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AFWAL-TR-80-3117, VOL. II

MARK IV SUPERSONIC-HYPERSONIC ARBITRARY-BODY PROGRAM - MODIFICATIONS AND COMPUTER GRAPHICS

VOLUME II - COMPUTER GRAPHICS

S. TAYLOR

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JUL 21 1981

SCIENCE APPLICATIONS, INC.
AERONAUTICAL SYSTEMS TECHNOLOGY DIVISION
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IRVINE, CALIFORNIA 92714

OCTOBER 1980

TECHNICAL REPORT AFWAL-TR-80-3117 VOL. II

Final Report for May 1978 - September 1980

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

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An interactive computer graphics program, TEKPIC, was developed for validating geometries prepared for the Mark IV Supersonic-Hypersonic Arbitrary-Body program. The TEKPIC program is also capable of displaying surface streamlines generated by the modified Mark IV program. A separate computer graphics program, HIDDEN, was constructed from existing computer codes and, unlike TEKPIC, is capable of removing hidden lines. Program HIDDEN is operated in a batch mode to produce Calcomp plots.

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FOREWORD

This report was prepared for the Flight Dynamics Laboratory/FIMG, Wright-Patterson Air Force Base, Ohio, under contract number F33615-78-C-3001. The contract was initiated under project number 2404, task number 240407 and work unit number 24040718. The work was performed by the Aeronautical Systems Technology Division, Science Applications, Inc. (SAI) in Irvine, California as part of the Hypersonic Aeromechanics Technology (HAT) program. The HAT program was initiated in May 1978 and completed in September 1980. Mr. R. D. Neumann was the Air Force Project Engineer. Mr. L. A. Cassel was the SAI Program Manager for the period May 1978 to December 1979 and Mr. S. Taylor assumed the responsibilities from January 1980. Mr. S. Taylor also served as Principal Investigator for the HAT program's Aerodynamics Task.

The author gratefully acknowledges the contributions of Mr. Don Shereda of the Air Force Wright Aeronautical Laboratories (FIMG) whose guidance was instrumental in the successful completion of the task. The author also wishes to thank Mr. John Farr, SAI, for his key efforts throughout the duration of the program.

This report is documented in two volumes. Volume I describes modifications made to the Mark IV Supersonic-Hypersonic Arbitrary-Body computer program, and Volume II documents two computer graphics codes used to validate Mark IV geometries.

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INTRODUCTION

The work described in this report is relevant to users of the Mark IV Supersonic-Hypersonic Arbitrary-Body Program (Reference 1), a FORTRAN computer program employing design methods for predicting the aerodynamics of complex configurations. The report is documented in two volumes. Volume I (Reference 2) describes the modifications made to the Mark IV code itself, including the replacement of the previous streamline method with one capable of tracing continuous surface streamlines. Volume I also documents changes made to the integral boundary layer methods used to predict detailed boundary layer properties along the inviscid surface streamlines. Volume II documents two computer graphics programs used to validate Mark IV geometries.

The primary objective of the work described in this volume was to develop an interactive computer graphics program capable of displaying Mark IV Element geometries. The result of this effort is the TEKtronix PICtures (TEKPIC) program which enables the user to examine any configuration from many select viewing angles in a minimal amount of time. Program TEKPIC also has the capability to display the surface streamlines generated by the modified Mark IV program. Both the geometry and the streamlines are displayed in true perspective.

The TEKPIC code, however, does not have the capability to remove from the plotting file those Elements obstructed from view by other Elements of the geometry. Such Elements are known as "hidden lines." Algorithms commonly used to remove hidden lines require large amounts of both CP time and core memory, and are therefore not amenable to interactive operation. One such computer program was written by Purdue University researchers (Reference 3), but the program is not compatible with Mark IV geometry formats. A separate geometry preprocessor program was later written (Reference 4) which converts Mark IV geometries to a format compatible with the Purdue hidden line program. A secondary objective of the work described in this volume was to couple the two programs into one computer code, HIDDEN, capable of producing true perspective, hidden line plots of Mark IV Element geometries.

As a first step in validating newly prepared Mark IV Element data, it is suggested that the TEKPIC program be used since the geometry can be rapidly rotated to any desired orientation. When examining complex configurations from certain viewing angles, however, the hidden lines tend to interfere with some of the truly visible lines. In such cases it is desirable to use the HIDDEN program to complete the geometry validation.

Part I of this volume gives a brief description of the Mark IV Element geometry and defines the nomenclature used in the remainder of the report. Part II contains a complete discussion of the theory and the operation of the TEKPIC program. Finally, Part III provides a user-oriented guide to the HIDDEN program. A detailed description of the theory and the coding of both the geometry preprocessor and the hidden line routines used in HIDDEN is given in Reference 4.

All computer codes developed or modified under this program are operational on the CDC CYBER 750 computer used by the ASD Computer Center, Wright-Patterson AFB, Ohio.

PART I

MARK IV GEOMETRY DESCRIPTION

Although a complete description of the Mark IV geometry data preparation is given in Reference 1, a brief discussion of the Element Data geometry option is presented here to familiarize new Mark IV users and to refresh seasoned users with the nomenclature used in subsequent sections of this report. The interactive graphics code, TEKPIC, and the Calcomp graphics code, HIDDEN, are compatible only with Mark IV Element Data geometries (Type 3 cards). Although the Elliptic-Cross Section, Parametric Cubin, and Aircraft Geometry options may not be used directly with either TEKPIC or HIDDEN, they can be used indirectly.

Geometries prepared for the Mark IV program are described in a cartesian coordinate system. Normally, a vehicle is described along the negative x-axis with its forward-most section located near the origin, as shown in Figure 1. The geometry is first divided into convenient parts called Sections as shown in Figure 2a. Sections may be grouped together to form Panels, but if the user wishes to use the streamline method in the modified Mark IV code (Reference 2), it is suggested that each Panel contain only one Section. (The inviscid pressure option of the Mark IV program analyzes user-specified groups of Panels known as Components. The user may select one pressure method for each Component. However, the term Component is not used here.)

Once the geometry has been Sectioned, an array of points must be prepared for each Section, as illustrated in Figure 2b. Each set of four related points within a Section is termed a surface Element. Therefore, for NR rows and NC columns of input points within a Section, there are (NR-1) rows and (NC-1) columns of surface Elements. The array of points for each Section are read by the program column-by-column. Since each Section has two surfaces, an outer and an inner surface, the order in which the columns are input is used to identify the outer surface. The first column of points may start from any one of the four corner points of a Section. For a given corner point, however,

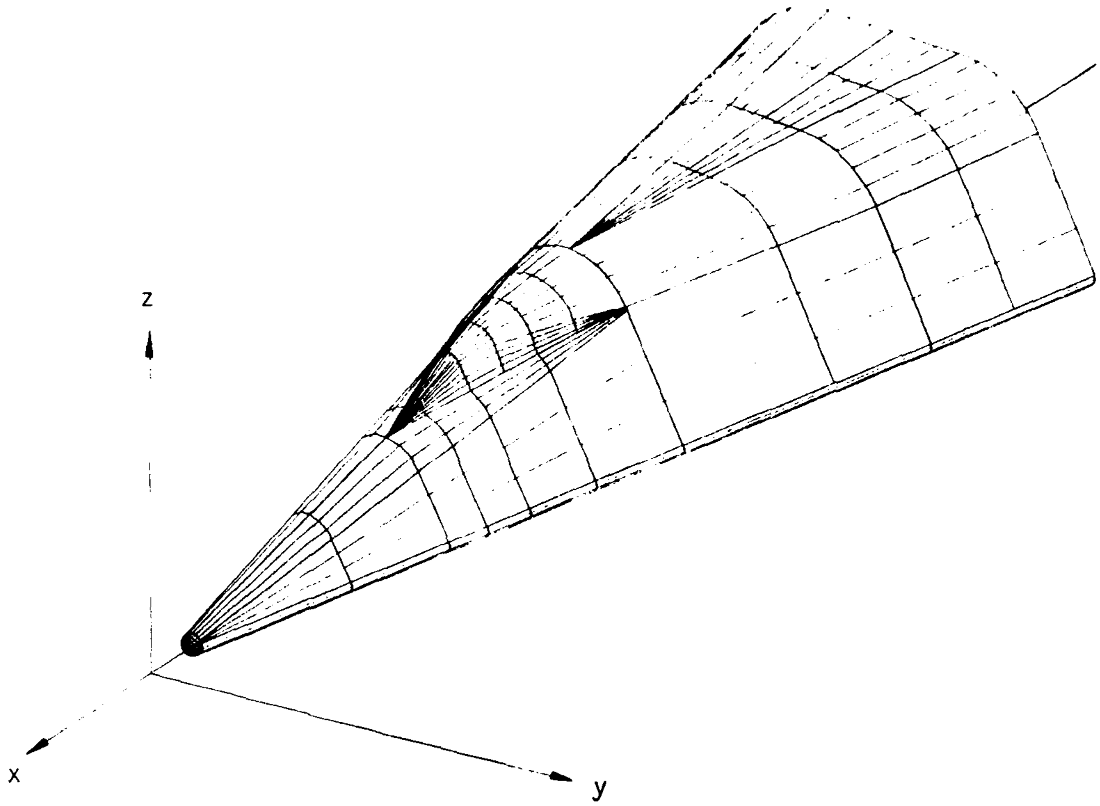
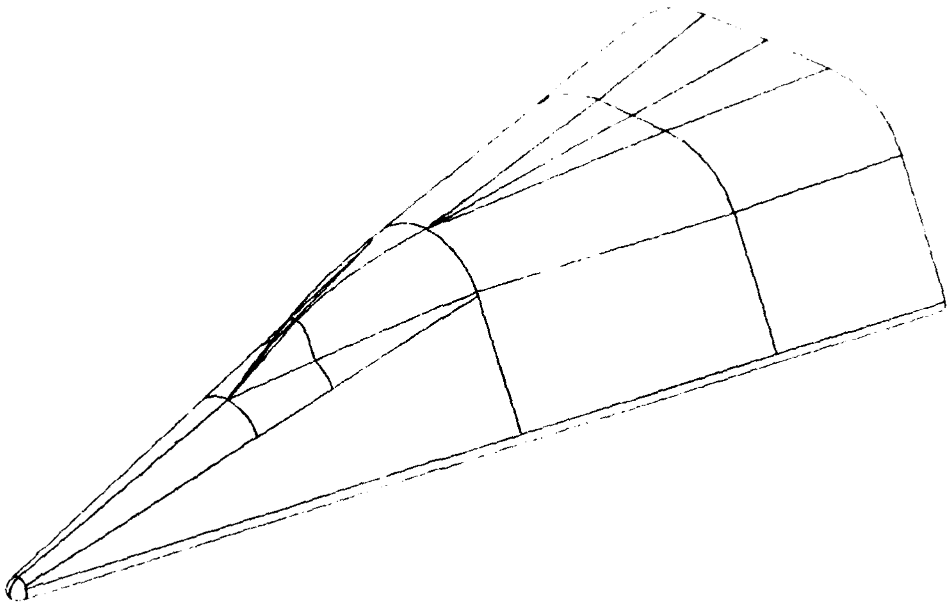
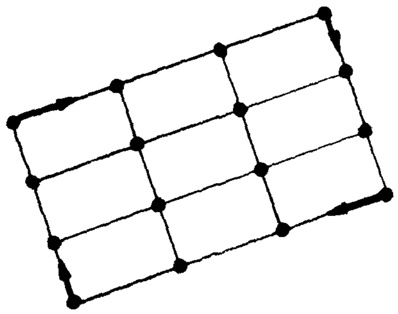
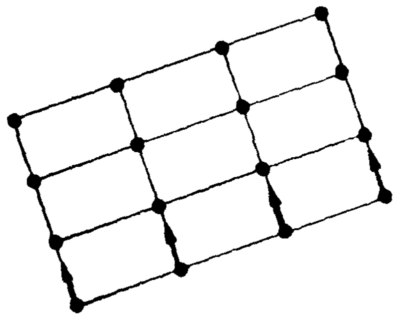


Figure 1. Mark IV Coordinate System



a. Sectioned geometry





b. Columns of points describing a Section (arrows indicate the four possible orders in which the first column of points may be input)

c. Succeeding ordering of columns (if lower left corner point chosen as first point)

Figure 2. Element Geometry Preparation

only one of the two sides intersecting the corner point may serve as the first column. The user may identify the correct side by first orienting one of the two sides such that the corner point is at the bottom of the column of points. If the adjacent column of points lies to the right of the first column, the user has selected the proper side. Otherwise, the other side must serve as the first column. The four possible choices for the first column are denoted by the heavy arrows in Figure 2b. The points of succeeding columns are also input from bottom to top as shown in Figure 2c.

Associated with each point is an integer status flag indicating whether a point is the beginning of a new Section, the beginning of a new column other than the first column of a Section, an interior point, or the last point of a Panel. Listed below is a key to each of the integer values of the status flag.

Status Flag	Explanation
0	Point is not the first point of a column or the last point of a Panel.
1	First point of a column other than the first column.
2	First point of a Section.
3	Last point of a Panel.

Geometry points are input two to a card. It is suggested that each column contain an even number of points (rows). The geometry deck will then be compatible with the Mark IV code, the TEKPIC code, and the HIDDEN code. If the last point of a column contains an odd number of points, repeat the last point (a dummy point). By adhering to the following geometry data format and by using an even number of points per column, the geometry deck is certain to be compatible with all three codes.

Element Data Input Cards

Column	Format	Explanation
1-10	F10.0	x-coordinate of surface point.
11-20	F10.0	y-coordinate of surface point.
21-30	F10.0	z-coordinate of surface point.
31	I1	Status flag for above set of coordinates. (=2, 1, or 0)
32-41	F10.0	x-coordinate of surface point.
42-51	F10.0	y-coordinate of surface point.
52-61	F10.0	z-coordinate of surface point.
62	I1	Status flag for above set of coordinates. (=0 or 3)
65-66	I2	Case number (optional).
67-70	A4	Alphanumeric characters identifying the vehicle Section (optional).
71-72	I2	Card type number = 03.
77-80	I4	Card sequence number used as an aid in keeping the cards in order (optional).

PART II

PROGRAM TEKPIC

One of the most time-consuming aspects of assembling input data for the Mark IV program is the preparation and checkout of the geometry data, particularly if the geometry is complex. Should the geometry data contain errors, aerodynamic results may be inaccurate or meaningless. Visual display of the vehicle geometry is an effective means for validating geometry data. An interactive computer graphics system is the most powerful tool available for displaying and checking out vehicle geometries. Therefore, the interactive Tektronix Pictures (TEKPIC) program was written to provide users of the Mark IV code with a means for rapidly validating newly prepared geometry data.

Since TEKPIC is an interactive program, the user may examine a vehicle at a large number of select orientations in a minimal amount of time. If a geometry error is located, TEKPIC allows the user to "zoom in" on any part of the geometry. The user may request that only certain geometry Panels be displayed, or that the entire vehicle be displayed. One unique feature of TEKPIC is its ability to plot the visible surface streamlines generated by the updated version of the Mark IV code (Reference 2). Since it is difficult to distinguish streamlines from the many Element lines of most vehicles, the option to plot either Element boundaries or Section boundaries (see Part I for Mark IV geometry nomenclature) has been included in TEKPIC. As a further aid in distinguishing streamlines from geometry lines, the streamlines may be plotted as solid or dotted lines. Both the streamlines and the geometry are displayed in true perspective.

One desirable feature that TEKPIC does not have is the capability to remove "hidden lines" from the plotting file. Hidden lines are those lines of the geometry that are obstructed from view by other components of the vehicle. The algorithms commonly used to remove hidden lines require a large amount of both CP (i.e. central processing) time and core memory, and therefore, are not amenable to interactive use. Instead, program TEKPIC uses an approximate method to determine which Elements of the geometry are visible. The technique, referred to as the Shadow Method, assumes that a visible Element is one whose outward normal makes an angle less than 90 degrees with the viewer's line of sight. Without a hidden line capability, certain orientations of the vehicle make it difficult for the user to determine if an error actually exists. However, since TEKPIC allows the user to select which panels are to be displayed, and since the geometry can be rapidly reoriented relative to the viewer, this problem can be alleviated. For certain orientations of many complex configurations, final checkout of the geometry requires the use of the use of the HIDDEN program (see Part III).

Program TEKPIC is a Fortran IV code designed for use on the CDC CYBER 750 machine operated by the ASD Computer Center, Wright-Patterson AFB, Ohio. The ASD Computer Center employs an NOS/BE operating system. of the $65000_{(8)}$ words of core memory allocated by the ASD system for interactive computer programs, TEKPIC requires approximately $57000_{(8)}$ words to execute. The interactive graphics terminal for which TEKPIC was designed is the Tektronix 4014 with the Enhanced Graphics capability. With some minor modifications, TEKPIC could be made to operate on systems other than the CYBER 750/Tektronix system.

A user-oriented description of the operation of TEKPIC is given in Section 1. Included is a general sample case which exercises all options of the code. A detailed description of the code itself is given in Section 2 for those who wish to modify the program. Since TEKPIC is a relatively small program, a dictionary of the FORTRAN variables used in the code is also included. The algorithms used in the TEKPIC program are presented in Section 3.

SECTION 1

INFORMATION FOR TEKPIC USERS

Functional Organization

The primary goal sought during the development of the TEKPIC code was to provide the user with a highly flexible computer code that does not require a large number of inputs. However, the amount of information required from the user naturally increases with increasing flexibility. Of the many possible options that could be incorporated into an interactive picture drawing program, only the most useful features have been retained in the TEKPIC program.

Shown in Figure 3 is a user-oriented flow diagram for the TEKPIC code. The rounded boxes represent operations performed by the program, and the sharp-cornered boxes signify that information is to be supplied by the user. The diamonds, in addition to indicating that the program expects a response from the user, signifies a possible transfer of control to other parts of the code. The diagram includes all questions that TEKPIC asks the user. Although a brief explanation of each of the questions and the required responses is given under the heading "Interactive Input/Output", most of the questions, as they actually appear on the CRT, are self-explanatory.

Geometry/Streamline Data Files Preparation

Prior to executing the TEKPIC code, the user must insure that the geometry data and the streamline data (if streamline plots are desired) may be accessed by the program. Since the Mark IV streamline calculation can be made only after the geometry data have been verified, program TEKPIC is normally used on at least two occasions if streamline plots are desired. One or more runs are required to validate the geometry data and, after the streamlines are generated by the modified version of the Mark IV code, another TEKPIC run is necessary to examine the

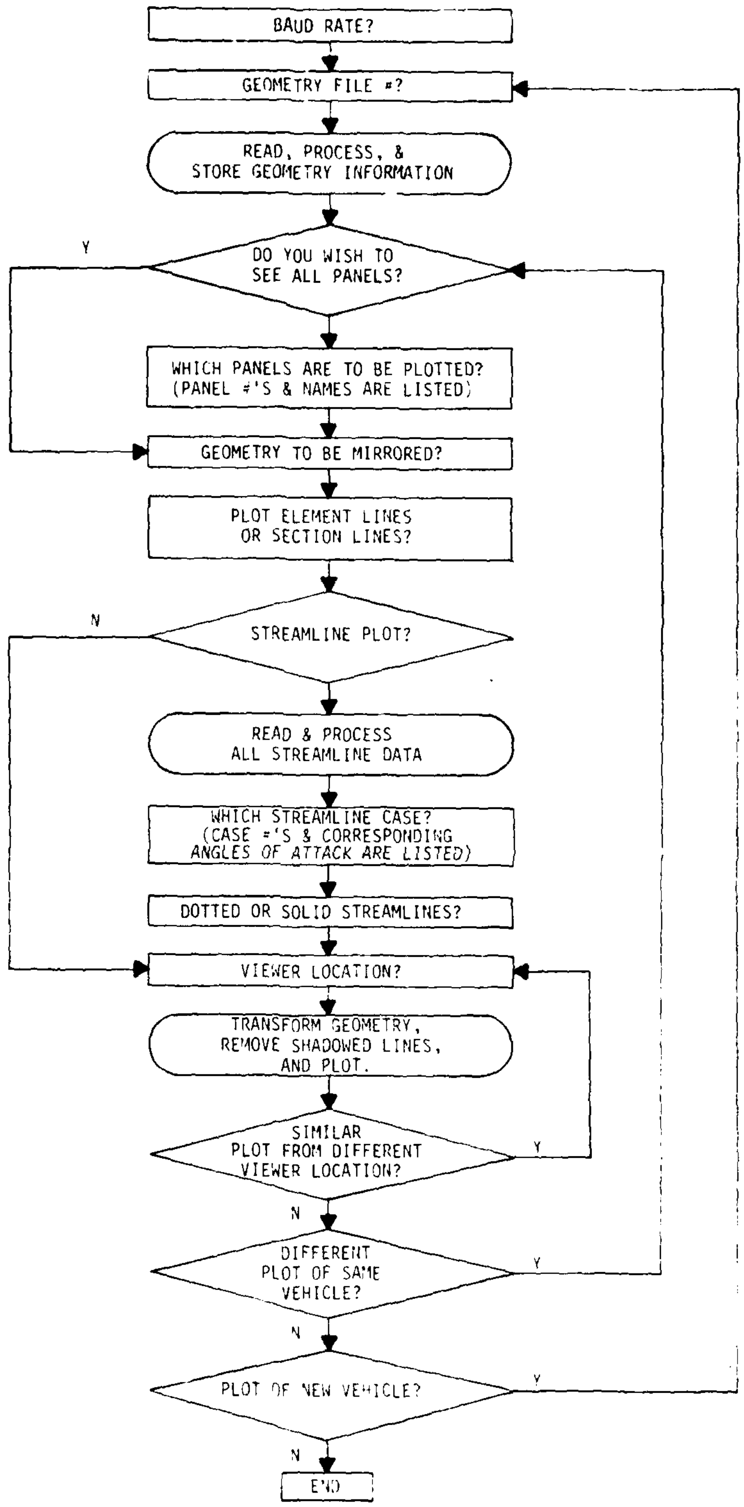


Figure 3. TEKPIC Flow Diagram

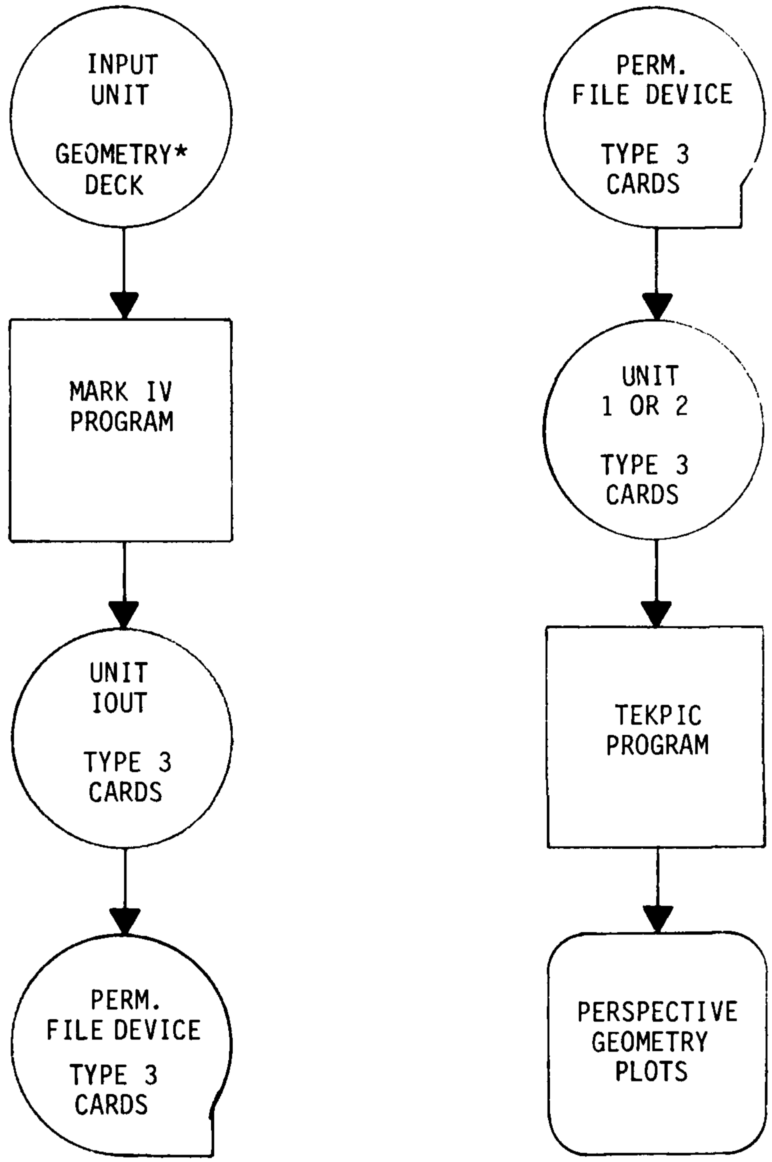
streamlines. (Reference 2 contains a completed description of both the theory and use of the new Mark IV streamline method).

The TEKPIC program accepts geometry data in the Element format (Type 3 cards), one of four geometry formats used in the Mark IV code. Program TEKPIC will not accept data in the Elliptic Cross-Section format, the Parametric Cubic format, or the Aircraft Geometry format. If any part of the geometry is described in any format other than the Element format, the Mark IV code may be used to convert the entire geometry description into Element form, as illustrated in Figure 4a. The local storage unit to which the Type 3 cards are copied is specified by IOUT on the Geometry Control Card (see Volume I of Reference 1). Following the termination of the Mark IV code, the contents of unit IOUT must be copied to a permanent file device if the data are to be used subsequently by the TEKPIC program.

If the entire geometry is described in the Element format, it is not necessary to use the Mark IV code to generate the TEKPIC geometry file. In this case, the Type 3 cards can be saved on a permanent file device in a variety of ways, depending on the user's preference and the computer system's capabilities. Regardless of the method used, the Type 3 cards must appear on the permanent file device as formatted data, one Element card per record. No other cards, including the Panel Identification cards or the Element Control cards, may appear with the Element cards on the permanent file.

Once the Type 3 geometry data have been saved, the user may then access the TEKPIC program and the geometry file, as shown in Figure 4b. Program TEKPIC permits the user to examine two geometries during the course of a run and, therefore, provisions have been made in the code to read the geometry data from either of two local storage units: unit 1 or unit 2. As shown in Figure 3, the user must indicate to TEKPIC which unit contains the geometry. After examining one vehicle's geometry, the user has the option of either terminating execution or specifying the storage unit containing the geometry data of another vehicle.

After validating a given geometry using TEKPIC, the updated version of the Mark IV program may be used to generate surface streamline



a. Mark IV conversion of geometry data to Type 3 format.

b. TEKPIC utilization of Type 3 geometry data.

*May include any collection of Type 3 cards, Elliptic Cross-Section cards, Parametric Cubic cards, and Aircraft Geometry cards.

Figure 4. Element Data Preparation and Use

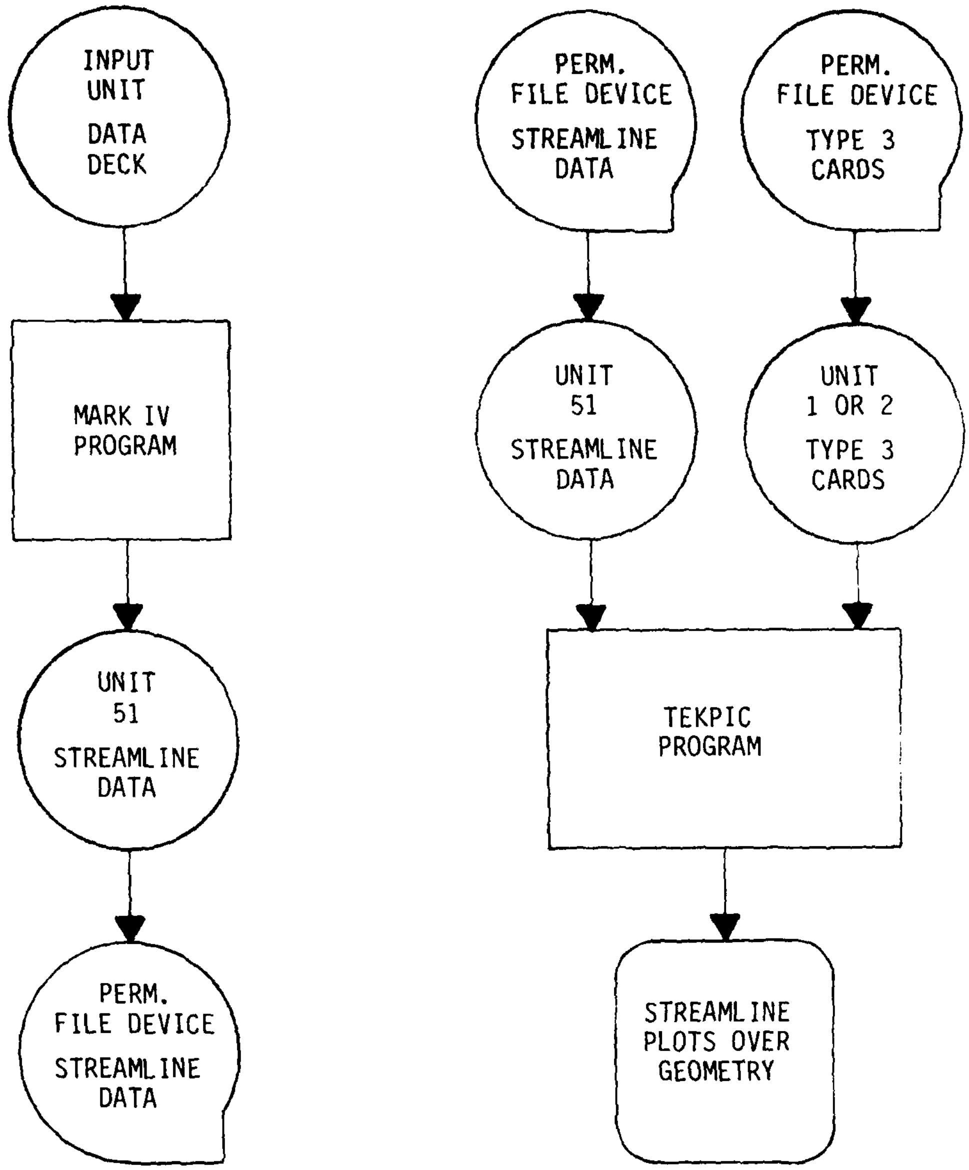
distributions for various angles of attack, as illustrated in Figure 5a. Streamline data are saved on unit 51, a random access (or mass storage) unit, if ISTORE = 1 on the Streamline Data card. As described in Reference 2, the Mark IV code can save as many as five streamline distributions on unit 51, one distribution for each set of freestream conditions. As with the geometry data, the streamline data generated by the Mark IV code must be saved on a permanent file device if the data are to be plotted subsequently by TEKPIC. If streamline plots are desired, both the geometry file and the streamline file must be available on local storage units prior to the execution of TEKPIC as shown in Figure 5b. As mentioned, the geometry data must be placed on unit 1 or unit 2. The streamline data must be available on unit 51.

Interactive Input/Output

After the geometry data and the streamline data have been saved on a permanent file device, the user is ready to access the TEKPIC program and the data file(s) from the interactive graphics terminal. The following discussion assumes that the data files are available on the appropriate units, as discussed in the previous section, and that TEKPIC is in execution.

Program TEKPIC always displays a question on the CRT whenever information is required from the user. After each question is displayed, the cursor is always returned to the next line. The cursor's position prior to data entry will be referred to as column 1. Free-field formats are used in TEKPIC for all numeric input data, regardless of whether the data are integer or real numbers. Free-field formatting allows the data to be typed into any column provided that each element of the data is followed by a comma. Each real number should also contain a decimal point. All non-numeric responses are read in an A-format beginning in column 1. Such responses involve a simple "Y" (yes) or "N" (no).

Referring to Figure 3, the first question asked is, "Baud rate? (characters per second)." The reply must be an integer number representing the baud rate of the telephone line currently in use. The telephone



a. Streamline data preparation

b. TEKPIC utilization of Streamline data

Figure 5. Streamline Data Preparation and Use

lines allocated for interactive use on many large computer systems are typically 30 or 120 character/second lines.

The next question displayed is, "File no. containing Type 3 geometry cards? (1 or 2)." The response should be an integer number, its value depending on whether unit 1 or unit 2 contains the geometry information. Program TEKPIC then reads the Type 3 cards, calculates the outward normal to each Element, and stores the information on local storage unit 3. This calculation procedure is performed only once for each vehicle examined.

Following the calculation of the Elements' outward normals, TEKPIC has all the vehicle geometry information required for the plots. The remaining inputs pertain to the manner in which the geometry and streamlines are to be displayed. The first of these inputs allows the user to specify which geometry panels are to be displayed. Often, however, the user wishes to see the entire vehicle, so the question, "Do you wish to see all panels? (Y/N)" is displayed on the CRT prior to the display of a Panel selection menu. A "Y" reply passes control to the next option. The Panel selection menu shown below follows a "N" response.

> Which panels from the table below are to be displayed? (An array of ten integer numbers, each separated by a comma, is expected. After the last desired panel no., fill the remaining array with zeroes. If all panels are desired, type: 10*0).

Panel No.	1	2	3	...	10
Panel Name	NAME	NAME	NAME		NAME

Panel No.	11	...	N
Panel Name	NAME		NAME

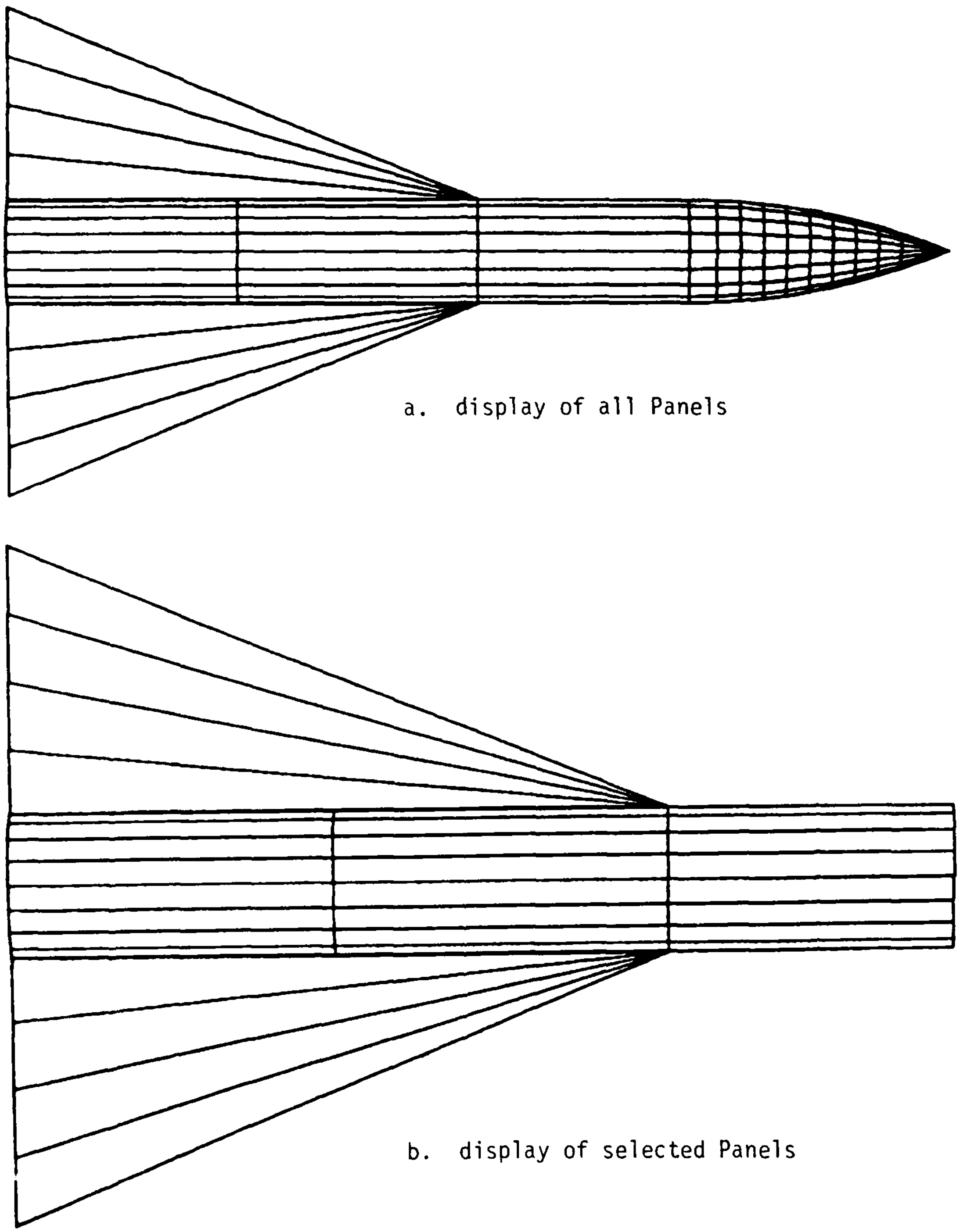
The total number of Panels, N, on unit 1 or 2 may be as large as 50. However, a maximum of only 10 Panels may be selected from the list. The specific Panel name, NAME, used for each Panel corresponds to the four characters in columns 67-70 on the first Type 3 card of each Panel. An example of the results of a Panel selection is shown in Figure 6.

After the user selects the Panels to be displayed, the question, "Is geometry to be reflected about x-z plane? (Y/N)" appears on the CRT. Most of the geometries prepared for the Mark IV code contain a plane of symmetry. Normally, the user only describes the geometry lying on one side of the symmetry plane. Both TEKPIC and the Mark IV code have the capability to generate the reflected half of the vehicle. However, the Mark IV code copies to unit IOUT only those Panels described by the user. Similarly, the Panel selection menu displayed by TEKPIC contains only those Panels provided on unit 1 or 2 by the user. Those panels selected from the panel will be reflected if the response to the above question is "Y".

The next question displayed is, "Should Element or Section boundaries be plotted? (0/1, respectively)." The response should be an integer number. This option is provided primarily for the case when streamlines are to be plotted. For many geometries, it is difficult to distinguish the streamlines from the many Element lines. This problem is alleviated if the streamlines are plotted over the Section geometry rather than the Element geometry, as illustrated in Figure 7. Section plots may be made without streamline plots.

Following the Section/Element option is the Streamline option. The Streamline option begins with the question, "Do you wish to see streamlines? (Y/N)." If streamlines are not available on unit 51, the user must respond with a "N" and control is then passed to the next option. If the streamline data are available on unit 51 and the user wishes to see streamlines, the following comments are displayed if the streamline data have not been accessed previously:

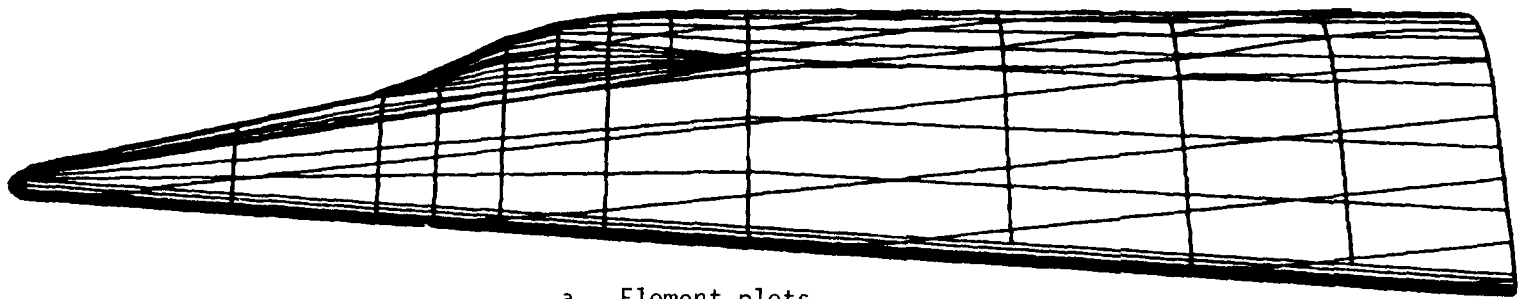
> A search for the outward normal to each streamline point is now being performed. If TAPE 51 is recataloged following



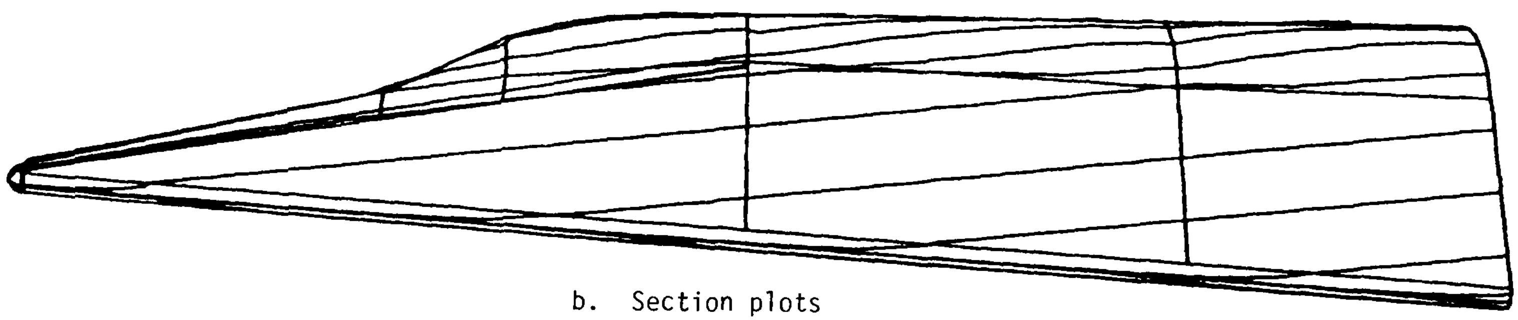
a. display of all Panels

b. display of selected Panels

Figure 6. Panel Selection Feature



a. Element plots



b. Section plots

Figure 7. Comparison of Element Plots with Section Plots (Solid Streamline Option)

the termination of this run, the search will not be necessary for future runs. Please be patient. Sit back and relax.

As with the geometry Elements, the outward normal of each streamline point must be known in order to determine which segments of the streamlines are visible. The search for the streamline outward normals, as described in Section 3, may require that the user wait for several minutes. The amount of time required depends on the number of Panels in the geometry, the total number of points in the streamline distributions, and the job load of the operating system at the time. Once the search is complete, a flag is set and stored with the streamlines' outward normals on unit 51. The flag indicates that the search has been performed. If the new contents of unit 51 are placed on a permanent file device following the termination of TEKPIC, the search will not be made during future TEKPIC runs.

If streamline plots are desired, a menu similar to the example shown below is displayed to allow the user to select which streamline distribution is to be plotted:

Which streamline case below is to be displayed? (1 or 2 or...)

Case No.	Alpha	Beta
1	0.	0.
2	10.	0.
3	20.	0.

The response should be an integer number. A maximum of 5 cases may be stored on unit 51.

The last streamline-related question is, "Streamlines to be plotted as solid or dotted lines? (0/1, respectively)." The number used in the response must be an integer. As illustrated in Figure 8, this option is included in TEKPIC to aid the user in distinguishing the streamlines from the geometry lines. Streamlines, dotted or solid, are displayed only on those panels selected from the Panel menu.

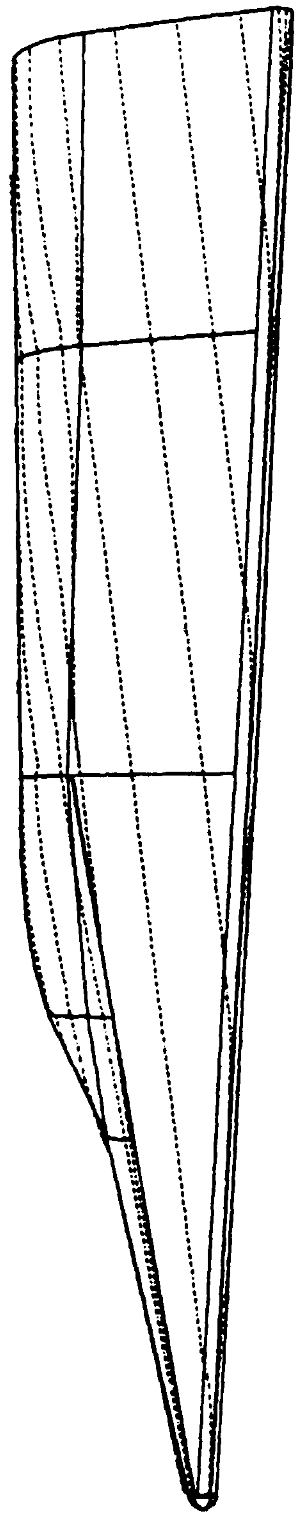


Figure 8. Dotted Streamlines Over Sectioned Geometry

The last question asked prior to the geometry display is, "Viewer location? (3 Cartesian coordinates)." The location of the viewer is specified with respect to the Mark IV Cartesian coordinate system, as shown in Figure 9. The first coordinate specified corresponds to the x-coordinate, the second to the y-coordinate, and the third to the z-coordinate. Real numbers must be used in the response. The viewer location is used with a second point to define the viewer's line-of-sight. That point is calculated automatically by the program, and it is taken to be the midpoint of the geometry along the x-axis.

The TEKPIC code also has the ability to produce perspective plots. Perspective geometry displays, however, require more information than just the viewer's line-of-sight. First, the distance between the viewer and a point on or near the geometry is needed. This point is taken to be the midpoint of the geometry along the x-axis (compatible with the line-of-sight calculation). Secondly, the location of the viewing plane must be specified. The viewing plane must be perpendicular to the line-of-sight and must lie between the viewer and the geometry. Since the perspectivity of the plots is not affected by its position along the line-of-sight, the viewing plane is arbitrarily located one unit in front of the viewer. After all geometry points are projected to the viewing plane, the coordinates of all points are automatically adjusted so that the plot fills a program-specified window on the Tektronix screen.

Therefore, to produce perspective plots of the geometry from any viewing angle, the user must simply specify the location of the viewer. However, one restriction is placed on the user's choice of a viewing location, as illustrated in Figure 10. The viewer must never be positioned such that the viewing plane, lying one unit ahead of the viewer, intersects any part of the geometry. Such problems may generally be avoided by placing the viewer at least one body length from the nearest surface of the geometry.

Upon receiving the coordinates of the viewer location, TEKPIC clears the CRT and begins to plot the geometry and, if so specified,

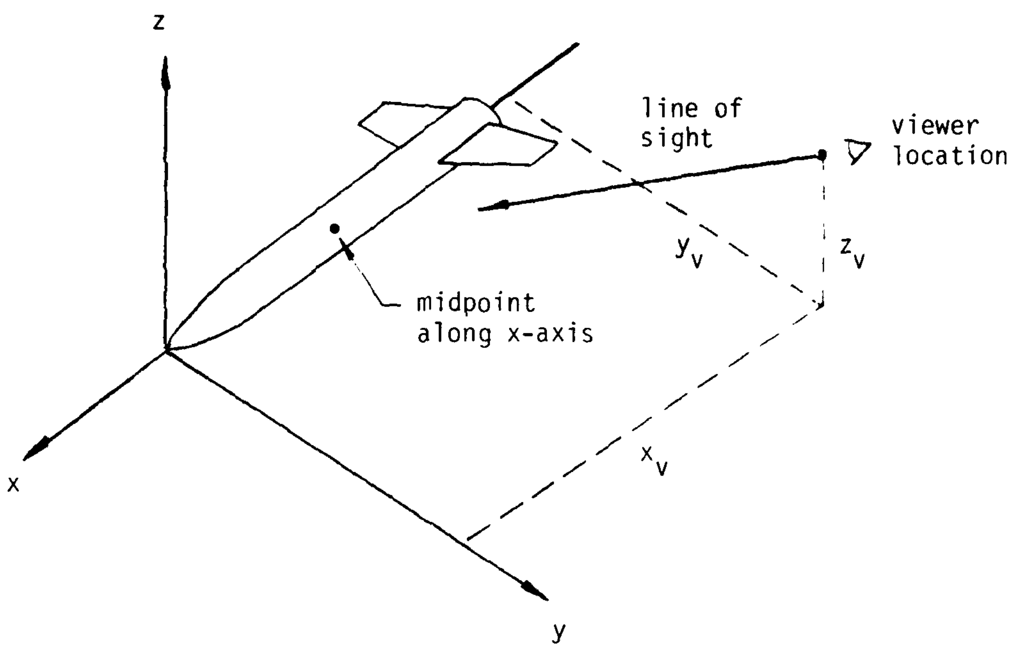
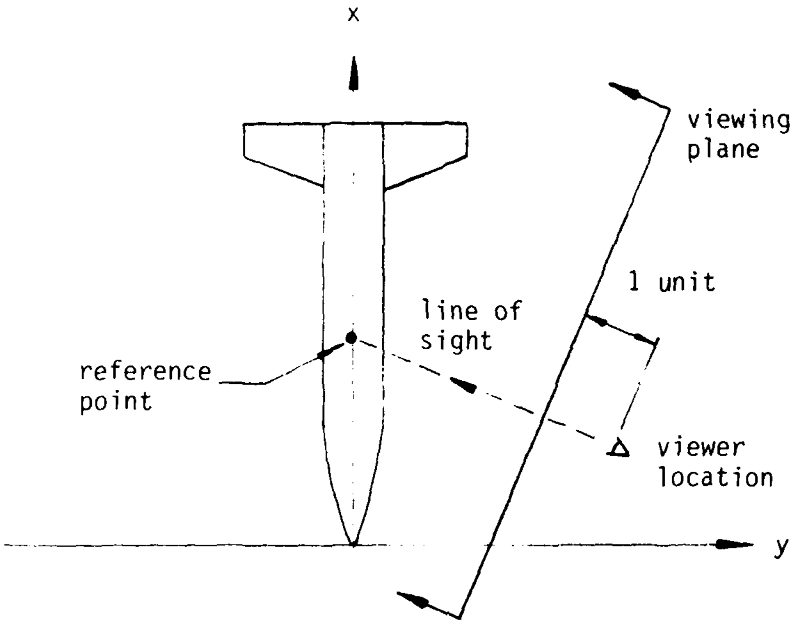
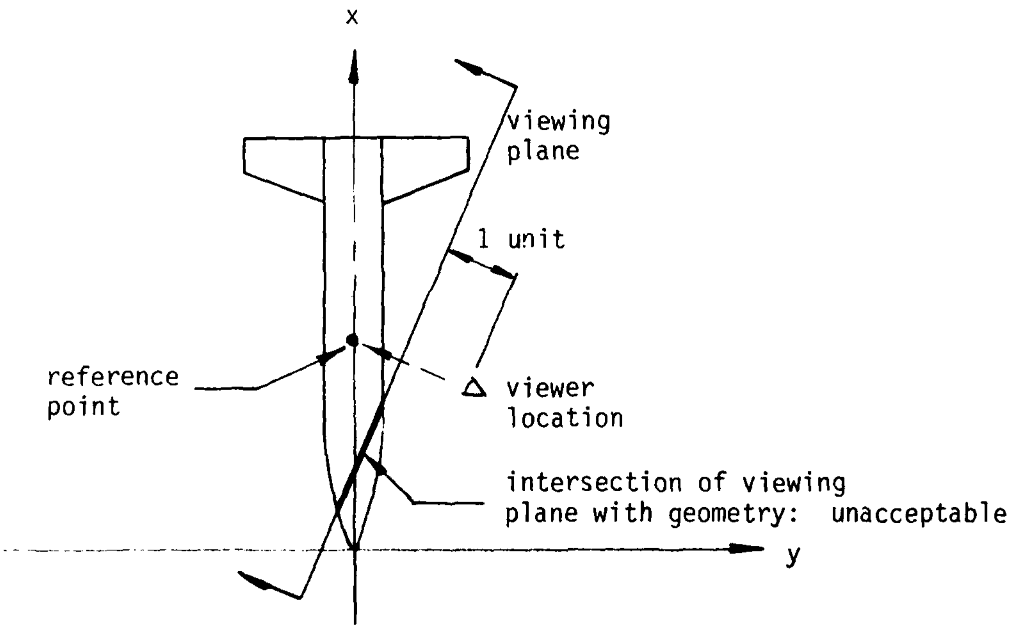


Figure 9. Viewer Placement



a. Acceptable viewer placement.



b. Unacceptable viewer placement.

Figure 10. Restriction on Viewer Placement

the surface streamlines. After all line segments are displayed, the terminal signals with two "beeps" to indicate to the user that the plot is complete. A hard copy may be made at this time if the terminal is so equipped. The geometry display will remain on the screen until the user types any alphanumeric character and presses the carriage return. The screen is then automatically cleared and the next question appears at the top of the screen.

Often the user wishes to view the same geometry Panels from a different viewing angle, and does not wish to change other options previously specified. Therefore, the question, "Do you wish to see similar plots from a different viewer location? (Y/N)" follows each plot as shown in Figure 3. If the response is "Y", control is given to the Viewer Location option where the user specifies the three coordinates of a new viewer location. The same geometry panels displayed for the previous viewer location are then displayed for the new viewer location. If streamlines were specified previously, they will also be plotted.

If the user wishes to make a change to any option other than the Viewer Location option, an "N" response must follow the last question. The question, "Do you wish to see different plots of same vehicle? (Y/N)" then appears on the CRT. A "Y" reply passes control to the Panel Selection option. The user must then respond to all options, in the order indicated in Figure 3, before the geometry can be displayed again. An "N" response signifies that the user has completed the examination of the vehicle.

The final question asked is, "Do you wish to see plots of a different vehicle? (Y/N)." If the answer is "Y", control is passed to the beginning of the program where the user must specify the number of the local storage unit (1 or 2) containing the new geometry. The subsequent sequence of questions asked by TEKPIC will be the same as that just described. Although TEKPIC allows two vehicle geometries to be examined during one run, streamlines may be examined for only one vehicle. If the user responds to the last question with an "N", execution of TEKPIC terminates.

Sample Case

In the following sample case, Type 3 Element cards for a winged ogive-cylinder geometry and for the forebody of the X-24C are made available on local storage units 1 and 2, respectively. Streamline data for the X-24C, as generated previously by the modified Mark IV code, are placed on unit 51. The sample case includes the system commands, peculiar to the ASD system, necessary to attach the data files, and to attach and execute TEKPIC. In the normal mode of operation, TEKPIC is an absolute file containing the basic program, the Tektronix library subroutines, and the appropriate system routines. However, in the sample case below the TEKPIC program exists as a COMPILE file which does not contain the Tektronix subroutines.

Comments have been inserted throughout the sample case and are identified by "C".

```
COMMAND- ATTACH,TEKPIC,ID=D780070,CY=1
 PFN IS
 TEKPIC
COMMAND- ATTACH,TAPE1,GEOM,ID=D780070
 PF CYCLE NO. = 001
COMMAND- ATTACH,TAPE2,X24C,ID=D780070
 PF CYCLE NO. = 001
COMMAND- ATTACH,TAPE51,X24STRM,ID=D780070
 PF CYCLE NO. = 001
COMMAND- ATTACH,TEKLIB,ID=LIBRARY,SN=ASD
 PFN IS
 TEKLIB
 PF CYCLE NO. = 999
COMMAND- LIBRARY,TEKLIB
COMMAND- FTN,I=TEKPIC,L=0
      1.641 CP SECONDS COMPILATION TIME
COMMAND- LGO
```

```
BAUD RATE? (CHARACTERS PER SECOND)
30
```

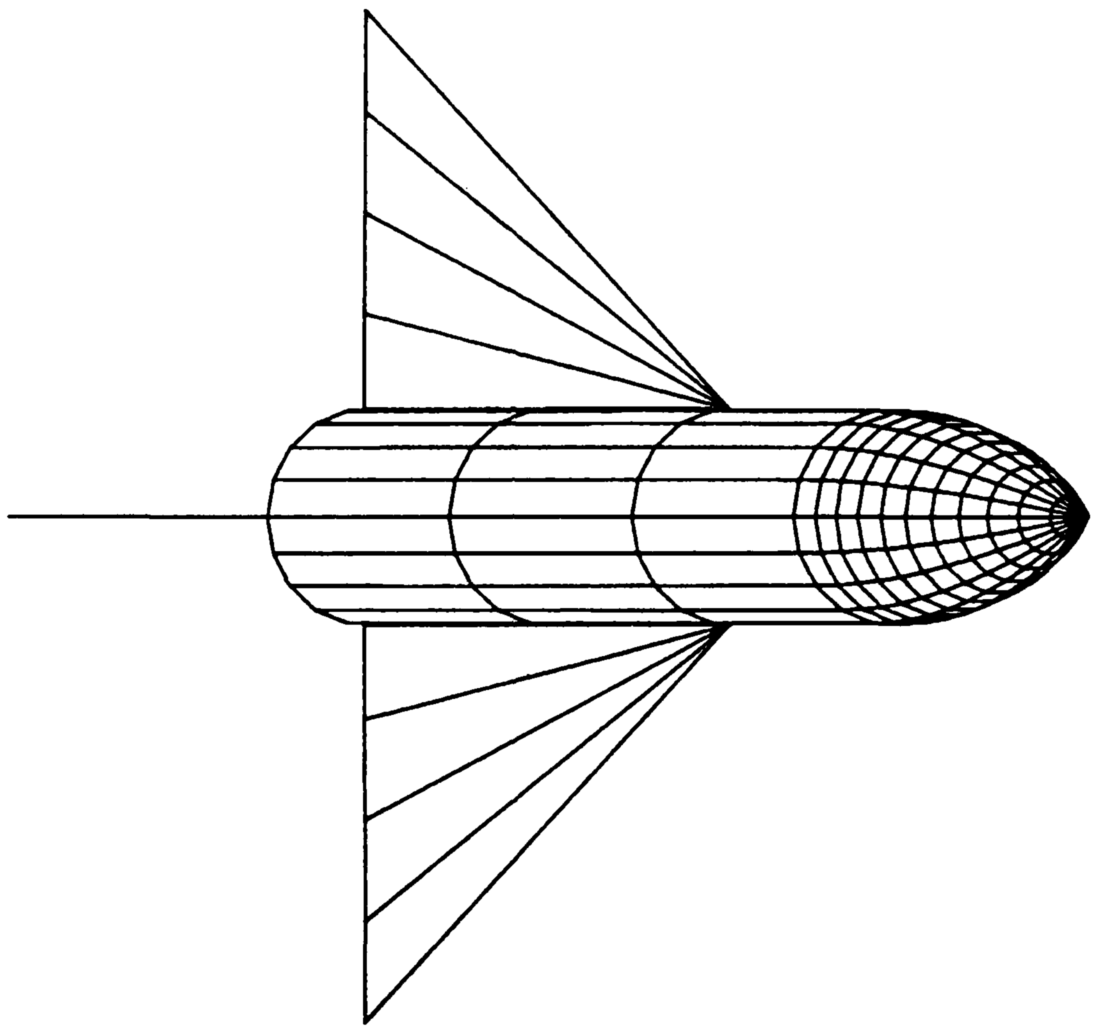
C: The baud rate is required to initialize the Tektronix routines. No Tektronix operations may be performed until baud rate is input.

TEKPIC automatically clears the screen following the baud rate response.

```
FILE NO. CONTAINING TYPE3 GEOMETRY CARDS? (1 OR 2)
1
DO YOU WISH TO SEE ALL PANELS? (Y/N)
Y
IS GEOMETRY TO BE REFLECTED ABOUT X-Z PLANE? (Y/N)
Y
SHOULD ELEMENT OR SECTION BOUNDARIES BE PLOTTED? (0/1, RESPECTIVELY)
0
DO YOU WISH TO SEE STREAMLINES? (Y/N)
N
VIEWER LOCATION? (3 CARTESIAN COORDINATES)
10000.,0.,4000.
```

C: This vehicle extends from x = 0. to x = -80. Therefore, the reference point used in the line-of-sight calculation is automatically placed at (x,y,z) = (-40,0.,0.).

Following the viewer location response, the screen is automatically cleared and the plot follows.

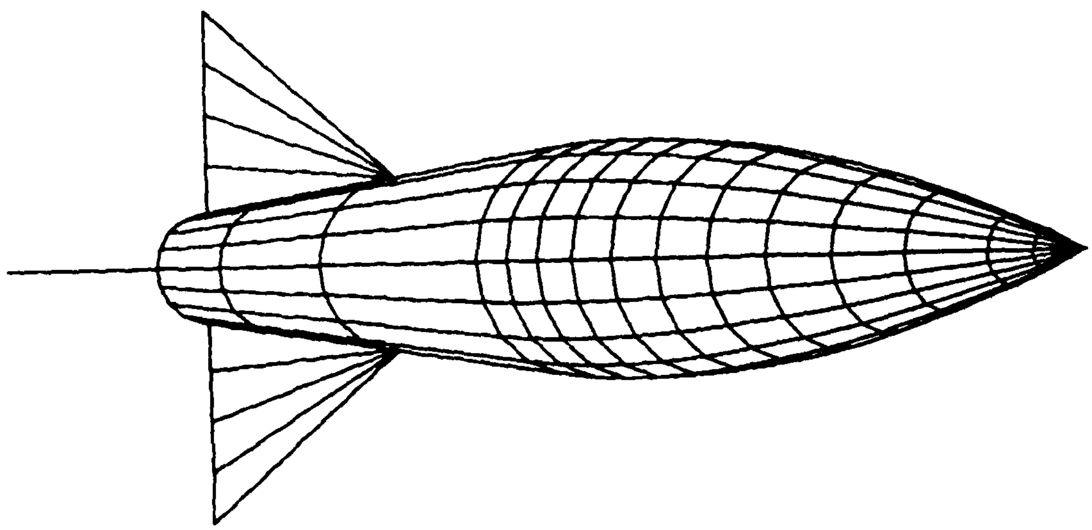


C: After the user inputs any alphanumeric character, the plot is cleared from the screen and the following question appears:

```
DO YOU WISH TO SEE SIMILAR PLOTS FROM A DIFFERENT VIEWER LOCATION? (Y/N)
Y
VIEWER LOCATION? (3 CARTESIAN COORDINATES)
20.,0.,25.
```

C: The user *now* wishes to "zoom in" on the geometry. The viewing <u>angle</u> is roughly the same as that used in the previous plot.

Screen is automatically cleared and plot follows.

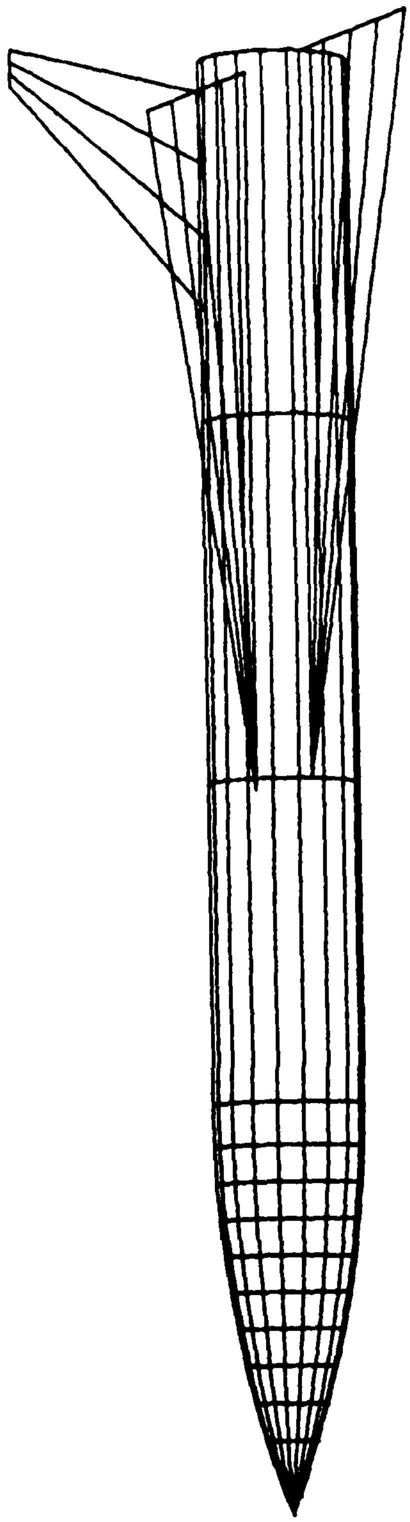


C: Alphanumeric character input; screen cleared.

```
DO YOU WISH TO SEE SIMILAR PLOTS FROM A DIFFERENT VIEWER LOCATION? (Y/N)
Y
VIEWER LOCATION? (3 CARTESIAN COORDINATES)
0.,500.,200.
```

C: User wishes to examine vehicle from different angle.

Screen automatically cleared following viewer location response.

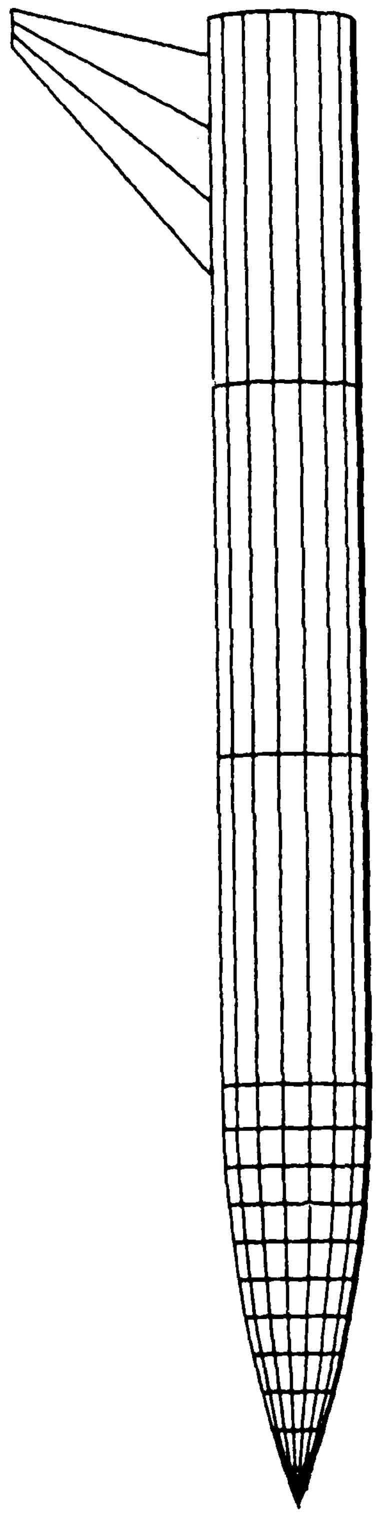


C: The "hidden lines" produced a confusing plot. User wishes to replot vehicle from the same viewing angle but without the wings.

Alphanumeric character input; screen automatically cleared.

```
DO YOU WISH TO SEE SIMILAR PLOTS FROM A DIFFERENT VIEWER LOCATION? (Y/N)
N

DO YOU WISH TO SEE DIFFERENT PLOTS OF SAME VEHICLE? (Y/N)
Y
DO YOU WISH TO SEE ALL PANELS? (Y/N)
N
WHICH PANELS FROM THE TABLE BELOW ARE TO BE DISPLAYED?
(AN ARRAY OF TEN INTEGER NUMBERS, EACH SEPARATED BY A COMMA, IS
 EXPECTED.  AFTER THE LAST DESIRED PANEL NO., FILL THE REMAINING
 ARRAY WITH ZEROES.  IF ALL PANELS ARE DESIRED, TYPE:  10*0)

PANEL NO.     1     2     3     4     5     0     0     0     0     0
PANEL NAME  OGIV  CYLN  UPWG  LOWG  VFIN  NONE  NONE  NONE  NONE  NONE
1,2,5,7*0
IS GEOMETRY TO BE REFLECTED ABOUT X-Z PLANE? (Y/N)
N
SHOULD ELEMENT OR SECTION BOUNDARIES BE PLOTTED? (0/1, RESPECTIVELY)
0
DO YOU WISH TO SEE STREAMLINES? (Y/N)
N
VIEWER LOCATION? (3 CARTESIAN COORDINATES)
0.,500.,200.
```

C: Screen automatically cleared; plot follows.

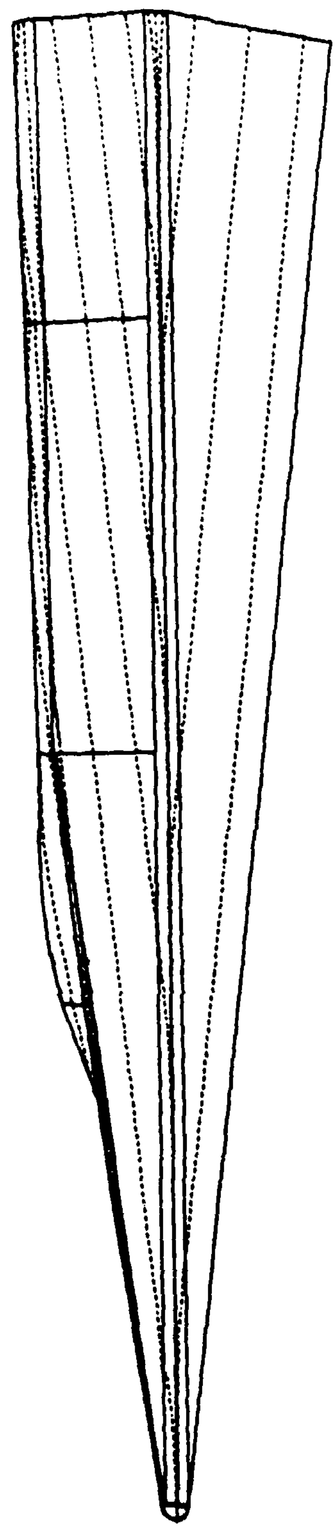


C: User now wishes to examine X-24C geometry with streamlines.

Alphanumeric character input; screen automatically cleared.

```
DO YOU WISH TO SEE SIMILAR PLOTS FROM A DIFFERENT VIEWER LOCATION? (Y/N)
N

DO YOU WISH TO SEE DIFFERENT PLOTS OF SAME VEHICLE? (Y/N)
N
DO YOU WISH TO SEE PLOTS OF A DIFFERENT VEHICLE? (Y/N)
Y
FILE NO. CONTAINING TYPE3 GEOMETRY CARDS? (1 OR 2)
2
DO YOU WISH TO SEE ALL PANELS? (Y/N)
Y
IS GEOMETRY TO BE REFLECTED ABOUT X-Z PLANE? (Y/N)
N
SHOULD ELEMENT OR SECTION BOUNDARIES BE PLOTTED? (0/1, RESPECTIVELY)
1
DO YOU WISH TO SEE STREAMLINES? (Y/N)
Y
WHICH STREAMLINE CASE BELOW IS TO BE DISPLAYED? (1 OR 2 OR ...)

     CASE NO.          ALPHA          BETA
        1                5.0           0.0
1
STREAMLINES TO BE PLOTTED AS SOLID OR DOTTED LINES? (0/1, RESPECTIVELY)
1
VIEWER LOCATION? (3 CARTESIAN COORDINATES)
0.,5000.,-3000.
```

C: See Comment at the end of this sample case regarding unit 51.

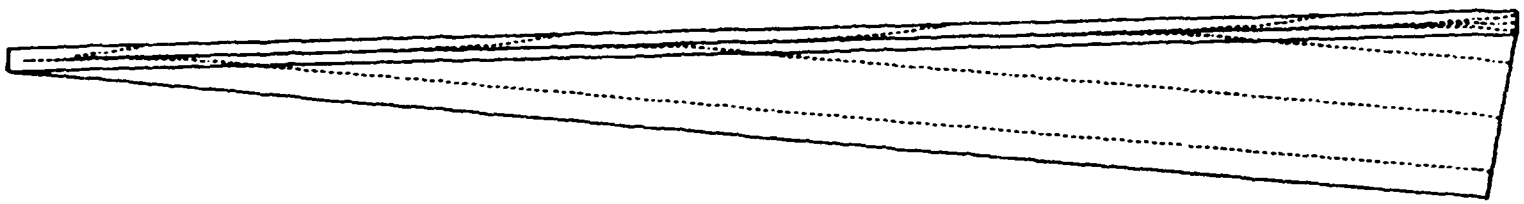


C: Alphanumeric character input; screen automatically cleared.

```
DO YOU WISH TO SEE SIMILAR PLOTS FROM A DIFFERENT VIEWER LOCATION? (Y/N)
N

DO YOU WISH TO SEE DIFFERENT PLOTS OF SAME VEHICLE? (Y/N)
Y
DO YOU WISH TO SEE ALL PANELS? (Y/N)
N
WHICH PANELS FROM THE TABLE BELOW ARE TO BE DISPLAYED?
(AN ARRAY OF TEN INTEGER NUMBERS, EACH SEPARATED BY A COMMA, IS
 EXPECTED.  AFTER THE LAST DESIRED PANEL NO., FILL THE REMAINING
 ARRAY WITH ZEROES.  IF ALL PANELS ARE DESIRED, TYPE:  10*0)

PANEL NO.     1    2    3    4    5    6    7    8    9    10
PANEL NAME   NOSE FBC1 LEDG FBFS RAMP FBC2 FBC3 CNP1 CNP2 FLT1

PANEL NO.    11   12   13   14   15    0    0    0    0    0
PANEL NAME   FLT2 AFC1 AFC2 MDFS AFFS NONE NONE NONE NONE NONE
3,5,8*0
IS GEOMETRY TO BE REFLECTED ABOUT X-Z PLANE? (Y/N)
N
SHOULD ELEMENT OR SECTION BOUNDARIES BE PLOTTED? (0/1, RESPECTIVELY)
1
DO YOU WISH TO SEE STREAMLINES? (Y/N)
Y
WHICH STREAMLINE CASE BELOW IS TO BE DISPLAYED? (1 OR 2 OR ...)

     CASE NO.        ALPHA        BETA
        1             5.0          0.0
1
STREAMLINES TO BE PLOTTED AS SOLID OR DOTTED LINES? (0/1, RESPECTIVELY)
1
VIEWER LOCATION? (3 CARTESIAN COORDINATES)
0.,5000.,-3000.
```

C: Screen automatically cleared; plot follows.

C: Same viewer location as previous plot but only Panels 3 and 5 are displayed. The streamlines are plotted only on those Panels selected.



C: Note that a dividing streamline exists along the leading edge which is circular in cross-section.

C: Alphanumeric character input; screen automatically cleared.

User now wishes to exit TEKPIC.

```
DO YOU WISH TO SEE SIMILAR PLOTS FROM A DIFFERENT VIEWER LOCATION? (Y/N)
N

DO YOU WISH TO SEE DIFFERENT PLOTS OF SAME VEHICLE? (Y/N)
N
DO YOU WISH TO SEE PLOTS OF A DIFFERENT VEHICLE? (Y/N)
N

END  TEKPIC
9.552 CP SECONDS EXECUTION TIME
```

C: In the streamline case presented, the streamline file had been accessed previously. Had it not, however, a relatively long pause would follow a "Y" response to the question, "Do you wish to see streamlines? (Y/N)." During the pause, TEKPIC would determine the outward normals associated with each streamline point and the data would be stored on local storage unit 51. This pause may be avoided during future TEKPIC runs if the streamline data on permanent file are extended to include the outward normal data. On the ASD computer system, this may be accomplished using the command EXTEND, TAPE51. Alternately, the data on local storage unit 51 may be recataloged. It is only necessary to extend or recatalog the streamline data once.

SECTION 2

INFORMATION FOR THE PROGRAMMER

Program Structure

The subroutine organization of the TEKPIC code is particularly simple as illustrated in Figure 11. Due to the peculiarities of the ASD computer system, interactive programs must be overlayed if they are to be stored as absolute programs. Therefore, program TEKPIC is actually a primary overlay which is called by a dummy main overlay. The only active FORTRAN statement in EXEC, the main overlay, is a call to program TEKPIC. If desired, the overlay structure of TEKPIC can be easily removed.

The main program of the primary overlay, TEKPIC, is responsible for all input/output, and contains all but one of the algorithms used in the code. The calculation of the Elements' outward normals is performed by subroutine NORMAL. All Tektronix subroutines used by TEKPIC, represented by the dashed boxes in Figure 11, should be available from the particular computer system used.

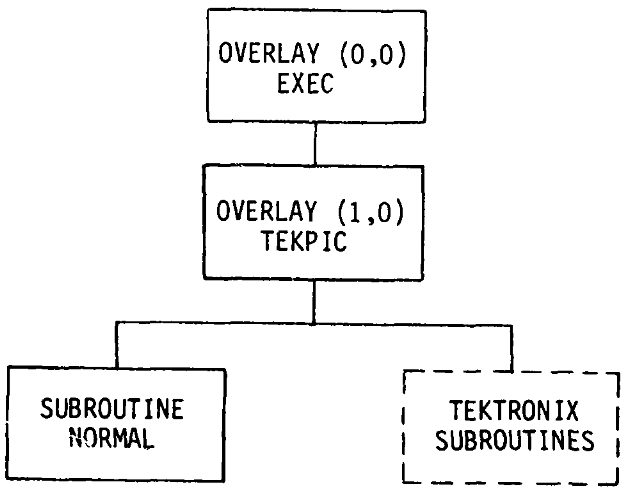


Figure 11. TEKPIC Program Structure

Local Data Files Description

A total of seven local storage units are used by TEKPIC, including the input and output files (units 5 and 6, respectively). Given in Table 1 is a brief description of the contents of each storage unit. Of the seven units, three are data files that may be supplied by the user (only one is necessary). Detailed descriptions of the local storage units follow Table 1.

Table 1. Local Storage Units Used By TEKPIC

Unit No.	Contents
1 and 2	Type 3 Element geometry cards.
3	Arrays of geometry points and corresponding outward normals for each geometry Section.
5	Input unit.
6	Output unit.
7	Plotting arrays for all visible geometry Sections.
51	Random access (mass storage) unit containing streamline coordinates and corresponding outward normals.

UNIT 3.

As TEKPIC reads Type 3 cards from unit 1 or 2, the geometry coordinates are placed in arrays, Section-by-Section. After filling the arrays for a given Section, the outward normals are calculated and all arrays for that Section are stored on unit 3.

Record No.	Variable	Explanation
1	NR	Number of rows of points in first Section.
	NC	Number of columns of points in first Section.
	X(30,15)	x-coordinates of geometry points in first Section.
	Y(30,15)	y-coordinates of geometry points in first Section.
	Z(30,15)	z-coordinates of geometry points in first Section.
	ENX(30,15)	x-components of outward normals in first Section.
	ENY(30,15)	y-components of outward normals in first Section.
	ENZ(30,15)	z-components of outward normals in first Section.
⋮		
NSECTS	NR	Number of rows of points in last (NSECTS) Section.
	NC	Number of columns of points in last Section.
	X(30,15)	x-coordinates of geometry points in last Section.
	Y(30,15)	y-coordinates of geometry points in last Section.
	Z(30,15)	z-coordinates of geometry points in last Section.
	ENX(30,15)	x-components of outward normals in last Section.
	ENY(30,15)	y-components of outward normals in last Section.
	ENZ(30,15)	z-components of outward normals in last Section.

UNIT 7.

This unit contains pairs of points representing the visible line segments of the geometry.

Record No.	Variable	Explanation
1	NPAIR	Number of pairs of points in first visible geometry Section.
	YPAIR(855,2)	y"-coordinates of pairs of points in first visible geometry Section.
	ZPAIR(855,2)	z"-coordinates of pairs of points in first visible geometry Section.
2	NPAIR	Number of pairs of points in second visible geometry Section.
	YPAIR(855,2)	y"-coordinates of pairs of points in second visible geometry Section.
	ZPAIR(855,2)	z"-coordinates of pairs of points in second visible gometry Section.
• • •		
NSPLOT	NPAIR	Number of pairs of points in last (NSPLOT) visible geometry Section.
	YPAIR(855,2)	y"-coordinates of pairs of points in last visible geometry Section.
	ZPAIR(855,2)	z"-coordinates of pairs of points in last visible geometry Section.

Note: The double primes signify that the coordinates are referenced to a Cartesian system fixed in the viewing plane (See Section 3 - Program Algorithms).

UNIT 51.

This unit is a random access (mass storage) unit which contains streamline coordinates generated by the modified version of the Mark IV program. The outward normals to the streamlines are determined by TEKPIC and saved with the coordinate data.

The first 5 records of unit 51 contain general information pertaining to each streamline distribution. A maximum of 5 distributions may be stored, and each distribution may contain as many as 25 streamlines.

Record No.	Variable	Explanation
1	IFLAG(1)	Flag indicating whether or not the search for the outward normals has been performed. IFLAG(1) = 1 indicates outward normals have been placed on unit 51.
	IFLAG(2)	Number of streamline distributions stored.
	IFLAG(3) to IFLAG(5)	Not used.
2	NSTRM(5)	Array indicating the number of streamlines in each of 5 possible streamline distributions.
3	ALPHS(5)	Array containing the pitch angle of attack for each of 5 possible streamline distributions.
4	BETAS(5)	Array containing the yaw angle of attack for each of 5 possible streamline distributions.
5	-	Not used.

The actual streamline data are stored on unit 51 in such a manner that a simple algebraic expression may be used to locate the coordinates and outward normals of any particular streamline within any given streamline distribution. A total of 10 records are allocated to the data of each streamline. Given the streamline number, ISL, of a specific streamline distribution, KASE, the following expression is used to locate the first record of the data,

$$IREC51 = 6 + 10*(ISL-1) + 250*(KASE-1)$$

Only 8 of the 10 allotted records are actually used as shown below.

Record No.	Variable	Explanation
IREC51	NPTS	Integer number of points along this streamline.
IREC51+1	NPSTRM(150)	Array containing the panel numbers associated with the streamline points.
IREC51+2	XS(150)	x-coordinates of streamline points.
IREC51+3	YS(150)	y-coordinates of streamline points.
IREC51+4	ZS(150)	z-coordinates of streamline points.
IREC51+5	ENXS(150)	x-components of streamline outward normals.
IREC51+6	ENYS(150)	y-components of streamline outward normals.
IREC51+7	ENZS(150)	z-components of streamline outward normals.

Dictionary of Variables

Since the user may wish to modify TEKPIC to suit his or her particular needs, the following dictionary is provided to aid the programmer. Unless otherwise indicated, variables beginning with I, J, K, L, M or N are integers.

The variables described below are referenced to one of three possible Cartesian coordinate systems used in the TEKPIC code. In the explanation below, unprimed coordinates refer to the original Mark IV coordinate system. Coordinates denoted by primes (') refer to a coordinate system in which the origin coincides with the vehicle's midpoint and in which the x'-axis points in the direction of the viewer. The y'- and z'-coordinates are then projected to the viewing plane in such a manner that the geometry appears in true perspective. The y- and z-coordinates in the viewing plane are denoted by double primes (").

ALPHS	Array containing the pitch angle of attack for each streamline distribution. (deg)
BETAS	Array containing the yaw angle of attack for each streamline distribution. (deg)
DEGRAD	Conversion factor for angles, $(180/\pi)$.
DIFF	Absolute distance between a particular streamline point and the average point of an Element.
DIFFMN	Minimum of all absolute distances between a given streamline point and the average Element points of a Panel.
DOT	Dot product of an Element's outward normal with a vector extending from the viewer to the Element's average point.
DOTS	Dot product of a streamline's outward normal with a vector extending from the viewer to the streamline point.
DP	Coordinate distance corresponding to one side of the square, program-specified raster window.
DUM	Dummy variable used to locate data on unit 3.

DYP	Difference between maximum and minimum values of all y"-coordinates (horizontal coordinate in the viewing plane).
DZDY	DZP/DYP.
DZDYMX	Ratio of maximum number of rasters used by TEKPIC along the z"-axis (vertical axis in viewing plane) to that used in specifying the raster window.
DZP	Difference between maximum and minimum values of z"-coordinates.
ENX	x-component of an Element's outward normal.
ENXS	x-component of the outward normal to a streamline point.
ENY	y-component of an Element's outward normal.
ENYS	y-component of the outward normal to a streamline point.
ENZ	z-component of an Element's outward normal.
ENZS	z-component of the outward normal to a streamline point.
IBAUD	Telephone baud rate. (characters/second)
ICASE	Streamline distribution to be plotted.
IDUM	Flag returned by subroutine NORMAL. IDUM = 1 indicates that a geometry Section is a dummy Section consisting of one Element whose surface area is less than 0.001.
IFLAG	Array of integer variables saved on unit 51. IFLAG(1) = ISERCH, IFLAG(2) = NCASES, IFLAG(3) through IFLAG(5) not used.
IFS	Number of the first Section within a particular Panel. (Section numbers are ordered sequentially as they are read from unit 1 or 2. Each Panel may contain one or more Sections).
IFSECT	Array indentifying the first Section of each Panel.
ILS	Number of the last Section within a particular Panel.

ILSECT	Array identifying the last Section of each Panel.
INDX51	Variable used to initialize random access unit 51.
INTIRE	Input by user. If INTIRE = 1HY, all panels are plotted.
IOK	If IOK = 2, indicates that a streamline segment should be plotted.
IPANEL	Number identifying a particular Panel to be plotted.
IPNO	Array containing integer numbers assigned sequentially to the Panels.
IPOSTN	Record position of unit 3.
IPSELC	Array of integer numbers indicating which Panels are to be plotted.
IPSL	Panel number associated with a particular streamline point.
IREC51	Record on unit 51 to be read.
ISERCH	Flag indicating whether or not the search for streamline outward normals has been performed. ISERCH = 1 if search completed.
ITELEM	Number of the local storage unit containing Type 3 Element cards. ITELEM = 1 or 2.
IYRAS1	Distance in raster units from the left side of the Tektronix screen (0 rasters) to the left border of the program-specified plotting window.
IYRAS2	Distance in raster units from the left side of the Tektronix screen to the right border of the program-specified plotting window.
IZRASM	Distance in raster units from the bottom of the Tektronix screen to the uppermost row of visible rasters.
IZRAS1	Distance in raster units from the bottom of the Tektronix screen to the lower border of the program-specified plotting window.

IZRAS2	Distance in raster units from the bottom of the Tektronix screen to the upper border of the program-specified plotting window. Note: For the Tektronix 4014 with the Enhanced Graphics Module, the horizontal and vertical dimensions of the raster window may be as large as 4096 rasters. However, only 3120 horizontal rows of rasters are visible. In TEKPIC, IZRASM < IZRAS2.
KBNDRY	Flag indicating whether Element boundaries (=0) or Section boundaries (=1) should be plotted.
KFIRST	Flag indicating whether or not the reflected geometry has been plotted. KFIRST = 0 if reflected side plotted.
KLINE	Flag indicating whether the streamlines should appear as solid (=0) or dotted (=1) lines.
KPT	Flag indicating which of the two points on a Type 3 card has been processed.
MIRROR	Flag indicating whether or not geometry is to be reflected about its plane of symmetry.
NC	Number of columns of points in a Section.
NCASES	Number of streamline distributions residing on unit 51.
NEWPNL	If NEWPNL = 1, indicates that a particular point is the first point of a Panel.
NEWVEH	User-specified flag. If NEWVEH = 1, indicates that a new vehicle geometry is to be accessed from unit 1 or 2.
NEWVU	User-specified flag input after each plot. If NEWVU = 1, indicates that another viewing angle will be input next.
NONE	Initial alphanumeric name of each Panel prior to reading SECT on the Type 3 cards. NONE = 10HNONEbbbbbb.
NPAIR	Number of line segments to be plotted for a given streamline.
NPANLS	Number of vehicle geometry Panels.
NPSELC	Number of individual Panels that may be selected for plotting if INTIRE ≠ 1HY.

NPSTRM	Array of integers identifying the Panel number associated with each point along a streamline.
NPTS	Number of points along a streamline.
NR	Number of rows of points in a Section.
NRSKIP	Number of records to be skipped on unit 3 to locate desired Section data.
NSECTS	Total number of geometry Sections.
NSL	Number of streamlines in a particular distribution.
NSPLOT	Number of Sections to be plotted.
NSTRM	Array of integers indicating the number of streamlines in each distribution.
NUPLOT	User-specified flag. If NUPLOT = 1, another plot of the same vehicle will be made but with different options selected, e.g. Element plots instead of Section plots, selected Panels instead of all Panels.
PFACTR	Factor applied to the coordinates of a given point so that the point appears in true perspective.
PHI (PHID)	Angular rotation in radians (deg) about the x-axis.
PNAME	Array containing the alphanumeric Panel names.
PRODCT	The DOT of one Element times the DOT of an adjoining Element.
PSI (PSID)	Angular rotation in radians (deg) about the z-axis.
SECT	The four user-specified alphanumeric characters appearing in columns 67-70 of a Type 3 card.
STAT	Integer status flag for the first point on a Type 3 card.
STATT	Integer status flag for the second point on a Type 3 card.
STREAM	Alphanumeric variable indicating whether or not streamlines are to be plotted. If STREAM = 1HY, streamlines will be plotted.
T	Transformation matrix used to rotate the Mark IV coordinate system so that the x-axis points in the direction of the viewer.

THETA (THETAD)	Angular rotation in radians (deg) about the y-axis.
WAKEUP	Dummy variable read when user types any character to signal that he or she has completed the examination of a plot.
X	Array of x-coordinates of the points in a Section.
XAVG	x-coordinate of an Element's average point.
XI	x-coordinate of the first geometry point on a Type 3 card.
XLOS	x-component of a vector extending from the viewer location to the average point of an Element.
XMAX	Largest x-component of all geometry points.
XMIN	Smallest x-component of all geometry points.
XP	Array containing the x'-coordinates of a geometry Section.
XREF	x-coordinate of the vehicle's midpoint. Used with the viewer location to determine viewer's line-of-sight.
XS	Array containing the x-coordinates of the points along a streamline.
XSP	Array containing the x'-coordinates of the points along a streamline.
XV	User-specified variable. x-coordinate of the viewer location.
XVMXPL	Absolute difference between the viewer and the viewing plane measured along the normal to the viewing plane. (Set = 1. in TEKPIC).
XVP	x'-coordinate of the viewer location.
XVTEMP	Temporary x-coordinate of the viewer location used during the coordinate transformation.
XXI	x-coordinate of the second geometry point on a Type 3 card.
Y	Array of y-coordinates of the points in a Section.
YAVG	y-coordinate of an Element's average point.

YI	y-coordinate of the first geometry point on a Type 3 card.
YLOS	y-component of a vector extending from the viewer location to the average point of an Element.
YP	Array containing the y'-coordinates of a geometry Section.
YPAIR	Array containing the y"-coordinates of the pairs of points in a Section that are to be plotted.
YPMAX	Maximum value of the y"-coordinates of all geometry points.
YPMIN	Minimum value of the y"-coordinates of all geometry points.
YREF	y-coordinate of vehicle's midpoint. (Set to zero in TEKPIC).
YS	Array containing the y-coordinates of the points along a streamline.
YSP	Array containing the y'-coordinates of the points along a streamline.
YV	User-specified variable. y-coordinate of the viewer location.
YVP	y'-coordinate of the viewer location.
YYI	y-coordinate of the second geometry point on a Type 3 card.
Z	Array of z-coordinates of the points in a Section.
ZAVG	z-coordinate of an Element's average point.
ZI	z-coordinate of the first geometry point on a Type 3 card.
ZLOS	z-component of a vector extending from the viewer location to the average point of an Element.
ZP	Array containing the z'-coordinates of a geometry Section.
ZPAIR	Array containing the z"-coordinates of the pairs of points in a Section that are to be plotted.

ZPMAX	Maximum value of the z"-coordinates of all geometry points.
ZPMIN	Minimum value of the z"-coordinates of all geometry points.
ZREF	z-coordinate of vehicle's midpoint. (Set to zero in TEKPIC).
ZS	Array containing the z-coordinates of the points along a streamline.
ZSP	Array containing the z'-coordinates of the points along a streamline.
ZV	User-specified variable. z-coordinate of the viewer location.
ZVP	z'-coordinate of the viewer location.
ZZI	z-coordinate of the second geometry point on a Type 3 card.

SECTION 3

PROGRAM ALGORITHMS

Outward Normal Calculation

Each Element of the geometry consists of four points that are not, in general, coplanar. However, each Element is treated as a planar surface in both the Mark IV and TEKPIC codes by the use of an "average" outward normal determined by the cross product of the Element's two diagonal vectors, as shown in Figure 12.

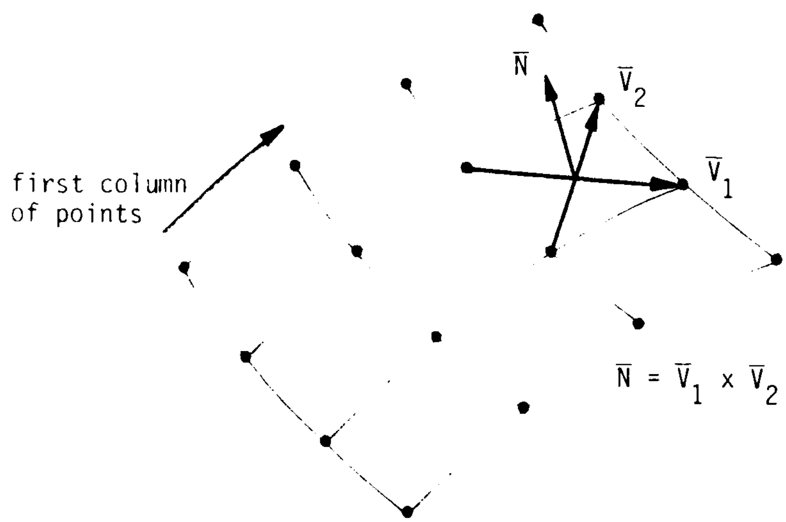


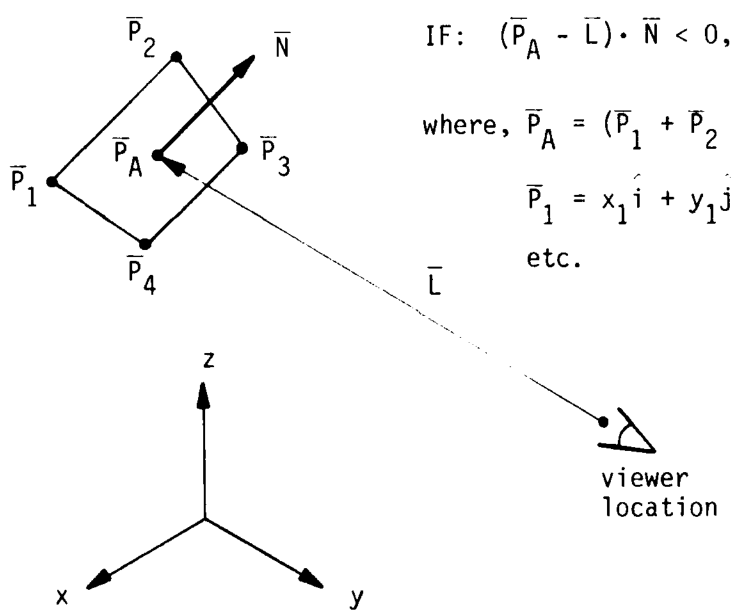
Figure 12. Outward Normal Calculation

The particular order in which the columns of points must be input (described in Reference 1 and in Part I of this report) indicates which of the two surfaces of a Section is the outer, visible surface. The vector cross product for each Element is defined accordingly to ensure that the outward normal points in the proper direction.

Visibility of Geometry Elements

A very simple method is used in TEKPIC to determine which Elements of the geometry are visible for any given viewer location. The visibility of each Element is considered independently of other Elements. If an Element is tilted in the direction of the viewer's line-of-sight, that Element is assumed to be visible, regardless of whether other Elements obstruct the view.

Mathematically, the visibility of an Element is determined by taking the dot product of the Element's outward normal with the vector extending from the viewer to the Element's average point, as shown in Figure 13. The Element is visible only if the dot product is negative.



IF: $(\overline{P}_A - \overline{L}) \cdot \overline{N} < 0$, element is visible

where, $\overline{P}_A = (\overline{P}_1 + \overline{P}_2 + \overline{P}_3 + \overline{P}_4)/4$

$\overline{P}_1 = x_1\hat{i} + y_1\hat{j} + z_1\hat{k}$

etc.

Figure 13. Element Visibility Algorithm

Once the visibility of each Element within a Section has been determined, a means must be available for connecting the points of the visible Elements. A simple but inefficient approach is to plot the four line segments of each Element. The result will be a duplicative plotting of many of the line segments.

A more efficient approach is to consider each line segment of a Section. Referring to Figure 14, an interior line segment is visible if either (or both) of the two Elements bordering a segment is visible. An exterior line setment should be plotted if its corresponding Element is visible. Although twice as many points must be saved using this method instead of the former approach, a savings is realized in the real time required to display a given geometry on the CRT, particularly if a slow telephone baud rate is used.

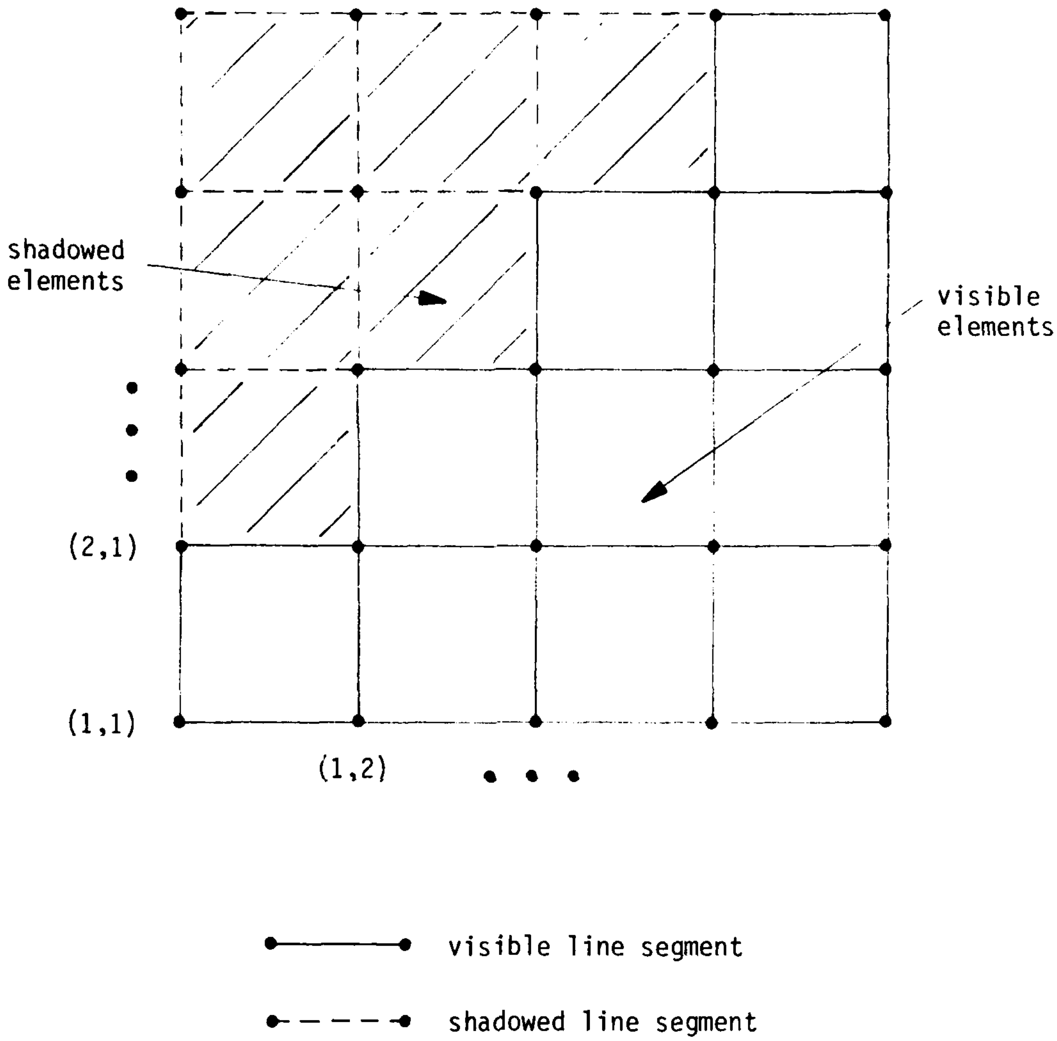
Visibility of Geometry Sections

Since the TEKPIC code has the ability to plot surface streamlines, a means was sought to reduce the number of geometry lines plotted so that the user could more easily distinguish the streamlines from the geometry lines. One way of accomplishing this will still retaining the general shape of the vehicle is to plot only the visible boundaries of the Sections.

The algorithm used is similar to that used for the donduplicative plotting of the Elements. As illustrated in Figure 15, a given interior line segment constitutes one segment of the visible Section boundaries only if one (not both) of the Elements bordering the segment is visible. An exterior line segment is plotted if its corresponding Element is visible.

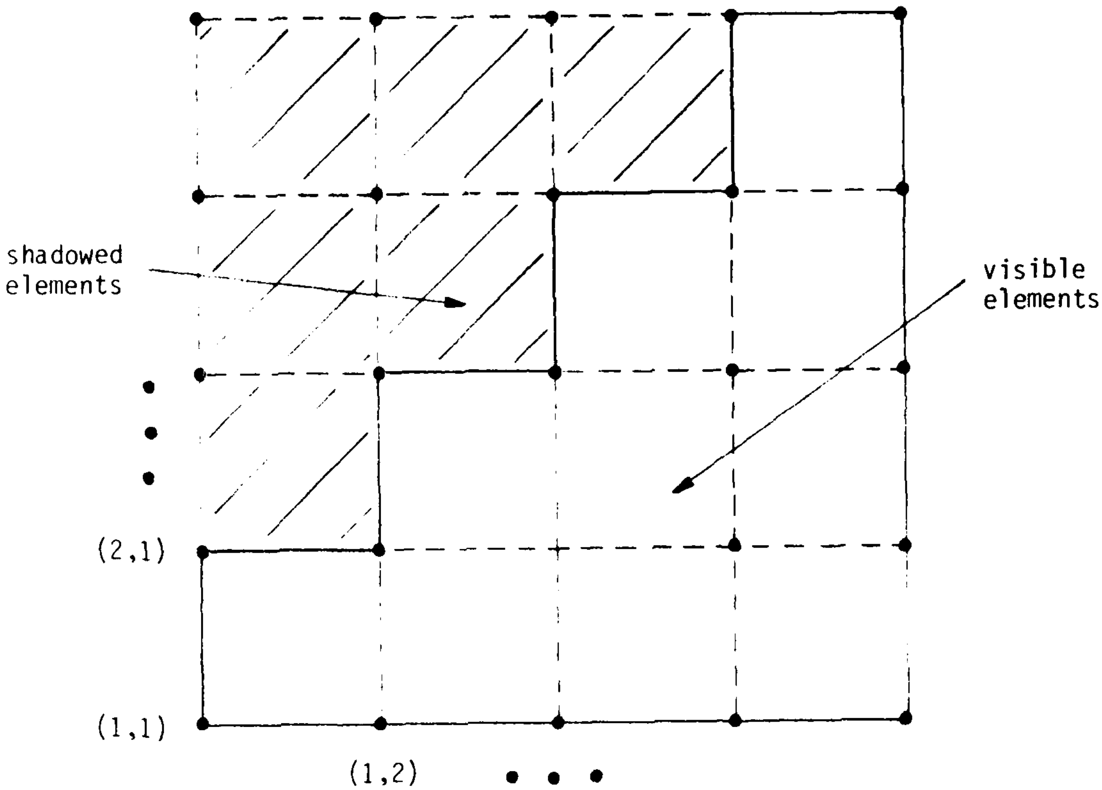
Visibility of Streamlines

Streamlines, the coordinates of which are determined in the Mark IV code, may be considered to be part of the surface of the geometry. Therefore, a given segment of a streamline is visible if the Element associated with it is visible. However, the points that are saved along a streamline do not conveniently coincide with the borders of each Element, and the segment between two streamline points may cross many Elements. Program TEKPIC assumes that a given segment of a streamline is visible only if both of its end points lie on visible Elements. Since



Considering each line segment of each row and column, an interior line segment is visible if either of the elements bordering the segment is visible. An exterior segment is visible if its corresponding exterior element is visible.

Figure 14. Nonduplicative Plotting of Visible Element Segments



visible segment of Section boundary

line segment not drawn

Considering each line segment of each row and column, an interior line segment is drawn only if <u>one</u> of the two elements bounding the segment is visible. An exterior line segment is visible if its exterior element is visible.

Figure 15. Nonduplicative Plotting of Visible Section Segments

this algorithm cannot determine the exact point from which a streamline bends out of view, part of the streamline that is actually visible may not be displayed.

To determine if a particular point along a streamline is visible, it is necessary that its outward normal be known. The dot product calculation used to determine the visibility of an Element can then be used to determine the visibility of the streamline point. However, the streamline data output by the modified Mark IV code does not contain outward normal information. Therefore, a search must be performed to determine the nearest Element to a given streamline point. The outward normal of the nearest Element is assumed to correspond to that of the streamline point. Fortunately, the streamline data from the Mark IV code contains the Panel number associated with each streamline point, thereby expediting the search procedure.

Perspective Display of Geometry/Streamlines

Any two-dimensional display of a three-dimensional body may be thought of as a projection of the points of the body onto a planar surface, or viewing plane. The viewing plane in this case is the CRT screen, and may be placed at any orientation relative to the body. Two approaches may be used to specify the relative orientation of the viewing plane and the geometry. The first approach fixes the position and line-of-sight of the viewer, and rotates the geometry through a user-specified yaw-pitch-roll sequence. If perspective plots are desired, this approach requires that the user also specify the distance between the viewer and the geometry. For example, the IMAGE picture drawing program (Reference 4) assumes the line-of-sight of the viewer to be directed along the negative x-axis. Since IMAGE (as it is described in Reference 4) does not have a perspective capability, the viewer is implicitly assumed to be located at $(x,y,z) = (+\infty,0,0)$. The geometry is then rotated to any desired orientation relative to the viewer.

A second approach fixes the position of the geometry and allows the viewer to move relative to the geometry. This approach has the advantage that the distance between the viewer and the vehicle need not be specified.

It is only necessary to specify the coordinates of the viewer's location. This latter method is employed in the TEKPIC code.

Although two approaches exist for specifying the relative orientation of the viewer and the geometry, both methods lead to the same mathematical results and both produce identical perspective plots. Referring to the "vehicle-fixed" approach, a translation and rotation of the coordinate axes is necessary to align the x'-axis with the viewer's line-of-sight, as shown in Figure 16. After calculating the yaw, ψ, and pitch, θ, angles from the user-specified line-of-sight vector, the following general transformation is applied to each of the geometry points,

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} T_{11} & T_{12} & T_{13} \\ T_{21} & T_{22} & T_{23} \\ T_{31} & T_{32} & T_{33} \end{bmatrix} \begin{bmatrix} x - x_0 \\ y - y_0 \\ z - z_0 \end{bmatrix} \qquad (1)$$

where,

$T_{11} = \cos\psi \cos\theta$
$T_{21} = \cos\psi \sin\theta \sin\phi - \sin\psi \cos\phi$
$T_{31} = \cos\psi \sin\theta \cos\phi + \sin\psi \sin\phi$
$T_{12} = \sin\psi \cos\theta$
$T_{22} = \sin\psi \sin\theta \sin\phi + \cos\psi \cos\phi$
$T_{32} = \sin\psi \sin\theta \cos\phi - \cos\psi \sin\phi$
$T_{13} = -\sin\theta$
$T_{23} = \cos\theta \sin\phi$
$T_{33} = \cos\theta \cos\phi$

ϕ = 0. in TEKPIC
x_0 = midpoint of geometry along x-axis
$y_0 = z_0$ = 0. in TEKPIC

Following the coordinate transformation the y'- and z'-coordinates are projected to the viewing plane. For picture drawing programs that do not have a perspective capability, the projection is trivial. Since the viewer is implicitly assumed to be located at $x' = \infty$, the lines along which the geometry points are projected are parallel to each other, and

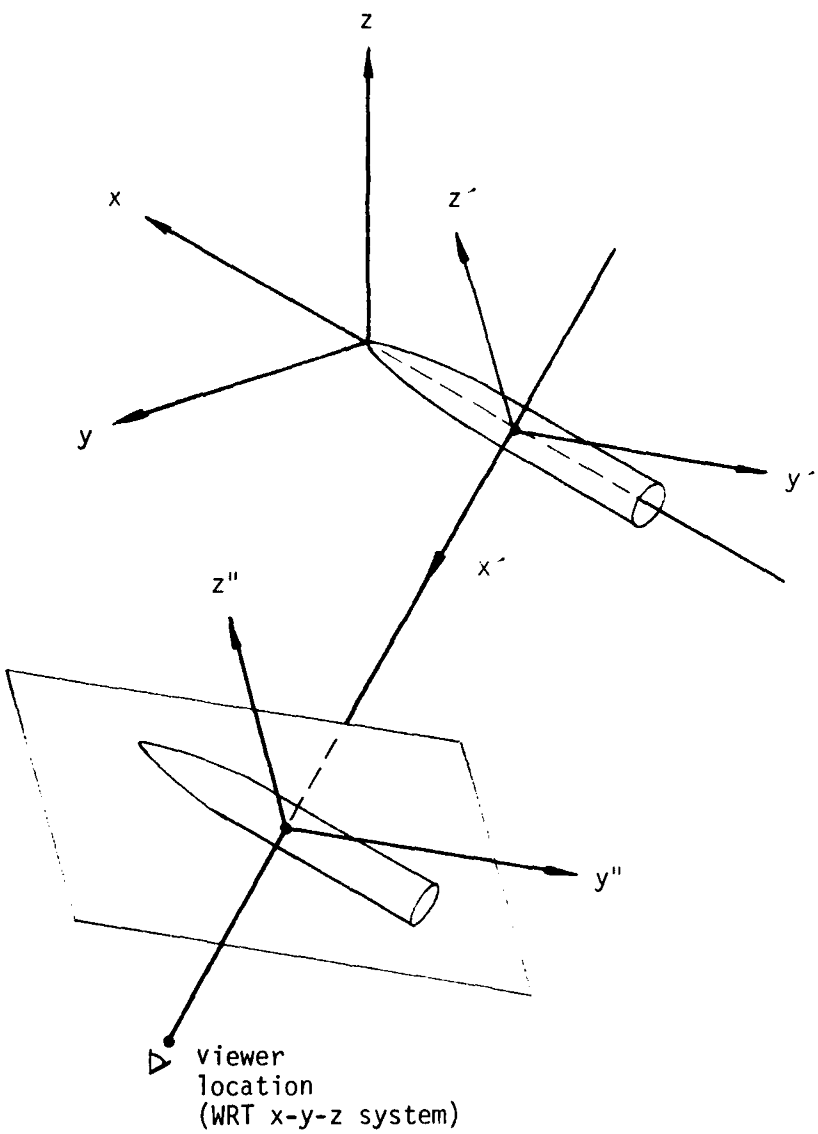


Figure 16. Coordinate Transformation

the y'- and z'-coordinates may be plotted directly. For true perspective pictures, however, each point must be projected to the viewing plane along a line extending from the geometry point to the viewer, located a finite distance from the vehicle, as illustrated in Figure 17. The coordinates in the viewing plane, denoted by y" and z", may be easily determined from geometric considerations. The relationships between the primed and double-primed coordinates is given by,

$$y'' = y' \frac{x_v - x_p}{x_v - x'}$$
$$z'' = z' \frac{x_v - x_p}{x_v - x'} \qquad (2)$$

where x_v and x_p are the distances along the x'-axis to the viewer and the viewing plane, respectively.

It may be shown that the perspectivity of the plots is independent of the viewing plane location along the viewer's line-of-sight (the viewing plane must, of course, be normal to the line-of-sight). Only the overall size of the projected geometry is affected. In the TEKPIC code, the viewing plane is arbitrarily placed one unit in front of the viewer and the geometry is uniformly contracted. However, the contraction has no effect on the final CRT plot size.

A similar procedure is followed for the perspective display of the streamlines. Both points of all visible streamline segments undergo the same transformation used for the geometry points. The streamline points are then projected to the viewing plane using equation (2).

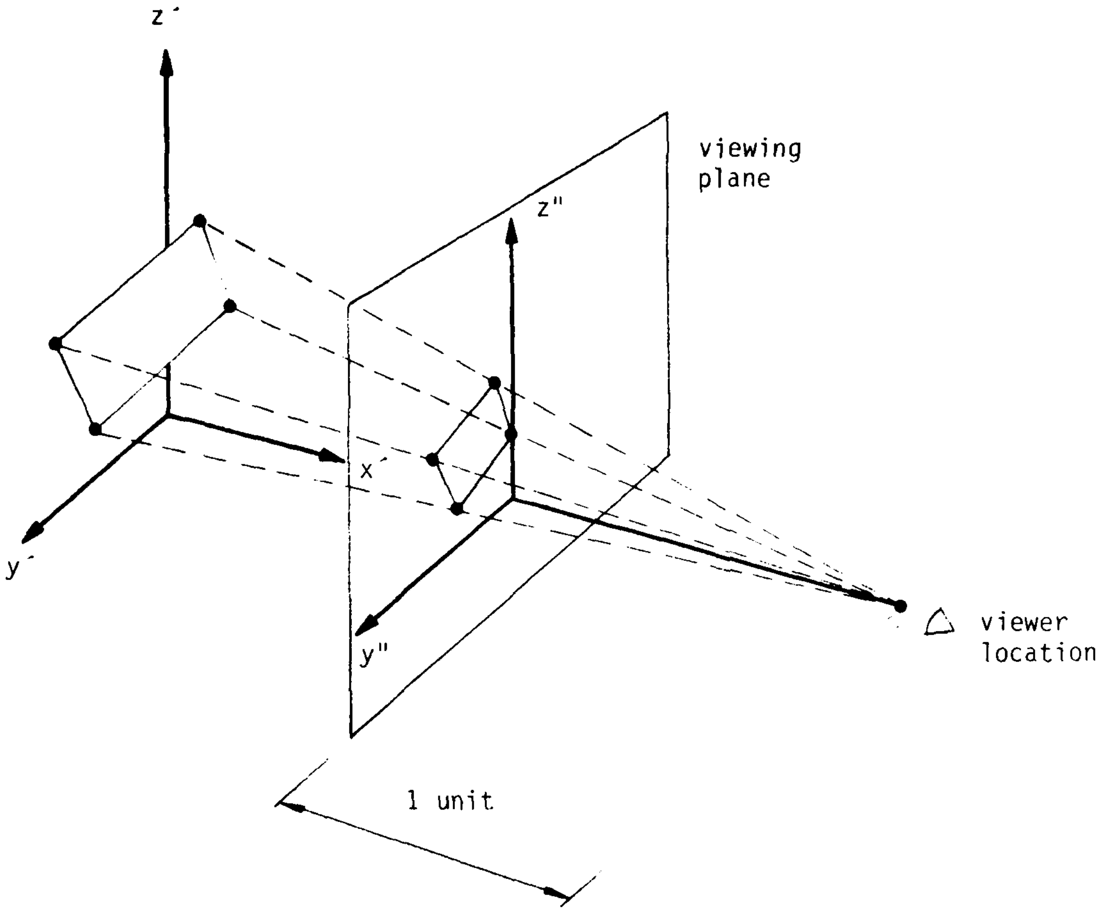


Figure 17. Projection of Coordinates for True Perspective

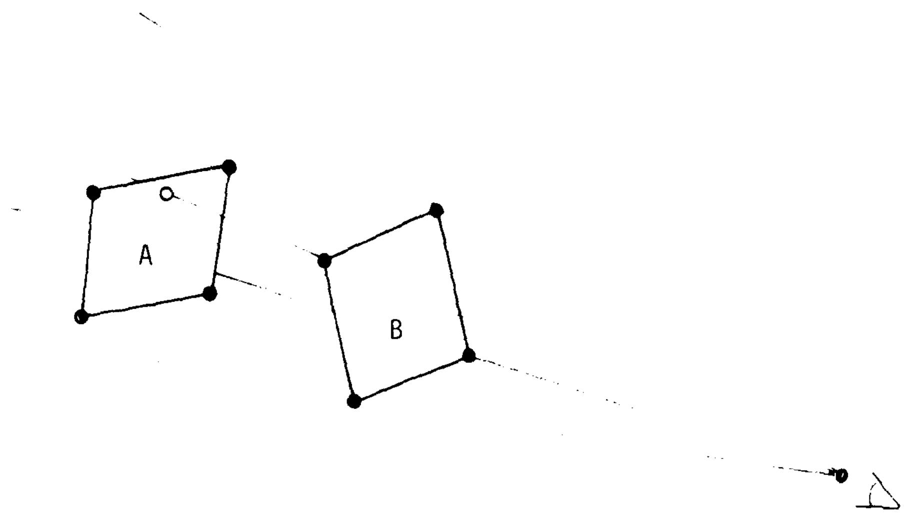
PART III

PROGRAM HIDDEN

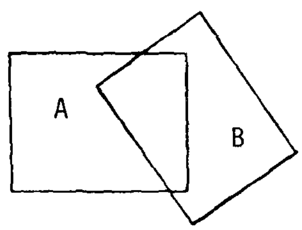
Although the interactive picture drawing program, TEKPIC, is an extremely valuable tool for validating Mark IV geometries, the program employs only an approximate method for determining which geometry lines are visible from a given viewer location. The method, known as the Shadow method, assumes that an Element is visible from a particular viewing location if its outer surface, identified by its outward normal, is tilted toward the viewer. However, the true visibility of an Element cannot be treated independently of other Elements. Although the outer surface of Element A may be tilted toward the viewer, Element B may obstruct part or all of A from the viewer, as illustrated in Figure 18. Those lines of Element A that are obstructed from the viewer are referred to as hidden lines.

The HIDDEN program in its present form has undergone several stages of development. Its foundation was laid when Purdue University researchers coded a hidden line algorithm (Reference 3) known as the piercing point method. However, the geometry format used in the code is not compatible with Mark IV geometry formats. Aerophysics Research Corp. later developed a geometry preprocessor (Reference 4) known as CVRTHD which converts Mark IV Element geometries to a format compatible with the Purdue hidden line code, HIDDN1. A third code, PLOTHD, also written by Aerophysics Research, reads the data generated by HIDDN1 and produces Calcomp plots of the visible geometry. As part of the overall effort described in this report, the three codes were combined into one program, HIDDEN, for use on the ASD computer system. Only minor modifications were made to each of the three codes.

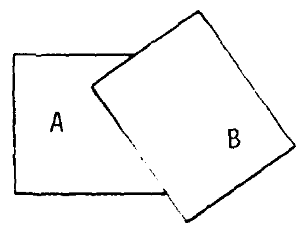
A complete description of each of the three codes, including the algorithms used, is given in Reference 4. Therefore, only a user-oriented guide to the coupled hidden line program, HIDDEN, is presented here.



a. Element A partially obstructed by Element B.



b. Elements A and B as seen by viewer in TEKPIC.



c. Elements A and B as seen by viewer in HIDDEN

Figure 18. Hidden Line Definition

Program Organization

The three hidden line related codes CVRTHD, HIDDN1, and PLOTHD were combined using overlays as shown in Figure 19. Each of the three previously independent codes comprises one overlay of the HIDDEN program. The main overlay simply calls each of the three primary overlays in consecutive order.

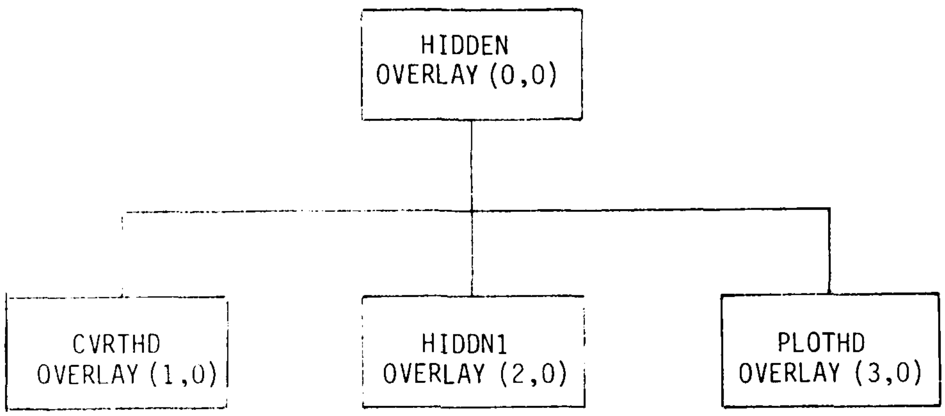


Figure 19. HIDDEN Overlay Structure

Overlay (1,0), CVRTHD, reads Mark IV Element data either from the input unit (5) or from local storage unit 8, and converts the data to a format compatible with the hidden line routines in overlay (2,0). After CVRTHD converts the data and stores it on unit 1, control is given to the second overlay, HIDDN1. Overlay (2,0) reads the geometry data from unit 1, applies the hidden line algorithm to the geometry segments, and stores the visible geometry on unit 3. Finally, the third overlay, PLOTHD, reads the visible line segments from unit 3 and generates Calcomp plots.

Input Data Preparation

Once the Element data have been prepared for a particular configuration, as described in Part I, it is a simple matter to assemble the HIDDEN input deck. The data deck is divided into three parts: (1) the Option Card, (2) the Element Data Cards, and (3) the Viewing Angle Cards. Instructions on how to prepare each part are given below.

1. Option Card

The first flag, IDIV, on the Option Card outlined below allows the user to request a reduction in the number of Elements in each Section by an averaging process. This averaging process is best understood if the term "card" is introduced. One "card" represents a set of two consecutive points along a column. Excluding the first and last card of each column, the IDIV parameter indicates the number of cards that will be averaged into one point along each column of all Sections. The averaging is applied consecutively to each set of IDIV cards along a column until all cards in the column are processed. If the number of remaining cards in a column is less than IDIV, those points are averaged into one point. Shown in Figure 20 are three examples of the averaging process for two of the columns in a Section. Note that the first and last cards of each column are never involved in the averaging. In most cases, however, no averaging is desired and IDIV is set to 0.

The second flag on the Option card, ITAPE, specifies from which unit the Element cards are to be read. If the geometry data have been placed on a permanent file device, the user must set ITAPE to 1 and the data will be read from local storage unit 8. If the data are located on the input unit (5) with the rest of the HIDDEN data deck, ITAPE should be set to 0.

The horizontal and vertical dimensions of the Calcomp plots (in inches) are specified by XPAGE and YPAGE, respectively. Since the Option Card is read only once, the plot dimensions may not be changed from viewing angle to viewing angle. Note that there is no default value for XPAGE and YPAGE.

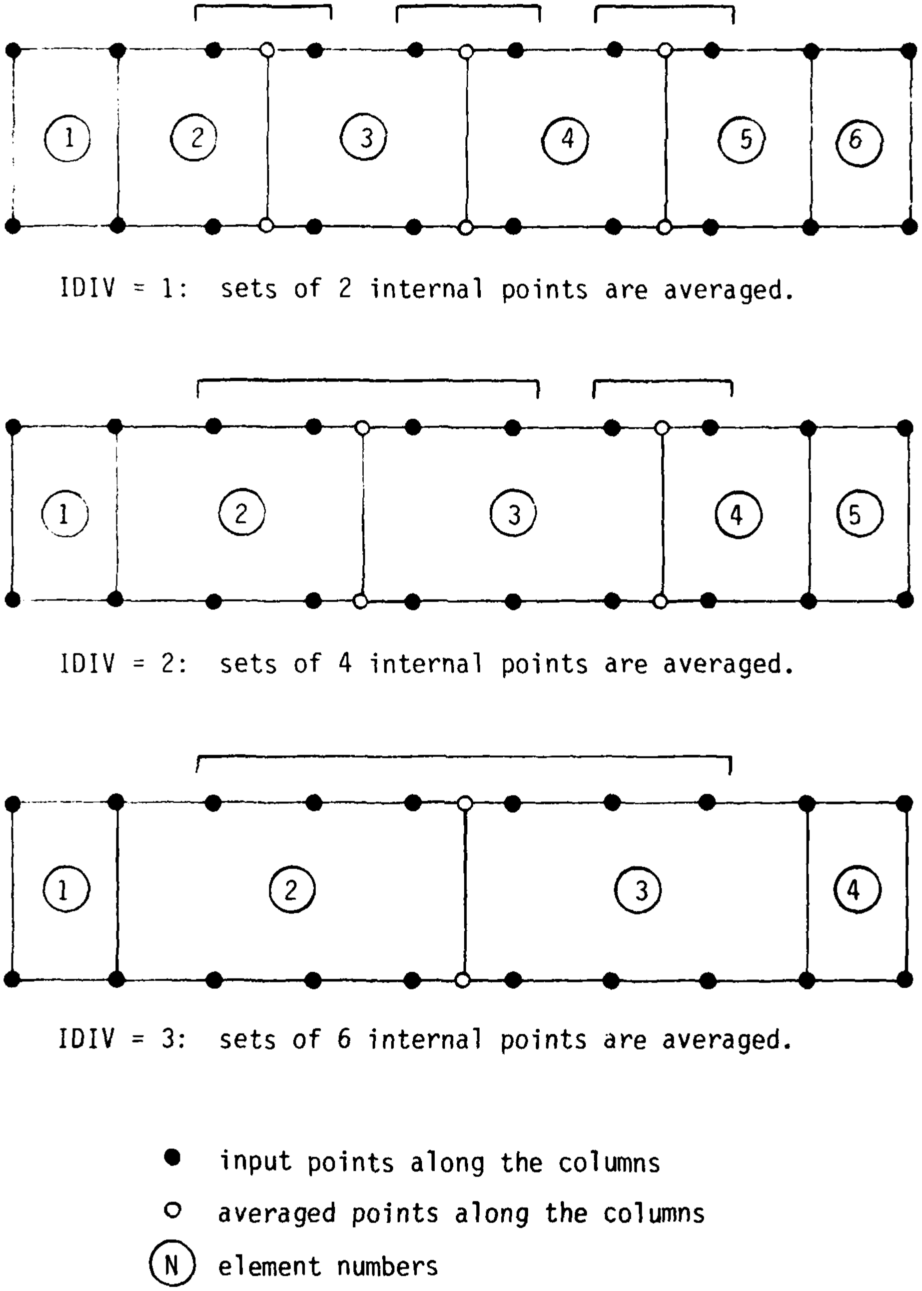


Figure 20. Averaging Process for Reducing the Number of Elements

1. Option Card (Continued)

Column	Code	Routine Format	Explanation
1-2	IDIV	CVRTHD I2	Averaging factor for reducing the number of Elements in the geometry. The points associated with the first and last cards cf each column remain fixed, but the remaining points on each set of IDIV cards along each column are averaged into one point. Usually, IDIV = 0 and no averaging is done.
3-4	ITAPE	CVRTHD I2	Option for reading the Element Data Cards. = 0 Read from input unit. = 1 Read from unit 8.
11-20	XPAGE	CVRTHD F10.0	Horizontal dimension desired for the Calcomp plot. (inches)
21-30	YPAGE	CVRTHD F10.0	Vertical dimensions desired for the Calcomp plot. (inches)

2. Element Data Cards

The HIDDEN program deals only with geometry Sections, not Panels. By requiring that all columns in the geometry data contain an even number of points, it is not necessary for the HIDDEN program to read the second status flag on each card. A Data Set Termination Card, shown below, signifies that all Element Data Cards have been read. This card is used only if ITAPE = 0. If the geometry data are read from unit 8, a Data Set Termination Card must not appear with the data.

Column	Code	Routine Format	Explanation
1-10	X1	CVRTHD F10.0	x-coordinate of the surface point.
11-20	Y1	CVRTHD F10.0	y-coordinate of the surface point.
21-20	Z1	CVRTHD F10.0	z-coordinate of the surface point.

2. Element Data Cards (Continued)

Column	Code	Routine Format	Explanation
31	IST	CVRTHD I1	Status flag for the above set of coordinates = 0 Point is a continuation of an existing column. = 1 Point is the first of a new column within an existing Section. = 2 Point is the first of a new Section.
32-41	X1	CVRTHD F10.0	x-coordinate of the surface point.
42-51	Y2	CVRTHD F10.0	y-coordinate of the surface point.
52-61	Z2	CVRTHD F10.0	z-coordinate of the surface point.

Note: The HIDDEN program automatically reflects the Element data about the symmetry plane.

Data Set Termination Card

This card follows the last Element Data Card if ITAPE = 0 on the Option Card. If the Element data are stored on unit 8, this card must not be used.

Column	Code	Routine Format	Explanation
71-72	IFIN	CVRTHD I2	This variable must be set equal to 99.

3. Viewing Angle Cards

These cards follow the Data Set Termination Card if ITAPE = 0, and follow the Option Card if ITAPE = 1. Each card contains the Cartesian coordinates, referenced to the Mark IV coordinate system, of two points used by HIDDEN to define the viewer's line-of-sight and distance from the geometry. As illustrated in Figure 21, both points must lie outside the volume defined by the geometry surface. The viewing plane to which the visible line segments are projected passes through the user-specified point near the geometry and lies normal to the line connecting the two points. The point near the body must therefore be far enough from the geometry surface that the viewing plane does not intersect any part of the vehicle.

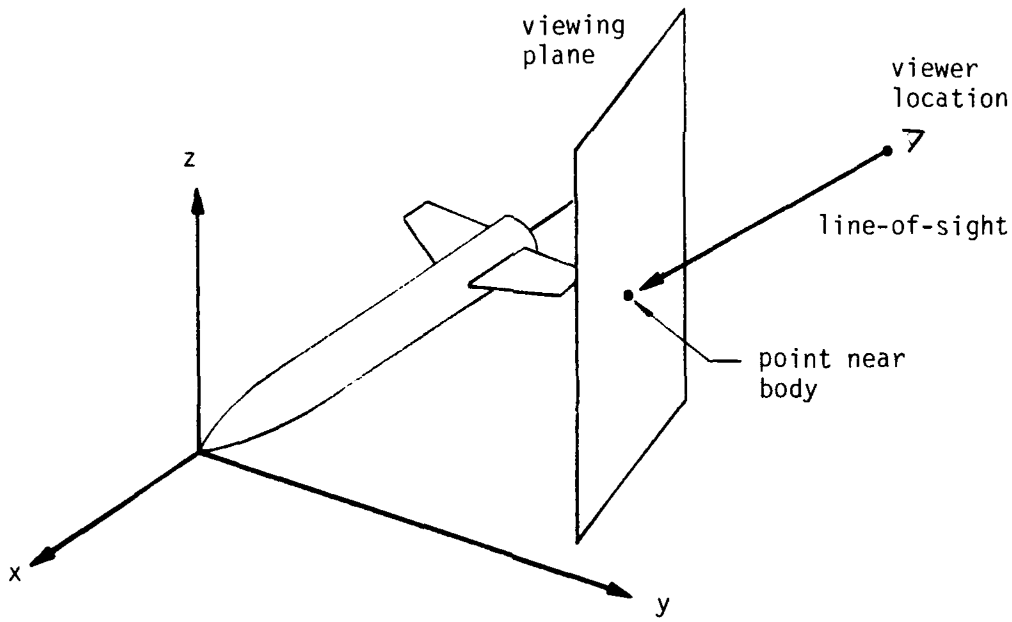


Figure 21. Line-of-Sight Specification

3. Viewing Angle Cards (Continued)

Any number of Viewing Angle Cards may be used. Following the last card must be a Data Set Termination Card.

Column	Code	Routine Format	Explanation
1-10	XL	SERVIC F10.0	x-coordinate of a point near the vehicle.
11-20	YL	SERVIC F10.0	y-coordinate of a point near the vehicle.
21-30	ZL	SERVIC F10.0	z-coordinate of a point near the vehicle.
31-40	XO	SERVIC F10.0	x-coordinate of the viewer's position.
41-50	YO	SERVIC F10.0	y-coordinate of the viewer's position.
51-60	ZO	SERVIC F10.0	z-coordinate of the viewer's position.

Data Set Termination Card

Column	Code	Routine Format	Explanation
71-72	IFIN	CVRTHD I2	This variable must be set equal to 99.

Sample Case

The following sample case produces plots of a winged ogive-cylinder geometry for two viewer locations. Two input decks are presented: (a) one in which the Element data are read from unit 8, and (b) one in which the Element data are input with the rest of the HIDDEN input data. Both decks produce the same two plots shown after the input data.

Case (a): Read Element data from unit 8.

```
0         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

 0 1      8.        5.                                                             Option Card
  20.     20.       20.         200.      200.      200.                           Viewing Angle Card
-100.     20.       20.        -300.      220.      220.                           Viewing Angle Card
                                                                   99              Data Set Term. Card
```

Case (b): Read Element data from input unit.

```
 0 0      8.        5.                                                                   Option Card
   0.0000    0.0000    0.00002    0.0000    0.0000    0.00000   1OGIV  3AERO   1    |
   0.0000    0.0000    0.00000    0.0000    0.0000    0.00000   1OGIV  3AERO   2    |
   0.0000    0.0000    0.00000    0.0000    0.0000    0.00000   1OGIV  3AERO   3    |
   0.0000    0.0000    0.00000    0.0000    0.0000    0.00000   1OGIV  3AERO   4    |
   0.0000    0.0000    0.00000    0.0000    0.0000    0.00000   1OGIV  3AERO   5    |
  -1.0000    0.0000   -.44661    -1.0000    .1527    -.41960    1OGIV  3AERO   6    Element Data Cards
  -1.0000    .2870    -.34210    -1.0000    .3867    -.22330    1OGIV  3AERO   7    |
  -1.0000    .4398    -.07750    -1.0000    .4398     .07750    1OGIV  3AERO   8    |
  -1.0000    .3867     .22330    -1.0000    .2870     .34210    1OGIV  3AERO   9    |
  -1.0000    .1527     .41960    -1.0000   -.0000     .44660    1OGIV  3AERO  10    |
```

Sample Case (Continued)

```
0         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

   -2.0000    0.0000   -.80531   -2.0000     .2754   -.75670  10GIV 3AERO  11
   -2.0000     .5176   -.61690   -2.0000     .6974   -.40260  10GIV 3AERO  12
   -2.0000     .7930   -.13980   -2.0000     .7930    .13980  10GIV 3AERO  13
   -2.0000     .6974    .40260   -2.0000     .5176    .61690  10GIV 3AERO  14
   -2.0000     .2754    .75670   -2.0000    -.0000    .80530  10GIV 3AERO  15
   -4.0000    0.0000  -1.46521   -4.0000     .5011  -1.37680  10GIV 3AERO  16
   -4.0000     .9418  -1.12240   -4.0000    1.2689   -.73260  10GIV 3AERO  17
   -,.0000    1.4429   -.25440   -4.0000    1.4429    .25440  10GIV 3AERO  18
   -4.0000    1.2689    .73260   -4.0000     .9418   1.12240  10GIV 3AERO  19
   -4.0000     .5011   1.37680   -4.0000    -.0000   1.46520  10GIV 3AERO  20
   -6.0000    0.0000  -2.05051   -6.0000     .7013  -1.92680  10GIV 3AERO  21
   -6.0000    1.3180  -1.57080   -6.0000    1.7758  -1.02520  10GIV 3AERO  22
   -6.0000    2.0193   -.35610   -6.0000    2.0193    .35610  10GIV 3AERO  23
   -6.0000    1.7758   1.02530   -6.0000    1.3180   1.57080  10GIV 3AERO  24
   -6.0000     .7013   1.92680   -6.0000    -.0000   2.05050  10GIV 3AERO  25
   -8.0000    0.0000  -2.56361   -8.0000     .8768  -2.40900  10GIV 3AERO  26
   -8.0000    1.6479  -1.96380   -8.0000    2.2201  -1.28180  10GIV 3AERO  27
   -8.0000    2.5247   -.44520   -8.0000    2.5247    .44520  10GIV 3AERO  28
   -8.0000    2.2201   1.28180   -8.0000    1.6479   1.96380  10GIV 3AERO  29
   -8.0000     .8768   2.40900   -8.0000    -.0000   2.56360  10GIV 3AERO  30
  -10.0000    0.0000  -3.00611  -10.0000    1.0281  -2.82480  10GIV 3AERO  31
  -10.0000    1.9323  -2.30280  -10.0000    2.6034  -1.50300  10GIV 3AERO  32
  -10.0000    2.9604   -.52200  -10.0000    2.9604    .52200  10GIV 3AERO  33
  -10.0000    2.6034   1.50310  -10.0000    1.9323   2.30280  10GIV 3AERO  34
  -10.0000    1.0281   2.82480  -10.0000    -.0000   3.00610  10GIV 3AERO  35
  -12.0000    0.0000  -3.37971  -12.0000    1.1559  -3.17590  10GIV 3AERO  36
  -12.0000    2.1724  -2.58900  -12.0000    2.9269  -1.68980  10GIV 3AERO  37
  -12.0000    3.3284   -.58690  -12.0000    3.3284    .58690  10GIV 3AERO  38
  -12.0000    2.9269   1.68990  -12.0000    2.1724   2.58900  10GIV 3AERO  39
  -12.0000    1.1559   3.17590  -12.0000    -.0000   3.37970  10GIV 3AERO  40
  -14.0000    0.0000  -3.68561  -14.0000    1.2605  -3.46330  10GIV 3AERO  41
  -14.0000    2.3691  -2.82330  -14.0000    3.1918  -1.84280  10GIV 3AERO  42
  -14.0000    3.6296   -.64000  -14.0000    3.6296    .64000  10GIV 3AERO  43
  -14.0000    3.1918   1.84280  -14.0000    2.3691   2.82330  10GIV 3AERO  44
  -14.0000    1.2605   3.46330  -14.0000    -.0000   3.68560  10GIV 3AERO  45
```

Element Data Cards
(Continued)

Sample Case (Continued)

```
0         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

   -16.0000    0.0000  -3.92491 -16.0000    1.3424  -3.68820 1OGIV 3AERO  46
   -16.0000    2.5229  -3.00660 -16.0000    3.3991  -1.96240 1OGIV 3AERO  47
   -16.0000    3.8653   -.68160 -16.0000    3.8653    .68160 1OGIV 3AERO  48
   -16.0000    3.3991   1.96250 -16.0000    2.5229   3.00660 1OGIV 3AERO  49
   -16.0000    1.3424   3.68820 -16.0000    -.0000   3.92490 1OGIV 3AERO  50
   -18.0000    0.0000  -4.09821 -18.0000    1.4017  -3.85100 1OGIV 3AERO  51
   -18.0000    2.6343  -3.13940 -18.0000    3.5491  -2.04910 1OGIV 3AERO  52
   -18.0000    4.0359   -.71160 -18.0000    4.0359    .71160 1OGIV 3AERO  53
   -18.0000    3.5491   2.04910 -18.0000    2.6343   3.13940 1OGIV 3AERO  54
   -18.0000    1.4017   3.85100 -18.0000    -.0000   4.09820 1OGIV 3AERO  55
   -20.0000    0.0000  -4.20621 -20.0000    1.4386  -3.95250 1OGIV 3AERO  56
   -20.0000    2.7037  -3.22210 -20.0000    3.6427  -2.10310 1OGIV 3AERO  57
   -20.0000    4.1423   -.73040 -20.0000    4.1423    .73040 1OGIV 3AERO  58
   -20.0000    3.6427   2.10310 -20.0000    2.7037   3.22210 1OGIV 3AERO  59
   -20.0000    1.4386   3.95250 -20.0000    -.0000   4.20620 1OGIV 3AERO  60
   -22.3250    0.0000  -4.25001 -22.3250    1.4536  -3.99370 1OGIV 3AERO  61
   -22.3250    2.7318  -3.25570 -22.3250    3.6806  -2.12500 1OGIV 3AERO  62
   -22.3250    4.1854   -.73800 -22.3250    4.1854    .73800 1OGIV 3AERO  63
   -22.3250    3.6806   2.12500 -22.3250    2.7318   3.25570 1OGIV 3AERO  64
   -22.3250    1.4536   3.99370 -22.3250    -.0000   4.25003 1OGIV 3AERO  65
   -22.3250    0.0000  -4.25002 -22.3250    1.4536  -3.99370 1CYLN 3AERO   1
   -22.3250    2.7318  -3.25570 -22.3250    3.6806  -2.12500 1CYLN 3AERO   2
   -22.3250    4.1854   -.73800 -22.3250    4.1854    .73800 1CYLN 3AERO   3
   -22.3250    3.6806   2.12500 -22.3250    2.7318   3.25570 1CYLN 3AERO   4
   -22.3250    1.4536   3.99370 -22.3250    -.0000   4.25000 1CYLN 3AERO   5
   -40.0000    0.0000  -4.25001 -40.0000    1.4536  -3.99370 1CYLN 3AERO   6
   -40.0000    2.7318  -3.25570 -40.0000    3.6806  -2.12500 1CYLN 3AERO   7
   -40.0000    4.1854   -.73800 -40.0000    4.1854    .73800 1CYLN 3AERO   8
   -40.0000    3.6806   2.12500 -40.0000    2.7318   3.25570 1CYLN 3AERO   9
   -40.0000    1.4536   3.99370 -40.0000    -.0000   4.25000 1CYLN 3AERO  10
   -60.0000    0.0000  -4.25001 -60.0000    1.4536  -3.99370 1CYLN 3AERO  11
   -60.0000    2.7318  -3.25570 -60.0000    3.6806  -2.12500 1CYLN 3AERO  12
   -60.0000    4.1854   -.73800 -60.0000    4.1854    .73800 1CYLN 3AERO  13
   -60.0000    3.6806   2.12500 -60.0000    2.7318   3.25570 1CYLN 3AERO  14
   -60.0000    1.4536   3.99370 -60.0000    -.0000   4.25000 1CYLN 3AERO  15
```

Element Data Cards
(Continued)

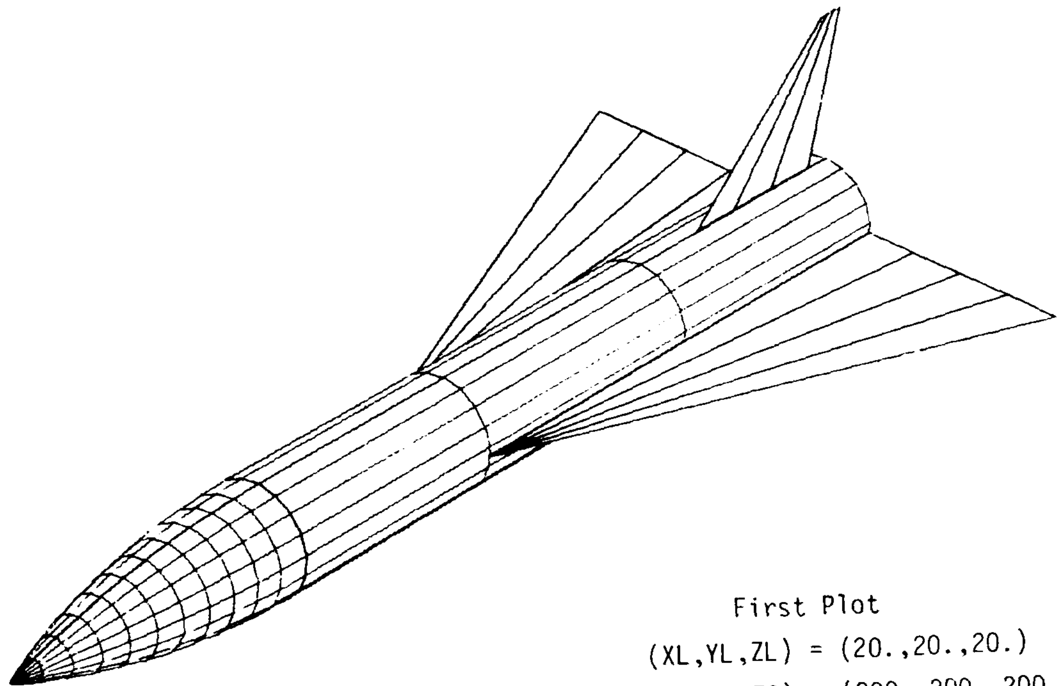
Sample Case (Continued)

```
0         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

  -80.0000    0.0000  -4.25001  -80.0000    1.4536  -3.99370  1CYLN 3AERO   16
  -80.0000    2.7318  -3.25570  -80.0000    3.6806  -2.12500  1CYLN 3AERO   17
  -80.0000    4.1854   -.73800  -80.0000    4.1854    .73800  1CYLN 3AERO   18
  -80.0000    3.6806   2.12500  -80.0000    2.7318   3.25570  1CYLN 3AERO   19
  -80.0000    1.4536   3.99370  -80.0000    -.0000   4.25003  1CYLN 3AERO   20
  -40.0000    4.2500   0.00002  -80.0000    4.2500   0.00000  0UPWG 3        0
  -40.0000    4.2500   0.00001  -80.0000    8.0000   0.00000  0     3        0
  -40.0000    4.2500   0.00001  -80.0000   12.0000   0.00000  0     3        0
  -40.0000    4.2500   0.00001  -80.0000   16.0000   0.00000  0     3        0
  -40.0000    4.2500   0.00001  -80.0000   20.0000   0.00003  0     3        0
  -40.0000    4.2500   0.00002  -80.0000   20.0000   0.00000  0LOWG 3        0
  -40.0000    4.2500   0.00001  -80.0000   16.0000   0.00000  0     3        0
  -40.0000    4.2500   0.00001  -80.0000   12.0000   0.00000  0     3        0
  -40.0000    4.2500   0.00001  -80.0000    8.0000   0.00000  0     3        0
  -40.0000    4.2500   0.00001  -80.0000    4.2500   0.00003  0     3        0
  -66.0000    0.0000   4.25002  -78.0000    0.0000  16.00000  0VFIN 3        0
  -70.0000    0.0000   4.25001  -78.6700    0.0000  16.00000  0     3        0
  -74.0000    0.0000   4.25001  -79.3300    0.0000  16.00000  0     3        0
  -78.0000    0.0000   4.25001  -80.0000    0.0000  16.00003  0     3        0
                                                                   99
  20.       20.       20.        200.       200.      200.
-100.       20.       20.       -300.       220.      220.

                                                                   99
```

Element Data Cards (Continued)

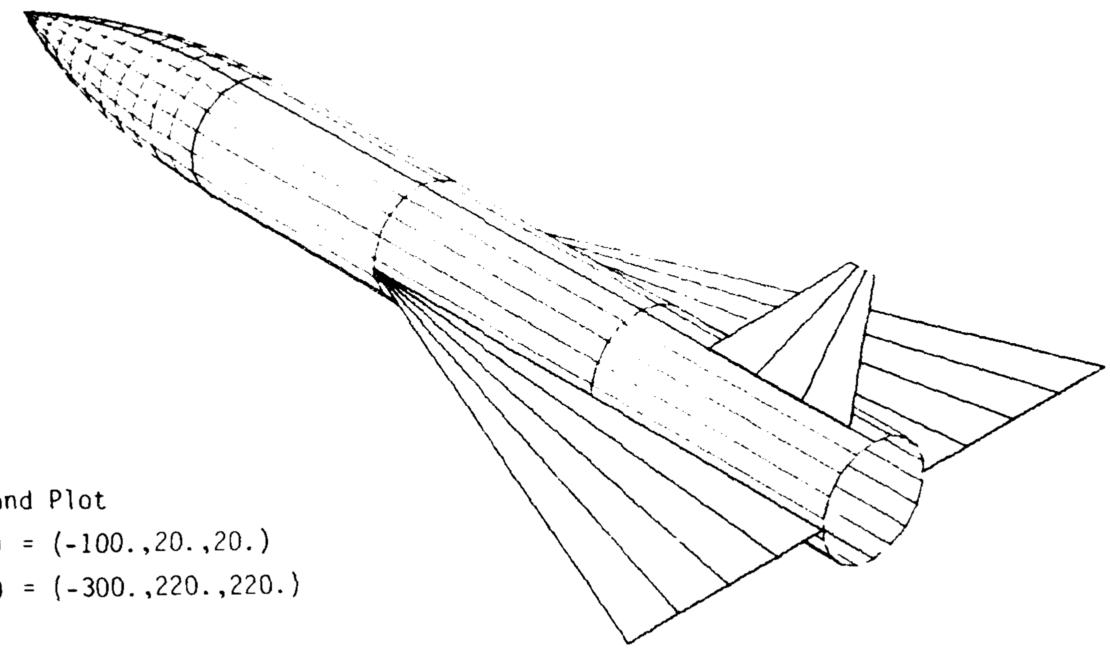
Data Set Term. Card
Viewing Angle Card
Viewing Angle Card
Data Set Term. Card

<u>Sample Case</u> (Continued)



First Plot
(XL,YL,ZL) = (20.,20.,20.)
(XO,YO,ZO) = (200.,200.,200.)

Sample Case (Continued)



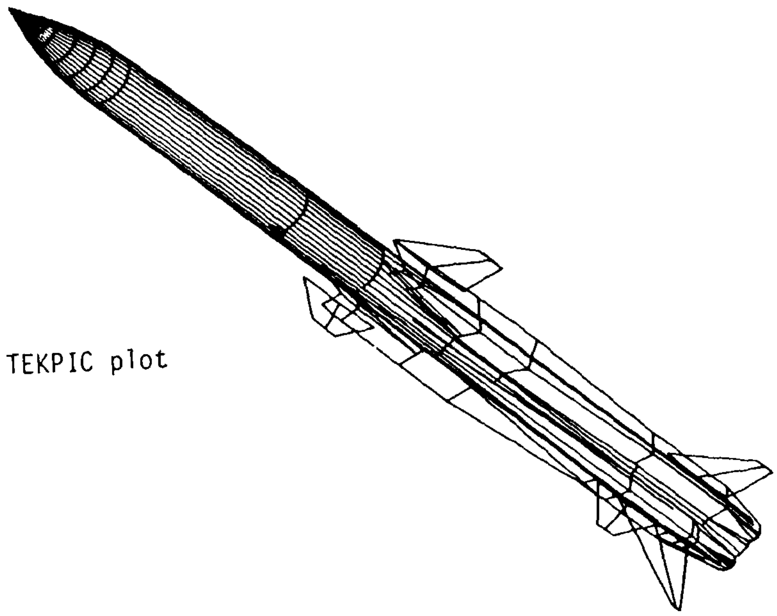
Second Plot

(XL,YL,ZL) = (-100.,20.,20.)

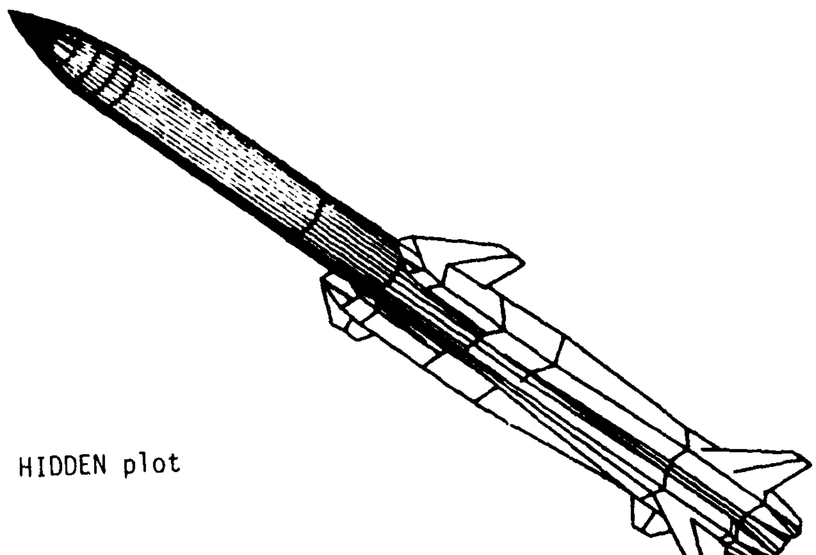
(XO,YO,ZO) = (-300.,220.,220.)

Comparison with TEKPIC Plots

The plots on the following pages illustrate the advantage of using the HIDDEN program to validate complex geometries. Although the Element data used to produce the plots are correct, the TEKPIC plots make it difficult for the user to know for certain whether the geometry actually contains errors. Since the TEKPIC code assumes that only the outer surface of each Element may be visible, the inner surfaces of vehicles (e.g. the interior of ducts) are not displayed unless Element data describing such interior surfaces are prepared. Therefore, some parts of the geometries in the following TEKPIC plots appear to be missing. The HIDDEN program, however, considers both sides of each Element for visibility, and the resulting hidden line plots are physically realistic.

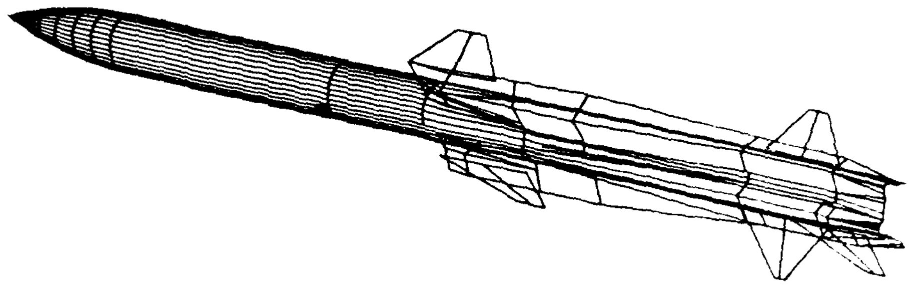


TEKPIC plot

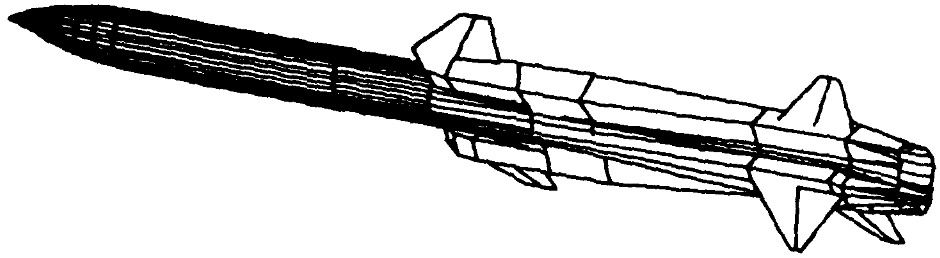


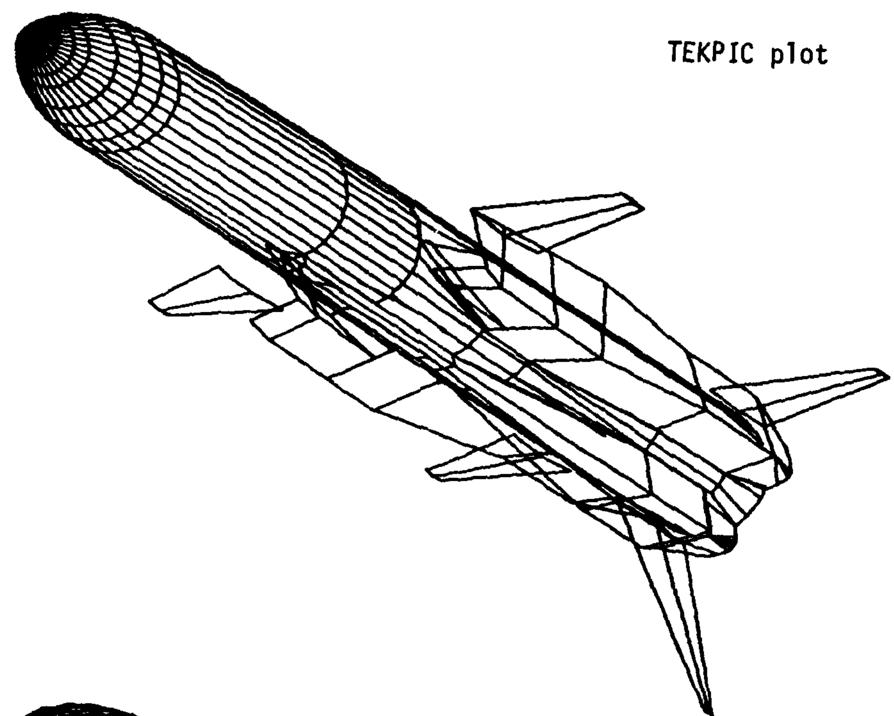
HIDDEN plot

TEKPIC plot

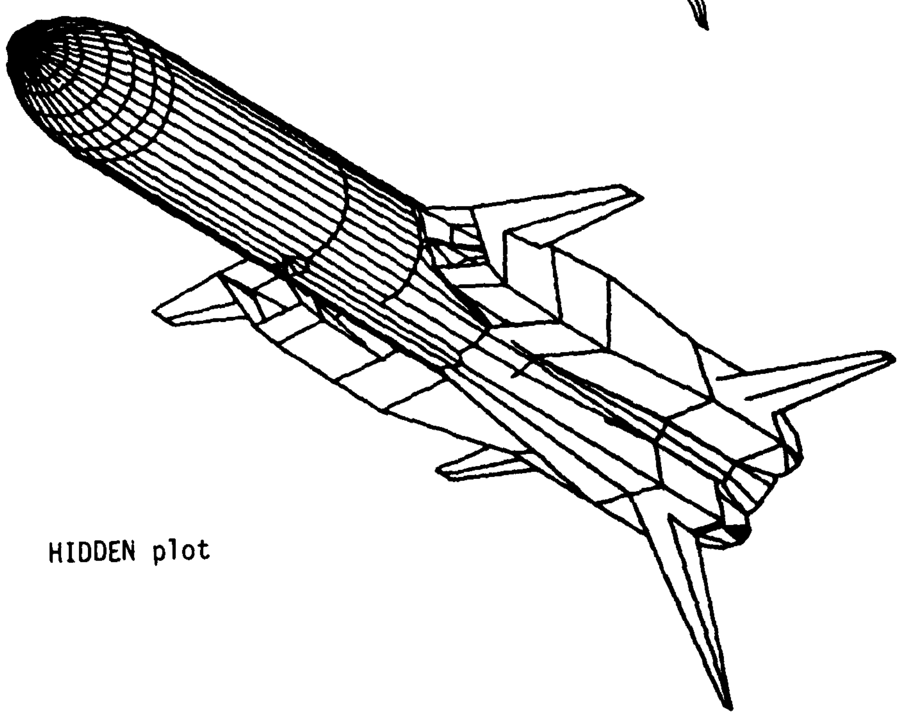


HIDDEN plot





TEKPIC plot



HIDDEN plot

REFERENCES

1. A. E. Gentry, D. N. Smyth, and W. R. Oliver, "The Mark IV Supersonic-Hypersonic Arbitrary-Body Program, Volume I - User's Manual, Volume II - Program Formulation," AFFDL-TR-73-159.

2. S. Taylor, "Mark IV Supersonic-Hypersonic Arbitrary-Body Program, Modifications and Computer Graphics, Volume I - Surface Streamline Tracing," AFWAL-TR-80-3117, Vol. I, October 1980.

3. Description of program HIDDEN, Purdue University final report for Grant NGR-15-05-180.

4. D. S. Hague and J. D. Vanderberg, "PCSYS: The Optimal Design Integration System Picture Drawing System with Hidden Line Algorithm Capability for Aerospace Vehicle Configurations," NASA-CR-2912, December 1977.

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