



Vehicle Countermeasures Against Incompatible Crashes

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Safety Improvement



Understand Problem

Field DATA



Way to Evaluate

Injury Criteria

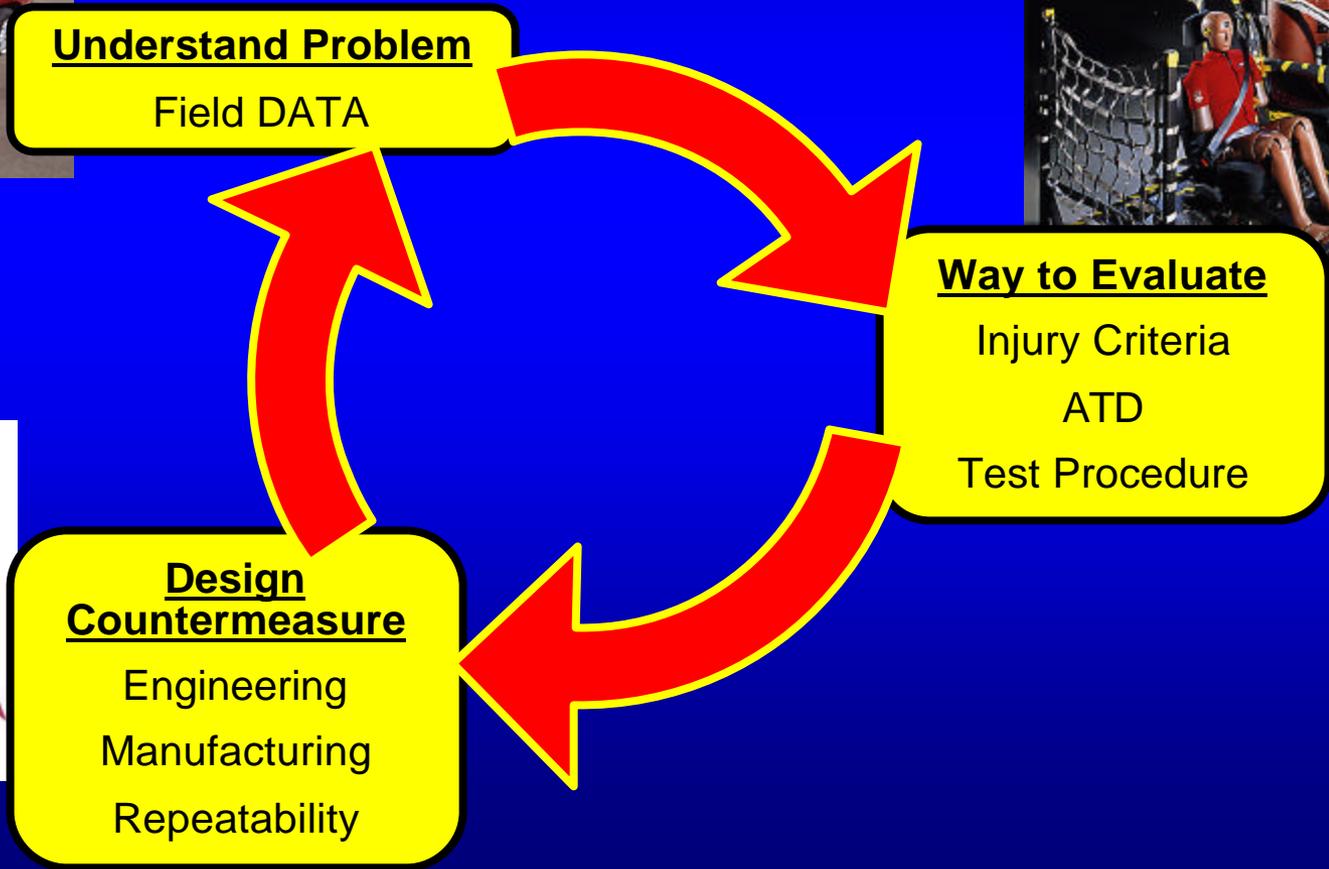
ATD

Test Procedure

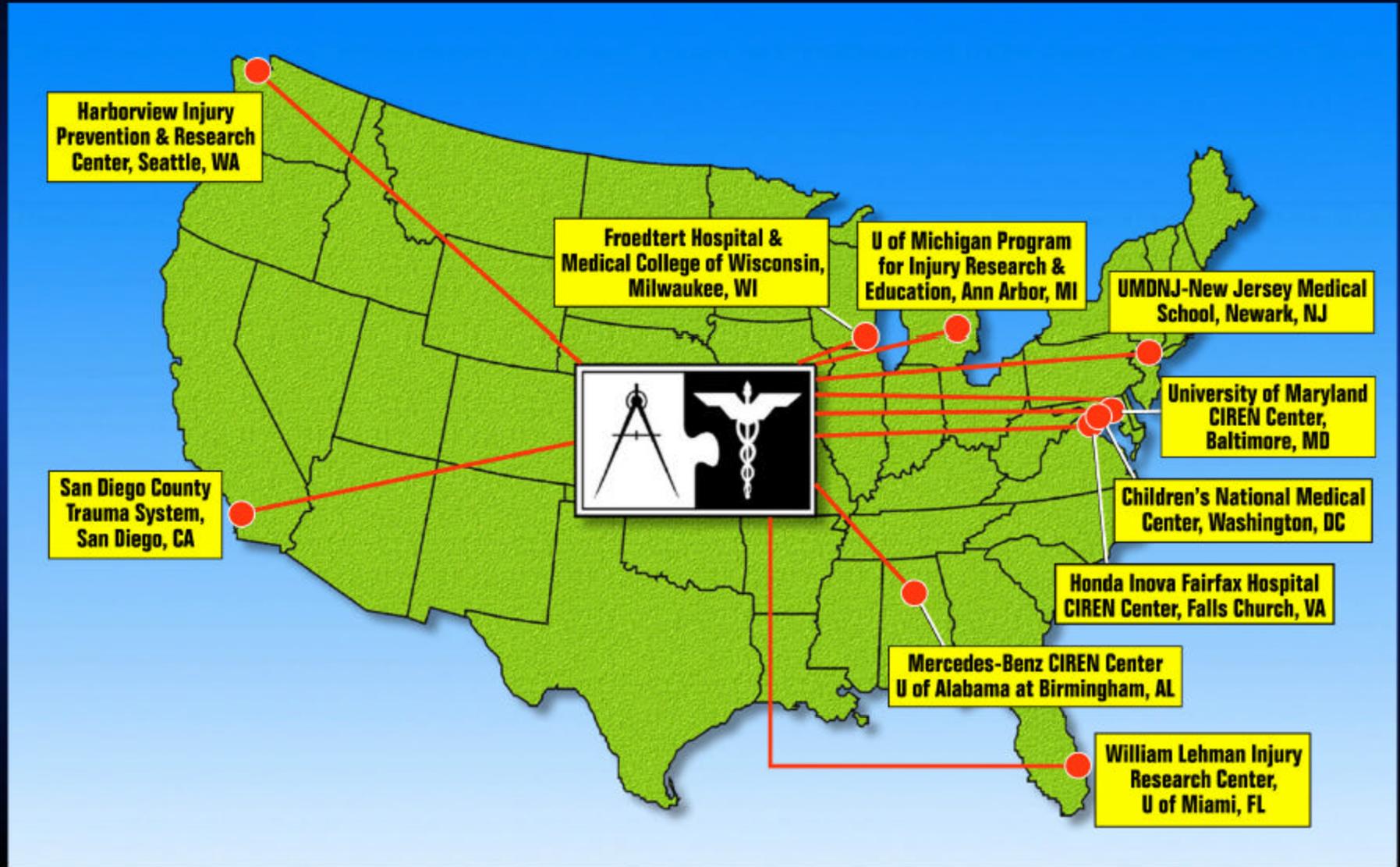


Design Countermeasure

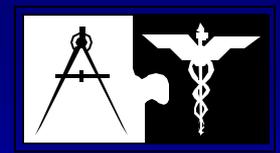
Engineering
Manufacturing
Repeatability



CIREN Network









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

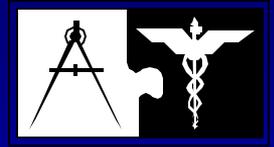


Vehicle Incompatibility

Mass, Stiffness, Geometry



Vehicle Incompatibility



Worst Case Scenario



Safety Improvement



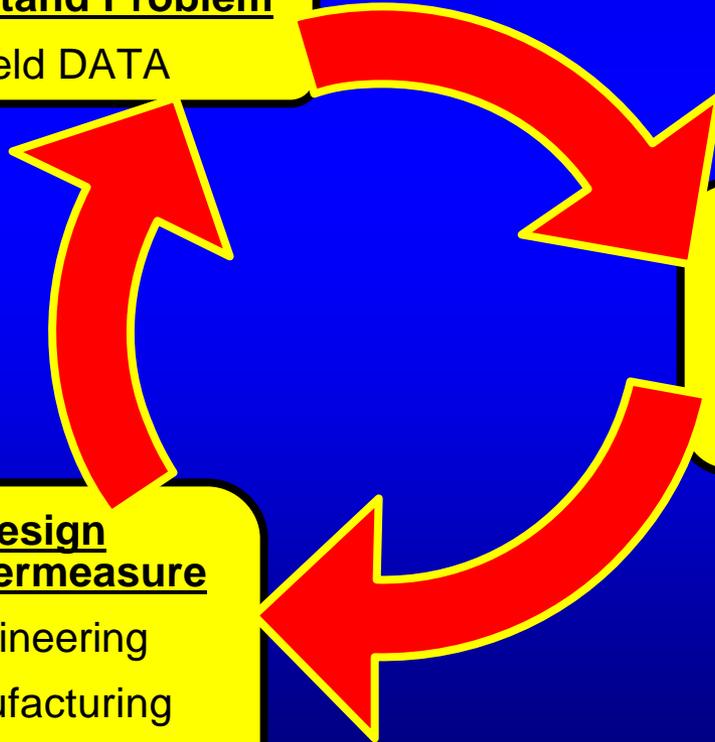
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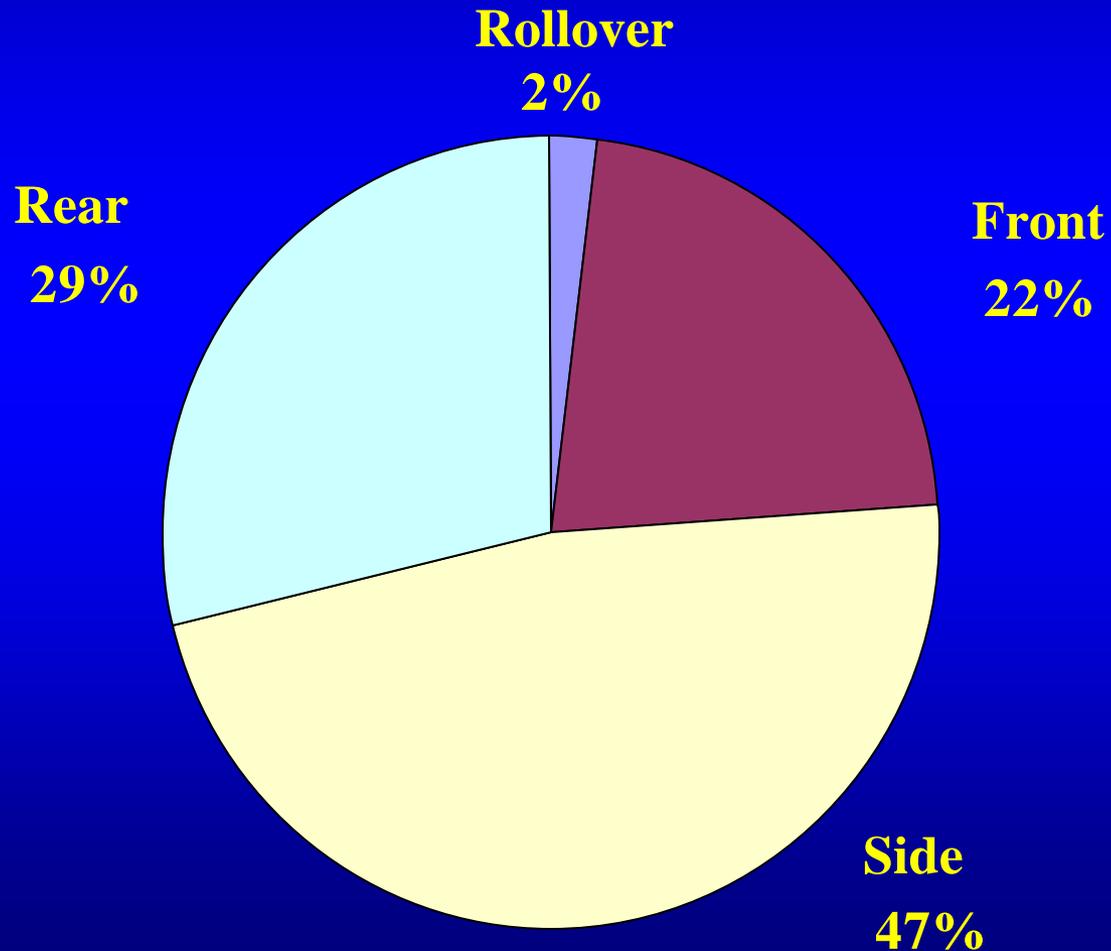
Design Countermeasure
Engineering
Manufacturing
Repeatability



LTV Front to Car Crashes (NASS 1997-2001)



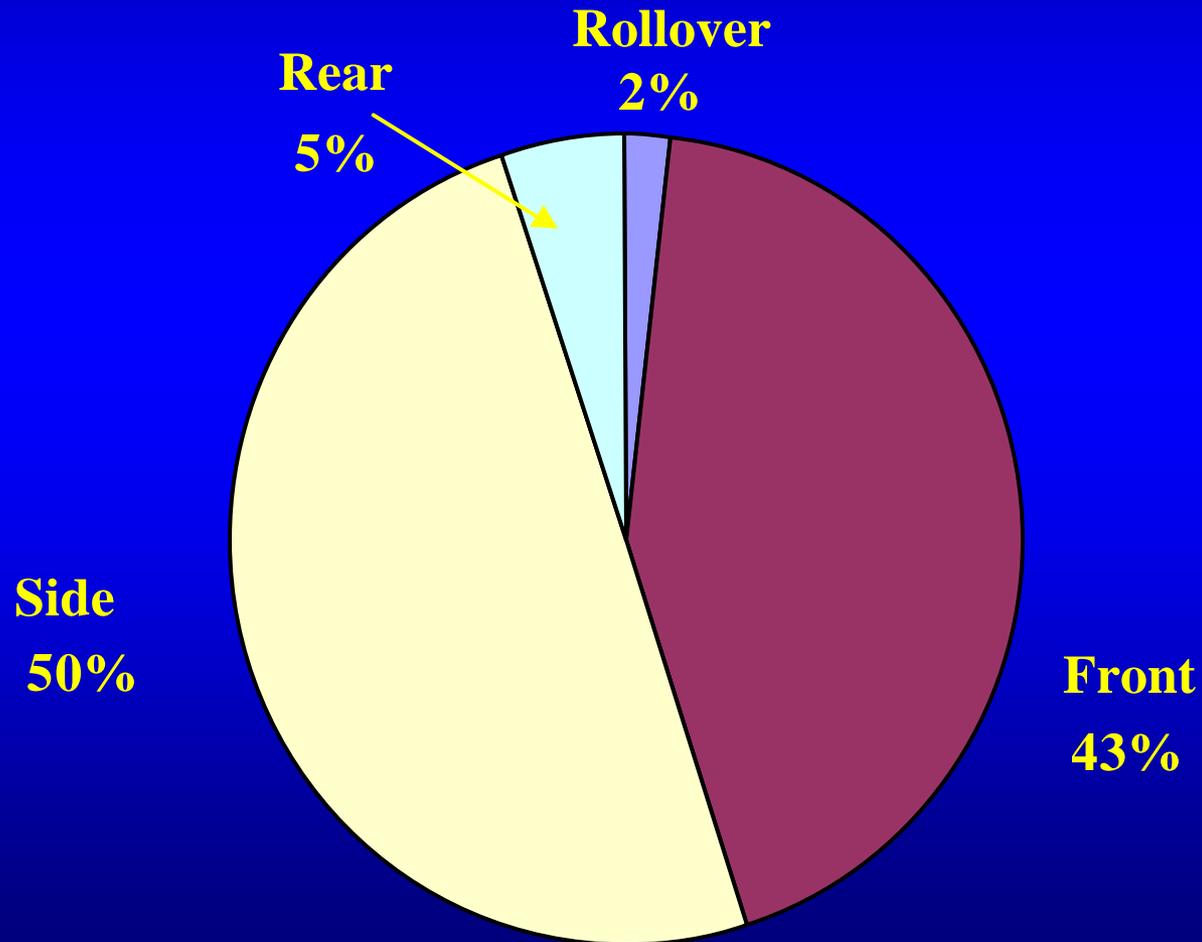
Frequency



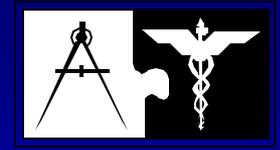
LTV Front to Car Crashes (NASS 1997-2001)



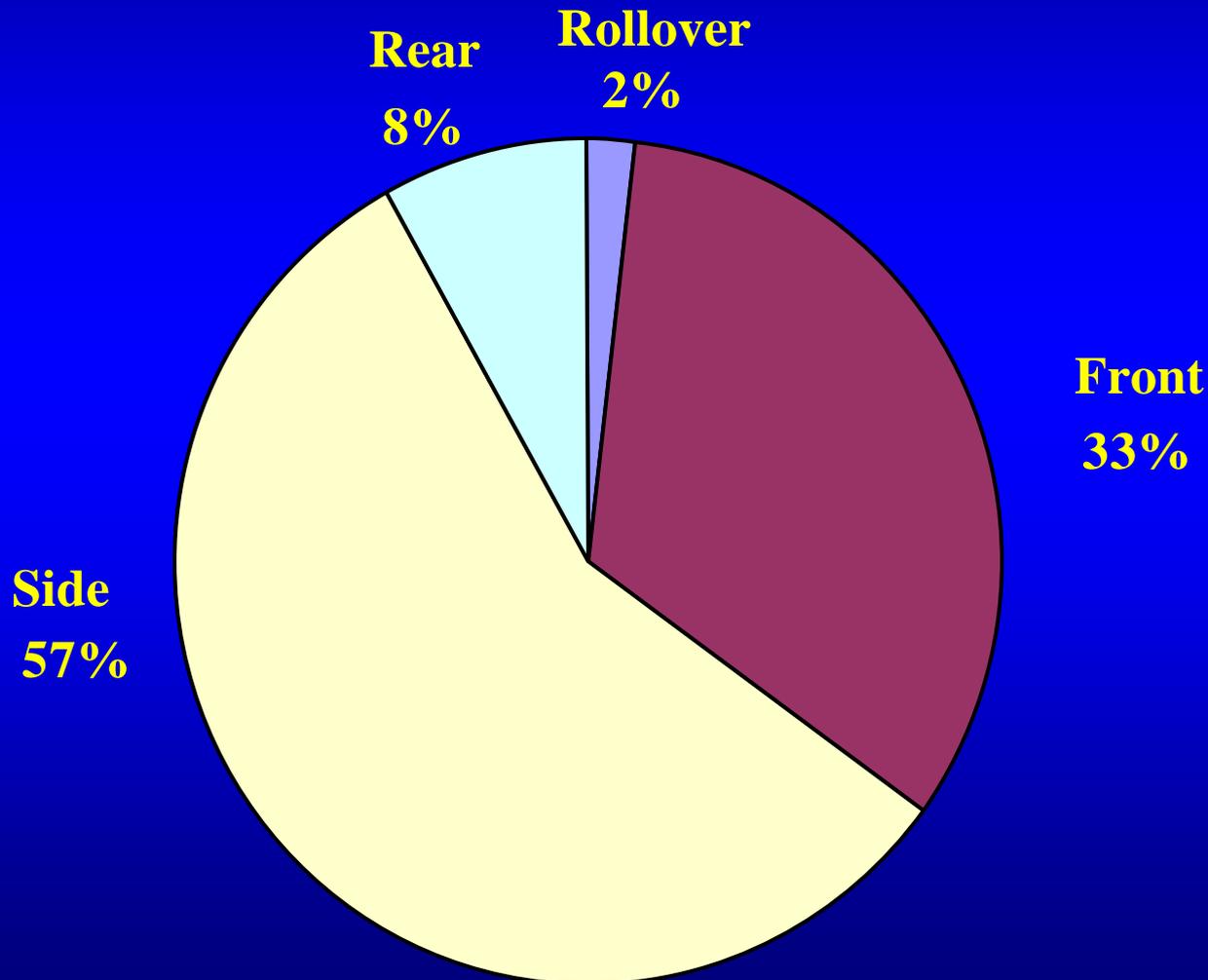
Distribution of Occupants with MAIS \geq 3



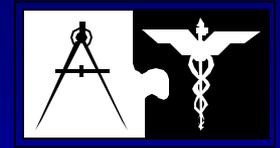
LTV Front to Car Crashes (NASS 1997-2001)



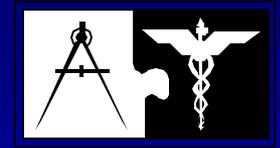
Distribution of Occupant Harm



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**



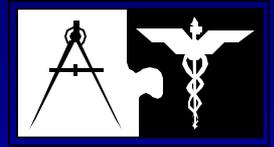
ATD's for Side Impact

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**

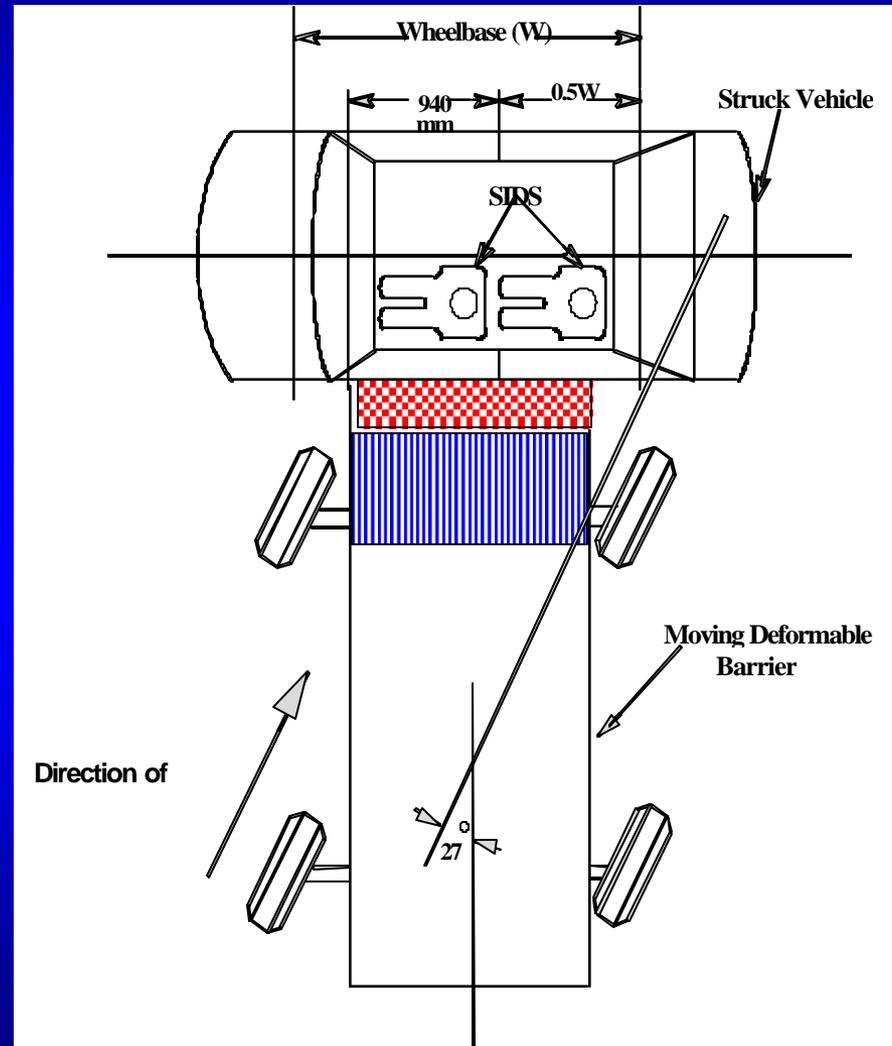
Every ATD style has advantages & disadvantages in testing & bio-fidelity

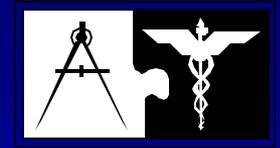
FMVSS 214 Load Case



- **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**

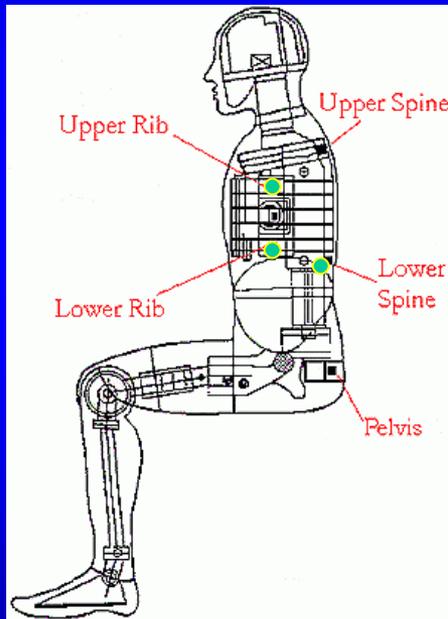




Thoracic Trauma Index

Thoracic Trauma Index (TTI)

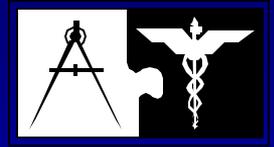
$$TTI = \frac{1}{2} (G_R + G_{LS})$$



G_R - Greater of the peak acceleration
of either the upper or lower rib
 G_{LS} - Peak acceleration of the lower
spine

Side Impact Dummy (SID)

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

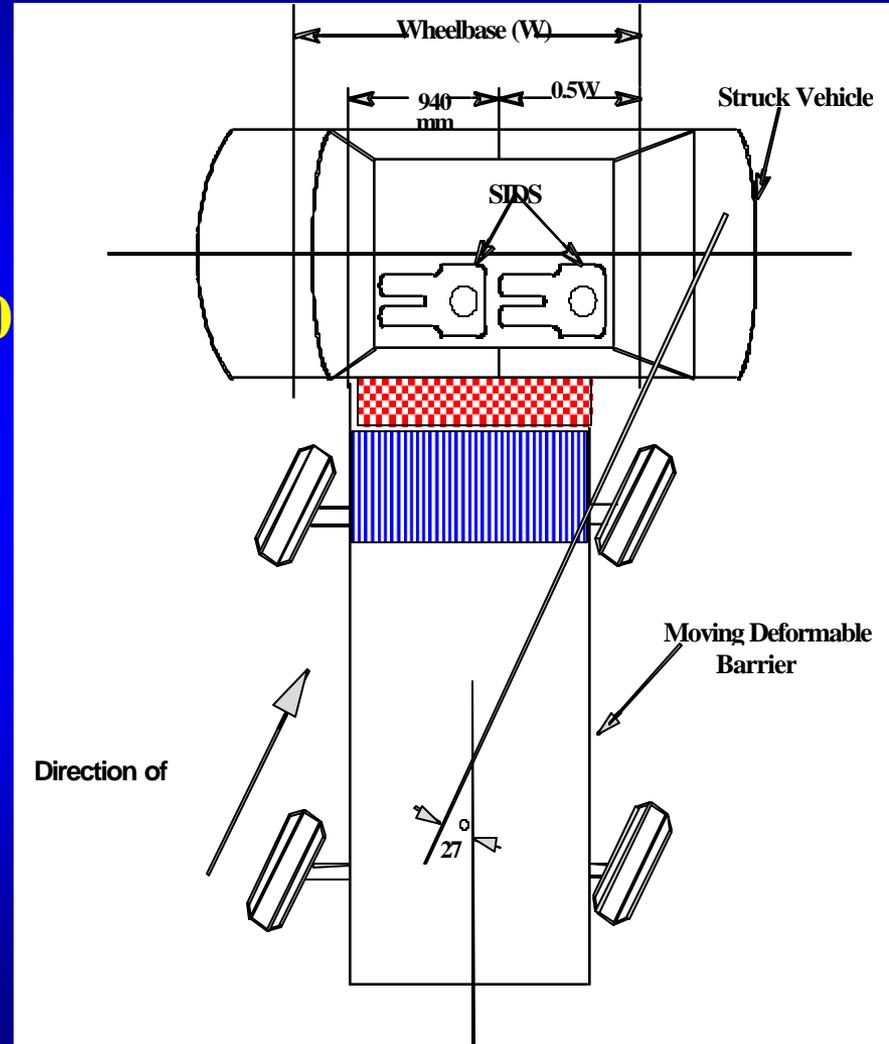
4 Star 57 < TTI ≤ 72

3 Star 72 < TTI ≤ 91

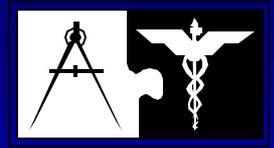
2 Star 91 < TTI ≤ 98

1 Star TTI > 98

Pelvis G's noted if exceeding 130g's

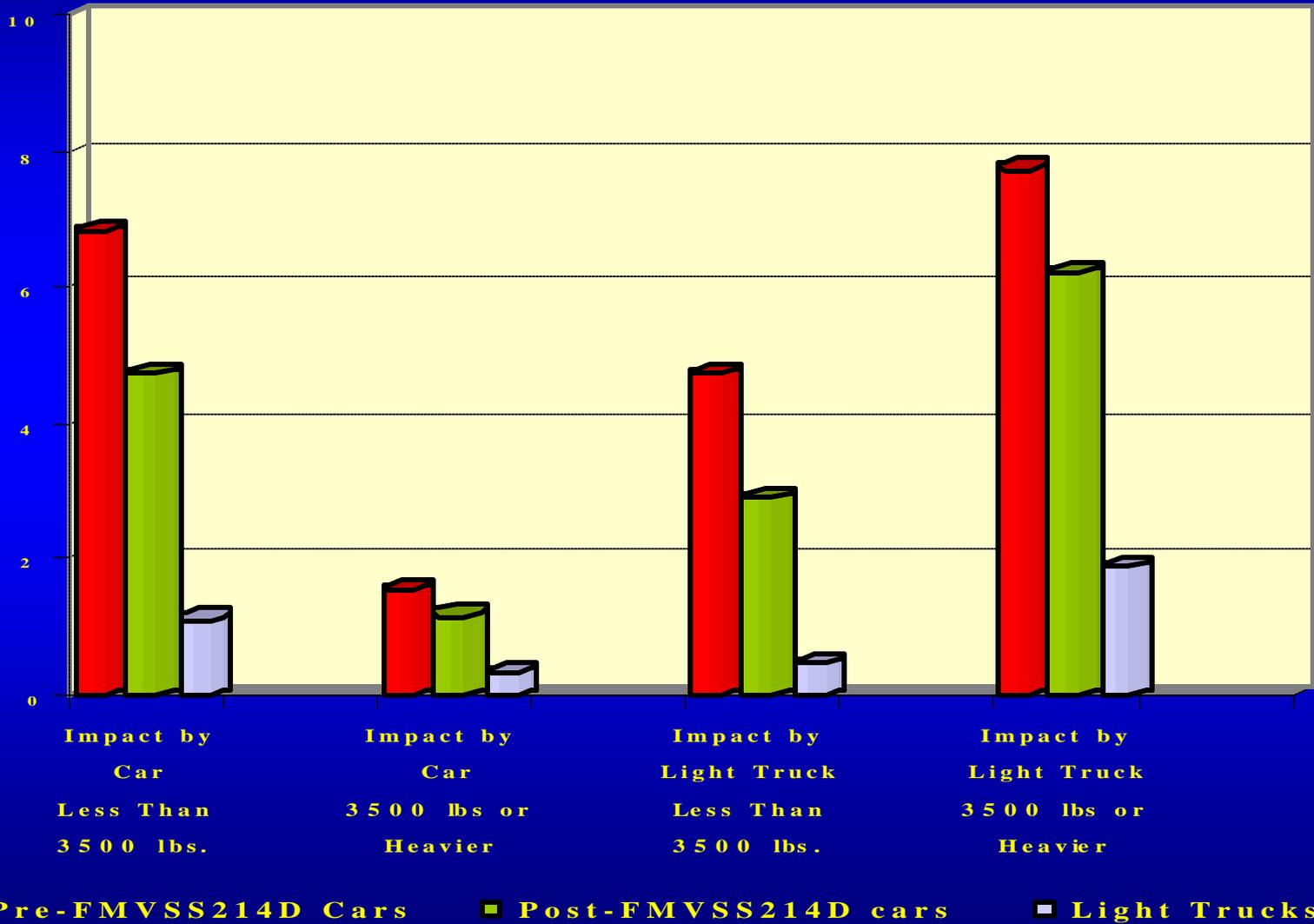


Fatal Injuries: Near-Side Occupants

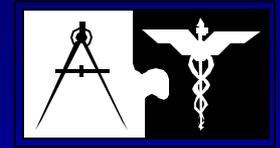


FARS 1993-1999, Model Years 1994-1999

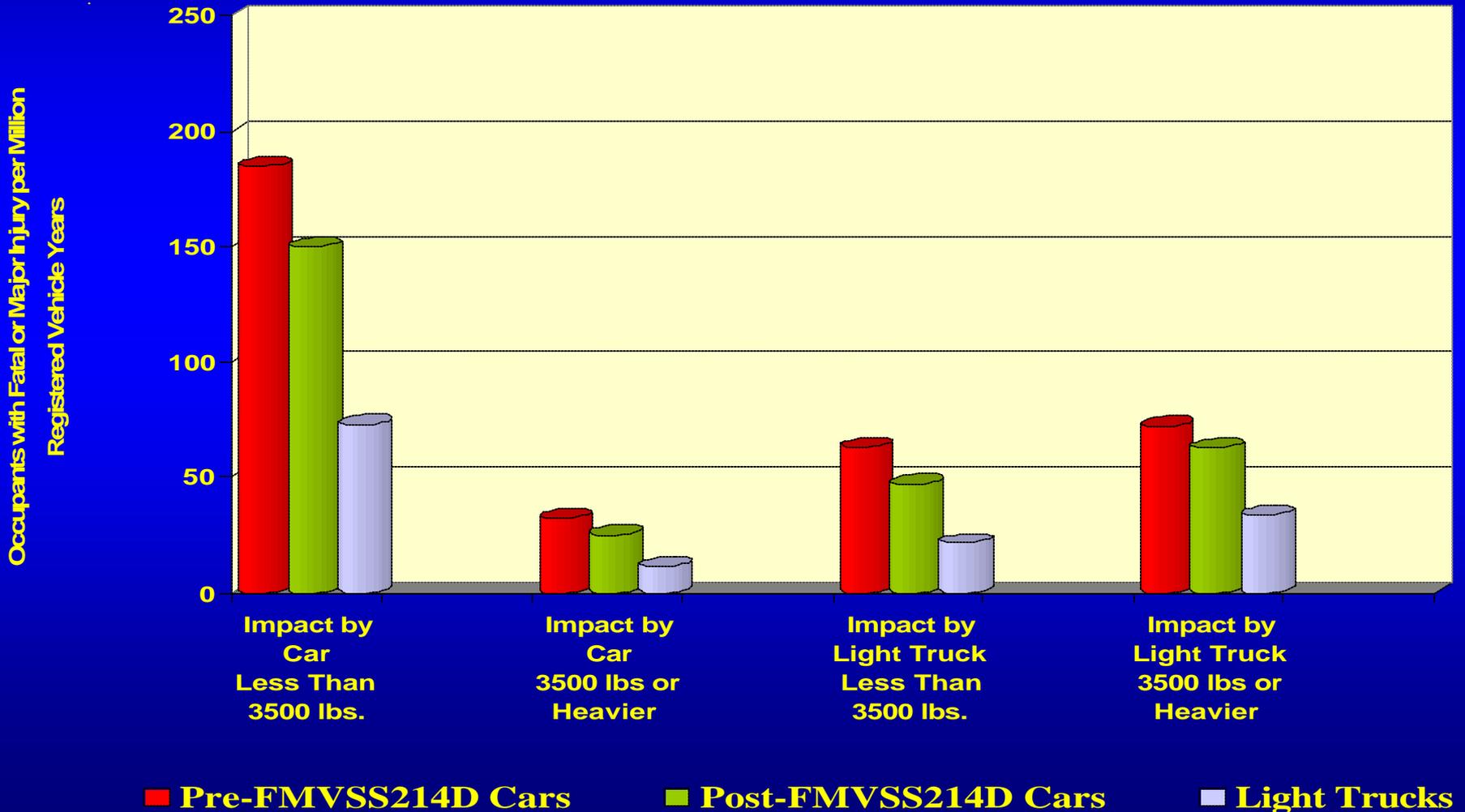
Occupant Fatality per Million Registered Vehicle Years



Fatal/Major Injuries: **Near-Side Occupants**

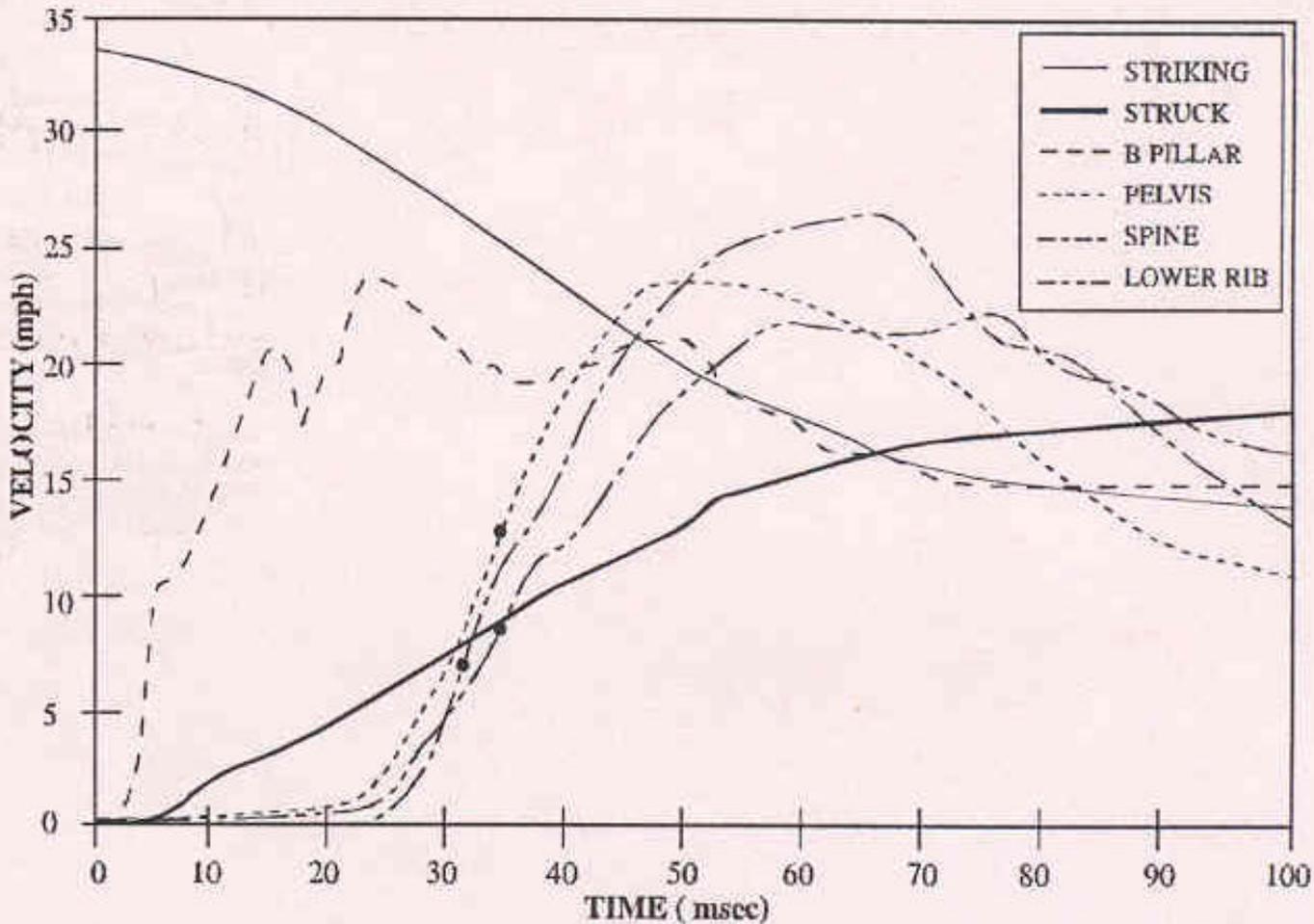


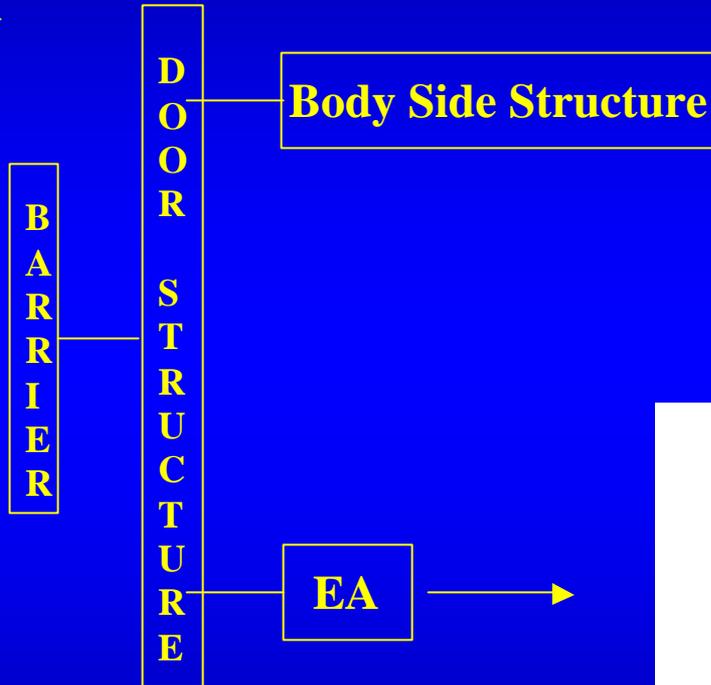
Five States (AL, FL, ID, MD, NC) 1994-1999, Model Years 1994-1999



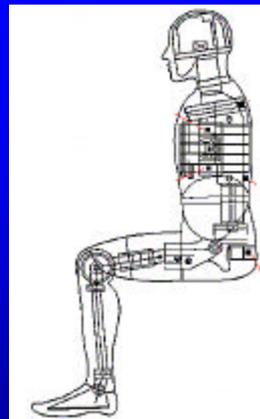


Velocity Time History – FMVSS 214 Side Impact Test (Mid-size Sedan)



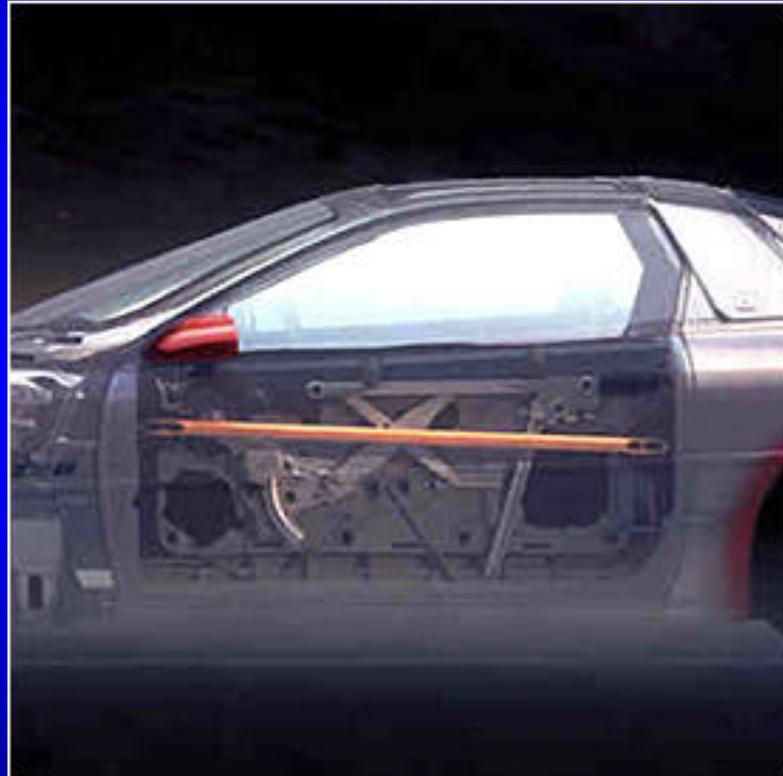
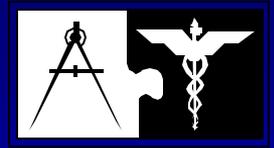


**Utilize structural load paths
to re-direct the energy**



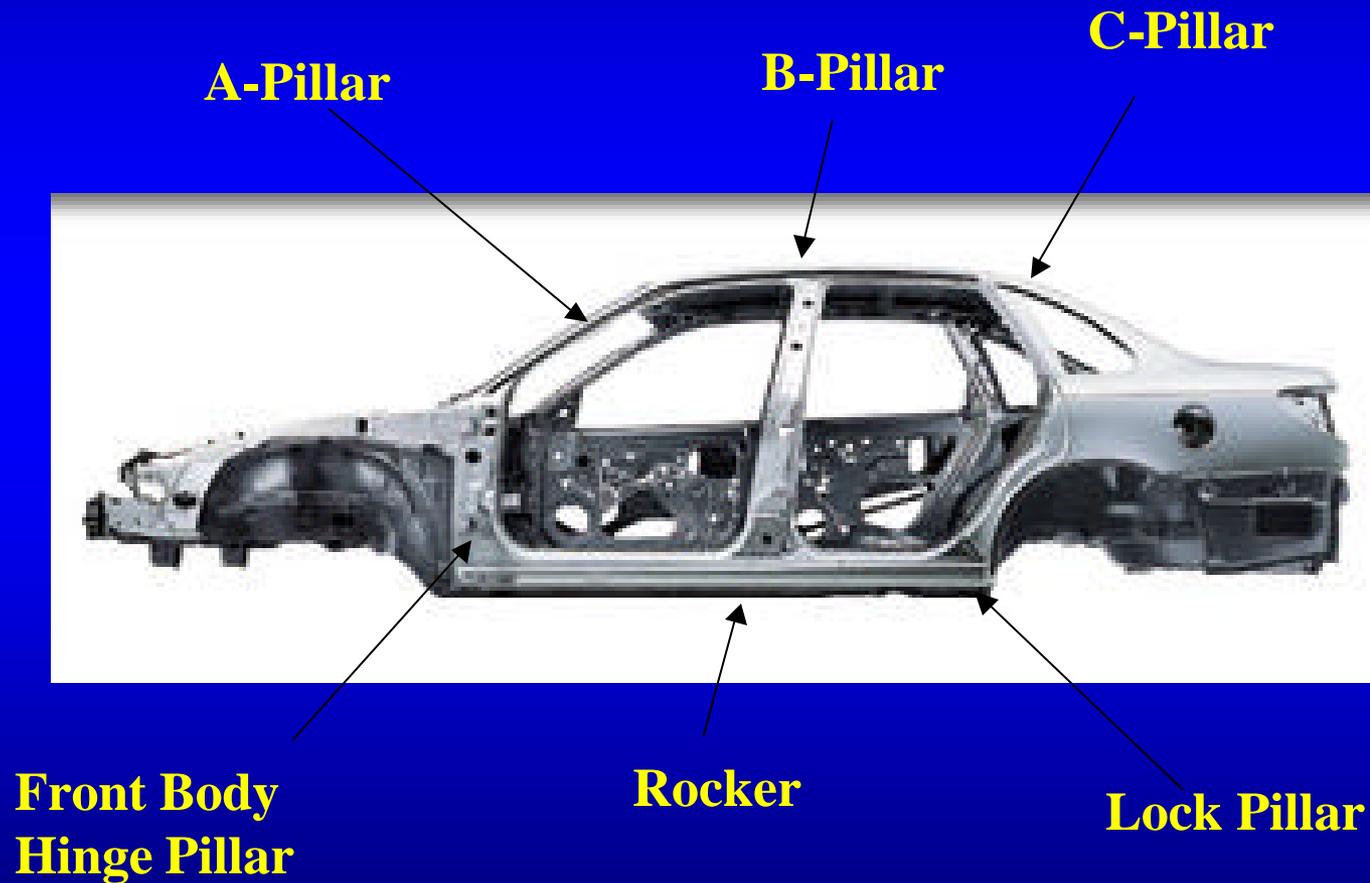
Manage the energy

Door Structure

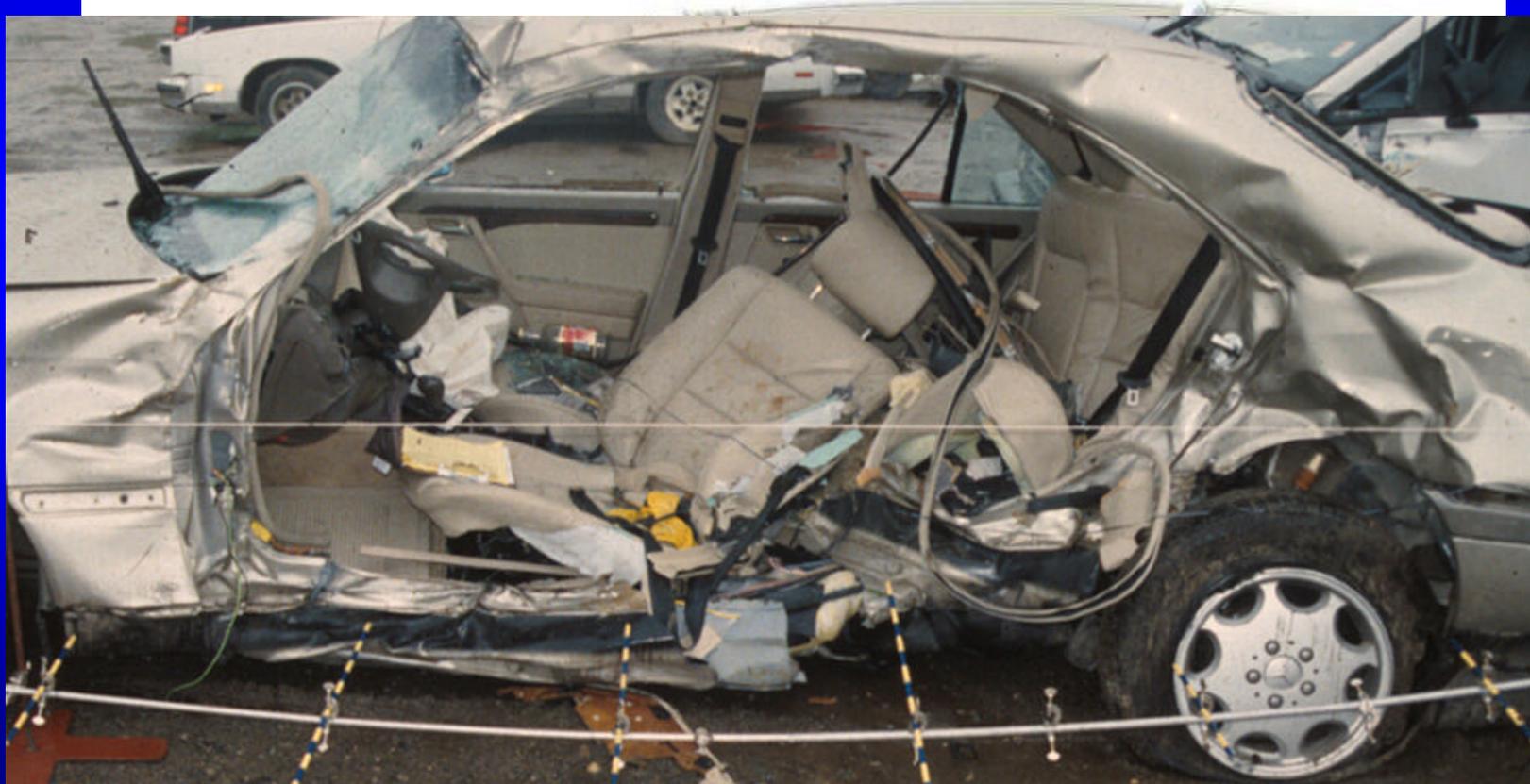




Body Side Structure



Passive Countermeasures (CM)



Safety Improvement



Understand Problem

Field DATA



Way to Evaluate

Injury Criteria

ATD

Test Procedure

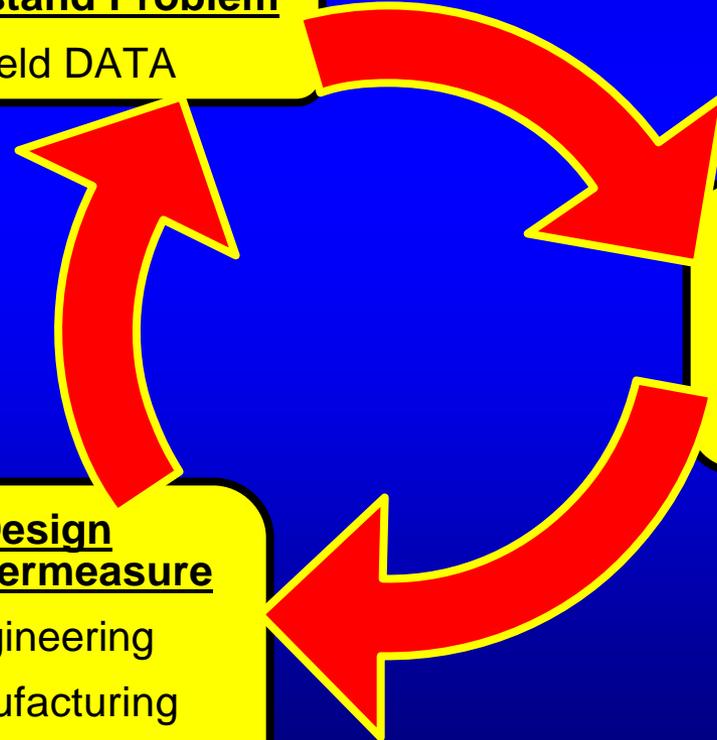


Design Countermeasure

Engineering

Manufacturing

Repeatability



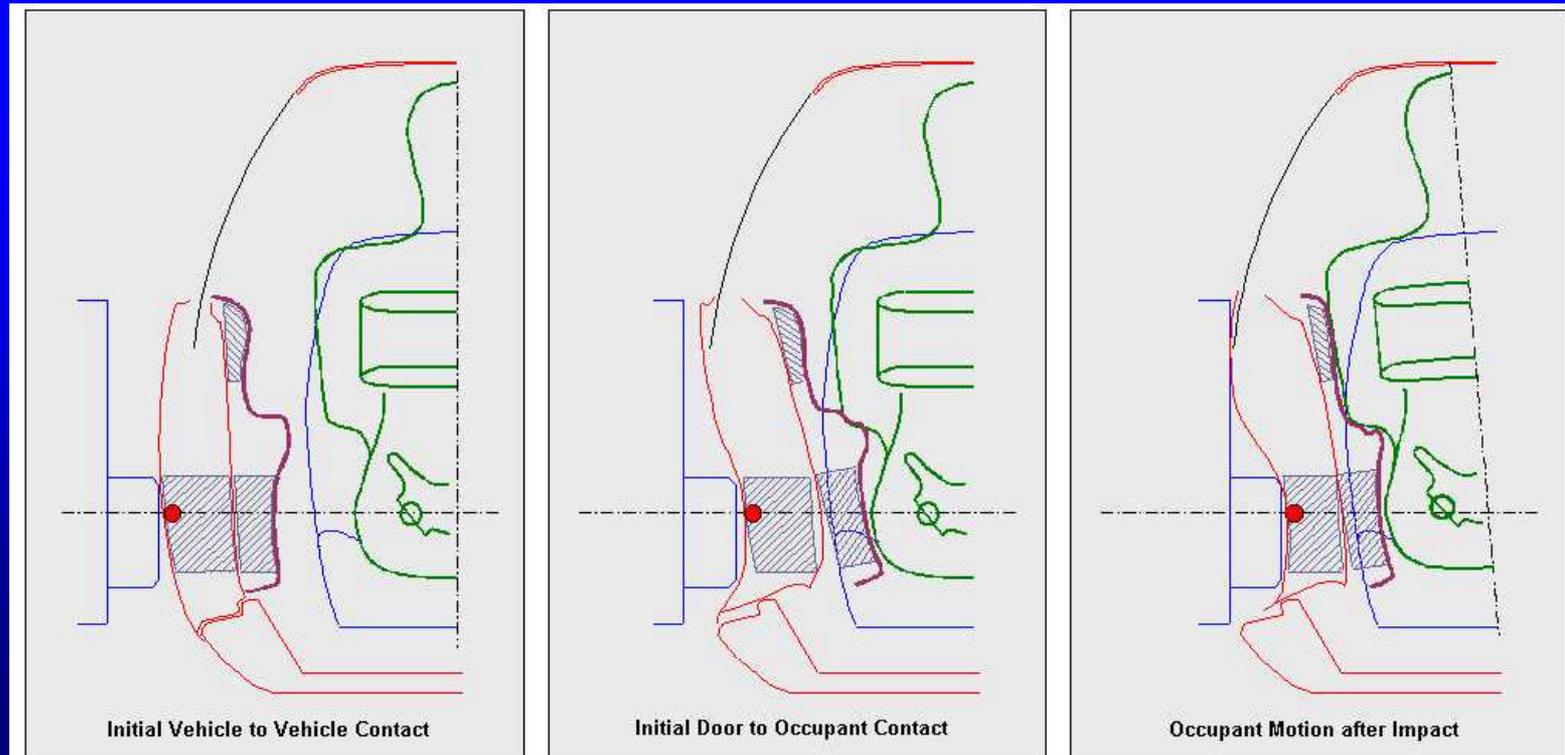
The Problem for Interior:

- 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.



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

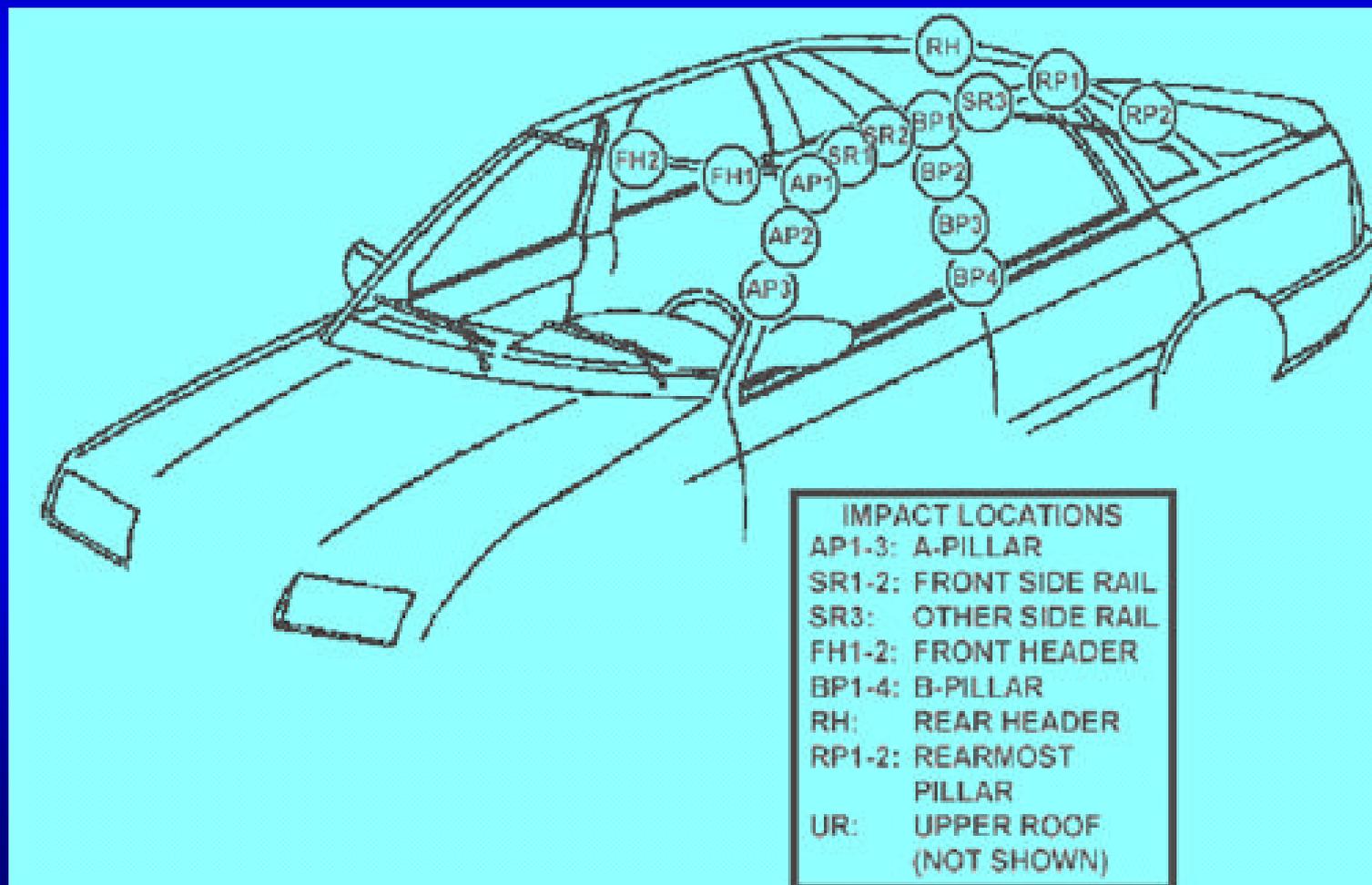
$$HIC = \left[\left[\frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} a_{res} dt \right]^{2.5} (t_2 - t_1) \right]_{Maximum}$$

Average Acceleration

Duration

- Regulation HIC below 1000
- Target HIC below 800

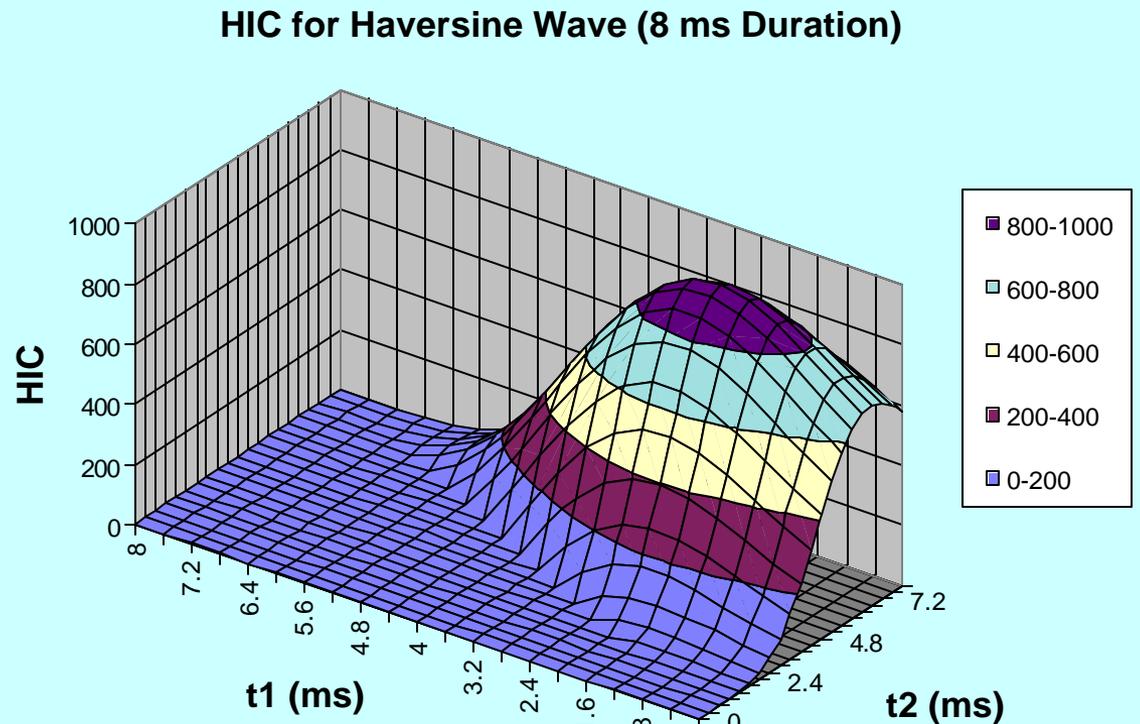
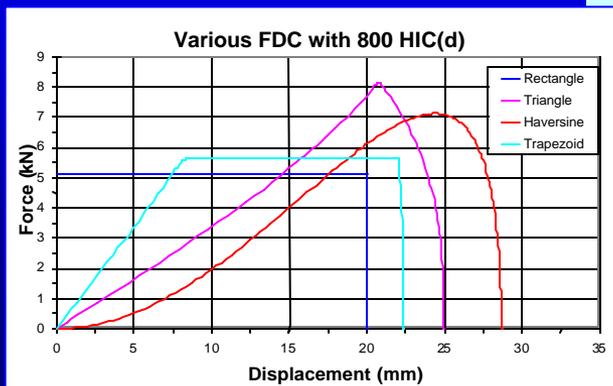
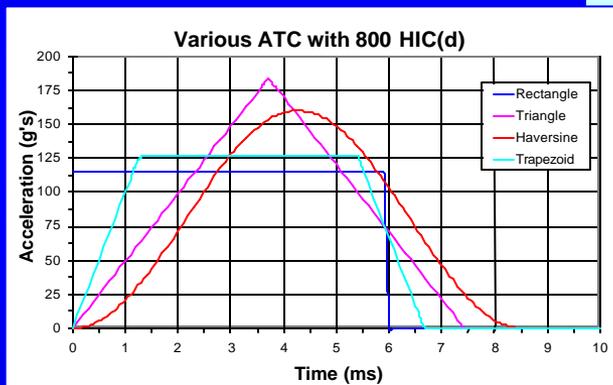
FMH Impact Locations





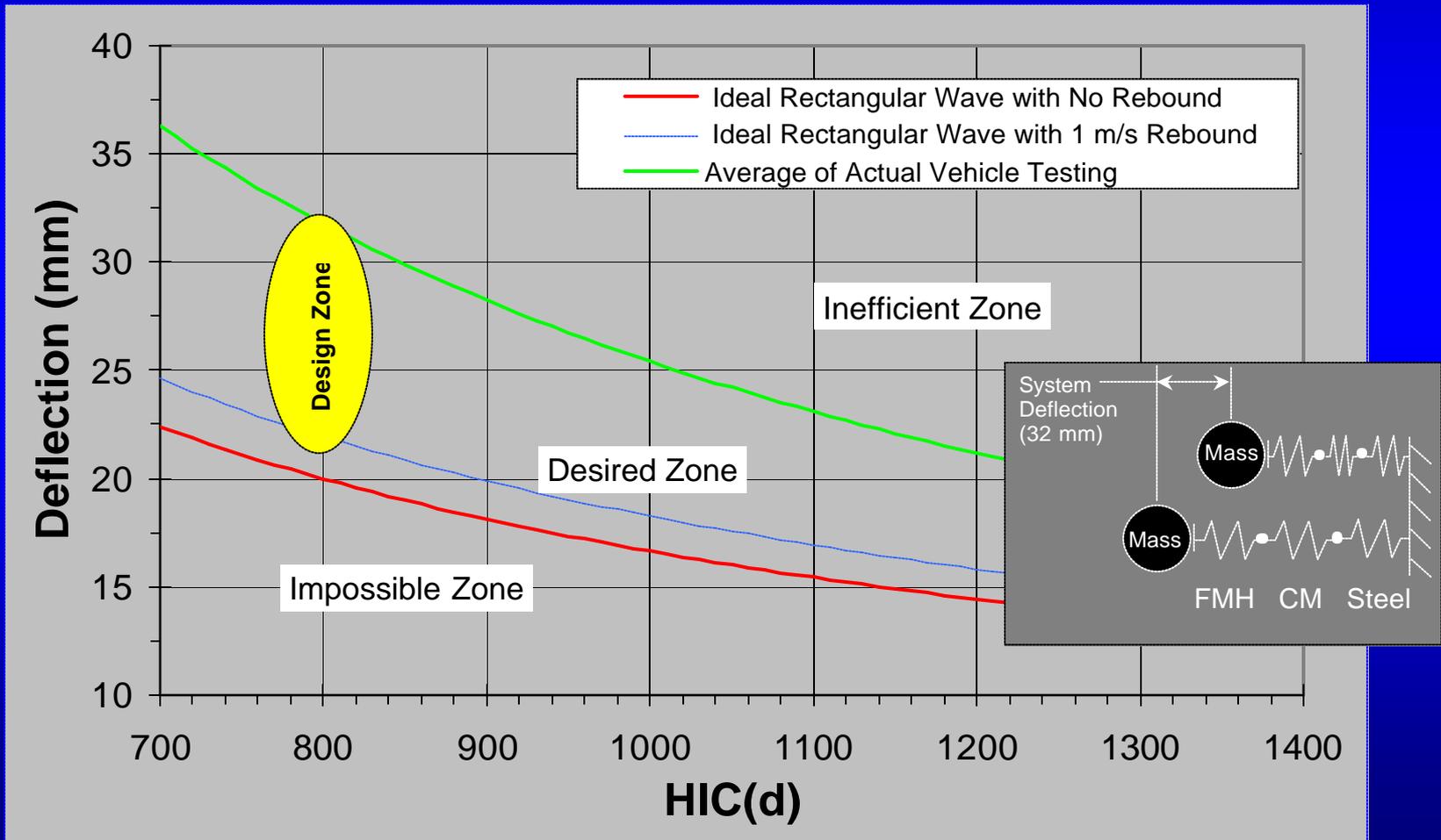
Theoretical Relations

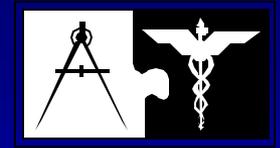
- We analyzed mathematically what drives the HIC number so that we could understand how to lower the number. We also studied the theoretical responses of various acceleration waveforms.



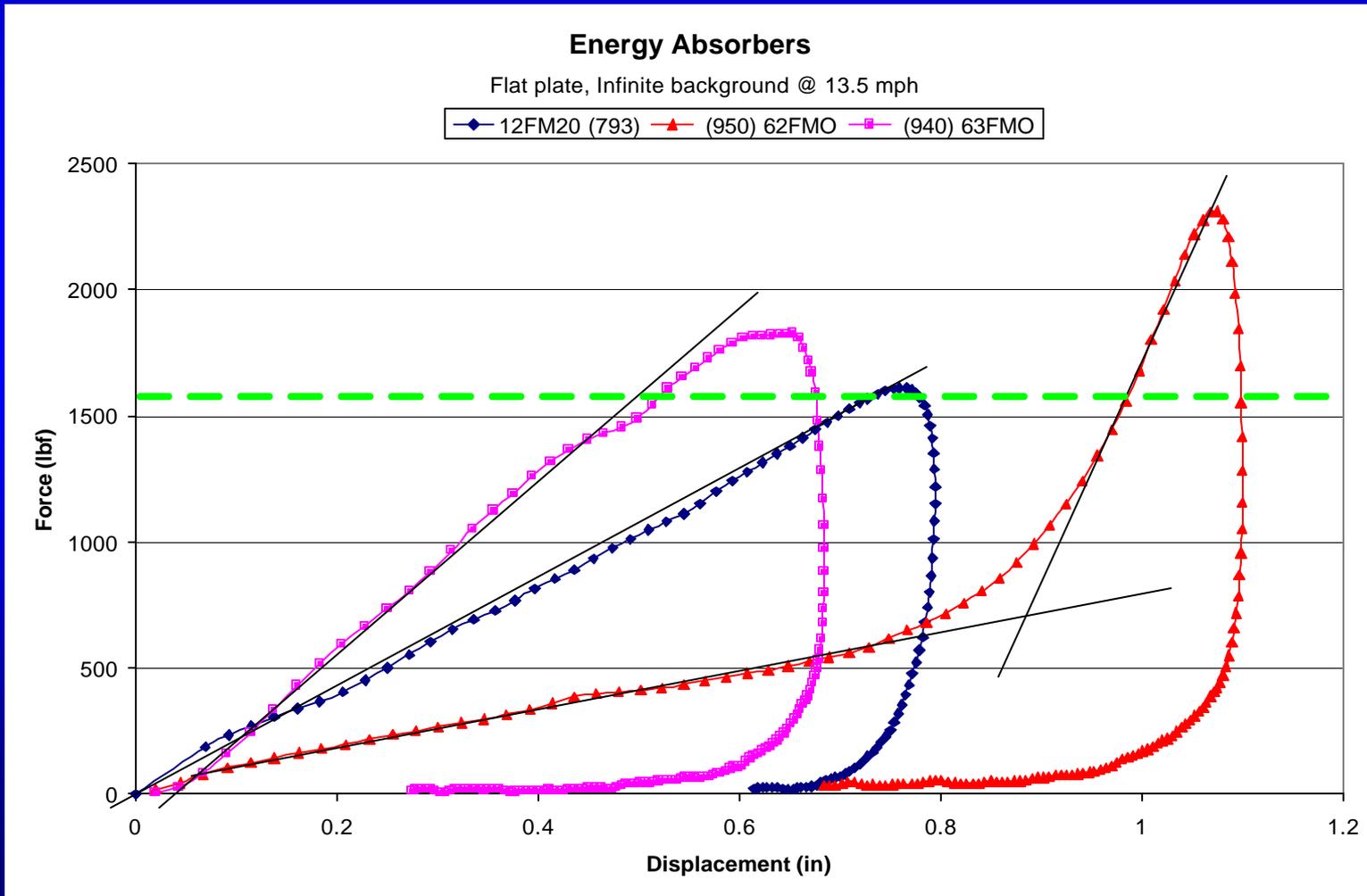


Space is Required

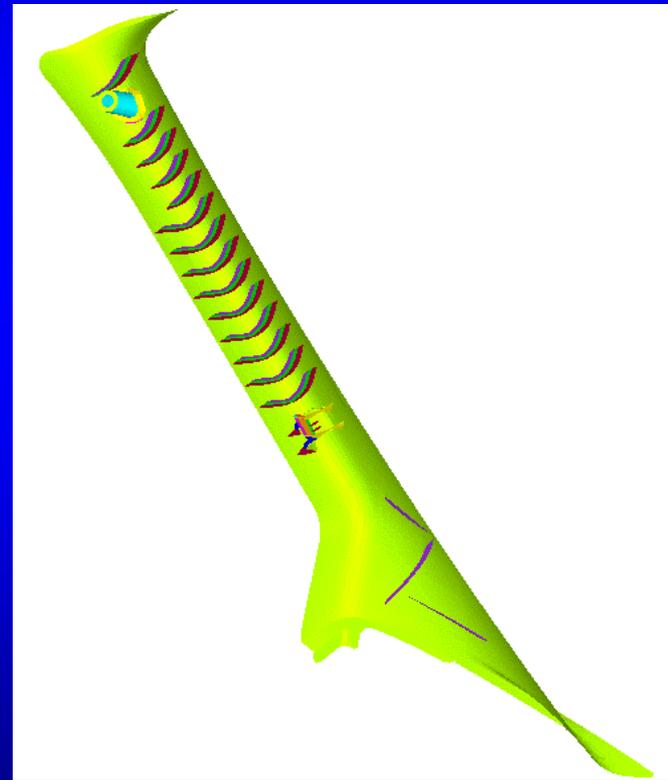
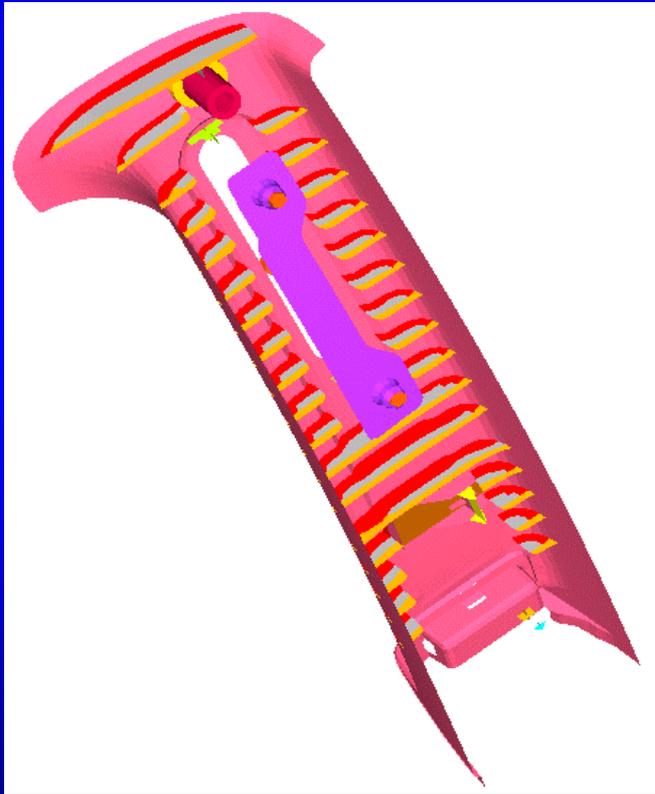




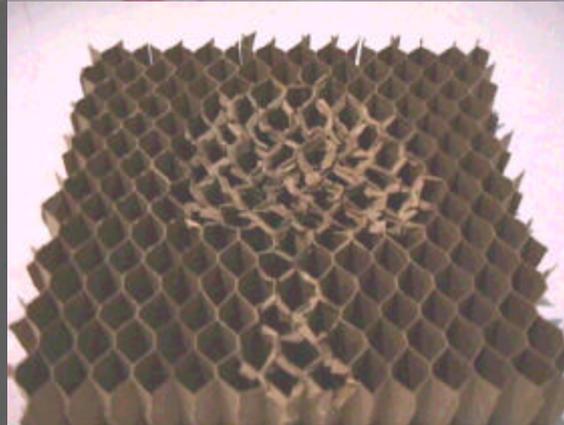
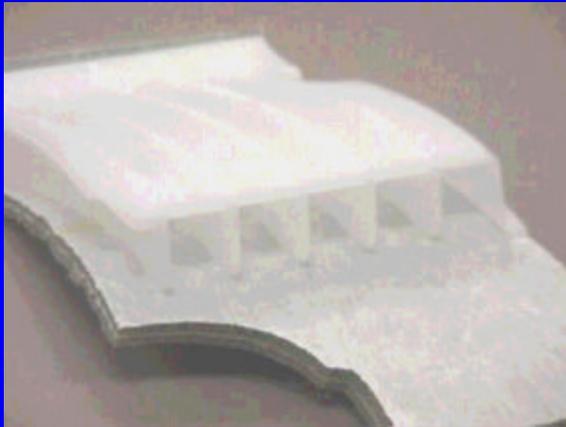
Force vs. Deflection Curves



Pillar Countermeasures

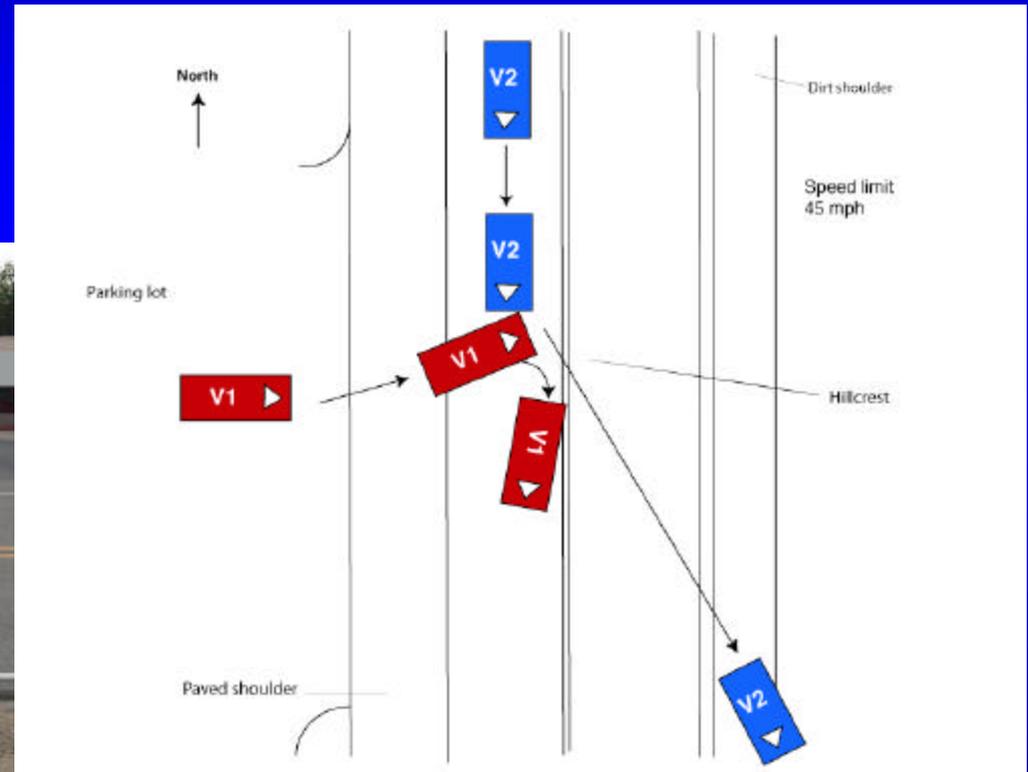


Countermeasure Materials



Case History 1: No Countermeasure

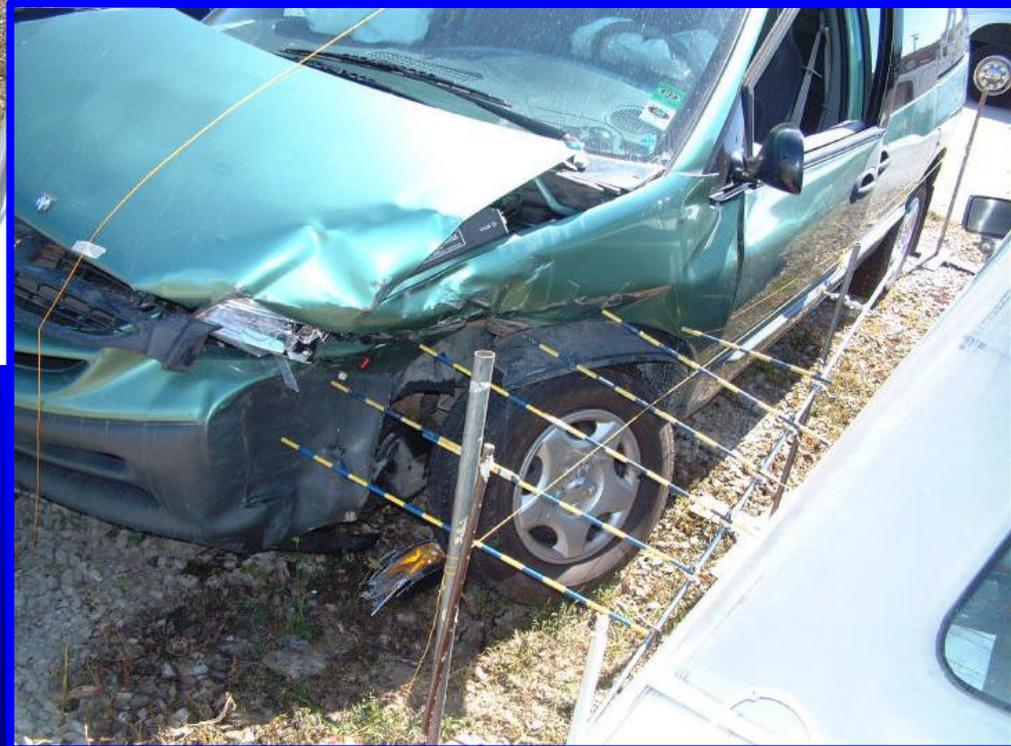
- 1998 Caravan
- Object: 2000 Taurus
- PDOF: 270
- 13 mph delta V
- 68 yo Male
- Restrained
- 172 lb, 5' 10"
(50%)



Case History 1: No Countermeasure



Impact



Interior Surfaces

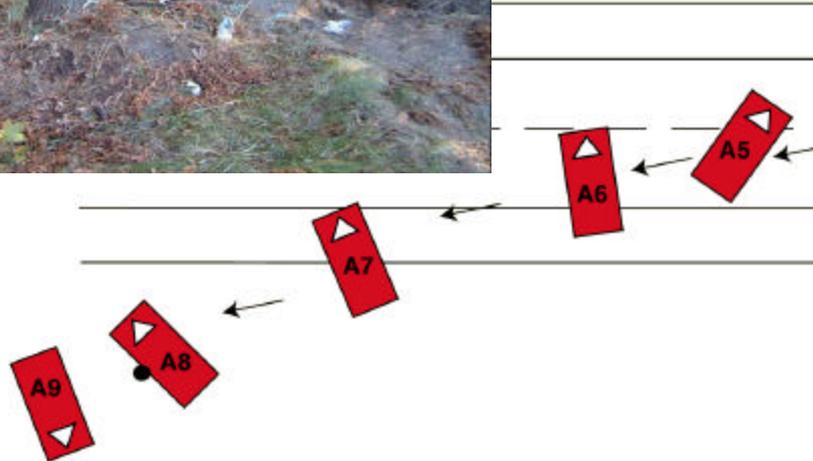




Head & Neck Injuries

- Medical data has been removed to protect patient confidentiality

Case History 2



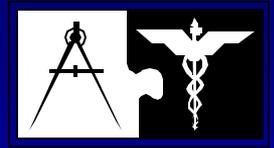
- 1999 Intrepid
- Object: Tree
- PDOF: 290
- 15 mph delta V
- 36 yo Male
- Restrained
- 165 lb, 6' 2"
- 26 cm @ sill
- 56 cm @ roof

Damage



Damage





Significant Injuries

- Medical data has been removed to protect patient confidentiality

Head Contact



Contact



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



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



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

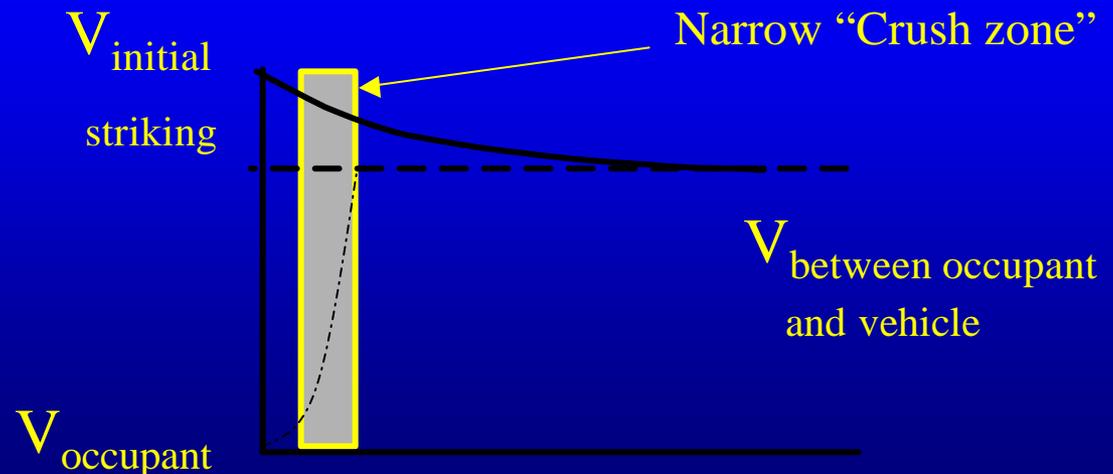
Frontal and lateral airbags operate differently in how they mitigate injury

Side Impact Air Bag Considerations

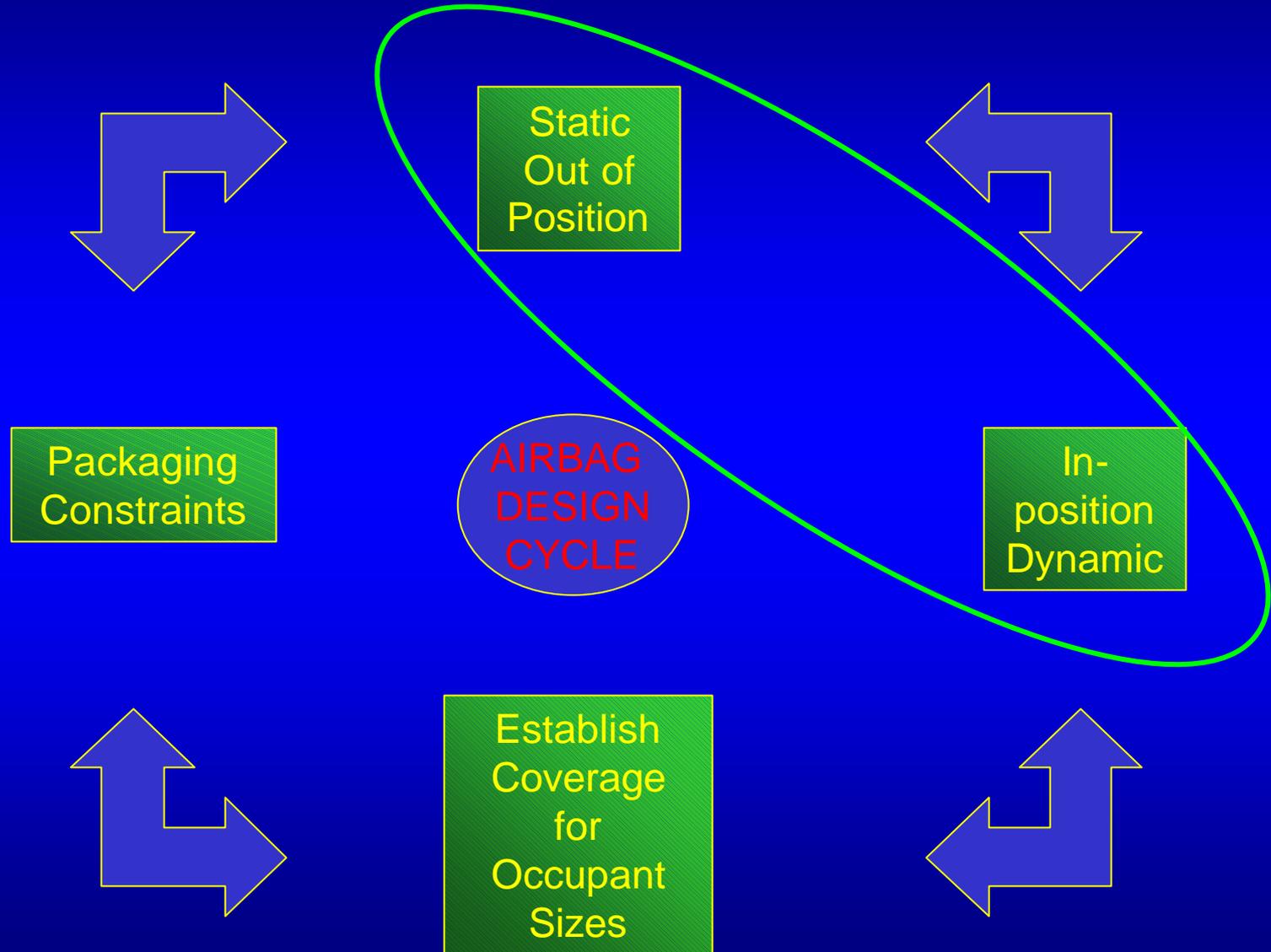
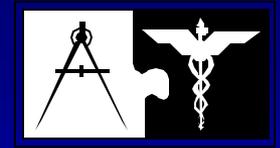


Additional Considerations for side vs frontal airbags:

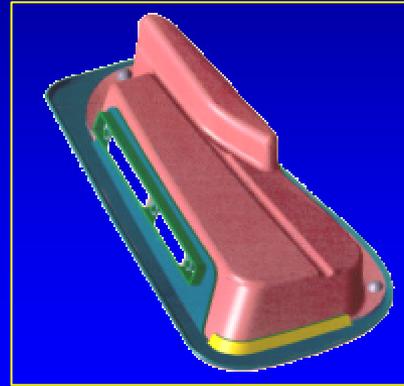
- ▶ there is little vehicle crush space to accelerate the occupant compartment before occupant loading.
- ▶ The occupant is impacted by the striking object with a portion of his vehicle side structure around it.
- ▶ The location of a side impact relative to the occupant has a major effect on the severity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

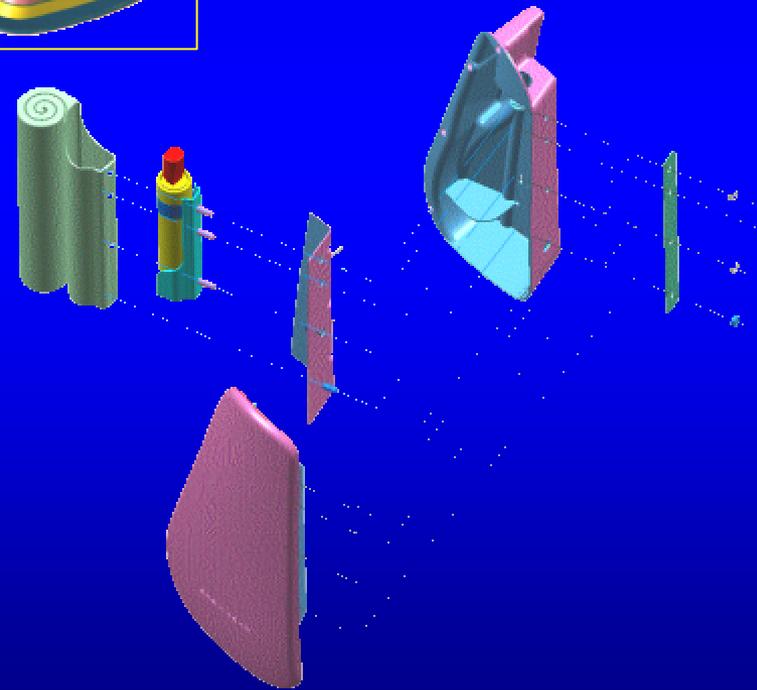
- 11 litre single chamber rollfold
- ventholes according to performance
- 700 dtex fabric uncoated with reinforcement and heatshields

Housing:

- single injection TPEE (Multiflex)
- colour black

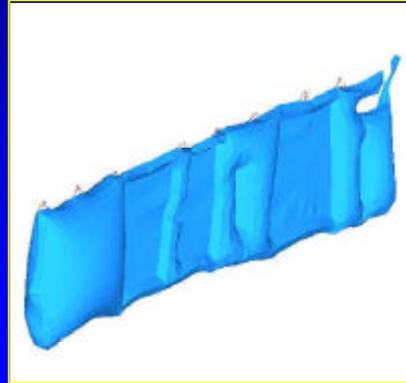
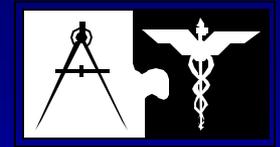
Cover:

- 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:

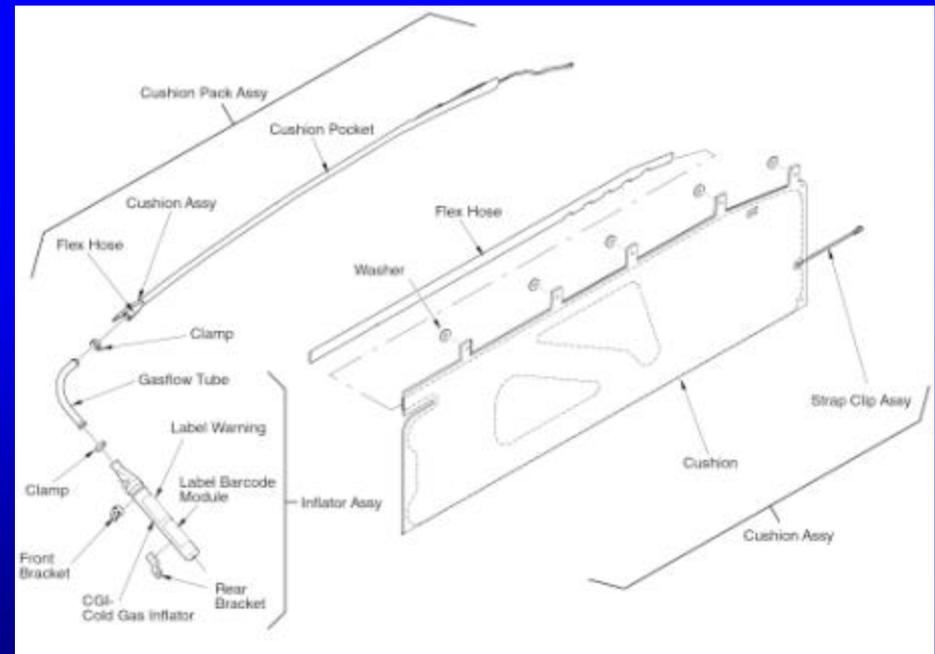
- Inflator Cold gas
- Filling - 100%He
- Pressure - 600bar
- Gas filling weight adjustable

Rollover Cushion:

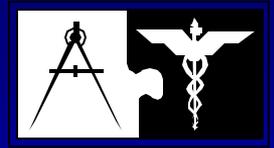
- Silicone coated, 470dtex, PA 6.6.
- Volume 30-35 ltr.
- Sewn bag design, liquid silicone sealing or OPW coated or STC

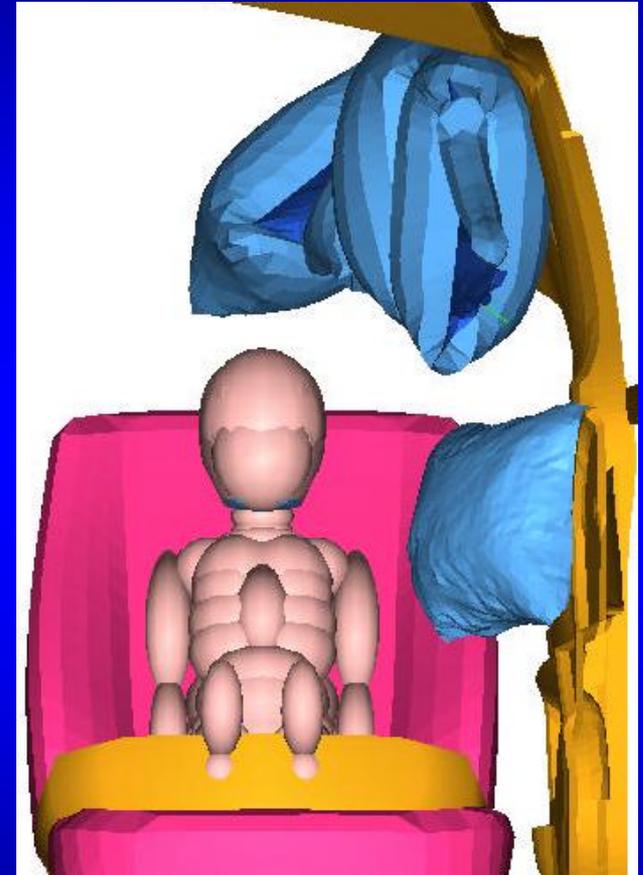
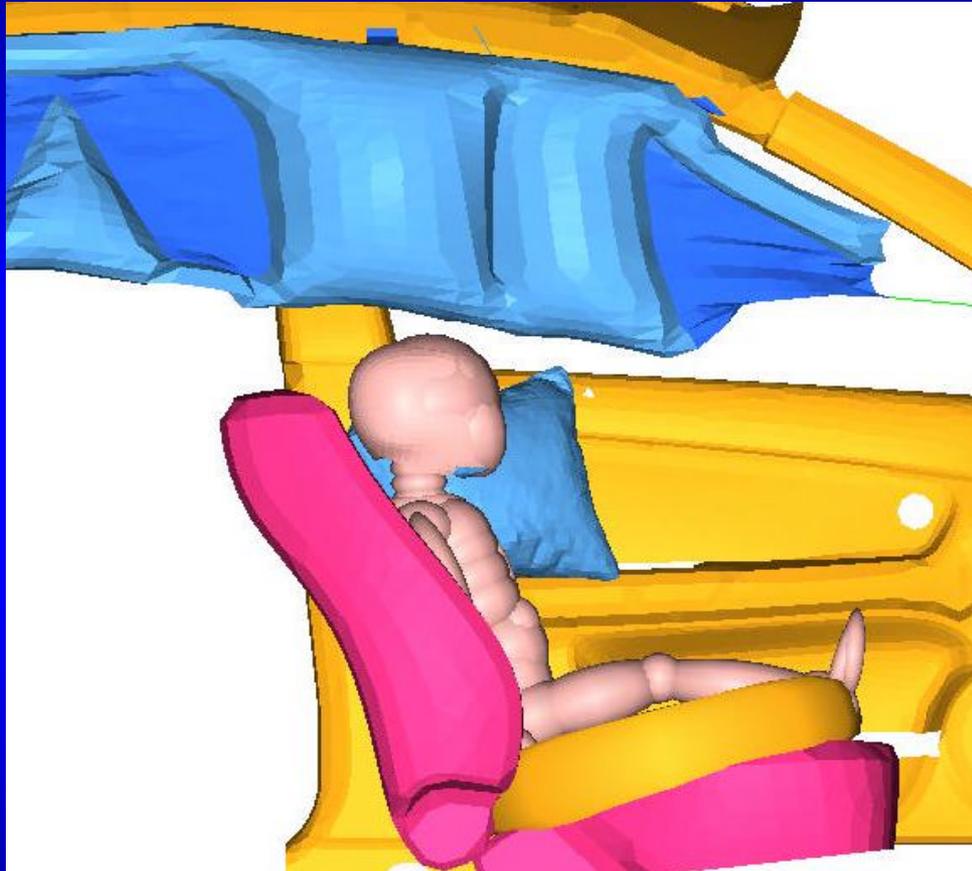
Cover:

- soft pack (pocket)

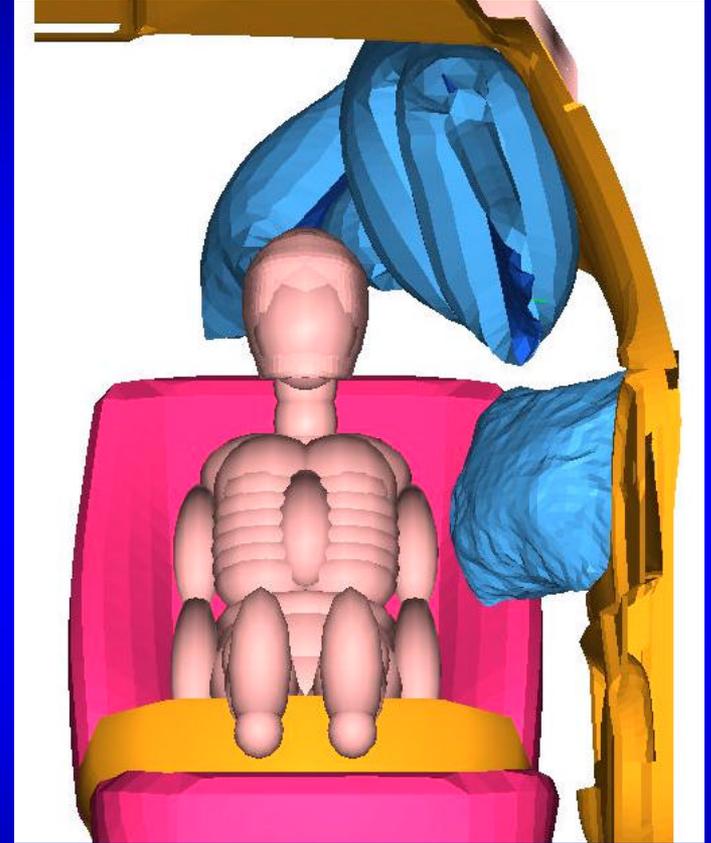
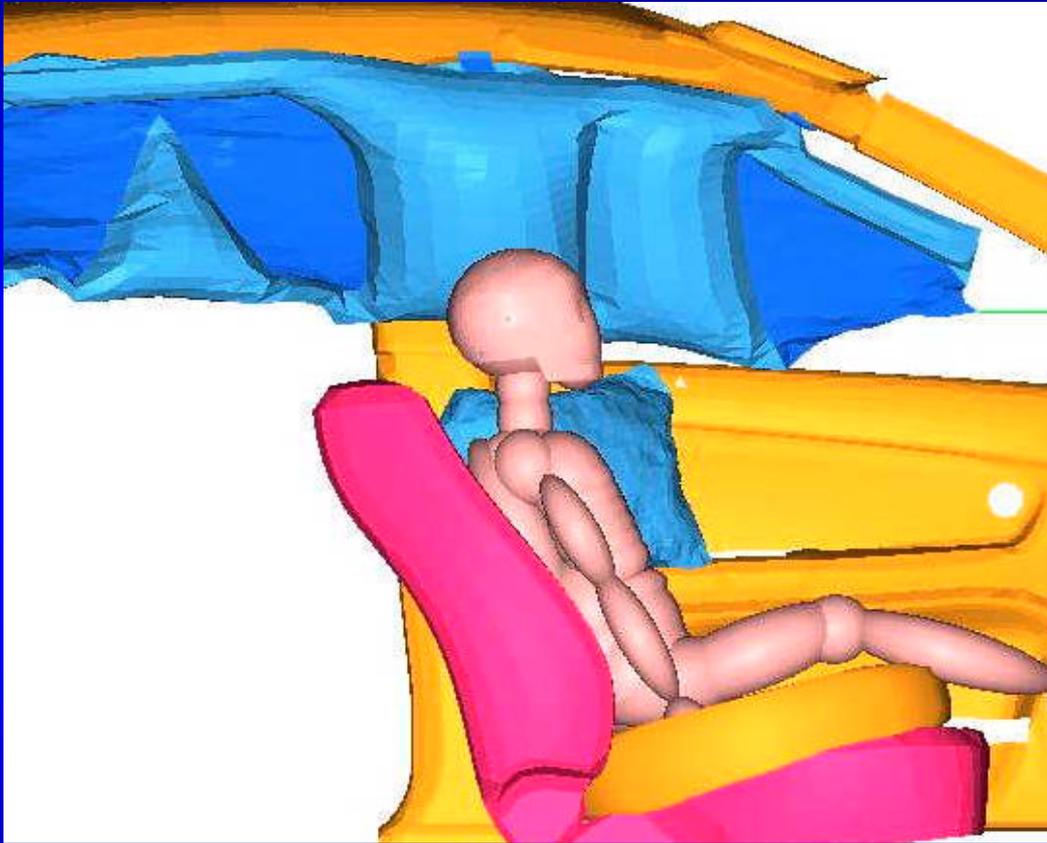




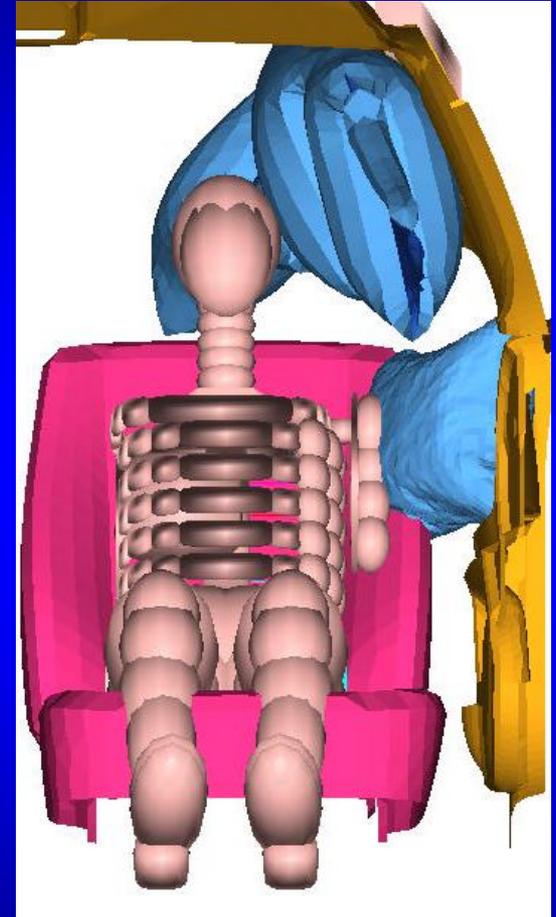
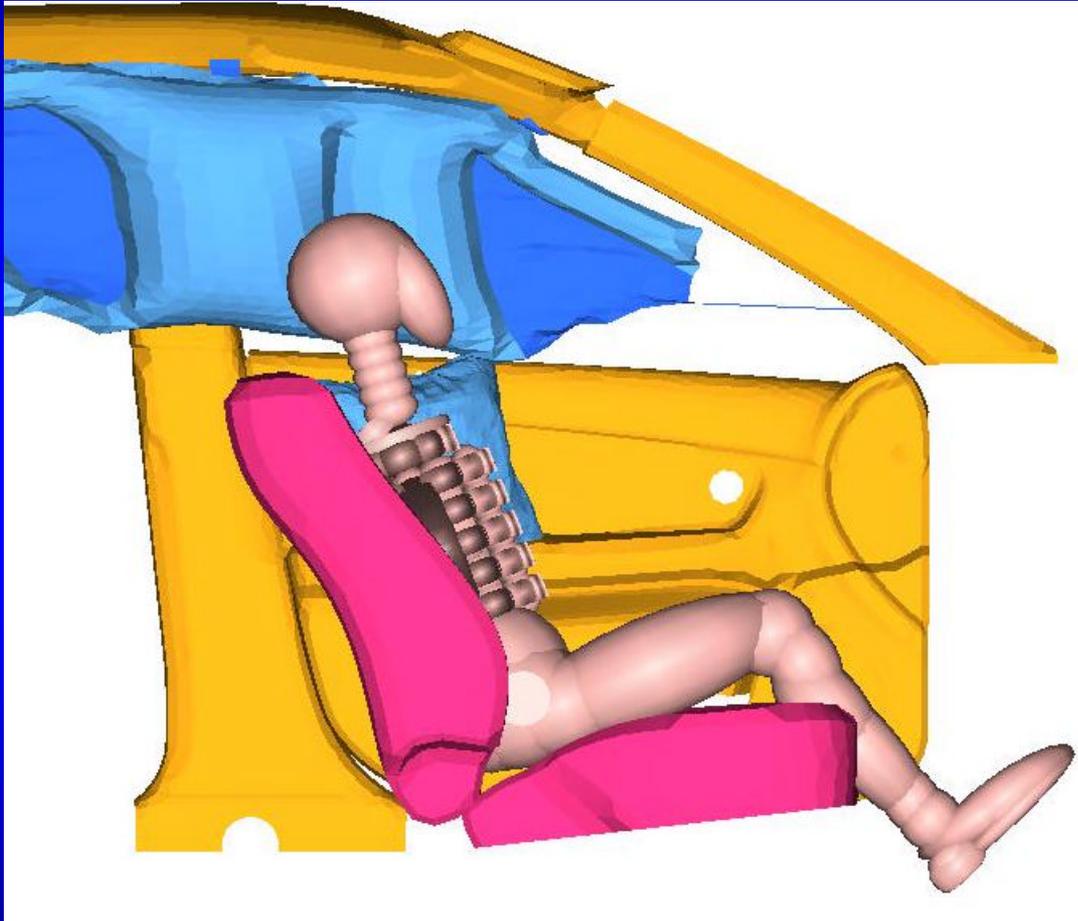




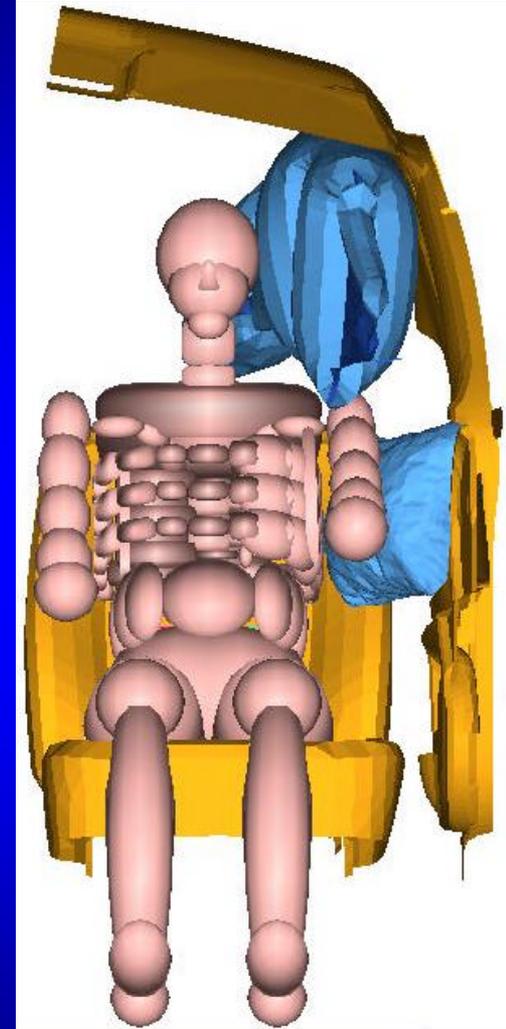
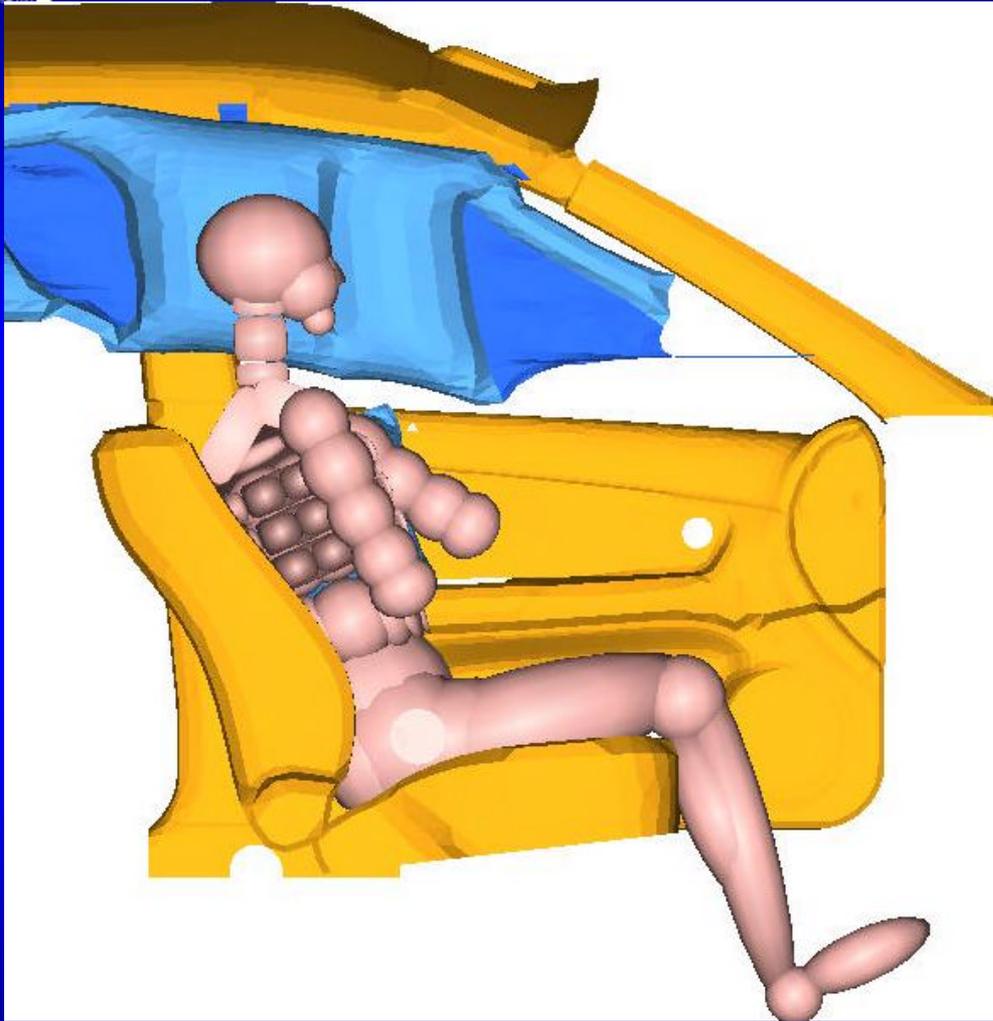
3 year old HIII Seating Position in Mid-Sized Sedan



6 year old HIII Seating Position in Mid-Sized Sedan

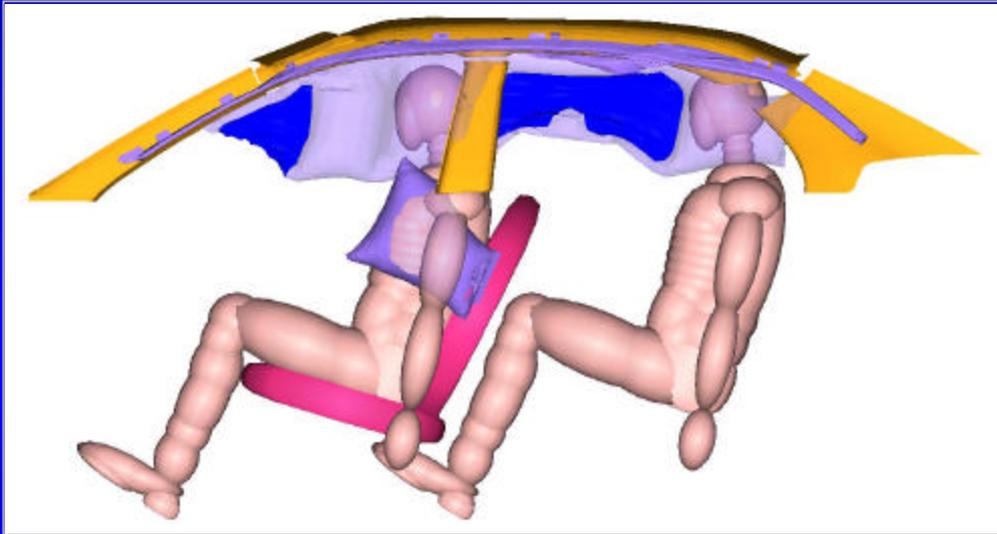


5th%ile (SID-IIs) Seating Position in Mid-Sized Sedan



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

? Coverage Zone Concept



“A-C” Pillar Protection Coverage

Mid-Seat Euro-SID

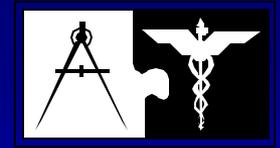


Full ForwardSID-IIs



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

Side Airbag OOP Injury
TWG

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



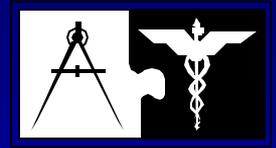
TWG injury values

Reference values



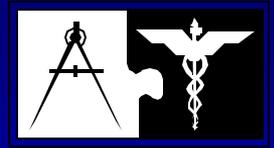
	Hybrid III 3-Yr Old	Hybrid III 6-Yr Old	Hybrid III Sm. Fem.	SID IIs
<u>HEAD</u>				
15ms HIC	570	723	779	779
<u>UPPER NECK</u>				
Nij (Ft/Fc/Mf/Me)	1 <i>2120/2120/68/27</i>	1 <i>2800/2800/93/37</i>	1 <i>3880/3880/55/61</i>	1 <i>3880/3880/155/61</i>
Tension (N)	1130	1490	2070	2070
Comp. (N)	1380	1820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

Side Impact Air Bag Challenges



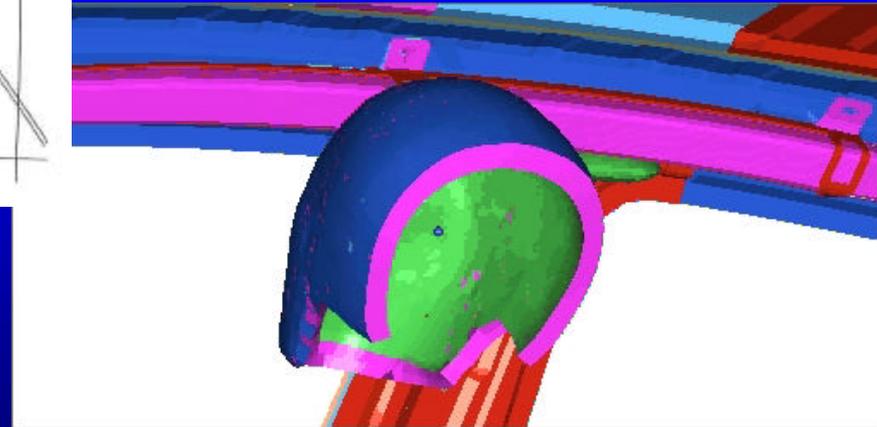
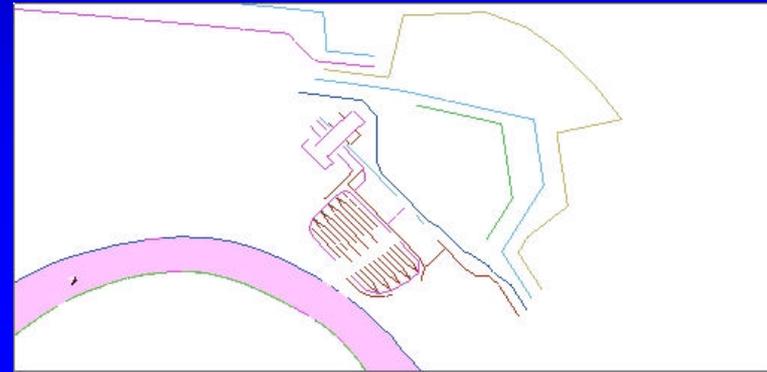
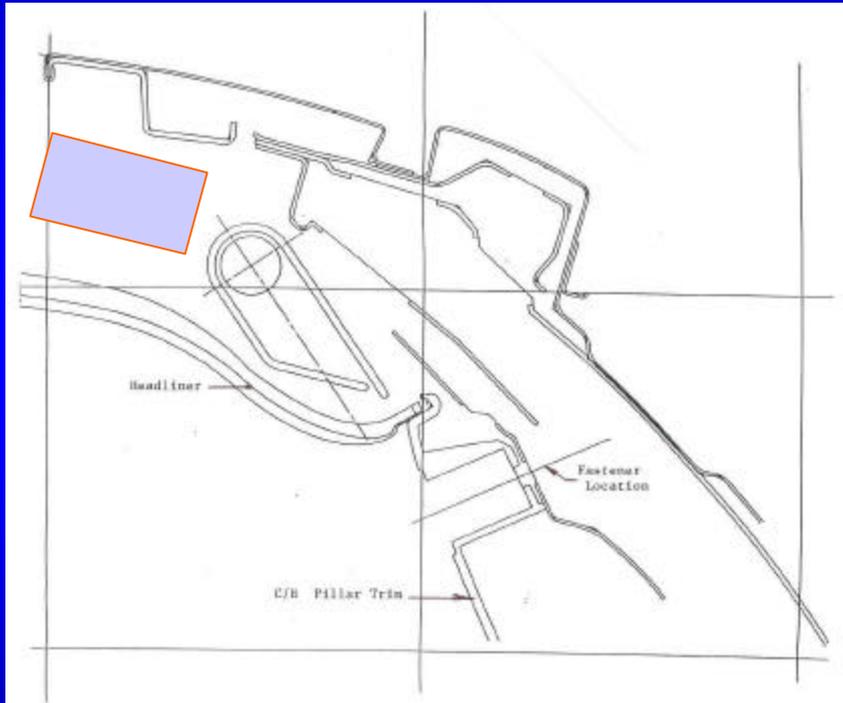
- **Crash sensing:**
 - ▶ Distinguishing the various side impact events (pole, car, truck) in time to fire the lateral airbag, and maintaining immunity from non-severe events (door-slam, ball-hit, bicycle etc.)
 - ▶ In general, lateral airbags need to begin deploy about 4 - 8 msec after initial contact . 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

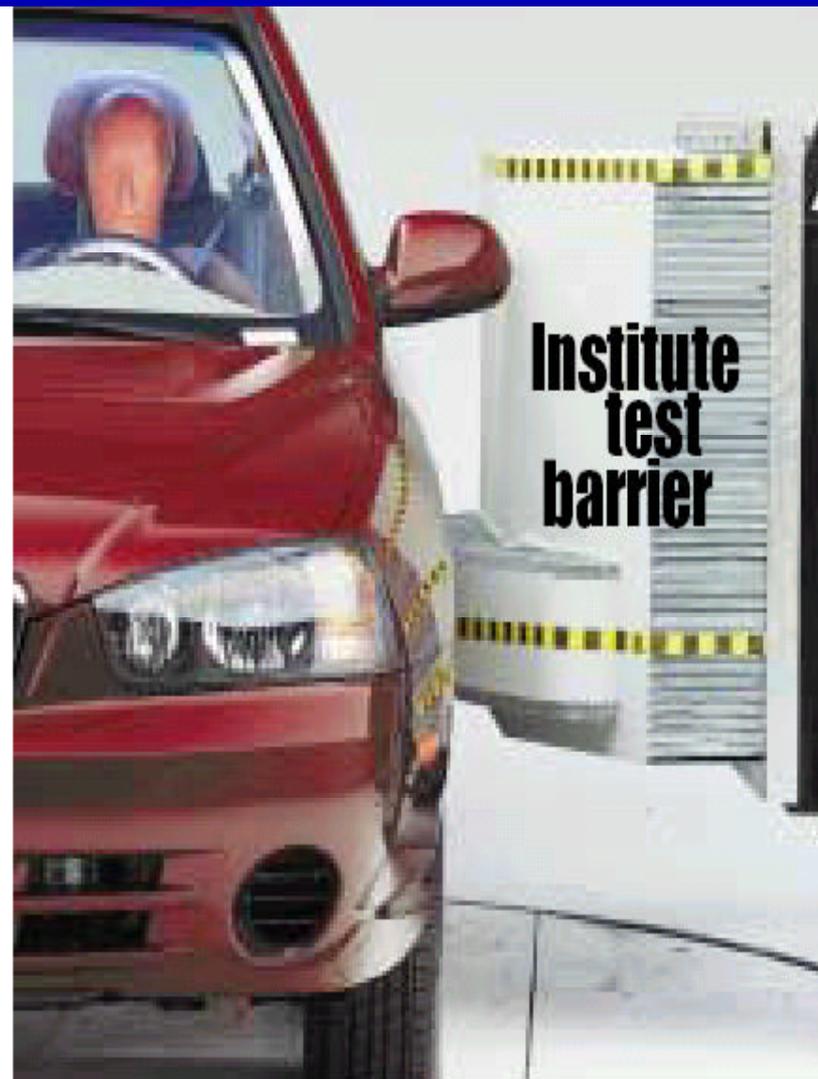


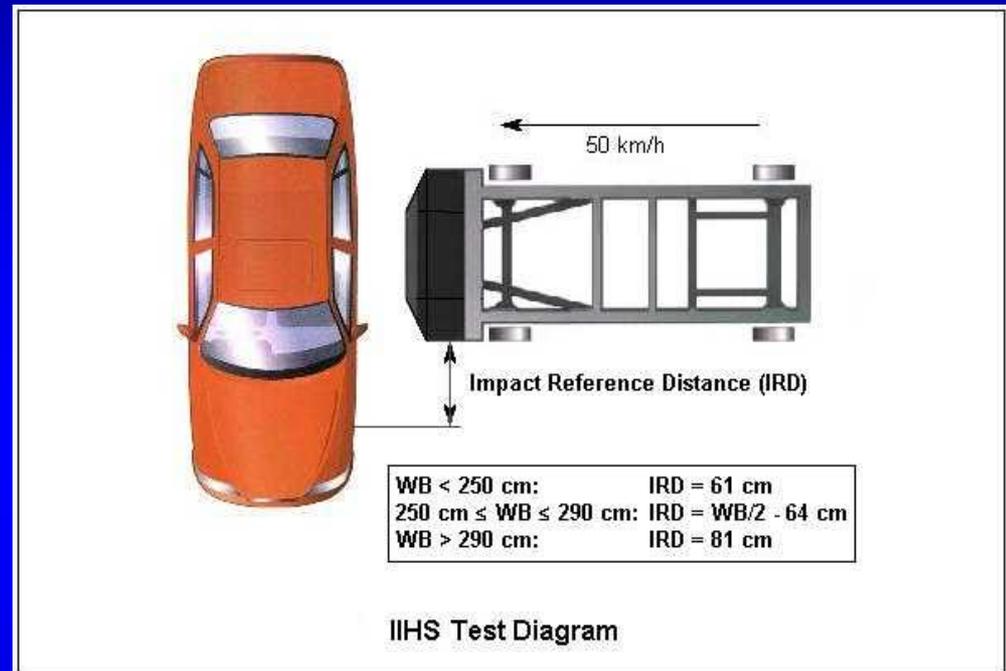
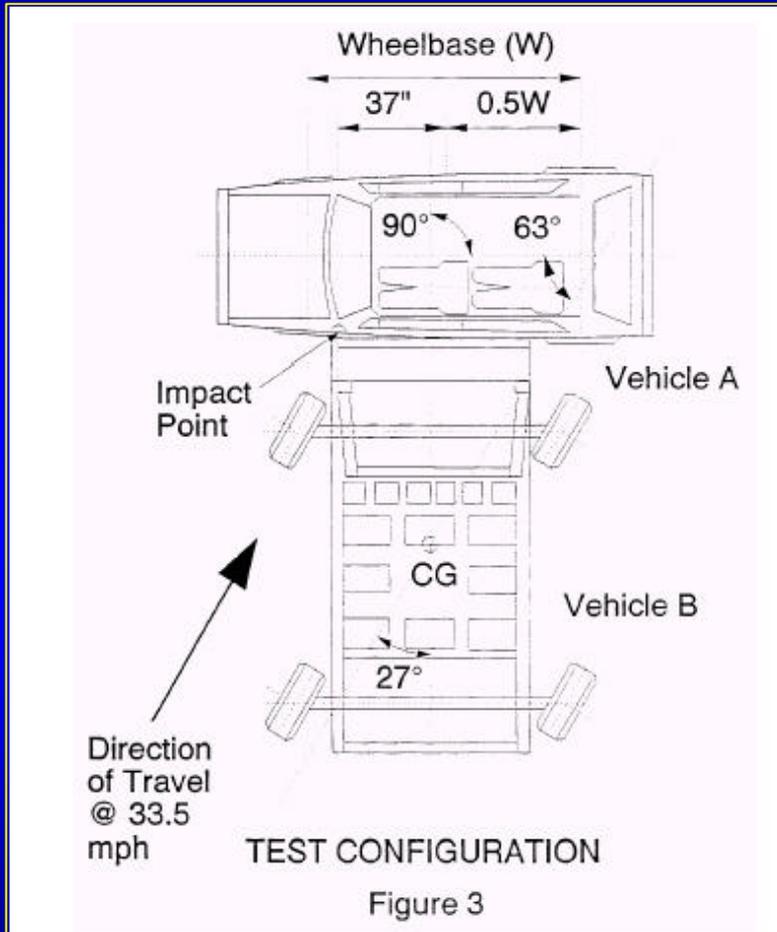
- **Thorax bags must deploy in gap between seat bolster and door trim, and occupant.**
 - ▶ Gap is small on small cars
 - ▶ Occupant size can affect deployment
- **Curtain airbags must deploy over the B- pillar trim, belts, and often over rapidly deforming sheet metal.**
 - ▶ There is often opportunity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

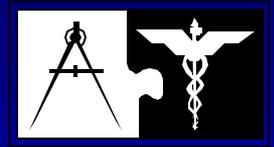




IIHS LTV

FMVSS 214

Comparison of IIHS High Hood and Regulatory Tests



Side Impact Crash Test Configurations

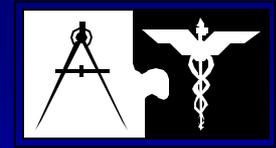
Description	IIHS High Hood	FMVSS 214	ECE R95
Impact Angle	90 degrees	63 degrees	90 Degrees
Bullet Weight	1,500 kg	1367 kg	950 kg
Bullet Speed	50 kph	54 kph in 63 deg. Direction (or 48 kph lat./ 24 kph long.)	50 kph
Impact Location	300 mm rear of FMVSS 214	Front edge of barrier face @940 mm from half 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	SIDIIIs 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



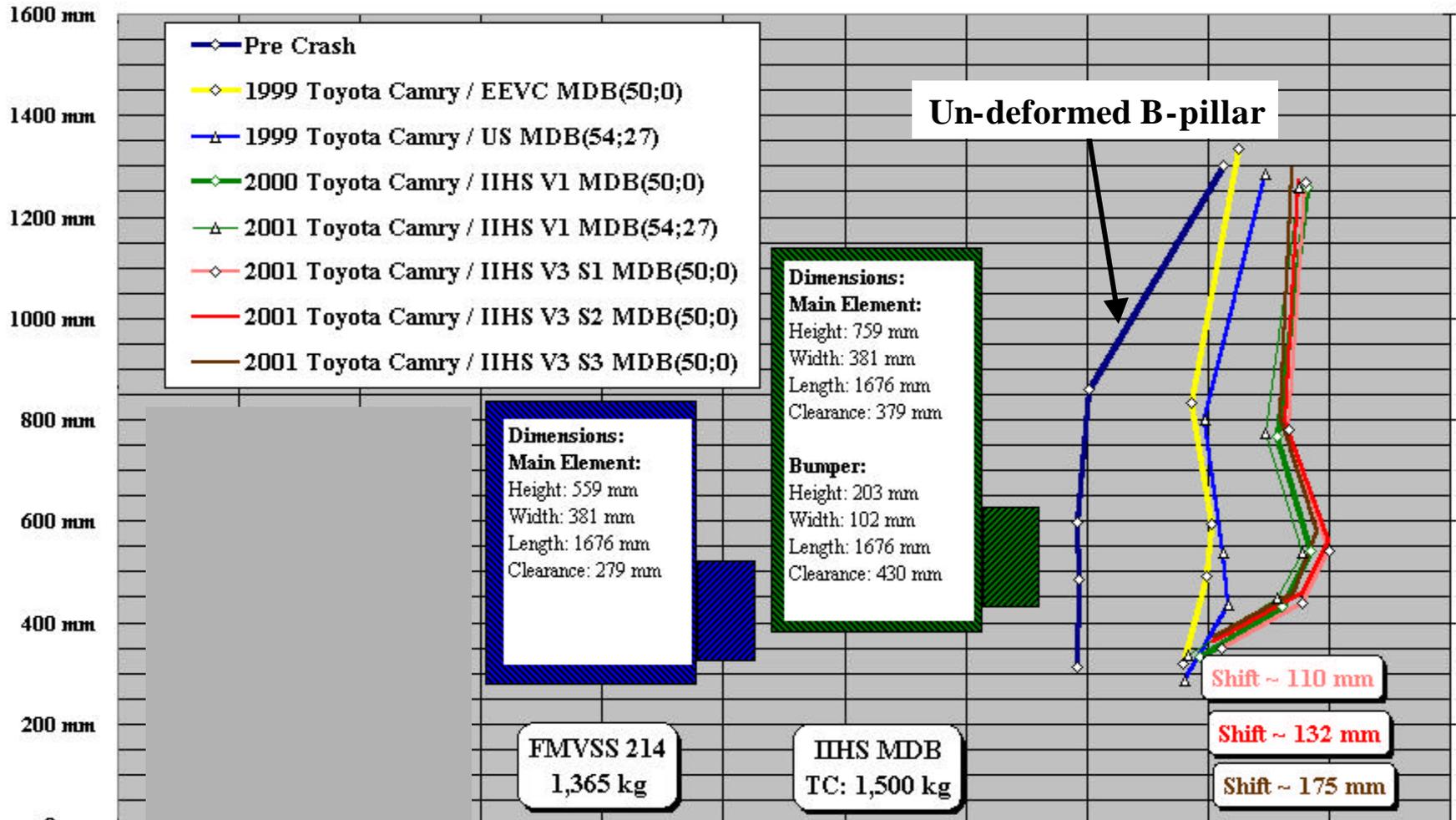
From the inflatable restraint viewpoint, the IIHS test protocol is the primary method to assess & improve “self-protection” for “incompatible” lateral crash modes.



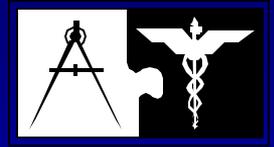
The IIHS LTV (incompatibility) test mode has several additional challenges for “Self - Protection” injury mitigation:

- **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

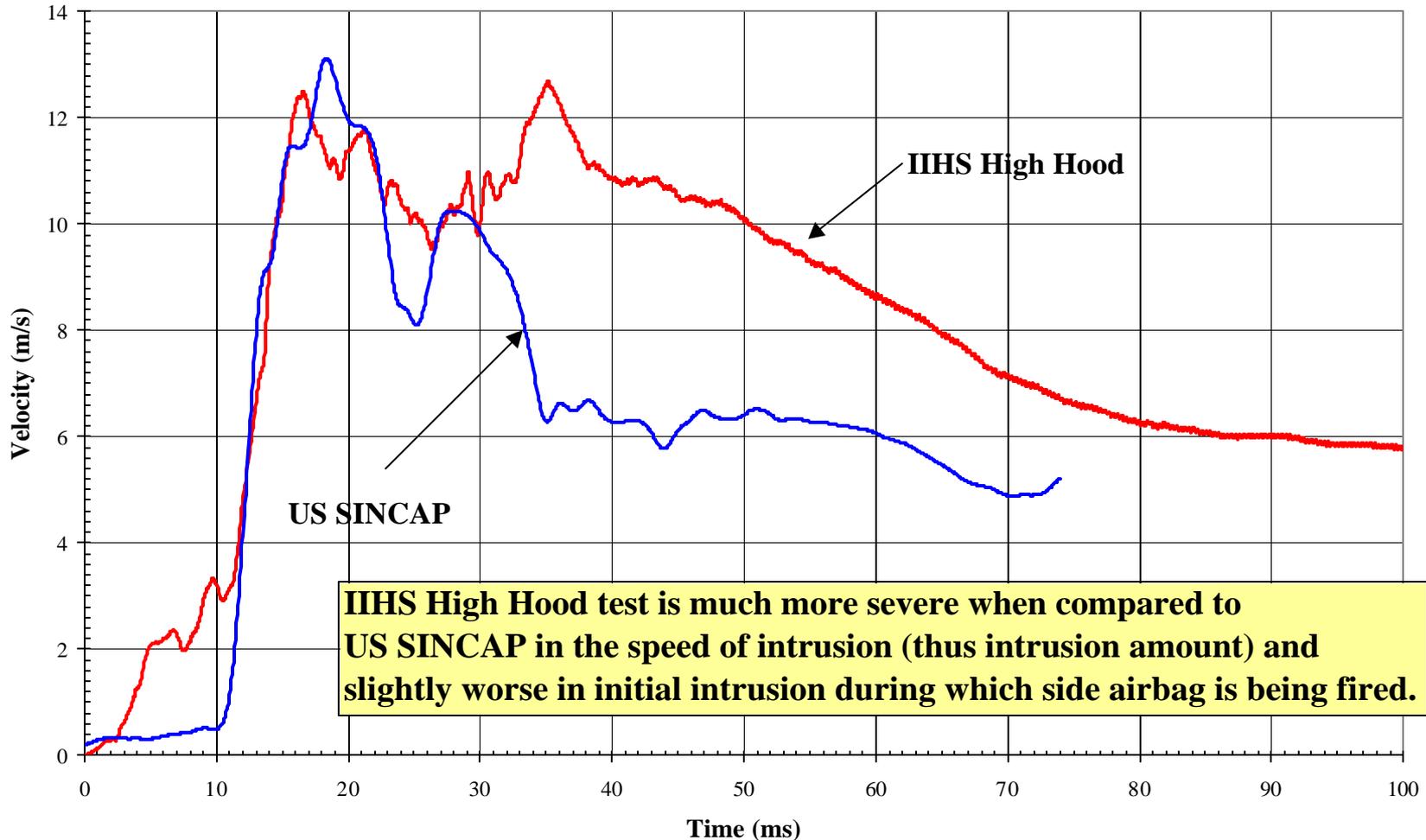
B-Pillar Crush Profiles Camry Test Series

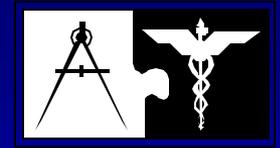


Comparison of IIHS High Hood vs. US SINCAP Door Motion

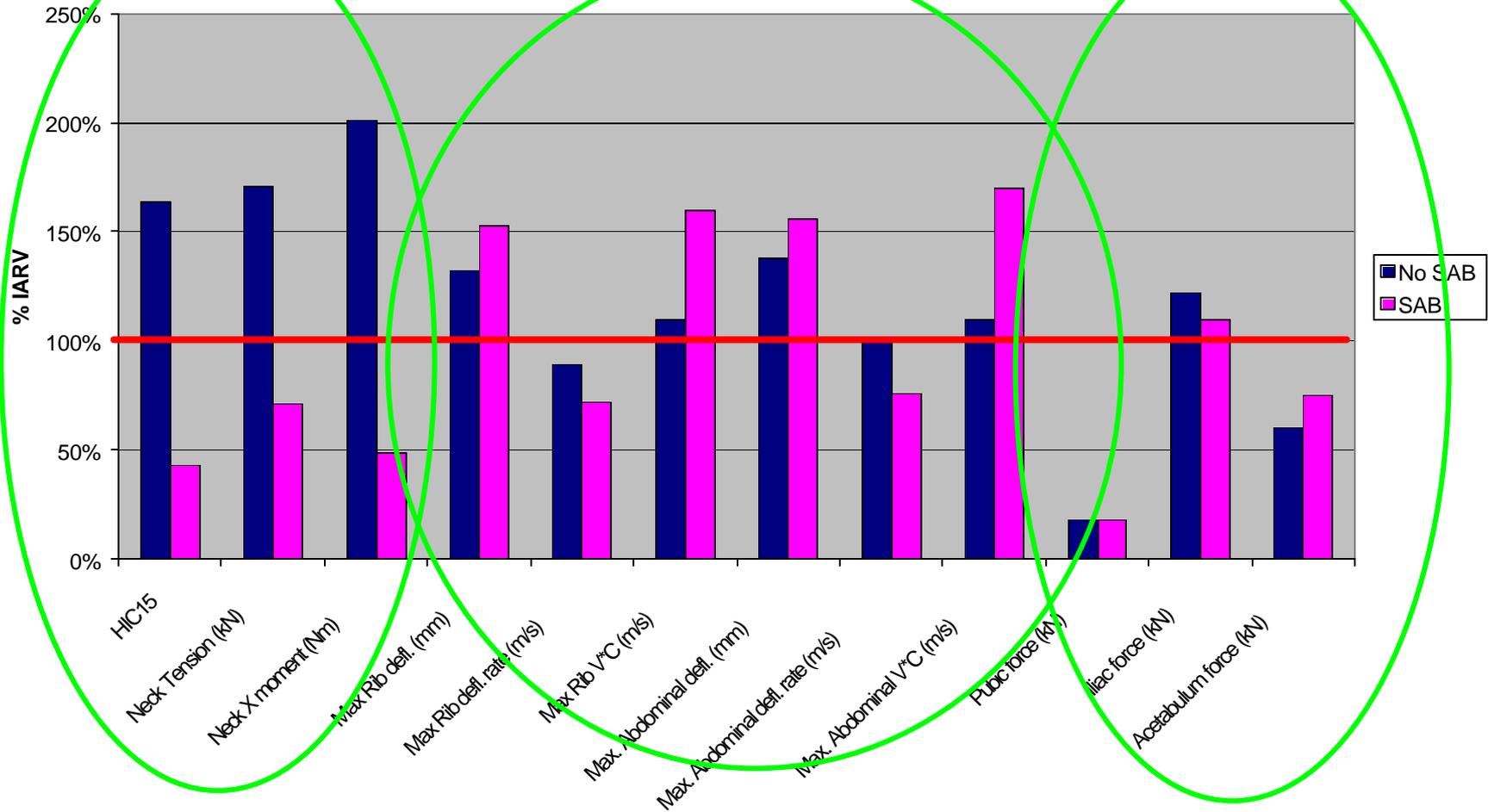


An Example of Generic Mid-Sized Sedan IIHS High Hood Full Scale vs. Test Door at Belt Line Velocity Pulse

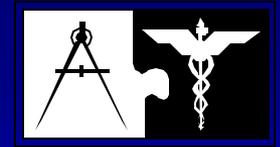




IIHS High Hood Barrier
Ford Focus
SAB vs. No SAB



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

