

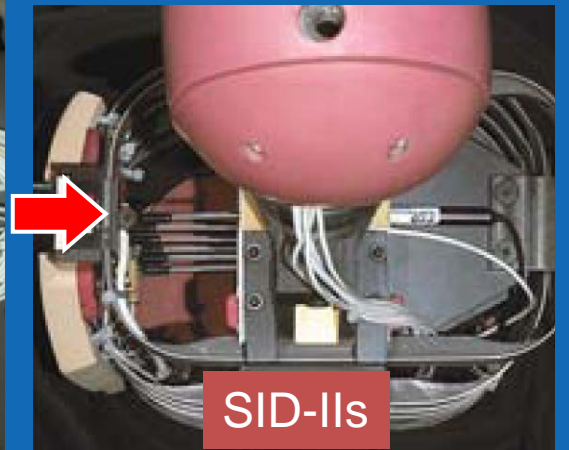
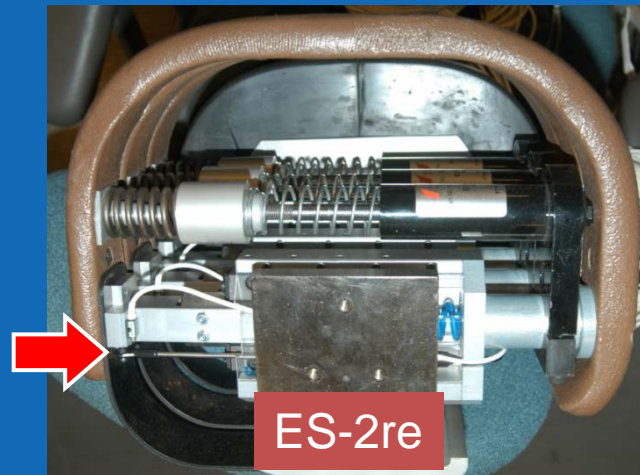
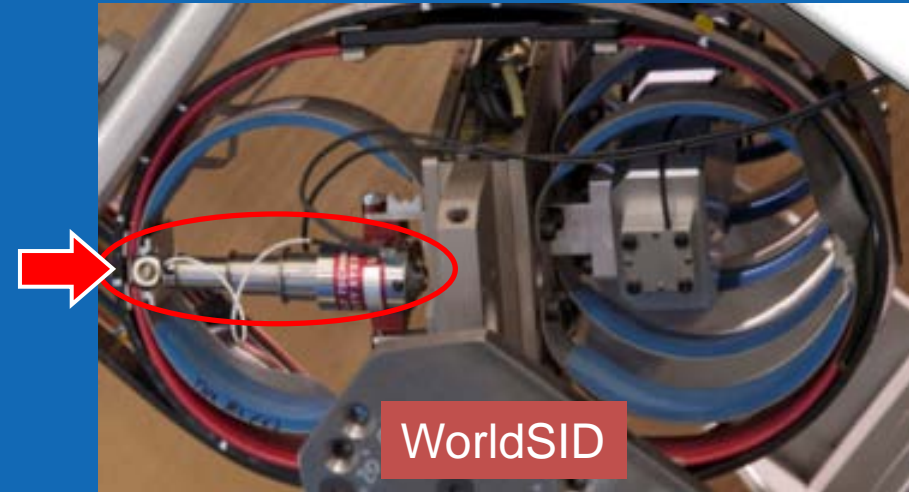
Evaluation of the RibEye™ Multipoint Deflection Measurement System installed in the WorldSID-50M Dummy

Heather Rhule
NHTSA

Jim Stricklin, Will Millis,
Brian Suntay, Ann Mallory
Transportation Research Center Inc.

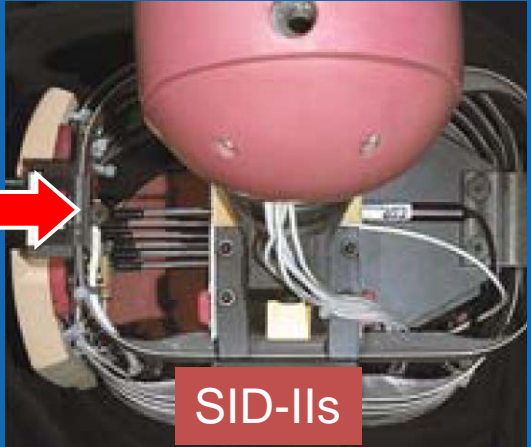
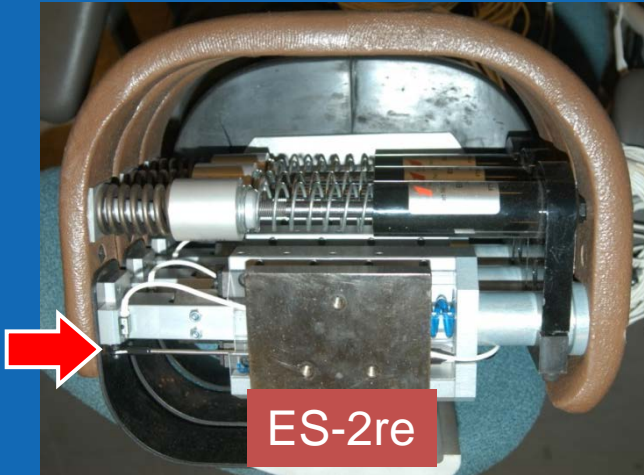
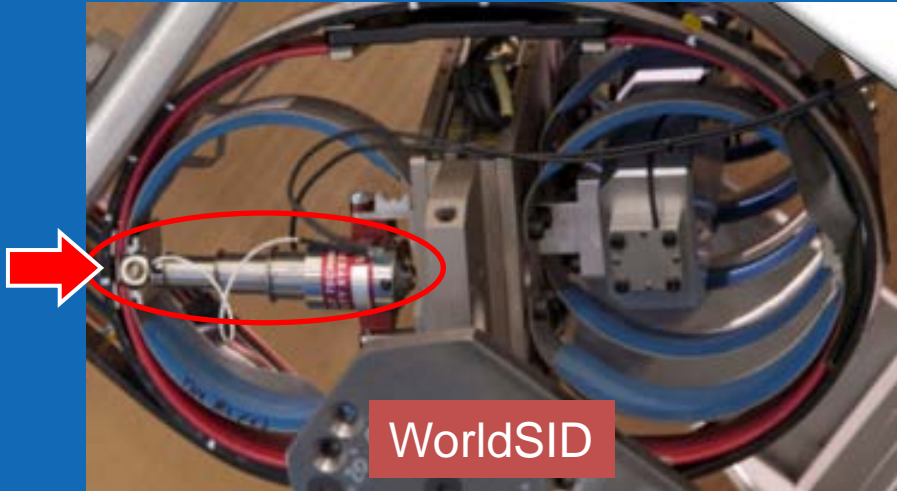
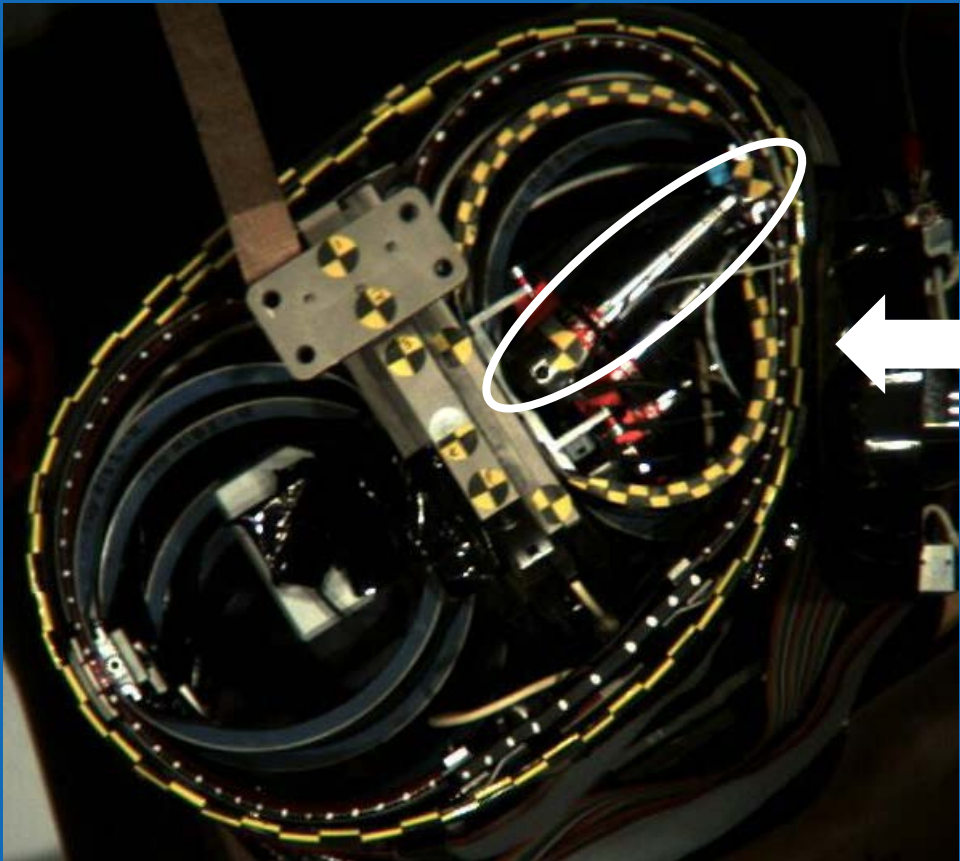
Motivation

- Measure deflection of a single point
- IRTRACCs
 - WorldSID-50M
 - WorldSID-5F
- Linear potentiometers
 - ES-2re
 - SID-1Is



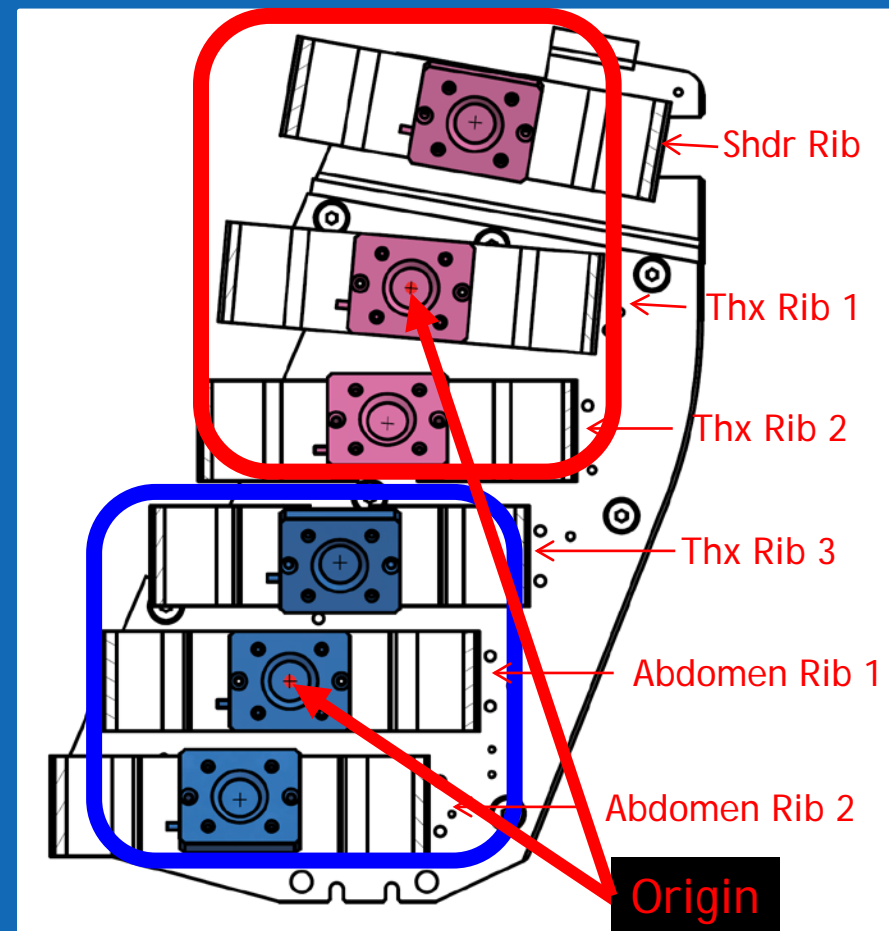
Motivation

- Measure deflection of a single point



RibEye™ Multipoint Optical Measurement System

- WorldSID-50M
 - x, y, z positions of 18 points
 - 2 sets of 3 sensors & 9 LEDs
 - Top set ~ red filters & LEDs
 - Bottom set ~ blue filters & LEDs
 - Origin is at center of lens of middle sensor
 - 9 LEDs can be anywhere
 - All 3 sensors must sense light from an LED to measure its position

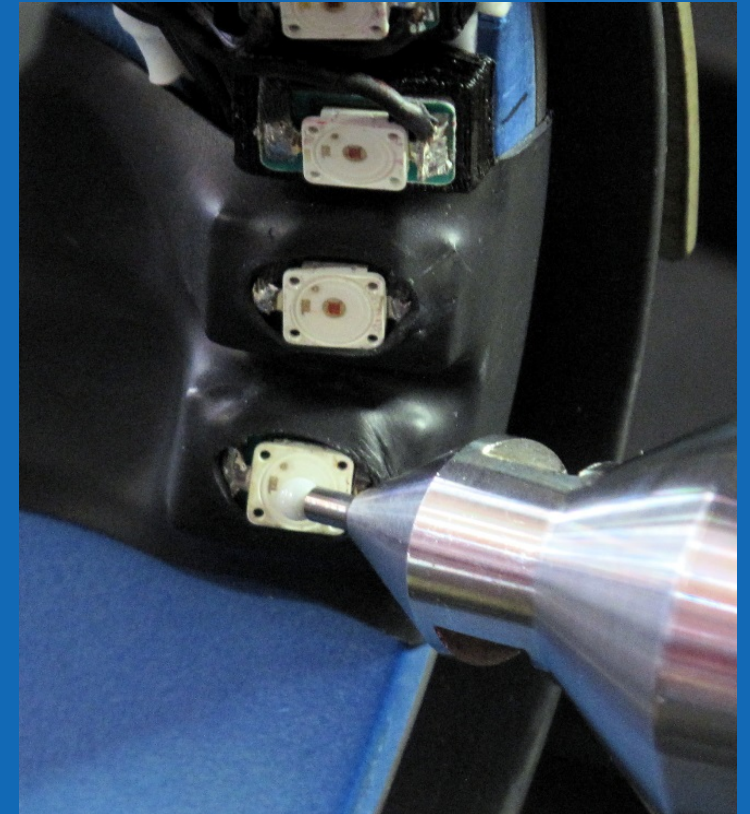
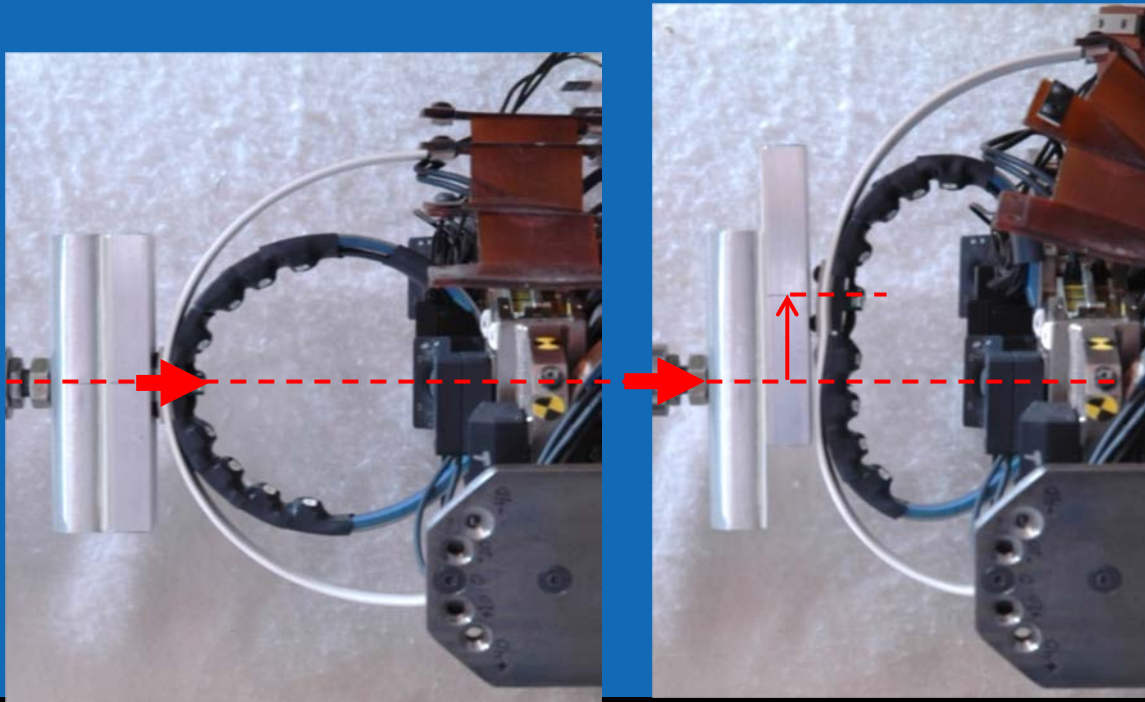


Objectives

1. Assess the accuracy of RibEye™ measurement
2. Assess ability of RibEye™ to capture max deflection
3. Determine optimal anterior and posterior LED locations
4. Evaluate RibEye™ in crash tests

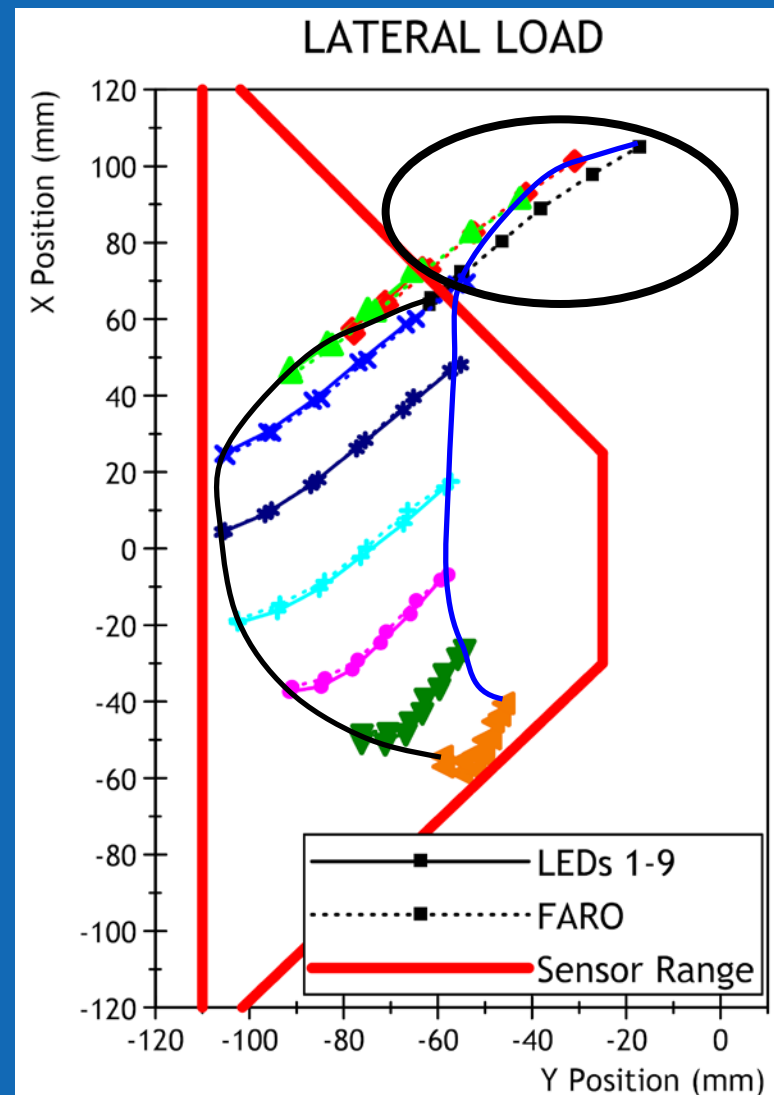
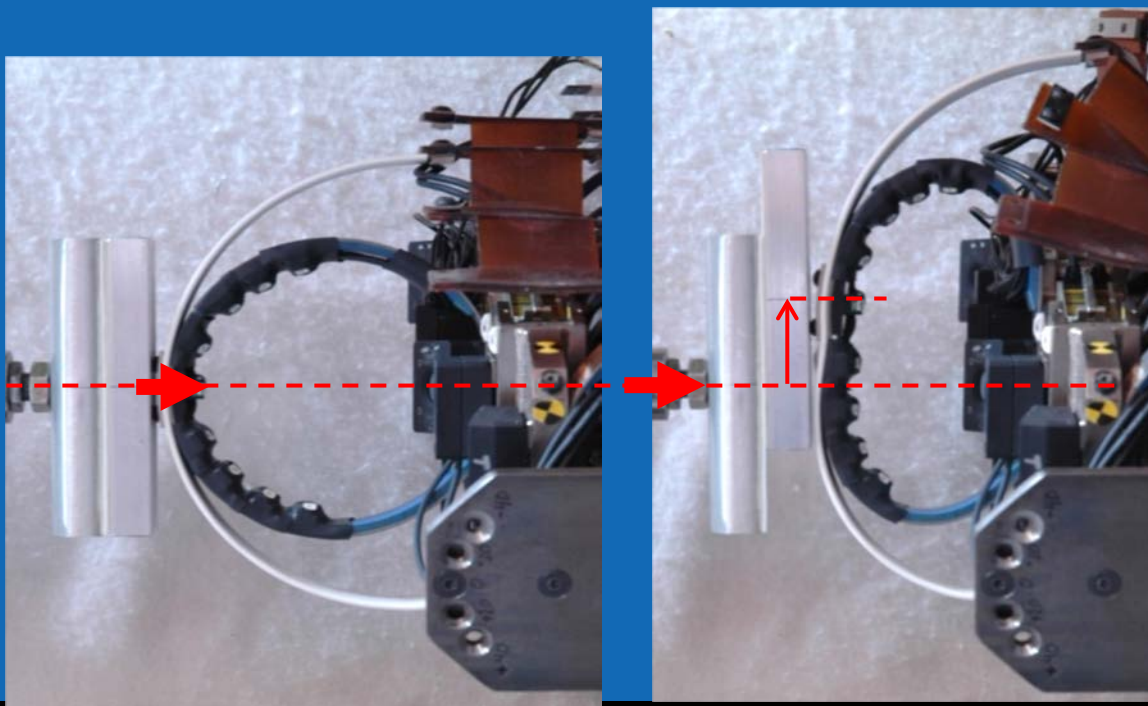
Is RibEye™ Accurate?

- Quasi-static tests w/9 LEDs on each rib
- Single ribs loaded at 0° , $\pm 10^\circ$, $\pm 20^\circ$, $\pm 30^\circ$, $+40^\circ$
- Loaded in 10 mm increments to 30, 40 or 50 mm
- LED positions measured with FARO and RibEye™



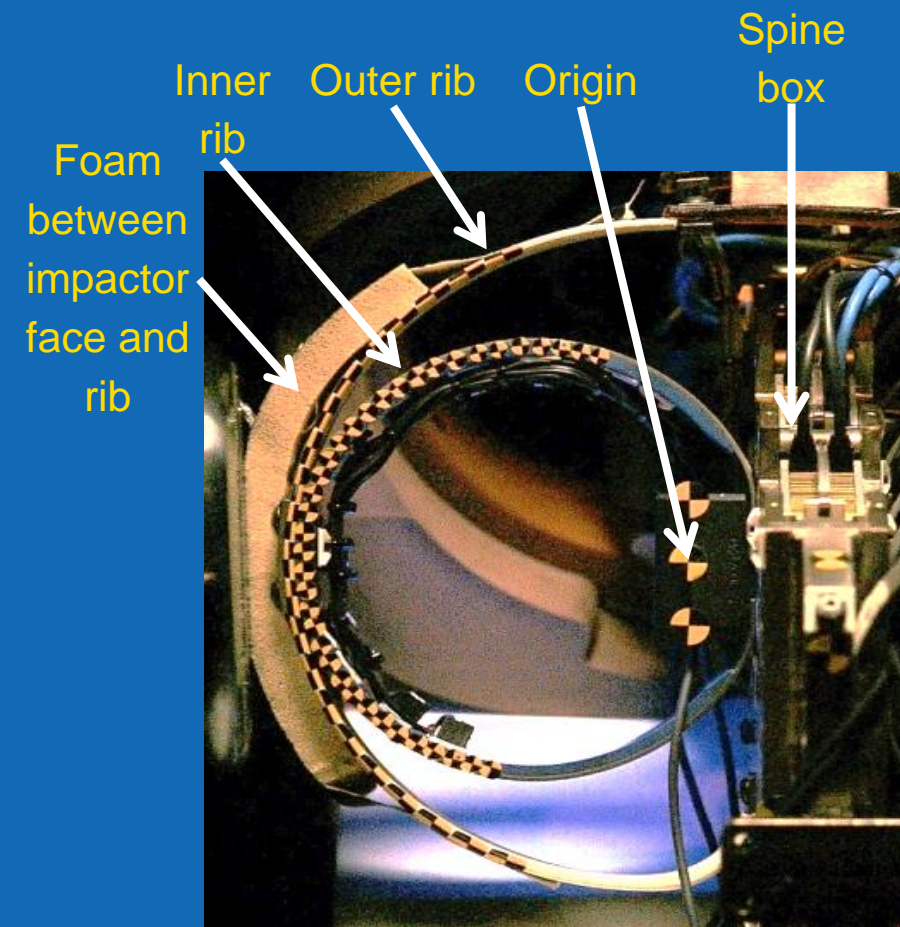
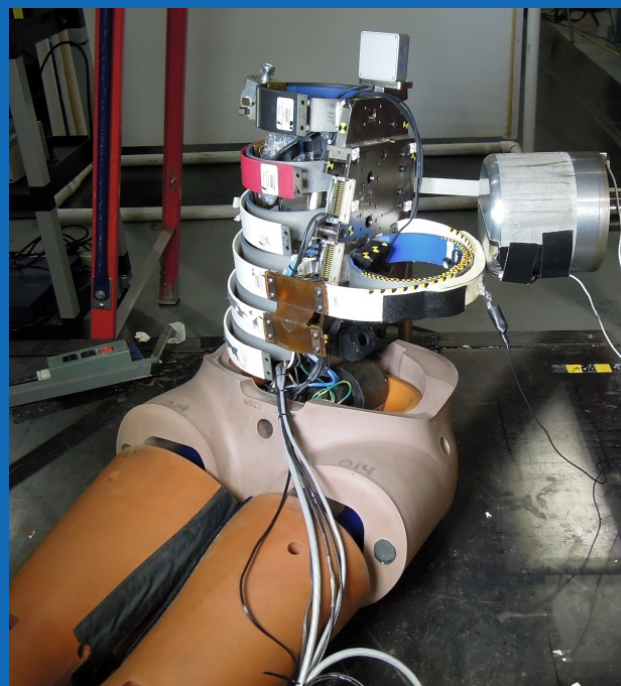
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Can RibEye™ Capture Max Deflection?

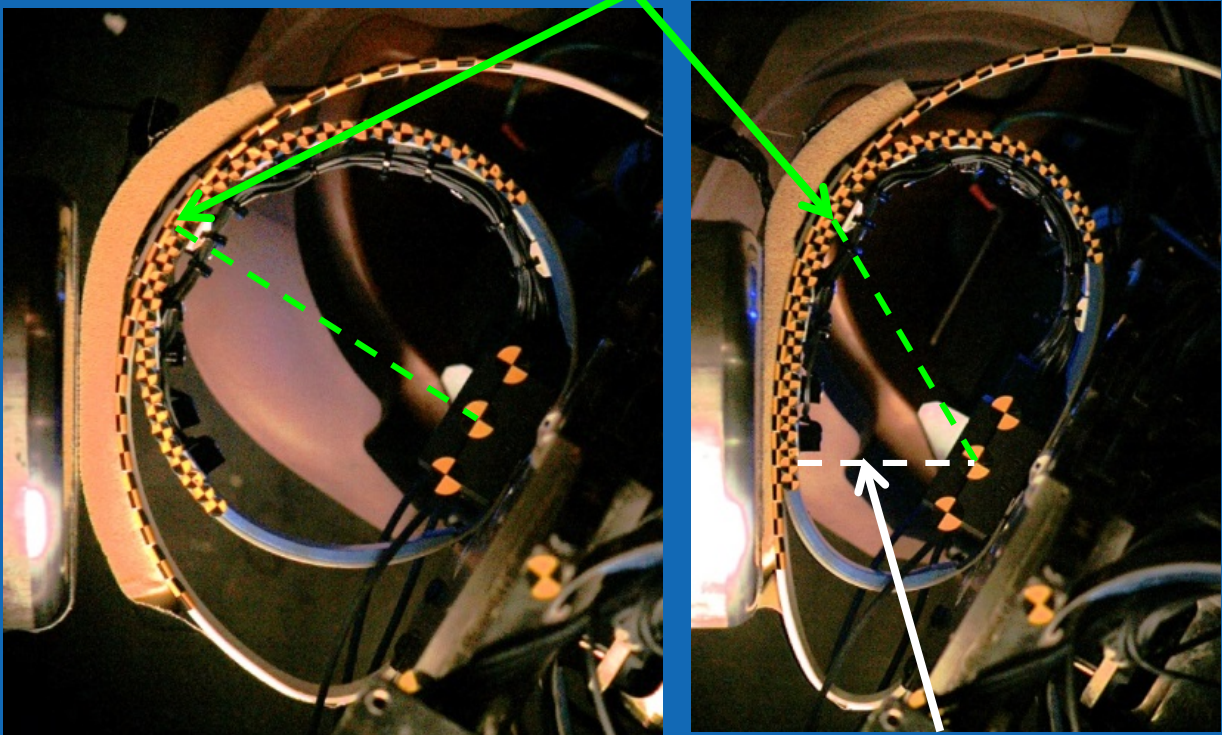
- Single rib dynamic impacts
- Thorax ribs 1-3 tested, each with 9 LEDs
- Impact speeds 2.0-4.3 m/s
- Impact angles 0° , $\pm 10^\circ$, $\pm 20^\circ$, $\pm 30^\circ$
- Impactor mass 23 kg
- Impactor face 152 mm dia.
- HS video - track targets



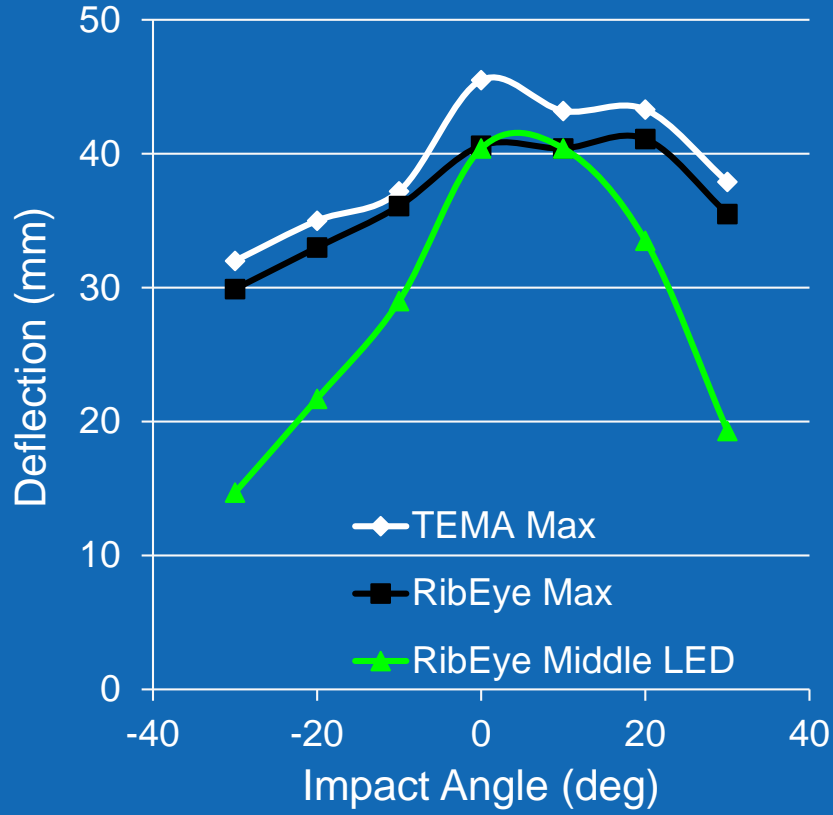
Can RibEye™ Capture Max Deflection?

30° posterior impact

Lateral-most point of rib
(location of single-point deflection measurement systems)

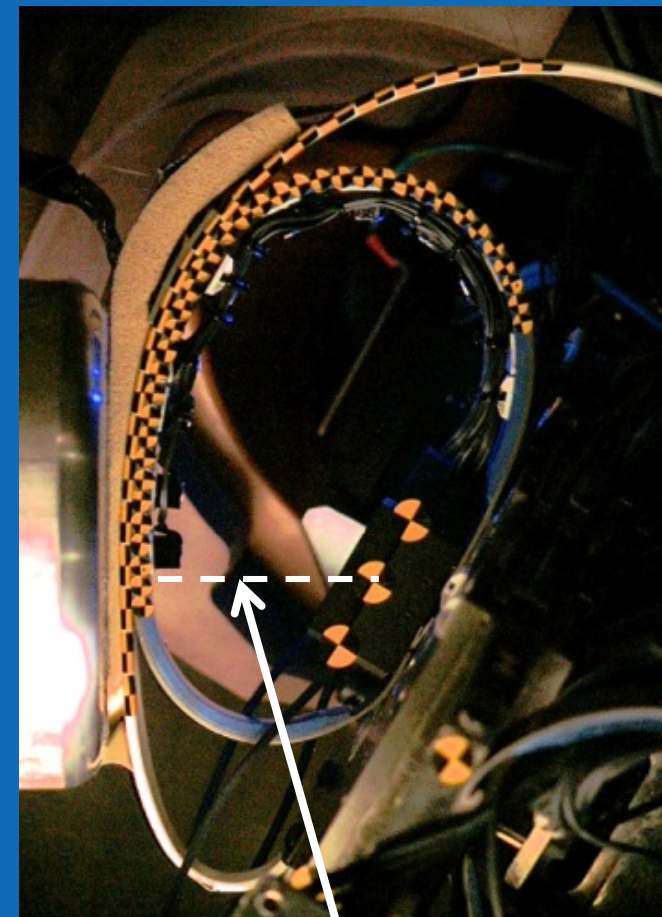


Max deflection



Where Are Optimal LED Locations?

- 3 LEDs per rib
- 1 LED at lateral-most rib location
- What locations are optimal for anterior & posterior LEDs?
 - Trio of LEDs that would give the estimate of deflection closest to the truth at every time point in every test
 - Average error among all data
 - Maximum error among all data



Max deflection

Best Combinations of 3 LED Locations (Sorted by Maximum Error, from least to most)

Trio			Mean Error (mm)	Max Error (mm)
A4	0	P5	0.85	7.16
A5	0	P5	0.92	7.16
A3	0	P5	0.92	7.16
A6	0	P5	1.08	7.16
A7	0	P5	1.32	7.16
A4	0	P6	0.88	9.04
A5	0	P6	0.95	9.04
A3	0	P6	0.95	9.04
A4	0	P7	0.96	9.04
A5	0	P7	1.03	9.04
A3	0	P7	1.03	9.04
A4	0	P8	1.09	9.04
A6	0	P6	1.11	9.04
A5	0	P8	1.16	9.04
A3	0	P8	1.16	9.04
A6	0	P7	1.18	9.04
A6	0	P8	1.32	9.04
A7	0	P6	1.34	9.04
A7	0	P7	1.42	9.04
A7	0	P8	1.56	9.04

Best Trio: avg error = 0.85-0.92 mm; max error = 7.2 mm

A8	0	P7	1.64	9.2
A9	0	P5	1.65	9.2
A9	0	P6	1.68	9.2
A9	0	P7	1.75	9.2

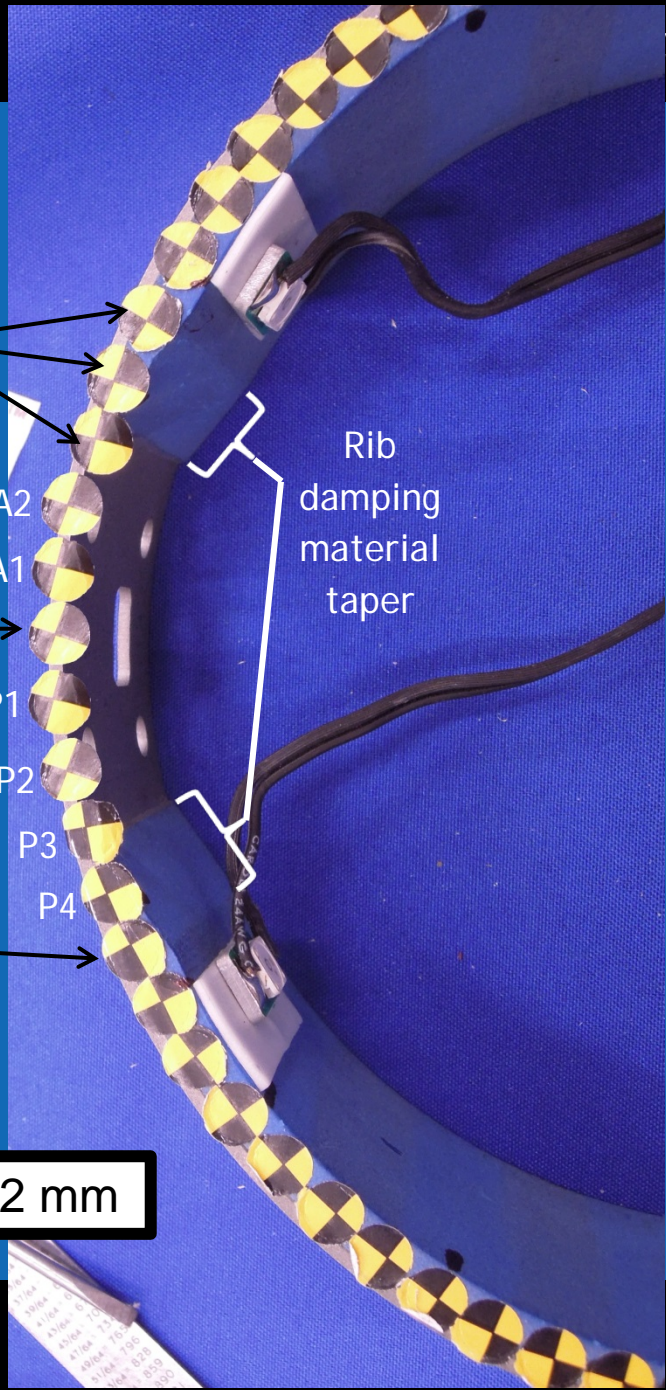
Anterior targets A3- A5

Target 0 (lateral position)

Posterior target P5

A2
A1
P1
P2
P3
P4

Rib damping material taper



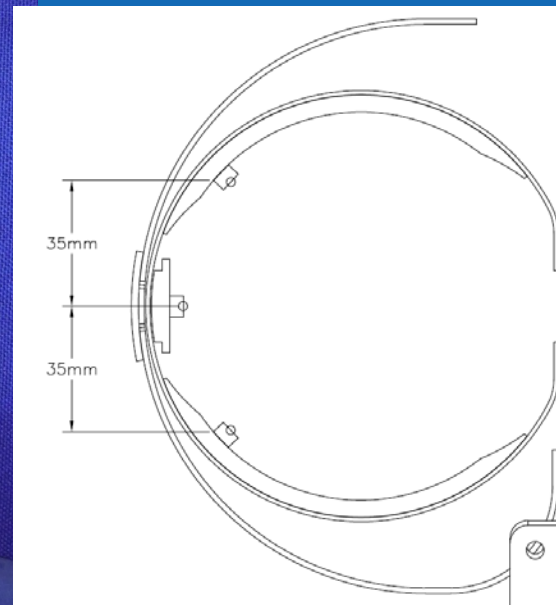
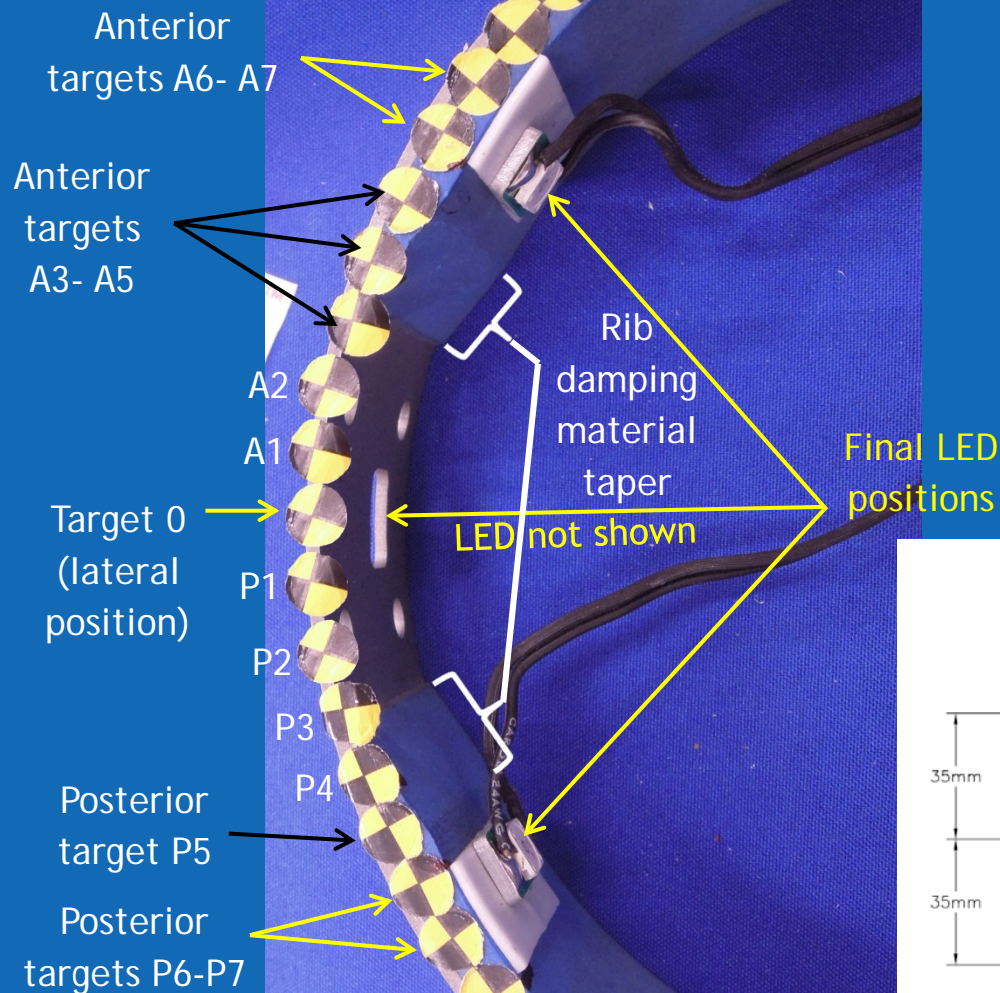
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A7	0	P8	1.56	9.04

Best Trio: avg error = 0.85-0.92 mm; max error = 7.2 mm

Final Trio: avg error = 1.1-1.4 mm; max error = 9 mm

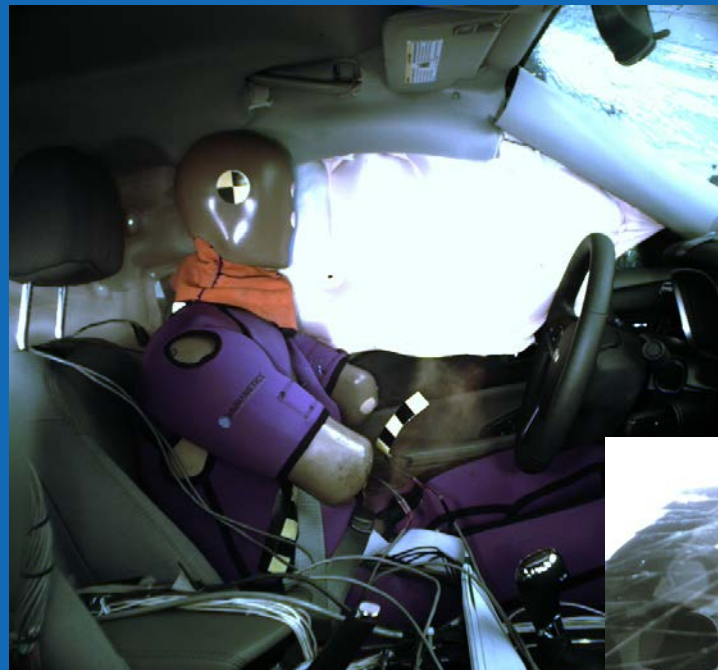
Middle LED only: avg error = 5.1 mm; max error = 30 mm



Evaluation of RibEye™

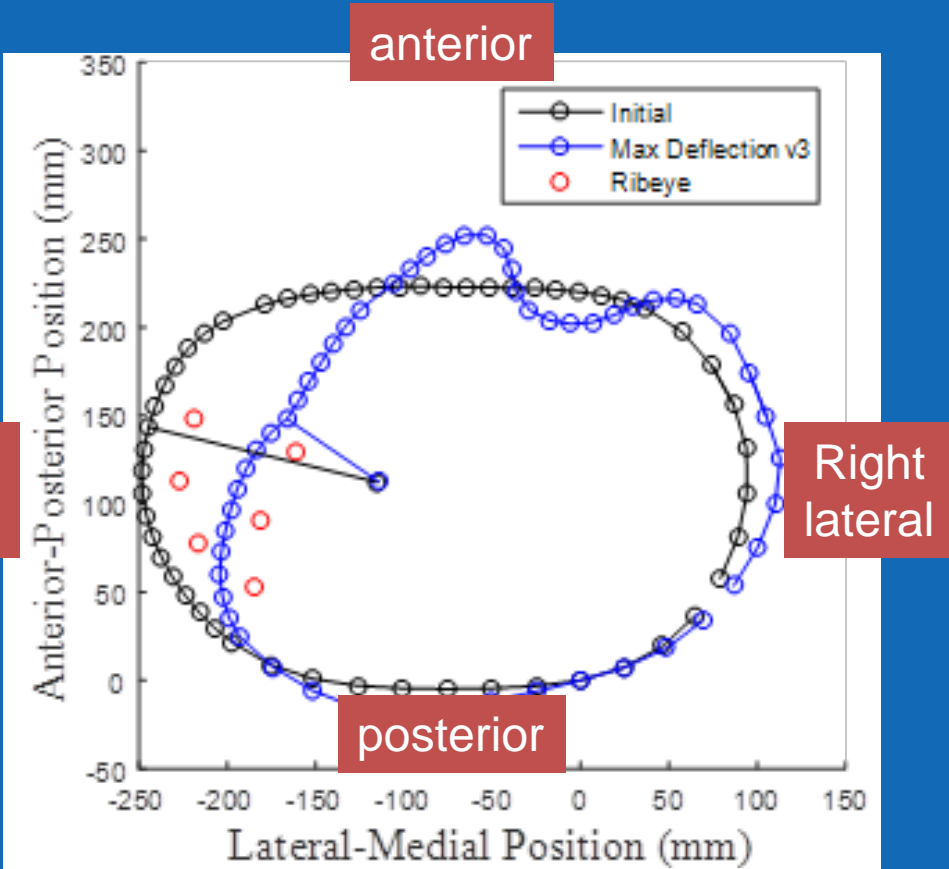
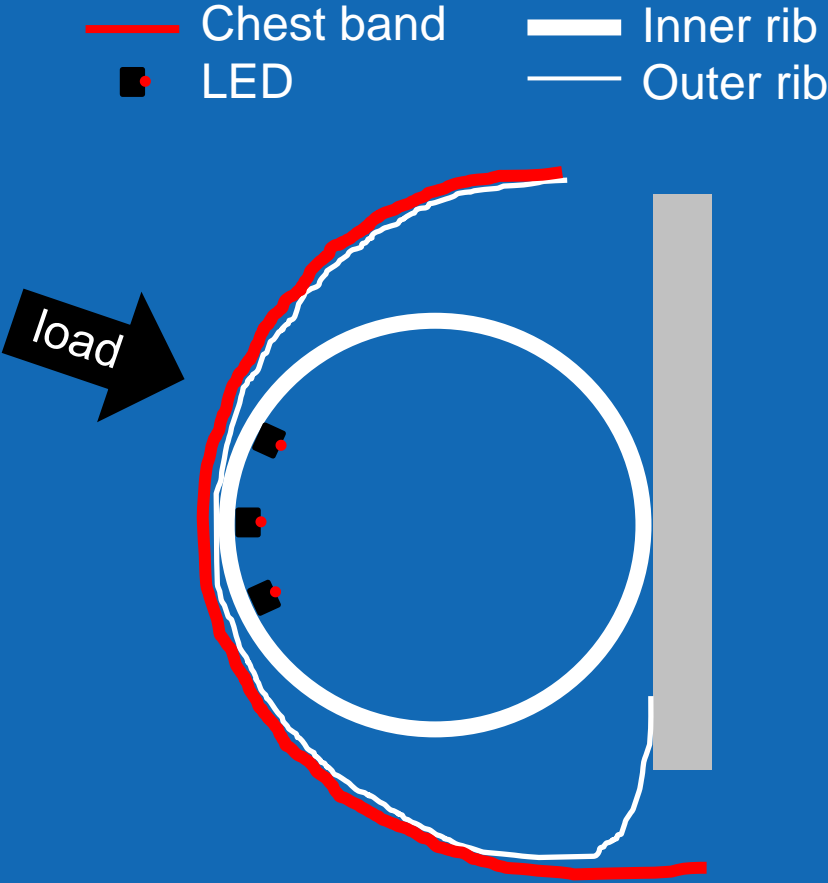
- Side NCAP crash tests
 - 6 Pole tests
 - 6 MDB tests
 - WorldSID-50M w/RibEye driver
 - Chest band on Thorax rib 1

Front left view of chest band on Thorax rib 1

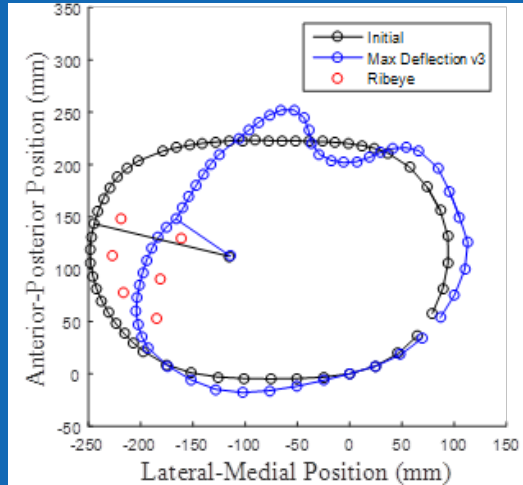
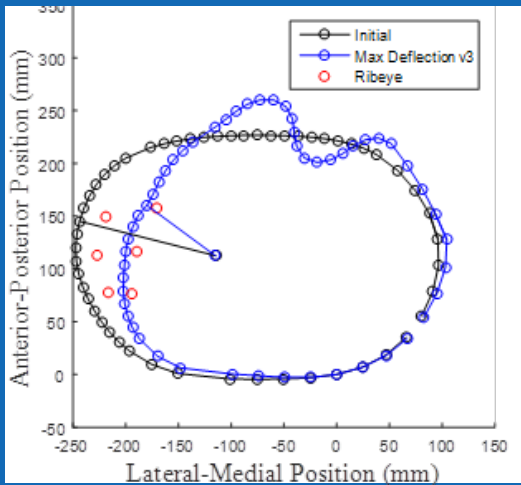
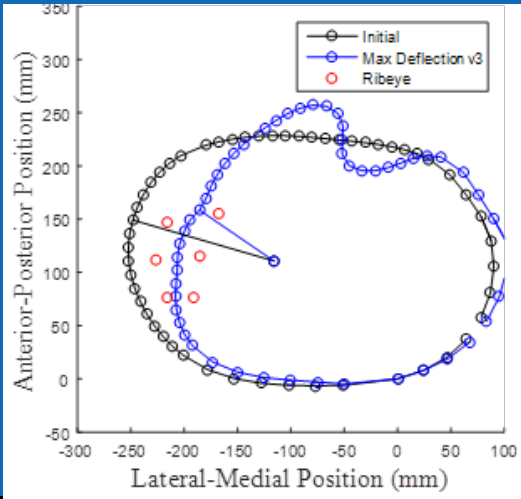
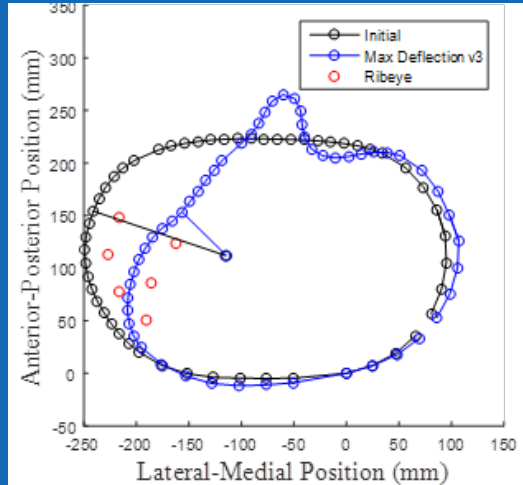
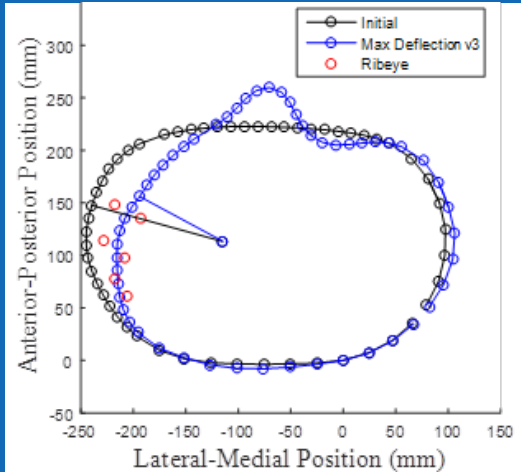
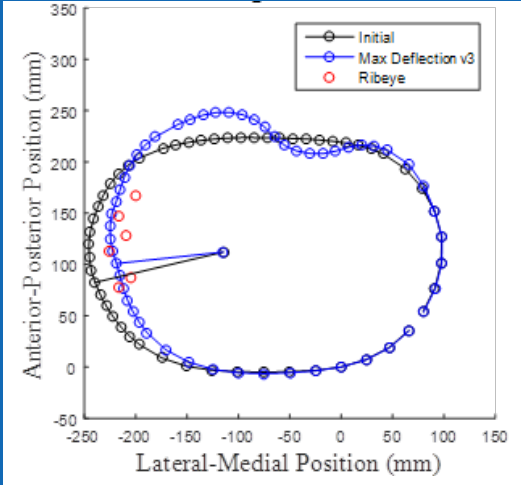


Evaluation of RibEye™

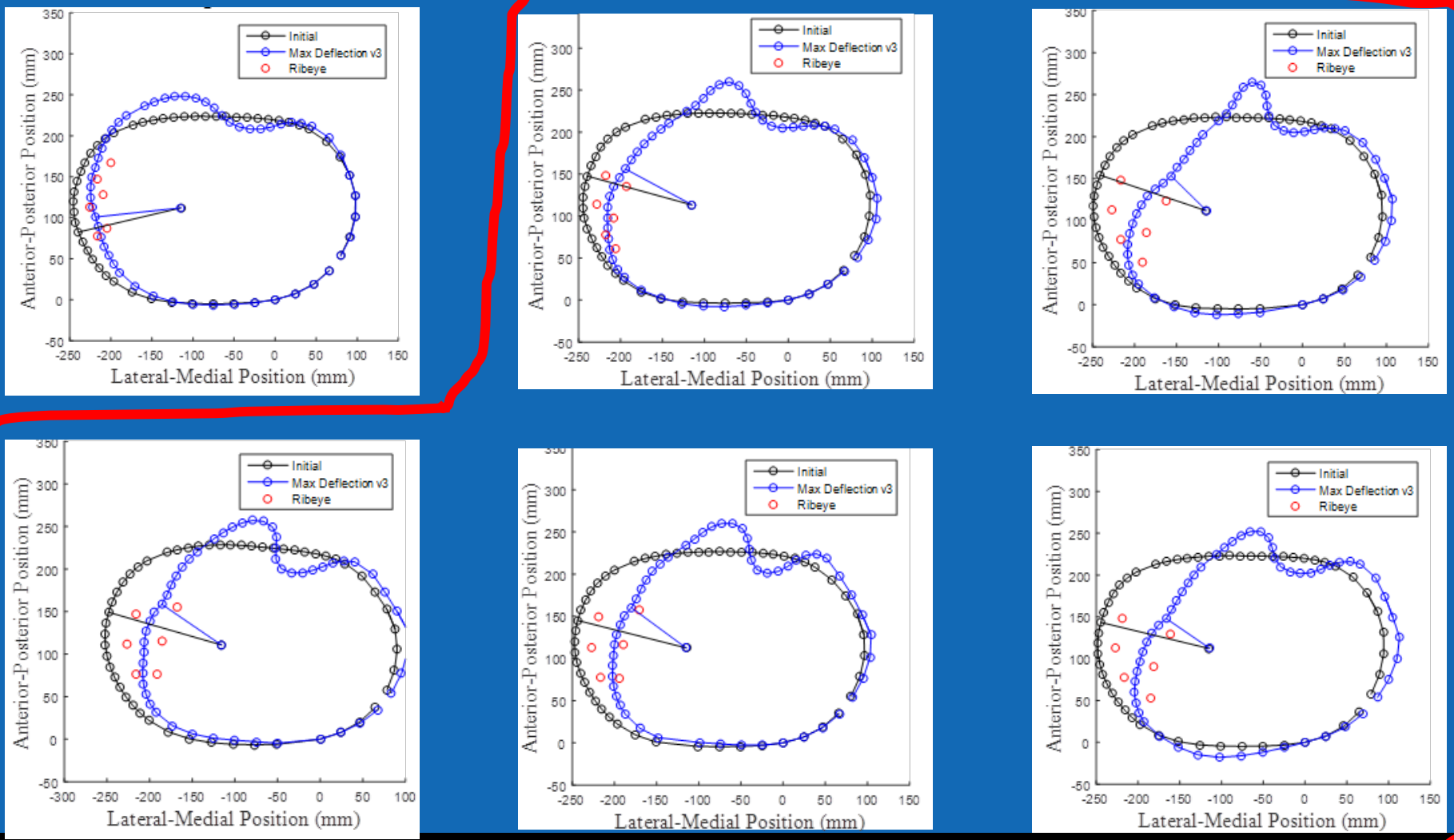
Chest band contours with RibEye™ LEDs



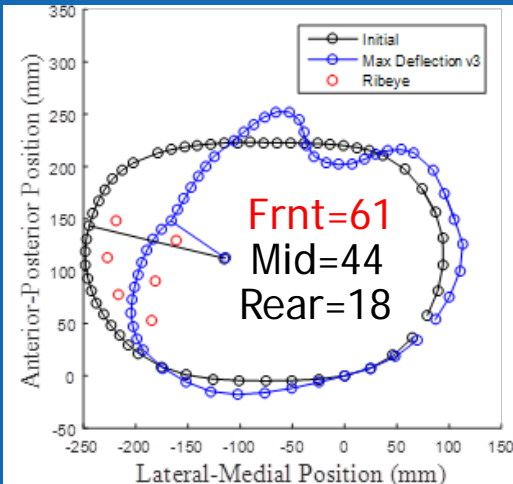
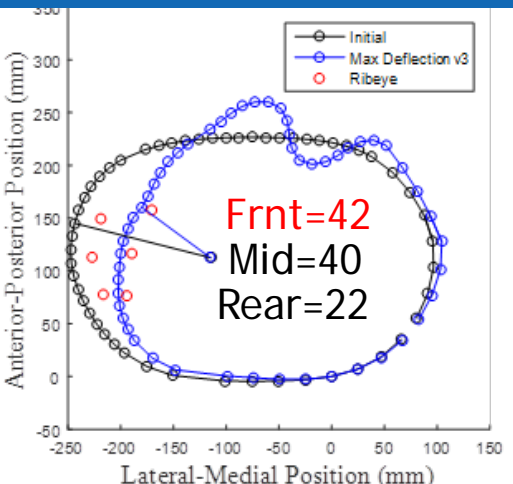
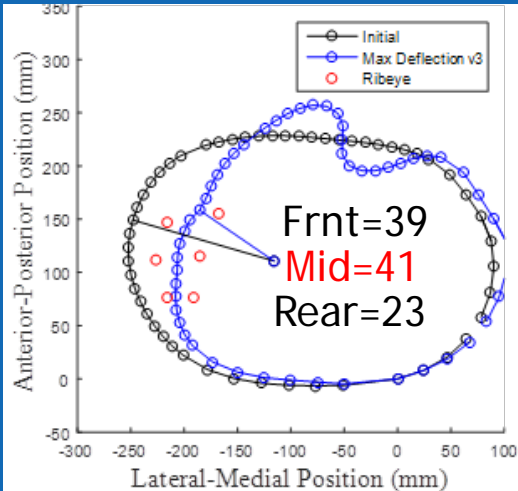
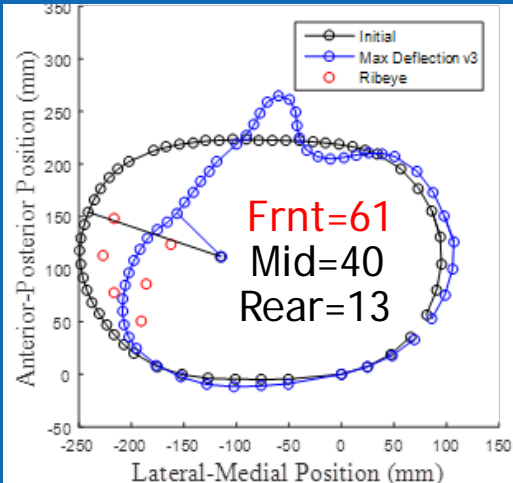
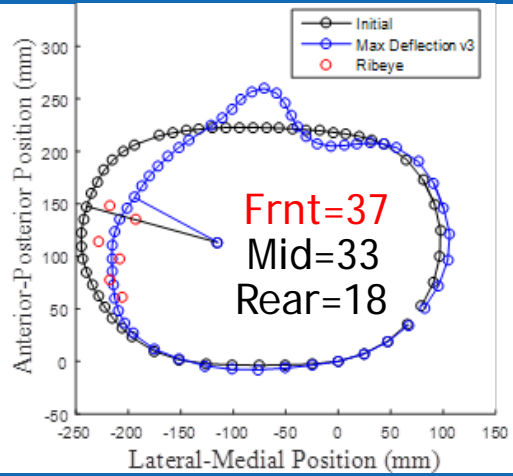
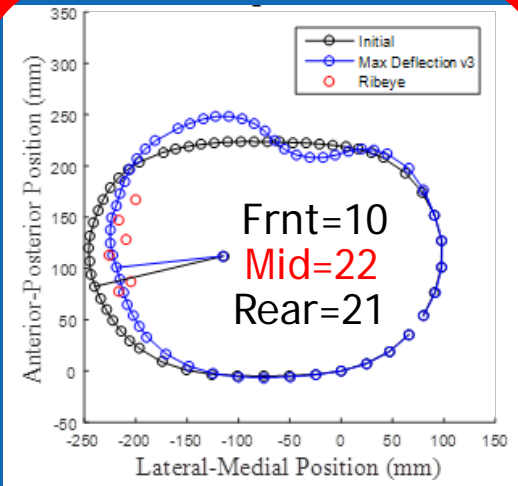
Evaluation of RibEye™ - Pole test results



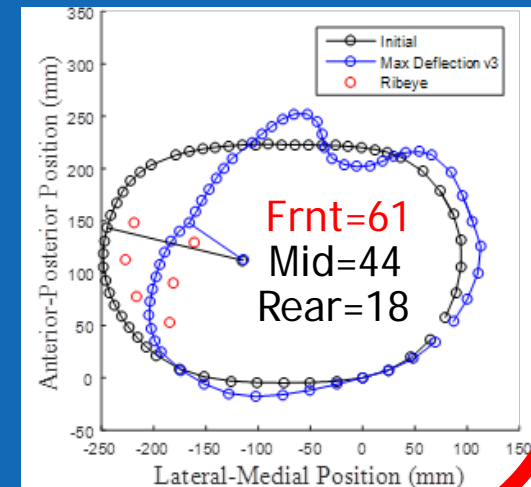
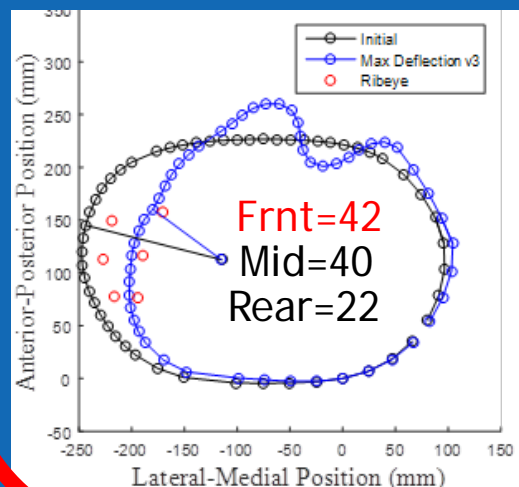
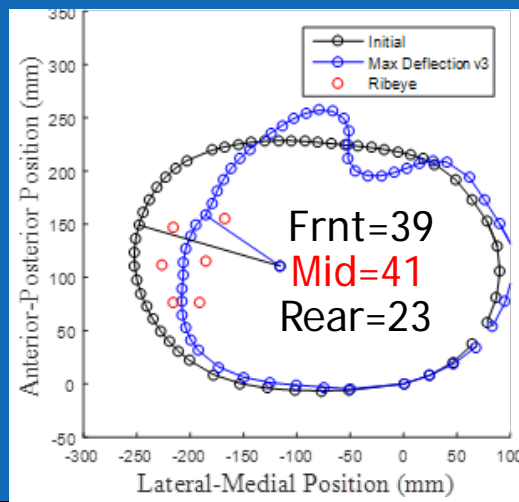
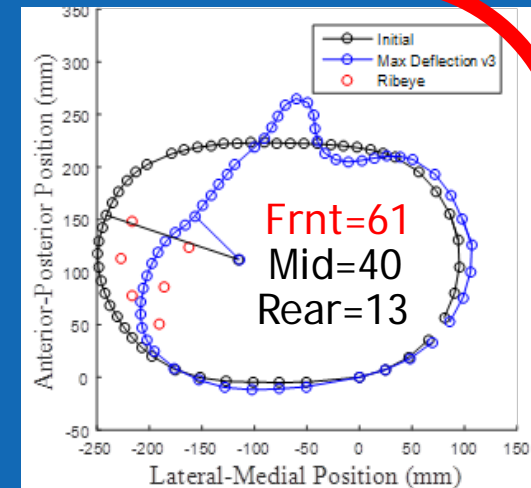
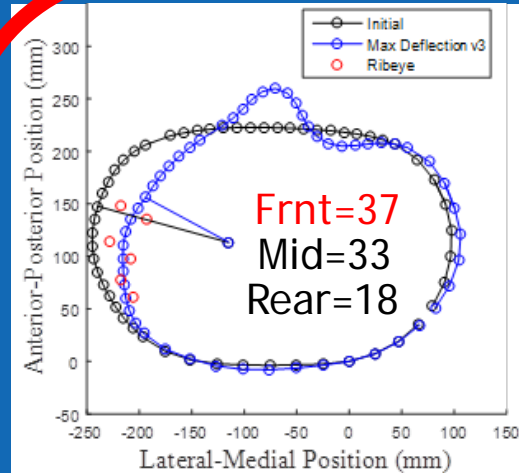
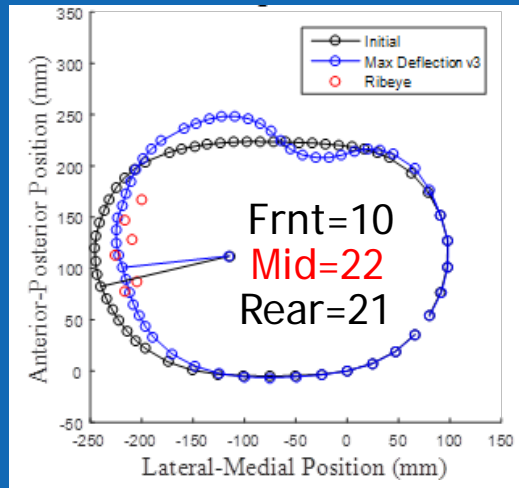
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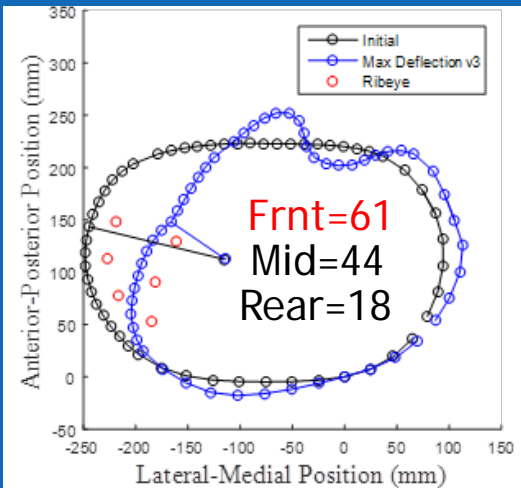
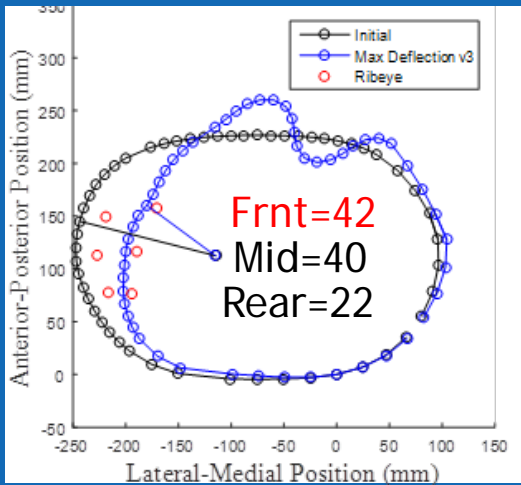
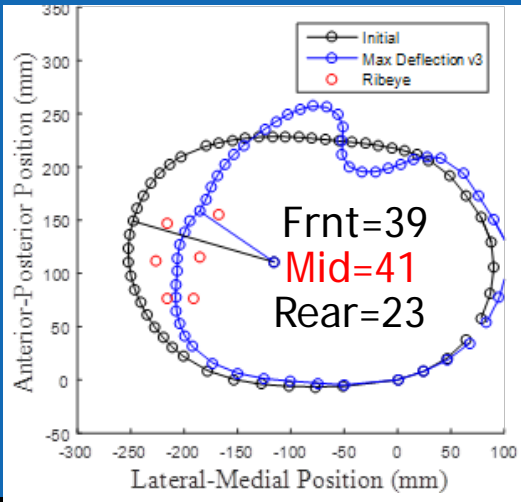
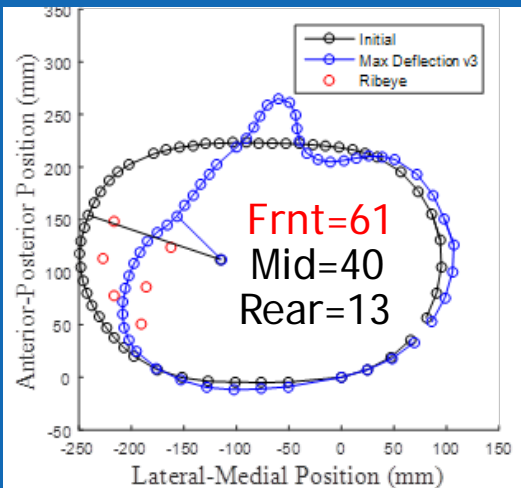
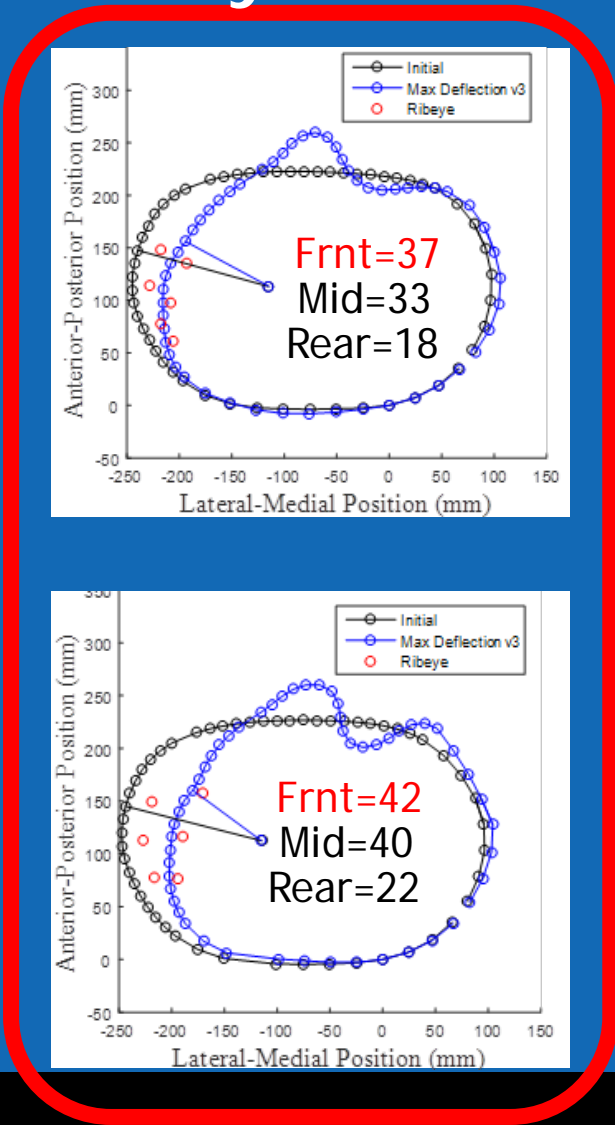
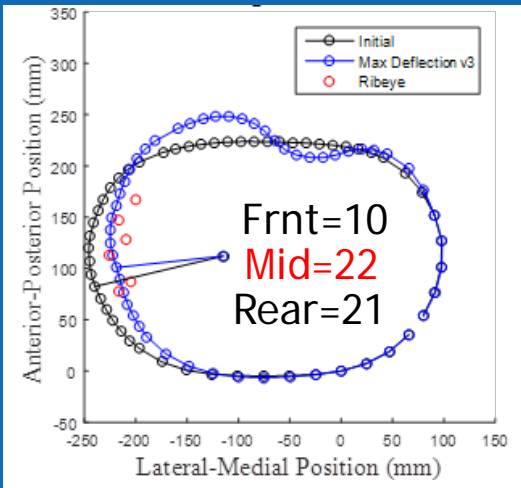
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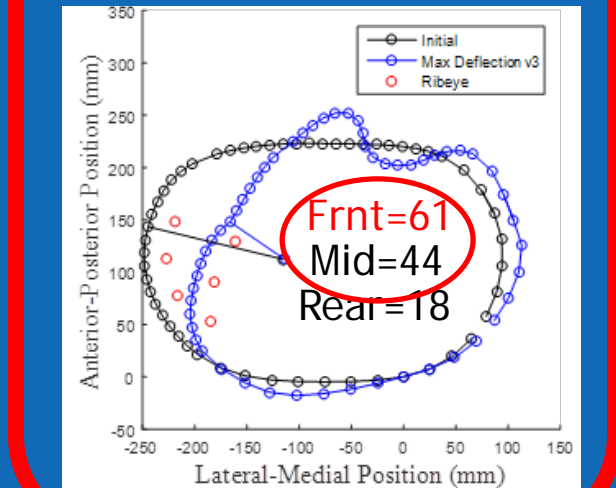
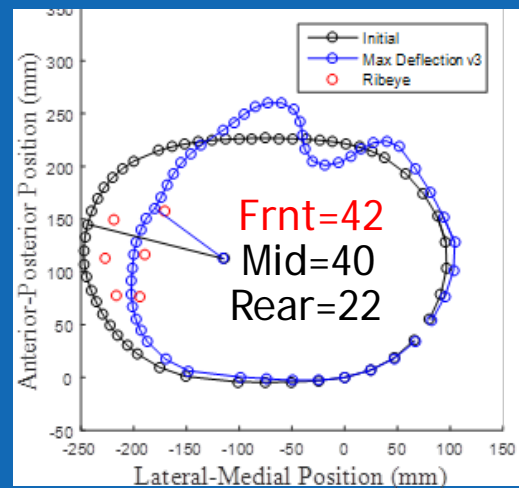
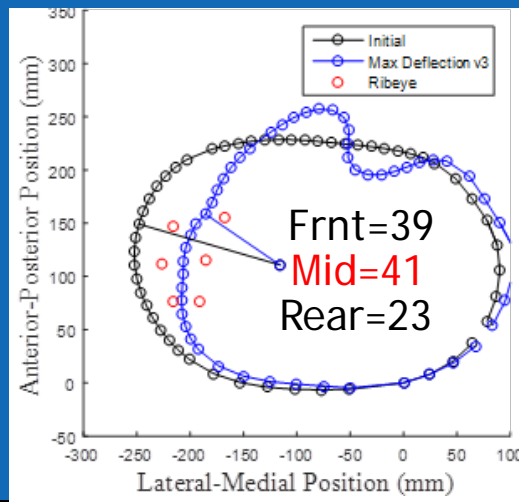
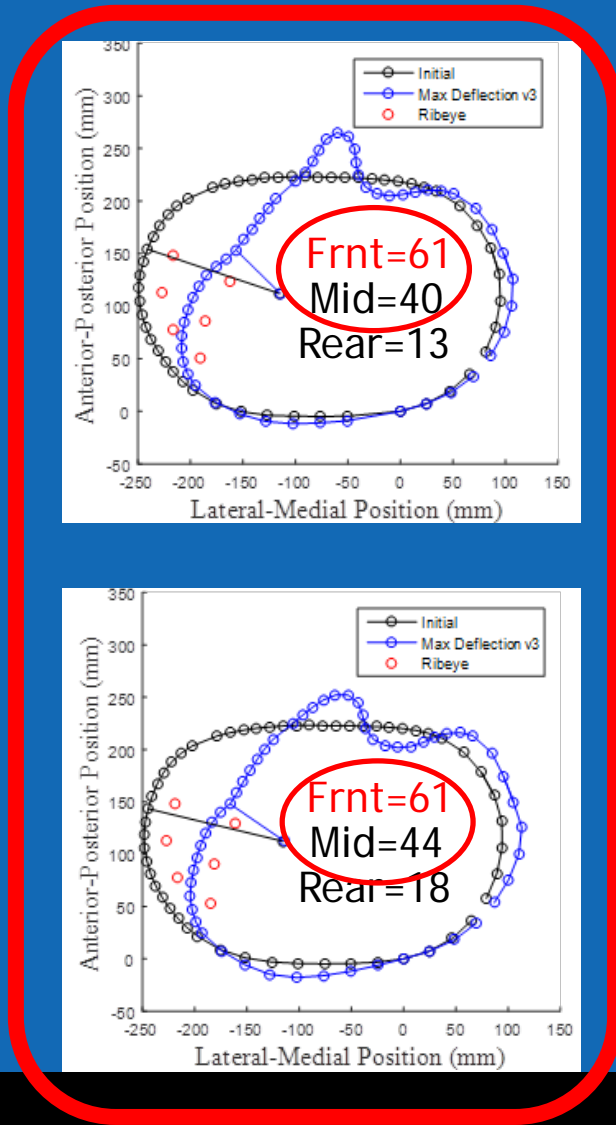
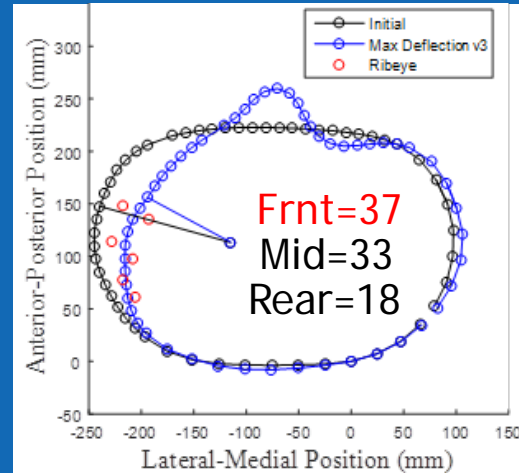
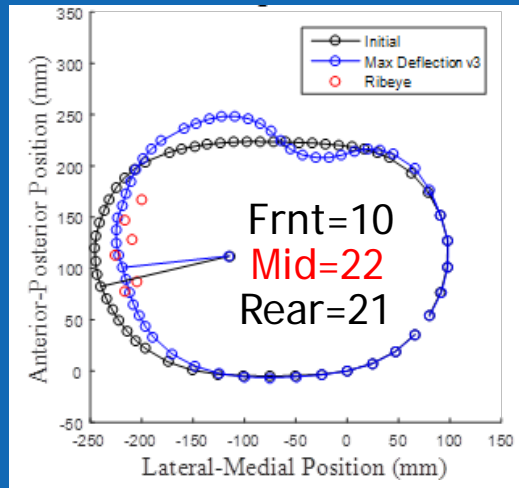
Evaluation of RibEye™ - Pole test results



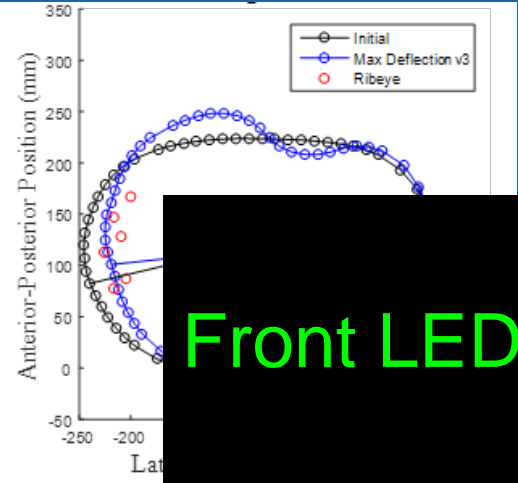
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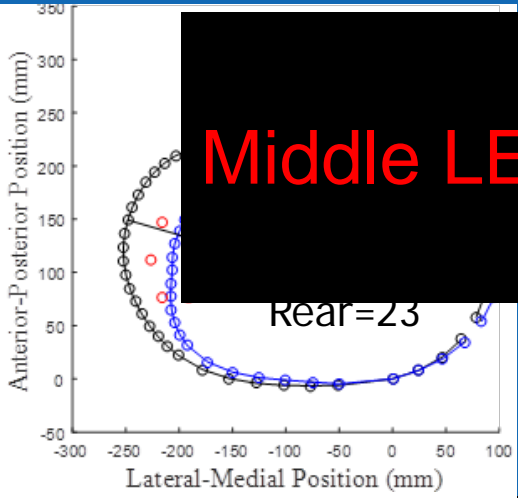
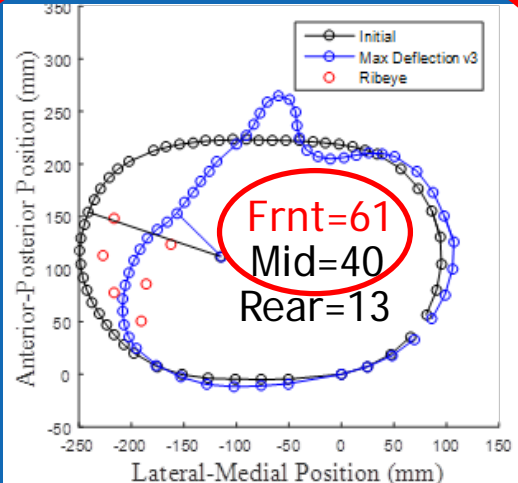
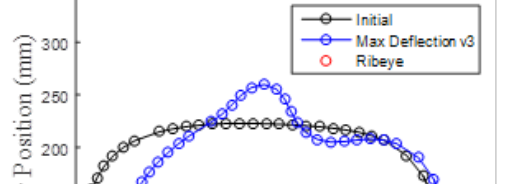
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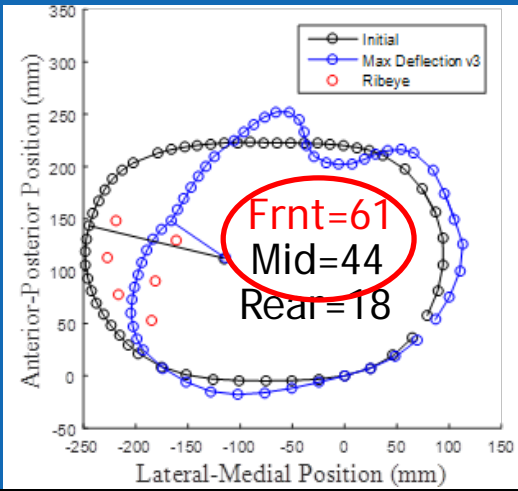
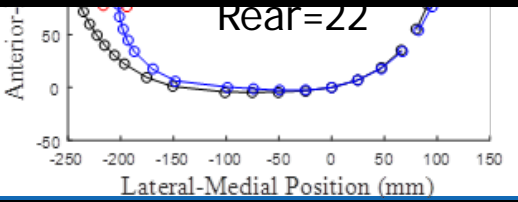
Evaluation of RibEye™ - Pole test results



Front LED: Risk AIS 3+ = 64%

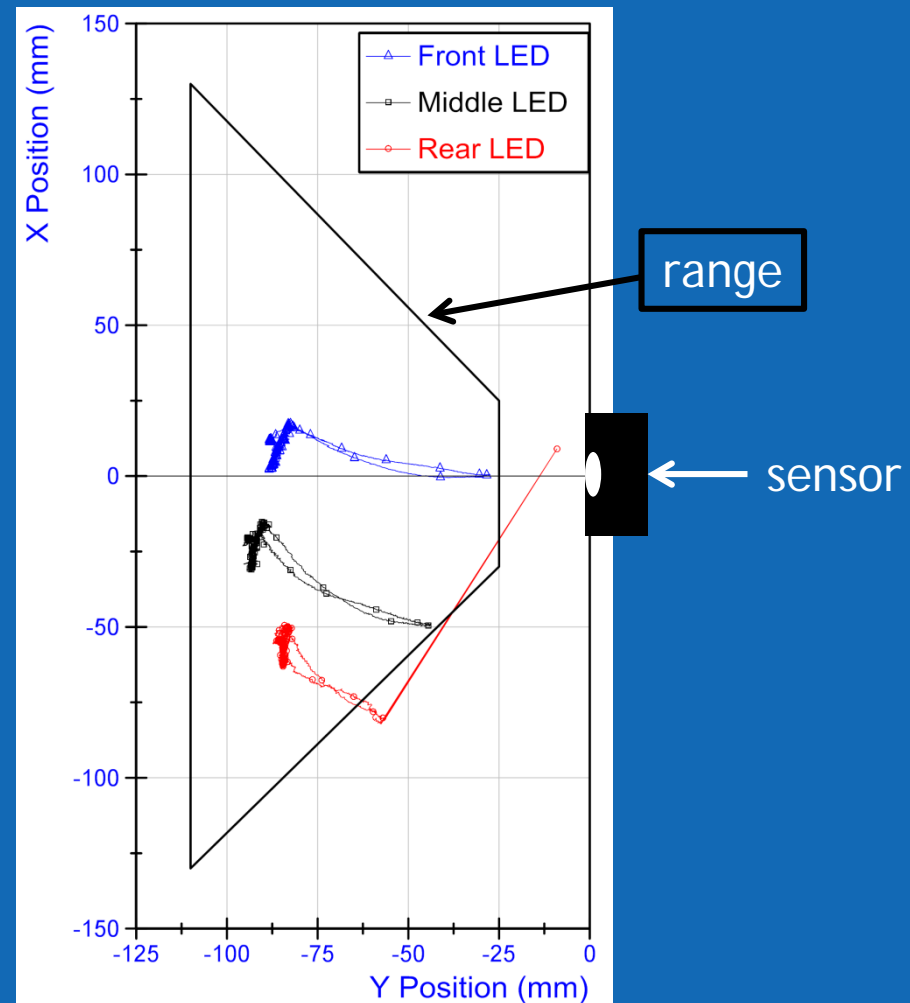
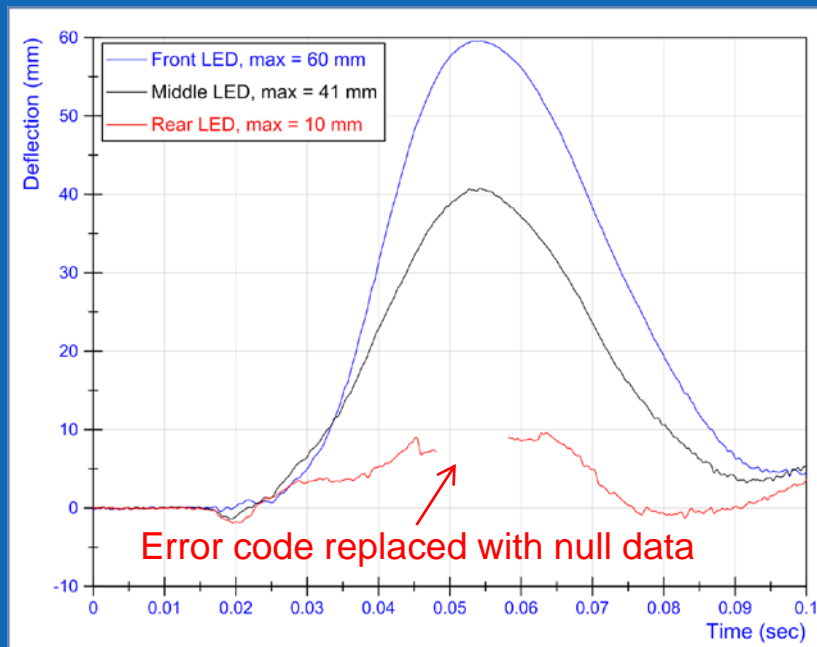


Middle LED: Risk AIS 3+ = 8%



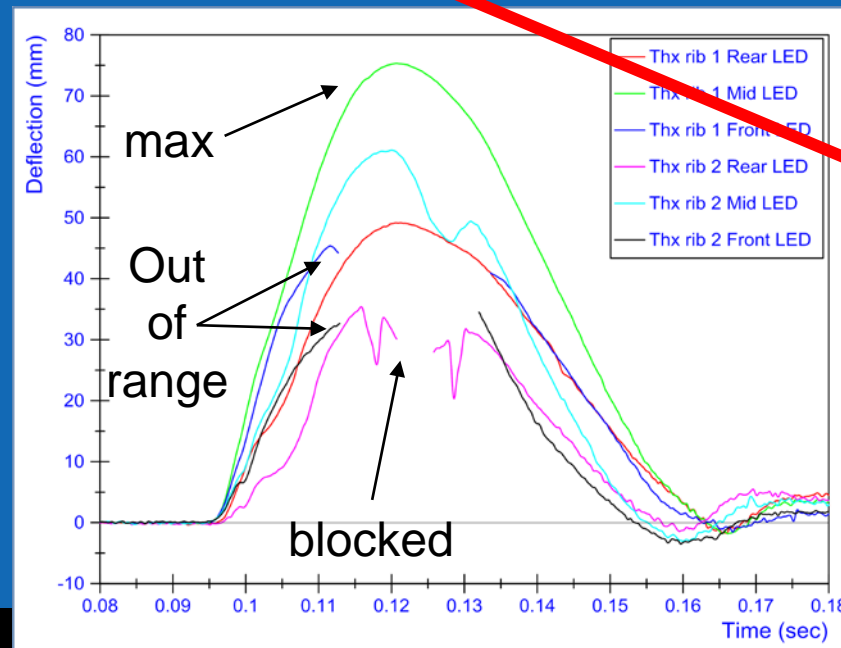
RibEye™ Idiosyncrasies

- Finite sensor measurement range
- Error codes
 - Exceed sensor range

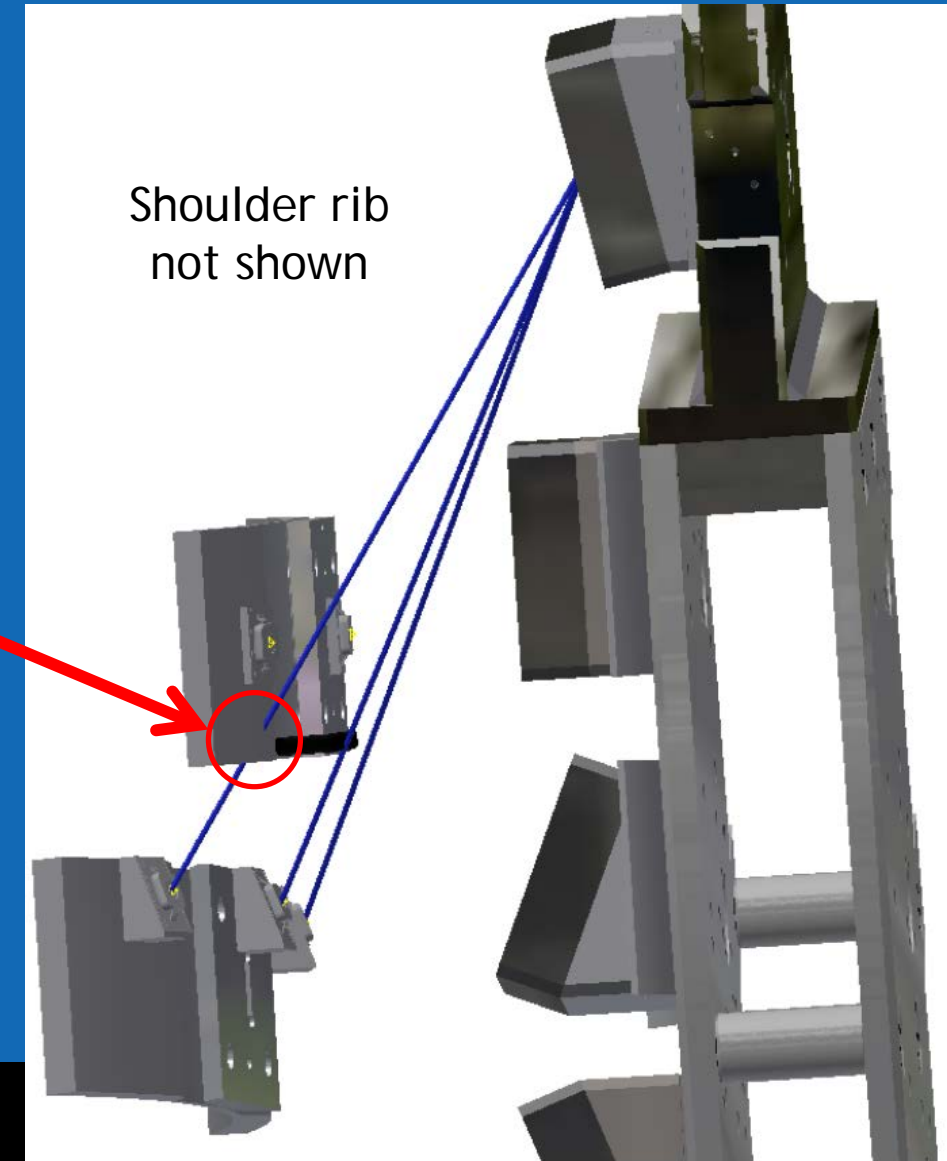


RibEye™ Idiosyncrasies

- Finite sensor measurement range
- Error codes
 - Exceed sensor range
 - One or more sensors are blocked or see too much ambient light



Error codes replaced with null data



Conclusions

- RibEye™ is sufficiently accurate
- In oblique single-rib dynamic loading conditions, RibEye™ successfully captured the maximum deflection of the rib (with 9 LEDs)
- Several crash tests demonstrated oblique loading to the thorax
- In all crash tests, RibEye™ LEDs followed the shape of the chest similar to the chest band
- In several crash tests, the front RibEye™ LED measured the maximum deflection of the rib, illustrating its advantage of measuring multiple points on a rib
- In a few crash tests, the front RibEye™ LED measured ~20 mm more than the middle LED, resulting in an injury risk difference of 56%, demonstrating the value of measuring multiple deflection points



**EVALUATION OF THE
RIBEYE™ MULTIPOINT
DEFLECTION MEASUREMENT
SYSTEM INSTALLED IN THE
WORLDSID-50M DUMMY**