

ES-2 Biofidelity and Injury Assessment Capability

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People Saving People
[Http://www.nhtsa.dot.gov](http://www.nhtsa.dot.gov)

Presentation Overview



NHTSA Side Impact Research

- **ES-2 Research Program Time Line**
- **Flat top and the ES-2**
- **Biofidelity of the ES-2 and SID**
- **Injury Assessment Capability of the ES-2 and SID**
- **Back Plate Loads in the ES-2**
- **Conclusions**
- **Future Work**

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Why ES-2?

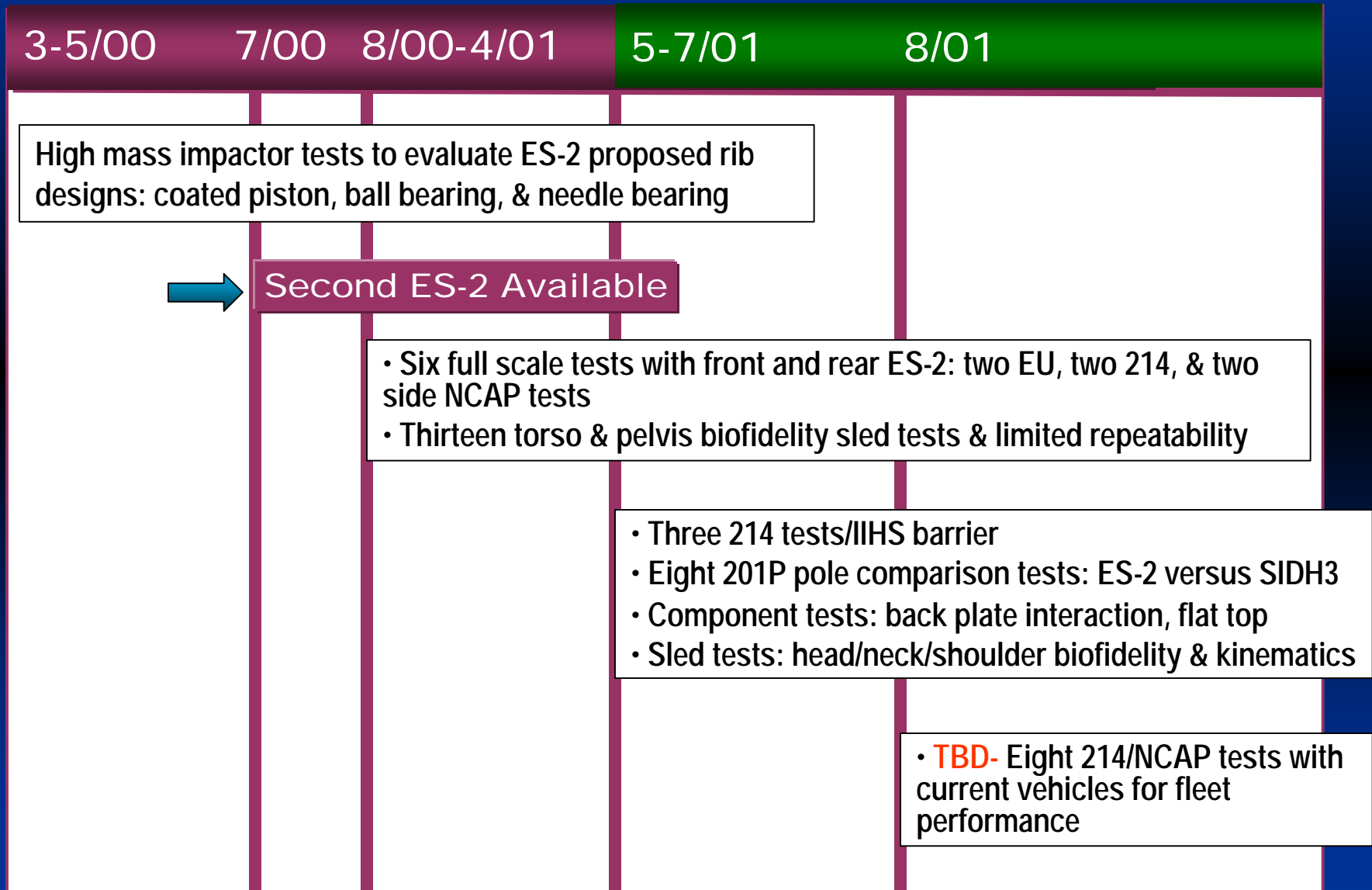


NHTSA Side Impact Research

- **NHTSA is evaluating the ES-2 . . .**
 - . . . to Improve safety for the US Driving Population, and
 - . . . for interim regulatory harmonization of a side impact dummy

ES-2 Research Testing

Planned



Presentation Overview



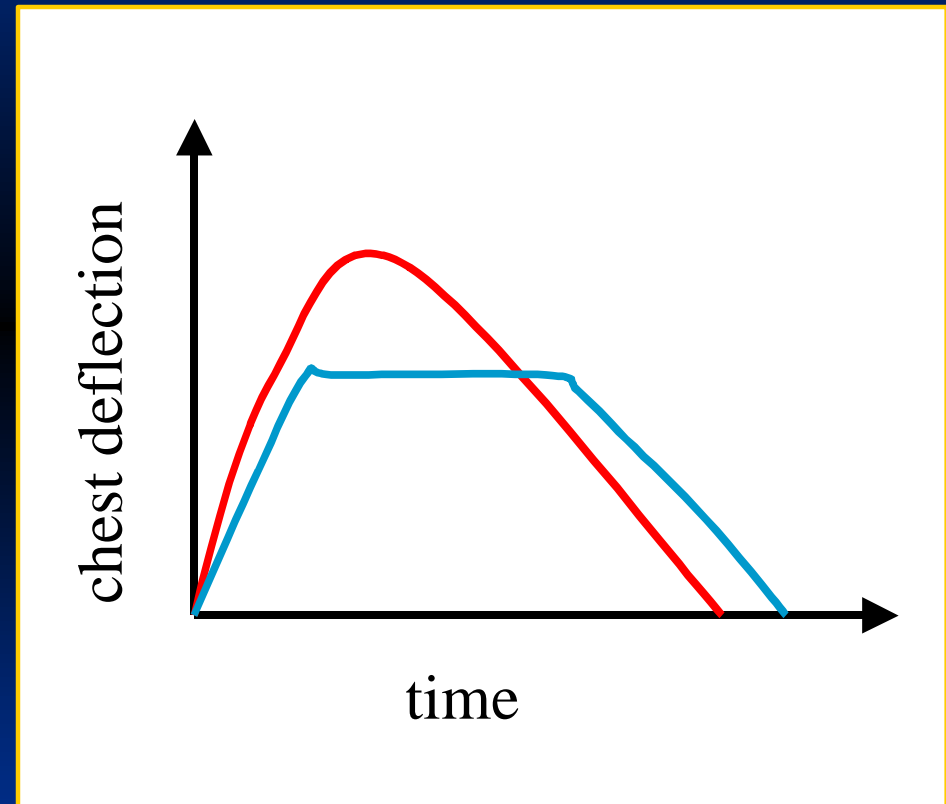
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ES-2 and Flat-Top

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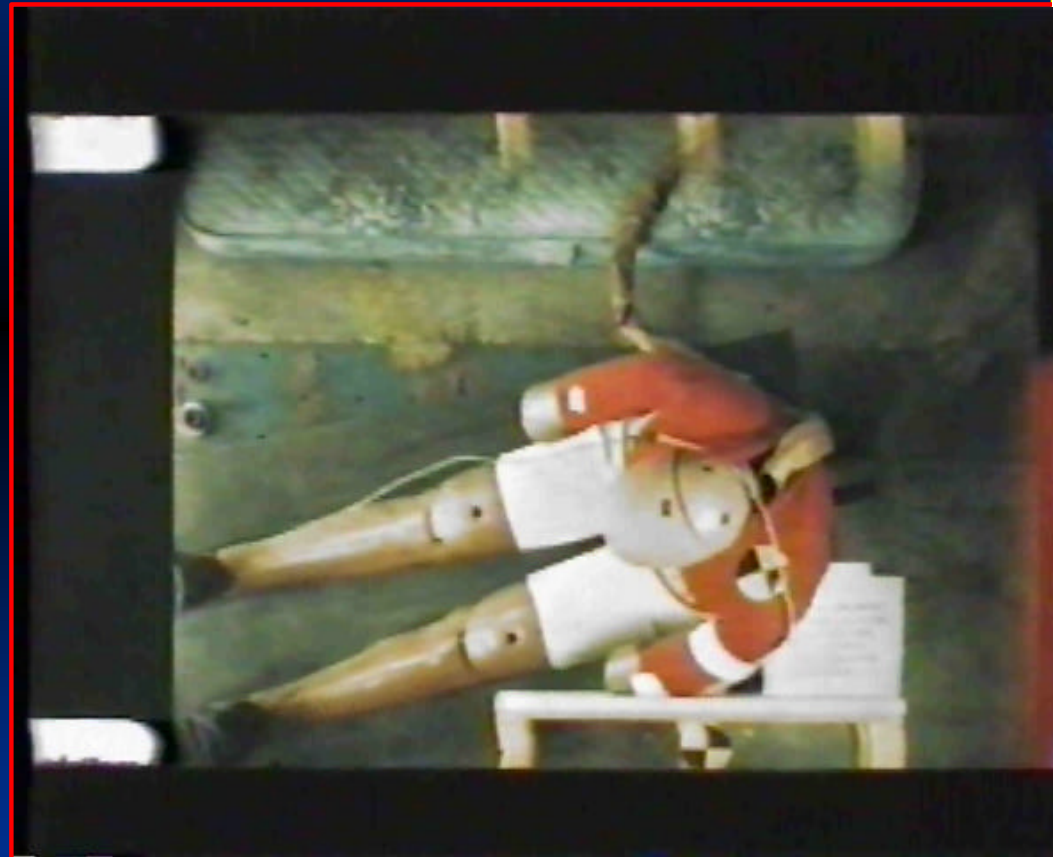
- Flat-top is a period of constant rib deflection over time.
- Flat-top is merely evidence that the ribs and the spine are moving at the same velocity relative to ground.
 - Flat-top is not necessarily evidence of rib binding.



“High Mass” Impactor Tests

NHTSA Side Impact Research

- Impactor: **907 kg at 5 m/s contacting the thorax and abdomen**
- Test conditions: **Impactor contacted the ES-2 at angles of 0, +10, +20, and -10 in the horizontal plane**
- ES-2 rib modules designs: **coated piston, ball and needle bearings**



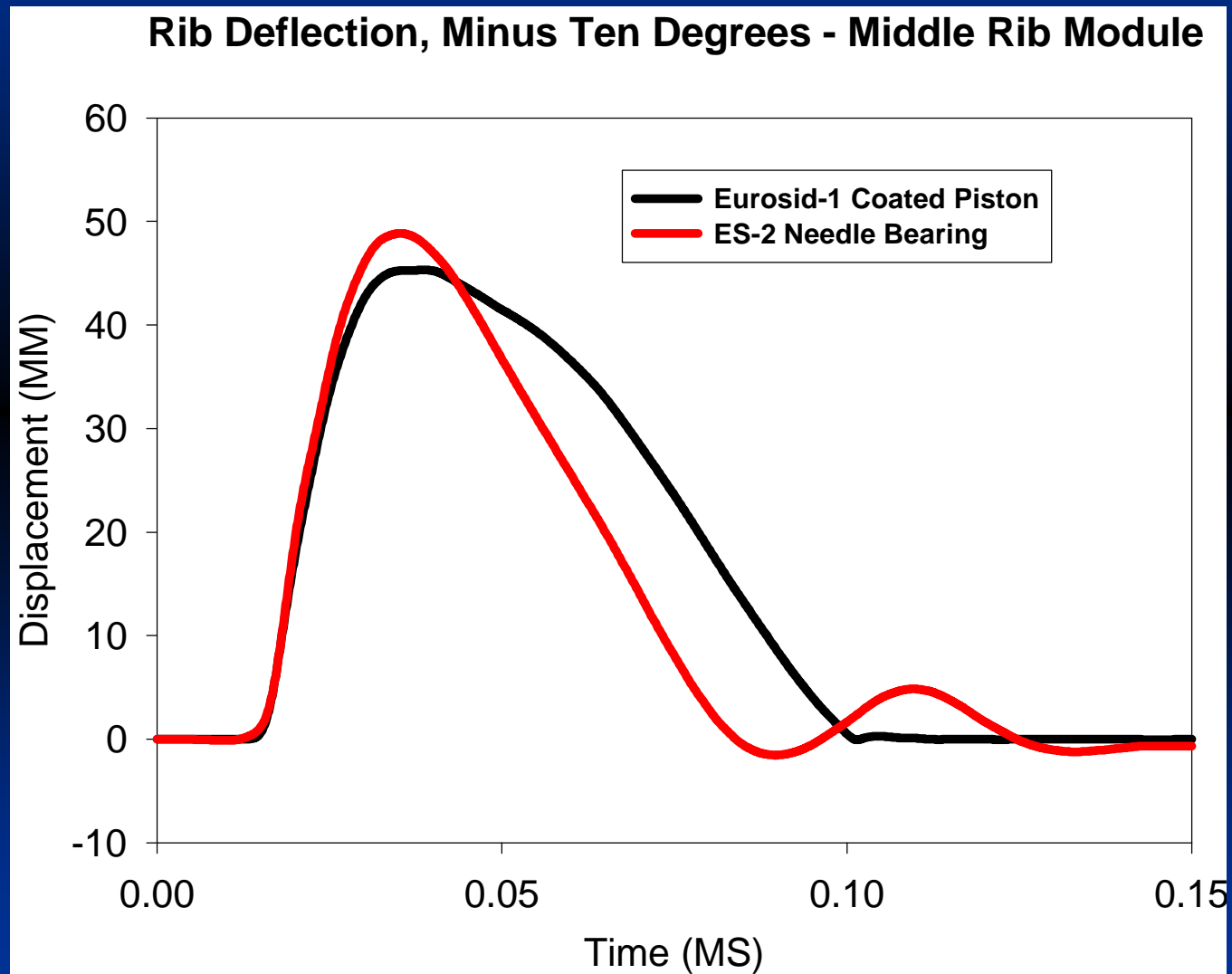
“High Mass” Impactor Tests - Results



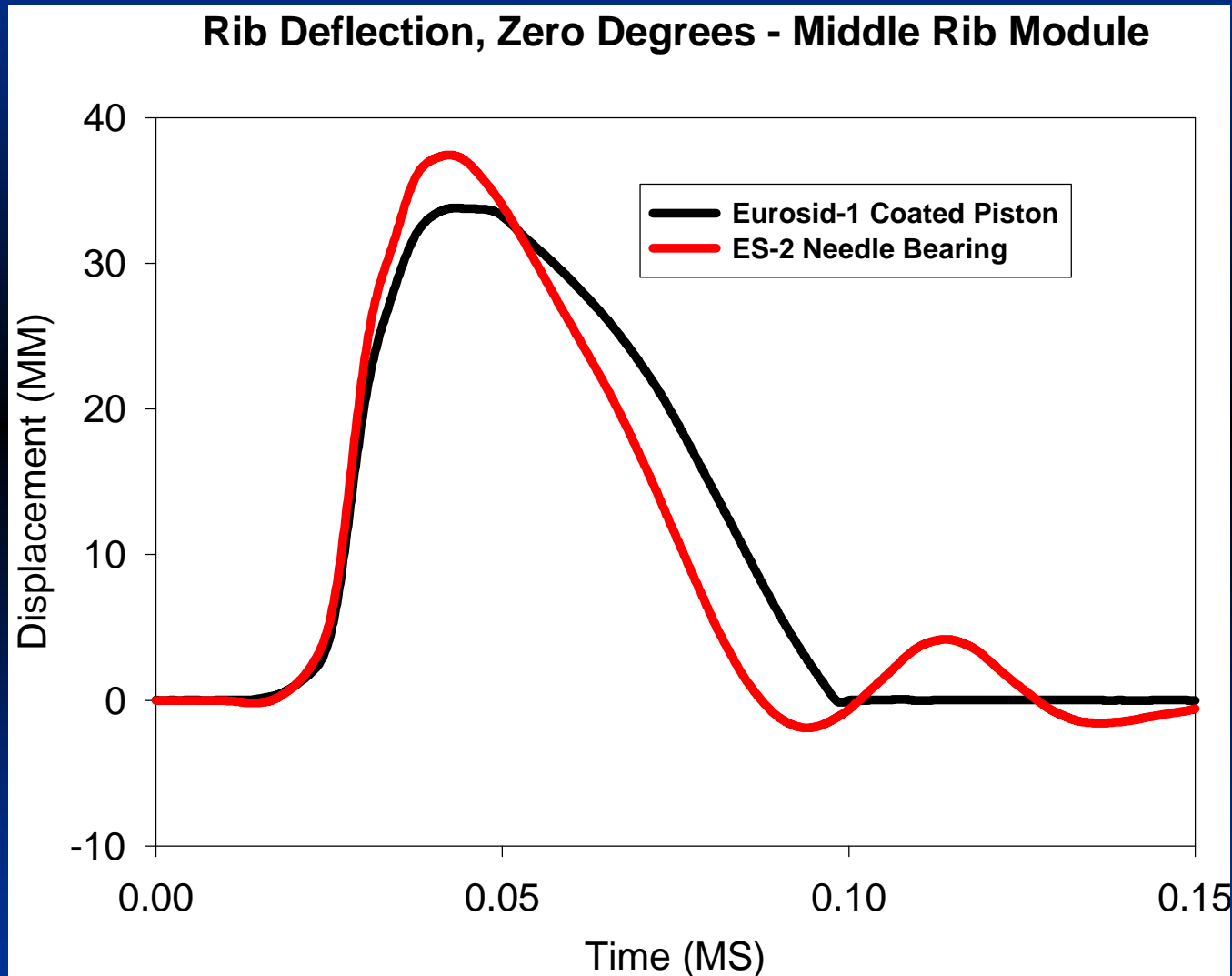
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- **No evidence of flat-top in ES-2 needle bearing rib modules**
- **Higher deflections in ES-2 compared to Eurosid-1**

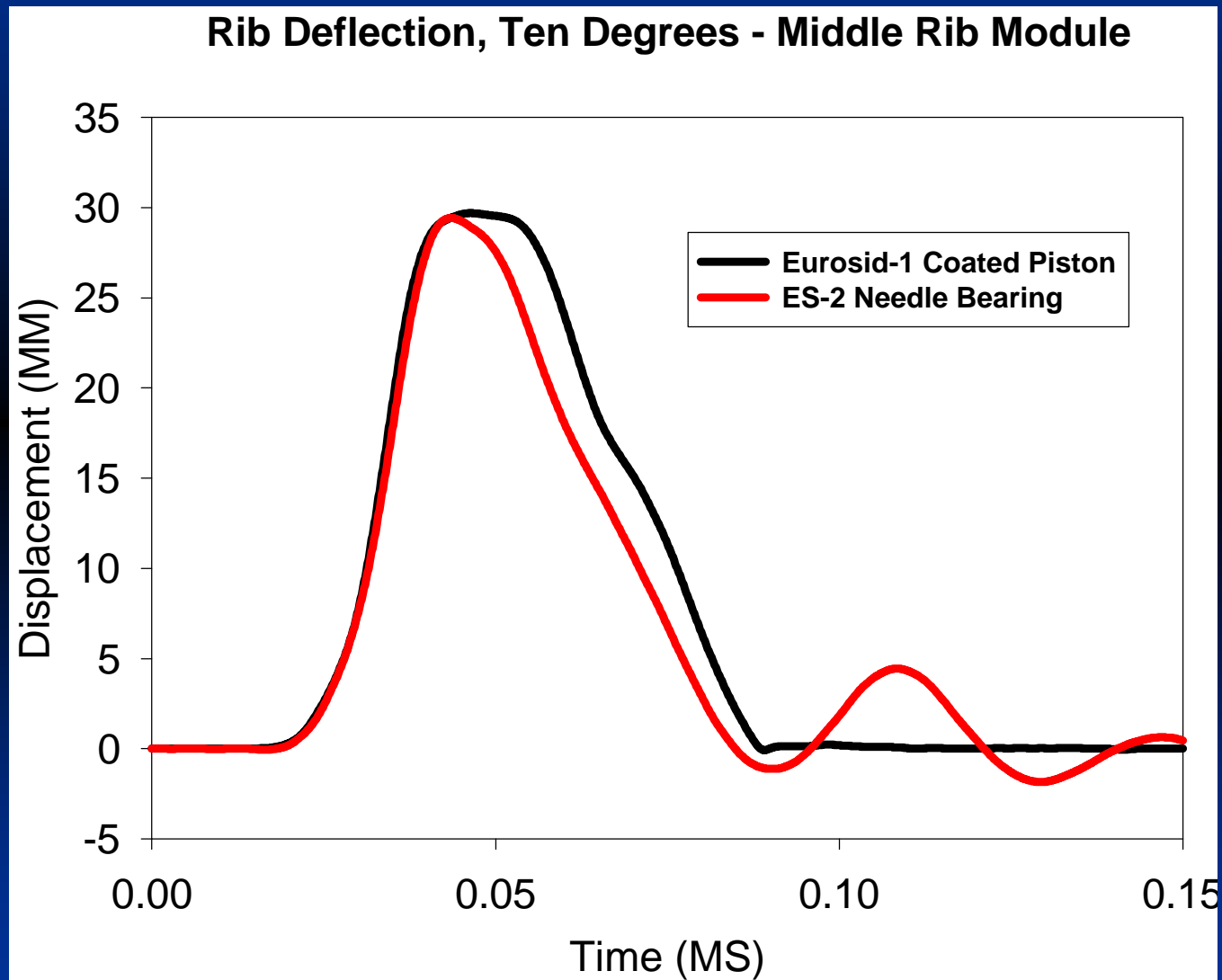
High-mass Pendulum Tests



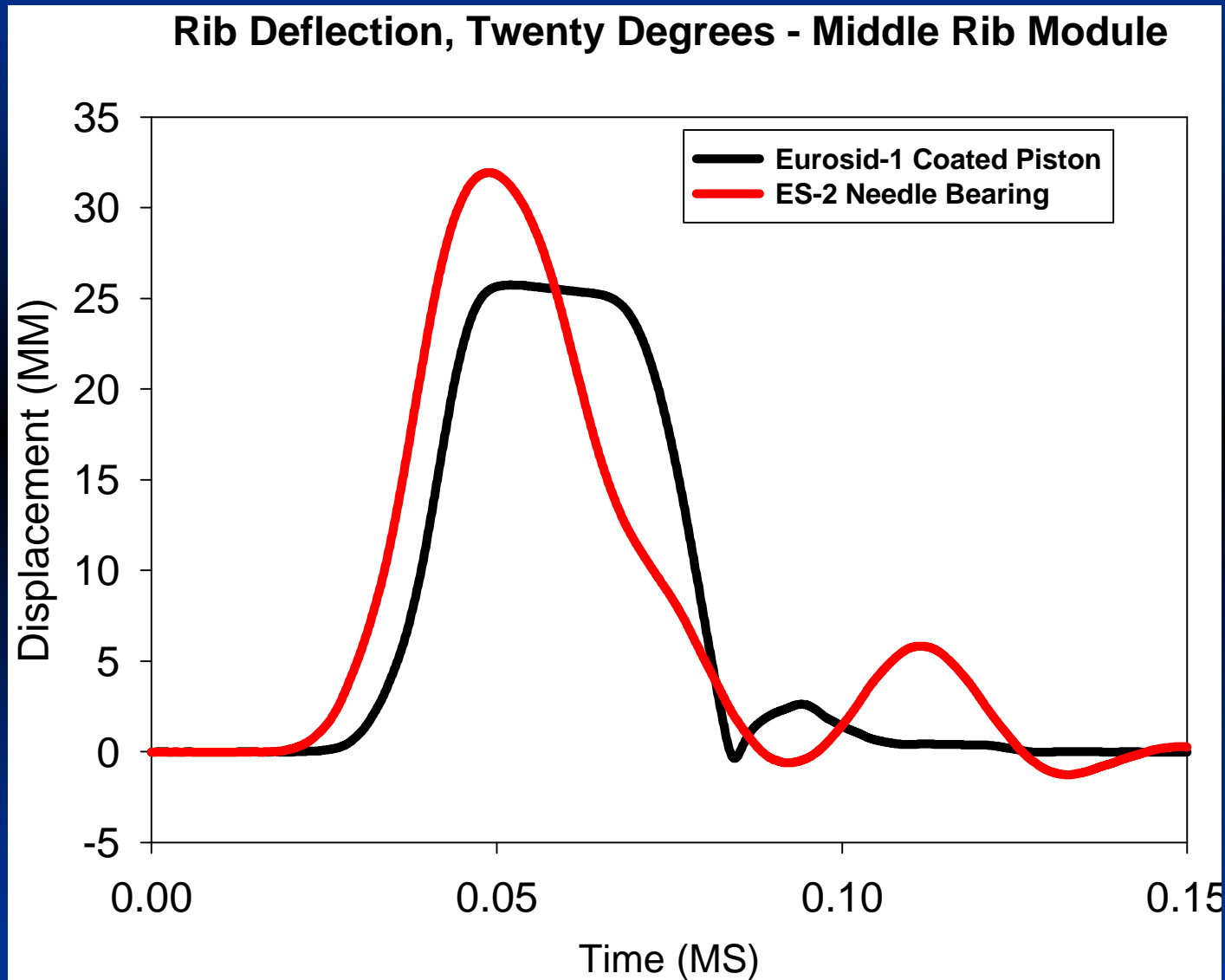
High-mass Pendulum Tests



High-mass Pendulum Tests



High-mass Pendulum Tests



ES-2 Phase I Full Scale Tests



NHTSA Side Impact Research

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

** Baseline Tests in 1997*

ES-2 Phase I Full Scale Tests



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** Baseline Tests in 1997*

Full Scale Test Rib Responses

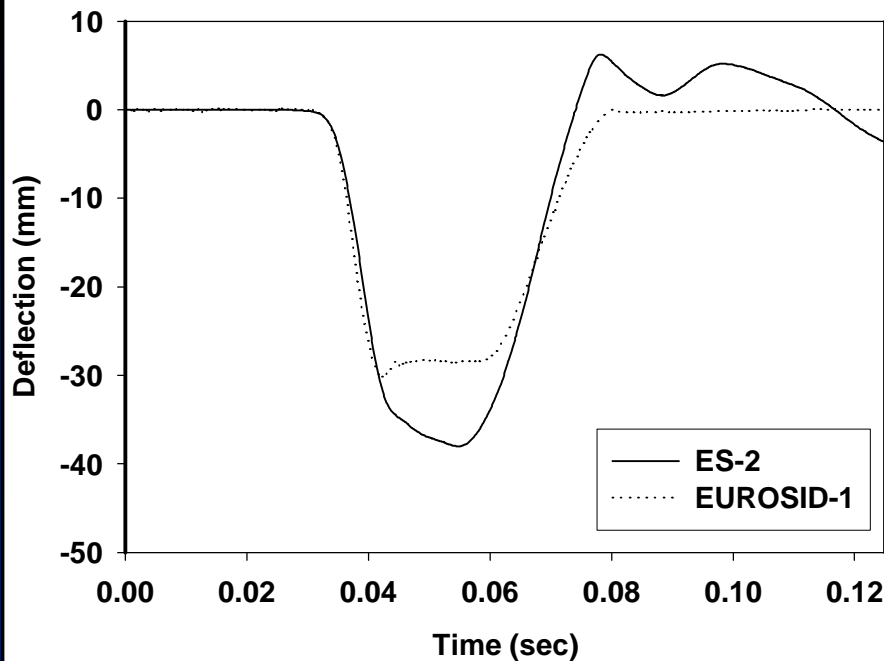
EU Tests: ES-2 Versus Eurosid-1



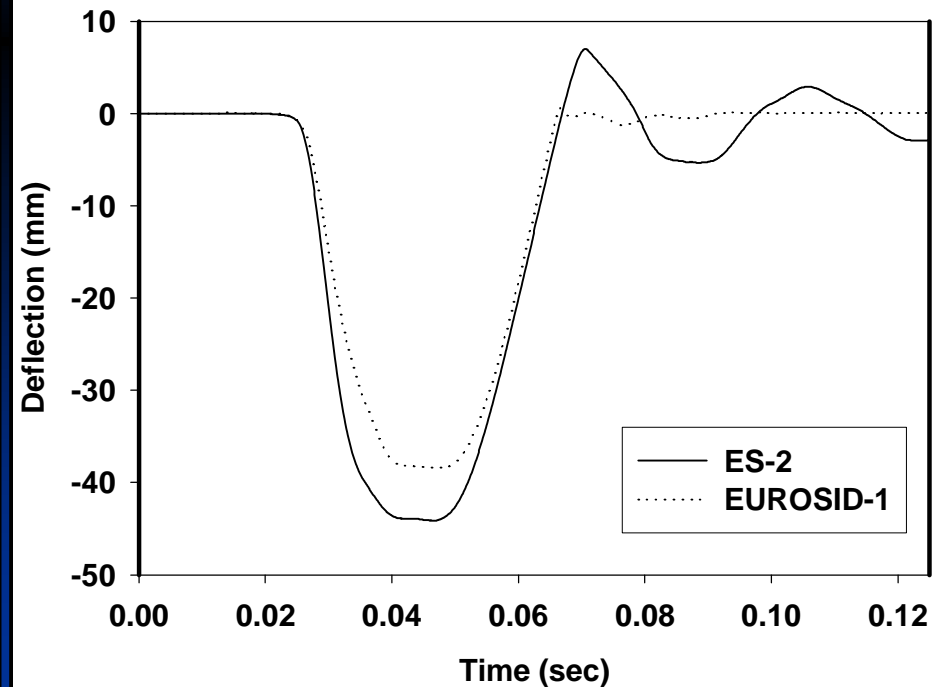
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- Deflection flat tops reduced but still present for ES-2
- Higher deflection for ES-2

EU Taurus ES-2 vs Eurosid-1
Driver Upper Rib Deflection



EU Metro ES-2 vs Eurosid-1
Driver Middle Rib Deflection



Full Scale Test Rib Responses

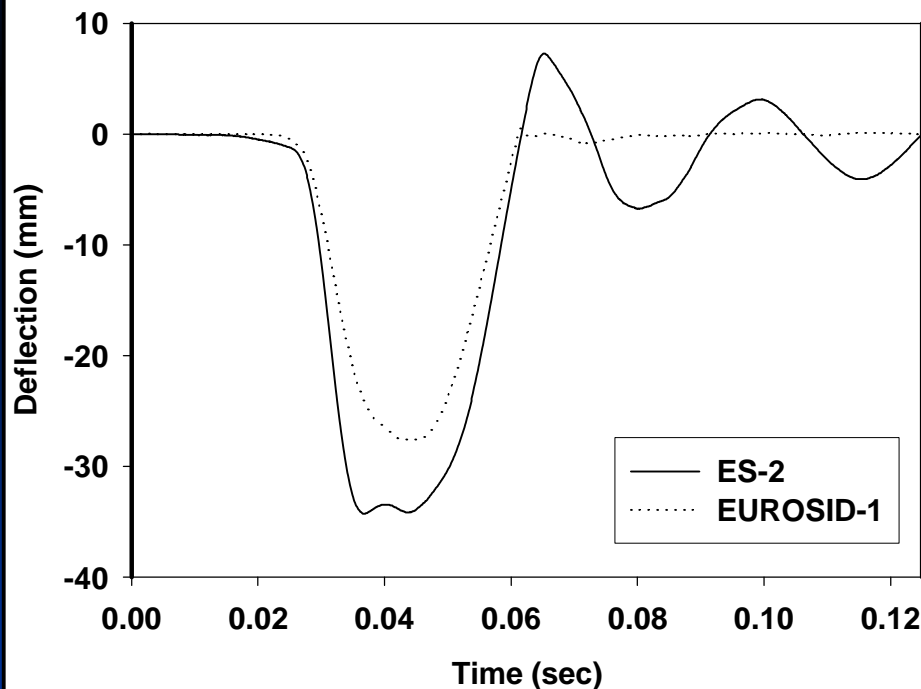
EU Tests: ES-2 Versus Eurosid-1



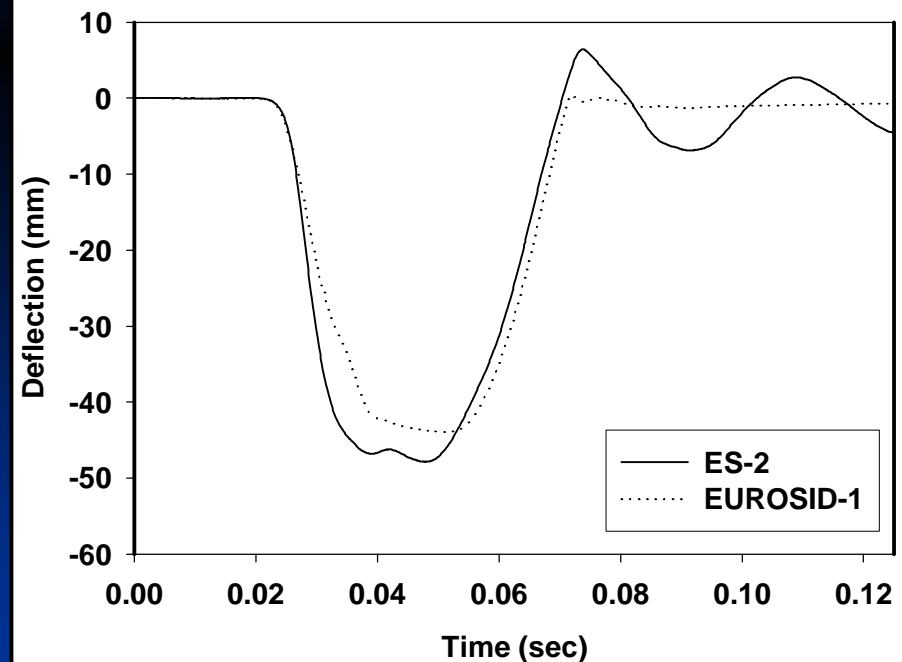
NHTSA Side Impact Research

- **Post-event oscillations in most rib deflections and minor oscillations near main event in a few deflections**

EU Metro ES-2 vs Eurosid-1
Driver Lower Rib Deflection



EU Metro ES-2 vs Eurosid-1
Driver Upper Rib Deflection



Full Scale Test Rib Responses

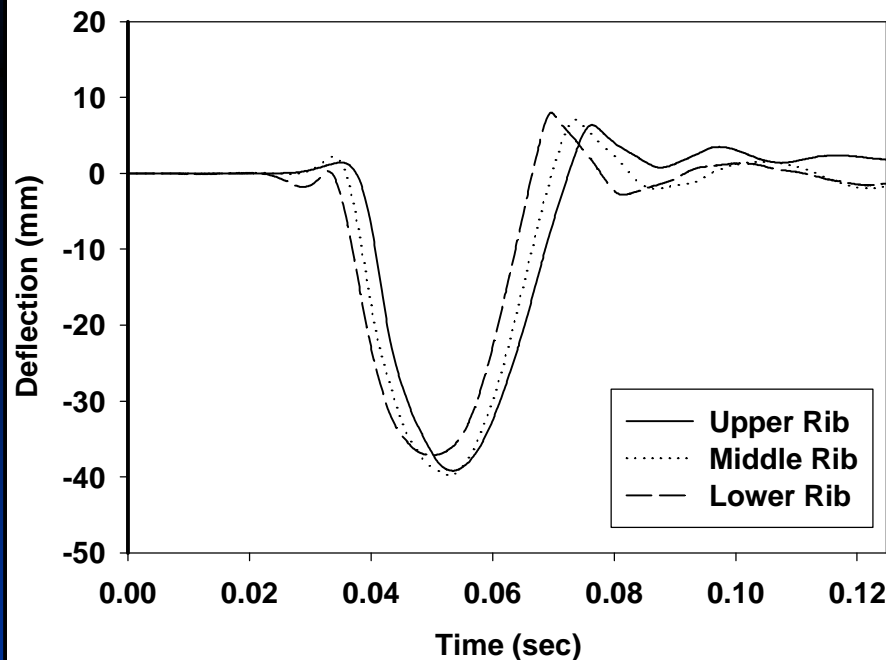
214/Side NCAP Tests: ES-2



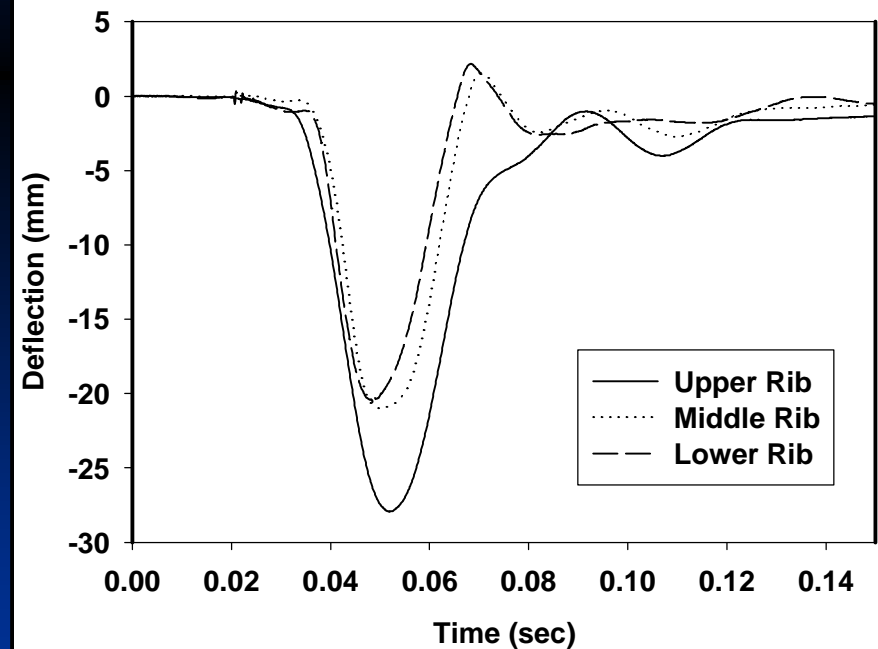
NHTSA Side Impact Research

- With one “exception” deflection flat tops not present

214 Taurus #1 with ES-2
Driver Rib Deflections



Side NCAP Grand Am with ES-2
Passenger Rib Deflections



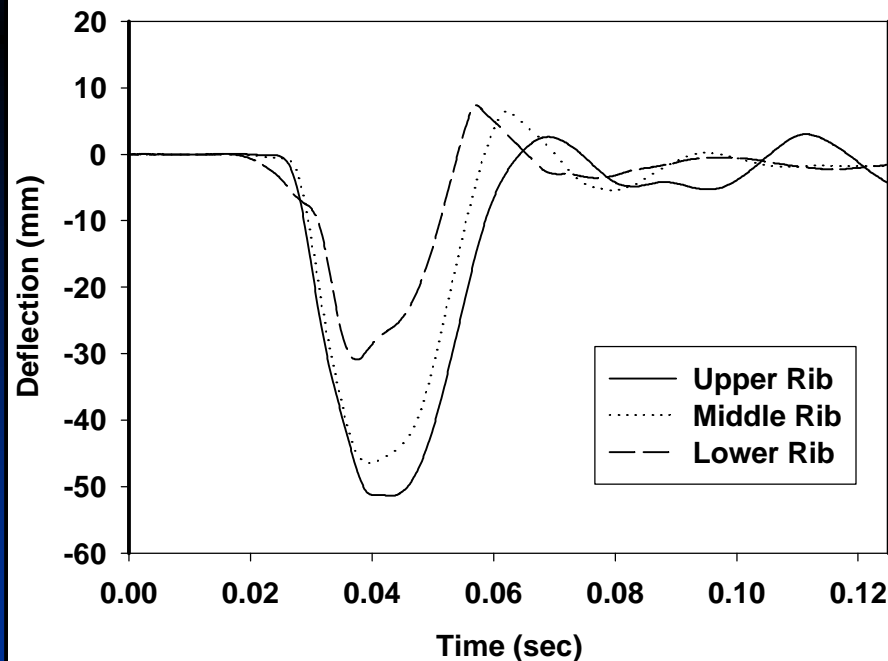
Full Scale Test Rib Responses 214/Side NCAP Tests: ES-2



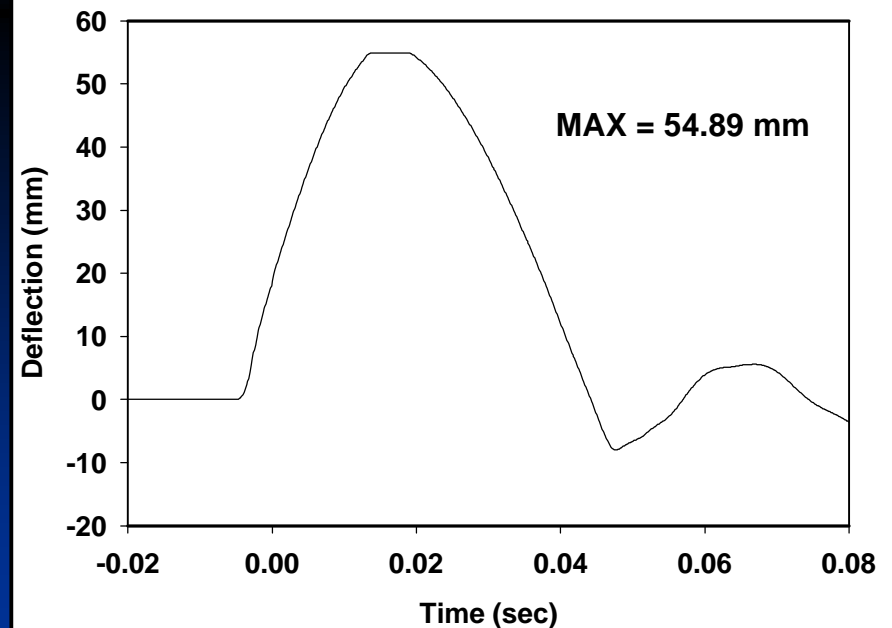
NHTSA Side Impact Research

- One rib deflection (of 24) exhibited flat top behavior ... close to full dynamic range of rib module.

Side NCAP Cavalier with ES-2
Driver Rib Deflections



ES-2 SN#001 Upper Rib Module Drop Test
Impact Speed 4.75 m/s



Presentation Overview

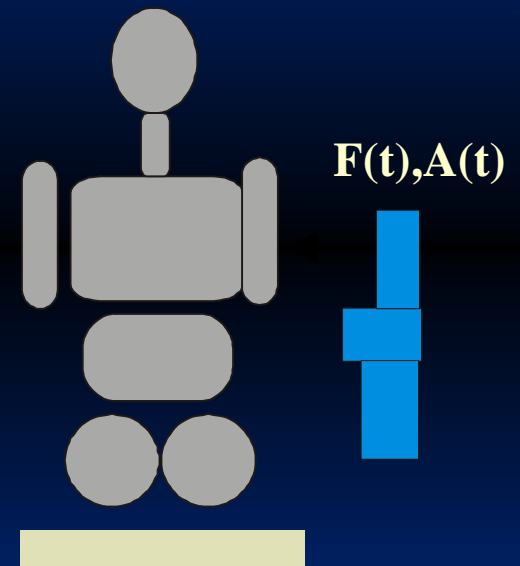


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Biofidelity – What is Important?

- **First and foremost, a dummy should interact with the vehicle environment in a human-like manner.**
 - Human-like force-area-time histories between occupant and vehicle.
- **Secondly, those measures necessary to calculate injury criteria should be similar to the same measures on the human.**

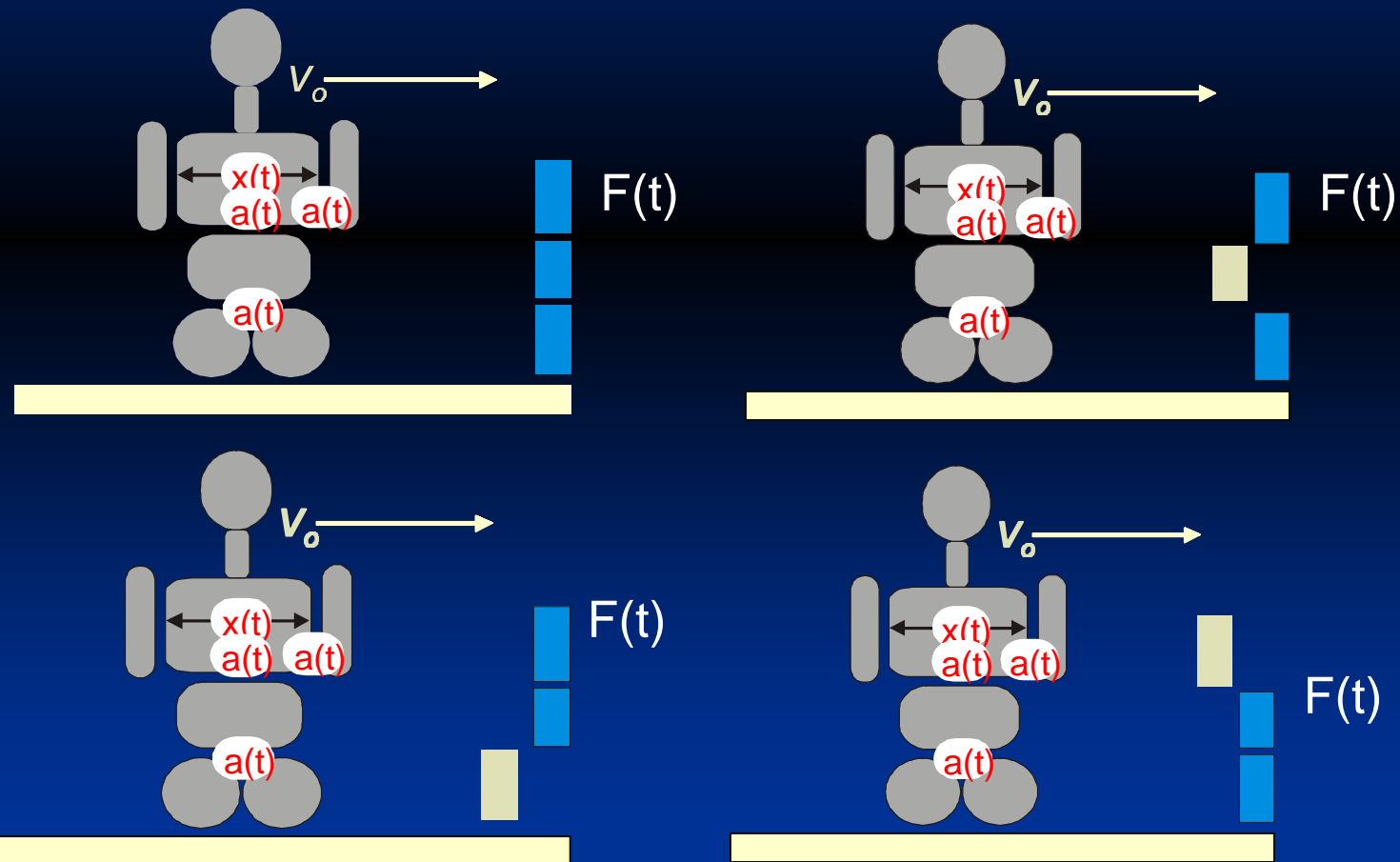


IHRA Side Impact Torso and Pelvis Sled Test Requirements

- **Shoulder to Pelvis evaluation**
- **Based upon 45 NHTSA sponsored cadaver tests**
- **Two door speeds - 6.7 and 8.9 m/s (15 and 20 mph)**
- **Two door stiffnesses - Padded and rigid**
- **Four door surface geometries**

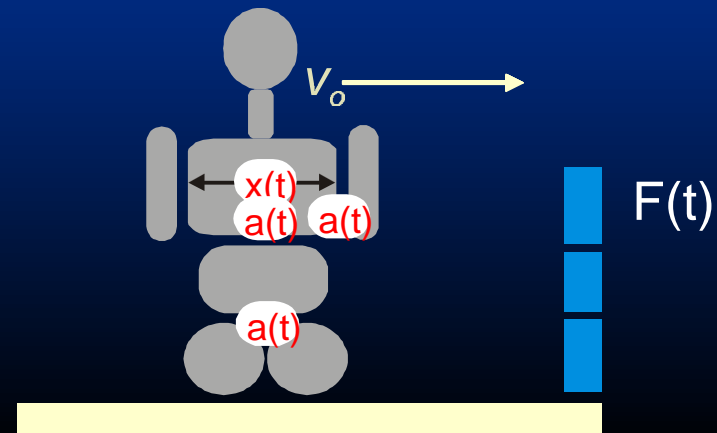


IHRA Side Impact Sled Test Load Wall Geometry

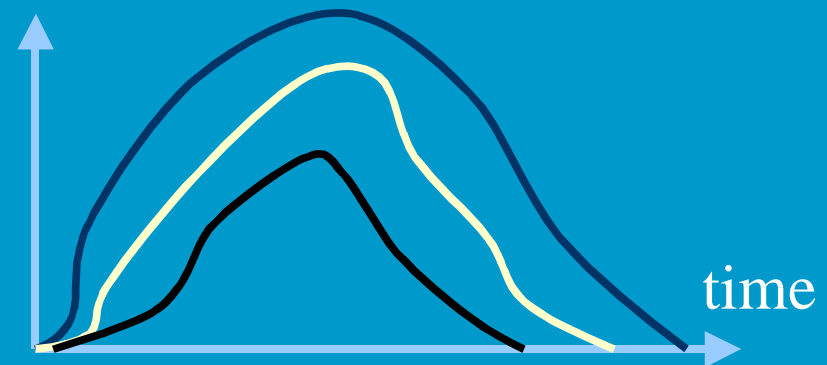


IHRA Side Impact Sled Requirements

- **Door Forces at the thorax, abdomen, pelvis and legs**
- **Deflection of the upper and lower thorax, and mid abdomen.**
- **Acceleration – spine, pelvis and ribs**



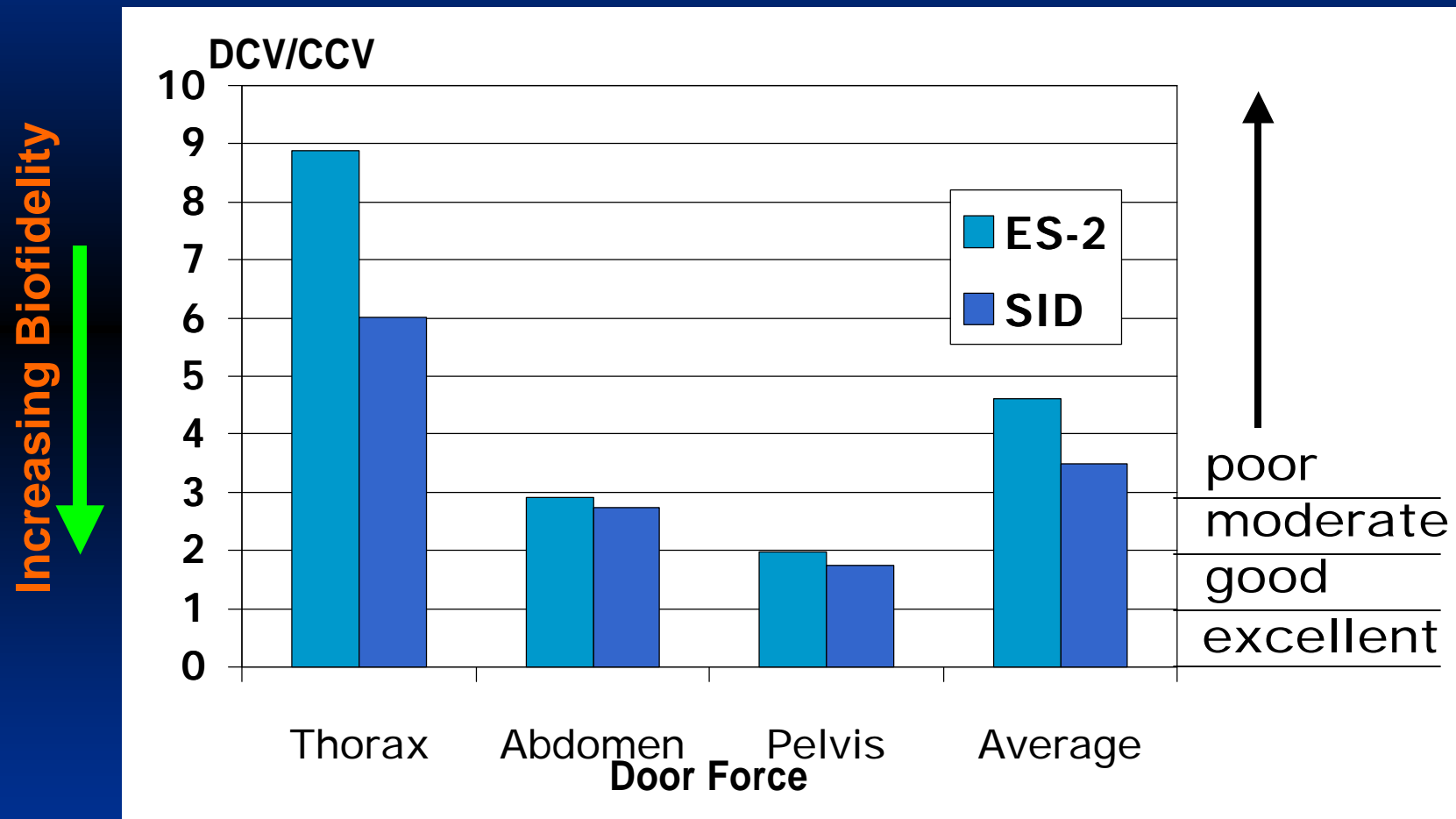
Force, Acceleration or
Deflection Corridor and Mean



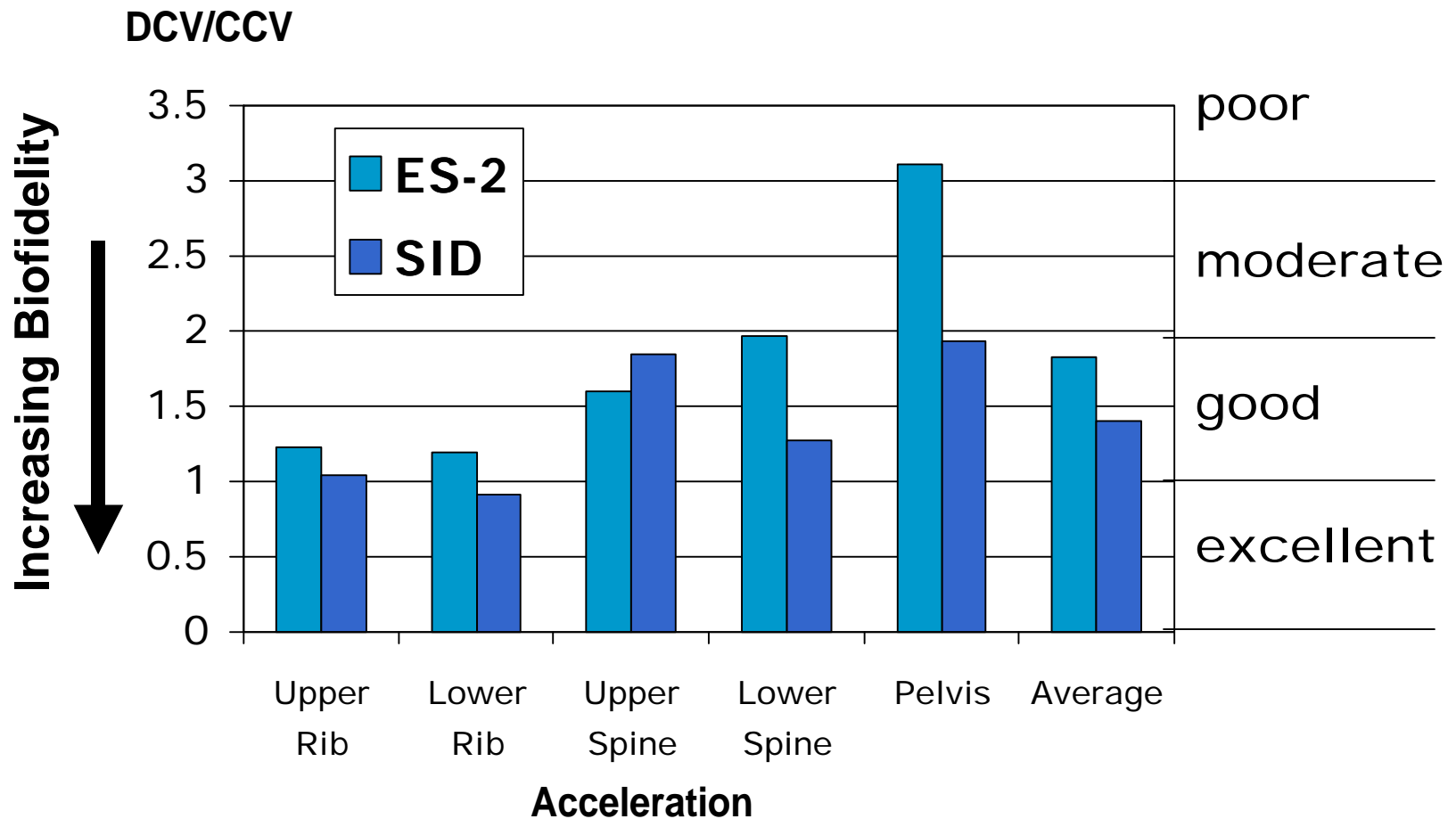
Rating Dummy Biofidelity - DCV/CCV Ratio

$0 \leq \text{DCV/CCV} < 1$	Excellent - Dummy is less variant than the cadaver sample.
$\text{DCV/CCV} = 1$	Excellent - Dummy is as variant as the cadaver sample.
$1 < \text{DCV/CCV} \leq 2$	Good - Dummy is between one and two times as variant as the cadaver sample.
$2 < \text{DCV/CCV} \leq 3$	Moderate - Dummy is between two and three times as variant as the cadaver sample.
$N < \text{DCV/CCV} \leq N+1$	Poor - Dummy is between n and n+1 times as variant as the cadaver sample.

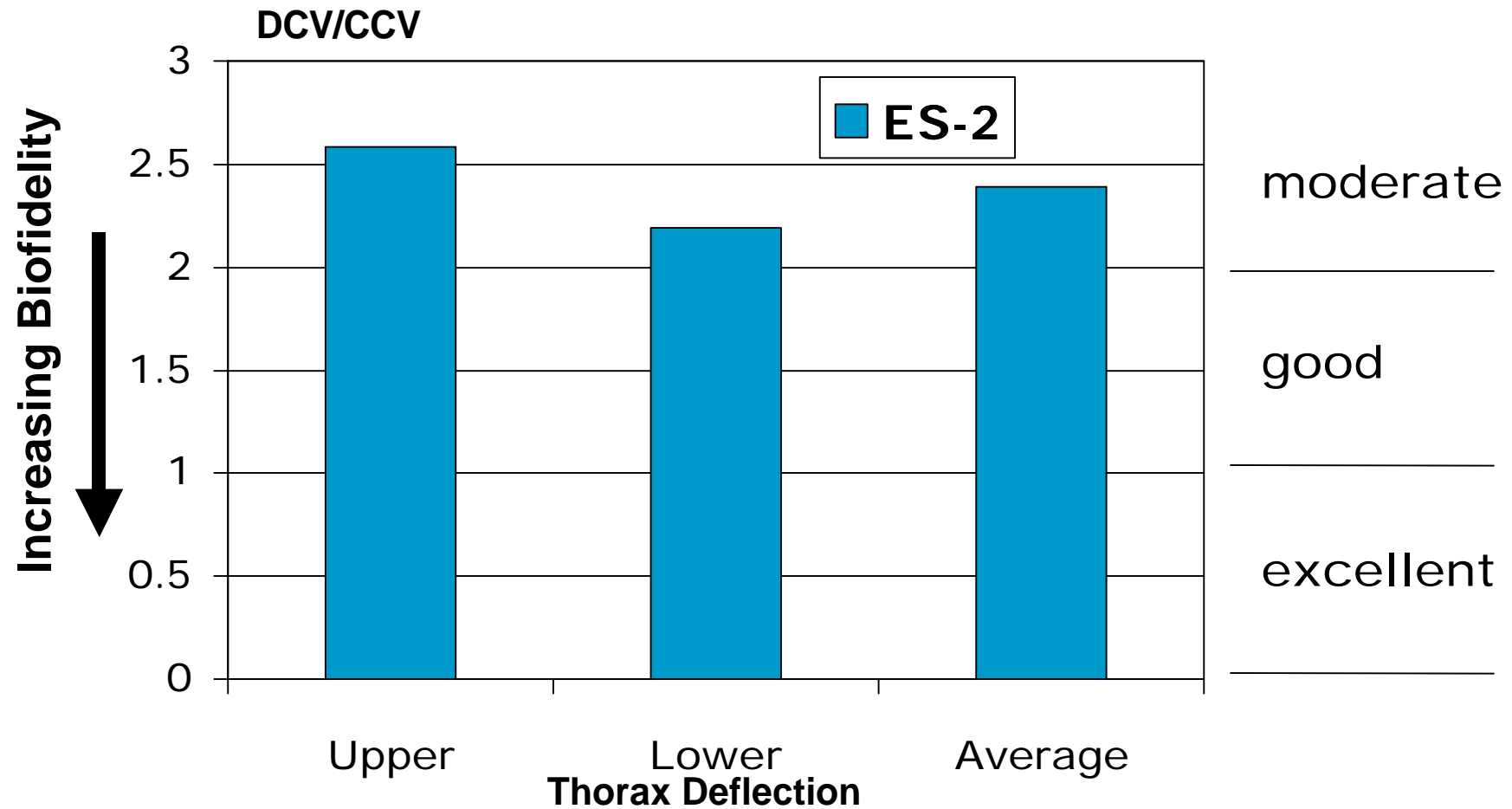
Results - Door Force DCV/CCV Ratio



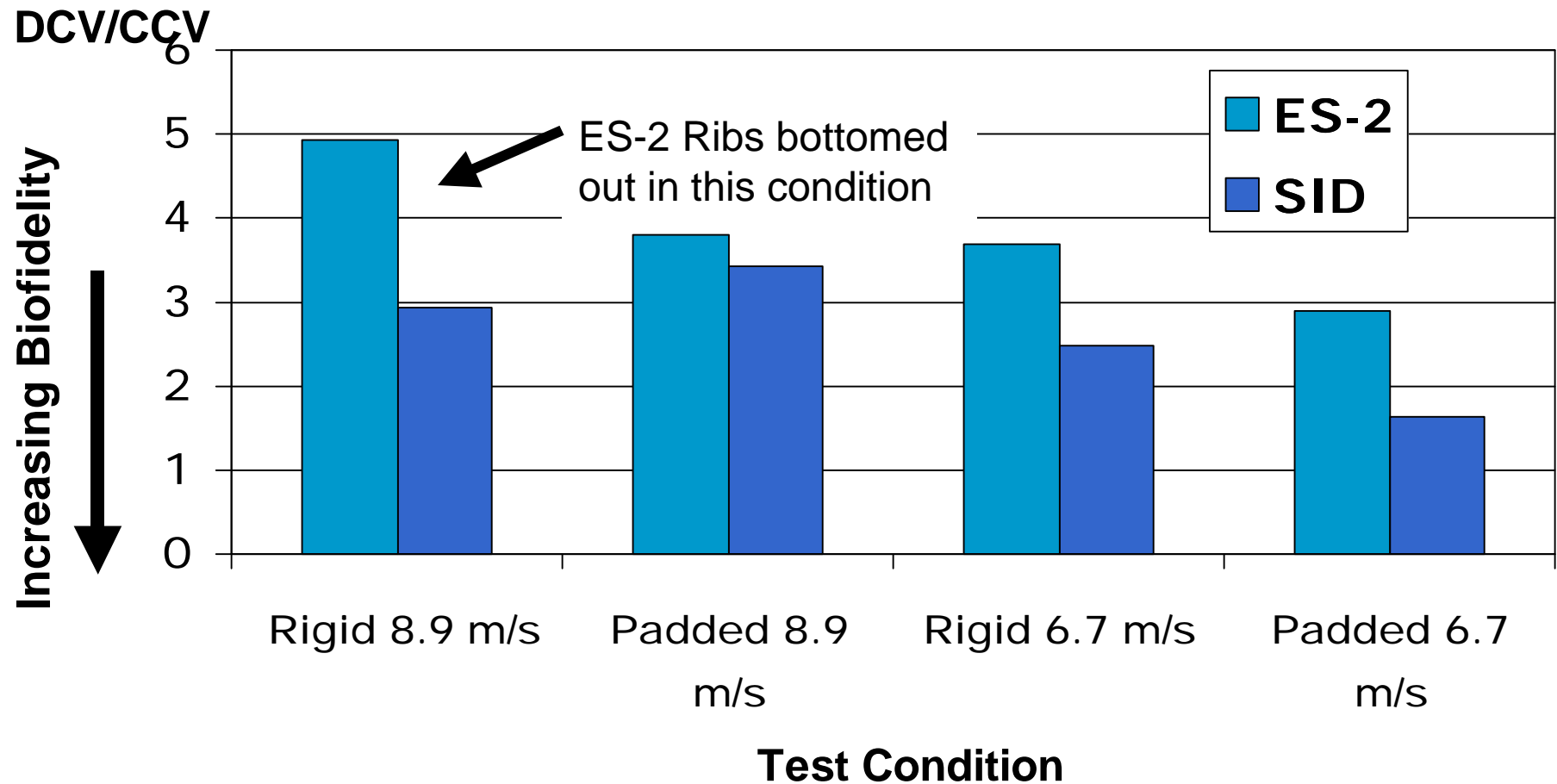
DCV/CCV Ratio – Acceleration



DCV/CCV Ratio – Deflection



DCV/CCV Ratio vs. Test Condition



Previous work - ISO Biofidelity Ratings

Note: Larger numbers indicate better biofidelity.

	Eurosid-1	SID
Head	3.33	0.0
Neck	3.70	2.55
Shoulder	3.90	0.0
Thorax	4.78	5.02
Abdomen	3.23	4.38
Pelvis	1.76	2.76
Overall	3.22	2.78

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Comparison of ES-2 and SID/H3 Instrumentation

	Measurement	ES-2	SID/HIII
Head	9 accel Array	U	U
Neck	Upper Loads	U	U
	Lower Loads	U	U
Shoulder	Load/Rotation	U	

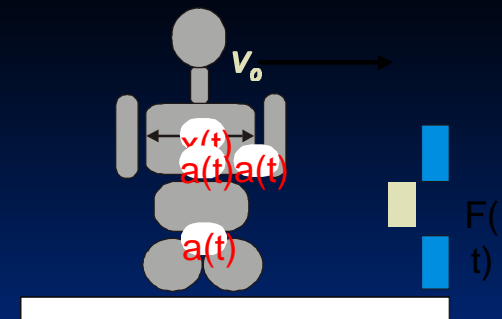
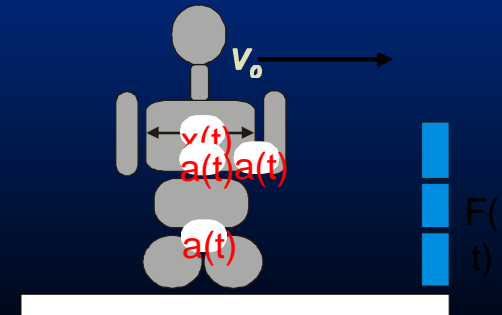
Comparison of ES-2 and SID/H3 Instrumentation

	Measurement	ES-2	SID/HIII
Thorax	Deflection	U	U
	Acceleration	U	U
Abdomen	Force	U	
Pelvis	Acceleration	U	U
	Force	U	

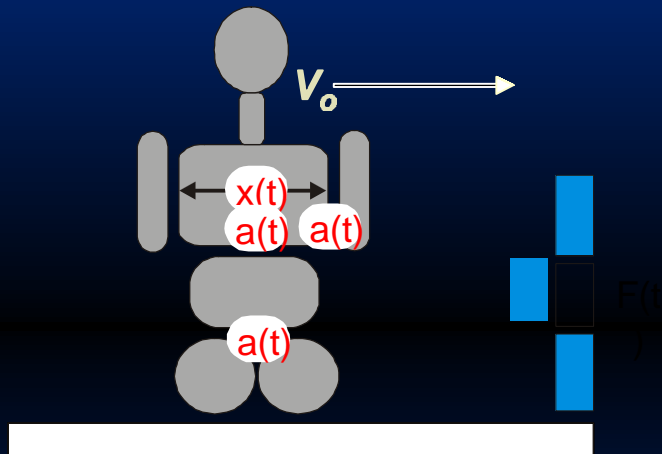


ES-2 Torso Injury Assessment Capability Compared to SID

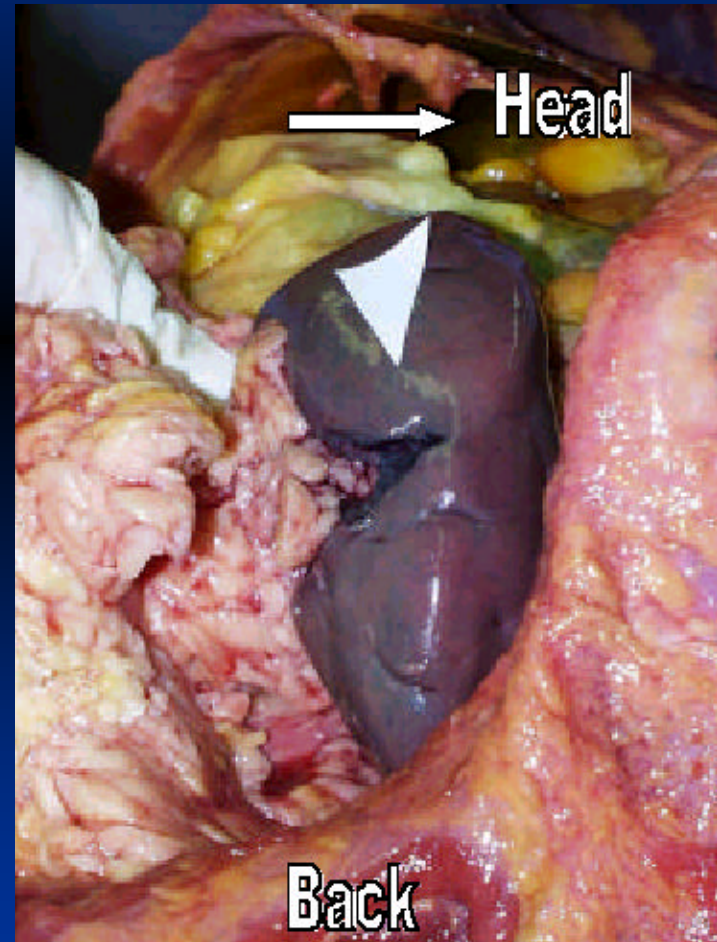
- Compare SID and ES-2 instrumentation output in flat wall and abdominal offset conditions
- Correlate instrumentation output with injuries in similar cadaver tests



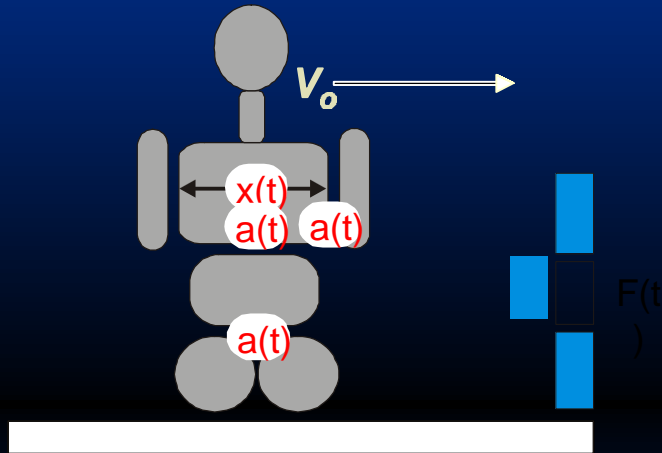
ES-2 Torso Injury Assessment Capability Compared to SID



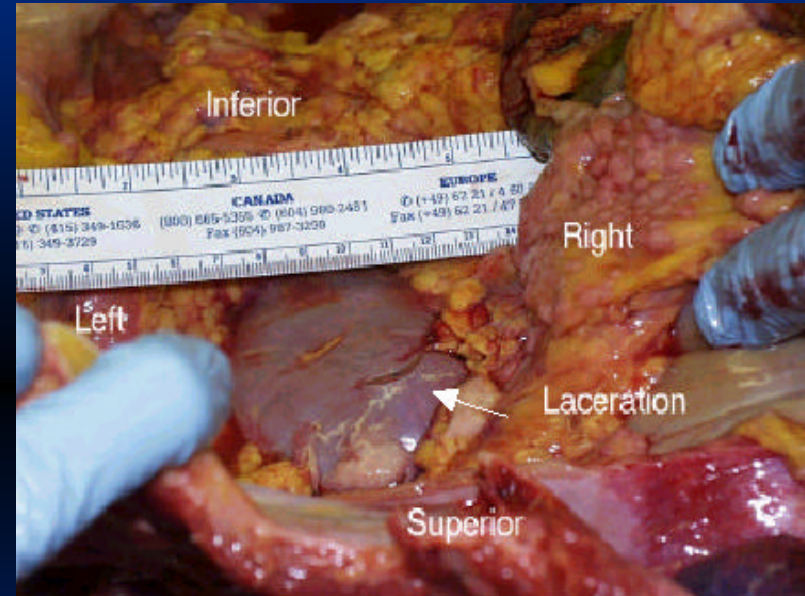
- Cadaver Test B4218
 - AIS 4 Kidney Laceration
 - 5 fractured Ribs



ES-2 Torso Injury Assessment Capability Compared to SID



- Cadaver Test B4268
 - AIS 3 Kidney Laceration
 - 7 fractured Ribs



ES-2 Torso Injury Assessment Capability Compared to SID

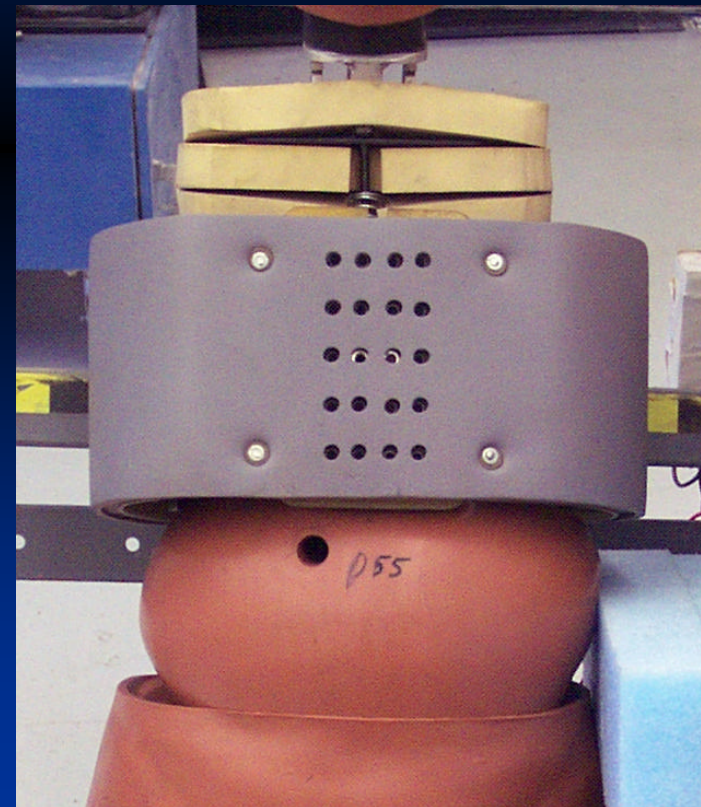
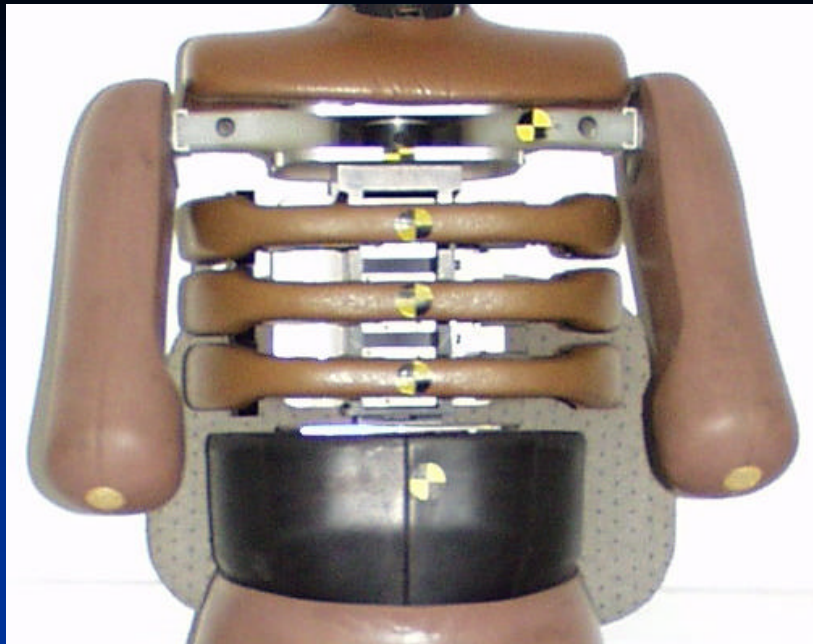
		Flat Wall	Abdominal Offset
SID	TTI (85 g)	71 g	52 g
	Pelvis Acceleration (120 g)	67 g	53 g
ES-2	Chest Deflection (42 mm)	52 mm	31 mm
	Abdominal Force (2500 N)	1402 N	8585 N

Cadaver Autopsy Results

Fractured Ribs	7	6
Soft Tissue	None	Kidney Laceration

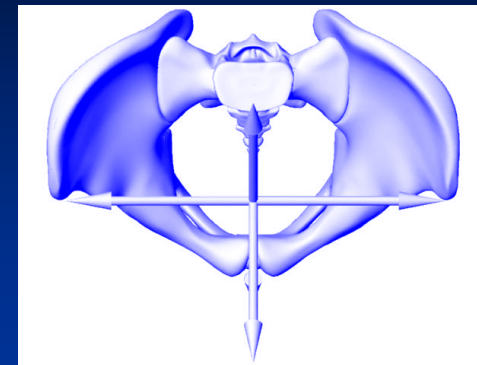
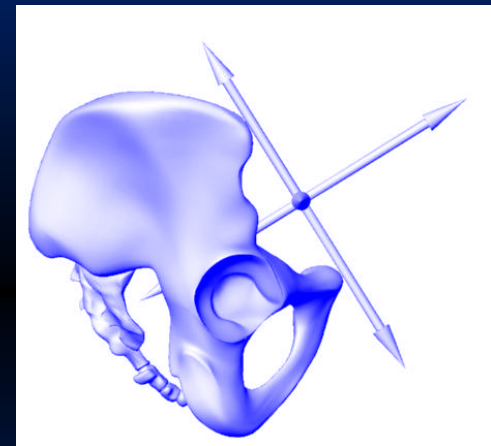
ES-2 Torso Injury Assessment Capability Compared to SID

- **Conclusion - ES-2 abdominal load measurement capability detects injuries the SID misses.**



ES-2 Pelvis

- **ES-2 measures Pelvis Acceleration and Pubic Symphysis Load (PSL), while SID only measures acceleration**
- **PSL may be a better measure of the load which is directed into the hip joint, and thus may be a better predictor of serious pelvic injury.**



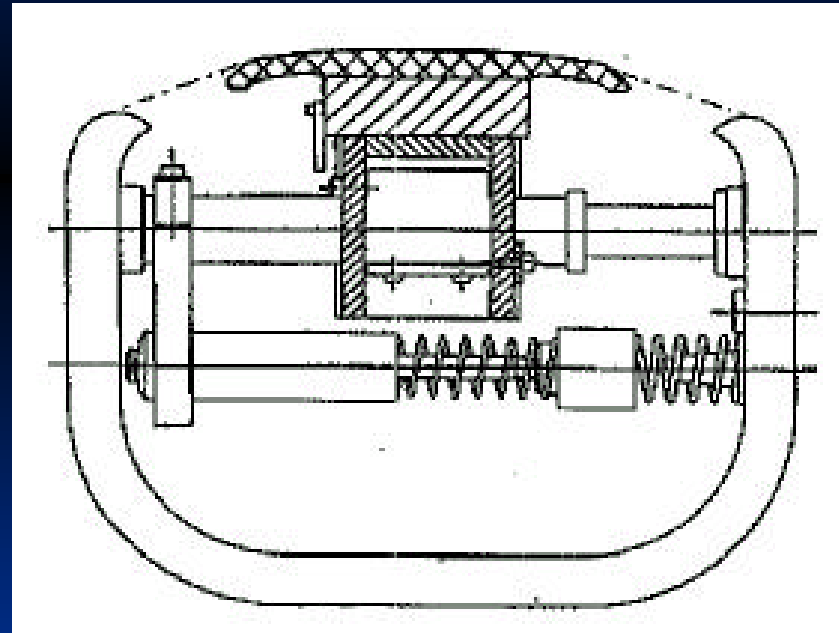
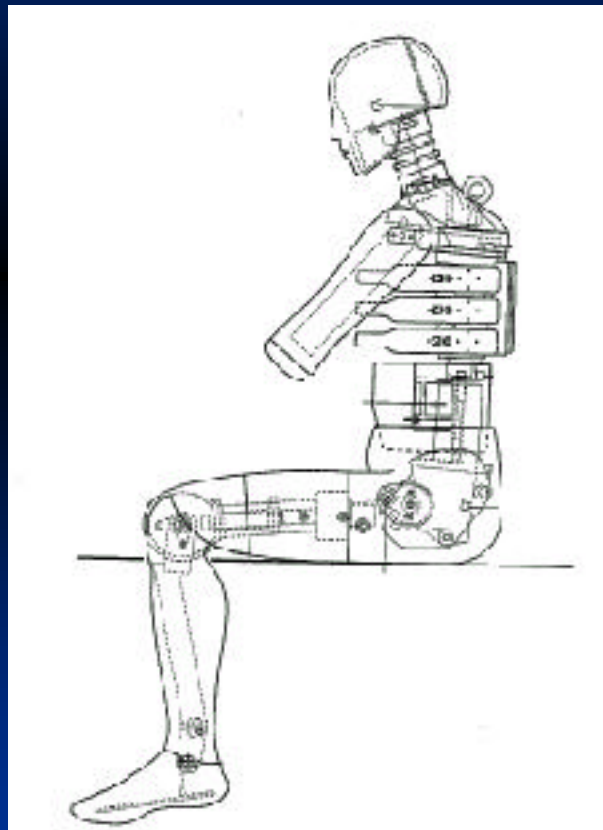
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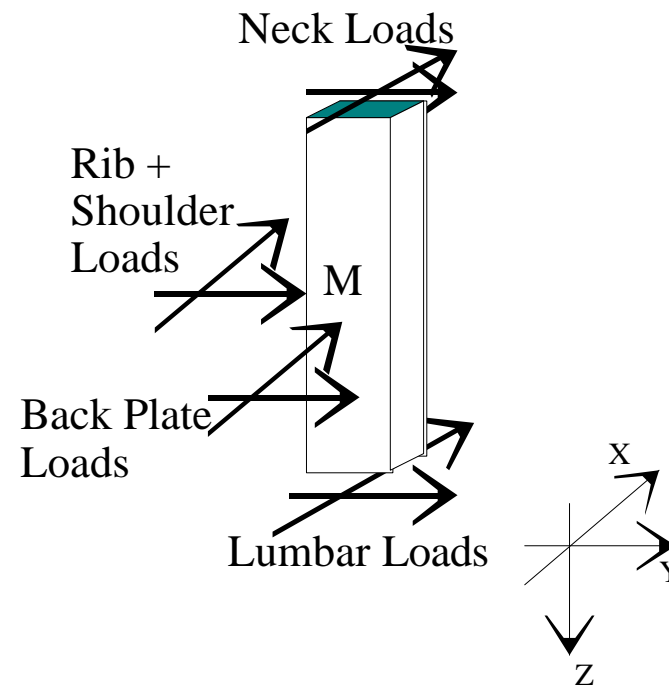
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ES-2 Back-plate

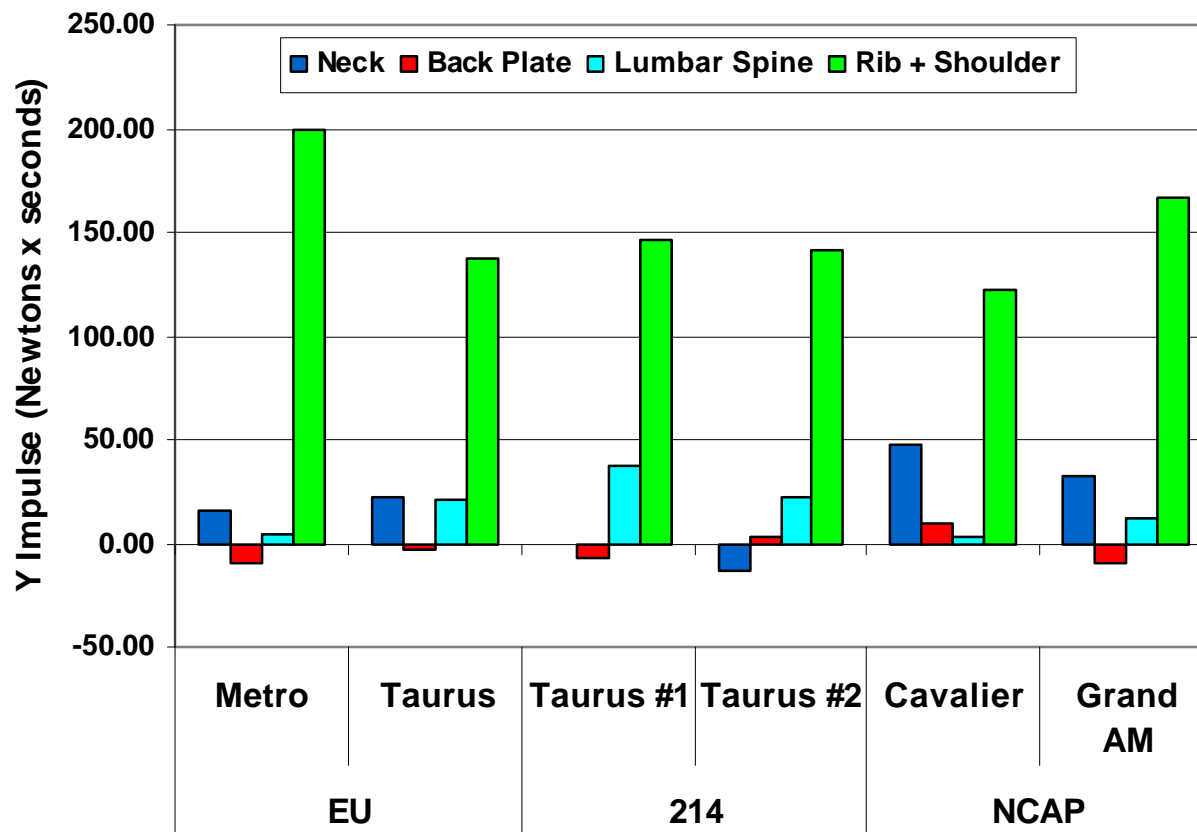


ES-2 Back-plate

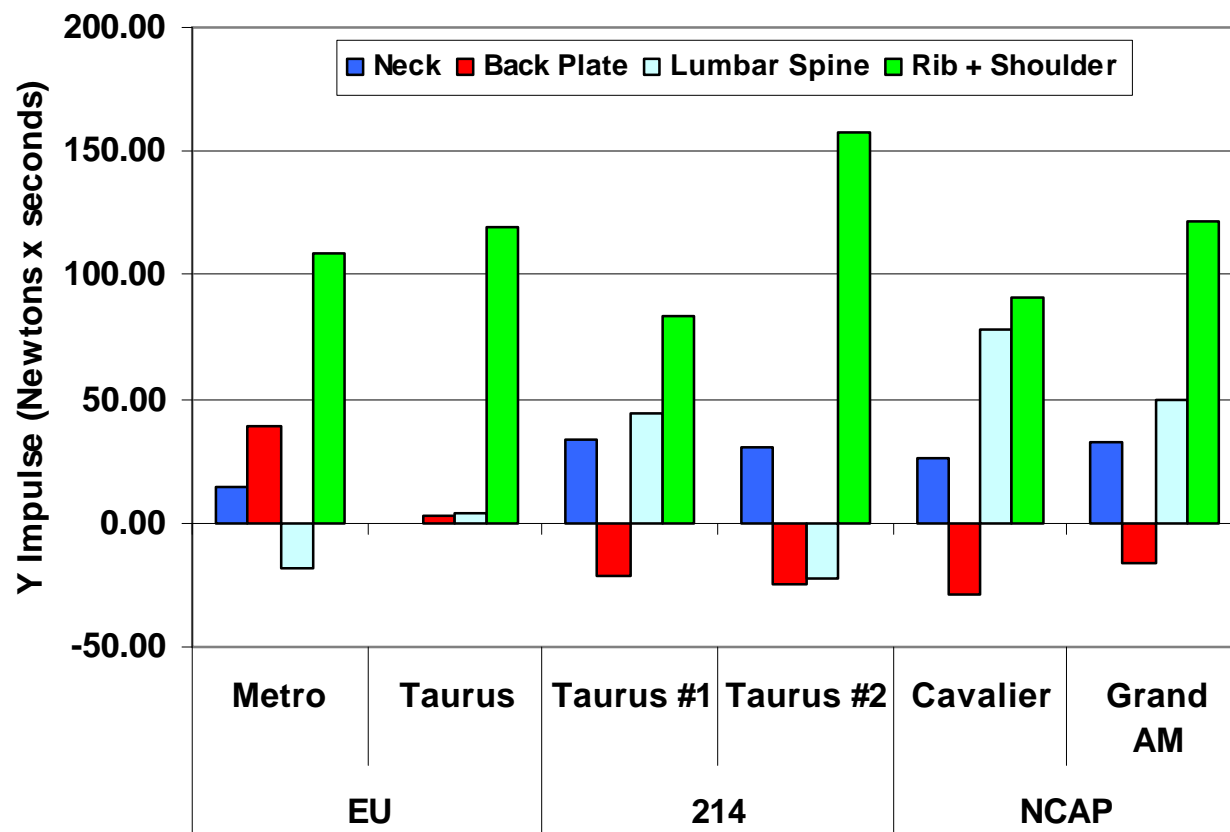
■ **Force Balance on ES-2 Spine**



Full-Scale Vehicle Test – Driver Impulse Analysis



Full-Scale Vehicle Test – Passenger Impulse Analysis



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Conclusions



NHTSA Side Impact Research

- The ES-2 thorax is less biofidelic than the SID while the ES-2 abdomen and pelvis biofidelity are roughly equivalent.
- ES-2 detects abdominal injuries that the SID misses.
- ES-2 has the potential to better detect serious pelvic injuries.
- More research is necessary to understand the biofidelity of the head/neck complex.
- ES-2 modifications appear to have addressed rib binding which is one mechanism of rib deflection flat top.
- Loads from the seat back through the ES-2 back plate transfer little momentum to the spine of the dummy.

Additional ES-2 Research



NHTSA Side Impact Research

- **Additional component/sled tests to provide a assessment of head/neck/shoulder biofidelity and kinematics (summer 01)**
- **Additional component test to ensure that the ES-2 ribs are not binding and that the dummy is repeatable (summer 01)**
- **Component tests to assess back plate interaction with the seat back (summer 01)**
- **Application of injury criteria for the ES-2 dummy (summer 01)**

NHTSA Side Impact Research

Thank you!