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# Using ATB Under the HVE Environment

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ABSTRACT

The Articulated Total Body (ATB) program has been used to study occupant kinematics in motor vehicle collisions for several years. The ATB model is a complex 3-dimensional lumped-mass model available for many different computer systems, including the personal computer, and requires formatted data files for the data input. A new version of this model, Graphical Articulated Total Body (GATB), has been developed to be operated under the HVE (Human, Vehicle, Environment) computer environment. The GATB program uses the graphical system built into HVE. This aids in set up and execution of the model to study human occupants in motor vehicle collisions. This paper addresses the integration of the ATB model with the HVE environment and includes a validation study comparing the GATB results to those of the ATB program.

## INTRODUCTION

The ATB (Articulated Total Body) computer model has been used in the collision reconstruction field for many years.[1,2,3,4]* Using the model to analyze occupant behavior in a motor vehicle collision requires a great deal of set up time. The user must assemble an input data file, see Figure 1, which is difficult to initially put together and even more difficult to edit or modify.

An ATB input data file consists of several sections, or groups, of "cards" defining the different data required. For instance, the A-cards define the simulation time parameters and control options, the B-cards define the occupant mass segments and joint parameters, the C-cards define the vehicle motion, etc. Most users start with an existing file and modify it to include the specific data for the intended run. There are also utility programs available to aid in setting up the initial data file.[2] These methods are workable, but can be tedious, particularly when editing a file.

The ATB program is a very general multiple-mass collision model and has many options available.[5] Thus, even the most seasoned ATB user will usually have the program manual nearby as the input file is modified, to ensure that the data being changed does what the user intends.

Output from the ATB model consists of tabular time-history data, often a hundred pages or more in length. There are also separate programs available to view the output graphically. These programs produce 3-dimensional graphics by representing the occupant as a series of topographical lines and the interior as flat panels.[2]

A version of the ATB model has been implemented for the HVE environment. The HVE environment is a graphical environment which includes multiple databases (Figure 2), editors (Figure 3), and visualization (animation) capabilities, as shown in Figure 4.[6,7,8,9]

*Numbers in brackets designate references found at the end of the paper.

```
JUL 28, 1996    0    0      0.0                                          CARD A1
DRIVER OF CHEVROLET CAVALIER, REAR IMPACT COLLISION
VEHICLE MOTION FROM EDSMAC COLLISION SIMULATION
INCH LBS SEC           .0            .0      386.088                     CARD A3
  4   4  .00500  .00050  .00100.0000625                                  CARD A4
 2 0 2 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1CARD A5
   17    16          FEMALE 61 IN 200 LBS                                CARD B.1
 LT  1 36.201.71531.64552.6393 5.738 8.490 5.281 0.383 0.000 2.027   1   CARD B.2
             0.00  0.00   0.0
 CT  2 11.140.42800.34290.7105 4.735 6.182 3.194-0.316 0.000-0.124   1   CARD B.2
             0.00  0.00   0.0
 UT  3 51.523.87882.96632.9742 6.212 6.845 5.400 1.553 0.000-0.636   1   CARD B.2
             0.00 19.10   0.0
 N   4  1.520.00990.01200.0169 2.383 2.383 3.587 0.681 0.000 1.220   1   CARD B.2
             0.00  0.00   0.0
 H   5  8.480.16880.18690.1277 3.699 3.006 5.535 0.740 0.000 0.000   1   CARD B.2
             0.00 42.20   0.0
 RUL 6 27.600.16440.16030.0144 4.219 4.21911.016 0.000-0.307 0.692   1   CARD B.2
            13.00  8.20   2.3
 RLL 7  8.470.42160.41740.0783 2.677 2.677 9.977 0.000-1.154 1.109   1   CARD B.2
             0.00  0.00   0.0
 RF  8  1.450.02270.02150.0051 1.275 1.844 4.775 0.113-0.584 0.000   1   CARD B.2
             2.00 -6.20 -16.6
 LUL 9 27.600.16440.16030.0144 4.219 4.21911.016 0.000 0.307 0.692   1   CARD B.2
           -13.00  8.20  -2.3
 LLL A  8.470.42160.41740.0783 2.677 2.677 9.977 0.000 1.154 1.109   1   CARD B.2
             0.00  0.00   0.0
```

**Figure 1- Partial listing of the numerical format in an ATB input data file.**

The new version of the ATB model, known as GATB for Graphical ATB, allows the user to set up, edit and run the ATB model in a graphical environment. In addition, GATB produces scientific visualizations quickly enough to be used as part of the analysis, not just as a presentation tool.

Human - contains human data / parameters for studying pedestrians and occupants.

Vehicle - contains data / parameters for automobiles, pickup trucks, vans, large trucks, trailers, etc.

Vehicle materials - contains data / parameters for the contact panels (interior and exterior) for the vehicles.

Tires - contains data / parameters for all the vehicle tires.

Environment - contains data for the roadway geometry, atmosphere, lighting, etc.

**Figure 2 - Partial listing of databases in HVE.**

This paper discusses the basic techniques used in implementing the GATB model, the capabilities of the model, and the results of a validation study comparing GATB to the standard ATB model.

## IMPLEMENTING GATB

ONE OF THE MOST IMPORTANT considerations in implementing GATB was maintaining complete

Human - for editing human data / parameters.

Vehicle - for editing vehicle and tire data / parameters, restraints, contact panels, etc.

Environment - for editing roadway geometry, atmosphere, lighting, etc.

Event - for setting up and executing simulations, analysis programs, entering damage profiles, collision pulse data, etc.

Playback - for generating printed output, graphical images, visualizations, etc.

**Figure 3 - Partial listing of the editors in HVE.**

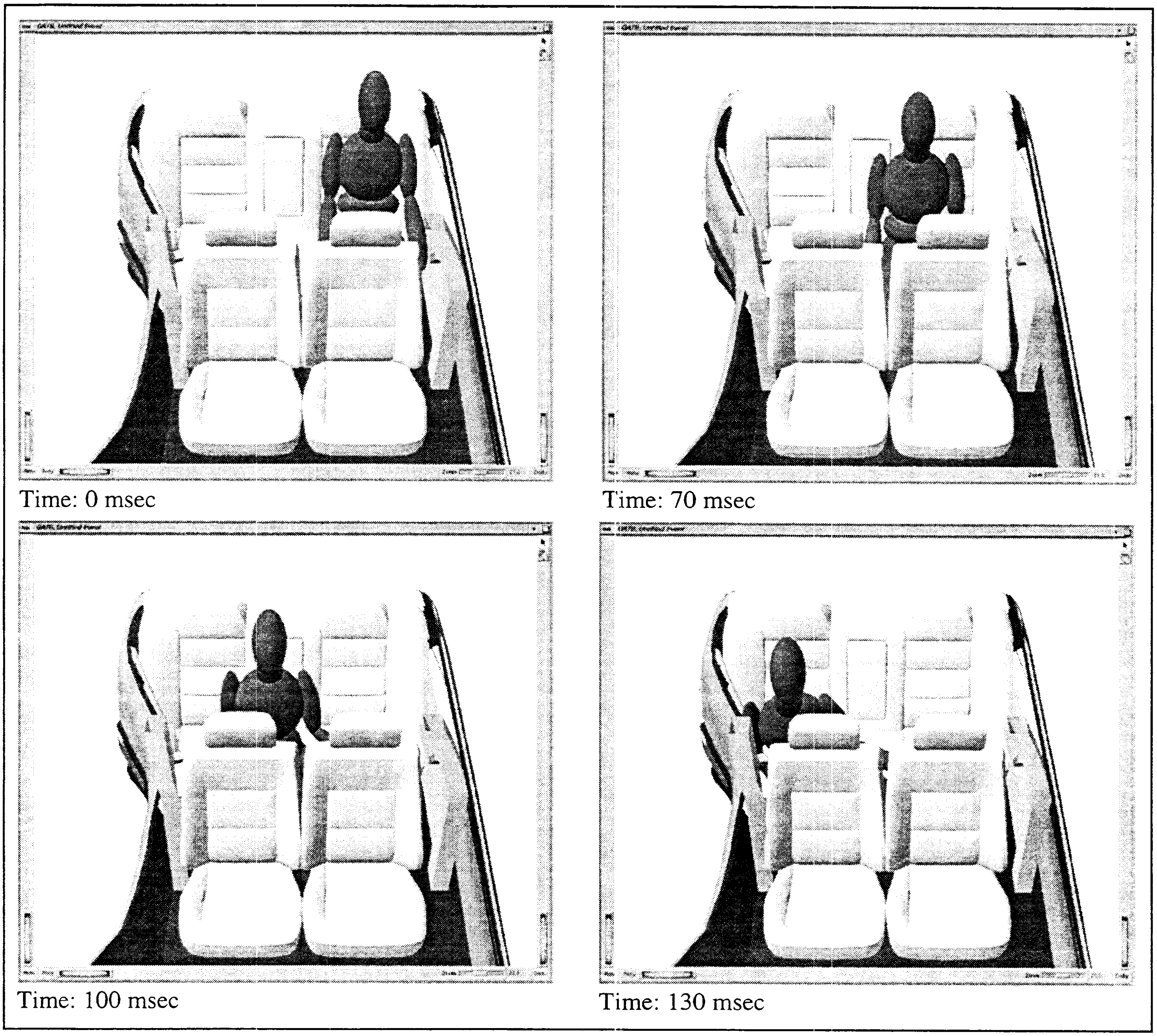


**Figure 4 - Graphical output from GATB, with a detailed vehicle interior and right side damage shown.**

cross-compatibility with the standard version of ATB. In other words, it is important that a user have the ability to take the GATB run and easily re-run the data on the standard ATB program. This is accomplished by maintaining an input file, created by HVE, that can be used as input to the standard ATB program. When the user starts the GATB program, the program assembles all the data from HVE and creates this data file (named gatb.ain). The GATB program then reads this data file just as ATB would. This data file can easily be used as input to the standard ATB program.

```
INCH LBS SEC          .0          .0      386.400                        CARD A3
   4 100 0.00200  .00050  .00100.0000625                                 CARD A4
 1 010 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1CARD A5
```

**Figure 5 - Listing of the default A-cards, showing the standard time-steps, etc.**

The GATB model is fully compatible with the ATB version V.1 model. As the GATB model was developed, there were certain assumptions made as to which default options would be utilized by the user. For instance, the time steps and other A-cards are initially set up as shown in Figure 5. The total number of iterations for the run is calculated based upon the default time-step of 2 msec and the maximum simulation time, entered in HVE. All of these default values are listed in Table 1.

## Table 1

Listing of GATB default parameters.

| Variable | Value |
|---|---|
| NDINT | 4 |
| NSTEPS | Calculated |
| DT | 0.002 sec |
| HO | 0.0005 sec |
| HMAX | 0.001 sec |
| HMIN | 0.0000625 sec |

EACH OCCUPANT in the GATB model is made up of the standard 15 segments, shown in Figure 6. The HVE human database is made up of several "standard" size and weight percentile combinations that are available to the user, as shown in Table 2.

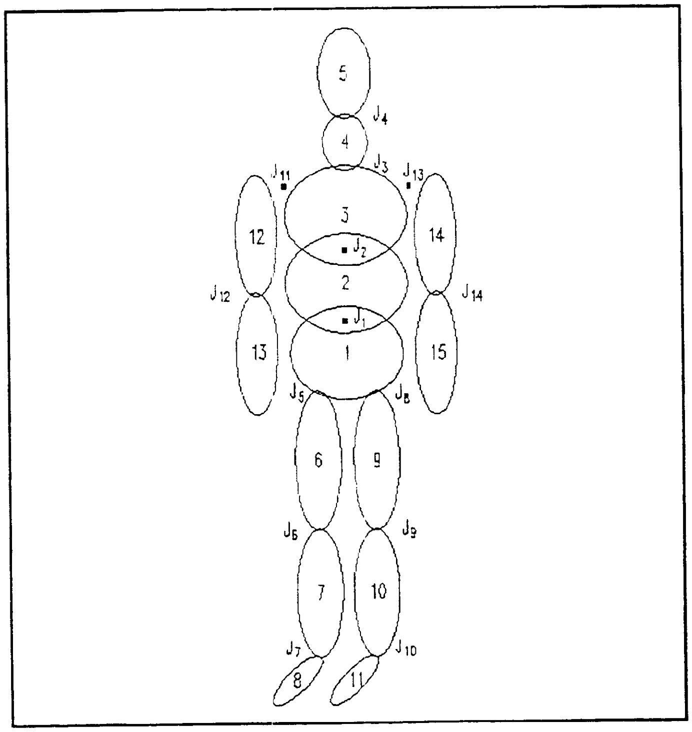


**Figure 6 - Standard 15-segment model used in GATB.**

## Table 2

Parameters defining HVE human.

Gender: Female, Male

Age: Adult, 12 yrs, 9 yrs, 3 yrs

Weight: 2.5%, 50%, 97.5 %

Height: 2.5%, 5%, 50%, 95%, 97.5%

These data are produced from the GEBOD IV program.[10] For example, a user can specify an adult female, 50 percentile in weight and 95 percentile in height. Users can easily modify any of the data for a specific human by using the Human Editor, as shown in Figure 7.

THE COLLISION PULSE in GATB is an acceleration pulse that can be entered directly in the HVE Event Editor or it can be obtained from any of the existing HVE events that generate a collision pulse. The HVE environment makes all collision pulse data available for the selected vehicle. For example, if there is an EDSMAC[11] event which models the collision being studied then one of the options in the Event Editor is to obtain the collision pulse directly from the EDSMAC model, as shown in Figure 8.

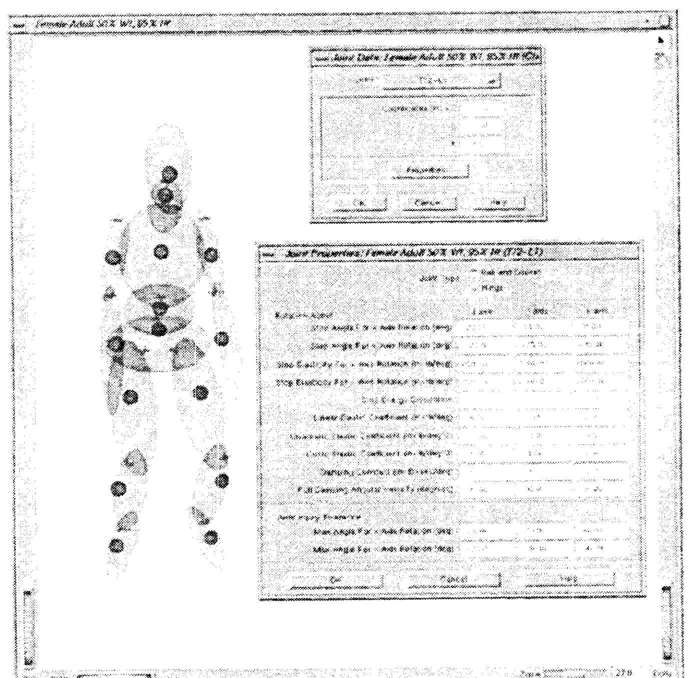

**Figure 7 - Example of the HVE Human Editor.**

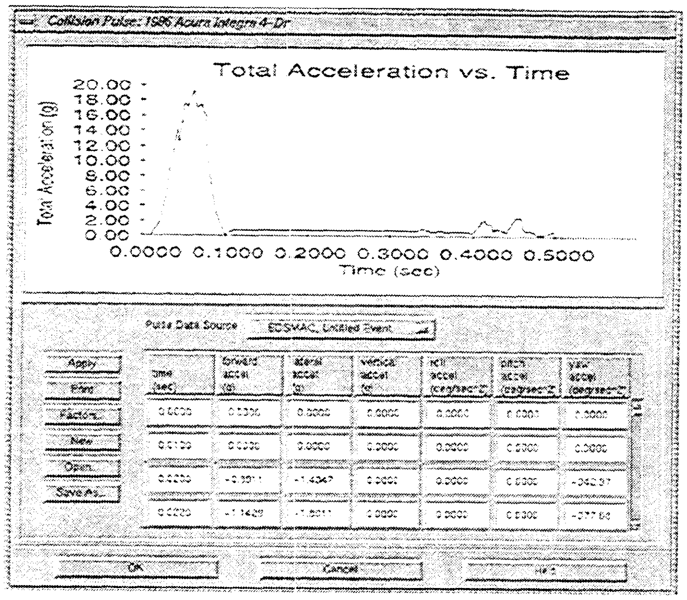


**Figure 8 - Using an EDSMAC collision pulse in the GATB program.**

The GATB program uses a 2nd order spline fit to generate the acceleration pulse. In the HVE environment, the collision pulse is directly connected to the vehicle. In this way, as the collision analysis is changed it is simple to update the acceleration pulse used in GATB. The acceleration pulse contains X, Y, Z, Yaw, Pitch, and Roll data.

CONTACT PANELS are defined and edited in the HVE Vehicle Editor, shown in Figure 9. One of the most convenient uses of HVE and GATB is the ability to show detailed vehicle interiors. This aids in quickly visualizing where the occupant is in relation to the vehicle interior surfaces and how the occupant is moving. Figure 10 shows an example of a detailed vehicle interior, while Figure 9 shows plain flat contact panels. The GATB model uses the flat contact panel data for occupant contacts. The detailed vehicle mesh is only used for generating the computer images, the occupant does not interact with the detailed mesh.

The contact panels are defined by entering three (3) distinctive points that define three (3) corners of the contact panel, entered in a counterclockwise order. The GATB program uses this information to produce the D-cards for the input data file. The order is changed according to the ATB input order such that the cross-product of P1P2 X P1P3 (P1P2 is the vector from point 1 to point 2) results in a vector pointing out of the "positive" side of the contact panel. [5]

There are several parameters required by the GATB program to define the contacts between a human segment and a contact panel, such as force-deflection curves, energy absorption coefficients (R-factor), permanent deflection coefficient (G-factor), etc. The HVE vehicle materials database contains the contact panel data shown in Table 3.

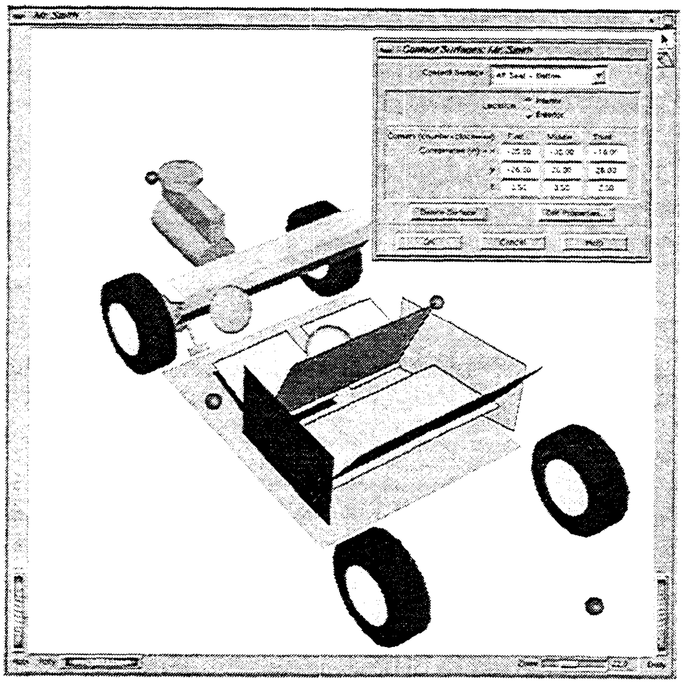

**Figure 9 - Editing the vehicle contact panels, when the panels are visible.**

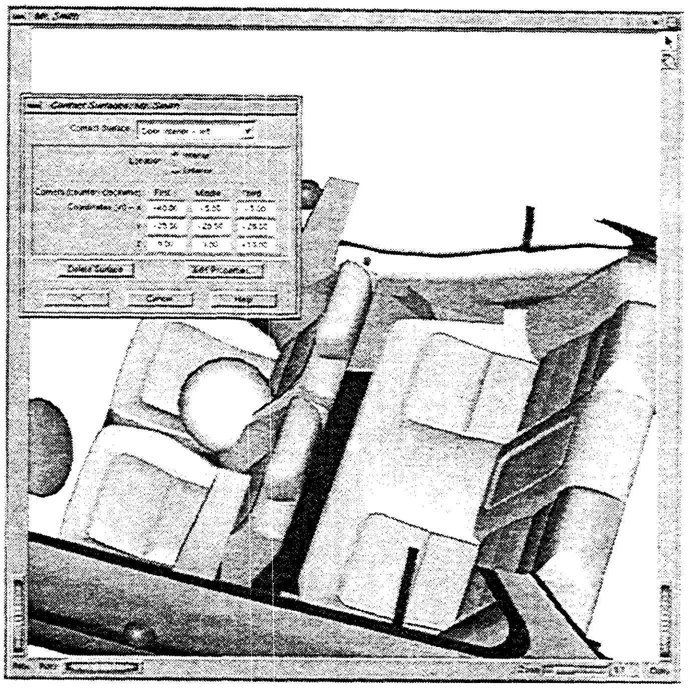

**Figure 10 - Detailed vehicle interior with the contact panels not shown.**

Force deflection data are entered as 3rd order polynomials. The R-factor and G-factor are calculated from the data in the HVE vehicle materials database. Using the "maximum force" parameter, a deflection-at-maximum-force is calculated. Using this deflection along with the "unloading slope", entered by the user, the permanent deflection (G-factor) is determined. The R-factor is determined by integrating the force-deflection curve and the unloading curve and calculating the ratio of the two.

**Table 3**

List of parameters in materials database

- Linear stiffness (lb/in)
- Quadratic stiffness (lb/in$^2$)
- Cubic stiffness (lb/in$^3$)
- Damping constant (lb-sec/in)
- Maximum penetration (in)
- Maximum force (lb)
- Edge constant
- Unloading slope (lb/in)

The other required data are simple constants, such as the coefficient of friction, edge-effect parameter, etc. As the various functions are assembled by the GATB program, an attempt is made to avoid duplicate functions. Thus, if three (3) different contact panels happen to have the same force-deflection curve, only one of these functions is used in the input data file.

EACH HUMAN-PANEL PAIR could be checked to see if there is contact occurring, but this would slow the performance of the program considerably. For instance, is it not expected that the left foot will contact the roof in a front impact. By using the "allowed contacts" dialog, shown in Figure 11, the GATB program only checks the specified contacts.

The term "allowed contacts" implies that the user is in some way manipulating which panels will be "allowed" to contact the human. This does not occur, in fact the program is a simulation and there is no direct control over the resultant motion of the humans. The "allowed contacts" simply limits when contact is checked for by the program.

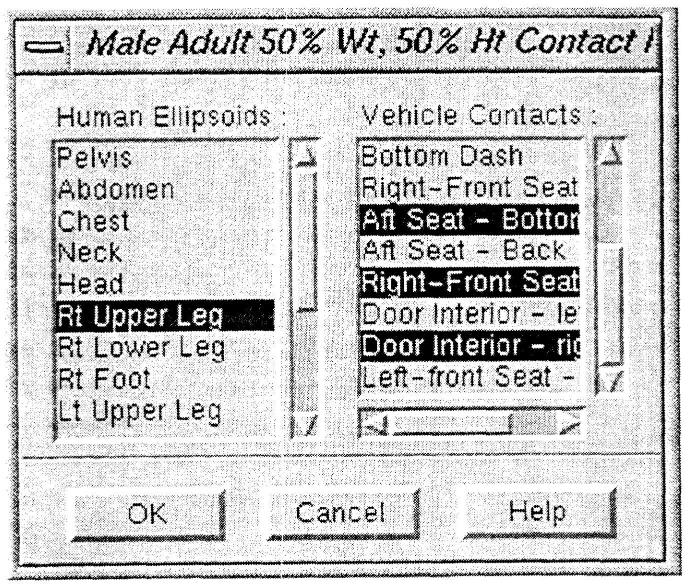


**Figure 11 - List of "allowed" contacts in GATB.**

For instance, if the head approaches the windshield panel and this contact pair is not specified then the head will simply pass through the panel with no force being applied. The allowed contacts are specified in the Event Editor while a human is selected in the current objects list (see Figure 11).

BASIC FEATURES

GATB IS DESIGNED to offer a fully graphical user interface. Using HVE technology, GATB allows the user to graphically select the humans to be modeled, and allows for a very intuitive method of editing the parameters. For example, to edit the parameters for the right upper leg, the user clicks the mouse on the right upper leg.

The program makes use of the power behind the HVE environment by allowing users to access the databases maintained by HVE and by making it extremely easy to create new entries in the databases. For example, if the user is studying a specific car and the car does not happen to be in the HVE database, it can easily be added. The HVE environment also allows access to many types of physics packages such as EDSMAC[11] (a vehicle collision model), EDVSM[12] (a vehicle handling/rollover model), etc.

ONE OF THE MOST IMPORTANT benefits to using GATB is the ability to visualize the results of the simulation quickly and accurately. The HVE tools allow the user to "see" the occupant interacting with the vehicle interior, and the interior can be made to look like the real interior and not simple flat panels, shown in Figure 4. Visualization becomes part of the analysis process, not just the presentation process.

## VALIDATION

VALIDATING GATB REQUIRED three separate tasks. The first task was to confirm that data being selected by the user was actually the data being used by GATB. The second task was to confirm that the data being presented by HVE to the user as results were, in fact, the actual calculated results. Finally, the third task involved comparing the results of GATB to a standard version of ATB. The ATB program has previously been validated so it is used as the basis of comparison. This validation effort is not concerned with comparing GATB or ATB to real collisions, staged collisions, or other laboratory tests. The only goal of this validation effort is to confirm that someone using GATB will get the same result as someone using ATB.

A side impact involving a passenger car was selected for the validation effort. The collision was first modeled with the EDSMAC program and then the collision pulse was used in the GATB model. In order to confirm that the collision pulse was being accurately passed through HVE, the pulse was compared to the printed tables produced by EDSMAC.

The contact panels were given default values for

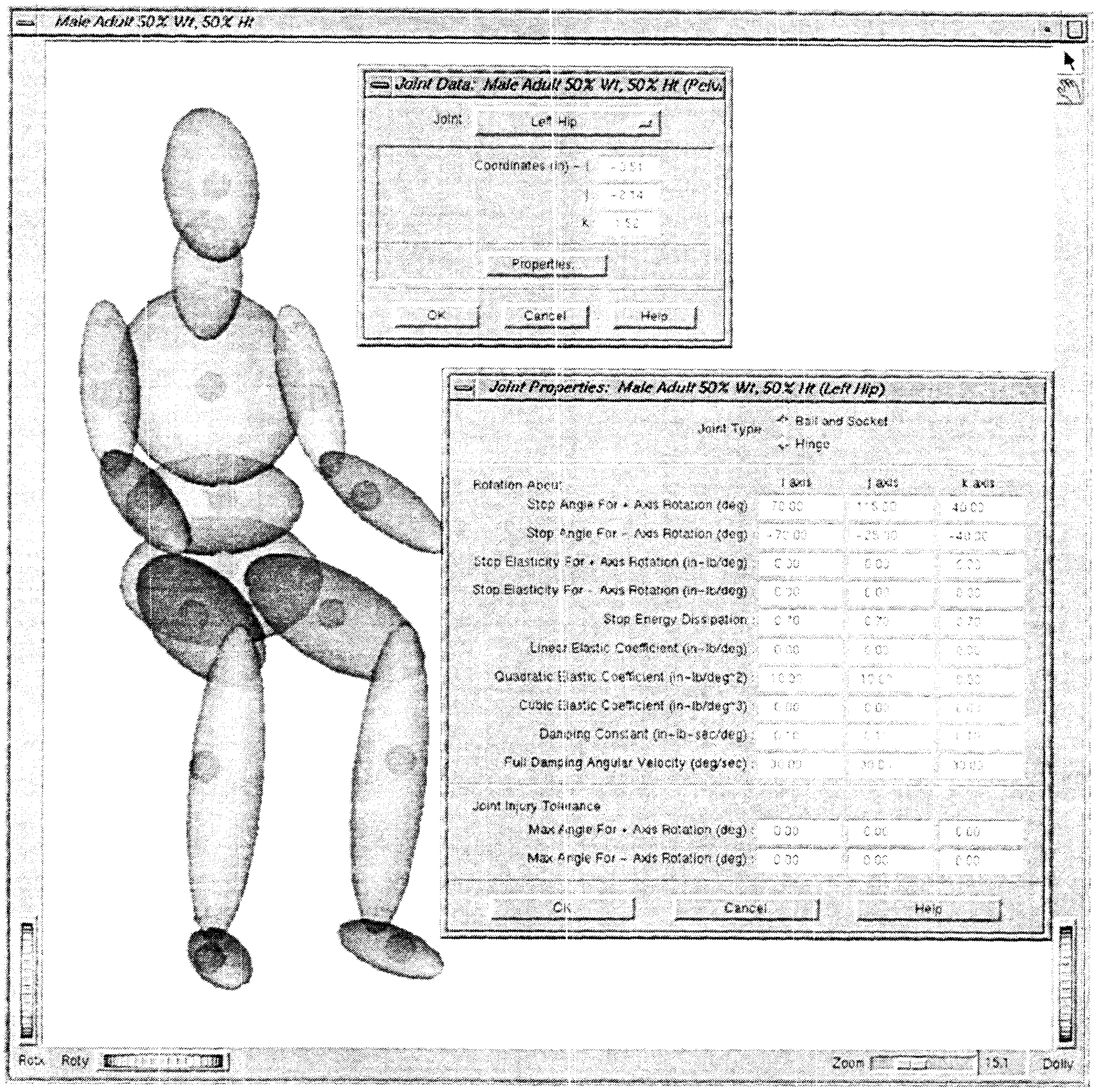


**Figure 12 - Joint parameter data available in the Human Editor in HVE.**

force-deflection curves for the appropriate surface, such as seat cushion, dash panel, etc. The detailed analysis of the contact panel parameters in the HVE databases are beyond the scope of this validation study. However, during the validation study the data used was checked for values consistent with data used in other studies.[13]

IN ORDER TO CONFIRM that the user-selected data was in fact used by GATB, every value in GATB input file was tracked back to the source dialog box. For instance, the segment mass and moments of inertia in the input file B-cards were compared to the dialog boxes in the Human Editor by clicking the mouse on the segments, one at a time, and comparing the data in the dialog box with the data in the input file, as shown in Figure 12. The GATB text output is shown in Figure 13.

GATB PRINTS OUT the standard ATB output file (called gatb.aou) along with several other files, listed in Table 4. Output files are broken up into many smaller files to aid in transferring the data into the HVE output reports. The HVE Output Reports are generated at the end of the GATB run, when the program simply copies the different output files into the appropriate Output Report, listed in Table 4.

Every program has "program units" which define what system of measure is used within the program algorithm. More sophisticated programs then allow the user to define what system of measure is used to display the results. For example, in the program code for EDSMAC all distances are calculated in inches, but most users prefer that these distances be displayed in feet, and some users want the distances in meters. Thus, program units are important to understand when transferring data back and forth between a physics program and HVE. Program units in the HVE environment are inches, radians, pounds, and seconds. In HVE, the units displayed are chosen by the user.

The output reports are directly copied from GATB output files so very little effort was required to confirm that the output reports matched the GATB output. In order to maintain close compatibility with the standard version of ATB, these output listings are not changed from either the format displayed or the units of measure used by ATB.

The HVE Output Tracks contain all of the time-dependant data produced by GATB. Every variable passed between HVE and GATB was checked for the value as well as the units of measure. This effort also confirmed that the results of GATB were essentially the same as results from ATB.

Table 4
Listing of output files produced by GATB.

| GATB File | HVE Report | Description |
|---|---|---|
| gatb.ain | | The standard ATB input data file generated by GATB. |
| gatb.aou | Program Data | The descriptive listing of the input file. |
| gatb.hou | Injury Data | HIC and CSI data calculated by GATB. |
| gatb.mou | Messages | Messages produced by GATB during execution, same as standard ATB. |
| gatb.pou | Results | Time-history output tables produced by GATB, standard tables produced by ATB. |

SUMMARY

The GATB program was found to be completely compatible with the standard version of ATB.

GATB has proven to be much more intuitive than ATB in setting up and editing simulation models of occupants involved in motor vehicle collisions.

The direct link between GATB and the collision simulation allows fast and accurate transfer of the collision pulse data.

The GATB program produced results matching the results on the ATB program.

The graphical output produced by GATB aids in visualizing the occupant movement inside the vehicle.

Using detailed vehicle interior images aids in visualization of the occupant contact locations.

The "Key Results" window allows any of the time-dependant data to be viewed while the simulation is running. This aids in the analysis of the occupant forces, accelerations, etc.

TRADEMARKS

HVE, EDSMAC, and EDVSM are trademarks of Engineering Dynamics Corporation.

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