

ES-2 Crash Test Performance

**SAE Government Industry Meeting
Side Impact Session**

April 2002

**Randa Radwan Samaha
Research and Development/NHTSA**

What Is Our Motivation?

- **Injury criteria: improve injury measurement capabilities in FMVSS 214 (thorax, abdomen, & pelvis)**
- **Harmonization: if viable, incorporate ES-2 in FMVSS 214 as an interim harmonized side impact dummy**

ES-2 Phase I Full Scale Tests (SAE G/I 2001)

- Results from initial NHTSA R&D testing showed promise that concerns with EUROSID-1 mechanical deficiencies have been mainly addressed with ES-2 upgrade
- Overall, ES-2 responses showed good repeatability in component level and limited sled tests

VEHICLE	DUMMY	TEST CONFIGURATION	SPEED (km/h)
96 Taurus- 4dr*	Eurosid-1	EU Side	48.3
96 Taurus- 4dr	ES-2	EU Side	49.2
95 Metro- 3 dr*	Eurosid-1	EU Side	50.3
96 Metro- 3 dr	ES-2	EU Side	50.5
96 Taurus- 4dr	ES-2	FMVSS 214	53.3
96 Taurus- 4dr	ES-2	FMVSS 214	52.3
98 Chevy Cavalier-4dr	ES-2	US Side NCAP	61.6
2000 Grand Am- 2dr	ES-2	US Side NCAP	62.1

NHTSA ES-2 Testing Update

- **Crash tests* (23 completed)**
 - High severity/upgrade 214 MDB tests
 - 201P pole side impact
 - NCAP side impact
- **Mechanical performance component tests**
 - Pendulum and rib drop tests
 - Seat back pressure maps
- **Biofidelity tests (total of 19 sled & 10 impactor)**
 - Head/neck/shoulder sled tests
 - Shoulder/thorax/pelvis impactor tests
 - Additional abdominal offset sled tests

* Since ESV 6/01

FMVSS 201P ES-2 Tests

201P – Side Impact Pole Tests		
VEHICLE	BAG	DUMMY
Dummy Evaluation Tests		
2001 Saturn	none	SIDH3/ES-2
2001 Saturn	curtain only	SIDH3/ES-2
1999 Maxima	none	SIDH3/ES-2
1999 Maxima	head/thorax combo	ES-2
Fleet Performance Tests		
1999 Volvo S80	curtain plus thorax	SIDH3/ES-2
1999 Cougar	head/thorax combo	ES-2
2000 Saab	head/thorax combo	ES-2
1999 Windstar	head/thorax combo	ES-2
2002 Explorer	curtain only	SIDH3*/ES-2

FMVSS 214 ES-2 Tests

FMVSS 214 MDB Upgrade - High Severity/Barrier Development Tests

VEHICLE	BAG	IMPACTOR	DUMMY	TEST CONDITION
1999 Prizm	none	IIHS MDB/F150	ES-2	214 speed/angle
1999 Cadillac Deville	none	IIHS MDB/F150	ES-2	214 speed/angle
1999 Maxima	none	IIHS MDB	ES-2	214 speed/angle
1999 Cadillac Deville	none	IIHS MDB/F150	ES-2	Side NCAP

Side NCAP- 2002 Fleet Performance Tests

VEHICLE	SIZE/CLASS	BAG	DUMMY
2001 Focus	compact PC	none	SID/ES-2
2003 Corolla	light PC	thorax	SID/ES-2
2002 Impala	medium PC	head/thorax combo	SID/ES-2
2001 LeSabre	heavy PC	thorax	SID/ES-2
2002 Escape	SUV	none	SID/ES-2
2002 Odyssey	van	thorax	SID/ES-2
2002 Tundra	pickup	none	SID/ES-2

Rib Deflection "Flat -Top" Not an Issue

- **Of 23 crash tests, corresponding to the measurement of 102 rib deflections for both front and rear dummies, there were three instances of “flat top” observed**
 - Two instances attributed to load sharing with other body regions
 - One instance attributed to response reaching maximum deflection
- **No “flat top” observed in oblique pendulum & rib drop tests**
- **Of 19 sled tests, with measurement of 57 rib deflections, there was one instance of “flat top” response in which rib did not bottom out (i.e. deflection at maximum range)**

ES-2 and Flat-Top

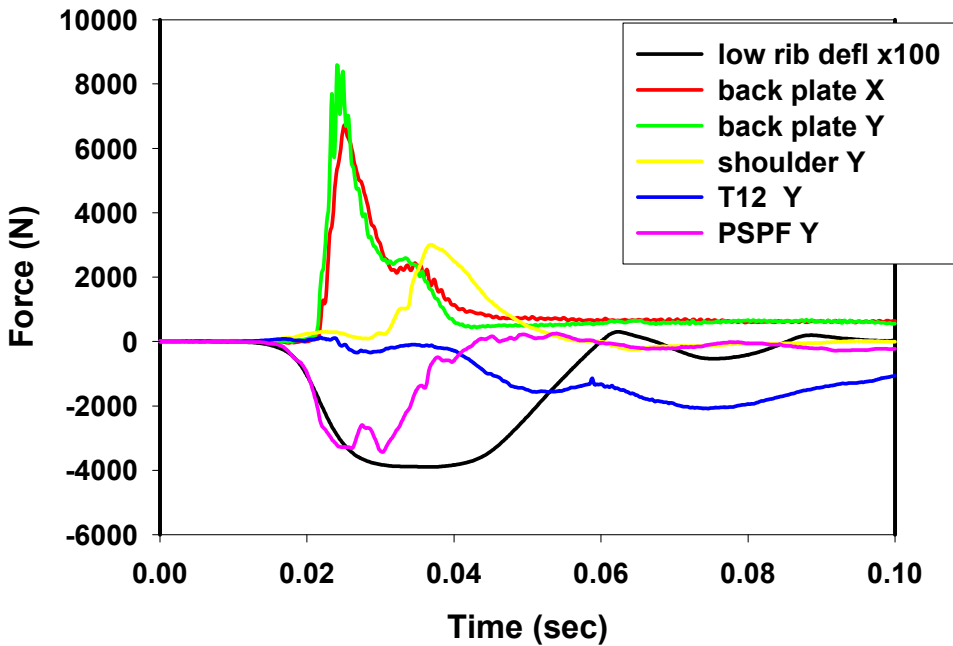
- **There are a number of causes of rib deflection flat-top***

Unacceptable	Acceptable
<ul style="list-style-type: none">■ Rib binding■ Shoulder binding■ Load sharing with back-plate	<ul style="list-style-type: none">■ Load sharing with other body regions■ Attenuation of input load■ Maximum range

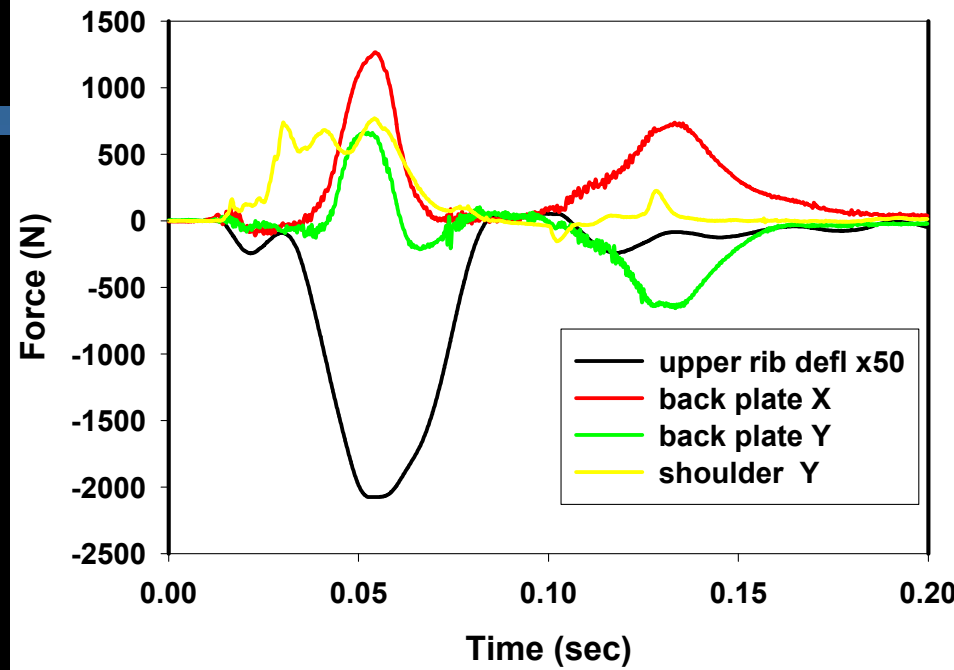
* Maltese et al 1999

Load Sharing With the Shoulder...

**Prizm/IIHS MDB with ES-2
 Driver Loads vs Upper Rib Deflection**

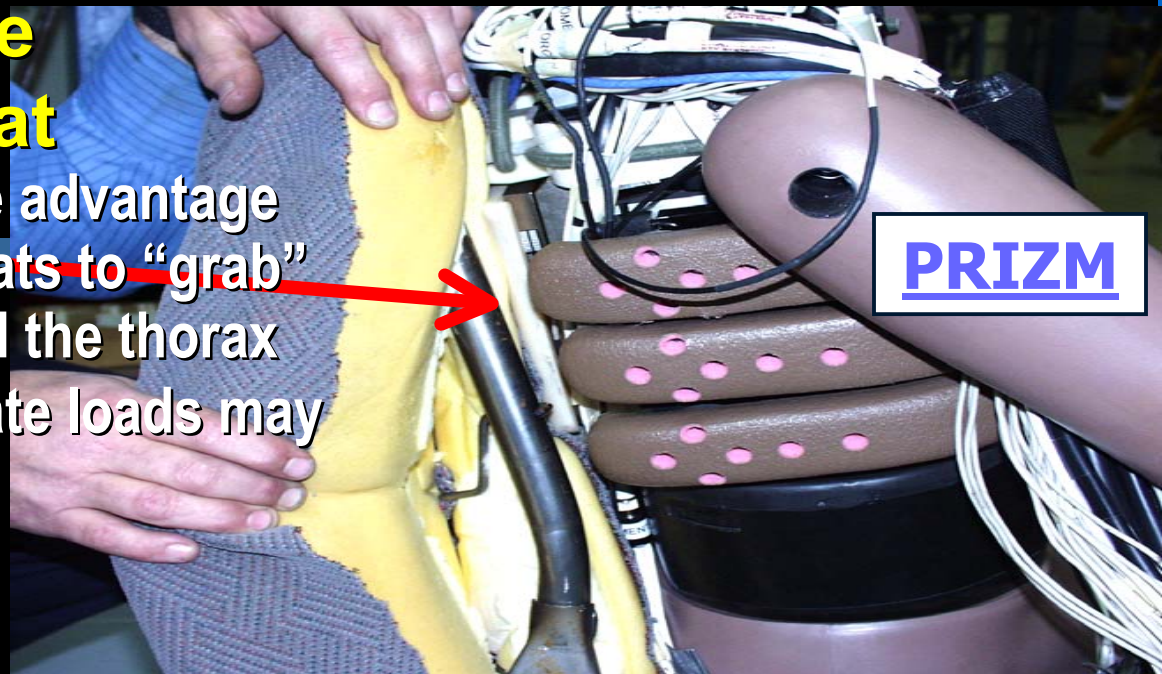


**Cougar/201 Pole with ES-2
 Driver Loads vs Upper Rib Deflection**



Potential back plate interaction with seat

- Manufacturers can take advantage of this by designing seats to “grab” the back plate & offload the thorax
- High and early back plate loads may affect injury criteria



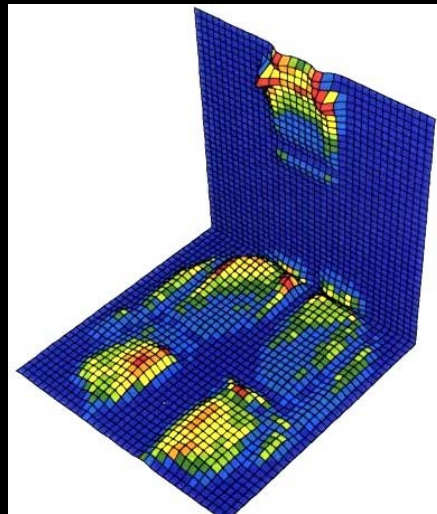
Back Plate/Seat Interaction

■ **Seat back pressure map measurements indicate that corners of ES-2 torso back plate are areas of high pressure**

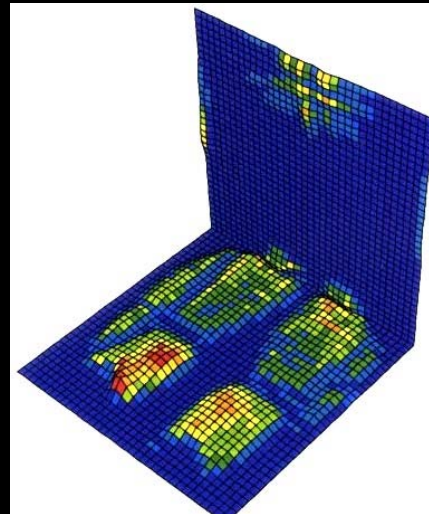
.SID-H3 only contacts at ~T-1 location (stiff, upright posture)

.ES-2 contact area is larger than SID-H3, but located high as well, indicating relatively stiff torso

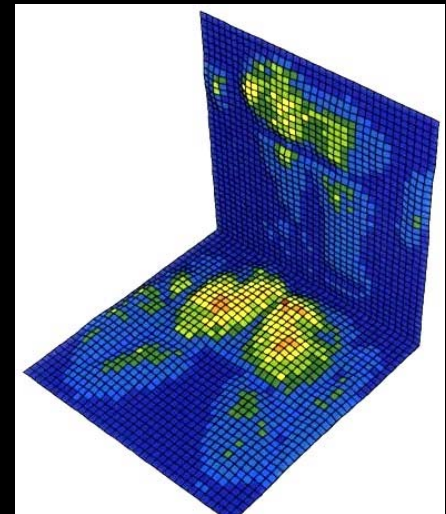
ES-2



SID-H3



50th% male volunteer

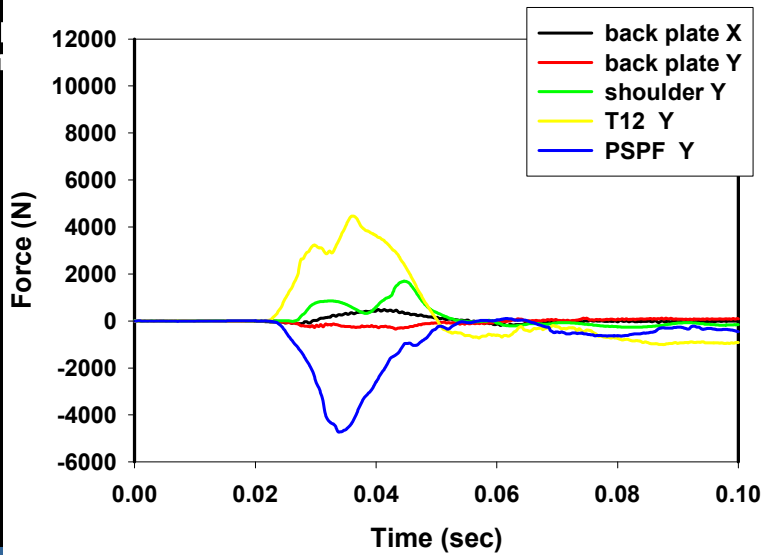


Back Pressure Maps With 40 lb. Frontal Force Applied

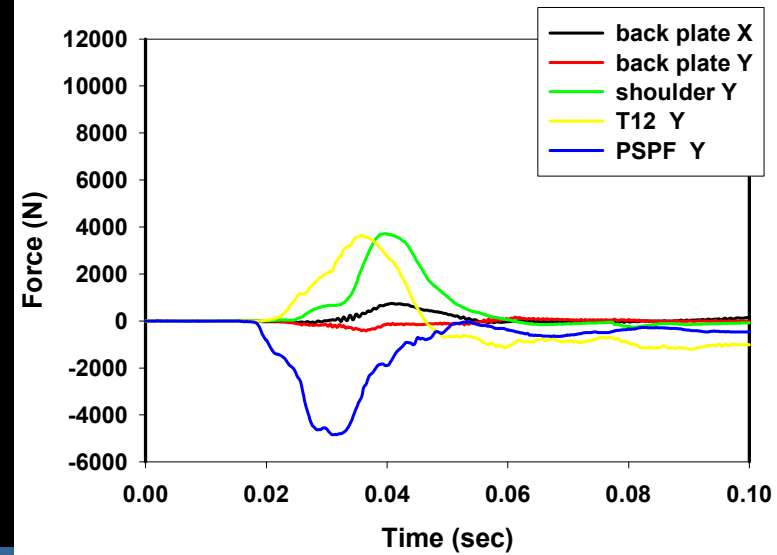
Back Plate/Seat Interaction

- **Data for two out of seventeen vehicle models crash tested suggest back plate “grabbing” by intruding structure. Large back plate loads occurring early in time relative to the lower spine loads were observed.**
- **Back plate loads and corresponding momentum contribution were low for the remaining fifteen vehicle models.**

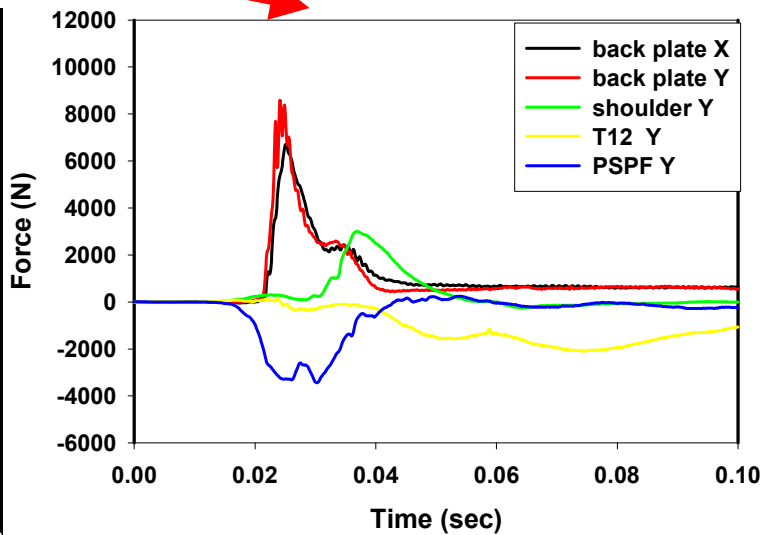
**Cadillac/IIHS MDB with ES-2
 Driver Loads**



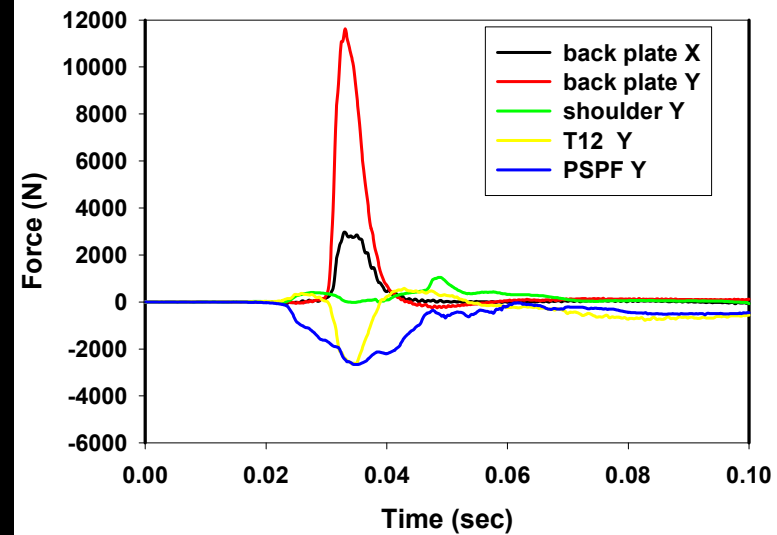
**Maxima/IIHS MDB with ES-2
 Driver Loads**



**Prizm/IIHS MDB with ES-2
 Driver Loads**



**Prizm/F150 with ES-2
 Driver Loads**

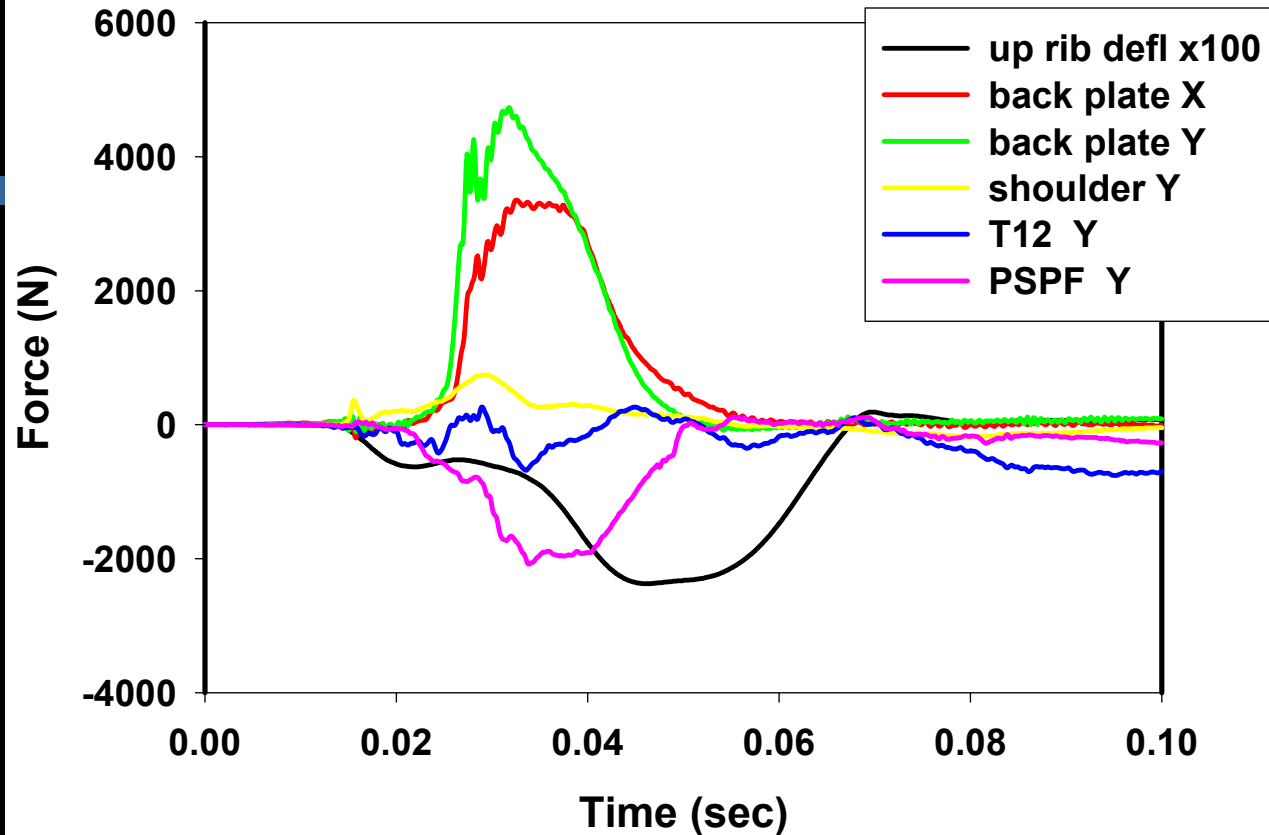


PRIZM

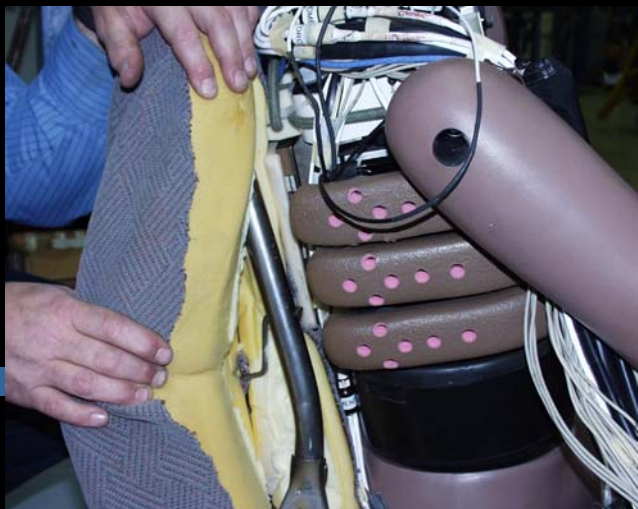


Back Plate "Grabbing" in Side NCAP Test of Impala

Impala/NCAP with ES-2
Driver Loads vs Upper Rib Deflection



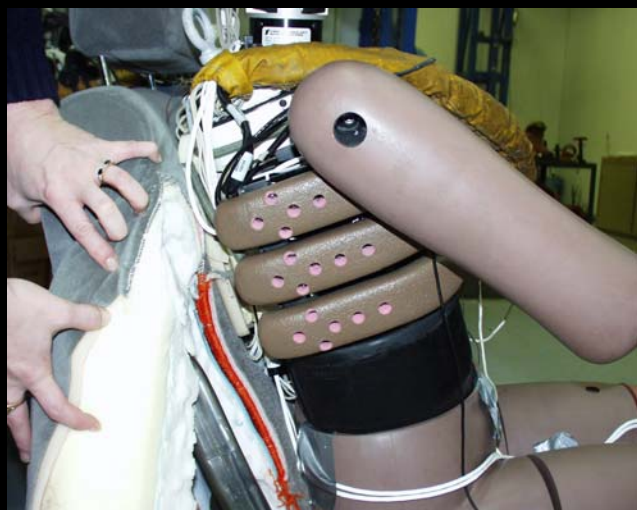
Side View of ES-2 Dummy in Seats



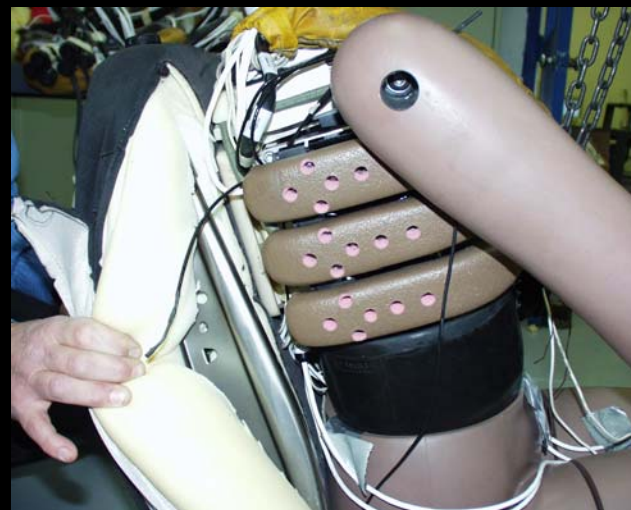
Prizm



Maxima



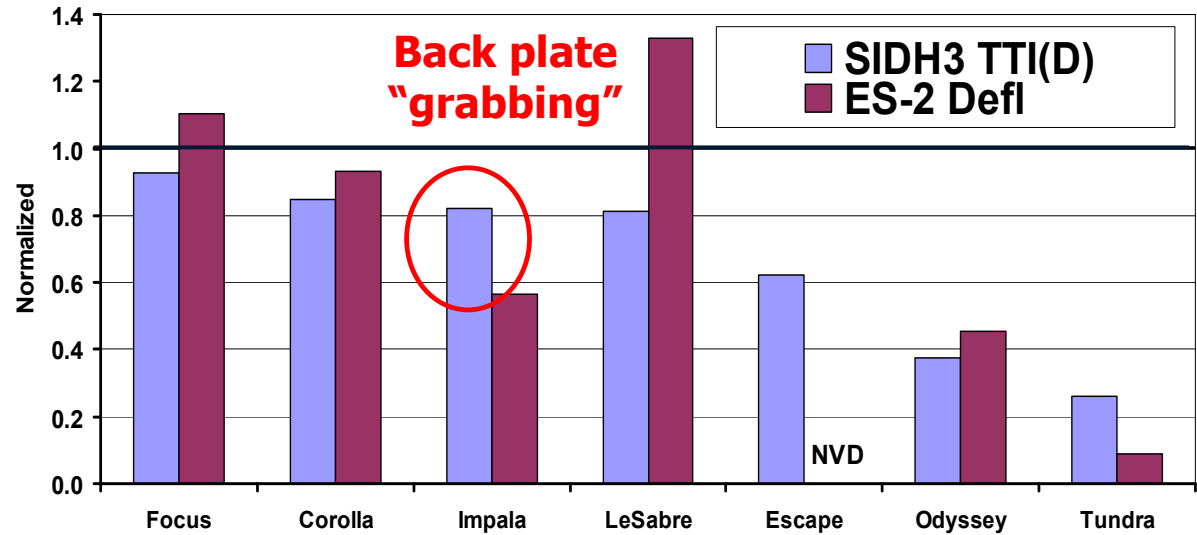
Impala



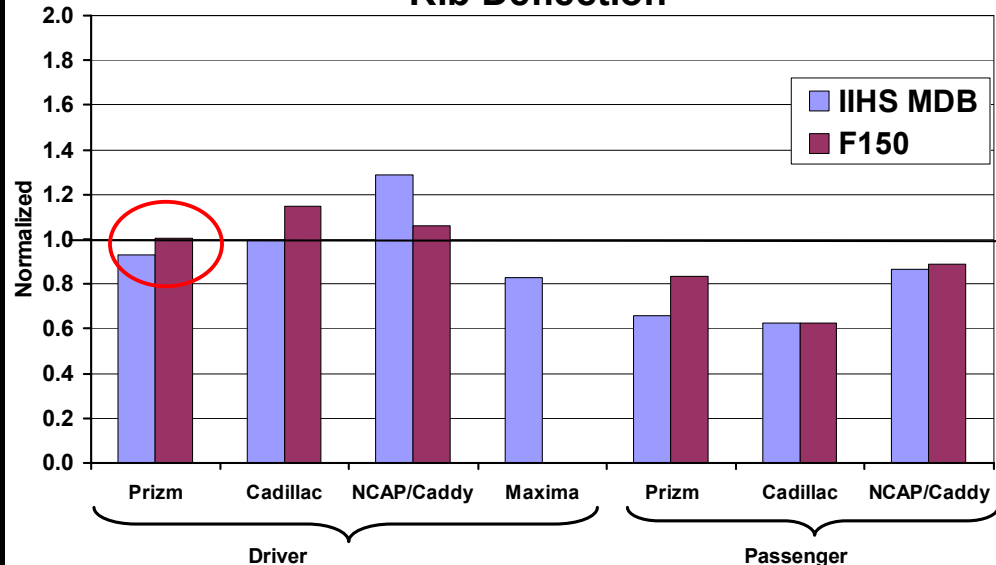
Focus

The high and "early" back plate loads may result in reduced injury criteria values??

2002 Side NCAP Fleet Performance Tests- Driver
 ES-2 rib deflection vs SID TTI(D)



High Sev/Upgrade Barrier ES-2 Tests
 Rib Deflection

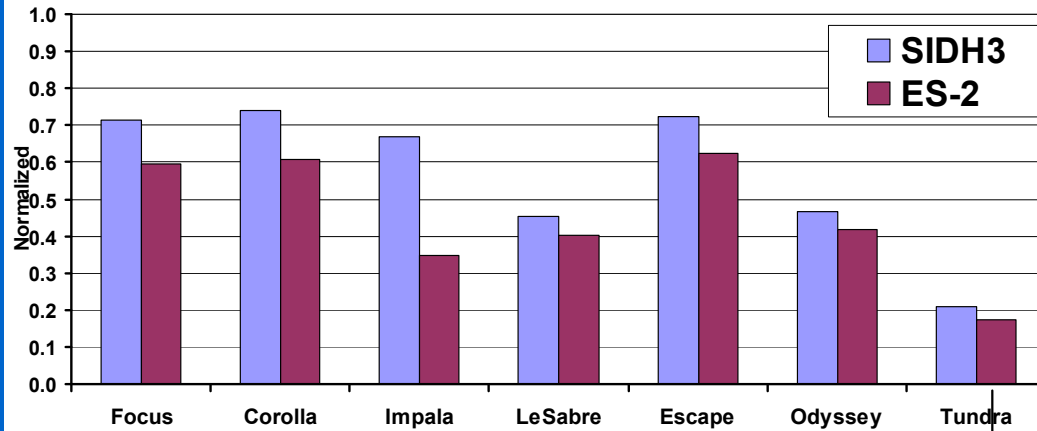


Deficiencies Noted in ES-2

- **Potential back plate interaction with seat**
- **Double peak in pubic symphysis load**
 - Magnitudes are small
 - All values are well below the threshold

2002 Side NCAP Tests- Driver

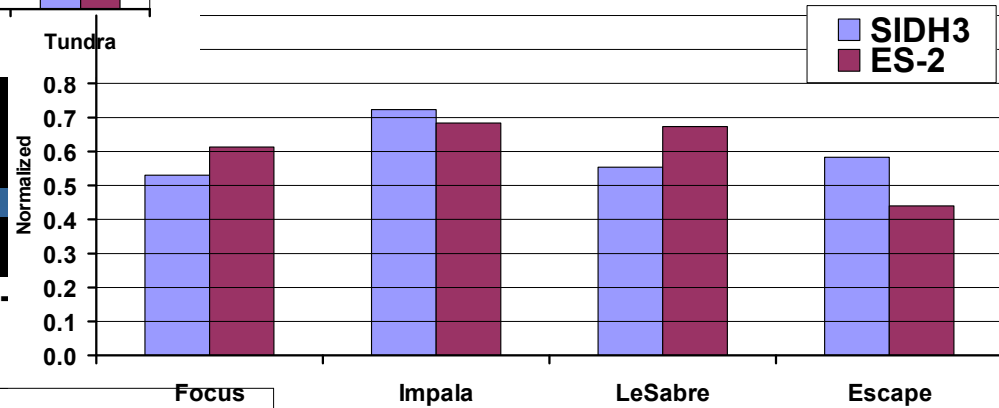
ES-2 pubic force vs SID pelvic Gs



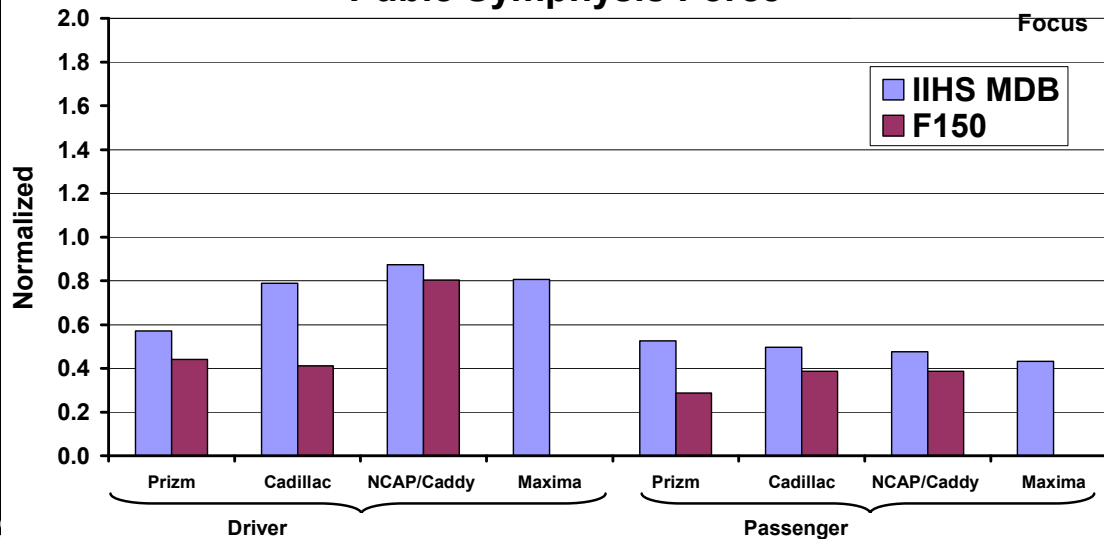
Pubic Symphysis Loads

2002 Side NCAP Tests- Rear Occupant

ES-2 pubic force vs SID pelvic Gs



High Severity/Upgrade Barrier ES-2 Pubic Symphysis Force



Pole Tests Performance

- **ES-2 demonstrated ability to detect usefulness of head protection**
 - Head/neck/shoulder kinematics comparable to SIDH3
 - Head loading levels and timing similar to SIDH3

- **Existing ES-2 rib deflection criterion indicate higher level of thoracic injury than the measured SIDH3 TTI(D) in the same vehicles**

Saturn – ES-2



Saturn – SIDH3



Maxima – ES-2



Maxima – SIDH3



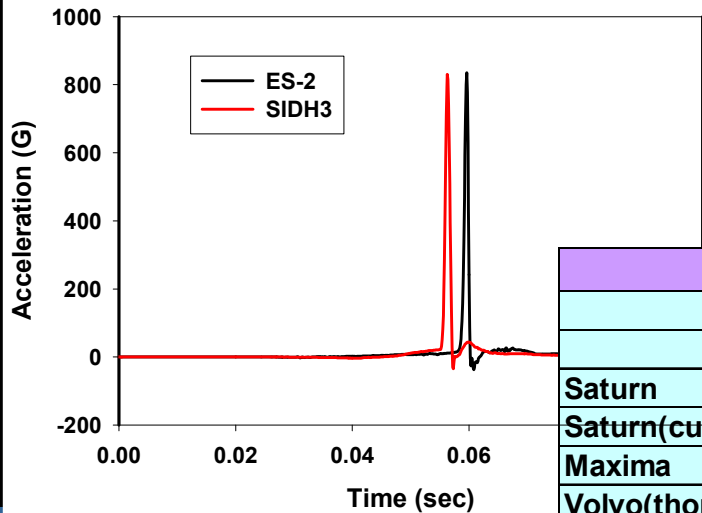
Saturn/curtain – ES-2



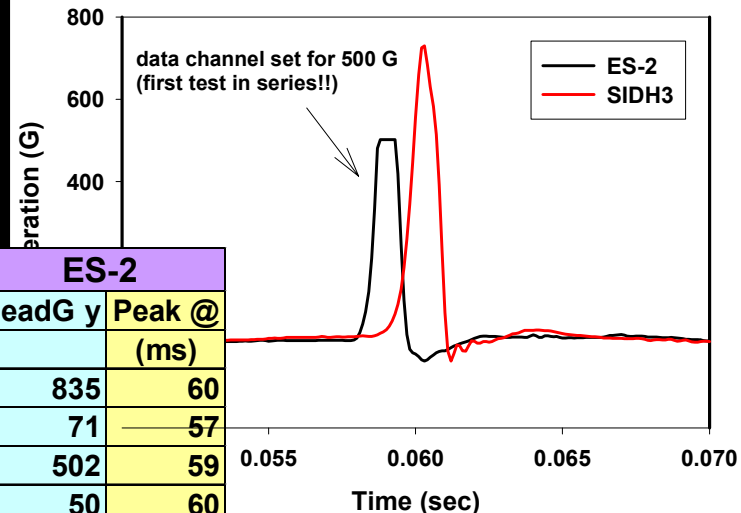
Maxima/bag – ES-2



Saturn- no curtain/201 Pole
Lateral Head Acceleration

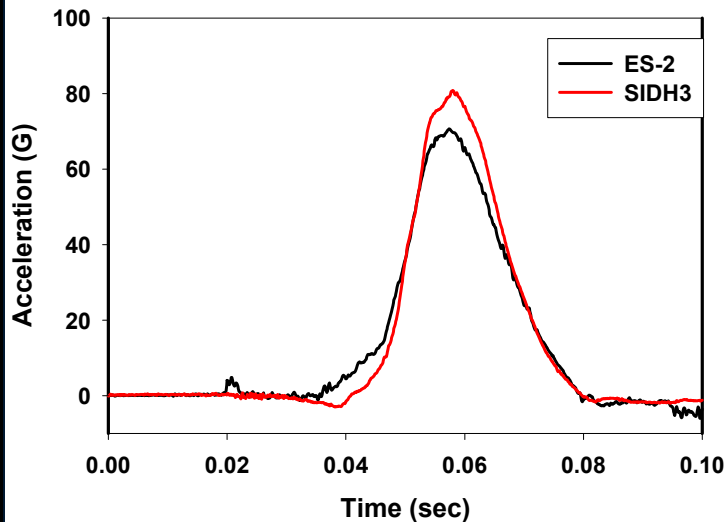


Maxima- no bag/201 Pole
Lateral Head Acceleration

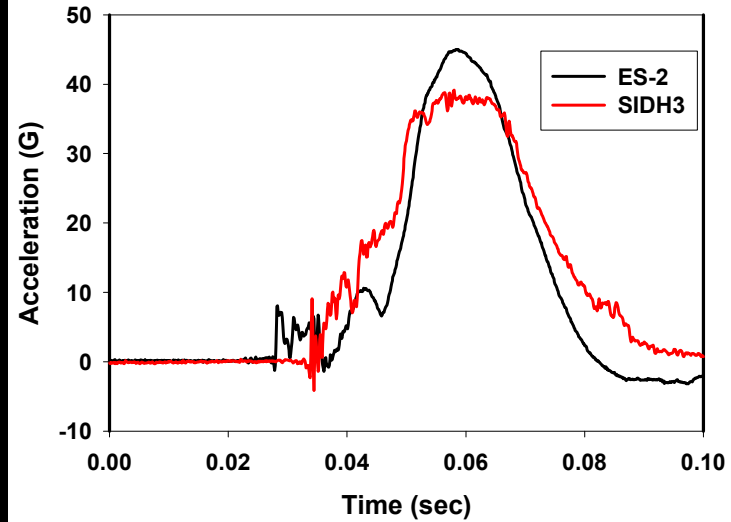


	SIDH3		ES-2	
	HeadG y	Peak @ (ms)	HeadG y	Peak @ (ms)
Saturn	830	56	835	60
Saturn(curtain)	81	58	71	57
Maxima	730	60	502	59
Volvo(thorax/curtain)	51	67	50	60
Explorer(curtain)	39	58	45	58

Saturn- with curtain/201 Pole
Lateral Head Acceleration

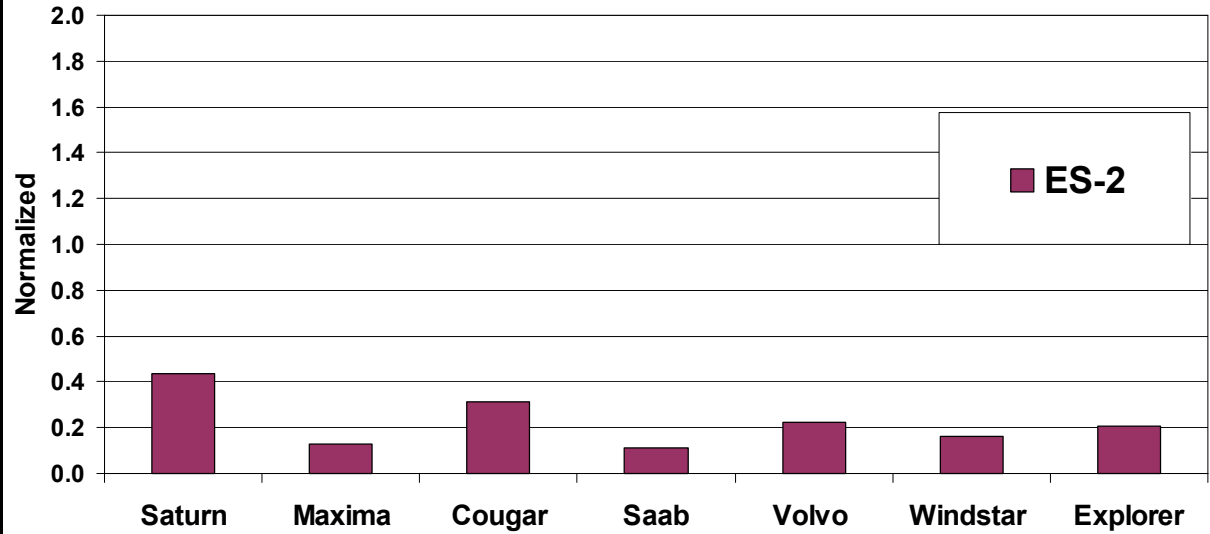


Explorer- with curtain/201 Pole
Lateral Head Acceleration

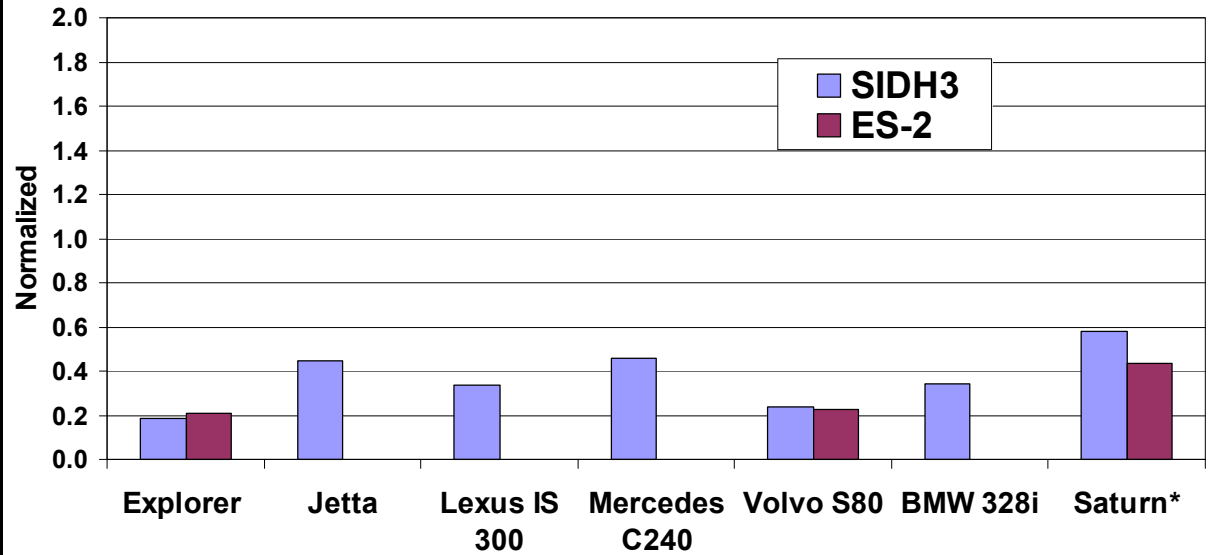


ES-2 & SIDH3 are similar in their ability to detect usefulness of head protection!

R&D 201P Fleet Performance Tests - HIC
Vehicles with Head Protection

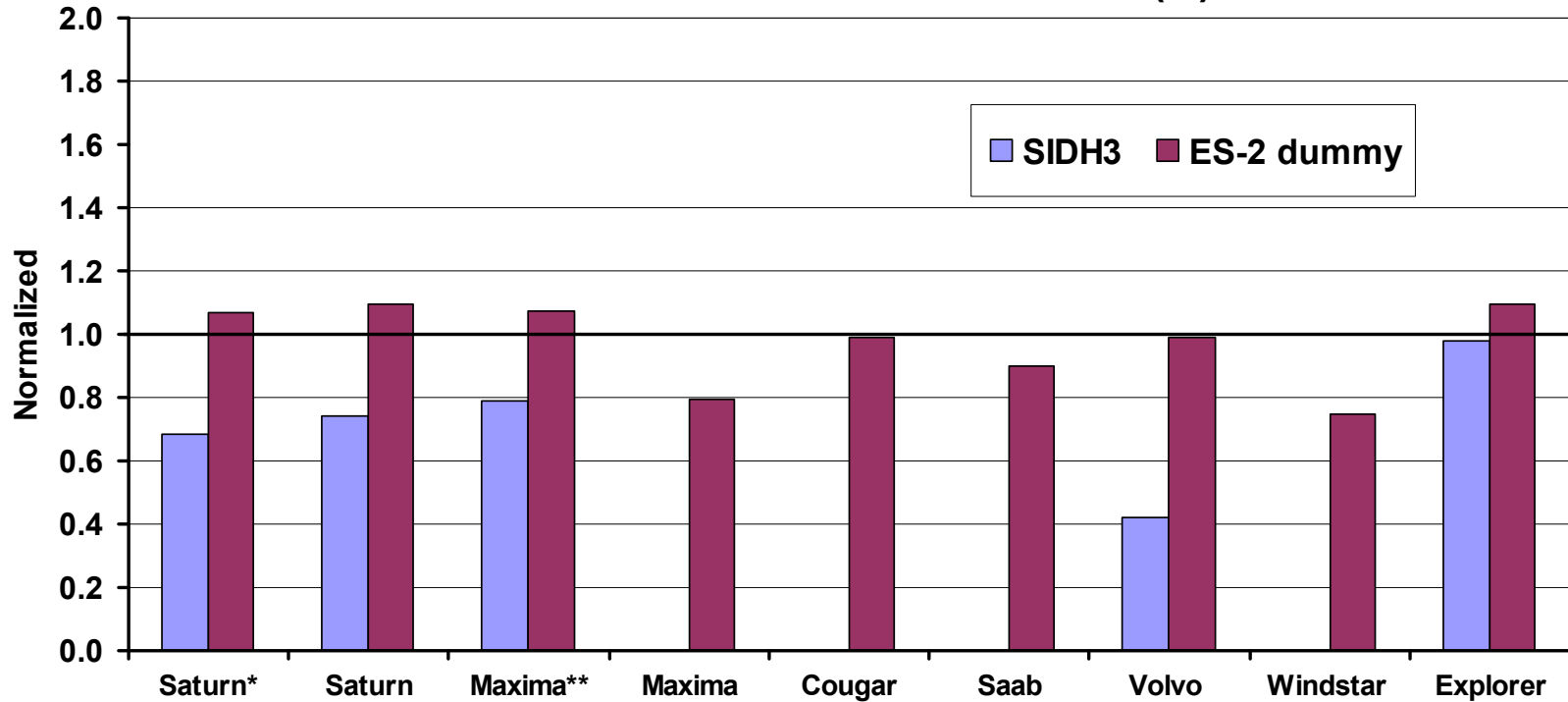


Compliance 201P Tests HIC - FY 00 & 01



ES-2 Detects High Thoracic Loads in a Side Pole Test

201P Pole Tests
ES-2 Rib Deflection vs SIDH3 TTI(D)



Saturn*	no bag	Saab	combo
Saturn	curtain only	Volvo	thorax/curtain
Maxima**	no bag	Windstar	combo
Maxima	combo	Explorer	curtain only
Cougar	combo		

Upgrade FMVSS 214 MDB/High Severity Tests Performance

ES-2 Research Findings

- **ES-2 demonstrated excellent durability**
- **Rib deflections within maximum range (max range reached only in IIHS MDB to Caddy test at NCAP speed)**
- **ES-2 demonstrated ability to detect high abdominal loads due to intruding armrest in IIHS MDB to Cadillac test**

IIHS MDB to Deville

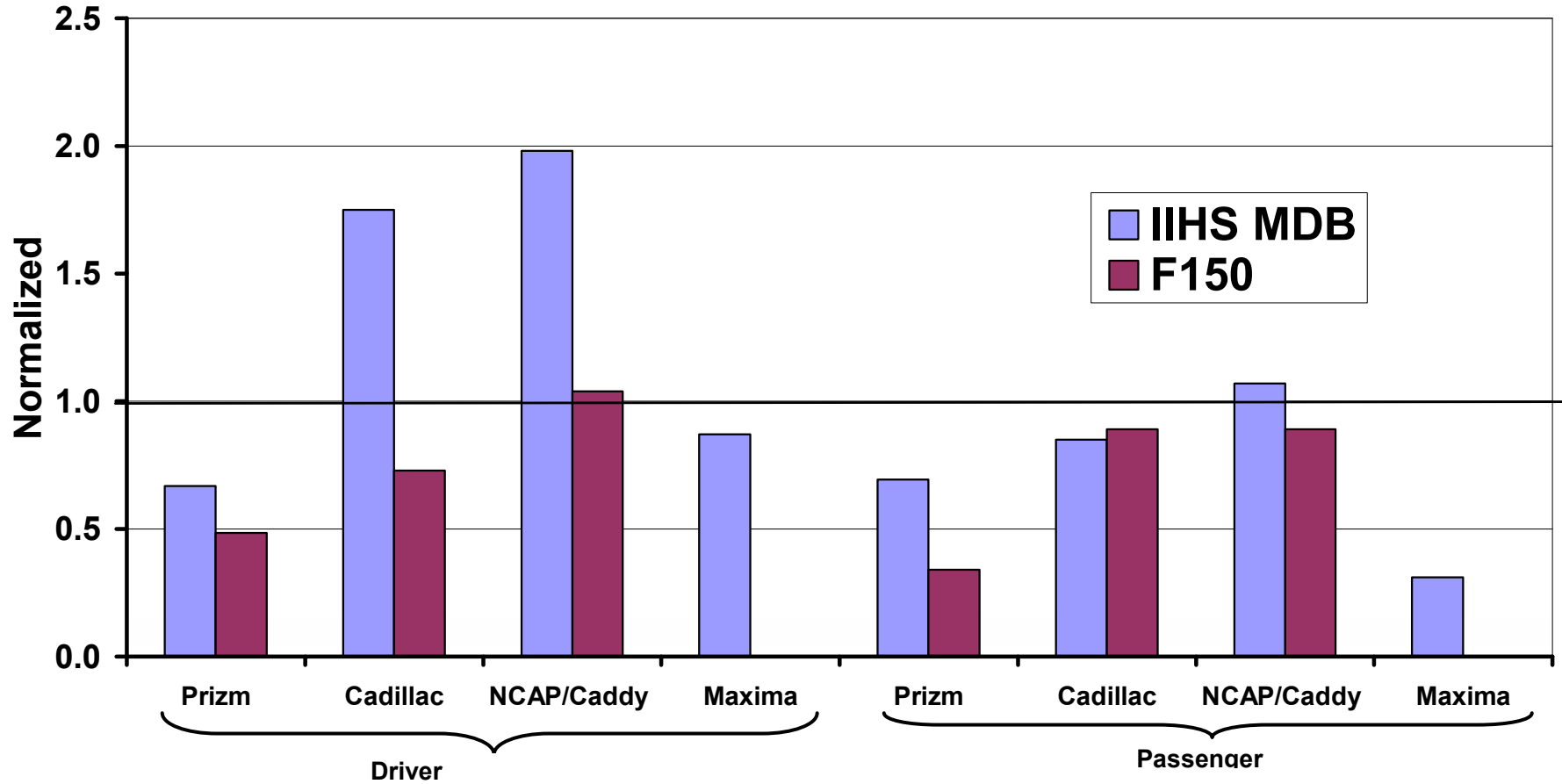


F150 to Deville

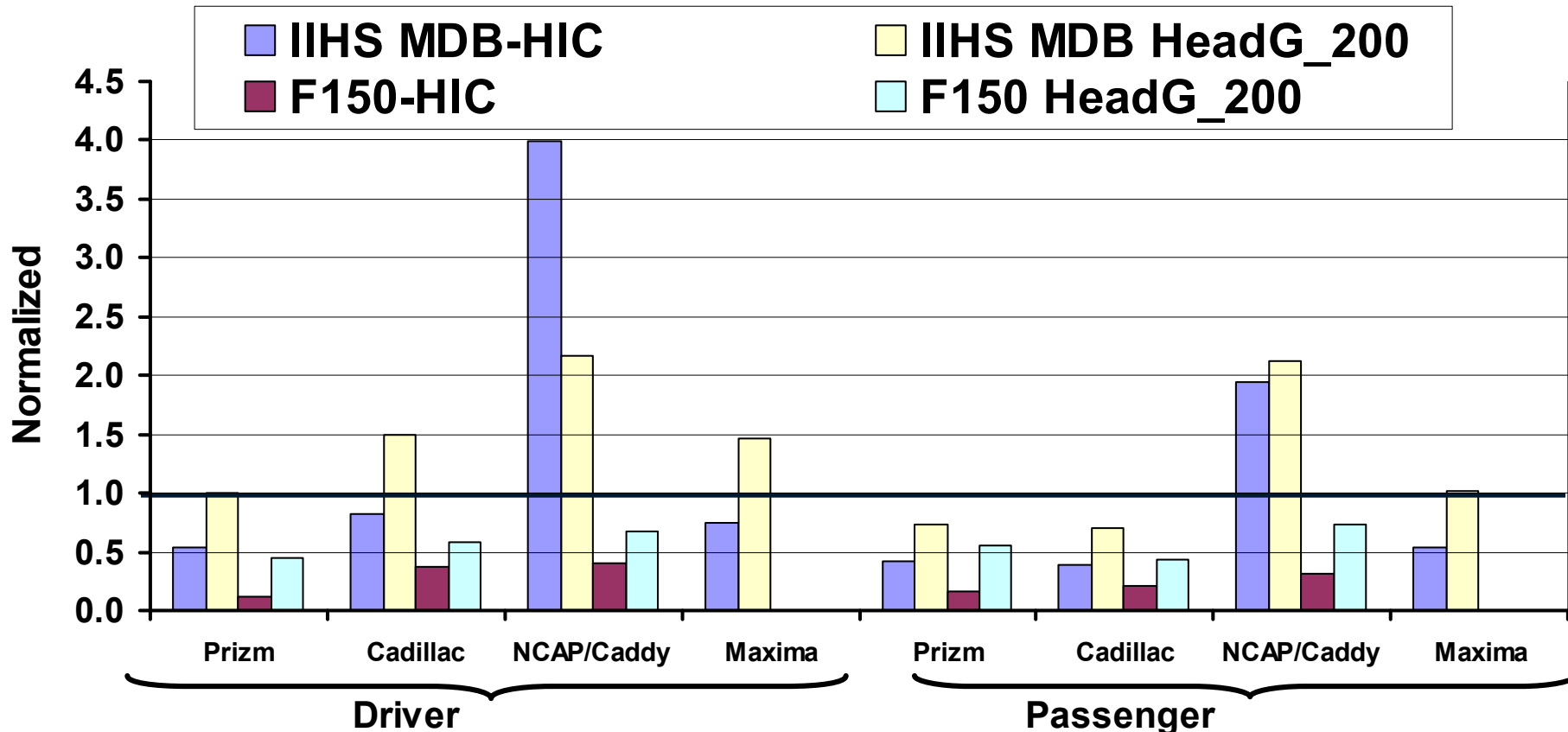


ES-2 Detected Intruding Armrest in IIHS MDB Cadillac Test

High Sev/Upgrade Barrier ES-2 Tests- Abdomen Force



High Severity/Upgrade Barrier ES-2 Tests - HIC



IIHS to Deville



F150 to Deville



IIHS to Prizm



F150 to Prizm



Side NCAP Fleet Tests Performance

VEHICLE	SIZE/CLASS
2001 Focus	compact PC
2003 Corolla	light PC
2002 Impala	medium PC
2001 LeSabre	heavy PC
2002 Escape	SUV
2002 Odyssey	van
2002 Tundra	pickup

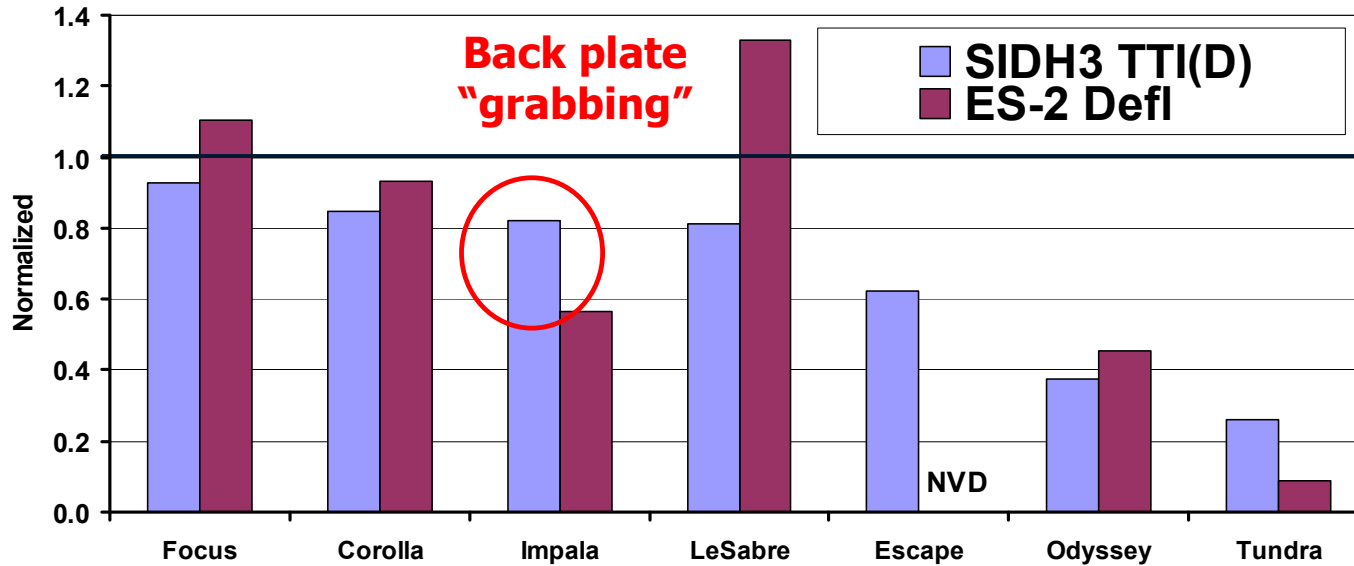
Exceeded one or more ES-2 injury criteria limits

All vehicles passed the SID injury criteria

- **ES-2 rib deflection maximum range reached only in one rib measurement for the LeSabre driver where both the door and hinge at A-pillar collapsed**

2002 Side NCAP Fleet Performance Tests- Driver

ES-2 rib deflection vs SID TTI(D)



Thorax

EU/214 Criteria Limits

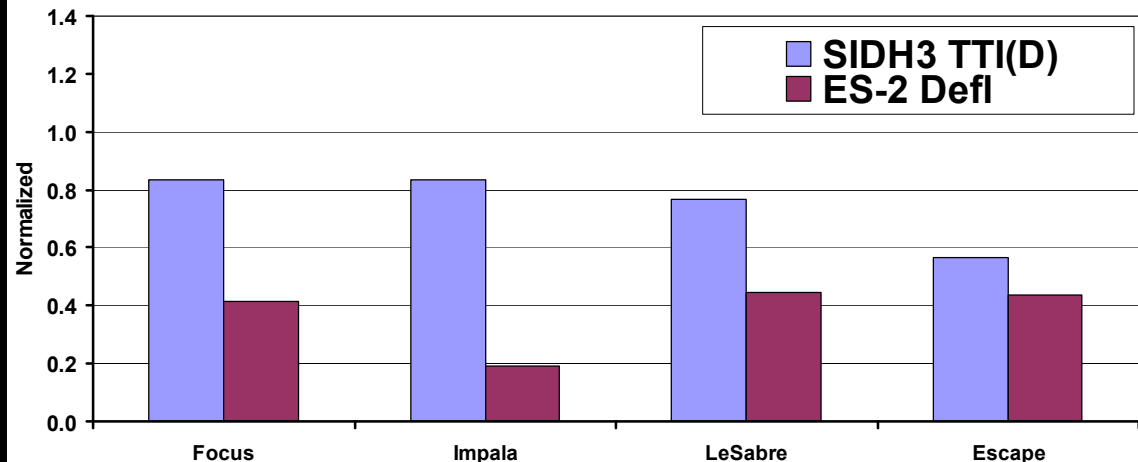
TTI=85/90

Defl=42 mm

ES-2 driver rib deflection exceeded limit for two of the vehicles for which TTI(D) was within the limits!

2002 Side NCAP Tests- Rear Occupant

ES-2 rib deflection vs SID TTI(D)



2002 Side NCAP Fleet Performance Tests- Driver

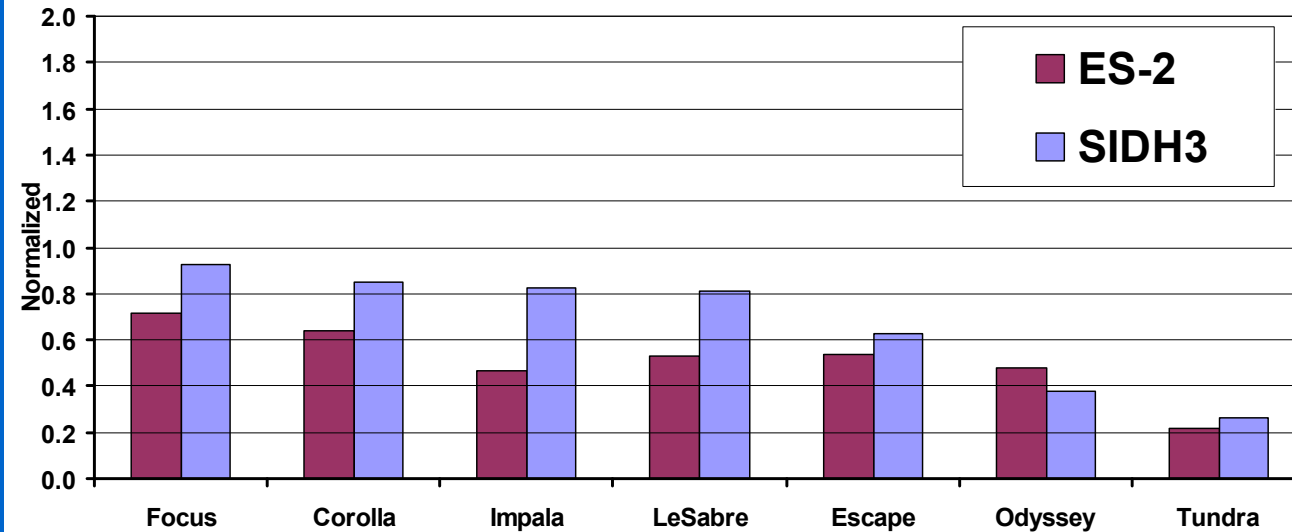
ES-2 abdomen force vs SID TTI(D)

Abdomen

EU/214 Criteria Limits

TTI=85/90

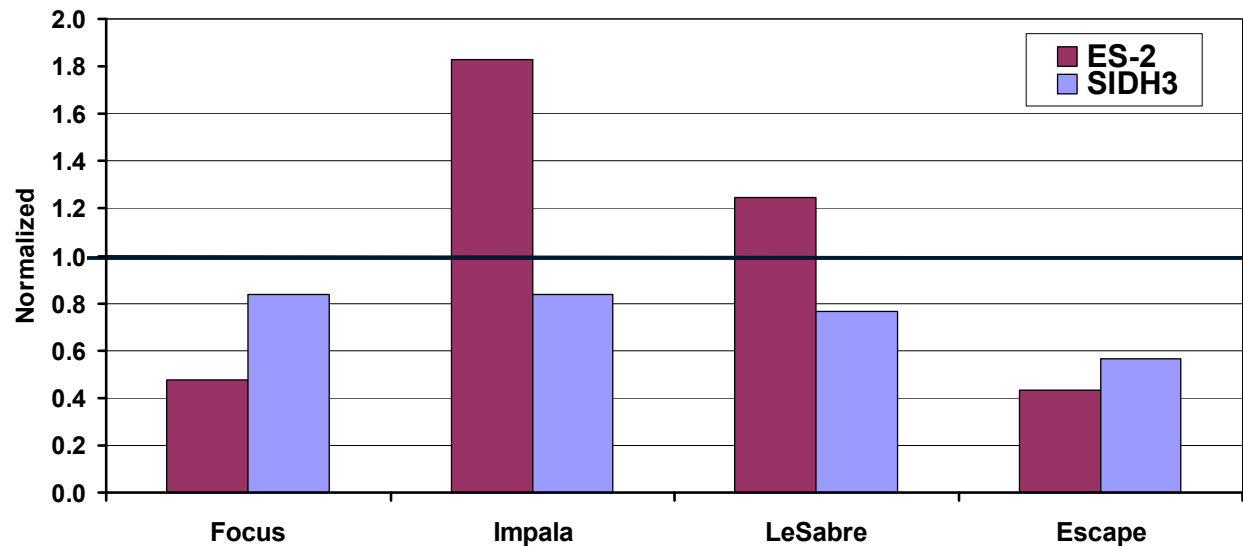
Abdomen Force=2500 N



ES-2 rear occupant exceeded abdominal load limit in two of the vehicles for which TTI(D) was within the limits!

2002 Side NCAP Tests- Rear Occupant

ES-2 abdomen force vs SID TTI(D)



Findings

- **Rib binding is gone**
- **Dummy is durable**
- **Back plate/seat interaction is an issue:**
 - **Possible solutions**
 - Internal dummy fix
 - Placing a limit on back plate loads
 - Use of protective shield
- **ES-2 demonstrated ability to detect usefulness of head protection**
- **ES2 exceeded thoracic and abdominal injury threshold in some vehicles (SID did not)**