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Vehicle Countermeasures Against Incompatible Crashes

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Safety Improvement

Understand Problem

Field DATA

Way to Evaluate

Injury Criteria

ATD

Test Procedure

Design Countermeasure

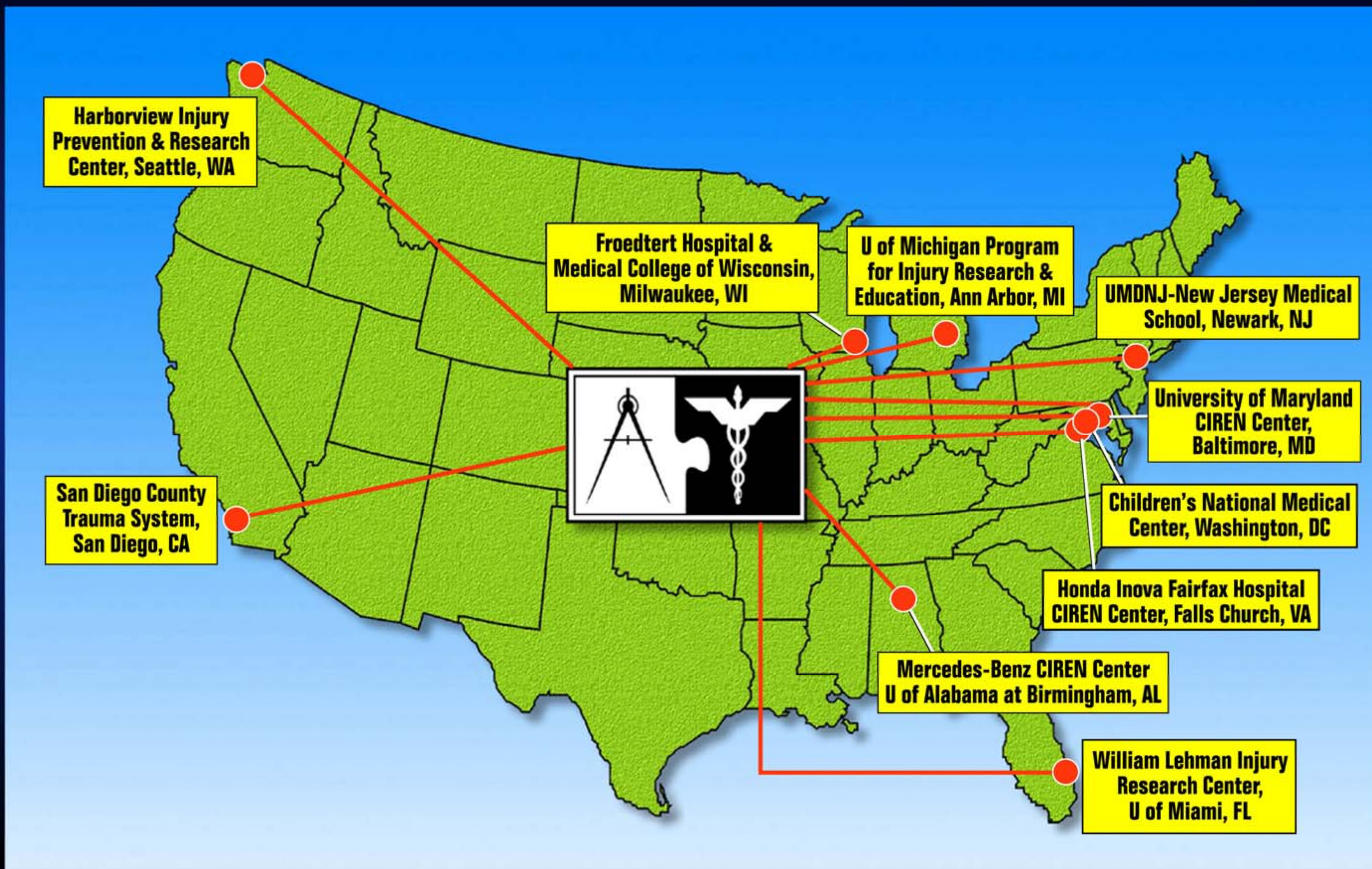
Engineering

Manufacturing

Repeatability

People Saving People
www.nhtsa.dot.gov

CIREN Network



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Half the vehicles sold in the USA
are SUVs, light trucks or vans

Vehicle Incompatibility

Mass, Stiffness, Geometry

Vehicle Incompatibility

Worst Case Scenario

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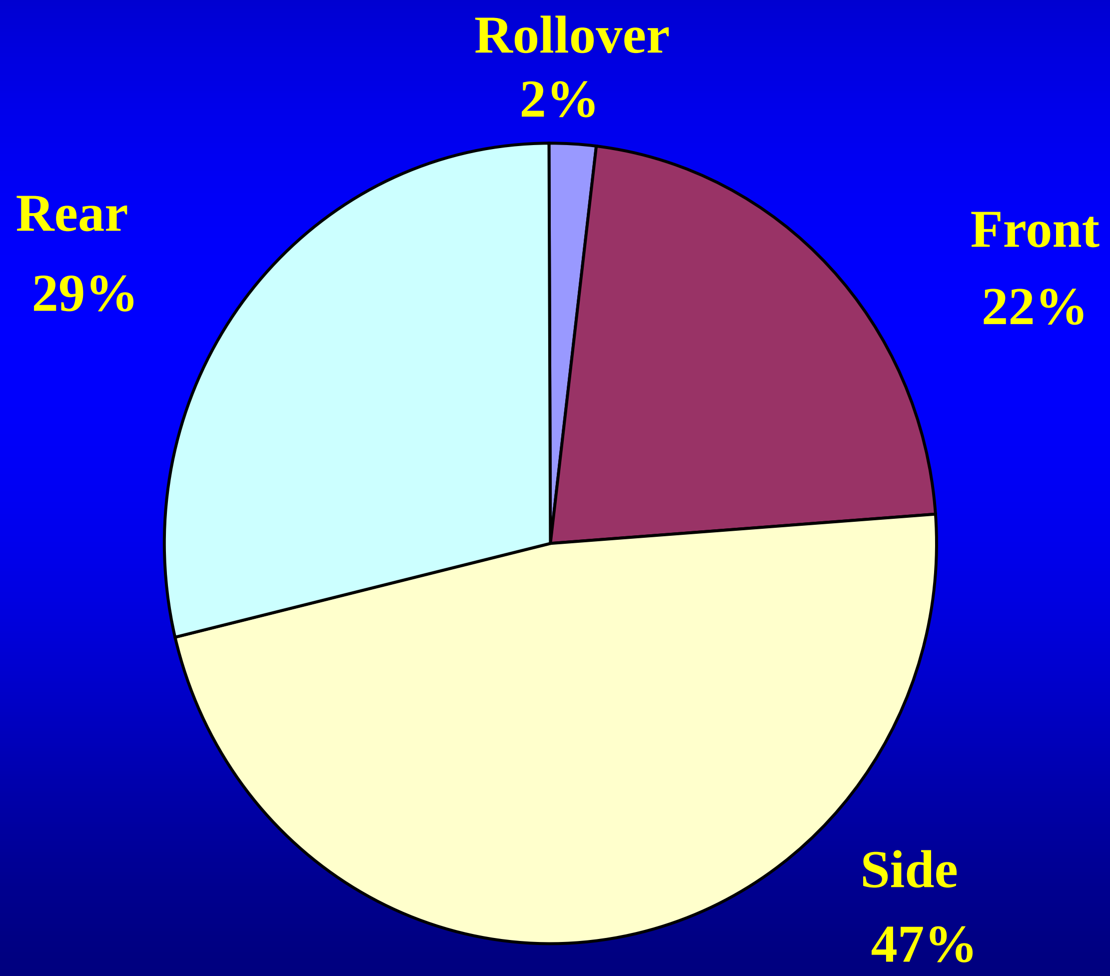
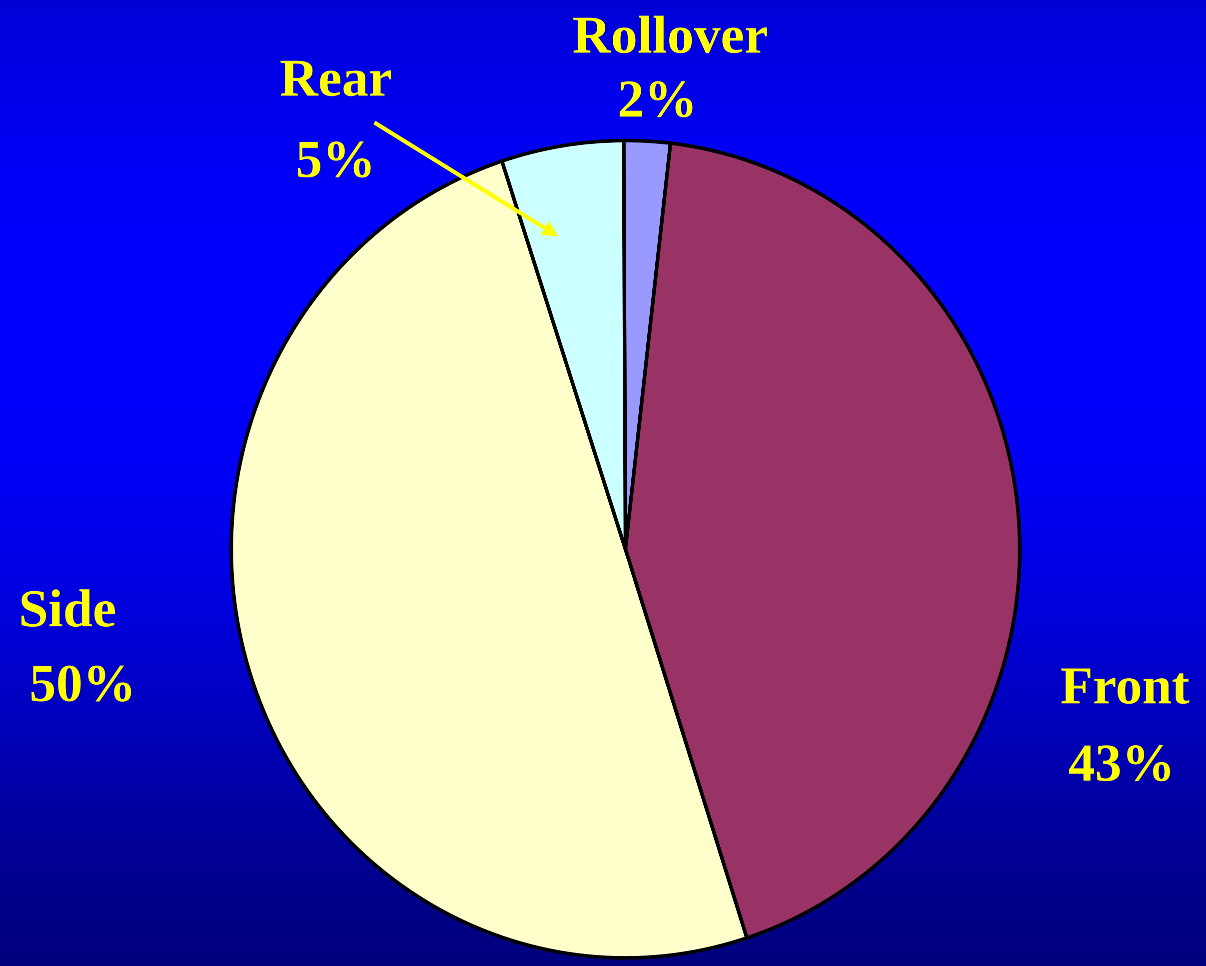
LTV Front to Car Crashes (NASS 1997-2001)

Frequency



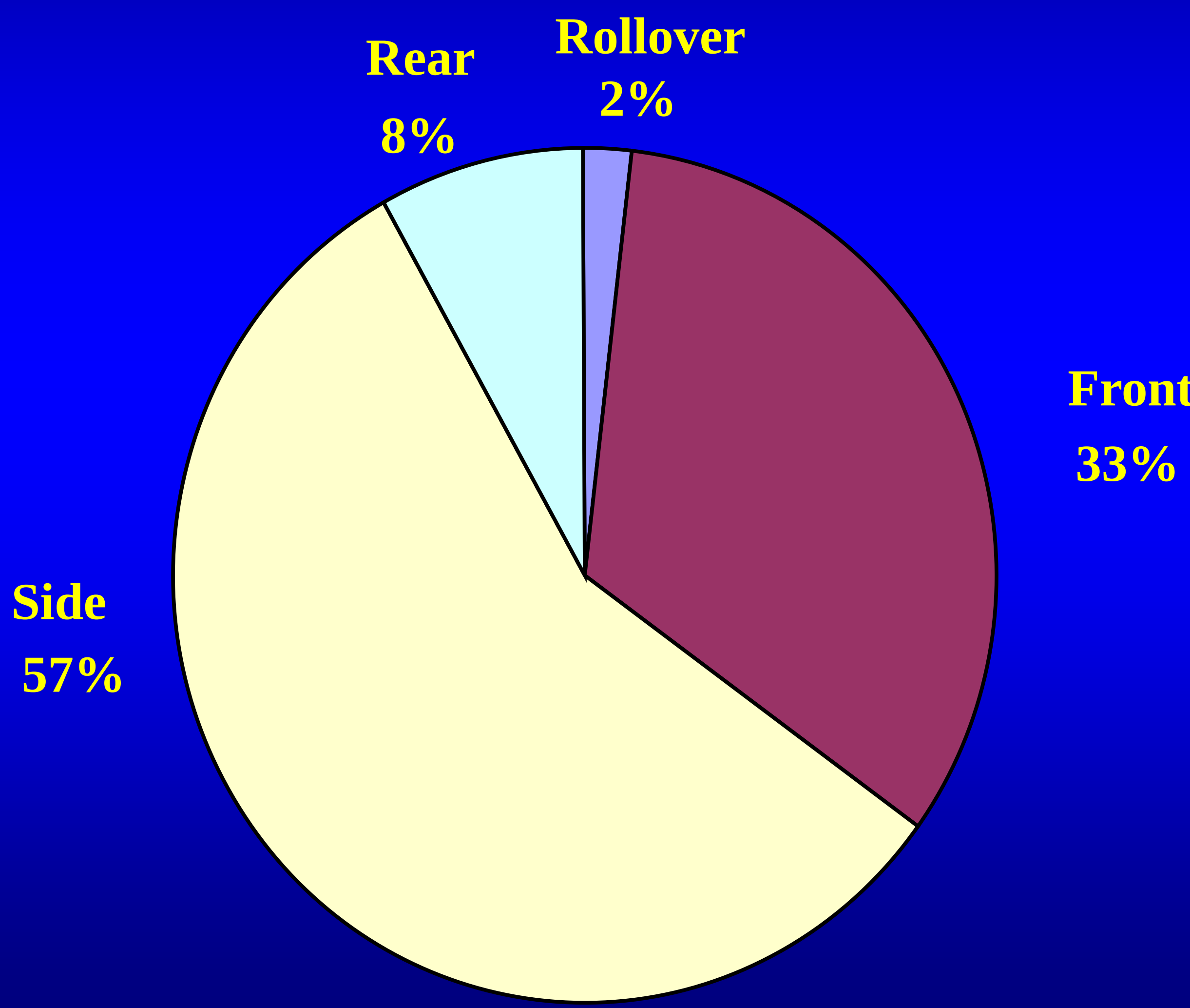
LTV Front to Car Crashes (NASS 1997-2001)

Distribution of Occupants with MAIS>=3



LTV Front to Car Crashes (NASS 1997-2001)

Distribution of Occupant Harm



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Test Modes/Regulations

- FMVSS 214 (Dynamic)
  - Roll-out began in MY 1994, applied to all passenger cars starting in MY 1997
- LINCAP
- ECE R95
- FMVSS 201
  - Upper interior requirements: Roll-out began in MY 1999 (Free Motion Headform)
  - Dynamic Pole test option for vehicles with side curtain airbag systems
- IIHS LTV Side Impact Test

ATD's for Side Impact

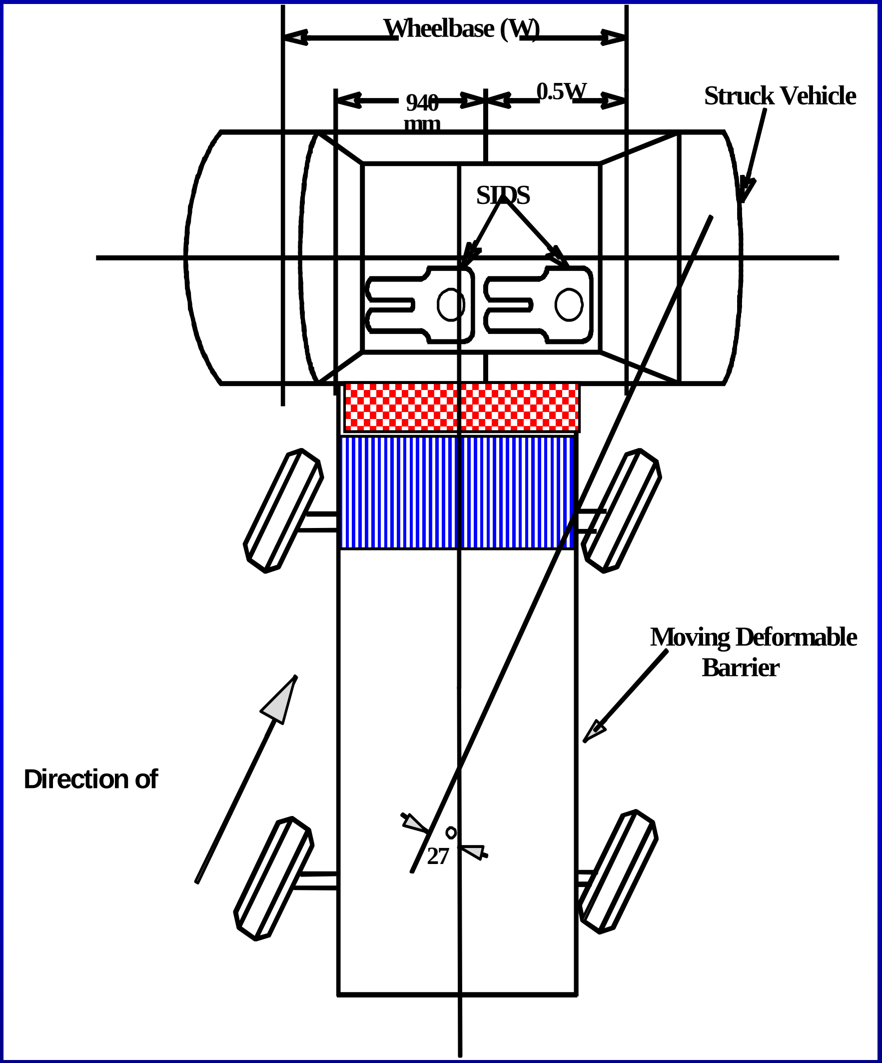
Several ATD's and multiple injury criteria are being used to assess lateral impact injury.

- **SID *(or US-SID)*** *(FMVSS 214)*
- **Euro-SID1** *(ECER95)*
- **ES-2**
- **BioSID**
- **SID-IIs** *(IIHS test ATD)*
- **US-SID with the Hybrid III head and neck** *(LINCAP, FMVSS 201)*
- **World SID**

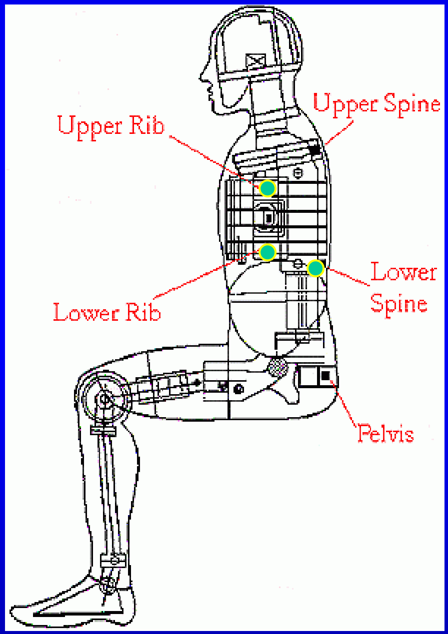
Every ATD style has advantages & disadvantages in testing & bio-fidelity

FMVSS 214 Load Case

- FMVSS 214
  - Impact Direction:Crab
  - Impact Speed: 33.5 mph
  - Barrier Bumper is 13” (330 mm) above Ground
  - 2 US SIDs
  - Requirement:
    - TTI <= 85 G
    - Pelvis Acc. <= 130 G



Thoracic Trauma Index



Side Impact Dummy (SID)

Thoracic Trauma Index (TTI)

$$TTI = ½ (G_R + G_{LS})$$

G_R - Greater of the peak acceleration of either the upper or lower rib

G_{LS} - Peak acceleration of the lower spine

LINCAP Load Case

- **LINCAP**
  - Impact Direction:Crab
  - Impact Speed: 38.5 mph
  - Barrier Bumper is 13” (330 mm) above Ground
  - 2 US SIDs
  - Rating: Stars

5 Star TTI≤57

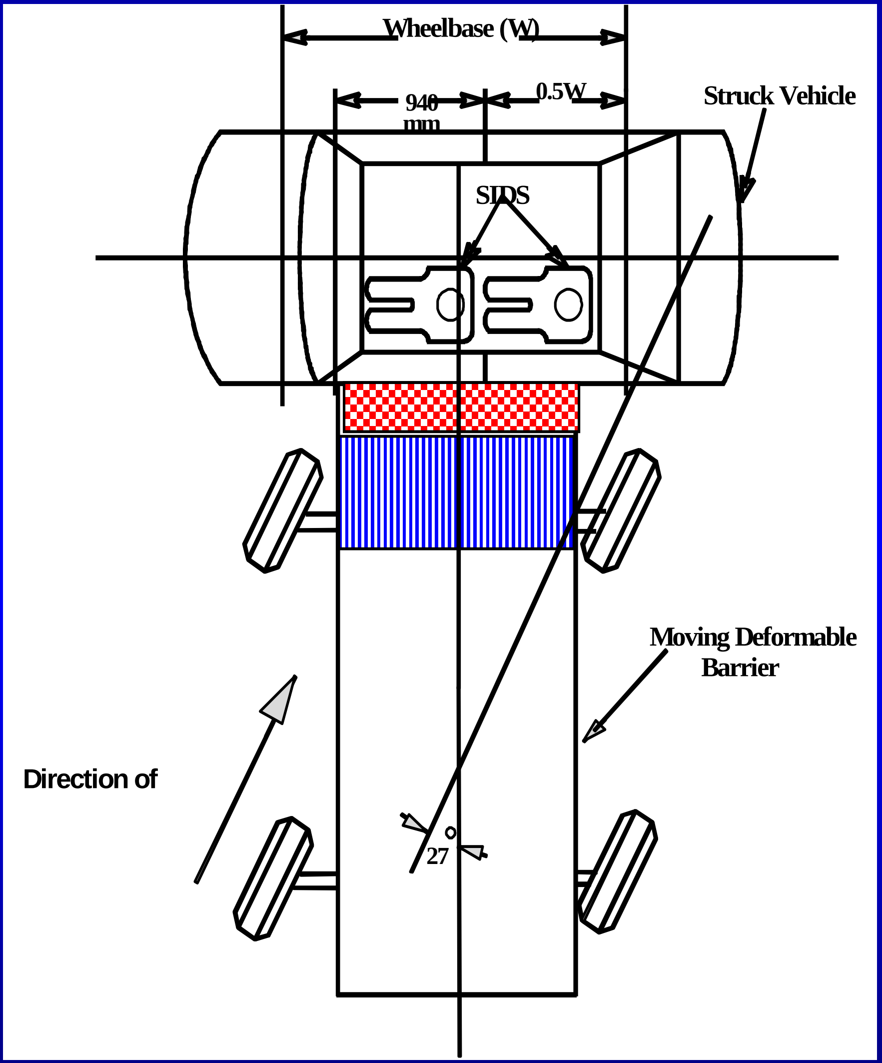
4 Star 57<TTI ≤72

3 Star 72<TTI ≤91

2 Star 91<TTI ≤98

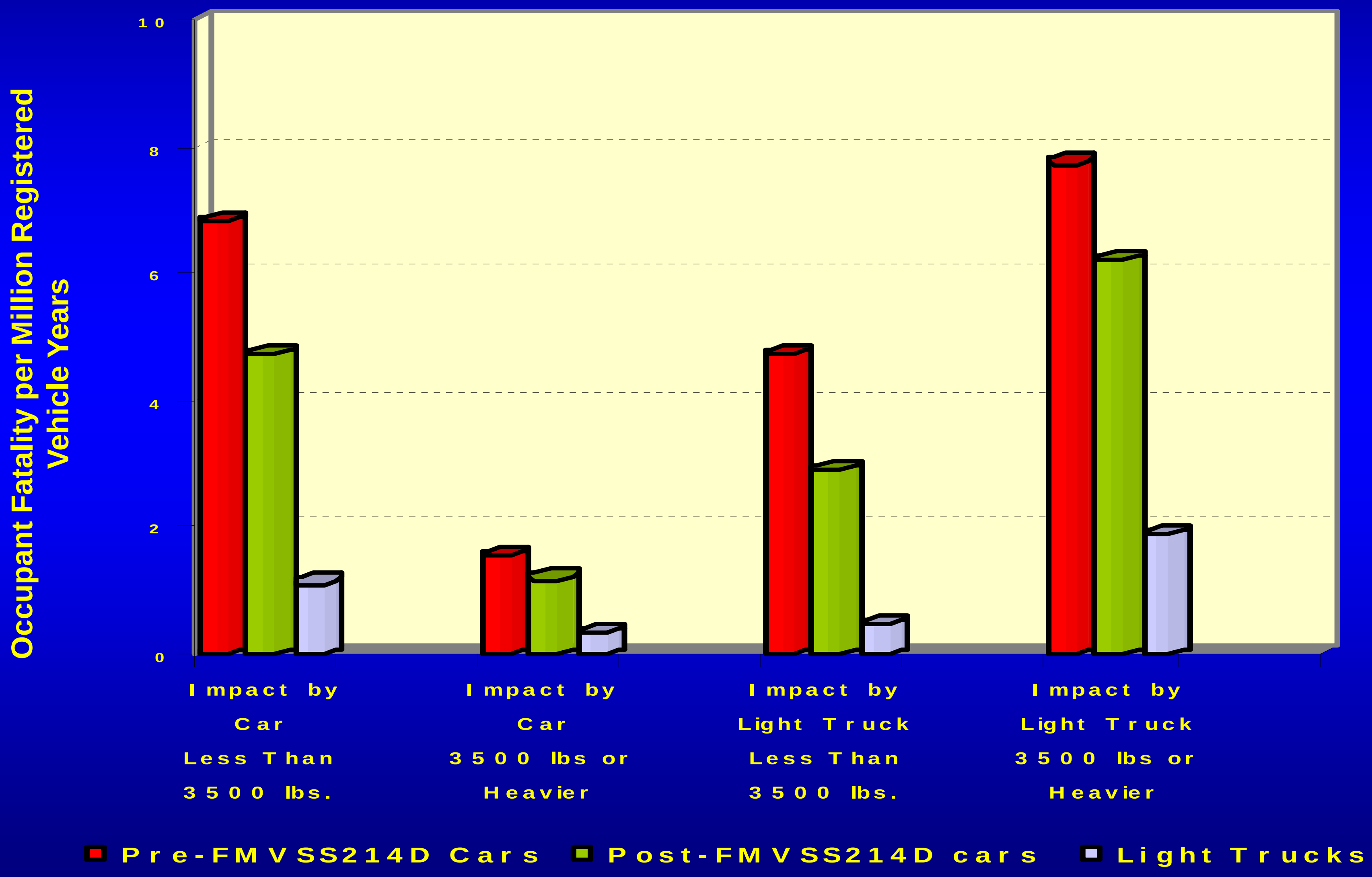
1 Star TTI>98

Pelvis G’s noted if exceeding 130g’s



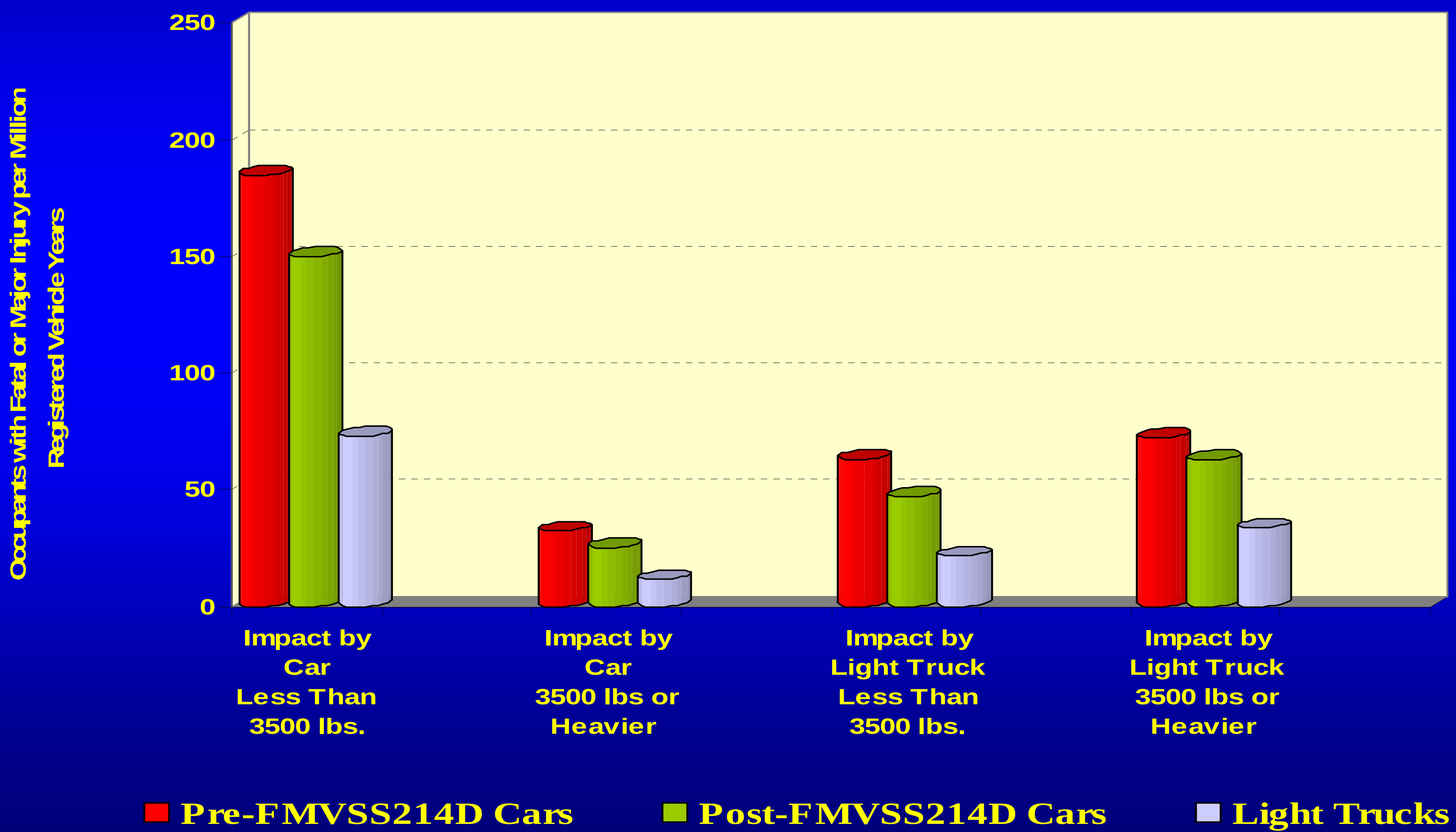
Fatal Injuries: Near-Side Occupants

FARS 1993-1999, Model Years 1994-1999

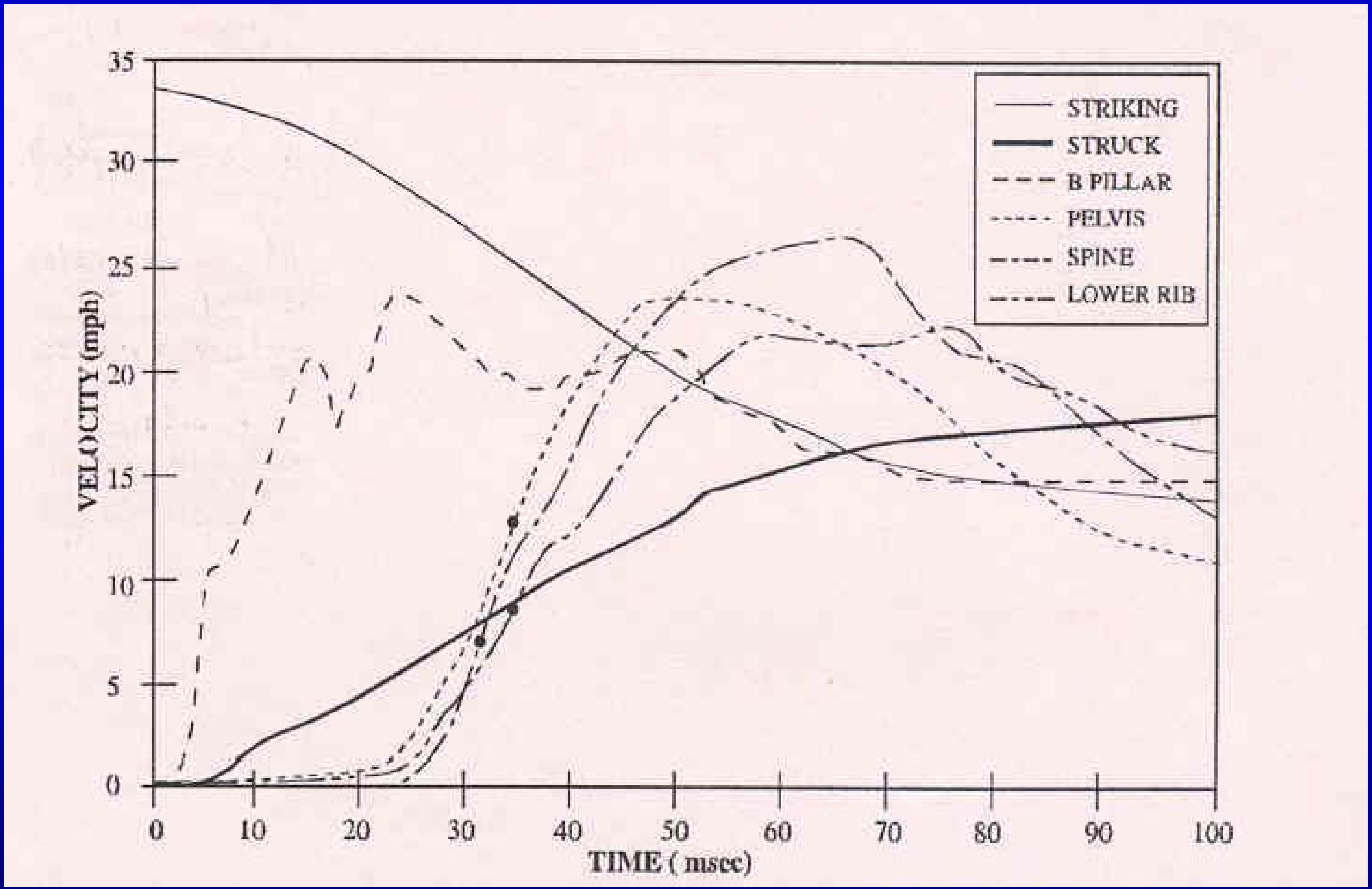


Fatal/Major Injuries: Near-Side Occupants

Five States (AL, FL, ID, MD, NC) 1994-1999, Model Years 1994-1999



Velocity Time History – FMVSS 214 Side Impact Test (Mid-size Sedan)



Side Impact Energy Management

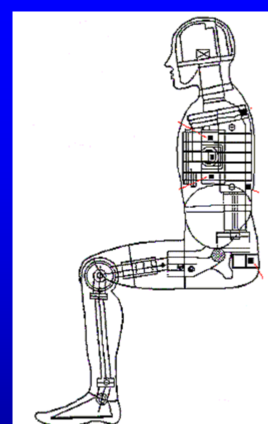
BARRIER

DOOR STRUCTURE

Body Side Structure

Utilize structural load paths to re-direct the energy

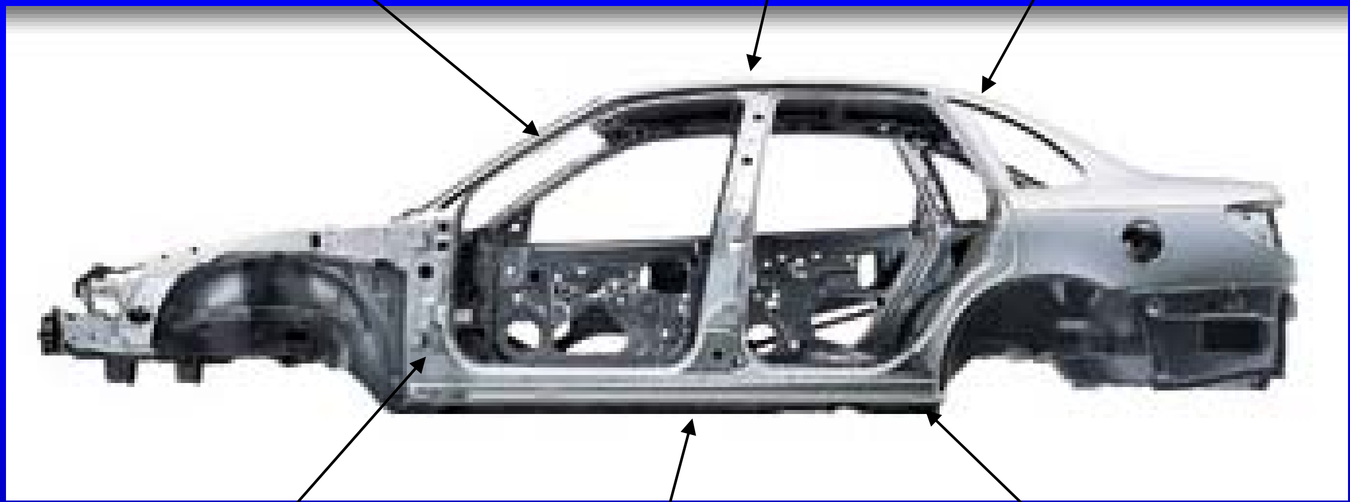
EA



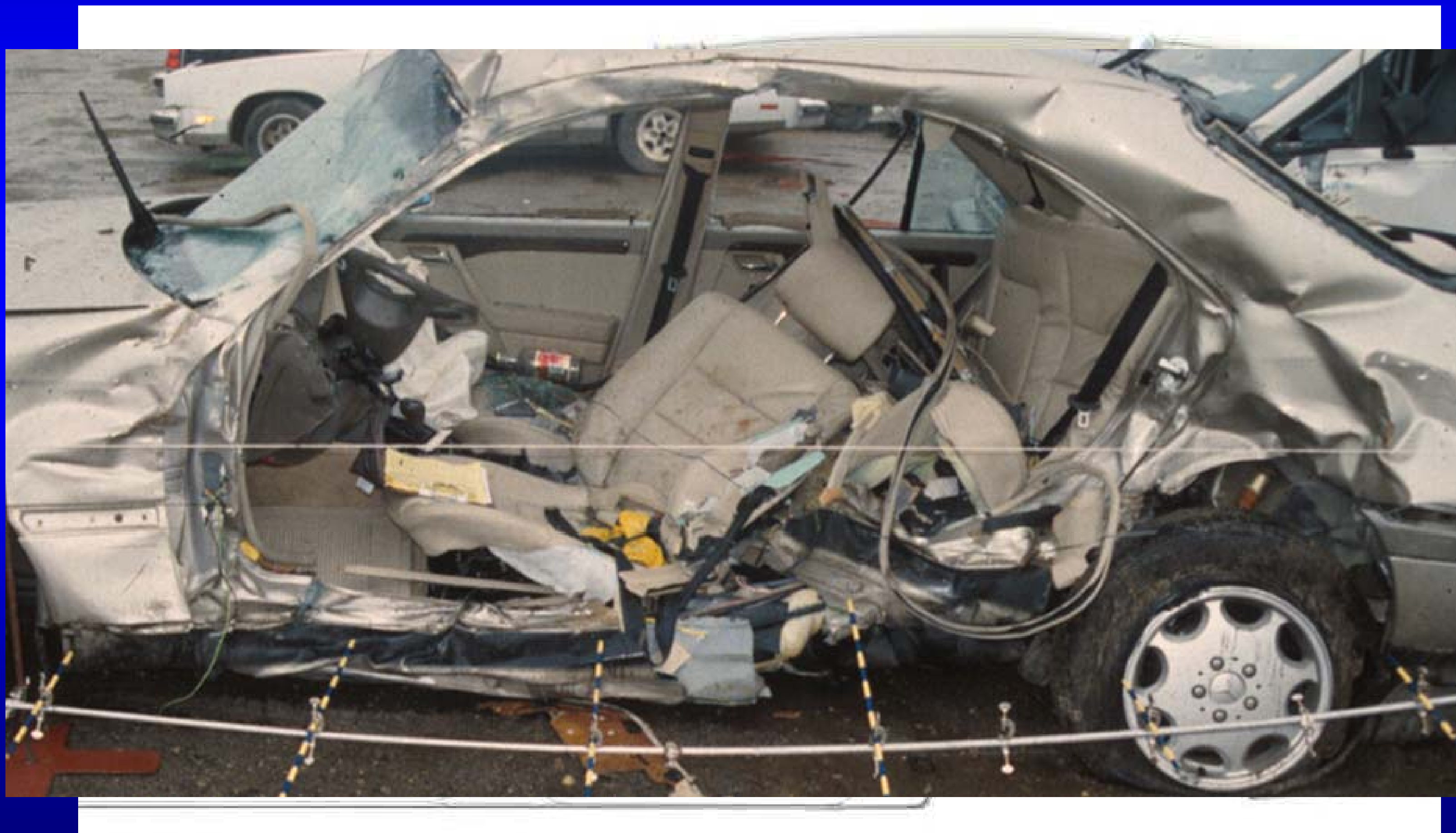
Manage the energy

Door Structure

Body Side Structure



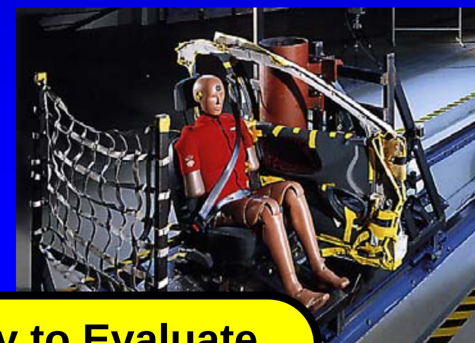
Passive Countermeasures (CM)



Safety Improvement

Understand Problem

Field DATA



Way to Evaluate

Injury Criteria

ATD

Test Procedure

Design Countermeasure

Engineering

Manufacturing

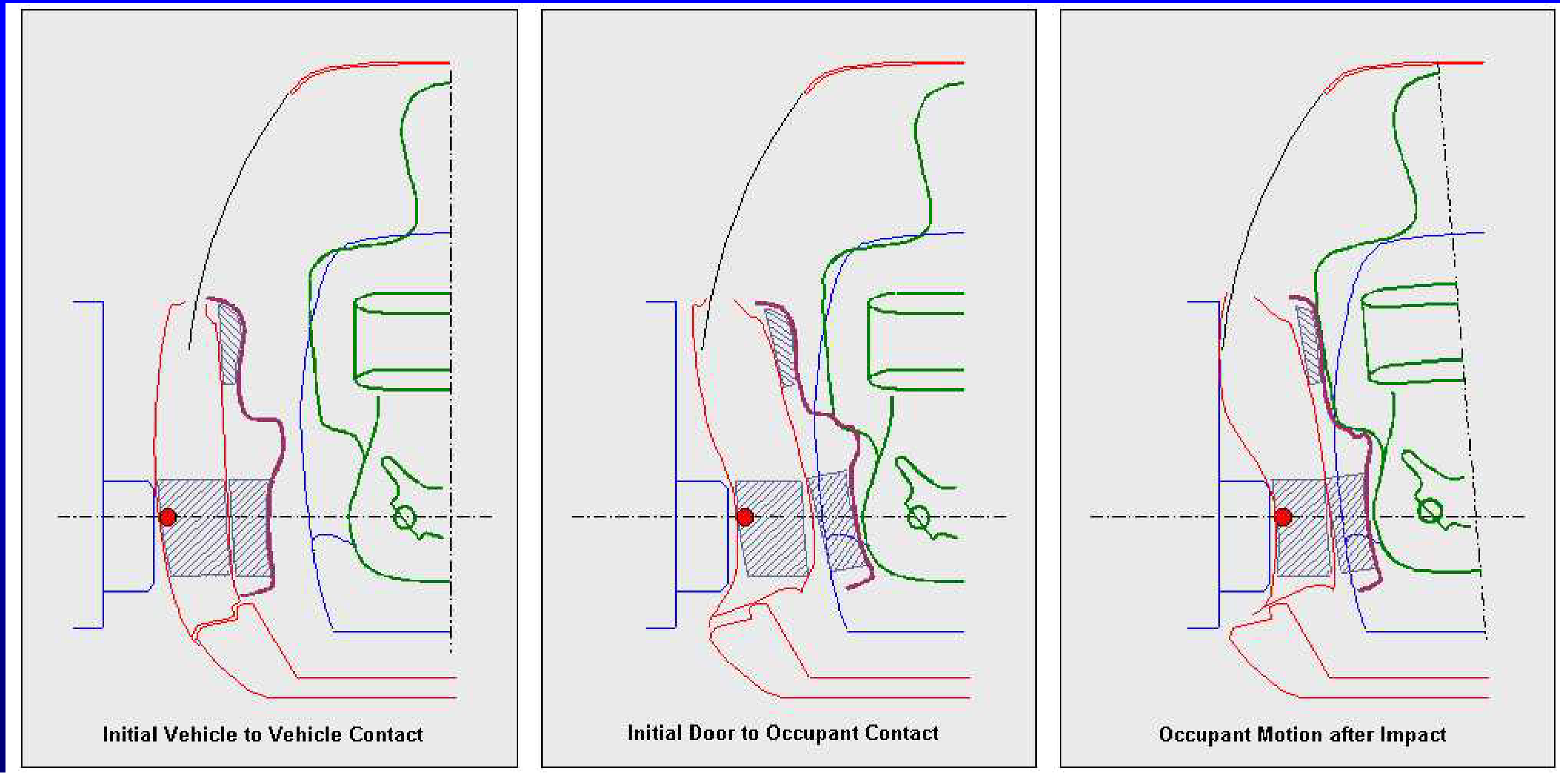
Repeatability

The Problem for Interior:

- Occupant is ACCELERATED by application of FORCE
- Contact from Vehicle, Tree, Door or Header

Understanding the Problem - Doors

- Example of low application of force through door.
- Hips are accelerated first followed by the shoulders.
- Application of force to abdomen through armrest is not desired.



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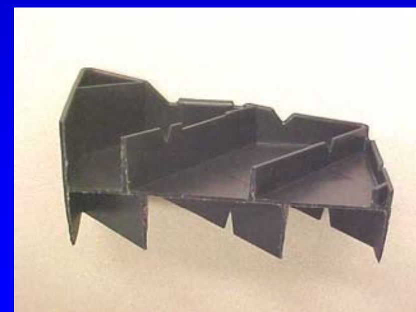
Passive side impact Countermeasures - Door



FMVSS201 Requirements

- Free Motion Headform (FMH)
- 10 lb
- 15 mph
- HIC number calculated from Acceleration.
- Phase-in (MY 1999-2002) will be complete by 2003

Formula from FMVSS201

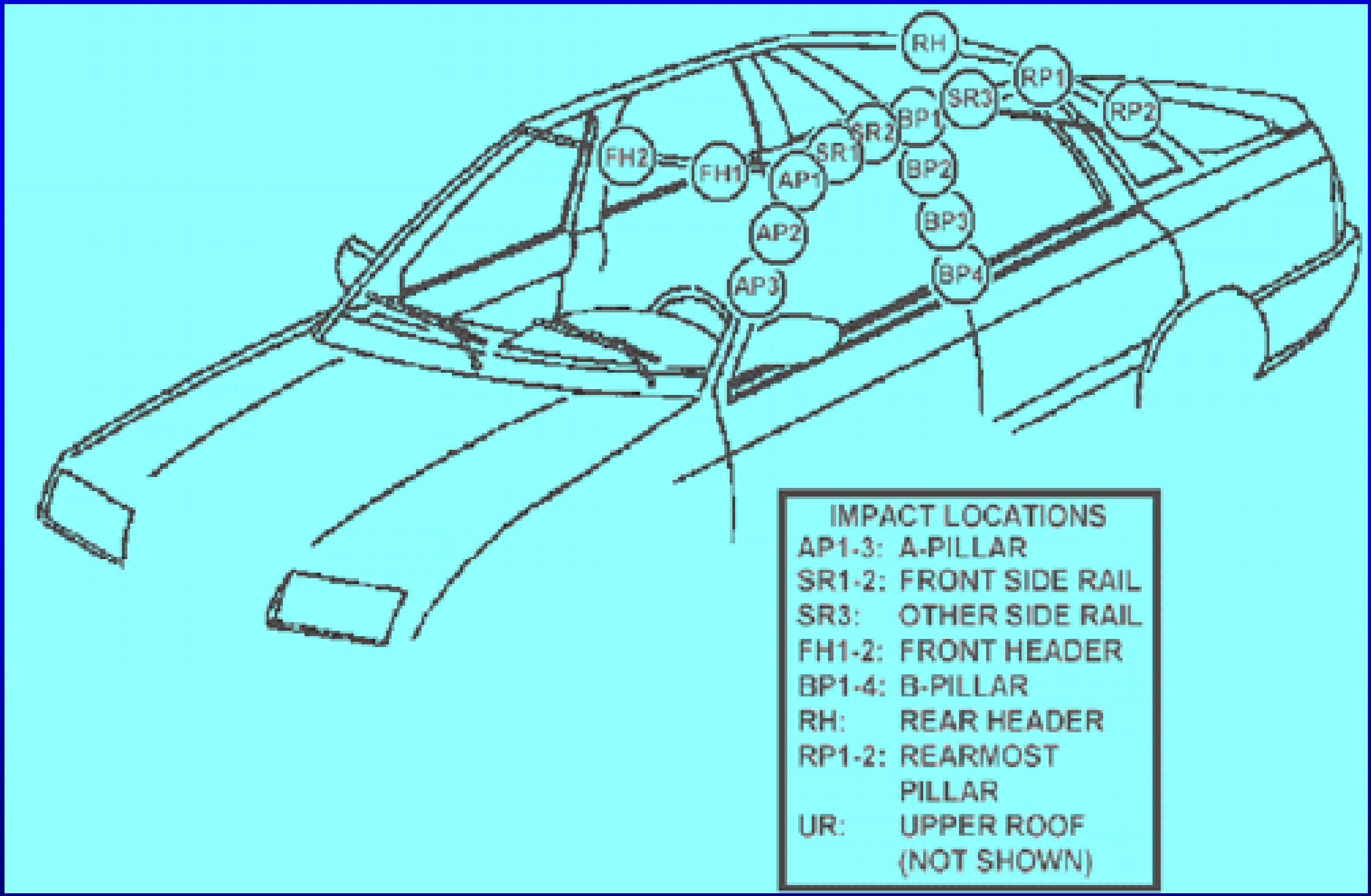
$$HIC = \left[\left[\frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} a_{res} \, dt \right]^{2.5} (t_2 - t_1) \right]_{Maximum}$$

Average Acceleration

Duration

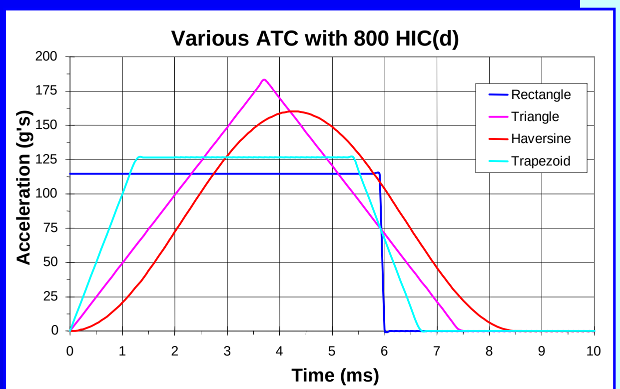
- Regulation HIC below 1000
- Target HIC below 800

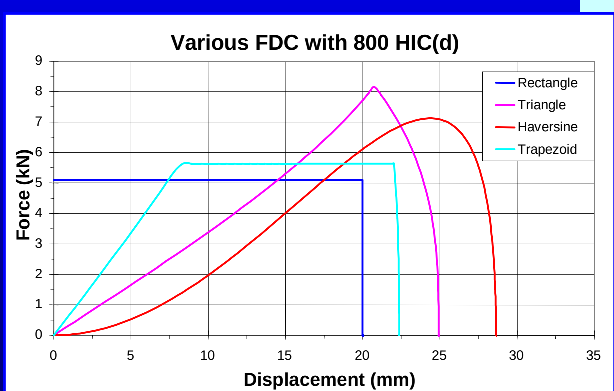
FMH Impact Locations

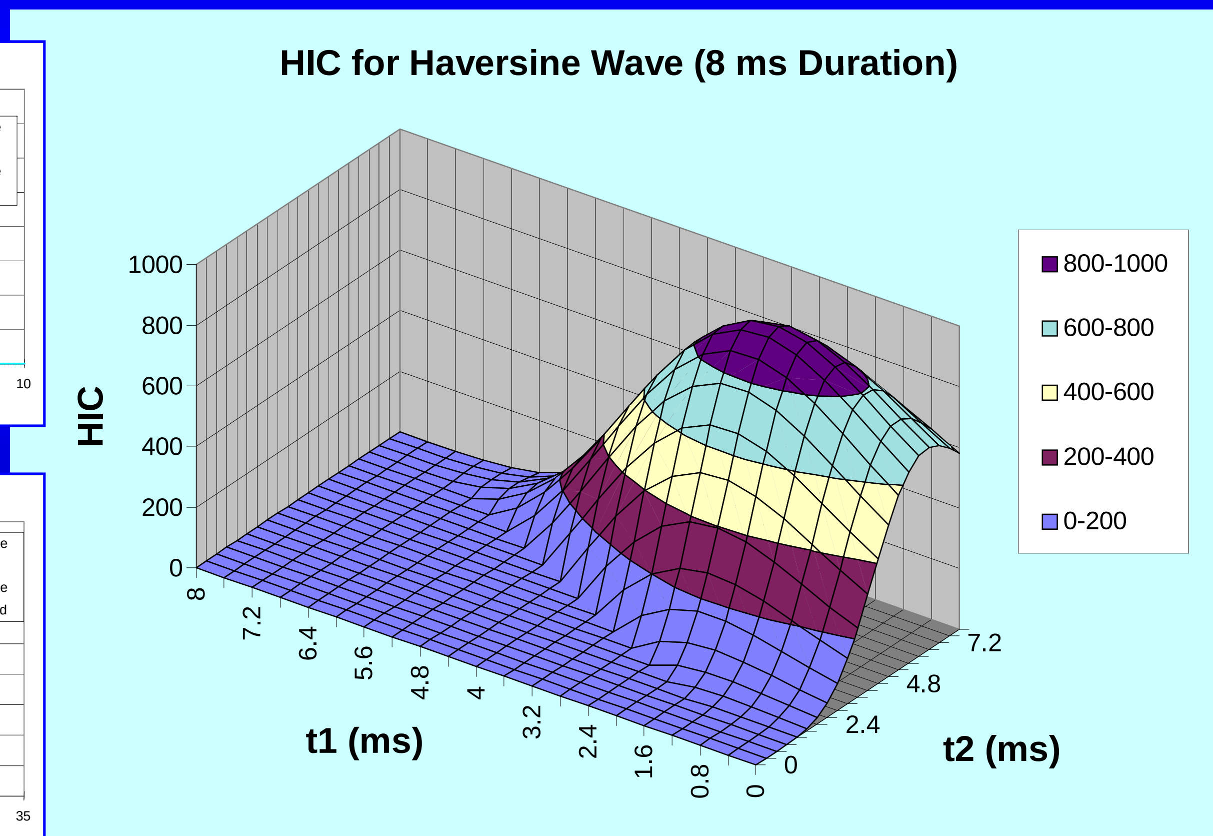


Theoretical Relations

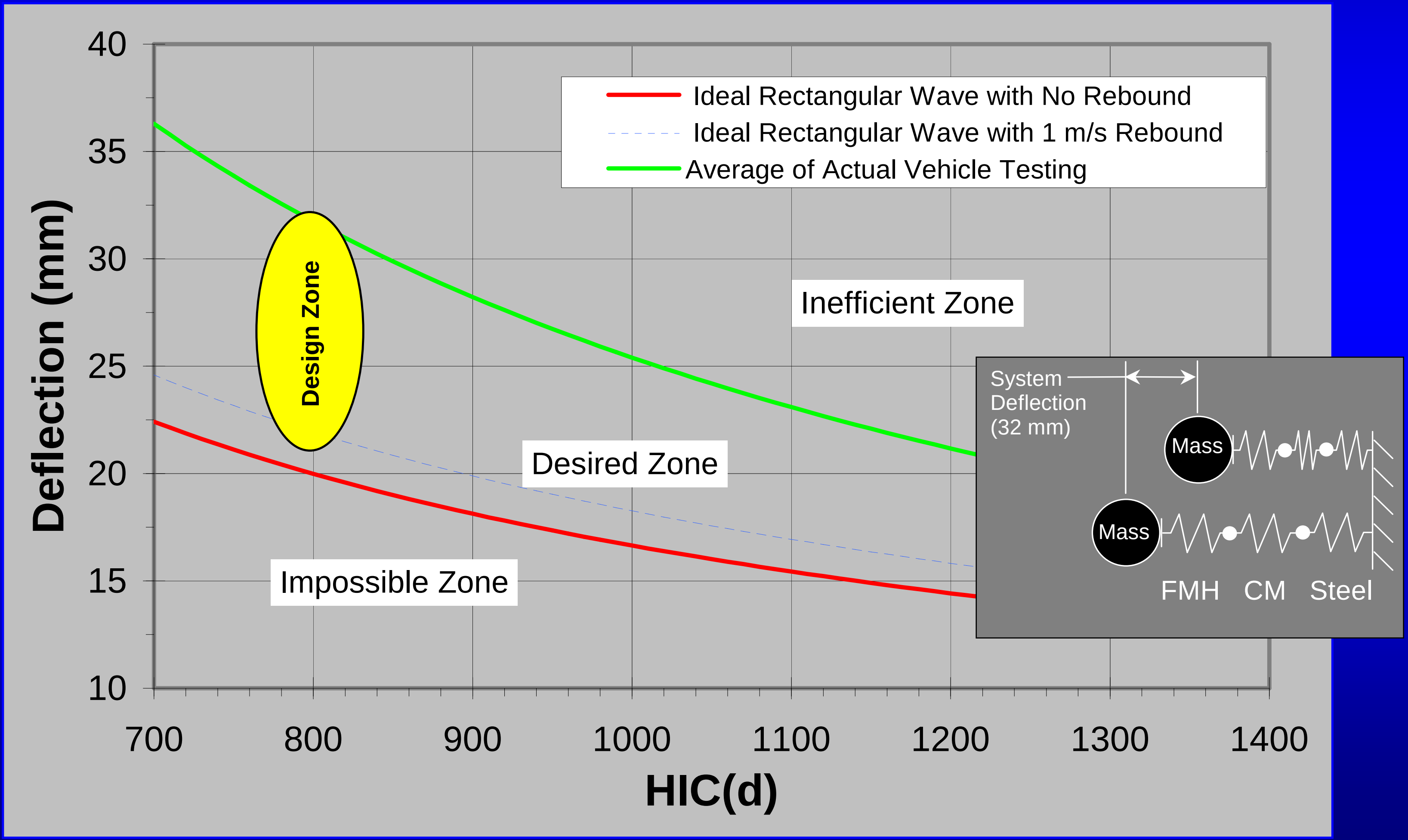
- We analyzed mathematically what drives the HIC number so that we could understand how to lower the number. We also studied the theoretical responses of various acceleration waveforms.



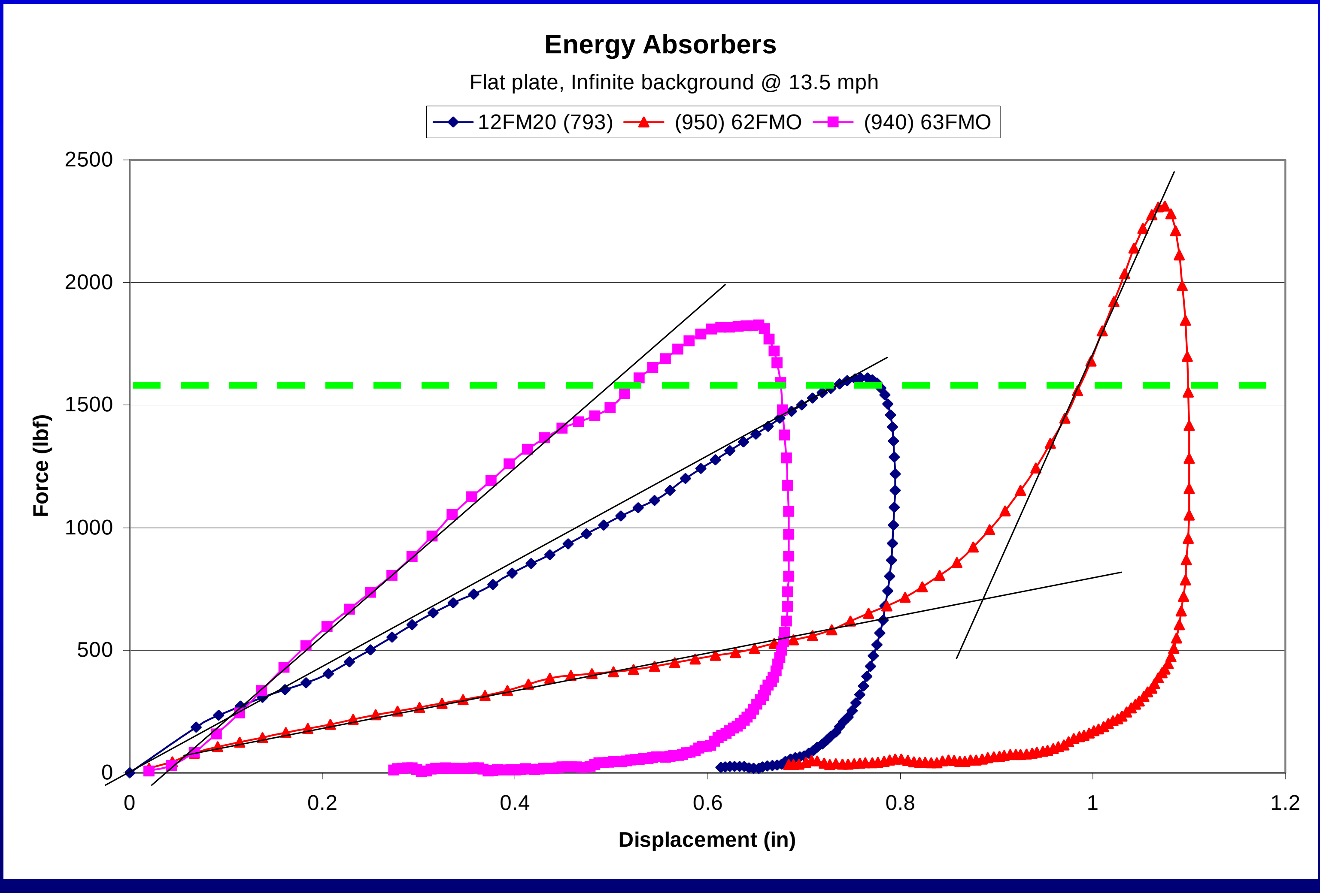




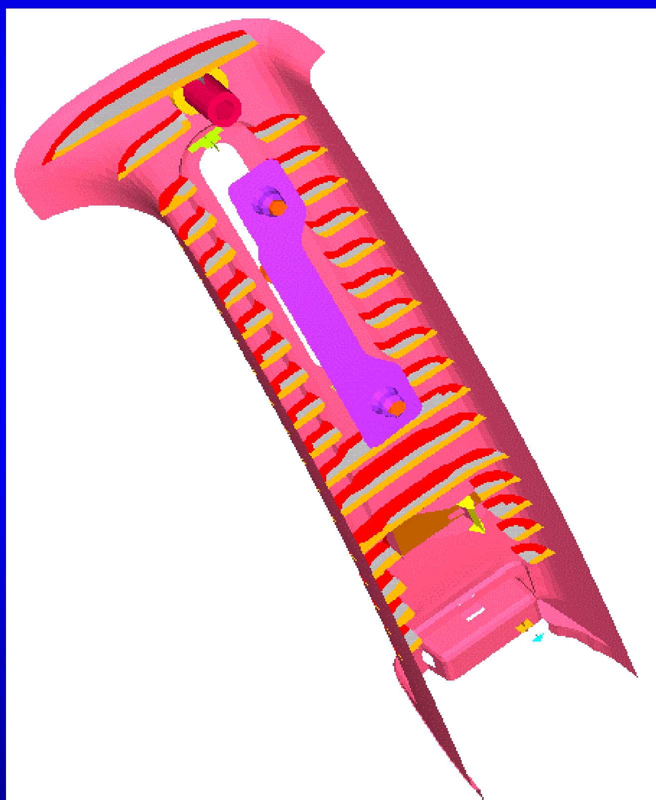
Space is Required



Force vs. Deflection Curves



Pillar Countermeasures



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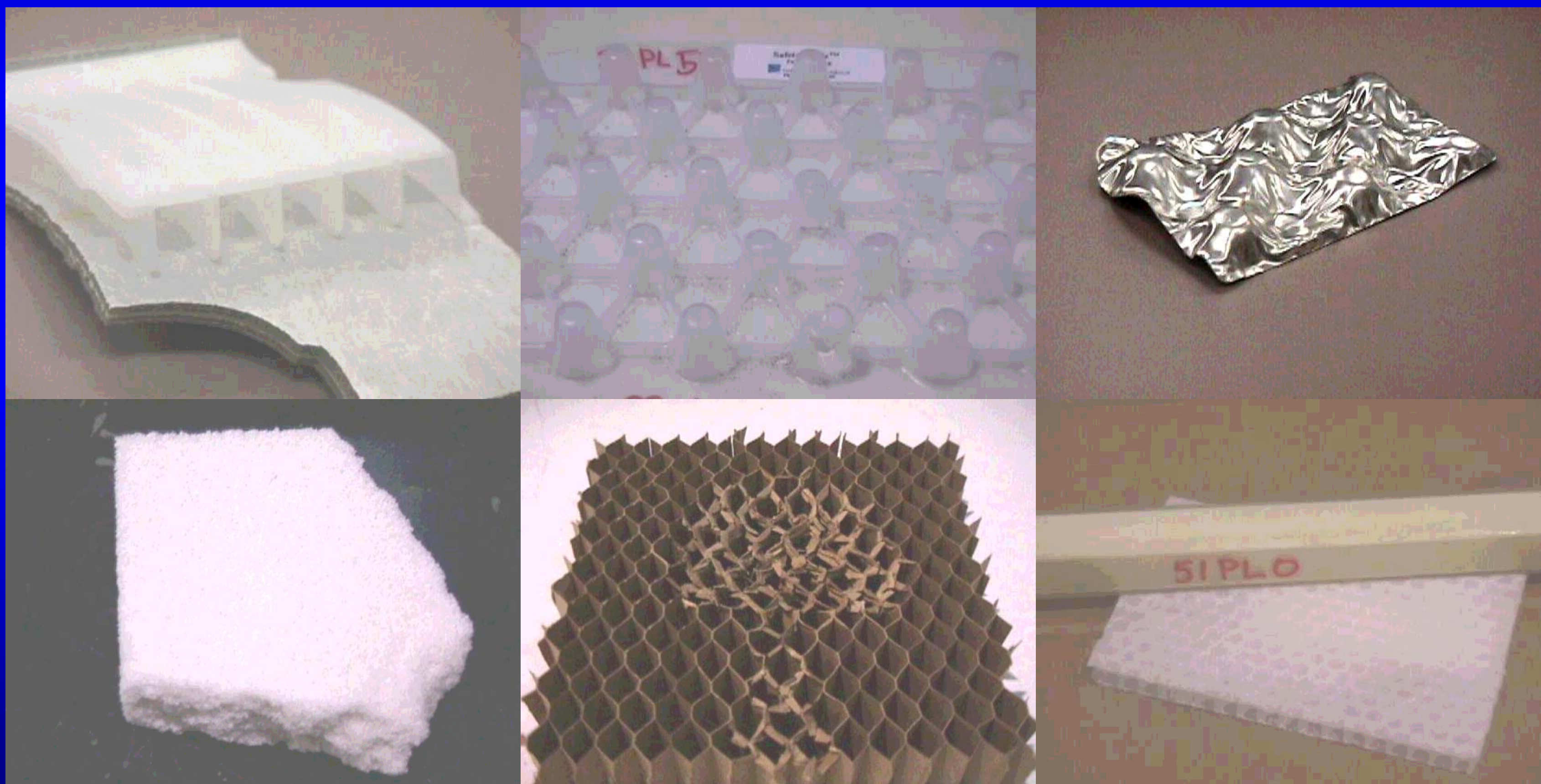
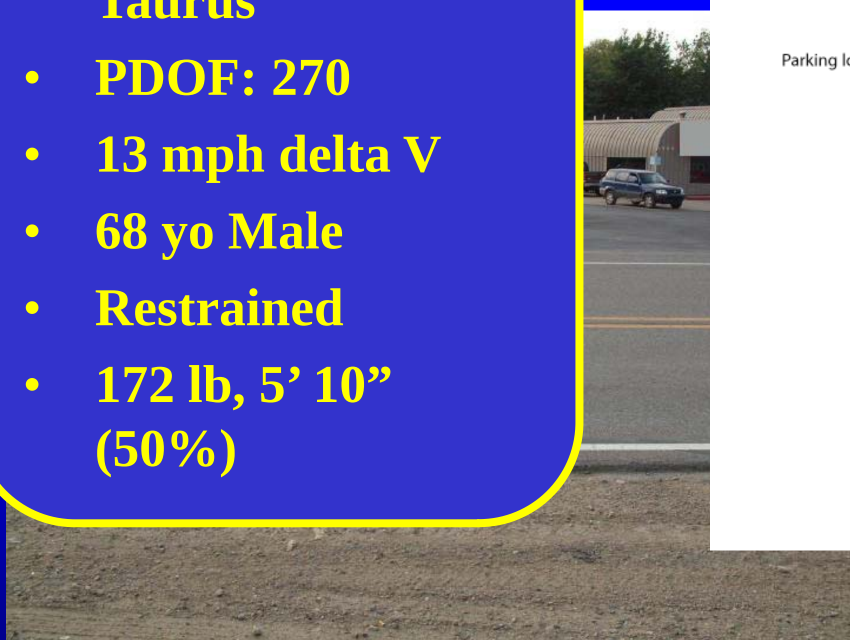
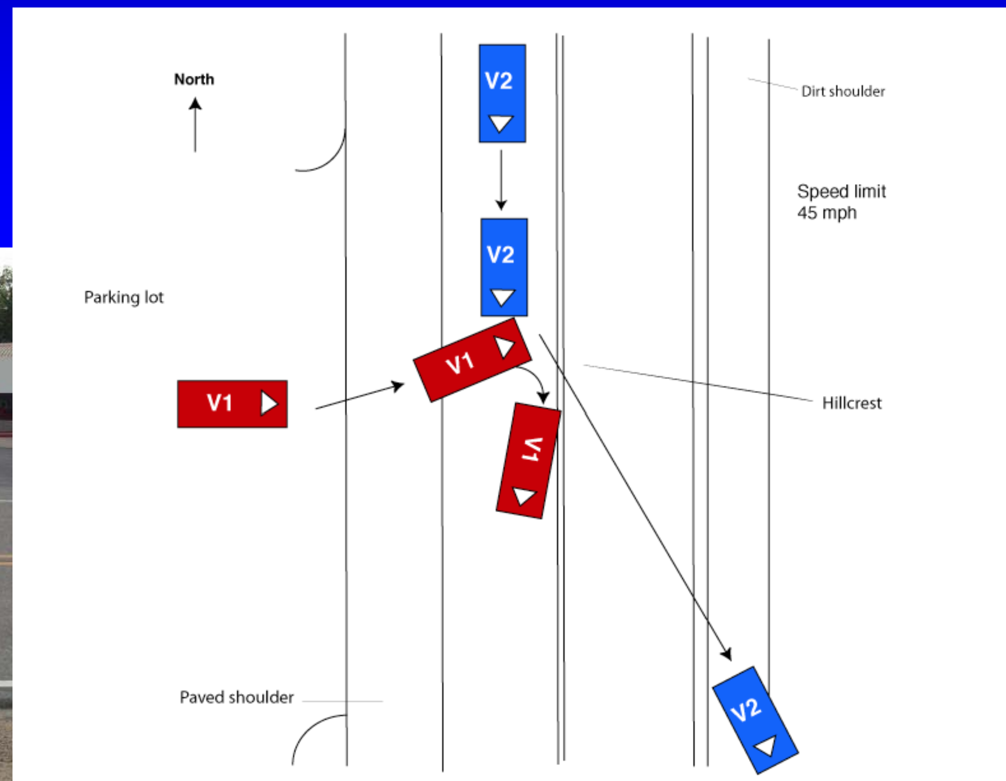
Countermeasure Materials



Case History 1: No Countermeasure

- 1998 Caravan
- Object: 2000 Taurus
- PDOF: 270
- 13 mph delta V
- 68 yo Male
- Restrained
- 172 lb, 5’ 10” (50%)





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Case History 1: No Countermeasure

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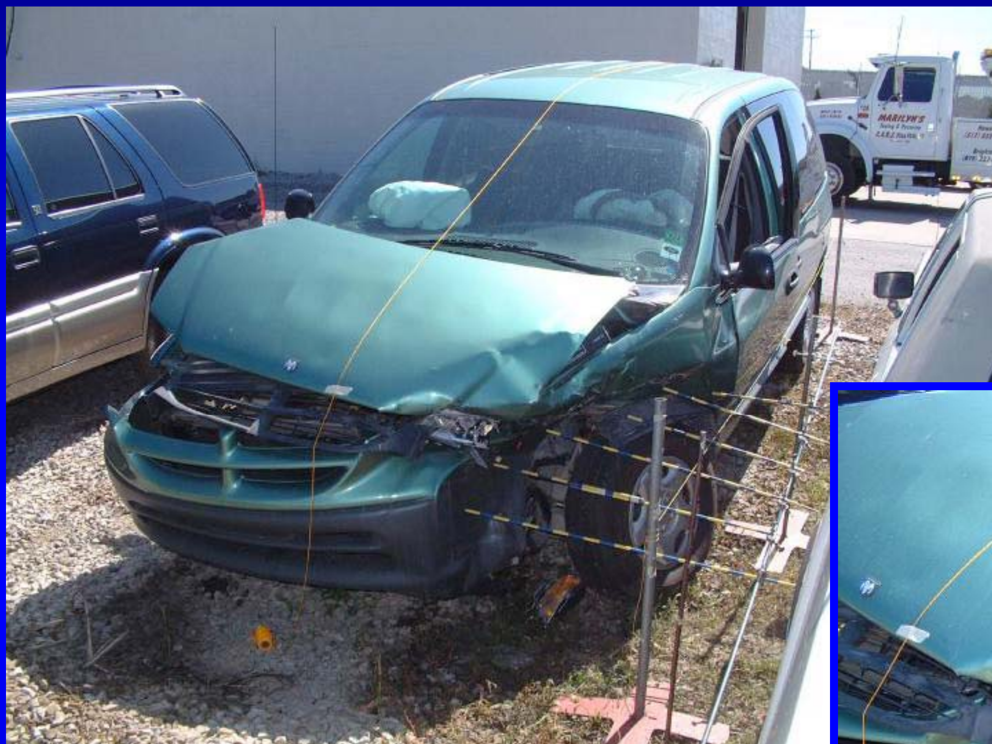

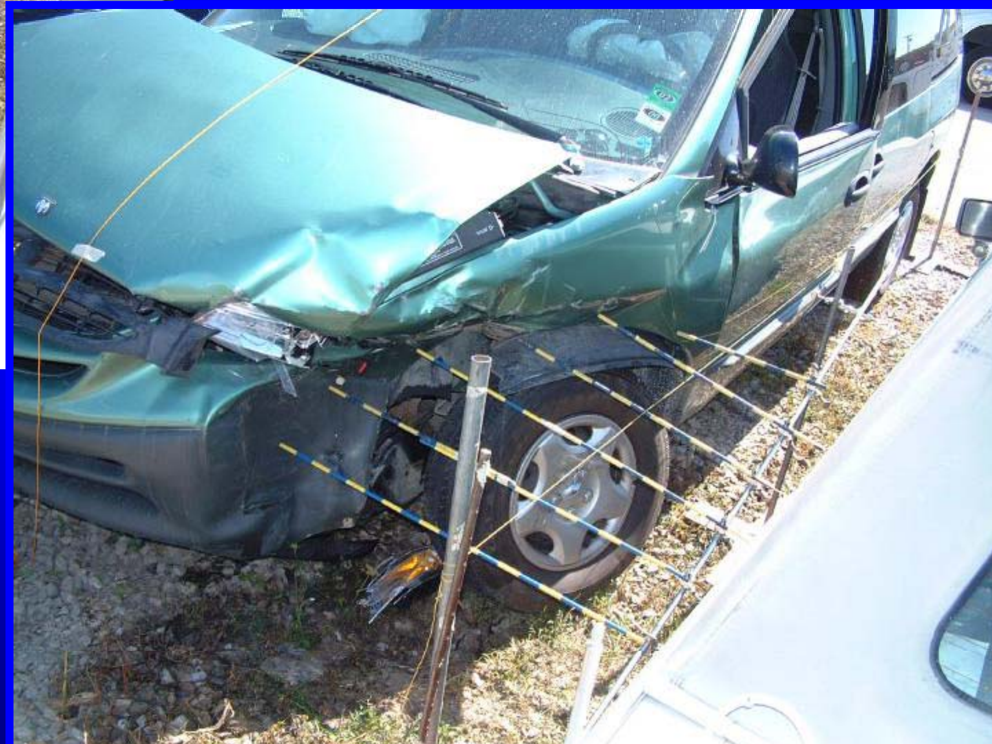

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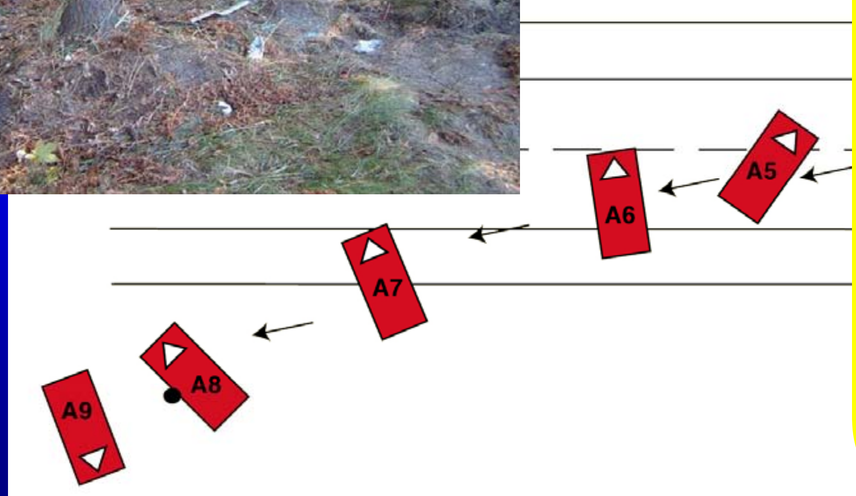
Interior Surfaces

Head & Neck Injuries

•Medical data has been removed to protect patient confidentiality

Case History 2



- 1999 Intrepid
- Object: Tree
- PDOF: 290
- 15 mph delta V
- 36 yo Male
- Restrained
- 165 lb, 6’ 2”
- 26 cm @ sill
- 56 cm @ roof

Damage

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Damage

Significant Injuries

- Medical data has been removed to protect patient confidentiality

Head Contact

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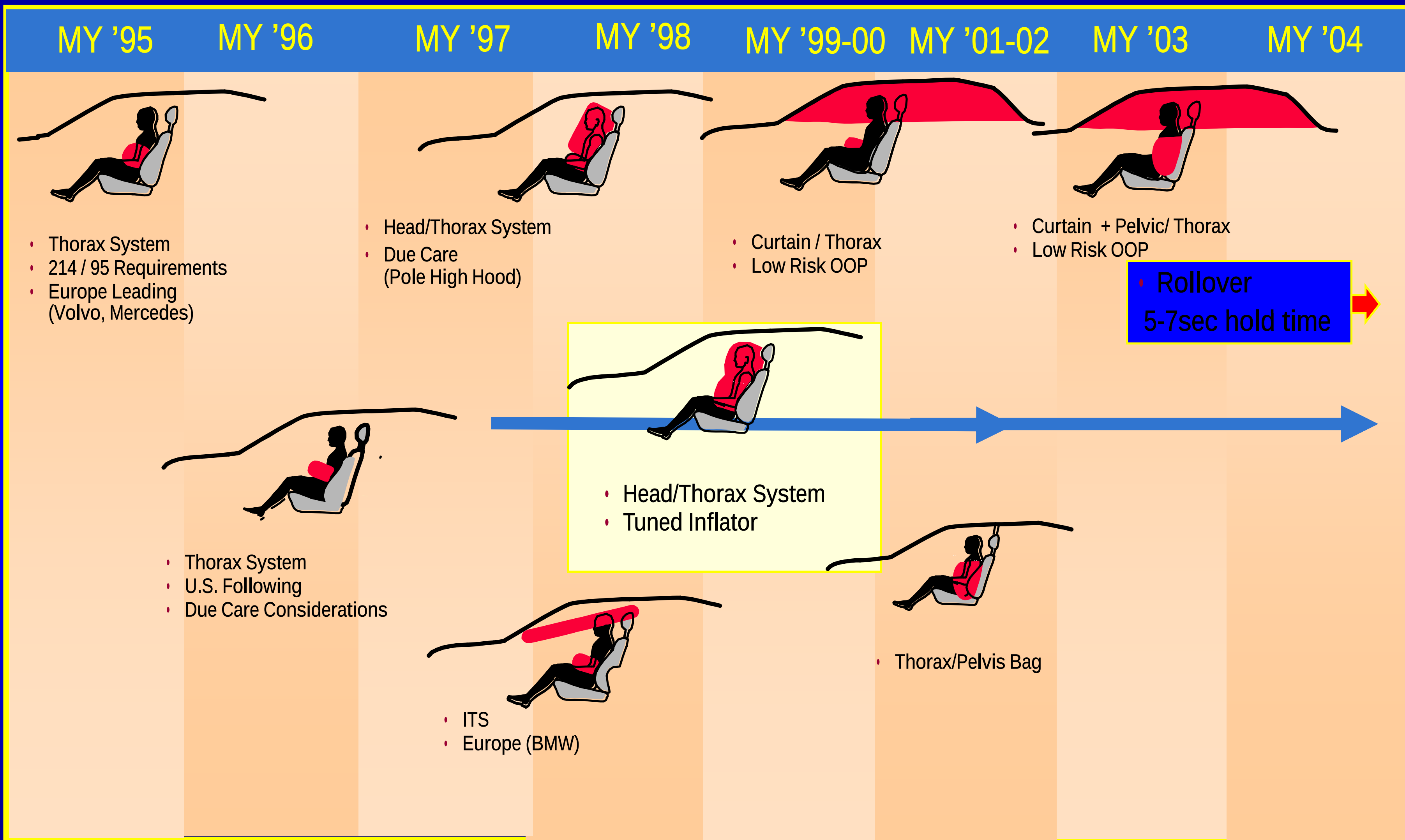
Side Impact Air Bag Countermeasures

- This section will focus on development of inflatable technology, and addressing what inflatable restraints can do to offer “self -protection” in lateral “incompatible” crashes.

Side Air Bag Evolution



Field Data

- To date, relatively little field crash experience is available with inflatable lateral protection devices.
- The data that is available does suggest minimal harm is being induced in field, and there is limited evidence of at least some benefits from lateral inflatables.

What does an airbag do?

Frontal:

The occupant is effectively accelerating towards Steering Wheel / IP as vehicle is decelerating

The frontal airbag:

- **Offers increased loading area**
- **Energy Absorbing (transfers KE into Work through vent holes or fabric) => gradual deceleration**
- **Prevents hard contacts with wheel, IP, Windshield, Pillars**

Lateral:

The vehicle is effectively accelerating towards occupant

The airbag:

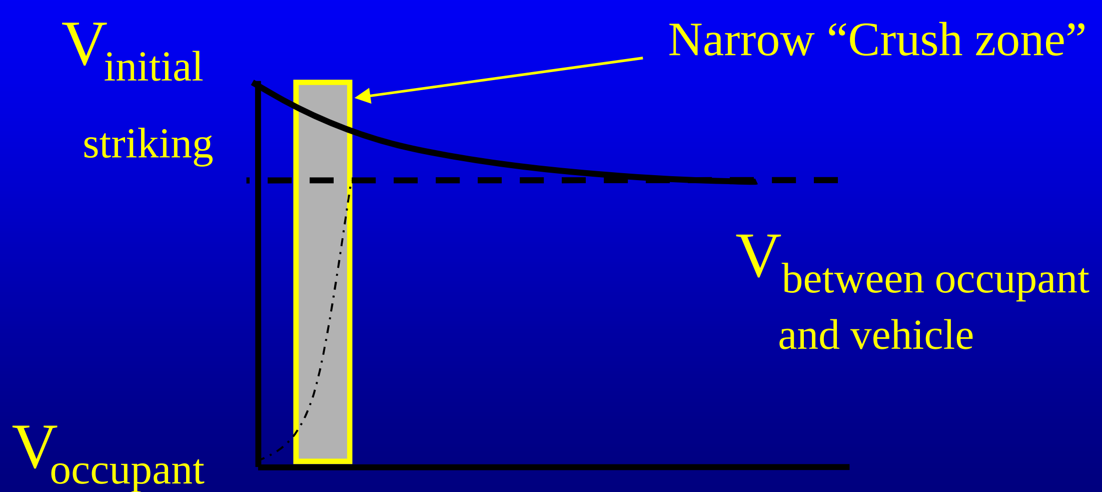
- **Prevents hard contacts between head & barrier/pole**
- **Offers stability for Head / Neck / Shoulder complex**
- **Reduces acceleration for Thorax / Abdomen/ Pelvic complex**

Frontal and lateral airbags operate differently in how they mitigate injury

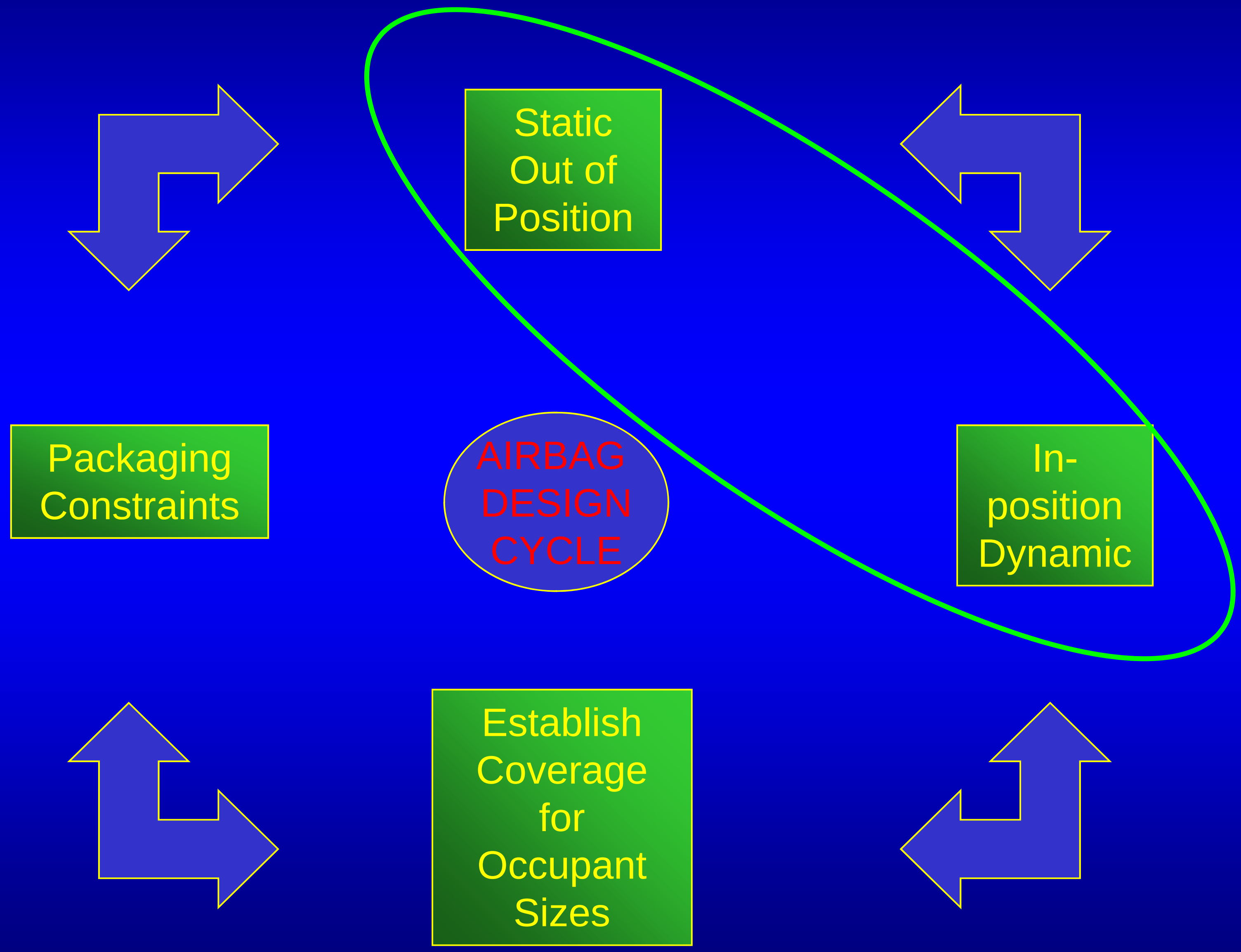
Side Impact Air Bag Considerations

Additional Considerations for side vs frontal airbags:

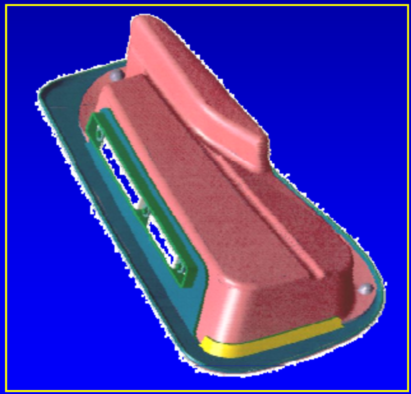
- there is little vehicle crush space to accelerate the occupant compartment before occupant loading.
- The occupant is impacted by the striking object with a portion of his vehicle side structure around it.
- The location of a side impact relative to the occupant has a major effect on the severity of the crash as seen by the occupant



Lateral Airbag System
Design Iteration/Balance



Example of Side Airbag Module



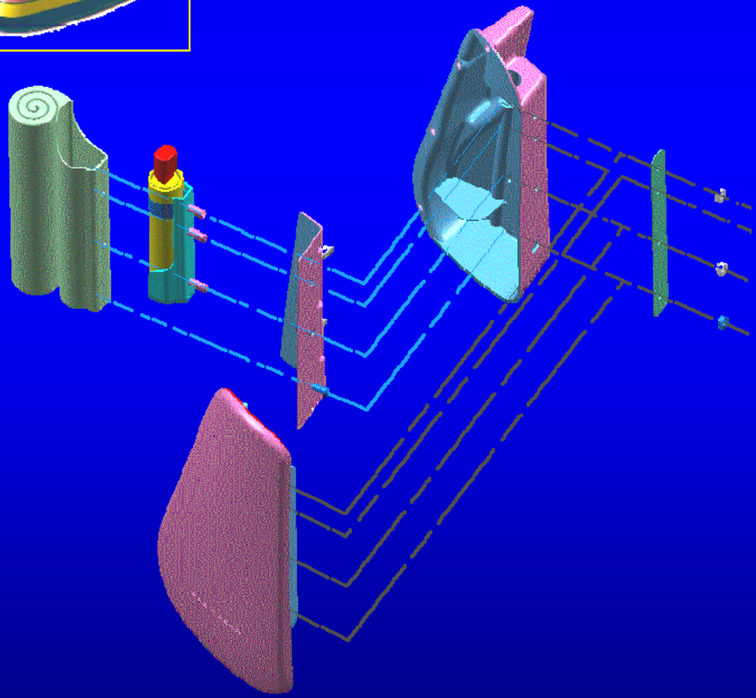
Side Airbag Module:

Inflator:
- Hybrid BREED HSI-140

Cushion:
- 11 litre single chamber rollfold
- ventholes according to performance
- 700 dtex fabric uncoated with reinforcement and heatshíelds

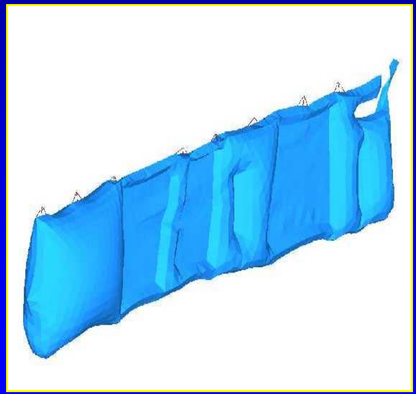
Housing:
- single injection TPEE (Multiflex)
- colour black

Cover:
- single injection TPEE (Multiflex), grained A-surface unpainted
- colours:
    - natural (Lancia 839 invisible)
    - black (Alfa 932 / Fiat 244 visible)
    - grey (ALFA 932 visible)
    - leather covered (blue / red / beige) (Alfa 932 visible)
- opening by tearing 4 pins (ultrasonic welded)



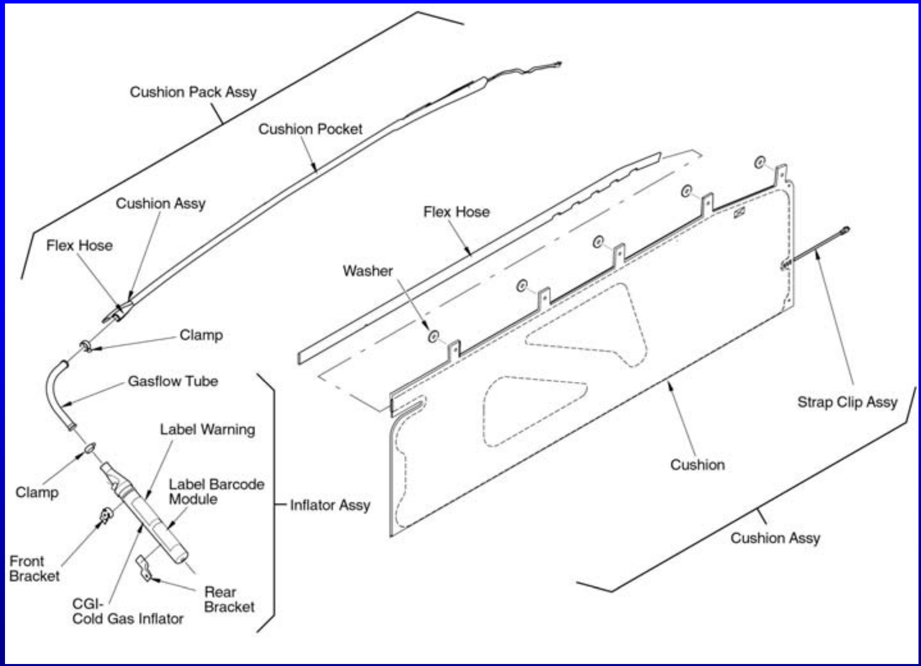
Curtain Airbag Module

Side Airbag Module Curtain Airbag (Product Description)



Roof Rail-AB Modul (CAD)

Roof Rail-AB Modul (Detail)



Module Concept:

- Deployment zone between A and C / D pillar.
- Maximum mass approx. 1600 gr
- Manifold: steel tube
- Filltime max 25ms @-30°C

Standard Cushion:

- Uncoated 470dtex PA 6.6.
- Volume 30-35 ltr.
- Sewn bag design,

Curtain Airbag Module:

Inflator:

- Inflator Cold gas
- Filling - 100%He
- Pressure - 600bar
- Gas filling weight adjustable

Rollover Cushion:

- Silicone coated, 470dtex, PA 6.6.
- Volume 30-35 ltr.
- Sewn bag design, liquid silicone sealing or OPW coated or STC

Cover:

- soft pack (pocket)

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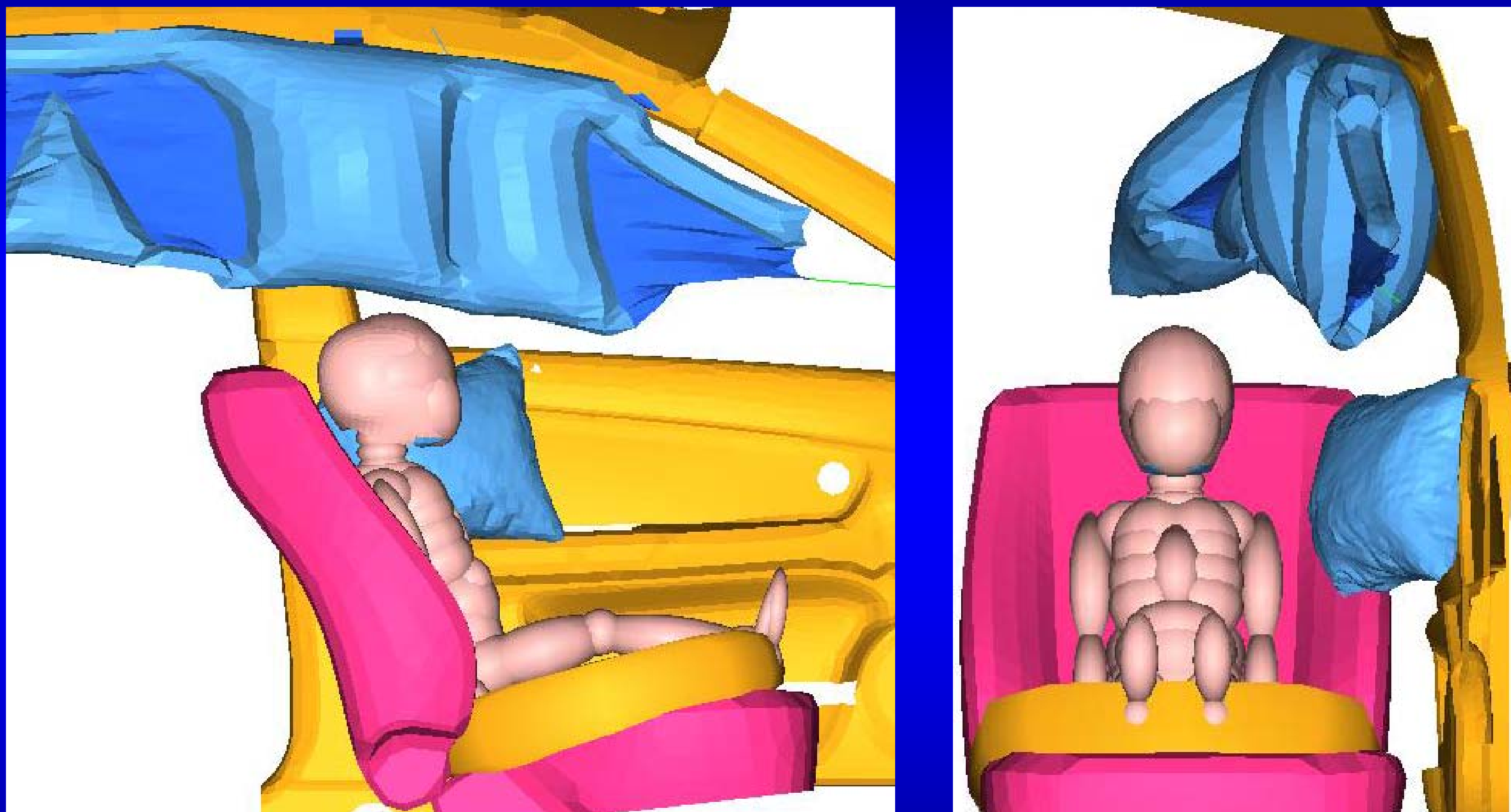
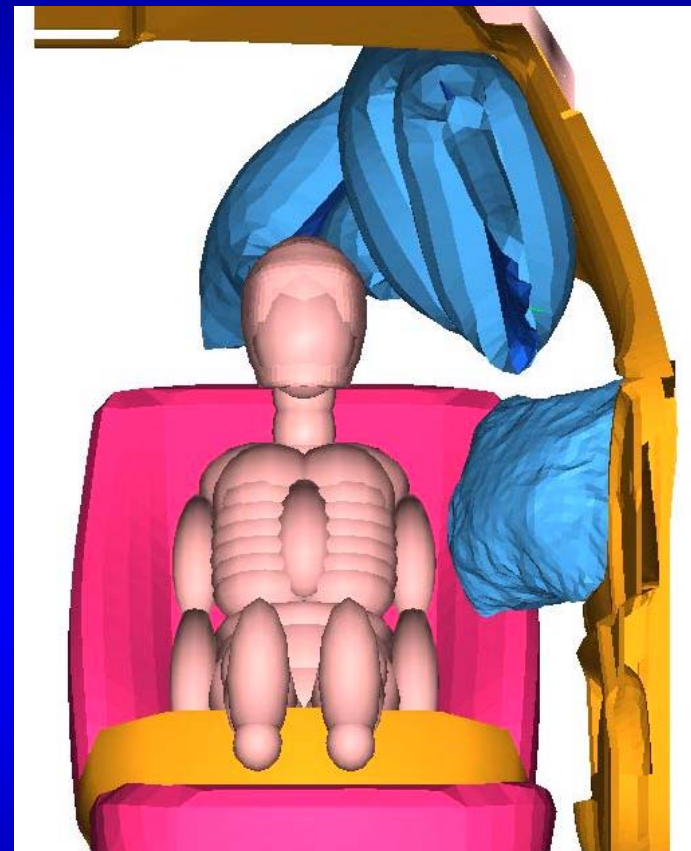
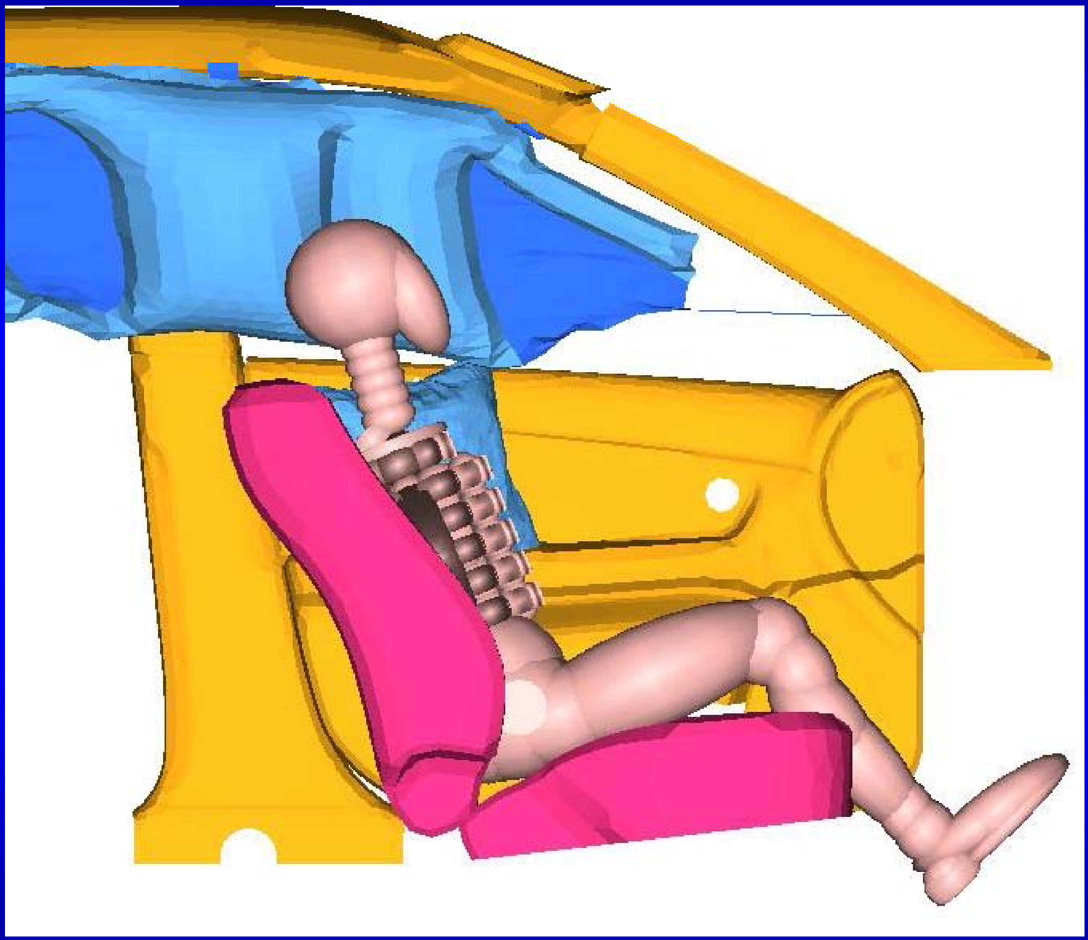
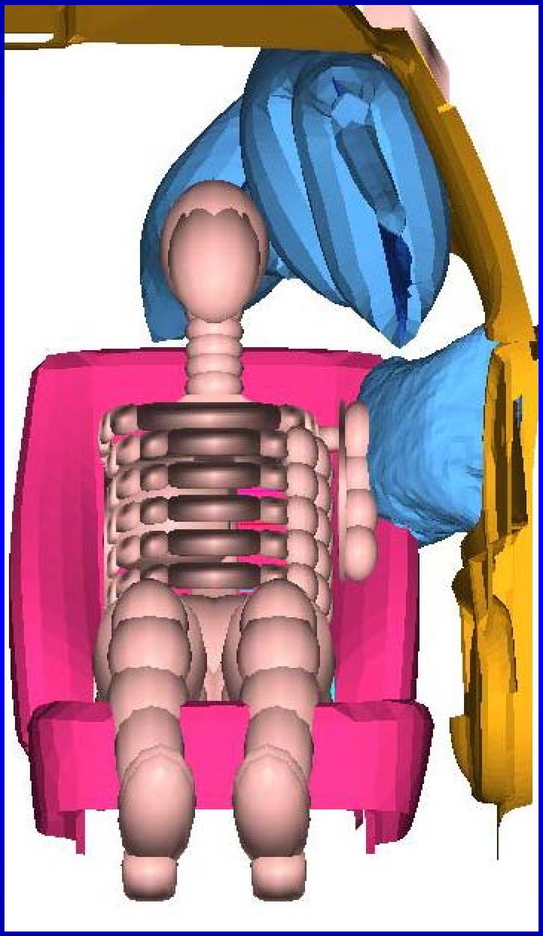


3 year old HIII Seating Position in Mid-Sized Sedan

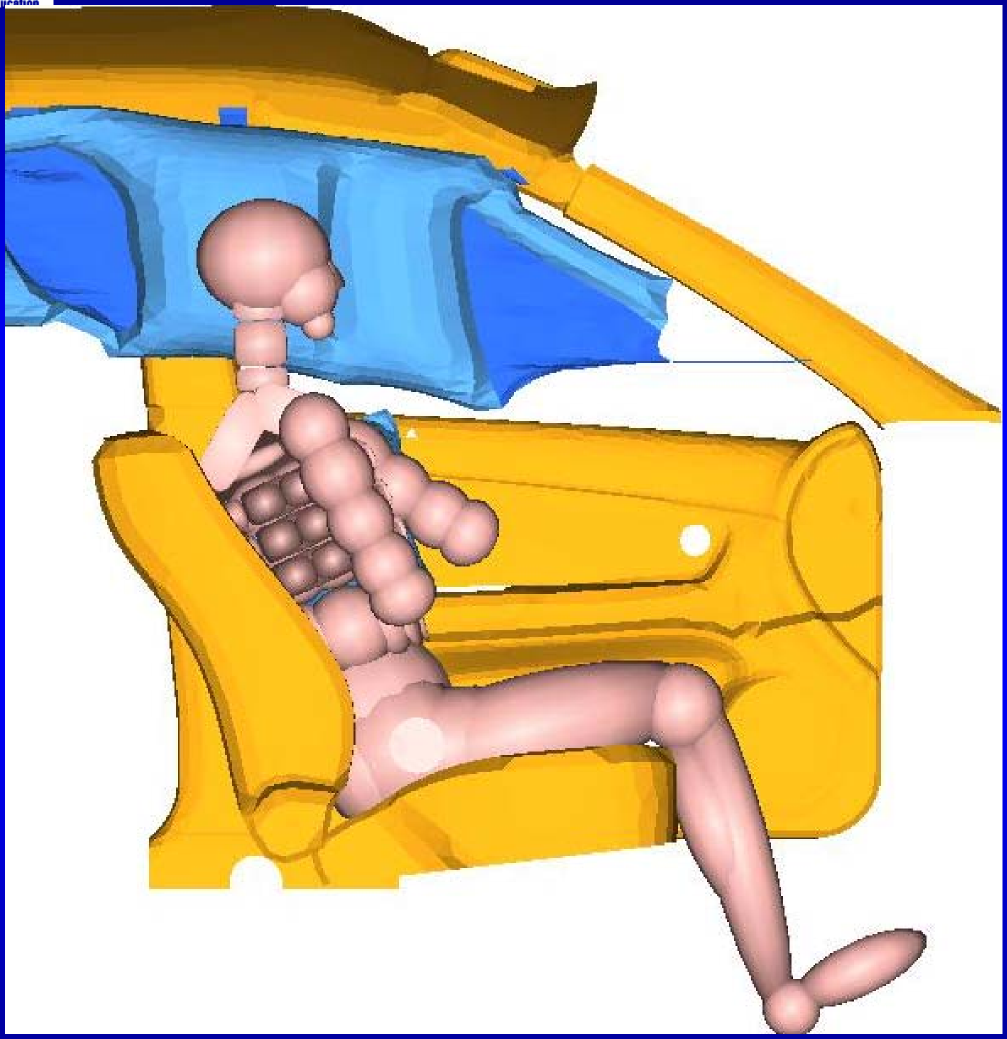


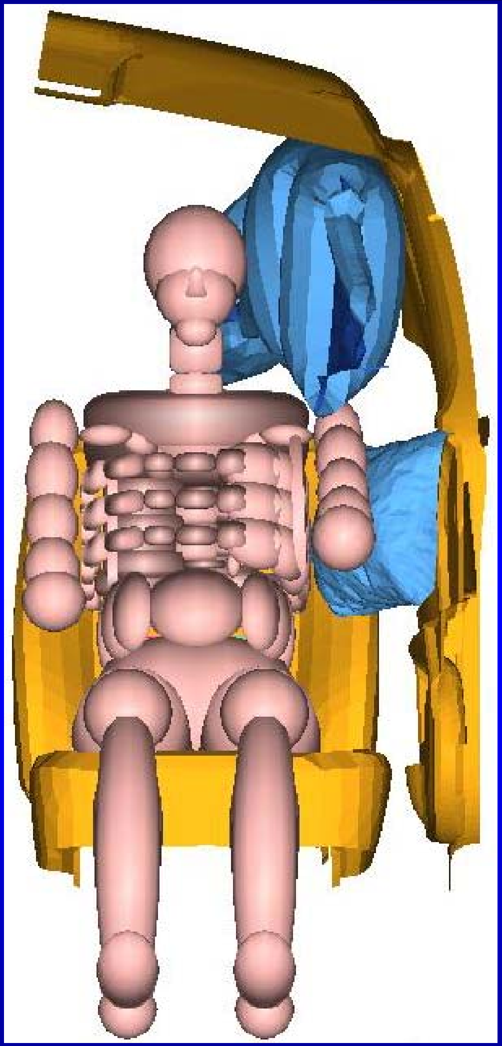
6 year old HIII Seating Position in Mid-Sized Sedan





5th%ile (SID-IIs) Seating Position in Mid-Sized Sedan

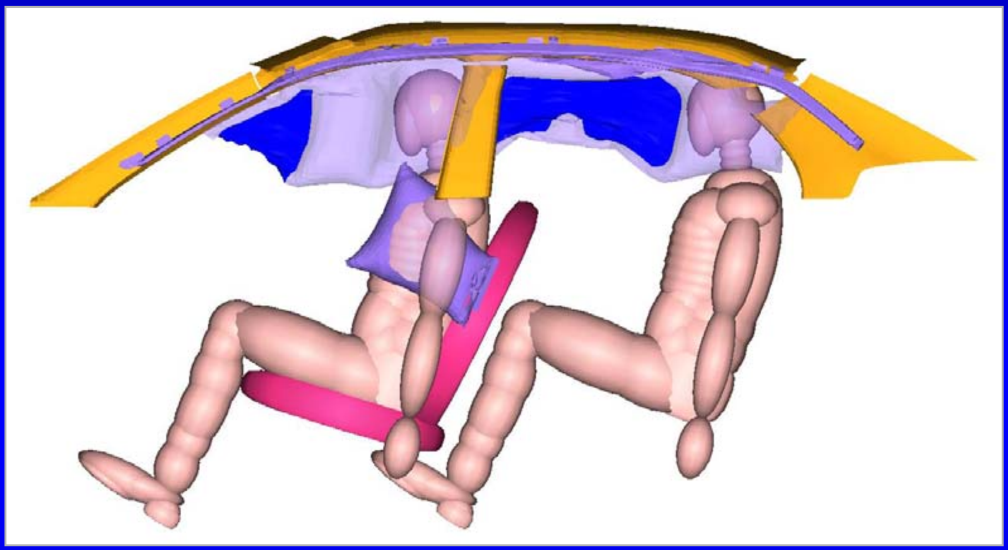




50th% (EuroSID) Seating Position in Mid-Sized Sedan

▸ Coverage Zone Concept

Mid-Seat Euro-SID



"A-C" Pillar Protection Coverage

Full ForwardSID-IIs

Rear Euro-SID

Static Out of Position

- **A Technical Work Group (TWG) - IIHS, Alliance, AIAM, AORC, Transport Canada - has developed voluntary OOP procedures and injury targets for:**
  - SID-IIs (5th%ile HIII) w/ instrumented arm
  - Hybrid III, 6 year old sized
  - Hybrid III, 3 year old sized

- **Evaluations vary by type of side impact air bag.**
  - Door mounted
  - Seat mounted
  - Roof rail mounted curtains and inflatable tubular structures

Out Of Position Test Configurations

7 static positions to assess SAB OOP performance.

3year old

6year old

3.3.2.1/5 Forward-facing 3Y & 6Y HIII

3.3.2.2 Rearward facing 3Y old HIII

3.3.2.3 Lying on seat, head on armrest 3Y HIII

3.3.2.4 Lying on seat 3Y HIII

3.3.2.6 Inboard facing SIDIIs

3.3.2.7 SIDIIs with instrumented arm

TWG injury values

Reference values

	Hybrid III 3-Yr Old	Hybrid III 6-Yr Old	Hybrid III Sm. Fem.	SID IIs
HEAD				
15ms HIC	570	723	779	779
UPPER NECK				
Nij	1	1	1	1
(Ft/Fc/Mf/Me)	2120/2120/68/27	2800/2800/93/37	3880/3880/55/61	3880/3880/155/61
Tension (N)	1130	1490	2070	2070
Comp. (N)	1380	1820	2520	2520
THORAX				
Defl. (mm)	36	40	—	34
Defl. Rate (m/s)	8.0	8.5	—	8.2

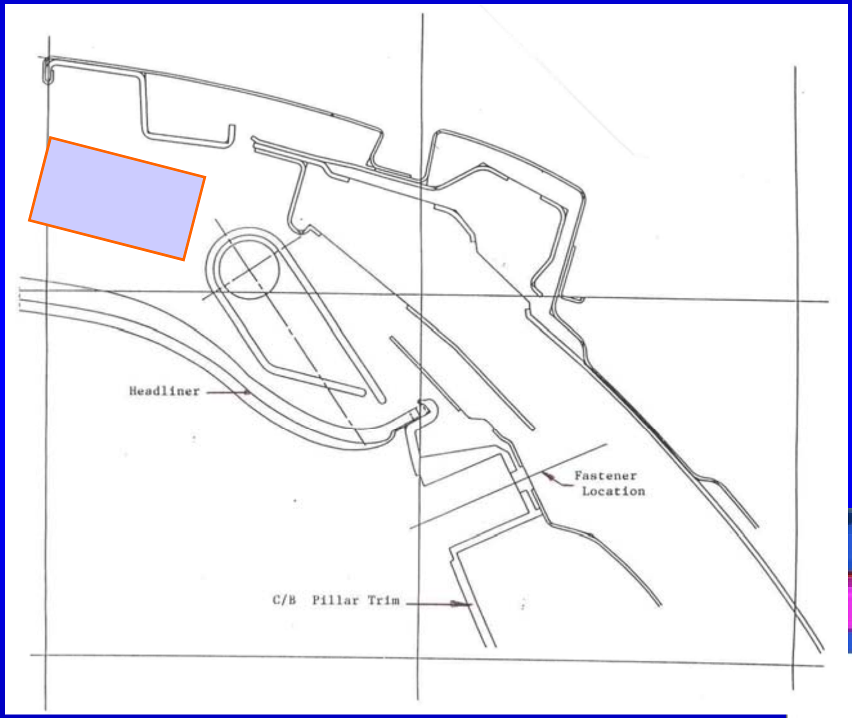
Side Impact Air Bag Challenges

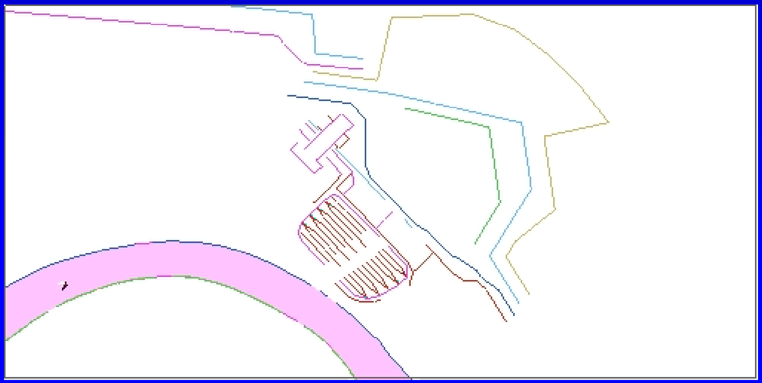
- **Crash sensing:**
  - Distinguishing the various side impact events (pole, car, truck) in time to fire the lateral airbag, and maintaining immunity from non-severe events (door-slam, ball-hit, bicycle etc.)
  - In general, lateral airbags need to begin deploy about 4 - 8 msec after initial contact . This is about 1/3rd the time: to sense the crash, process the algorithm, and initiate a fire-command , as compared to frontal impact air bags.
  - Thorax cushion requires about ~ 10msec to fill
  - Curtain Airbags require about ~ 25 msec to fill.

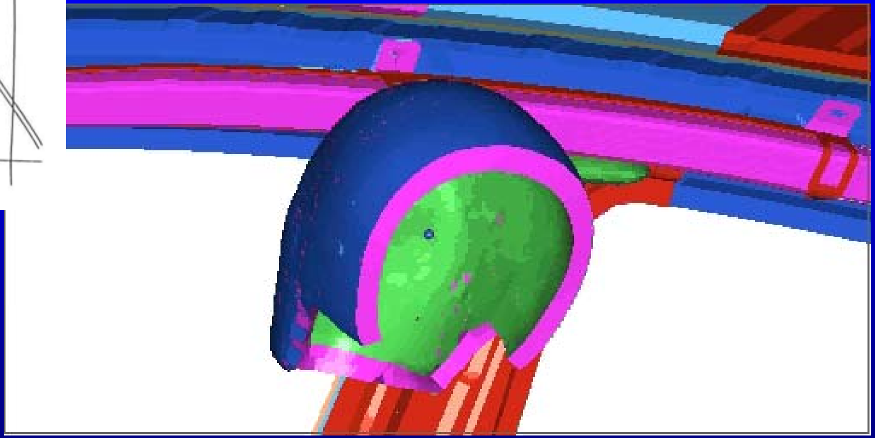
Side Impact Air Bag Challenges

- **Thorax bags must deploy in gap between seat bolster and door trim, and occupant.**
  - Gap is small on small cars
  - Occupant size can affect deployment
- **Curtain airbags must deploy over the B- pillar trim, belts, and often over rapidly deforming sheet metal.**
  - There is often opportunity for Curtain to interact negatively with structure

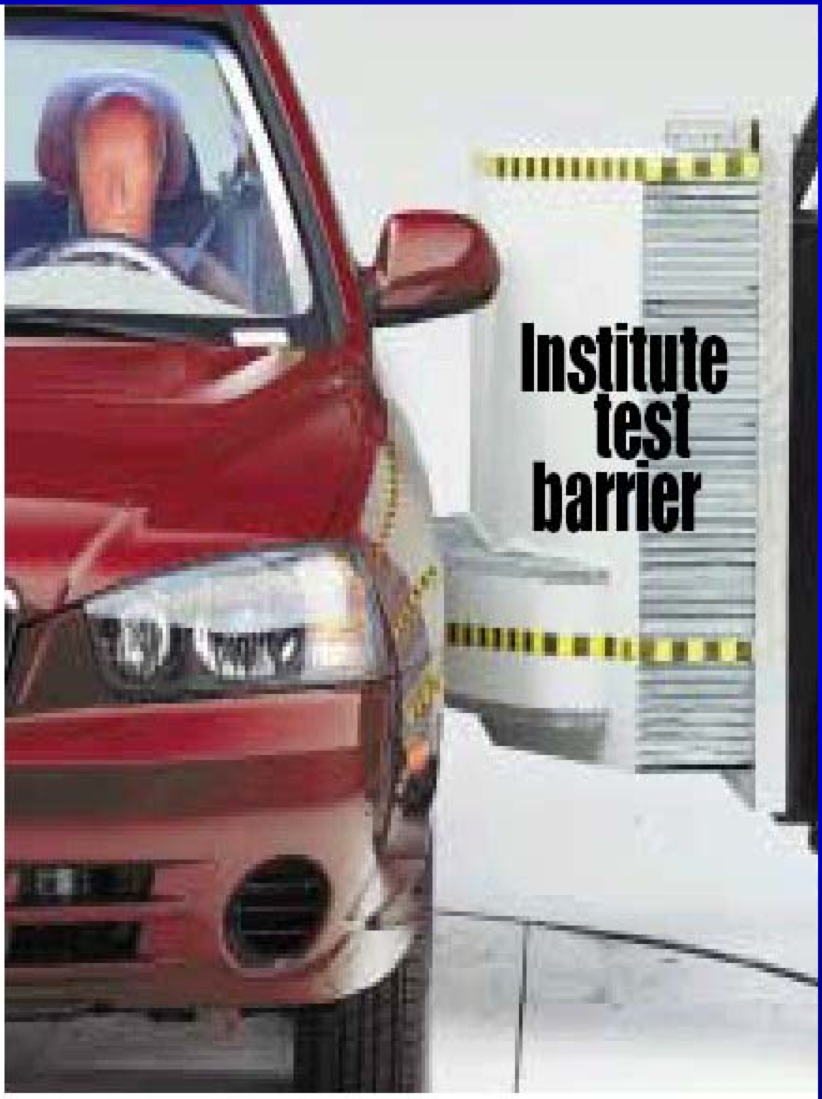
Packaging: Decreased packaging volume due to presence of curtain in the roofrail area increases the challenge of meeting FMVSS 201 type head impacts

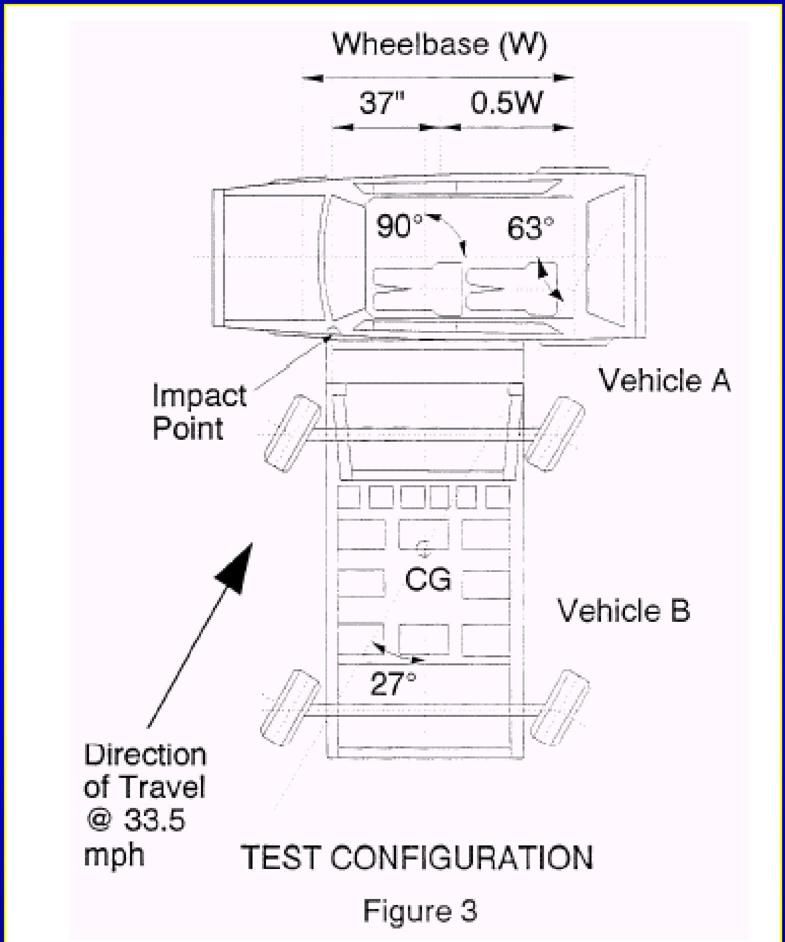




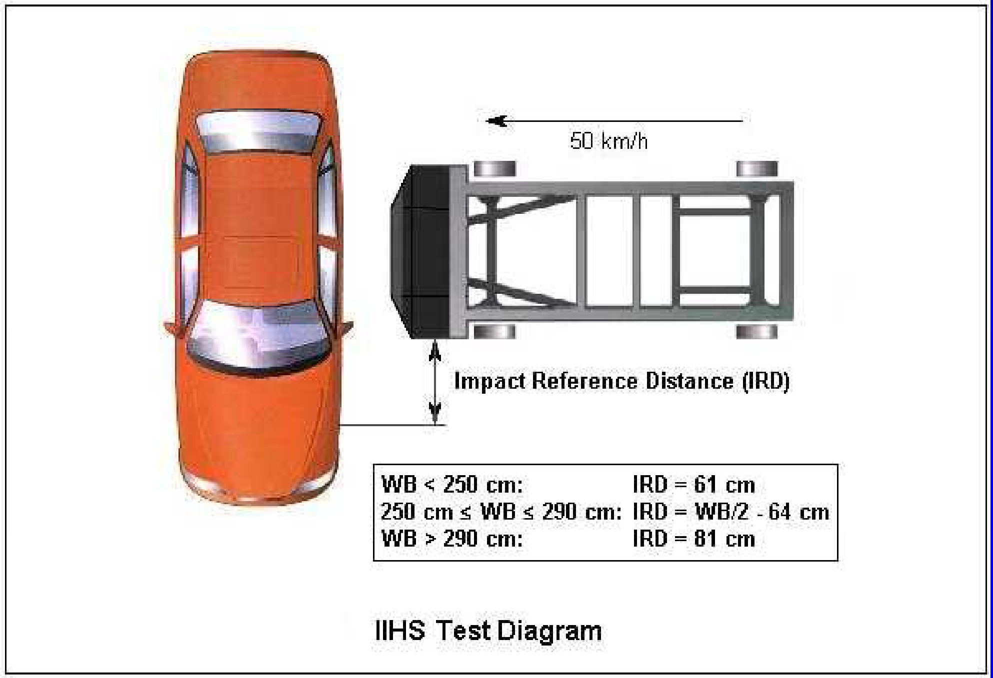


FMVSS 214 Barrier vs IIHS LTV Barrier Height





FMVSS 214



IIHS LTV

Comparison of IIHS High Hood and Regulatory Tests

Side Impact Crash Test Configurations

Description	IIHS High Hood	FMVSS 214	ECE R95
Impact Angle	90 degrees	63 degrees	90 Degrees
Bullet Weight	1,500 kg	1367 kg	950 kg
Bullet Speed	50 kph	54 kph in 63 deg. Direction (or 48 kph lat./ 24 kph long.)	50 kph
Impact Location	300 mm rear of FMVSS 214	Front edge of barrier face @940 mm from half wheelbase plane	Middle plane of barrier face in line with front row SRP
Barrier Face Size	762 mm H x 1,676 mm W with tapered on both side edges	559 mm H x 1,676 mm W	500 mm H x 1,500 mm W
Ground Clearance	381 mm	279 mm	300 mm
Seating Position	UMTRI position	Designed seatback angle Mid- seat travel lowest seat cushion.	Designed torso angle (25 if unknown) , mid seat travel, same height as non-adjustable, or mid height.
Dummy	SIDIIs front and rear	US SID front and rear	EuroSID front only

Because IIHS LTV crash test specifies heavier barrier mass and higher ground clearance than FMVSS 214, the injury values are more severe.

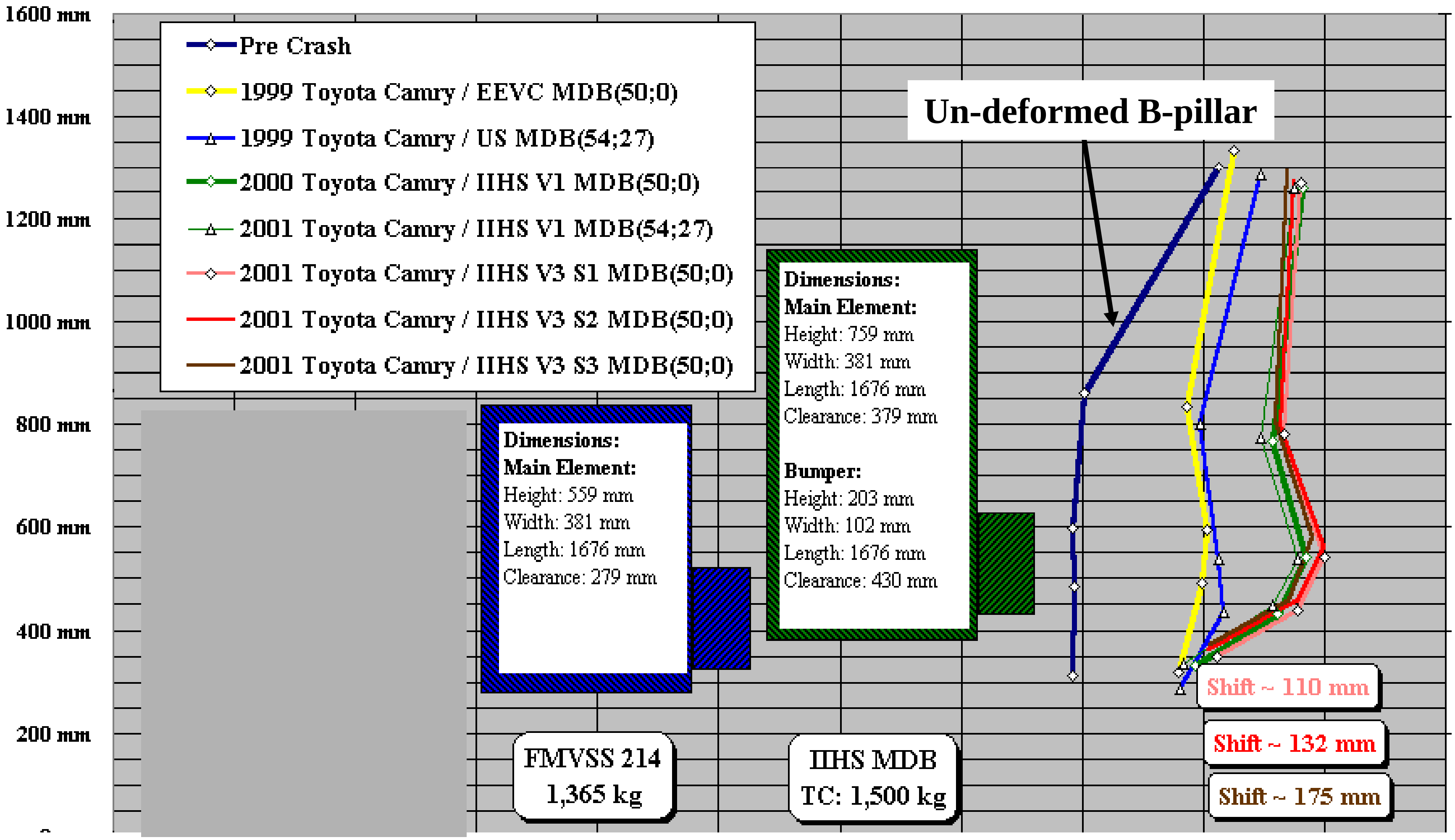
Regulations / Test Modes

From the inflatable restraint viewpoint, the IIHS test protocol is the primary method to assess & improve “self-protection” for “incompatible” lateral crash modes.

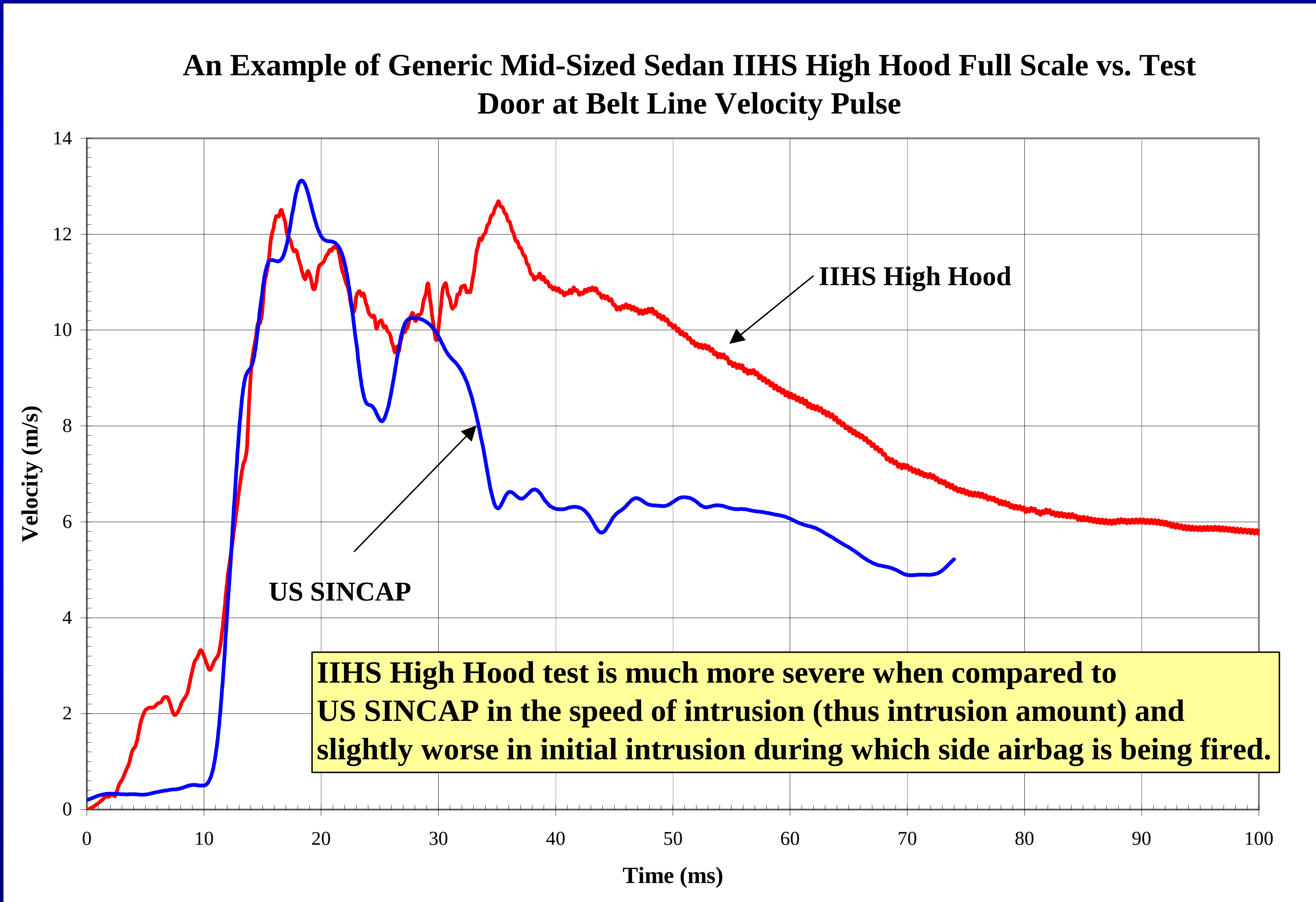
The IIHS LTV (incompatibility) test mode has several additional challenges for "Self - Protection" injury mitigation:

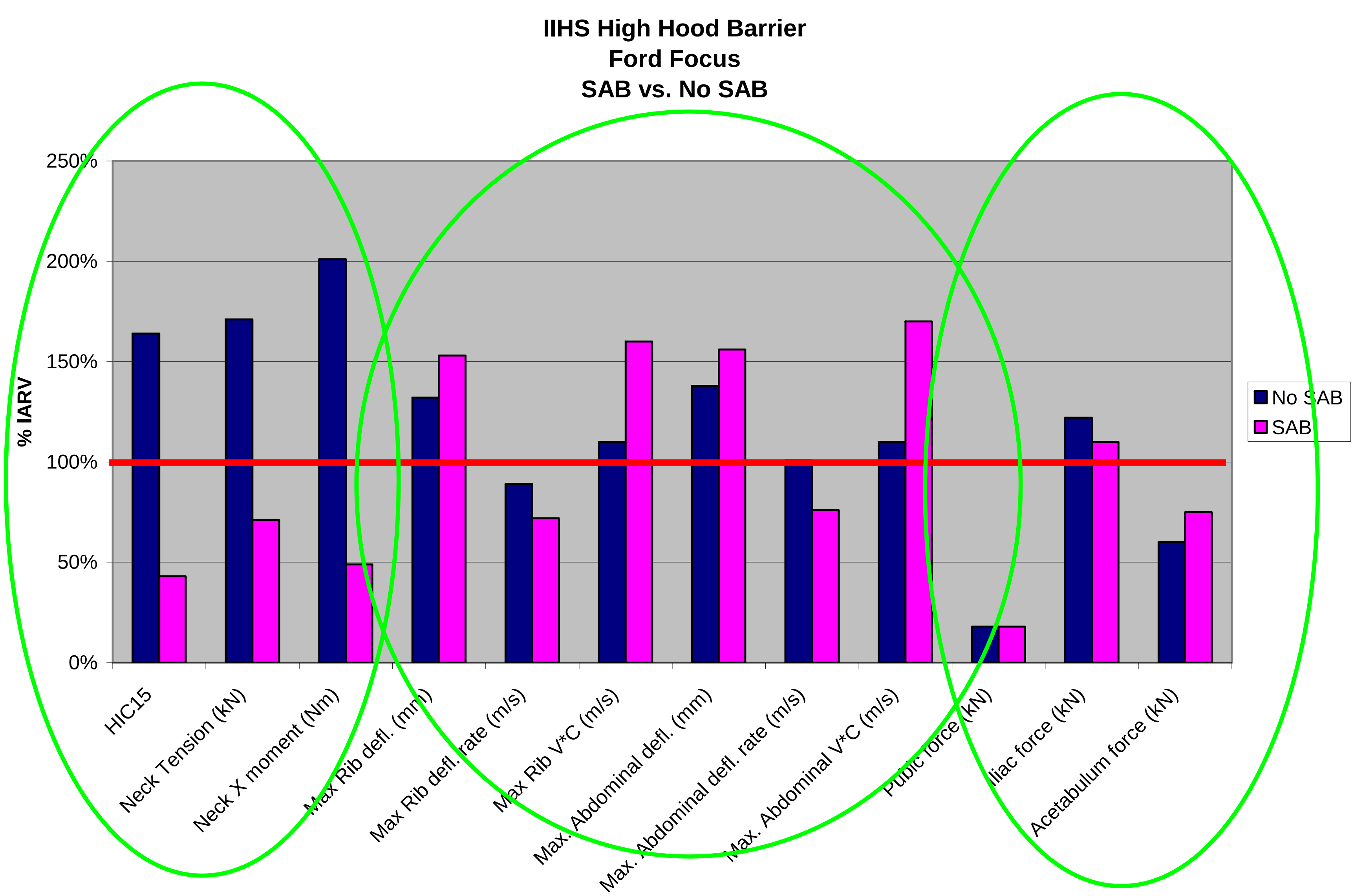
- **Likely head-to-barrier contact requires inflatable head protection:**
  - Curtain or Head cushions
- **Higher ATD loads on Thorax / Abdomen / Pelvis (than with LINCAP)**
  - Improved door padding
  - Structural stiffness
  - **Increased Airbag pressures and/or hold times in order to offer some protection for thorax / abdomen / pelvis.**
- **Sensor Fire time:**
  - Current sensor are either acceleration or pressure based
  - Current sensor are typically located at bottom of B- (and C-) pillar / rocker panel

B-Pillar Crush Profiles
Camry Test Series

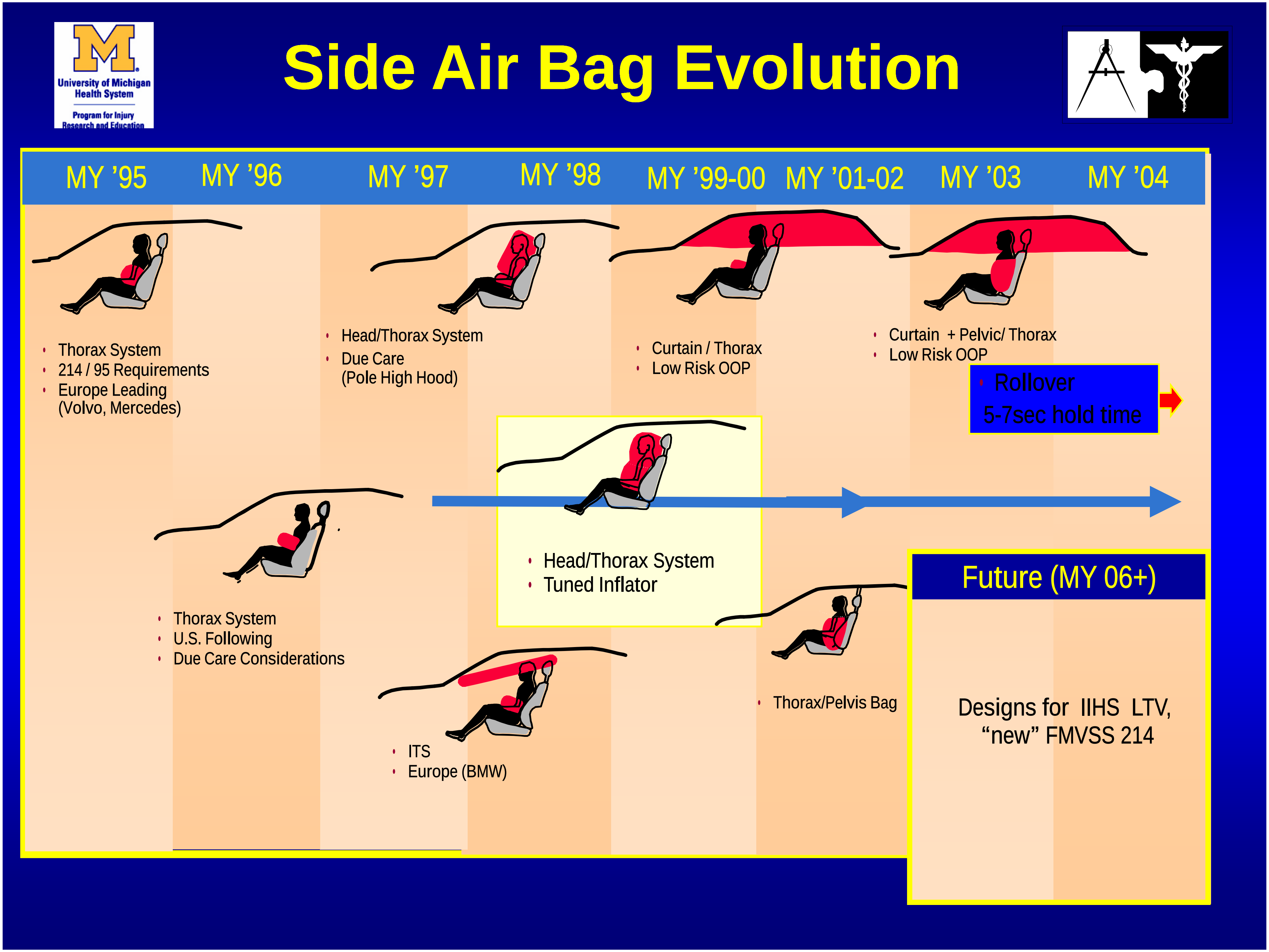


Comparison of IIHS High Hood vs. US SINCAP Door Motion





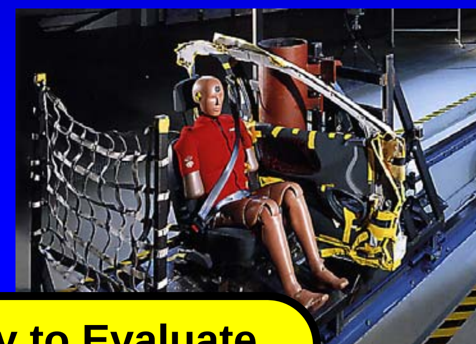
IIHS High Hood Barrier
Ford Focus
SAB vs. No SAB
% IARV
250%
200%
150%
100%
50%
0%
HIC15
Neck Tension (kN)
Neck X moment (Nm)
Max Rib defl. (mm)
Max Rib defl. rate (m/s)
Max Rib V*C (m/s)
Max. Abdominal defl. (mm)
Max. Abdominal defl. rate (m/s)
Max. Abdominal V*C (m/s)
Pubic force (kN)
Iliac force (kN)
Acetabulum force (kN)
No SAB
SAB


University of Michigan Health System
Program for Injury Research and Education
Side Air Bag Evolution
MY '95
MY '96
MY '97
MY '98
MY '99-00
MY '01-02
MY '03
MY '04
Thorax System
214 / 95 Requirements
Europe Leading (Volvo, Mercedes)
Head/Thorax System
Due Care (Pole High Hood)
Curtain / Thorax
Low Risk OOP
Curtain + Pelvic/ Thorax
Low Risk OOP
Rollover
5-7sec hold time
Thorax System
U.S. Following
Due Care Considerations
Head/Thorax System
Tuned Inflator
ITS
Europe (BMW)
Thorax/Pelvis Bag
Future (MY 06+)
Designs for IIHS LTV, "new" FMVSS 214

Safety Improvement

Understand Problem

Field DATA



Way to Evaluate

Injury Criteria

ATD

Test Procedure

Design Countermeasure

Engineering

Manufacturing

Repeatability