APPENDIX 1

OCCUPANT TRAJECTORY AND HIC

There has been an extensive amount of research focusing on the analytical prediction of HIC, head impact velocity, head impact angle, and other analytical data related to full-scale dynamic testing. The information provided in this Appendix will illustrate some of the items to consider when conducting a HIC and head path trajectory validation (reference Section 7.1.1.1 and 7.1.1.4). Figures 1 through 4 in this Appendix were generated and provided by the National Institute for Aviation Research (NIAR) at Wichita State University.

Figure 1 shows an XZ-Plane view of a Hybrid II ATD MADYMO model in a pretest state at 1G. In addition to the Hybrid II ATD, the following items are modeled:

- Seat back
- 2-point restraint
- Seat pan
- Bulkhead
- Foot rest
- Floor

Consistent with Section 7.1.1.1, occupant trajectory or position is established using the Seat Reference Point (SRP) as the datum. The SRP is identified in Figure 1. In addition, the seat setback, or distance from the SRP to the bulkhead, is also shown. In general, the information provided in Figure 1 is considered a minimum for this type of analysis.

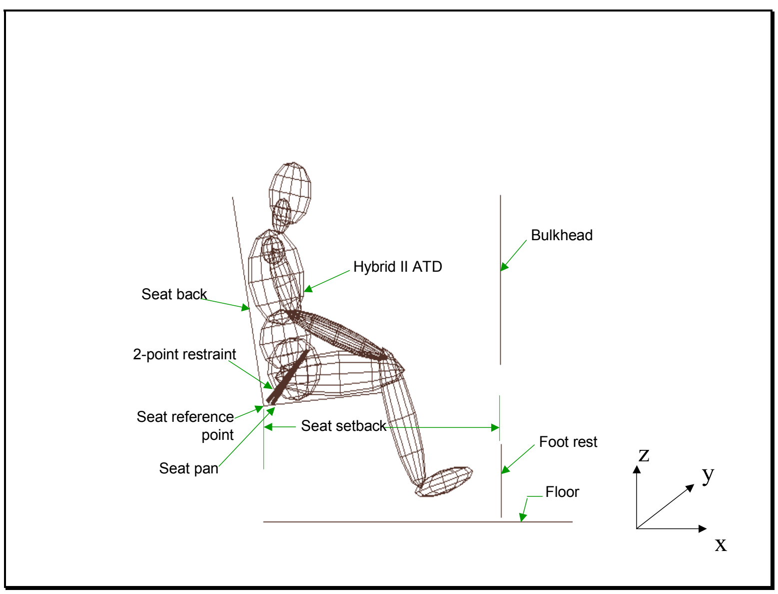

Figure 1 - Pretest Geometry at 1G

Figure 2 presents the ATD motion from a dynamic sled test and the corresponding MADYMO model simulation. The sled test and simulation were conducted using the deceleration forcing function provided in § 25.562(b)(2).

There are two occupant trajectory items to compare in this figure: head path and pelvic displacement. As discussed in Section 7.1.1.1, visual comparison may be used when precise occupant trajectory is not required. For a HIC analysis, the visual evaluation is probably not sufficient, but it will offer some confidence in the model. This evaluation will be followed by a quantitative comparison of the head paths (Figure 3).

Notice that there is a considerable amount of pelvic displacement, which is expected when using a simple 2-point restraint. Section 7.1.1.1 states that the trajectory of the occupant may include head path, pelvic displacement, or torso displacement. Pelvic displacement will clearly contribute to the final head path, but that does not necessarily mean pelvic displacement requires a separate validation. If the head path compares well, and the pelvic displacement compares well, that is usually sufficient for validating the occupant trajectory.

For this particular data, the MADYMO simulation compares well to the ATD motion. Notice that we are not concerned with arm or leg flail. With the possible exception of femur loads, there is no regulatory requirement to measure arm/leg flail.

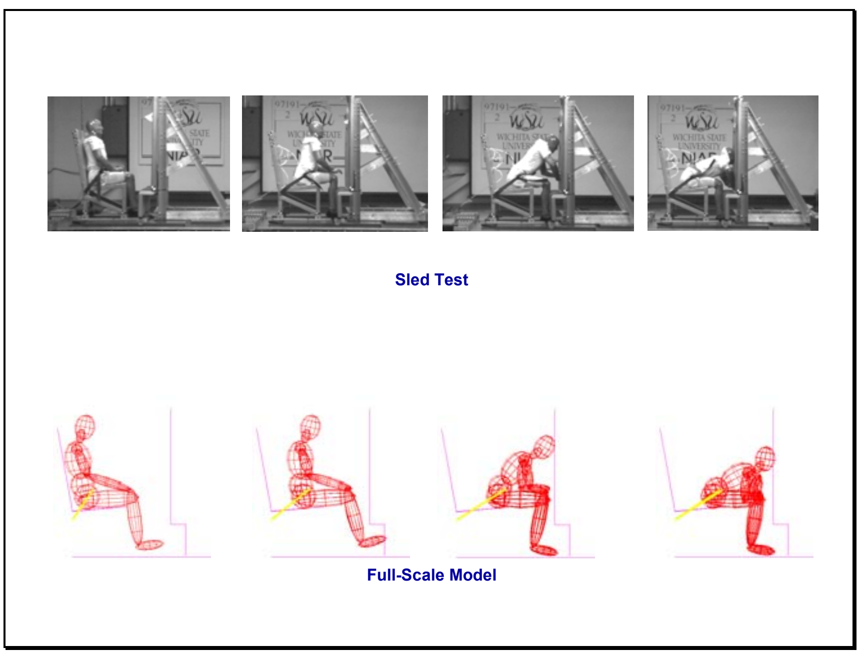

Figure 2 – Occupant Displacement, ATD versus MADYMO

Figure 3 is one more element of the HIC/occupant trajectory validation. Figure 3 compares head path in the XZ plane. This data supports the guidance provided in Section 7.1.1.1, which states that the ability of the computer model to predict occupant trajectory can be established by comparing planar space time history plots. If the applicant is required to evaluate XY plane trajectory, it too should be validated. It is not considered in this example.

Head path trajectory can be, in and of itself, a validation item. For example, if an applicant conducted a validation effort to support a claim that **no** head contact occurs, then head path is a unique validation item. However, in this example, it is used to support or verify another parameter (HIC).

The head path in the XZ plane indicates a greater travel in the Z direction for the ATD, compared to the MADYMO model. Likewise, the MADYMO model appears to travel further along the X direction than the ATD. This is explained by noting that the head paths do not diverge until contact with the glareshield. Correlating post-impact trajectory is difficult and can often be ignored during the validation process.

In general, it is appropriate to ask the applicant to explain discrepancies and to present data to defend these explanations. This is not the same as allowing the applicant to rationalize the differences. An explanation can be supported with data. A rationalization cannot usually stand to this type of scrutiny.

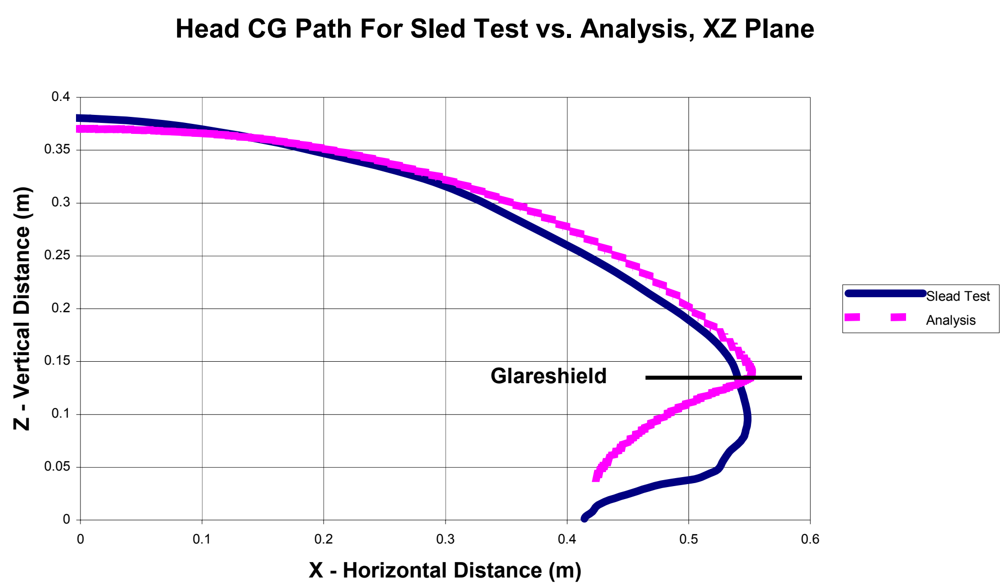

Figure 3 – Comparison of Head Path

The goal of this particular example is to validate HIC predictions. We are provided data to compare the test generated HIC to the analytical prediction. Figure 4 presents comparisons for the Head CG Resultant Acceleration time history, final HIC values, the delta t, and the average acceleration.

As explained in 7.1.1.4, it is unlikely that tight correlation will exist between the analytical head deceleration time history function and the test generated head deceleration time history function. However, there are other parameters that should indicate correlation between test and analysis.

For example, the HIC values between the test data and analysis data compare well (within the limit of 50 HIC units), with the analytical data being slightly conservative. The delta-t time and average G values are also comparable. These three items, when evaluated collectively, suggest the ability of the computer model to perform and predict HIC values.

It is worth noting that Figure 4 also illustrates the difficulty associated with validation. A cursory inspection shows that the peak test values are greater than the analytical peaks. It is not clear, however, if this is real data or a data spike (noise). Therefore, as indicated in the previous paragraph, it may be necessary to evaluate data in a collective manner. For this example, the maximum HIC value, the average G value, and delta-t were used to assess the analysis.

If an ACO engineer still doubted the accuracy of the model, then the applicant should offer further explanation on the items of concern. For this particular example, the ACO engineer may ask for a comparison between test data and analytical predictions for the head impact velocity and head impact angle, which also influence HIC values.

In addition, the ACO engineer may ask for modeling details to help explain the differences in the head acceleration time-history curves. This gives the applicant the opportunity to explain their modeling techniques, assumptions used during modeling, and any limitations associated with those assumptions. The ACO engineer and the applicant would make use of engineering judgment at this point to determine the capability of the model to predict HIC. As discussed numerous times in the AC, engineering judgment is an integral part of model validation.

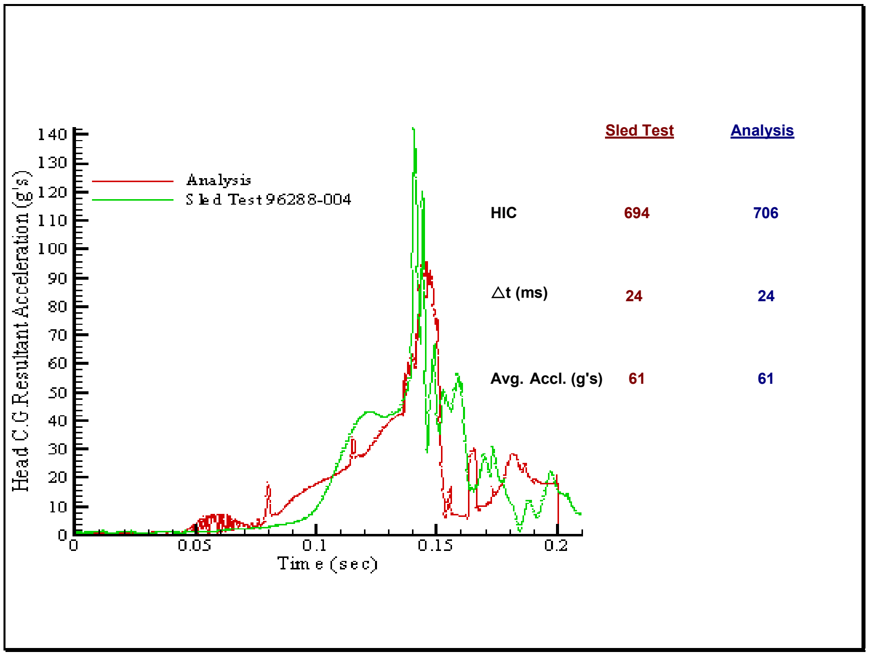

Figure 4 – Test and Analytical HIC Values

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