apply the recorded vehicle accelerations to the FE model:

$$\vec{a}_{NASCAR} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \vec{a}_{\mathrm{SAE}} \quad (1)$$

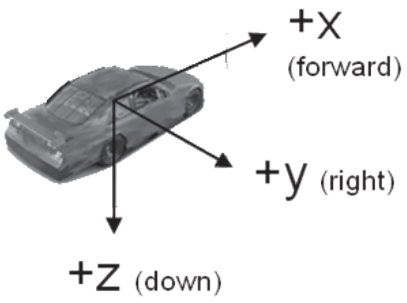

Figure 4. NASCAR (SAE) coordinate system.

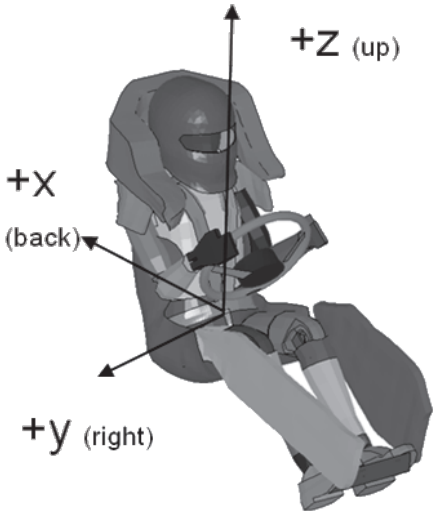

Figure 5. NASCAR LS-DYNA seat model coordinate system.

In addition to the coordinate system convention, NASCAR employs a unique convention for describing the angle of impact. Their convention defines 0° for a rear impact, +90° for a left impact, -90° for a right-side impact, and ±180° for a frontal impact. Although this convention could have been used, a different convention was chosen because it was felt to be more intuitive and avoids any occurrence of negative values for angles, which could cause issues later with the statistical analysis. As Figure 6 shows, the convention starts with 0° at the front of the vehicle and proceeds clockwise around the vehicle.

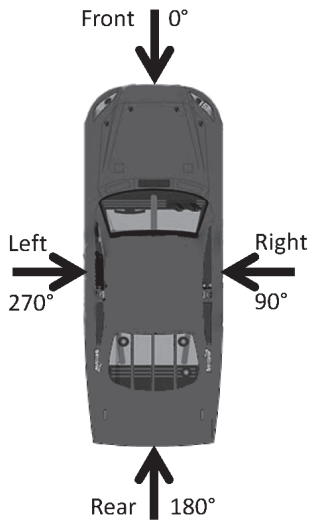

Figure 6. NASCAR impact angle definitions.

Modeling Methodology

The explicit dynamic Finite Element (FE) analysis software LS-DYNA (Livermore Software Technology Corporation 2009) was employed with a 50th percentile male Hybrid III Anthropomorphic Test Device (ATD) finite element model (FEM) developed and validated by Humanetics Innovative Solutions, Inc. (formerly First Technology Safety Systems) (Humanetics Innovative Solutions, Inc. 2009). Humanetics validated the Hybrid III FEM using standard Hybrid III ATD certification tests. These tests consisted of head impact, neck flexion and extension, chest impact, and knee impact. Sled tests and modeling were conducted by NASA and the U.S. Air Force in multiple orientations to validate the FE model in additional orientations. The results of the NASA sled testing are summarized in Appendix A.

The Hybrid III FEM was configured in an FE model of a NASCAR seat with a modified HANS® head and neck restraint device, helmet, and head surround. Individual model components such as the seat, harness, and helmet and HANS device were provided by Paul Begeman at Wayne State University. Below is a brief description of the model primary components.

A 5-point harness was modeled using the preprocessor LS-PrePost (Livermore Software Technoloogy Corporation 2009). The Hybrid III FEM was imported into the preprocessor; then "segment sets" were defined on the FE model where