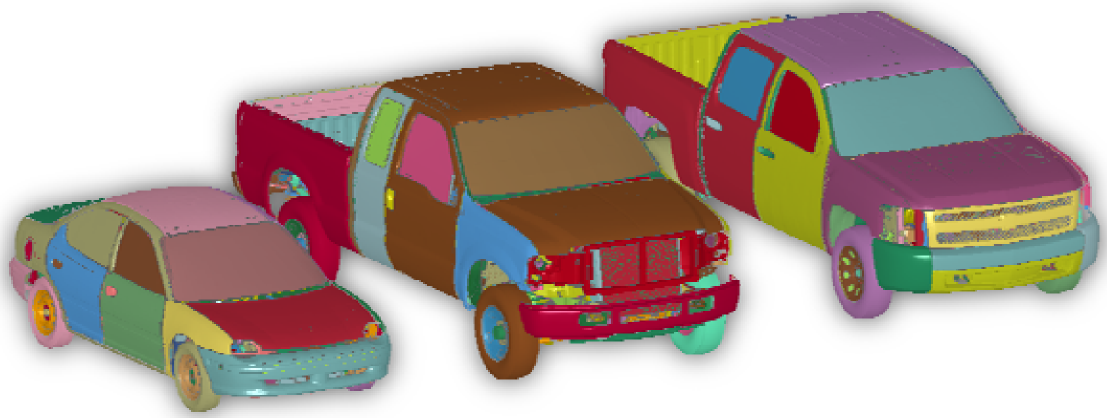

Figure 2-1: Vehicle FE Models Used in this Study (Neon, F250 and Silverado)

The frontal Force-Deformation (F-D) characteristics for the Neon, F250 and Silverado in a full frontal rigid barrier impact are shown in Figure 2-2. True AHOF400[2] and Kw400[3] were calculated for each of the vehicles. Table 2-1 summarizes the difference in mass, geometry and stiffness between the target vehicle (Neon) and the two bullet vehicles (F250 and Silverado). From the F-D curves, it is evident that the frontal structure of the F250 and the Silverado are much stronger than that of the Neon. Consequently, the energy required to crush 400 mm of the front end of the F250 and the Silverado is much higher than the Neon as reflected by their respective Kw400 measures. Vehicle-to-vehicle full frontal simulations were conducted between Neon-F250 and Neon-Silverado. The closing speed was chosen such that the Neon experiences a Delta-V similar to that in a Frontal NCAP simulation.

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[2] AHOF400 is defined as a metric to quantify vertical geometric alignment of a vehicle. The True AHOF400 is calculated from a full frontal impact into a rigid wall instrumented with load cells that can measure both Forces and Moments [3].

[3] Kw400 (Crush-work stiffness) is defined as a metric to quantify front-end stiffness of the vehicles. The area under the F-D curve between 25 and 400 mm of front-end crush is equated to ideal spring energy. The resulting "K" value is termed Kw400 [3].

Table 2-1: Mass, AHOF400 and Kw400 for Neon, F250 and Silverado

		Target Veh.	Bullet 1	Bullet 2
		Neon	F250	Silverado
Mass	kg	1335	2998	2622
Mass Ratio			2.25	1.96
True AHOF400	mm	448	704	584
AHOF Ratio			1.57	1.30
Kw400	N/mm	1251	2940	2550
Kw400 Ratio			2.35	2.04
Approach Velocity	mph	35	15.59	17.8
Closing Speed	mph		50.59	52.80

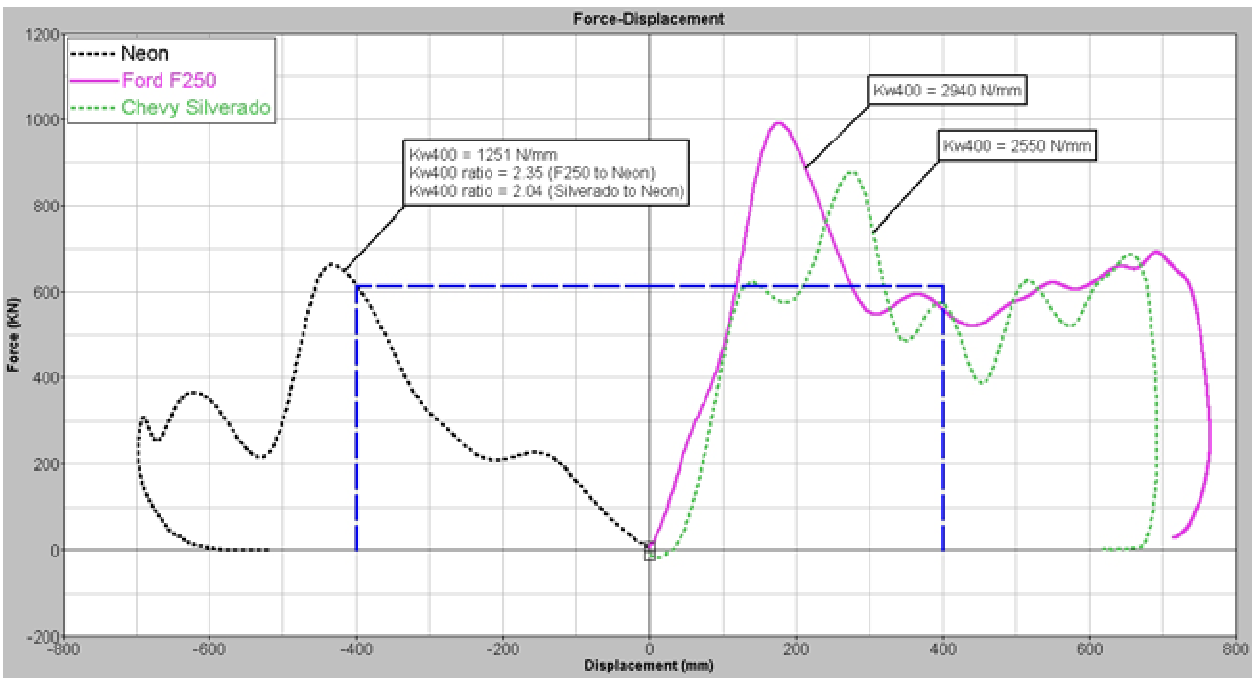


Figure 2-2: Force Deformation Comparison of Neon, F250 and Silverado

The structural alignment between Neon-F250 and Neon-Silverado is shown in Figure 2-3 and Figure 2-4, respectively. There is a significant vertical geometric mismatch between the PEAS of the Neon and F250. The SEAS positioned below the PEAS of the F250 overlaps 50% of the Neon PEAS as required by the AAM voluntary commitment to improve compatibility in frontal impacts for Option 2 LTV's. Based on the location and dimensions of the Silverado PEAS, it comes very close to being classified as an Option 1 LTV. Geometrically, the vertical mismatch of the PEAS is much lower between Neon-Silverado when compared to Neon-F250.

The lateral overlap of the PEAS in full frontal impact between Neon-F250 and Neon-Silverado is shown in Figure 2-5 and Figure 2-6. The results from these simulations are presented in the next chapter.

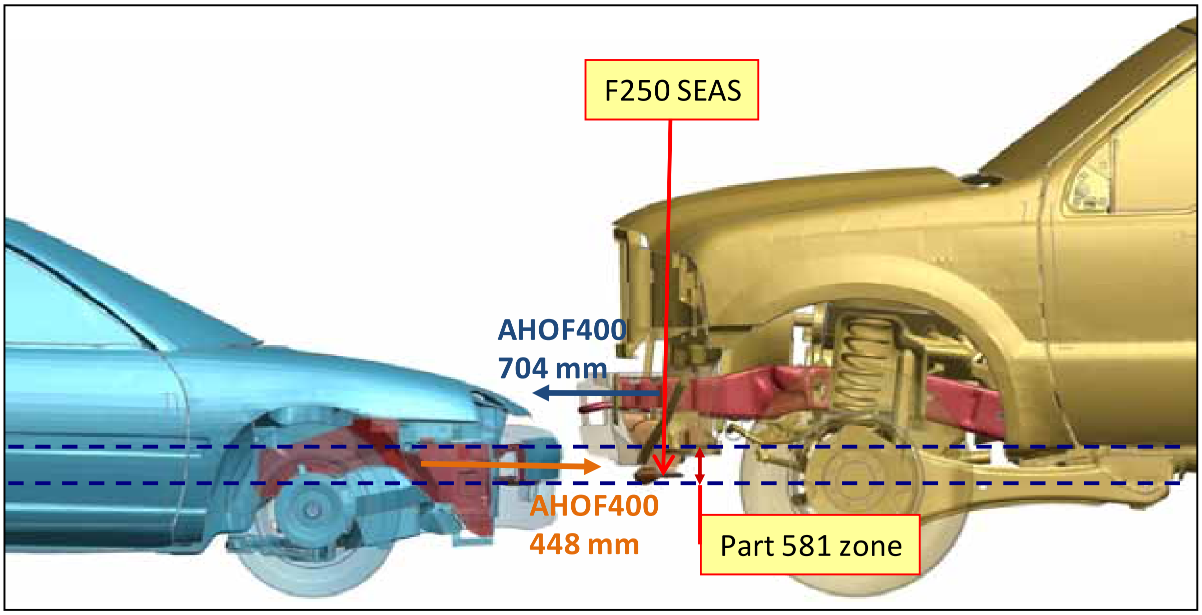


Figure 2-3: Geometric Alignment, Neon and F250

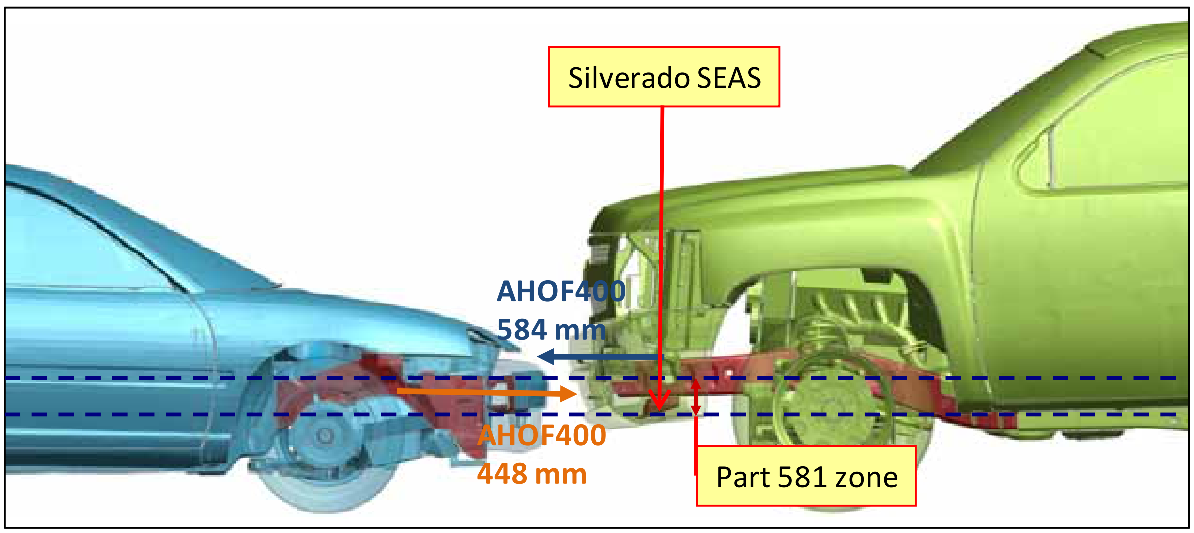


Figure 2-4: Geometric Alignment, Neon and Silverado

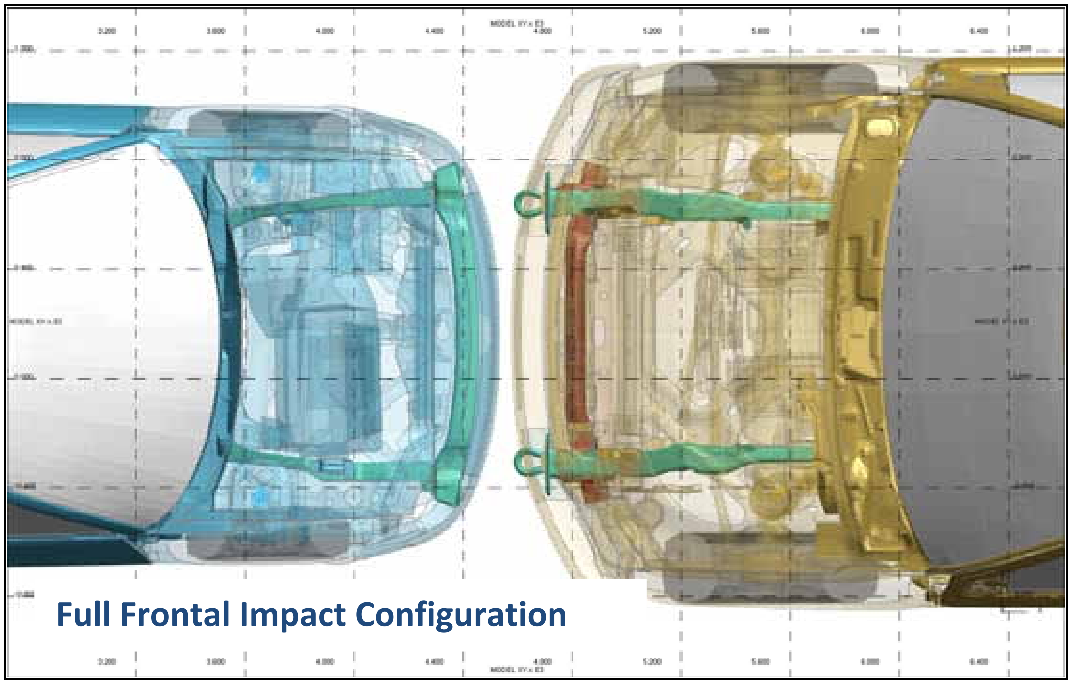


Figure 2-5: Lateral Overlap of PEAS, Neon and F250

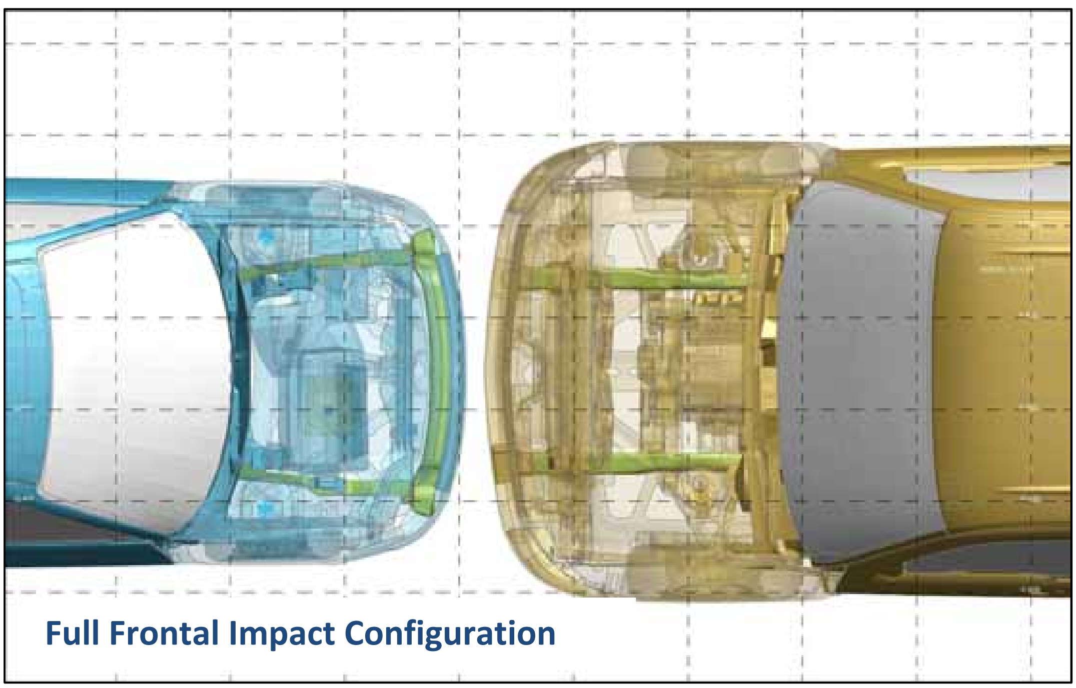


Figure 2-6: Lateral Overlap of PEAS, Neon and Silverado

3 Vehicle-to-Vehicle Simulation Results

3.1 Neon-F250

Full frontal and 40% offset frontal simulations were conducted between Neon and F250. Each of these simulations was conducted with and without the SEAS of the F250 to evaluate the influence of the SEAS on structural interaction between the two vehicles. The interaction between the PEAS of the Neon and the F250 is illustrated in Figure 3-1 (with SEAS) and Figure 3-2 (without SEAS). The SEAS on the F250 prevents the Neon from completely under riding the F250. The front of the Neon PEAS interacts with the F250 SEAS and crushes axially in the beginning, but as the SEAS starts to fail the Neon PEAS starts to bend towards the ground. Without the SEAS on the F250, the structural interaction is significantly reduced resulting in notable under riding of the Neon front end.

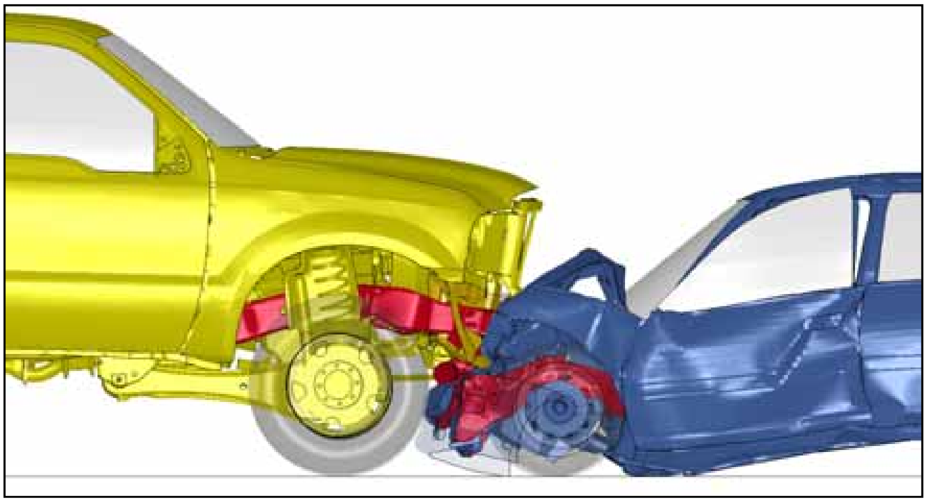


Figure 3-1: Structural Interaction between Neon and F250 (with SEAS)

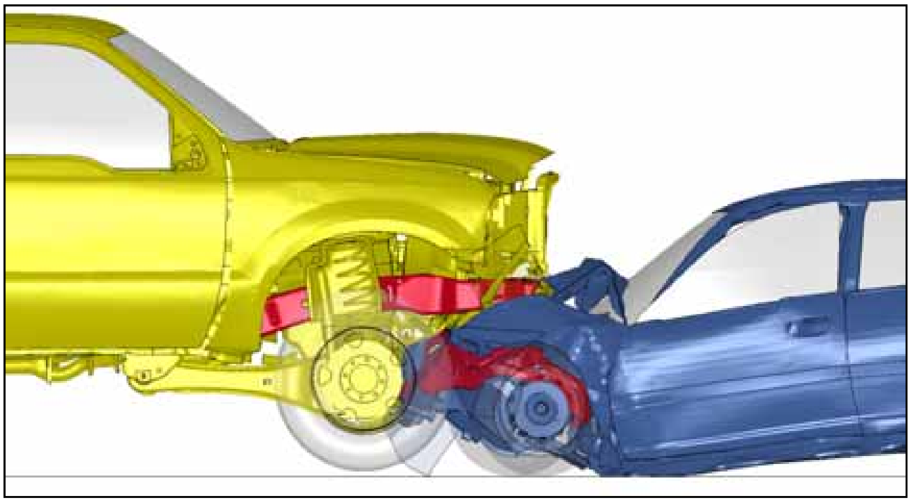


Figure 3-2: Structural Interaction between Neon and F250 (without SEAS)

The change in structural interaction was primarily investigated based on the amount of crash energy absorbed by the vehicles involved in the crash. In addition to the crash energy, the amount of structural intrusion into the occupant compartment of the vulnerable vehicle was compared.

The crash energy absorbed by the vulnerable vehicle (Dodge Neon in this research) is further divided into two groups:

- Front engine compartment energy
- Occupant compartment energy

The front engine compartment energy is the energy absorbed by the components that are designed to absorb the crash energy. This includes the longitudinal frame rails, upper rails and the sub-frame etc., as shown in the front section of the Neon (picture of front section in Figure 3-3). The occupant compartment energy is the energy absorbed by the occupant compartment, which is primarily designed to prevent any structural collapse into the occupant compartment. This includes the A, B and C pillars, roof rail, doors, fire wall etc., as shown in the occupant compartment of the Neon (picture of occupant compartment in Figure 3-3). The internal energy absorbed by each of the components as a function of time, in the two groups was summed from the simulation results.

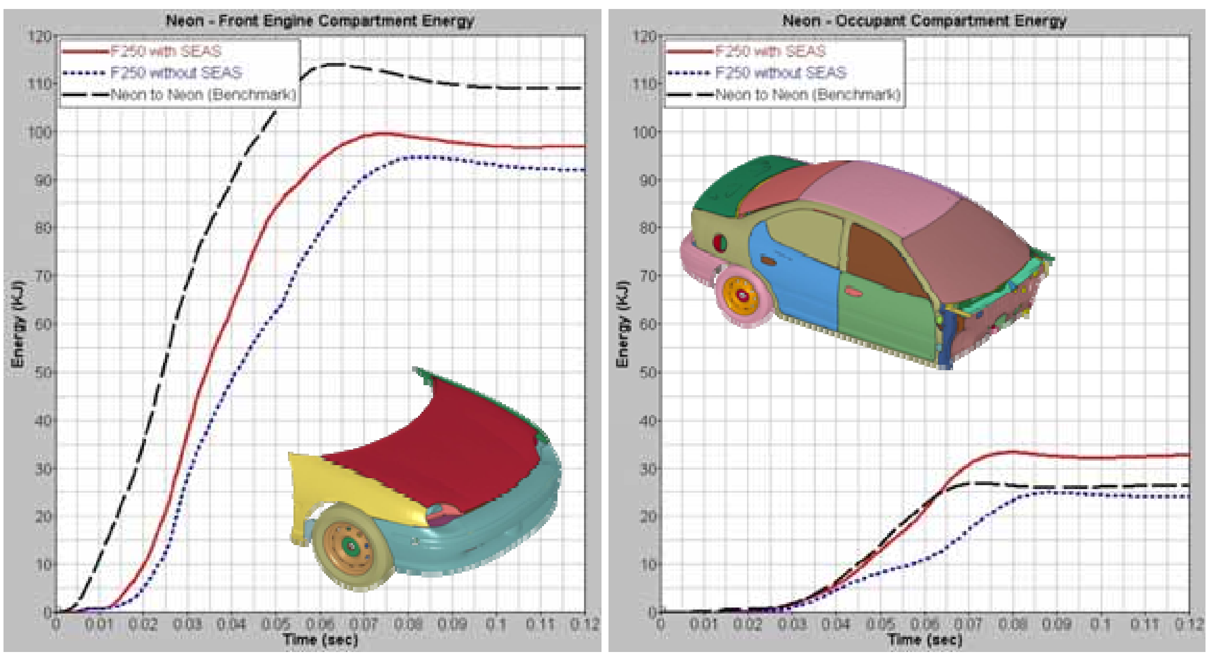


Figure 3-3: Energy Distribution, Neon-F250 Full Frontal Impact

The benchmark for energy comparison is a full frontal simulation between identical Neon's. The mass ratio, the AHOF400 ratio, and the Kw400 ratio are all equal to one. The energy distribution between the front engine compartment and occupant compartment for full frontal impact between Neon-F250 (with SEAS), Neon-F250 (without SEAS) and Neon-Neon is shown in Figure 3-3. "Due to significant mismatch between the Neon PEAS and the F250 PEAS, the Neon frontal structures do not deform as observed in the Neon-Neon benchmark simulations".

Consequently, the energy absorbed by the Neon front engine compartment is lower compared to the benchmark simulation between identical Neon's. The presence of the SEAS shows that the occupant compartment energy initially follows the benchmark simulation, but due to taller, stiffer and heavier F250 the Neon occupant compartment continues to crush and absorb more energy to satisfy the conservation of energy principle. On the other hand, without the SEAS, there is significant underride of the Neon frontal structures and hence, the energy absorbed by the Neon occupant compartment converges to the benchmark simulation. This cannot be conceived to offer better protection to the Neon occupants. Though structural mismatch is desired in low severity crashes to reduce compartment accelerations, the problems associated with geometrical mismatch outweigh their benefits. Typically, crash sensors are positioned on the PEAS and the bumper structure to trigger air bags and pretensioners in the event of a crash. A frontal crash resulting in underride may not trigger these countermeasures. This may reduce their effectiveness in reducing risk of serious injuries to the occupants. This phenomenon was observed in a laboratory test between Ford F250 with and without the SEAS and the Ford Focus. The probability of injuries increased for the Ford Focus driver in a frontal impact with the Ford F250 without the SEAS [4].

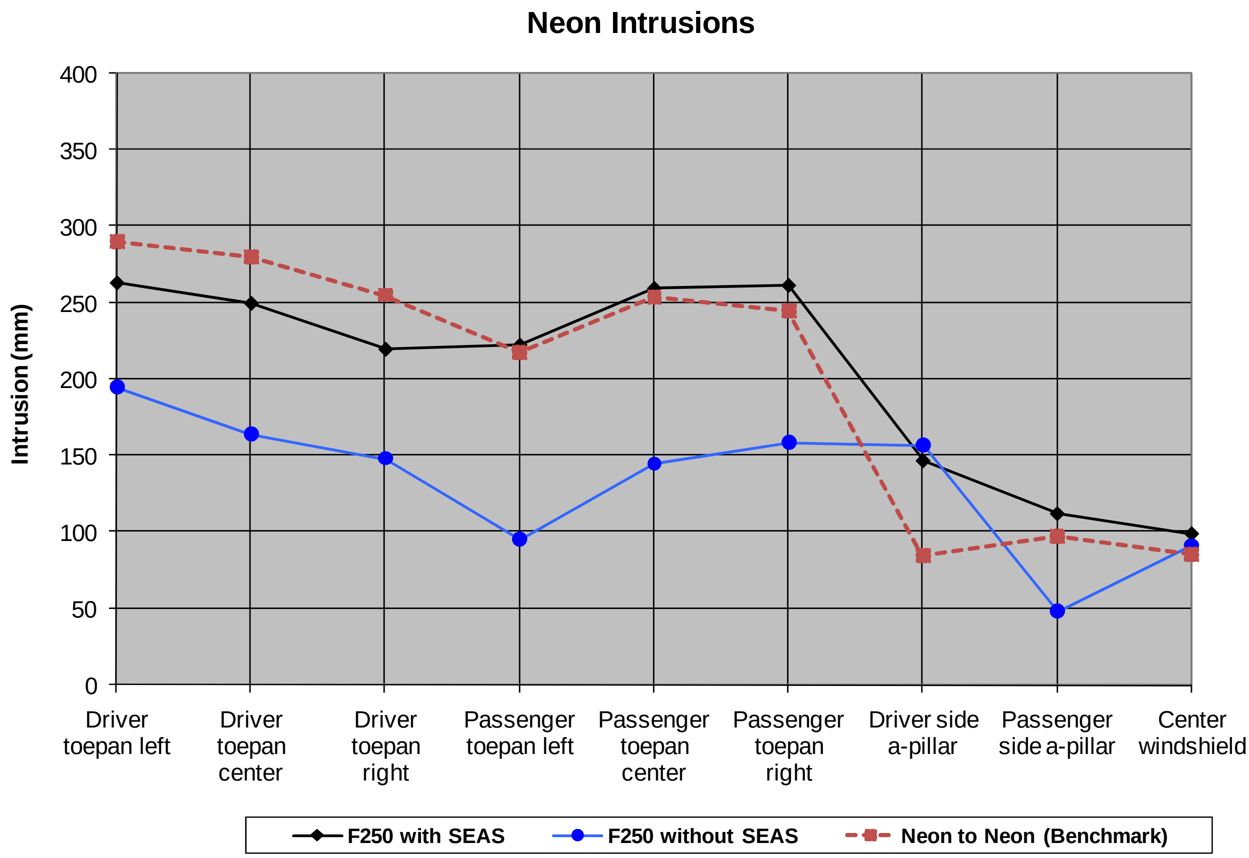


Figure 3-4: Neon Intrusions, Neon-F250 Full Frontal Impact

The energy comparison won't be conclusive without evaluating the resulting intrusions into the occupant compartment of the vulnerable vehicle. The intrusion into the Neon occupant compartment in full frontal impact with F250 (with and without SEAS) and Neon is shown in Figure 3-4. The structural underride between Neon and F250 without the SEAS results in lower toe pan intrusions compared to impact between Neon and F250 with the SEAS. This is expected as the lower load path is not initiated due to the geometrical mismatch of the structures without the SEAS on the F250. The toe pan intrusions in the case of Neon to F250 with the SEAS are very similar to the benchmark impact between identical Neon's. However, in both cases (Neon to F250 with the SEAS and without the SEAS) the driver side A-pillar intrusions are nearly twice that of the benchmark impact between identical Neon's.

3.2 Neon-Silverado

The structural interaction between the PEAS of the Neon and the Silverado is illustrated in Figure 3-5 (with SEAS) and Figure 3-6 (without SEAS). The SEAS in the Silverado is laser welded to the PEAS and cannot be easily separated as in the Ford F250, where the SEAS is a bolted structure to the PEAS. However, separating the SEAS from the Silverado PEAS is possible in computer simulations. The simulation results showed that the presence or absence of the SEAS on the Silverado has negligible effect in the overall crush kinematics of the Neon frontal structures. This is because of the vertical geometric overlap between the PEAS of the Neon and Silverado (Figure 2-4).

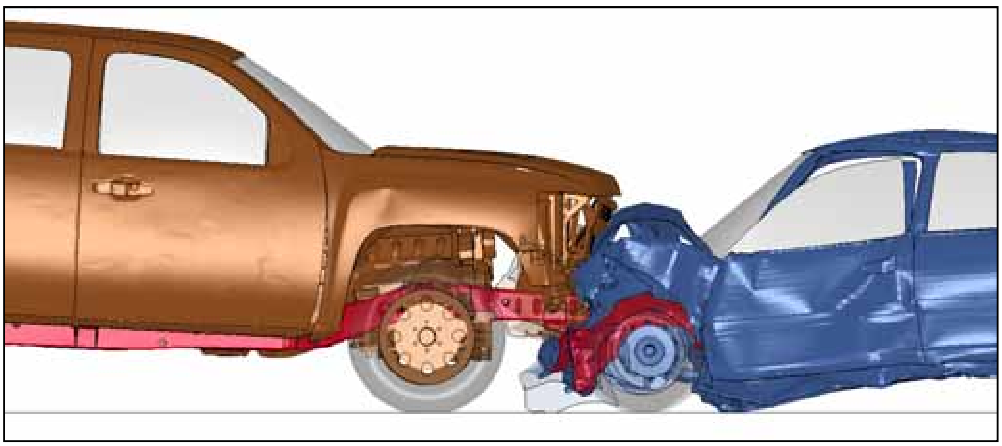


Figure 3-5: Structural Interaction between Neon and Silverado (with SEAS)

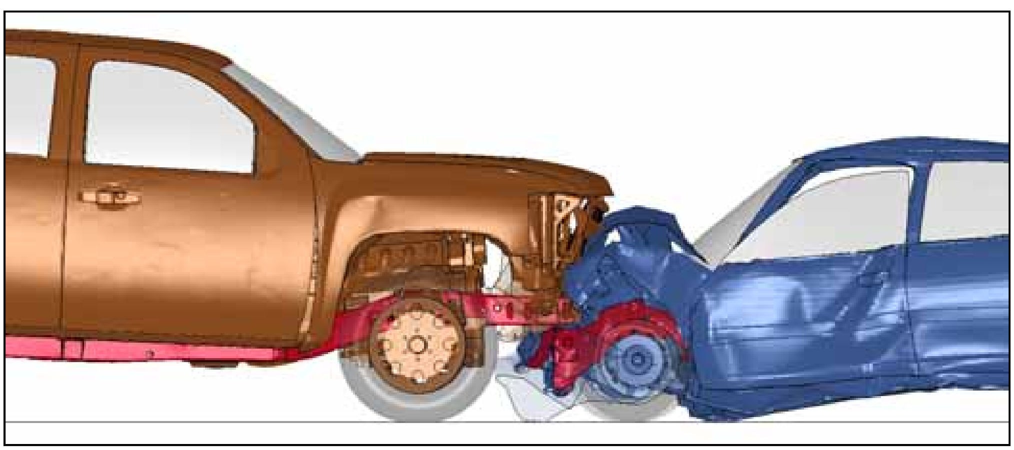


Figure 3-6: Structural Interaction between Neon and Silverado (without SEAS)

The energy distribution between the front engine compartment and occupant compartment of the Neon for full frontal impact between Neon-Silverado (with SEAS), Neon-Silverado (without SEAS) and Neon-Neon is shown in Figure 3-7. The energy absorbed by the Neon frontal structures in a frontal impact between Neon-Silverado is similar to the benchmark simulation between identical Neon's. The Neon frontal structures deformed, primarily, in axial compression which is consistent with full-width barrier tests. However, the energy absorbed by the occupant compartment is significantly higher when compared to the benchmark simulation. Since, the Silverado is much heavier and stiffer than the Neon; the Neon structure has to absorb the remainder of the crash energy to satisfy the conservation of energy principle.

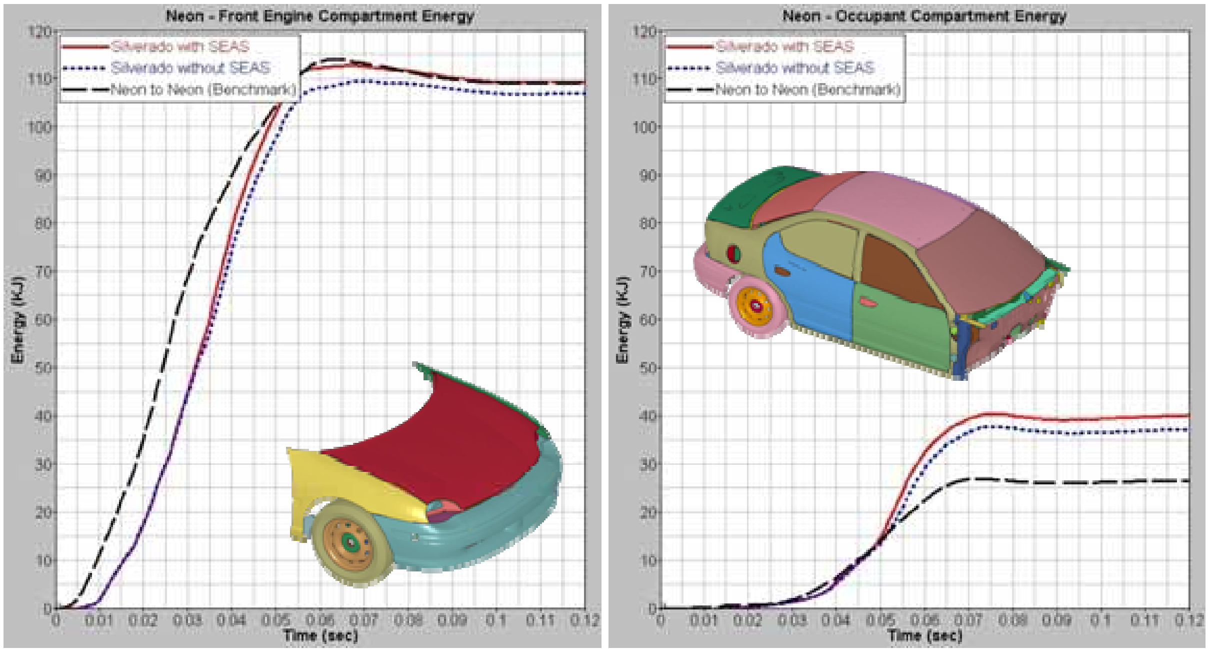


Figure 3-7: Energy Distribution, Neon-Silverado Full Frontal Impact

One interesting observation is the front engine compartment and occupant compartment energies of the Neon are only marginally lower when impacted by the Silverado without the SEAS compared to the Silverado with the SEAS simulation. The design and placement of the SEAS makes the Silverado PEAS stiffer and reduces its contribution to energy absorption in a frontal impact with Neon. When the SEAS is removed, there is slightly higher energy absorption by the Silverado PEAS and this lowers the amount of energy to be absorbed by the Neon frontal structure. Since the Silverado PEAS without SEAS absorbed more energy than the Silverado PEAS with SEAS, the Neon frontal compartment and the occupant compartment had to absorb less energy in the Neon-Silverado without SEAS compared to Neon-Silverado with SEAS.

The resulting Neon compartment intrusions complement the observation above on energy distribution. The resulting toe pan and A-pillar intrusions are higher for the Neon-Silverado (with and without SEAS) simulation compared to the benchmark simulation Figure 3-8. Without the SEAS, the intrusions at the toe pan are lower as some of the crash energy is absorbed by the Silverado PEAS.

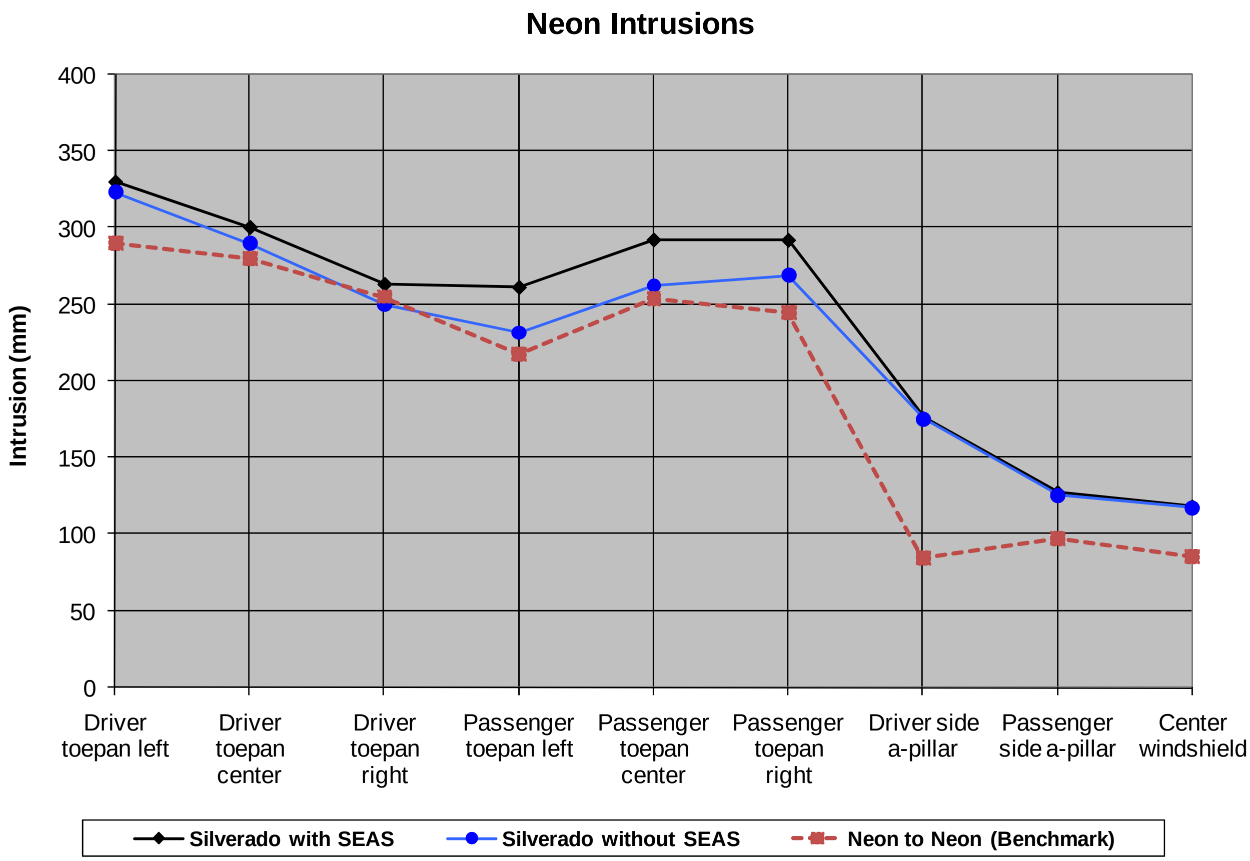


Figure 3-8: Neon Intrusions, Neon-Silverado Full Frontal Impact

3.3 Summary

The observations from the Neon-F250 simulations demonstrate that the cross-member type SEAS design helps prevent under-riding of the Neon frontal structures. Under-riding of Neon structures was not observed in the structural interaction (Figure 3-5 & Figure 3-6) between Neon and Silverado with and without SEAS. The SEAS in the Silverado was a non-contributing factor in the overall crush kinematics of the Neon frontal structures, mainly because of the vertical overlap of the PEAS structures of the Neon and Silverado. The Neon intrusions and occupant compartment energy were higher than the benchmark simulations between identical Neon's.

This preliminary analysis was limited to understanding the structural interaction in full frontal and offset frontal impacts. Other frontal and oblique impact conditions and impact locations and their effect on structural interaction were not considered in this preliminary analysis. The effect of these impacts on occupant injury was also not considered in this study at this time. A validated occupant compartment model with the necessary restraints required for this analysis is not available at this time. Future passenger car models planned to be developed can be used to extend this study to evaluating injury risks.

4 Over Ride Barrier Development

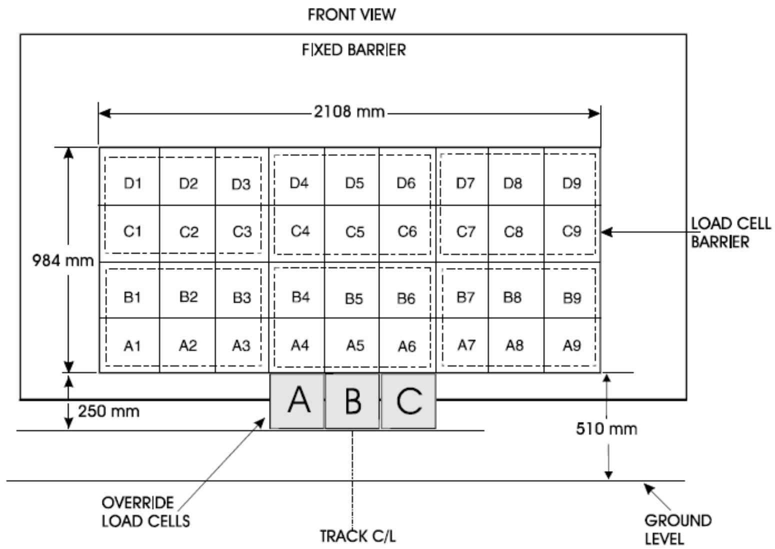
4.1 Overview

The Compatibility Technical Working Group (TWG) proposed that the SEAS withstand a load of at least 100 KN exerted by a loading device, before this loading device travels 400 mm as measured from a vertical plane at the forward-most point of the significant structure of the vehicle [1]. The TWG investigated and recommended a dynamic over ride barrier (ORB) test to evaluate the proposed SEAS strength requirements. The various SEAS designs on option 2 LTVs posed a unique challenge in developing a robust test procedure to evaluate the strength of SEAS.

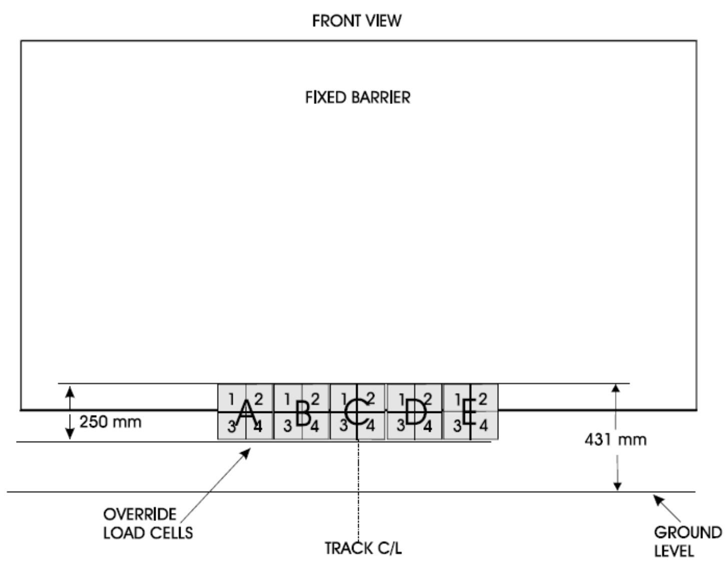
NHTSA developed a concept ORB to study the emerging SEAS designs and its effect on structural interaction in frontal collisions [5]. A 2006 Ford F250 (cross-member type SEAS) and 2007 Chevy Silverado (non cross-member type SEAS) (Figure 4-1) were used in this series of tests. Since the vertical location of the PEAS and the SEAS differed for the LTV's, two different ORBs were used in these tests. The Ford F250 impacted into 750 mm wide ORB with 510 mm of ground clearance while, the Silverado impacted into 1250 mm wide ORB with 431 mm of ground clearance (Figure 4-2). In both tests, there was extensive damage to the SEAS and its connecting brackets.

The objective of this task was to develop a laboratory test procedure, based on and building upon the tests conducted at VRTC, for evaluating the strength of SEAS to promote structural interaction in frontal collisions between option 2 LTV's and passenger cars. A simulation based parametric study was conducted to identify the barrier construction, impact velocity and assessment metrics to evaluate the strength of the SEAS.

Figure 4-1: Different Type of Secondary Energy Absorbing Structure (SEAS)



(a) 750mm wide ORB with 510mm of ground clearance



(b) 1250mm wide ORB with 430mm of ground clearance

Figure 4-2: Different ORB used in Tests

4.2 Model Validation

The Ford F250 and Chevy Silverado FE models were validated to the ORB tests conducted at VRTC. Figure 4-3 shows the time history comparison for the Ford F250 test and simulation. In the physical test, there was extensive deformation of the SEAS and its brackets primarily by metal rupture and bolt failures. The failure and rupture in the physical vehicle was a continuous process while it was discontinuous in the simulation because of element size limitations. Several different modeling approaches were examined to capture the deformation mode observed in the ORB test. Reasonable correlation was achieved for the acceleration and velocity signals between the test and simulation (Figure 4-3). However, matching the forces on the ORB was extremely difficult due to bolt separation and failure during loading of the SEAS. Figure 4-4 shows the deformation of the SEAS structure for the test and simulation. Overall, the model was deemed adequate to capture the response of the ORB test and sufficient enough for the objective of this task (parametric study).

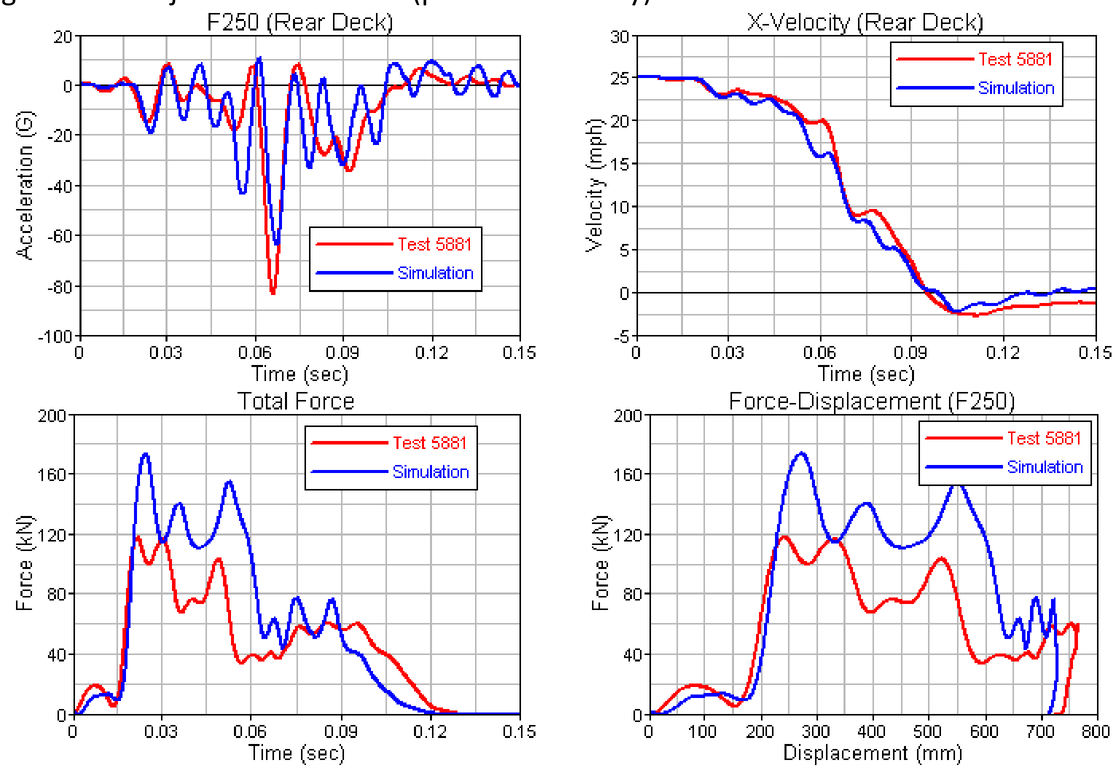


Figure 4-3: Validation of F250 ORB Test

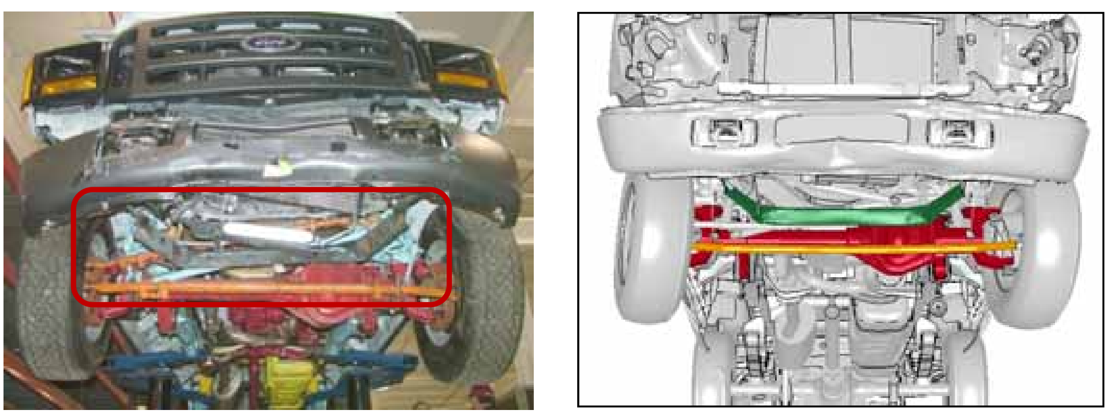


Figure 4-4: Comparison of the SEAS Deformation of F250

Figure 4-5 presents the correlation of Silverado ORB test and simulation. The model showed reasonable correlation for the acceleration and velocity at vehicle rear deck and total wall force. Similar deformation modes were observed between the test and simulation for the Chevy Silverado (Figure 4-6). The PEAS bends upwards as the SEAS loads the ORB. Once the load exceeds the failure limit, the SEAS shears off by tearing the bottom section of the PEAS. This is followed by the suspension components loading onto the ORB.

The rupture observed in the PEAS and the SEAS in the physical test was again the limiting factor to effectively correlate the model. The first peak in the ORB wall force was generated by the impact of SEAS and the second peak was generated by the subsequent impact of the suspension components into the ORB. This essentially means that the SEAS of the Silverado reached its failure load quickly and did not absorb crash energy as the SEAS in the F250. Even though the peak force levels are similar between the F250 and Silverado, the Silverado SEAS did not sustain the force once it reached the failure load which led to relatively lower energy absorption compared to the F250 SEAS.

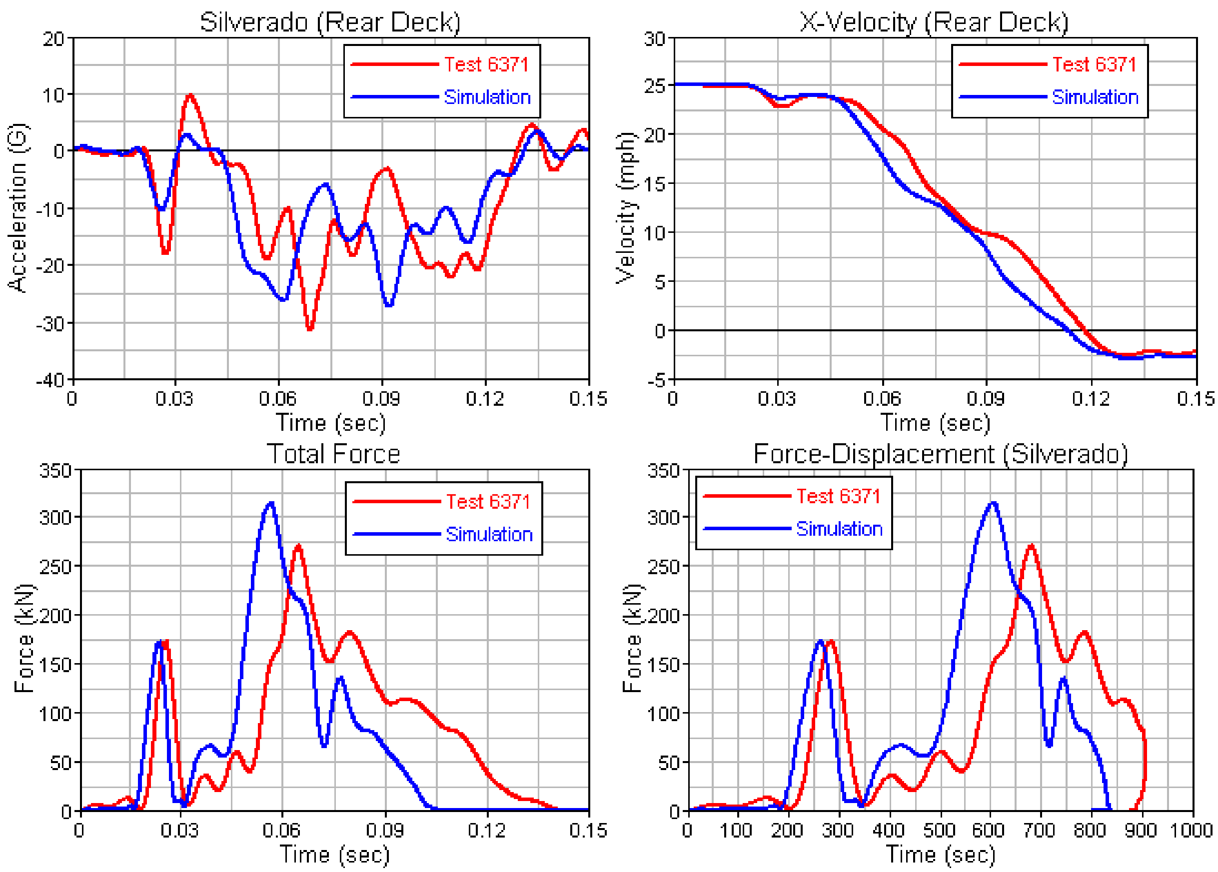


Figure 4-5: Validation of Silverado ORB Test

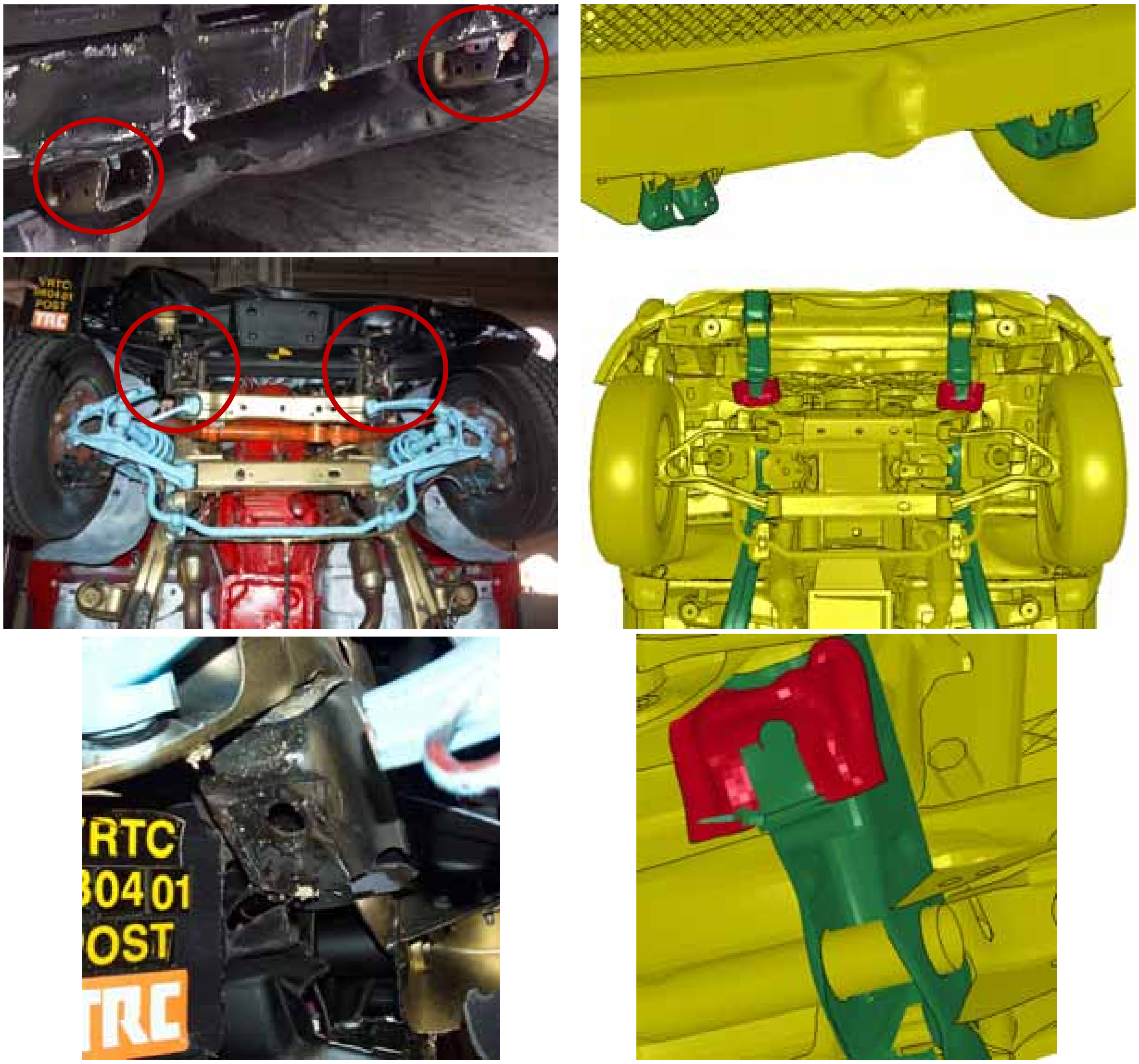


Figure 4-6: Comparison of the SEAS Deformation of Silverado

4.3 Parametric Study

The two LTV FE models were used in a parametric study to identify a suitable test condition, barrier design and assessment metrics to evaluate the strength of SEAS to improve structural interaction in frontal collisions. Two different barrier widths (750mm and 1250mm) were considered based on the physical tests conducted at VRTC. In addition, a 50% offset impact into an ORB was investigated. The impact velocity, width and height of the ORB and assessment metrics are recommended based on this parametric study.

Impact velocity

The ORB simulations were performed at five different impact velocities starting from 15 mph and in increments of 5 mph thereafter till 35 mph. Both the 750 mm and 1250 mm wide ORB barrier were used. These simulations were performed with the F250. The top of the ORB was aligned at 510 mm as in the tests conducted at VRTC. Figure 4-7 shows the force-displacement (F-D) response for each of the ORB at different impact velocities. These F-D curves were generated from the total force on the ORB and the displacement of the vehicle as measured by the accelerometer mounted at the rear deck[4]. Impact velocities over 25 mph resulted in a secondary impact on the ORB by the power train and suspension components (Figure 4-8 and Figure 4-9). This secondary impact will have confounding effects on the assessment metrics to effectively evaluate the strength of SEAS. The impact velocities of 15, 20 and 25 mph resulted in very similar F-D response. The only noticeable difference was the increased crush at higher velocities in order to manage the increase in kinetic energy. Hence, an upper limit of 25 mph was recommended for the ORB test based on the SEAS design for the F250.

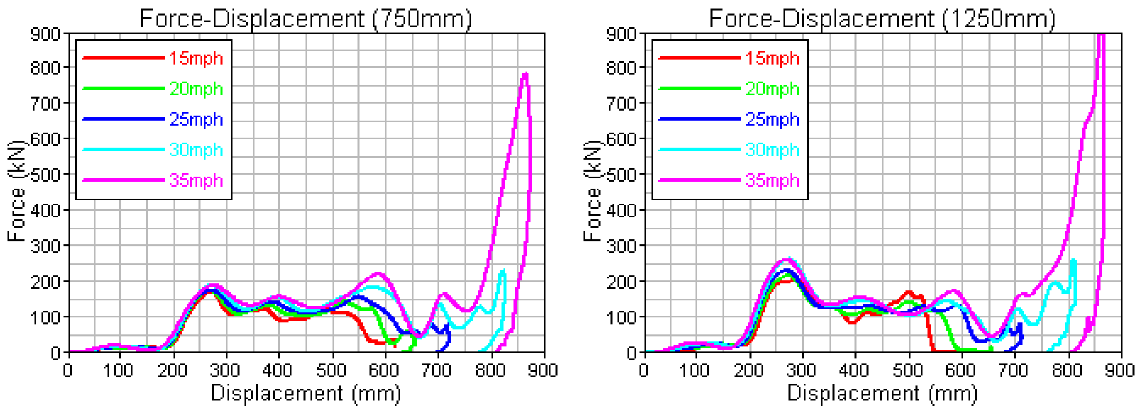
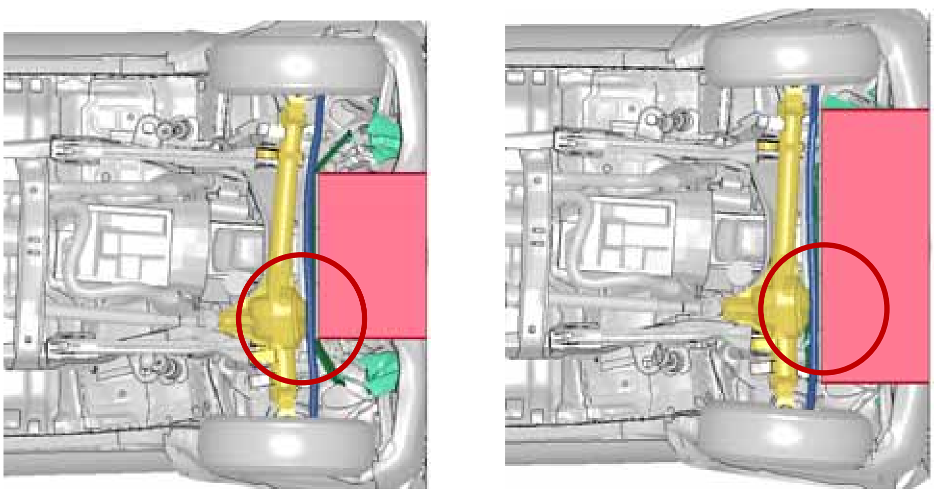


Figure 4-7: F-D Curves at varying Impact Velocities (F250)



(a) 750mm wide ORB (b) 1250mm wide ORB

Figure 4-8: Interaction of Underbody Component at 35mph Impact (F250)

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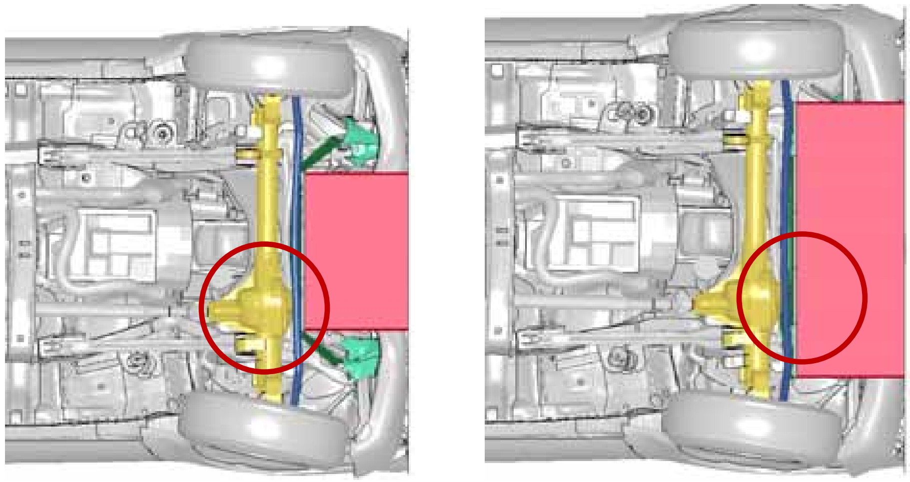
[4] The accelerometer response from the rear deck was chosen rather than from the CG to eliminate the second order effects experienced by the accelerometer at the CG due to the compliance in the body mounts. The accelerometer response at the rear deck is a first order effect which captures the SEAS loading without any interference from the body mount compliance.



(a) 750mm wide ORB (b) 1250mm wide ORB

Figure 4-9: Interaction of Underbody Components at 30mph Impact (F250)

Width of ORB

The width of the ORB should be selected such that the ORB can effectively evaluate the strength of SEAS for the different SEAS designs (F250 and Silverado). For example, the 750 mm wide ORB does not completely overlap the SEAS structure of the Silverado (Figure 4-10). Hence, the SEAS evaluated using the 750 mm ORB may result in a loading pattern much different from that in the real world vehicle-to-vehicle impacts. The deformation mode of the SEAS in the ORB test was compared to SEAS deformation in a full frontal simulation between F250-Neon. The SEAS loading in the F250-to-ORB simulation for the 750 mm ORB is quite different from what was observed in a full frontal vehicle-to-vehicle simulation (Figure 4-11). The 750 mm wide barrier misses the two mounting brackets of the F250 SEAS and forces the entire load onto the cross-member which is different from what is observed in a full frontal vehicle-to-vehicle simulation. On the other hand, the 1250 mm wide ORB generates very similar deformation mode as in the full frontal vehicle-to-vehicle test (Figure 4-11). Both the F250 and Silverado SEAS overlaps the full face of the 1250 mm wide barrier (Figure 4-12).

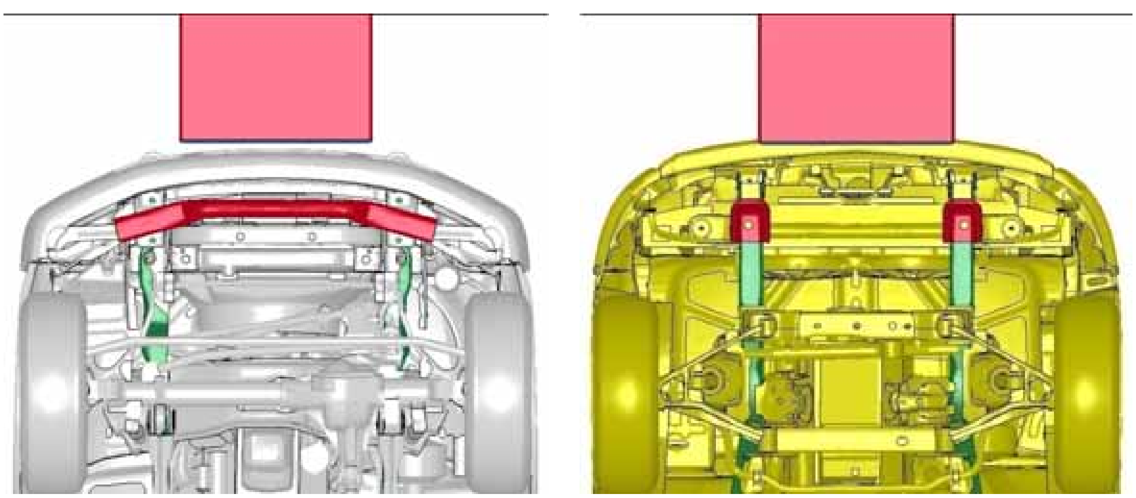
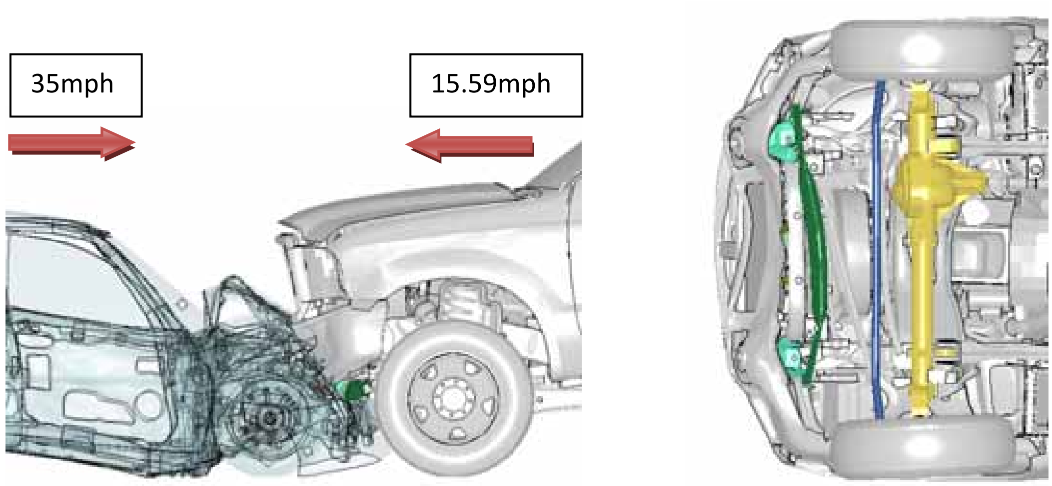
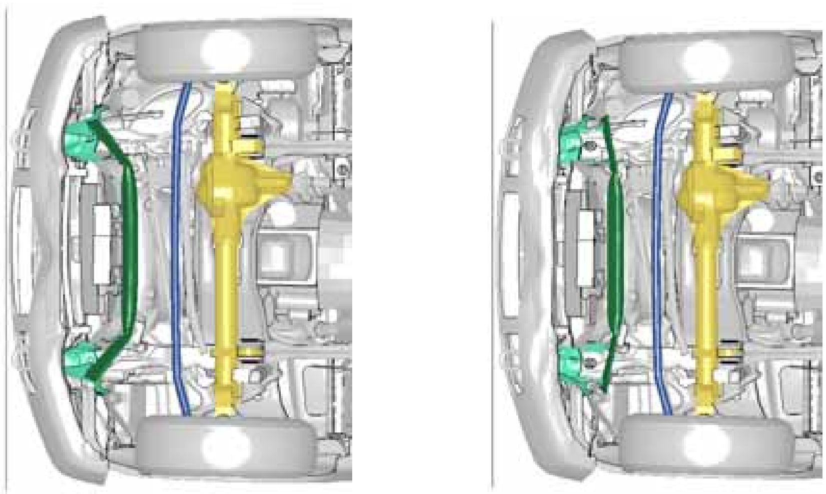


Figure 4-10: SEAS overlap for 750 mm wide ORB (F250 & Silverado)



(a) Deformation Shape of SEAS in Vehicle to Vehicle Impact Simulation (Neon – F250)



(b) Deformation Shape of SEAS (Left: 750mm wide ORB, Right: 1250mm wide ORB)

Figure 4-11: Comparison of Deformation Shape of SEAS in V-t-V Impact and ORB Test

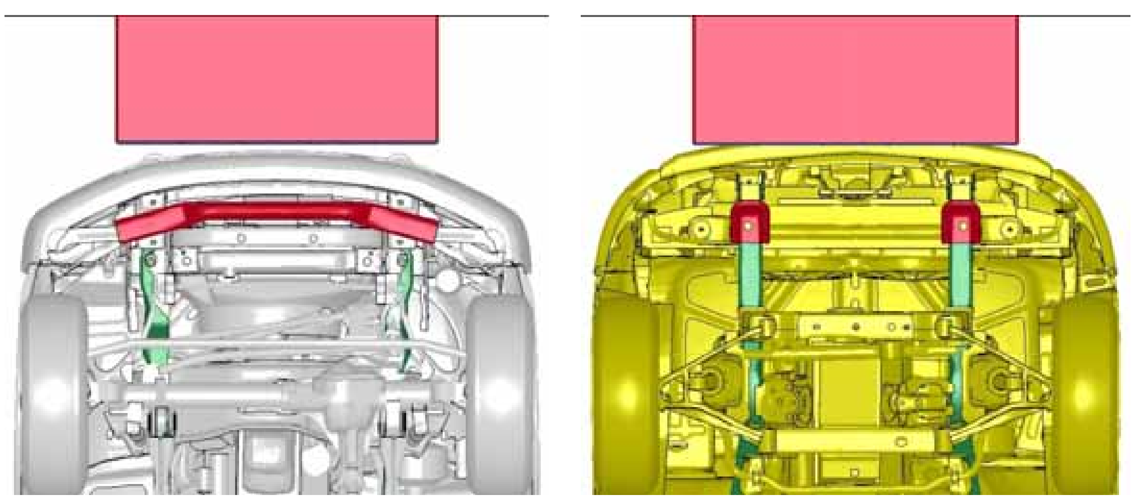


Figure 4-12: SEAS overlap for 1250 mm wide ORB (F250 & Silverado)

Height of ORB

According to the AAM voluntary commitment, for option 2 LTVs, the SEAS shall be no higher than the bottom of the Part 581 zone (16 to 20 inches above ground level). Having the SEAS structure overlap the Part 581 zone might improve structural interaction in frontal collisions between passenger cars and option 2 LTVs preventing underride of the frontal structures. Hence, designing the top height of the ORB to the top of the Part 581 zone (20 inches or 508 mm) would ensure good SEAS overlap with the passenger car primary structures. Figure 4-13 shows the F250 and Silverado alignment with the ORB (top height of 510 mm) before and after impact. The strength of the F250 SEAS can be effectively evaluated with this ORB since no part of the PEAS interacts with the barrier. This would closely resemble the SEAS interaction with a passenger car. The Silverado SEAS design is a different design approach compared to the F250. The PEAS of the Silverado overlaps more than 50% of the Part 581 zone, hence the strength of the SEAS cannot be evaluated with the ORB with a top height of 510 mm.

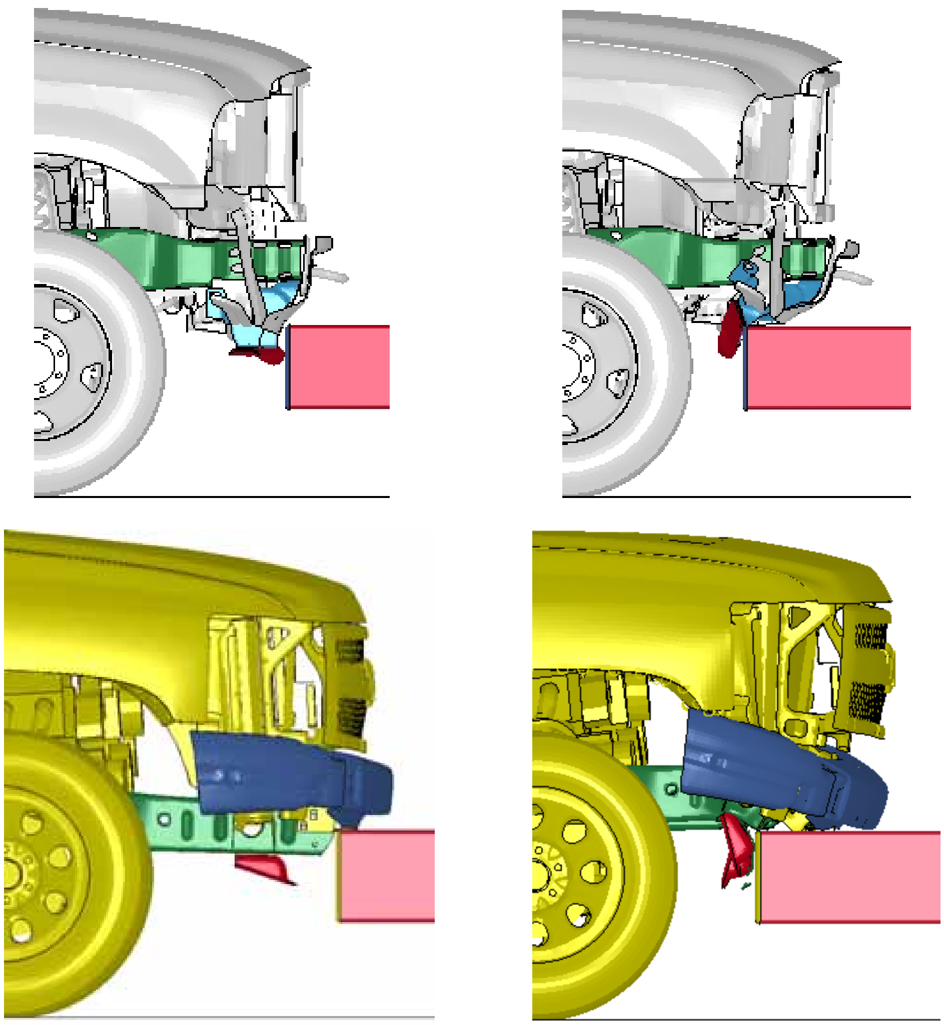
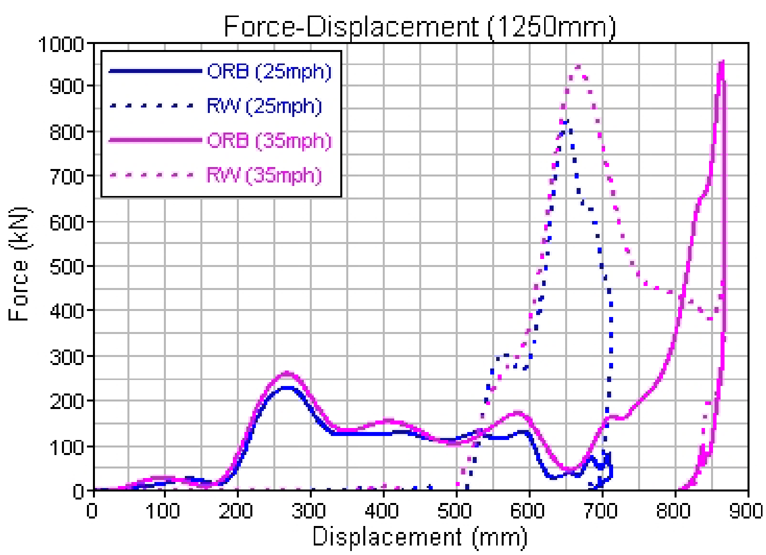


Figure 4-13: Top height of ORB at 510 mm (F250 & Silverado)

The SEAS designs of the F250 and the Silverado present unique challenges to design and develop a laboratory test procedure for SEAS strength evaluation. The F250 design relies on the blocker beam type SEAS to prevent passenger cars from under-riding in frontal collisions. On the other hand, the Silverado design relies more on the vertical height of the PEAS to improve structural interaction in frontal collisions. The presence of SEAS in the Silverado confirms to the AAM voluntary agreement. New and emerging SEAS designs should be monitored to study its influence in structural interaction in frontal collisions. More research is required to better understand the requirements of an ORB test for SEAS evaluation.

Assessment metrics

The ORB is instrumented with load cells to measure the impact force. The F-D characteristic was evaluated using the total force on the ORB and the displacement of the vehicle as measured by the accelerometer mounted at the rear deck of the LTV. Figure 4-14 shows the F-D response for the F250 as measured at the ORB and at the rigid wall. The force measured by the ORB starts increasing when the SEAS impact the ORB at about 200 mm of vehicle displacement. The SEAS continues to load the ORB till the front of the vehicle engages the rigid wall. The rigid wall is offset 500 mm behind the front surface of the ORB. Up until this point, the F-D response on the ORB is purely the result of SEAS loading the ORB.



ORB – Over ride barrier simulation
RW – Rigid wall barrier simulation

Figure 4-14: F-D response as measured at the ORB and the rigid wall barrier test (F250)

Measurement of energy absorption of the SEAS is an appropriate method to evaluate the efficiency of the SEAS but, practically, the energy cannot be measured in physical tests. Therefore, a measure of stiffness derived from F-D relationship would be an appropriate metric to evaluate the strength of SEAS. Therefore, the stiffness of the SEAS can be evaluated using the Kw400 method [3]. The Kw400 evaluation would encourage SEAS structures to be positioned as forward as possible to the front surface of the vehicle. This would help engage the frontal structures of the passenger cars and prevent potential underriding. Table 4-1 shows the Kw400 values from the F-D response measured on the ORB for the 750 mm and 1250 mm wide ORB at different impact velocities. These Kw400 values were much lower than the Kw400 values of the compact and mid-size passenger cars (Figure 4-15). In a full frontal impact between the F250 and a compact car, the SEAS of the F250 would deform more than the frontal structure of the passenger car due to the Kw400 mismatch. This may reduce the effectiveness of structural interaction between the SEAS and the front of the passenger car. Additional work is required to define the limits of the Kw400 for the ORB test to evaluate the SEAS strength.

Table 4-1: Kw400 (N/mm) of F250 in ORB Simulations

Impact Speed	Width of Over Ride Barrier	
	750 mm	1250 mm
15mph	313.89	379.28
20mph	333.47	397.06
25mph	352.08	426.39
30mph	378.38	478.61
35mph	393.63	493.89

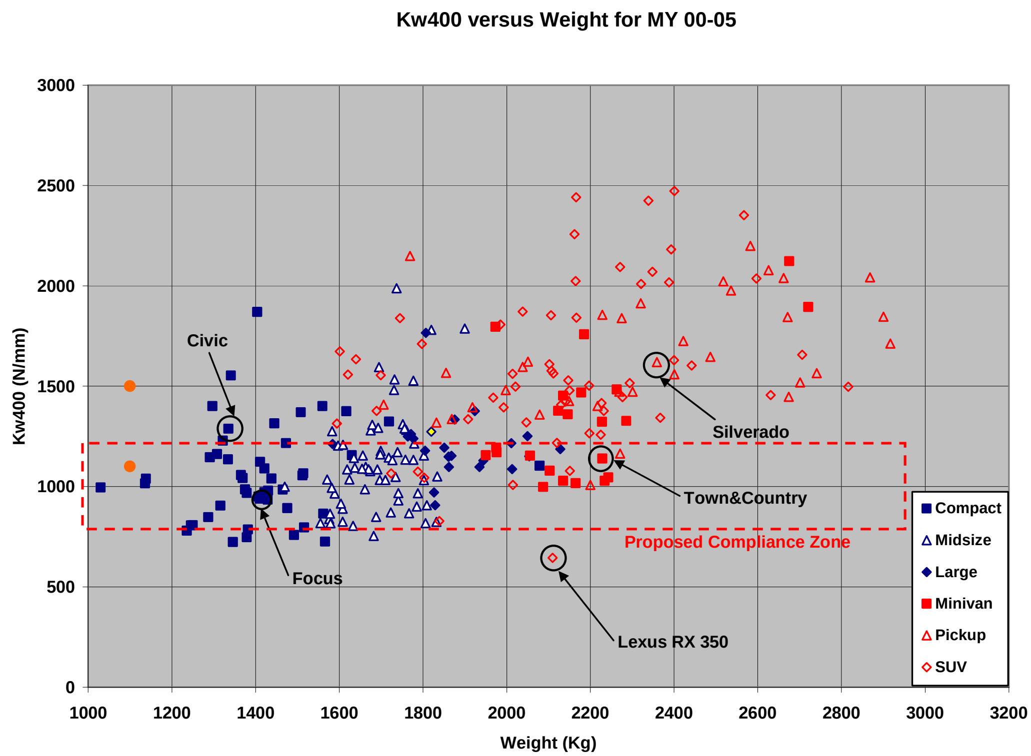
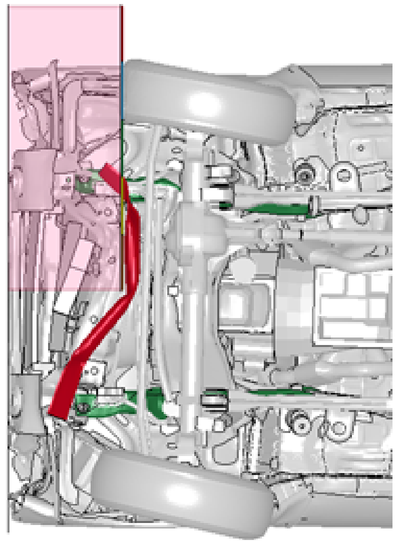


Figure 4-15: Kw400 for MY 2000-05 vehicles from NCAP tests

50% frontal offset test

In the real world, there is significant number of frontal crashes between passenger cars and LTVs with partial overlap. Considering this, it might be beneficial to evaluate the SEAS structure in an offset ORB test. 50% offset ORB (1250 mm wide barrier) simulations were conducted with the F250 at different impact velocities. Figure 4-16 shows the deformation mode of SEAS in a 50% frontal offset ORB simulation. The Kw400 values decreased around 35% for the offset ORB simulations compared to the full frontal ORB simulations (Table 4-2). The range of Kw400 values and the need for an offset ORB test needs further investigation.



(a) F250 at 25mph

Figure 4-16: 50% Offset Simulation

Table 4-2: Kw400 (N/mm) of F250 in full frontal and 50% offset frontal ORB simulations

Impact Speed	Type of Over Ride Barrier		Kw400 difference (%)
	Full overlap	50% Offset	
15mph	379.28	253.20	33%
20mph	397.06	256.45	35%
25mph	426.39	284.67	33%
30mph	478.61	300.14	37%
35mph	493.89	309.13	37%

4.4 Summary

A feasibility study of an ORB test condition, barrier design and assessment metric were investigated using FE models of option 2 LTVs. The two LTV FE models were validated in both NCAP tests and ORB tests performed at VRTC. A parametric study was conducted to identify impact velocity, width and height of the ORB and the relevant assessment metrics to evaluate the strength of the SEAS. Based on this study, an impact velocity of 25 mph was identified as a potential impact speed for the ORB test. A 1250 mm wide barrier with a top height aligned with the top of the Part 581 zone (508 mm) may be considered as a potential barrier. It may also be beneficial to consider an offset ORB test rather than the full overlap test and place a requirement for minimum force in each load cell. Kw400 could be potentially used as an assessment metric for determining the strength of the SEAS structure. This is a limited study; additional work is required to determine the range of Kw400 values appropriate to promote good SEAS structures. In addition, this study was limited to the two SEAS designs that were available in the virtual vehicles. Other SEAS designs and their performance should be considered before an appropriate ORB test procedure is identified.

5 References

[1] Barbat, S., "Status of Enhanced Front-To-Front Vehicle Compatibility Technical Working Group Research and Commitments", 19th Enhanced Safety of Vehicles, Paper Number 05-0463, Washington D.C., June 2005.

[2] http://www.access.gpo.gov/nara/cfr/waisidx_99/49cfr581_99.html

[3] Mohan, P., "Development of Objective Metrics to Improve Compatibility in Frontal Collisions", Doctoral Dissertation, The National Crash Analysis Center, The George Washington University, Washington DC, August 2008.

[4] Patel, S., Smith, D., Prasad, A., Mohan, P., "NHTSA's Recent Vehicle Crash Test Program on Compatibility in Front-to-Front Impacts", 20th Enhanced Safety of Vehicles, Paper Number 07-0231, Lyon, France, June 2007.

[5] Patel, S., Prasad, A., Mohan, P., "NHTSA's Recent Test Program on Vehicle Compatibility", 21st Enhanced Safety of Vehicles, Paper Number 09-0416, Stuttgart, Germany, June 2009.

6 Appendix A

6.1 Dodge Neon NCAP Validation Summary

FHWA/NHTSA National Crash Analysis Center

Finite Element Model of Dodge Neon

Model Year 1996
Version 7

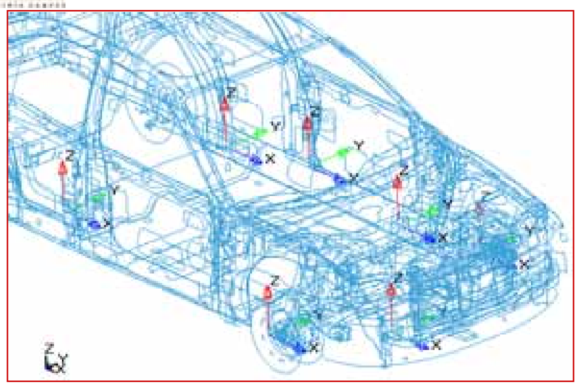
FE Model of Dodge Neon

- **Model developed mainly for frontal impacts**
- **Material data derived from coupon testing**
- **Frontal NCAP validation complete**

Number of Parts	- 336
Number of Nodes	- 283859
Number of Solids	- 2852
Number of Beams	- 122
Number of Shells	- 267786
Number of Elements	- 270768

11/6/2008

Accelerometer Locations



Location	- Node ID
Left seat	– 2800320
Right seat	– 2800328
Engine Top	– 2800336
Engine Bottom	– 2800344
R brake caliper	– 2800352
L brake caliper	– 2800360
IP top	– 2800368

Benchmark Data

LS-DYNA

Version: mpp970
Revision: 6763.226
Platform: Itanium 2
OS level: Linux 2.6
Precision: Single precision (I4R4)
Total Elapsed time: ~ 6 hrs 43min (for 150 ms)
Number of processors: 8

NCAP Comparison

	FE Model	Test Vehicle
Weight (Kgs)	1333	1354
Engine Type	2.0L I4	2.0L I4
Tire size	P185/65R15	P185/65R14
Attitude (mm) As delivered	F – 675	F – 660
	R – 665	R – 676
Wheelbase (mm)	2648	2642
CG (mm) Rearward of front wheel C/L	1046	1022

11/6/2008

NCAP Test Summary

Test No.: 2320
Contract or Study Title: 1996 DODGE NEON INTO FLAT FRONTAL BARRIER (Load cell wall)
Test Performer: TRC OF OHIO
Test Reference No.: 951026
Test Type: NEW CAR ASSESSMENT TEST
Test Configuration: VEHICLE INTO BARRIER
Closing Speed (kph): 56.5
Impact Angle (degrees): 0
Offset Distance (mm):
Version No.: 2
Test Objectives: OBTAIN 35 MPH NEW CAR ASSESSMENT AND RESEARCH DATA
Test Date: 10/26/1995
Contract No.: DTNH22-90-D-22121
Test Track Surface: CONCRETE
Test Track Condition: DRY
Ambient Temperature (degrees Celsius): 0
Type of Recorder: FM MULTIPLEXOR TAPE RECORDER
Total No. of Curves: 130
Test Commentary: THIS IS A 1995 TEST CONDUCTED ON 1996 VEHICLE

11/6/2008

NCAP Test Vehicle Data

Table 2. Test Vehicle Information

Vehicle year/make/ model/body style:	1996/Dodge/Neon/4-door sedan
Color:	White
VIN:	1B3ES43C7TD121089
NHTSA number:	MT0301
Engine data:	
Placement:	transverse
Cylinders:	4
Displacement:	2.0 liters
Transmission data:	3 speed, _manual, X automatic, _overdrive
	X FWD, _RWD, _4WD
Date vehicle received:	10/23/95
Odometer reading:	75
Dealer's name and address:	Trader Bud's Westside Dodge, 4000 West Broad Street, Columbus, OH 43228

Accessories:

Power steering	Yes	Automatic transmission	Yes
Power brakes	Yes	Automatic speed control	No
Power seats	No	Tilting steering wheel	No
Power windows	No	Telescoping steering wheel	No
Tinted glass	Yes	Air conditioning	No
Radio	Yes	Anti-skid brake	No
Clock	Yes	Rear window defroster	Yes
Other	None		

Test vehicle attitude:

Delivered attitude:	LF 661 mm;	RF 659 mm;	LR 677 mm;	RR 676 mm
Pre-test attitude:	LF 644 mm;	RF 640 mm;	LR 648 mm;	RR 651 mm
Post-test attitude:	LF 754 mm;	RF 782 mm;	LR 643 mm;	RR 630 mm

Table 2. Test Vehicle Information Cont'd

Weight of test vehicle as received (with maximum fluids):

Right front	368	kg	Right rear	200	kg
Left front	377	kg	Left rear	210	kg
Total front weight	745	kg	(64.5% of total vehicle weight)		
Total rear weight	410	kg	(35.5% of total vehicle weight)		
Total delivered weight	1155	kg			

Calculation of test vehicle's target test weight:

RCLW = Rated cargo and luggage weight

UDW = Unloaded delivered weight (1155 kg)

VCW[a] = Vehicle capacity weight (392 kg)

DSC = Designated seating capacity (5)

RCLW = VCW - 68 (DSC) = 392 - 68(5) = 52 kg

Target test weight = UDW + RCLW + (Number of Hybrid III dummies x 76 kg/dummy)

Target test weight = 1155 + 52 + 152

Target test weight = 1359 kg

Weight of test vehicle with required dummies and 47 kg of cargo weight:

Right front	411	kg	Right rear	255	kg
Left front	419	kg	Left rear	269	kg
Total front weight	830	kg	(61.3% of total vehicle weight)		
Total rear weight	524	kg	(38.7% of total vehicle weight)		
Total test weight	1354	kg	(0.4% under target test weight)		

Weight of ballast secured in vehicle: 0 kg

Components removed to meet target test weight: Rear bumper skin, tail lights, rear bumper foam, back seat, rear deck, and trunk seal

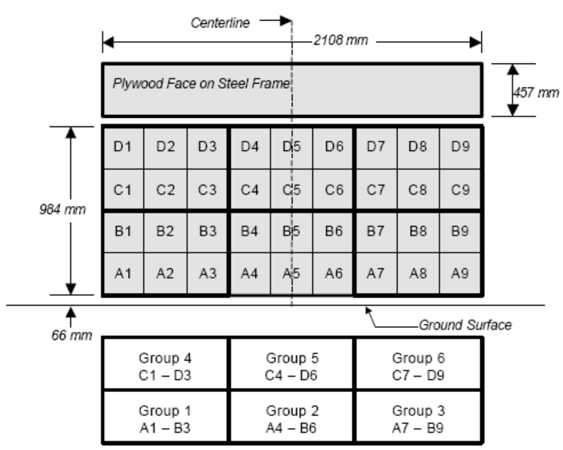
CG rearward of front wheel centerline: 1022 mm

Vehicle wheelbase: 2642 mm

11/6/2008

NCAP 36 load cell wall

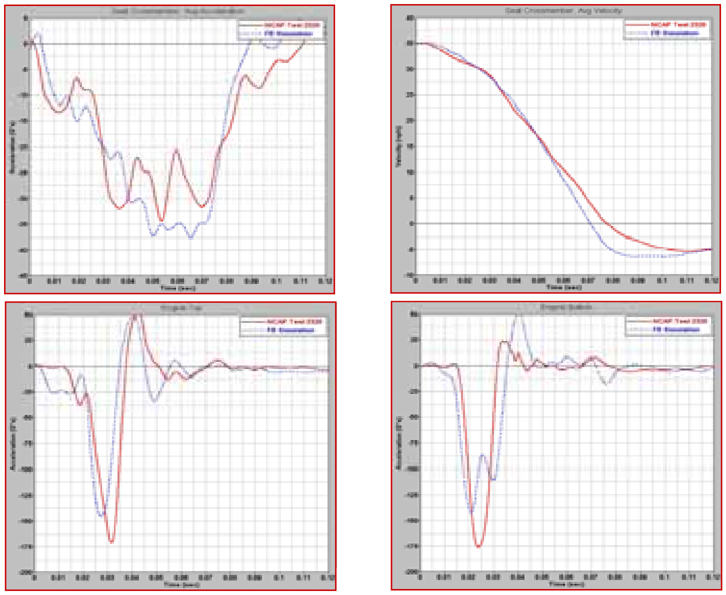
36 Load Cell Rigid Barrier (NHTSA Standard)
Load Cell Locations on Fixed Barrier



6 Groups of 6 Load Cells Each

11/6/2008

Accelerometer Data



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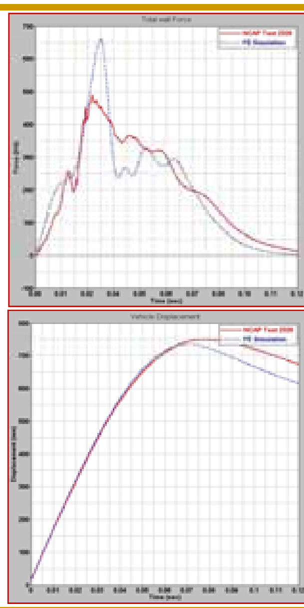
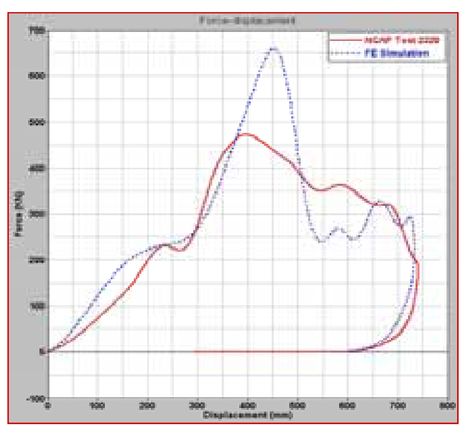
Total wall force & displacement





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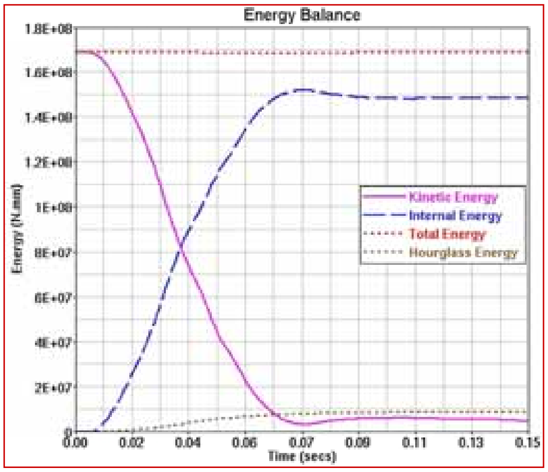
Energy Balance



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Notes

- FE simulation is correlated to NCAP test. FE simulation shows higher wall force compared to the NCAP test.
- FE model is stable in full frontal flat rigid wall simulations (Model has been run at 25, 30, 35 and 40 mph to ensure stability).

11/6/2008

6.2 Ford F250 NCAP Validation Summary

NCAC

FHWA/NHTSA National Crash Analysis Center

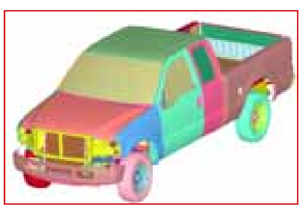
Finite Element Model of Ford F250

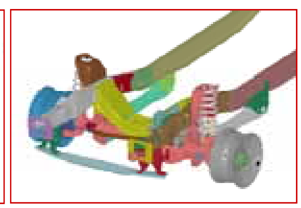
Model Year 2006
Version 1

FE Model of Ford F250

THE GEORGE WASHINGTON UNIVERSITY

VIN 1FTSX21516EA73254, 2006 SD F250 4x4 SUPERCAB





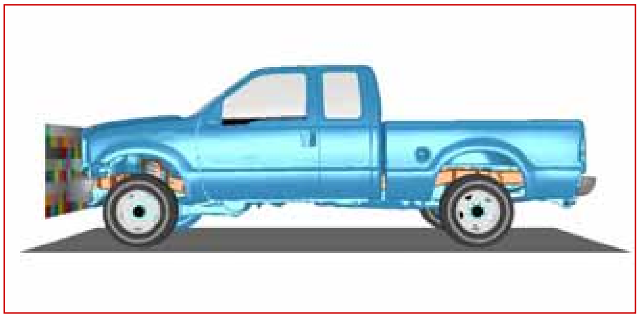
- **Detailed model, can be used for most impact scenarios**
- **Interiors will be added in the next release**
- **Material data derived from coupon testing**
- **Frontal impact into a high resolution load cell wall complete**

Number of Parts	- 871
Number of Nodes	- 738165
Number of Shells	- 698501
Number of Beams	- 2353
Number of Solids	- 25905
Number of Elements	- 726759

11/6/2008

NCAC

Benchmark Data



LS-DYNA
Version: 971
Revision: 7600.398
Platform: Itanium 2
OS level: Linux 2.4.21
Precision: Single precision (I4R4)
Total Elapsed time: ~ 31 hrs (for 150 ms)
Number of processors: 8

Vehicle Comparison

Body Mount Failure

	FE Model	High Res Test 5820
Weight (Kgs)	3016	3054
Engine Type	5.4L EFI V8	5.4L EFI V8
Tire size	LT245/75R 17E	LT245/75R 17E
Attitude (mm) As delivered	F – 1016	F – 1013
	R – 1043	R – 1055
Wheelbase (mm)	3610	3610
CG (mm) Rearward of front wheel C/L	1499	1489
Body Style	Extended Cab	Extended Cab

High Res Barrier Test Summary

Test No.:	5820
Contract or Study Title:	2006 FORD F250 INTO FLAT HIGH RESOLUTION LOAD CELL BAR.
Test Performer:	TRC OF OHIO
Test Reference No.:	060629-2
Test Type:	RESEARCH SAFETY VEHICLE TEST
Test Configuration:	VEHICLE INTO BARRIER
Closing Speed (kph):	55.70
Impact Angle (degrees):	0
Offset Distance (mm):	0
Version No.:	V5
Test Objectives:	EVALUATE VEHICLE AGGRESSIVITY AND FLEET COMPATABILITY
Test Date:	6/29/2006
Contract No.:	VRTC-DC08510
Test Track Surface:	CONCRETE
Test Track Condition:	DRY
Ambient Temperature (degrees Celsius):	21
Type of Recorder:	DIGITAL DATA ACQUISITION
Total No. of Curves:	316
Test Commentary:	

11/6/2008

Test Vehicle Data – 5820

Table 2. General Test and Vehicle Parameter Data

Year/make/model/body style:	2006/Ford/F250/4-door pickup truck
VIN:	1FTSX21546EB57844
Model year:	2006
Body style:	4-door pickup truck
Color:	Dark grey
Engine data:	
Cylinders:	8
Displacement:	5.4 liters
Type:	V
Placement:	Inline
Transmission data:	_5_ speed, __ manual, _X_ automatic, __ overdrive
Final drive:	__ FWD, __ RWD, _X_ 4WD
Date vehicle received:	06/21/06
Odometer reading:	174 miles
Dealer's name and address:	Vehicle provided by VRTC

Accessories:

Power steering	Yes	Automatic transmission	Yes
Power brakes	Yes	Automatic speed control	Yes
Power seats	No	Tilting steering wheel	Yes
Power windows	No	Telescoping steering wheel	No
Tinted glass	Yes	Air conditioning	Yes
Radio	Yes	Anti-skid brake	Yes
Clock	Yes	Rear window defroster	No
Other	None	Power door locks	No

Certification data from vehicle's label:

Vehicle manufactured by:	Ford Motor Co.
Date of manufacture:	10/05
VIN:	1FTSX21546EB57844
GVWR:	9200 lbs. (4173 kg)
GAWR: Front:	5200 lbs. (2359 kg)
Rear:	6100 lbs. (2767 kg)

Tires on vehicle (mfr., line, size):	Continental, A/S, LT245/75R17
Tire pressure with maximum capacity vehicle load:	
Front:	80 psi (550 kPa)
Rear:	80 psi (550 kPa)
Spare tire (mfr., line, size):	Continental, A/S, LT245/75R17
Type of seats:	
Front:	Bench
Rear:	Split bench
Maximum width:	2030 mm
Wheelbase:	3610 mm

Vehicle capacity weight:	1241 kg (2736 lbs.)
Rated cargo/luggage weight:	883 kg (1947 lbs.)

Test vehicle attitude:

Delivered attitude:	LF 1007 mm;	RF 1018 mm;	LR 1049 mm;	RR 1060 mm
Pre-test attitude:	LF 999 mm;	RF 1011 mm;	LR 1049 mm;	RR 1055 mm
Post-test attitude:	LF 1000 mm;	RF 982 mm;	LR 1088 mm;	RR 1073 mm

Weight of test vehicle with required dummies and cargo weight:

Right front	878.4 kg	Right rear	631.4 kg
Left front	916.4 kg	Left rear	628.0 kg
Total front weight	1794.8 kg	(58.8% of total vehicle weight)	
Total rear weight	1259.4 kg	(41.2% of total vehicle weight)	
Total test weight	3054.2 kg	(22.4 kg over target test weight)	

Weight of ballast secured in vehicle: 0.0 kg

Components removed to meet target test weight: tailgate, spare tire with mount, taillights, rear bumper, and tow hitch, jack, rear windows

Location of Vehicle's CG: 1489 mm rearward of front wheel centerline

Fuel System Data:

Usable fuel system capacity	143.8 liters (from owner's manual)
Actual test volume:	0.0 liters (0% of usable)

11/6/2008

High resolution load cell wall

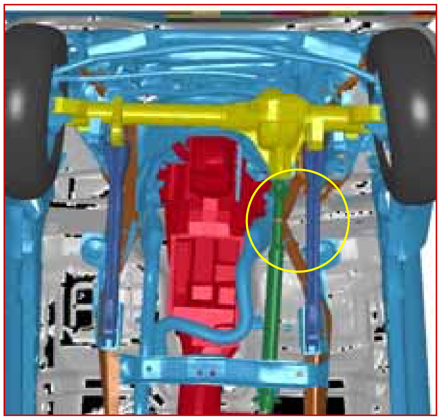
						091	029	131	073						
093	028	024	003	011	123	036	048	111	039	013	017	125	097	096	020
045	015	009	040	069	100	112	075	101	053	117	032	014	090	079	071
082	006	118	001	122	002	060	108	050	124	086	004	026	116	056	010
038	083	018	042	084	099	089	088	129	067	081	054	063	46	052	094
087	092	127	076	057	107	030	016	078	072	064	051	121	049	025	055
043	126	103	130	031	095	106	047	005	021	058	022	007	065	119	133
120	027	034	019	035	113	105	114	109	044	008	134	115	037	070	110
059	085	041	074	023	033	102	061	098	128	068	104	012	088	062	077

330 mm to ground

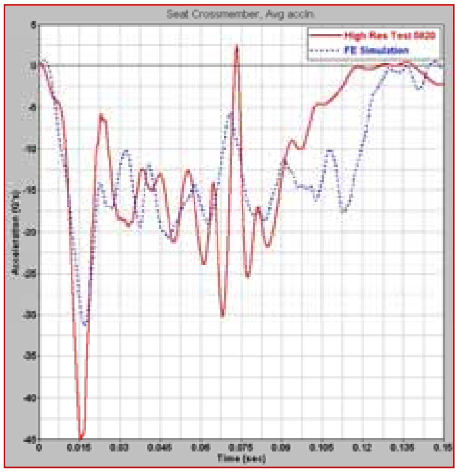
Track C/L

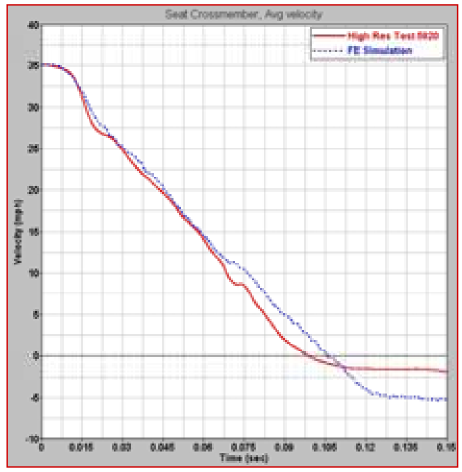
Crush Modes

Bending of the rails



Accelerometer Data





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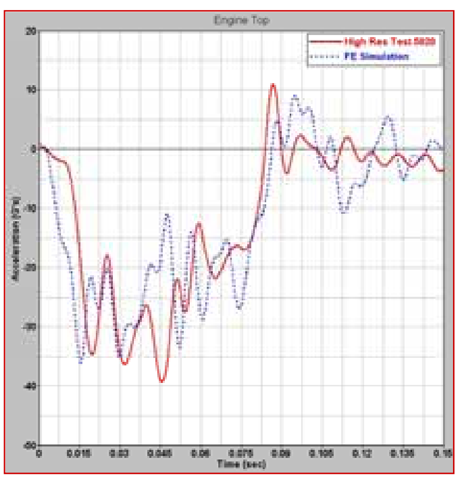
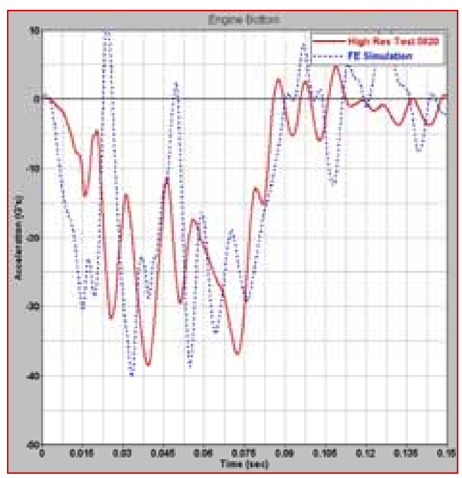
Accelerometer Data





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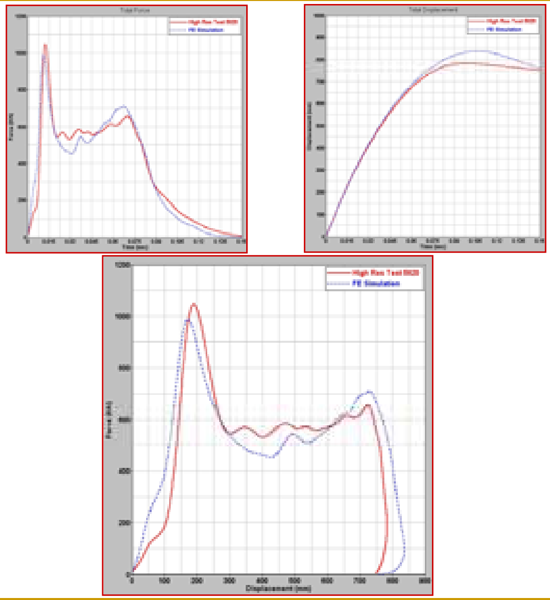
Total wall force & displacement



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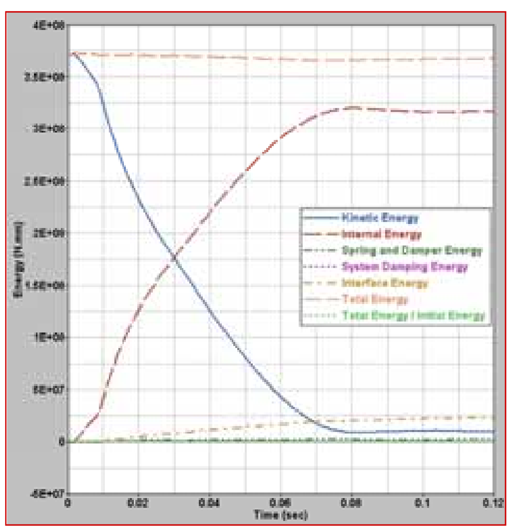
FE Model, Energy Balance



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Summary

- The crush mode of the rails and the structural members shows good correlation between test and simulation which is also reflected in the total wall force
- The initial 150 mm crush in the simulation shows stiffer response compared to the crash test
- Body mount failure plays a critical role in the validation process as the accelerometer is mounted in the cab
  - Further work is required to improve the failure model for the body mounts
- FE model is stable in full frontal flat rigid wall simulations (Model has been run at 25, 30, 35 and 40 mph to ensure stability)

11/6/2008

6.3 Chevy Silverado NCAP Validation Summary

FHWA/NHTSA National Crash Analysis Center

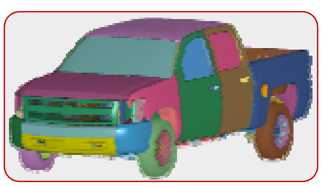
Finite Element Model of Chevy Silverado

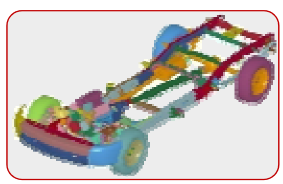
Model Year 2007
Version 1

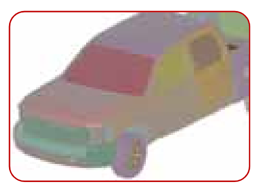
THE GEORGE WASHINGTON UNIVERSITY VIRGINIA CAMPUS

FE Model of Chevy Silverado

VIN 2GCEC13C771511793, 2007 Chevy Silverado 1500 2WD Crew Cab Short Box





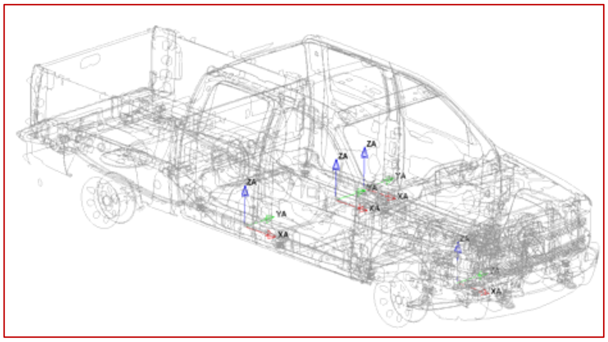


- **Detailed model, can be used for most impact scenarios**
- **Interiors will be added in the next release**
- **Material data derived from coupon testing**
- **Frontal impact validation into a rigid load cell wall complete**

Number of Parts	- 676
Number of Nodes	- 942491
Number of Shells	- 872960
Number of Beams	- 2654
Number of Solids	- 53286
Number of Elements	- 928932

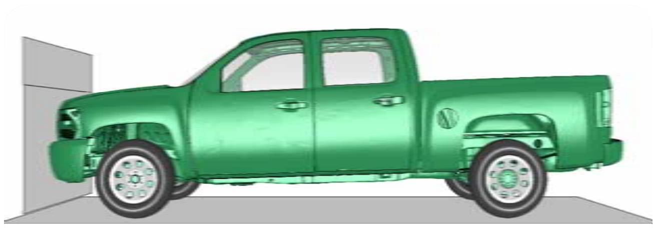
11/6/2008

Accelerometer Locations



Location	- Node ID
Right seat	- 2739121
Left seat	- 2739129
Engine bottom	- 2939137
Vehicle CG	- 2942560

Benchmark Data



LS-DYNA
Version: mpp971
Revision: 7600.1224
Platform: SGI Altix (Itanium 2)
OS level: Linux 2.4
Precision: Single precision (I4R4)
Total Elapsed time: ~ 10 hrs (for 150 ms)
Number of processors: 16

Vehicle Comparison

Left Side View

Right Side View

	FE Model	NCAP Test 5877
Weight (Kgs)	2622	2622
Engine Type	4.8 L V8	4.8 L V8
Tire size	P245/70R17	P245/70R17
Attitude (mm) As delivered	F – 1016 R – 1043	F – 929 R – 1002
Wheelbase (mm)	3660	3664
CG (mm) Rearward of front wheel C/L	1670	1664
Body Style	4-door crew cab	4-door crew cab

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NCAC

NCAP Test Summary

Test No.:	5877
Contract or Study Title:	35 MPH NCAP FRONTAL - 2007 CHEVROLET SILVERADO LT1 4-DOOR TRUCK
Test Performer:	KARCO ENGINEERING
Test Reference No.:	M70109
Test Type:	NEW CAR ASSESSMENT TEST
Test Configuration:	VEHICLE INTO BARRIER
Closing Speed (kph):	56.15
Impact Angle (degrees):	0
Offset Distance (mm):	0
Version No.:	V5
Test Objectives:	OBTAIN ATD AND VEHICLE DATA
Test Date:	11/9/2006
Contract No.:	DTNH22-06-D-00027
Test Track Surface:	CONCRETE
Test Track Condition:	DRY
Ambient Temperature (degrees Celsius):	19
Type of Recorder:	DIGITAL DATA ACQUISITION
Total No. of Curves:	132
Test Commentary:	DATALINK IS NONE, ON-BOARD DAS

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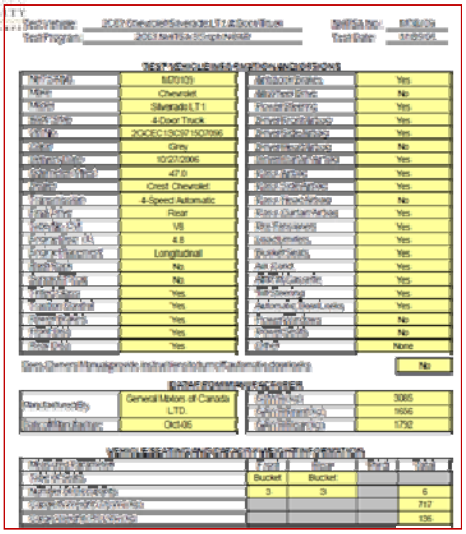
NCAC

NCAP Test Vehicle Data


Test Vehicle: 2007 Chevrolet Silverado LT1 4 Door Truck
Test Program: 2007 NHTSA [illegible] NCAP

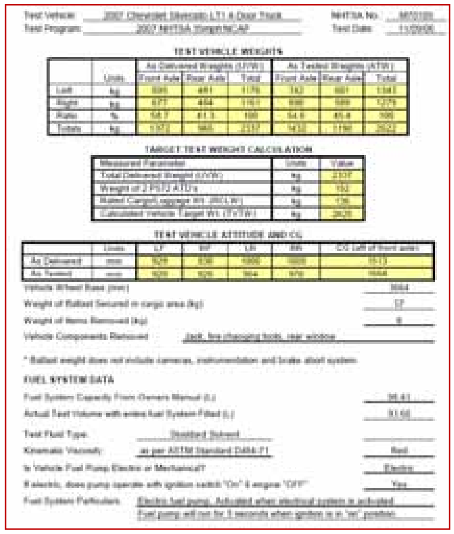
TEST VEHICLE DESCRIPTION AND OPTIONS

[illegible]	MD0109	[illegible]	Yes
Make	Chevrolet	[illegible]	No
Model	Silverado LT1	[illegible]	Yes
Body Style	4-Door Truck	[illegible]	Yes
VIN	2GCEC13C971507096	[illegible]	Yes
Color	Grey	[illegible]	No
[illegible]	10/27/2006	[illegible]	Yes
[illegible]	47.0	[illegible]	Yes
Dealer	Crest Chevrolet	[illegible]	Yes
Transmission	4-Speed Automatic	[illegible]	No
Final Drive	Rear	[illegible] Curtain Airbag	Yes
[illegible]	V8	[illegible]	Yes
[illegible]	4.8	[illegible]	Yes
[illegible]	Longitudinal	Bucket Seats	Yes
[illegible]	No	Air Cond.	Yes
[illegible]	No	[illegible]	Yes
[illegible]	Yes	Tilt Steering	Yes
Traction Control	Yes	Automatic Seat Locks	Yes
Power Brakes	Yes	Power Windows	No
[illegible]	Yes	Power Seats	No
[illegible]	Yes	Other	None

Manufactured By	General Motors of Canada LTD.
[illegible]	Oct/06
[illegible]	3085
[illegible]	1656
[illegible]	1792

VEHICLE SEATING AND CARGO WEIGHT INFORMATION

[illegible]	Front	Rear	Third	Total
[illegible]	Bucket	Bucket		
[illegible]	3	3		6
[illegible]				717
[illegible]				136


Test Vehicle: 2007 Chevrolet Silverado LT1 4 Door Truck
Test Program: 2007 NHTSA [illegible] NCAP

TEST VEHICLE WEIGHTS

TARGET TEST WEIGHT CALCULATION

TEST VEHICLE ATTITUDE AND CG

FUEL SYSTEM DATA

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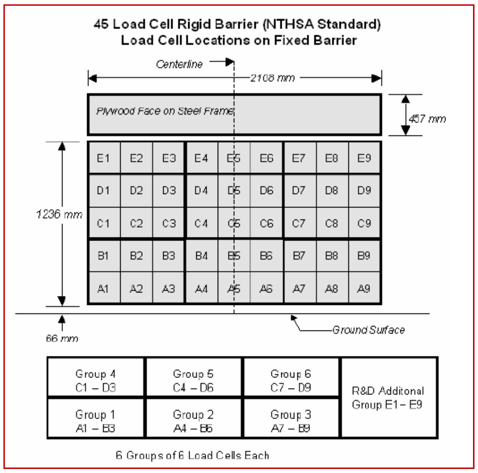
NCAP load cell wall



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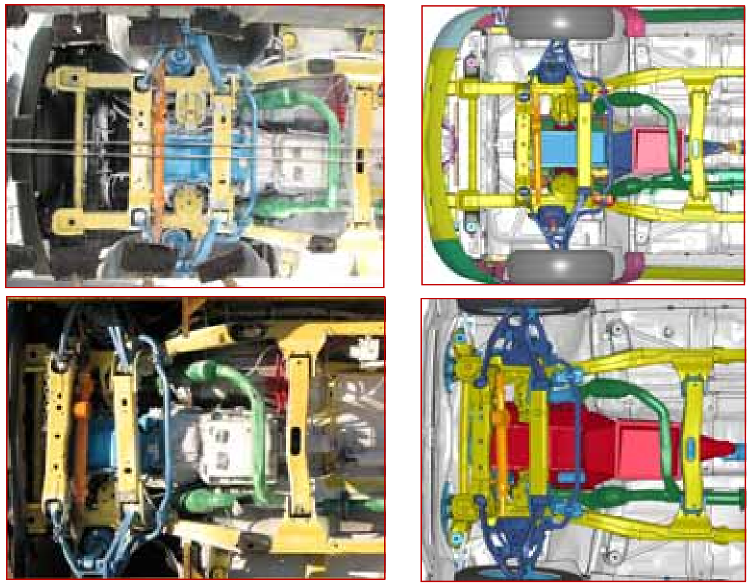
Crush Modes

Pre-Test

Post-Test



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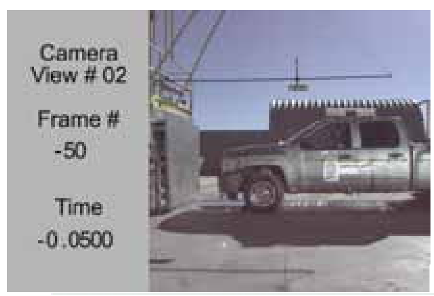
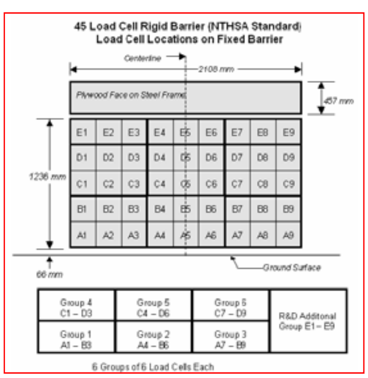
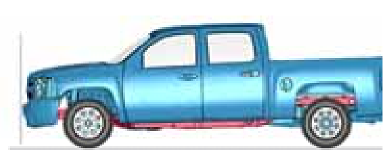
NHTSA Test

- **NHTSA Test 5877, frontal NCAP**
  - 2007 Chevy Silverado NCAP test
  - 45 load cell wall







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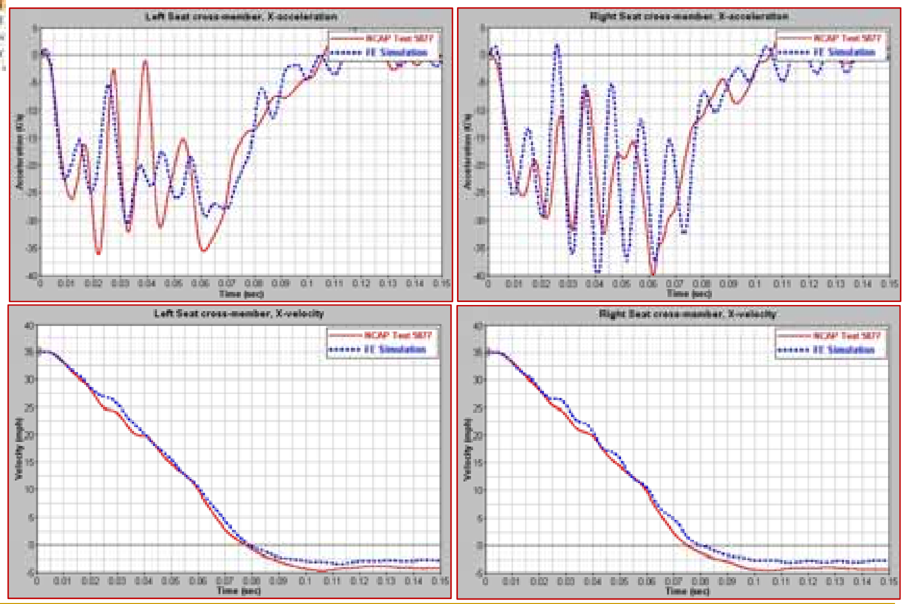
Accelerometer Data



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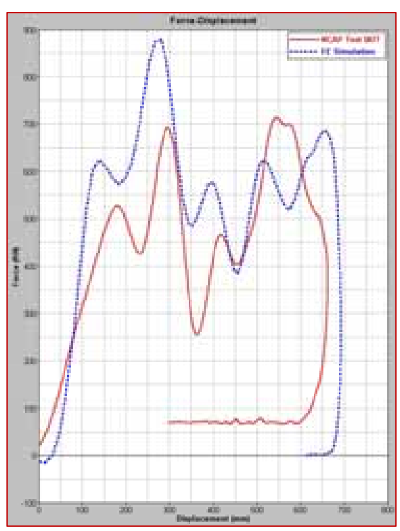
NCAC

Force-displacement

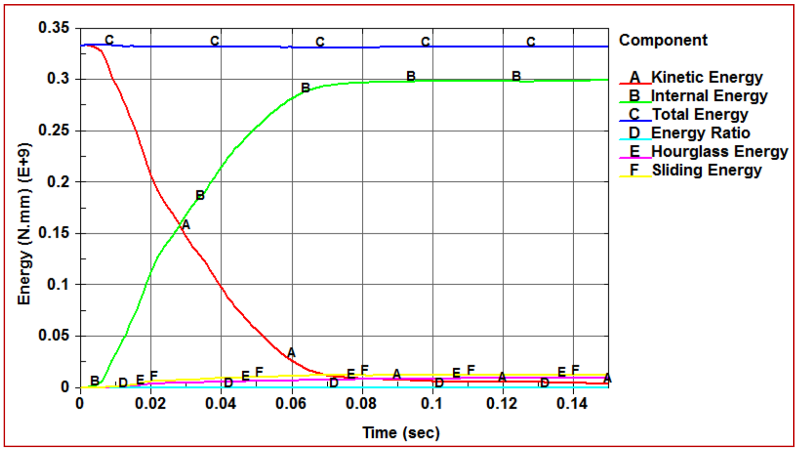


Note: Missing data from Load Cell C3 in Test 5877

11/6/2008

NCAC

Energy Balance



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Summary

- Model verified against frontal NCAP test (NHTSA Test No. 5877).
- The crush mode of the rails and the structural members shows good correlation between test and simulation.
- Engine and Body mount failure were observed in the NCAP test. Current model does not include failure of these components to ensure robustness.
- Suspension system is modeled in greater detail.
- Vehicle is set to equilibrium position under gravity loading.
- Future updates will include verification against low speed bump and terrain tests conducted at FOIL.
- FE model is stable in full frontal flat rigid wall simulations (Model has been run at 25, 30 and 35 mph to ensure stability).

11/6/2008

DOT HS 811 293
March 2010

U.S. Department
of Transportation

National Highway
Traffic Safety
Administration

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