THE RELATIONSHIP BETWEEN CRASH SEVERITY AND INCOMPATIBILITY IN FRONTAL CRASHES

A CIREN CENTER
THE WILLIAM LEHMAN INJURY RESEARCH CENTER
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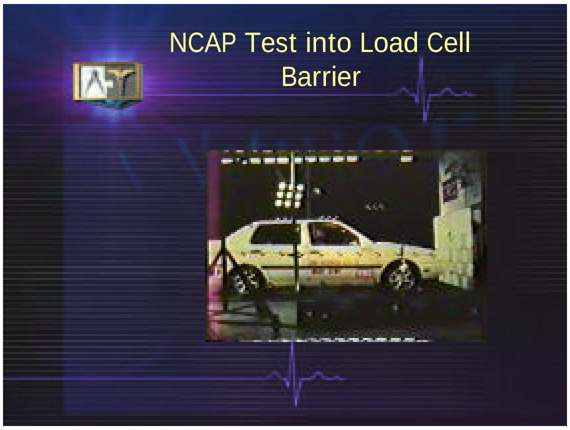
Director, WLIRC

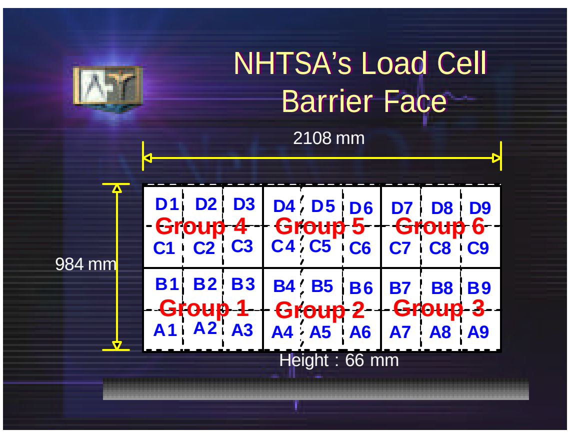
Incompatibility Issues

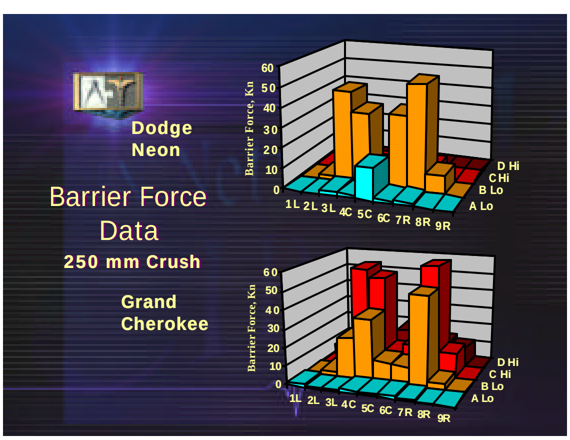
- Mass difference is a well known incompatibility
- Other incompatibilities - Stiffness & Geometry
- Regulations to control stiffness and geometry under consideration
- What role does stiffness and geometry play in real world crashes?
- Would control of stiffness and geometry in barrier crashes provide real world benefits?

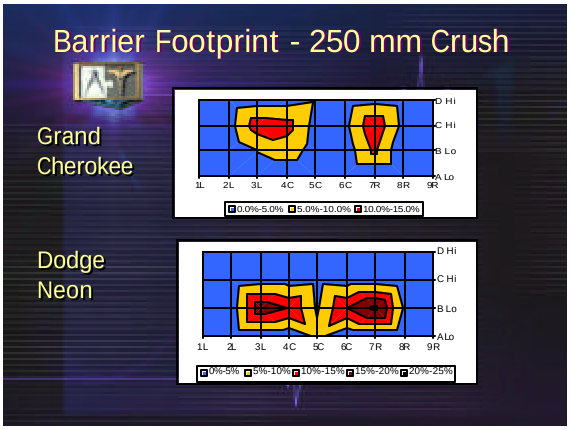
Past NHTSA Research

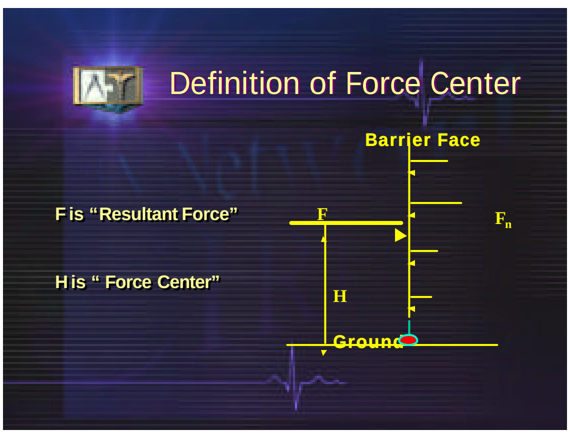
- Analysis of FARS car to truck crashes showed passenger cars occupants at disadvantage
- Barrier crash data shows light trucks are stiffer and have higher center of force

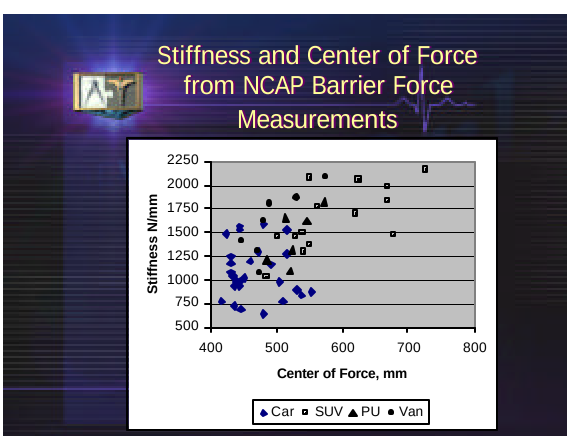

NCAP Test into Load Cell
Barrier

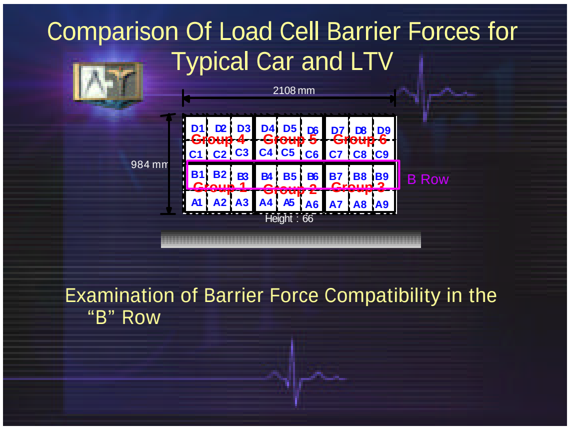

NHTSA's Load Cell
Barrier Face
2108 mm
984 mm
D1 D2 D3 D4 D5 D6 D7 D8 D9
Group 4 Group 5 Group 6
C1 C2 C3 C4 C5 C6 C7 C8 C9
B1 B2 B3 B4 B5 B6 B7 B8 B9
Group 1 Group 2 Group 3
A1 A2 A3 A4 A5 A6 A7 A8 A9
Height : 66 mm

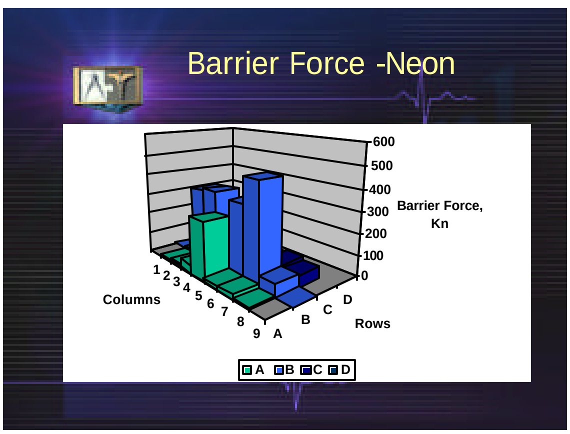

Dodge
Neon
Barrier Force
Data
250 mm Crush
Grand
Cherokee
Barrier Force, Kn
0 10 20 30 40 50 60
1L 2L 3L 4C 5C 6C 7R 8R 9R
D Hi
C Hi
B Lo
A Lo

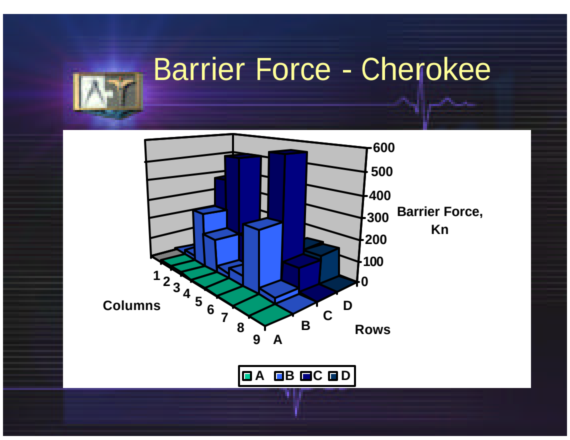

Barrier Footprint - 250 mm Crush
Grand Cherokee
Dodge Neon
D Hi
C Hi
B Lo
A Lo
1L 2L 3L 4C 5C 6C 7R 8R 9R
0.0%-5.0% 5.0%-10.0% 10.0%-15.0%
0%-5% 5%-10% 10%-15% 15%-20% 20%-25%


Definition of Force Center
Barrier Face
F is "Resultant Force"
H is " Force Center"
F
H
Ground

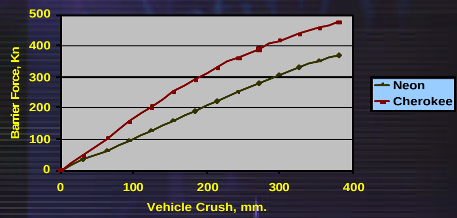

Stiffness and Center of Force from NCAP Barrier Force Measurements
Stiffness N/mm
2250
2000
1750
1500
1250
1000
750
500
400 500 600 700 800
Center of Force, mm
Car SUV PU Van


Comparison Of Load Cell Barrier Forces for Typical Car and LTV
2108 mm
984 mm
D1 D2 D3 D4 D5 D6 D7 D8 D9
Group 4 Group 5 Group 6
C1 C2 C3 C4 C5 C6 C7 C8 C9
B1 B2 B3 B4 B5 B6 B7 B8 B9
Group 1 Group 2 Group 3
A1 A2 A3 A4 A5 A6 A7 A8 A9
B Row
Height : 66
Examination of Barrier Force Compatibility in the "B" Row

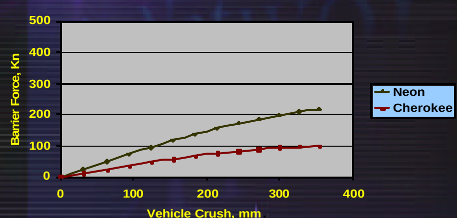

Barrier Force -Neon
600
500
400
300
200
100
0
Barrier Force, Kn
Columns
1 2 3 4 5 6 7 8 9
A B C D
Rows
A B C D


Barrier Force - Cherokee
600
500
400
300
200
100
0
Barrier Force, Kn
Columns
1 2 3 4 5 6 7 8 9
A B C D
Rows
A B C D

Barrier Force vs. Vehicle Crush
All Load Cell Rows



Barrier Force vs. Vehicle Crush
Only 'B' Load Cell Row



Observation

- Max force of most cars in "B" row
- May produce forces of greater magnitude than SUV forces in the "B" row
- Mismatch may reduce stiffness mismatch in lower severity crashes – until occupant compartment intrusion occurs
- Injuries will be intrusion related rather than acceleration related
- Lower limbs most vulnerable

Research Questions

- Does the higher center-of-force on light trucks lead to reduced injury risk in cars when the crash severity is low?
- What happens to the injury risk in high severity car-to-LTV crashes?
- What is the role of intrusion vs. acceleration in car-to-LTV crashes?

Data for NASS/CDS Study SAE 2001

- 1997 & 1998 Car to LTV Frontal Crashes
- Crush Measurements on Both Vehicles
- Pictures of Both Vehicles
- Delta-V Known for Both Vehicles
- Injury Data for Occupants Available
- 44 Cases
- 23 with MAIS 3+ Injuries to Car Drivers

NASS Case Study of Car Drivers 23 Cases with MAIS 3+

- 9 injuries with no compatibility influence
- 5 cases with injuries explained by mass
- 5 cases in which geometry or stiffness were influential factors increasing injuries
- 4 cases in which geometric incompatibility may have decreased or prevented injuries
- All MAIS 3+ injuries at lower Delta-V were lower limb injuries

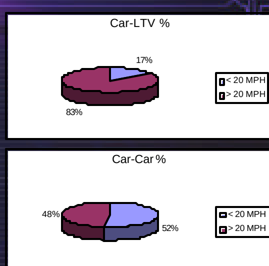
Examination of Frontal Crashes in NASS 1997-2000

- Distribution
- Injury risk

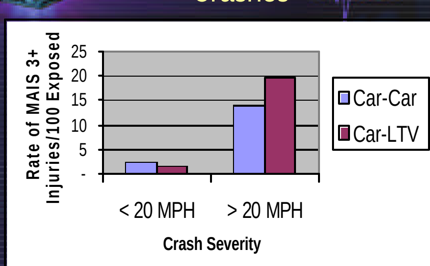
- Car-to-car
- Car-to-LTV

- Above 20 mph
- Below 20 mph

Distribution of Crashes Above and Below 20 mph



Injury Rate for Car-to-Car and Car-to-LTV Frontal Crashes

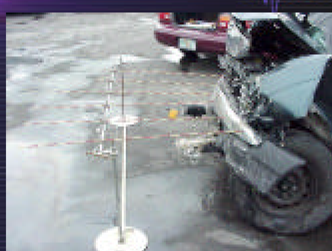


Crash Investigation to Examine Effect of Geometric and Stiffness Compatibility

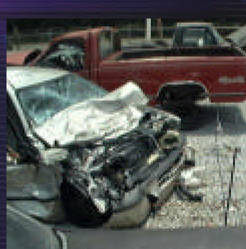
To evaluate the effect of stiffness and geometry

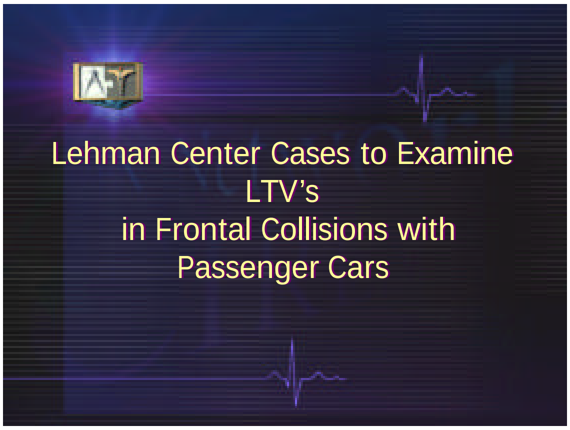
- Need to collect data on POV
- Need to document underride/override
- Need to evaluate frequency of intrusion vs acceleration injuries
- Need to document frame deformation modes

Ramrod Effect of Frame

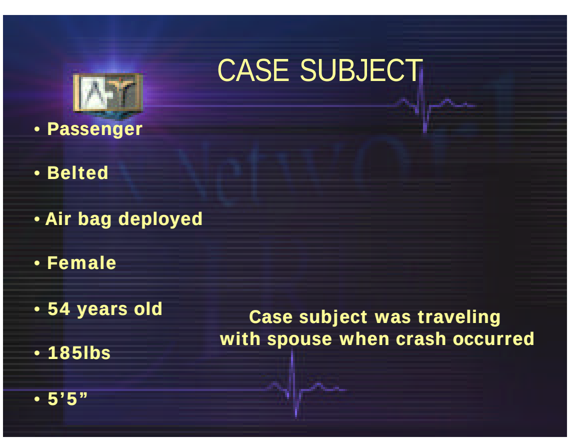


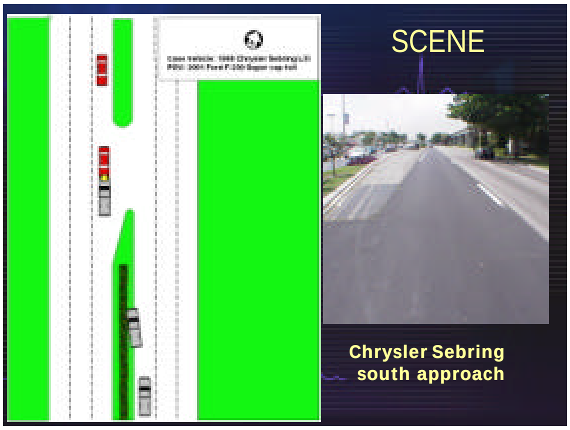
Vehicle Override



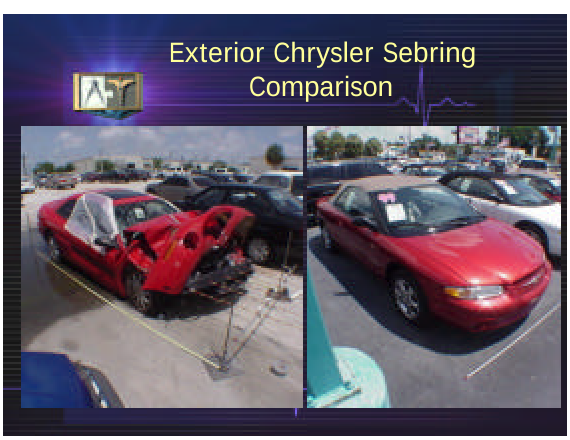

Lehman Center Cases to Examine LTV’s
in Frontal Collisions with Passenger Cars

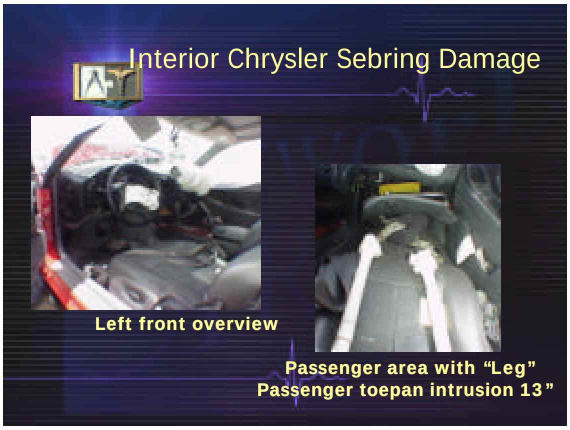

MODERATE
SEVERITY CRASH
1998 Chrysler Sebring
VS
2001 Ford F-250


CASE SUBJECT
• Passenger
• Belted
• Air bag deployed
• Female
• 54 years old
• 185lbs
• 5’5”
Case subject was traveling with spouse when crash occurred

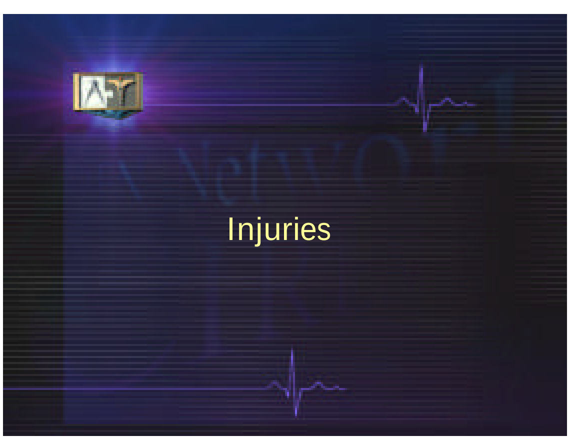

SCENE
Chrysler Sebring
south approach

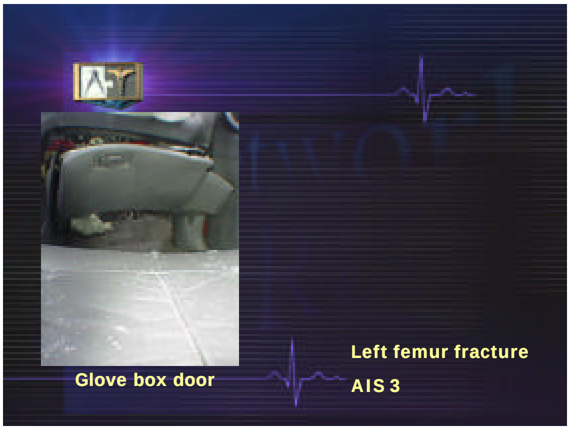

EXTERIOR CHRYSLER
SEBRING DAMAGE
Right side
Reduction in
wheelbase 6.7 ”
Left front quarter view

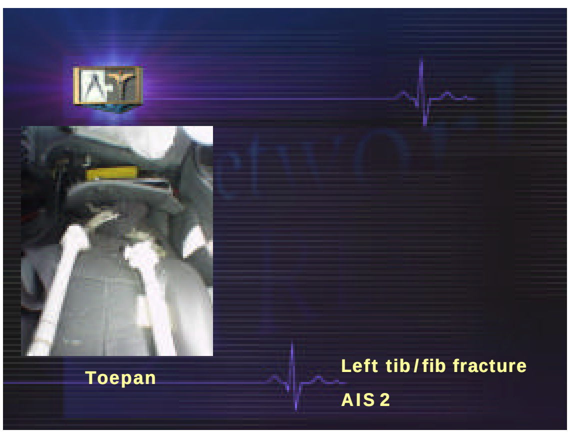

Exterior Chrysler Sebring
Comparison

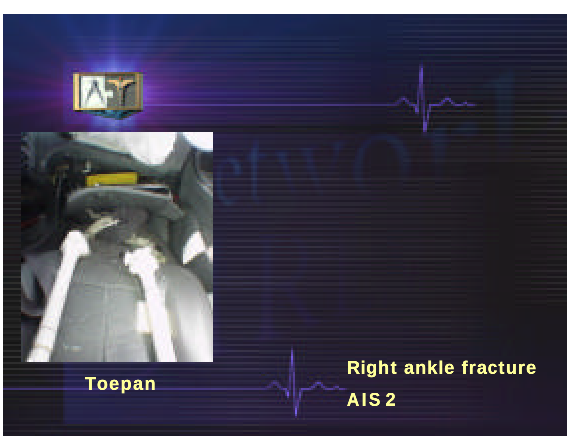

Interior Chrysler Sebring Damage
Left front overview
Passenger area with “Leg”
Passenger toepan intrusion 13”


Interior Chrysler Sebring
Comparison


Injuries


Glove box door
Left femur fracture
AIS 3


Toepan
Left tib/fib fracture
AIS 2


Toepan
Right ankle fracture
AIS 2

CONTACTS SUMMARY

Injury / Contact source	AIS
• Fracture, Right Midshaft Femur — Glove Box Door	AIS 3
• Fracture, Left Distal Tibia — Right Toe pan	AIS 2
• Fracture, Left Distal Fibula — Right Toe Pan	AIS 2
• Fracture, Right Ankle — Right Toe Pan	AIS 1
• Contusion, Right Knee — Glove Box Door	AIS 1
• Fracture, Left Rib — Belt Restraint	AIS 1
• Contusion, Left Breast — Belt Restraint	AIS 1

Comparison of Vehicle Dimensions

1998 Chrysler Sebring		2001 Ford F-250	
Bumper Height:	25”	Bumper Height:	31.25”
Frame Rail Upper:	20.25”	Frame Rail Upper:	29”
Frame Rail Lower:	16.5”	Frame Rail Lower:	23.5”
Mass:	2908lb	Mass:	5635lb
Stiffness:	Moderate	Stiffness:	Very High

Case Significance

- 25 mph crash with
  - 13” of pass toepan intrusion
  - 0” of driver toepan intrusion
- Driver OK – low intrusion
- Passenger with lower extremity injuries due to intrusion
- No head or chest injuries
- Incompatibility increased intrusion
- Incompatibility may have prevented head and chest injuries to driver and passenger

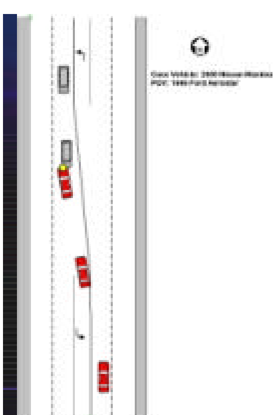
Moderate Severity Crash

2000 Nissan Maxima
VS
1996 Ford Aerostar

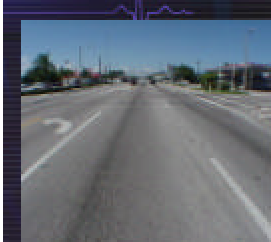
Case Subject

- Driver
- Male
- Unbelted
- Air bag deployed
- 45 years old
- 185lbs
- 5’11”

Case subject was under the influence of alcohol when this late night crash occurred

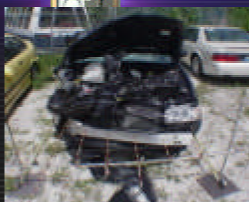


Scene



Nissan Maxima north approach

Exterior Nissan Maxima Damage



Frontal view

DeltaV:	25.6mph
Max crush:	18.1”
Position:	C6
PDOF: o’clock	1

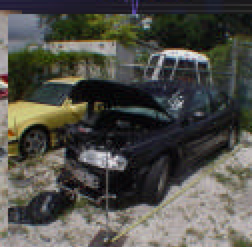
Wheelbase

Pre: 108.1” Post: 101.9”

Reduction: 6.4”

Exterior Nissan Maxima Damage

Lateral view from right

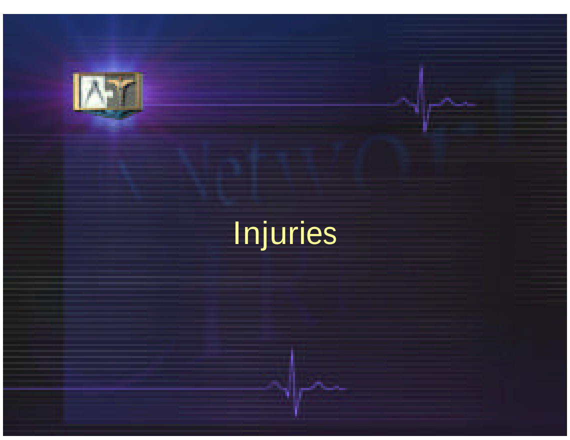


Left front quarter view

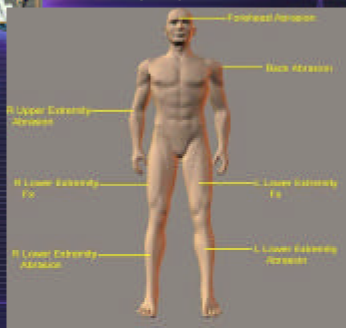
Exterior Nissan Maxima Comparison


Lateral view of steering wheel from right


Interior Nissan Maxima
Comparison
No driver toepan intrusion!


Injuries

Injury Overview



Contacts Summary

Fracture, Left & right femurs	**AIS 3**
Knee bolster	
Fracture, Left 5th & 6th Rib	**AIS 2**
Driver air bag	
Abrasion, Forehead	**AIS 1**
Windshield	
Abrasion, Right elbow	**AIS 1**
Windshield	
Abrasion, Left & right shin	**AIS 1**
Left instrument panel and below	

Contacts Summary

Fracture, Left & right femurs	**AIS 3**
Knee bolster	
Fracture, Left 5th & 6th Rib	**AIS 2**
Driver air bag	
Abrasion, Forehead	**AIS 1**
Windshield	
Abrasion, Right elbow	**AIS 1**
Windshield	
Abrasion, Left & right shin	**AIS 1**
Left instrument panel and below	

Comparison of Vehicle Dimensions

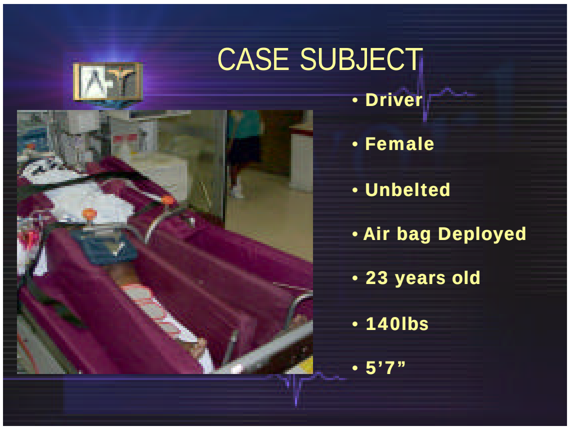
2000 Nissan Maxima		1996 Ford Aerostar	
Bumper Height:	28.25"	Bumper Height:	23"
Frame Rail Upper:	21.5"	Frame Rail Upper:	21.5"
Frame Rail Lower:	15.5"	Frame Rail Lower:	15.75"
Mass:	3294lb	Mass:	3500lb
Stiffness:	Moderate	Stiffness:	High

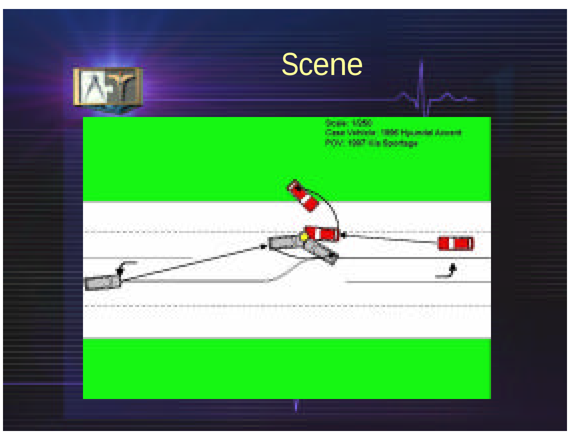
Case Significance

- 45 Year old Driver in 25+ mph delta V
- 5.1" right toepan intrusion (No toepan intrusion on left)
- Left Femur Fracture- AIS 3
- Rib Fracture – AIS 2
- Good geometric and mass compatibility
- Intrusion not an issue
- Stiffness incompatibility may have contributed to the injury

HIGH SEVERITY CRASH

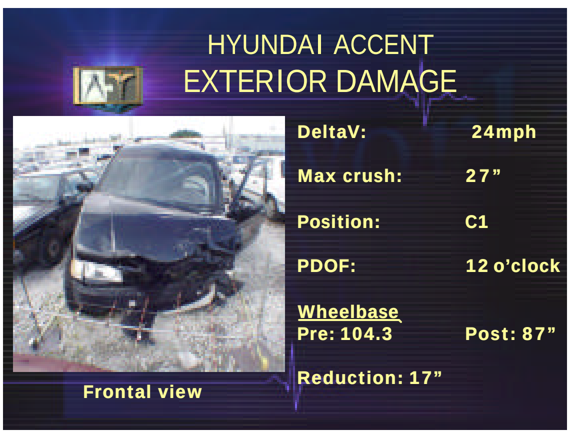
1996 Hyundai Accent
VS
1997 Kia Sportage

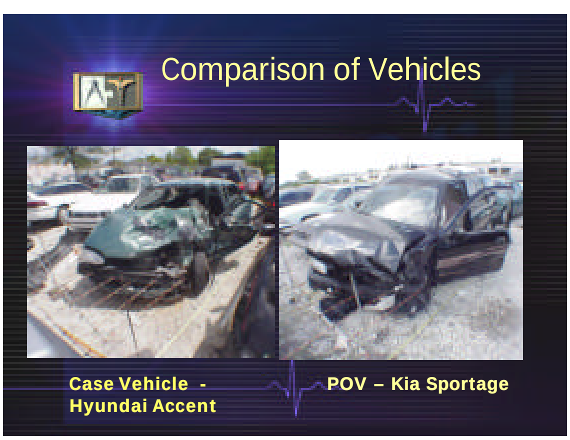

CASE SUBJECT
• Driver
• Female
• Unbelted
• Air bag Deployed
• 23 years old
• 140lbs
• 5’7”

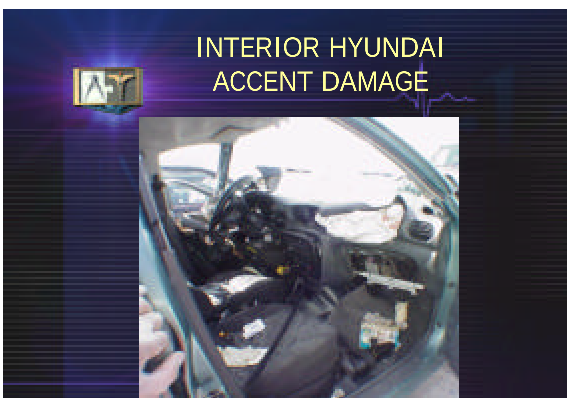

Scene


EXTERIOR HYUNDAI ACCENT DAMAGE
DeltaV: 35mph
Max crush: 33”
Position: C1
PDOF: 12 o’clock
Wheelbase
Pre: 95.4” Post: 71”
Reduction: 24.4”
Frontal view

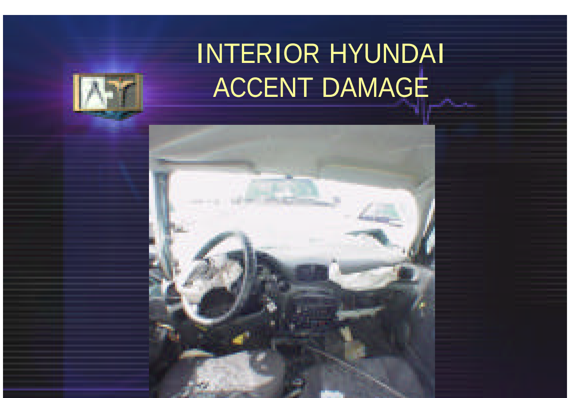

EXTERIOR HYUNDAI
ACCENT COMPARISON


HYUNDAI ACCENT
EXTERIOR DAMAGE
DeltaV: 24mph
Max crush: 27”
Position: C1
PDOF: 12 o’clock
Wheelbase
Pre: 104.3 Post: 87”
Reduction: 17”
Frontal view


Comparison of Vehicles
Case Vehicle -
Hyundai Accent
POV – Kia Sportage



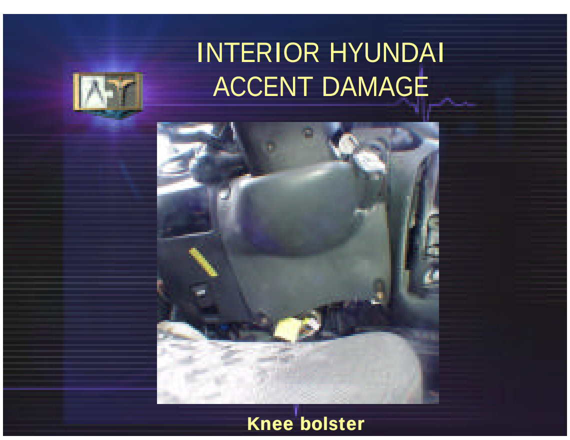
Right front overview



Instrument panel


INTERIOR HYUNDAI
ACCENT DAMAGE
Left instrument panel intrusion 15”


INTERIOR HYUNDAI
ACCENT DAMAGE
Driver area overview
Toepan intrusion 18.5”


INTERIOR HYUNDAI
ACCENT DAMAGE
Knee bolster

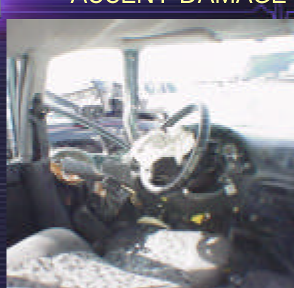
INTERIOR HYUNDAI ACCENT DAMAGE

Driver air bag

INTERIOR HYUNDAI ACCENT DAMAGE

Steering wheel

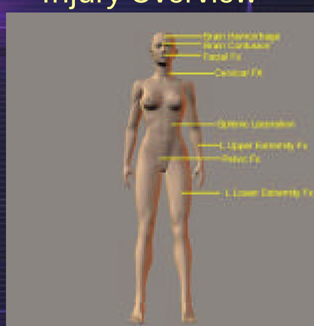
INTERIOR HYUNDAI ACCENT DAMAGE

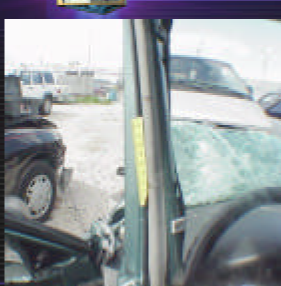


Driver area overview

Injuries

Injury Overview

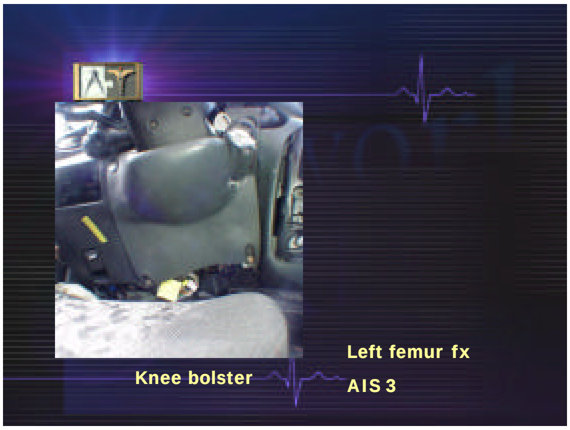




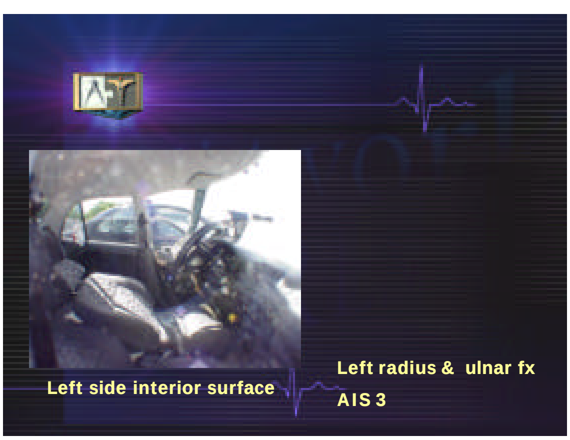
A pillar

Left radius & ulnar fx

AIS 3


Knee bolster
Left femur fx
AIS 3


Left side interior surface
Bilateral inferior pubis rami fx
AIS 2


Left side interior surface
Left radius & ulnar fx
AIS 3

Contacts Summary

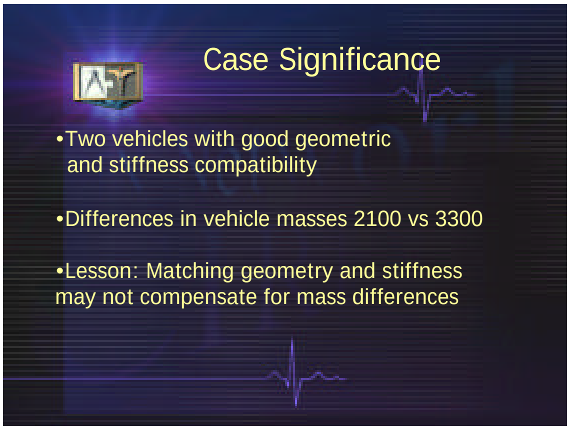
Fracture, Left femur Knee bolster	AIS 3
Fracture, Left ulna Left A pillar	AIS 3
Fracture, Left radius Left A pillar	AIS 3
Fracture, Third cervical vertebra Left A pillar	AIS 3
Hemorrhage, Subarachnoid space Left A pillar	AIS 3
Contusion, Frontal Lobe Left A pillar	AIS 3

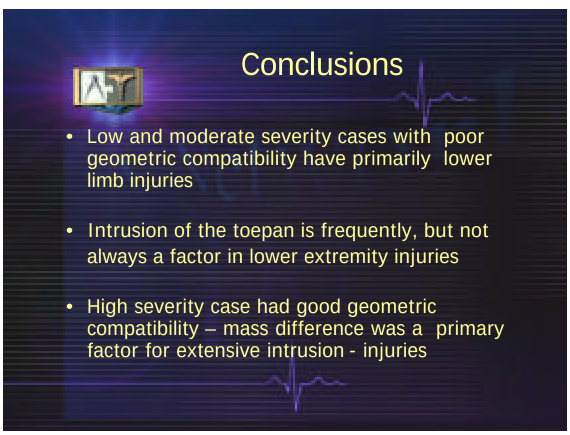
Contacts Summary

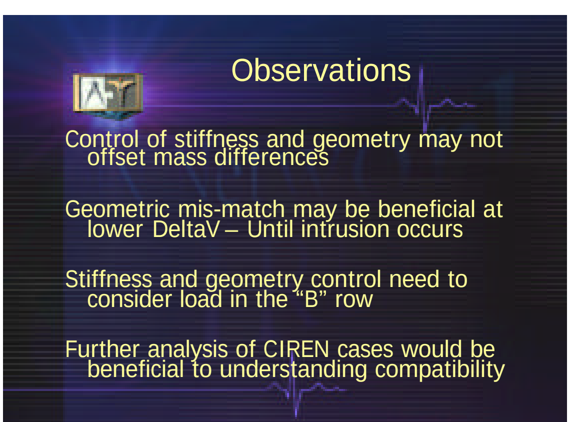
Fracture, Anterior maxilla Left A pillar	AIS 2
Fracture, Fourth cervical vertebra Left A pillar	AIS 2
Laceration, Spleen Left side hardware & armrest	AIS 2
Fracture, Bilateral pubis rami Left side interior surface excluding hardware & armrest	AIS 2

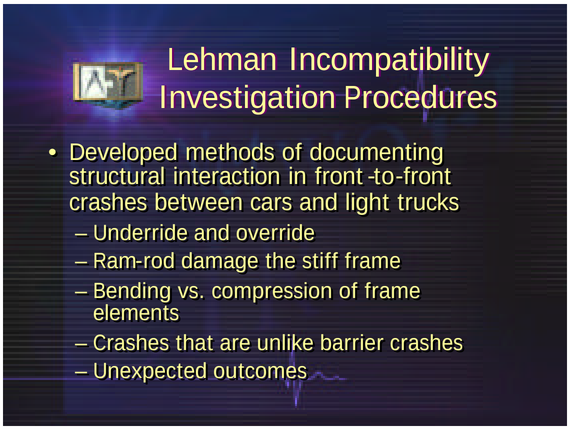
Comparison of Vehicle Dimensions

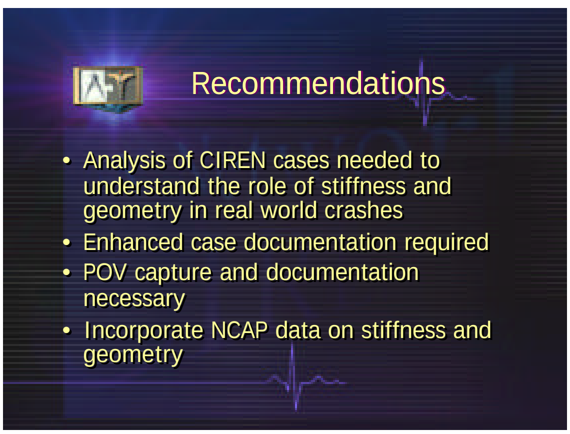
1996 Hyundai Accent		1997 Kia Sportage	
Bumper Height:	21”	Bumper Height:	25.5”
Frame Rail Upper:	19.75”	Frame Rail Upper:	19”
Frame Rail Lower:	15	Frame Rail Lower:	15.25”
Mass:	2105lb	Mass:	3280lb
Stiffness:	Moderate	Stiffness:	Moderate


Case Significance
•Two vehicles with good geometric and stiffness compatibility
•Differences in vehicle masses 2100 vs 3300
•Lesson: Matching geometry and stiffness may not compensate for mass differences


Conclusions
• Low and moderate severity cases with poor geometric compatibility have primarily lower limb injuries
• Intrusion of the toepan is frequently, but not always a factor in lower extremity injuries
• High severity case had good geometric compatibility – mass difference was a primary factor for extensive intrusion - injuries


Observations
Control of stiffness and geometry may not offset mass differences
Geometric mis-match may be beneficial at lower DeltaV – Until intrusion occurs
Stiffness and geometry control need to consider load in the "B" row
Further analysis of CIREN cases would be beneficial to understanding compatibility


Lehman Incompatibility Investigation Procedures
• Developed methods of documenting structural interaction in front-to-front crashes between cars and light trucks
– Underride and override
– Ram-rod damage the stiff frame
– Bending vs. compression of frame elements
– Crashes that are unlike barrier crashes
– Unexpected outcomes


Recommendations
• Analysis of CIREN cases needed to understand the role of stiffness and geometry in real world crashes
• Enhanced case documentation required
• POV capture and documentation necessary
• Incorporate NCAP data on stiffness and geometry