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PHOTOMETRIC METHODS FOR THE ANALYSIS OF HUMAN KINEMATIC RESPONSES TO IMPACT ENVIRONMENTS

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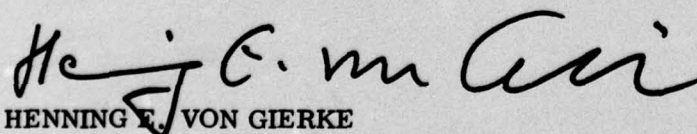
The experiments reported herein were conducted according to the "Guide for the Care and Use of Laboratory Animals," Institute of Laboratory Animal Resources, National Research Council.

The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 80-33.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER



HENNING E. VON GIERKE

Director

Biodynamics and Bioengineering Division
Aerospace Medical Research Laboratory

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report presents the processes, procedures, and techniques developed to evaluate the biodynamic response of body segments to laboratory simulations of aircraft crash and escape system environments. These simulations were conducted on the test facilities, principally the Vertical Drop Tower, the Horizontal Impulse Accelerator, and the Square Wave Impact System, located at the Aerospace Medical Research Laboratory, Impact Branch (presently known as Biomechanical Protection Branch), Wright-Patterson Air Force			

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Base, Ohio, by personnel of that Branch.

The processes described were developed to determine the time histories of coordinate locations of anthropometric points during the impact and immediately post impact phases during which the anthropometric points demonstrated planar or nonplanar motion.

Coordinate systems were defined for each of the various test facilities. Reference points were marked with fiducials and their coordinates were surveyed. Body segments of the subjects were defined by fiducials affixed to anthropometric points which were measured prior to each test. The tracks of these points were recorded on high speed (500 fps) 16mm motion picture cameras throughout each test event. The film frame coordinates of the points were digitized and electronically processed to define the time-seat coordinate position history of the motion for linear and angular displacement, velocity, and acceleration analysis.

PREFACE

The data reduction processes described herein were developed and implemented for the benefit of the Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, under Contract F33615-73-C-4157, which was partially funded by the Department of Transportation, National Highway Traffic Safety Administration, under Interagency Agreement DOT-HS-017-1-017-IA. This contract was monitored initially by Capt John T. Shaffer and later by Maj John P. Kilian of the Impact Branch (presently known as Biomechanical Protection Branch), Aerospace Medical Research Laboratory.

University of Dayton personnel who made major contributions to the program include W. J. Hovey, Project Supervisor, H. T. Mohlman and R. C. Reboulet, Research Mathematicians, and P. A. Graf, Research Technician.

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SECTION I
INTRODUCTION

Accelerations of less than one second duration occur in a variety of aerospace environments including escape system and aircraft and surface vehicle crash environments. The 6570th Aerospace Medical Research Laboratory (AMRL), Bionics and Biodynamics Division, Impact Branch (BBI) has been engaged in the conduct of experimental tests to assess the effectiveness of a variety of restraint systems and protective devices by evaluating biomechanical responses of manikins, primates, and humans to exposure to laboratory simulations of these environments. The biomechanical responses to such exposure were evaluated from strategically located and oriented monitoring devices, such as accelerometers and load cells whose outputs were recorded on magnetic tape, and high-speed motion picture cameras mounted offboard and onboard the test vehicles.

The reduction of electronically recorded data was accomplished in routine fashion using accepted methods to derive the Gadd Severity Index (SI) and/or Head Injury Criterion (HIC) from triaxial acceleration time-histories. While these are recognized indicators of the probability of injury resulting from exposure to an impact environment, they do not describe the motion of body segments other than at the point, or points monitored. To adequately describe the responsive motion of the many body segments, quantitative analysis of time displacement data of the anthropometric points defining the various body segments was required. The photometric system designed and implemented to satisfy this requirement was an integrated data acquisition, data reduction system.

Data were recorded on at least three 16mm cameras mounted offboard, or in a combination of offboard and onboard, depending on the environment being simulated. If vehicle accelerations were not to exceed a peak acceleration of 20g, two

cameras were mounted onboard the vehicle with two others mounted offboard. If peak vehicle accelerations in excess of 20g were anticipated, all cameras were mounted offboard.

When the photo instrumentation plan specified that all cameras be offboard, one or two primary data cameras (depending on the vehicle displacement during the event), were mounted normal to the plane of principal predicted motion. Two other cameras were mounted such that their optical axes were mutually perpendicular to the optical axis of the primary data camera.

When the photo instrumentation plan required the onboard/offboard combination, the two onboard cameras were located and oriented with respect to a vehicle coordinate system. The locations and orientations of these cameras varied from one test program to another depending on the size of the test subjects, type of predicted motion, etc., with principal consideration being given to the fact that all tracked points had to be observed by both cameras throughout the entire event. Of the offboard cameras one was located with its optical axis normal to the plane of principal motion and the other was located such that its optical axis was aligned parallel, or as nearly parallel as practical, to the axis of vehicle motion.

Prior to each test, fiducials, one-inch diameter circles with alternating black and yellow quadrants, were applied in accordance with the recommended practice, SAE J138 (see Figures B1 and B3). After the subject was adjusted to the initial position, the locations of the applied fiducials were measured and recorded. Reference fiducials, installed on the test fixture and surveyed at initiation of a test series, were checked prior to each test to determine if any required replacement.

The data reduction phase of the system involved digitizing the film plane coordinates of the reference fiducials and tracking fiducials, time synchronizing of film frames, calculation of conversion factors, and electronic data processing.

The projected film frame coordinates were digitized, frame by frame, using a Producers' Service Corporation model PVR film analyzer interfaced to a type 35 teletype terminal (TTY). The TTY generated a listing and punched paper tape of formatted digital values.

The digitized data were transmitted from the TTY tape reader to the computer via voice quality telephone line. The data file was edited to correct format or characters as required then saved on disk file and copied to punched cards which served as the permanent file.

The system contained three processing programs. HIFPD was used to process planar motion of points as observed by a camera mounted normal to the plane of motion. This program was initially written to yield time histories of coordinate points relative to the test vehicle and of the test vehicle relative to the range. It was shortly thereafter modified to derive relative linear and angular velocities and accelerations of the points and to prepare plots of these data.

Program SLED was designed to take data digitized from two camera views, synchronize the data timewise, and solve for the most likely points of intercept of up to four pairs of rays in a three-dimensional rectilinear coordinate system. The successful operation of this program required precise determination of the coordinates of the focal point of each camera and the azimuth, elevation, and roll angles of each of the cameras. Physical measurements of these parameters proved inadequate, thus the third program in the system, POOCH, was developed.

Program POOCH is used to derive the location and orientation of a camera and a factor including the focal length of the camera lens and the magnification of the projector. It optimizes these parameters based upon the surveyed coordinates of up to 20 reference points.

The cameras were operated at a nominal film speed of 500 frames per second, with exposure time of 0.4 msec to 0.8 msec depending upon predicted maximum velocities of tracked points and illumination intensity. Film timing and camera synchronization were provided for by the use of pulsed LED's, driven by a common pulse generator at a rate of 100 pulses per second, recorded on one side of the film just beyond the edge of the image frame. Due to the location of the LED in the film path, any given pulse was recorded 11 to 13 frames behind the coincident image frame, depending on the size of the film slack loop between the supply reel and the film gate. To minimize the error due to this variance, a synchronizing pulse, recorded on the electronic data recording system, was used to fire a strobe light, the flash of which was observed by all cameras.

SECTION 2

ANALYSIS OF DATA FROM ONE CAMERA

Horizontal Impact Facility Photometric Data Analysis Program (HIFPD) is a digital computer program developed to analyze the Hyge Impact Facility Photometric data for Impact Branch of the Biodynamics and Bionics Division of the 6570th AMRL. The program was compiled and executed on the CDC computers at Wright-Patterson Air Force Base. The standard CALCOMP plot package is used to plot data and thus must be attached to load and execute the program.

This program inputs the code sheet data and program control parameters described in Appendix A and a maximum of 300 (MAXN) frames of X, Z position data for the range, sled, hip, knee, shoulder, elbow, head point 1 and head point 2 for ITYPE = 0 or range, sled, head point 1 and head point 2 for ITYPE = 1. The data card format are also described in Appendix A.

The program computes the following four types of data as requested by the program control parameters:

(a) The input data versus frame number and the frame to frame differences are printed in counts. The range difference is subtracted from the frame to frame differences for each of the seven parameters. The only value of this difference data would be to spot errors in the data.

(b) The displacements (X and Z) of the hip, knee, shoulder, elbow, head point 1 and head point 2 relative to the sled are computed, and a moving eleven point (NP = 11) quadratic least square fit is used to smooth the data. These data are also plotted, if requested on the test setup card.

(c) The angles in radians between the shoulder and hip and between the head point 1 and head point 2 are computed using the above smoothed data. The angular velocity is computed in

radians per second using a moving 11 point quadratic fit of the angle versus time data (computes derivative of least squares equation). The angular acceleration is computed using a moving eleven point quadratic fit of the velocity versus time data. These data are also plotted as requested on the test setup card.

(d) The linear velocity and acceleration data for any combination of the eight variables are computed as requested on the test setup card. For example, the linear velocity and acceleration of the head pt 1 relative to the range, sled relative to the range or the head pt 1 relative to the sled can all be computed. Note that range relative to some other parameter cannot be computed. To compute these linear velocity and acceleration data, the X and Z displacements are computed for the variable of interest relative to the reference variable. A moving eleven point (NP = 11) quadratic least square smoothing function is applied to both the X and Z time histories. The resultant displacement in feet is computed from this smoothed data. A moving eleven point quadratic fit is applied to this resultant data to obtain the velocity in feet per second and a second eleven point quadratic fit is applied to the velocity data to obtain the acceleration data in feet per second squared and in G's. These data are printed and plotted as requested on the test setup card.

The three external files used by this program are the input file (unit 5) used to read all code sheet and data cards, the output file (unit 6) used to print all output, and TAPE7 (unit 7) used to generate the plotter tape. A magnetic tape must be requested with TAPE7 as the local file name.

The following sections of this report present a general description of the main program and all subroutines except the CALCOMP plot routines. Flow charts are also included for each routine. Appendix C contains a complete listing of the program source deck and Appendix D contains a sample run complete with all input and output data (including CALCOMP plots).

2.1 PROGRAM HIFPD

This main routine controls all input, output, and computations requested by the test setup card parameters. All subroutines required to smooth the data, compute derivatives, and plot results are called by this routine. All program diagnostics resulting from errors in setup or data card formats are printed by this routine.

Method

The program reads the code sheet control cards described in Appendix A and initializes the program print and plot control parameters. The program reads the card code, frame number, and X and Z axis data for four (ITYPE = 1) or eight (ITYPE = 0) variables (index J) for each frame (index I) in the test. Frame number and card code are checked for input errors; errors in input cause diagnostics to be printed and the test to be terminated. If more than MAXN frames are read, diagnostics are printed and all frames beyond MAXN are omitted from the analysis. The T(I) time data are computed from the frame number as follows:

$$T(I) = IFR(I)/DT$$

where IFR(I) is the frame number and DT is the number of frames per second. If setup card parameter IRX is greater than zero, the sign of all X axis data are changed. After all data are read, a summary page is printed listing all types of analyses to be computed, printed, and plotted for this test.

When program control parameter IPR \geq 0, all raw input X and Z axis data are printed in counts. The frame to frame difference data are computed and printed for all J variables from frames 1 equal 2 to N as follows:

$$XD(1) = X(I,1) - X(I-1, 1)$$

$$XD(J) = X(I,J) - X(I-1,J) - XD(1).$$

$XD(1)$ is the range difference from the I^{th} frame and $XD(J)$ is the variable minus range difference for the J^{th} variable and the I^{th} frame. The above are also computed and printed for the Z axis data.

All X and Z axis data are adjusted for shifts in the range reference reading and then converted from counts to feet:

$$H1 = X(I,1) - X(1,1)$$

$$H2 = Z(I,1) - Z(1,1)$$

$$X(I,J) = (X(I,J) - H1) * CAL(J)$$

$$Z(I,J) = (Z(I,J) - H2) * CAL(J)$$

where $CAL(J)$ is the calibration factor for the J^{th} variable ($J = 2$ to 8).

When program control parameters $IPC < 2$ or $IPA < 2$, X and Z axis motion relative to the sled are computed for variables 3 to 8 (or 7 and 8 for $ITYPE = 1$):

$$XD(I) = X(I,J) - X(I,2)$$

$$ZD(I) = Z(I,J) - Z(I,2).$$

Subroutine SM is called to compute a moving eleven point ($NP = 11$) quadratic least square fit to smooth the X and Z axis data. The smoothed data are stored in arrays $XX(I,JJ)$ and $ZZ(I,JJ)$ where $JJ = J-2$. As a result of the eleven point smoothing, five frames are lost at the beginning and end of the test data; this is true each time the data are smoothed by subroutine SM or derivatives are computed by subroutine DERIV1. If parameter $IPC < 2$, these smoothed data relative to the sled are printed; if $IPC < 1$, subroutine CPLT is called to generate a CALCOMP plot of X versus Z for all variables ($J = 3$ to 8).

The angle between the shoulder and the hip is computed for each frame using the above smooth data when program control parameter IPA < 2. The angle in radians is computed as follows:

$$HI = ZZ(I,3) - ZZ(I,1)$$

$$H2 = XX(I,3) - XX(I,1)$$

$$XD(I) = \arctan (H1/H2)$$

where index 3 is shoulder data and index 1 is hip data in the XX and ZZ arrays. Angles XD(I) are adjusted by factors of 2π to make them continuous. Subroutine DERIV1 is called to compute the angular velocity in radians per second from a moving eleven point (NP = 11) quadratic fit of the XD(I) data and angular acceleration in radians per second squared from an eleven point quadratic fit of the velocity data. The angular data are printed and, for IPA = 0, subroutine CPLT is called to generate CALCOMP plots of the angular velocity and acceleration versus time (IP = 2). All above angular data are computed in a similar manner for head point 1 minus head point 2 data (indices 5 and 6 in arrays XX and ZZ).

Parameter M contains the number of sets of linear velocity and acceleration data to be computed for one variable (array ID) relative to another (array IR). For example, if ID(1) = 3, and IR(1) = 2, then for set M = 1 the hip motion relative to the sled is computed for all available frames.

If M < 0 and IPL < 2, all data for variables J = 2 to 8 are adjusted by subtracting the initial value as follows:

$$X(I,J) = X(I,J) - X(1,J)$$

$$Z(I,J) = Z(I,J) - Z(1,J)$$

where all X and Z data have previously been converted from counts to feet. For each of the M sets the following are computed:

JD = ID(K)

JR = IR(K)

DI(I) = X(I,JD) - X(I,JR)

DC(I) = Z(I,JD) - Z(I,JR)

where K is the set index (K = 1 to M). When JR is 1 above, X(I,JR) and Z(I,JR) data are deleted, because motion relative to the range has already been removed from the data (see calibration equations). Subroutine SM is called to apply the eleven point quadratic smoothing function to the DI(I) and DC(I) displacement data; the smoothed data are stored in arrays XD(I) and ZD(I). The resultant displacement RES(I) is computed as follows:

$$RES(I) = \sqrt{XD(I)^2 + ZD(I)^2}.$$

The maximum XD(I), ZD(I) and resultant and the minimum XD(I) and ZD(I) are also determined from the above data. Subroutine DERIV1 is called to compute the velocity, VEL(I), from the resultant data and the acceleration, ACC(I), from the resultant data using eleven point quadratic smoothing functions in each case. The acceleration data are converted from feet per second squared to G's:

$$ACCG(I) = ACC(I)/32.2.$$

All the above displacement, velocity and acceleration data are printed versus time. Also, if IPL = 0, subroutine CPLT is called (IP - 3) to plot the velocity in feet per second and the acceleration in G's versus time in seconds.

After all tests are analyzed, the CALCOMP plot subroutine PLOTE is called to terminate the CALCOMP plot routines.

A flow chart for this routine is shown in Figure 1 and a sample test complete with all input and output is listed in Appendix D.

<u>Error Diagnostics:</u>	YES
<u>Subroutines Required:</u>	CPLT, DERIV1, SM, PLOTS, and PLOTE (PLOTS and PLOTE are part of the CALCOMP plot package.)
<u>COMMON Required:</u>	The COMMON variables actually used to transfer data are described in subroutine CPLT. Many of the blank COMMON variables in this routine are in COMMON only to reduce required compilation storage.
<u>Program Length:</u>	5342 ₈
<u>Labeled Common Length:</u>	23 ₈
<u>Blank Common Length:</u>	12616 ₈
<u>CM Required to Load Program:</u>	Approximately 50000 ₈

2.1.1 Subroutine CPLT (T, Y, Z, IP)

Subroutine CPLT generates a CALCOMP plot of: (a) X versus Z displacement with respect to the sled for all available parameters, (b) time versus angular velocity and acceleration, or (c) time versus linear velocity and acceleration depending on the value of parameter IP. The standard CALCOMP plot package is required to load and execute the program.

Method

For parameter IP = 1, CPLT generates one composite plot of X versus Z displacement for variable motion with respect to the sled. All X and Z scaling are set by CPLT independent of the data and are defined as follows.

- (a) The minimum X value: $XMIN = -1.4 - 2.2 * IRX$.
- (b) The minimum Z value: $MIN = 0.0$.
- (c) The X and Z increments per inch: $DX = DZ = 0.4$.
- (d) The X and Z axis lengths: $SX = SY = 10$.

The variables are defined and thus plotted (all on one graph) from indices I1 to I2 when flag ICAL(J) > 0 for J = 3 to 8. Data to be plotted are stored in blank common arrays XX and ZZ. All data are checked to be sure they are within the plot scale values; if not, they are set equal to the minimum or maximum value. Subroutines LINE and SYMBOL are called to plot the data and print the legend on the graphs.

For parameter IP = 2, CPLT generates one plot of time (T or X array) in seconds versus angular velocity (Y) in radians per second and acceleration (Z) in radians per second squared. The time scaling is determined by the program as follows:

- (a) the minimum time value (XMIN) is determined from the initial time value, X(1), adjusted to the nearest 0.01 less than X(1);

- (b) the time increment per inch, $DX = 0.02$;

- (c) The time axis length (SX) is determined from DX and the total range $X(N) - XMIN$

$$SX = \text{FLOAT}(\text{IFIX}((X(N) - XMIN)/DX) + 1).$$

The angular velocity and acceleration minimum and increment per inch scaling are set up by calling subroutine SCALE which checks the data and sets values accordingly. The velocity scale is printed on the left side of the graph and the acceleration scale on the right side. Subroutines LINE and SYMBOL are called to plot the data and print the legend on the graph.

For parameter IP = 3, CPLT generates one plot of time (T or X array) in seconds versus linear velocity (Y) in feet per second and acceleration (Z) in G's. The time scaling is

computed as per $IP = 2$ above. The velocity and acceleration are plotted using the same ordinate scale. The ordinate length SX is always 10 inches. The minimum value, $YMIN$, and the increment per inch, DY , are determined from the data. DY will always be 10, 20, or 30 depending on the total range required. If the total range is greater than 300, some of the data will be lost. All data are checked to be sure they are within the scale values; if not, they are set equal to the maximum or minimum value. Subroutine $LINE$ is called to plot the data and subroutines $SYMBOL$ and $NUMBER$ are called to print the legend on the graph.

A flow chart for this routine is shown in Figure 2 and sample graphs are shown in Appendix D.

Error Diagnostics: NONE

Subroutines Required: $AXIS$, $LINE$, $NUMBER$, $PLOT$, $SCALE$, and $SYMBOL$ (all are in the standard $CALCOMP$ plot package).

Argument List:

- T - array of time data points in velocity and acceleration plots.
- Y - array of velocity data points.
- Z - array of acceleration data points.
- IP - flag which determines the type of graph
 - 1 - composite plot of variable displacement with respect to the sled
 - 2 - angular velocity and acceleration
 - 3 - linear velocity and acceleration

Blank and Labeled COMMON Variables:

- JD - integer used to print parameter name in legend
- JR - integer used to print parameter name in legend
- N - number of data points used in velocity and acceleration plots
- NP - number of points used in least square fit

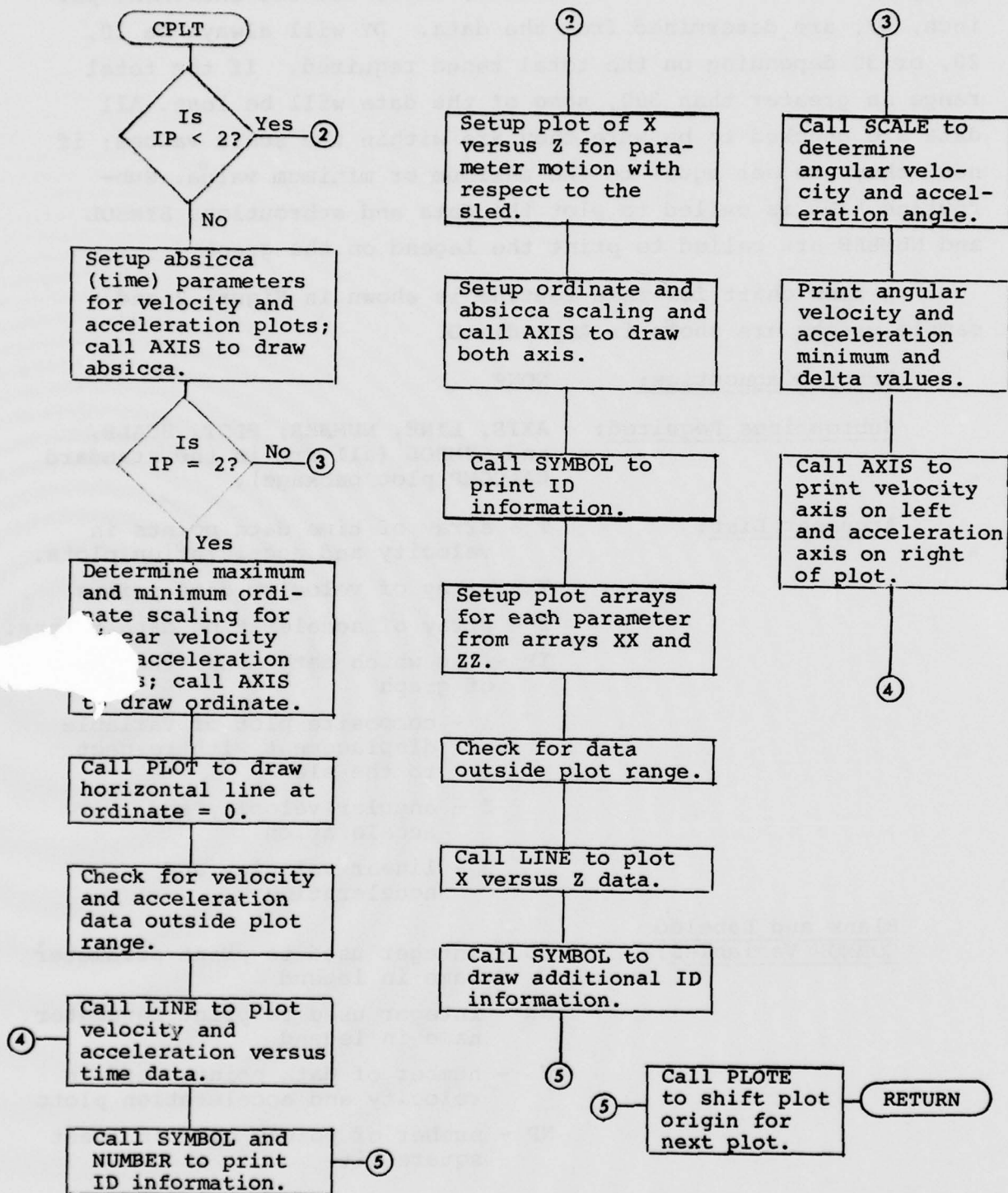


Figure 2. CPLT Flow Chart.

I1 - first point used in composite plot
 I2 - last point used in composite plot
 XX - array of X axis displacement data
 ZZ - array of Z axis displacement data
 ICAL - flag array which identifies defined data
 ICAL(J) = 0 - Jth variable undefined
 ICAL(J) = 1 - Jth variable is defined
 HEADL - array containing variable names used in legend
 TEST - test identification used in legend
 IRX - flag used to setup composite plot X axis scale

Subroutine Length: 1363₈

Labeled Common Length: 23₈

Blank Common Length: 3456₈

2.1.2 Subroutine XM(X, Y, YC, N, NP)

Subroutine SM is a smoothing routine which computes a quadratic least square fit of NP dependent variable data points (Y) to compute each smoothed data point (YC). Since NP data points are used to compute each smoothed point, M data points are lost at the beginning and end of array YC, where

$$M = (NP - 1)/2.$$

Method

The first (MM) and last (NN) array indices for which YC(I) are computed are determined as follows:

$$MM = M + 1$$

$$NN = N - M$$

where M is defined above and N is the number of original displacement points in array Y. Subroutine QLSQ is called to compute the C_1 , C_2 , and C_3 coefficients for each of the I smoothed points which are then computed as follows:

$$YC(I) = C_1 * X(I)^2 + C_2 * X(I) + C_3.$$

A flow chart for this routine is shown in Figure 3.

Error Diagnostics: NONE

Subroutines Required: QLSQ

Argument List:

- X = array of independent variable
- Y = array of dependent variable
- YC = array of smoothed dependent variable data
- N = number of original displacement versus time data points
- NP = number of points used to compute each smoothed data point

Subroutine Length: 113₈

2.1.3 Subroutine DERIV1 (X, YP, N, NP, ID)

Subroutine DERIV1 computes the derivative (YP) of the dependent variable Y. A quadratic least square fit of NP points is used to compute each derivative point; thus K points are lost at the beginning and end of array UP:

where

$$\begin{aligned} K &= M + M * ID, \\ M &= (NP - 1)/2, \\ ID &= 1 \text{ for first derivative, and} \\ ID &= 2 \text{ for second derivative.} \end{aligned}$$

Note that for ID = 1, array Y contains displacement data which have already been smoothed using a quadratic least square fit over NP points; thus, M points have already been lost from the original displacement data. For ID = 2, array Y contains first derivative (velocity) data which starts at array location $Y(2*M + 1)$.

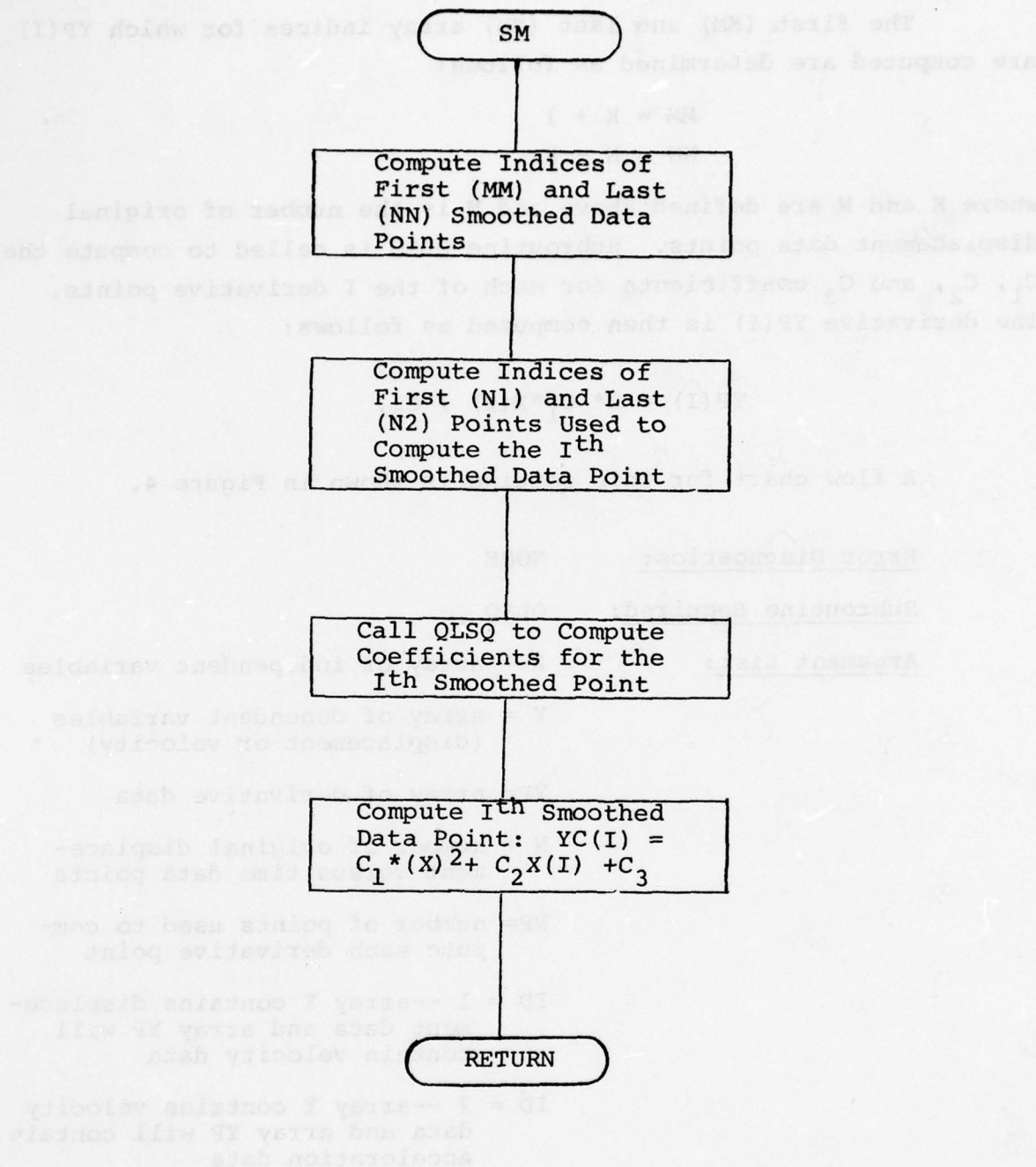


Figure 3. SM Flow Chart.

Method

The first (MM) and last (NN) array indices for which YP(I) are computed are determined as follows:

$$MM = K + 1$$

$$NN = N - K$$

where K and M are defined above and N is the number of original displacement data points. Subroutine QLSQ is called to compute the C_1 , C_2 , and C_3 coefficients for each of the I derivative points. The derivative YP(I) is then computed as follows:

$$YP(I) = 2 * C_1 * X(I) + C_2.$$

A flow chart for this routine is shown in Figure 4.

<u>Error Diagnostics:</u>	NONE
<u>Subroutine Required:</u>	QLSQ
<u>Argument List:</u>	X = array of independent variables
	Y = array of dependent variables (displacement or velocity)
	YP= array of derivative data
	N = number of original displacement versus time data points
	NP= number of points used to compute each derivative point
	ID = 1 --array Y contains displacement data and array YP will contain velocity data
	ID = 2 --array Y contains velocity data and array YP will contain acceleration data
<u>Subroutine Length:</u>	117 ₈

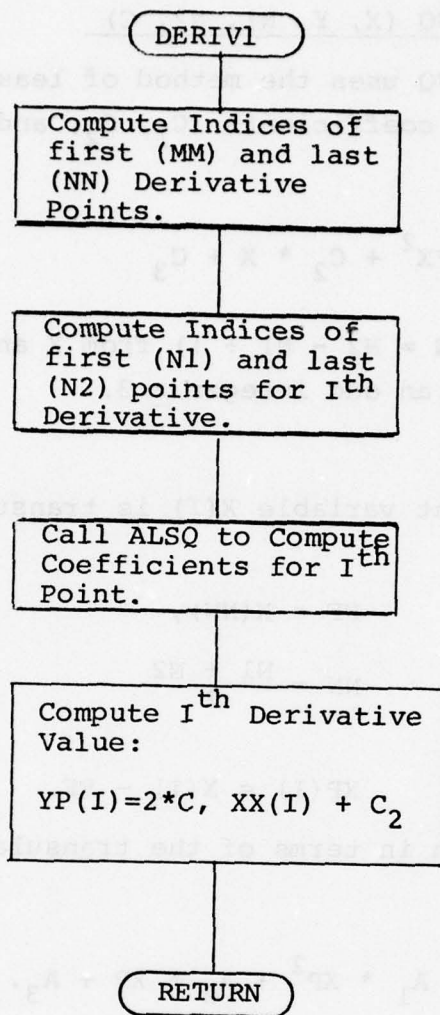


Figure 4. DERIV1 Flow Chart.

2.1.4 Subroutine QLSQ (X, Y, N1, N2, C)

Subroutine QLSQ uses the method of least squares to compute the quadratic coefficients (C_1 , C_2 , and C_3) for an equation of the form:

$$Y = C_1 * X^2 + C_2 * X + C_3$$

for FN data points ($FN = N2 - N1 + 1$) from X and Y array indices N1 to N2. FN must be an odd integer ≥ 3 .

Method

The independent variable X(I) is translated by a factor FF, where

$$FF = X(NN),$$

$$NN = \frac{N1 + N2}{2}$$

and

$$XP(I) = X(I) - FF.$$

The quadratic equation in terms of the translated independent variable is

$$Y = A_1 * XP^2 + A_2 * XP + A_3.$$

The least square residuals are a minimum when the following equations are satisfied:

$$A_1 * \sum XP^4 + A_2 * \sum XP^3 + A_3 * \sum XP^2 = \sum XP^2 * Y$$

$$A_1 * \sum XP^3 + A_2 * \sum XP^2 + A_3 * \sum XP = \sum XP * Y$$

$$A_1 * \sum XP^2 + A_2 * \sum XP + A_3 * FN = \sum Y$$

where summations of XP and Y are computed for index I equal N1 to N2. Determinants are used to solve the above system of equations for the coefficients A_1 , A_2 , and A_3 . The C_1 , C_2 , and C_3 coefficients are computed from A_1 , A_2 , and A_3 as follows:

$$C_1 = A_1$$

$$C_2 = A_2 - 2 * A_1 * FF$$

$$C_3 = A_3 + A_1 * FF^2 - A_2 * FF.$$

A flow chart for this routine is shown in Figure 5.

Error Diagnostics: NONE

Subroutines Required: NONE

Argument List: X = array of independent variables

Y = array of dependent variables

N1 = index of first point used
in fit

N2 = index of last point used
in fit

C = array containing quadratic
coefficients.

Subroutine Length: 134₈

2.2 DATA PREPARATION FOR INPUT TO HIFPD

Preparation of data for input to HIFPD consists of editing and digitizing. The editing function provides film frame-to-time conversion and film frames coordinates to plane of motion coordinates conversion factors. The digitizing function provides the frame-by-frame "reading" of the projected film frame coordinates. The references, or "standards," required to process the data are film time reference pulses and surveyed fiducials in two planes normal to the optical axis of the camera.

Timing of the film frames was accomplished by calculating the average film speed over a span of approximately 150 frames. The procedure employed to determine the average film speed is described in Appendix B, Paragraph 3.2.

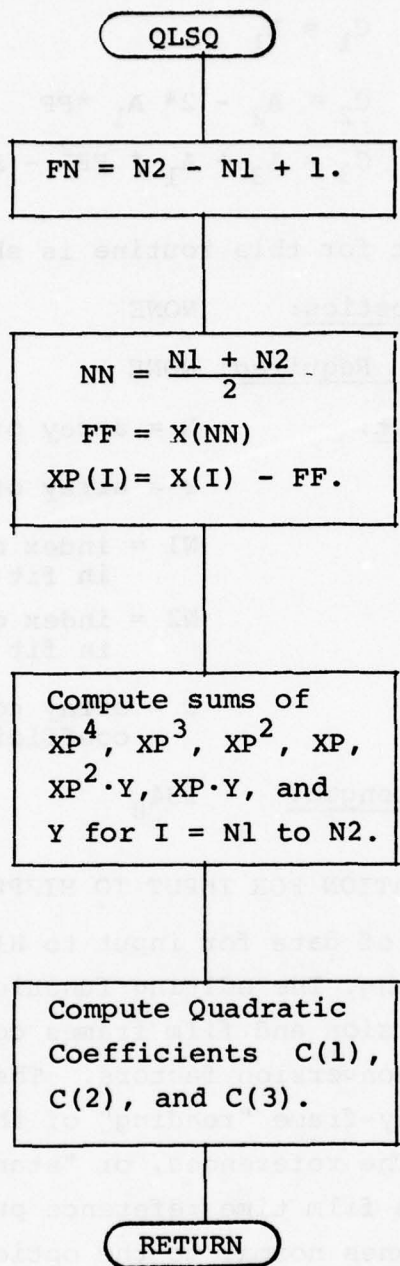


Figure 5. QLSQ Flow Chart.

The first frame in which the stroboscopic flash was observed was defined as $t = 0$. The strobe, initiated by a time synchronizing pulse which was also recorded on the magnetic tape recordings, actually gives t_0 indication within 2.0 milliseconds accuracy at the nominal film speed of 500 frames per second with a 140° shutter. Since the flash is not observed in film frame -0001 and is observed in film frame 0000, it is apparent that it was initiated between the closing of the shutter on film frame -0001 and the closing of the shutter on film frame 0000. During most tests, the intensity of the first observed flash would indicate that it was initiated between the closing of the shutter on frame -0001 and the opening of the shutter on frame 000. If this is the case, the t_0 indication could be considered to be accurate to 1.2 milliseconds, i.e.,:

$$\frac{360^\circ - 140^\circ}{360^\circ} \times 2 \text{ msec} = 1.22 \text{ msec.}$$

Determination of conversion constants to be applied to the digitized readings of the anthropometric points on the subject required that the following be known.

- a. The distance, normal to the plane of symmetry of the subject, from that plane to the left edge of the seat pan.
- b. The distance, normal to the plane of symmetry of the subject from that plane, to the lexan panel above the side edge of the sled deck.
- c. The distances, normal to the plane of symmetry of the subject, from that plane to the anthropometric points to be tracked.
- d. That the optical axis of the primary camera was normal to the plane of symmetry of the subject.
- e. The distances, between centers, of the fiducials mounted on the edge of the seat pan and of the fiducials mounted on the lexan panel.

The coordinates of the reference fiducials on the seat pan and the lexan panel were digitized five times. The readings of these coordinates were then averaged and the digital distance between the averaged coordinates of each pair was calculated. Dividing each of these digital distances by the corresponding measured dimension between fiducials yielded conversion constants, in terms of "counts per foot", in two planes normal to the optical axis. Having determined these conversion constants, and having measured the distance between the parallel planes in which the fiducials lay, the distance along the optical axis from the focal point of the lens to each of these planes and the plane of symmetry could then be calculated.

Prior to each test run the breadth of the subject was measured at each tracking fiducial location with an anthropometer. Assuming that each subject was symmetrical, the distance from the plane of symmetry to each tracking fiducial was defined as one-half the measured breadth of the subject of each fiducial location. Conversion constants for each plane parallel to the plane of symmetry, thus normal to the optical axis in which a tracking fiducial lay were then calculated by similar triangles.

The actual digitization of the photometric data was accomplished on a Producers Service Corporation model PVR film analyzer. The magnification factor of the projector was approximately 19.6, giving a projected frame image of 8 x 5.8-inches. The optical encoders were coupled to the reading cross-hairs through drive wires in such a manner that a displacement of either crosshair of one-inch caused the associated optical encoder to increase or decrease the reading by one thousand count.

The operator located the first frame in which the synchronizing flash was observed and reset the frame counter to 0000. The optical center of the film frame was found by

numerically bisecting the vertical and horizontal dimensions of the frame image. The operator then positioned the crosshairs over the range reference fiducial and depressed the record switch causing the frame number and coordinates of the fiducial to be punched into paper tape and typed on the carriage of the teletype terminal. He then proceeded to position the crosshairs over the seat reference fiducial. Again, depressing the record switch caused the coordinates to be recorded on the listing and the paper tape. In this manner he would proceed to each of the other points mentioned in Section 2.1, recording their coordinates, until all readings had been extracted from that frame.

After advancing the film to the next frame, the operator would check the coordinates of the range and seat fiducials. If the frame-to-frame variation of these coordinates exceeded ± 10 counts he would again locate the optical center of the film frame image before proceeding.

This procedure was repeated for each film frame until the subject appeared to have attained a static position after the impact.

The resulting paper tape was read into file on the CYBER 74 at the ASD computer center from the teletype terminal via data modem on a voice quality line, and the file was edited and corrected when necessary. At this time the control and title data were added to the file. This file was then copied on the card punch and printer as a time saving measure in case the disk file should be accidentally purged.

At this point the program HIFPD could have been attached and executed; however, the normal procedure was to obtain the card files and submit them in the batch mode on an overnight schedule. This permitted the connect time to be used for read-in and editing of additional data files.

A typical standard practice procedure detailing the data preparation is given in Appendix B.

SECTION 3
ANALYSIS OF DATA FROM TWO CAMERAS

Tracking of objects moving through the space of a three-dimensional coordinate system, using analysis of phototheodolite recordings, has been accomplished with a great degree of accuracy for many years. The recognized requirements to accomplish these analyses are quite simple, viz., cameras at two or more tracking stations with precisely synchronized shutters, time for frame signal numbers, azimuth and elevation indicators, and relatively massive mounted systems having provision for leveling and plumbing the cameras. Additionally, the locations of the camera mounts must be accurately surveyed.

When one attempts to track the motion of several points with respect to a three-dimensional coordinate system on a moving vehicle, all the simplicity of the large tracking range disappears, and an entirely new set of problems confront the investigator. Camera weight must be kept to a minimum and light-weight, rigid mounting systems must be devised. Actual shutter synchronization is not practical at the high film transport speeds necessary to record the motion. The precise locations and orientations of the cameras are subject to change, not only from test to test, but even during a test.

To solve the above mentioned problems, two processes were developed, one to accurately determine the location and orientation of a camera with respect to the coordinate system, and the second to track the coordinates of identified points with respect to the origin of the coordinate system.

The processing programs developed to accomplish these solutions, "POOCH" and "SLED" respectively, are described in the following discussions.

3.1 CAMERA LOCATION AND ORIENTATION

The value of a program which can determine the location, orientation, and focal length of a camera by examination of the film frame images of a set of accurately surveyed object prints is rather obvious. Regardless of the care exercised, if a large enough amount of camera data is taken, sooner or later a camera will be jarred or moved or a set of camera data will be misplaced or mislabeled, or a camera mounted aboard a moving vehicle may vibrate on its mount and one may wish to do a frame by frame correction of the camera position and orientation.

There are seven unknowns to be determined in this problem. They are the location of the camera focal point (xx , yy , zz), the camera focal length (ff), and azimuth angle (th) and the elevation angle (ph) of the camera optical axis, and the angle (α) by which the camera is tilted from horizontal about its optical axis.

Before proceeding with the main theme, a comment must be made regarding the relationship between camera focal length and the distance of the camera from the scene. There is a misconception that if a camera of one focal length is used to photograph a scene, a camera of a shorter focal length will photograph precisely the same scene if taken somewhat closer. That is not true in general. It is true only in the case that every point of the scene being photographed lies in a plane normal to the optical axes of the two cameras.

Although not physically correct, one loses nothing mathematically by assuming that the film frame is interposed between the camera focal point and the scene and that film frame images are created by light rays emanating from the object points and passing through the film to the camera focal point. See Figure 6.

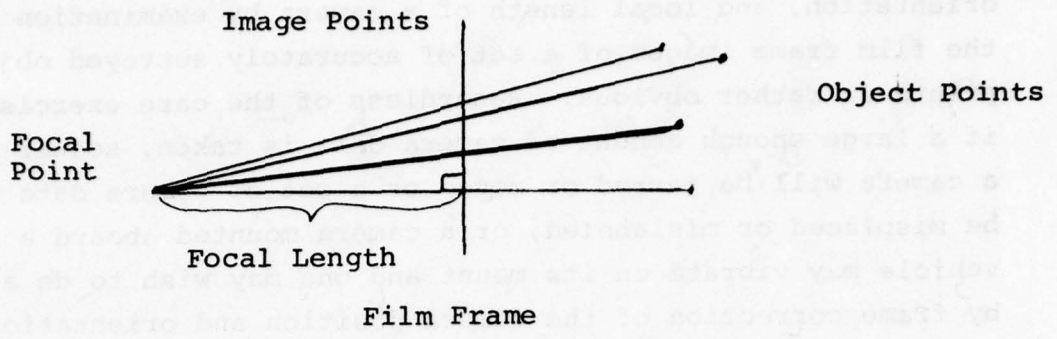


Figure 6.

Assume first that a camera of focal length ff lies at a distance d from a scene composed of two object points at heights h_a and h_b above its optical axis. See Figure 7.

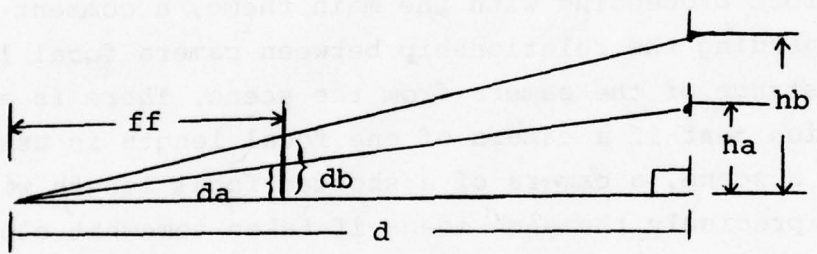


Figure 7.

Both object points lie in a plane normal to the camera optical axis. By similar triangles

$$\frac{d}{ff} = \frac{h_a}{d_a} = \frac{h_b}{d_b}$$

If $k > 0$, by the equation

$$\frac{kd}{kff} = \frac{d}{ff} .$$

It is obvious a camera at distance kd from the object points with a focal length of kff gives exactly the same image points at the original camera at distance d with focal length ff . Thus, if the object points are all in a plane normal to the camera optical axis, it is impossible to determine from the image and object point locations both the camera focal length and its distance from the scene.

If the two object points have different spacings along the camera optical axis, the situation is quite different. See Figure 8.

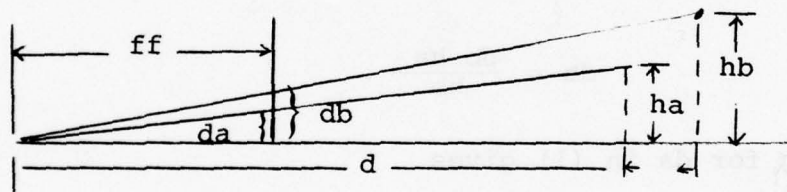


Figure 8.

In Figure 8 the project of the two object points on the camera optical axis are spaced a distance e apart where e is known and $e \neq 0$. da , db , ha , and hb are known. ff and d are unknown.

Again by similar triangles

$$(1) \quad \frac{d}{ha} = \frac{ff}{da}$$

$$(2) \quad \frac{d + e}{hb} = \frac{ff}{db}$$

From (1)

$$d = \frac{ha \, ff}{da}$$

Substituting in (2)

$$\frac{\frac{ha \, ff}{da} + e}{hb} = \frac{ff}{db}$$

or

$$\frac{ha \, ff + da \, e}{da \, hb} = \frac{ff}{db}$$

or

$$db \, ha \, ff + da \, db \, e = da \, hb \, ff.$$

$$(3) \quad (da \, hb - db \, ha) \, ff = da \, db \, e.$$

Now if it is assumed that $da \, hb - db \, ha = 0$, we get

$$db = \frac{db \, ha}{hb}.$$

Substituting for da in (1) gives

$$\frac{d}{ha} = \frac{ff}{\left(\frac{db \, ha}{hb}\right)} = \frac{hb \, ff}{db \, ha}.$$

or

$$\frac{ff}{db} = \frac{ha \, d}{hb \, ha} = \frac{d}{hb}.$$

But (2) is

$$\frac{ff}{db} = \frac{d + e}{hb}.$$

Therefore,

$$\frac{ff}{db} = \frac{d + e}{hb} = \frac{d}{hb}$$

$$\frac{e}{hb} = 0$$

$e = 0$ contrary to the problem statement.

Therefore in (3) the coefficient of $ff \neq 0$ and we may solve for ff :

$$(4) \quad ff = \frac{da \, db \, e}{da \, hb - db \, ha} .$$

Substituting for ff in (1) gives

$$(5) \quad d = \frac{ha}{da} ff = \frac{ha \, db \, e}{da \, hb - db \, ha}$$

and we have in (4) and (5) unique solutions for both ff and d .

However, two object points with different spacings along the camera optical axis are not sufficient to locate the camera because the camera may be rotated in space about an axis between two object points without disturbing any of the geometrical relationships in Figure 8. See Figure 9.

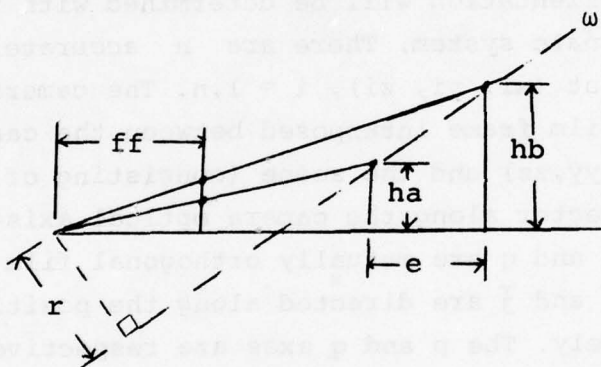


Figure 9.

Figure 9 shows the axis of rotation ω and the radius r of the circle the camera focal point can describe in space. A third object point lying on the axis between the first two object points does not help to locate the camera. To be of help, the third object point must lie at a distance from the line passing through the other two object points. The conclusion is then that in order to completely locate, orient, and determine the focal length of a camera, one requires an absolute minimum of three accurately surveyed object points forming a nondegenerate triangle whose plane was not normal to the camera optical axis when the picture was taken.

With the minimum of three object points, small reading errors can easily distort the solution. In practice it is best to have at least five to eight object points with a good spread normal to the camera optical axis and significant differences in spacing along the optical axis.

The above discussion demonstrating the necessity of at least three object points is in no way indicative of the solution scheme used in the camera location program. The analysis used in the program will now be discussed.

3.1.1 Mathematical Models

The problem is modeled or indicated in Figure 10. The principal coordinate system is a right hand mutually orthogonal $x y z$ coordinate system. Unit vectors \bar{e} , \bar{n} , and \bar{h} are directed along the positive x , y , and z axis respectively. The camera position and orientation will be determined with respect to the x, y, z coordinate system. There are n accurately surveyed object points at (x_i, y_i, z_i) , $i = 1, n$. The camera itself is modeled as a film frame interposed between the camera focal point at (x_c, y_c, z_c) and the scene (consisting of n object points). \bar{f}_n is a unit vector along the camera optical axis normal to the film frame. p and q are mutually orthogonal film frame axes. Unit vectors \bar{i} and \bar{j} are directed along the positive p and q axes respectively. The p and q axes are respectively horizontal and vertical with respect to the film frame. Throughout this report ff will be referred to as the camera focal length, but it is actually the product of the true camera focal length and the magnification of the film frame reader. To each of the object points (x_i, y_i, z_i) , $i=1, n$ corresponds to a film frame image point with known film frame coordinates (p_i, q_i) , $i= 1, n$. The unit vectors \bar{f}_n , \bar{i} , and \bar{j} form a mutually orthogonal right hand set, i.e., $\bar{j} = \bar{f}_n \times \bar{i}$.

To reiterate, the unknowns in this problem are the location of the camera focal point (x_c, y_c, z_c) , the focal length ff , the azimuth angle, θ , and the elevation angle, ϕ , of the camera optical axis, and the angle, γ , by which the camera is

tilted from horizontal about its optical axis. Of these seven unknowns, the last three are not explicit in Figure 10. If the components of the unit vector \bar{f}_n are found with respect to the $x y z$ system, then the azimuth and elevation angles of the camera optical axis are easily found. See Figure 11.

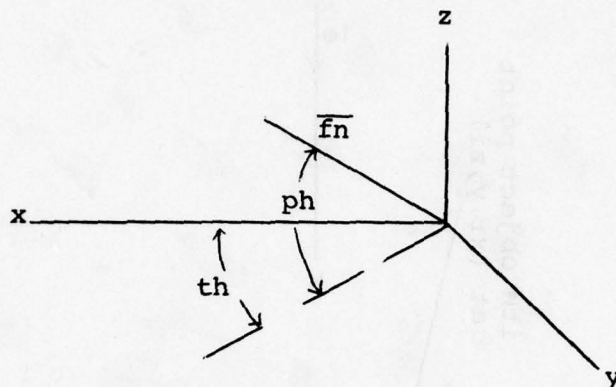


Figure 11.

$$\begin{aligned}\bar{f}_n &= \cos ph \cos th \bar{e} + \cos ph \sin th \bar{n} + \sin ph \bar{h} \\ &= fn1 \bar{e} + fn2 \bar{n} + fn3 \bar{h}, \text{ if } ph \text{ and } th \text{ are known.}\end{aligned}$$

Similarly, if $fn1, fn2, fn3$ are known, i.e.,

$$\bar{f}_n = fn1 \bar{e} + fn2 \bar{n} + fn3 \bar{h}$$

Then

$$ph = \sin^{-1} (fn3)$$

$$th = \cos^{-1} (\sqrt{fn1^2 + fn2^2})$$

$$th = -th \text{ if } fn2 < 0.$$

Therefore, knowledge of \bar{f}_n is precisely equivalent to knowledge of th and ph and vice-versa. Similarly \bar{I} determines γ but the details will be deferred until later.

The solution is done in two parts. In the first part the unknowns xx, yy, zz , and ff are found. The angle subtended at the camera focal point by the i th and j th image points is \ddot{g}_y ($j \neq i$). See Figure 12.

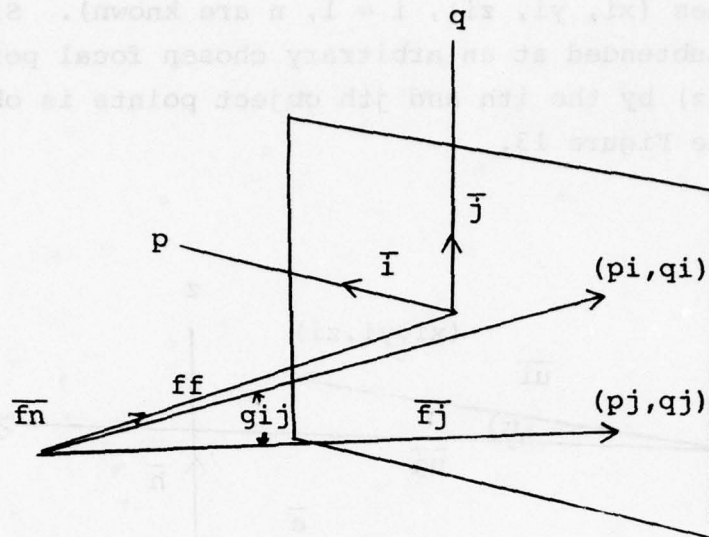


Figure 12.

Although the components of the unit vectors \bar{f}_n , \bar{i} , and \bar{j} are not known at present with respect to the xyz system, it is known that they form a right hand mutually orthogonal set. So vectors \bar{f}_i and \bar{f}_j to the i th and j th image points may be written:

$$\bar{f}_i = ff \bar{f}_n + p_i \bar{i} + q_i \bar{j}$$

$$\bar{f}_j = ff \bar{f}_n + p_j \bar{i} + q_j \bar{j}$$

Then the angle g_{ij} subtended by \bar{f}_i and \bar{f}_j at the camera focal point is:

$$g_{ij} = \cos^{-1} \left(\frac{\bar{f}_i \cdot \bar{f}_j}{|\bar{f}_i| |\bar{f}_j|} \right)$$

$$g_{ij} = \cos^{-1} \left\{ \frac{ff^2 + p_i p_j + q_i q_j}{(ff^2 + p_i^2 + q_i^2)^{1/2} (ff^2 + p_j^2 + q_j^2)^{1/2}} \right\}$$

and the only unknown appearing in the equation for \ddot{y} is ff . (All image point coordinates (p_i, q_i) , $i = 1, n$ and all object point coordinates (x_i, y_i, z_i) , $i = 1, n$ are known). Similarly, the angle \ddot{h}_y subtended at an arbitrary chosen focal point location (x_x, y_y, z_z) by the i th and j th object points is obtained as follows. See Figure 13.

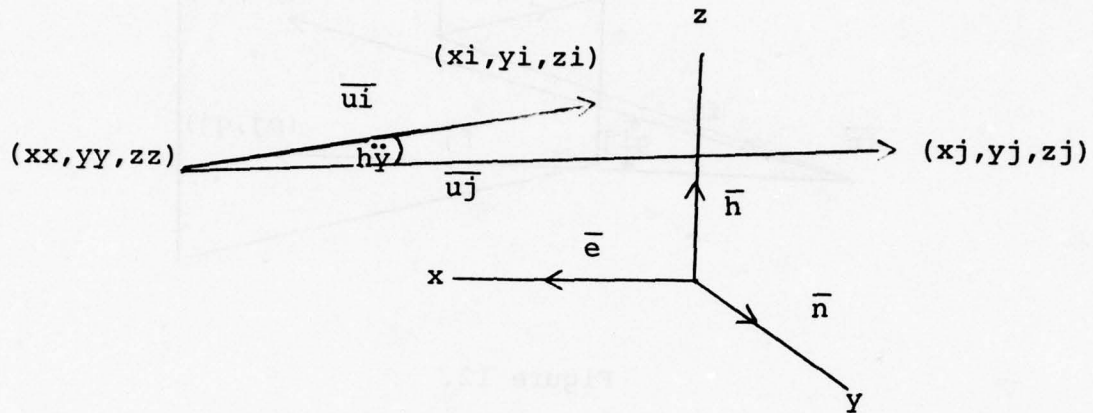


Figure 13.

$$\ddot{h}_y = \cos^{-1} \left(\frac{\overline{u}_i \cdot \overline{u}_j}{|\overline{u}_i| |\overline{u}_j|} \right)$$

where

$$\overline{u}_i = (x_i - x_x) \overline{e} + (y_i - y_y) \overline{n} + (z_i - z_z) \overline{h}$$

$$\overline{u}_j = (x_j - x_x) \overline{e} + (y_j - y_y) \overline{n} + (z_j - z_z) \overline{h}$$

$$\ddot{h}_y = \cos^{-1} \left\{ \frac{(x_i - x_x)(x_j - x_x) + (y_i - y_y)(y_j - y_y) + (z_i - z_z)(z_j - z_z)}{[(x_i - x_x)^2 + (y_i - y_y)^2 + (z_i - z_z)^2]^{1/2} [(x_j - x_x)^2 + (y_j - y_y)^2 + (z_j - z_z)^2]^{1/2}} \right\}$$

and the only unknowns in the \ddot{h}_y equation are x_x , y_y , and z_z .

Thus we have

$$\ddot{g}_y = g_y (ff),$$

a function of ff , and

$$\ddot{h}_y = \ddot{h}_y (xx, yy, zz),$$

a function of focal point position. If the correct values of ff , xx, yy, zz are inserted in these two equations, we should have

$$\ddot{g}_y(ff) = \ddot{h}_y (xx, yy, zz).$$

Define $\text{err}_y = (\ddot{g}_y - \ddot{h}_y)^2$, and

$$\text{err}_y = \text{err}_y (ff, xx, yy, zz).$$

Then the total error err taken over all possible pairs of points is, for an arbitrary choice of ff, xx, yy, zz

$$\text{err} = \sum_{i=1}^{n-1} \sum_{j=1}^n \text{err}_{ij} (= \text{err}(ff, xx, yy, zz)).$$

Then we should have at the correct values ff, xx, yy, zz $\text{err} = 0$.

Due to the film frame reading errors, errors in the surveyed object points, lens distortion, $\text{err} \neq 0$ at the correct value of ff, xx, yy, zz , but it will attain a relative minimum there. Let f_p and f_q be numbers chosen so as to be generous bounds on the true focal length ff . $0 < f_p < ff < f_q$. Let (x_q, y_q, z_q) be the x, y, z values that minimize $\text{err}(f_q, x, y, z)$, that is, $\text{err}(f_q, x_q, y_q, z_q)$ is the smallest value of err that can be obtained for focal length of f_q . Similarly, let $\text{err}(f_p, x_p, y_p, z_p)$ be the minimum of err for focal length f_p . As one would expect, the optimized position of the focal point is closer to the scene for the smaller value of focal length. See Figure 14.

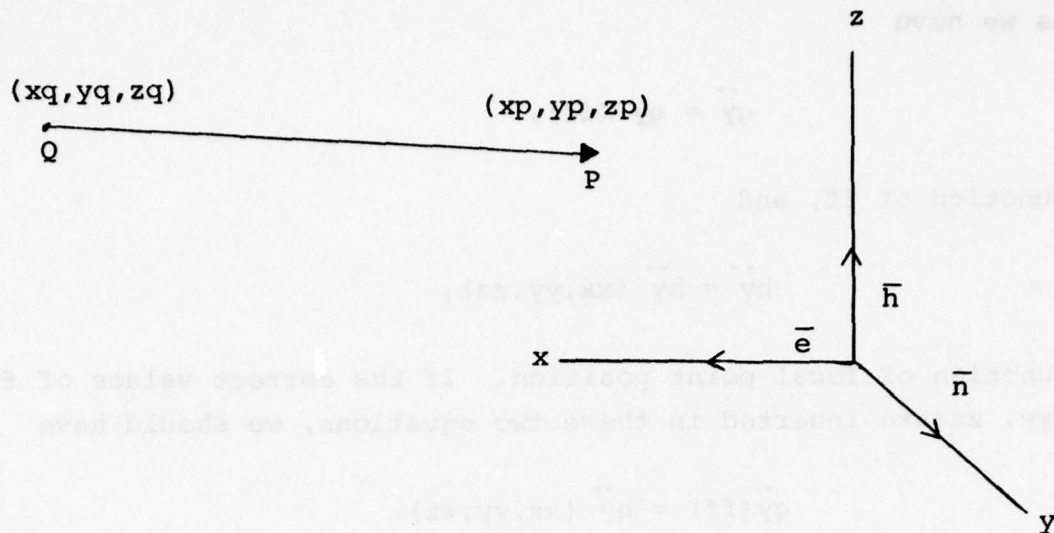


Figure 14.

Let f_s be any focal length value such that $f_p < f_s < f_q$. Let (x_s, y_s, z_s) be that point that minimizes err , i.e., $\text{err}(f_s, x_s, y_s, z_s)$ is a minimum for focal length f_s . Then the following proportions furnish excellent estimates of x_s , y_s , and z_s for a given focal length f_s .

$$\frac{x_s - x_p}{x_q - x_p} = \frac{f_s - f_p}{f_q - f_p}$$

$$\frac{y_s - y_p}{y_q - y_p} = \frac{f_s - f_p}{f_q - f_p}$$

$$\frac{z_s - z_p}{z_q - z_p} = \frac{f_s - f_p}{f_q - f_p}$$

In other words, as f_s varies from f_p to f_q , it is very nearly true that the point (x_s, y_s, z_s) moves a proportional amount of the distance from p to q along the line segment. Solving the equation for (x_s, y_s, z_s) gives

$$x_s = x_p + (x_q - x_p) \frac{f_s - f_p}{f_q - f_p}$$

$$y_s = y_p + (y_q - y_p) \frac{f_s - f_p}{f_q - f_p}$$

$$z_s = z_p + (z_q - z_p) \frac{f_s - f_p}{f_q - f_p} .$$

The application of these equations will be discussed shortly.

A graph of the minimized value of err versus focal length has the form illustrated in Figure 15.

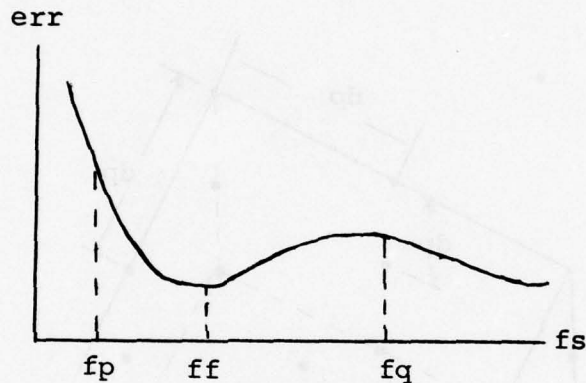


Figure 15.

The relative minimum of err for $f_s \in [f_p, f_q]$ occurs at f_f . Of course as $f_s \rightarrow \infty$, both the scene and the film frame shrink to points with respect to the camera focal point, so err will approach the f_s axis asymptotically from above.

When data is input to the program, rough estimates of f_f , x_x , y_y , z_z are read in. Also input are two generous bounds on f_f , f_p , and f_q where $0 < f_p < f_f < f_q$. The first step is to locate the points P and Q. Assume we are searching for point P in Figure 14, that point (x_p, y_p, z_p) that makes err (f_p, x_p, y_p, z_p) a minimum for focal length f_p .

A cube of 27 points is centered at the input point (xx, yy, zz) . See Figure 16. The cube's edges are parallel to the principal coordinate system axes and it has edge length $2 dp$ where dp is an internally defined value. $Err (fp, x, y, z)$ is computed at each of the cube points. Then (xx, yy, zz) are set equal to the coordinates of that point that resulted in the smallest value of err . Then a new cube is constructed centered on a new point (xx, yy, zz) and the process repeated. Ultimately a cube is found whose center point gives the smallest value of

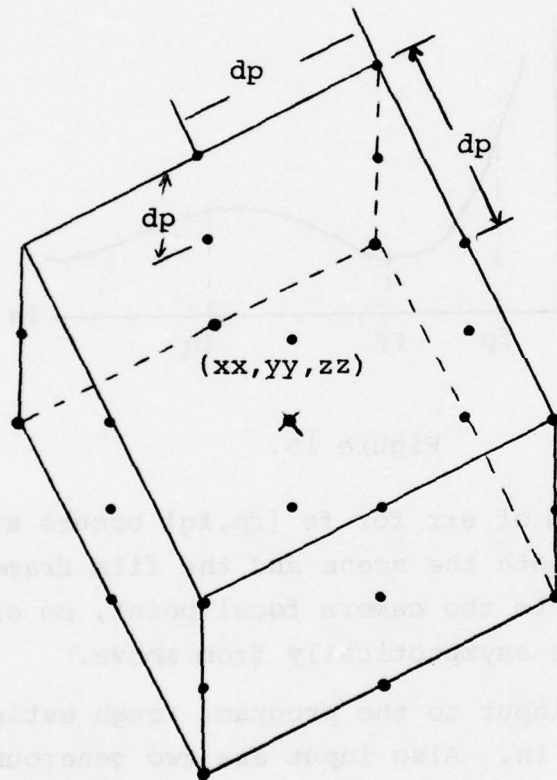


Figure 16.

err. This cube then contains the optimum point. dp is then reduced to a tenth of its previous value, a new smaller cube centered on the minimum point is constructed and the whole process is repeated again. This iterative process is terminated when dp falls below a certain test value. Then (x_p, y_p, z_p) is set equal to the coordinates of the last minimum point determined. This is the process used to determine for $ff = fp$, and $ff = fq$ the best camera focal point locations (x_p, y_p, z_p) and (x_q, y_q, z_q) respectively. The above process is capable of moving the focal point many feet through space from a grossly inaccurate first estimate to the final optimizing point. But this iteration is quite time consuming. For example, if 20 cubes are required to locate an optimum point, it requires the computation of err at $20 \times 27 = 540$ points. And if there are, say, 9 object points, there are $\frac{9 \times 8}{2} = 36$ values of $h\dot{y}$ and $g\dot{y}$ that must be computed, differenced, squared, and added for each computation of err . For this reason, the above process is not used to make the final determination of the focal length. Rather for each value of focal length f_s used in this determination, a very nearly optimum point for optimizing err is gotten from the three proportions mentioned earlier on page 38.

$$x_s = x_p + \frac{f_s - f_p}{f_q - f_p} (x_q - x_p)$$

$$y_s = y_p + \frac{f_s - f_p}{f_q - f_p} (y_q - y_p)$$

$$z_s = z_p + \frac{f_s - f_p}{f_q - f_p} (z_q - z_p).$$

Then err is minimized at f_s by checking points very close to (x_s, y_s, z_s) by a simpler, faster process to be described shortly. To find the correct value of ff we set

$$dist = (f_q - f_p) / 6.0.$$

Then f_s is set equal to $f_q + i \text{ dist}$, $i = 0, 1, 2, \dots, 6$ in succession and the minimum error values err found for each f_s .

Say it occurs at $f_s = f_{s0}$. Then we redefine $f_q = f_{s0} + \text{dist}$ and $f_p = f_{s0} - \text{dist}$, set $\text{dist} = (f_q - f_p) / 6.0$ and go through the same process all over again. This is continued until dist falls below a present value. Then f_f is set equal to the last f_s computed and (x_x, y_y, z_z) to the last optimized value of (x_s, y_s, z_s) . This is the final step in solving for these first four of the seven unknowns in this problem.

In order to construct the routine which is used to optimize the initial values of (x_s, y_s, z_s) gotten from the three equations above, reference must be made to Figure 17.

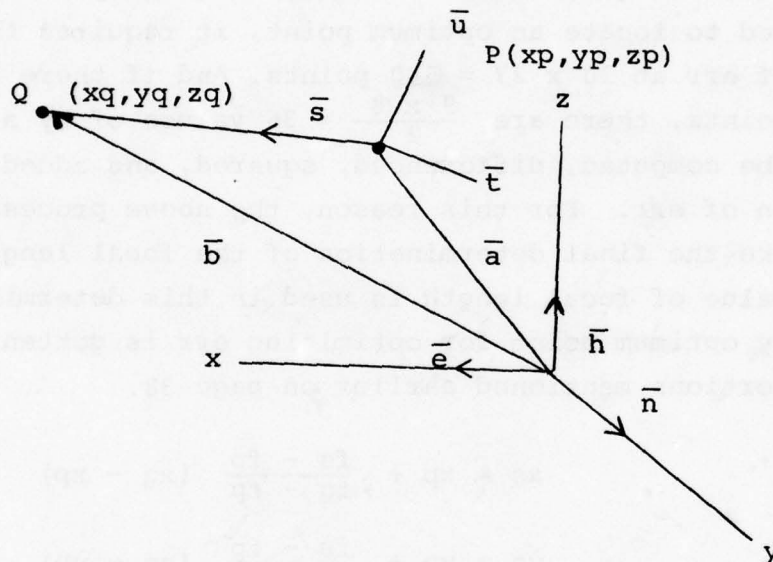


Figure 17.

$$\bar{a} = f_p \bar{e} + y_p \bar{n} + z_p \bar{h}$$

$$\bar{b} = x_q \bar{e} + y_q \bar{n} + z_q \bar{h}.$$

The unit vectors defined as follows are the directions in space along which the iterative procedure searches in order to optimize the initial values of (x_s, y_s, z_s) to find the minimum value of err for focal length f_s .

$$\bar{s} = \frac{\bar{b} - \bar{a}}{|\bar{b} - \bar{a}|}$$

$$\bar{t} = \frac{\bar{h} \times \bar{s}}{|\bar{h} \times \bar{s}|}$$

$$\bar{u} = \bar{s} \times \bar{t} .$$

Defined in this way, \bar{s} , \bar{t} , and \bar{u} form a right hand set of mutually orthogonal unit vectors with \bar{s} lying along the line segment between points p and q. A maximum of six computations of err are required for each iteration as opposed to the 27 required for the cube search. The order in which the points are tried is indicated in Figure 18.

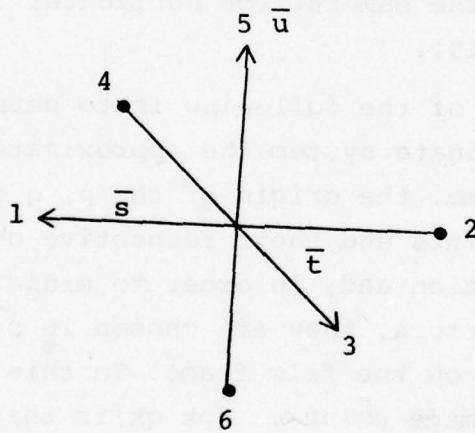


Figure 18.

The value of err is known at the junction of \bar{s} , \bar{t} , and \bar{u} (referred to as the center point). The points 1 through 6 are tried in order. If the value of err at any of points 1 through 6 is smaller than that at the center point, the next step will be in the same direction. For example, if point 3 should be the first point to yield a smaller value of err than that at the center point, the routine will continue to step in the t direction so long as successively smaller values of err are obtained.

Similarly as for the cube search, when all of points 1 through 6 yield a higher value of err than that at the center point, the step size is reduced and the whole process repeated. This continues until the step distance falls below a certain present value.

The location of the camera focal point and its focal length have now been found to be (xx, yy, zz) and ff respectively. As mentioned previously, the determination of the components of the unit vectors \bar{fn} and \bar{i} with respect to the principal coordinate system is equivalent to finding the azimuth and elevation of the optical axis and the tilt angle of the camera from horizontal about the optical axis (refer to Figure 10).

The whole point of the following is to determine with respect to the principal coordinate system the approximate location of the center of the film frame, the origin of the p, q film frame coordinate system. Three image points and their respective object points are required to get a solution and, in order to minimize the effects of reading and other errors, they are chosen in such a way as to form a large triangle on the film frame. To this end, three sorts are performed on the image points. (pk, qk) is that point farthest from the film frame origin. (pl, ql) is that point farthest from (pk, qk) . (pm, qm) is that point the sum of whose distances from (pk, qk) and (pl, ql) is the greatest. See Figure 19.

The vectors from the camera focal point to the k th, l th, and m th image points are respectively:

$$\overline{skc} = ff \overline{fn} + pk \overline{i} + qk \overline{j}$$

$$\overline{slc} = ff \overline{fn} + pl \overline{i} + ql \overline{j}$$

$$\overline{smc} = ff \overline{fn} + pm \overline{i} + qm \overline{j}$$

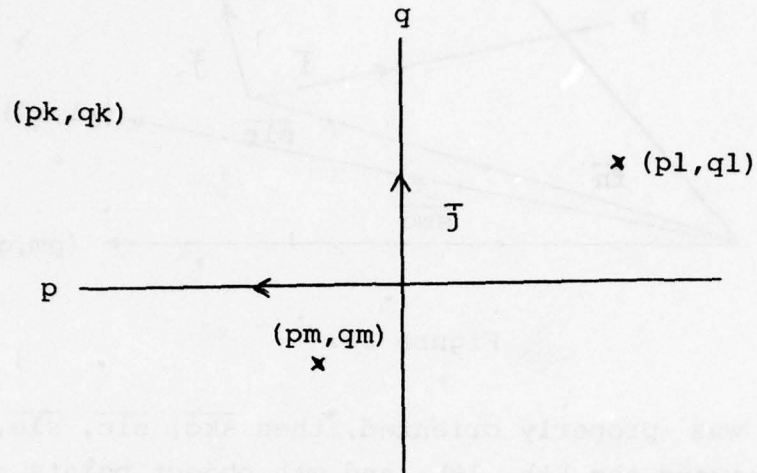


Figure 19.

where these three vectors have been written in terms of their components with respect to these as-yet-unknown unit vectors, \overline{fn} , \overline{i} , \overline{j} of the camera coordinate system. The vector magnitudes are

$$dfk = (ff^2 + pk^2 + qk^2)^{1/2}$$

$$dfl = (ff^2 + pl^2 + ql^2)^{1/2}$$

$$dfm = (ff^2 + pm^2 + qm^2)^{1/2}$$

See Figure 20.

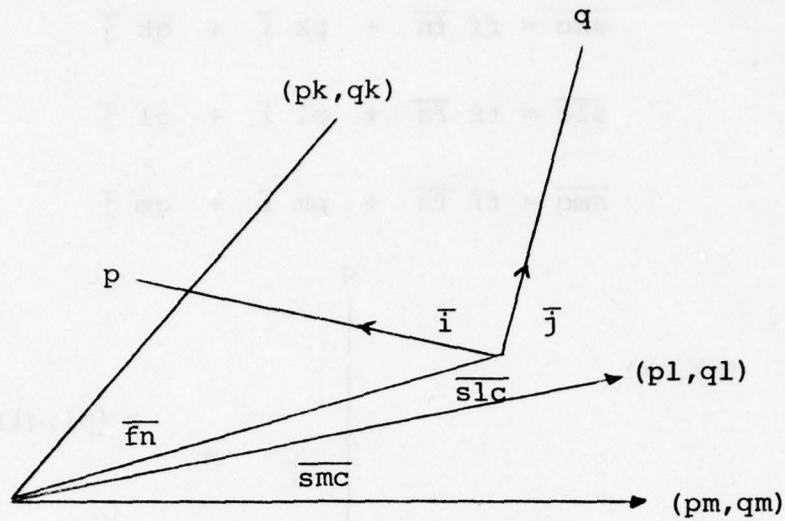


Figure 20.

If the camera was properly oriented, then \overline{skc} , \overline{sic} , \overline{sle} , and \overline{sme} should point toward the k th, l th, and m th object points respectively. Unit vectors \overline{nfa} , \overline{nfb} , and \overline{nfc} pointing at the k th, l th, and m th object points respectively obtained as follows:

$$\overline{fa} = (x_k - x_x) \overline{e} + (y_k - y_y) \overline{n} + (z_k - z_z) \overline{h}$$

$$\overline{fb} = (x_l - x_x) \overline{e} + (y_l - y_y) \overline{n} + (z_l - z_z) \overline{h}$$

$$\overline{fc} = (x_m - x_x) \overline{e} + (y_m - y_y) \overline{n} + (z_m - z_z) \overline{h}$$

$$d_{am} = /\overline{fa}/ = [(x_k - x_x)^2 + (y_k - y_y)^2 + (z_k - z_z)^2]^{1/2}$$

$$d_{bm} = /\overline{fb}/ = [(x_l - x_x)^2 + (y_l - y_y)^2 + (z_l - z_z)^2]^{1/2}$$

$$d_{cm} = /\overline{fc}/ = [(x_m - x_x)^2 + (y_m - y_y)^2 + (z_m - z_z)^2]^{1/2}$$

$$\overline{nfa} = \overline{fa}/d_{am}$$

$$\overline{nfb} = \overline{fb}/d_{bm}$$

$$\overline{nfc} = \overline{fc}/d_{cm}$$

Multiplying these unit vectors by the magnitudes of \overline{skc} , \overline{slc} , and \overline{smc} gives \overline{sk} , \overline{sl} , and \overline{sm} below

$$\overline{sk} = dfk \overline{nfa}$$

$$\overline{sl} = dfl \overline{nfb}$$

$$\overline{sm} = dfm \overline{nfc}$$

The vectors \overline{sk} , \overline{sl} , and \overline{sm} so defined are known with respect to the principal program coordinate system. More over, they are very nearly equal to \overline{skc} , \overline{slc} , and \overline{smc} ; that is:

$$sk \approx skc$$

$$sl \approx slc$$

$$sm \approx smc.$$

See Figure 21.

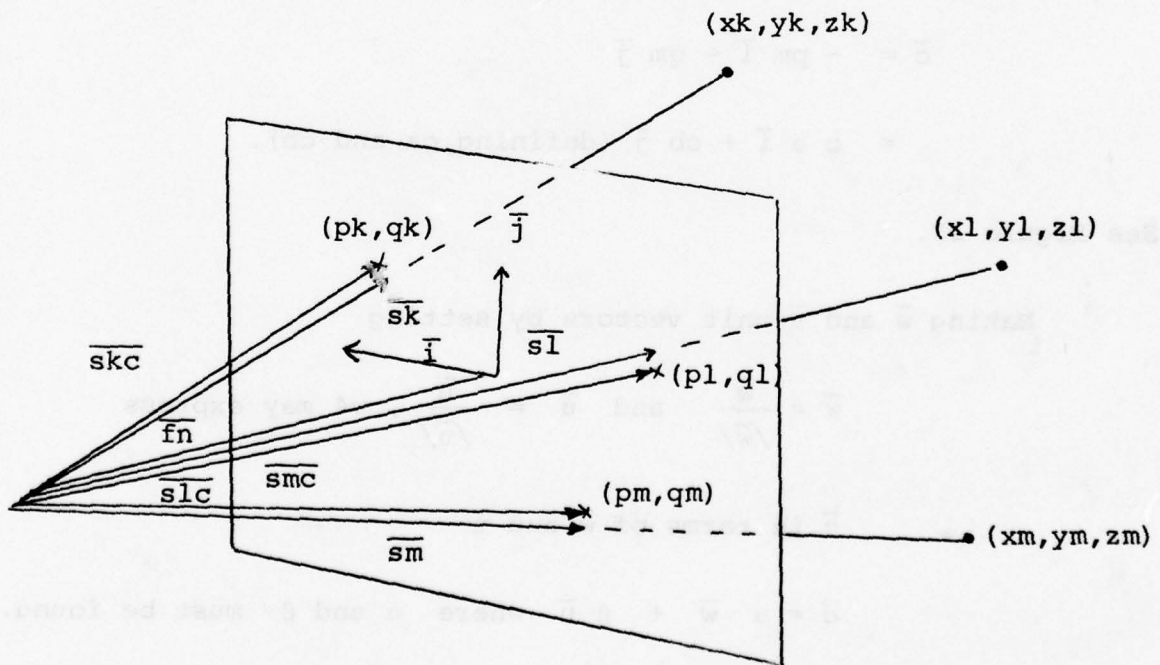


Figure 21.

Were it not for the various errors, the above equivalence would be exact and the unknown unit vectors \bar{f}_n , \bar{i} , and \bar{j} could be solved for directly. The solution could be done anyway, but the resulting solution vectors \bar{f}_n , \bar{i} , and \bar{j} would in general be neither unit vectors nor would they be mutually perpendicular. Of course, the resulting system could be made orthonormal algebraically, but it was not known at the time how large errors would be nor how much distortion would be produced by the errors. It was decided to take advantage of the approximate vector equivalence above in the following manner in order to determine \bar{f}_n , \bar{i} , and \bar{j} .

Let

$$\bar{w} = \overline{skc} - \overline{smc} = (pk - pm) \bar{i} + (qk - qm) \bar{j}$$

$$\bar{u} = \overline{slc} - \overline{smc} = (pl - pm) \bar{i} + (ql - qm) \bar{j}.$$

A vector \bar{c} from the image point in to the center of the film frame is

$$\begin{aligned} \bar{c} &= - pm \bar{i} - qm \bar{j} \\ &= ca \bar{i} + cb \bar{j} \text{ (defining } ca \text{ and } cb\text{).} \end{aligned}$$

See Figure 22.

Making \bar{w} and \bar{u} unit vectors by setting

$$\bar{w} = \frac{\bar{w}}{|\bar{w}|} \quad \text{and} \quad \bar{u} = \frac{\bar{u}}{|\bar{u}|}, \text{ we may express}$$

\bar{c} in terms of \bar{w} and \bar{u}

$$\bar{c} = \alpha \bar{w} + \beta \bar{u} \text{ where } \alpha \text{ and } \beta \text{ must be found.}$$

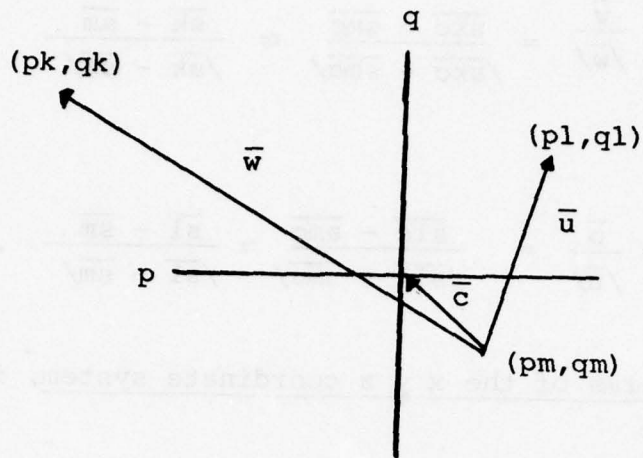


Figure 22.

Equating \bar{i} and \bar{j} components gives:

$$\alpha wa + \beta ua = ca$$

$$\alpha wb + \beta ub = cb$$

and

$$\alpha = \begin{vmatrix} ca & ua \\ cb & ub \end{vmatrix}$$

$$\beta = \begin{vmatrix} wa & ca \\ wb & cb \end{vmatrix}$$

where

$$\Delta = \begin{vmatrix} wa & ua \\ wb & ub \end{vmatrix}.$$

Now,

$$\bar{w} = \frac{\bar{w}}{|\bar{w}|} = \frac{\overline{skc} - \overline{smc}}{|\overline{skc} - \overline{smc}|} \approx \frac{\overline{sk} - \overline{sm}}{|\overline{sk} - \overline{sm}|}$$

and

$$\bar{u} = \frac{\bar{u}}{|\bar{u}|} = \frac{\overline{slc} - \overline{smc}}{|\overline{slc} - \overline{smc}|} \approx \frac{\overline{sl} - \overline{sm}}{|\overline{sl} - \overline{sm}|} .$$

Therefore, in terms of the x y z coordinate system, it is approximately true that

$$c = \alpha \frac{\overline{sk} - \overline{sm}}{|\overline{sk} - \overline{sm}|} + \beta \frac{\overline{sl} - \overline{sm}}{|\overline{sl} - \overline{sm}|} .$$

So a vector from the focal point to the center of the film frame is approximately:

$$\overline{cff} = \overline{sm} + \bar{c}$$

and

$$\begin{aligned} \bar{fn} &= \frac{\overline{cff}}{|\overline{cff}|} \\ &= fn_1 \bar{e} + fn_2 \bar{n} + fn_3 \bar{h}. \end{aligned}$$

See Figure 23.

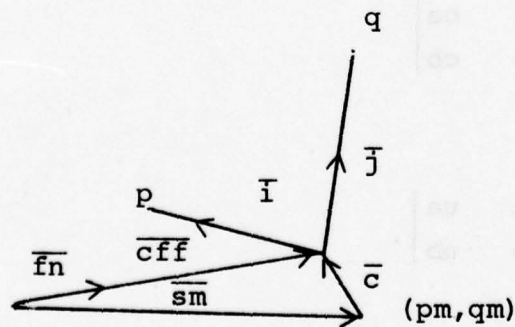


Figure 23.

Then the azimuth th and the elevation ph of the optical axis are approximately

$$th = \cos^{-1} \left[\frac{fn \ 1}{\{(fn \ 1)^2 + (fn \ a)^2\}^{1/2}} \right]$$

If $(fn \ 2 < 0.0)$, $th = -th$ ($-\pi \leq th \leq \pi$)

$$ph = \sin^{-1} (fn \ 3) \quad \left(\frac{\pi}{2} \leq ph \leq \frac{\pi}{2} \right)$$

In order to find the approximate direction of the film frame vector \bar{i} with respect to the $x \ y \ z$ coordinate system two new unit vectors \bar{i}' and \bar{j}' are constructed. These lie in the film frame as do \bar{i} and \bar{j} and they also form with $fn \ a$ a right-handed trio of mutually orthogonal vectors. See Figure 24.

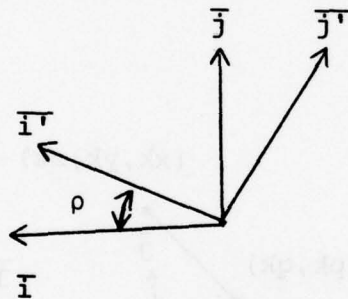


Figure 24.

In order to have a unit vector \bar{i}' which will always be well defined regardless of the orientation of the camera optical axis \bar{fn} , \bar{i}' is derived from that component of the vector joining object points k and l that lies parallel to the film frame, that is, normal to \bar{fn} . It will be recalled that image points k and l had the greatest separation of any point pair on the film frame. ρ is the angle to be solved for once \bar{i}' and \bar{j}' have been found.

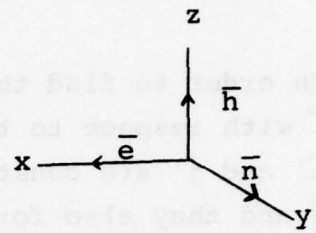
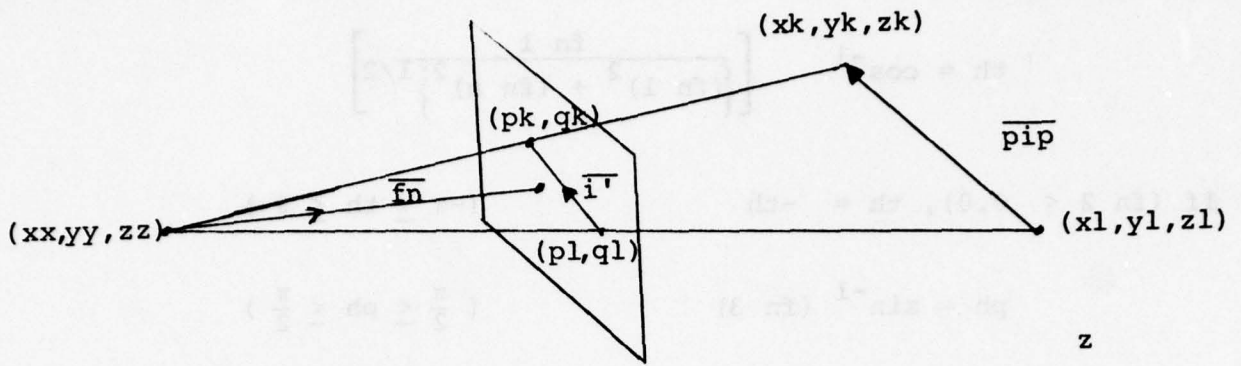


Figure 25.

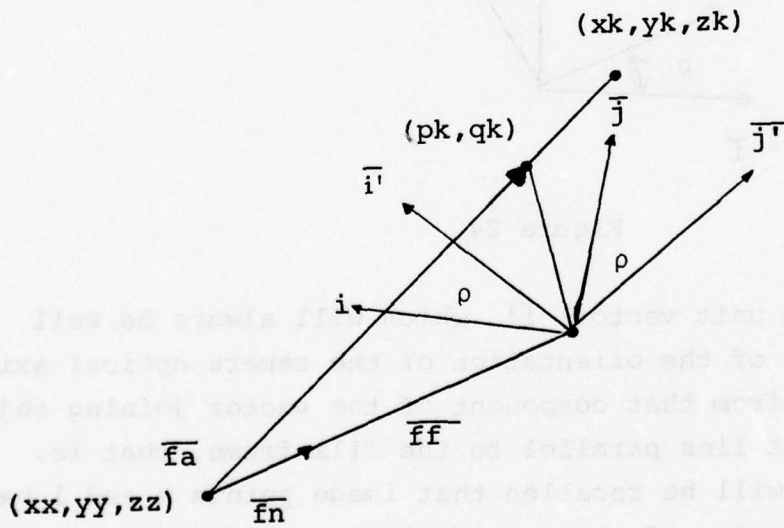


Figure 26.

Figure 25 and the following discussion give the derivation of \bar{i}' and \bar{j}' .

$$\begin{aligned} \text{pip} &= (x_k - x_l) \bar{e} + (y_k - y_l) \bar{n} + (z_k - z_l) \bar{h} \\ &= \text{pipa} \bar{e} + \text{pipb} \bar{n} - \text{pipc} \bar{h}. \end{aligned}$$

To subtract from $\overline{\text{pip}}$ a vector parallel to $\overline{\text{fn}}$ leaving a difference vector $\overline{\text{pi}}$ normal to $\overline{\text{fn}}$ requires the solution of the following equation for the scalar a .

$$(\overline{\text{pip}} - a \overline{\text{fn}}) \cdot \overline{\text{fn}} = 0$$

$$\overline{\text{pip}} \cdot \overline{\text{fn}} - a \overline{\text{fn}} \cdot \overline{\text{fn}} = 0$$

or, since $|\overline{\text{fn}}| = (\overline{\text{fn}} \cdot \overline{\text{fn}})^{1/2} = 1$,

$$a = \overline{\text{pip}} \cdot \overline{\text{fn}}.$$

So $\overline{\text{pi}} = \overline{\text{pip}} - \overline{\text{pip}} \cdot \overline{\text{fn}} \overline{\text{fn}}$ is parallel to the film frame, i.e., normal to $\overline{\text{fn}}$.

$$\bar{i}' = \frac{\overline{\text{pi}}}{|\overline{\text{pi}}|}$$

$$\bar{j}' = \overline{\text{fn}} \cdot \bar{i}'.$$

To find ρ the k th image and object points are used as follows. See Figure 26.

$$\bar{r} = p_k \bar{i} + q_k \bar{j}$$

$$\bar{i} = \cos \rho \bar{i}' + \sin \rho \bar{j}'$$

$$\bar{j} = \cos \left(\rho + \frac{\pi}{2} \right) \bar{i}' + \sin \left(\rho + \frac{\pi}{2} \right) \bar{j}'$$

$$= -\sin \rho \bar{i}' + \cos \rho \bar{j}'$$

$\bar{f}a$ is a vector from the focal point to the impage point (pk, qk).

$$\bar{f}a = (ff^2 + pk^2 + qk^2)^{1/2} \frac{[(xk-xx)\bar{e} + (yk-yy)\bar{n} + (zk-zz)\bar{h}]}{[(xk-xx)^2 + (yk-yy)^2 + (zk-zz)^2]^{1/2}}$$

$$\bar{f}a = faa \bar{e} + fab \bar{n} + fac \bar{h}$$

$$\bar{f}f = ff \bar{f}n - ff fn1\bar{e} + ff fn2\bar{n} + ff fn3\bar{h}$$

$$= ffa \bar{e} + ffb \bar{n} + ffc \bar{h}$$

$$\bar{r} = \bar{f}a - \bar{f}f.$$

$$\text{So } pk \bar{i} + qk \bar{j} = \bar{f}a - \bar{f}f.$$

Substituting for \bar{i} and \bar{j} their expressions in \bar{i}' and \bar{j}' gives

$$pk \cos \rho \bar{i}' + pk \sin \rho \bar{j}' - qk \sin \rho \bar{i}' + qk \cos \rho \bar{j}' = \bar{f}a - \bar{f}f$$

$\bar{f}a - \bar{f}f$ can then be written as

$$\bar{f}a - \bar{f}f = (\bar{f}a - \bar{f}f) \cdot \bar{i}' \bar{i}' + (\bar{f}a - \bar{f}f) \cdot \bar{j}' \bar{j}'$$

Equating components of \bar{i}' and \bar{j}' gives the following scalar equations in which ρ is the only unknown.

$$pk \cos \rho - qk \sin \rho = (\bar{f}a - \bar{f}f) \cdot \bar{i}' = \text{ela (defining ela)}$$

$$pk \sin \rho + qk \cos \rho = (\bar{f}a - \bar{f}f) \cdot \bar{j}' = \text{elb (defining elb)}.$$

Solving the above equations gives ρ .

Then $\bar{i} = \cos \rho \bar{i}' + \sin \rho \bar{j}'$ where the components of \bar{i}' and \bar{j}' are known with respect to the x y z coordinate system. So we get $\bar{i} = g_{ia} \bar{e} + g_{ib} \bar{n} + g_{ic} \bar{h}$ where the g_{ia} , g_{ib} , g_{ic} are obtained by substituting for \bar{i}' and \bar{j}' their expressions in \bar{e} , \bar{n} , and \bar{h} . Then the azimuth θ and elevation ϕ of \bar{i} are found as follows:

$$thi = \cos^{-1} \left[\frac{gia}{(gia^2 + gib^2)^{1/2}} \right]$$

If gib is less than 0.0, set $thi = -thi$.

$$phi = \sin^{-1} (gic).$$

The unit vectors \bar{fn} and \bar{i} obtained above complete the orientation of the camera, but they are only approximate. They depend on the values of th , ph , and ρ . The values of th , ph , and ρ found above should be very close to the correct values. To find that combination of th , ph , and ρ which best aligns all the image points we construct an error sum as follows. Due to the various errors, the point at which a ray from the focal point to an object point pierces the film frame is not identical to the image point of that object point. This is illustrated in Figure 27 for the i th image and object points.

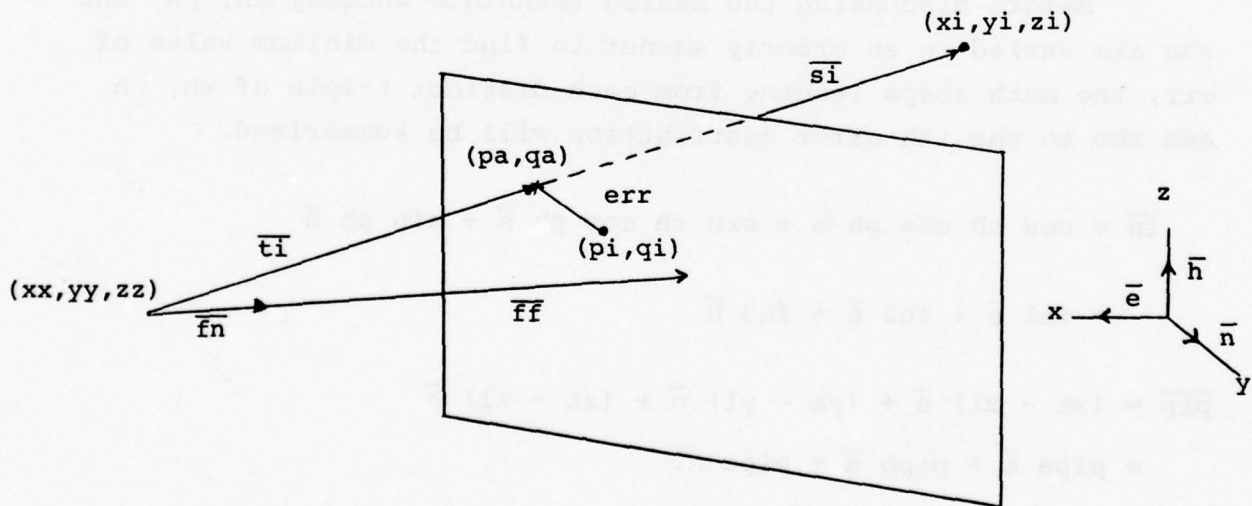


Figure 27.

Let (p_a, q_a) denote the film frame coordinates of the i th pierce point and $erri$ be the distance between $(p_a$ and $q_a)$ and the i th image point at (p_i, q_i) .

$$\text{Then } erri = [(p_i - p_a)^2 + (q_i - q_a)^2]^{1/2}$$

and

$$err = \sum_{i=1}^n erri.$$

Any change in any of the three angles th , ph , or ρ gives a new set of unit vectors $\bar{f}_n, \bar{i}, \bar{j}$ and causes the coordinates of the i th pierce point (p_a, q_a) to change. That combination of th , ph and ρ which results in the minimum value of err is considered to be the best fit. Of course, other definitions of err are possible, the most obvious being to define err as the sum of the squares of the miss distances rather than as their sum, but it was felt that this would allow one badly read image point or badly surveyed object point to have an unduly high distorting influence on the solution.

Before discussing the search technique whereby th , ph , and ρ are varied in an orderly manner to find the minimum value of err , the math steps leading from each distinct triple of th , ph , and ρ to the i th error contribution will be summarized.

$$\begin{aligned} \bar{f}_n &= \cos th \cos ph \bar{e} + \sin th \cos ph \bar{n} + \sin ph \bar{h} \\ &= fn1 \bar{e} + fn2 \bar{n} + fn3 \bar{h} \end{aligned}$$

$$\begin{aligned} \bar{p}_i \bar{p} &= (x_k - x_l) \bar{e} + (y_k - y_l) \bar{n} + (z_k - z_l) \bar{h} \\ &= pip_a \bar{e} + pip_b \bar{n} + pip_c \bar{h}. \end{aligned}$$

(Refer to Figure 25 and its discussion.)

$$a = \overline{p_i p} \cdot \overline{f_n} = p_{ipa} f_{n1} + p_{ipb} f_{n2} + p_{ipc} f_{n3}$$

$$\overline{p_i} = \overline{p_i p} - a \overline{f_n}$$

$$= (p_{ipa} - a f_{n1}) \overline{e} + (p_{ipb} - a f_{n2}) \overline{n} + (p_{ipc} - a f_{n3}) \overline{h}$$

$$= p_{ia} \overline{e} + p_{ib} \overline{n} + p_{ic} \overline{h}$$

$$p_{id} = \sqrt{\overline{p_i}} = (p_{ia}^2 + p_{ib}^2 + p_{ic}^2)^{1/2}$$

$$\overline{i^T} = \frac{\overline{p_i}}{\sqrt{\overline{p_i}}} = \frac{p_{ia}}{p_{id}} \overline{e} + \frac{p_{ib}}{p_{id}} \overline{n} + \frac{p_{ic}}{p_{id}} \overline{h}$$

= $p_{ia} \overline{e} + p_{ib} \overline{n} + p_{ic} \overline{h}$ (Redefining p_{ia} , p_{ib} , p_{ic} to be components of the unit vector $\overline{i^T}$.)

$$\overline{j^T} = \overline{f_n} \times \overline{i^T}$$

$$= (f_{n2} p_{ic} - f_{n3} p_{ib}) \overline{e} + (f_{n3} p_{ia} - f_{n1} p_{ic}) \overline{n}$$

$$+ (f_{n1} p_{ib} - f_{n2} p_{ia}) \overline{h}$$

$$= p_{ja} \overline{e} + p_{jb} \overline{n} + p_{jc} \overline{h}.$$

From the discussion following Figure 26,

$$\overline{i} = \cos \rho \overline{i^T} + \sin \rho \overline{j^T}.$$

Inserting the equation $\overline{i^T}$ and $\overline{j^T}$ and grouping \overline{e} , \overline{n} , and \overline{h}

$$\overline{i} = (p_{ia} \cos \rho + p_{ja} \sin \rho) \overline{e} + (p_{ib} \cos \rho + p_{jb} \sin \rho) \overline{n}$$

$$+ (p_{ic} \cos \rho + p_{jc} \sin \rho) \overline{h}$$

$$= t_{ia} \overline{e} + t_{ib} \overline{n} + t_{ic} \overline{h}.$$

Similarly, $\overline{j} = -\sin \rho \overline{i^T} + \cos \rho \overline{j^T}$

$$= (-p_{ia} \sin \rho + p_{ja} \cos \rho) \overline{e} + (-p_{ib} \sin \rho + p_{jb} \cos \rho) \overline{n}$$

$$+ (-p_{ic} \sin \rho + p_{jc} \cos \rho) \overline{h}$$

$$= t_{ja} \overline{e} + t_{jb} \overline{n} + t_{jc} \overline{h}$$

Referring now to Figure 27,

\bar{t}_i is the vector locating the pierce point (pa, qa) due to the i th object point. \bar{t}_i is a scalar multiple of \bar{s}_i $\bar{t}_i = w \bar{s}_i$ where w is unknown.

The projection of \bar{t}_i on \bar{f}_n must equal the focal length ff .

$$\bar{t}_i \cdot \bar{f}_n = ff$$

or

$$w \bar{s}_i \cdot \bar{f}_n = ff.$$

So

$$w = \frac{ff}{\bar{s}_i \cdot \bar{f}_n}.$$

In component form

$$\bar{s}_i = (x_i - x_x) \bar{e} + (y_i - y_y) \bar{n} + (z_i - z_z) \bar{h}$$

and

$$w = \frac{ff}{(x_i - x_x) f_{n1} + (y_i - y_y) f_{n2} + (z_i - z_z) f_{n3}}.$$

A vector \bar{r} from the center of the film frame to the pierce point is gotten from the equation

$$\bar{r} = \bar{t}_i - ff \bar{f}_n.$$

See Figure 28.

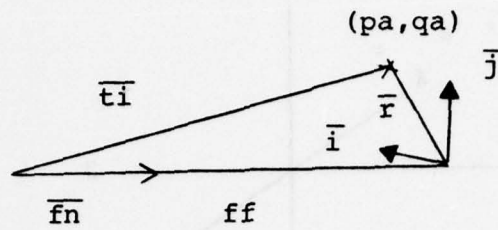


Figure 28.

In component form:

$$\begin{aligned} \bar{r} &= (w (x_i - x_x) - ff \, fn_1) \bar{e} + (w (y_i - y_y) - ff \, fn_2) \bar{n} \\ &+ (w (z_i - z_z) - ff \, fn_3) \bar{h} \\ &= r_a \bar{e} + r_b \bar{n} + r_c \bar{h}. \end{aligned}$$

Now since \bar{r} lies entirely in the film plane, it may be represented in terms of \bar{i} and \bar{j} components as follows:

$$\begin{aligned} \bar{r} &= \bar{r} \cdot \bar{i} \bar{i} + \bar{r} \cdot \bar{j} \bar{j} \\ &= p_a \bar{i} + q_a \bar{j}. \end{aligned}$$

Explicitly,

$$p_a = \bar{r} \cdot \bar{i} = r_a t_{ia} + r_b t_{ib} + r_c t_{ic}$$

$$q_a = \bar{r} \cdot \bar{j} = r_a t_{ja} + r_b t_{jb} + r_c t_{jc}$$

Let $\bar{r}_i = p_i \bar{i} + q_i \bar{j}$

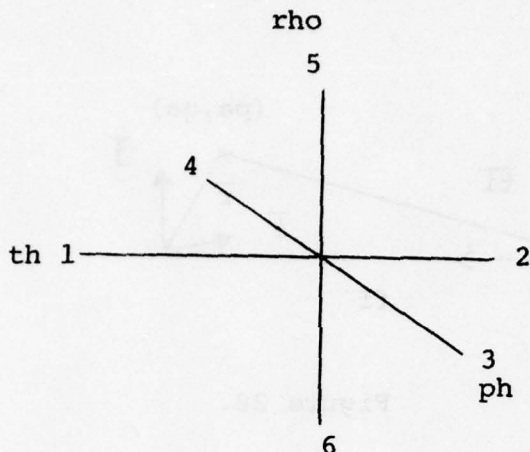


Figure 29.

Then

$$\begin{aligned} \text{erri} &= \sqrt{r_i} - \bar{r} / \\ &= [(p_i - p_a)^2 + (q_i - q_a)^2]^{1/2}. \end{aligned}$$

Then

$$\text{err} = \sum_{i=1}^m \text{erri}.$$

The scheme whereby th, ph, and rho are varied to minimize err is indicated in Figure 29.

The points numbered 1 through 6 indicate the order in which th, ph, and rho are varied. If point 1 (indicating a positive increment added to the present value of th) gives a lower err than exists at the origin, then successive increments are added to th so long as the value of err continues to fall. Points 1, 3, and 5 correspond to increases in th, ph, and rho respectively and 2, 4, and 6 to decreases. Although the axes in Figure 24 serve merely to indicate the order of variation, the procedure is precisely the same as that used to minimize err (fr, xx, ys, zs).

See Figure 18.

When $\text{err}(\text{th}, \text{ph}, \text{rho})$ has been minimized, the final values of \bar{f}_n , \bar{i} , and \bar{j} are computed. Also computed are the azimuth and elevation of the vector \bar{i} , th_i , and phi respectively.

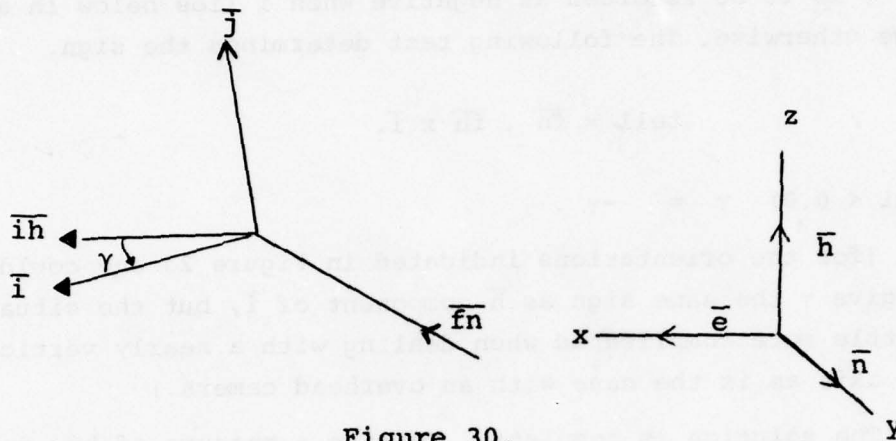


Figure 30.

At this point the camera has been located, oriented, and its focal length determined. The only one of the seven unknowns not yet solved for is the tilt angle, γ , of the camera from the horizontal about its optical axis. Knowing the azimuth th_i and the elevation phi of the unit vector \bar{i} makes γ redundant, but it is among the output of the program, so its derivation will be given.

See Figure 30.

\bar{i}_h is a unit vector in the film frame which is parallel to the $x y$ plane (i.e., horizontal) of the main coordinate system.

$$\bar{i}_h = \frac{\bar{h} \times \bar{f}_n}{|\bar{h} \times \bar{f}_n|}$$

By definition of the cross product \bar{i}_h is normal to both \bar{f}_n and \bar{h} . Therefore, it both lies in the film frame and is parallel to the xy plane. It is obviously a unit vector.

$$\gamma = \cos^{-1} (\bar{i}\bar{h} \cdot \bar{h})$$

γ is to be recorded as negative when \bar{i} lies below $\bar{i}\bar{h}$ and positive otherwise. The following test determines the sign.

$$\text{tell} = \bar{f}\bar{n} \cdot \bar{i}\bar{h} \times \bar{i}$$

If ($\text{tell} < 0.0$) $\gamma = -\gamma$.

(for the orientations indicated in Figure 25 one could simply give γ the same sign as \bar{h} component of \bar{i} , but the situation is a little more complicated when dealing with a nearly vertical optical axis as is the case with an overhead camera.)

The solution is complete. To give a measure of how good the whole situation is, the following check was devised. See Figure 31.

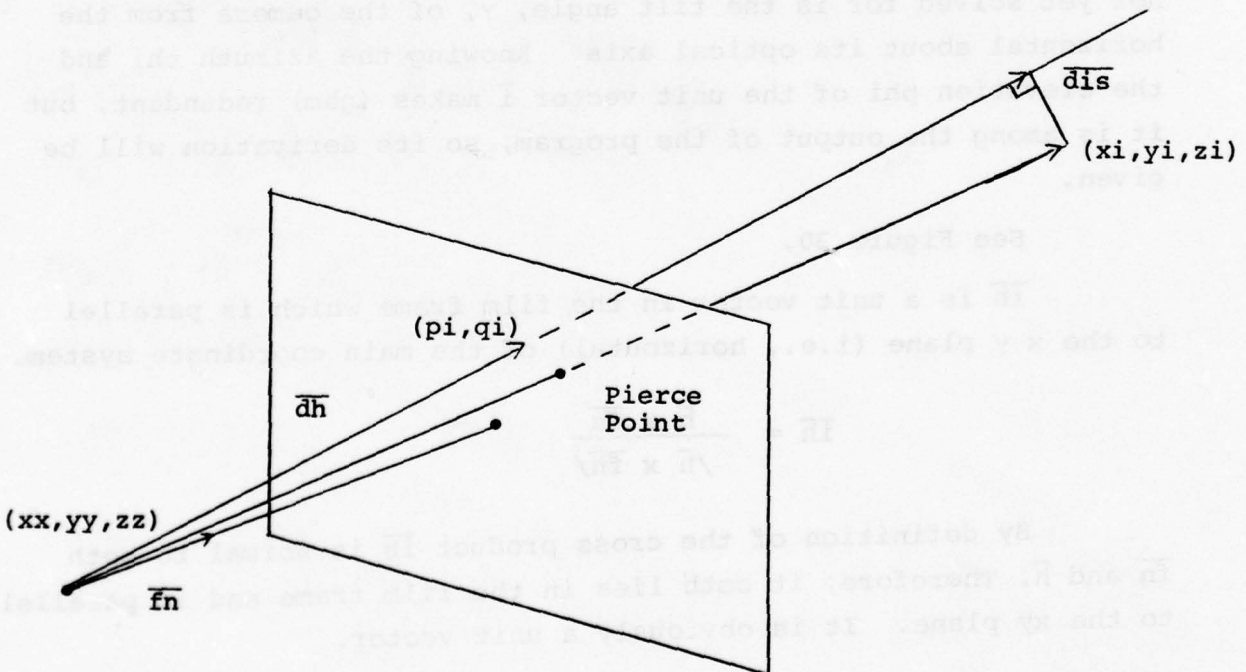


Figure 31.

A ray is extended from the camera focal point through each image point (p_i, q_i) past its corresponding object point and the distance vector \overline{dis} of the ray's nearest approach to the object point is computed. If all distances \overline{dis} so computed are of small magnitude, the fit is obviously good.

$$\begin{aligned}\overline{dh} &= ff \overline{fn} + p_i \overline{i} + q_i \overline{j} \\ &= dha \overline{e} + dhb \overline{n} + dhc \overline{h}\end{aligned}$$

where the final form is obtained by expressing \overline{fn} , \overline{i} , and \overline{j} in terms of their components in the principal coordinate system and then grouping on the principal coordinate system unit vectors \overline{e} , \overline{n} , and \overline{h} .

$$\begin{aligned}\overline{sh} &= (x_i - x_x) \overline{e} + (y_i - y_y) \overline{n} + (z_i - z_z) \overline{h} \\ &= sha \overline{e} + shb \overline{n} + shc \overline{h}\end{aligned}$$

$$dh = \frac{\overline{dh}}{|\overline{dh}|} \quad (\text{a unit vector in the direction of the}$$

i th image point (p_i, q_i) .)

There is a scalar coefficient, $acof$, such that

$$acof \overline{dh} = \overline{sh} + \overline{dis}.$$

Dotting through by \overline{dh}

$$acof \overline{dh} \cdot \overline{dh} = \overline{sh} \cdot \overline{dh} + \overline{dis} \cdot \overline{dh}$$

$$= \overline{sh} \cdot \overline{dh} \quad (\text{since } \overline{dis} \text{ is perpendicular to } \overline{dh})$$

$$acof = \overline{sh} \cdot \overline{dh} \quad \text{since } \overline{dh} \cdot \overline{dh} = 1.$$

So, $\overline{dis} = acof \overline{dh} - \overline{sh}$ and the miss distance is dis where $dis = |\overline{dis}|$.

These miss distances have characteristically fallen into a range of 0.05-inches to 0.22-inches in the solutions run thus far. Good agreement in this check indicates not only that the camera data found is correct, but also that the survey of the object points and the reading of the image points were probably both quite accurate. In closing the discussion of the mathematics used, it should be mentioned that one or two grossly inaccurate image or object point locations can completely swamp out the relative minimum indicated in Figure 15.

3.1.2 Program POOCH

A brief discussion of the overall program operation will be given before going into input and output in detail. A reduced-size-copy of the program is included in Appendix E. Figure 32 contains a block diagram of the program.

The main program POOCH reads in and scales the data. Subroutine FIND together with its auxiliary subroutines, HORSY, REFIN, and ANGLE, computes the correct values of focal point position (xx, yy, zz) and focal length ff. FIND calls HORSY twice to locate points P and Q (shown in Figures 14 and 17). HORSY performs the 27 point cube search displayed in Figure 16. Subroutine ANGLE computes the value of err for any focal length fs and focal point location (sx, ys, zs). After points P and Q (see Figures 14 and 17) have been found, FIND uses subroutine REFIN to find the best values of focal length ff and focal point location (xx, yy, zz). REFIN performs the six point search illustrated in Figure 29. Both HORSY and REFIN use ANGLE to compute err (fx, xs, ys, zs).

Program POOCH then calls subroutine SERCH which provides approximate values of the camera orientation variables th, ph, and rho. Finally, subroutine DANG is called to optimize the approximate camera orientation produced by SERCH. DANG's auxiliary subroutine WRANG computes an error value which is the sum of the distances of all pierce points from their corresponding image points.

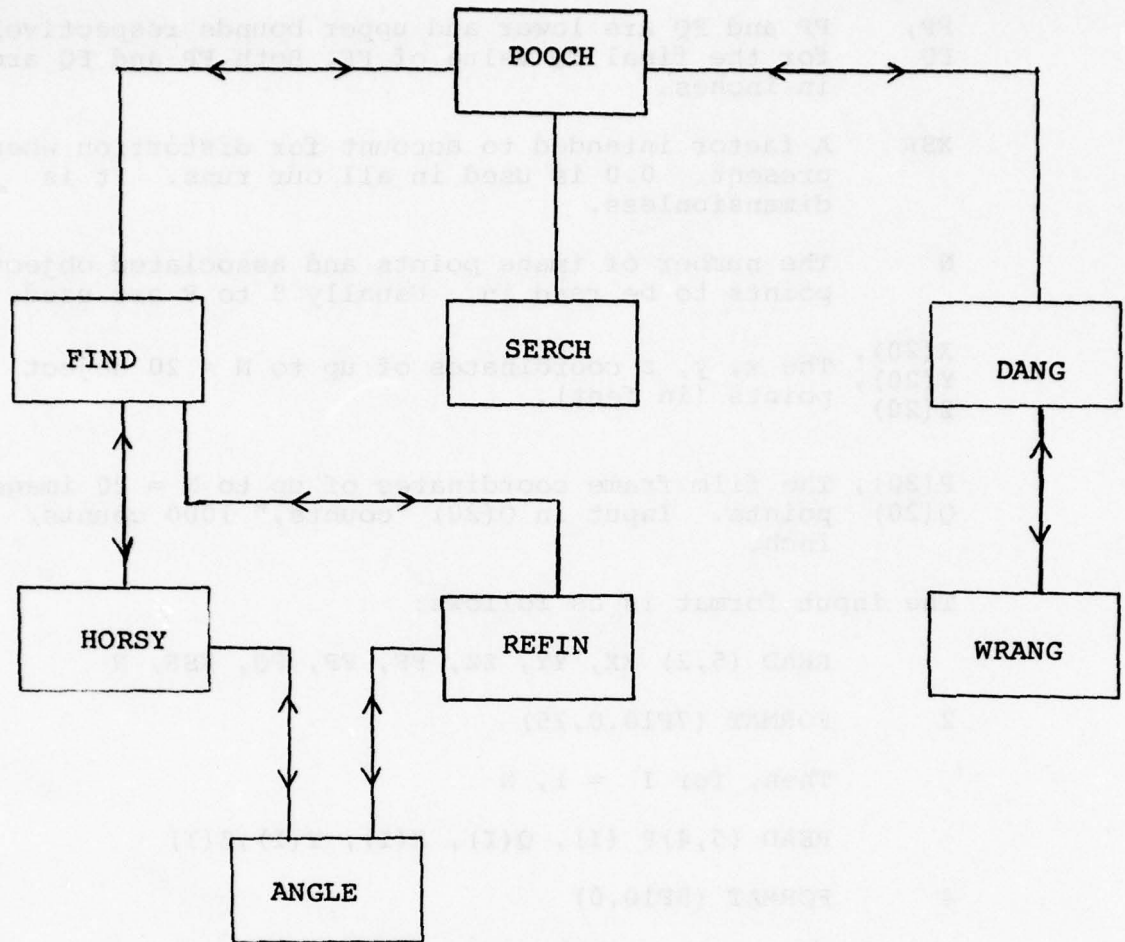


Figure 32. Block Diagram of Program POOCH.

See Figures 27 and 28 and the associated discussion.

The following list contains the variables which must be input to the program:

- XX The x, y, and z coordinates of the estimated camera position.
- YY Input in feet.
- ZZ
- FF The nominal focal length of the camera in inches times the magnification of the film frame reader used.

FP, FP and FQ are lower and upper bounds respectively
FQ for the final FQ value of FF. Both FP and FQ are
in inches.

XSR A factor intended to account for distortion when
present. 0.0 is used in all our runs. It is
dimensionless.

N The number of image points and associated object
points to be read in. Usually 5 to 8 are used.

X(20), The x, y, z coordinates of up to N = 20 object
Y(20), points (in feet).
Z(20)

P(20), The film frame coordinates of up to N = 20 image
Q(20) points. Input in Q(20) "counts," 1000 counts/
inch.

The input format is as follows:

```
READ (5,2) XX, YY, ZZ, FF, FP, FQ, XSR, N
```

```
2 FORMAT (7F10.0,I5)
```

Then, for I = 1, N

```
READ (5,4) P (I), Q(I), X(I), Y(I), Z(I)
```

```
4 FØRMAT (5F10.0)
```

Where each image point P(I), Q(I) is on the same
card as its associated object point X(I), Y(I),
Z(I).

Multiple cases may be read into the program. Figure 33
shows a sample data deck for a case run.

There is at present a great deal of working output taken
from the program but most of it was used for debug purposes and
is of little consequence now and can be eliminated. Rather
than waste many pages describing this debug output, that part
of the output giving the camera location and orientation and
the various checks on the goodness of the solution will be
discussed.

The first three lines of the tab section contain the check values for the first image point. The first pair of values after the image point number are the p and q coordinates of the first film frame image point in feet. The second pair of values are the p and q coordinates of the pierce point due to object point 1, that is, the p and q coordinates of the point of the film that would be pierced by a ray from the camera focal point to the first (refer to Figure 31) object point. The last value is the distance in feet between the image point and the pierce point. It must, of course, be remembered as explained previously, that the magnification of the film frame reader enlarges the actual film frame size by about a factor of 20. However, these distances may be usefully compared both with one another in a single run, and also between runs to see if reasonable results are being obtained. To determine how far apart the image point and its associated pierce point are on the real film frame, the distance given could be divided by about 20.4, the approximate magnification of the reader used.

The last line of output for the first image and object points gives the object point number, then the x, y, and z coordinates in feet of the object point. The fifth, sixth, and seventh values are the x, y, and z components, respectively, of the miss vector \overline{dis} described in Figure 31 and the text pertaining thereto. Its components are given in feet. The last value is the magnitude of \overline{dis} in feet. This is the most important value for judging how good the solution is. The numbers written into the right of these values are the magnitude of \overline{dis} in inches, and as can be seen, are quite reasonable. This assures that not only did the program provide a good solution, but also that the object points were correctly surveyed and their film frame images were correctly read. In short, when the magnitudes of \overline{dis} are small for each object point, it provides a comprehensive check on the entire data reduction scheme.

In the run illustrated, there were seven points available on which to base the solution. Immediately after the listing of the above data for the last of these points, the camera solution data is output. In the line beginning X, Y, Z, F ... the first three numerical values are the x, y, and z coordinates of the location of the camera focal point (in feet). The fourth value is the fictitious program focal length, i.e., it is the product of the true camera focal length and the film reader magnification and is given in feet. The fifth and sixth values are the azimuth and elevation angles of the camera optical axis, both given in radians. The last value in this line of output is the angle that has been referred to us as rho. It is of no consequence after the camera solution has been generated.

The line beginning DAMG,.. gives the azimuth and elevation angles of the film frame \bar{I} axis and the tilt angle of the camera from horizontal about the optical axis in that order. All angles are in radians.

It yet remains to explain a minor point regarding coordinate systems. The experimental coordinate system is a left hand system. See Figure 35.

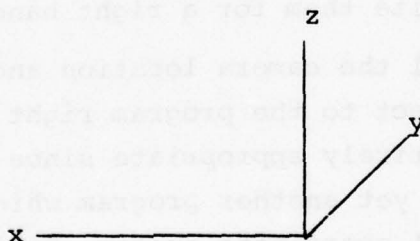


Figure 35.

The input coordinates of all object points (x_i, y_i, z_i) and the estimated initial camera position (x_x, y_y, z_z) are input with respect to this coordinate system. The program changes the sign of the y coordinate of each of these points so that they are properly represented for the right hand coordinate system used in the program. See Figure 36.

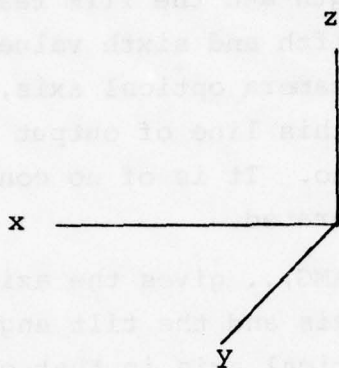


Figure 36.

This change was made so that it would not be necessary to define the components of every vector cross product used for a left hand coordinate system when it is second nature to most to automatically write them for a right handed system.

Moreover all the camera location and orientation data is output with respect to the program right hand coordinate system. This is entirely appropriate since the camera solution is used as input to yet another program which also contains a right hand principal coordinate system. Similarly, the coordinates of the object points are also output with respect to the program right hand system rather than with respect to the original experimental left hand system.

The film frame reader has a coordinate system as indicated in Figure 37 with the horizontal axis positive to the right.

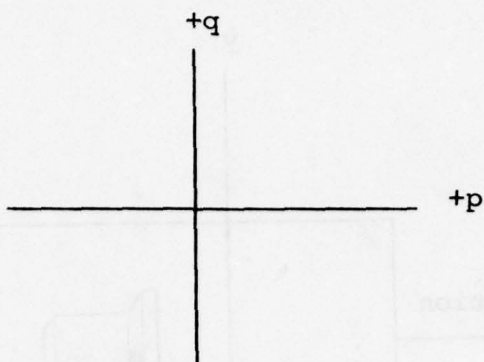


Figure 37.

In order that the unit vectors $\bar{f}_n, \bar{i}, \bar{j}$ (refer to Figure 12) in that order form a right hand system, the sign of the horizontal coordinate of each image point is changed. Moreover the film frame coordinates are output with the signs of their horizontal coordinates still reversed.

There is nothing very involved about these sign changes, but one should be aware of what has been done if he attempts to use the program. These sign changes are clearer from the tab of program POOCH than from all the explanation above, and could be easily changed to suit if one were going to use the program for an experiment in which the experimental coordinate system itself were right handed.

3.2 TWO-RAY SOLUTIONS OF COORDINATES OF POINTS

The Camera Location Program has direct application in Program Sled which performs the reduction of data taken during seat harness tests. A dummy and an animal, or two dummies, are strapped into seats mounted aboard an acceleration sled. Also rigidly mounted aboard the sled are two high-speed cameras which photograph the reactions of the test subjects as the sled accelerates down its track in the $+x$ direction. See Figure 38.

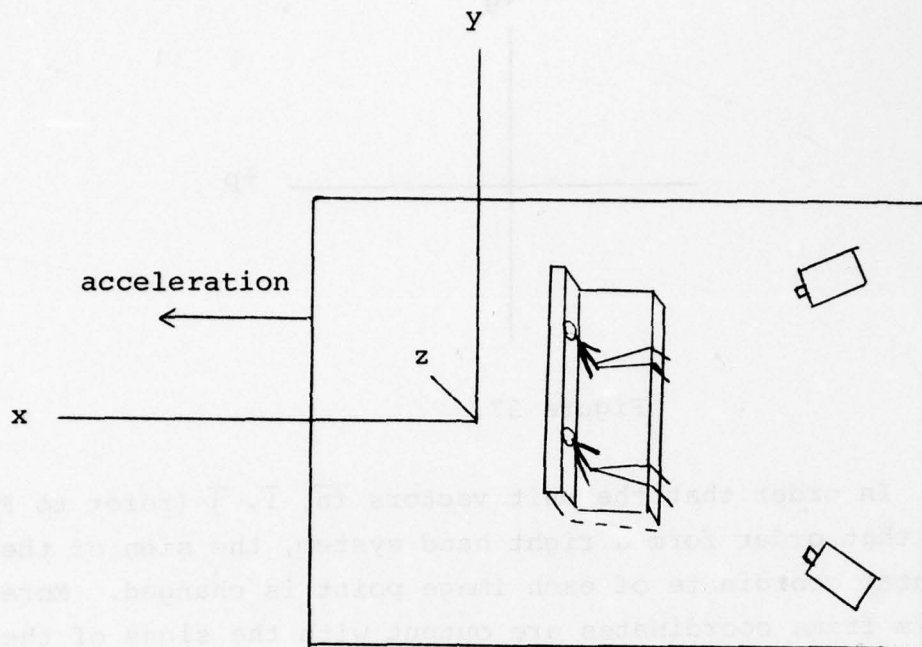


Figure 38.

The experimental coordinate system is a left-hand $x y z$ system affixed to the moving sled. All subject motion recorded is understood to be relative to the sled. In cases run so far, two targets (plastic disks marked so as to be easily discerned on the film frame reader) are attached to each test subject. For a dummy, the forehead and chin have been targeted. When the subject was an animal, head accelerometer pack and tip of the snout were chosen as target points. The whole purpose of program Sled is to provide displacement versus time graphs of each of the targeted points on each of the test subjects.

The camera location program is used first to accurately locate and orient each of the two cameras. The coordinates of a number of points rigidly affixed to the sled are accurately measured. Their film frame image coordinates are determined for each camera. The camera location and orientation data obtained from the camera location program is then input to the Sled program.

The principal coordinate system in the Sled program is a right hand x y z system, not the experimental left-hand system indicated in Figure 38. This change is accomplished simply by changing the sign of the y coordinate of every point after it has been input to Sled. Also, so that the camera system axes will constitute a right-hand coordinate system, the horizontal film frame coordinate is reversed in sign. Unit vectors \bar{e} , \bar{n} , and \bar{h} are directed along the x, y, z axes respectively. See Figure 39. The x, y, and z axes are mutually perpendicular.

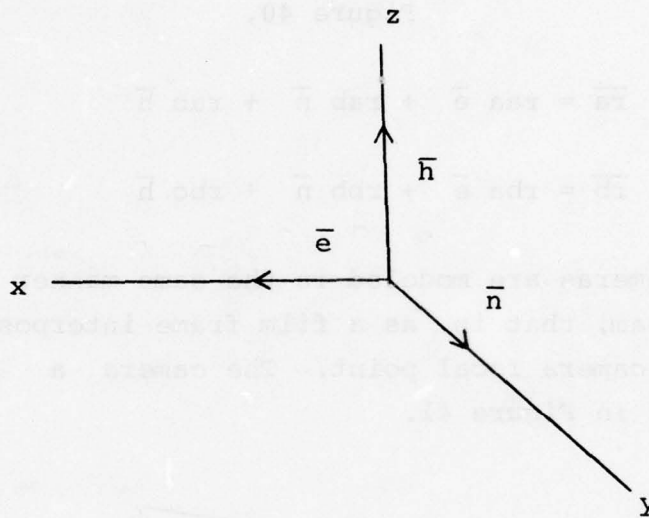


Figure 39.

The two cameras are designated camera a and camera b and their focal points are located by vectors \bar{ra} and \bar{rb} respectively. See Figure 40.

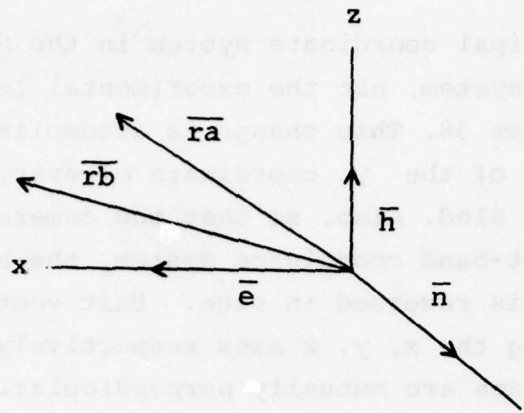


Figure 40.

$$\bar{r}_a = r_{aa} \bar{e} + r_{ab} \bar{n} + r_{ac} \bar{h}$$

$$\bar{r}_b = r_{ba} \bar{e} + r_{bb} \bar{n} + r_{bc} \bar{h}$$

The cameras are modeled in the same manner as in the camera location program, that is, as a film frame interposed between the scene and the camera focal point. The camera a coordinate system is illustrated in Figure 41.

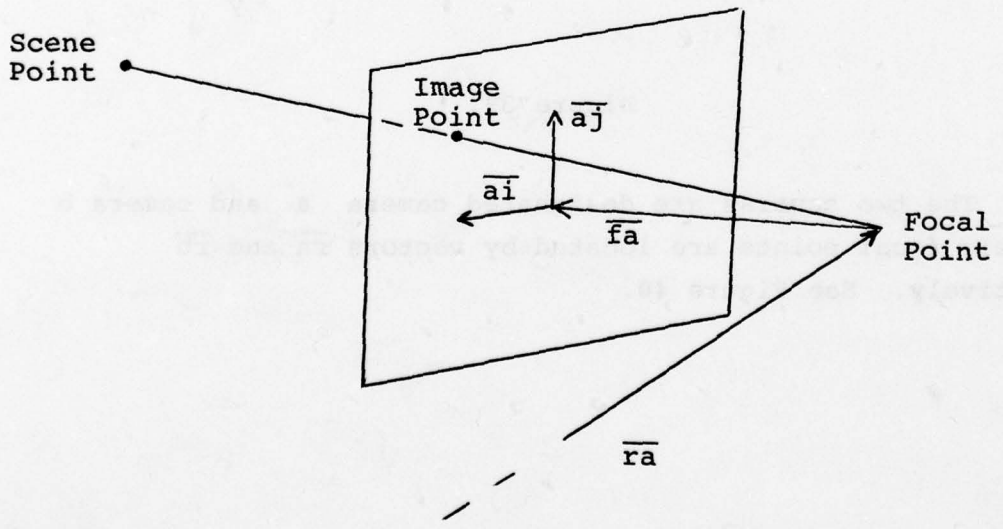


Figure 41.

\bar{f}_a lies along the camera optical axis and is perpendicular to the horizontal and vertical film frame unit vectors \bar{a}_i and \bar{a}_j . The magnitude of \bar{f}_a is f_a , the camera a focal length. (As in the camera location program, \bar{f}_a is actually the product of the true camera focal length and the film reader magnification. The analogous vectors for camera b are \bar{b}_i , \bar{b}_j , \bar{f}_b .)

The data that must be supplied to completely define camera a consists of the three components of its position vector, r_{aa} , r_{ab} , r_{ac} , the azimuth, elevation, and magnitude of \bar{f}_a which are θ_{aa} , ϕ_{aa} , f_a , the azimuth and elevation of \bar{a}_i which are θ_{ia} , ϕ_{ia} . For camera b the analogous quantities are in the same order: r_{ba} , r_{bb} , r_{bc} , f_b , θ_{ib} , ϕ_{ib} , θ_{ib} , ϕ_{ib} .

We will now discuss the principal parts of the analysis in the various subroutines. The first topic will be the derivation of the α camera ray solution. See Figure 42.

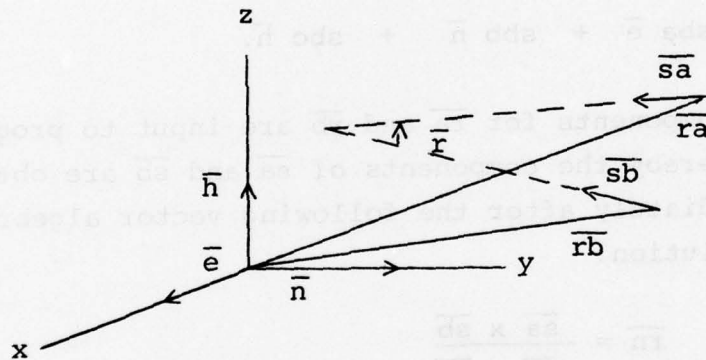


Figure 42.

\bar{r}_a and \bar{r}_b are the position vectors locating cameras a and b respectively. \bar{s}_a and \bar{s}_b are unit vectors along the ray direction from the camera focal point toward the film frame image of one of the moving points on a dummy, a point whose position is to be determined with respect to the x, y, z coordinate

system. Due to film frame reading errors, camera location and orientation errors, and also to the interpolation used to find \overline{sa} and \overline{sb} at the same instant in time, the rays will not in general intersect, but will miss each other by a small distance denoted by the vector \overline{r} . \overline{r} is necessarily perpendicular to both rays.

The position of the moving point on the dummy is assumed to lie at the midpoint of \overline{r} . \overline{ra} , \overline{rb} , \overline{sa} , and \overline{sb} are known completely. Although the vector algebra solution below does not explicitly use the names of the components of these vectors, we will list them for completeness sake:

$$\overline{ra} = r_{aa} \overline{e} + r_{ab} \overline{n} + r_{ac} \overline{h}$$

$$\overline{rb} = r_{ba} \overline{e} + r_{bb} \overline{n} + r_{bc} \overline{h}$$

$$\overline{sa} = s_{aa} \overline{e} + s_{ab} \overline{n} + s_{ac} \overline{h}$$

$$\overline{sb} = s_{ba} \overline{e} + s_{bb} \overline{n} + s_{bc} \overline{h}.$$

The components for \overline{ra} and \overline{rb} are input to program SLED. The method whereby the components of \overline{sa} and \overline{sb} are obtained is taken up immediately after the following vector algebra two ray solution. Solution:

$$\overline{rn} = \frac{\overline{sa} \times \overline{sb}}{|\overline{sa} \times \overline{sb}|}$$

is a unit vector collinear with \overline{r} , that is, \overline{r} is perpendicular to both \overline{sa} and \overline{sb} .

Let $\overline{r} = d \overline{rn}$ where d is the as-yet-unknown-scalar multiple of \overline{rn} which yields \overline{r} . (d will be negative if the \overline{sb} ray passes over the \overline{sa} ray in a particular case.)

(1) $\overline{ra} + \text{coa } \overline{sa} = \overline{rb} + \text{cob } \overline{sb} + \overline{r}$ where coa and cob are scale factors to be solved for.

Substituting for \overline{r} gives

$$(2) \quad \overline{ra} + \text{coa } \overline{sa} = \overline{rb} + \text{cob } \overline{sb} + d \overline{rn}.$$

Dotting through by \overline{rn} gives

$$\overline{ra} \cdot \overline{rn} + \text{coa } \overline{sa} \cdot \overline{rn} = \overline{rb} \cdot \overline{rn} + \text{cob } \overline{sb} \cdot \overline{rn} + d \overline{rn} \cdot \overline{rn}$$

$$\overline{ra} \cdot \overline{rn} - \overline{rb} \cdot \overline{rn} = d.$$

$$(3) \quad \text{or } d = (\overline{ra} - \overline{rb}) \cdot \overline{rn}$$

Rewriting (2) in an altered form gives:

$$(4) \quad \text{coa } \overline{sa} - \text{cob } \overline{sb} = \overline{rb} - \overline{ra} + d \overline{rn}.$$

Dotting through (4) by \overline{sa} gives:

$$\text{coa} - \text{cob } \overline{sb} \cdot \overline{sa} = (\overline{rb} - \overline{ra}) \cdot \overline{sa}$$

or (5) $\text{coa} = (\overline{rb} - \overline{ra}) \cdot \overline{sa} + \text{cob } \overline{sa} \cdot \overline{sb}$

Dotting through (4) by \overline{sb} gives:

$$(6) \quad \text{coa } \overline{sa} \cdot \overline{sb} - \text{cob} = (\overline{rb} - \overline{ra}) \cdot \overline{sb}.$$

Substituting (5) for coa in (6) gives

$$[(\overline{rb} - \overline{ra}) \cdot \overline{sa} + \text{cob } \overline{sa} \cdot \overline{sb}] \cdot \overline{sb} - \text{cob} = (\overline{rb} - \overline{ra}) \cdot \overline{sb}.$$

Solving for cob gives:

$$(7) \quad \text{cob} = \frac{(\overline{rb} - \overline{ra}) \cdot \overline{sa} \overline{sa} \cdot \overline{sb} - (\overline{rb} - \overline{ra}) \cdot \overline{sb}}{1 - (\overline{sa} \cdot \overline{sb})^2}$$

Substituting the value of cob into (5) gives coa.

A vector \overline{sol} locating the solution point (midpoint of \overline{r}) can be computed by either of two equivalent vector sums.

$$\overline{sol} = \overline{rb} + \text{cob} \overline{sb} + 0.5 \overline{r} \quad (\text{see Figure 9})$$

or
$$\overline{sol} = \overline{ra} + \text{coa} \overline{sa} = 0.5 \overline{r}.$$

The ray miss distance dis is gotten from $\text{dis} = /d/ \cdot d$ in the equation below

$$\overline{r} = d \overline{rn}$$

will be negative if \overline{rn} should have a direction or sense opposite to \overline{r} . Its sign depends on the order in which the cameras were read in and which ray is uppermost.

The above solution is performed in subroutine SOLVE. In order that the unit vectors \overline{sa} and \overline{sb} have their components computed with respect to the main coordinate system, the components of each camera coordinate system vector must be known with respect to the main coordinate system. Let (pa, qa) be the film frame coordinates of camera a, fa , its focal length, tha and pha the azimuth and elevation of its optical axis, $thia$ and $phia$ the azimuth and elevation of the camera a \overline{sa} film frame unit vector. See Figure 43.

Now $\overline{ra} = raa \overline{e} + rab \overline{n} + rac \overline{h}$ is known, its components being read in.

$$\begin{aligned} \overline{fa} &= fa \cos tha \cos pha \overline{e} + fa \sin tha \cos pha \overline{n} \\ &+ \overline{fa} \sin pha \overline{h} = faa \overline{e} + fab \overline{n} + fac \overline{h} \end{aligned}$$

$$\begin{aligned} ai &= \cos thia \cos phia \overline{e} + \sin thia \cos phia \overline{n} \\ &+ \sin phia \overline{h} = aia \overline{e} + aib \overline{n} + aic \overline{h} \end{aligned}$$

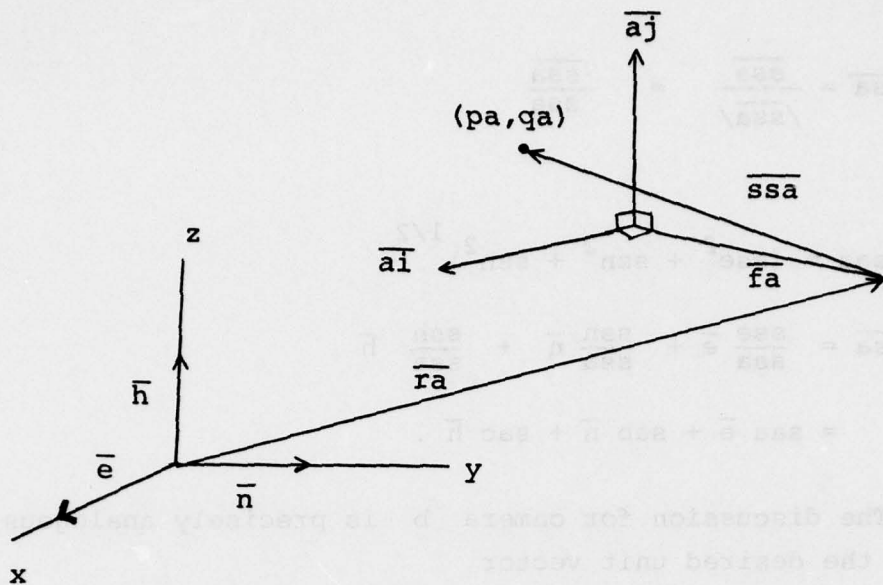


Figure 43.

$$\begin{aligned}
 \overline{a_j} &= \frac{\overline{f_a} \times \overline{a_i}}{f_a} \\
 &= \frac{f_{ab} a_{ic} - f_{ac} a_{ib}}{f_a} \overline{e} + \frac{f_{ac} a_{ia} - f_{aa} a_{ic} n}{f_a} \\
 &\quad + \frac{f_{oa} a_{ib} - f_{ab} a_{ia}}{f_a} \overline{h} \\
 &= a_{jae} + a_{jbn} + a_{jch} \\
 \overline{ssa} &= \overline{f_a} + p_a \overline{a_i} + q_a \overline{a_j} \\
 &= (f_{aa} + p_a a_{ia} + q_a a_{ja}) \overline{e} + (f_{ab} + p_a a_{ib} + q_a a_{jb}) \overline{n} \\
 &\quad + (f_{ac} + p_a a_{ic} + q_a a_{jc}) \overline{h} \\
 &= s_{se} \overline{e} + s_{sn} \overline{n} + s_{sh} \overline{h}.
 \end{aligned}$$

\overline{ssa} is a vector from the camera a focal point to the film frame image point (p_a, q_a) . It has the same direction as the desired unit vector \overline{sa} but its magnitude is in general not 1. So,

$$\bar{s}_a = \frac{\overline{ssa}}{/ssa/} = \frac{\overline{ssa}}{ssa}$$

where

$$saa = (sse^2 + ssn^2 + ssh^2)^{1/2}$$

$$\begin{aligned} \bar{s}_a &= \frac{sse}{ssa} \bar{e} + \frac{ssn}{ssa} \bar{n} + \frac{ssh}{ssa} \bar{h} \\ &= saa \bar{e} + sab \bar{n} + sac \bar{h} . \end{aligned}$$

The discussion for camera b is precisely analogous, yielding the desired unit vector

$$s_b = s_{ba} \bar{e} + s_{bb} \bar{n} + s_{bc} \bar{h} .$$

In determining the solution point the unit vectors \bar{s}_a and \bar{s}_b in the ray directions must be known at the same instant. Since solutions are desired at equally spaced time points, a method of interpolating between two camera rays is needed.

Although there are timing flash marks on each roll of film which allow the time at which each frame was exposed to be determined very closely, the shutters of the two cameras are not synchronized. Moreover, the picture-taking rates of the two cameras are not quite equal.

Assume that we have two successive frames from either one of the cameras taken at times t_{as} and t_{bs} where $t_{as} < t_{bs}$. Let the film frame coordinates of the moving point's image be (ppa, qqa) at time t_{as} and (ppb, qqb) at time t_{bs} .

Figure 44 shows vectors \bar{a} and \bar{b} to the image points of the moving object point at times t_{as} and t_{bs} respectively. Now to get what would have been the ray direction to the moving point's image at time t_s ($t_{as} < t_s < t_{bs}$), we assume that the ray turns with constant angular velocity through the angle θ in time interval $t_{bs} - t_{as}$. That is, the angle θ_s turned through in time $t_s - t_{as}$ is $\theta_s = \frac{t_s - t_{as}}{t_{bs} - t_{as}} \theta$. See Figure 45.

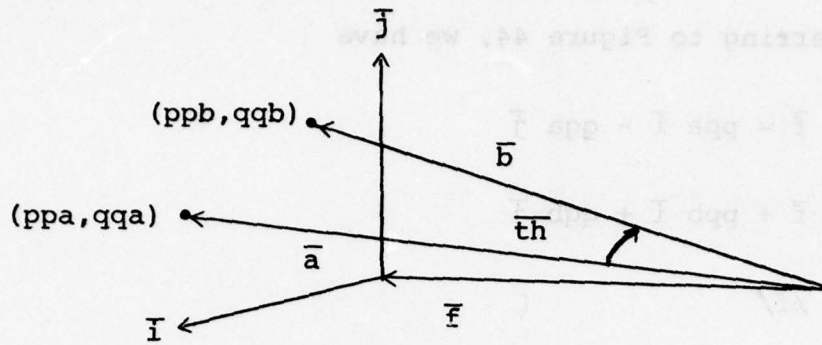


Figure 44.

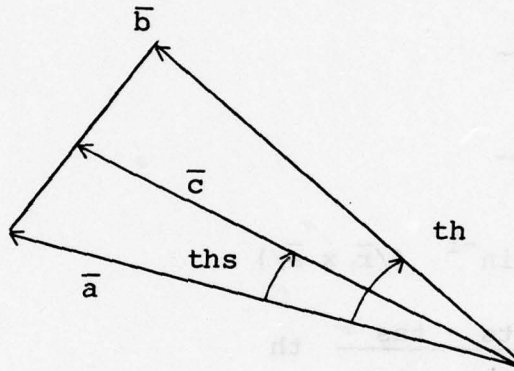


Figure 45.

Figure 45 shows vectors \bar{a} , \bar{b} , and the angles th and ths . Vector \bar{c} is that vector which picks out on the film frame the image point position that would have occurred had a picture been taken at time t_s . (The assumptions that the moving point remains in the plane of its rays \bar{a} and \bar{b} from time t_s to time t_b , and that it moves in such a way that its angular velocity with respect to the camera focal point is constant are in general not exactly true, but if the film frame rate is high enough to faithfully record the experiment, they should be good assumptions. The simple error statistics on the program output seem to indicate the above is a good interpolation.)

Referring to Figure 44, we have

$$\bar{a} = \bar{f} + ppa \bar{i} - qqa \bar{j}$$

$$b = \bar{f} + ppb \bar{i} + qqb \bar{j}$$

$$f = |\bar{f}|$$

$$a = |\bar{a}| = (f^2 + ppa^2 + qqa^2)^{1/2}$$

$$b = |\bar{b}| = (f^2 + ppb^2 + qqb^2)^{1/2}$$

$$\bar{r} = \frac{\bar{a}}{a}$$

$$\bar{s} = \frac{\bar{b}}{b}$$

$$th = \sin^{-1} (|\bar{r} \times \bar{s}|)$$

$$ths = \frac{ts - tas}{tbs - tas} \quad th$$

$$tht = th - ths.$$

Let \bar{rs} be a unit vector in the direction of c . See Figure 46.

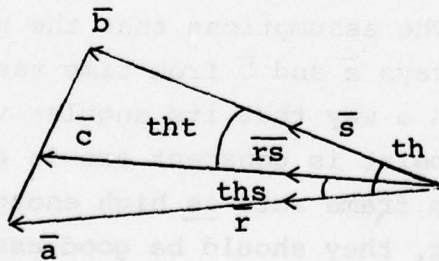


Figure 46.

So,

$$\overline{rs} = A \overline{r} + B \overline{s} \text{ where } A \text{ and } B \text{ must be found.}$$

Dotting through by \overline{r} gives:

$$\overline{r} \cdot \overline{rs} = A \overline{r} \cdot \overline{r} + B \overline{r} \cdot \overline{s}$$

or $\cos ths = A + B \cos th.$

Dotting through by \overline{s} gives:

$$\overline{rs} \cdot \overline{s} = A \overline{r} \cdot \overline{s} + B \overline{s} \cdot \overline{s}$$

or $\cos tht = A \cos th + B$

$$\begin{aligned} A &= \frac{\begin{vmatrix} \cos ths & \cos th \\ \cos tht & 1 \end{vmatrix}}{\begin{vmatrix} 1 & \cos th \\ \cos th & 1 \end{vmatrix}} \\ &= \frac{\cos (ths) - \cos th \cos tht}{1 - \cos^2 th} \\ &= \frac{\cos (th - tht) - \cos th \cos tht}{\sin^2 th} \\ &= \frac{\sin th \sin tht}{\sin^2 th} \\ A &= \frac{\sin tht}{\sin th} \end{aligned}$$

$$\begin{aligned} B &= \frac{\begin{vmatrix} 1 & \cos ths \\ \cos th & \cos tht \end{vmatrix}}{\sin^2 th} \\ &= \frac{\cos tht - \cos ths \cdot \cos th}{\sin^2 th} \end{aligned}$$

$$B = \frac{\sin ths}{\sin th}$$

So,

$$\overline{rs} = A \overline{r} + B \overline{s}$$

$$\overline{rs} = \frac{\sin tht}{\sin th} \overline{r} + \frac{\sin ths}{\sin th} \overline{s}$$

where \overline{rs} is a unit vector in the direction of the image of the moving point at time ts .

We need only scale \overline{rs} so that its tip just touches the film frame. See Figure 47.

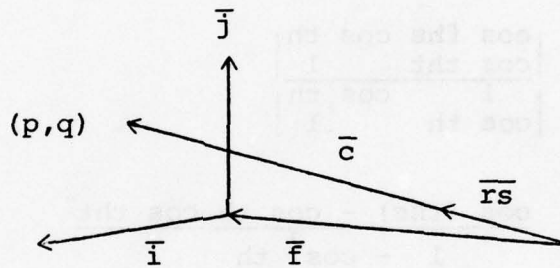


Figure 47.

The length of f is \overline{f} , i.e., $f = \overline{f}$

$\overline{c} = xk \overline{rs}$ where xk must be found.

$xk \overline{rs} \cdot \frac{\overline{f}}{\overline{f}} = f$ (the component of \overline{c} in the direction of the camera optical axis must equal the focal length, f , of the camera.)

So,

$$xk = \frac{f^2}{\overline{rs} \cdot \overline{f}}$$

and

$$\bar{c} = xk \bar{rs}.$$

The coordinates of the image point at time t_s are:

$$(p,q) \text{ where } p = \bar{c} \cdot \bar{i}$$
$$\text{and } q = \bar{c} \cdot \bar{j}.$$

This essentially concludes the discussion of the math modeling used in the program. The rest of the program is principally concerned with bookkeeping.

It is worth mentioning that the ray interpolation probably could have been done more economically. However, an additional complication with the runs is that some slight camera movement is experienced during periods of peak sled acceleration. It is very slight on the great majority of runs. There are, however, one or two runs in which camera vibration was rather severe. In order to deal with this problem, additional analysis (not reported in detail) has been done to allow frame-by-frame reorienting of the cameras. To insert this correction into the program would require a different ray interpolation routine.

The assumption of an absolutely rigid camera mounting appears to be justified in view of the data obtained so far. But reorienting of the cameras frame-by-frame might give some improvement. Also, taking the solutions from the program as it presently stands and actually going back and computing the angular accelerations of the moving points at each camera would provide an interesting check on the ray interpolation assumptions presently in the program. It might even allow a reinterpolation and a better final solution.

In short, there are a number of areas that remain to be investigated in this problem, perhaps with profit, perhaps not.

3.2.1 Program SLED

Program SLED uses four subroutines. Its block diagram appears in Figure 48.

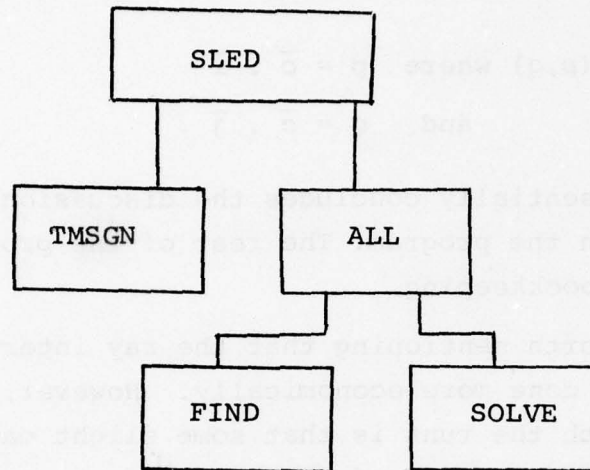


Figure 48. Block Diagram of Program SLED.

A brief overview of the program operation will be given before the more detailed discussion. The main program SLED reads in the input data, scales it where necessary, and writes it out. In broad outline this input data consists of location and orientation data for each of the two cameras and the position coordinates of certain reference points rigidly affixed to the sled. Also, the film frame coordinates of the moving points are input for each of the cameras for each film frame. The film frame coordinates of some of the fixed reference points are also input, but at present no use is being made of this information in program SLED. The time increment desired between solution points is input and a run identification number. The exact reference times for at least two frames are read in for each camera. Subroutine TMSGN (Time Assign) then, by linear interpolation, assigns to each of the other film frames its correct time.

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Subroutine ALL is then called. It computes the time, t_s , at which each of the four moving points is to be determined. It then finds that pair of film frames from each camera whose times bracket the present t_s value. Then, for the first targeted point ALL calls FIND once for each camera to get the interpolated rays toward that point at time t_s . ALL then calls SOLVE to find the position of the point at time t_s . This is done in succession for each of the four moving points on the test subjects. Then, t_s is increased by the desired time increment between solution points and the whole process repeated again. This continues until a time, t_s , is requested which exceeds the time of the last frame input for one of the cameras. Throughout this process the sum of the two ray solution miss distances are stored for each of the four moving points. Also stored is the sum of the squares of these miss distances. After the four moving points have been located for the last value of t_s , the sample mean and sample standard deviation of the miss distances is computed for each of the four points.

The principal symbols used in the program will now be defined. This first list consists of those variables appearing in COMMON. COMMON consists solely of camera location and orientation data.

RAA	}	Camera a position coordinates (feet).
RAB		
RAC		
FA		Camera a focal length (feet).
THA		Camera a optical axis azimuth (radians).
PHA		Camera a optical axis elevation (radians).
GA		Camera a tilt angle in radians. Not presently used.
THIA		Azimuth of the camera a film frame \bar{i} factor (radians).
PHIA		Elevation of the camera a film frame \bar{i} vector (radians).

RBA	}	Camera b positon coordinates (feet).
RBB		
RBC		
FB	Camera b focal length (feet).	
THB	Camera b optical axis azimuth (radians).	
PHB	Camera b optical axis elevation (radians).	
GB	Camera b tilt angle in radians. Not presently used.	
THIB	Camera b \bar{i} axis azimuth (radians).	
PHIB	Camera b \bar{i} axis elevation (radians).	

The next part of the symbol list consists principally of the dimensioned variables used by the program. A short discussion follows this list.

NA	Number of frames of camera a data.
NFRA(I), I = 1, NA	Frame number of the ith frame of camera a data.
NB	Number of frames of camera b data.
NFRB(I), I = 1, NB	Frame number of the ith frame of camera b data.
TA(I), I = 1, NA	Time at which camera a shot ith frame (seconds).
TB(I), I = 1, NB	Time at which camera b shot ith frame (seconds).
XA(I,J), I = 1, NA; J = 1, 8	The horizontal film frame coordinate of the jth image point on the ith film frame of camera a (counts: 1000/counts/inch).
YA (I,J), I = 1, NA; J = 1, 8	The vertical film frame coordinate of the jth image point on the ith film frame of camera a (counts: 1000/counts/inch).
XB (I,J), I = 1, NB; J = 1, 8	The analogous quantities for camera b.
YB (I,J), I = 1, NB; J = 1, 8	

NREFA(I), I = 1, 10	Up to 10 camera a frame numbers and their associated times may be read in and used by TMSGN to assign the correct times to all the camera a film frames (TREFA (I) values in seconds).
TREFA (I), I = 1, 10	
NREFB(I), I = 1, 10	The analogous quantities for camera b.
TREFB(I), I = 1, 10	In practice only two reference frame numbers and times need be used.
SMEAN (J), J = 5, 8	The sample mean and the sample standard deviation of the two-ray-solution miss distances for each of the four targeted points (inches).
SSDEV(J), J = 5, 8	
XX(10) YY(10) ZZ(10)	The position coordinates of up to 10 reference points rigidly attached to the sled (feet).

The above list can be further clarified by discussing those quantities in the above list that pertain only to camera a. The cameras are brought up to speed shortly before the sled begins to accelerate in order that the picture-taking rate of each camera be constant during the actual experiment. Thus, the first frame of camera a containing data of interest might be frame 80. Assume there are 33 frames of camera a data numbered consecutively from 80 to 112.

```

Then   NA = 33
        NFRA(1) = 80
        NFRA(2) = 81
        .
        .
        .
        NFRA(33) = 112

```

Now there are eight points on each of these frames whose coordinates are read on the film frame reader. The program stores these as XA (I,J), YA(I,J) I = 1, 33; J = 1, 8. Thus, the fifth point read on the ninth frame would have coordinates XA (9,5), YA (9,5). This is on frame number 88, i.e., NFRA (9) = 88.

The cameras do run at a constant rate once they have come up to speed. There are timing flashes of light superimposed on the negative from which the time an individual frame was shot can be determined quite accurately. Suppose that frame 80 is found to have been taken at time 0.142 seconds and frame 112 at 0.208 seconds. Then the program would store

NREFA(1) = 80 NREFA (2) = 112
TREFA(1) = 0.142 TREFA (2) = 0.208.

Subroutine TMSGN then assigns the correct time to each frame of camera a data by linear interpolation and stores them in TA(I), I = 1, 33, i.e.,

TA (1) = 0.142
TA (2) = 0.144
.
.
.
TA (32) = 0.206
TA (33) = 0.208.

It is not necessary to use the first and last frame of data. Had frames 88 and 99 been used as reference frames, TMSGN would linearly extrapolate to those frames outside the interval.

Precisely the same discussion applies to those variables associated with camera b. Since the two cameras are not synchronized, the only connection between their data is the time flash which is inscribed on both film strips simultaneously. Thus, camera a and camera b in general have different numbers of frames and in general, no two frames from a and b are snapped simultaneously. Moreover, it is generally true that a test time t_s at which the position of the moving points are to be output is not coincident with that of any frame from either camera.

The input for the program will now be discussed.

The first four cards contain the location and orientation information for camera a and b as follows:

Cards 1 and 2: RAA, RAB, RAC, FA, THA, PHA, GA
THIA, PHIA

Format (4F10.0/5F10.0)

Cards 3 and 4: RBA, RBB, RBC, FB, THB, PHB, GB, THIB,
PHIB

Format (4F 10.0/5F10.0).

The input of camera a and camera b film frame data is terminated by signal cards at the ends of their respective data decks. The numbers NA and NB are determined during the read-in of this data. The data for each film frame requires two cards. The first card for each frame contains the frame number and then the film frame coordinates for the images of the four fixed points. The second card contains the same frame number and then the film frame coordinates for the four moving points. NA is incremented by one as the two cards for each new frame of camera a data are read in.

Camera a data input for each frame

NFRA(NA), ((XA(NA,I), YA(NA,I)), I = 1, 8)

Format (I5, 8F7.0/5X, 8F7.0).

Termination cards for camera a input consists of two cards, the first with 9's in columns 1-5, the second blank.

99999

A BLANK CARD

Camera b data input for each frame is

NFRB(NB), ((XB(NB,I), YB(NB,I)), I = 1, 8)

Format (I5, 8F7.0 / 5X, 8F7.0).

Termination is the same as camera a.

99999

A BLANK CARD.

Next the position coordinates of some reference points are read in. NHP, the number of reference points, is defined as they are read in. Again, the read-in is terminated by a signal card. The format is

```
XX(NHP), YY(NHP), ZZ(NHP)
Format (3F10.0).
```

The termination card has 100000.0 punched in the first ten columns and is otherwise blank.

The reference times and the reference frame numbers for camera a are then input to the program. NTMA, the number of reference times for camera a, is determined when the read-in is terminated by a card with 99999 in columns 12-16.

Camera a data input for each reference time and frame number is

```
TREFA (NTMA), NREFA (NTMA)
Format (F10.0, I6)
```

The termination card is
99999 (in columns 12-16).

The camera b time reference input is precisely analogous and is terminated in the same way.

```
TREFB (NTMB), NREFB (NTMB)
Format (F10.0, I6)
```

with termination card

99999 (in columns 12-16).

The last input card contains the run identification number DESIG and the time increment DT (in seconds) desired between position solutions for the moving points. The format is

```
DT, DESIG
Format (2F10.0).
```

Figure 49 indicates the various sections of a typical input deck.

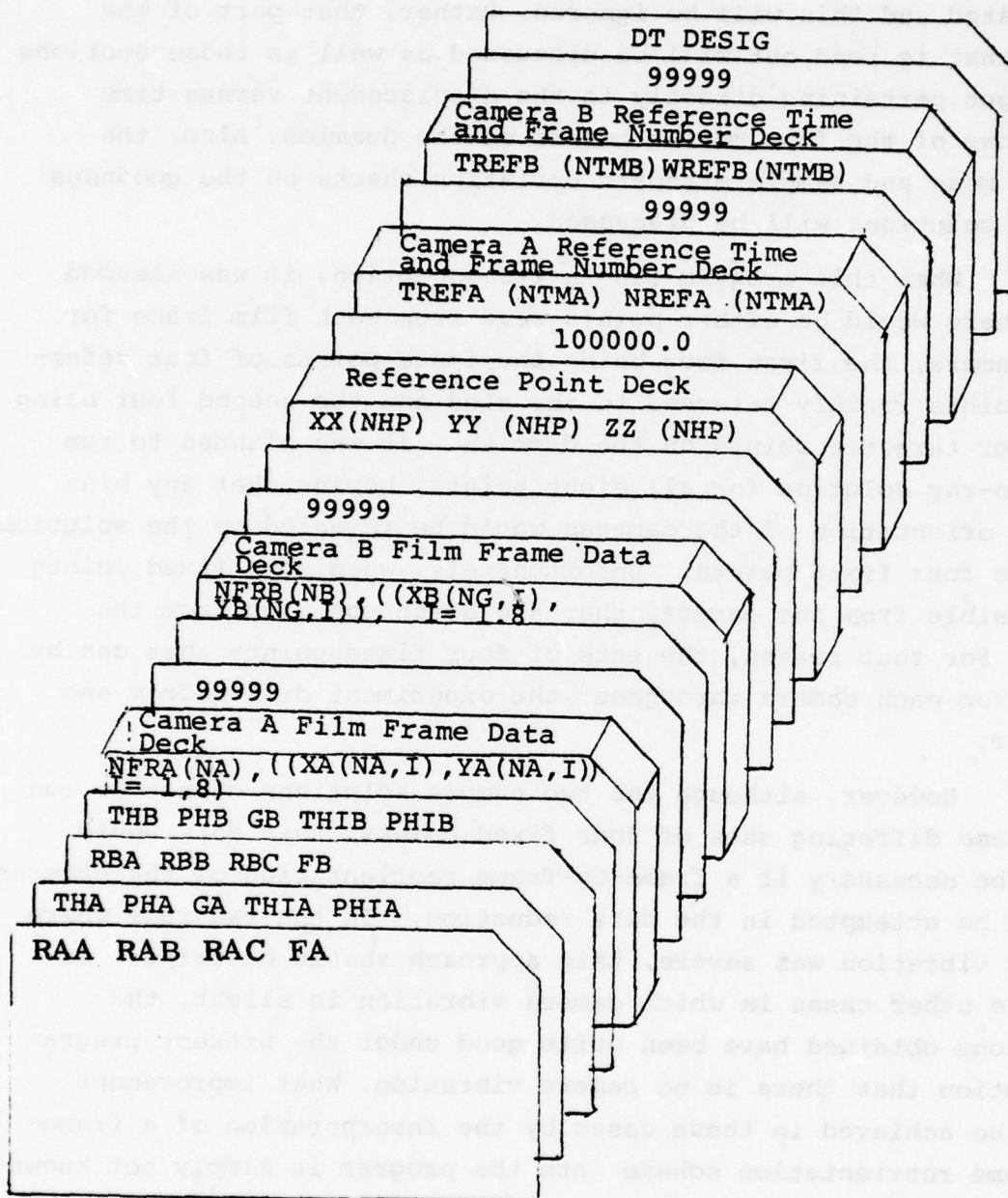


Figure 49. Typical Data Deck Input to Program SLED.

There is a great deal of output presently taken from the program. Much of this is debug output which can now be eliminated and this will be ignored. Rather, that part of the input that is read out will be discussed as well as those sections of output pertaining directly to the displacement versus time solutions of the four moving points on the dummies. Also, the sample mean and sample standard deviation checks on the goodness of the solutions will be discussed.

When this program was in its inception, it was assumed that there would be either points read from each film frame for each camera, the first four being the image points of four reference points rigidly attached to the sled and the second four being the four targeted points on the dummies. It was planned to run the two-ray solution for all eight points, hoping that any bias in the orientation of the cameras would be revealed by the solutions for the four fixed points. Unfortunately, when some fixed points are visible from one camera, they are often obscured from the other. For that reason, the sets of four fixed-points that can be read from each camera throughout the experiment differ from one another.

However, although the two camera solutions cannot be run for these differing sets of four fixed points, this data would still be necessary if a frame-by-frame reorientation of the cameras should be attempted in the data reduction. In the two runs where camera vibration was severe, this approach should be tried. In all the other cases in which camera vibration is slight, the solutions obtained have been quite good under the present program assumption that there is no camera vibration. What improvement could be achieved in these cases by the incorporation of a frame-by-frame reorientation scheme into the program is simply not known at this time.

As the program presently stands, it makes no use whatsoever of the first four image points read in for each frame of each camera. Nor is any use made of position coordinates of the

reference points read in. This information is being retained with a view as to modifications yet to be made to program SLED. For the above reasons, the sample mean and sample standard deviation read-out for the first four points are recorded as 0.0 since no solutions are attempted for these points.

Figure 50 is a tab page showing some of the output. The first two lines are the camera location and orientation data for cameras a and b. Position coordinates and focal lengths are in feet and all the angles in radians.

The bracketed data immediately below consists of the position coordinates of each of the reference points input. These are in feet and are given with respect to the program right-hand coordinate system as are the camera positions above. The reference times are in seconds. Part of the frame data for camera a is output. There are three lines for each frame of data. Taking the first frame as an example, the "1" identifies this as the first frame of camera a data, the "80" is the film frame number, and the .141864E + 00 is the time in seconds at which it was snapped. The next line gives the film frame image coordinates of the four fixed points read for camera a and the following line contains the coordinates of the four targeted points on the dummies. All these film frame image coordinates are output in feet. After all the film frame data for both cameras a and b has been output, the time increment, dt, desired between solution positions for each of the four points is printed out in seconds. Refer to the complete listing beginning on page F-15 to see this.

Figure 51 displays that page of the tab on which the sample mean and the sample standard deviation for each of the four targeted points (point numbers 5 through 8) are provided. These quantities are the mean and the standard deviation of all the miss distances, d, in the two-ray solutions for each of the moving points. They are output in inches.

CAMERA DATA	RAB	RAC	FA	TJA	PHA	GA	THIA	PHIA
346011E+01	510635E+01	37772E+01	560667E+00	-550555E+00	-313275E+00	+413100E-01	.374504E+00	.332092E-01
CAMERA JATYRA	RRB	RBC	TJA	PHB	GB	THIB	PHIB	PHIB
337545E+01	313917E+01	363636E+01	562761E+00	-223053E+00	-147775E-01	.221300E+01	.141150E-01	.141150E-01
HARD PT LOCATIONS	376317E+01	143750E+01	176311E+01	562761E+00	-223053E+00	-147775E-01	.221300E+01	.141150E-01
HARD PT LOCATIONS	500167E+01	325840E+00	376311E+01	562761E+00	-223053E+00	-147775E-01	.221300E+01	.141150E-01
HARD PT LOCATIONS	541002E+01	-840530E+00	376311E+01	562761E+00	-223053E+00	-147775E-01	.221300E+01	.141150E-01
HARD PT LOCATIONS	550000E-01	403333E+01	406670E+00	562761E+00	-223053E+00	-147775E-01	.221300E+01	.141150E-01
HARD PT LOCATIONS	733309E-01	563300E+01	643330E+00	562761E+00	-223053E+00	-147775E-01	.221300E+01	.141150E-01
HARD PT LOCATIONS	733300E-01	-951670E+00	656670E+00	562761E+00	-223053E+00	-147775E-01	.221300E+01	.141150E-01
HARD PT LOCATIONS	755000E-01	-106290E+01	507500E+00	562761E+00	-223053E+00	-147775E-01	.221300E+01	.141150E-01
HARD PT LOCATIONS	758300E-01	0	575670E+00	562761E+00	-223053E+00	-147775E-01	.221300E+01	.141150E-01
HARD PT LOCATIONS	759000E-02	0	221570E+00	562761E+00	-223053E+00	-147775E-01	.221300E+01	.141150E-01
REF TIMEFRAME NOS	141064E+00	80	2	2	2	2	2	2
REF TIMEFRAME NOS	209136E+00	112	2	2	2	2	2	2
REF TIMEFRAME NOS	146412E+00	20	2	2	2	2	2	2
REF TIMEFRAME NOS	196144E+00	103	2	2	2	2	2	2
1	141064E+00							
153333E+00	213563E+00	511557E-01	213750E+00	-101003E+00	-216667E+00	-257417E+00	-196667E+00	
732500E-01	137435E+00	477500E-01	127333E+00	-151167E+00	131750E+00	-119000E+00	-35833E-01	
153750E+00	213167E+00	619167E-01	213417E+00	-101250E+00	-213000E+00	-257750E+00	-196167E+00	
743333E-01	136817E+00	416667E-01	124167E+00	-157817E+00	123667E+00	-1138500E+00	-767500E-01	
153833E+00	212417E+00	623333E-01	212917E+00	-101250E+00	-213000E+00	-257750E+00	-196167E+00	
696667E-01	134633E+00	416667E-01	122833E+00	-158750E+00	119667E+00	-1138250E+00	-746667E-01	
153317E+00	211917E+00	395833E-01	212833E+00	-101500E+00	-217500E+00	-256500E+00	-197667E+00	
662500E-01	132250E+00	395833E-01	122833E+00	-158750E+00	119667E+00	-1138250E+00	-746667E-01	
153667E+00	211816E+00	613333E-01	212500E+00	-101500E+00	-217500E+00	-256500E+00	-196500E+00	
632167E-01	132250E+00	360333E-01	121033E+00	-166317E+00	116750E+00	-117000E+00	-197000E+00	
153333E+00	214417E+00	613333E-01	215033E+00	-100917E+00	-217583E+00	-256167E+00	-196500E+00	
612500E-01	126250E+00	391667E-01	117500E+00	-162750E+00	113250E+00	-1136500E+00	-719167E-01	
152500E+00	215833E+00	505667E-01	215033E+00	-100500E+00	-217583E+00	-256167E+00	-196500E+00	
593157E-01	124167E+00	392500E-01	113317E+00	-164000E+00	1108917E+00	-134500E+00	-698333E-01	
151500E+00	216583E+00	595000E-01	216500E+00	-993167E-01	-217750E+00	-256167E+00	-196500E+00	
568333E-01	117750E+00	401667E-01	109750E+00	-165167E+00	1103917E+00	-134500E+00	-657500E-01	
150833E+00	216917E+00	597500E-01	216500E+00	-994167E-01	-217333E+00	-257167E+00	-196000E+00	
570000E-01	112000E+00	411667E-01	977500E-01	-164500E+00	994167E-01	-133633E+00	-640000E-01	
150750E+00	216500E+00	590000E-01	216833E+00	-995633E-01	-217667E+00	-257500E+00	-196500E+00	
573157E-01	105333E+00	420000E-01	896333E-01	-168250E+00	965000E-01	-130917E+00	-625000E-01	
151417E+00	217093E+00	598333E-01	216750E+00	-995833E-01	-217667E+00	-257500E+00	-196500E+00	
574157E-01	990833E-01	441667E-01	804167E-01	-163417E+00	936667E-01	-128917E+00	-623333E-01	
151333E+00	217250E+00	598333E-01	216833E+00	-101750E+00	-207083E+00	-258167E+00	-197000E+00	
581667E-01	100417E+00	466033E-01	784167E-01	-162000E+00	100667E+00	-127333E+00	-705833E-01	
152500E+00	216167E+00	612500E-01	216167E+00	-102000E+00	-217250E+00	-258333E+00	-195917E+00	
590000E-01	630000E-01	502500E-01	572500E-01	-161417E+00	689167E-01	-123667E+00	-604167E-01	
152533E+00	216000E+00	605633E-01	216000E+00	-102333E+00	-216917E+00	-258333E+00	-195500E+00	
583333E-01	752500E-01	533333E-01	444167E-01	-159417E+00	860833E-01	-123000E+00	-601667E-01	
152250E+00	214250E+00	605000E-01	214250E+00	-102583E+00	-217333E+00	-259000E+00	-196583E+00	
575667E-01	675000E-01	576667E-01	314167E-01	-159000E+00	640033E-01	-121167E+00	-582500E-01	
151750E+00	214833E+00	662500E-01	216033E+00	-103167E+00	-217333E+00	-259000E+00	-196433E+00	
562500E-01	613333E-01	601667E-01	229167E-01	-159667E+00	816667E-01	-116667E+00	-576667E-01	
17	175000E+00							

Reference Point Position Coordinates

Reference Times and Frame Numbers for Camera A
 Reference Times and Frame Numbers for Camera B

First Frame of
 Camera A Data

Figure 50. Typical Listing of Data Input to Program SLED.

FIND	.202268E+00	--.150750E+00	.465000E-01	--.152333E+00	.500000E-01	.204000E+00							
SOLVE	.153546E+00	.900216E-01	--.152300E+00	.494396E-01	.700017E+00	.110425E+01	126						
FIND	.203338E+00	--.113417E+00	.600000E-01	--.117750E+00	.612500E-01	.204000E+00							
FIND	.202268E+00	--.143167E+00	.199167E-01	--.149750E+00	.195633E-01	.204000E+00	127						
SOLVE	--.113429E+00	.600036E-01	--.149657E+00	.114537E-01	.245403E+00	--.149721E+00							
CORR	.588556E+00	--.121360E+00	.977255E+00	.143717E-01	.157776E-01								
FIND	.644825E+00	--.299439E+00	.220532E+01	.300164E-01	.326705E-01								
FIND	.203944E+00	.593333E-01	.250000E-01	.610000E-01	.206000E+00								
FIND	.204330E+00	.104167E+00	.551667E-01	.101667E+00	.525000E-01	.206000E+00	126						
SOLVE	.609376E-01	.256879E-01	.102141E+00	.582342E-01	.178173E+01	.223448E+01							
FIND	.203944E+00	.765833E-01	--.975000E-02	.794167E-01	.800333E-02	.206000E+00							
FIND	.204330E+00	.126917E+00	.500000E-01	.130667E+00	.430000E-01	.206000E+00	129						
SOLVE	.793276E-01	--.813573E-02	.123954E+00	.491901E-01	.624939E+00	.876576E+00							
FIND	.203944E+00	--.150541E+00	.300433E-01	--.151667E+00	.931647E-01	.206000E+00							
FIND	.204330E+00	--.152333E+00	.500000E-01	--.156250E+00	.520333E-01	.206000E+00	130						
SOLVE	.191633E+00	.930637E-01	.800000E-01	.117750E+00	.695149E+00	.112611E+01							
FIND	.203944E+00	--.113617E+00	.195833E-01	--.117567E+00	.612500E-01	.206000E+00							
FIND	.204330E+00	--.149750E+00	.195833E-01	--.156667E+00	.153187E-01	.206000E+00							
SOLVE	--.117614E+00	.612107E-01	--.152322E+00	.186194E-01	.992893E+00	--.151842E+01	131						
CORR	.588556E+00	--.149750E+00	.977112E+00	.158571E-01	.165019E-01								
FIND	.644774E+00	--.299451E+00	.220601E+01	.295619E-01	.323806E-01								
FIND	.206055E+00	.610000E-01	.259167E-01	.531667E-01	.235000E-01	.208000E+00							
FIND	.206392E+00	.101667E+00	.552500E-01	.101417E+00	.550000E-01	.208000E+00	132						
SOLVE	.630424E-01	.292644E-01	.101472E+00	.550550E-01	.126043E-01	--.130000E+00							
FIND	.206392E+00	.794167E-01	.800333E-02	.813333E-01	.341667E-02	.208000E+00							
FIND	.206392E+00	.130667E+00	.490000E-01	.131000E+00	.480833E-01	.208000E+00	133						
SOLVE	.812374E-01	--.172145E-02	.130427E+00	.462850E-01	.941703E+00	.861044E+00							
FIND	.206055E+00	--.151667E+00	.931667E-01	--.149417E+00	.941667E-01	.208000E+00							
FIND	.206392E+00	--.156250E+00	.520333E-01	--.155750E+00	.526667E-01	.208000E+00	134						
SOLVE	.143563E+00	.978300E-01	.612500E-01	--.115667E+00	.633333E-01	.208000E+00							
FIND	.206055E+00	--.117750E+00	.612500E-01	--.115667E+00	.633333E-01	.208000E+00							
FIND	.206392E+00	--.153667E+00	.159167E-01	--.154250E+00	.191567E-01	.208000E+00	135						
SOLVE	.115804E+00	.631965E-01	--.154422E+00	.153167E-01	.197679E+00	--.151894E+01							
CORR	.588556E+00	--.121290E+00	.976985E+00	.162101E-01	.170864E-01								
FIND	.644703E+00	--.299369E+00	.220610E+01	.290838E-01	.310613E-01								
NO OF PTS,PT NO,MEAN,DEV	34	1	0	0	0								
NO OF PTS,PT NO,MEAN,DEV	34	2	0	0	0								
NO OF PTS,PT NO,MEAN,DEV	34	3	0	0	0								
NO OF PTS,PT NO,MEAN,DEV	34	4	0	0	0								
NO OF PTS,PT NO,MEAN,DEV	34	5	.558133E+00	.243503E+00									
NO OF PTS,PT NO,MEAN,DEV	34	6	.776817E+00	.395669E+00									
NO OF PTS,PT NO,MEAN,DEV	34	7	.245523E+00	.142561E+00									
NO OF PTS,PT NO,MEAN,DEV	34	8	.647961E+00	.670091E+00									
.142	11.57-10.07	36.30	7.90	-9.64	37.36	RUN	680	PTS	5	AND	6	.381361E+01	.123246E+01
.144	10.96-10.21	36.24	7.46	-9.70	37.26	RUN	680	PTS	5	AND	6	.366363E+01	.110931E+01
.146	10.53-10.32	36.09	6.92	-9.66	37.24	RUN	680	PTS	5	AND	6	.376601E+01	.118239E+01
.148	9.85-10.38	37.98	6.38	-9.79	37.27	RUN	680	PTS	5	AND	6	.359589E+01	.996137E+00
.150	9.25-10.49	37.93	5.98	-9.97	37.22	RUN	680	PTS	5	AND	6	.336147E+01	.940312E+00
.152	8.61-10.57	37.70	5.67	-10.20	37.07	RUN	680	PTS	5	AND	6	.308748E+01	.821324E+00
.154	8.24-10.63	37.42	5.26	-10.46	36.79	RUN	680	PTS	5	AND	6	.304960E+01	.865799E+00
.156	7.83-10.85	37.01	4.94	-10.76	36.37	RUN	680	PTS	5	AND	6	.296415E+01	.864760E+00
.158	7.38-10.90	36.62	4.64	-11.07	35.85	RUN	680	PTS	5	AND	6	.284278E+01	.773129E+00
.160	7.00-11.26	36.17	4.27	-11.41	35.30	RUN	680	PTS	5	AND	6	.287458E+01	.703944E+00
.162	6.78-11.42	35.69	4.06	-11.73	34.84	RUN	680	PTS	5	AND	6	.290028E+01	.703202E+00
.164	6.63-11.50	35.43	3.97	-11.96	34.17	RUN	680	PTS	5	AND	6	.297112E+01	.751161E+00
.166	6.62-11.66	34.72	3.96	-12.37	33.26	RUN	680	PTS	5	AND	6	.311219E+01	.814235E+00
.168	6.61-11.77	34.02	4.00	-12.76	32.23	RUN	680	PTS	5	AND	6	.331528E+01	.842256E+00
.170	6.46-11.84	33.44	4.11	-13.11	31.21	RUN	680	PTS	5	AND	6	.346010E+01	.438044E+00
.172	6.52-11.71	32.78	4.41	-13.29	30.26	RUN	680	PTS	5	AND	6	.364792E+01	.620875E+00
.174	6.54-11.63	32.22	4.7	-13.27	29.49	RUN	680	PTS	5	AND	6	.365967E+01	.570896E+00
.176	6.54-11.57	31.75	4.94	-13.10	28.72	RUN	680	PTS	5	AND	6	.375794E+01	.761358E+00
.178	6.71-11.35	31.31	5.15	-12.76	28.10	RUN	680	PTS	5	AND	6	.383673E+01	.809497E+00
.180	6.70-11.26	30.98	5.27	-12.60	27.84	RUN	680	PTS	5	AND	6	.383673E+01	.735467E+00
.182	6.77-11.16	30.59	5.61	-12.79	27.82	RUN	680	PTS	5	AND	6	.369901E+01	.627485E+00
.184	6.86-11.11	30.20	5.61	-12.97	27.50	RUN	680	PTS	5	AND	6	.339556E+01	.536444E+00
.186	7.15-11.00	29.95	6.08	-12.99	27.03	RUN	680	PTS	5	AND	6	.333760E+01	.629389E+00
.188												.368597E+01	.412102E+00
.190												.300545E+00	.315409E+00

Sample Means and Standard Deviations
for Points 5 through 8

Figure 51. Typical Listing of Data Output from Program SLED.

The last section of output gives the positions of the moving points on the subjects versus time. See Figure 52.

The position versus time data is first output for points 5 and 6, the forehead and chin of the subject in the passenger seat. The first quantity is the time in seconds. The next three numbers are the x, y, and z coordinates of point five in inches. The next three numbers are the coordinates of point six in inches. The coordinates of the moving points are output with respect to the original left-hand experimental coordinate system affixed to the sled. The run number is just an identifier. Then points 5 and 6 are specified. All this data is also punched out on cards for input to other programs. The last three numbers of each line of this output are not punched on the cards.

These numbers are debug output. The first is the distance between the point pair 5 and 6 to the left. The second and third are the miss distance, d , that occurred in the computation of the positions of points 5 and 6.

A complete listing of program SLED is presented in Appendix F.

FIND	.202264E+00	-.150750E+00	.665000E-01	-.152333E+00	.500000E-01	.204000E+00			
SOLVE	-.151585E+00	.300921E-01	-.152000E+00	.439336E-01	.700617E+00	.118425E+01			
FIND	.203398E+00	-.113417E+00	.600000E-01	-.117790E+00	.612800E-01	.204000E+00			
FIND	.202268E+00	-.149167E+00	.600000E-01	-.149750E+00	.195633E-01	.204000E+00			
SOLVE	-.113423E+00	.600036E-01	-.149657E+00	.196357E-01	.945439E+00	-.143721E+01			
CORR	-.588562E+00	-.121360E+00	.972555E+00	.143717E-01	.157796E-01	.255607E+01			
FIND	.644625E+00	-.299439E+00	.250532E+01	.300166E-01	.326768E-01	.206000E+00			
FIND	.203948E+00	.593333E-01	.250000E-01	.610000E-01	.259167E-01	.206000E+00			
FIND	.204330E+00	.104167E+00	.551667E-01	.101667E-01	.552500E-01	.206000E+00			
SOLVE	.603476E-01	.254479E-01	.102141E+00	.552342E-01	.126178E+01	.223462E+01			
FIND	.203394E+00	.765833E-01	.975000E-02	.734167E-01	.808333E-02	.206000E+00			
FIND	.204330E+00	.126917E+00	.500000E-01	.130667E+00	.430000E-01	.206000E+00			
SOLVE	.733276E-01	-.813573E-02	.123954E+00	.491901E-01	.824934E+00	.876576E+00			
FIND	.203948E+00	-.150583E+00	.900433E-01	-.151667E-01	.931667E-01	.206000E+00			
FIND	.204330E+00	-.152333E+00	.500000E-01	-.156250E+00	.528333E-01	.206000E+00			
SOLVE	-.151633E+00	.930697E-01	-.155505E+00	.522933E-01	.699138E+00	.112611E+01			
FIND	.203948E+00	-.113541E+00	.600000E-01	-.117750E+00	.612500E-01	.206000E+00			
FIND	.204330E+00	-.149750E+00	.195833E-01	-.153667E+00	.153167E-01	.206000E+00			
SOLVE	-.117611E+00	.612107E-01	-.152322E+00	.186140E-01	.982693E+00	-.151642E+01			
CORR	-.588738E+00	-.321274E+00	.977112E+00	.196574E-01	.165019E-01	.257922E+01			
FIND	.644778E+00	-.299439E+00	.220601E+01	.295619E-01	.323806E-01	.200000E+00			
FIND	.206055E+00	.610000E-01	.259167E-01	.631667E-01	.293000E-01	.200000E+00			
FIND	.206392E+00	.101667E+00	.552500E-01	.101478E+00	.550000E-01	.200000E+00			
SOLVE	.639242E-01	.292644E-01	.101472E+00	.550550E-01	.126043E+01	.223321E+01			
FIND	.206055E+00	.794167E-01	.800833E-02	.643333E-01	.344667E-02	.200000E+00			
FIND	.206392E+00	.130667E+00	.490000E-01	.131000E+00	.480033E-01	.200000E+00			
SOLVE	.102074E-01	-.372341E-02	.130427E+00	.482850E-01	.541703E+00	.881044E+00			
FIND	.206055E+00	-.151667E+00	.931667E-01	-.149447E+00	.981667E-01	.200000E+00			
FIND	.206392E+00	-.156250E+00	.528333E-01	-.156750E+00	.526667E-01	.200000E+00			
SOLVE	-.149365E+00	.978380E-01	-.156640E+00	.527033E-01	.637825E+00	.113332E+01			
FIND	.206055E+00	-.117750E+00	.612500E-01	-.115567E-01	.633333E-01	.200000E+00			
FIND	.206392E+00	.631965E-01	.159157E-01	.154250E+00	.153167E-01	.200000E+00			
SOLVE	-.115404E+00	.631965E-01	-.154125E+00	.153167E-01	.976738E+00	-.151894E+01			
CORR	-.588166E+00	-.321298E+00	.976985E+00	.152101E-01	.170844E-01	.259988E+01			
FIND	.644703E+00	-.299369E+00	.220610E+01	.290898E-01	.318613E-01	.200000E+00			
NO OF PTS:PT NO,MEAN,DEV	34	1 0.	0.	0.	0.	.381361E+01			
NO OF PTS:PT NO,MEAN,DEV	34	2 0.	0.	0.	0.	.366363E+01			
NO OF PTS:PT NO,MEAN,DEV	34	3 0.	0.	0.	0.	.376601E+01			
NO OF PTS:PT NO,MEAN,DEV	34	4 0.	0.	0.	0.	.359505E+01			
NO OF PTS:PT NO,MEAN,DEV	34	5 .658133E+00	.249503E+00			.300874E+01			
NO OF PTS:PT NO,MEAN,DEV	34	6 .776817E+00	.395659E+00			.308744E+01			
NO OF PTS:PT NO,MEAN,DEV	34	7 .245523E+00	.142561E+00			.308744E+01			
NO OF PTS:PT NO,MEAN,DEV	34	8 .847936E+00	.670091E+00			.298415E+01			
.142	11.57-10.07	38.30	7.90	-9.64	37.36	RUN 680.	PTS 5	AND 6	.381361E+01
.146	10.96-10.21	38.24	7.46	-9.70	37.26	RUN 680.	PTS 5	AND 6	.366363E+01
.144	10.53-10.32	38.09	6.92	-9.66	37.24	RUN 680.	PTS 5	AND 6	.376601E+01
.148	9.85-10.38	37.98	6.38	-9.79	37.22	RUN 680.	PTS 5	AND 6	.359505E+01
.150	9.22-10.49	37.93	5.98	-9.97	37.22	RUN 680.	PTS 5	AND 6	.300874E+01
.152	8.67-10.57	37.70	5.67	-10.20	37.07	RUN 680.	PTS 5	AND 6	.308744E+01
.154	8.24-10.63	37.42	5.26	-10.46	36.79	RUN 680.	PTS 5	AND 6	.298415E+01
.156	7.83-10.65	37.01	4.94	-10.76	36.37	RUN 680.	PTS 5	AND 6	.284798E+01
.158	7.38-10.98	36.62	4.64	-11.07	35.85	RUN 680.	PTS 5	AND 6	.268498E+01
.160	6.94-11.26	35.87	4.27	-11.41	35.30	RUN 680.	PTS 5	AND 6	.250028E+01
.162	6.53-11.52	35.09	3.87	-11.73	34.64	RUN 680.	PTS 5	AND 6	.229028E+01
.164	6.12-11.78	34.72	3.56	-12.07	33.26	RUN 680.	PTS 5	AND 6	.206613E+01
.166	5.72-12.03	34.02	3.25	-12.37	32.23	RUN 680.	PTS 5	AND 6	.184233E+01
.168	5.33-12.28	33.94	2.94	-12.66	31.21	RUN 680.	PTS 5	AND 6	.162256E+01
.170	4.94-12.53	33.78	2.63	-12.95	30.26	RUN 680.	PTS 5	AND 6	.140464E+01
.172	4.55-12.78	33.62	2.32	-13.24	29.39	RUN 680.	PTS 5	AND 6	.118676E+01
.174	4.16-13.03	33.46	2.01	-13.53	28.52	RUN 680.	PTS 5	AND 6	.096888E+01
.176	3.77-13.28	33.30	1.70	-13.82	27.65	RUN 680.	PTS 5	AND 6	.075100E+01
.178	3.38-13.53	33.14	1.39	-14.11	26.78	RUN 680.	PTS 5	AND 6	.053312E+01
.180	2.99-13.78	32.98	1.08	-14.40	25.91	RUN 680.	PTS 5	AND 6	.031524E+01
.182	2.60-14.03	32.82	0.77	-14.69	25.04	RUN 680.	PTS 5	AND 6	.009736E+01
.184	2.21-14.28	32.66	0.46	-14.98	24.17	RUN 680.	PTS 5	AND 6	.007948E+01
.186	1.82-14.53	32.50	0.15	-15.27	23.30	RUN 680.	PTS 5	AND 6	.006160E+01
.188	1.43-14.78	32.34	0.04	-15.56	22.43	RUN 680.	PTS 5	AND 6	.004372E+01
.190	1.04-15.03	32.18	0.03	-15.85	21.56	RUN 680.	PTS 5	AND 6	.002584E+01
.192	0.65-15.28	32.02	0.02	-16.14	20.69	RUN 680.	PTS 5	AND 6	.000796E+01
.194	0.26-15.53	31.86	0.01	-16.43	19.82	RUN 680.	PTS 5	AND 6	.000008E+01
.196	0.00-15.78	31.70	0.00	-16.72	18.95	RUN 680.	PTS 5	AND 6	.000000E+01

Point 5 and 6
Positions versus
Time in Seconds

Figure 52. Typical Listing of Solutions Output from Program SLED.

SECTION 4
CONCLUSIONS AND RECOMMENDATIONS

The processes developed and applied during the period of performance have satisfied the basic requirements for which they were developed. There is still much that could be accomplished to refine the programs for the purposes of improving cost effectiveness and user confidence in the solutions generated. Continuing review is recommended for the purpose of accomplishing the following.

- A. Modify program HIFPD to include a computerized analysis of differences between the raw and smoothed solution points.
- B. Modify program HIFPD to provide computerized calculations of conversion factors for the various anthropometric points being tracked.
- C. Investigate the desirability of employing smoothing techniques other than the moving arc quadratic fit currently being used.
- D. Determine accuracy requirements and criteria for analyzing the accuracy of solutions prior to applications of these processes to future studies.

DESCRIPTION OF PROGRAM INPUT DATA AND PARAMETER CODES

1. PROGRAM SETUP CARDS

- A) The first card in the setup deck must contain the data in columns 1 to 10; for example, 11 22 33 44 or 11 22 11, 22 (only one date card per job).
- B) The following four cards are required for each test in the computer job:

Card Number	Format	Data Description
1-5	11-55	Test number
6	11	11X--flag controlling polarity of X-axis data-blank or 0--no change
7	11	11Y--flag controlling polarity of Y-axis data-blank or 0--no change
8	11	11Z--flag controlling polarity of Z-axis data-blank or 0--no change
9	11	11V--flag controlling linear velocity and acceleration data-blank or 0--print and plot data
10	11	11A--flag controlling angular velocity and acceleration data (angular-vel and head pos.), blank or 0--print and plot data
11	11	11P--flag controlling variable displacement with respect to lead data-blank or 0--print and plot data
14-16	11-11	First frame included in displacement with respect to the lead plot (if blank, the first available frame is plotted).
17-19	11-11	Last frame in displacement with respect to the lead plot (if blank, the last frame is plotted).

APPENDIX A

DESCRIPTION OF PROGRAM HIFPD INPUT DATA AND PARAMETER CODES

DESCRIPTION OF PROGRAM INPUT DATA AND PARAMETER CODES

I. PROGRAM SETUP CARDS

- A) The first card in the setup deck must contain the date in columns 1 to 10; for example, 12 FEB 74 or FEB 11,74 (only one date card per job).
- B) The following four cards are required for each test in the computer job:

Card Number 1

Column	Format	Data Description
1-5	A5	Test number
6	11	IRX--flag controlling polarity of X-axis data- blank or 0---no change 1---change sign of X-axis data
7	11	IPR--flag controlling input data and difference printout -blank or 0---print data 1---omit printout
8	11	ITYPE--flag controlling input data-blank or 0 ---read and process all 8 variables 1 ---read and process only variables 1,2,7, and 8
9	11	IPL--flag controlling linear velocity and acceleration data -blank or 0---print and plot data 1---print only 2---omit all linear data
11	11	IPA--flag controlling angular velocity and acceleration data (shoulder-hip and head pt.1, head pt.2)--blank or 0---print and plot data 1---print only 2---omit all angular data
13	11	IPC--flag controlling variable displacement with respect to sled data -blank or 0---print and plot data 1---print only 2---omit these computations
14-16	13	First frame included in displacement with respect to the sled plot (if blank, the first available frame is plotted).
17-19	13	Last frame in displacement with respect to the sled plot (if blank, the last frame is plotted).

Card Number 2 (Continued)

<u>Column</u>	<u>Format</u>	<u>Data Description</u>
20-21	12	The number of sets (M) of linear velocity and acceleration to be computed.
23-24	211	Variable code of variable and reference respectively (see variable codes in Item II) for first set of linear data; for example, 21---sled relative to range or 32---hip relative to sled
26-27	211	Same as above for the 2nd set of linear data
29-30	211	Same as above for 3rd set

Repeat the above for each of the M (maximum of 12) sets of linear motion (Format: IX, 211 for each set).

Card Number 3

1-10	F10.0	Time calibration---number of frames per second. May be left blank if film speed is 500 frames per second.
11-20	F10.0	SLED calibration in counts per foot
21-30	F10.0	HIP calibration in counts per foot*
31-40	F10.0	KNEE calibration in counts per foot*
41-50	F10.0	SHOULDER calibration in counts per foot*
51-60	F10.0	ELBOW calibration in counts per foot*
61-70	F10.0	HEAD POINT 1 calibration in counts per foot
71-80	F10.0	HEAD POINT 2 calibration in counts per foot

NOTE: The decimal must be punched in the above data fields unless the data are integer and are right justified.

Card Number 4

1 11 9 in column 1 to indicate the end of test input

NOTE: Cards 1, 2, and 3 are placed in front of the test deck and card 4 is placed after the last frame in the test.

C) The last card in the input deck (before the end of job card) contains the word "END" in columns 1 to 3.

* The calibration field for these variables must be zero or blank for ITYPE = 1.

II. VARIABLE CODE IDENTIFICATION

The following code versus variable name list is used throughout the program and card 2 in Item 1-B:

<u>Code</u>	<u>Name</u>
1	Range
2	Sled
3	Hip
4	Knee
5	Shoulder
6	Elbow
7	Head Point 1
8	Head Point 2

III. CARD FORMATS FOR THE TEST INPUT DATA CARDS FOR ITYPE=0

Card Number 1

<u>Column</u>	<u>Format</u>	<u>Data Description</u>
1	11	Card identification (must be 1).
2-5	14	Frame number
6-12	17	X reading in counts for Range data
13-19	17	Z reading in counts for Range data
20-26	17	X for Sled
27-33	17	Z for Sled
34-40	17	X for Hip
41-47	17	Z for Hip
48-54	17	X for Knee
55-61	17	Z for Knee

Card Number 2

1	11	Card identification (must be 2)
2-5	14	Frame Number
6-12	17	X reading in counts for Shoulder data
13-19	17	Z reading in counts for Shoulder data
20-26	17	X for Elbow
27-33	17	Z for Elbow
34-40	17	X for Head Point 1
41-47	17	Z for Head Point 1
48-54	17	X for Head Point 2
55-61	17	Z for Head Point 2

IV. CARD FORMATS FOR THE TEST INPUT DATA CARDS FOR ITYPE=1

Card Number 1

<u>Column</u>	<u>Format</u>	<u>Data Description</u>
1	11	Card identification (must be 1).
2-5	14	Frame number
6-12	17	X reading in counts for Range data
13-19	17	Z reading in counts for Range data
20-26	17	X for Sled
27-33	17	Z for Sled
34-40	17	X for Head Point 1
41-47	17	Z for Head Point 1
48-54	17	X for Head Point 2
55-61	17	Z for Head Point 2

NOTE: For ITYPE = 1, only 1 data card is read for each frame.

V. GENERAL COMMENTS

- A) If there are any errors in frame or card identification numbers, error statements will be printed at the top of the first output page for the test and all computations after the listing of the input data will be deleted.
- B) A maximum of 150 frames (MAXN) will be read for each test. If the test input deck contains more than 150 frames, only the first 150 will be processed. This could be changed by changing MAXN and the array dimensions in the program.
- C) If the calibration factor for a variable is missing, flag ICAL(J) is set equal to zero and that variable will be deleted from the analysis.
- D) An eleven point quadratic least-square fit is used throughout the program. This could be changed by changing the value of "NP" in the program.
- E) The CALCOMP plot abscissa and ordinate scales for the velocity and acceleration data are determined by the plot subroutine (CPLT). The X (abscissa) and Z (ordinate) scales for the variable relative to the sled data are constants. The X-scale ranges from -1.4 to 2.6 feet for IRX = 0 and -3.6 to 0.4 feet for IRX = 1 and Z scale ranges from 0.0 to 4.0 feet. Any displacements outside this range will be set equal to the limiting value.

HYGE Program Setup Cards

- 1) DATA card, used once per job:
 Col.1 Col.10
 e.g. 12 FEB 74 (first card in input deck).

- 2) The following four cards are required for each test:

CARD No. 1 TITLE Card --80 columns of alphanumeric information.

80
 Col.1

CARD No. 2

TEST No. IRX IPR ITYPE IPL IPA IPC
 1 5 6 7 8 9 11 13
 M Sets +
 FIRST FRAME LAST FRAME M
 2 3 4 5 6 7 8 9

 26 27 29 30 32 33 35 36 37 39 41 42 44 45 47 48
 10 11 12
 (Maximum of 12 sets; usually 3 or 4.)
 50 51 53 54 56 57

CARD NO. 3 Calibration Data (frames/second or counts/foot).

TIME: SLED HIP * KNEE*
 1 10 11 20 21 30 31 40
 SHOULDER* ELBOW* HEAD PT.1 HEAD
 41 50 51 60 61 70 PT.2 71 80

* Must be 0 or blank for "ITYPE = 1".

CARD NO. 4

Card No. 4 has a "9" in column 1 (insert after the last frame in the data deck).

- 3) **END Card**, used once per job: Punch "END" in columns 1 to 3. (last card in input deck; before "END OF JOB" Card).

V. General Comments:

- A) If there are any errors in frame or card identification numbers, error statements will be printed at the top of the first output page for the test and all computations after the listing of the input data will be deleted.
- B) A maximum of 150 frames (MAXN) will be read for each test. If the test input deck contains more than 150 frames, only the first 150 will be processed. This could be changed by changing MAXN and the array dimensions in the program.
- C) If the calibration factor for a variable is missing, flag ICAL(J) is set equal to zero and that variable will be deleted from the analysis.
- D) An eleven point quadratic least square fit is used throughout the program. This could be changed by changing the value of "NP" in the program.
- E) The CALCOMP plot abscissa and ordinate scales for the velocity and acceleration data are determined by the plot subroutine (CPLT). The X (abscissa) and Z (ordinate) scales for the variable relative to the sled data are constants. The X scale ranges from -1.4 to 2.6 feet for IRX = 0 and -3.6 to 0.4 feet for IRX = 1 and the Z scale ranges from 0.0 to 4.0 feet. Any displacements outside this range will be set equal to the limiting value.

- A) If there are any errors in frame or card identification numbers, error statements will be printed at the top of the first output page for the test and all computations after the listing of the input data will be deleted.
- B) A maximum of 150 frames (MAXN) will be read for each test. If the test input deck contains more than 150 frames, only the first 150 will be processed. This could be changed by changing MAXN and the array dimensions in the program.
- C) If the calibration factor for a variable is missing, the ICALF is set equal to zero and that variable will be deleted from the output.
- D) An eleven point quadratic least squares fit is used throughout the program. This could be changed by changing the value of "FIT" in the program.
- E) The CALCOMP plot routine and various scales for the velocity and acceleration data are controlled by the plot routine (CPLOT).

APPENDIX B

PREPARATION OF DATA FOR INPUT TO HIFPD

The data are prepared for input to the HIFPD program. The X scale ranges from -1.4 to 1.4 feet for $10X = 0$ and -1.4 to 1.4 feet for $10X = 1$ and the Y scale ranges from 0.0 to 4.0 feet. Any displacements outside this range will be set equal to the limiting value.

STANDARD PRACTICE PROCEDURE
93291-02-1 (Rev. "I", 4 Oct. '76)

This procedure describes the process to be employed in the reduction of photometric data acquired during experimental tests conducted on the Horizontal Impulse Accelerator during the Restraint Systems Dynamics (RSD) investigation.

1. Source Documents

- 1.1 16 mm motion picture film from cameras mounted:
 - a. Onboard Lateral view
 - b. Onboard Oblique view
 - c. Offboard Lateral view (Backup for "A")
 - d. Offboard Downtrack view
 - e. Offboard Overhead view
- 1.2 Restraint System Dynamic Pretest Anthropometric Measurements data sheet.
- 1.3 Sled Coordinate System and Camera Scheme, (RSD).

2. Equipment Required

- 2.1 Producers Service Corp. film digitizer coupled to Teletype w/tape punch.
- 2.2 Teletype Terminal w/tape reader and telephone coupler.
- 2.3 IBM Key punch, Type 029.

3. Editing Requirements

The following sequence of operations shall be followed to determine if all necessary data have been adequately recorded.

- 3.1 Preview Onboard lateral view film to determine if the following points are observable throughout the test period from first motion of the subject with respect to the seat through return to rest of the subject with respect to the seat. (Refer to Figure B-1).

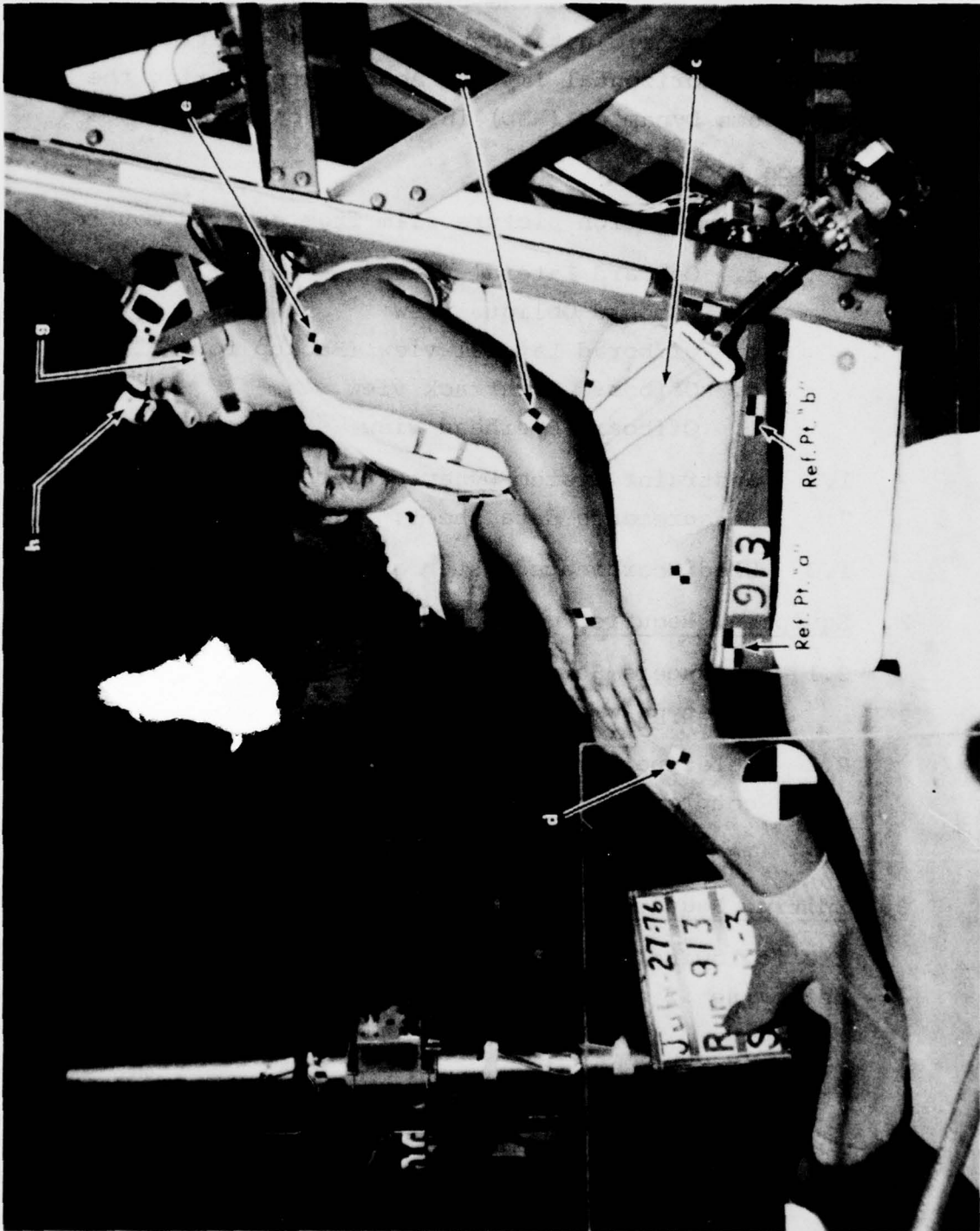


Figure B-1. Anthropometric Points to be Tracked.

- a. Forward fiducial, LH side of seat
- b. Aft fiducial, LH side of seat
- c. Fiducial over hip (or fiducial over iliac creat)
- d. Fiducial on knee
- e. Fiducial on shoulder
- f. Fiducial on elbow
- g. Fiducial on jaw hinge (or head mount)
- h. Accelerometer at origin of 9TAP accelerometer assembly.

3.2 Determine time - film frame table. Assume time to be 0.000 seconds at upper edge of frame in which the synchronizing flash is first observed, set frame counter to 00000. Interpolate time lapse between this point and next 0.1-second time pulse. (Refer to Figure B-2). Set this value to t_{e1} .

Using the same method, determine the time lapse between the last .01 second time pulse prior to the frame at which the subject returns to rest with respect to the seat (Frame "n" and the start (or top) of this frame. Let this value be t_{e2} .

Count the 0.01 second time intervals between the first pulse after frame 000 and the last pulse prior to frame "n". Multiply the number of intervals by 0.01 seconds and let this value be t_c (calibrated time).

The total elapsed time can now be calculated by summing $t_{e1} + t_{e2} + t_c$.

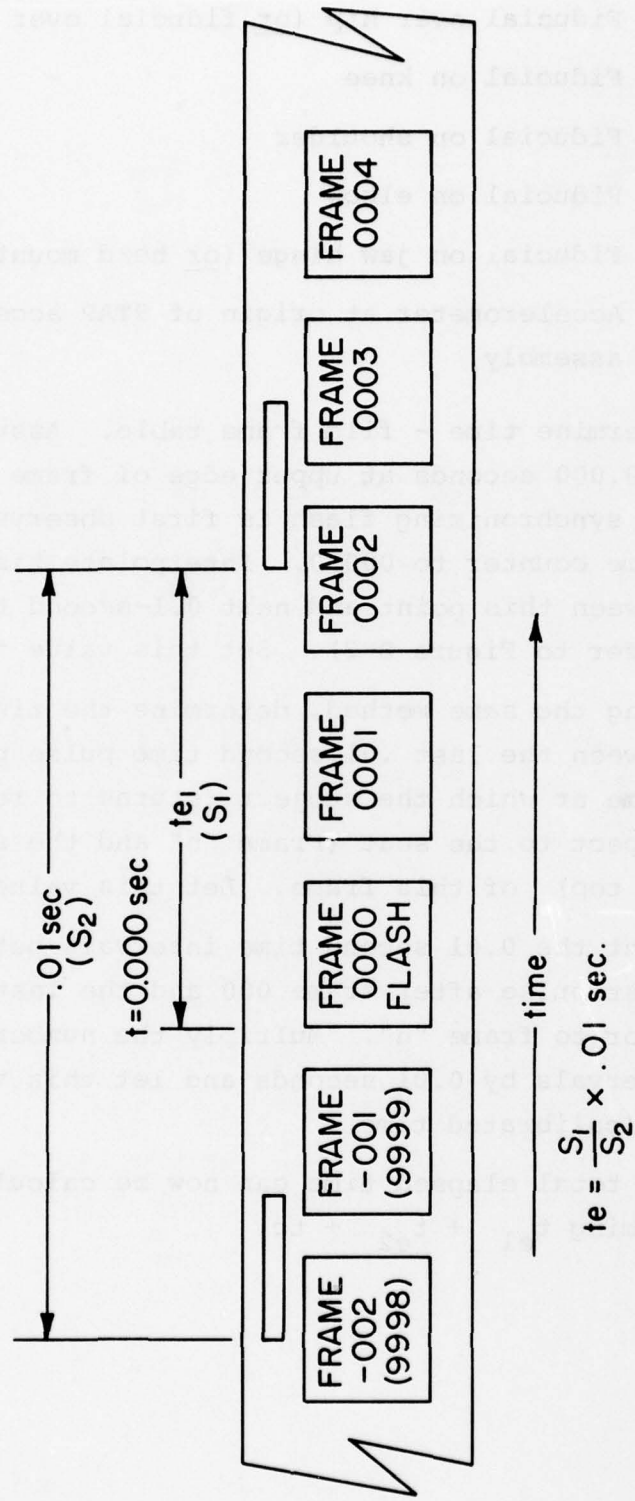


Figure B-2. Time Lapse Determination.

The film speed (or frames per second), which is required as input to the computer program "HIFPD" can now be calculated:

$$\text{Film Speed} = \frac{\text{Frame Count at Frame "n"}}{t_{e1} + t_e + t_{e2}}$$

- 3.3 Determine Conversion Constants using the "widths" information recorded on the "Restraint Systems Dynamics Pretest Anthropometric Measurements" data sheet, (Figure B-3) the "Sled Coordinate System and Camera Scheme" (Figure B-4) and the PSC digitizer.

Read the coordinate of the fiducials mounted on the side of the seat. Record these on the Calibration Form (Figure B-5).

Calculate resultant scalar dimension between the fiducials on the panel (s_{pi}) and the seat (s_{si}):

$$s_{pi} = (x_{p1} - x_{p2})^2 + (y_{p1} - y_{p2})^2$$

$$s_{si} = (x_{s1} - x_{s2})^2 + (y_{s1} - y_{s2})^2.$$

Calculate conversion constants for these dimensions:

$$f_p = \frac{s_{pi}}{\frac{11.96875}{12}}$$

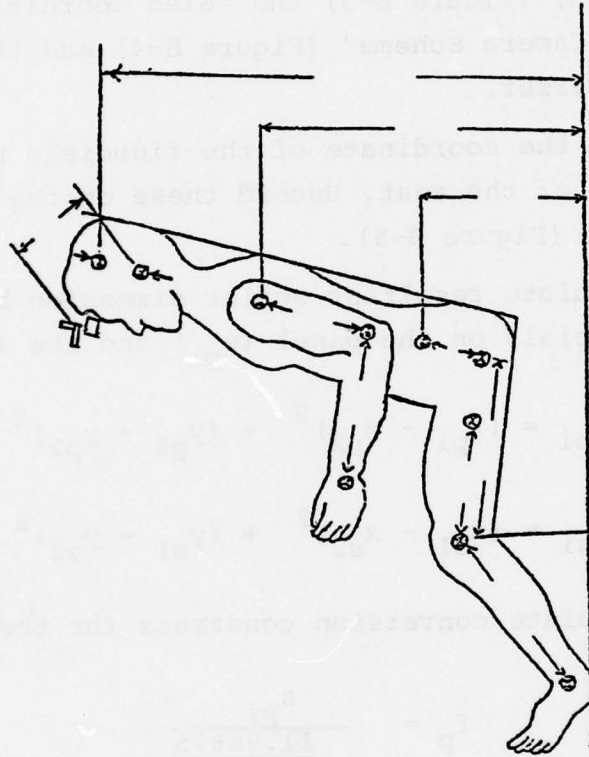
In like manner:

$$f_s = \frac{s_{si}}{\frac{12.0}{12}}$$

Where f_p and f_s are conversion constants in terms of counts/foot.

RESTRAINT SYSTEM DYNAMICS
Pretest Dimensions

Run _____ Subject _____ Seat _____ Velocity _____
 Date _____ Restraint _____ Seat Back _____ Acceleration _____



WIDTHS:

- Jaws _____
- Shoulders _____
- Elbows _____
- Hips _____
- Knees _____
- Ankles _____

Mid shoulder height _____

Figure B-3. Restraint System Dynamics Pretest Anthropometric Measurements Data Form.

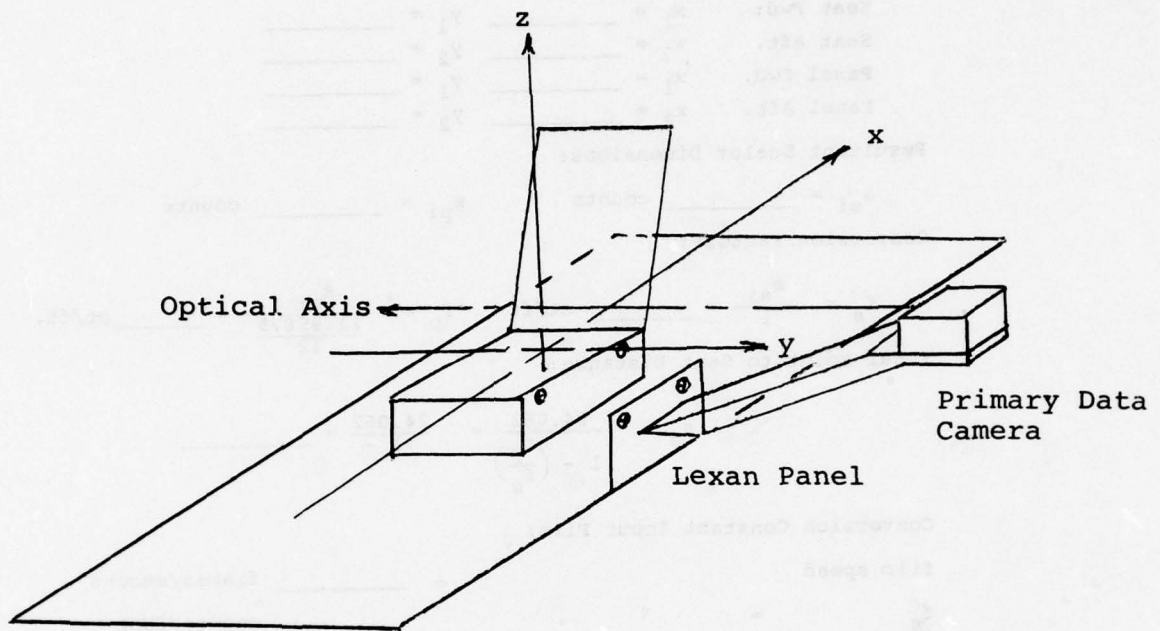


Figure B-4. Sled Coordinate System and Camera Scheme.

RESTRAINT SYSTEM DYNAMICS
Photometric Calibration Form

TEST _____

Fiducial Readings:

Seat Fwd:	x ₁ = _____	y ₁ = _____
Seat Aft.	x ₂ = _____	y ₂ = _____
Panel Fwd.	x ₁ = _____	y ₁ = _____
Panel Aft.	x ₂ = _____	y ₂ = _____

Resultant Scalar Dimensions:

s_{si} = _____ counts s_{pi} = _____ counts

Conversion Factors:

$$f_s = \frac{s_{si}}{1} = \text{_____ ct/ft} \quad f_p = \frac{s_{pi}}{\frac{11.96875}{12}} = \text{_____ ct/ft.}$$

Focal Point to Seat Distance:

$$s_s = \frac{24.062}{1 - \left(\frac{f_p}{f_s}\right)} = \frac{24.062}{1 - \text{_____}} = \text{_____}$$

Conversion Constant Input File:

film speed		= _____ frames/second
f _s	=	_____ counts/foot
f _{hip}	=	$\frac{s_s}{s_s + 8 - \text{_____}} \times f_s = \text{_____ counts/foot}$
f _{knee}	=	$\frac{s_s}{s_s + 8 - \text{_____}} \times f_s = \text{_____ counts/foot}$
f _{shoulder}	=	$\frac{s_s}{s_s + 8 - \text{_____}} \times f_s = \text{_____ counts/foot}$
f _{elbow}	=	$\frac{s_s}{s_s + 8 - \text{_____}} \times f_s = \text{_____ counts/foot}$
f _{jaw}	=	$\frac{s_s}{s_s + 8 - \text{_____}} \times f_s = \text{_____ counts/foot}$
f _{accel.}	=	$\frac{s_s}{s_s + 8 - \text{_____}} \times f_s = \text{_____ counts/foot}$

TEST _____

Figure B-5. Photometric Calibration Form.

The distance from the focal point of the camera to the vertical plane of the edge of the seat can now be calculated (Reference Figures B-6 and B-7).

Since the distance from the transparent panel to the seat edge has been measured to be 24.062-inches and the approximate distance from the focal plane of the camera to the seat edge plane was measured to be 60.625-inches then the distance from the focal point of the lens to the lexan panel, the seat edge, and thus the seat G_L can be calculated by similar triangles (Reference Figure B-7).

$$\frac{s_p}{s_s} = \frac{s_{si} \times f_p}{s_{si} \times f_s} = \frac{f_p}{f_s}$$

Knowing the measured distance $s_s - s_p$ to be 24.062 inches, thus $s_p = s_s - 24.062$, by substituting we have:

$$\frac{s_s - 24.062}{s_s} = \frac{f_p}{f_s}$$

and

$$\frac{1 - 24.062}{s_s} = \frac{f_p}{f_s}$$

By subtracting $\frac{f_p}{f_s}$ from both terms and adding $\frac{24.062}{s_s}$ to both terms:

$$1 - \frac{f_p}{f_s} = \frac{24.062}{s_s}$$

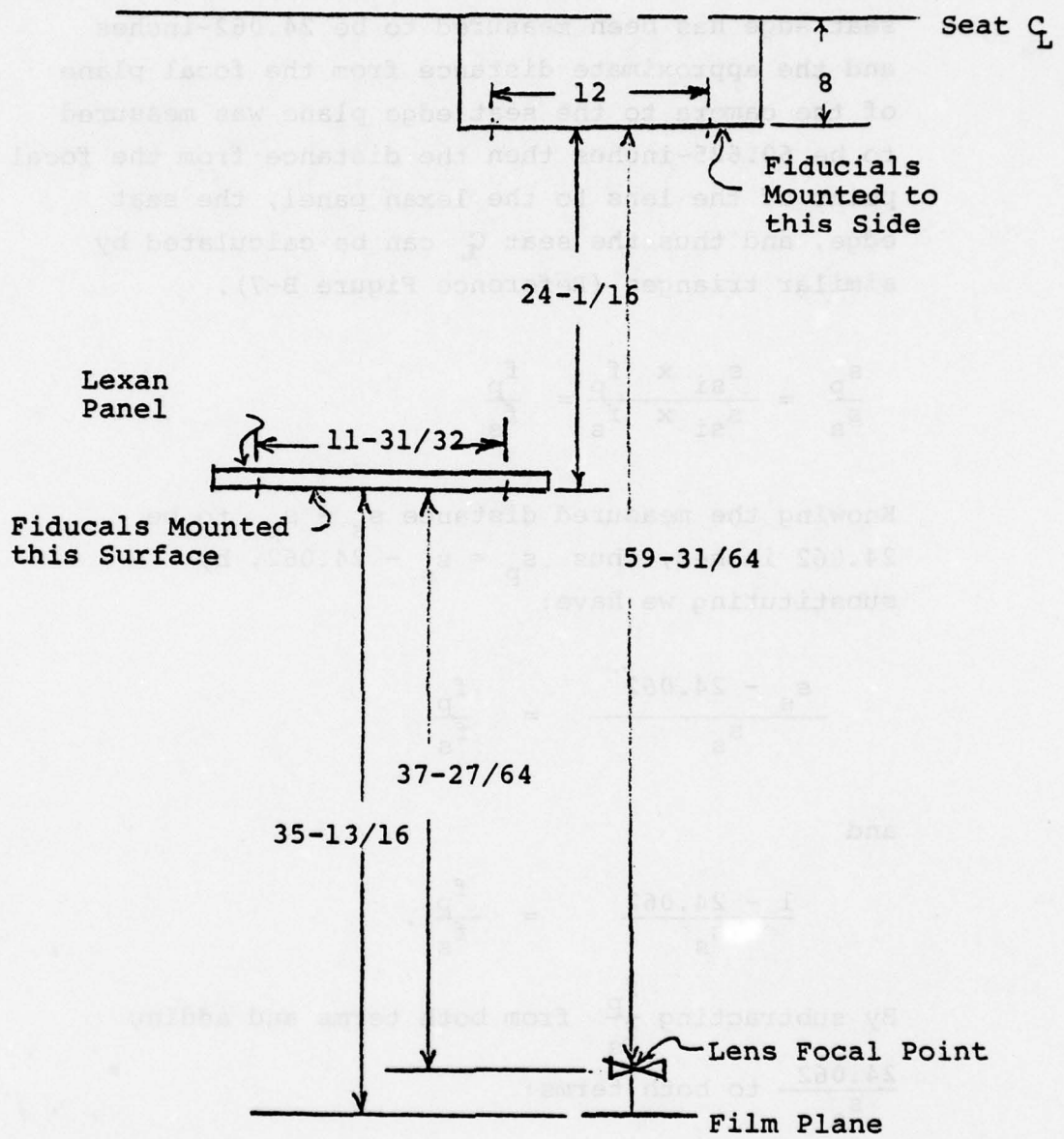


Figure B-6. Schematic of Camera-Reference Fiducials.

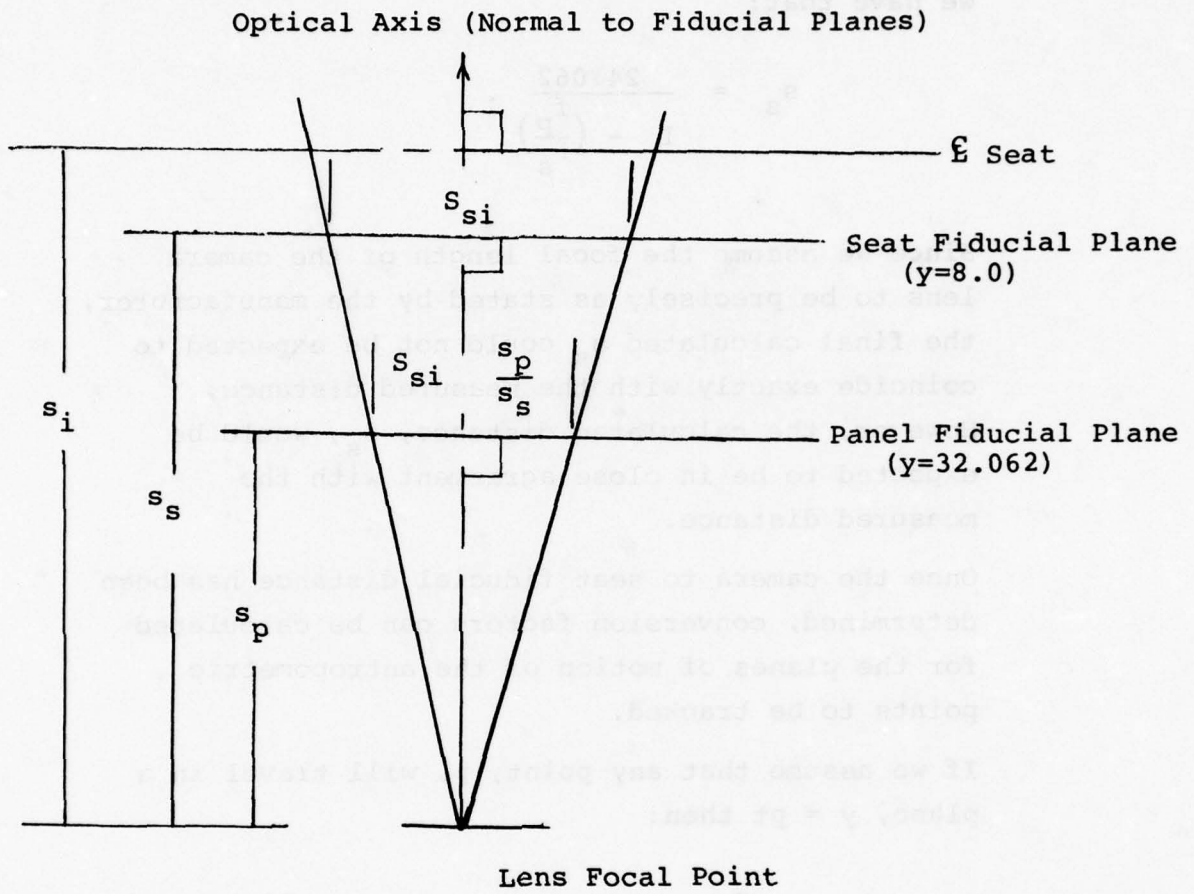


Figure B-7. Photometric Calibration Scheme.

and by multiplying both terms by s_s and by

$$\frac{1}{1 - \frac{f_p}{f_s}}$$

we have that:

$$s_s = \frac{24.062}{1 - \left(\frac{f_p}{f_s}\right)} .$$

Since we assume the focal length of the camera lens to be precisely as stated by the manufacturer, the final calculated s_s could not be expected to coincide exactly with the measured distance. However, the calculated distance, s_s , would be expected to be in close agreement with the measured distance.

Once the camera to seat fiducial distance has been determined, conversion factors can be calculated for the planes of motion of the antropometric points to be tracked.

If we assume that any point, p , will travel in a plane, $y = pt$ then:

$$\frac{f_{pt}}{f_s} = \frac{s_{pt}}{s_s}$$

where: f_{pt} = conversion factor in plane $y = pt$
(ft/count)

f_s = conversion factor in plane of seat
fiducials

s_{pt} = distance along optical axis from
focal point to the plane $y = pt$,

and:

s_s = distance along optical axis from focal point to the plane of the seat fiducials

s_{pt} is determined by:

$$s_{pt} = s_s + 8 \text{ inches} - \frac{w_p}{2}$$

where w_p is the width measurement between the anthropometric points on opposite sides of the subject as noted on the pretest anthropometric measurements form, and $s_s = 8 \text{ inches} = S_{QL}$ and the subject is assumed to be seated such that his plane of symmetry coincides with the seat Q_L and that the anthropometric points on the left and right sides of the subject are symmetrical about that plane.

All of the preceding calculations are provided for on the photometric calibration form.

4. Film Digitizing

The anthropometric points are tracked by digitizing the "x" and "y" coordinated of each point as projected from each frame during the impact response period. The film must be mounted in such a manner that the subject appears to face the left as viewed on the projection screen. Because of the smoothing routines utilized in the computer processing of the data, care must be taken to start digitizing the data at least fifteen (15) frames before the subject starts to move relative to the seat and it must be continued at least fifteen (15) frames after the subject returns to rest relative to the seat.

Data points are digitized as follows:

Line 1: Frame Number

- a. Forward seat reference fiducial; x,y
- b. Aft seat reference fiducial; x,y
- c. Hip (or iliac crest) fiducial; x,y
- d. Knee fiducial; x,y

Line 2: Frame Number

- e. Should fiducial; x,y
- f. Elbow fiducial; x,y
- g. Jaw (or accel. pack mount) fiducial; x,y
- h. 9TAP accelerometer reference; x,y

The above data are to be listed on the teletype printer and punched into paper tape on the teletype. Care must be taken to punch a series of rubouts before and after digitizing the data.

```

000100      PROGRAM
000110      NAME
000120      MTR
000130      SPED
000140      MTRC
000150
000160      CODE
000170      MTRC
000180      MTRC
000190      MTRC
000200      MTRC
000210      MTRC
000220      MTRC
000230      MTRC
000240      MTRC
000250      MTRC
000260      MTRC
000270      MTRC
000280      MTRC
000290      MTRC
000300      MTRC
000310      MTRC
000320      MTRC
000330      MTRC
000340      MTRC
000350      MTRC
000360      MTRC
000370      MTRC
000380      MTRC
000390      MTRC
000400      MTRC
000410      MTRC
000420      MTRC
000430      MTRC
000440      MTRC
000450      MTRC
000460      MTRC
000470      MTRC
000480      MTRC
000490      MTRC
000500      MTRC
000510      MTRC
000520      MTRC
000530      MTRC
000540      MTRC
000550      MTRC
000560      MTRC
000570      MTRC
000580      MTRC
000590      MTRC
000600      MTRC
000610      MTRC
000620      MTRC
000630      MTRC
000640      MTRC
000650      MTRC
000660      MTRC
000670      MTRC
000680      MTRC
000690      MTRC
000700      MTRC
000710      MTRC
000720      MTRC
000730      MTRC
000740      MTRC
000750      MTRC
000760      MTRC
000770      MTRC
000780      MTRC
000790      MTRC
000800      MTRC
000810      MTRC
000820      MTRC
000830      MTRC
000840      MTRC
000850      MTRC
000860      MTRC
000870      MTRC
000880      MTRC
000890      MTRC
000900      MTRC
000910      MTRC
000920      MTRC
000930      MTRC
000940      MTRC
000950      MTRC
000960      MTRC
000970      MTRC
000980      MTRC
000990      MTRC
001000      MTRC

```

APPENDIX C
PROGRAM HIFPD


```

C      6      ELBOW      000390
C      7      HEAD PACK  000400
C      8      SNOUT     000410
C      *      *      *      000420
C      *      *      *      000430
C      *      *      *      000440
C      *      *      *      000450
C      *      *      *      000460
C      *      *      *      000470
C      *      *      *      000480
C      *      *      *      000490
C      *      *      *      000500
C      *      *      *      000510
C      *      *      *      000520
C      *      *      *      000530
C      *      *      *      000540
C      *      *      *      000550
C      *      *      *      000560
C      *      *      *      000570
C      *      *      *      000580
C      *      *      *      000590
C      *      *      *      000600
C      *      *      *      000610
C      *      *      *      000620
C      *      *      *      000630
C      *      *      *      000640
C      *      *      *      000650
C      *      *      *      000660
C      *      *      *      000670
C      *      *      *      000680
C      *      *      *      000690
C      *      *      *      000700
C      *      *      *      000710

```

IRX=0 --- NO X-AXIS CHANGE
IRX=1 --- CHANGE POLARITY OF X-AXIS DATA (MULT.BY -1.0)
ITYPE=0 - READ AND PROCESS ALL 8 PARAMETERS.
ITYPE=1 - READ AND PROCESS ONLY PARAMETERS 1, 2, 7 AND 8.
IPR<1 --- PRINT RAW DATA IN COUNTS
IPL=0 --- PRINT AND PLOT LINEAR VEL AND ACCEL DATA
IPL=1 --- PRINT LINEAR VEL AND ACCEL DATA
IPL=2 --- OMIT LINEAR VEL AND ACCEL DATA
IPA=0 --- PRINT AND PLOT ANGULAR VEL AND ACCEL DATA
IPA=1 --- PRINT ANGULAR VEL AND ACCEL DATA
IPA=2 --- OMIT ANGULAR VEL AND ACCEL DATA
IPC=0 --- PRINT AND PLOT PARAMETER VERSUS SLED DATA
IPC=1 --- PRINT PARAMETER VERSUS SLED DATA
IPC=2 --- OMIT PARAMETER VERSUS SLED DATA
DISPLACEMENT, VEL AND ACCEL DATA ARE COMPUTED FOR 'M' SETS OF
DATA. ID(I) AND IR(I) CONTAIN THE 'M' SETS OF PARAMETER CODES
FOR PARAMETER AND REFERENCE RESPECTIVELY.
ID(I) --- CONTAINS PARAMETER IDENT CODE
IR(I) --- CONTAINS REFERENCE IDENT CODE

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C      TITLE(1) --- CONTAINS THE DATE
C      TITLE(2) --- CONTAINS THE TEST NUMBER
C      TITLE(3) ---> TITLE(10) --- CONTAIN AN 80 CHARACTER PAGE TITLE.
C      CAL(J) --- CONTAINS THE CALIBRATION FACTORS FOR PARAMETERS 2
C      THROUGH 8.
C      JD --- FRAME NUMBER OF FIRST FRAME PLOTTED ON PARAMETER VERSUS
C      SLED PLOT. (REDEFINED AFTER INPUT)
C      JR --- FRAME NUMBER OF LAST FRAME PLOTTED ON PARAMETER VERSUS
C      SLED PLOT. (REDEFINED AFTER INPUT)
C      CALL PLOTS(DATA,1024,7)
C      MAXN IS THE MAXIMUM NUMBER OF FRAMES WHICH CAN BE PROCESSED WITH
C      ABOVE ARRAY DIMENSIONS.
C      MAXN=300
C      C1=-1.0E10
C      CAL(1)=0.0
C      ICAL(1)=1
C      PI=3.1415927
C      PI2=2.0*PI
C      PI34=3.0*PI/4.0
C      NP IS THE NUMBER OF POINTS USED IN THE QUADRATIC LEAST SQUARE FIT.
C      NP=11
C      READ TEST SETUP CARDS.
C      TITLE(1) CONTAINS THE DATE.
C      READ(5,1010)TITLE(1)
C      5 READ(5,1010)(TITLE(I),I=3,10)
C      IF (TITLE(3) .EQ. ENDJ) GO TO 999
C      READ(5,1005) NP1,NP2,JD,JR
000720
000730
000740
000750
000760
000770
000780
000790
000800
000810
000820
000830
000840
000850
000860
000870
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000900
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000930
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000950
000960
000970
000980
000990
001000
001010
001020
001030
001040

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001050
 001060
 001070
 001080
 001090
 001100
 001110
 001120
 001130
 001140
 001150
 001160
 001170
 001180
 001190
 001200
 001210
 001220
 001230
 001240
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 001300
 001310
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 001350
 001360
 001370

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C      IF (NP1 .LT. 3) NP1=11
C      IF (NP2 .LT. 3) NP2=11
C      TITLE(2) CONTAINS THE TEST NUMBER.
C
      READ(5,1030) TITLE(2), IRX, IPR, ITYPE, IPL, IPA, IPC, JD, JR, M,
      1 (ID(I), IR(I), I=1, M)
      READ(5,1020) DT, (CAL(J), J=2, 8)
      IF (JD .LT. 1) JD=1
      IF (JR .LT. 1) JR=999
      WRITE(6,2500) TITLE, NP
      IF (IRX) 480, 480, 490
480  IRX=0
      GO TO 495
490  IRX=1
495  IF (IPR) 500, 500, 505
500  IPR=0
      GO TO 510
505  IPR=1
510  IF (IPL-1) 515, 525, 520
515  IPL=0
      GO TO 525
520  IPL=2
525  IF (IPA-1) 530, 540, 535
530  IPA=0
      GO TO 540
535  IPA=2
540  IF (IPC-1) 545, 560, 550
545  IPC=0
      GO TO 560
550  IPC=2
560  I=1
      TFLAG=N
  
```

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001380
001390
001400
001410
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001430
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001560
001570
001580
001590
001600
001610
001620
001630
001640
001650
001660
001670
001680
001690
001700

NC1=1
NC2=999
IFRD=-100
IF (OT) 565,565,570
>65 OI=500.0
570 IF (ITYPE) 575,575,580
>75 ITYPE=0
J1=3
GO TO 10
580 ITYPE=1
J1=7
>85 READ(5,1000) ICD,IFRD(I),(X(I,J),Z(I,J),J=1,2),(X(I,J),Z(I,J),J=7,8)
1)
DO 590 J=3,6
X(I,J)=0.0
590 Z(I,J)=0.0
IF (ICD-1) 595,595,100
>95 IF (IFRD(I)-IFRD) 600,600,610
600 WRITE(6,2410) IFR(I)
IFLAG=1
610 IFRD=IFRD(I)
GO TO 40

C FROM HERE TO LABEL 115: READ A MAXIMUM OF 'MAXN' FRAMES OF INPUT DATA
C
C 10 READ(5,1000) ICD,IFRD(I),(X(I,J),Z(I,J),J=1,4)
C FOLLOWING CARD CHANGED TO INPUT PAPER TAPE DATA:
IF (ICD-1) 15,15,100
C IF (ICD-1) 100,15,100
15 IF (IFRD(I)-IFRD) 20,20,25
20 WRITE(6,2410) IFR(I)
IFLAG=1
25 READ(5,1000) ICD,IFRD,(X(I,J),Z(I,J),J=5,8)

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C FOLLOWING CARD CHANGED TO INPUT PAPER TAPE DATA:
C IF (ICD-2) 30,30,70
  IF (ICD-2) 70,30,70
  30 IF (IFR(I)-IFRD) 35,40,35
  35 WRITE(6,2400) IFR(I),IFRD
     IFLAG=1
  40 T(I)=FLOAT(IFR(I))/DT
     IF (IFR(I) .EQ. JD) NC1=I
     IF (IFR(I) .EQ. JR) NC2=I
     IF (I-MAXN) 50,50,60
  50 I=I+1
     IF (ITYPE) 10,10,585
  60 WRITE(6,2840) MAXN,IFR(I)
     IF (ITYPE) 10,10,585
  70 WRITE(6,2000) ICD,IFRD
     IFLAG=1
     GO TO 10
 100 IF (ICD-9) 110,115,110
 110 WRITE(6,2000) ICD,IFR(I)
     IFLAG=1
     IF (ITYPE) 10,10,585
 115 N=I-1
     DTI=(T(N)-T(1))/FLOAT(N-1)
     IF (IRX) 118,118,116
 116 DO 117 I=1,N
     DO 117 J=1,8
 117 X(I,J)=-X(I,J)
C PRINT TEST PARAMETER SUMMARY PAGE.
C
 118 WRITE(6,2100) (I,I=1,M)
     WRITE(6,2110) TITLE(2),N,DT,IRX,ITYPE,IPR,IPL,IPA,IPC,M,
     1 (ID(I),IR(I),I=1,M)

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001710
001720
001730
001740
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001760
001770
001780
001790
001800
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001870
001880
001890
001900
001910
001920
001930
001940
001950
001960
001970
001980
001990
002000
002010
002020
002030

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002040
 002050
 002060
 002070
 002080
 002090
 002100
 002110
 002120
 002130
 002140
 002150
 002160
 002170
 002180
 002190
 002200
 002210
 002220
 002230
 002240
 002250
 002260
 002270
 002280
 002290
 002300
 002310
 002320
 002330
 002340
 002350
 002360

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WRITE(6,2120) (HEADL(I),I=2,8)
WRITE(6,2130) (CAL(I),I=2,8)
WRITE(6,2140) DTT
WRITE(6,2150) N
WRITE(6,2155) YNPL(2-IRX)
WRITE(6,2160) YNPR(IPR+1)
WRITE(6,2190) YNPR(IPL+1),YNPL(IPL+1)
WRITE(6,2180) YNPR(IPA+1),YNPL(IPA+1)
WRITE(6,2170) YNPR(IPC+1),YNPL(IPC+1)
DO 130 J=2,8
IF (ABS(CAL(J))) 120,125,120
120 CAL(J)=1.0/CAL(J)
ICAL(J)=1
GO TO 130
125 ICAL(J)=0
130 CONTINUE
WRITE(6,2570)
IF (M) 137,137,132
132 DO 135 K=1,M
JD=ID(K)
JK=IR(K)
IF (ICAL(JD) .LT. 1 .OR. ICAL(JR) .LT. 1) GO TO 135
WRITE(6,2210) K,HEADL(JD),HEADL(JR)
135 CONTINUE
137 IF (IPR) 140,140,165
C
C PRINT RAW INPUT DATA IN COUNTS.
C
140 WRITE(6,2500) TITLE,NP
WRITE(6,2550)
WRITE(6,2560) HEADC
DO 145 I=1,N

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002370
 002380
 002390
 002400
 002410
 002420
 002430
 002440
 002450
 002460
 002470
 002480
 002490
 002500
 002510
 002520
 002530
 002540
 002550
 002560
 002570
 002580
 002590
 002600
 002610
 002620
 002630
 002640
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 002660
 002670
 002680
 002690

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145 WRITE(6,2580) IFR(I), (X(I,J), Z(I,J), J=1,8)
    WRITE(6,2500) TITLE, NP
    WRITE(6,2552)
    WRITE(6,2560) HEADC
C
C COMPUTE AND PRINT FRAME TO FRAME DIFFERENCES IN COUNTS
C
    IF (ITYPE) 148,148,146
146 DO 147 J=3,6
    XD(J)=0.0
147 XD(J)=0.0
148 DO 160 I=2,N
    XD(1)=X(I,1)-X(I-1,1)
    ZD(1)=Z(I,1)-Z(I-1,1)
    XD(2)=X(I,2)-X(I-1,2)-XD(1)
    ZD(2)=Z(I,2)-Z(I-1,2)-ZD(1)
    DO 150 J=J1,8
    XD(J)=X(I,J)-X(I-1,J)-XD(1)
    ZD(J)=Z(I,J)-Z(I-1,J)-ZD(1)
150 WRITE(6,2580) IFR(I), (XD(J), ZD(J), J=1,8)
160 CONTINUE
C CONVERT DATA FROM COUNTS TO FEET.
165 IF (IFLAG) 170,170,167
167 WRITE(6,2500) TITLE, NP
    WRITE(6,2830)
    GO TO 5
170 DO 185 I=1,N
C
C H1 AND H2 ADJUST DATA FOR SHIFT IN RANGE REFERENCE READING.
C
    H1=X(I,1)-X(1,1)
    H2=Z(I,1)-Z(1,1)
    X(I,2)=(X(I,2)-H1)*CAL(2)

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```

Z(I,2)=(Z(I,2)-H2)*CAL(2)
00 180 J=J1,8
X(I,J)=(X(I,J)-H1)*CAL(J)
180 Z(I,J)=(Z(I,J)-H2)*CAL(J)
185 CONTINUE
C DO 800 NP=NP1,NP2,2
N1=(NP-1)/2+1
N2=N-N1+1
N3=3*N1-2
N4=N-N3+1
NN=N2-N1+1
IF (IPC+IPA-4) 700,800,800
C***** COMPUTE PARAMETER VERSUS SLED DISPLACEMENTS.
C
700 00 725 J=3,8
JJ=J-2
IF (ICAL(J)) 715,715,705
705 00 710 I=1,N
XD(I)=X(I,J)-X(I,2)
710 ZD(I)=Z(I,J)-Z(I,2)
I=1
CALL SM(T,XD,XX(I,JJ),N,NP)
CALL SM(T,ZD,ZZ(I,JJ),N,NP)
GO TO 725
715 00 720 I=N1,N2
XX(I,JJ)=0.0
720 ZZ(I,JJ)=0.0
725 CONTINUE
IF (IPC-1) 728,728,743
728 LINE=60
00 740 I=N1,N2
IF (LINE-50) 735,730,730
002700
002710
002720
002730
002740
002750
002760
002770
002780
002790
002800
002810
002820
002830
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002850
002860
002870
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002930
002940
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002960
002970
002980
002990
003000
003010
003020

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003030
003040
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003100
003110
003120
003130
003140
003150
003160
003170
003180
003190
003200
003210
003220
003230
003240
003250
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003270
003280
003290
003300
003310
003320
003330
003340
003350

730 WRITE(6,2500) TITLE,NP
    WRITE(6,2555)
    WRITE(6,2565) (HEADC(J),J=3,8)
    LINE= J
C PRINT PARAMETER VERSUS SLED DATA.
735 WRITE(6,2585) IFR(I),T(I),(XX(I,JJ),ZZ(I,JJ),JJ=1,6)
    LINE=LINE+1
740 CONTINUE
    IF (IPC) 742,742,743
742 IF (NC1 .LT. N1) NC1=N1
    IF (NC2 .GT. N2) NC2=N2
    NN=NC2-NC1+1
    IP=1
C PLOT PARAMETER VERSUS SLED DATA.
    CALL CPLT(T,DI,DC,IP)
    WRITE(6,2595) IFR(NC1),IFR(NC2)
743 IF (IPA-2) 745,800,800
C*****
C COMPUTE ANGULAR VELOCITY AND ACCELERATION; HERE TO LABER 775.
C*****
745 XD(N1-1)=PI
    ZD(N1-1)=PI
    IF (ICAL(3)+ICAL(5)-2) 756,750,750
750 00 755 I=N1,N2
    H1=ZZ(I,3)-ZZ(I,1)
    H2=XX(I,3)-XX(I,1)
C SHOULDER - HIP ANGLE
    XD(I)=ATAN2(H1,H2)
    IF (XD(I) .LT. 0.0) XD(I)=XD(I)+PI2
    IF (ABS(XD(I)-XD(I-1)) .GT. PI34) XD(I)=XD(I)+PI2
755 CONTINUE
    CALL DERIV1(T,XD,WS,N,NP,1)
    CALL DERIV1(T,WS,WS2,N,NP,2)

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003360
003370
003380
003390
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003520
003530
003540
003550
003560
003570
003580
003590
003600
003610
003620
003630
003640
003650
003660
003670
003680

GO TO 758
756 DO 757 I=N1,N2
XD(I)=0.0
MS(I)=0.0
757 MS2(I)=0.0
758 IF (ICAL(7)+ICAL(8)-2) 762,759,759
759 DO 760 I=N1,N2
H1=ZZ(I,5)-ZZ(I,6)
H2=XX(I,5)-XX(I,6)
C HEAD PACK - SNOUT ANGLE
ZD(I)=ATAN2(H1,H2)
IF (ZD(I) .LT. 0.0) ZD(I)=ZD(I)+PI2
IF (ABS(ZD(I)-ZD(I-1)) .GT. PI34) ZD(I)=ZD(I)+PI2
760 CONTINUE
CALL DERIV1(T,ZD,MH,N,NP,1)
CALL DERIV1(T,MH,MH2,N,NP,2)
GO TO 768
762 DO 764 I=N1,N2
ZD(I)=0.0
MH(I)=0.0
764 MH2(I)=0.0
768 LINE=60
DO 775 I=N3,N4
IF (LINE-50) 772,770,770
770 WRITE(6,2500) TITLE,NP
WRITE(6,2551)
WRITE(6,2520)
LINE = 0
C PRINT ANGULAR VELOCITY AND ACCELERATION.
772 WRITE(6,2590) IFR(I),T(I),XD(I),MS(I),MS2(I),ZD(I),MH(I),MH2(I)
LINE=LINE+1
775 CONTINUE
IF (IPA) 780,780,800

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003690
 003700
 003710
 003720
 003730
 003740
 003750
 003760
 003770
 003780
 003790
 003800
 003810
 003820
 003830
 003840
 003850
 003860
 003870
 003880
 003890
 003900
 003910
 003920
 003930
 003940
 003950
 003960
 003970
 003980
 003990
 004000
 004010

```

780 IP=2
   NN=N4-N3+1
   JD=5
   JR=3
   IF (ICAL(3)+ICAL(5)-2) 790,785,785
C PLOT ANGULAR VELOCITY AND ACCELERATION DATA.
785 CALL CPLT(T(N3),MS(N3),MS2(N3),IP)
790 JD=7
   JR=8
   IF (ICAL(7)+ICAL(8)-2) 800,795,795
795 CALL CPLT(T(N3),MH(N3),WH2(N3),IP)
800 CONTINUE
   IF (M.LT. 1 .OR. IPL .EQ. 2) GO TO 5
   DO 200 J=2,8
   IF (ICAL(J)) 200,200,190
190 DO 195 I=2,N
   X(I,J) = X(I,J)-X(1,J)
195 Z(I,J) = Z(I,J)-Z(1,J)
   X(1,J) = 0.0
   Z(1,J) = 0.0
200 CONTINUE
   IP=3
C 202 DO 410 NP=NP1,NP2,2
C   N1=(NP-1)/2+1
C   N2=N-N1+1
C   N3=3*N1-2
C   N4=N-N3+1
C   NN=N4-N3+1
C *****
C COMPUTE LINEAR VELOCITY AND ACCEL DATA FOR PARAMETER ID(K) WITH
C RESPECT TO IR(K); HERE TO LABEL 400.
C *****

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004020
 004030
 004040
 004050
 004060
 004070
 004080
 004090
 004100
 004110
 004120
 004130
 004140
 004150
 004160
 004170
 004180
 004190
 004200
 004210
 004220
 004230
 004240
 004250
 004260
 004270
 004280
 004290
 004300
 004310
 004320
 004330
 004340

```

C
  DO 400 K=1,M
  JD=ID(K)
  IF (JD .LE. 1) GO TO 390
  JR=IR(K)
  IF (JR .LT. 1) GO TO 395
  IF (ICAL(JD) .LT. 1 .OR. ICAL(JR) .LT. 1) GO TO 400
  XMP=C1
  ZMP=C1
  RM= C1
  XMN=-C1
  ZMN=-C1
  DO 212 I=1,N
  IF (JR-1) 205,205,210
  205 OI(I)=X(I,JD)
  DC(I)=Z(I,JD)
  GO TO 212
  210 OI(I)=X(I,JD)-X(I,JR)
  DC(I)=Z(I,JD)-Z(I,JR)
  212 CONTINUE
  CALL SM(T,DI,XD,N,NP)
  CALL SM(T,DC,ZD,N,NP)
C
C  COMPUTE MAXIMUM X, Z AND RESULTANT DISPLACEMENT.
C
  DO 260 I=N1,N2
  RES(I)=SQRT(XD(I)*XD(I)+ZD(I)*ZD(I))
  IF (XD(I)-XMP) 220,220,215
  215 XMP=XD(I)
  TXMP=T(I)
  GO TO 230
  220 IF (XD(I)-XMN) 225,230,230
  225 XMN=XD(I)

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```

TXMN=T(I)
230 IF (ZD(I)-ZMP) 240,240,235
235 ZMP=ZD(I)
TZMP=T(I)
GO TO 250
240 IF (ZD(I)-ZMN) 245,245,250
245 ZMN=ZD(I)
TZMN=T(I)
250 IF (RES(I)-RM) 260,260,255
255 RM=RES(I)
TRM= T(I)
260 CONTINUE
C COMPUTE LINEAR VELOCITY.
CALL DERIV1(T,RES,VEL,N,NP,1)
C COMPUTE LINEAR ACCELERATION DATA.
CALL DERIV1(T,VEL,ACC,N,NP,2)
LINE=60
DO 280 I=N3,N4
IF (LINE=50) 275,270,270
270 WRITE(6,2500) TITLE,NP
WRITE(6,2200) HEADR(JD),HEADL(JR)
WRITE(6,2510)
LINE= J
C PRINT LINEAR DISPL, VEL AND ACCEL DATA.
275 ACCG(I)=ACC(I)/32.2
WRITE(6,2600) IFR(I),T(I),XD(I),ZD(I),RES(I),VEL(I),ACCG(I)
LINE=LINE+1
280 CONTINUE
IF (LINE=40) 330,330,320
320 WRITE(6,2500) TITLE,NP
330 WRITE(6,2200) HEADR(JD),HEADL(JR)
WRITE(6,2700) XMP, TXMP
WRITE(6,2710) XMN, TXMN

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004350
004360
004370
004380
004390
004400
004410
004420
004430
004440
004450
004460
004470
004480
004490
004500
004510
004520
004530
004540
004550
004560
004570
004580
004590
004600
004610
004620
004630
004640
004650
004660
004670

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004680
 004690
 004700
 004710
 004720
 004730
 004740
 004750
 004760
 004770
 004780
 004790
 004800
 004810
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 004880
 004890
 004900
 004910
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 004930
 004940
 004950
 004960
 004970
 004980
 004990
 005000

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WRITE(6,2720)ZMP,TZMP
WRITE(6,2730) ZMN,TZMN
WRITE(6,2740) RM,TRM

C
C PLOT LINEAR VELOCITY AND ACCELERATION DATA.
C
350 IF (IPL) 360,360,400
360 CALL CPLT(T(N3),VEL(N3),ACCG(N3),IP)
GO TO 400
390 WRITE(6,2500) TITLE,NP
WRITE(6,2800) K
GO TO 400
395 WRITE(6,2500) TITLE,NP
WRITE(6,2810) K
400 CONTINUE
410 CONTINUE
GO TO 5
999 WRITE(6,2900)
CALL PLOTE
STOP

C FOLLOWING CARD CHANGED TO INPUT PAPER TAPE DATA:
1000 FORMAT(I1,I4,8F7.0)
C1000 FORMAT(I1,I5,8F6.0)
1010 FORMAT(8A10)
1020 FORMAT(8F10.0)
1030 FORMAT(A5,4I1,2I2,2I3,I2,12(I2,I1))
2000 FORMAT(/ 4X,*ERROR IN CARD IDENTIFICATION NUMBER; CARD ID=*,I2,
1 *; FRAME NUMBER =*,I4)
2100 FORMAT(/ / 4X,*TEST N OT IRX ITYPE IPR IPL IPA
1IPC M SETS:*,12I4)
2110 FORMAT( 3X,A5,I6,F10.3,I4,5I6,I5,7X,12(I3,I1))
2120 FORMAT(/ / 36X,7(A10,2X))
2130 FORMAT( 4X,*CALIB DATA IN COUNTS PER FOOT:*,F9.3,6F12.3)

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2140 FORMAT(/ 4X, *AVERAGE TIME INCREMENT BETWEEN POINTS:*, F10.5) 005010
2150 FORMAT(/4X, *NUMBER OF FRAMES READ: *, I4, * FRAMES*) 005020
2155 FORMAT(/4X, *REVERSE POLARITY OF X-AXIS DATA (MULT. BY -1.0): *, A3) 005030
2160 FORMAT(/4X, *PRINT LISTING OF INPUT DATA IN COUNTS: *, A3) 005040
2170 FORMAT(/4X, *PARAMETERS RELATIVE TO SLED DISPLACEMENTS: PRINT? *, 005050
1A3, 4X, *PLOT? *, A3) 005060
2180 FORMAT(/4X, *ANGULAR VELOCITY AND ACCELERATION DATA: PRINT? *, 005070
1A3, 4X, *PLOT? *, A3) 005080
2190 FORMAT(/4X, *LINEAR VELOCITY AND ACCELERATION DATA: PRINT? *, 005090
1A3, 4X, *PLOT? *, A3) 005100
2200 FORMAT(/ 31X, A9, * MOTION RELATIVE TO THE *, A9) 005110
2210 FORMAT(/10X, I2, *) *, A9, * MOTION RELATIVE TO THE *, A9) 005120
2400 FORMAT(/ 4X, *ERROR IN FRAME NUMBERS; FRAME NUMBER ON CARD 1 =*, I4, 005130
1 * FRAME NUMBER ON CARD 2 =*, I4) 005140
2410 FORMAT(/ 4X, *FRAME NUMBER IS NOT INCREASING; CHECK FRAME COUNT FOR 005150
1 CARD 1, FRAME= *, I5) 005160
2500 FORMAT(1H1, 3X, *DATE: *, A10, 20X, *TEST NUMBER: *, A5/ 005170
1/ 4X, 8A10, 5X, I2, * POINT QUADRATIC FIT*) 005180
2510 FORMAT(/ 32X, *DISPLACEMENT*, 15X, *VELOCITY *, 2(5X, *ACCELERATION*)/ 005190
A 4X, *FRAME*, 005200
1 4X, *TIME*, 8X, *X*, 10X, *Z *, 2(5X, *RESULTANT*), 2(8X, *RESULTANT*)/ 005210
B 4X, * NO. *, 005220
2 4X, *(SEC)*, 2(5X, *(FEET)*), 6X, *(FEET)*, 7X, *(FT/SEC)*, 7X, *(FT/SEC 005230
3SQ)*, 10X, *(G)*) 005240
2520 FORMAT(/ 29X, *SHOULDER - HIP*, 23X, *HEAD PACK - SHOULDER/ 005250
1 * FRAME TIME*, 2( 7X, *THETA*, 8X, *W*, 10X, *W-ACC*, 4X)/ 005260
2 * NO. (SEC)*, 2(4X, *(RADIAN)) (RAD/SEC) (RAD/SEC SQ) *) 005270
2550 FORMAT(/ 4X, *THE FOLLOWING IS A LISTING OF THE INPUT DATA IN COUNT 005280
1S:*) 005290
2551 FORMAT(/ 4X, *THE FOLLOWING IS A LISTING OF THE ANGULAR MOTION OF T 005300
1HE HEAD AND SHOULDER:*) 005310
2552 FORMAT(/ 4X, *THE FOLLOWING IS A LISTING OF D(I)-DR(I)-D(I-1)+DR(I- 005320
11) IN COUNTS:*) 005330

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2555 FORMAT(//4X,*THE FOLLOWING IS A LISTING OF PARAMETER - SLED DISPLA005340
    1CEMENT IN FEET:*) 005350
2560 FORMAT(// * FRAME *, 8(6X,A10)/ 2X,*NO.*, 8(8X,*X*,6X,*Z*)) 005360
2565 FORMAT(// * FRAME TIME *,6( 7X,A10)/ 005370
    1 * NO. (SEC)*, 6( 7X,*X*,6X,*Z *)) 005380
2570 FORMAT(//4X,*LINEAR DISPLACEMENT, VELOCITY AND ACCELERATION DATA M005390
    1ILL BE COMPUTED FOR THE FOLLOWING:*) 005400
2580 FORMAT(1X,I4,2X,8(F9.0,F7.0)) 005410
2585 FORMAT(1X,I4,F11.5,6(F10.3,F7.3)) 005420
2590 FORMAT(1X,I4,F11.5,2(F10.3,F11.3,F13.3,6X)) 005430
2595 FORMAT(//4X,*THE ABOVE DATA WAS PLOTTED (X VERSUS Z) FOR FRAME NUM005440
    1BER*,I4,* TO FRAME NUMBER*,I4) 005450
2600 FORMAT(4X,I4, F11.5,F10.3,F11.3,F12.3,F15.3,F16.3,F17.3) 005460
2700 FORMAT(/ 4X,*MAXIMUM POSITIVE X DISPLACEMENT=*,F8.3, * AT TIME *005470
    1, F8.5) 005480
2710 FORMAT(/ 4X,*MAXIMUM NEGATIVE X DISPLACEMENT=*,F8.3, * AT TIME *005490
    1, F8.5) 005500
2720 FORMAT(/ 4X,*MAXIMUM POSITIVE Z DISPLACEMENT=*,F8.3, * AT TIME *005510
    1, F8.5) 005520
2730 FORMAT(/ 4X,*MAXIMUM NEGATIVE Z DISPLACEMENT=*,F8.3, * AT TIME *005530
    1, F8.5) 005540
2740 FORMAT(/ 4X,*MAXIMUM RESULTANT DISPLACEMENT=*,F8.3, * AT TIME *005550
    1, F8.5) 005560
2800 FORMAT(//4X, *OMIT COMPUTATIONS FOR SET*,I3/ 4X,*THE PROGRAM IS005570
    1 NOT DESIGNED TO COMPUTE RANGE DISPLACEMENT, VELOCITY AND ACCELE005580
    2TION.* 4X,*DATA PARAMETER CODE IS LESS THAN OR EQUAL TO 1*) 005590
2810 FORMAT(//4X, *OMIT COMPUTATIONS FOR SET*,I3/ 005600
    1 4X,*REFERENCE PARAMETER CODE IS LESS THAN 1*) 005610
2820 FORMAT(/ 4X,*CALIBRATION FACTOR IS 0.0 THUS COMPUTATIONS WILL BE 0005620
    1MITTED FOR THE FOLLOWING PARAMETER: *,A10) 005630
2830 FORMAT(//1X,134(1H*))//4X, *OMIT THE REMAINDER OF THE COMPUTATIONS005640
    1 FOR THIS TEST BECAUSE OF INPUT CARD PROBLEMS.* 005650
    2 4X,*SEE ERROR STATEMENTS AT THE BEGINNING OF THE OUTPUT FOR THIS 005660

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```

3TEST*/ 1X,134(1H*))
2840 FORMAT(/4X,*NUMBER OF FRAMES IS >*,I4,*; OMIT DATA FOR FRAME NUMB
1ER*,I4)
2900 FORMAT(*1 END OF JOB*)
END
SUBROUTINE CPLT(T,Y,Z,IP)
DIMENSION X(302),T(1),Y(1),Z(1)
COMMON JD,JR, NP,I1,I2,XX(302,6),ZZ(302,6),ICAL(8)
COMMON /CPLTC/ HEADL(8),DATE,TEST,TITLE(8),IRX
C IP=1 --- COMPOSITE PLOT OF PARAMETER VERSUS SLED DATA
C IP=2 --- PLOT OF ANGULAR VEL AND ACCEL
C IP=3 --- PLOT OF VEL AND ACCEL
C SXMAX IS THE MAXIMUM LENGTH OF THE TIME SCALE IN INCHES.
SXMAX=32.0
SY=10.0
DX=0.02
N1=N+1
N2=N+2
IF (IP-2) 300,5,5
5 DO 10 J=1,N
10 X(J)=T(J)
X(N1)=FLOAT(IFIX(X(1)*100.01))*0.01
X(N2)=DX
SX= FLOAT(IFIX((X(N)-X(N1))/DX)+1)
IF (SX .GT. SXMAX) SX= SXMAX
CALL AXIS(0.0,0.0,12HTIME IN SEC.,-12,SX,0.0,X(N1),DX)
IF (IP .EQ. 2) GO TO 400
AMX=-1.0E10
AMN= 1.0E10
DO 15 J=1,N
AMX=AMAX1(AMX,Y(J))
AMN=AMIN1(AMN,Z(J))
AMN=AMIN1(AMN,Y(J))

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005670
005680
005690
005700
005710
005720
005730
005740
005750
005760
005770
005780
005790
005800
005810
005820
005830
005840
005850
005860
005870
005880
005890
005900
005910
005920
005930
005940
005950
005960
005970
005980
005990

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```

AMN=AMIN1(AMN,Z(J))
15 CONTINUE
IF (AMN) 30,20,20
20 AMN=0.0
GO TO 40
30 AMN=FLOAT(IFIX(AMN/10.0)-1)*10.0
40 AMX=FLOAT(IFIX(AMX/10.0)+1)*10.0
DYY=(AMX-AMN)/SY
IF (DYY-10.0) 50,50,60
50 DY=10.0
YMIN=AMN
GO TO 100
60 IF (DYY-20.0) 70,70,80
70 DY=20.0
GO TO 90
80 DY=30.0
90 YMIN=FLOAT(IFIX(AMN/DY) ) *DY
IF (YMIN .GT. AMN) YMIN=YMIN-DY
100 YMAX=SY*DY+YMIN
IF (AMX .GT. YMAX) YMIN=YMIN+DY
Y(N1)=YMIN
Z(N1)=YMIN
Y(N2)=DY
Z(N2)=DY
CALL AXIS(0.0,0.0,26HVEL IN FT/SEC --- ACC IN 6,26,SY,90.,YMIN,DY)
105 Y0=ABS(YMIN/DY)
CALL PLOT(0.0,Y0,3)
CALL PLOT(SX, Y0,2)
110 DO 120 I=1,N
IF (Y(I) .GT. YMAX) Y(I)=YMAX
IF (Z(I) .GT. YMAX) Z(I)=YMAX
IF (Y(I) .LT. YMIN) Y(I)=YMIN

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006000
006010
006020
006030
006040
006050
006060
006070
006080
006090
006100
006110
006120
006130
006140
006150
006160
006170
006180
006190
006200
006210
006220
006230
006240
006250
006260
006270
006280
006290
006300
006310
006320

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```

120 IF (Z(I) .LI. YMIN) Z(I)=YMIN
130 CONTINUE
140 CALL LINE(X,Y,N,1,10,1)
    CALL LINE(X,Z,N,1,10,3)
    H1=HEADL(JD)
    CALL SYMBOL(0.25,9.5,0.105,H1,0.0,9)
    CALL SYMBOL(0.25,9.3,0.105,6HREL TO,0.0,6)
    H1=HEADL(JR)
    CALL SYMBOL(0.25,9.1,0.105,H1,0.0,9)
    J=1
    CALL SYMBOL(0.5, 8.8,0.105,J,0.0,-1)
    CALL SYMBOL(0.65,8.75,0.105,3HVEL,0.0,3)
    J=3
    CALL SYMBOL(0.5, 8.55,0.105,J,0.0,-1)
    CALL SYMBOL(0.65,8.50,0.105,3HACC,0.0,3)
    CALL SYMBOL(0.25,9.8,0.105,4HTEST,0.0,4)
    CALL SYMBOL(0.75,9.8,0.105,TEST,0.0,5)
    CALL NUMBER(1.75,9.8,0.105,FLOAT(NP),0.0,-1)
    CALL SYMBOL(2.05,9.8,0.105,9HPOINT FIT,0.0,9)
    GO TO 999

C
C PLOT THE COMPOSITE PLOT OF PARAMETERS VERSUS SLED.
C NOTE: ORDINATE AND ABSCISSA SCALING IS FIXED.
C
C 300 ZMIN=0.0
    XMIN=-1.4-2.2*FLOAT(IRX)
    YMIN=-1.0
    DZ=0.4
    DX=0.4
    SX=10.0
    CALL AXIS(0.0,0.0,14HX DISP IN FEET,-14,SX,0.0,XMIN,DX)
    CALL AXIS(0.0,0.0,14HZ DISP IN FEET, 14,SY,90.0,ZMIN,DZ)
    CALL SYMBOL(0.25,9.5,0.105,16HDATA REL TO SLED,0.0,16)

```

```

006330
006340
006350
006360
006370
006380
006390
006400
006410
006420
006430
006440
006450
006460
006470
006480
006490
006500
006510
006520
006530
006540
006550
006560
006570
006580
006585
006590
006600
006610
006620
006630
006640

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006650
 006660
 006670
 006680
 006690
 006700
 006710
 006720
 006730
 006740
 006750
 006760
 006770
 006780
 006790
 006800
 006810
 006820
 006830
 006840
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 006880
 006890
 006900
 006910
 006920
 006930
 006940
 006950
 006960
 006970

```

X(N1)=XMIN
X(N2)=DX
Z(N1)=ZMIN
Z(N2)=DZ
XMAX=SX*DX+XMIN
ZMAX=SY*DZ+ZMIN
Y0=10.0
DO 310 J=1,6
IF (ICAL(J+2)) 310,310,305
H1=HEADL(J+2)
Y0=Y0-0.25
CALL SYMBOL(-1.75,Y0+0.05,0.105,J,0.0,-1)
CALL SYMBOL(-1.60,Y0,0.105,H1,0.0,9)
CONTINUE
DO 325 J=1,6
IF (ICAL(J+2)) 325,325,315
II=0
DO 320 I=II,I2
II=II+1
X(II)=XX(I,J)
Z(II)=ZZ(I,J)
IF (X(II) .GT. XMAX) X(II)=XMAX
IF (X(II) .LT. XMIN) X(II)=XMIN
IF (Z(II) .GT. ZMAX) Z(II)=ZMAX
IF (Z(II) .LT. ZMIN) Z(II)=ZMIN
320 CONTINUE
CALL LINE(X,Z,N,1,-1,J)
325 CONTINUE
GO TO 140
C
C SETUP AND PLOT ANGULAR VEL AND ACCEL.
C
C 400 CALL SCALE(Y,SY,N,1)

```

```

006980 CALL SCALE(Z,SY,N,1)
006990 YMIN=Y(N1)
007000 ZMIN=Z(N1)
007010 DY= Y(N2)
007020 DZ= Z(N2)
007030 WRITE(6,2000) YMIN,DY,ZMIN,DZ
007040 CALL AXIS(0.0,0.0,22HANGULAR VEL -- RAD/SEC, 22,SY,90.,YMIN,DY)
007050 CALL AXIS(SX,0.0,26HANGULAR ACC -- RAD/SEC/SEC,-26,SY,90.,ZMIN,DZ)
007060 GO TO 130
007070
007080
007090
007100
007110
007120
007130
007140
007150
007160
007170
007180
007190
007200
007210
007220
007230
007240
007250
007260
007270
007280
007290
007300

CALL SCALE(Z,SY,N,1)
YMIN=Y(N1)
ZMIN=Z(N1)
DY= Y(N2)
DZ= Z(N2)
WRITE(6,2000) YMIN,DY,ZMIN,DZ
CALL AXIS(0.0,0.0,22HANGULAR VEL -- RAD/SEC, 22,SY,90.,YMIN,DY)
CALL AXIS(SX,0.0,26HANGULAR ACC -- RAD/SEC/SEC,-26,SY,90.,ZMIN,DZ)
GO TO 130

999 CALL PLOT(SX+3.0,0.0,-3)
RETURN
2000 FORMAT(/,4X,*THE ABOVE VEL AND ACCEL DATA ARE PLOTTED; YMIN=*,
1F10.2,* DY=*,F8.2 ,5X,* ZMIN=*,F10.2,* DZ=*,F8.2)
END
SUBROUTINE SM(X,Y,YC,N,NP)
C NP MUST BE AN ODD INTEGER .GE. 3.
C COMPUTE THE COEFFICIENTS FOR A QUADRATIC LEAST SQUARES FIT OF 'NP'
C POINTS AND COMPUTE THE FIT OF THE DATA (NO DERIVATIVES) 'YC(I)'.
C DIMENSION C(3),X(1),Y(1),YC(1)
M=(NP-1)/2
NN=N-M
N1=NN+1
DO 10 I=1,M
10 YC(I)=J.0
DO 20 I=N1,N
20 YC(I)=J.0
MM=M+1
DO 100 I=MM,NN
N1=I-M
N2=I+M
CALL QLSQ(X,Y,N1,N2,C)
YC(I)=C(1)*X(I)+C(2)*X(I)+C(3)
YP(I)=2.0*C(1)*X(I)+C(2)
C

```

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007310
007320
007330
007340
007350
007360
007370
007380
007390
007400
007410
007420
007430
007440
007450
007460
007470
007480
007490
007500
007510
007520
007530
007540
007550
007560
007570
007580
007590
007600
007610
007620
007630

C   YPP(I)=2.0*C(1)
100 CONTINUE
    RETURN
    END
    SUBROUTINE DERIV1(X,Y,YP,N,NP,IO)
C   NP MUST BE AN ODD INTEGER .GE. 3.
C   ID=1 FOR FIRST DERIVATIVE.
C   ID=2 FOR SECOND DERIVATIVE.
C   COMPUTE THE COEFFICIENTS FOR A QUADRATIC LEAST SQUARES FIT OF 'NP'
C   POINTS AND COMPUTE THE FIRST DERIVATIVE 'YP(I)'.
C   DIMENSION C(3),X(1),Y(1),YP(1)
      M=(NP-1)/2
      K=M+M*IO
      NN=N-K
      N1=NN+1
      DO 10 I=1,K
10   YP(I)=0.0
      DO 20 I=N1,N
20   YP(I)=0.0
      MM=K+1
      DO 100 I=MM,NN
100  N1=I-M
      N2=I+M
      CALL QLSQ(X,Y,N1,N2,C)
      YP(I)=2.0*C(1)*X(I)+C(2)
      YC(I)=C(1)*X(I)+C(2)+X(I)*X(I)+C(3)
      YPP(I)=2.0*C(1)
100 CONTINUE
    RETURN
    END
    SUBROUTINE QLSQ(X,Y,N1,N2,C)
      DIMENSION X(1),Y(1),C(1)

```

```

C THIS SUBROUTINE COMPUTES THE QUADRATIC LEAST SQUARE COEFFICIENTS
C 'C(3)' FOR NP DATA POINTS (NP MUST BE AN ODD INTEGER .GE. 3).
C THE DATA NEED NOT BE EQUALLY SPACED.
C C(1)*(X**2)+C(2)*X+C(3)=Y
C C(1)*X+C(2)=Y
C SUBSTITUTE XP=X-FF, WHERE FF IS X((N1+N2)/2)
C THEN C(3)=C(3)+C(1)*FF+FF-C(2)*FF
C C(2)=C(2)-2.0*C(1)*FF
C C(1)=C(1)
C
F(A1,A2,A3,B1,B2,B3,C1,C2,C3)=A1*(B2*C3-B3*C2)+A2*(B3*C1-B1*C3)+A3
1*(B1*C2-B2*C1)
FN=FLOAT(N2-N1+1)
NN=(N1+N2)/2
FF=X(NN)
Z1=0
Z2=0
Z3=0
Z4=0
Z5=0
Z6=0
Z7=0
10 DO 20 I=N1,N2
X2=X(I)-FF
X1=X2*X2
Z1=Z1+X2
Z2=Z2+X1
Z3=Z3+X1*X2
Z4=Z4+X1*X1
Z5=Z5+Y(I)
Z6=Z6+X2*Y(I)
Z7=Z7+X1*Y(I)
20 CONTINUE

```

```

007640
007650
007660
007670
007680
007690
007700
007710
007720
007730
007740
007750
007760
007770
007780
007790
007800
007810
007820
007830
007840
007850
007860
007870
007880
007890
007900
007910
007920
007930
007940
007950
007960

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```

DEN=F(Z4,Z3,Z2,Z1,Z2,Z1,Z2,Z1,Z2,Z1, FN)
C(1)=F(Z7,Z6,Z5,Z3,Z2,Z1,Z2,Z1, FN)/DEN
C(2)=F(Z4,Z3,Z2,Z7,Z6,Z5,Z2,Z1, FN)/DEN
C(3)=F(Z4,Z3,Z2,Z3,Z2,Z1,Z7,Z6,Z5)/DEN
C(3)=C(3)+C(1)*FF+FF-C(2)*FF
C(2)=C(2)-2.0*C(1)*FF
RETURN
END

```

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007970
0J7980
007990
008000
008010
008020
008030
0J8040

```

APPENDIX D
TYPICAL LISTINGS AND PLOTS
GENERATED BY HIFPD

DATE: 9 JUN 77 TEST NUMBER: 1039

RSD STUDY SUBJECT: 2, SUBJECT: 2, 7, 11, 17, NKLON

11 POINT QUADRATIC FIT

TEST N 77 TPX TYPE IPP IPL IPA IPC M SETSI 1 2 3 4 5 6
1039 151 133.243 1 0 0 0 0 0 32 42 52 62 72 82

CALIB DATA IN COUNTS PER FOOT: 155.745 1637.378 1644.497 1681.373 1715.118 1519.793 1464.613
SLED HIP KNEE SHOULDER ELBOW HEAD PT. 1 HEAD PT. 2

AVERAGE TIME INCORPORATED BETWEEN POINTS: 0.020
NUMBER OF FRAMES DATA: 151 FRAMES

REVERSE POLARITY OF X-AXIS DATA (MULTIPLY BY -1 IF): YES

PRINT LISTING OF INPUT DATA IN COUNTS: YES

LINEAR VELOCITY AND ACCELERATION DATA: PRINT? YES PLOT? YES

ANGULAR VELOCITY AND ACCELERATION DATA: PRINT? YES PLOT? YES

PARAMETERS RELATIVE TO SLED DISPLACEMENTS: PRINT? YES PLOT? YES

LINEAR DISPLACEMENT, VELOCITY AND ACCELERATION DATA WILL BE COMPUTED FOR THE FOLLOWING:

- 1) HIP MOTION RELATIVE TO THE SLED
- 2) KNEE MOTION RELATIVE TO THE SLED
- 3) SHOULDER MOTION RELATIVE TO THE SLED
- 4) ELBOW MOTION RELATIVE TO THE SLED
- 5) HEAD PT. 1 MOTION RELATIVE TO THE SLED
- 6) HEAD PT. 2 MOTION RELATIVE TO THE SLED

DATE: 9 JUN 77 TEST NUMBER: 1039

RSD STUDY, SUBJECT C-2, RUNNING, 25417, NYLON

11 POINT QUADRATIC FIT

THE FOLLOWING IS A LISTING OF THE INPUT DATA IN COUNTS:

FRAME NO.	SLED			HIP			KNEE			SHOULDER			ELBOW			HAND PT. 1			HAND PT. 2			
	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	
0	-154	-2134	-1817	-2357	-1893	-1849	650	-1716	-2689	967	-2519	-919	-2483	1719	-1976	-2484	1719	-1976	-2484	1719	-1976	-2484
1	-155	-2193	-1819	-2395	-1899	-1849	652	-1712	-2694	963	-2520	-914	-2494	1742	-1966	-2389	1742	-1966	-2389	1742	-1966	-2389
2	-155	-2192	-1821	-2383	-1892	-1845	648	-1712	-2693	966	-2521	-914	-2497	1732	-1976	-2396	1732	-1976	-2396	1732	-1976	-2396
3	-152	-2197	-1820	-2374	-1899	-1855	649	-1716	-2694	956	-2518	-923	-2482	1717	-1979	-2395	1717	-1979	-2395	1717	-1979	-2395
4	-153	-2222	-1818	-2372	-1898	-1853	652	-1716	-2696	956	-2522	-929	-2497	1723	-1978	-2394	1723	-1978	-2394	1723	-1978	-2394
5	-161	-2203	-1820	-2372	-1900	-1858	657	-1718	-2694	955	-2520	-922	-2495	1723	-1974	-2400	1723	-1974	-2400	1723	-1974	-2400
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123	-163	-2205	-1829	-2375	-1641	-1779	572	-1351	-2370	1193	-1472	-272	-1685	1641	-880	1897
124	-170	-2242	-1835	-2373	-1657	-1786	560	-1347	-2380	1179	-1486	-287	-1698	1632	-898	1892
125	-165	-2201	-1827	-2374	-1655	-1783	565	-1339	-2398	1184	-1488	-288	-1703	1631	-916	1910
126	-158	-2183	-1820	-2371	-1651	-1781	579	-1325	-2374	1189	-1478	-283	-1705	1630	-907	1913
127	-168	-2199	-1821	-2357	-1660	-1774	568	-1319	-2382	1181	-1480	-281	-1714	1653	-918	1920
128	-165	-2201	-1823	-2359	-1667	-1787	563	-1320	-2390	1176	-1487	-280	-1718	1643	-927	1933
129	-169	-2201	-1825	-2370	-1671	-1778	558	-1311	-2399	1176	-1491	-285	-1736	1636	-946	1933
130	-167	-2197	-1831	-2358	-1669	-1776	554	-1307	-2405	1166	-1490	-283	-1743	1634	-958	1938
131	-159	-2201	-1821	-2371	-1666	-1783	558	-1299	-2402	1164	-1490	-286	-1759	1637	-957	1943
132	-162	-2202	-1826	-2371	-1667	-1781	561	-1296	-2412	1161	-1493	-240	-1758	1656	-943	1948
133	-169	-2203	-1829	-2372	-1672	-1786	554	-1300	-2421	1161	-1500	-237	-1766	1663	-980	1947
134	-166	-2201	-1827	-2376	-1675	-1789	560	-1289	-2428	1149	-1497	-241	-1778	1655	-998	1957
135	-166	-2196	-1827	-2370	-1672	-1787	554	-1289	-2440	1143	-1499	-233	-1801	1654	-1014	1956
136	-165	-2201	-1823	-2378	-1666	-1789	559	-1289	-2440	1139	-1501	-237	-1801	1654	-1014	1956
137	-167	-2203	-1830	-2377	-1672	-1794	562	-1285	-2453	1146	-1505	-231	-1816	1657	-1039	1974
138	-168	-2202	-1830	-2384	-1668	-1792	564	-1284	-2460	1137	-1509	-227	-1824	1677	-1039	1975
139	-168	-2201	-1828	-2373	-1669	-1791	566	-1283	-2468	1136	-1506	-221	-1827	1676	-1045	1977
140	-174	-2203	-1834	-2375	-1670	-1794	558	-1275	-2479	1139	-1513	-219	-1835	1674	-1053	1983
141	-170	-2202	-1835	-2381	-1666	-1798	555	-1292	-2485	1131	-1516	-229	-1850	1677	-1080	1993
142	-171	-2198	-1835	-2375	-1669	-1796	559	-1284	-2494	1131	-1519	-219	-1850	1677	-1080	1993
143	-183	-2198	-1841	-2372	-1666	-1800	548	-1291	-2505	1126	-1534	-228	-1878	1678	-1104	2008
144	-179	-2203	-1837	-2377	-1667	-1806	561	-1294	-2510	1120	-1533	-229	-1886	1676	-1128	2014
145	-185	-2198	-1848	-2375	-1665	-1805	554	-1286	-2526	1130	-1545	-225	-1898	1695	-1138	2030
146	-179	-2201	-1840	-2373	-1666	-1802	547	-1298	-2530	1126	-1545	-224	-1909	1730	-1156	2024
147	-181	-2205	-1844	-2377	-1651	-1809	558	-1306	-2542	1107	-1545	-245	-1930	1674	-1175	2021
148	-183	-2205	-1846	-2379	-1653	-1811	551	-1309	-2552	1119	-1544	-252	-1927	1687	-1178	2044
149	-185	-2201	-1850	-2373	-1647	-1810	542	-1310	-2550	1118	-1557	-245	-1942	1695	-1192	2048
150	-188	-2204	-1848	-2383	-1650	-1816	550	-1328	-2557	1110	-1555	-252	-1937	1697	-1204	2046

DATE: 9 JUN 77

TEST NUMBER: 1629

11 POINT QUADRATIC FIT

ASD STUDY SUBJECT: C-2, DUNELFA, 761117, NAWLON

THE FOLLOWING IS A LISTING OF D(I)-DR(I)-D(I-1)+DR(I-1) IN COUNTS:

FRAME NO.	RANGE			SHOULDER			KNEE			HIP			SLEED			HEAD PT. 1			HEAD PT. 2			
	X	Z		X	Z		X	Z		X	Z		X	Z		X	Z		X	Z		
1	-11	1	3	5	1	3	6	5	3	3	3	10	4	2	0	0	2	23	-16			
2	0	1	-2	1	3	-4	1	2	-1	1	2	1	-1	-1	2	-11	6	-12	6			
3	3	-3	-2	-4	3	-2	-4	3	-2	-4	3	-2	-4	3	-2	-4	3	-2	-4	3		
4	-3	3	5	5	5	6	3	3	6	3	3	1	-3	1	3	-2	1	4	2			
5	-4	4	-5	-4	5	-5	-4	5	-4	5	-4	5	-4	5	-4	5	-4	5	-4	5		
6	6	3	-4	2	3	-5	-3	2	-8	-3	2	3	-3	2	3	5	0	-5	3			
7	-7	2	-5	6	0	11	8	0	8	0	8	0	8	0	8	0	8	0	8	0		
8	-1	5	-2	1	-2	-4	3	6	-4	3	6	-4	3	6	-4	3	6	-4	3	6		
9	7	0	-1	-4	-4	-5	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4		
10	-6	5	0	-5	2	-3	-4	2	-4	2	-4	2	-4	2	-4	2	-4	2	-4	2		
11	3	-8	-2	1	6	3	7	6	7	6	7	6	7	6	7	6	7	6	7	6		
12	3	3	3	-6	-1	-2	-9	-5	-9	-5	-9	-5	-9	-5	-9	-5	-9	-5	-9	-5		
13	-1	-2	0	6	-2	2	5	3	5	3	5	3	5	3	5	3	5	3	5	3		
14	8	-1	-2	-1	1	-6	3	-1	-4	3	-1	-4	3	-1	-4	3	-1	-4	3	-1		
15	-6	4	3	3	3	6	3	6	3	6	3	6	3	6	3	6	3	6	3	6		
16	-1	4	3	0	2	2	-1	-5	-1	-5	-1	-5	-1	-5	-1	-5	-1	-5	-1	-5		
17	2	2	-2	-1	2	-2	0	2	-2	0	2	-2	0	2	-2	0	2	-2	0	2		
18	-1	1	-2	-2	5	-2	6	1	0	0	0	-3	3	-6	7	-2	2	-3	3	-6		
19	-2	1	6	6	-2	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1		
20	0	-1	-1	4	2	1	0	-6	3	-2	2	2	-3	-2	2	2	-3	-2	2	2		
21	4	4	2	4	3	2	4	6	3	2	4	6	3	2	4	6	3	2	4	6		
22	-5	-4	-4	-4	3	-4	-4	8	-4	8	-4	8	-4	8	-4	8	-4	8	-4	8		
23	1	4	-3	3	6	3	6	3	6	3	6	3	6	3	6	3	6	3	6	3		
24	8	2	3	-1	2	-6	-2	-11	-4	-2	-4	-2	-4	-2	-4	-2	-4	-2	-4	-2		
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26	7	-5	-1	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4		
27	8	6	3	3	3	4	3	4	3	4	3	4	3	4	3	4	3	4	3	4		
28	1	0	-2	7	3	2	7	0	2	2	2	7	0	2	2	2	7	0	2	2		
29	-2	-6	-1	-1	3	-2	6	5	-1	5	-1	5	-1	5	-1	5	-1	5	-1	5		
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34	4	2	-3	-1	-5	-3	-1	-3	3	-6	6	-7	3	-5	5	-7	3	-5	5	-7		
35	5	-4	3	8	4	6	4	5	4	5	4	5	4	5	4	5	4	5	4	5		
36	-2	-5	-3	2	4	-1	0	-7	7	-7	7	10	-5	-2	10	-5	-2	10	-5	-2		
37	-1	4	3	9	2	9	12	9	12	9	12	9	12	9	12	9	12	9	12	9		
38	-1	0	0	9	-9	4	4	-5	7	10	6	14	5	-17	15	6	14	5	-17	15		
39	-4	-4	-3	7	6	17	4	2	13	2	13	2	13	2	13	2	13	2	13	2		
40	12	7	2	-5	8	14	5	-6	13	3	20	4	13	24	13	24	13	24	13	24		
41	-5	-4	3	4	2	4	2	8	2	8	2	8	2	8	2	8	2	8	2	8		
42	13	6	9	0	0	11	2	11	2	11	2	11	2	11	2	11	2	11	2	11		
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44	-6	-7	4	11	5	17	-3	-7	24	3	25	-4	24	3	25	-4	24	3	25	-4		
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58	3	-1	-3	1	7	7	9	-3	32	8	37	8	22	7	51	11
59	-9	-11	-2	1	7	0	14	0	16	3	48	5	30	-1	32	-21
60	4	-5	-2	5	10	3	-2	3	9	3	43	12	23	-22	32	-17
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63	-1	3	-4	-6	3	-4	3	3	9	2	35	9	7	-9	21	-18
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67	-8	5	-3	-2	-4	-5	-9	-6	0	-9	42	23	8	-24	34	-42
68	-4	10	2	1	-7	0	-9	-2	3	8	45	24	17	3	31	-21
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74	4	-1	7	-1	-2	0	-6	8	-9	-7	31	26	-1	-22	56	57
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76	2	-8	-2	-2	-16	-6	-5	3	-2	8	32	27	5	8	0	-46
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123	6	0	-1	3	4	-6	7	4	-5	6	-6	-6	13
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125	5	1	3	-2	-3	0	-13	4	-7	-2	-14	-31	14
126	7	3	0	0	-3	7	7	2	3	12	-9	16	0
127	-6	-1	7	5	-1	3	0	-7	6	3	-1	4	-3
128	1	-2	-3	0	-8	-6	-9	-3	-8	3	-8	-10	15
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135	0	5	0	1	-6	-5	-12	-11	-2	3	-21	4	-16
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137	-2	-2	-5	3	-4	5	-11	9	-2	8	-11	3	-18
138	-1	1	1	-5	1	3	-6	-10	-3	3	-7	9	1
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141	1	1	-2	-7	3	-18	-7	-9	-4	-11	-16	2	-28
142	-1	4	1	2	8	4	-8	-4	-2	6	-11	5	-12
143	-12	0	6	3	-4	-7	1	-5	3	-8	-14	-8	5
144	4	-5	0	0	5	2	-9	-1	-3	4	-12	3	-26
145	-6	5	-5	-3	-2	3	-18	5	-6	-1	-6	14	-6
146	6	-3	2	5	3	-9	-10	-1	4	4	-17	9	-24
147	-2	-4	-2	0	7	-13	-10	-15	-8	-17	-19	-23	-3
148	-2	0	0	-2	0	-3	-8	12	-7	-7	5	13	-1
149	-2	4	-2	2	-1	-7	-4	-5	-1	3	-13	4	-15
150	-3	-3	5	-7	-3	11	-15	-5	5	-4	8	5	-6

DATE: 9 JUN 77

TEST NUMBER: 1039

ESD STUDY, SUBJECT C 2, RUN 019, 76117, NYLON

11 POINT QUADRATIC FIT

THE FOLLOWING IS A LISTING OF PARAMETER - SLED DISPLACEMENT IN FEET:

FRAME NO.	TIME (SEC)	HIP			KNEE			SHOULDER			ELBOW			HEAD PT. 1			HEAD PT. 2		
		X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
5	0.1020	-0.055	315	1.509	375	-5.00	2.005	-3.66	898	-539	2.574	-246	3.076	-540	2.574	-249	3.079	-253	3.033
6	0.1224	-0.055	306	1.510	375	-4.99	2.007	-3.65	901	-540	2.574	-253	3.033	-539	2.574	-257	3.045	-264	3.037
7	0.1428	-0.055	315	1.512	375	-4.99	2.008	-3.65	902	-538	2.579	-254	3.037	-538	2.579	-264	3.037	-264	3.037
8	0.1632	-0.055	305	1.513	375	-4.98	2.010	-3.65	903	-538	2.579	-254	3.037	-538	2.579	-264	3.037	-264	3.037
9	0.1836	-0.055	315	1.513	375	-4.99	2.011	-3.66	904	-538	2.580	-254	3.031	-538	2.580	-254	3.031	-254	3.031
10	0.2040	-0.055	305	1.513	374	-4.99	2.011	-3.66	904	-538	2.580	-254	3.031	-538	2.580	-254	3.031	-254	3.031
11	0.2244	-0.056	304	1.513	374	-4.99	2.011	-3.66	904	-538	2.580	-254	3.031	-538	2.580	-254	3.031	-254	3.031
12	0.2448	-0.056	304	1.511	375	-4.99	2.010	-3.66	903	-538	2.579	-254	3.031	-538	2.579	-254	3.031	-254	3.031
13	0.2652	-0.056	304	1.510	376	-5.00	2.010	-3.66	903	-538	2.579	-254	3.031	-538	2.579	-254	3.031	-254	3.031
14	0.2856	-0.056	304	1.509	376	-5.00	2.009	-3.66	903	-538	2.579	-254	3.031	-538	2.579	-254	3.031	-254	3.031
15	0.3060	-0.056	304	1.509	376	-5.00	2.008	-3.66	902	-541	2.577	-278	3.039	-541	2.577	-278	3.039	-278	3.039
16	0.3264	-0.055	303	1.509	375	-5.00	2.006	-3.65	901	-541	2.577	-278	3.039	-541	2.577	-278	3.039	-278	3.039
17	0.3468	-0.056	304	1.509	374	-4.99	2.007	-3.65	902	-541	2.577	-278	3.039	-541	2.577	-278	3.039	-278	3.039
18	0.3672	-0.056	304	1.510	373	-4.99	2.007	-3.65	901	-539	2.576	-277	3.038	-539	2.576	-277	3.038	-277	3.038
19	0.3876	-0.055	304	1.511	372	-4.99	2.007	-3.65	901	-537	2.576	-277	3.038	-537	2.576	-277	3.038	-277	3.038
20	0.4080	-0.055	304	1.512	372	-4.99	2.007	-3.66	902	-535	2.575	-277	3.038	-535	2.575	-277	3.038	-277	3.038
21	0.4284	-0.055	305	1.513	372	-4.98	2.007	-3.66	903	-534	2.575	-278	3.038	-534	2.575	-278	3.038	-278	3.038
22	0.4488	-0.054	305	1.513	373	-4.98	2.008	-3.65	903	-534	2.576	-279	3.039	-534	2.576	-281	3.040	-281	3.040
23	0.4692	-0.054	306	1.513	375	-4.98	2.009	-3.65	904	-534	2.576	-281	3.040	-534	2.576	-281	3.040	-281	3.040
24	0.4896	-0.054	306	1.514	375	-4.98	2.009	-3.65	904	-536	2.576	-282	3.040	-536	2.576	-282	3.040	-282	3.040
25	0.5100	-0.054	307	1.514	375	-4.99	2.008	-3.65	904	-539	2.577	-281	3.039	-539	2.577	-281	3.039	-281	3.039
26	0.5304	-0.053	307	1.514	375	-5.00	2.008	-3.64	904	-539	2.577	-282	3.039	-539	2.577	-281	3.039	-281	3.039
27	0.5508	-0.053	307	1.514	376	-5.00	2.008	-3.64	904	-540	2.577	-283	3.039	-540	2.577	-283	3.039	-283	3.039
28	0.5712	-0.053	307	1.514	377	-5.00	2.007	-3.63	903	-540	2.577	-283	3.039	-540	2.577	-283	3.039	-283	3.039
29	0.5916	-0.051	307	1.516	378	-4.99	2.007	-3.62	903	-540	2.577	-282	3.039	-540	2.577	-282	3.039	-282	3.039
30	0.6120	-0.049	308	1.517	378	-4.99	2.006	-3.61	903	-539	2.577	-282	3.039	-539	2.577	-282	3.039	-282	3.039
31	0.6324	-0.047	309	1.519	380	-4.97	2.006	-3.59	903	-540	2.577	-281	3.039	-540	2.577	-281	3.039	-281	3.039
32	0.6528	-0.044	309	1.521	381	-4.95	2.007	-3.55	903	-539	2.577	-281	3.039	-539	2.577	-281	3.039	-281	3.039
33	0.6731	-0.042	309	1.525	382	-4.92	2.006	-3.52	902	-536	2.576	-280	3.038	-536	2.576	-280	3.038	-280	3.038
34	0.6935	-0.038	309	1.528	383	-4.89	2.006	-3.48	901	-534	2.577	-278	3.037	-534	2.577	-278	3.037	-278	3.037
35	0.7139	-0.034	307	1.534	383	-4.85	2.006	-3.43	900	-530	2.575	-275	3.035	-530	2.575	-275	3.035	-275	3.035
36	0.7343	-0.030	306	1.540	383	-4.79	2.006	-3.37	900	-525	2.574	-271	3.035	-525	2.574	-271	3.035	-271	3.035
37	0.7547	-0.026	303	1.546	382	-4.72	2.006	-3.30	900	-517	2.573	-265	3.035	-517	2.573	-265	3.035	-265	3.035
38	0.7751	-0.022	302	1.552	382	-4.65	2.005	-3.21	899	-509	2.572	-259	3.033	-509	2.572	-259	3.033	-259	3.033
39	0.7955	-0.017	301	1.559	381	-4.55	2.005	-3.12	898	-488	2.572	-251	3.032	-488	2.572	-251	3.032	-251	3.032
40	0.8159	-0.011	302	1.565	382	-4.46	2.006	-3.01	899	-468	2.571	-241	3.032	-468	2.571	-241	3.032	-241	3.032
41	0.8363	-0.005	303	1.572	383	-4.35	2.007	-2.90	899	-447	2.572	-230	3.032	-447	2.572	-230	3.032	-230	3.032
42	0.8567	0.003	305	1.579	383	-4.23	2.008	-2.77	898	-424	2.572	-215	3.032	-424	2.572	-215	3.032	-215	3.032
43	0.8771	0.010	307	1.588	385	-4.10	2.008	-2.63	898	-401	2.571	-200	3.031	-401	2.571	-200	3.031	-200	3.031
44	0.8975	0.019	307	1.598	385	-3.97	2.007	-2.49	898	-377	2.570	-184	3.031	-377	2.570	-184	3.031	-184	3.031
45	0.9179	0.028	306	1.610	386	-3.82	2.006	-2.34	897	-352	2.569	-167	3.030	-352	2.569	-167	3.030	-167	3.030
46	0.9383	0.038	306	1.621	386	-3.67	2.006	-2.18	897	-327	2.568	-150	3.029	-327	2.568	-150	3.029	-150	3.029
47	0.9587	0.047	305	1.633	384	-3.52	2.004	-2.02	896	-302	2.566	-133	3.025	-302	2.566	-133	3.025	-133	3.025
48	0.9791	0.057	306	1.645	384	-3.36	2.003	-1.84	896	-277	2.564	-115	3.022	-277	2.564	-115	3.022	-115	3.022
49	0.9995	0.066	306	1.657	382	-3.20	2.003	-1.64	895	-252	2.563	-99	3.020	-252	2.563	-99	3.020	-99	3.020
50	1.0199	0.075	308	1.669	381	-3.04	2.003	-1.45	897	-227	2.563	-82	3.018	-227	2.563	-82	3.018	-82	3.018
51	1.0403	0.083	308	1.681	380	-2.87	2.003	-1.24	897	-202	2.562	-65	3.015	-202	2.562	-65	3.015	-65	3.015
52	1.0607	0.093	308	1.692	379	-2.71	2.004	-1.01	898	-177	2.560	-48	3.012	-177	2.560	-48	3.012	-48	3.012
53	1.0811	0.101	308	1.703	378	-2.56	2.004	-0.77	900	-152	2.558	-31	3.009	-152	2.558	-31	3.009	-31	3.009
54	1.1015	0.110	308	1.712	375	-2.41	2.004	-0.53	901	-127	2.555	-14	3.006	-127	2.555	-14	3.006	-14	3.006

DATE: 9 JUN 77

TEST NUMBER: 1039

RSD STUDY SUBJECT: G-2, RUMIC-79, 7-1117, NYLON

11 POINT QUADRATIC FIT

THE FOLLOWING IS A LISTING OF PARAMETER - SLED DISPLACEMENT IN FEET:

FRAME NO.	TIME (SEC)	HIP			KNEE			SHOULDER			ELBOW			HEAD PT. 1			HEAD PT. 2		
		X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
55	11249	118	437	1.721	1.773	2.005	1.029	1.903	2.556	2.337	2.556	0.56	3.055						
56	11423	126	316	1.727	3.71	2.015	0.004	9.06	2.554	2.216	2.554	0.83	3.032						
57	11627	133	346	1.734	3.68	2.021	0.001	9.09	2.551	1.97	2.551	1.11	3.048						
58	11831	139	307	1.739	3.66	2.005	0.001	9.12	2.548	1.80	2.548	1.38	3.043						
59	12035	145	289	1.743	3.64	2.006	0.001	9.15	2.546	1.65	2.546	1.64	3.037						
60	12239	149	310	1.745	3.63	2.007	0.001	9.20	2.544	1.53	2.544	1.84	3.029						
61	12443	152	240	1.746	3.62	2.007	0.001	9.25	2.538	1.44	2.538	2.02	3.019						
62	12647	154	311	1.746	3.64	2.007	0.001	9.30	2.534	1.36	2.534	2.19	3.008						
63	12851	155	310	1.744	3.65	2.007	0.001	9.37	2.527	1.31	2.527	2.32	2.993						
64	13055	155	310	1.742	3.66	2.006	0.001	9.45	2.522	1.26	2.522	2.46	2.978						
65	13259	157	268	1.738	3.66	2.005	0.001	9.54	2.517	1.24	2.517	2.60	2.962						
66	13463	151	306	1.734	3.66	2.004	0.001	9.64	2.509	1.15	2.509	2.77	2.942						
67	13667	148	286	1.728	3.66	2.003	0.001	9.75	2.501	1.08	2.501	2.97	2.921						
68	13871	144	306	1.723	3.65	2.002	0.001	9.86	2.493	1.03	2.493	3.19	2.904						
69	14075	141	336	1.717	3.64	2.001	0.001	9.99	2.486	0.97	2.486	3.38	2.874						
70	14279	136	364	1.711	3.64	1.998	0.001	1.014	2.478	0.93	2.478	3.55	2.843						
71	14483	132	395	1.702	3.65	1.996	0.001	1.029	2.469	0.89	2.469	3.70	2.813						
72	14687	126	305	1.695	3.68	1.994	0.001	1.044	2.462	0.88	2.462	3.87	2.793						
73	14891	121	334	1.687	3.70	1.993	0.001	1.062	2.452	0.88	2.452	3.99	2.751						
74	15095	115	313	1.678	3.73	1.994	0.001	1.080	2.446	0.89	2.446	4.09	2.722						
75	15299	109	342	1.670	3.75	1.994	0.001	1.098	2.440	0.89	2.440	4.19	2.695						
76	15503	104	301	1.660	3.77	1.994	0.001	1.115	2.432	0.87	2.432	4.30	2.670						
77	15707	99	330	1.654	3.79	1.994	0.001	1.132	2.425	0.85	2.425	4.39	2.648						
78	15911	94	330	1.647	3.80	1.994	0.001	1.150	2.418	0.82	2.418	4.49	2.628						
79	16115	89	300	1.634	3.82	1.962	0.001	1.166	2.412	0.77	2.412	4.55	2.595						
80	16319	85	370	1.625	3.83	1.959	0.001	1.182	2.405	0.74	2.405	4.62	2.567						
81	16523	81	346	1.617	3.86	1.956	0.001	1.196	2.400	0.72	2.400	4.69	2.541						
82	16727	75	300	1.609	3.89	1.955	0.001	1.209	2.396	0.69	2.396	4.77	2.518						
83	16931	68	234	1.604	3.92	1.953	0.001	1.219	2.391	0.68	2.391	4.79	2.497						
84	17135	61	298	1.593	3.97	1.952	0.001	1.228	2.390	0.66	2.390	4.78	2.473						
85	17339	56	236	1.585	4.02	1.952	0.001	1.238	2.389	0.64	2.389	4.70	2.455						
86	17543	50	216	1.578	4.08	1.954	0.001	1.245	2.391	0.61	2.391	4.77	2.455						
87	17747	46	236	1.574	4.15	1.958	0.001	1.253	2.393	0.57	2.393	4.77	2.458						
88	17951	42	237	1.565	4.22	1.962	0.001	1.259	2.394	0.52	2.394	4.79	2.446						
89	18155	39	297	1.560	4.30	1.965	0.001	1.265	2.396	0.48	2.396	4.83	2.443						
90	18359	36	238	1.553	4.37	1.974	0.001	1.268	2.396	0.43	2.396	4.88	2.443						
91	18563	33	238	1.547	4.45	1.981	0.001	1.272	2.400	0.38	2.400	4.95	2.445						
92	18767	31	238	1.539	4.53	1.989	0.001	1.273	2.401	0.33	2.401	5.01	2.447						
93	18971	29	238	1.534	4.61	1.996	0.001	1.273	2.404	0.28	2.404	5.07	2.450						
94	19175	27	238	1.528	4.68	2.005	0.001	1.273	2.409	0.23	2.409	5.12	2.455						
95	19379	25	238	1.523	4.75	2.014	0.001	1.273	2.415	0.18	2.415	5.10	2.460						
96	19583	25	302	1.519	4.82	2.024	0.001	1.274	2.421	0.13	2.421	5.23	2.457						
97	19786	25	304	1.515	4.88	2.034	0.001	1.274	2.425	0.08	2.425	5.30	2.475						
98	19990	25	337	1.514	4.94	2.044	0.001	1.274	2.429	0.03	2.429	5.37	2.491						
99	20194	25	319	1.511	4.99	2.054	0.001	1.273	2.433	0.00	2.433	5.44	2.488						
100	20398	25	312	1.509	5.05	2.064	0.001	1.273	2.437	0.01	2.437	5.50	2.498						
101	20602	25	344	1.508	5.10	2.073	0.001	1.271	2.442	0.02	2.442	5.57	2.518						
102	20806	25	316	1.507	5.15	2.082	0.001	1.269	2.444	0.04	2.444	5.62	2.518						
103	21010	25	348	1.506	5.20	2.091	0.001	1.267	2.450	0.08	2.450	5.67	2.525						
104	21214	24	321	1.505	5.24	2.098	0.001	1.266	2.455	0.12	2.455	5.70	2.536						

DATE: 9 JUN 77

TEST NUMBER: 1039

SSO STUDY, SUBJECT: C-2, FUNCTION: 761117, NYLON

11 POINT QUADRATIC FIT

THE FOLLOWING IS A LISTING OF PARAMETER - SLED DISPLACEMENT IN FEET:

FRAME NO.	TIME (SEC)	HIP			KNEE			SHOULDER			ELBOW			HEAD PT. 1			HEAD PT. 2		
		X	Z	Y	X	Z	Y	X	Z	Y	X	Z	Y	X	Z	Y	X	Z	Y
105	21418	0.24	323	1.503	528	-0.262	2.105	360	1.264	0.33	2.461	572	2.547						
106	21622	0.22	325	1.502	532	-0.262	2.112	351	1.262	0.34	2.466	573	2.560						
107	21826	0.21	328	1.500	536	-0.263	2.116	340	1.261	0.35	2.470	574	2.573						
108	22030	0.20	331	1.498	541	-0.261	2.120	331	1.260	0.35	2.474	574	2.582						
109	22234	0.18	333	1.495	545	-0.261	2.123	322	1.259	0.34	2.478	574	2.594						
110	22438	0.17	336	1.493	551	-0.261	2.126	314	1.259	0.35	2.482	573	2.608						
111	22642	0.15	337	1.491	555	-0.263	2.130	305	1.259	0.34	2.485	571	2.621						
112	22846	0.13	339	1.488	559	-0.265	2.133	298	1.260	0.35	2.487	569	2.632						
113	23050	0.10	340	1.486	563	-0.267	2.136	290	1.261	0.34	2.490	567	2.643						
114	23254	0.07	343	1.484	567	-0.271	2.139	282	1.263	0.32	2.494	564	2.656						
115	23458	0.04	344	1.481	571	-0.274	2.143	276	1.265	0.29	2.498	561	2.669						
116	23662	0.01	344	1.479	574	-0.279	2.144	271	1.267	0.26	2.499	557	2.680						
117	23866	0.02	345	1.477	578	-0.283	2.144	266	1.268	0.24	2.502	553	2.688						
118	24070	0.05	346	1.475	583	-0.287	2.144	261	1.270	0.20	2.503	547	2.696						
119	24274	0.07	347	1.474	587	-0.290	2.144	258	1.271	0.15	2.505	540	2.705						
120	24478	0.09	348	1.471	591	-0.292	2.144	256	1.273	0.13	2.506	533	2.712						
121	24682	0.12	349	1.467	594	-0.297	2.143	252	1.274	0.09	2.508	524	2.718						
122	24886	0.15	349	1.465	598	-0.300	2.143	250	1.276	0.05	2.510	515	2.724						
123	25090	0.18	350	1.463	603	-0.302	2.144	247	1.279	0.00	2.513	507	2.729						
124	25294	0.21	350	1.461	606	-0.305	2.143	245	1.281	0.00	2.514	498	2.735						
125	25498	0.25	350	1.459	610	-0.308	2.143	242	1.284	0.02	2.517	490	2.741						
126	25702	0.29	349	1.457	612	-0.312	2.140	241	1.287	0.01	2.518	484	2.744						
127	25906	0.32	348	1.455	616	-0.315	2.137	239	1.290	0.02	2.521	475	2.747						
128	26110	0.34	349	1.454	620	-0.317	2.135	238	1.292	0.02	2.522	469	2.752						
129	26314	0.34	349	1.453	623	-0.320	2.133	237	1.295	0.03	2.525	465	2.756						
130	26518	0.35	349	1.452	627	-0.322	2.131	237	1.297	0.03	2.526	461	2.759						
131	26722	0.36	348	1.451	629	-0.326	2.128	236	1.299	0.04	2.528	454	2.763						
132	26926	0.35	348	1.451	632	-0.329	2.126	235	1.298	0.04	2.528	447	2.765						
133	27130	0.35	348	1.451	635	-0.333	2.124	234	1.299	0.05	2.529	438	2.768						
134	27334	0.35	347	1.452	638	-0.337	2.122	233	1.299	0.06	2.530	429	2.773						
135	27538	0.36	347	1.453	640	-0.342	2.121	231	1.301	0.07	2.534	420	2.777						
136	27742	0.35	346	1.454	642	-0.347	2.119	231	1.303	0.07	2.536	412	2.790						
137	27946	0.35	346	1.455	644	-0.351	2.118	230	1.305	0.08	2.538	404	2.794						
138	28150	0.33	346	1.456	646	-0.356	2.117	230	1.308	0.09	2.541	398	2.789						
139	28354	0.31	345	1.456	648	-0.360	2.116	229	1.309	0.09	2.543	393	2.792						
140	28558	0.30	344	1.457	645	-0.363	2.115	228	1.309	0.10	2.543	386	2.797						
141	28762	0.28	343	1.458	644	-0.367	2.113	226	1.309	0.10	2.543	379	2.801						
142	28966	0.25	342	1.457	643	-0.371	2.111	224	1.309	0.11	2.546	371	2.806						
143	29170	0.23	340	1.458	641	-0.376	2.109	223	1.308	0.11	2.546	360	2.810						
144	29374	0.21	339	1.459	639	-0.381	2.108	220	1.307	0.12	2.548	349	2.816						
145	29578	0.19	338	1.459	637	-0.385	2.106	218	1.304	0.13	2.548	339	2.820						

THE ABOVE DATA WAS PLOTTED (Y VERSUS Z) FOR FRAME NUMBER 5 TO FRAME NUMBER 145

DATE: 9 JUN 77 TEST NUMBER: 1039

RSD STUDY, SUBJECT C-2, RUN#1033, 761117, NYLON

11 POINT QUADRATIC FIT

THE FOLLOWING IS A LISTING OF THE ANGULAR MOTION OF THE HEAD AND SHOULDER:

FRAME NO.	TIME (SEC)	SHOULDER			HIP			HEAD PT. 1			HEAD PT. 2		
		THETA (RAD/SEC)	W (RAD/SEC)	M-ACC (RAD/SEC SQ)	THETA (RAD/SEC)	W (RAD/SEC)	M-ACC (RAD/SEC SQ)	THETA (RAD/SEC)	W (RAD/SEC)	M-ACC (RAD/SEC SQ)	THETA (RAD/SEC)	W (RAD/SEC)	M-ACC (RAD/SEC SQ)
15	0.3060	1.826	0.09	3.238	4.245	.314	-123.689						
16	0.3264	1.826	0.15	3.559	4.238	0.183	-71.485						
17	0.3468	1.826	0.11	4.948	4.237	0.225	-30.479						
18	0.3672	1.826	0.17	6.848	4.239	0.398	-5.766						
19	0.3876	1.825	0.19	8.727	4.242	0.785	.313						
20	0.4080	1.825	0.45	10.361	4.246	0.997	-9.816						
21	0.4284	1.826	0.69	11.615	4.250	0.974	-30.971						
22	0.4488	1.826	1.11	12.300	4.251	0.660	-54.315						
23	0.4692	1.826	1.57	11.838	4.256	0.359	-72.928						
24	0.4896	1.826	1.75	9.896	4.266	0.058	-78.107						
25	0.5100	1.827	1.94	6.764	4.253	-0.189	-67.430						
26	0.5304	1.824	2.16	2.210	4.248	-0.393	-45.350						
27	0.5508	1.824	2.25	-3.726	4.248	-0.476	-16.652						
28	0.5712	1.828	2.20	-10.365	4.247	-0.446	13.359						
29	0.5916	1.829	2.05	-19.079	4.247	-0.305	40.800						
30	0.6120	1.829	1.67	-29.604	4.247	-0.096	62.486						
31	0.6324	1.830	1.08	-39.750	4.245	0.103	75.077						
32	0.6528	1.830	0.21	-49.790	4.246	0.268	75.868						
33	0.6731	1.830	-0.109	-58.457	4.249	0.463	63.996						
34	0.6935	1.830	-0.264	-64.906	4.248	0.670	42.411						
35	0.7139	1.830	-0.428	-68.230	4.249	0.931	13.715						
36	0.7343	1.829	-0.604	-68.239	4.251	0.881	-18.547						
37	0.7547	1.827	-0.757	-65.068	4.255	0.804	-52.677						
38	0.7751	1.825	-0.904	-59.511	4.257	0.580	-85.525						
39	0.7955	1.823	-1.022	-53.106	4.261	0.316	-114.251						
40	0.8159	1.821	-1.111	-46.762	4.262	-0.014	-134.868						
41	0.8363	1.818	-1.181	-41.813	4.260	-0.370	-146.104						
42	0.8567	1.816	-1.236	-38.064	4.259	-0.749	-151.439						
43	0.8771	1.813	-1.294	-37.640	4.254	-1.061	-152.442						
44	0.8975	1.811	-1.354	-37.296	4.251	-1.376	-153.746						
45	0.9179	1.808	-1.423	-37.115	4.249	-1.628	-156.628						
46	0.9383	1.805	-1.529	-36.351	4.247	-1.852	-161.180						
47	0.9587	1.802	-1.636	-34.047	4.243	-2.193	-167.862						
48	0.9791	1.798	-1.723	-29.605	4.239	-2.521	-178.670						
49	0.9995	1.795	-1.788	-20.847	4.233	-2.931	-191.741						
50	1.0199	1.791	-1.824	-9.059	4.227	-3.387	-207.970						
51	1.0403	1.786	-1.855	5.722	4.220	-3.800	-222.968						
52	1.0607	1.782	-1.852	22.395	4.208	-4.231	-234.342						
53	1.0811	1.779	-1.801	40.248	4.201	-4.705	-244.451						
54	1.1015	1.775	-1.697	58.553	4.191	-5.270	-252.862						
55	1.1219	1.772	-1.542	75.783	4.181	-5.860	-262.048						
56	1.1423	1.768	-1.353	89.592	4.171	-6.399	-273.047						
57	1.1627	1.765	-1.139	97.451	4.158	-6.912	-284.622						
58	1.1831	1.763	-0.978	97.962	4.142	-7.466	-296.547						
59	1.2035	1.761	-0.801	90.873	4.122	-8.051	-316.581						
60	1.2239	1.760	-0.618	76.837	4.105	-8.699	-350.725						
61	1.2443	1.760	-0.465	57.856	4.089	-9.387	-397.080						
62	1.2647	1.760	-0.367	35.824	4.071	-10.117	-451.762						
63	1.2851	1.762	-0.343	13.910	4.052	-10.880	-507.644						
64	1.3055	1.763	-0.334	-3.899	4.029	-12.003	-556.958						

DATE: 9 JUN 77 TEST NUMBER: 1029

PSO STUDY, SUBJECT C-2, PUN1039, 751117, NYLON

11 POINT QUADRATIC FIT

THE FOLLOWING IS A LISTING OF THE ANGULAR MOTION OF THE HEAD AND SHOULDER:

FRAME NO.	TIME (SEC)	SHOULDER - HIP		HEAD PT. 1		HEAD PT. 2	
		THETA (RAD/SEC)	W-ACC (RAD/SEC SQ)	THETA (RAD/SEC)	W-ACC (RAD/SEC SQ)	THETA (RAD/SEC)	W-ACC (RAD/SEC SQ)
65	13259	1.763	-1.175	4.003	-13.408	591.529	-591.529
66	13663	1.761	-1.264	3.926	-14.885	601.486	-601.486
67	13667	1.750	-1.392	3.945	-16.117	576.300	-576.300
68	13871	1.753	-1.453	3.915	-17.858	608.092	-608.092
69	14075	1.757	-1.444	3.869	-19.088	403.173	-403.173
70	14273	1.756	-1.375	3.826	-20.049	278.699	-278.699
71	14483	1.755	-1.278	3.783	-20.565	150.738	-150.738
72	14687	1.755	-1.174	3.736	-20.937	30.220	-30.220
73	14891	1.755	-1.073	3.691	-19.959	72.227	-72.227
74	15085	1.753	-1.020	3.648	-19.765	150.015	-150.015
75	15299	1.756	-0.94	3.607	-18.837	200.912	-200.912
76	15503	1.756	-1.48	3.573	-18.362	228.483	-228.483
77	15707	1.756	-1.81	3.544	-17.914	244.644	-244.644
78	15911	1.757	-2.02	3.519	-17.493	267.248	-267.248
79	16115	1.757	-2.21	3.471	-17.085	317.325	-317.325
80	16319	1.757	-2.28	3.434	-16.661	389.602	-389.602
81	16523	1.758	-2.22	3.397	-16.070	476.951	-476.951
82	16727	1.759	-1.80	3.361	-15.166	570.300	-570.300
83	16931	1.759	-1.06	3.332	-13.832	657.955	-657.955
84	17135	1.760	-0.403	3.304	-11.951	730.141	-730.141
85	17339	1.760	-1.144	3.280	-10.065	775.077	-775.077
86	17543	1.760	-3.12	3.263	-8.163	783.670	-783.670
87	17747	1.759	-4.68	3.248	-6.329	756.393	-756.393
88	17951	1.758	-6.22	3.238	-4.715	697.214	-697.214
89	18155	1.756	-7.41	3.231	-3.275	617.266	-617.266
90	18359	1.754	-8.23	3.231	-2.144	534.977	-534.977
91	18563	1.752	-9.58	3.228	-1.295	458.171	-458.171
92	18767	1.749	-8.63	3.228	0.541	393.038	-393.038
93	18971	1.747	-8.37	3.228	0.049	342.121	-342.121
94	19175	1.746	-8.19	3.229	0.558	305.297	-305.297
95	19379	1.745	-8.05	3.227	1.074	281.731	-281.731
96	19583	1.744	-7.97	3.229	1.662	266.213	-266.213
97	19786	1.742	-8.03	3.234	2.248	254.866	-254.866
98	19990	1.740	-8.16	3.239	2.768	245.136	-245.136
99	20194	1.738	-8.25	3.245	3.283	233.282	-233.282
100	20398	1.736	-8.13	3.256	3.750	220.808	-220.808
101	20602	1.735	-7.81	3.264	4.158	210.246	-210.246
102	20806	1.733	-7.16	3.275	4.589	204.351	-204.351
103	21010	1.731	-6.47	3.280	4.932	202.070	-202.070
104	21214	1.730	-5.90	3.291	5.224	199.520	-199.520
105	21418	1.729	-5.41	3.301	5.620	195.078	-195.078
106	21622	1.728	-4.87	3.314	6.100	186.473	-186.473
107	21826	1.728	-4.34	3.330	6.608	170.565	-170.565
108	22030	1.727	-3.83	3.340	7.056	163.411	-163.411
109	22234	1.725	-3.32	3.354	7.381	119.088	-119.088
110	22438	1.725	-2.70	3.373	7.601	77.922	-77.922
111	22642	1.725	-1.90	3.390	7.717	32.650	-32.650
112	22846	1.724	-0.93	3.408	7.693	-11.725	-11.725
113	23050	1.724	0.10	3.421	7.648	-52.450	-52.450
114	23254	1.724	0.91	3.438	7.437	-88.205	-88.205

THE FOLLOWING IS A LISTING OF THE ANGULAR MOTION OF THE HEAD AND SHOULDER:

FRAME NO.	TIME (SECS)	SHOULDER - HIP		HEAD ON 1		HEAD ON 2	
		THETA (RAD/SEC)	W-ACC (RAD/SEC SQ)	THETA (RAD/SEC)	W-ACC (RAD/SEC SQ)	THETA (RAD/SEC)	W-ACC (RAD/SEC SQ)
115	23654	1.724	11.8	3.453	7.101	-118.900	
116	23662	1.725	19.8	3.469	6.817	-144.749	
117	23866	1.725	232	3.480	6.521	-165.617	
118	24070	1.726	234	3.493	6.159	-183.657	
119	24274	1.727	211	3.506	5.755	-196.935	
120	24478	1.727	163	3.518	5.331	-207.965	
121	24682	1.728	114	3.529	4.876	-215.525	
122	24886	1.728	71	3.540	4.412	-216.960	
123	25090	1.729	35	3.546	3.935	-210.148	
124	25294	1.728	363	3.555	3.398	-195.997	
125	25498	1.727	990	3.560	2.929	-175.375	
126	25702	1.728	154	3.566	2.546	-150.315	
127	25906	1.728	275	3.569	2.299	-121.739	
128	26110	1.728	418	3.575	2.121	-93.884	
129	26314	1.729	572	3.576	2.005	-65.917	
130	26518	1.728	726	3.579	1.949	-43.845	
131	26722	1.722	871	3.586	1.896	-23.606	
132	26926	1.725	1084	3.588	1.912	-4.575	
133	27130	1.737	1126	3.592	1.884	13.874	
134	27334	1.719	1224	3.600	1.876	33.023	
135	27538	1.742	1315	3.601	1.920	54.079	

THE ABOVE VEL AND ACCEL DATA ARE PLOTTED: YMIN=-2.00 DY=-4.0 ZMIN=-60.00 DZ=20.00

THE ABOVE VEL AND ACCEL DATA ARE PLOTTED: YMIN=-800.00 DZ=200.00

DATE: 9 JUN 77 TEST NUMBER: 1039
 RSD STUDY SUBJECT: C-2, PUM189, 764117, NYLON 11 POINT QUADRATIC FIT

HIP MOTION RELATIVE TO THE SLED

FRAME NO.	TIME (SEC)	DISPLACEMENT			VELOCITY			ACCELERATION		
		X (FEET)	Z (FEET)	RESULTANT (FEET)	RESULTANT (FT/SEC)	RESULTANT (FT/SEC SO)	RESULTANT (G)	RESULTANT (G)	RESULTANT (G)	
15	.03050	-.001	-.001	.002	.023	-7.061	.219			
16	.03254	-.001	-.002	.002	-.019	-5.713	-.177			
17	.03458	-.001	-.001	.001	-.032	-2.754	-.046			
18	.03672	-.001	-.002	.002	-.030	.415	.013			
19	.03876	-.001	-.001	.001	-.024	4.962	.184			
20	.04080	-.001	-.001	.001	-.016	10.425	.324			
21	.04284	-.000	-.000	.001	-.025	16.436	.510			
22	.04489	.001	-.000	.001	.078	22.309	.693			
23	.04692	.001	.001	.001	.091	28.798	.894			
24	.04895	.001	.001	.001	.155	36.117	1.122			
25	.05100	.001	.001	.002	.232	44.059	1.388			
26	.05304	.002	.002	.003	.332	52.225	1.622			
27	.05508	.002	.002	.003	.443	61.046	1.896			
28	.05712	.002	.002	.003	.580	69.379	2.155			
29	.05916	.004	.002	.005	.736	75.723	2.352			
30	.06120	.006	.003	.006	.910	80.949	2.514			
31	.06324	.008	.004	.009	1.098	84.843	2.655			
32	.06528	.011	.004	.011	1.301	86.286	2.742			
33	.06731	.013	.004	.014	1.489	91.660	2.847			
34	.06935	.017	.004	.017	1.647	95.600	2.969			
35	.07139	.021	.002	.021	1.831	100.663	3.126			
36	.07343	.025	.000	.025	2.013	106.909	3.320			
37	.07547	.029	.002	.029	2.210	113.934	3.548			
38	.07751	.033	-.003	.033	2.473	121.089	3.761			
39	.07955	.038	-.004	.038	2.741	128.464	3.927			
40	.08159	.044	-.003	.044	3.036	128.596	3.994			
41	.08363	.050	-.002	.050	3.340	126.287	3.922			
42	.08567	.058	-.000	.058	3.636	118.556	3.682			
43	.08771	.065	.002	.065	3.946	105.893	3.289			
44	.08975	.074	.002	.074	4.132	89.146	2.769			
45	.09179	.083	.001	.083	4.316	69.381	2.156			
46	.09383	.093	.001	.093	4.430	48.147	1.495			
47	.09587	.102	.000	.102	4.488	26.808	.833			
48	.09791	.112	.001	.112	4.501	6.257	.194			
49	.09995	.121	.001	.121	4.481	-13.024	-.406			
50	.10199	.130	.003	.130	4.425	-31.201	-.969			
51	.10403	.138	.002	.138	4.343	-48.587	-1.509			
52	.10607	.148	.003	.148	4.234	-66.777	-2.074			
53	.10811	.156	.003	.156	4.093	-86.165	-2.676			
54	.11015	.165	.003	.165	3.915	-107.090	-3.326			
55	.11219	.173	.002	.173	3.692	-129.302	-4.016			
56	.11423	.181	.001	.181	3.426	-152.272	-4.729			
57	.11627	.188	.001	.188	3.075	-174.818	-5.429			
58	.11831	.194	.002	.194	2.660	-195.437	-6.069			
59	.12035	.200	.004	.200	2.234	-212.277	-6.592			
60	.12239	.205	.005	.204	1.747	-224.026	-6.957			
61	.12443	.207	.005	.207	1.233	-229.455	-7.126			
62	.12647	.209	.006	.209	.713	-228.544	-7.098			
63	.12851	.210	.005	.210	.204	-221.892	-6.691			
64	.13055	.210	.004	.210	-.264	-210.315	-6.532			

DATE: 9 JUN 77 TEST NUMBER: 1039

ESD STUDY, SUBJECT C-2, SUBJECTS, 24117, NXLON

4 POINT QUADRATIC FIT

HIP MOTION RELATIVE TO THE SLED

FRAME NO.	TIME (SEC)	DISPLACEMENT		VELOCITY		ACCELERATION	
		X (FEET)	Z (FEET)	RESULTANT (FEET)	(FT/SEC)	RESULTANT (FT/SEC SOI)	RESULTANT (G)
65	13.259	208	303	208	-1.693	-134.796	-6.050
66	13.433	205	301	206	-1.072	-176.906	-5.482
67	13.557	203	301	203	-1.413	-156.927	-4.861
68	13.671	199	301	199	-1.702	-135.565	-4.210
69	14.023	196	301	196	-1.963	-114.263	-3.549
70	14.273	191	301	191	-2.180	-92.648	-2.877
71	14.433	187	300	187	-2.354	-71.280	-2.214
72	14.637	181	300	181	-2.481	-50.968	-1.583
73	14.841	176	301	176	-2.556	-33.244	-1.032
74	15.033	170	302	170	-2.583	-19.104	-0.593
75	15.233	164	303	164	-2.556	-9.736	-0.302
76	15.613	159	301	159	-2.522	-4.994	-0.155
77	15.737	154	303	154	-2.481	-3.977	-0.123
78	15.911	149	305	149	-2.469	-5.239	-0.163
79	16.115	145	305	145	-2.494	-6.573	-0.204
80	16.313	140	305	140	-2.554	-5.868	-0.182
81	16.523	135	305	136	-2.620	-4.177	-0.077
82	16.727	130	305	130	-2.656	8.594	0.267
83	16.931	123	307	123	-2.678	22.997	0.714
84	17.135	116	307	117	-2.631	40.451	1.256
85	17.333	111	309	111	-2.521	58.412	1.814
86	17.543	105	309	106	-2.351	74.700	2.320
87	17.747	101	309	101	-2.132	87.749	2.725
88	17.951	97	308	97	-1.836	96.723	3.004
89	18.153	90	308	94	-1.456	101.275	3.145
90	18.333	81	307	81	-1.440	102.113	3.171
91	18.533	73	307	73	-1.233	100.119	3.109
92	18.757	66	307	66	-1.035	96.053	2.983
93	18.921	53	307	53	-0.846	90.351	2.806
94	19.175	42	307	42	-0.656	83.100	2.581
95	19.273	34	306	34	-0.487	74.552	2.315
96	19.543	28	307	28	-0.317	63.997	1.987
97	19.745	20	301	20	-0.173	51.805	1.609
98	19.931	10	302	10	-0.074	38.557	1.197
99	20.126	0	306	0	-0.015	25.101	0.780
100	20.338	0	307	0	0.015	12.609	0.385
101	20.642	0	309	0	0.000	1.363	0.042
102	20.875	0	311	0	-0.033	-7.485	-0.232
103	21.040	0	313	0	-0.078	-14.116	-0.438
104	21.214	0	316	0	-0.124	-18.967	-0.589
105	21.414	0	318	0	-0.161	-22.632	-0.700
106	21.622	0	320	0	-0.201	-25.296	-0.786
107	21.825	0	323	0	-0.249	-28.218	-0.876
108	22.030	0	325	0	-0.308	-31.175	-0.968
109	22.234	0	323	0	-0.375	-33.503	-1.040
110	22.434	0	320	0	-0.447	-34.497	-1.071
111	22.642	0	322	0	-0.534	-33.507	-1.041
112	22.845	0	323	0	-0.633	-30.503	-0.947
113	23.050	0	325	0	-0.721	-25.663	-0.797
114	23.254	0	327	0	-0.777	-19.794	-0.615

DATE: 9 JUN 77 TEST NUMBER: 1039
 PSD STUDY, SUBJECT: C-2, RUN: 1039, 751117, NYLON 11 POINT QUADRATIC FIT

HIP MOTION RELATIVE TO THE SLED

FRAME NO.	TIME (SEC)	DISPLACEMENT			VELOCITY		ACCELERATION	
		X (FEET)	Y (FEET)	Z (FEET)	RESULTANT (FT/SEC)	RESULTANT (FT/SEC SQ)	RESULTANT (G)	
115	23458	.059	.039	.071	-.802	-13.936	-.433	
116	23662	.056	.039	.068	-.804	-8.641	-.266	
117	23856	.053	.043	.067	-.795	-5.193	-.161	
118	24070	.050	.041	.065	-.773	-3.594	-.112	
119	24274	.048	.042	.064	-.761	-3.100	-.096	
120	24479	.046	.043	.063	-.772	-2.445	-.076	
121	24682	.043	.044	.061	-.790	-.745	-.023	
122	24895	.040	.044	.059	-.837	2.621	.081	
123	25090	.037	.045	.058	-.851	7.789	.242	
124	25294	.034	.045	.056	-.851	15.043	.467	
125	25498	.030	.045	.054	-.804	23.415	.727	
126	25702	.026	.044	.051	-.731	31.234	.970	
127	25905	.023	.043	.049	-.640	37.356	1.160	
128	26110	.021	.044	.048	-.537	40.379	1.254	
129	26314	.021	.044	.049	-.418	46.481	1.257	
130	26518	.020	.044	.048	-.311	38.433	1.194	
131	26722	.019	.043	.047	-.233	34.004	1.084	
132	26925	.020	.043	.047	-.180	30.483	.947	
133	27130	.019	.043	.047	-.141	26.031	.808	
134	27334	.020	.042	.046	-.103	22.368	.695	
135	27538	.019	.042	.045	-.061	20.038	.622	

MAXIMUM POSITIVE X DISPLACEMENT = .210 AT TIME 12851

MAXIMUM NEGATIVE X DISPLACEMENT = -.001 AT TIME 03672

MAXIMUM POSITIVE Z DISPLACEMENT = .045 AT TIME 25294

MAXIMUM NEGATIVE Z DISPLACEMENT = -.009 AT TIME 17543

MAXIMUM RESULTANT DISPLACEMENT = .210 AT TIME 12851

DATE: 9 JUN 72 TEST NUMBER: 1039 11 POINT QUADRATIC FIT
 ASD STUDY, SUBJECT: G-2, RUN: 1117, NYLON

KNEE MOTION RELATIVE TO THE SLED

FRAME NO.	TIME (SEC)	DISPLACEMENT		VELOCITY		ACCELERATION	
		X (FEET)	Z (FEET)	RESULTANT (FT/SEC)	RESULTANT (FT/SEC SO)	RESULTANT (G)	RESULTANT (G)
15	.33050	.006	.005	.008	.130	21.088	.655
16	.33254	.005	.004	.007	.037	28.307	.879
17	.33458	.006	.003	.006	.068	30.862	.958
18	.33672	.006	.002	.006	.151	28.949	.899
19	.33875	.008	.001	.008	.213	26.813	.746
20	.34030	.009	.001	.009	.266	18.240	.566
21	.34234	.009	.001	.009	.291	14.165	.440
22	.34488	.010	.002	.010	.277	12.735	.396
23	.34632	.010	.004	.010	.257	15.376	.478
24	.34835	.011	.004	.011	.254	21.858	.679
25	.35039	.011	.004	.011	.276	32.482	1.007
26	.35214	.010	.004	.010	.351	46.891	1.456
27	.35399	.010	.005	.010	.454	53.581	1.975
28	.35712	.011	.006	.012	.608	79.998	2.484
29	.35946	.013	.007	.014	.709	94.640	3.039
30	.36120	.014	.007	.016	1.027	106.551	3.309
31	.36324	.016	.009	.018	1.299	115.891	3.574
32	.36528	.018	.010	.021	1.576	120.304	3.736
33	.36731	.021	.011	.024	1.838	122.387	3.881
34	.36935	.025	.012	.028	2.094	122.526	3.805
35	.37139	.031	.012	.033	2.343	121.719	3.780
36	.37343	.037	.012	.038	2.583	121.972	3.788
37	.37547	.043	.011	.044	2.806	124.179	3.856
38	.37751	.050	.011	.050	3.033	128.486	3.990
39	.37955	.055	.010	.056	3.275	134.141	4.166
40	.38159	.061	.011	.062	3.549	139.755	4.340
41	.38363	.069	.012	.070	3.864	143.504	4.457
42	.38567	.076	.012	.077	4.192	144.129	4.476
43	.38771	.085	.014	.086	4.533	139.838	4.318
44	.38975	.095	.014	.096	4.870	126.916	3.941
45	.39179	.106	.014	.107	5.168	106.964	3.322
46	.39383	.118	.013	.119	5.400	79.678	2.474
47	.39587	.129	.012	.130	5.583	46.512	1.444
48	.39791	.141	.011	.142	5.659	8.855	.275
49	.39995	.154	.011	.154	5.642	-31.187	-1.969
50	.40199	.166	.010	.166	5.521	-71.503	-2.221
51	.40403	.177	.009	.178	5.313	-111.012	-3.448
52	.40607	.189	.008	.189	5.023	-148.279	-4.605
53	.40811	.200	.006	.200	4.660	-181.552	-5.638
54	.41015	.209	.004	.209	4.238	-210.315	-6.532
55	.41219	.217	.002	.217	3.762	-234.050	-7.269
56	.41423	.224	.000	.224	3.219	-253.012	-7.858
57	.41627	.230	.003	.230	2.652	-267.279	-8.301
58	.41831	.236	.005	.236	2.062	-276.587	-8.590
59	.42035	.240	.007	.240	1.468	-280.366	-8.707
60	.42239	.242	.008	.242	.877	-278.112	-8.637
61	.42443	.243	.009	.243	.283	-270.863	-8.442
62	.42647	.243	.007	.243	-.304	-259.737	-8.066
63	.42851	.241	.006	.241	-.857	-245.002	-7.609
64	.43055	.238	.005	.239	-1.350	-227.813	-7.075

DATE: 9 JUN 77 TEST NUMBER: 1039

RSO STUDY SUBJECT C-2, BUNIFIA, 76117, NYLON

11 POINT QUADRATIC FIT

KNEE MOTION RELATIVE TO THE SLED

FRAME NO.	TIME (SEC)	DISPLACEMENT Z			VELOCITY RESULTANT (FT/SEC)	ACCELERATION RESULTANT (FT/SEC ²)		ACCELERATION RESULTANT (G)
		X (FEET)	Y (FEET)	Z (FEET)		ACCELERATION RESULTANT (FT/SEC ²)	ACCELERATION RESULTANT (G)	
56	13239	.235	.005	.235	-4.775	-208.858	-6.486	
56	13454	.230	.005	.231	-2.181	-189.088	-5.872	
57	13637	.225	.005	.225	-2.545	-169.685	-5.270	
58	13871	.219	.006	.220	-2.855	-151.542	-4.706	
59	14075	.214	.007	.214	-3.139	-134.696	-4.183	
70	14279	.207	.007	.207	-3.387	-117.919	-3.662	
71	14483	.199	.006	.199	-3.614	-100.238	-3.113	
72	14637	.192	.003	.192	-3.813	-82.512	-2.562	
73	14811	.184	.001	.184	-3.985	-64.663	-2.008	
74	15035	.175	.002	.175	-4.114	-45.979	-1.428	
75	15239	.167	.004	.167	-4.178	-26.370	-.819	
76	15503	.157	.006	.157	-4.193	-5.130	-.159	
77	15737	.148	.004	.148	-4.187	17.785	.552	
78	15911	.139	.009	.139	-4.147	42.616	1.323	
79	16145	.131	.013	.131	-4.057	69.576	2.161	
80	16319	.123	.012	.123	-3.916	98.592	3.062	
81	16523	.114	.015	.115	-3.710	130.158	4.042	
82	16727	.105	.018	.107	-3.419	163.402	5.075	
83	16931	.097	.021	.100	-3.052	196.468	6.101	
84	17135	.089	.026	.093	-2.599	226.537	7.035	
85	17339	.082	.031	.087	-2.073	251.263	7.803	
86	17543	.075	.037	.084	-1.474	268.483	8.338	
87	17747	.068	.044	.081	-.840	276.352	8.582	
88	17951	.062	.051	.080	-.184	273.507	8.494	
89	18155	.056	.056	.081	.433	260.241	8.082	
90	18359	.050	.065	.083	1.002	237.996	7.391	
91	18553	.044	.074	.086	1.508	208.605	6.478	
92	18757	.036	.082	.090	1.914	174.618	5.423	
93	18971	.030	.093	.095	2.218	138.336	4.206	
94	19175	.024	.097	.100	2.438	102.502	3.183	
95	19379	.019	.104	.106	2.589	68.795	2.136	
96	19583	.016	.111	.111	2.575	38.684	1.201	
97	19786	.012	.117	.118	2.710	14.015	.435	
98	19990	.010	.123	.123	2.670	-5.054	-.157	
99	20134	.008	.128	.128	2.605	-18.798	-.584	
100	20398	.006	.134	.134	2.518	-27.152	-.863	
101	20602	.005	.139	.139	2.413	-38.480	-.947	
102	20806	.003	.144	.144	2.333	-29.412	-.913	
103	21010	.003	.149	.149	2.262	-25.154	-.781	
104	21214	.001	.153	.153	2.206	-19.233	-.597	
105	21418	.000	.157	.157	2.161	-13.173	-.409	
106	21622	-.001	.161	.161	2.175	-8.357	-.260	
107	21825	-.003	.165	.165	2.185	-5.840	-.181	
108	22030	-.006	.170	.170	2.201	-5.089	-.158	
109	22234	-.008	.174	.174	2.212	-5.807	-.180	
110	22438	-.010	.180	.180	2.204	-7.454	-.231	
111	22642	-.013	.184	.184	2.173	-9.077	-.282	
112	22845	-.016	.188	.188	2.126	-9.966	-.310	
113	23050	-.018	.192	.192	2.085	-9.559	-.297	
114	23234	-.020	.196	.197	2.035	-7.923	-.246	

KNEE MOTION RELATIVE TO THE SLED

FRAME NO.	TIME (SEC)	X (FEET)	Y (FEET)	Z (FEET)	DISPLACEMENT RESULTANT (FEET)	VELOCITY RESULTANT (FT/SEC)	ACCELERATION RESULTANT (FT/SEC SQ)	ACCELERATION RESULTANT (G)
115	.23433	-.022	.200	.204	.204	2.040	-5.447	-.168
116	.23652	-.024	.213	.204	.204	2.037	-3.055	-.095
117	.23856	-.026	.217	.209	.209	2.049	-1.938	-.060
118	.24070	-.028	.211	.213	.213	2.059	-2.183	-.068
119	.24274	-.030	.216	.218	.218	2.082	-3.835	-.119
120	.24478	-.032	.220	.222	.222	2.085	-6.592	-.205
121	.24682	-.036	.223	.226	.226	2.093	-10.203	-.317
122	.24885	-.038	.227	.230	.230	2.016	-14.485	-.450
123	.25089	-.040	.231	.235	.235	1.980	-18.789	-.584
124	.25293	-.042	.235	.239	.239	1.936	-22.479	-.698
125	.25497	-.045	.239	.243	.243	1.892	-25.844	-.803
126	.25701	-.047	.243	.246	.246	1.840	-28.936	-.899
127	.25905	-.048	.245	.250	.250	1.773	-32.524	-1.010
128	.26109	-.049	.249	.254	.254	1.705	-36.828	-1.144
129	.26313	-.051	.252	.257	.257	1.639	-41.726	-1.296
130	.26517	-.051	.255	.261	.261	1.552	-47.734	-1.482
131	.26721	-.052	.258	.264	.264	1.455	-54.746	-1.699
132	.26925	-.052	.261	.267	.267	1.334	-62.659	-1.946
133	.27129	-.052	.264	.269	.269	1.212	-71.514	-2.221
134	.27333	-.052	.267	.272	.272	1.059	-80.491	-2.500
135	.27537	-.051	.269	.274	.274	.889	-88.709	-2.755

MAXIMUM POSITIVE X DISPLACEMENT= .243 AT TIME .12647

MAXIMUM NEGATIVE X DISPLACEMENT= -.052 AT TIME .26926

MAXIMUM POSITIVE Z DISPLACEMENT= .275 AT TIME .28150

MAXIMUM NEGATIVE Z DISPLACEMENT= -.009 AT TIME .12443

MAXIMUM RESULTANT DISPLACEMENT= .279 AT TIME .28150

DATE: 9 JUN 77

TEST NUMBER: 1039

TEST SUBJECT: C-2, RUN 1039, 761117, NYLON

11 POINT QUADRATIC FIT

SHOULDER MOTION RELATIVE TO THE SLED

FRAME NO.	TIME (SEC)	DISPLACEMENT			VELOCITY			ACCELERATION		
		X (FEET)	Z (FEET)	RESULTANT (FEET)	X (FT/SEC)	Z (FT/SEC)	RESULTANT (FT/SEC SO)	X (FT/SEC SO)	Z (G)	RESULTANT (G)
15	.03030	-.002	-.002	.002	.056	.056	-4.115	-4.115	-.128	
16	.03254	-.002	-.003	.003	.044	.044	-9.131	-9.131	-.284	
17	.03468	-.001	-.002	.002	.024	.024	-10.770	-10.770	-.334	
18	.03672	-.001	-.002	.002	-.038	-.038	-9.515	-9.515	-.295	
19	.03876	-.000	-.002	.002	-.084	-.084	-6.202	-6.202	-.193	
20	.04080	-.000	-.002	.002	-.114	-.114	-2.008	-2.008	-.062	
21	.04284	-.000	-.002	.002	-.111	-.111	2.001	2.001	.090	
22	.04488	.001	-.001	.001	-.072	-.072	8.076	8.076	.276	
23	.04692	.000	.000	.000	-.034	-.034	15.937	15.937	.495	
24	.04896	.000	.000	.000	.005	.005	22.730	22.730	.706	
25	.05100	-.001	-.001	.001	.050	.050	30.126	30.126	.936	
26	.05304	-.001	-.001	.001	.099	.099	39.148	39.148	1.216	
27	.05508	-.001	-.001	.001	.169	.169	51.642	51.642	1.598	
28	.05712	-.002	-.002	.002	.267	.267	67.981	67.981	2.111	
29	.05916	-.001	-.002	.002	.378	.378	88.829	88.829	2.759	
30	.06120	.000	-.003	.003	.543	.543	113.012	113.012	3.510	
31	.06324	.004	-.003	.003	.778	.778	139.404	139.404	4.329	
32	.06528	.004	-.002	.005	1.099	1.099	155.775	155.775	5.148	
33	.06731	.007	-.003	.007	1.485	1.485	190.527	190.527	5.947	
34	.06935	.010	-.003	.010	1.944	1.944	212.168	212.168	6.589	
35	.07139	.014	-.003	.014	2.443	2.443	228.728	228.728	7.103	
36	.07343	.019	-.003	.020	2.975	2.975	239.342	239.342	7.433	
37	.07547	.026	-.003	.027	3.501	3.501	243.666	243.666	7.567	
38	.07751	.034	-.004	.034	4.024	4.024	242.515	242.515	7.532	
39	.07955	.043	-.004	.043	4.539	4.539	236.311	236.311	7.339	
40	.08159	.053	-.003	.053	5.032	5.032	226.357	226.357	7.030	
41	.08363	.064	-.002	.064	5.497	5.497	213.376	213.376	6.627	
42	.08567	.076	-.001	.076	5.924	5.924	198.278	198.278	6.158	
43	.08771	.089	-.001	.089	6.322	6.322	180.363	180.363	5.601	
44	.08975	.102	-.002	.102	6.677	6.677	159.615	159.615	4.957	
45	.09179	.116	-.003	.116	6.996	6.996	135.961	135.961	4.222	
46	.09383	.131	-.003	.131	7.272	7.272	109.871	109.871	3.412	
47	.09587	.146	-.005	.146	7.504	7.504	81.296	81.296	2.525	
48	.09791	.162	-.006	.162	7.652	7.652	49.575	49.575	1.540	
49	.09995	.178	-.006	.178	7.727	7.727	14.353	14.353	-.446	
50	.10199	.195	-.006	.195	7.720	7.720	-24.825	-24.825	-1.771	
51	.10403	.211	-.006	.211	7.656	7.656	-67.656	-67.656	-2.101	
52	.10607	.228	-.005	.228	7.510	7.510	-113.935	-113.935	-3.538	
53	.10811	.242	-.005	.243	7.260	7.260	-163.036	-163.036	-5.063	
54	.11015	.257	-.005	.257	6.892	6.892	-214.259	-214.259	-6.654	
55	.11219	.271	-.004	.271	6.403	6.403	-264.813	-264.813	-8.224	
56	.11423	.285	-.004	.285	5.801	5.801	-310.396	-310.396	-9.640	
57	.11627	.298	-.004	.298	5.076	5.076	-345.747	-345.747	-10.737	
58	.11831	.308	-.004	.308	4.232	4.232	-366.893	-366.893	-11.394	
59	.12035	.316	-.003	.316	3.305	3.305	-371.123	-371.123	-11.526	
60	.12239	.322	-.002	.322	2.375	2.375	-358.020	-358.020	-11.119	
61	.12443	.326	-.002	.326	1.536	1.536	-329.300	-329.300	-10.227	
62	.12647	.327	-.002	.327	.836	.836	-288.477	-288.477	-8.959	
63	.12851	.325	-.002	.325	.285	.285	-241.419	-241.419	-7.497	
64	.13055	.323	-.003	.323	-.101	-.101	-195.804	-195.804	-6.081	

SHOULDER MOTION RELATIVE TO THE SLED

FRAME NO.	TIME (SEC)	DISPLACEMENT (FEET)		VELOCITY RESULTANT (FT/SEC)	ACCELERATION RESULTANT (FT/SEC SQ)	ACCELERATION RESULTANT (G)
		X (FEET)	Z (FEET)			
55	13259	.322	.322	.354	-157.742	-4.899
56	13453	.322	.322	.516	-130.516	-4.053
57	13657	.321	.321	.584	-113.790	-3.524
58	13871	.320	.320	.772	-105.289	-3.270
59	14075	.319	.319	.993	-84.959	-3.465
60	14279	.318	.318	1.265	-99.498	-3.090
61	14483	.315	.315	1.549	-94.916	-2.948
62	14687	.311	.311	1.798	-86.535	-2.687
63	14891	.305	.306	1.994	-74.518	-2.344
64	15095	.299	.300	2.129	-60.900	-1.891
65	15299	.294	.295	2.191	-49.189	-1.525
66	15503	.289	.291	2.208	-41.307	-1.283
67	15707	.284	.287	2.215	-37.424	-1.162
68	15911	.280	.283	2.249	-35.844	-1.113
69	16115	.275	.279	2.336	-33.938	-1.054
70	16319	.270	.275	2.465	-26.625	-.889
71	16523	.264	.278	2.642	-17.184	-.534
72	16727	.258	.284	2.716	-1.184	.037
73	16931	.251	.296	2.754	26.068	.889
74	17135	.244	.291	2.695	54.801	1.702
75	17339	.238	.284	2.521	83.554	2.595
76	17543	.232	.278	2.250	108.599	3.373
77	17747	.224	.264	1.988	126.862	3.948
78	17951	.226	.251	1.574	136.337	4.296
79	18155	.225	.238	1.231	143.881	4.468
80	18359	.224	.227	.923	145.256	4.511
81	18563	.224	.226	.653	144.649	4.492
82	18767	.224	.225	.417	143.961	4.471
83	18971	.224	.224	.159	143.442	4.454
84	19175	.223	.223	.132	142.569	4.428
85	19379	.223	.223	.451	139.782	4.389
86	19583	.223	.224	.783	132.401	4.112
87	19787	.224	.225	1.115	118.392	3.677
88	19991	.227	.229	1.410	97.058	3.014
89	20195	.229	.234	1.538	70.215	2.481
90	20399	.232	.238	1.778	40.516	1.258
91	20603	.234	.242	1.841	10.234	.318
92	20807	.235	.246	1.732	-18.378	-.571
93	21011	.236	.250	1.597	-43.083	-1.338
94	21215	.237	.253	1.444	-62.668	-1.946
95	21419	.237	.256	1.287	-76.848	-2.488
96	21623	.236	.258	1.109	-86.867	-2.898
97	21827	.234	.259	.917	-94.892	-2.947
98	22031	.237	.262	.721	-102.844	-3.194
99	22235	.238	.264	.519	-109.915	-3.414
100	22439	.238	.265	.307	-114.866	-3.567
101	22643	.236	.263	.083	-117.083	-3.636
102	22847	.234	.265	-.232	-115.903	-3.599
103	23051	.231	.264	-.542	-110.564	-3.434
104	23255	.228	.263	-.796	-100.881	-3.133

DATE: 9 JUN 77

TEST NUMBER: 1039

RSO STUDY, SUBJECT C-2, PUNIC19, 76411Z, NYLON

11 POINT QUADRATIC FIT

SHOULDER MOTION RELATIVE TO THE SLED

FRAME NO.	TIME (SSC)	DISPLACEMENT			VELOCITY		ACCELERATION	
		X (FEET)	Z (FEET)	7 (FEET)	RESULTANT (FT/SEC)	RESULTANT (FT/SEC SQ)	RESULTANT (G)	RESULTANT
115	23458	.224	.134	.261	-.996	-87.184	-2.708	
116	23652	.220	.135	.258	-1.173	-70.481	-2.189	
117	23855	.215	.135	.254	-1.298	-53.292	-1.655	
118	24070	.212	.134	.251	-1.363	-38.769	-1.204	
119	24274	.200	.135	.249	-1.389	-28.271	-.878	
120	24478	.206	.135	.246	-1.387	-20.996	-.652	
121	24682	.202	.134	.242	-1.390	-16.886	-.524	
122	24896	.199	.134	.240	-1.403	-16.993	-.528	
123	25030	.196	.135	.238	-1.462	-24.223	-.628	
124	25234	.193	.134	.235	-1.516	-24.512	-.761	
125	25438	.190	.134	.233	-1.564	-28.718	-.892	
126	25702	.187	.131	.228	-1.604	-31.755	-.986	
127	25906	.184	.128	.224	-1.703	-33.273	-1.033	
128	26110	.181	.126	.221	-1.799	-33.678	-1.046	
129	26314	.179	.124	.218	-1.868	-33.409	-1.028	
130	26518	.177	.122	.215	-1.934	-30.796	-.956	
131	26722	.173	.119	.210	-1.993	-25.918	-.805	
132	26926	.169	.117	.206	-2.054	-19.394	-.602	
133	27130	.165	.115	.201	-2.112	-12.980	-.403	
134	27334	.161	.113	.197	-2.139	-7.497	-.233	
135	27538	.156	.112	.192	-2.132	-2.926	-.091	

MAXIMUM POSITIVE X DISPLACEMENT = .327 AT TIME .12647

MAXIMUM NEGATIVE X DISPLACEMENT = -.042 AT TIME .03254

MAXIMUM POSITIVE Z DISPLACEMENT = .135 AT TIME .23662

MAXIMUM NEGATIVE Z DISPLACEMENT = -.057 AT TIME .17435

MAXIMUM RESULTANT DISPLACEMENT = .327 AT TIME .12647

DATE: 9 JUN 77

TEST NUMBER: 1039

TEST SUBJECT: C-2, SERIAL 19, 24117, NYLON

11 POINT QUADRATIC FIT

ELBOW MOTION RELATIVE TO THE SLED

FRAME NO.	TIME (SEC)	DISPLACEMENT (FEET)		VELOCITY RESULTANT (FT/SEC)	ACCELERATION RESULTANT (FT/SEC ²)	ACCELERATION RESULTANT (G)
		X	Z			
15	0.0000	0.00	0.00	0.00	0.00	0.00
16	0.0000	0.00	0.00	0.00	0.00	0.00
17	0.0000	0.00	0.00	0.00	0.00	0.00
18	0.0000	0.00	0.00	0.00	0.00	0.00
19	0.0000	0.00	0.00	0.00	0.00	0.00
20	0.0000	0.00	0.00	0.00	0.00	0.00
21	0.0000	0.00	0.00	0.00	0.00	0.00
22	0.0000	0.00	0.00	0.00	0.00	0.00
23	0.0000	0.00	0.00	0.00	0.00	0.00
24	0.0000	0.00	0.00	0.00	0.00	0.00
25	0.0000	0.00	0.00	0.00	0.00	0.00
26	0.0000	0.00	0.00	0.00	0.00	0.00
27	0.0000	0.00	0.00	0.00	0.00	0.00
28	0.0000	0.00	0.00	0.00	0.00	0.00
29	0.0000	0.00	0.00	0.00	0.00	0.00
30	0.0000	0.00	0.00	0.00	0.00	0.00
31	0.0000	0.00	0.00	0.00	0.00	0.00
32	0.0000	0.00	0.00	0.00	0.00	0.00
33	0.0000	0.00	0.00	0.00	0.00	0.00
34	0.0000	0.00	0.00	0.00	0.00	0.00
35	0.0000	0.00	0.00	0.00	0.00	0.00
36	0.0000	0.00	0.00	0.00	0.00	0.00
37	0.0000	0.00	0.00	0.00	0.00	0.00
38	0.0000	0.00	0.00	0.00	0.00	0.00
39	0.0000	0.00	0.00	0.00	0.00	0.00
40	0.0000	0.00	0.00	0.00	0.00	0.00
41	0.0000	0.00	0.00	0.00	0.00	0.00
42	0.0000	0.00	0.00	0.00	0.00	0.00
43	0.0000	0.00	0.00	0.00	0.00	0.00
44	0.0000	0.00	0.00	0.00	0.00	0.00
45	0.0000	0.00	0.00	0.00	0.00	0.00
46	0.0000	0.00	0.00	0.00	0.00	0.00
47	0.0000	0.00	0.00	0.00	0.00	0.00
48	0.0000	0.00	0.00	0.00	0.00	0.00
49	0.0000	0.00	0.00	0.00	0.00	0.00
50	0.0000	0.00	0.00	0.00	0.00	0.00
51	0.0000	0.00	0.00	0.00	0.00	0.00
52	0.0000	0.00	0.00	0.00	0.00	0.00
53	0.0000	0.00	0.00	0.00	0.00	0.00
54	0.0000	0.00	0.00	0.00	0.00	0.00
55	0.0000	0.00	0.00	0.00	0.00	0.00
56	0.0000	0.00	0.00	0.00	0.00	0.00
57	0.0000	0.00	0.00	0.00	0.00	0.00
58	0.0000	0.00	0.00	0.00	0.00	0.00
59	0.0000	0.00	0.00	0.00	0.00	0.00
60	0.0000	0.00	0.00	0.00	0.00	0.00
61	0.0000	0.00	0.00	0.00	0.00	0.00
62	0.0000	0.00	0.00	0.00	0.00	0.00
63	0.0000	0.00	0.00	0.00	0.00	0.00
64	0.0000	0.00	0.00	0.00	0.00	0.00

ELBOW MOTION RELATIVE TO THE SLED

FRAME NO.	TIME (SEC)	X (FEET)	Z (FEET)	DISPLACEMENT RESULTANT (FEET)	VELOCITY RESULTANT (FT/SEC)	ACCELERATION RESULTANT (FT/SEC SQ)	ACCELERATION RESULTANT (G)
62	13233	.524	.856	.587	12.548	3.622	.112
66	13453	.610	.056	.613	12.630	-19.692	-6.612
67	13657	.636	.077	.640	12.574	-50.292	-1.562
68	13871	.661	.049	.667	12.466	-85.636	-2.660
69	14075	.686	.031	.694	12.246	-123.140	-3.824
70	14279	.709	.116	.719	11.927	-159.528	-4.954
71	14433	.731	.131	.743	11.512	-193.236	-6.001
72	14637	.751	.148	.766	11.036	-224.273	-6.965
73	14831	.770	.164	.788	10.529	-253.476	-7.872
74	15035	.789	.182	.808	9.989	-281.772	-8.751
75	15239	.804	.200	.828	9.423	-310.435	-9.641
76	15513	.819	.217	.848	8.830	-339.601	-10.547
77	15717	.833	.234	.865	8.108	-368.507	-11.444
78	15911	.845	.252	.882	7.323	-394.888	-12.264
79	16115	.856	.268	.897	6.443	-416.008	-12.920
80	16319	.864	.284	.910	5.485	-429.308	-13.333
81	16523	.870	.298	.920	4.494	-432.686	-13.735
82	16727	.875	.311	.929	3.517	-425.520	-13.215
83	16931	.877	.321	.934	2.602	-408.826	-12.696
84	17135	.877	.330	.937	1.759	-385.009	-11.957
85	17339	.875	.340	.939	1.005	-357.499	-11.102
86	17543	.872	.347	.939	.336	-329.216	-10.224
87	17747	.869	.354	.938	-.267	-302.835	-9.405
88	17951	.866	.361	.938	-.819	-278.902	-8.662
89	18155	.862	.366	.936	-1.343	-256.870	-7.977
90	18359	.857	.370	.934	-1.855	-235.624	-7.318
91	18563	.851	.373	.929	-2.330	-213.666	-6.636
92	18767	.844	.375	.924	-2.789	-189.684	-5.891
93	18971	.836	.374	.916	-3.183	-163.730	-5.085
94	19175	.828	.375	.909	-3.510	-136.728	-4.246
95	19379	.819	.375	.901	-3.757	-110.218	-3.423
96	19583	.810	.375	.893	-3.923	-86.163	-2.676
97	19786	.801	.376	.884	-4.016	-65.617	-2.038
98	19990	.792	.376	.876	-4.073	-49.752	-1.545
99	20194	.782	.375	.867	-4.124	-38.136	-1.184
100	20398	.773	.374	.859	-4.180	-29.757	-.924
101	20602	.765	.373	.851	-4.243	-23.591	-.720
102	20806	.756	.371	.842	-4.307	-16.243	-.504
103	21010	.747	.369	.833	-4.363	-8.753	-.210
104	21214	.738	.367	.825	-4.395	6.060	.188
105	21418	.728	.366	.815	-4.300	22.345	.694
106	21622	.719	.364	.806	-4.351	41.291	1.282
107	21826	.708	.363	.796	-4.254	61.546	1.911
108	22030	.699	.362	.787	-4.094	81.494	2.531
109	22234	.689	.351	.778	-3.691	99.874	3.102
110	22438	.682	.361	.771	-3.638	115.708	3.593
111	22642	.673	.361	.764	-3.355	128.206	3.982
112	22846	.666	.361	.757	-3.056	136.388	4.236
113	23050	.658	.363	.751	-2.755	140.616	4.367
114	23254	.650	.365	.746	-2.448	141.088	4.382

DATE: 9 JUN 77 TEST NUMBER: 1099
 RSD STUDY, SUBJECT C-2, RUN#039, 764447, NYLON 11 POINT QUADRATIC FIT

FLODM MOTION RELATIVE TO THE SLED

FRAME NO.	TIME (SEC)	DISPLACEMENT		VELOCITY		ACCELERATION	
		X (FEET)	Z (FEET)	RESULTANT (FT/SEC)	RESULTANT (FT/SEC SQ)	RESULTANT (G)	RESULTANT
115	23458	644	367	741	2.141	137.829	4.280
116	23652	639	368	737	-1.846	131.894	4.096
117	23846	634	370	734	-1.578	124.814	3.851
118	24070	629	372	731	-1.317	114.974	3.571
119	24274	626	373	729	-1.090	105.419	3.274
120	24478	624	375	728	-0.899	95.998	2.981
121	24682	620	376	725	-0.725	87.133	2.706
122	24886	618	378	724	-0.569	78.204	2.429
123	25090	615	381	724	-0.424	68.750	2.135
124	25294	613	383	723	-0.282	59.007	1.833
125	25498	610	386	722	-0.149	48.545	1.508
126	25702	609	388	722	-0.032	37.617	1.168
127	25906	607	391	722	0.032	26.904	0.836
128	26110	606	394	723	0.062	17.203	0.534
129	26314	605	397	724	0.065	9.113	0.283
130	26518	605	399	724	0.036	3.098	0.096
131	26722	604	399	724	-0.012	-0.57	-0.27
132	26926	603	400	724	-0.005	-3.271	-0.102
133	27130	602	401	723	-0.03	-5.593	-0.174
134	27334	601	401	722	0.008	-9.365	-0.291
135	27538	599	403	722	0.017	-16.962	-0.499

MAXIMUM POSITIVE X DISPLACEMENT= .877 AT TIME 16931
 MAXIMUM NEGATIVE X DISPLACEMENT= .002 AT TIME 02244
 MAXIMUM POSITIVE Z DISPLACEMENT= .411 AT TIME 28559
 MAXIMUM NEGATIVE Z DISPLACEMENT= -.002 AT TIME 09791
 MAXIMUM RESULTANT DISPLACEMENT= .939 AT TIME 17747

DATE: 9 JUN 77

TEST NUMBER: 1039

RSD STUDY, SUBJECT C-2, RUN 1013, 761117, NYLON

11 POINT QUADRATIC FIT

HEAD PT. 1 MOTION RELATIVE TO THE SLED

FRAME NO.	TIME (SEC)	DISPLACEMENT		VELOCITY		ACCELERATION	
		X (FEET)	Z (FEET)	RESULTANT (FEET)	RESULTANT (FT/SEC)	RESULTANT (FT/SEC SQ)	RESULTANT (G)
15	.03090	.005	-.001	.005	-.027	-.409	-.546
16	.03264	-.008	-.001	.008	-.040	-17.596	-.501
17	.03438	.008	-.002	.008	-.110	-16.123	-.266
18	.03612	-.006	-.002	.007	-.194	-8.553	-.077
19	.03786	.004	-.003	.005	-.246	13.525	.420
20	.04090	-.002	-.003	.004	-.259	22.749	.884
21	.04234	.001	-.003	.003	-.203	28.365	.881
22	.04638	-.001	-.002	.002	-.060	21.059	.301
23	.04842	-.001	-.002	.002	-.094	-6.884	-.214
24	.04896	-.001	-.003	.003	.205	-1.951	-.016
25	.05130	-.003	-.002	.004	.275	19.894	-.618
26	.05314	-.006	-.001	.006	.128	53.184	2.995
27	.05538	-.007	-.001	.007	.248	148.191	4.602
28	.05712	-.007	-.001	.008	.128	203.121	6.314
29	.05916	-.007	-.001	.007	.126	253.032	7.858
30	.06120	-.006	-.001	.006	-.138	289.413	8.988
31	.06324	-.007	-.001	.007	-.112	310.727	9.650
32	.06528	-.006	-.001	.006	.151	315.880	9.810
33	.06731	-.003	-.002	.003	.558	309.415	9.609
34	.06935	-.001	-.001	.001	1.126	293.680	8.120
35	.07139	.003	-.003	.004	4.778	272.927	8.476
36	.07343	.008	-.004	.009	5.265	249.993	7.764
37	.07547	.016	-.005	.017	5.759	227.216	7.056
38	.07751	.024	-.006	.025	6.183	209.293	6.500
39	.07955	.035	-.006	.035	6.605	197.013	6.118
40	.08159	.045	-.007	.045	4.067	188.244	5.846
41	.08363	.056	-.006	.056	4.732	180.634	5.610
42	.08567	.069	-.006	.070	8.098	172.674	5.363
43	.08771	.082	-.006	.082	8.476	161.165	5.005
44	.08975	.095	-.007	.095	8.826	143.539	4.458
45	.09179	.110	-.009	.111	7.372	116.711	3.625
46	.09383	.126	-.010	.127	7.741	78.612	2.441
47	.09587	.142	-.012	.143	8.098	28.897	.897
48	.09791	.159	-.014	.160	9.137	-31.563	-.980
49	.09995	.176	-.015	.177	9.703	-99.233	-3.082
50	.10199	.194	-.015	.195	9.445	-169.726	-5.271
51	.10403	.214	-.016	.214	8.974	-236.021	-7.330
52	.10607	.234	-.018	.235	8.330	-249.670	-8.996
53	.10811	.254	-.021	.255	6.648	-325.095	-10.096
54	.11015	.275	-.023	.276	5.736	-329.459	-10.232
55	.11219	.296	-.022	.297	4.933	-301.676	-9.369
56	.11423	.317	-.024	.318	4.307	-261.063	-8.108
57	.11627	.336	-.027	.337	3.832	-214.897	-6.674
58	.11831	.353	-.030	.355	3.532	-171.199	-5.317
59	.12035	.368	-.032	.369			
60	.12239	.380	-.034	.381			
61	.12443	.389	-.040	.391			
62	.12647	.397	-.044	.400			
63	.12851	.402	-.051	.406			
64	.13055	.407	-.056	.411			

TABLE NO. 3 MOTION RELATIVE TO THE SLED

FRAME NO.	TIME (SEC)	X (FEET)	DISPLACEMENT (FEET)	VELOCITY RESULTANT (FT/SEC)	ACCELERATION RESULTANT (FT/SEC SQ)	ACCELERATION RESULTANT (G)
64	13230	412	-0.51	3.348	-137.442	-4.259
65	13633	418	-0.59	3.238	-115.890	-3.599
66	13633	420	-0.67	3.133	-105.565	-3.278
67	13871	430	-0.85	2.992	-101.818	-3.162
68	14023	436	-0.92	2.762	-100.242	-3.112
69	14273	441	-1.00	2.444	-95.678	-2.971
70	14433	444	-1.09	2.123	-85.413	-2.653
71	14637	445	-1.16	1.873	-57.850	-2.107
72	14831	445	-1.24	1.717	-44.863	-1.393
73	15035	444	-1.33	1.574	-44.863	-1.393
74	15239	444	-1.43	1.433	-20.569	-0.639
75	15443	444	-1.53	1.300	-3.339	-0.111
76	15647	446	-1.67	1.182	10.937	0.340
77	15851	451	-1.80	1.082	12.821	0.376
78	16055	456	-1.96	1.000	5.193	0.161
79	16259	459	-2.13	0.933	-6.219	-0.193
80	16463	459	-2.31	0.880	-17.425	-0.541
81	16667	461	-2.48	0.846	-24.442	-0.759
82	16871	465	-2.67	0.827	-24.628	-0.765
83	17075	467	-2.87	0.820	-16.580	-0.515
84	17279	467	-3.07	0.820	-2.108	-0.065
85	17483	469	-3.28	0.827	14.175	0.440
86	17687	472	-3.49	0.842	27.123	0.842
87	17891	476	-3.71	0.858	33.459	1.039
88	18095	481	-3.94	0.874	31.478	0.978
89	18299	488	-4.18	0.882	21.921	0.681
90	18503	494	-4.42	0.866	7.701	0.239
91	18707	494	-4.67	0.831	-7.790	-0.242
92	18911	507	-4.92	0.777	-21.176	-0.658
93	19115	512	-5.17	0.704	-29.561	-0.918
94	19319	518	-5.42	0.618	-32.146	-0.998
95	19523	522	-5.67	0.518	-30.864	-0.934
96	19727	526	-5.92	0.418	-26.988	-0.838
97	19931	531	-6.17	0.318	-26.362	-0.819
98	20135	536	-6.42	0.218	-30.101	-0.935
99	20339	541	-6.67	0.118	-39.769	-1.235
100	20543	546	-6.92	0.018	-54.443	-1.691
101	20747	551	-7.17	0.000	-72.108	-2.239
102	20951	557	-7.42	0.000	-89.571	-2.782
103	21155	561	-7.67	0.000	-103.348	-3.210
104	21359	565	-7.92	0.000	-111.077	-3.450
105	21563	566	-8.17	0.000	-112.624	-3.498
106	21767	567	-8.42	0.000	-109.219	-3.392
107	21971	568	-8.67	0.000	-102.560	-3.185
108	22175	568	-8.92	0.000	-94.267	-2.928
109	22379	567	-9.17	0.000	-87.212	-2.708
110	22583	568	-9.42	0.000	-82.845	-2.573
111	22787	567	-9.67	0.000	-81.008	-2.516
112	22991	568	-9.92	0.000	-81.627	-2.535
113	23195	567	-10.17	0.000	-82.862	-2.573
114	23399	565	-10.42	0.000	-83.046	-2.579

DATE: 9 JUN 77

TEST NUMBER: 1039

RD. STUDY, SUBJECT: C. 2. RUNIC19, 764117, NYLON

11 POINT QUADRATIC FIT

HEAD PT. 1 MOTION RELATIVE TO THE SLED

FRAME NO.	TIME (SEC)	X (FEET)	DISPLACEMENT Z (FEET)	VELOCITY RESULTANT (FT/SEC)	ACCELERATION RESULTANT (FT/SEC SQ)	ACCELERATION RESULTANT (G)
115	23438	.582	-.050	-1.310	-82.157	-2.551
116	23652	.559	-.079	-1.492	-80.630	-2.504
117	23856	.557	-.076	-1.657	-78.566	-2.440
118	24070	.553	-.075	-1.792	-75.429	-2.343
119	24274	.549	-.073	-1.912	-71.008	-2.285
120	24473	.545	-.072	-2.058	-66.095	-2.051
121	24632	.542	-.071	-2.218	-60.449	-1.877
122	24836	.538	-.069	-2.357	-54.625	-1.696
123	25090	.533	-.066	-2.472	-48.694	-1.512
124	25294	.528	-.064	-2.571	-43.193	-1.341
125	25498	.524	-.061	-2.635	-38.992	-1.211
126	25732	.516	-.050	-2.671	-37.277	-1.158
127	25906	.511	-.057	-2.715	-37.666	-1.178
128	26110	.505	-.056	-2.757	-36.884	-1.208
129	26314	.500	-.053	-2.835	-39.374	-1.223
130	26518	.496	-.052	-2.957	-39.066	-1.182
131	26722	.491	-.052	-3.102	-32.885	-1.031
132	26926	.484	-.050	-3.214	-23.197	-.720
133	27130	.476	-.049	-3.283	-11.099	-.364
134	27334	.469	-.048	-3.298	1.538	.048
135	27538	.460	-.044	-3.265	11.955	.371

MAXIMUM POSITIVE X DISPLACEMENT= .568 AT TIME .21826

MAXIMUM NEGATIVE X DISPLACEMENT= -.008 AT TIME .03264

MAXIMUM POSITIVE Z DISPLACEMENT= .002 AT TIME .02244

MAXIMUM NEGATIVE Z DISPLACEMENT= -.188 AT TIME .17339

MAXIMUM RESULTANT DISPLACEMENT= .579 AT TIME .21826

DATE: 9 JUN 77 TEST NUMBER: 1029

RSD STUDY SUBJECT: C-2, RUN# 13, 76117, NYLON 11 POINT QUADRATIC FIT

HEAD PM. 2 MOTION RELATIVE TO THE SLED

FRAME NO.	TIME (SEC)	X (FEET)	Z (FEET)	DISPLACEMENT RESULTANT (FEET)	VELOCITY RESULTANT (FT/SEC)	ACCELERATION RESULTANT (FT/SEC SQ)	ACCELERATION RESULTANT (G)
15	03652	-0.32	0.15	0.35	0.42	-61.569	-2.884
16	03254	-0.30	0.14	0.33	-0.30	-29.260	-1.312
17	03454	-0.29	0.14	0.32	-0.195	-1.757	-0.055
18	03572	-0.29	0.13	0.31	0.082	17.246	0.794
19	03875	-0.29	0.13	0.31	0.167	23.648	1.133
20	04030	-0.29	0.13	0.31	0.359	14.279	0.643
21	04234	-0.30	0.13	0.32	0.376	-14.158	-0.640
22	04438	-0.31	0.14	0.34	0.341	-42.291	-1.917
23	04632	-0.32	0.15	0.36	0.169	-56.170	-2.607
24	04835	-0.33	0.15	0.37	-0.055	-89.934	-4.143
25	05039	-0.34	0.15	0.38	-0.331	-93.935	-4.446
26	05234	-0.34	0.15	0.38	-0.331	-75.189	-3.381
27	05438	-0.35	0.15	0.38	-0.110	-35.829	-1.607
28	05712	-0.34	0.15	0.37	-1.442	25.972	1.133
29	05915	-0.34	0.15	0.37	-1.579	18.862	0.807
30	06120	-0.33	0.15	0.36	-1.393	20.648	0.913
31	06324	-0.33	0.14	0.36	-0.834	30.946	1.413
32	06529	-0.33	0.14	0.36	0.052	4.07000	0.170
33	06731	-0.32	0.14	0.34	1.198	4.85496	0.217
34	06935	-0.30	0.12	0.32	2.529	5.31603	0.246
35	07139	-0.27	0.11	0.29	3.926	5.286	0.235
36	07343	-0.22	0.10	0.25	5.286	4.87705	0.214
37	07547	-0.17	0.09	0.19	6.494	4.40468	0.190
38	07751	-0.11	0.07	0.13	7.480	3.91865	0.170
39	07955	-0.03	0.07	0.07	8.473	3.48878	0.153
40	08159	0.107	0.07	0.10	9.487	3.15574	0.140
41	08363	0.149	0.07	0.20	9.748	2.92683	0.130
42	08567	0.33	0.06	0.34	10.457	2.67734	0.120
43	08771	0.48	0.06	0.49	10.981	2.60219	0.115
44	08975	0.64	0.06	0.65	11.592	2.32658	0.105
45	09179	0.81	0.05	0.81	12.163	1.88147	0.085
46	09383	0.98	0.03	0.98	12.646	1.27941	0.065
47	09587	1.16	0.00	1.16	12.980	1.172	0.055
48	09791	1.34	-0.04	1.34	13.089	0.990	0.045
49	09995	1.54	-0.07	1.54	12.895	0.800	0.035
50	10199	1.75	-0.10	1.75	12.695	0.610	0.025
51	10403	1.97	-0.13	1.98	12.475	0.420	0.015
52	10607	2.24	-0.16	2.25	11.894	0.230	0.005
53	10811	2.49	-0.19	2.50	11.433	0.040	0.000
54	11015	2.77	-0.20	2.78	10.888	-0.150	-0.005
55	11219	3.04	-0.20	3.05	10.268	-0.340	-0.015
56	11423	3.32	-0.24	3.33	9.541	-0.530	-0.025
57	11627	3.59	-0.27	3.60	8.715	-0.720	-0.035
58	11831	3.87	-0.30	3.88	7.788	-0.910	-0.045
59	12035	4.12	-0.33	4.14	6.761	-1.100	-0.055
60	12239	4.32	-0.46	4.35	5.634	-1.290	-0.065
61	12443	4.51	-0.56	4.54	4.407	-1.480	-0.075
62	12647	4.67	-0.67	4.72	3.080	-1.670	-0.085
63	12851	4.80	-0.82	4.87	1.753	-1.860	-0.095
64	13055	4.91	-0.97	5.04	0.426	-2.050	-0.105

DATE: 9 JUN 77

TEST NUMBER: 1033

RSD STUDY, SUBJECT C-2, RUN 139, 761117, NYLON

11 POINT QUADRATIC FIT

HEAD PT. 2 RELATIVE TO THE SLED

FRAME NO.	TIME (SEC)	DISPLACEMENT			VELOCITY RESULTANT (FT/SEC)	ACCELERATION RESULTANT (FT/SEC SO)	ACCELERATION RESULTANT (G)
		X (FEET)	Y (FEET)	Z (FEET)			
55	13233	509	-114	521	10.171	340.843	4.368
56	13453	526	-134	543	10.744	169.821	5.274
57	13637	545	-154	567	11.381	168.549	5.234
58	13871	568	-171	593	11.956	138.347	4.296
59	14075	587	-202	621	12.317	88.326	2.743
70	14279	603	-232	646	12.444	30.041	0.933
71	14433	619	-263	672	12.344	-27.118	-0.842
72	14637	635	-293	699	12.046	-76.164	-2.965
73	14841	648	-324	724	11.615	-112.669	-3.499
74	15035	658	-353	747	11.242	-137.034	-4.256
75	15233	668	-381	768	10.938	-154.654	-4.800
76	15533	678	-406	790	10.670	-171.809	-5.336
77	15737	688	-427	810	10.446	-194.255	-6.033
78	15911	697	-447	828	10.184	-226.650	-7.039
79	16115	703	-481	852	9.799	-270.946	-8.414
80	16319	710	-508	873	9.243	-320.570	-9.956
81	16523	718	-534	895	8.488	-367.530	-11.414
82	16737	726	-558	915	7.583	-404.045	-12.548
83	16941	727	-579	930	6.541	-421.920	-13.103
84	17135	727	-596	940	5.424	-418.328	-12.992
85	17319	726	-610	948	4.394	-394.625	-12.255
86	17513	726	-619	954	3.508	-355.213	-11.031
87	17717	726	-625	958	2.814	-306.670	-9.530
88	17921	727	-630	962	2.348	-255.345	-7.930
89	18125	727	-632	967	2.005	-206.857	-6.424
90	18329	736	-632	970	1.734	-166.884	-5.183
91	18533	744	-630	975	1.494	-137.219	-4.261
92	18737	749	-628	978	1.251	-116.947	-3.632
93	18941	755	-625	980	1.033	-103.636	-3.219
94	19175	761	-620	982	0.836	-94.685	-2.941
95	19379	766	-615	983	0.653	-89.784	-2.788
96	19593	772	-608	982	0.472	-89.380	-2.776
97	19735	778	-600	983	0.29	-94.405	-2.932
98	19930	785	-594	985	0.214	-104.572	-3.248
99	20134	792	-587	986	0.058	-117.941	-3.663
100	20338	799	-577	985	-0.171	-132.966	-4.129
101	20632	806	-567	985	-0.482	-148.805	-4.615
102	20875	811	-559	985	-0.881	-162.853	-5.058
103	21040	816	-550	984	-1.295	-172.092	-5.344
104	21214	819	-539	981	-1.686	-173.720	-5.395
105	21413	821	-528	976	-2.067	-167.858	-5.213
106	21622	821	-515	970	-2.456	-155.586	-4.832
107	21826	822	-503	963	-2.739	-139.386	-4.329
108	22030	822	-493	959	-3.056	-122.659	-3.809
109	22234	822	-481	953	-3.254	-106.777	-3.316
110	22438	822	-467	945	-3.425	-91.705	-2.848
111	22642	820	-454	937	-3.559	-79.474	-2.468
112	22845	817	-443	930	-3.686	-71.910	-2.233
113	23030	816	-432	923	-3.825	-68.343	-2.122
114	23224	812	-419	914	-3.955	-66.521	-2.066

DATE 9 JUN 77 TEST NUMBER 1039 11 POINT QUADRATIC FIT
 PSD STUDY, SUBJECT C 2, RUN#039, 76447, NYLON

HEAD PT. 2 ON RELATIVE TO THE SLED

FRAME NO.	TIME (SEC)	X (FEET)	Z (FEET)	DISPLACEMENT RESULTANT (FEET)	VELOCITY RESULTANT (FT/SEC)	ACCELERATION RESULTANT (FT/SEC SQ)	ACCELERATION RESULTANT (G)
115	23.453	8.09	4.06	9.06	4.035	65.296	-2.028
116	23.652	8.06	4.396	8.98	4.198	62.992	-1.956
117	23.856	8.04	4.387	8.90	4.367	58.279	-1.810
118	24.070	7.95	4.379	8.81	4.517	49.322	-1.532
119	24.224	7.84	4.370	8.71	4.630	35.453	-1.194
120	24.473	7.81	4.363	8.62	4.734	16.505	-0.513
121	24.642	7.72	4.357	8.51	4.777	6.544	-0.206
122	24.895	7.63	4.351	8.40	4.779	30.165	.937
123	25.090	7.55	4.346	8.31	4.679	49.883	1.952
124	25.234	7.47	4.340	8.20	4.490	63.385	1.968
125	25.499	7.39	4.334	8.11	4.248	68.152	2.117
126	25.772	7.32	4.331	8.03	3.989	63.344	1.967
127	25.935	7.23	4.328	7.94	3.787	50.262	1.561
128	26.110	7.18	4.324	7.87	3.669	30.516	.948
129	26.244	7.13	4.320	7.82	3.636	8.952	.278
130	26.513	7.10	4.316	7.77	3.712	-10.324	-.321
131	26.722	7.02	4.312	7.69	3.833	-22.944	-.713
132	26.926	6.95	4.310	7.61	3.973	-28.485	-.885
133	27.130	6.86	4.307	7.52	4.109	-28.448	-.883
134	27.334	6.78	4.302	7.42	4.176	-25.637	-.796
135	27.538	6.68	4.298	7.32	4.199	-22.713	-.705

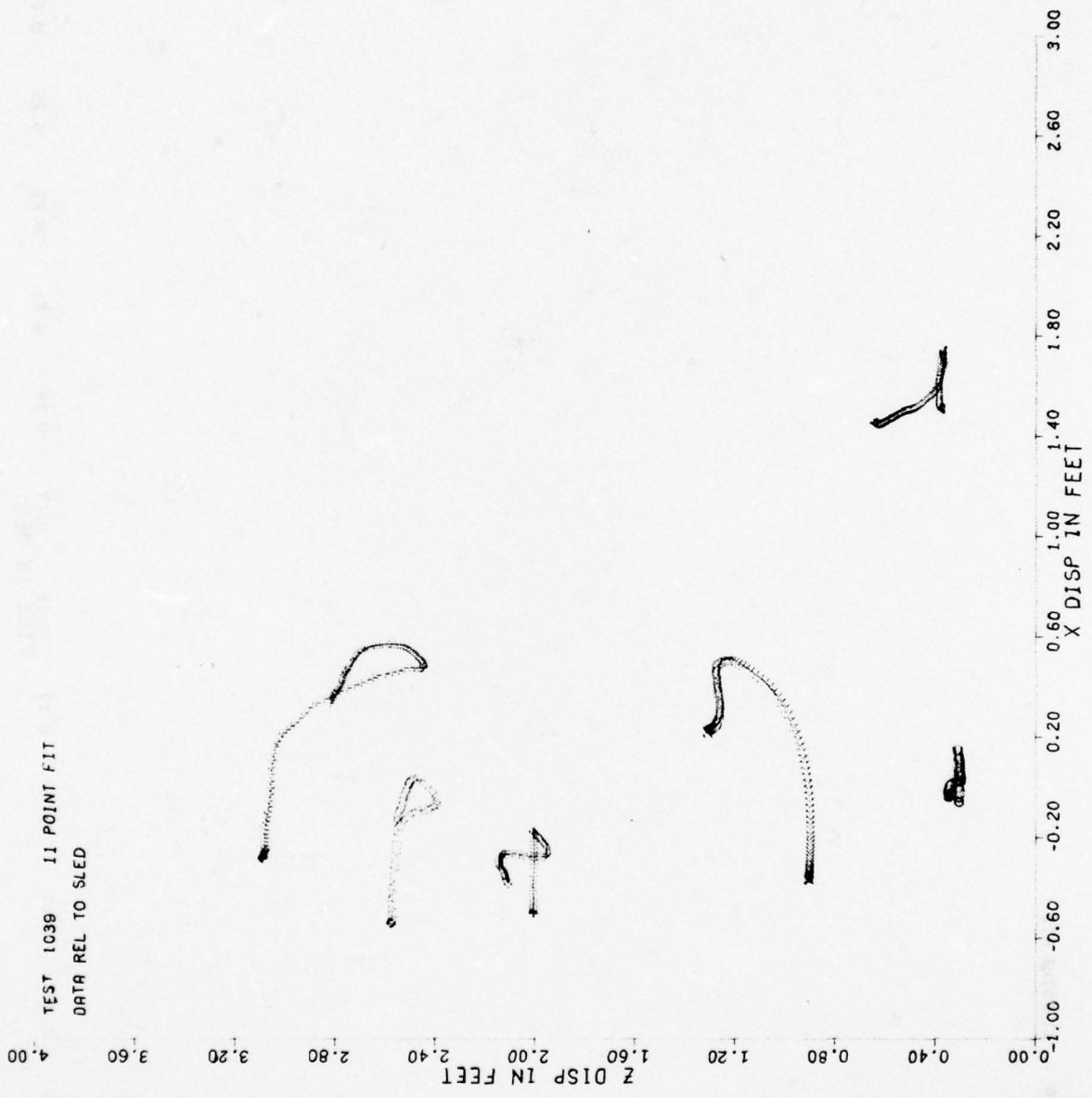
MAXIMUM POSITIVE X DISPLACEMENT= .822 AT TIME .22030

MAXIMUM NEGATIVE X DISPLACEMENT= -.035 AT TIME .05508

MAXIMUM POSITIVE Z DISPLACEMENT= .017 AT TIME .02652

MAXIMUM NEGATIVE Z DISPLACEMENT= -.632 AT TIME .18155

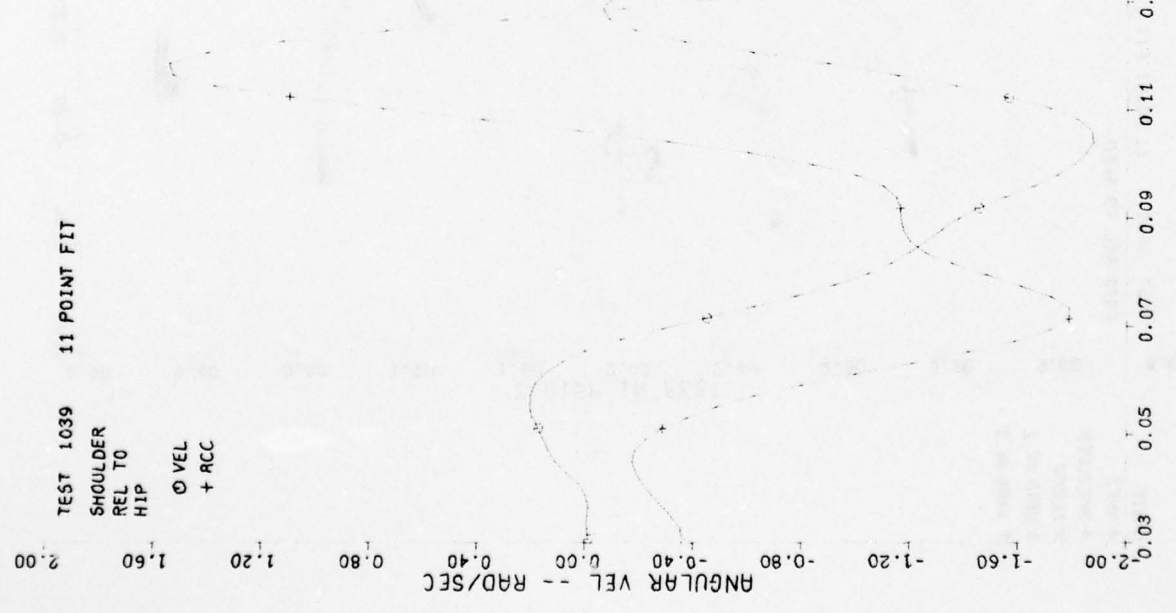
MAXIMUM RESULTANT DISPLACEMENT= .986 AT TIME .20194



- HIP
- △ KNEE
- + SHOULDER
- x ELBOW
- ◇ HEAD PT. 1
- ♣ HEAD PT. 2

ANGULAR ACC -- RAD/SEC/SEC

80.00
-60.00
-40.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00



TEST 1039 11 POINT FIT

SHOULDER
REL TO
HIP

○ VEL
+ ACC

AD-A062 006

DAYTON UNIV OHIO RESEARCH INST
PHOTOMETRIC METHODS FOR THE ANALYSIS OF HUMAN KINEMATIC RESPON--ETC(U)
OCT 78 P A GRAF, H T MOHLMAN, R C REBOULET F33615-73-C-4157

F/G 5/5

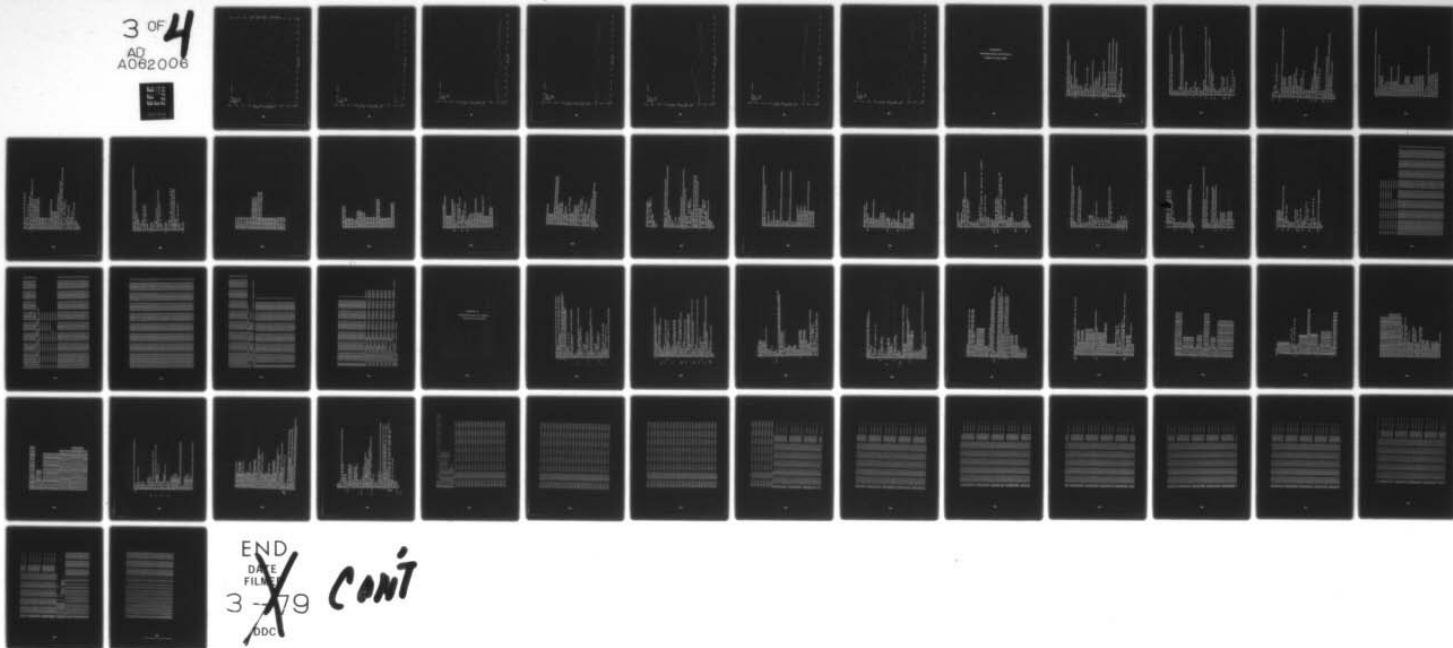
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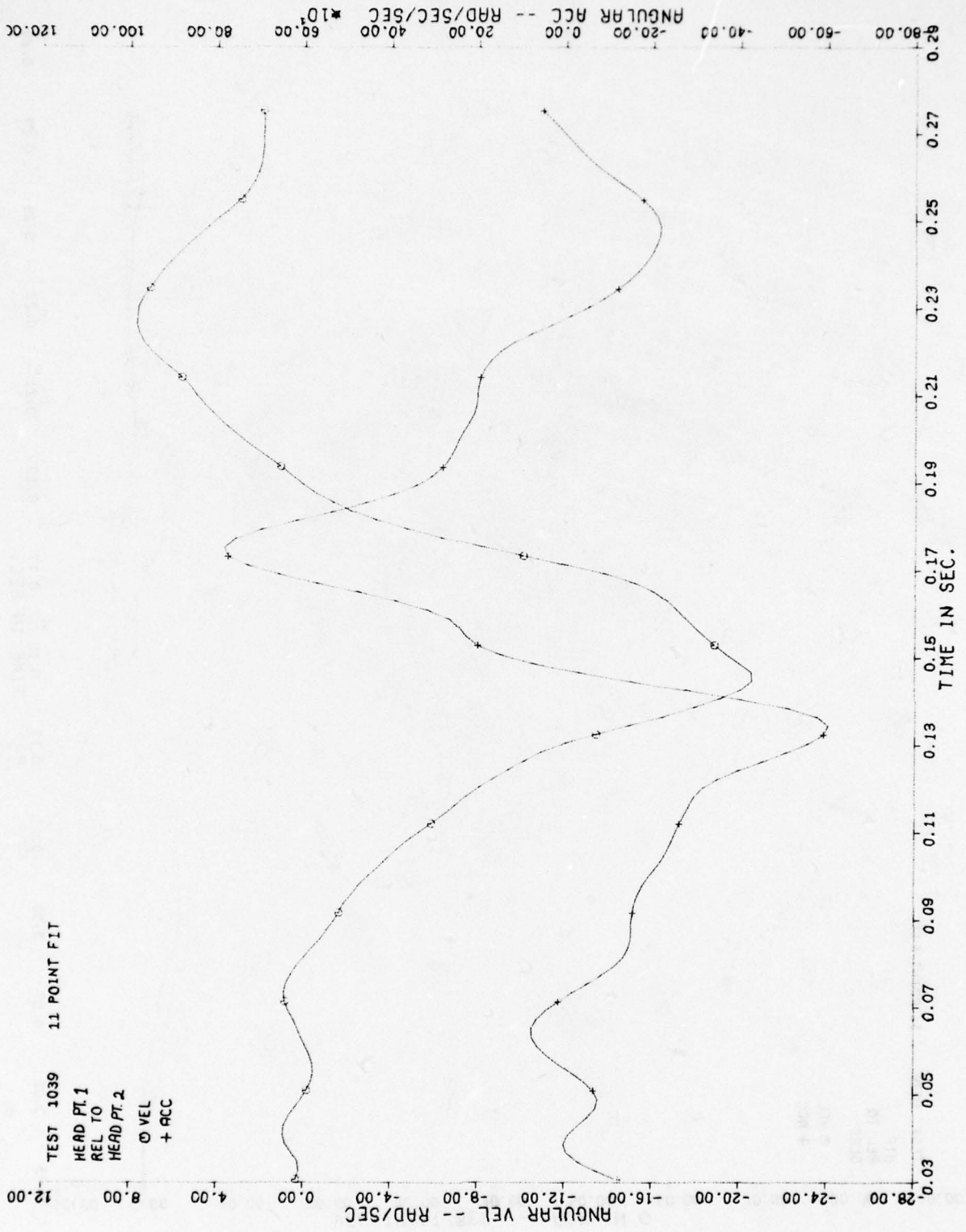
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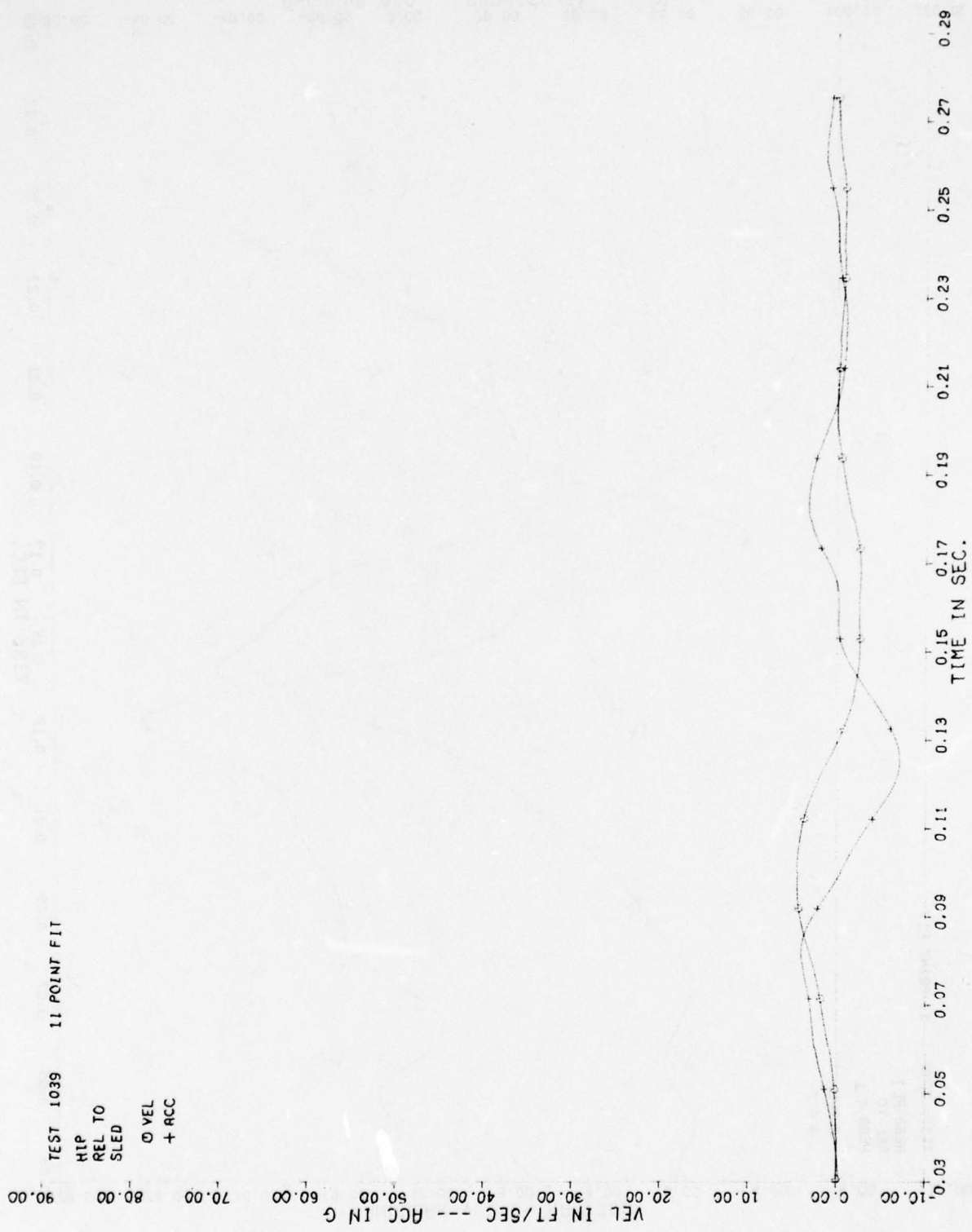
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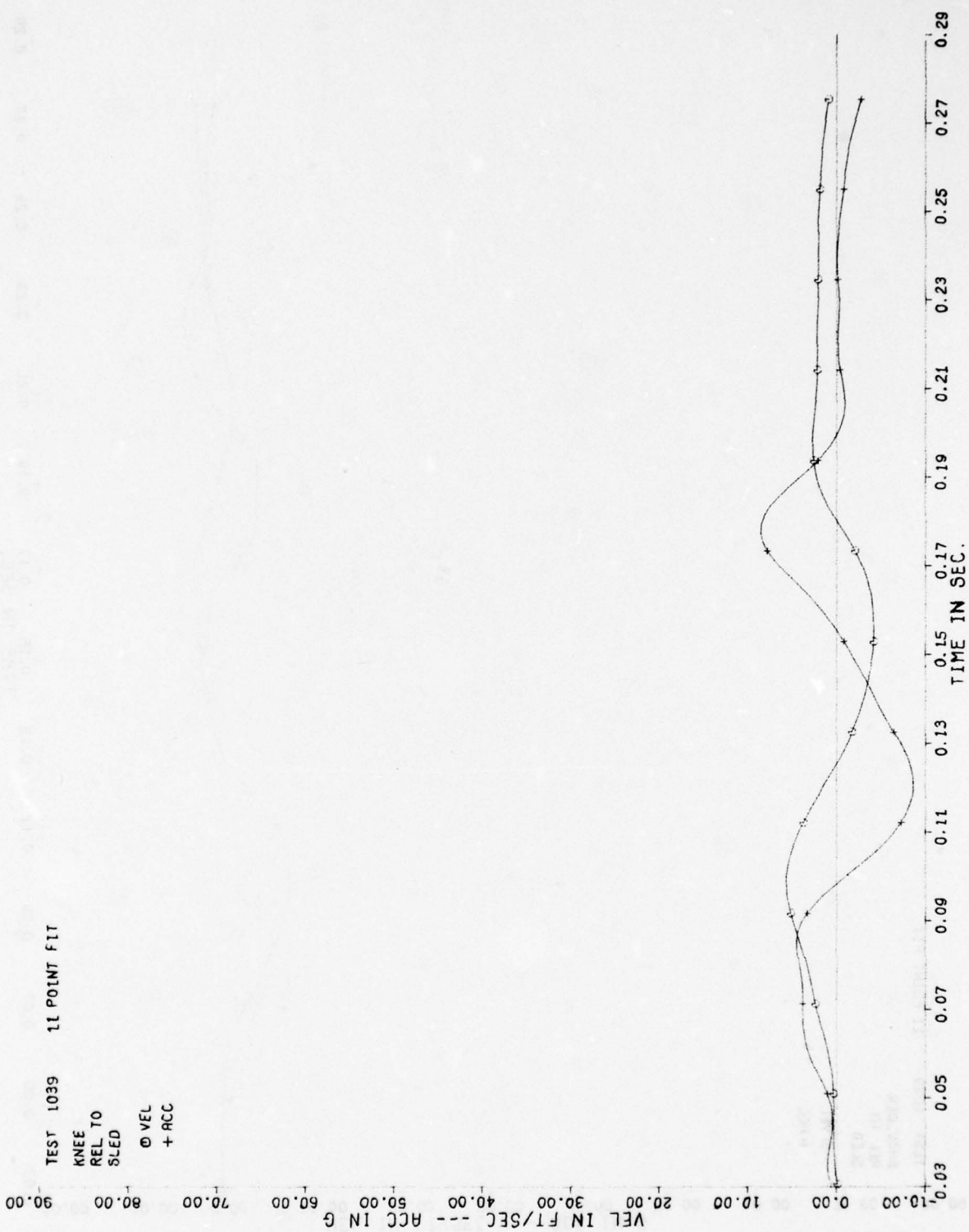
3 OF 4
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CONT







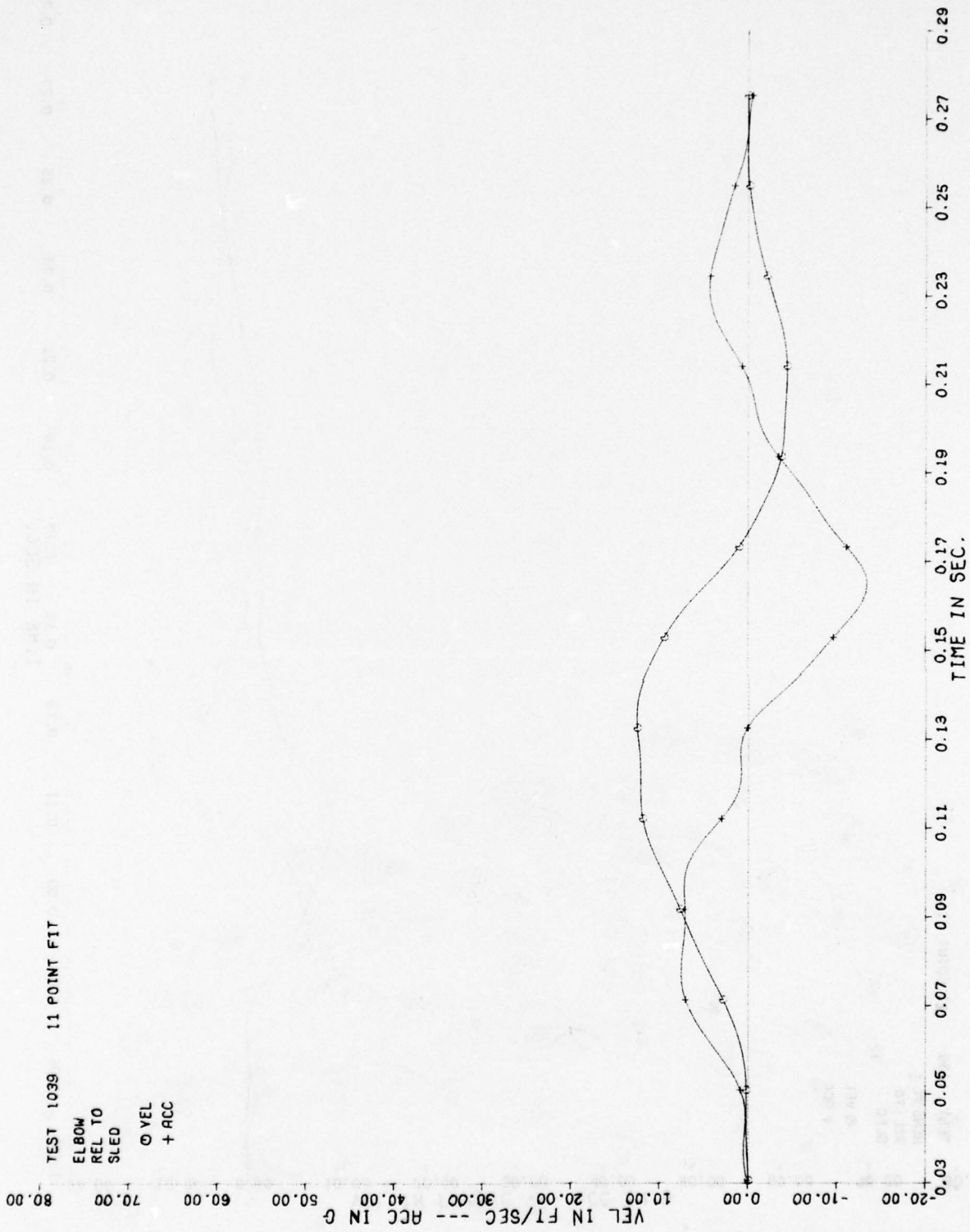
TEST 1039 11 POINT FIT

SHOULDER
REL TO
SLED

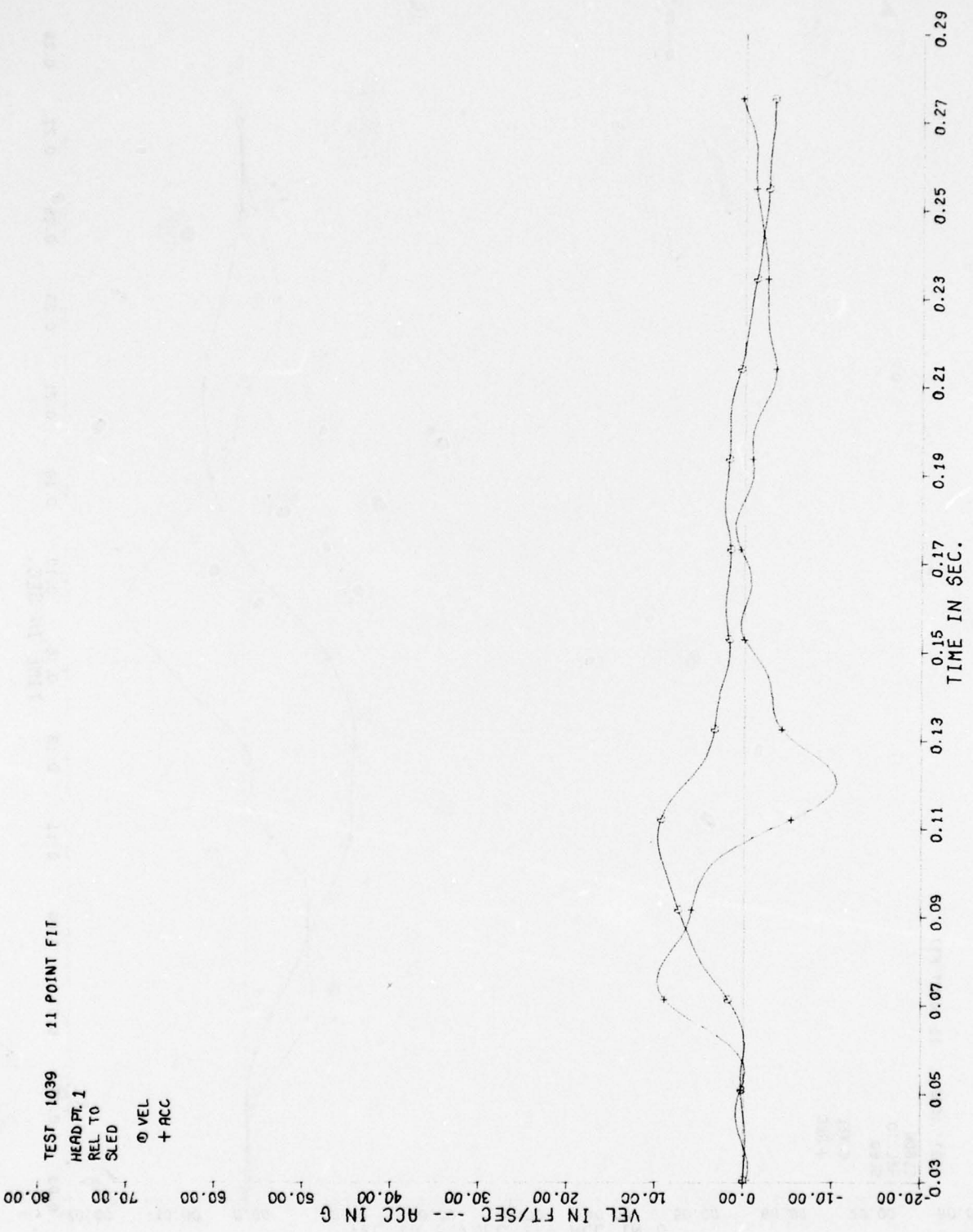
○ VEL
+ ACC

VEL IN FT/SEC --- ACC IN G

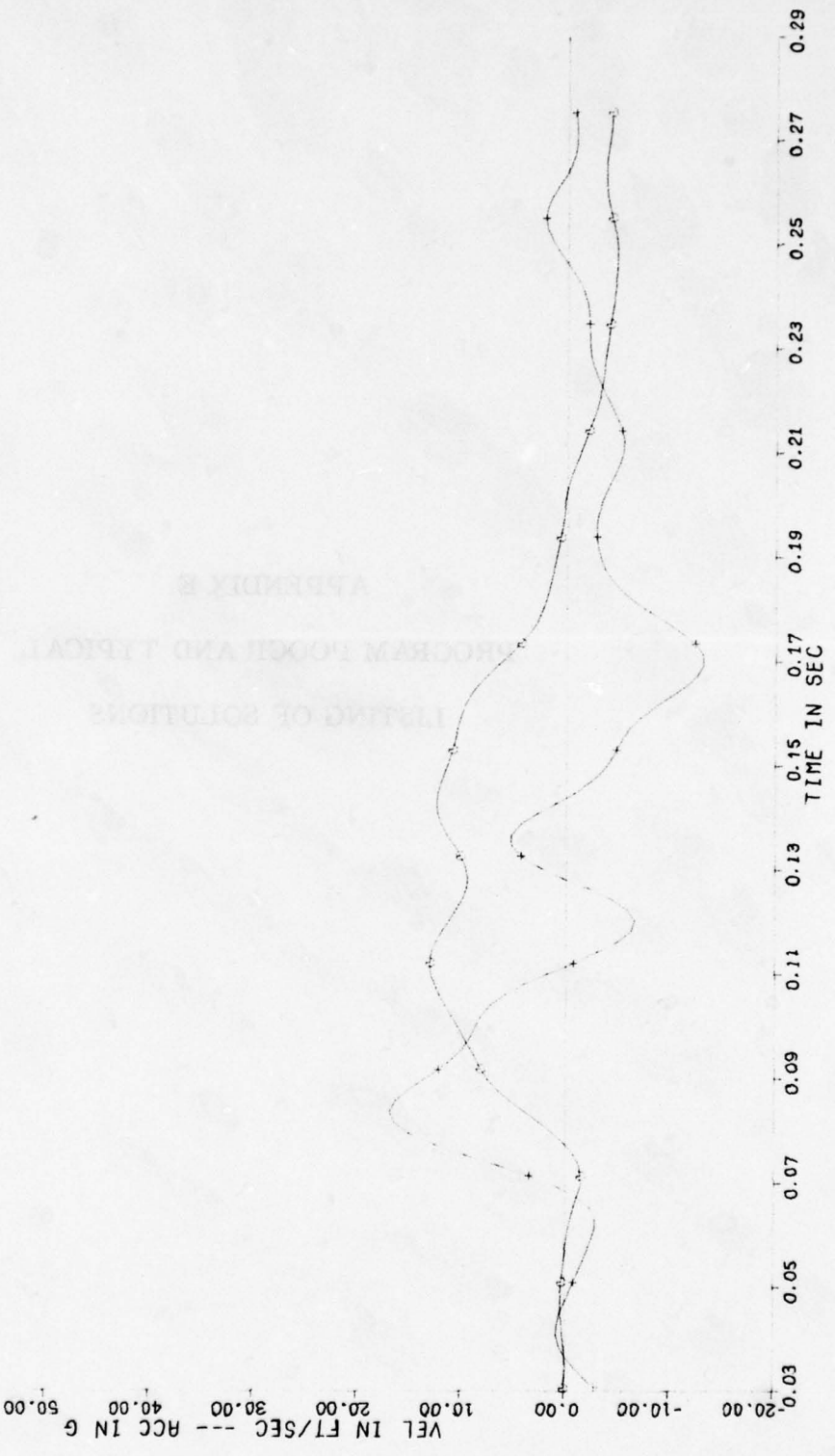




TEST 1039 11 POINT FIT
 HEAD PT. 1
 REL TO
 SLED
 O VEL
 + ACC



TEST 1039 11 POINT FIT
 HEAD PT. 2
 REL TO
 SLED
 O VEL
 + ACC



APPENDIX E
PROGRAM POOCH AND TYPICAL
LISTING OF SOLUTIONS

```

PROGRAM POOCH(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
DIMENSION X(20),Y(20),Z(20),P(20),Q(20)
DTR=3.14159265/180.0
RTD=1.0/DTR
1 READ(5,2)XX,YY,ZZ,FF,FP,FQ,XSR,N
2 FORMAT(7F10.0,I5)
FF=FF/12.0
FP=FP/12.0
FQ=FQ/12.0
YY=-YY
ICLK=EOF(5)
IF (ICLK .NE. 0) GO TO 2000
NSTOP=0
DO 3 I=1,N
  READ(5,4) P(I),Q(I),X(I),Y(I),Z(I)
4  FORMAT(5F10.0)
  P(I)=-P(I)/12000.0
  Q(I)=Q(I)/12000.0
  Q(I)=Q(I)*(1.0-XSR*P(I))
  Y(I)=-Y(I)
  WRITE(6,6)P(I),Q(I),X(I),Y(I),Z(I)
6  FORMAT(6H P00CJ,5E13.6/)
3  CONTINUE
  CALL FIND(XX,YY,ZZ,FF,ERR,X,Y,Z,P,Q,N,NSTOP,FP,FQ)
  IF (NSTOP .EQ. 1) GO TO 1
  CALL SERCH(XX,YY,ZZ,FF,X,Y,Z,P,Q,N,NSTOP,TH,PH,GAM,K,L)
  IF (NSTOP .EQ. 1) GO TO 1
  CALL DANG(XX,YY,ZZ,FF,TH,PH,GAM,X,Y,Z,P,Q,N,DNG,K,L)
  GO TO 1
2000 WRITE(6,2001)
2001 FORMAT(18H NORMAL COMPLETION )
STOP
END

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SUBROUTINE DANG(XX,YY,ZZ,FF,TH,PH,GAM,X,Y,Z,P,Q,N,DNG,K,L)
DIMENSION X(20),Y(20),Z(20),P(20),Q(20)
NRE=0
KTR=1
NTR=0
DNG=0.03
CALL WRANG(XX,YY,ZZ,FF,TH,PH,GAM,X,Y,Z,P,Q,N,ERR,NRE,K,L,THI,PHI)
WRITE(6,11)XX,YY,ZZ,FF,TH,PH,GAM,ERR,NTR
XMO=1.0
1 TS=TH+XMO*DNG
  PS=PH
  GAS=GAM
  GO TO 20
2 TS=TH
  PS=PH+XMO*DNG
  GAS=GAM
  GO TO 20
3 TS=TH
  PS=PH
  GAS=GAM+XMO*DNG
20 CALL WRANG(XX,YY,ZZ,FF,TS,PS,GAS,X,Y,Z,P,Q,N,ERS,NRE,K,L,THI,PHI)
  NTR=NTR+1
  IF (NTR .LT. 51) WRITE(6,100)TS,PS,GAS,ERS,DNG,XMO,KTR
100 FORMAT(5H DANG,6E13.6,I5)
  IF (ERR=ERS) 22,22,21
21 ERR=ERS
  TH=TS
  PH=PS
  GAM=GAS
  GO TO (1,2,3),KTR
22 IF (XMO) 24,23,23
23 XMO=-1.0
  GO TO (1,2,3),KTR
24 XMO=1.0
  KTR=KTR+1
  IF (KTR .GT. 3) GO TO 25
  GO TO (1,2,3),KTR

```

```

25 KTR=1
   DNG=J.1*DNG
   IF (DNG .LT. J.00000029) GO TO 26
   GO TO 1
26 NRE=1
   CALL WRANG(XX,YY,ZZ,FF,TH,PH,GAM,X,Y,Z,P,Q,N,ERR,NRE,K,L,THI,PHI)
   RFA=COS(TH)*COS(PH)
   RFB=SIN(TH)*COS(PH)
   RFC=SIN(PH)
   RIA=COS(THI)*COS(PHI)
   RIB=SIN(THI)*COS(PHI)
   RIC=SIN(PHI)
   RFM=SQRT(RFA**2+RFB**2)
   IF (RFM-0.00000001) 30,30,31
31 SIA=-RFB/RFM
   SIB=RFA/RFM
   HAG=SIA*RIA+SIB*RIB
   IF (HAG .GT. J.0) GO TO 34
   SIA=-SIA
   SIB=-SIB
   SIC=-SIC
   HAG=-HAG
34 CALL AKOS(HAG,TILT)
   IF (ABS(TILT)-0.000000001) 30,30,32
32 TELL=RFA*(SIB*RIC-RIB*SIC)-RFB*(SIA*RIC-SIC*RIA)+
   1RFC*(SIA*RIB-SIB*RIA)
   IF (TELL .LT. 0.0) TILT=-TILT
   GO TO 33
30 TILT=0.0
33 CONTINUE
11 WRITE(6,11)XX,YY,ZZ,FF,TH,PH,GAM,ERR,NTR
11 FORMAT(19H X,Y,Z,F,AZ,EL,TILT,7E13.6/12H ERROR ITER.,E13.6,I5)
10 WRITE(6,10)THI,PHI,TILT
10 FORMAT(18H DAMS,THI,PHI,TILT,3E13.6)
   RETURN
   END

```

```

SUBROUTINE WRANG (XX, YY, ZZ, FF, TH, PH, GAM, X, Y, Z, P, Q, N, ERR, NRE, K, L,
1THI, PHI)
DIMENSION X(20), Y(20), Z(20), P(20), Q(20), R(20)
FN1=COS(TH)*COS(PH)
FN2=SIN(TH)*COS(PH)
FN3=SIN(PH)
PIPA=X(K)-X(L)
PIPB=Y(K)-Y(L)
PIPC=Z(K)-Z(L)
A=FN1*PIPA+FN2*PIPB+FN3*PIPC
PIA=PIPA-A*FN1
PIB=PIPB-A*FN2
PIC=PIPC-A*FN3
PIU=SQRT(PIA**2+PIB**2+PIC**2)
PIA=PIA/PIU
PIB=PIB/PIU
PIC=PIC/PIU
PJA=FN2*PIC-FN3*PIB
PJB=FN3*PIA-FN1*PIC
PJC=FN1*PIB-FN2*PIA
COG=COU(GAM)
SIG=SIN(GAM)
TIA=COG*PIA+SIG*PJA
TIB=COG*PIB+SIG*PJB
TIC=COG*PIC+SIG*PJC
TJA=-SIG*PIA+COG*PJA
TJB=-SIG*PIB+COG*PJB
TJC=-SIG*PIC+COG*PJC
ERR=J.0
DO 1 I=1,N
W=FF/(X(I)-XX)*FN1+(Y(I)-YY)*FN2+(Z(I)-ZZ)*FN3
RA=W*(X(I)-XX)-FF*FN1
RB=W*(Y(I)-YY)-FF*FN2
RC=W*(Z(I)-ZZ)-FF*FN3
PA=RA*TIA+RB*TIB+RC*TIC
QA=RA*TJA+RB*TJB+RC*TJC

```

```

ERA=SQRT((P(I)-PA)**2+(Q(I)-QA)**2)
ERR=ERR+ERA
IF (NRE .EQ. 0) GO TO 1
WRITE(6,2) I, P(I), Q(I), PA, QA, ERA
2 FORMAT(26H READ PT. PIERCE PT., ERROR, I5, 5E13.6)
PHA=FF*FN1+P(I)*TIA+Q(I)*TJA
PHB=FF*FN2+P(I)*TIB+Q(I)*TJB
PHC=FF*FN3+P(I)*TIC+Q(I)*TJC
DPH=SQRT(PHA**2+PHB**2+PHC**2)
PHA=PHA/DPH
PHB=PHB/DPH
PHC=PHC/DPH
SHA=X(I)-XX
SHB=Y(I)-YY
SHC=Z(I)-ZZ
ACOF=PHA*SHA+PHB*SHB+PHC*SHC
DISA=ACOF*PHA-SHA
DISB=ACOF*PHB-SHB
DISC=ACOF*PHC-SHC
DIS=SQRT(DISA**2+DISB**2+DISC**2)
WRITE(6,3) I, X(I), Y(I), Z(I), DISA, DISB, DISC, DIS
3 FORMAT(37H ITH OBJECT POINT AND DISTANCE VECTOR/I5, 7E13.6)
IF (TIC .GT. 1.0) TIC=1.0
IF (TIC .LT. -1.0) TIC=-1.0
PHI=ASIN(TIC)
TJM=SQRT(TIA**2+TIB**2)
ARG=TIA/TJM
CALL AKOS(ARG, THI)
IF (TIB .LT. 0.0) THI=-THI
1 CONTINUE
RETURN
END

```

```

SUBROUTINE SERCH(XX,YY,ZZ,FF,XX,Y,Z,P,Q,N,NSTOP,TH,PH,GAM,K,L)
DIMENSION X(20),Y(20),Z(20),P(20),Q(20)
DIR=0.01745329252
RTD=1.0/DIR
STO=0.0
DO 1 I=1,N
STA=SQRT(P(I)**2+Q(I)**2)
IF (STA .LE. STO) GO TO 1
STO=STA
K=I
1 CONTINUE
STO=0.0
DO 2 I=1,N
IF (K .EQ. I) GO TO 2
STA=SQRT((P(K)-P(I))**2+(Q(K)-Q(I))**2)
IF (STA .LE. STO) GO TO 2
STO=STA
L=I
2 CONTINUE
STO=0.0
DO 3 I=1,N
IF ((I .EQ. K) .OR. (I .EQ. L)) GO TO 3
STA=SQRT((P(I)-P(K))**2+(Q(I)-Q(K))**2)
STB=SQRT((P(I)-P(L))**2+(Q(I)-Q(L))**2)
STA=STA+STB
IF (STA .LE. STO) GO TO 3
STO=STA
M=I
3 CONTINUE

```

FAA=X(K)-XX
 FAB=Y(K)-YY
 FAC=Z(K)-ZZ
 FBA=X(L)-XX
 FBB=Y(L)-YY
 FBC=Z(L)-ZZ
 FCA=X(M)-XX
 FCB=Y(M)-YY
 FCC=Z(M)-ZZ
 DAM=SQRT(FAA**2+FAB**2+FAC**2)
 DBM=SQRT(FBA**2+FBB**2+FBC**2)
 DCM=SQRT(FCA**2+FCB**2+FCC**2)
 DAM=DAM/SQRT(FF**2+P(K)**2+Q(K)**2)
 DBM=DBM/SQRT(FF**2+P(L)**2+Q(L)**2)
 DCM=DCM/SQRT(FF**2+P(M)**2+Q(M)**2)
 FAA=FAA/DAM
 FAB=FAB/DAM
 FAC=FAC/DAM
 FBA=FBA/DBM
 FBB=FBB/DBM
 FBC=FBC/DBM
 FCA=FCA/DCM
 FCB=FCB/DCM
 FCC=FCC/DCM
 MA=P(K)-P(M)
 MB=Q(K)-Q(M)
 UA=P(L)-P(M)
 UB=Q(L)-Q(M)

WAB=SQRT(WA**2+WB**2)
UAB=SQRT(UA**2+UB**2)
WA=WA/WAB
WB=WB/WAB
UA=UA/UAB
UB=UB/UAB
CA=-P(M)
CB=-Q(M)
FLAM=WA*UB-WB*UA
COFA=CA*UB-CB*UA
COFB=WA*CB-WB*CA
COFA=COFA/FLAM
COFB=COFB/FLAM
WA=FAA-FCA
WB=FAB-FCB
WC=FAC-FCC
UA=FBA-FCA
UB=FBB-FCB
UC=FBC-FCC
WAB=SQRT(WA**2+WB**2+WC**2)
UAB=SQRT(UA**2+UB**2+UC**2)
WA=WA/WAB
WB=WB/WAB
WC=WC/WAB
UA=UA/UAB
UB=UB/UAB
UC=UC/UAB
FN1=FCA+COFA+WA+COFB*UA
FN2=FCB+COFA*WB+COFB*JB

```

FN3=FCC+COFA*WC+COFB*UC
DCKN=SQRT(FN1**2+FN2**2+FN3**2)
FN1=FN1/DCKN
FN2=FN2/DCKN
FN3=FN3/DCKN
WRITE(6,12)FN1, FN2, FN3, DCKN
12 FORMAT(6H SERCH, 4E13.6)
TH=0.0
DJK=SQRT(FN1**2+FN2**2)
IF (DIM -0.00000001) 13,13,14
14 ARG=FN1/DIM
CALL AKOS(ARG,TH)
IF (FN2 .LT. 0.0) TH=-TH
13 CONTINUE
PH=ASIN(FN3)
PIPA=X(K)-X(L)
PIPB=Y(K)-Y(L)
PIPC=Z(K)-Z(L)
A=FN1*PIPA+FN2*PIPB+FN3*PIPC
PIA=PIPA-A*FN1
PIB=PIPB-A*FN2
PIC=PIPC-A*FN3
PIO=SQRT(PIA**2+PIB**2+PIC**2)
PIA=PIA/PIO
PIB=PIB/PIO
PIC=PIC/PIO
PJA=FN2*PIC-FN3*PIB
PJB=FN3*PIA-FN1*PIC

```

```

PJC=FN1*PIB-FN2*PIA
FFA=FF*FN1
FFB=FF*FN2
FFC=FF*FN3
ELA=(FAA-FFA)*PIA+(FAB-FFB)*PIB+(FAC-FFC)*PIC
ELB=(FAA-FFA)*PJA+(FAB-FFB)*PJB+(FAC-FFC)*PJC
DEL=P(K)**2+Q(K)**2
DSA=P(K)*ELB-Q(K)*ELA
DCA=P(K)*ELA+Q(K)*ELB
ARG=DCA/DEL
CALL AKOS(ARG,GAM)
ARG=DSA/DEL
IF (ARG .LT. 0.0) GAM=-GAM
COG=COS(GAM)
SIG=SIN(GAM)
GIA=COG*PIA+SIS*PJA
GIB=COG*PIB+SIG*PJB
GIC=COG*PIC+SIG*PJC
IF (GIC .GT. 1.0) GIC=1.0
IF (GIC .LT. -1.0) GIC=-1.0
PHI=ASIN(GIC)
GDM=SQRI(GIA**2+GIB**2)
ARG=GIA/GDM
CALL AKOS(ARG,IHI)
IF (GIB .LT. 0.0) THI=-THI
WRITE(6,20) XX,YY,ZZ,FF,TH,PH,GAM,THI,PHI
20 FORMAT(6H SERCH,5E13.6/6X,4E13.6)
RETURN
END

```

```

SUBROUTINE AKOS(ARG,ANG)
IF (ARG .GT. 1.0) ARG=1.0
IF (ARG .LT. -1.0) ARG=-1.0
ANG=ACOS(ARG)
RETURN
END

SUBROUTINE ANGLE (XX,YY,ZZ,FF,ERR,X,Y,Z,P,Q,N)
DIMENSION X(20),Y(20),Z(20),P(20),Q(20),G(20,20),H(20,20)
DIR=0.01745329252
RTO=1.0/DTR
ERR=0.0
M=N-1
DO 1 I=1,M
K=I+1
DO 1 J=K,N
ROM=FF**2+P(I)*P(J)+Q(I)*Q(J)
ORAD=SQRT(FF**4+(P(I)**2+Q(I)**2+P(J)**2+Q(J)**2)*FF**2
1+(P(I)**2+Q(I)**2)*(P(J)**2+Q(J)**2))
ARG=ROM/RAD
IF (ARG .GT. 1.0) ARG=1.0
IF (ARG .LT. -1.0) ARG=-1.0
G(I,J)=ACOS(ARG)
RAD1=SQRT((X(I)-XX)**2+(Y(I)-YY)**2+(Z(I)-ZZ)**2)
RAD2=SQRT((X(J)-XX)**2+(Y(J)-YY)**2+(Z(J)-ZZ)**2)
DOM=(X(I)-XX)*(X(J)-XX)+(Y(I)-YY)*(Y(J)-YY)+(Z(I)-ZZ)*
1(Z(I)-ZZ)*(Z(J)-ZZ)
ARG=DOM/(RAD1*RAD2)
IF (ARG .LT. -1.0) ARG=-1.0
IF (ARG .GT. 1.0) ARG=1.0
H(I,J)=ACOS(ARG)
ERR=ERR+(G(I,J)-H(I,J))**2
1 CONTINUE
RETURN
END

```

```

SUBROUTINE FIND (XX, YY, ZZ, FF, ERR, X, Y, Z, P, Q, N, NSTOP, FP, FQ)
DIMENSION X(20), Y(20), Z(20), P(20), Q(20)
M=6
ERS=1000000.0
XM=M
NTRY=1
DUST=(FQ-FP)/XM
DP=1.5
DF=30.1
DPP=DP
CALL HORSY (XX, YY, ZZ, FP, ERR, X, Y, Z, P, Q, N, NSTOP, DPP, DF)
XA=XX
YA=YY
ZA=ZZ
DPP=DP
CALL HORSY (XX, YY, ZZ, FQ, ERR, X, Y, Z, P, Q, N, NSTOP, DPP, DF)
XB=XX
YB=YY
ZB=ZZ
COXB=(XB-XA)/(FQ-FP)
COXA=XA-COXB*FP
COYB=(YB-YA)/(FQ-FP)
COYA=YA-COYB*FP
COZB=(ZB-ZA)/(FQ-FP)
COZA=ZA-COZB*FP
DAST=SQRT((XB-XA)**2+(YB-YA)**2+(ZB-ZA)**2)
SX=(XB-XA)/DAST
SY=(YB-YA)/DAST
SZ=(ZB-ZA)/DAST

```

```

DOM=SQRT(SX**2+SY**2)
IF (DOM-0.0001) 50,50,51
50 TX=1.0-SX**2
   TY=-SX*SY
   TZ=-SX*SZ
   TD=SQRT(TX**2+TY**2+TZ**2)
   TX=TX/TD
   TY=TY/TD
   TZ=TZ/TD
   UX=SY*TZ-SZ*TY
   UY=SZ*TX-SX*TZ
   UZ=SX*TY-SY*TX
   GO TO 52
51 TX=-SY/DOM
   TY=SX/DOM
   TZ=0.0
   UX=-TY*SZ
   UY=TX*SZ
   UZ=DOM
52 CDDP=DAST/(FQ-FP)
   FS=FP
   K=M+1
2  DIST=(FQ-FP)/XM
   FF=FP-DIST
   DO 3 I=1,K
   FF=FF+DIST
   XX=COXA+COXB*FF
   YY=COYA+COYB*FF

```

```

ZZ=C0ZA+C0ZB*FF
OPP=DP
OPCK=C0DP*DIST
IF (OPCK .LT. DPP) OPP=OPCK
CALL REFIN(XX,YY,ZZ,FF,ERR,X,Y,Z,P,Q,N,NSTOP,OPP,DF,
1SX,SY,SZ,IX,IY,IZ,UX,UY,UZ)
IF (ERR .GT. ERS) GO TO 1
XS=XX
YS=YY
ZS=ZZ
FS=FF
ERS=ERR
1 IF (I .LT. K) GO TO 3
IF ((ABS(FS-FP) .LT. 0.5*DIST) .OR. (ABS(FS-FQ) .LT. 0.5*DIST))
1GO TO 1000
IF (DIST .LT. 0.001) GO TO 900
FP=FS-DIST
FQ=FS+DIST
GO TO 2
3 CONTINUE
1000 NSTOP=1
WRITE(6,1001) FS,FP,FQ,DIST
1001 FORMAT(11H NO BRACKET,4E13.6)
IF (ABS(DUST-DIST+0.000001) .GT. 0.000001) GO TO 900
IF (ABS(FS-FQ+0.000001) .GT. 0.000001) GO TO 300
NTRY=NTRY+1
IF (NTRY .GT. 3) GO TO 900
NSTOP=0
TEMP=FQ-FP
FP=FQ-DIST
FQ=FQ+TEMP-DIST
GO TO 2
900 XX=XS
YY=YS
ZZ=ZS
FF=FS
ERR=ERS
WRITE(6,901) XX,YY,ZZ,FF,ERR
901 FORMAT(13H NEW POSITION,5E13.6)
RETURN
END

```

```

SUBROUTINE HORSY (XX,YY,ZZ,FF,ERR,X,Y,Z,P,Q,N,NSTOP,DP,DF)
DIMENSION X(20),Y(20),Z(20),P(20),Q(20)
NTR=DF
KTR=0
CALL ANGLE (XX,YY,ZZ,FF,ERR,X,Y,Z,P,Q,N)
WRITE(6,8) XX,YY,ZZ,FF,ERR,DP,DF,KTR
XS=XX
YS=YY
ZS=ZZ
FT=FF
1 XT=XX-2.0*DP
  YT=YY-2.0*DP
  ZT=ZZ-2.0*DP
  KTR=KTR+1
  IF (KTR .GT. NTR) GO TO 7
  DO 2 I=1,3
    XT=XT+DP
    DO 3 J=1,3
      YT=YT+DP
      DO 4 K=1,3
        ZT=ZT+DP
        CALL ANGLE (XT,YT,ZT,FT,ERR,X,Y,Z,P,Q,N)
        IF (ERR .GE. ERR) GO TO 4
        XS=XT
        YS=YT
        ZS=ZT
        ERR=ERR
      4 CONTINUE
    3 CONTINUE
    2 CONTINUE
  2 CONTINUE

```

```

IF (ABS (XX-XS) .GT. 0.01) GO TO 6
IF (ABS (YY-YS) .GT. 0.01) GO TO 6
IF (ABS (ZZ-ZS) .GT. 0.01) GO TO 6
IF (OP .LT. 0.01) GO TO 7
OP=0.1*DP
6 XX=XS
  YY=YS
  ZZ=ZS
  GO TO 1
7 XX=XS
  YY=YS
  ZZ=ZS
  WRITE(6,8) XX,YY,ZZ,FF,ERR,DP,DF,KTR
8 FORMAT(20H HARSY,XYZFERR,DP,DF,7E13.6,I5)
1000 RETURN
END

```

```

SUBROUTINE REFIN(XX,YY,ZZ,FF,ERR,X,Y,Z,P,Q,N,NSTOP,DP,DF,
1 SX,SY,SZ,IX,IY,IZ,UX,UY,UZ)
  DIMENSION X(20),Y(20),Z(20),P(20),Q(20)
  NTR=0
  KTR=1
  CALL ANGLE (XX,YY,ZZ,FF,ERR,X,Y,Z,P,Q,N)
  WRITE(6,11) XX,YY,ZZ,FF,ERR,DP,DF,KTR
11 FORMAT (20H REFIN,XYZFERR,DP,DF,7E13.6,I5)
  OPO=DP/3.0
  XMO=1.0
1 XS=XX+XMO*SX*DP
  YS=YY+XMO*SY*DP
  ZS=ZZ+XMO*SZ*DP
  GO TO 20
2 XS=XX+XMO*TX*DP0
  YS=YY+XMO*TY*DP0
  ZS=ZZ+XMO*TZ*DP0
  GO TO 20

```

```

3  XS=XX+XMO*UX*DPO
   YS=YY+XMO*UY*DPO
   ZS=ZZ+XMO*UZ*DPO
20 CALL ANGLE(XS,YS,ZS,FF,ERS,X,Y,Z,P,Q,N)
   NTR=NTR+1
   IF (ERR-ERS) 22,22,21
21 ERR=ERS
   XX=XS
   YY=YS
   ZZ=ZS
   GO TO (1,2,3),KTR
22 IF (XMO) 24,23,23
23 XMO=-1.0
   GO TO (1,2,3) ,KTR
24 XMO=1.0
   KTR=KTR+1
   IF (KTR.GT. 3) GO TO 25
   GO TO (1,2,3) ,KTR
25 KTR=1
   DP=0.1*DP
   IF (DP.LT. 0.0009) GO TO 26
   DPO=DP/3.0
   GO TO 1
26 WRITE(6,11)XX,YY,ZZ,FF,ERR,DP,DF,NTR
   RETURN
   END

```


KEFIN,XYZFERR,UP,DF -.460494E+01 .397950E+01 .433650E+01 .814815E+00 .199986E-03 .174604E+00 .301000E+02 1
 KEFIN,XYZFERR,UP,DF -.455237E+01 .406197E+01 .419542E+01 .814815E+00 .129183E-03 .174604E-03 .301000E+02 125
 KEFIN,XYZFERR,UP,DF -.474650E+01 .407392E+01 .437507E+01 .833333E+00 .199986E-03 .174604E+00 .301000E+02 1
 KEFIN,XYZFERR,UP,DF -.469295E+01 .415643E+01 .423799E+01 .833333E+00 .137415E-03 .174604E-03 .301000E+02 120
 KEFIN,XYZFERR,UP,DF -.488806E+01 .414844E+01 .441484E+01 .851852E+00 .201888E-03 .174604E+00 .301000E+02 1
 KEFIN,XYZFERR,UP,DF -.483515E+01 .424988E+01 .428492E+01 .851852E+00 .148210E-03 .174604E-03 .301000E+02 113
 KEFIN,XYZFERR,UP,DF -.502961E+01 .426275E+01 .445400E+01 .870370E+00 .205168E-03 .174604E+00 .301000E+02 1
 KEFIN,XYZFERR,UP,DF -.497616E+01 .434394E+01 .432693E+01 .870370E+00 .157835E-03 .174604E-03 .301000E+02 108
 KEFIN,XYZFERR,UP,DF -.517117E+01 .435717E+01 .449317E+01 .888889E+00 .209450E-03 .174604E+00 .301000E+02 1
 KEFIN,XYZFERR,UP,DF -.511750E+01 .443751E+01 .436093E+01 .888889E+00 .167817E-03 .174604E-03 .301000E+02 102
 NO BRACKET .777778E+00 .777778E+00 .688889E+00 .185185E-01
 NEW POSITION -.426765E+01 .387836E+01 .410252E+01 .777778E+00 .113512E-03
 P00CJ -.400833E-01 .215833E+00 .378908E+01 .149210E+01 .376825E+01
 P00CJ -.120750E+00 .218000E+00 .380208E+01 .325500E+00 .376300E+01
 P00CJ -.230583E+00 .220917E+00 .380992E+01 -.841167E+00 .376567E+01
 P00CJ .156833E+00 -.158417E+00 .546670E-01 .109370E+01 .487000E+00
 P00CJ .110833E+00 -.159167E+00 .729170E-01 .583330E+00 .648417E+00
 P00CJ .672500E-01 -.170917E+00 .833330E-01-0. .677083E+00
 P00CJ .695833E-01 -.224083E+00 .783300E-02-0. .291667E+00
 HARSY,XVZFERR,UP,DF -.344942E+01 -.349358E+01 .357292E+01 .333333E+00 .379146E+01 .150000E+01 .301000E+02 0
 HARSY,XVZFERR,UP,DF -.100592E+01 -.125258E+01 .318592E+01 .333333E+00 .107208E-01 .150000E-02 .301000E+02 30
 HARSY,XVZFERR,UP,DF -.100592E+01 -.125258E+01 .318592E+01 .133333E+01 .915475E+01 .150000E+01 .301000E+02 0
 HARSY,XVZFERR,UP,DF -.815942E+01 -.719558E+01 .407392E+01 .133333E+01 .459038E-03 .150000E-02 .301000E+02 29
 KEFIN,XYZFERR,UP,DF -.100592E+01 -.125258E+01 .318592E+01 .333333E+00 .107208E-01 .150000E+01 .301000E+02 1
 KEFIN,XYZFERR,UP,DF -.100018E+01 -.125214E+01 .318641E+01 .333333E+00 .107208E-01 .150000E-03 .301000E+02 26
 KEFIN,XYZFERR,UP,DF -.219817E+01 -.224308E+01 .343392E+01 .500000E+00 .102213E-02 .150000E+01 .301000E+02 1
 KEFIN,XYZFERR,UP,DF -.339042E+01 -.323358E+01 .360192E+01 .500000E+00 .901434E-03 .150000E-03 .301000E+02 103
 KEFIN,XYZFERR,UP,DF -.336763E+01 -.320210E+01 .357316E+01 .666667E+00 .739412E-04 .150000E-03 .301000E+02 1
 KEFIN,XYZFERR,UP,DF -.458267E+01 -.422408E+01 .392992E+01 .833333E+00 .268528E-04 .150000E-03 .301000E+02 125
 KEFIN,XYZFERR,UP,DF -.453619E+01 -.429402E+01 .386651E+01 .833333E+00 .213020E-03 .150000E-03 .301000E+02 1
 KEFIN,XYZFERR,UP,DF -.577492E+01 -.521458E+01 .417922E+01 .100000E+01 .194705E-03 .150000E+01 .301000E+02 54
 KEFIN,XYZFERR,UP,DF -.574110E+01 -.524889E+01 .411802E+01 .100000E+01 .365069E-03 .150000E+01 .301000E+02 1
 KEFIN,XYZFERR,UP,DF -.696717E+01 -.620506E+01 .442592E+01 .116667E+01 .437847E-03 .150000E-03 .301000E+02 1
 KEFIN,XYZFERR,UP,DF -.694958E+01 -.622792E+01 .441137E+01 .116667E+01 .437847E-03 .150000E-03 .301000E+02 48
 KEFIN,XYZFERR,UP,DF -.815942E+01 -.719558E+01 .467392E+01 .133333E+01 .459038E-03 .150000E+01 .301000E+02 1
 KEFIN,XYZFERR,UP,DF -.815910E+01 -.719598E+01 .467392E+01 .133333E+01 .459038E-03 .150000E-03 .301000E+02 25
 KEFIN,XYZFERR,UP,DF -.219752E+01 -.226295E+01 .332459E+01 .500000E+00 .102213E-02 .523244E+00 .301000E+02 1
 KEFIN,XYZFERR,UP,DF -.259559E+01 -.257322E+01 .351659E+01 .555556E+00 .906490E-03 .523244E-03 .301000E+02 55
 KEFIN,XYZFERR,UP,DF -.258990E+01 -.259573E+01 .342104E+01 .555556E+00 .387812E-03 .523244E+00 .301000E+02 1
 KEFIN,XYZFERR,UP,DF -.299300E+01 -.290341E+01 .359925E+01 .611111E+00 .305357E-03 .523244E-03 .301000E+02 59
 KEFIN,XYZFERR,UP,DF -.297755E+01 -.293592E+01 .351059E+01 .611111E+00 .137382E-03 .523244E+00 .301000E+02 1
 KEFIN,XYZFERR,UP,DF -.297755E+01 -.293592E+01 .351059E+01 .611111E+00 .6747531E-04 .523244E-03 .301000E+02 54

REFIN,XYZFERR,UP,DF	-339042E+01	-323358E+01	368192E+01	666667E+00	739412E-04	523244E+00	301000E+02	1
REFIN,XYZFERR,UP,DF	-337390E+01	-326299E+01	351048E+01	666667E+00	341850E-04	523244E+00	301000E+02	52
REFIN,XYZFERR,UP,DF	-37874E+01	-356375E+01	376453E+01	722222E+00	954083E-04	523244E+00	301000E+02	1
REFIN,XYZFERR,UP,DF	-375843E+01	-369861E+01	368970E+01	722222E+00	617868E-04	523244E+00	301000E+02	48
REFIN,XYZFERR,UP,DF	-418255E+01	-389395E+01	384725E+01	777778E+00	150172E-03	523244E+00	301000E+02	1
REFIN,XYZFERR,UP,DF	-415839E+01	-393282E+01	378787E+01	777778E+00	128443E-03	523244E+00	301000E+02	44
REFIN,XYZFERR,UP,DF	-458267E+01	-422468E+01	392932E+01	833333E+00	213020E-03	523244E+00	301000E+02	1
REFIN,XYZFERR,UP,DF	-455273E+01	-426497E+01	387743E+01	833333E+00	197232E-03	523244E+00	301000E+02	42
REFIN,XYZFERR,UP,DF	-299300E+01	-290341E+01	359925E+01	611111E+00	137382E-03	174415E+00	301000E+02	1
REFIN,XYZFERR,UP,DF	-297533E+01	-292652E+01	347050E+01	629630E+00	715006E-04	174415E+00	301000E+02	109
REFIN,XYZFERR,UP,DF	-312548E+01	-301347E+01	352601E+01	648148E+00	101912E-03	174415E+00	301000E+02	1
REFIN,XYZFERR,UP,DF	-310842E+01	-303694E+01	350322E+01	629630E+00	819672E-04	174415E+00	301000E+02	111
REFIN,XYZFERR,UP,DF	-323192E+01	-314641E+01	355362E+01	648148E+00	306616E-04	174415E+00	301000E+02	101
REFIN,XYZFERR,UP,DF	-339042E+01	-323358E+01	368192E+01	666667E+00	819672E-04	174415E+00	301000E+02	1
REFIN,XYZFERR,UP,DF	-336954E+01	-326989E+01	360417E+01	666667E+00	259237E-04	174415E+00	301000E+02	118
REFIN,XYZFERR,UP,DF	-352289E+01	-334364E+01	370948E+01	685185E+00	7495547E-04	174415E+00	301000E+02	1
REFIN,XYZFERR,UP,DF	-349987E+01	-338192E+01	363402E+01	685185E+00	352779E-04	174415E+00	301000E+02	110
REFIN,XYZFERR,UP,DF	-363020E+01	-349401E+01	373703E+01	703704E+00	468731E-04	174415E+00	301000E+02	111
REFIN,XYZFERR,UP,DF	-37874E+01	-356375E+01	376453E+01	722222E+00	954083E-04	174415E+00	301000E+02	1
REFIN,XYZFERR,UP,DF	-325795E+01	-312352E+01	365436E+01	648148E+00	819672E-04	581382E-01	301000E+02	55
REFIN,XYZFERR,UP,DF	-323569E+01	-316294E+01	356733E+01	648148E+00	293439E-04	581382E-01	301000E+02	45
REFIN,XYZFERR,UP,DF	-330211E+01	-316021E+01	356355E+01	654321E+00	781233E-04	581382E-01	301000E+02	1
REFIN,XYZFERR,UP,DF	-328706E+01	-318806E+01	358800E+01	654321E+00	351481E-04	581382E-01	301000E+02	41
REFIN,XYZFERR,UP,DF	-334266E+01	-319689E+01	367273E+01	660494E+00	754833E-04	581382E-01	301000E+02	1
REFIN,XYZFERR,UP,DF	-332974E+01	-322600E+01	359910E+01	660494E+00	334002E-04	581382E-01	301000E+02	41
REFIN,XYZFERR,UP,DF	-339042E+01	-323358E+01	368192E+01	666667E+00	739412E-04	581382E-01	301000E+02	1
REFIN,XYZFERR,UP,DF	-337266E+01	-326418E+01	360828E+01	666667E+00	327445E-04	581382E-01	301000E+02	42
REFIN,XYZFERR,UP,DF	-343458E+01	-327027E+01	369111E+01	672840E+00	73987E-04	581382E-01	301000E+02	1
REFIN,XYZFERR,UP,DF	-341682E+01	-330088E+01	361747E+01	672840E+00	340776E-04	581382E-01	301000E+02	42
REFIN,XYZFERR,UP,DF	-347873E+01	-330692E+01	370029E+01	679012E+00	737647E-04	581382E-01	301000E+02	1
REFIN,XYZFERR,UP,DF	-352289E+01	-333904E+01	370948E+01	685185E+00	7495547E-04	581382E-01	301000E+02	1
REFIN,XYZFERR,UP,DF	-350366E+01	-337553E+01	363752E+01	685185E+00	381658E-04	581382E-01	301000E+02	42
REFIN,XYZFERR,UP,DF	-334606E+01	-319689E+01	367273E+01	660494E+00	754833E-04	193794E-01	301000E+02	1
REFIN,XYZFERR,UP,DF	-332498E+01	-323381E+01	359081E+01	660494E+00	286215E-04	193794E-01	301000E+02	99
REFIN,XYZFERR,UP,DF	-336098E+01	-324912E+01	367580E+01	662551E+00	748523E-04	193794E-01	301000E+02	1
REFIN,XYZFERR,UP,DF	-333963E+01	-324597E+01	359451E+01	662551E+00	286954E-04	193794E-01	301000E+02	98
REFIN,XYZFERR,UP,DF	-337370E+01	-322135E+01	367886E+01	664609E+00	743395E-04	193794E-01	301000E+02	1
REFIN,XYZFERR,UP,DF	-335933E+01	-325869E+01	359752E+01	664609E+00	285725E-04	193794E-01	301000E+02	99
REFIN,XYZFERR,UP,DF	-339042E+01	-323358E+01	368192E+01	666667E+00	739412E-04	193794E-01	301000E+02	1
REFIN,XYZFERR,UP,DF	-336824E+01	-327142E+01	360063E+01	666667E+00	285623E-04	193794E-01	301000E+02	100
REFIN,XYZFERR,UP,DF	-340314E+01	-324581E+01	364998E+01	668724E+00	730542E-04	193794E-01	301000E+02	1
REFIN,XYZFERR,UP,DF	-338288E+01	-328352E+01	360433E+01	668724E+00	289512E-04	193794E-01	301000E+02	99
REFIN,XYZFERR,UP,DF	-341986E+01	-325800E+01	368804E+01	670782E+00	734742E-04	193794E-01	301000E+02	1
REFIN,XYZFERR,UP,DF	-339718E+01	-329631E+01	360739E+01	670782E+00	291494E-04	193794E-01	301000E+02	100
REFIN,XYZFERR,UP,DF	-344588E+01	-327027E+01	369111E+01	672840E+00	733987E-04	193794E-01	301000E+02	1
REFIN,XYZFERR,UP,DF	-341192E+01	-331023E+01	361586E+01	672840E+00	305367E-04	193794E-01	301000E+02	102

REFIN,XYZFERR,DP,DF	--.337570E+01	--.322135E+01	.367886E+01	.664609E+00	.743395E-04	.645980E-02	.301000E+02	1
REFIN,XYZFERR,DP,DF	--.330058E+01	--.324457E+01	.362996E+01	.664609E+00	.459363E-04	.645980E-03	.301000E+02	40
REFIN,XYZFERR,DP,DF	--.338061E+01	--.322543E+01	.367988E+01	.665295E+00	.741942E-04	.645980E-02	.301000E+02	1
REFIN,XYZFERR,DP,DF	--.337123E+01	--.324843E+01	.363310E+01	.665295E+00	.459637E-04	.645980E-03	.301000E+02	39
REFIN,XYZFERR,DP,DF	--.338551E+01	--.322950E+01	.368109E+01	.665981E+00	.740615E-04	.645980E-02	.301000E+02	1
REFIN,XYZFERR,DP,DF	--.337613E+01	--.325251E+01	.363412E+01	.665981E+00	.460005E-04	.645980E-03	.301000E+02	39
REFIN,XYZFERR,DP,DF	--.339042E+01	--.323358E+01	.368192E+01	.666667E+00	.739412E-04	.645980E-02	.301000E+02	1
REFIN,XYZFERR,DP,DF	--.338104E+01	--.325658E+01	.363514E+01	.666667E+00	.460490E-04	.645980E-03	.301000E+02	39
REFIN,XYZFERR,DP,DF	--.339533E+01	--.323766E+01	.368294E+01	.667353E+00	.738833E-04	.645980E-02	.301000E+02	1
REFIN,XYZFERR,DP,DF	--.338959E+01	--.326066E+01	.363616E+01	.667353E+00	.461092E-04	.645980E-03	.301000E+02	39
REFIN,XYZFERR,DP,DF	--.340023E+01	--.32473E+01	.368336E+01	.668038E+00	.737376E-04	.645980E-02	.301000E+02	1
REFIN,XYZFERR,DP,DF	--.339085E+01	--.326473E+01	.363718E+01	.668038E+00	.461809E-04	.645980E-03	.301000E+02	39
REFIN,XYZFERR,DP,DF	--.340514E+01	--.324581E+01	.368498E+01	.668724E+00	.736545E-04	.645980E-02	.301000E+02	1
REFIN,XYZFERR,DP,DF	--.339576E+01	--.326881E+01	.363820E+01	.668724E+00	.462641E-04	.645980E-03	.301000E+02	39
NEW POSITION	--.336763E+01	--.326210E+01	.357316E+01	.666667E+00	.268528E-04			
SERCH	.705517E+00	.576095E+00	--.286528E+00	.666667E+00				
SERCH	--.336763E+01	--.326210E+01	.357316E+01	.666667E+00	.645135E+00			
--.290601E+00	--.236612E+01	.221354E+01	.799274E-02					
X,Y,Z,F,AZ,EL,TILT	--.336763E+01	--.326210E+01	.357316E+01	.666667E+00	.645135E+00	--.290601E+00	--.236612E+01	
LNKORBITER.	.53967E-02							
DANG	.675135E+00	--.290601E+00	--.236612E+01	.142770E+00	.300000E-01	.100000E+01	1	
DANG	.615135E+00	--.290601E+00	--.236612E+01	.137032E+00	.300000E-01	--.100000E+01	1	
DANG	.645135E+00	--.260601E+00	--.236612E+01	.151804E+00	.300000E-01	.100000E+01	2	
DANG	.645135E+00	--.290601E+00	--.236612E+01	.542399E-01	.300000E-01	.100000E+01	3	
DANG	.648135E+00	--.290601E+00	--.236612E+01	.439179E-01	.300000E-01	--.100000E+01	3	
DANG	.642135E+00	--.290601E+00	--.236612E+01	.129730E-01	.300000E-02	--.100000E+01	1	
DANG	.645135E+00	--.287601E+00	--.236612E+01	.174169E-01	.300000E-02	--.100000E+01	2	
DANG	.645135E+00	--.293601E+00	--.236612E+01	.160607E-01	.300000E-02	--.100000E+01	3	
DANG	.645135E+00	--.290601E+00	--.236312E+01	.102064E-01	.300000E-02	.100000E+01	3	
DANG	.645135E+00	--.290601E+00	--.236912E+01	.484586E-02	.300000E-02	--.100000E+01	3	
DANG	.645135E+00	--.290601E+00	--.237212E+01	.790717E-02	.300000E-02	--.100000E+01	3	
DANG	.644835E+00	--.290601E+00	--.236912E+01	.550630E-02	.300000E-03	.100000E+01	1	
DANG	.645135E+00	--.290601E+00	--.236912E+01	.486589E-02	.300000E-03	--.100000E+01	1	
DANG	.645135E+00	--.290601E+00	--.236912E+01	.513745E-02	.300000E-03	.100000E+01	2	
DANG	.645135E+00	--.290601E+00	--.236912E+01	.510764E-02	.300000E-03	--.100000E+01	2	
DANG	.645135E+00	--.290601E+00	--.236882E+01	.474646E-02	.300000E-03	.100000E+01	3	
DANG	.645135E+00	--.290601E+00	--.236882E+01	.470477E-02	.300000E-03	.100000E+01	3	
DANG	.645135E+00	--.290601E+00	--.236792E+01	.469564E-02	.300000E-03	.100000E+01	3	
DANG	.645165E+00	--.290601E+00	--.236882E+01	.470477E-02	.300000E-03	--.100000E+01	3	
DANG	.645105E+00	--.290601E+00	--.236822E+01	.463811E-02	.300000E-04	.100000E+01	1	
DANG	.645075E+00	--.290601E+00	--.236822E+01	.458907E-02	.300000E-04	--.100000E+01	1	
DANG	.645045E+00	--.290601E+00	--.236822E+01	.454415E-02	.300000E-04	.100000E+01	1	
DANG	.645015E+00	--.290601E+00	--.236822E+01	.450367E-02	.300000E-04	--.100000E+01	1	
DANG	.644985E+00	--.290601E+00	--.236822E+01	.446817E-02	.300000E-04	.100000E+01	1	
DANG	.644955E+00	--.290601E+00	--.236822E+01	.443865E-02	.300000E-04	--.100000E+01	1	
DANG	.644925E+00	--.290601E+00	--.236822E+01	.441708E-02	.300000E-04	.100000E+01	1	

APPENDIX F
PROGRAM SLED AND TYPICAL
LISTING OF SOLUTIONS

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PROGRAM SLED (INPUT, OUTPUT, PUNCH, TAPE5=INPUT, TAPE6=OUTPUT,
1 TAPE7=PUNCH)
COMMON KAA, RAB, KAC, FA, THA, PHA, GA, RBA, RBB, RBC, FB, THB, PHB,
1GB, THIA, PHIA, THIB, PHIB
DIMENSION NFKA(150), NFRB(150), XA(150,8), YA(150,8), XB(150,8),
1YB(150,8), TA(150), TB(120), XX(10), YY(10), ZZ(10), TRFA(10),
2TRFB(10), NREFA(10), NREFB(10), SMEAN(8), SDEV(8)
1 READ(2,2) RAA, KAB, KAC, FA, THA, PHA, GA, THIA, PHIA
1 IF(CHK=0) GO TO 399
NCHK=NCHK+1
READ(2,2) RBA, KBB, RBC, FB, THB, PHB, GB, THIB, PHIB
FORMAT(4F10.0/5F10.0)
NA=J
NB=J
NA=NA+1
NFKA(NA), ((XA(NA,I), YA(NA,I)), I=1,8)
READ(2,4) NFKA(NA), ((XA(NA,I), YA(NA,I)), I=1,8)
FORMAT(15,8F7.0/5X,8F7.0)
IF(NFKA(NA).NE.99999) GO TO 3
NA=NA-1
DO 100 I=1,NA
DO 100 J=1,8
XA(I,J)=-XA(I,J)/12000.0
YA(I,J)=YA(I,J)/12000.0
NB=NB+1
READ(2,4) NFRB(NB), ((XB(NB,I), YB(NB,I)), I=1,8)
IF(NFRB(NB).NE.99999) GO TO 5
NB=NB-1
DO 101 I=1,NB
DO 101 J=1,8
XB(I,J)=-XB(I,J)/12000.0
YB(I,J)=YB(I,J)/12000.0
NHP=NHP+1
READ(2,7) XX(NHP), YY(NHP), ZZ(NHP)
FORMAT(3F10.0)
IF(XX(NHP).LT.99999.0) GO TO 6
NHP=NHP-1
WRITE(6,6) KAA, RAB, RAC, FA, THA, PHA, GA, THIA, PHIA

```

```

WRITE (6,8) KBA,KBX,KBZ,FB,THB,PHB,GU,TH1B,PH1B
FORMAT (12H CAMERA DATA/9E13.6)
DO 9 I=1,NHP
WRITE (6,10) XX(I),YY(I),ZZ(I)
FORMAT (16H HAKO PI LOCATIONS,3E13.6)
CONTINUE
NTMA=J
NTMA=NTMA+1
READ (5,12) TREFB(NTMA),NREFA(NTMA)
FORMAT (F10.0,16)
IF (NREFA(NTMA).LT.99999) GO TO 11
NTMA=NTMA-1
NTMB=J
NTMB=NTMB+1
READ (5,12) TREFB(NTMB),NREFB(NTMB)
IF (NREFB(NTMB).LT.99999) GO TO 13
NTMB=NTMB-1
DO 14 I=1,NTMA
WRITE (6,15) TREFB(I),NREFA(I),NTMA
FORMAT (20H REF TIMES&FRAME NOS,c13.0,215)
CONTINUE
DO 16 I=1,NTMB
WRITE (6,15) TREFB(I),NREFB(I),NTMB
CONTINUE
CALL TMSGN(NTMA,NA,NREFA,TREFA,NFRA,IA)
CALL TMSGN(NTMB,NB,NREFB,TREFB,NFRB,IB)
DO 17 I=1,NA
WRITE (6,18) I,NFRA(I),IA(I),((XA(I,J),YA(I,J)),J=1,8)
FORMAT (2I0,E13.6/8E13.6)
CONTINUE
DO 19 I=1,NB
WRITE (6,18) I,NFRB(I),IB(I),((XB(I,J),YB(I,J)),J=1,8)
CONTINUE
READ (7,20) DT,DESIG
FORMAT (2F10.0)
WRITE (6,21) DT
FORMAT (15H TIME INCREMENT,E13.6)
CALL ALL(CNA,NB,IA,TB,NFRA,NFRB,XA,YA,XB,YB,SMEAN,SSDEV,
10I,XX,YY,ZZ,DESIG,NCHK)
GO TO 1
WRITE (6,1000)
FORMAT (16H NORMAL COMPLETION)
STOP
END

```

```

1
1000
BOT = SIN(TH)
AA = SIN(TH) / BOT
BB = SIN(THS) / BOT
TF = AA * RF + BB * SF
TI = AA * RI + BB * SI
IJ = AA * KJ + BB * SJ
TIM = SQR(TF**2 + TI**2 + IJ**2)
XK = F / TF
P = XK * TI
Q = XK * IJ
GO TO 1000
P = PPA
Q = QQA
RETURN
END
SUBROUTINE SOLVE(PA,QA,PB,QB,NT,SOLA,SOLB,SOLC,D,J,NCHK,NTR)
COMMON KAA,RAB,KAC,FA,THA,PHI,PHIB,PHIC
IF (NCHK .GT. 0) GO TO 1
IF (NCHK .EQ. 0) GO TO 2
THA = THAP
PHI = PHIAP
PHIB = PHIAP
PHIC = PHIAP
GA = GAP
GB = GBP
FAA = FA * COS(THA) * COS(PHA)
FAB = FA * SIN(THA) * COS(PHA)
FAC = FA * SIN(PHA) * COS(PHA)
FBA = FB * COS(THB) * COS(PHB)
FBC = FB * SIN(THB) * COS(PHB)
FAAB = ABS(FA)
FBAAB = ABS(FB)
CHKA = (FAA * FBA + FAB * FAC * FBC) / (FAAB * FBAAB)
IF (CHKA .GT. 1.0) CHKA = 1.0
IF (CHKA .LT. -1.0) CHKA = -1.0
CHAN = ACOS(CHKA)
IF (CHAN .LT. 1.57079) GO TO 101
WRITE(6,102) FA,THA,PHA,FB,THB,PHB,CHAN

```

```

SUBROUTINE TMSGN(NTM,N,NKREF,TREF,NFR,I)
DIMENSION NREF(1J),TREF(1U),NFR(15U),T(15U)
NST=NTM-1
DO 2 J=1,NST
K=J+1
DO 4 L=1,N
IF (NFR(L) .NE. NREF(K)) GO TO 4
M=L
GO TO 7
CONTINUE
4 IF (J.EQ. 1) NB=1
7 IF (K.EQ.NTM) GO TO 3
NE=M
GO TO 6
NE=N
DNU=TREF(K)-TREF(J)
DEN=NREF(K)-NREF(J)
DO 5 I=NB,NE,1
FAC=M-I
I(I)=TREF(K)-FAC*FAC
5 IF (NE.EQ.N) GO TO 1000
NB=NE
CONTINUE
RETURN
END
SUBROUTINE FIND(F,PPA,QQA,PPB,QQB,TS,TAS,TBS,P,Q)
R=ABS(PPA-PPB)
S=ABS(QQA-QQB)
IF (R.LT.0.000001).AND.(S.LT.0.000001) GO TO 1
WRITE(6,100)TAS,PPA,QQA,PPB,QQB,TS
FORMAT(5H,FINU,6E13.6)
R=SQRT(F**2+PPA**2+QQA**2)
S=SQRT(F**2+PPB**2+QQB**2)
RF=F/R
RI=PPA/R
KJ=QQA/K
SF=F/S
SI=PPB/S
SJ=QQB/S
ARGU=SQRT((RI*SJ-RJ*SI)**2+(RJ*SF-RF*SJ)**2+(RF*SI-RI*SF)**2)
TH=ASIN(ARGU)
IHS=(TS-TAS)*TH/(TBS-TAS)
THI=TH-THS

```


102 FORMAT (35H BAU CAMERA DATA PROBABLE SEE SOLVE/7E13.6)

```

101 CONTINUE
AIA=COS(THIA)*COS(PHIA)
AIB=SIN(THIA)*COS(PHIA)
AIC=SIN(THIB)*COS(PHIB)
BIB=SIN(THIB)*COS(PHIB)
BIC=SIN(PHIB)
AJA=(FAB*AIC-FAC*AIB)/FA
AJB=(FAC*AIB-FAA*AIC)/FA
AJC=(FAA*AIB-FAB*AIA)/FA
BJB=(FBC*BIA-FBA*BIB)/FB
BJC=(FBA*BIB-FBB*BIA)/FB
SAA=FAA+PA+AIA+QA+PB, QB, SOLA, SOLB, SOLC, NT
WRITE(6,105) PA, QA, PB, QB, SOLA, SOLB, SOLC, NT
FORMAT(6H SOLVE,7E13.6,15)
SAB=FAB+PA+AIB+QA+AJB
SAC=FAC+PA+AIC+QA+AJC
SDB=FBA+PB+BIB+QB+BJB
SDA=FBC+PB+BIA+QB+BJC
DSA=SQR(SAA**2+SAB**2+SAC**2)
DSB=SQR(SBA**2+SBB**2+SBC**2)
SAA=SAA/DSA
SAB=SAB/DSA
SBA=SBA/DSB
SBB=SBB/DSB
SBC=SBC/DSB
CHKA=SAA*SBA+SAB*SBB+SAC*SBC
IF(CHKA.GT.1.0) CHKA=1.0
IF(CHKA.LT.-1.0) CHKA=-1.0
CHAN=ACOS(CHKA)
IF(CHAN.LT.1.57079) GO TO 103
WRITE(6,104) PA, QA, PB, QB, CHAN
FORMAT(39H BAD FILM FRAME DATA PROBABLE SEE SOLVE,5E13.6)
103 CONTINUE
RNA=SAC*SBB+SBC*SAB-SAA*SBB
RNB=SAC*SBA-SAA*SBC
RNC=SAA*SBB-SAB*SBA
DRN=SQR(RNA**2+RNB**2+RNC**2)
RNB=RNB/DRN

```

UBF=SQRT (TBF (1) **2+TBF (2) **2+TBF (3) **2)
USAF=SQRT (SAE (1) **2+SAE (2) **2+SAE (3) **2)
DSBE=SQRT (SBE (1) **2+SBE (2) **2+SBE (3) **2)
DSBF=SQRT (SBF (1) **2+SBF (2) **2+SBF (3) **2)
DO 8 I=1,3
TAE (I)=TAE (I)/DTAE
TAF (I)=TAF (I)/DTAF
TBE (I)=TBE (I)/DTBE
TBF (I)=TBF (I)/DTBF
SAE (I)=SAE (I)/DSAE
SBE (I)=SBE (I)/DSBE
SBF (I)=SBF (I)/DSBF

8

CONTINUE

DO 9 I=1,3
TAG (I)=TAE (I)+TAF (I)
TBG (I)=TBE (I)+TBF (I)
SAG (I)=SAE (I)+SAF (I)
SBG (I)=SBE (I)+SBF (I)
CONTINUE
DTAG=SQRT (TAG (1) **2+TAG (2) **2+TAG (3) **2)
DTBG=SQRT (TBG (1) **2+TBG (2) **2+TBG (3) **2)
DSAG=SQRT (SAG (1) **2+SAG (2) **2+SAG (3) **2)
DSBG=SQRT (SBG (1) **2+SBG (2) **2+SBG (3) **2)
DO 6 I=1,3
TAG (I)=TAG (I)/DTAG
TBG (I)=TBG (I)/DTBG
SAG (I)=SAG (I)/DSAG
SBG (I)=SBG (I)/DSBG

9

6

CONTINUE

TAH (1)=TAE (1)+TAF (1)
TBH (1)=TBE (1)+TBF (1)
SAH (1)=SAE (1)+SAF (1)
SBH (1)=SBE (1)+SBF (1)
TAH (2)=TAE (2)+TAF (2)
TBH (2)=TBE (2)+TBF (2)
SAH (2)=SAE (2)+SAF (2)
SBH (2)=SBE (2)+SBF (2)
TAH (3)=TAE (3)+TAF (3)
TBH (3)=TBE (3)+TBF (3)
SAH (3)=SAE (3)+SAF (3)
SBH (3)=SBE (3)+SBF (3)

```

1 K=J-4
  I(1,K)=SOLA
  I(2,K)=SOLC
  I(3,K)=SOLD
  SA(1,K)=SAAA
  SA(2,K)=SAB
  SA(3,K)=SAC
  SB(1,K)=SBA
  SB(2,K)=SBB
  SB(3,K)=SBC
  DER(K)=0
  IF (K.LT.4) GO TO 1000
  DO 2 I=1,4
  IF (DERK(I).GT.0.75) GO TO 1000
2 CONTINUE
  NTR=NTR+1
  DO 3 I=1,4
  IA(1,I)=I(1,I)-RAA
  IA(2,I)=I(2,I)-RAB
  IA(3,I)=I(3,I)-RBA
  IB(1,I)=I(1,I)-RBB
  IB(2,I)=I(2,I)-RBC
  IB(3,I)=I(3,I)-KBC
  UAM=SQRT(IA(1,I)**2+IA(2,I)**2+IA(3,I)**2)
  DBM=SQRT(IB(1,I)**2+IB(2,I)**2+IB(3,I)**2)
  IA(1,I)=IA(1,I)/OAM
  IA(2,I)=IA(2,I)/OAM
  IA(3,I)=IA(3,I)/OAM
  IB(1,I)=IB(1,I)/DBM
  IB(2,I)=IB(2,I)/DBM
  IB(3,I)=IB(3,I)/DBM
3 CONTINUE
  DO 4 I=1,3
  IAF(I)=IA(I,1)+IA(I,2)+IA(I,3)
  TBE(I)=IB(I,1)+IB(I,2)+IB(I,3)
  SAE(I)=SA(I,1)+SA(I,2)+SA(I,3)
  SBE(I)=SB(I,1)+SB(I,2)+SB(I,3)
4 CONTINUE
  DIAE=SQRT(IAE(1)**2+IAE(2)**2+IAE(3)**2)
  DTBE=SQRT(TBE(1)**2+TBE(2)**2+TBE(3)**2)

```

BIGG=3IA*SBG(1)+BIB*SBG(2)+BIC*SBG(3)
 BII=3IA*SBH(1)+BIB*SBH(2)+BIC*SBH(3)
 BIH=3IA*SBG(1)+BIB*SBG(2)+BIC*SBG(3)
 BJG=3JA*SBH(1)+BIB*SBH(2)+BIC*SBH(3)
 BJI=3JA*SBH(1)+BIB*SBH(2)+BIC*SBH(3)
 BJH=3JA*SBG(1)+BIB*SBG(2)+BIC*SBG(3)
 FBX=FBGG*IBG(1)+FBII*IBI(1)+FBHH*IBH(1)
 FBY=FBGG*IBG(2)+FBII*IBI(2)+FBHH*IBH(2)
 FBZ=FBGG*IBG(3)+FBII*IBI(3)+FBHH*IBH(3)
 BIX=3IGG*IBG(1)+BIII*IBI(1)+BIHH*IBH(1)
 BIY=3IGG*IBG(2)+BIII*IBI(2)+BIHH*IBH(2)
 BIZ=3IGG*IBG(3)+BIII*IBI(3)+BIHH*IBH(3)
 BJX=3JGG*IBG(1)+BJII*IBI(1)+BJHH*IBH(1)
 BJI=3JGG*IBG(2)+BJII*IBI(2)+BJHH*IBH(2)
 BJZ=3JGG*IBG(3)+BJII*IBI(3)+BJHH*IBH(3)
 THB=ACOS(FBXX/SQRT(FBXX**2+FBYY**2))
 IF (FBYY .LT. 0.0) THB=-THB
 PHBP=ASIN(FBZZ)
 THAP=ACOS(FAXX/SQRT(FAXX**2+FAYY**2))
 IF (FAYY .LT. 0.0) THAP=-THAP
 PHAP=ASIN(FAXX**2+FAYY**2)
 DFA=SQRT(FAXX/DFA)
 FAHY=FAHX/DFA
 GAP=ACOS(AIXX*FAHX+AIYY*FAHY)
 IF (AIZZ .LT. 0.0) GAP=-GAP
 DFB=SQRT(FBXX/DFB)
 FBHY=FBXX/DFB
 GBP=ACOS(BIXX*FBHX+BIYY*FBHY)
 IF (BIZZ .LT. 0.0) GBP=-GBP
 SPHAP=STHAP+PHAP
 SGAP=SGAP+GAP
 STHBP=STHBP+THBP
 SPHBP=SPHBP+PHBP
 SGBP=SGBP+GBP
 XNTR=NTR
 THAP=STHAP/XNTR
 PHAP=SPHAP/XNTR
 GAP=SGAP/XNTR
 THBP=STHBP/XNTR
 PHBP=SPHBP/XNTR
 GBP=SGBP/XNTR
 FAXX=COS(THAP)*COS(PHAP)

DIAH=SQRT(TAH(1)) **2+TAH(2) **2+TAH(3) **2
 DTBH=SQRT(TBH(1)) **2+TBH(2) **2+TBH(3) **2
 DSAH=SQRT(SAH(1)) **2+SAH(2) **2+SAH(3) **2
 DSBH=SQRT(SBH(1)) **2+SBH(2) **2+SBH(3) **2
 DO 7 I=1,TAH(I)/DIAH
 TBH(I)=TBH(I)/DTBH
 SAH(I)=SAH(I)/DSAH
 SBH(I)=SBH(I)/DSBH
 CONTINUE
 TAI(1)=TAH(2) *TAG(3) -TAH(3) *TAG(2) TAG(2)
 TAI(2)=TAH(3) *TAG(1) -TAH(1) *TAG(3) TAG(3)
 TAI(3)=TAH(1) *TAG(2) -TAH(2) *TAG(1) TAG(1)
 TBI(1)=TBH(2) *TBG(3) -TBH(3) *TBG(2) TBG(2)
 TBI(2)=TBH(3) *TBG(1) -TBH(1) *TBG(3) TBG(3)
 TBI(3)=TBH(1) *TBG(2) -TBH(2) *TBG(1) TBG(1)
 SAI(1)=SAH(2) *SAG(3) -SAH(3) *SAG(2) SAG(2)
 SAI(2)=SAH(3) *SAG(1) -SAH(1) *SAG(3) SAG(3)
 SAI(3)=SAH(1) *SAG(2) -SAH(2) *SAG(1) SAG(1)
 SBI(1)=SBH(2) *SBG(3) -SBH(3) *SBG(2) SBG(2)
 SBI(2)=SBH(3) *SBG(1) -SBH(1) *SBG(3) SBG(3)
 SBI(3)=SBH(1) *SBG(2) -SBH(2) *SBG(1) SBG(1)
 FAJG=FAE *SAI(1) +FAN *SAG(2) +FAH *SAG(3)
 FAIH=FAE *SAI(2) +FAN *SAG(3) +FAH *SAI(3)
 FAGG=FAE *SAG(1) +AIB *SAG(2) +AIC *SAG(3)
 AIIL=AI A *SAI(1) +AIB *SAI(2) +AIC *SAI(3)
 AIHG=AI A *SAH(1) +AIB *SAH(2) +AIC *SAH(3)
 AJJI=AJA *SAI(1) +AJB *SAI(2) +AJC *SAI(3)
 AJJH=AJA *SAH(1) +AJB *SAH(2) +AJC *SAH(3)
 FAXX=FAJG *TAG(1) +FAII *TAI(1) +FAHH *TAH(2)
 FAYY=FAJG *TAG(2) +FAII *TAI(2) +FAHH *TAH(3)
 FAZZ=FAJG *TAG(3) +FAII *TAI(3) +FAHH *TAH(1)
 AIYX=AIIGG *TAG(1) +AIII *TAI(1) +AIHH *TAH(2)
 ALZZ=AIIGG *TAG(2) +AIII *TAI(2) +AIHH *TAH(3)
 AJYX=AJJGG *TAG(1) +AJJII *TAI(1) +AJJH *TAH(2)
 AJZZ=AJJGG *TAG(2) +AJJII *TAI(2) +AJJH *TAH(3)
 FBGG=FB E *SBI(1) +FBN *SBG(2) +FBBH *SBH(3)
 FBII=FB E *SBI(2) +FBN *SBG(3) +FBBH *SBH(1)
 FBBH=FB E *SBI(3) +FBN *SBG(1) +FBBH *SBH(2)

7

```

2, IIM(150), X(150,4), Y(150,4), Z(150,4), DD(150,4)
9 NTR=-1
TS=AMAX1(TA(1),TB(1))
N=IS/DT
XN=XN+DT
NTE=SP=0
NAS=1
DO 8 J=1,8
SMEAN(J)=0.0
SSDEV(J)=0.0
TS=IS+DT
IF(TS.GT.AMAX1(TA(1),TB(1))) GO TO 2
GO TO 1
IF(TS.GT.AMIN1(TA(NA),TB(NB))) GO TO 1000
DO 3 I=NAS,NA+1
IF(TS.GE.TA(I)) GO TO 3
GO TO 4
CONTINUE
NAS=I-1
DO 5 I=NBS,NB,1
IF(TS.GE.TB(I)) GO TO 5
GO TO 6
CONTINUE
NBS=I-1
DO 7 J=5,8,1
PPA=XA(NAS,J)
QQA=YA(NAS,J)
PPB=XA(NAS+1,J)
QQB=YA(NAS+1,J)
TAS=TA(NAS)
TBS=TB(NAS+1)
CALL FIND(FA,PPA,PPB,QQB,TS,TAS,TBS,P,Q)
PA=P
QA=Q
PPA=XB(NBS,J)
QQA=YB(NBS,J)
PPB=XB(NBS+1,J)
QQB=YB(NBS+1,J)
TAS=TB(NBS)
TBS=TB(NBS+1)
CALL FIND(FB,PPA,PPB,QQB,TS,TAS,TBS,P,Q)

```

8 1
2
3 4
5 6

```

FAYY=SIN(THAP)*COS(PHAP)
FAZZ=SIN(PHAP)
FBXX=COS(THBP)*COS(PHBP)
FBYY=SIN(THBP)*COS(PHBP)
FBZZ=SIN(PHBP)
DFA=SQRT(FAXX**2+FAYY**2)
FAHX=-FAYY/DFA
FAHY=FAXX/DFA
FAVX=-FAHY*FAZZ
FAVY=FAHX*FAZZ
FAVZ=FAHY*FAHX-FAHX*FAYY
COGAP=COS(GAP)
SIGAP=SIN(GAP)
AIXX=COGAP*FAHX+SIGAP*FAVX
AIYY=COGAP*FAHY+SIGAP*FAVY
AIZZ=SIGAP*FAVZ
THIAP=ACOS(AIXX/SQRT(AIXX**2+AIYY**2))
IF (AIYY.LT.0.0) THIAP=-THIAP
PHIAP=ASIN(AIZZ)
DFB=SQRT(FBXX**2+FBYY**2+FBZZ**2)
FBHY=FBXX/DFB
FBVX=-FBHY*FBZZ
FBVY=FBHY*FBZZ
FBVZ=FBHY*FBXX-FBHX*FBYY
COGBP=COS(GBP)
SIGBP=SIN(GBP)
BIXX=COGBP*FBHX+SIGBP*FBVX
BIYY=COGBP*FBHY+SIGBP*FBVY
BIZZ=SIGBP*FBVZ
THIBP=ACOS(BIXX/SQRT(BIXX**2+BIYY**2))
IF (BIYY.LT.0.0) THIBP=-THIBP
PHIBP=ASIN(BIZZ)
WRITE(6,999)THAP,PHAP,THIAP,PHIAP,GAP,THBP,
1PHBP,THIBP,PHIBP,GBP
999 FORMAT(5H CORR,5E13.6/5X,5E13.6)
1000 RETURN
END
SUBROUTINE ALL(NA,NB,IA,IB,NFRA,NFRB,XA,YA,XB,YB,SMEAN,
1SDEV,DI,XX,YY,ZZ,DESIG,NCHK)
COMMON RAA,RAB,KAC,FA,THA,PHA,GA,RBA,RBB,RBC,FB,THB,PHB,
1GB,THIA,PHIA,THIB,PHIB
DIMENSION TA(150),TB(120),NFRA(150),NFRB(150),XA(150,8),YA(150,8),
1XB(15),YB,YSDEV(8),XSDEV(8),SSDEV(8),XX(IJ),YY(IJ),ZZ(IJ)

```

```

PB=P
QB=Q
NT=NT+1
CALL SOLVE(PA,QA,PB,QB,NT,SOLA,SOLB,SOLC,D,J,NCHK,NTR)
IF (J.NE.5) GO TO 15
NTESP=NTESP+1
TIM(NTESP)=TS
15 ID=J-+
X(NTESP, ID)=SOLA*12.0
Y(NTESP, ID)=SOLB*12.0
Z(NTESP, ID)=SOLC*12.0
D=ABS(D)
DU(NTESP, ID)=D*12.0
SMEAN(J)=SMEAN(J)+D
SSDEV(J)=SSDEV(J)+D**2
CONTINUE
GO TO 1
7
1000 XN=NTESP
DO 10 J=1, 8
ARGA=SMEAN(J)**2/XN
SSDEV(J)=(SSDEV(J)-ARGA)/(XN-1.0)
SSDEV(J)=SQRT(SSDEV(J))*12.0
SMEAN(J)=SMEAN(J)+12.0/XN
WRITE(6,11) NTESP, J, SMEAN(J), SSDEV(J)
11 10 FORMAT(25H NO OF PTS,PT NO,MEAN,DEV,2I5,2E13.6)
CONTINUE
DO 12 J=5,7,2
K=J+1
IO=J-4
JD=J-3
00 12 I=1, NTESP
DIS=SQRT((X(I,JD)-X(I,IO))**2+(Y(I,JD)-Y(I,IO))**2+(Z(I,JD)-
1Z(I,IO))**2)
WRITE(6,14) IM(I), X(I,IO), Y(I,IO), Z(I,IO), X(I,JD), Y(I,JD),
1Z(I,JD), DESIG, J, K, DIS, DU(I,IO), DU(I,JD)
WRITE(7,13) IM(I), X(I,IO), Y(I,IO), Z(I,IO), X(I,JD), Y(I,JD),
1Z(I,JD), DESIG, J, K
14 FORMAT(F5.3,6F6.2,5H KUN ,F5.0,5H PTS ,I2,5H AND ,I2,3E13.6)
13 FORMAT(F5.3,6F6.2,5H KUN ,F5.0,5H PTS ,I2,5H AND ,I2}
12 CONTINUE
IF (NCHK .GT. 0) GO TO 1001
NCHK=1
GO TO 9
1001 RETURN
END
" "
" "

```

GAMES DATA
 --.346011E+01 .518633E+01 .37772E+01 .56667E+00 -.68555E+00 -.31127E+00 -.41318E-01 .74504E+00 .352092E-01
 GAMES DATA
 --.33754E+01 .50167E+01 .37636E+01 .67250E+00 .57603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01
 HARD PT LOCATIONS 37603E+01 .14395E+00 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01
 HARD PT LOCATIONS 50167E+01 .32554E+00 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01
 HARD PT LOCATIONS 36100E+01 .38005E+00 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01
 HARD PT LOCATIONS 59000E-01 .49713E+01 .46667E+00 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01
 HARD PT LOCATIONS 73300E-01 .59330E+00 .64533E+00 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01
 HARD PT LOCATIONS 57500E-01 .59167E+00 .65667E+00 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01
 HARD PT LOCATIONS 75800E-01 .10627E+00 .50750E+00 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01
 HARD PT LOCATIONS 75000E-02 0 .21573E+00 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01 .37603E+01
 REF TIME\$NAME NOS 14186E+00 112 2
 REF TIME\$NAME NOS 20813E+00 112 2
 REF TIME\$NAME NOS 14661E+00 103 2
 REF TIME\$NAME NOS 118614E+00 103 2
 1 00 .14186E+00
 .15333E+00 .21573E+00 .11567E-01 .21875E+00 -.10108E+00 -.21866E+00 -.25741E+00 -.19666E+00
 .73250E-01 .13983E+00 .87750E-01 .12733E+00 -.15316E+00 .13750E+00 -.11900E+00 .63833E-01
 2 01 .14395E+00
 .15375E+00 .21316E+00 .11567E-01 .21875E+00 -.10108E+00 -.21866E+00 -.25741E+00 -.19666E+00
 .71333E-01 .13647E+00 .85667E-01 .12550E+00 -.15575E+00 .12350E+00 -.11869E+00 .60500E-01
 3 02 .14600E+00
 .15383E+00 .21247E+00 .11567E-01 .21875E+00 -.10108E+00 -.21866E+00 -.25741E+00 -.19666E+00
 .69667E-01 .13463E+00 .84167E-01 .12415E+00 -.15741E+00 .12366E+00 -.11865E+00 .76750E-01
 4 03 .14807E+00
 .15321E+00 .21191E+00 .11567E-01 .21875E+00 -.10108E+00 -.21866E+00 -.25741E+00 -.19666E+00
 .66250E-01 .13225E+00 .83583E-01 .12283E+00 -.15675E+00 .11966E+00 -.11825E+00 .74666E-01
 5 04 .15014E+00
 .15366E+00 .21167E+00 .11567E-01 .21875E+00 -.10108E+00 -.21866E+00 -.25741E+00 -.19666E+00
 .63916E-01 .13225E+00 .83583E-01 .12283E+00 -.15675E+00 .11966E+00 -.11825E+00 .74666E-01
 6 05 .15221E+00
 .15333E+00 .21447E+00 .11567E-01 .21875E+00 -.10108E+00 -.21866E+00 -.25741E+00 -.19666E+00
 .61250E-01 .12826E+00 .83167E-01 .12103E+00 -.16031E+00 .11675E+00 -.11370E+00 .73833E-01
 7 06 .15429E+00
 .15250E+00 .21583E+00 .11567E-01 .21875E+00 -.10108E+00 -.21866E+00 -.25741E+00 -.19666E+00
 .59357E-01 .12417E+00 .82500E-01 .11931E+00 -.16275E+00 .11325E+00 -.11365E+00 .71516E-01
 8 07 .15636E+00
 .15150E+00 .21683E+00 .11567E-01 .21875E+00 -.10108E+00 -.21866E+00 -.25741E+00 -.19666E+00
 .57457E-01 .12179E+00 .81833E-01 .11779E+00 -.16400E+00 .11091E+00 -.11345E+00 .69833E-01
 9 08 .15843E+00
 .15083E+00 .21891E+00 .11567E-01 .21875E+00 -.10108E+00 -.21866E+00 -.25741E+00 -.19666E+00
 .55700E-01 .12167E+00 .81416E-01 .11667E+00 -.16458E+00 .10891E+00 -.11345E+00 .68167E+00
 10 09 .16050E+00
 .15075E+00 .21550E+00 .11567E-01 .21875E+00 -.10108E+00 -.21866E+00 -.25741E+00 -.19666E+00
 .53917E-01 .12033E+00 .80933E-01 .11533E+00 -.16425E+00 .10691E+00 -.11345E+00 .66500E-01
 11 90 .16257E+00
 .15181E+00 .21705E+00 .11567E-01 .21875E+00 -.10108E+00 -.21866E+00 -.25741E+00 -.19666E+00
 .52167E-01 .11908E+00 .80416E-01 .11416E+00 -.16347E+00 .10591E+00 -.11345E+00 .64833E-01
 12 91 .16464E+00
 .15133E+00 .21725E+00 .11567E-01 .21875E+00 -.10108E+00 -.21866E+00 -.25741E+00 -.19666E+00
 .50416E-01 .11804E+00 .80000E-01 .11300E+00 -.16263E+00 .10491E+00 -.11345E+00 .63167E+00
 13 92 .16671E+00
 .15258E+00 .21617E+00 .11567E-01 .21875E+00 -.10108E+00 -.21866E+00 -.25741E+00 -.19666E+00
 .48750E-01 .11700E+00 .79583E-01 .11183E+00 -.16181E+00 .10391E+00 -.11345E+00 .61500E-01
 14 93 .16878E+00
 .15253E+00 .21500E+00 .11567E-01 .21875E+00 -.10108E+00 -.21866E+00 -.25741E+00 -.19666E+00
 .47083E-01 .11600E+00 .79167E-01 .11067E+00 -.16067E+00 .10291E+00 -.11345E+00 .59833E-01
 15 94 .17085E+00
 .15225E+00 .21450E+00 .11567E-01 .21875E+00 -.10108E+00 -.21866E+00 -.25741E+00 -.19666E+00
 .45416E-01 .11500E+00 .78750E-01 .10950E+00 -.15950E+00 .10191E+00 -.11345E+00 .58167E+00
 16 95 .17292E+00
 .15175E+00 .21483E+00 .11567E-01 .21875E+00 -.10108E+00 -.21866E+00 -.25741E+00 -.19666E+00
 .43750E-01 .11400E+00 .78333E-01 .10833E+00 -.15833E+00 .10091E+00 -.11345E+00 .56500E-01
 17 96 .17500E+00

152035E+00	.215333E+00	.595107E-01	.215333E+00	-.112500E+00	-.217500E+00	-.258333E+00	-.197250E+00
.556637E-01	.568933E-01	.601567E-01	.149533E-01	-.159500E+00	.610533E-01	-.111000E+00	.36167E-01
18	97	177071E+00	.216000E+00	.216000E+00	.216000E+00	.216000E+00	.216000E+00
.543333E+00	.533197E-01	.503197E-01	.595033E-01	.217500E+00	.217500E+00	.217500E+00	.217500E+00
13	93	.79142E+00	.506667E-01	.216000E+00	.216000E+00	.216000E+00	.216000E+00
.506667E+00	.215417E+00	.463167E-01	.161213E+00	.216667E+00	.216667E+00	.216667E+00	.216667E+00
20	93	.161213E+00	.216667E+00	.216667E+00	.216667E+00	.216667E+00	.216667E+00
.150750E+00	.517500E-01	.420000E-01	.183284E+00	.216000E+00	.216000E+00	.216000E+00	.216000E+00
21	100	.183284E+00	.216000E+00	.216000E+00	.216000E+00	.216000E+00	.216000E+00
.150657E+00	.509333E-01	.381667E-01	.185355E+00	.216000E+00	.216000E+00	.216000E+00	.216000E+00
22	101	.185355E+00	.216000E+00	.216000E+00	.216000E+00	.216000E+00	.216000E+00
.151433E+00	.511667E-01	.463167E-01	.161213E+00	.216667E+00	.216667E+00	.216667E+00	.216667E+00
51	95	.161213E+00	.216667E+00	.216667E+00	.216667E+00	.216667E+00	.216667E+00
23	102	.167426E+00	.215667E+00	.215667E+00	.215667E+00	.215667E+00	.215667E+00
.152417E+00	.509167E-01	.320633E-01	.194977E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
509167E-01	24	103	.194977E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.152035E+00	.518333E-01	.463167E-01	.161213E+00	.216667E+00	.216667E+00	.216667E+00	.216667E+00
518333E-01	25	104	.191566E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.152157E+00	.572500E-01	.212500E-01	.191566E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
572500E-01	25	105	.191566E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.151917E+00	.543333E-01	.264167E-01	.195710E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
543333E-01	27	105	.195710E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.15157E+00	.540000E-01	.234167E-01	.19781E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
540000E-01	29	107	.19781E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.150750E+00	.533333E-01	.250000E-01	.206055E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
533333E-01	32	111	.206055E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.150917E+00	.610000E-01	.254167E-01	.208136E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
610000E-01	33	112	.208136E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.151583E+00	.631667E-01	.295000E-01	.216000E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
631667E-01	1	00	.140412E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.391667E-01	.209417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
209417E+00	2	01	.142474E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.389333E-01	.210033E+00	.210033E+00	.210033E+00	.210033E+00	.210033E+00	.210033E+00	.210033E+00
210033E+00	3	02	.144535E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.390833E-01	.211000E+00	.211000E+00	.211000E+00	.211000E+00	.211000E+00	.211000E+00	.211000E+00
211000E+00	4	03	.146596E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.391667E-01	.211631E+00	.211631E+00	.211631E+00	.211631E+00	.211631E+00	.211631E+00	.211631E+00
211631E+00	5	04	.148656E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.392417E-01	.212333E+00	.212333E+00	.212333E+00	.212333E+00	.212333E+00	.212333E+00	.212333E+00
212333E+00	6	05	.150722E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.389167E-01	.213333E+00	.213333E+00	.213333E+00	.213333E+00	.213333E+00	.213333E+00	.213333E+00
213333E+00	7	06	.152722E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.390333E-01	.214417E+00	.214417E+00	.214417E+00	.214417E+00	.214417E+00	.214417E+00	.214417E+00
214417E+00	8	07	.155167E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.391167E-01	.215417E+00	.215417E+00	.215417E+00	.215417E+00	.215417E+00	.215417E+00	.215417E+00
215417E+00	9	08	.156917E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.392000E-01	.216417E+00	.216417E+00	.216417E+00	.216417E+00	.216417E+00	.216417E+00	.216417E+00
216417E+00	10	09	.158417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.392833E-01	.217417E+00	.217417E+00	.217417E+00	.217417E+00	.217417E+00	.217417E+00	.217417E+00
217417E+00	11	10	.160417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.393667E-01	.218417E+00	.218417E+00	.218417E+00	.218417E+00	.218417E+00	.218417E+00	.218417E+00
218417E+00	12	11	.162417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.394500E-01	.219417E+00	.219417E+00	.219417E+00	.219417E+00	.219417E+00	.219417E+00	.219417E+00
219417E+00	13	12	.164417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.395333E-01	.220417E+00	.220417E+00	.220417E+00	.220417E+00	.220417E+00	.220417E+00	.220417E+00
220417E+00	14	13	.166417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.396167E-01	.221417E+00	.221417E+00	.221417E+00	.221417E+00	.221417E+00	.221417E+00	.221417E+00
221417E+00	15	14	.168417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.397000E-01	.222417E+00	.222417E+00	.222417E+00	.222417E+00	.222417E+00	.222417E+00	.222417E+00
222417E+00	16	15	.170417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.397833E-01	.223417E+00	.223417E+00	.223417E+00	.223417E+00	.223417E+00	.223417E+00	.223417E+00
223417E+00	17	16	.172417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.398667E-01	.224417E+00	.224417E+00	.224417E+00	.224417E+00	.224417E+00	.224417E+00	.224417E+00
224417E+00	18	17	.174417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.399500E-01	.225417E+00	.225417E+00	.225417E+00	.225417E+00	.225417E+00	.225417E+00	.225417E+00
225417E+00	19	18	.176417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.400333E-01	.226417E+00	.226417E+00	.226417E+00	.226417E+00	.226417E+00	.226417E+00	.226417E+00
226417E+00	20	19	.178417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.401167E-01	.227417E+00	.227417E+00	.227417E+00	.227417E+00	.227417E+00	.227417E+00	.227417E+00
227417E+00	21	20	.180417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.402000E-01	.228417E+00	.228417E+00	.228417E+00	.228417E+00	.228417E+00	.228417E+00	.228417E+00
228417E+00	22	21	.182417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.402833E-01	.229417E+00	.229417E+00	.229417E+00	.229417E+00	.229417E+00	.229417E+00	.229417E+00
229417E+00	23	22	.184417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.403667E-01	.230417E+00	.230417E+00	.230417E+00	.230417E+00	.230417E+00	.230417E+00	.230417E+00
230417E+00	24	23	.186417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.404500E-01	.231417E+00	.231417E+00	.231417E+00	.231417E+00	.231417E+00	.231417E+00	.231417E+00
231417E+00	25	24	.188417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.405333E-01	.232417E+00	.232417E+00	.232417E+00	.232417E+00	.232417E+00	.232417E+00	.232417E+00
232417E+00	26	25	.190417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.406167E-01	.233417E+00	.233417E+00	.233417E+00	.233417E+00	.233417E+00	.233417E+00	.233417E+00
233417E+00	27	26	.192417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.407000E-01	.234417E+00	.234417E+00	.234417E+00	.234417E+00	.234417E+00	.234417E+00	.234417E+00
234417E+00	28	27	.194417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.407833E-01	.235417E+00	.235417E+00	.235417E+00	.235417E+00	.235417E+00	.235417E+00	.235417E+00
235417E+00	29	28	.196417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.408667E-01	.236417E+00	.236417E+00	.236417E+00	.236417E+00	.236417E+00	.236417E+00	.236417E+00
236417E+00	30	29	.198417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.409500E-01	.237417E+00	.237417E+00	.237417E+00	.237417E+00	.237417E+00	.237417E+00	.237417E+00
237417E+00	31	30	.200417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.410333E-01	.238417E+00	.238417E+00	.238417E+00	.238417E+00	.238417E+00	.238417E+00	.238417E+00
238417E+00	32	31	.202417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.411167E-01	.239417E+00	.239417E+00	.239417E+00	.239417E+00	.239417E+00	.239417E+00	.239417E+00
239417E+00	33	32	.204417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.412000E-01	.240417E+00	.240417E+00	.240417E+00	.240417E+00	.240417E+00	.240417E+00	.240417E+00
240417E+00	34	33	.206417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.412833E-01	.241417E+00	.241417E+00	.241417E+00	.241417E+00	.241417E+00	.241417E+00	.241417E+00
241417E+00	35	34	.208417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.413667E-01	.242417E+00	.242417E+00	.242417E+00	.242417E+00	.242417E+00	.242417E+00	.242417E+00
242417E+00	36	35	.210417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.414500E-01	.243417E+00	.243417E+00	.243417E+00	.243417E+00	.243417E+00	.243417E+00	.243417E+00
243417E+00	37	36	.212417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.415333E-01	.244417E+00	.244417E+00	.244417E+00	.244417E+00	.244417E+00	.244417E+00	.244417E+00
244417E+00	38	37	.214417E+00	.215000E+00	.215000E+00	.215000E+00	.215000E+00
.416167E-01	.245417E+00	.245417E+00	.245417E+00	.245417E+00	.245417E+00	.245417E+00	.245417E+00
245417E+00	39	38	.216417E+00	.2			

-385	300E-01	213633E+00	-125000E+00	219503E+00	-227333E+00	217750E+00	233033E+00	-203667E+00
-113	417E+00	142003E+00	132500E+00	130003E+00	-130667E+00	631667E-01	-110917E+00	274000E-01
7	35	152766E+00	-125533E+00	216067E+00	-220033E+00	213003E+00	231677E+00	-203333E+00
-387	50E-01	214553E+00	136500E+00	131003E+00	-128000E+00	701667E-01	-110750E+00	246667E-01
-117	500E+00	134533E+00	154000E+00	214003E+00	-124500E+00	220033E+00	232500E+00	-20393E+00
3	97	154000E+00	-124500E+00	126250E+00	-125063E+00	731667E-01	-130333E+00	215000E-01
-383	333E-01	214633E+00	142000E+00	217003E+00	-125063E+00	220033E+00	232500E+00	-20393E+00
-121	157E+00	135633E+00	142000E+00	126250E+00	-125063E+00	731667E-01	-130333E+00	215000E-01
3	03	156307E+00	-124617E+00	217177E+00	-227667E+00	221667E+00	231033E+00	-204063E+00
-373	333E-01	215500E+00	145500E+00	217500E+00	-122177E+00	603333E-01	-132417E+00	201567E-01
-125	250E+00	131500E+00	145500E+00	121750E+00	-122177E+00	603333E-01	-132417E+00	201567E-01
10	03	158969E+00	-122917E+00	219500E+00	-226167E+00	222633E+00	231750E+00	-204500E+00
-361	667E-01	216417E+00	150250E+00	114633E+00	-120333E+00	547500E-01	-128450E+00	207500E-01
-129	333E+00	127333E+00	150250E+00	114633E+00	-120333E+00	547500E-01	-128450E+00	207500E-01
11	30	161031E+00	-120333E+00	201500E+00	-118667E+00	613333E-01	-129333E+00	220667E+00
-335	000E-01	216333E+00	155333E+00	107500E+00	-117750E+00	562500E-01	-130500E+00	235833E-01
-134	167E+00	121917E+00	155333E+00	107500E+00	-117750E+00	562500E-01	-130500E+00	235833E-01
12	31	163093E+00	-120317E+00	223003E+00	-223667E+00	227033E+00	231167E+00	-204000E+00
-339	333E-01	217033E+00	157000E+00	107500E+00	-117750E+00	562500E-01	-130500E+00	235833E-01
-134	750E+00	116833E+00	157000E+00	107500E+00	-117750E+00	562500E-01	-130500E+00	235833E-01
13	92	165155E+00	-124217E+00	224003E+00	-225033E+00	227033E+00	231167E+00	-204000E+00
-343	333E-01	220750E+00	159567E+00	111833E+00	-119300E+00	553333E-01	-130500E+00	235833E-01
-137	033E+00	111833E+00	159567E+00	111833E+00	-119300E+00	553333E-01	-130500E+00	235833E-01
14	93	167216E+00	-123633E+00	224167E+00	-226317E+00	226333E+00	230250E+00	-204317E+00
-368	167E-01	221000E+00	160667E+00	884167E-01	-119063E+00	522500E-01	-133417E+00	200503E+00
-138	417E+00	106500E+00	160667E+00	884167E-01	-119063E+00	522500E-01	-133417E+00	200503E+00
15	34	163279E+00	-123000E+00	222417E+00	-226333E+00	226333E+00	232917E+00	-203667E+00
-359	157E-01	219633E+00	162417E+00	791667E-01	-110333E+00	431667E-01	-132750E+00	23333E-01
-138	333E+00	101633E+00	162417E+00	791667E-01	-110333E+00	431667E-01	-132750E+00	23333E-01
15	95	171360E+00	-125000E+00	215503E+00	-228000E+00	222167E+00	233063E+00	-203333E+00
-373	167E-01	217250E+00	161333E+00	682500E-01	-119317E+00	367500E-01	-131667E+00	263667E-01
-135	500E+00	94500E-01	161333E+00	682500E-01	-119317E+00	367500E-01	-131667E+00	263667E-01
17	33	173402E+00	-124000E+00	217000E+00	-227333E+00	219000E+00	234500E+00	-20333E-01
-377	500E-01	214917E+00	157917E+00	514167E-01	-119033E+00	385000E-01	-135333E+00	26333E-01
-135	000E+00	87333E-01	157917E+00	514167E-01	-119033E+00	385000E-01	-135333E+00	26333E-01
13	97	179648E+00	-124033E+00	215033E+00	-227667E+00	219033E+00	234500E+00	-20333E+00
-380	000E-01	214503E+00	155157E+00	540000E-01	-121903E+00	367500E-01	-139417E+00	267500E-01
-133	417E+00	821667E-01	155157E+00	540000E-01	-121903E+00	367500E-01	-139417E+00	267500E-01
13	33	177526E+00	-125000E+00	216750E+00	-227317E+00	221417E+00	231583E+00	-203417E+00
-385	000E-01	215917E+00	155000E+00	466333E-01	-123563E+00	355000E-01	-135500E+00	31583E-01
-131	53E+00	778333E-01	155000E+00	466333E-01	-123563E+00	355000E-01	-135500E+00	31583E-01
20	99	179580E+00	-123333E+00	220917E+00	-227063E+00	224333E+00	231917E+00	-202917E+00
-378	333E-01	216833E+00	147003E+00	445000E-01	-123563E+00	355000E-01	-135500E+00	31583E-01
-130	833E+00	751667E-01	147003E+00	445000E-01	-123563E+00	355000E-01	-135500E+00	31583E-01
21	100	181603E+00	-123333E+00	220917E+00	-227063E+00	224333E+00	231917E+00	-202917E+00
-363	157E-01	218000E+00	147003E+00	445000E-01	-123563E+00	355000E-01	-135500E+00	31583E-01
-123	417E+00	716667E-01	147003E+00	445000E-01	-123563E+00	355000E-01	-135500E+00	31583E-01
22	101	183711E+00	-123553E+00	221750E+00	-226667E+00	224750E+00	232250E+00	-202033E+00
-375	000E-01	216917E+00	142550E+00	446667E-01	-122667E+00	332500E-01	-139033E+00	301667E-01
-128	500E+00	672500E-01	142550E+00	446667E-01	-122667E+00	332500E-01	-139033E+00	301667E-01
23	102	185773E+00	-123003E+00	222750E+00	-226083E+00	225917E+00	233500E+00	-20033E+00
-363	333E-01	220500E+00	143750E+00	357500E-01	-125667E+00	371667E-01	-138417E+00	301667E-01
-124	917E+00	665833E-01	143750E+00	357500E-01	-125667E+00	371667E-01	-138417E+00	301667E-01
24	103	187835E+00	-122000E+00	222033E+00	-225250E+00	226000E+00	233583E+00	-201417E+00
-357	500E-01	219417E+00	143000E+00	410000E-01	-133633E+00	332500E-01	-14417E+00	33000E-01
-124	250E+00	642500E-01	143000E+00	410000E-01	-133633E+00	332500E-01	-14417E+00	33000E-01
25	104	189870E+00	-122500E+00	222833E+00	-225083E+00	226750E+00	233333E+00	-201917E+00
-357	500E-01	219750E+00	1436083E+00	374167E-01	-133191E+00	332500E-01	-146563E+00	330333E-01
-120	917E+00	61467E-01	1436083E+00	374167E-01	-133191E+00	332500E-01	-146563E+00	330333E-01
25	105	191999E+00	-122500E+00	223033E+00	-225667E+00	227667E+00	230750E+00	-201583E+00
-360	833E-01	220667E+00	136633E+00	431667E-01	-136167E+00	421667E-01	-146917E+00	239167E-01
-116	750E+00	590833E-01	136633E+00	431667E-01	-136167E+00	421667E-01	-146917E+00	239167E-01
27	105	194021E+00	-123417E+00	223157E+00	-226750E+00	227500E+00	236333E+00	-201583E+00
-365	833E-01	220083E+00	136917E+00	451667E-01	-1336083E+00	420833E-01	-149750E+00	232500E-01
-113	333E+00	579167E-01	136917E+00	451667E-01	-1336083E+00	420833E-01	-149750E+00	232500E-01
28	107	196062E+00						

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--375060E-01 224417E+00 -124333E+00 223003E+00 -227587E+00 226417E+00 -231417E+00 -200000E+00
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29 108 190144E+00
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31 111 202688E+00
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34 113 208454E+00
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*101417E+00 550000E-01 131000E+00 480333E-01 -156750E+00 526667E-01 -154250E+00 159167E-01
TIME INCREMENT .200000E-02
FIND 141904E+00 732500E-01 133333E+00 713333E-01 136417E+00 136417E+00 142000E+00
FIND 140812E+00 800000E-01 150333E+00 742500E-01 146917E+00 146917E+00 142000E+00
SOLVE 731240E-01 139740E+00 723125E-01 147817E+00 649395E+00 -133776E+01 272575E+01 0
FIND 141904E+00 477500E-01 127333E+00 456667E-01 126500E+00 142000E+00
FIND 140812E+00 111003E+00 136333E+00 115205E+00 135500E+00 142000E+00
SOLVE 473133E-01 127213E+00 114933E+00 135812E+00 363984E+00 36819E+00 319109E+01 1
FIND 140812E+00 -153167E+00 131750E+00 -115750E+00 126500E+00 142000E+00
FIND 141904E+00 -146250E+00 106667E+00 -144417E+00 101667E+00 142000E+00
SOLVE 141364E+00 -131500E+00 131500E+00 103274E+00 658074E+00 603676E+00 311333E+01 2
FIND 140812E+00 -137050E+00 635833E-01 -133917E+00 605000E-01 142000E+00
SOLVE 591807E+00 -326242E+00 757300E+00 106675E-01 112613E+00 -143914E+01 234750E+01 3
645346E+00 -294181E+00 113635E+00 339305E-01 324565E-01 144300E+00
FIND 143335E+00 713333E-01 138417E+00 696667E-01 136833E+00 144000E+00
SOLVE 142874E+00 342500E-01 146317E+00 931667E-01 136833E+00 144000E+00
FIND 143335E+00 133004E+00 133004E+00 78876E-01 146937E+00 144000E+00
FIND 142874E+00 456667E-01 125500E+00 416667E-01 137157E+00 144000E+00
SOLVE 655403E-01 116083E-01 133500E+00 113250E+00 133003E+00 144000E+00
FIND 143335E+00 -157500E+00 113426E+00 133132E+00 123567E+00 144000E+00
FIND 142874E+00 -14147E+00 101667E+00 -157417E+00 123567E+00 144000E+00
SOLVE 143335E+00 126340E+00 133999E+00 901503E-01 965167E-01 144000E+00
FIND 142874E+00 138917E+00 605000E-01 -136500E+00 622057E+00 608621E+00
SOLVE 1435904E+00 136417E+00 386667E-01 -136417E+00 354167E-01 144000E+00
CORR 591333E+00 -326240E+00 575600E+00 362611E-01 333765E+00 -143914E+01 259131E+01 7
645132E+00 -234222E+00 220663E+01 295392E-01 118917E-01 146000E+00
FIND 143335E+00 713333E-01 138417E+00 696667E-01 136833E+00 144000E+00
FIND 144536E+00 91667E-01 146317E+00 931667E-01 146317E+00 144000E+00
SOLVE 699718E-01 136444E+00 101474E+00 146306E+00 124467E+00 146000E+00
FIND 143335E+00 456667E-01 119250E+00 123500E+00 486667E-01 124167E+00 146000E+00
FIND 144536E+00 157500E+00 133083E+00 123250E+00 132250E+00 146000E+00
SOLVE 645731E-01 124170E+00 120309E+00 132492E+00 877114E+00 859004E+00
FIND 143335E+00 -157500E+00 126500E+00 -157417E+00 123567E+00 146000E+00
FIND 144536E+00 -139000E+00 963167E-01 -137633E+00 920833E-01 146000E+00
SOLVE 143535E+00 123600E+00 137633E+00 934334E-01 573355E+00 604756E+00
FIND 143335E+00 -134417E+00 354167E-01 -134500E+00 767500E+00 604756E+00
FIND 144536E+00 -134417E+00 354167E-01 -134417E+00 767500E+00 604756E+00
CORR 591205E+00 767607E-01 136455E+00 354167E-01 354167E+00 146000E+00
645204E+00 -234566E+00 257515E+00 146344E+00 146344E-01 121047E-01 9
146000E+00 536667E-01 134633E+00 146344E-01 935171E+00 325033E-01 146000E+00
FIND 146000E+00 234662E+01 146344E+00 146344E-01 121047E-01 322346E-01 10
146590E+00 636667E-01 134633E+00 662500E-01 295713E-01 322346E-01 11
146590E+00 145750E+00 145750E+00 103333E+00 1446667E+00 148000E+00 12
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FIND	.54476E+00	-.245319E+00	.220677E+01	.27590E-01	.302621E-01	.158000E+00	
FIND	.158361E+00	.58633E-01	.117750E+00	.57000E-01	.112845E+00	.158000E+00	
FIND	.158361E+00	.125250E+00	.131500E+00	.12933E+00	.127335E+00	.158000E+00	
SOLVE	.573617E-01	.113264E+00	.127414E+00	.129322E+00	.981650E+00	.233089E+01	32
FIND	.158361E+00	.401667E-01	.106750E+00	.411667E-01	.577500E-01	.158000E+00	
FIND	.158361E+00	.145503E+00	.121750E+00	.150250E+00	.116833E+01	.158000E+00	
SOLVE	.409344E-01	.996243E-01	.140401E+00	.119144E+00	.614638E+00	.305160E+01	33
FIND	.158361E+00	.165167E+00	.103317E+00	.158333E+00	.944678E-01	.158000E+00	
FIND	.164795E+00	.12297E+00	.60333E-01	.120833E+00	.647503E-01	.158000E+00	
SOLVE	.104354E+00	.134833E+00	.121612E+00	.664832E-01	.356708E+00	.258774E+01	34
FIND	.158361E+00	.132417E+00	.201607E-01	.133633E+00	.356708E+00	.158000E+00	
FIND	.158361E+00	.643648E-01	.130207E+00	.204760E-01	.640000E-01	.158000E+00	
SOLVE	.13042E+00	.325219E+00	.575785E+00	.204760E-01	.207500E-01	.158000E+00	
CORR	.590437E+00	.295561E+00	.220677E+01	.134163E+00	.573199E+00	.158000E+00	
FIND	.54430E+00	.245561E+00	.27500E-01	.27500E-01	.304074E-01	.270515E+01	35
FIND	.158361E+00	.57000E-01	.112083E+00	.573167E-01	.304074E-01	.160000E+00	
FIND	.158361E+00	.12933E+00	.12733E+00	.134167E+00	.10533E+00	.160000E+00	
SOLVE	.575943E-01	.106571E+00	.131750E+00	.124625E+00	.361558E+00	.231966E+01	36
FIND	.158361E+00	.411667E-01	.977500E-01	.42000E-01	.121317E+00	.160000E+00	
FIND	.158361E+00	.150250E+00	.116833E+00	.15333E+00	.69633E-01	.160000E+00	
SOLVE	.43792E-01	.31757E-01	.152792E+00	.113166E+00	.109500E+00	.160000E+00	
FIND	.158361E+00	.164863E+00	.994167E-01	.164253E+00	.563330E+00	.301435E+01	37
FIND	.158361E+00	.120833E+00	.647500E-01	.118667E+00	.565000E-01	.160000E+00	
SOLVE	.16433E+00	.97200E-01	.113749E+00	.630406E-01	.61333E-01	.160000E+00	
FIND	.158361E+00	.133833E+00	.640300E-01	.630406E-01	.355543E+00	.294124E+01	38
FIND	.158361E+00	.128250E+00	.207500E-01	.130317E+00	.625000E-01	.160000E+00	
SOLVE	.131624E+00	.624640E-01	.207500E-01	.12933E+00	.22633E-01	.160000E+00	
CORR	.590437E+00	.325219E+00	.128792E+00	.217315E-01	.672441E+00	.266036E+01	39
FIND	.64439E+00	.295813E+00	.975962E+00	.124716E-01	.136885E-01	.160000E+00	
FIND	.160303E+00	.579167E-01	.220669E+00	.28120E-01	.309423E-01	.160000E+00	
FIND	.161031E+00	.19467E+00	.10533E+00	.57450E-01	.998633E-01	.160000E+00	
SOLVE	.57557E-01	.19467E+00	.121317E+00	.134750E+00	.116833E-01	.231460E+01	40
FIND	.160303E+00	.82000E-01	.134441E+00	.114925E+00	.995547E+00	.160000E+00	
FIND	.160303E+00	.15833E+00	.441667E-01	.441667E-01	.604167E-01	.152000E+00	
SOLVE	.435669E-01	.830235E-01	.103500E+00	.157000E+00	.102588E+00	.162000E+00	
FIND	.160303E+00	.164863E+00	.96500E-01	.163417E+00	.561951E+00	.297435E+01	41
FIND	.161031E+00	.118667E+00	.61333E-01	.117750E+00	.535667E-01	.162000E+00	
SOLVE	.163647E+00	.944514E-01	.118235E+00	.598837E-01	.338335E+00	.268643E+01	42
FIND	.160303E+00	.130917E+00	.62500E-01	.128917E+00	.62333E-01	.162000E+00	
FIND	.161031E+00	.12933E+00	.22633E-01	.128917E+00	.231667E-01	.162000E+00	
SOLVE	.12371E+00	.62375E-01	.123137E+00	.22990E-01	.670013E+00	.265737E+01	43
CORR	.590437E+00	.324862E+00	.976174E+00	.123437E-01	.130256E-01	.160000E+00	
FIND	.64439E+00	.296037E+00	.220669E+00	.28120E-01	.315047E-01	.164000E+00	
FIND	.162374E+00	.574167E-01	.998633E-01	.561667E-01	.104417E+00	.164000E+00	
FIND	.163193E+00	.134750E+00	.116833E+00	.137083E+00	.11833E+00	.231266E+01	44
SOLVE	.57330E-01	.10000E+00	.135777E+00	.114633E+00	.101665E-01	.164000E+00	
FIND	.162374E+00	.441667E-01	.604167E-01	.460333E-01	.784167E-01	.164000E+00	
FIND	.163033E+00	.157000E+00	.102588E+00	.159667E+00	.96250E-01	.295221E+01	45
SOLVE	.454865E-01	.790395E-01	.158174E+00	.99760E-01	.552335E+00	.164000E+00	
FIND	.162574E+00	.163417E+00	.916667E-01	.162083E+00	.100667E+00	.284785E+01	46
FIND	.163033E+00	.117750E+00	.582500E-01	.118000E+00	.55333E-01	.164000E+00	
SOLVE	.162374E+00	.128917E+00	.117960E-01	.569665E-01	.330531E+00	.266462E+01	47
FIND	.163033E+00	.944852E+00	.62333E-01	.12733E+00	.70583E-01	.164000E+00	
SOLVE	.127027E+00	.680127E-01	.231667E-01	.130500E+00	.235833E-01	.164000E+00	
CORR	.590437E+00	.325219E+00	.97621E+00	.119595E-01	.126211E-01	.164000E+00	
FIND	.54430E+00	.245561E+00	.220669E+00	.28120E-01	.313752E-01	.160000E+00	
FIND	.16445E+00	.581667E-01	.100417E+00	.59000E-01	.63000E-01	.166000E+00	
FIND	.165155E+00	.137083E+00	.11833E+00	.135417E+00	.106503E+00	.233845E+01	48
SOLVE	.587125E-01	.89000E-01	.136399E+00	.103645E+00	.103234E+01	.166000E+00	
FIND	.16445E+00	.460833E-01	.784167E-01	.50250E-01	.572500E-01	.166000E+00	
FIND	.165155E+00	.159667E+00	.962500E-01	.160667E+00	.284167E-01	.166000E+00	
SOLVE	.484120E-01	.645548E+00	.160077E+00	.930301E-01	.951433E+00	.269386E+01	49
FIND	.16445E+00	.162083E+00	.100667E+00	.154147E+00	.859167E-01	.166000E+00	
FIND	.165155E+00	.118000E+00	.55333E-01	.119308E+00	.52250E-01	.166000E+00	
SOLVE	.161647E+00	.929721E-01	.119444E+00	.540691E-01	.330144E+00	.277174E+01	50

FIND	.154643E+00	-.127333E+00	.705333E-01	-.112657E+00	.634157E-01	.165000E+00	
FIND	.165155E+00	-.130500E+00	.235333E-01	-.133471E+00	.236667E-01	.156000E+00	
SOLVE	-.124932E+00	.639259E-01	-.131095E+00	.236175E-01	.262795E+01	.51	
CORR	-.590424E+00	-.325155E+00	.376169E+00	.118580E+00	.125143E-01		
FIND	.544774E+00	-.295552E+00	.226644E+00	.267203E-01	.313913E-01		
FIND	.166719E+00	.530000E-01	.830300E-01	.594333E-01	.752500E-01	.168000E+00	
FIND	.167219E+00	.135417E+00	.106650E+00	.134333E+00	.101933E+00	.168000E+00	
SOLVE	.589396E-01	.781925E-01	.139522E+00	.104726E+00	.121222E+01	.231196E+01	.52
FIND	.166719E+00	.592500E-01	.572500E-01	.533333E-01	.444167E-01	.166000E+00	
FIND	.167219E+00	.160667E+00	.568167E-01	.162437E+00	.731667E-01	.168000E+00	
SOLVE	.521624E-01	.492390E-01	.161332E+00	.540994E-01	.551136E+00	.263405E+01	.53
FIND	.166719E+00	-.161417E+00	.889167E-01	-.159477E+00	.660333E-01	.168000E+00	
FIND	.167219E+00	-.119083E+00	.522500E-01	-.116333E+00	.431667E-01	.168000E+00	
SOLVE	-.160170E+00	.871592E-01	-.110798E+00	.506377E-01	.333712E+00	.266575E+01	.54
FIND	.166719E+00	-.123667E+00	.604167E-01	-.123033E+00	.601667E-01	.168000E+00	
FIND	.167219E+00	-.133471E+00	.236667E-01	-.132750E+00	.293333E-01	.168000E+00	
SOLVE	-.123305E+00	.602617E-01	-.133163E+00	.256136E-01	.170334E+00	-.136143E+01	.55
CORR	-.590113E+00	.324576E+00	.976495E+00	.118264E-01	.124742E-01		
FIND	.544900E+00	-.296265E+00	.220635E+00	.249560E-01	.115671E-01	.170000E+00	
FIND	.168707E+00	.548333E-01	.752500E-01	.576667E-01	.675000E-01	.170000E+00	
FIND	.169275E+00	.138333E+00	.101833E+00	.136500E+00	.945000E-01	.170000E+00	
SOLVE	.541496E-01	.707001E-01	.533333E-01	.137691E+00	.926333E-01	.128803E+01	.56
FIND	.166719E+00	.162417E+00	.444167E-01	.576667E-01	.314167E-01	.170000E+00	
FIND	.167219E+00	.162417E+00	.731667E-01	.161333E+00	.682500E-01	.170000E+00	
SOLVE	.599720E-01	.368000E-01	.162037E+00	.753408E-01	.539051E+00	.386288E+00	.57
FIND	.166719E+00	-.159417E+00	.60833E-01	-.159033E+00	.840833E-01	.170000E+00	
FIND	.167219E+00	-.118333E+00	.481667E-01	-.113917E+00	.421667E-01	.170000E+00	
SOLVE	.159221E+00	.649117E-01	-.118888E+00	.466066E-01	.322502E+00	.109327E+01	.58
FIND	.166719E+00	-.123083E+00	.601667E-01	-.121167E+00	.582500E-01	.170000E+00	
FIND	.169275E+00	-.132750E+00	.293333E-01	-.131667E+00	.316667E-01	.170000E+00	
SOLVE	-.121960E+00	.590437E-01	.132333E+00	.701501E-01	.703495E+01	-.136036E+01	.59
CORR	-.590214E+00	.324603E+00	.976580E+00	.133977E-01	.122368E-01		
FIND	.544444E+00	-.296585E+00	.220628E+00	.239314E-01	.320934E-01	.172000E+00	
FIND	.170359E+00	.576667E-01	.675000E-01	.562500E-01	.613333E-01	.172000E+00	
FIND	.171340E+00	.135000E+00	.945000E-01	.135000E+00	.673333E-01	.230721E+01	.60
SOLVE	.668951E-01	.640939E-01	.136019E+00	.922039E-01	.110170E+01	-.127304E+01	
FIND	.170359E+00	.576667E-01	.314167E-01	.601667E-01	.223167E-01	.172000E+00	
FIND	.171340E+00	-.267291E-01	.602500E-01	.157317E+00	.614167E-01	.172000E+00	
SOLVE	.530454E-01	.267291E-01	.160236E+00	.660603E-01	.543436E+00	.375395E+00	.61
FIND	.170359E+00	-.159083E+00	.84033E-01	-.159667E+00	.616667E-01	.172000E+00	
FIND	.171340E+00	-.119917E+00	.421667E-01	-.114333E+00	.39000E-01	.172000E+00	
SOLVE	.159405E+00	.827506E-01	-.119890E+00	.403933E-01	.367795E+00	.110730E+01	.62
FIND	.170359E+00	-.121167E+00	.582500E-01	-.139667E+00	.576667E-01	.172000E+00	
FIND	.171340E+00	-.131667E+00	.316667E-01	-.135333E+00	.263333E-01	.172000E+00	
SOLVE	-.113780E+00	.578252E-01	.132833E+00	.234604E-01	.712540E+00	-.136891E+01	.63
CORR	-.590138E+00	.324423E+00	.976866E+00	.112161E-01	.113334E-01		
FIND	.544900E+00	-.296620E+00	.220614E+00	.297265E-01	.325696E-01	.174000E+00	
FIND	.172929E+00	.562500E-01	.613333E-01	.655667E-01	.565833E-01	.174000E+00	
SOLVE	.554482E-01	.135000E+00	.873333E-01	.135417E+00	.21667E-01	.174000E+00	
FIND	.172929E+00	.588761E-01	.135121E+00	.858341E-01	.112417E+01	.229667E+01	.64
FIND	.173402E+00	.601667E-01	.229167E-01	.601667E-01	.145834E-01	.174000E+00	
SOLVE	.601667E-01	.186064E-01	.157118E-01	.155167E+00	.54000E-01	.174000E+00	
FIND	.172929E+00	-.159667E+00	.816667E-01	-.159263E-01	.944671E-01	.969379E+00	.65
FIND	.173402E+00	-.119833E+00	.365000E-01	-.121953E+00	.367503E-01	.174000E+00	
SOLVE	.153365E+00	.813690E-01	.365000E-01	-.121953E+00	.367503E-01	.174000E+00	
FIND	.172929E+00	-.118667E+00	.379928E-01	-.120341E+00	.374928E-01	.174000E+00	
FIND	.173402E+00	-.135333E+00	.263333E-01	-.139417E+00	.267503E-01	.174000E+00	
SOLVE	-.113322E+00	.572703E-01	.136516E+00	.264541E-01	.714894E+00	-.137262E+01	.66
CORR	-.590065E+00	.324313E+00	.977064E+00	.110903E-01	.115087E-01		
FIND	.644964E+00	-.296965E+00	.220633E+00	.320033E-01	.325015E-01	.176000E+00	
FIND	.175000E+00	.556667E-01	.565833E-01	.543333E-01	.505167E-01	.176000E+00	
FIND	.175464E+00	.135417E+00	.821667E-01	.131583E+00	.773333E-01	.176000E+00	
SOLVE	.550226E-01	.538460E-01	.134419E+00	.411385E-01	.115909E-01	.227276E+01	.68
FIND	.175000E+00	.601667E-01	.165833E-01	.575333E-01	.500000E-02	.176000E+00	
FIND	.175464E+00	.155516E+00	.540000E-01	.150063E+00	.446333E-01	.176000E+00	

FIND	.185773E+00	.124917E+00	.605048E-01	.124259E+00	.612533E-01	.612533E-01	.156000E+00	.227016E+01	08
SOLVE	.334030E-01	.124043E+00	.605206E-01	.605206E-01	.121673E-01	.121673E-01	-.121711E+01		
FIND	.185355E+00	.048333E-01	.596733E-02	.596733E-02	.400000E-01	.400000E-01	.156000E+00	.249379E+01	09
FIND	.185773E+00	.143750E+00	.337500E-01	.141000E+00	.393075E-01	.393075E-01	.156000E+00		
SOLVE	.624074E-01	.600380E-02	.143644E+00	.143644E+00	.601167E-01	.601167E-01	.156000E+00		
FIND	.185355E+00	.155167E+00	.765933E-01	.155331E+00	.325039E-01	.325039E-01	.156000E+00		
FIND	.185773E+00	.125667E+00	.371607E-01	.131831E+00	.325039E-01	.325039E-01	.156000E+00		
SOLVE	.152213E+00	.743030E-01	.126344E+00	.373395E-01	.506729E-01	.506729E-01	.102408E+01	.225241E+01	10
FIND	.185355E+00	.112500E+00	.555400E-01	.112033E+00	.567503E-01	.567503E-01	.156000E+00		
FIND	.185773E+00	.138417E+00	.301607E-01	.141817E+00	.330000E-01	.330000E-01	.156000E+00		
SOLVE	.112606E+00	.555779E-01	.133874E+00	.306700E-01	.776503E-01	.776503E-01	.133850E+01	.249307E+01	11
CORR	.503314E+00	.323457E+00	.316044E+00	.330303E-02	.987239E-02	.987239E-02			
FIND	.187426E+00	.509167E-01	.548222E+00	.321605E-01	.351347E-01	.351347E-01			
FIND	.187355E+00	.128250E+00	.320333E-01	.519333E-01	.316667E-01	.316667E-01	.156000E+00		
SOLVE	.511707E-01	.319679E-01	.642500E-01	.120917E+00	.614167E-01	.614167E-01	.156000E+00	.226734E+01	12
FIND	.187426E+00	.503333E-01	.123383E+00	.640231E-01	.122450E-01	.122450E-01	-.112649E+01		
FIND	.187355E+00	.503333E-01	.950000E-02	.566300E-01	.925000E-02	.925000E-02	.156000E+00		
SOLVE	.573251E-01	.943070E-02	.410000E-01	.136008E+00	.374167E-01	.374167E-01	.156000E+00		
FIND	.187426E+00	.155333E+00	.059167E-01	.156667E+00	.437129E-01	.437129E-01	.156000E+00	.247861E+01	13
FIND	.187355E+00	.131633E+00	.332500E-01	.131317E+00	.325039E-01	.325039E-01	.156000E+00		
SOLVE	.158671E+00	.011015E-01	.131840E+00	.332500E-01	.563364E+00	.563364E+00	.156000E+00	.224566E+01	14
FIND	.187426E+00	.112633E+00	.557500E-01	.113167E+00	.584167E-01	.584167E-01	.156000E+00		
FIND	.187355E+00	.148417E+00	.330000E-01	.148066E+00	.306335E-01	.306335E-01	.156000E+00		
SOLVE	.112326E+00	.593347E-01	.184182E+00	.328234E+00	.940180E-01	.940180E-01	-.141222E+01	.250053E+01	15
CORR	.503355E+00	.298140E+00	.220535E+01	.322911E-01	.353413E-01	.353413E-01			
FIND	.189497E+00	.518333E-01	.316667E-01	.116750E+00	.530633E-01	.530633E-01	.130000E+00		
FIND	.189497E+00	.120917E+00	.614167E-01	.116750E+00	.530633E-01	.530633E-01	.130000E+00	.227542E+01	16
SOLVE	.531488E-01	.291336E-01	.120708E+00	.612949E-01	.123690E-01	.123690E-01	-.128090E+00		
FIND	.189497E+00	.565000E-01	.925000E-02	.560000E-01	.120000E-01	.120000E-01	.130000E+00		
FIND	.189497E+00	.136683E+00	.374167E-01	.136633E+00	.431667E-01	.431667E-01	.130000E+00	.244323E+01	17
SOLVE	.561746E-01	.931786E-02	.136121E+00	.377040E-01	.637788E+00	.637788E+00	.542376E+00		
FIND	.189497E+00	.153667E+00	.355333E-01	.153750E+00	.600333E-01	.600333E-01	.130000E+00		
FIND	.189337E+00	.133917E+00	.332500E-01	.133167E+00	.421667E-01	.421667E-01	.130000E+00		
SOLVE	.133667E+00	.012190E-01	.132129E+00	.339396E-01	.531110E+00	.531110E+00	.102182E+01	.222243E+01	18
FIND	.189497E+00	.113167E+00	.564167E-01	.113963E+00	.567503E-01	.567503E-01	.130000E+00		
FIND	.189397E+00	.146583E+00	.302333E-01	.149917E+00	.239167E-01	.239167E-01	.130000E+00		
SOLVE	.112268E+00	.564976E-01	.146700E+00	.307675E-01	.319200E+00	.319200E+00	-.140904E+01	.249361E+01	19
CORR	.509424E+00	.323071E+00	.370163E+00	.958733E-02	.101104E-01	.101104E-01			
FIND	.191366E+00	.572500E-01	.220535E-01	.323457E-01	.354549E-01	.354549E-01	.132000E+00		
FIND	.191366E+00	.116750E+00	.530633E-01	.113333E-01	.573167E-01	.573167E-01	.132000E+00	.226461E+01	100
SOLVE	.563416E-01	.223277E-01	.116682E+00	.590600E-01	.126451E+01	.126451E+01	-.131121E+01		
FIND	.191366E+00	.560000E-01	.120000E-01	.931667E-01	.130333E-01	.130333E-01	.132000E+00		
FIND	.191366E+00	.136833E+00	.431667E-01	.136317E+00	.431667E-01	.431667E-01	.132000E+00	.240396E+01	101
SOLVE	.579337E-01	.116005E-01	.135835E+00	.432087E-01	.866494E+00	.866494E+00	.326634E+00		
FIND	.191366E+00	.153750E+00	.600333E-01	.153250E+00	.614167E-01	.614167E-01	.132000E+00		
FIND	.191393E+00	.136157E+00	.421667E-01	.134083E+00	.420833E-01	.420833E-01	.132000E+00	.224231E+01	102
SOLVE	.153646E+00	.803614E-01	.135225E+00	.421650E-01	.530415E+00	.530415E+00	.103688E+01		
FIND	.191366E+00	.113568E+00	.575000E-01	.112917E+00	.563333E-01	.563333E-01	.132000E+00		
FIND	.191393E+00	.140917E+00	.239167E-01	.149750E+00	.232500E-01	.232500E-01	.132000E+00		
SOLVE	.113444E+00	.565568E-01	.148333E+00	.284033E-01	.840354E+00	.840354E+00	-.142626E+01	.250372E+01	103
CORR	.509333E+00	.322777E+00	.978116E+00	.101274E-01	.106769E-01	.106769E-01			
FIND	.193346E+00	.298526E+00	.220534E+00	.322391E-01	.355549E-01	.355549E-01	.134000E+00		
FIND	.193346E+00	.543333E-01	.264167E-01	.540000E-01	.234167E-01	.234167E-01	.134000E+00	.225202E+01	104
FIND	.191393E+00	.116750E+00	.530633E-01	.113333E+00	.579167E-01	.579167E-01	.134000E+00		
SOLVE	.542752E-01	.256893E-01	.113367E+00	.579262E-01	.127638E+01	.127638E+01	.133649E+01		
FIND	.193393E+00	.631667E-01	.100933E-01	.649633E-01	.112503E-01	.112503E-01	.134000E+00		
FIND	.191393E+00	.136633E+00	.431667E-01	.136917E+00	.431667E-01	.431667E-01	.134000E+00	.240857E+01	105
SOLVE	.638135E-01	.102866E-01	.136917E+00	.461467E-01	.699847E+00	.699847E+00	.663352E+00		
FIND	.193393E+00	.153250E+00	.814167E-01	.151917E+00	.823333E-01	.823333E-01	.134000E+00		
FIND	.191393E+00	.136167E+00	.421667E-01	.134083E+00	.420833E-01	.420833E-01	.134000E+00	.225090E+01	106
SOLVE	.153016E+00	.817507E-01	.139054E+00	.420842E-01	.559314E+00	.559314E+00	.106829E+01		
FIND	.193393E+00	.112917E+00	.558333E-01	.112500E+00	.542503E-01	.542503E-01	.134000E+00		
FIND	.191393E+00	.149317E+00	.239167E-01	.149750E+00	.232500E-01	.232500E-01	.134000E+00		

FIND	.202268E+00	-.150750E+00	.465000E-01	-.152333E+00	.500000E-01	.234000E+00	.224603E+01	126						
SOLVE	.203394E+00	.200921E-01	-.152030E+00	.494395E-01	.700017E+00	.110425E+01								
FIND	.203394E+00	-.113417E+00	.600000E-01	.117750E+00	.619500E-01	.204000E+00								
FIND	.202268E+00	-.149167E+00	.193167E-01	-.149750E+00	.195633E-01	.214000E+00								
SOLVE	-.113423E+00	.600033E-01	-.149667E+00	.149636E-01	.945432E+00	.149721E+01	.255607E+01	127						
CORR	-.588956E+00	-.321360E+00	.272555E+00	.143717E-01	.157746E-01									
FIND	.644325E+00	-.25939E+00	.220532E+01	.300166E-01	.326785E-01									
FIND	.203394E+00	.593333E-01	.203000E-01	.610000E-01	.259167E-01	.206000E+00								
FIND	.204330E+00	.104467E+00	.551667E-01	.101667E+00	.552500E-01	.206000E+00								
SOLVE	.603476E-01	.256879E-01	.102141E+00	.552342E-01	.129174E+01	-.134204E+01	.223448E+01	128						
FIND	.203394E+00	.765833E-01	-.375000E-02	.734167E-01	-.400333E-02	.206000E+00								
FIND	.204330E+00	.126917E+00	.500000E-01	.130667E+00	.430000E-01	.206000E+00								
SOLVE	.793276E-01	-.813573E-02	.123954E+00	.491901E-01	.824936E+00	.076576E+00	.237075E+01	129						
FIND	.203394E+00	-.150583E+00	.90033E-01	-.151667E+00	.931667E-01	.206000E+00								
FIND	.204330E+00	-.152333E+00	.500000E-01	-.156250E+00	.523333E-01	.206000E+00								
SOLVE	.151633E+00	.930697E-01	-.15505E+00	.522934E-01	.569513E+00	.112611E+01	.224345E+01	130						
FIND	.203394E+00	-.113417E+00	.600000E-01	-.117750E+00	.612500E-01	.206000E+00								
FIND	.204330E+00	-.149750E+00	.193167E-01	-.153667E+00	.193167E-01	.206000E+00								
SOLVE	-.117914E+00	.612107E-01	-.152322E+00	.166634E-01	.932893E+00	-.151842E+01	.257922E+01	131						
CORR	-.588973E+00	-.321274E+00	.977112E+00	.196571E-01	.165019E-01									
FIND	.644774E+00	-.299451E+00	.220601E+01	.295619E-01	.323806E-01									
FIND	.206055E+00	.610000E-01	.259167E-01	.631667E-01	.295000E-01	.208000E+00								
FIND	.206332E+00	.101667E+00	.552500E-01	.101417E+00	.550000E-01	.208000E+00								
SOLVE	.633242E-01	.292644E-01	.101472E+00	.550550E-01	.126043E+01	.223321E+01	132							
FIND	.206055E+00	.794167E-01	-.60833E-02	.833333E-01	-.341667E-02	.208000E+00								
FIND	.206332E+00	-.130667E+00	.490000E-01	.131000E+00	.480433E-01	.208000E+00								
SOLVE	.812074E-01	-.372341E-02	.130427E+00	.642295E-01	.841733E+00	.280104E+00	.238001E+01	133						
FIND	.206055E+00	-.151667E+00	.931667E-01	-.143417E+00	.981667E-01	.208000E+00								
FIND	.206332E+00	-.156250E+00	.523333E-01	-.156750E+00	.526667E-01	.208000E+00								
SOLVE	.143265E+00	.378380E-01	-.156840E+00	.527033E-01	.637825E+00	.113392E+01	.226163E+01	134						
FIND	.206055E+00	-.117750E+00	.612500E-01	-.115667E+00	.633333E-01	.208000E+00								
FIND	.206332E+00	-.153667E+00	.159157E-01	-.154250E+00	.153167E-01	.208000E+00								
SOLVE	-.115404E+00	.631965E-01	-.154222E+00	.153167E-01	.1976738E+00	-.151894E+01	.253988E+01	135						
CORR	-.588916E+00	-.321290E+00	.976949E+00	.162101E-01	.170844E-01									
FIND	.644703E+00	-.299369E+00	.220610E+01	.290493E-01	.316613E-01									
NO OF	PTS,PT	NO,MEAN,DEV	34	1	0									
NO OF	PTS,PT	NO,MEAN,DEV	34	2	0									
NO OF	PTS,PT	NO,MEAN,DEV	34	3	0									
NO OF	PTS,PT	NO,MEAN,DEV	34	4	0									
NO OF	PTS,PT	NO,MEAN,DEV	34	5	.658133E+00	.243203E+00								
NO OF	PTS,PT	NO,MEAN,DEV	34	6	.776817E+00	.395669E+00								
NO OF	PTS,PT	NO,MEAN,DEV	34	7	.245523E+00	.142561E+00								
NO OF	PTS,PT	NO,MEAN,DEV	34	8	.847361E+00	.470091E+00								
.142	11.57-10.07	38.33	7.50	-9.64	37.36	RUN	680.	PTS	5	AND	6	.381361E+01	.934730E+00	.123246E+01
.144	10.36-10.21	38.24	7.46	-9.70	37.26	RUN	680.	PTS	5	AND	6	.366368E+01	.981252E+00	.118991E+01
.146	10.53-10.32	38.09	6.92	-9.66	37.24	RUN	680.	PTS	5	AND	6	.376601E+01	.781985E+00	.114239E+01
.148	9.85-10.38	37.98	6.38	-9.75	37.27	RUN	680.	PTS	5	AND	6	.359585E+01	.686543E+00	.996137E+00
.150	3.22-10.49	37.93	5.98	-9.97	37.22	RUN	680.	PTS	5	AND	6	.336167E+01	.900878E+00	.940312E+00
.152	3.67-10.57	37.70	5.67	-10.20	37.07	RUN	680.	PTS	5	AND	6	.308744E+01	.859161E+00	.821324E+00
.154	3.24-10.63	37.42	5.26	-10.46	36.79	RUN	680.	PTS	5	AND	6	.304805E+01	.866795E+00	.863834E+00
.156	7.83-10.85	37.01	4.34	-10.76	36.37	RUN	680.	PTS	5	AND	6	.284415E+01	.801822E+00	.864760E+00
.158	7.38-10.98	36.82	4.84	-11.07	35.85	RUN	680.	PTS	5	AND	6	.284478E+01	.773129E+00	.706766E+00
.160	5.74-11.26	36.17	4.06	-11.41	35.33	RUN	680.	PTS	5	AND	6	.287856E+01	.770970E+00	.730344E+00
.162	5.63-11.50	35.83	3.97	-11.96	34.17	RUN	680.	PTS	5	AND	6	.290028E+01	.806443E+00	.781320E+00
.164	5.62-11.66	34.72	3.96	-12.37	33.26	RUN	680.	PTS	5	AND	6	.297812E+01	.124887E+01	.115226E+01
.166	6.61-11.77	34.02	4.00	-12.76	32.23	RUN	680.	PTS	5	AND	6	.311219E+01	.674235E+00	.753161E+00
.170	6.46-11.84	33.44	4.11	-13.11	31.21	RUN	680.	PTS	5	AND	6	.331528E+01	.432256E+00	.426664E+00
.172	6.52-11.71	32.78	4.41	-13.29	30.26	RUN	680.	PTS	5	AND	6	.348010E+01	.438404E+00	.464156E+00
.174	6.54-11.63	32.22	4.73	-13.27	29.49	RUN	680.	PTS	5	AND	6	.364792E+01	.570896E+00	.620472E+00
.176	6.54-11.57	31.75	4.34	-13.10	28.72	RUN	680.	PTS	5	AND	6	.365967E+01	.761358E+00	.624323E+00
.178	6.71-11.35	31.31	5.15	-12.76	28.10	RUN	680.	PTS	5	AND	6	.375798E+01	.809437E+00	.624323E+00
.180	5.70-11.26	30.98	5.27	-12.60	27.84	RUN	680.	PTS	5	AND	6	.383673E+01	.735467E+00	.523390E+00
.182	6.77-11.16	30.59	5.67	-12.79	27.82	RUN	680.	PTS	5	AND	6	.389980E+01	.627485E+00	.538444E+00
.184	6.66-11.11	30.20	6.23	-12.97	27.82	RUN	680.	PTS	5	AND	6	.333760E+01	.594613E+00	.660283E+00
.186	7.15-11.00	29.95	6.08	-12.95	27.03	RUN	680.	PTS	5	AND	6	.336897E+01	.380954E+00	.315409E+00

188	7.25-10.57	25.75	6.37-12.55	25.35	RUN	600.	PTS	5	AND	6	344261E+01	441776E+00	145865E+00	
189	7.56-10.55	29.39	6.37-12.66	26.67	RUN	600.	PTS	5	AND	6	320008E+01	445703E+00	140335E-02	
190	8.24-11.05	26.39	6.37-12.44	26.91	RUN	600.	PTS	5	AND	6	303544E+00	127539E+00	277021E+00	
191	8.53-10.57	26.39	6.71-12.62	27.41	RUN	600.	PTS	5	AND	6	333194E+01	450327E+00	156633E+00	
192	8.55-11.55	26.75	6.76-12.36	27.05	RUN	600.	PTS	5	AND	6	342119E+01	218001E+00	945558E+00	
193	8.77-10.47	28.50	6.76-13.20	27.43	RUN	600.	PTS	5	AND	6	364566E+01	304660E+00	159525E+01	
200	9.12-10.46	29.66	7.23-13.01	27.17	RUN	600.	PTS	5	AND	6	350566E+01	231951E+00	159798E+01	
201	9.42-10.40	28.52	7.74-13.11	27.11	RUN	600.	PTS	5	AND	6	340759E+01	44447E+00	146400E+01	
204	9.53-10.53	23.47	8.41-13.25	26.96	RUN	600.	PTS	5	AND	6	333697E+01	568908E+00	113580E+01	
206	9.30-10.52	28.45	8.34-13.51	26.39	RUN	600.	PTS	5	AND	6	367608E+01	642773E+00	769882E+00	
208	10.10-10.57	28.56	8.37-13.61	27.14	RUN	600.	PTS	5	AND	6	375926E+01	387781E+00	240305E+00	
184	10.07	17.27	35.03	11.66	16.52	29.33	RUN	600.	PTS	7	AND	6	161303E-01	240593E+00
185	9.76	17.22	34.52	11.55	16.40	29.51	RUN	600.	PTS	7	AND	6	151303E-01	210333E+00
186	9.44	17.07	34.28	11.46	16.22	29.16	RUN	600.	PTS	7	AND	6	157375E+01	359404E-01
187	9.08	17.02	33.39	11.50	16.11	29.79	RUN	600.	PTS	7	AND	6	156834E-01	665372E-01
188	8.77	16.59	33.65	11.54	16.08	29.56	RUN	600.	PTS	7	AND	6	163103E+00	668392E-01
189	8.49	16.90	33.27	11.71	15.90	29.29	RUN	600.	PTS	7	AND	6	118876E+00	263601E+00
190	8.24	16.82	32.95	11.76	16.03	27.97	RUN	600.	PTS	7	AND	6	958170E-01	507635E+00
191	8.15	16.69	32.46	11.76	15.90	27.64	RUN	600.	PTS	7	AND	6	146221E+00	363693E+00
192	8.05	16.44	31.89	12.20	15.56	27.75	RUN	600.	PTS	7	AND	6	263690E+00	118701E+00
193	8.14	16.42	31.98	12.40	15.56	27.74	RUN	600.	PTS	7	AND	6	82507E+00	601892E-02
194	8.25	16.40	31.54	12.65	15.51	27.74	RUN	600.	PTS	7	AND	6	267262E+00	267262E+00
195	8.52	16.34	31.05	13.13	15.46	27.57	RUN	600.	PTS	7	AND	6	388707E+00	384764E+00
196	8.51	16.32	30.72	13.22	15.28	27.63	RUN	600.	PTS	7	AND	6	246502E+00	244323E+00
197	8.55	15.43	30.33	13.49	15.19	27.56	RUN	600.	PTS	7	AND	6	100323E+00	207933E+00
198	8.75	16.55	30.03	13.91	15.35	27.27	RUN	600.	PTS	7	AND	6	429629E+00	605945E+00
199	8.58	16.47	30.17	13.91	15.35	27.27	RUN	600.	PTS	7	AND	6	120415E+00	124400E+00
200	9.10	16.73	29.95	14.25	15.49	27.24	RUN	600.	PTS	7	AND	6	281415E+00	605945E+00
201	9.34	16.63	29.95	14.33	15.42	27.35	RUN	600.	PTS	7	AND	6	120415E+00	124400E+00
202	9.20	16.71	29.92	14.42	15.42	27.22	RUN	600.	PTS	7	AND	6	320275E-01	115897E+01
203	9.28	16.64	29.91	14.60	15.25	27.10	RUN	600.	PTS	7	AND	6	606514E-01	136819E+01
204	9.34	16.63	29.89	14.69	15.19	27.21	RUN	600.	PTS	7	AND	6	132471E+00	164546E+01
205	9.70	15.95	30.01	14.67	15.17	27.31	RUN	600.	PTS	7	AND	6	220391E+00	142337E+01
206	9.84	16.91	30.00	15.17	15.73	27.16	RUN	600.	PTS	7	AND	6	291376E+00	151029E+01
207	10.08	17.12	30.02	15.31	15.90	27.11	RUN	600.	PTS	7	AND	6	334220E+00	156730E+01
208	10.32	17.28	30.06	15.44	15.92	26.99	RUN	600.	PTS	7	AND	6	231483E+00	163233E+01
209	10.65	17.47	30.13	15.51	15.90	26.97	RUN	600.	PTS	7	AND	6	211664E+00	166095E+01
210	10.72	17.60	30.15	15.54	15.96	26.83	RUN	600.	PTS	7	AND	6	170331E+01	165311E+01
211	10.84	17.76	30.27	15.37	16.06	26.81	RUN	600.	PTS	7	AND	6	588218E+00	165311E+01
212	11.04	17.95	30.41	15.34	16.08	26.66	RUN	600.	PTS	7	AND	6	455129E+01	171366E+01
213	11.34	17.97	30.67	15.38	16.10	26.82	RUN	600.	PTS	7	AND	6	369540E+00	171366E+01
214	11.43	18.22	30.95	15.13	16.57	26.80	RUN	600.	PTS	7	AND	6	193208E+01	193208E+01
215	11.72	18.23	31.20	15.41	16.59	26.83	RUN	600.	PTS	7	AND	6	126741E+01	126741E+01
216								680.	PTS	7	AND	6	402911E+00	402911E+00
217								680.	PTS	7	AND	6	344346E+00	344346E+00
218								680.	PTS	7	AND	6	222677E+00	785342E-01
219								680.	PTS	7	AND	6	302144E+00	232454E+00

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UNCLASSIFIED UDRI-TR-76-88 AMRL-TR-78-94 NL

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ERRATA STATEMENT

AD-A062006
AMRL-TR-78-94, "Photometric Methods for the Analysis of Human Kinematic Responses to Impact Environments", October 1978 is revised as follows:

1. Page 11 - First complete paragraph, sixth and seventh sentences,

"The resultant displacement . . . and in G's.",
is changed to read,

A moving eleven point quadratic least square fit is then applied to these smoothed x and z-axis displacement data to obtain the x and z components of velocity. Next this same smoothing routine is applied to these x and z-axis velocity data to compute the x and z components of acceleration. The resultant displacement, velocity, and acceleration data are then computed using these smoothed x and z component data.

2. Page 15 - The equation used to calculate resultant displacement is changed to read:

$$RES(I) = \sqrt{XD(I)^2 + ZD(I)^2}$$

The second sentence following this equation,
"Subroutine DERIV1 . . . in each case.", is changed to read,

Next subroutine DERIV1 is called to compute the X and Z components of velocity from the X and Z displacement data and then to compute the X and Z components of acceleration from the X and Z velocity data. In each case an eleven point quadratic smoothing

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function is applied to the input displacement or velocity data. The velocity components are stored in arrays VX(I) and VZ(I) and the acceleration components in arrays AX(I) and AZ(I). The resultant velocity and acceleration data are computed as follows:

$$VEL(I) = \sqrt{VX(I)^2 + VZ(I)^2}$$

$$ACC(I) = \sqrt{AX(I)^2 + AZ(I)^2}$$

3. Appendix C - as follows:

Page 130 ---

Insert line 125:

2, VX(302), VZ(302), AX(302), AZ(302)

Insert line 185:

2, (XX(1,1), VX(1)), (XX(1,2), AX(1)), (ZZ(1,1),
VZ(1)), (ZZ(1,2), AZ(1))

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Change Line 4480 to:

CALL DERIV1 (T, XD, VX, N, NP, 1)

Change Line 4500 to:

CALL DERIV1 (T, VX, AX, N, NP, 2)

Insert Line 4485:

CALL DERIV1 (T, ZD, VZ, N, NP, 1)

Insert Line 4505:

CALL DERIV1 (T, VZ, AZ, N, NP, 2)

Insert Line 4525:

VEL(I) = SQRT(VX(I) * VX(I) + VZ(I) * VZ(I))

Insert Line 4527:

ACC(I) = SQRT(AX(I) * AX(I) + AZ(I) * AZ(I))

4. Appendix D - Disregard tabular listings and plots of Resultant Velocity and Resultant Accelerations.

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