GENERAL DESCRIPTION OF CVS/ATB MODEL

The ATB model is a lumped mass dynamic model. The model applies Newton's laws of motion to chains of masses linked by joints (Dummy) which are in a reference frame (Vehicle) subjected to acceleration. Three dimensional (six degrees of freedom) motion of the dummy is permitted. Forces are transmitted between the masses by internal joint resistive torques. The lumped masses are influenced by external forces applied by contacts with the environment (Vehicle Surfaces, Belts, Air Bags, and Aerodynamic Forces).

A typical dummy, made up of 15 lumped masses, and 14 joints is shown in Figure 1. The lumped masses are assigned mass and inertia properties, based on the equivalent body segment. In addition, they are visually represented by ellipsoids, which also serve as contact surfaces.

The joints are defined in such a way that they can be represented as a single pin, a ball and socket, a combination of pin joints connected together (Euler joint), a slip joint, and a variety of combinations as shown in Figure 2. The torque characteristics of the joints are specified by functions of the type shown in Figure 3. Five parameters are used in the specification: The joint stop angle, the energy dissipation function, and the linear, square, and cubic torque coefficients. In addition, friction and damping can be specified. Recent improvements in joint specification, permit the restoring torque to be specified by contours on a spherical joint surface.

External forces are applied to the ellipsoids by contacts with planes or with other ellipsoids. Planes are commonly used to represent vehicle surfaces. The planes are defined by three points specified in the order shown in Figure 4. This Figure shows that the coordinates of the points are specified in order P1, P2, P3. When the right hand rule is applied, rotating P2 toward P3, the thumb should point toward the contacting ellipsoid.

The basis for determining the magnitude, direction, and location of ellipsoid to plane contact forces is shown in Figure 5. This Figure shows an ellipsoid to plane contact. The intersection of the ellipsoid and the plane forms an ellipse. A perpendicular from this intersection to the point of maximum penetration defines the penetration function "d". This "d" function used to calculate the normal and frictional force. The point of application can be specified at the ellipse center (point 1), the point of maximum penetration (point 0), or anywhere in between.

The relationship between "d" and force can be specified for each allowed contact between an ellipse and a plane, as shown in Figure 6. In addition, three other parameters can be specified: an inertia spike (which simulates breaking glass), an energy absorbing function (R), and a permanent deformation function (G). R and G are defined in Figure 6.

The harness belt is represented by a string which connects a series of points on the surface of one or more contact ellipsoids. A belt configuration is shown Figure 7. Initially, a series of belt contact points is specified for each ellipsoid. At the beginning of the simulation, the algorithm simulates stretching a string between the anchor points, and across the ellipsoids. Those points which cause the belt to kink between ellipsoids or between ellipsoids and anchor points are dropped. The others are relocated to the surface of the ellipsoid. The belt has force-strain properties specified as in Figure 6. In addition, it has friction applied at each point. Two friction coefficients are required, one along the belt, and one perpendicular to the belt. The algorithm moves points across the surface, as the simulation progresses. The point locations are determined by obtaining equilibrium in the stretched string.

PROGRAM OPERATION

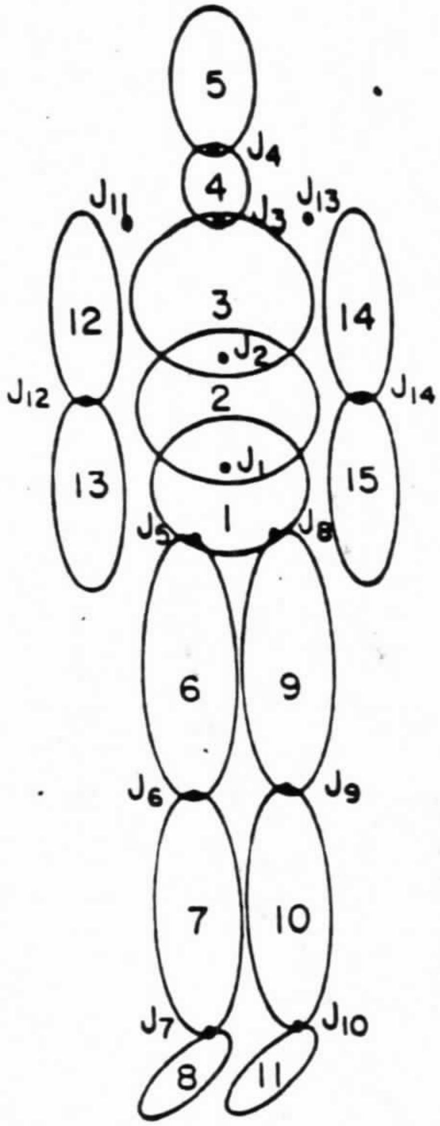
The operational configuration of the CVS/ATB Program is outlined in Figure 8. The ATB Simulation Program is shown in the central block of Figure 8. The input data set uses logical unit 5 in mainframes, while the outputs use units 1,6,8 and 9. These outputs include: (unit 1) position data for plotting the dummy movement; (unit 6) unformatted results of each calculation step; (unit 9) data for input to a plotter; (unit 6) tabular data, as specified by input. For the PC version, unit 9 is not used. The input data generally carries the file extension of .AIN or .DYN. The nature of the input data is outlined in Figure 9. Detailed descriptions of data and format may be found in the Input Data Manual.

The dummy or human model is described in the "B" Cards of the input data. Validated data sets for Hybrid II and Hybrid III dummies are available. A program named GEBOD produces data for other sizes of human models, based on scaling the height and weight specified by the user. The output of GEBOD is data in a format that can be directly inserted in the B cards to produce different size human models.

The graphical output file for plotting vehicle and dummy movements uses the extension .TP1 (or .001). The data from the .TP1 (.001) file can be post processed using the View program to show the dummy position at specified time elements. These pictures can be showed sequentially using commercially available software to produce animation.

The Table/Plot binary output file carries the extension .TP8 (or .008). This file contains the time history of selected variables at each integration step. This output is used by commercial software to develop graphical outputs of the time history of selected variables.

The program can provide either a combined file of all specified output data, or individual files of tabular data for each requested variable. The tabular data is for uniform time increments specified by the user. The combined file has an extension of .AOU (or .006). The individual files use the extension .T21; .T22; T23;....T2n. The tabular outputs are in ASCII format. They can be viewed and edited with a text editor, or analyzed and plotted with spread sheet or other commercial software.



Joint j connects segment JNT(j) with segment j+1

JNT(i)=	1	2	3	4	1	6	7	1	9	10	3	12	3	14
(i)=	1	2	3	4	5	6	7	8	9	10	11	12	13	14

Figure **2.** 15 Segment model configuration with segment and joint numbering scheme.

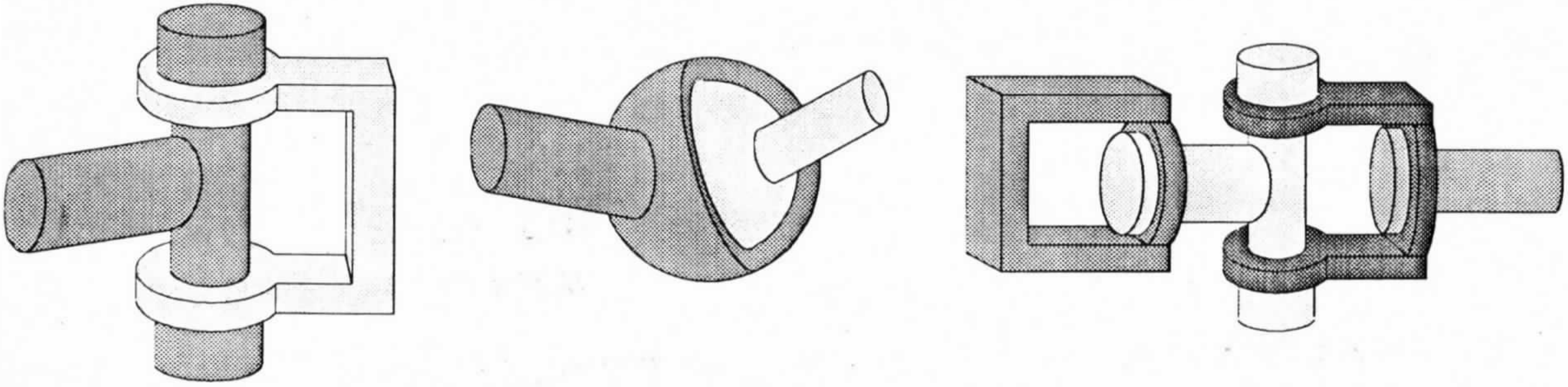
Figure 1

JOINT TYPES

Pin (Hinge)

Ball & Socket or Free

Euler



Slip With Rotation About Z Axis

Slip With Rotation About Y Axis

Slip With Complete Angular Freedom

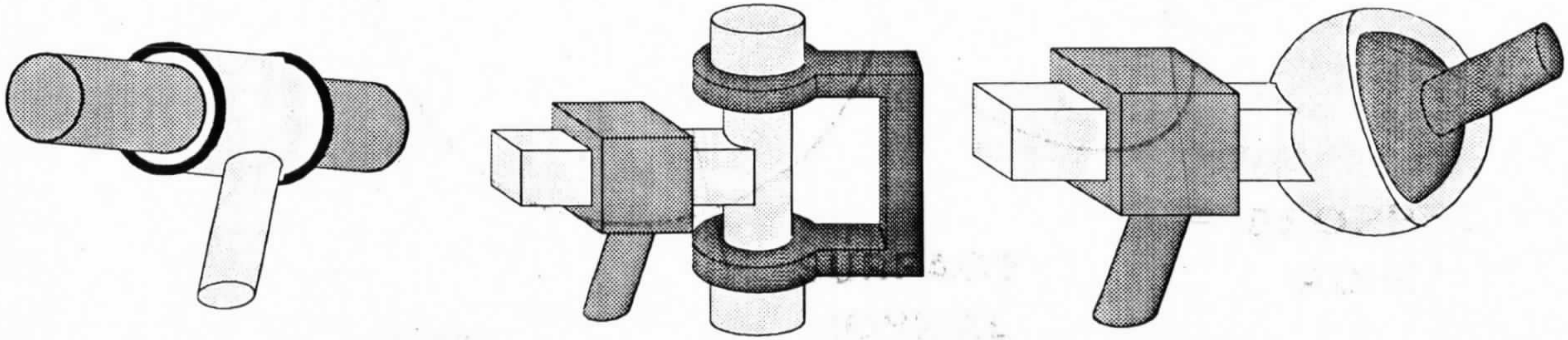


Figure 2

JOINT SPRING TORQUE

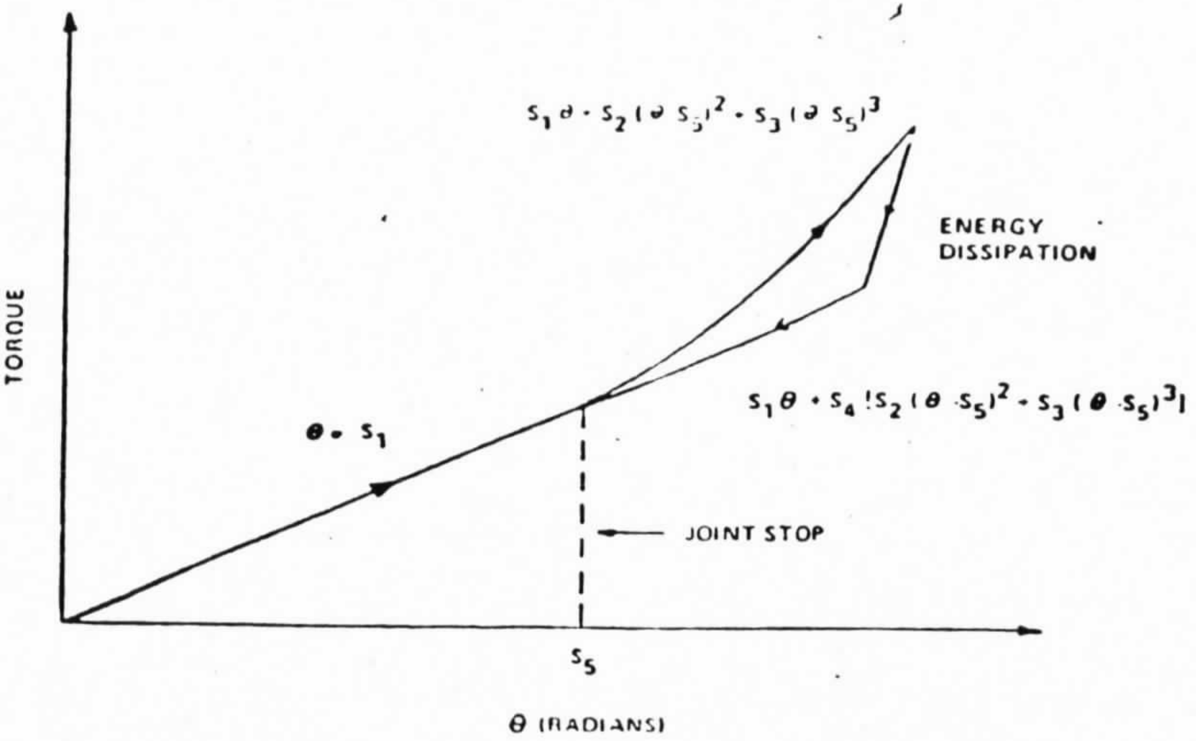


Figure 3

POSITIVE SIDE OF PLANE

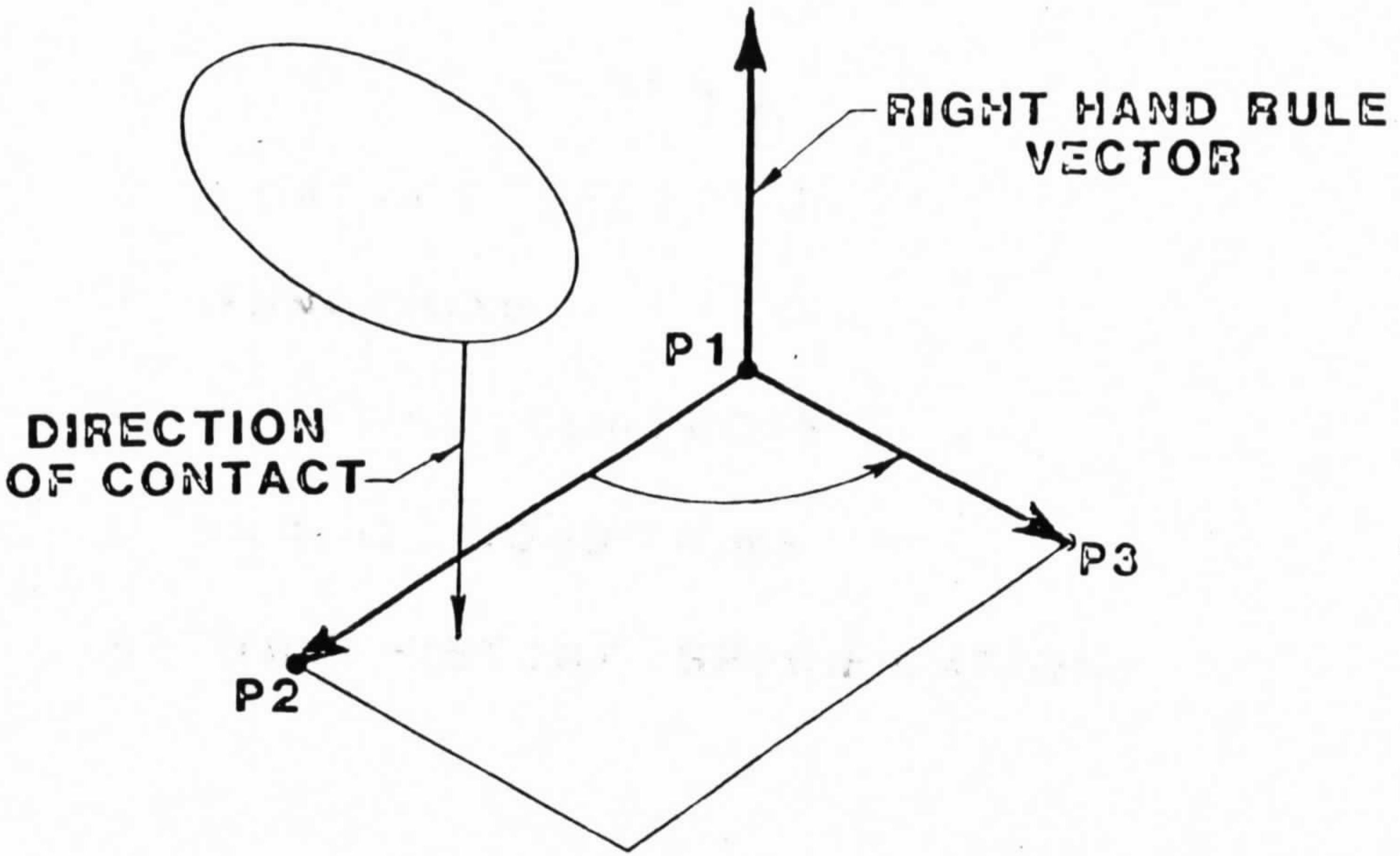


Figure 4

PLANE-SEGMENT CONTACT

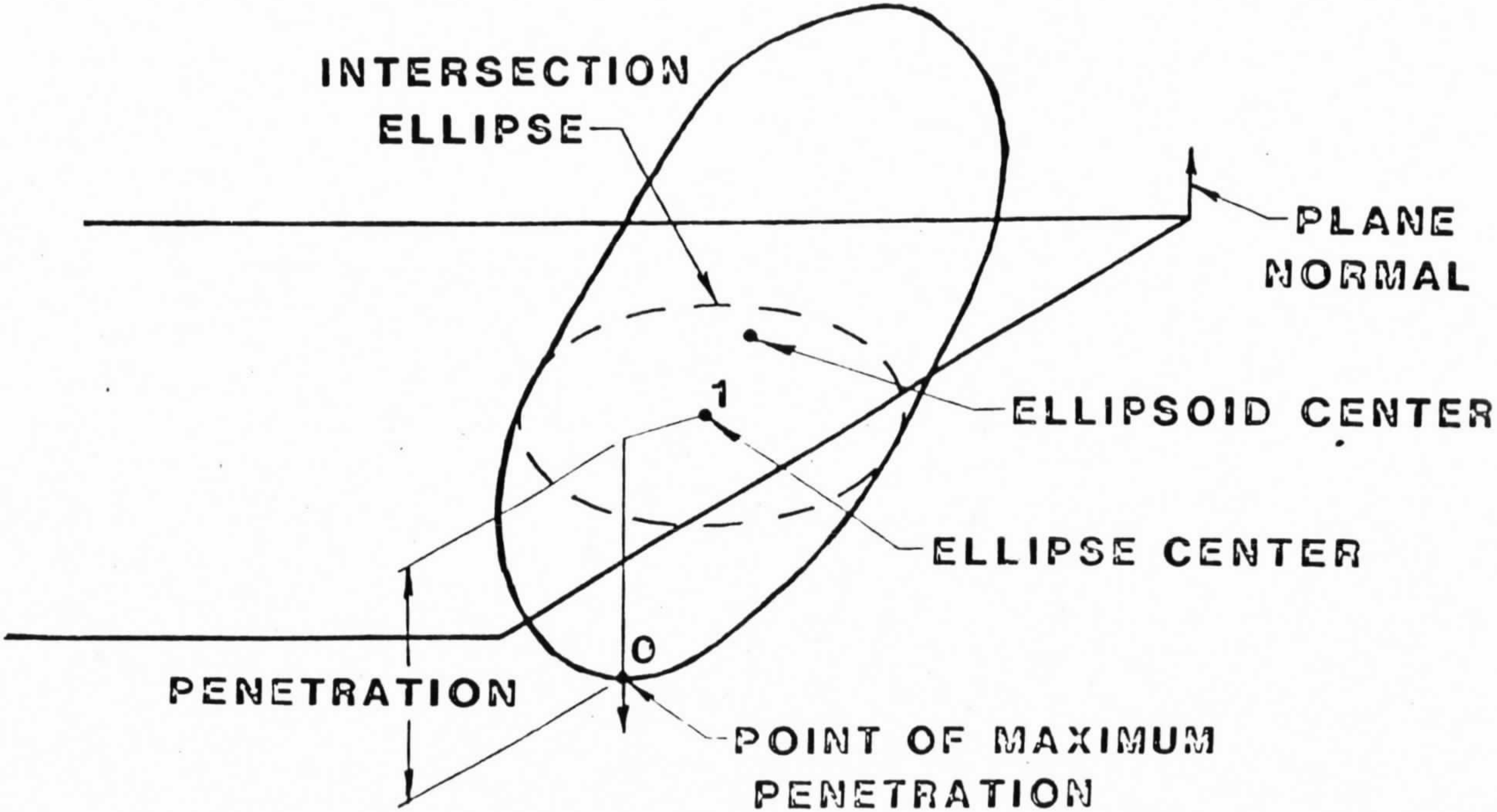


Figure 5

FORCE DEFLECTION CURVE

$$R = \frac{A_t}{A_c + A_t}$$

R = 0; all energy absorbed

$$G = \frac{d_q}{d_{ref}}$$

G = 1; no elastic response

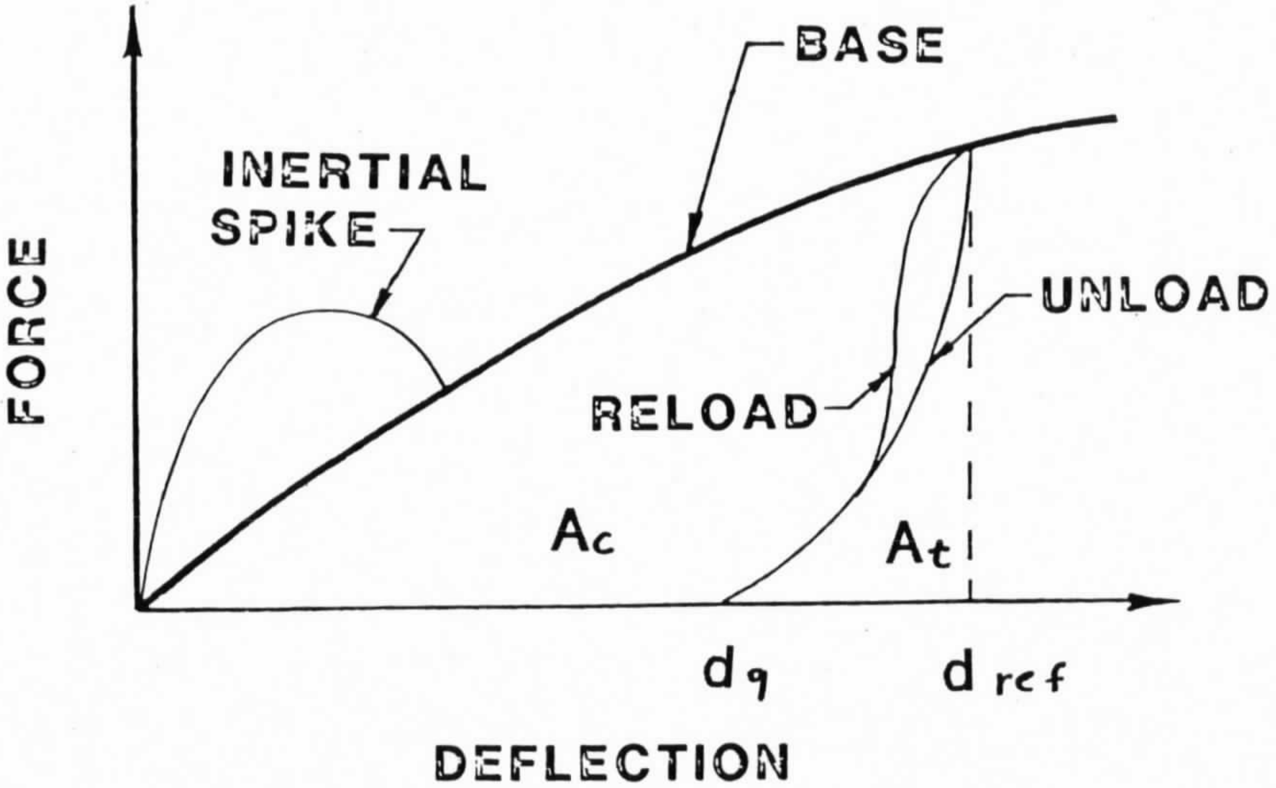


Figure 6

HARNESS BELT

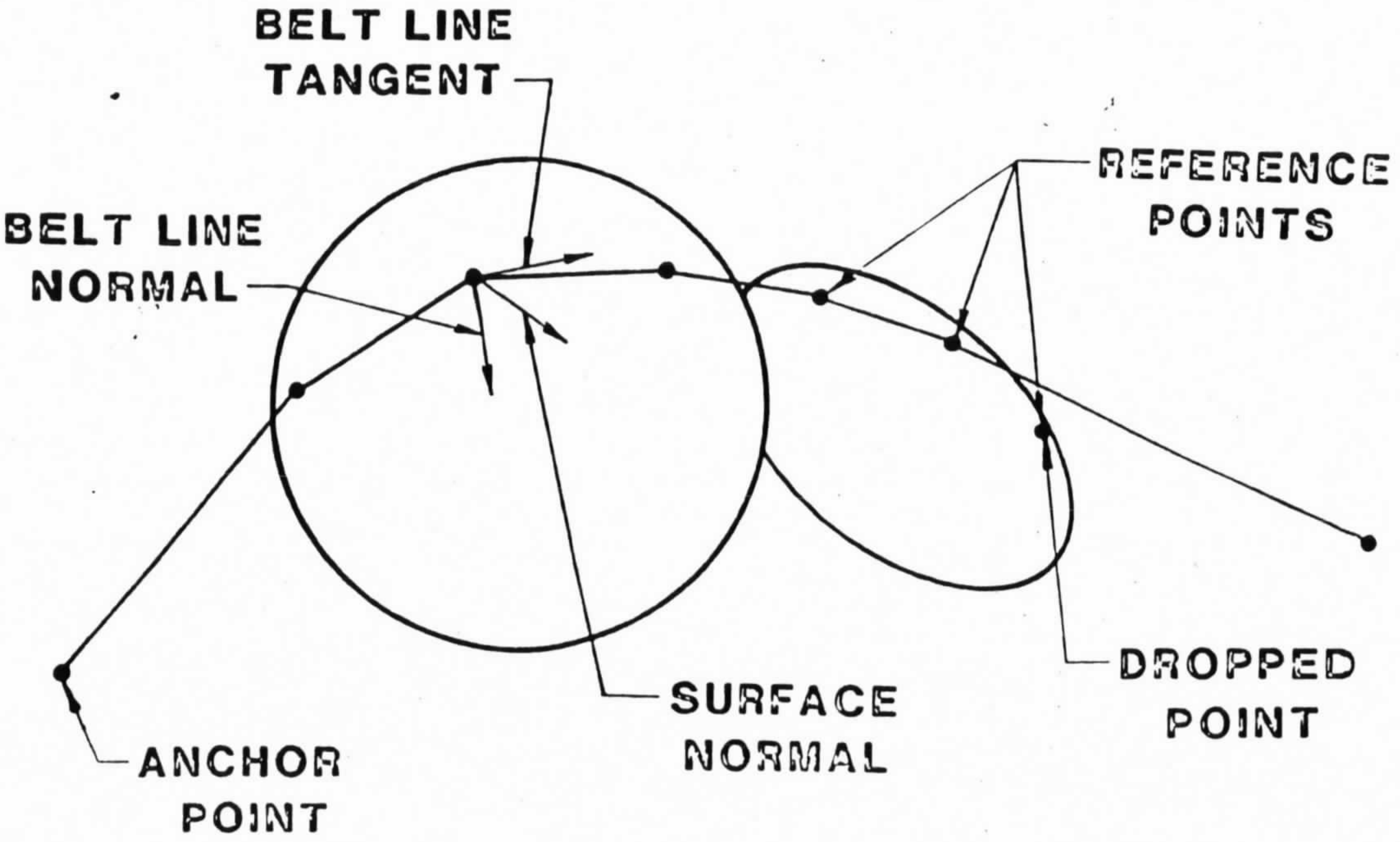


Figure 7

ATB Program Files

File & Program Interconnectivity

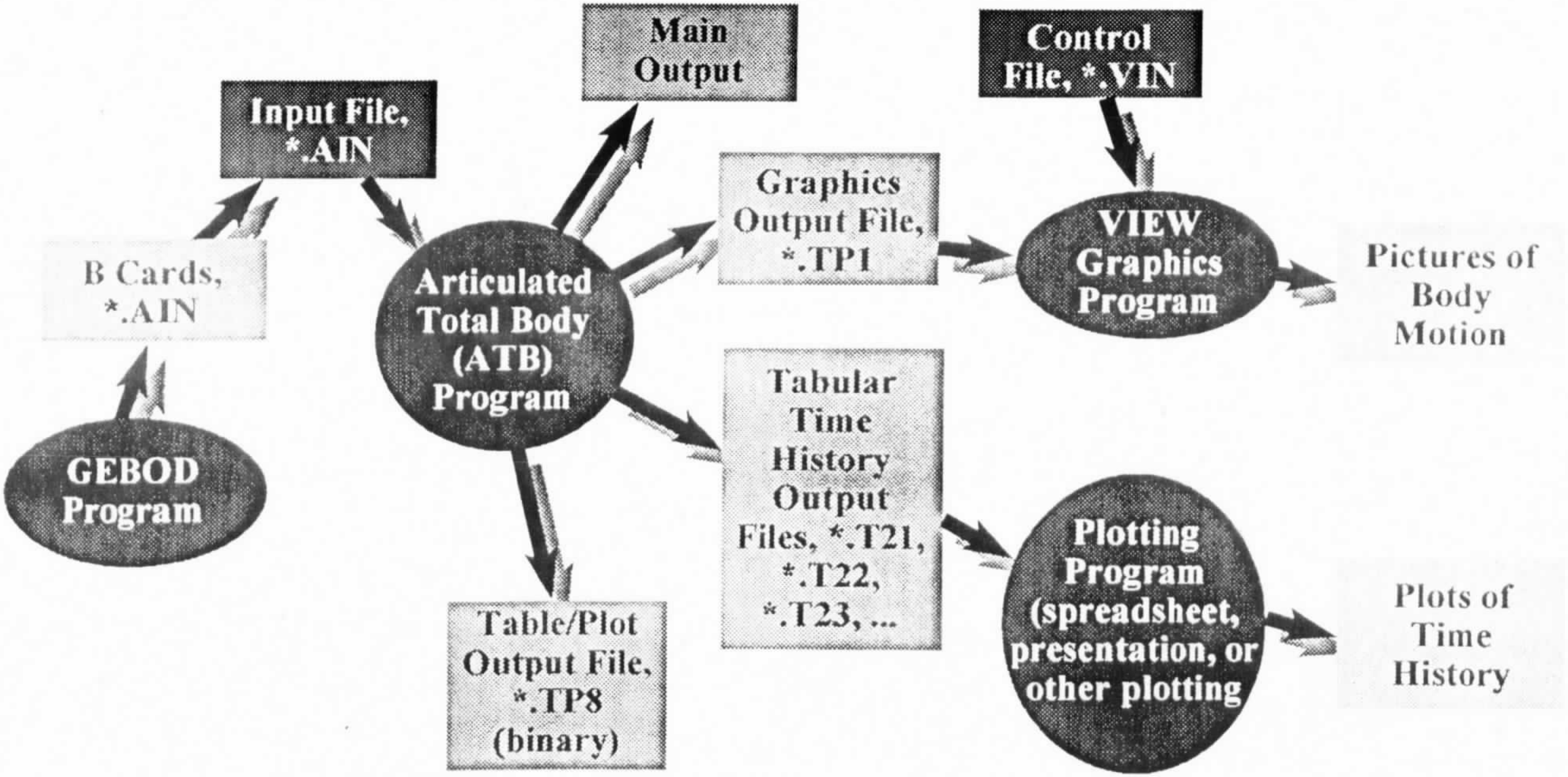


Figure 8

INPUT DATA REQUIREMENTS

A. RUN CONTROL

B. OCCUPANT DESCRIPTION

C. VEHICLE MOTION

D. CONTACT DEFINITIONS

E. FUNCTIONS

F. ALLOWED CONTACTS

G. INITIAL CONDITIONS

H. TIME HISTORY SPECIFICATIONS

Figure 9