Assessing the Accuracy of Surrogate Child Restraint Seat Models in Frontal Impact Simulations

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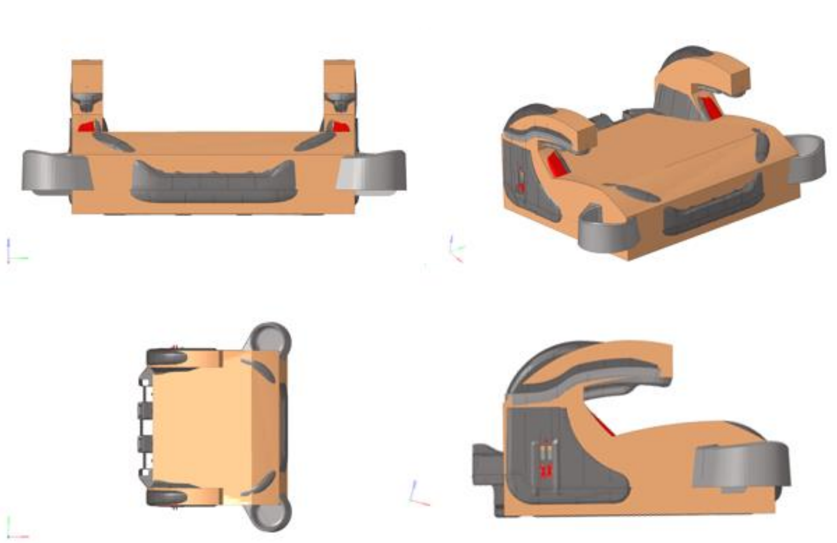
BACKGROUND AND OBJECTIVE

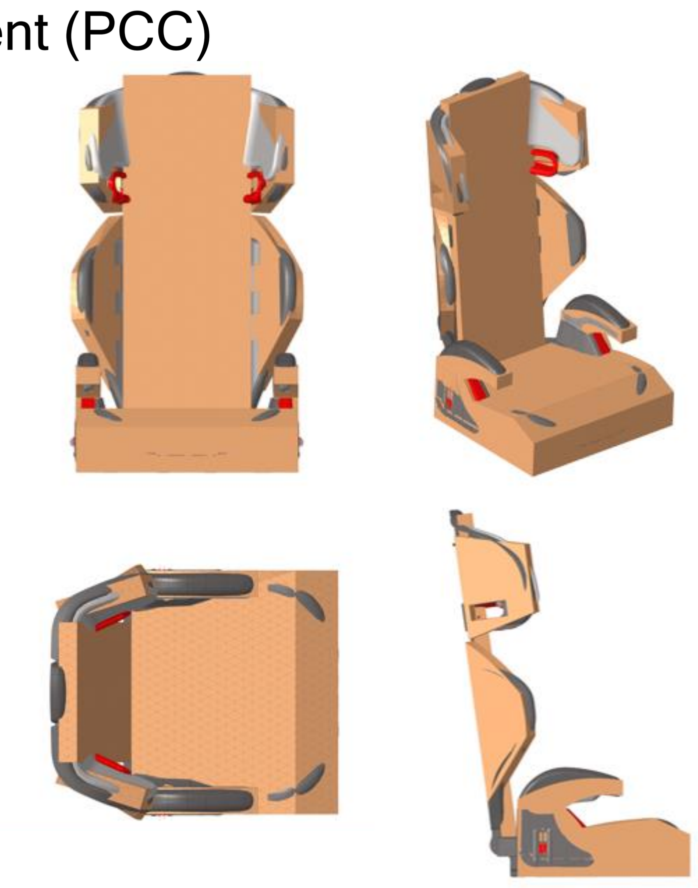
- Developing actual, detailed child restraint seat (CRS) finite element (FE) models is time-consuming and computationally expensive
- Surrogate models mimic the shape and weight of real CRS
- Could streamline investigating large-scale booster parametric studies without having to develop detailed CRS models
- **Objective:** To determine whether simple surrogate models of booster CRSs can accurately represent actual detailed CRSs in finite element (FE) simulations

METHODOLOGY

- Surrogate FE models of a low-back (LBB) and a high-back (HBB) booster were created from actual models
- Booster features captured using simple geometrical representations
- Modeled as a solid using polypropylene plastic material properties
- PIPER 6-year-old child human body model was restrained in actual and surrogate models of CRSs on the FMVSS No. 213 test bench using 3-point lap-shoulder belt with a retractor and pretensioner
- Environment subject to FMVSS No. 213 frontal impact pulse (24g)
- Four simulations (2 LBB + 2 HBB) were ran using LS-DYNA
- Kinematic and kinetic data was extracted, filtered as per SAE J-211 conventions, and compared across each metric
- Similarity in the time-series for each kinetic metric was assessed with the Pearson Correlation Coefficient (PCC)

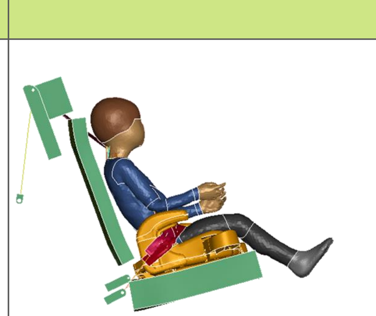
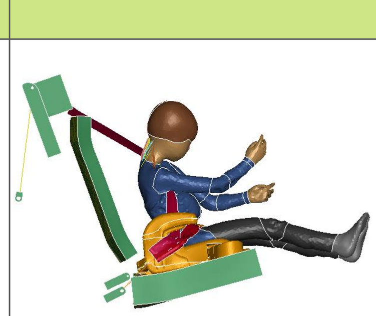
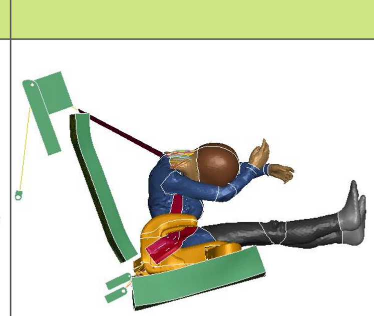
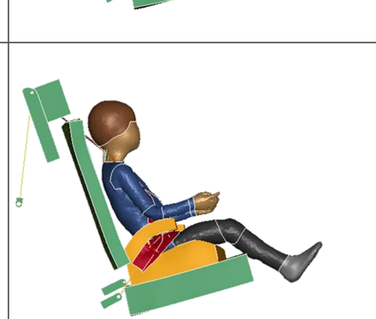
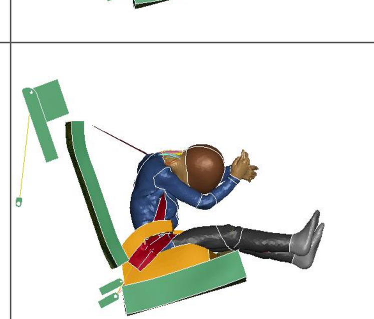
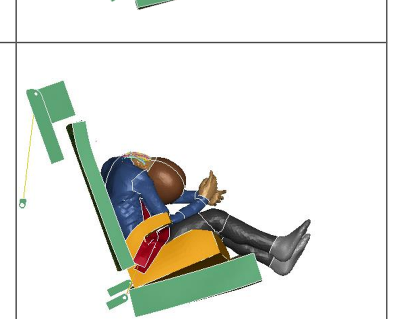
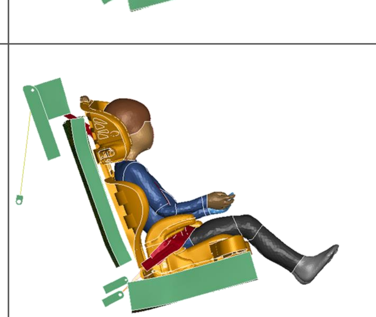
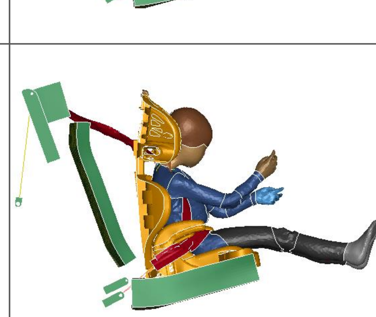
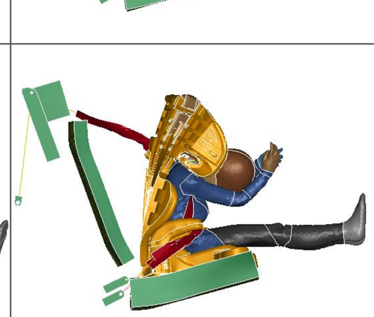
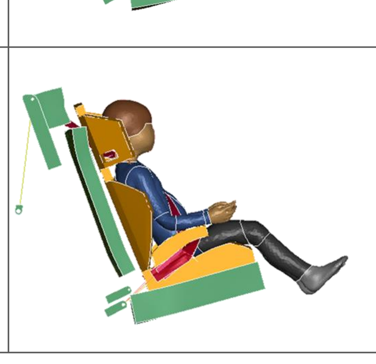
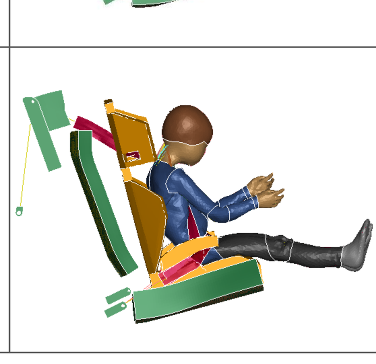


LBB Actual (Grey) and LBB Surrogate (Brown) overlayed



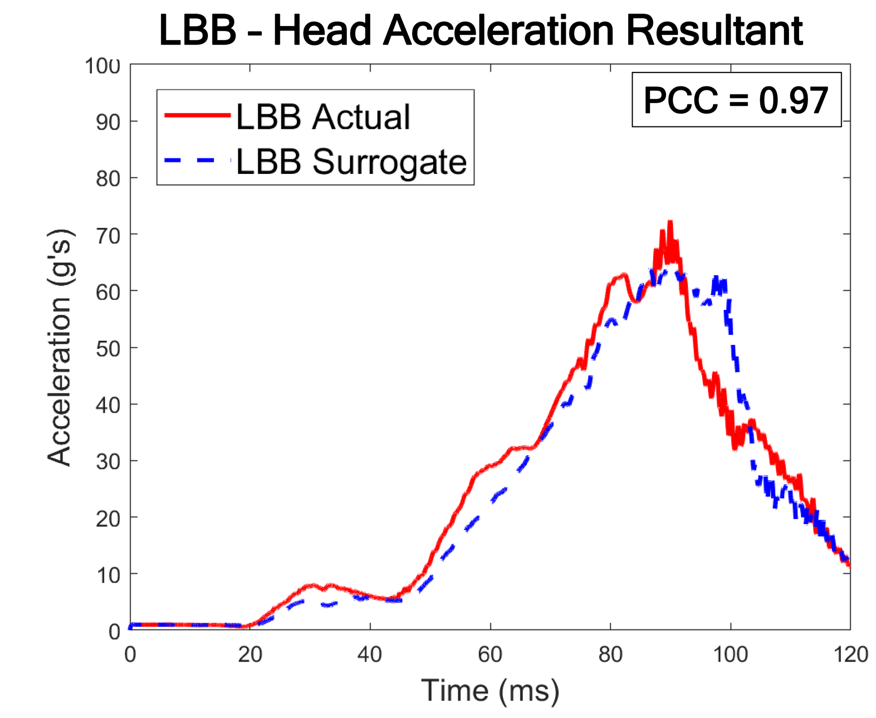
HBB Actual (Grey) and HBB Surrogate (Brown) overlayed

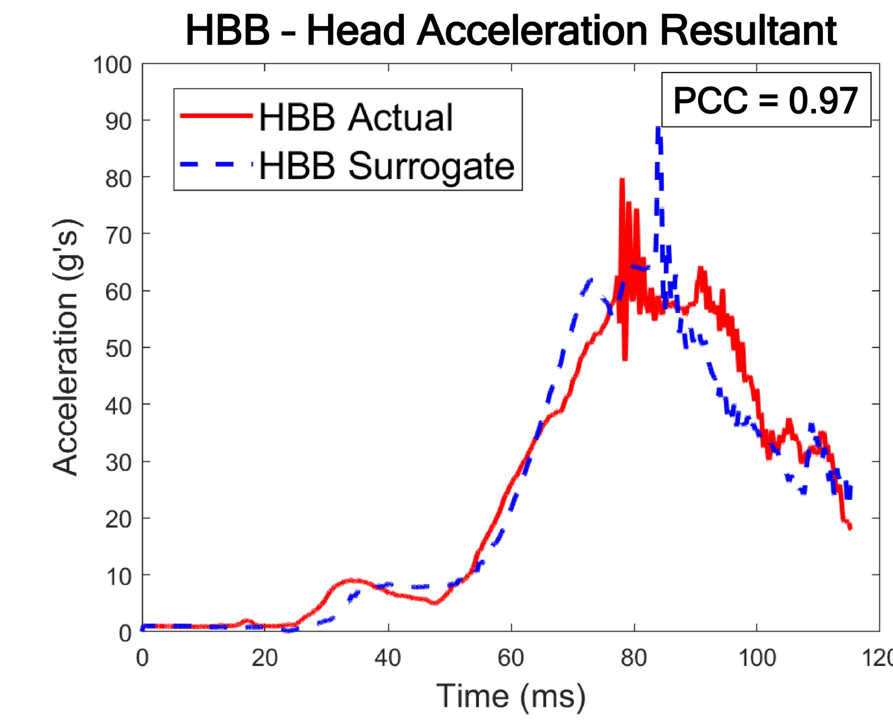
RESULTS AND DISCUSSION

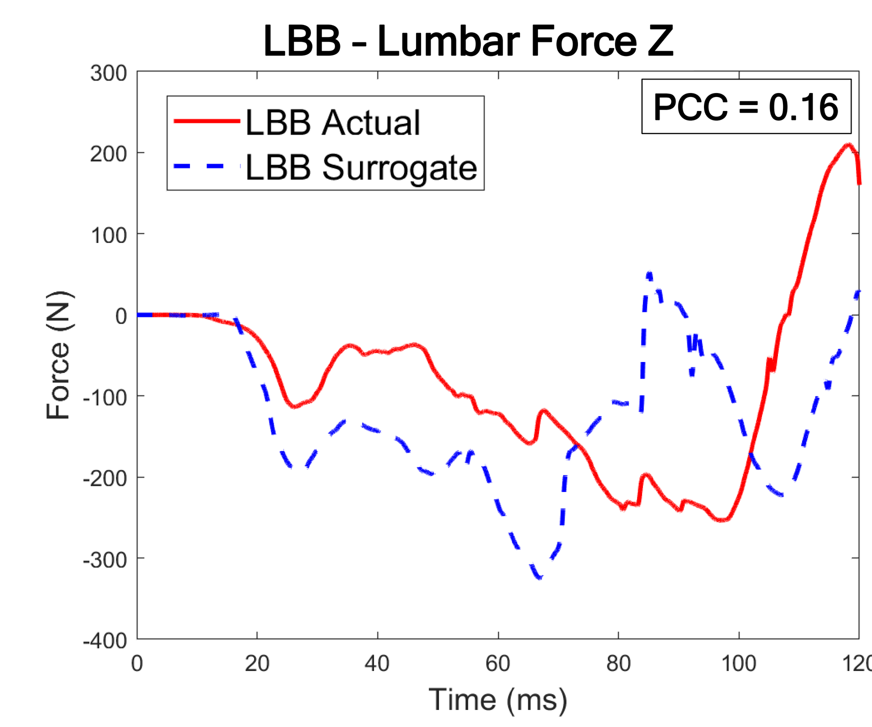
Booster Model	t = 30 ms	t = 60 ms	t = 90 ms	t =120 ms
LBB Actual				
LBB Surrogate				
HBB Actual				
HBB Surrogate				

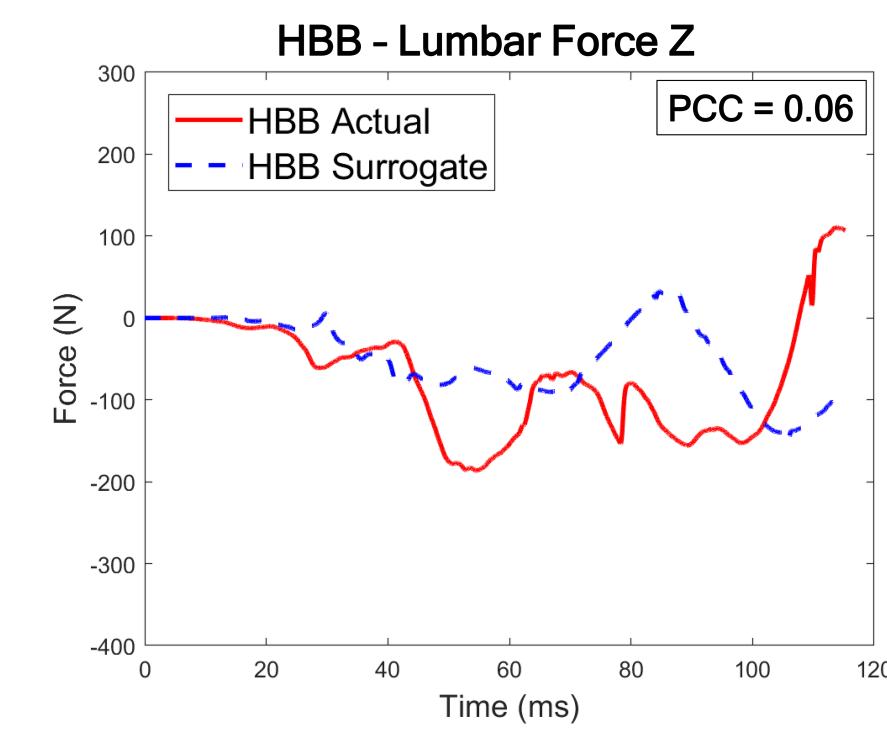
LBB Parameters	PCC
Head Acceleration Resultant	0.97
Upper Neck Moment Y	0.93
Upper Neck Force Z	0.95
Lower Neck Moment Y	0.99
Lower Neck Force Z	0.94
Chest Acceleration Resultant	0.75
Sternum Deflection Resultant	0.94
Lumbar Moment Y	0.98
Lumbar Force Z	0.16
Pelvis Acceleration Resultant	0.90

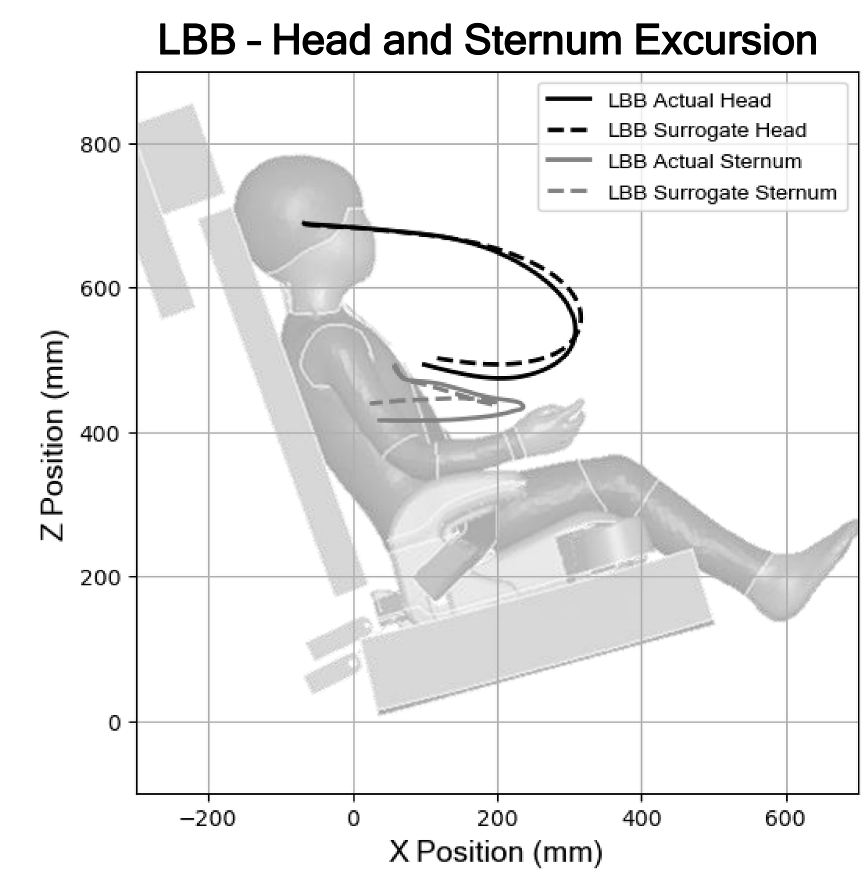
HBB Parameters	PCC
Head Acceleration Resultant	0.97
Upper Neck Moment Y	0.94
Upper Neck Force Z	0.95
Lower Neck Moment Y	0.99
Lower Neck Force Z	0.97
Chest Acceleration Resultant	0.47
Sternum Deflection Resultant	0.89
Lumbar Moment Y	0.97
Lumbar Force Z	0.06
Pelvis Acceleration Resultant	0.54

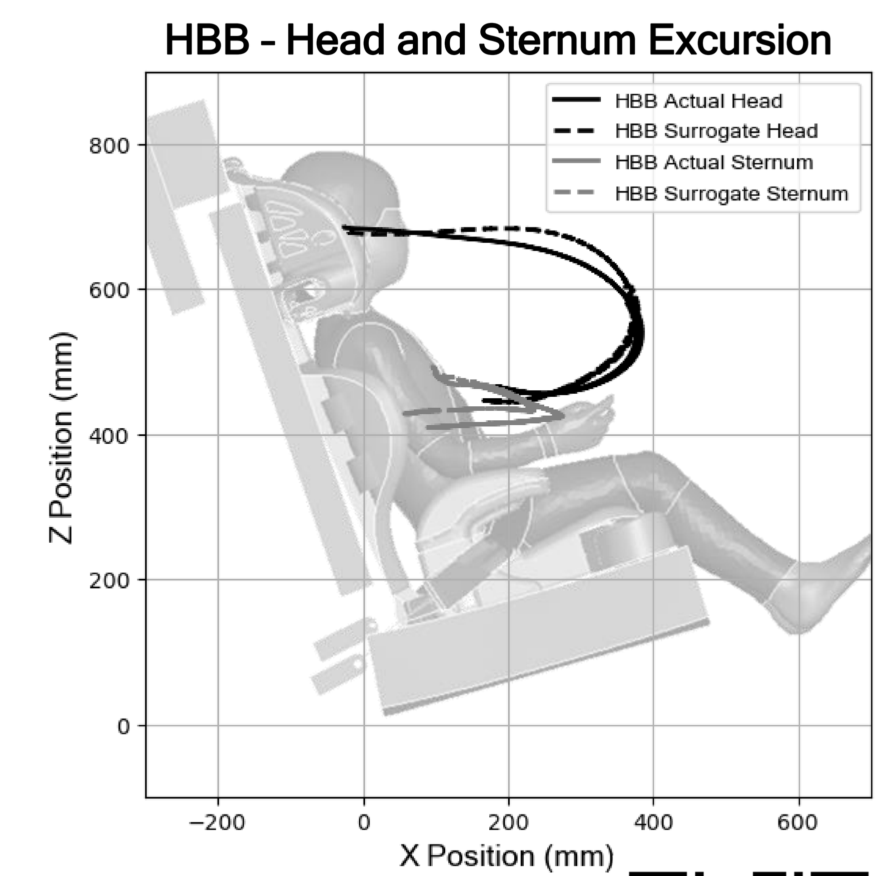












- LBB Comparison:
  - 9 out of 10 metrics showed PCC ≥ 0.5
- HBB Comparison:
  - 8 out of 10 metrics showed PCC ≥ 0.5
- Strong correlation observed for both LBB and HBB kinetic data
- Lumber Force Z showed lowest correlation on both booster types
- HBB Actual has more intricate components in the seatback, allowing it to flex during impact, resulting in a slight variation in booster kinematics from HBB surrogate, which had a relatively stiffer back
  - Does not seem to have a large impact on occupant kinematics and kinetics

CONCLUSIONS

- The PIPER 6YO model demonstrated similar kinematics and kinetics in both the surrogate and actual boosters for LBB and HBB conditions in frontal impacts
- This study supports the use of surrogate models as a computationally simplistic and time-efficient alternative to detailed booster CRS models in frontal impact CRS simulations
- Accuracy of surrogate models in other impacts (oblique, nearside, farside) and for additional booster designs needs to be evaluated